Modular Sulfondiimine and Sulfondiimidamide Synthesis Using Stable Sulfinylamine Reagents

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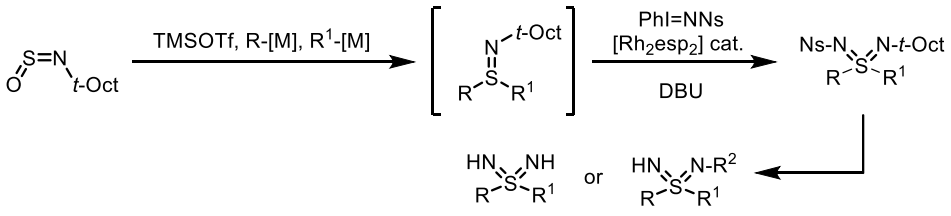
Abstract

In this thesis, novel methods for the synthesis of sulfondiimines and sulfondiimidamides are described. The use of sulfinylamine linchpins in combination with commercially available organometallic reagents and amines provides access to a broad range of sulfondiimines and sulfondiimidamides.

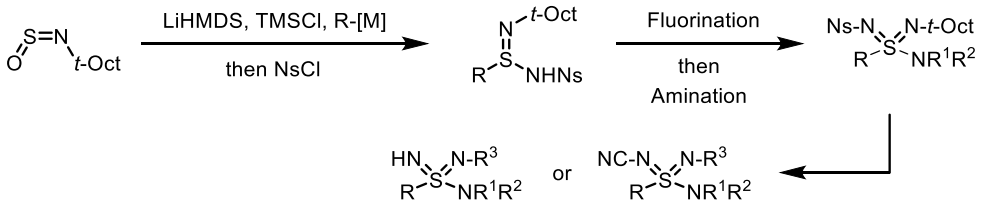
Chapter 1 provides an overview of the properties of S(VI)-functionalities such as sulfoximines, sulfonimidamides, sulfondiimines and sulfondiimidamides, as well as synthetic strategies to access them.

Chapter 2 documents a novel strategy for the preparation of sulfondiimines. A stable sulfinylamine linchpin, *N*-sulfinyl-*tert*-octylamine (*t*-Oct-NSO), is selected as the starting reagent. The combination of two different organometallic reagents with *t*-Oct-NSO in the presence of Lewis acid generates the sulfilimine intermediate. This is followed by a rhodium-catalysed imination, providing a broad range of orthogonal *N*-protected sulfondiimines. Deprotection and various functionalisation reactions provide the most diverse range of sulfondiimines to date.

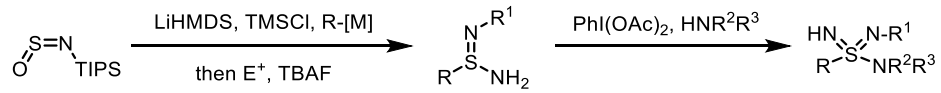


Chapter 3 describes the exploration of a novel functional group, sulfondiimidamides, which are the di-aza analogues of widely explored sulfonamides. The combination of *t*-Oct-NSO with LiHMDS, TMSCl and various organometallic reagents provides the corresponding *N*-*t*-Oct primary sulfinamidines. Protection with a nosyl group provides orthogonally *N*-protected sulfinamidines. Oxidative fluorination followed by $Ca(NTf_2)_2$-mediated amination

converts the sulfinamidines to the corresponding sulfondiimidoyl fluorides and sulfondiimidamides, respectively. Imidazole-substituted sulfondiimidamides are also shown to be effective intermediates, allowing primary amines and challenging *N*-nucleophiles to be used. A series of deprotection and further functionalisation reactions using sulfondiimidamides are described, indicating the possible application of these interesting functional groups in the pharmaceutical industry. An analogue of the COX-2 inhibitor, Celecoxib, was prepared using this methodology.



Chapter 4 details the discovery of a novel sulfinylamine linchpin, *N*-sulfinyl-triisopropylsilylamine (TIPS-NSO). The reaction of the TIPS-NSO with LiHMDS, TMSCl and various organometallic reagents followed by *N*-protection and *N*-TIPS deprotection, enables the synthesis of *N*-substituted primary sulfinamidines. A robust sulfondiimidamide synthesis method is developed from these primary sulfinamidines *via* $PhI(OAc)_2$-promoted amination. Celecoxib analogue is prepared using this methodology in only four steps, and a sulfondiimidamide analogue of Sildenafil is accessed in just two steps.



Chapter 5 discusses the conclusion of our research and future plans.

Chapter 6 presents the experimental procedures and data.

Declaration

The work described in this thesis is entirely the work of the author except where specifically indicated. This thesis has not been previously submitted for a degree, diploma or any other qualification at the University of Oxford or elsewhere.

ZeXin Zhang

01.2022

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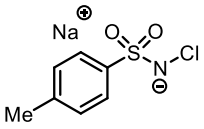
Abbreviation and Acronyms

acac	acetylacetone
Ac	acetyl
i-AmONO	*i*-Amyl nitrite
aq.	aqueous
Ar	aryl
barbituric acid	2,4,6-trihydroxypyrimidine
Bn	benzyl
Boc	*t*-butyloxycarbonyl
Bu	butyl
Bz	benzoyl
CAN	ammonium cerium(IV) nitrate
cat.	catalyst *or* catalytic
Cbz	benzyl carbamate
CPME	cyclopentyl methyl ether
Cy	cyclohexyl
DBU	1,8-diazabicyclo[5.4.0]undec-7-ene
decomp.	decomposition
DMAP	4-dimethylaminopyridine
DMC	dimethyl carbonate
DMF	*N*,*N*-dimethylformamide
DMSO	dimethyl sulfoxide
DPH	2,4-dinitrophenylhydroxylamine
equiv.	equivalents
ESI	electrospray ionisation
EDTA	ethylenediaminetetraacetic acid
FT	Fourier transform
h	hour(s)
Het	heteroaryl
HOBt	1-hydroxybenzotriazole hydrate
HMDS	hexamethyldisilazane
HRMS	high resolution mass spectrometry
Hz	Hertz

i	*iso*
IR	infrared
J	coupling constant
L	litre
LiHMDS	lithium bis(trimethylsilyl)amide
LRMS	low resolution mass spectrometry
M	metal *or* molar
m	*meta*
*m*CPBA	3-chloroperoxybenzoic acid
MS	molecular sieve
Ms	methanesulfonyl
MSH	*O*-mesitylenesulfonylhydroxylamine
NCS	*N*-chlorosuccinimide
NBS	*N*-bromosuccinimide
NFSI	*N*-fluorobenzenesulfonimide
NMO	4-methylmorpholine *N*-oxide
NMR	nuclear magnetic resonance
Ns	nosyl, 4-nitrobenzenesulfonyl
NTf	trifluoromethanesulfonimide
Nuc	nucleophile
O	*ortho*
OTf	trifluoromethanesulfonate
p	*para*
PG	protecting group
Ph	phenyl
ppm	parts per million
quant.	quantitative
R	generic group/substituent
rt	room temperature
sat.	saturated
Ses	2-(trimethylsilyl)ethanesulfonyl
t	*tert*
t-AmylOH	2-methylbutan-2-ol
t-BuOCl	*t*-butyl hypochlorite

TASF	tris(dimethylamino)sulfonium difluorotrimethylsilicate
TBS	*t*-butyldimethylsilyl
TBAF	tetra-*n*-butylammonium fluoride
temp.	temperature
TES	triethylsilyl
Tf	trifluoromethanesulfonyl
TFA	trifluoroacetic acid
TFE	2,2,2-trifluoroethanol
THF	tetrahydrofuran
TIPS	tri-*iso*propylsilyl
TLC	thin layer chromatography
TMS	trimethylsilyl
Tol	tolyl
TPAP	tetrapropylammonium perruthenate
Tr	trityl, triphenylmethyl
Ts	tosyl, 4-toluenesulfonyl
UV	ultraviolet
wt	weight
X	(pseudo)halide (unless stated otherwise)
μ	micro
ν	frequency

Chemical Structures



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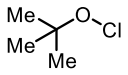

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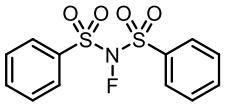

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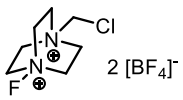

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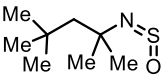
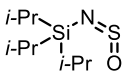
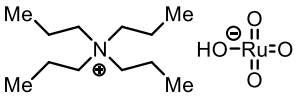


t-oct-NSO



TIPS-NSO



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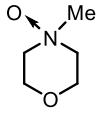

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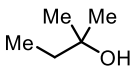
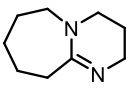


t-AmylOH



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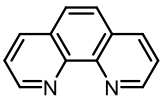

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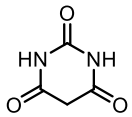
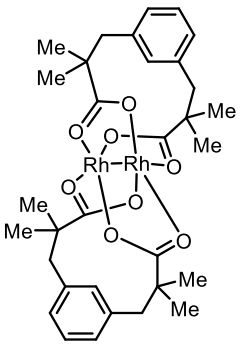


barbituric acid



Rh_2esp_2

Chapter 1 - Introduction

1.1 Properties of Sulfondiimines and Sulfondiimidamides

1.1.1 Sulfondiimines

Sulfones **1** have been used in a variety of commercialised drug molecules in the past twenty years.[1-3] including Zolimidine **1a** (in the treatment of gastro-oesophageal reflux disease and peptic ulcer), Casodex **1b** (an anti-androgen medication that is primarily used in the treatment of prostate cancer) and Rofecoxib **1c** (in the therapy of chronic arthritis and mild-to-moderate musculoskeletal pain) which are shown in **Figure 1.1**. Their mono-aza analogues, sulfoximines **2**, have also received significant interest in medicinal chemistry since the discovery of methionine sulfoximine (MSO) **2a** due to their unique properties.[4-5] For example, Roniciclib **2b**, an orally bioavailable cyclin dependent kinase (CDK) inhibitor with potential antineoplastic activity. Replacing the two oxygen atoms of a sulfone with nitrogen atoms gives di-aza analogues, sulfondiimines **3**, whose chemical properties differ significantly from those of the parent sulfone. The presence of the two nitrogen atoms can increase the polarity and aqueous solubility of sulfondiimines compared to sulfones and sulfoximines.[6] The two nitrogen atoms also provide more options for the functionalisation of these molecules. These features give sulfondiimines great potential in the field of medicinal chemistry and have recently been exhibited in a CDK inhibitor **3a** from Bayer (**Figure 1.1**).

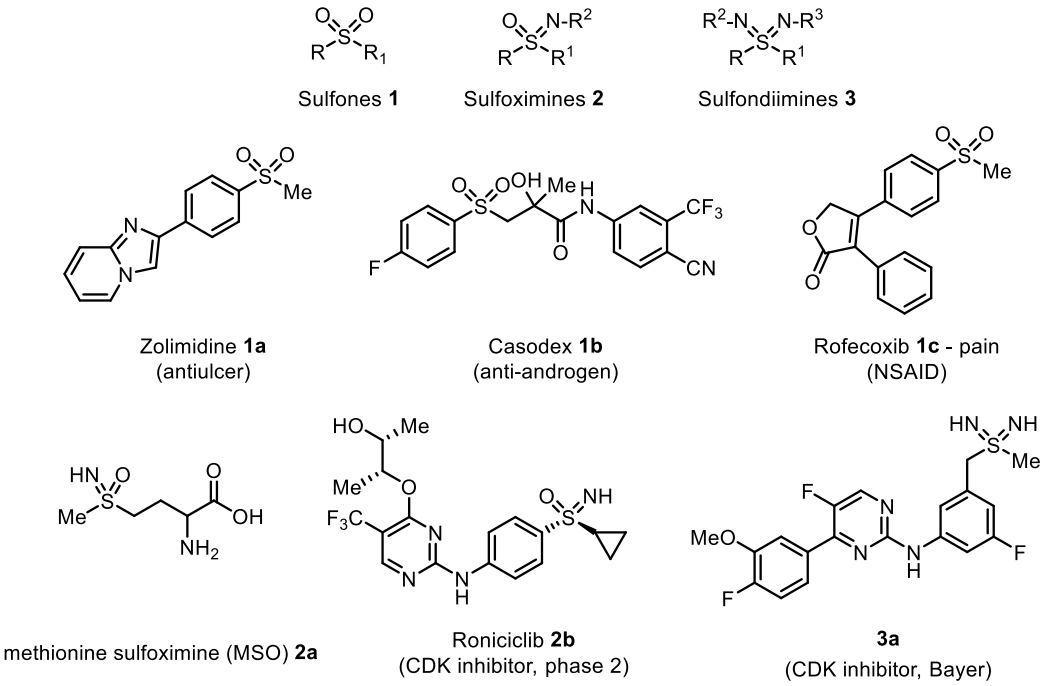


Figure 1.1. Examples of bioactive sulfones, sulfoximines and sulfondiimines

Sulfondiimines **3** also have the potential to act as chiral ligands (for example in which R and R^1 are different, R^2 and R^3 are different for **3**). However, only limited studies have been made with these compounds due to the difficulties in their synthesis. Outside of the work presented in this thesis, there is currently only one strategy to synthesise sulfondiimines, and this is achieved by starting from a sulfide and passing through two rounds of halogenation-imination (**Figure 1.2**). [7-13]

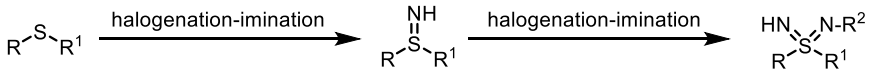


Figure 1.2. Previous method of sulfondiimines synthesis

1.1.2 Sulfondiimidamides

Compared with sulfones, sulfonamides **4** have been more widely applied in the field of pharmaceuticals and agrochemicals.[1,14] Sulfonamides accounted for 15% of the top 100 most prescribed drugs in the past ten years, including Celecoxib **4a** (a COX-2 inhibitor and nonsteroidal anti-inflammatory drug), Sildenafil **4b** (in the treatment of erectile dysfunction) and Almotriptan **4c** (in the treatment of heavy migraine headache).

Sulfonimidamides **5**, the mono-aza analogues of sulfonamides, are currently rising in popularity as novel pharmacophores, with bioactive sulfonimidamides being used in a diverse range of applications (**Figure 1.3**).[15-17] Similar to sulfonamides, sulfonimidamides exhibit high chemical and metabolic stability. Additionally, the introduction of an extra nitrogen atom allows another vector to diversify the *N*-H sulfonimidamide *via* different *N*-substituents, as well as providing another site with hydrogen bond donor/acceptor capabilities. However, the double-aza analogues, sulfondiimidamides **6**, are unknown in medicinal chemistry. In fact, sulfondiimidamides are essentially unexplored functional groups as they lack simple and efficient methods to synthesise them,[18,19] and there is little data on their stability and physical properties. Based on the important role of sulfonamides and sulfonimidamides in the field of medicinal chemistry, sulfondiimidamides should also have great potential in this field due to the additional structural diversity, tuneable basicity, and unexplored chemical space they encompass.

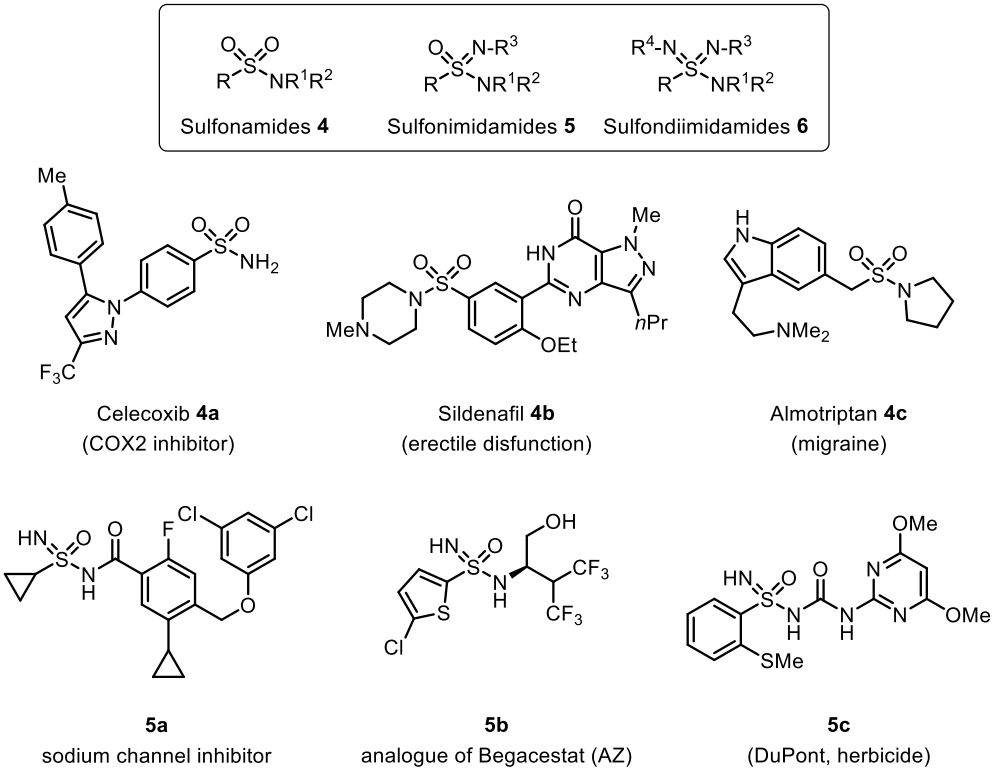


Figure 1.3. Examples of bioactive sulfonamides and sulfonimidamides

1.2 Synthesis of sulfoximines

There is currently only one reported strategy to synthesise sulfondiimines,[7-13] and no general method to make sulfondiimidamides. Therefore, in this section and the one that follows we will introduce the synthesis of sulfoximines and sulfonimidamides, as the methods used to synthesise these molecules are informative when considering approaches to sulfondiimines and sulfondiimidamides.

There are currently three main strategies for the synthesis of sulfoximines: imination of sulfoxides, oxidation of sulfilimines, and nucleophilic substitution of sulfonimidoyl halides or sulfonimidates by a carbon nucleophile (**Figure 1.4**).

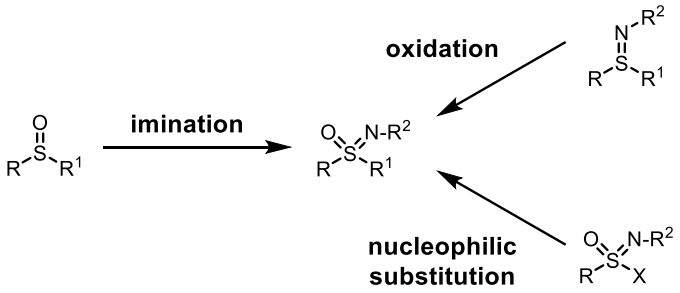


Figure 1.4. Strategies for the synthesis of sulfoximines

1.2.1 Imination of Sulfoxides

The imination of sulfoxides with nitrenes or nitrene equivalents are by far the most widely used method for the synthesis of sulfoximines.[20] Many metal catalysts and nitrene equivalents have been developed to enable this transformation. This section will briefly introduce the most commonly used imination reactions, as well as focus on some recently reported methods that directly generate *N*-H sulfoximines under mild conditions.

Early methods used azides as the nitrene source, which can generate the highly reactive but explosive hydrazoic acid (HN_3) species *in-situ* in the presence of strong acid.[21] An alternative approach uses the explosive reagent *O*-mesitylenesulfonylhydroxylamine (MSH) (**Figure 1.5**).[22]

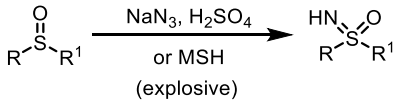


Figure 1.5. Traditional methods for the synthesis of sulfoximines

Given the toxicity and explosion risk of azides and MSH, iminoiodinanes (PhI=NR) were developed as alternative imination reagents for sulfoxides. In general, they can convert sulfoxides into sulfoximines under mild reaction conditions with or without a metal catalyst. Copper was the first metal used as the catalyst to transform sulfoxides to sulfoximines with iminoiodinanes in 1998.[23] After that, Cu(II), Rh(II), Fe(II), Ag(I) and Fe(III) catalysts have also been developed to generate the corresponding metal nitrene complexes *in-situ* from iminoiodinanes.[24-28] The majority of these advances were carried out by the Bolm group at Aachen university (**Figure 1.6**).

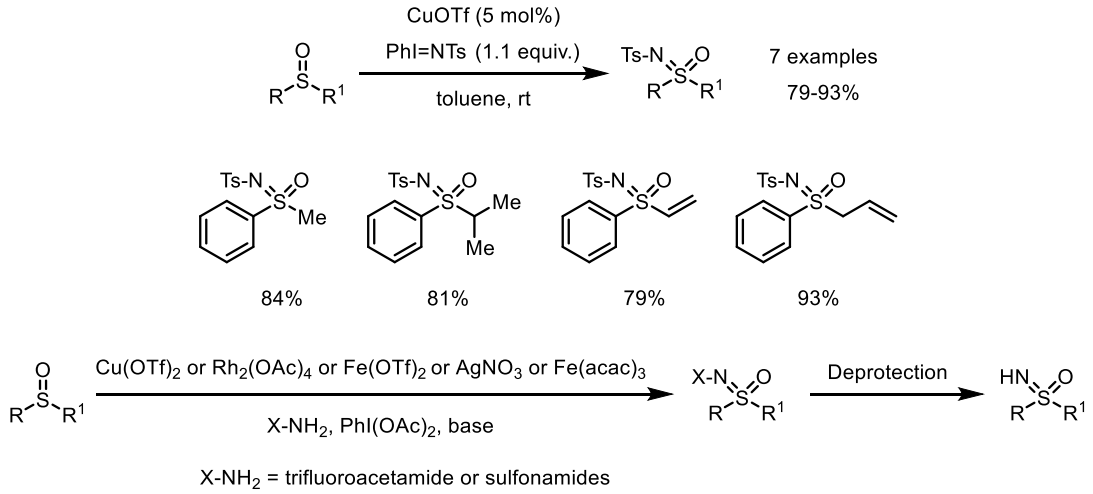


Figure 1.6. Metal-catalysed imination methods for the synthesis of sulfoximines

In 2014, the Ge group reported the first method to generate *N*-H sulfoximines directly using metal-catalysed imination of sulfoxides under mild reaction conditions.[29] $Rh_2(esp)_2$ and *O*-(2,4-dinitrophenyl)hydroxylamine (DPH) were used to generate the reactive rhodium-nitrene species *in-situ*, which in turn was used to iminate the metal-coordinated sulfoxides to the corresponding *N*-H sulfoximines (**Figure 1.7**). Limitations of this method are the low

yields obtained when sterically demanding sulfoxides are used, and the need for a large excess of DPH.

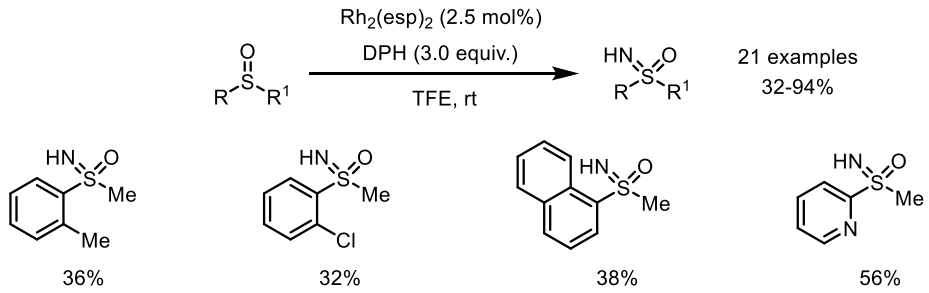


Figure 1.7. Ge's rhodium-catalysed imination for the synthesis of *N*-H sulfoximines

Another metal-catalysed iminaiton for the synthesis of *N*-H sulfoximines was developed by the Bolm group in 2018.[30] In this approach, a Fe(II)-catalyst was used in combination with *O*-acylhydroxylammonium salt **7** as the nitrene source to prepare a range of *N*-H sulfoximines in good yields. One limitation of this methodology was the need for an excess of the *O*-acylhydroxylammonium salt **7**, which itself requires two steps to synthesise (**Figure 1.8**).

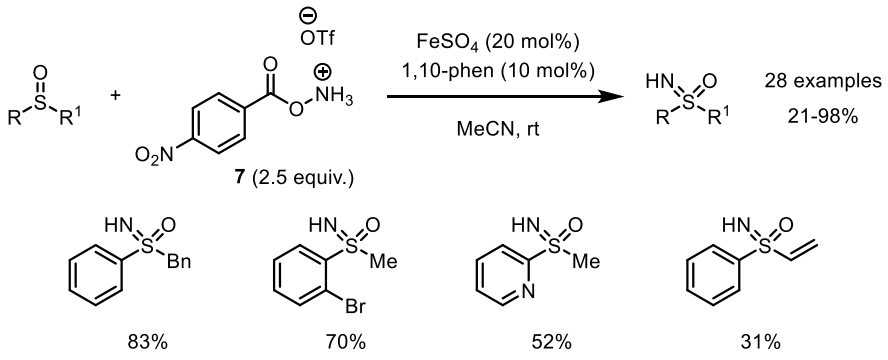


Figure 1.8. Bolm's iron-catalysed imination for the synthesis of *N*-H sulfoximines

A metal-free imination method for preparing *N*-H sulfoximines was reported by the Bull group at Imperial College in 2016.[31] A broad range of *S,S*-dialkyl, *S*-alkyl-*S*-aryl and *S,S*-diaryl sulfoxides were transformed to the corresponding *N*-H sulfoximines with reasonable yields in the presence of $PhI(OAc)_2$ and $NH_2CO_2NH_4$. Low yields were obtained with some electron-poor substrates. Possible intermediates iminoiodinane **8** and iodonitrene **9** were

detected by flow HRMS. In 2017, the Bull group used the same strategy to synthesise *N*-H sulfoximine by employing the corresponding sulfides as the starting materials. Low yields were obtained for vinyl substrates (**Figure 1.9**). [32]

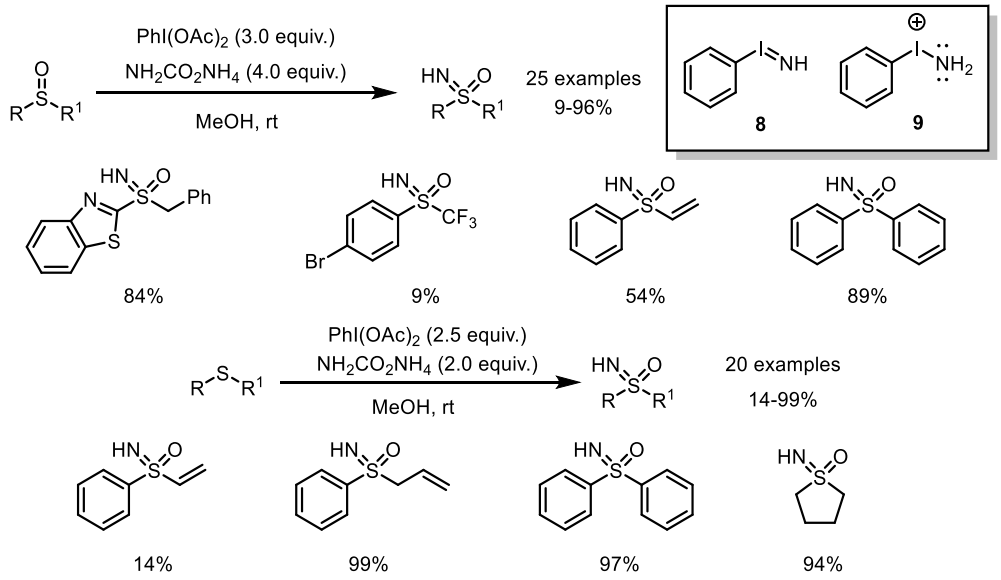


Figure 1.9. Bull's metal-free imination for the synthesis of *N*-H sulfoximines

1.2.2 Oxidation of Sulfilimines

The earliest example of sulfoximine preparation is from the oxidation of tosyl-protected sulfilimines in the 1950s.[33] $KMnO_4$ was employed as the oxidant to convert the sulfilimines to sulfoximines using harsh reaction conditions (**Figure 1.10**). Nevertheless, this strategy was not widely developed due to the instability of sulfilimines under the hot, basic conditions and paucity of methods for sulfilimine synthesis.

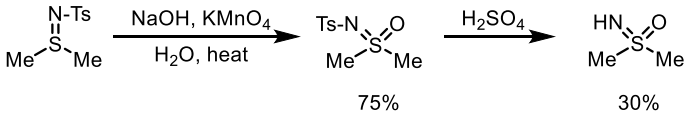


Figure 1.10. Synthesis of sulfoximines through sulfilimine oxidation

1.2.3 Nucleophilic Substitution of Sulfonimidoyl Electrophiles

Conceptually, using electrophilic sulfonimidoyl species is potentially advantageous because it allows for a range of different carbon nucleophiles to attack a common sulfur electrophile

to quickly obtain a variety of different products. However, in practice, this method has a number of problems. Electrophiles such as sulfonimidoyl chlorides are usually unstable and tend to undergo reduction reactions or hydrolysis. For example, carbon nucleophiles such as organolithium reagents and Grignard reagents often attack at the chlorine atom rather than at sulfur, leading to reduction of the sulfonimidoyl chloride rather than displacement of the chlorine atom. Although sulfonimidoyl fluorides and sulfonimidates have been developed to replace sulfonimidoyl chlorides to try to solve the problem of reduction, the corresponding sulfoximines can still only be obtained with modest yields.

In 1979, a sulfoximine synthesis was developed by the Johnson group using nucleophilic substitution of sulfonimidates with different organolithium reagents.[34] The sulfonimidates were prepared from sulfonimidoyl chlorides using sodium phenoxide. Several *S*-aryl-*S*-alkyl sulfoximines were obtained by this method in modest yields (**Figure 1.11**).

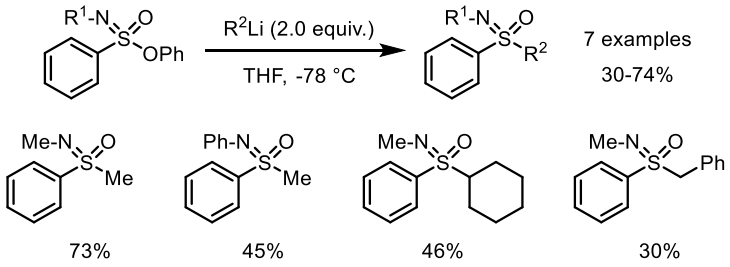


Figure 1.11. Johnson's synthesis of sulfoximines from sulfonimidates

In 2018, the Stockman group reported a similar method for the synthesis of sulfoximines using nucleophilic substitution of sulfonimidates with Grignard reagents.[35] The sulfonimidates were prepared from the corresponding sulfinamides in the presence of PhI=O. Limitations of this method include the need for an excess of Grignard reagents and the modest yields obtained for most substrates (**Figure 1.12**).

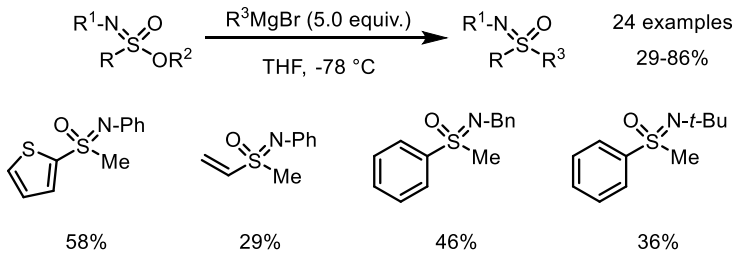


Figure 1.12. Stockman's synthesis of sulfoximines from sulfonimidates

The Johnson group reported another nucleophilic substitution method in 1983, this time using sulfonimidoyl fluorides as the starting materials.[36] The sulfonimidoyl fluorides were generated from the reaction of the corresponding sulfonimidoyl chlorides with TBAF. When methyl and *n*-butyllithium reagents were used as the nucleophiles, reasonable yields of the desired sulfoximines were obtained (**Figure 1.13**). When using Grignard reagents as nucleophiles, mixtures of sulfoximines and the corresponding sufinamides were obtained. In 2018, the Sharpless group revisited this approach, and using the gaseous reagent $S(O)F_4$ **10** as the initial starting material they were able to prepare a series of sulfoximines (**Figure 1.14**).[37]

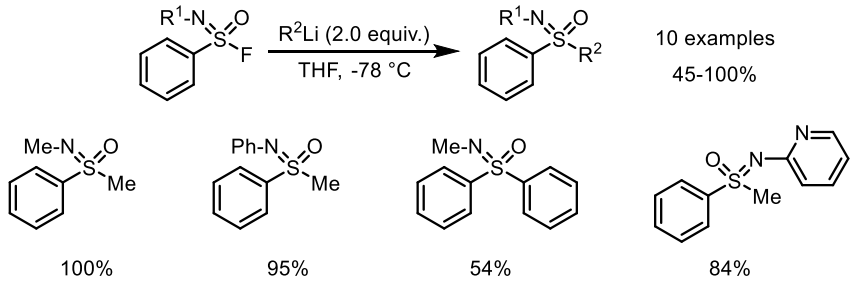


Figure 1.13. Johnson's synthesis of sulfoximines from sulfonimidoyl fluorides

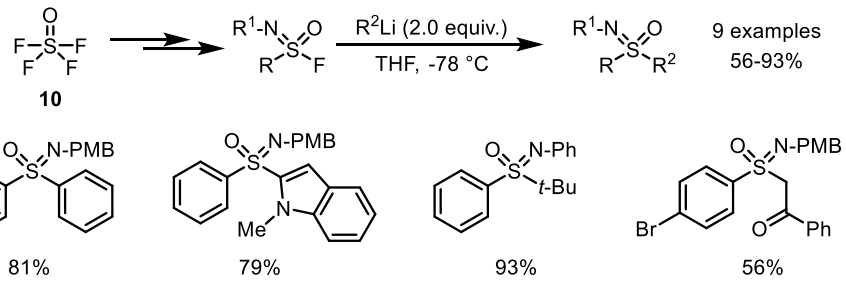


Figure 1.14. Sharpless's synthesis of sulfoximines from sulfonimidoyl fluorides

In 2010, the Bolm group used sulfonimidoyl fluorides to synthesise the *S*-CF_3-*S*-aryl sulfoximines.[38] $TMSCF_3$ and TBAF were combined to generate the trifluoromethyl anion *in-situ*, which attacked the sulfur centre of the sulfonimidoyl fluorides to deliver the *S*-CF_3-*S*-aryl sulfoximines with modest to good yields (**Figure 1.15**). This methodology shows the obvious advantage of a nucleophilic substitution strategy when synthesising some very electron-poor sulfoximines, which have been difficult to prepare using the imination of sulfoxides.

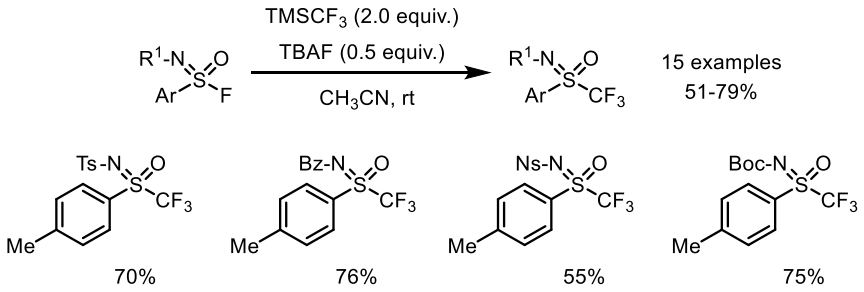


Figure 1.15. Bolm's synthesis of *S*-CF_3-*S*-aryl sulfoximines

In 2020, the Willis group reported a novel and bench-stable *N*-sulfinylhydroxylamine reagent, BiPhONSO **11**, which was employed in a three-component synthesis of sulfoximines.[39] When reacting the BiPhONSO reagent **11** with different organometallic reagents at low temperature, corresponding sulfinyl nitrene intermediates **12** were generated *in-situ*. A second organometallic reagent was then added to combine with the sulfinyl nitrenes to give the corresponding *N*-H sulfoximines (**Figure 1.16**). A broad range of *N*-H sulfoximines were prepared in good to excellent yields using this strategy. Some *N*-substituted sulfoximines could also be prepared by the addition of simple electrophiles after the two organometallic reagents, allowing the isolation of *N*-functionalised products.

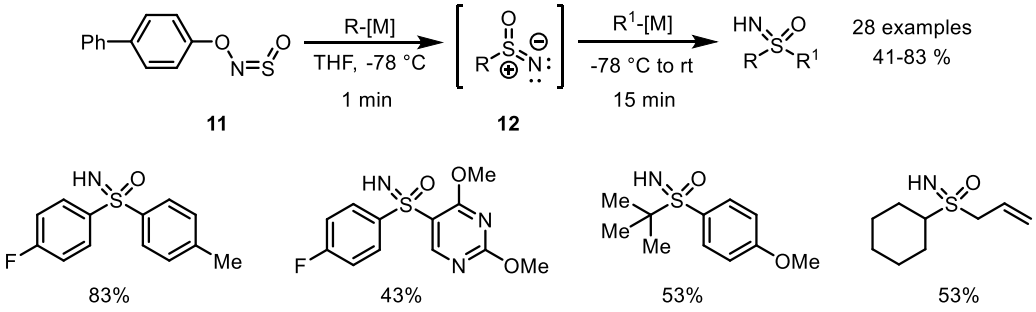


Figure 1.16. Willis' synthesis of sulfoximine from BiPhONSO

1.2.4 Other Methods

Apart from the above three strategies, in 2019, the Maruoka group developed a new strategy to synthesise sulfoximines from the corresponding sulfinamides by *S*-arylation or *S*-alkylation.[40,41] For *S*-arylation, diaryliodonium salts **13** were selected as carbocation equivalent, as they can generate a highly reactive copper-aryl species under mild conditions in the presence of a copper catalyst. In order to achieve the *S*-arylation instead of *N*-arylation, a pivaloyl group was chosen as the protecting group on the sulfinamides, which provided high sulfur selectivity (**Figure 1.17**). Pivaloyl-protected sulfinamides were also selected as the starting reagent to enable *S*-alkylation when reacting with alkyl halides. Good yields and sulfur selectivity were obtained for *S*-alkyl sulfoximines from the reagent combination of NaH and 15-crown-5. $LiAlH_4$ could be used to subsequently achieve the deprotection of pivaloyl group effectively (**Figure 1.18**).

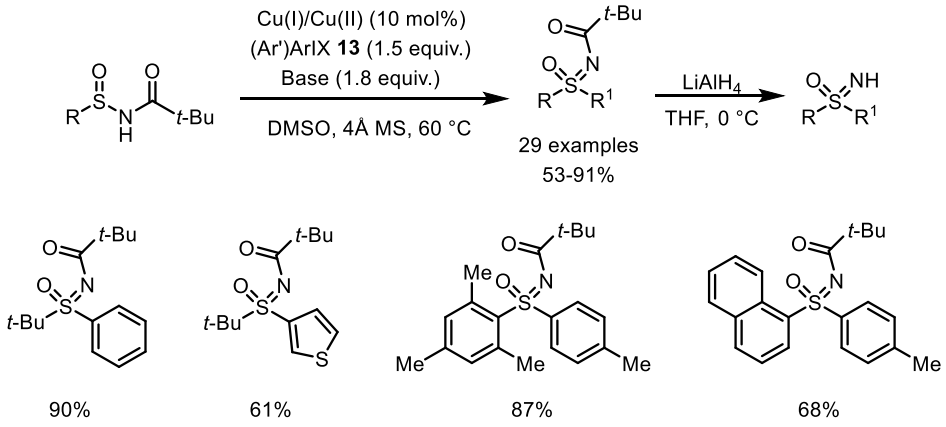


Figure 1.17. Maruoka's synthesis of sulfoximines *via* *S*-arylation

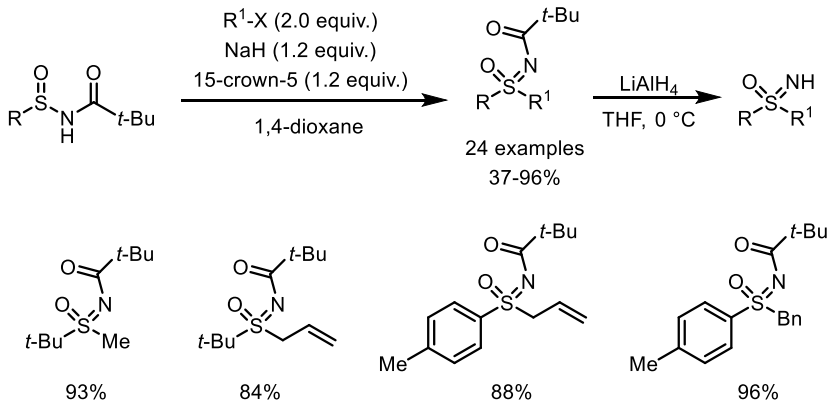


Figure 1.18. Maruoka's synthesis of sulfoximines *via S*-alkylation

1.3 Synthesis of Sulfonimidamides

The earliest known report for the synthesis of sulfonimidamides is from the Phillips group in 1930.[42] The sodium salt of di-tosyl-protected sulfinamidine (obtained from the reaction of chloramine-T and ethanethiol) was oxidised with potassium permanganate to afford the corresponding sulfonimidamide. However, this method has an obvious limitation due to the use of a strong oxidant, resulting in the methyl groups on the tosyl substituents being oxidised to carboxylic acids (**Figure 1.19**).

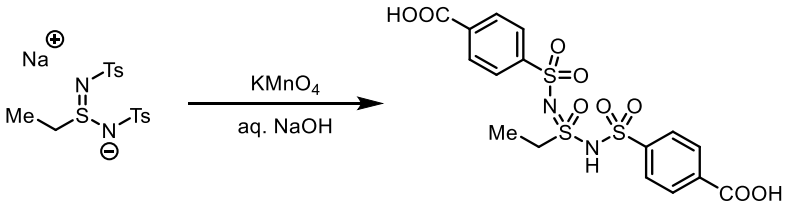


Figure 1.19. First report for the synthesis of sulfonimidamide

Levchenko and co-workers developed a more general method based on the nucleophilic substitution of sulfonimidoyl chlorides in 1962.[43] The key sulfonimidoyl chloride intermediate was prepared by the reaction of a sulfinyl chloride and chloramine-T. This method has some limitations when applied to the synthesis of *N*-aryl and *N*-alkyl sulfonimidoyl chlorides due to the instability of corresponding chloroamines. In general, the nucleophilic substitution of sulfonimidoyl chlorides with amines has been proved by many

subsequent applications to be one of the most effective methods for preparing various sulfonimidamides (**Figure 1.20**).

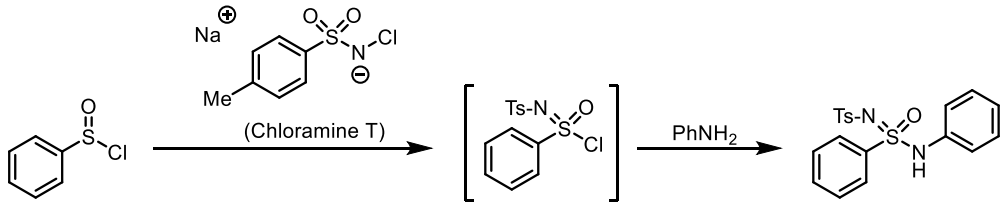


Figure 1.20. Levchenko's synthesis of sulfonimidamide from sulfonimidoyl chloride

Using the nucleophilic substitution of sulfonimidoyl bromides to synthesise sulfonimidamides was reported by Takei, Watanabe and Mukaiyama in 1965.[44] The sulfonimidoyl bromides were obtained *in-situ* by the bromination of sulfinamides with *N*-bromosuccinimide (NBS). In addition to NBS, bromine and *N*-bromophthalimide have also been used as bromination reagents, although they are not as efficient as NBS. The limitation of this method is that the intermediate sulfonimidoyl bromides are even more unstable than the corresponding sulfonimidoyl chlorides, so the yields are relatively low (**Figure 1.21**).

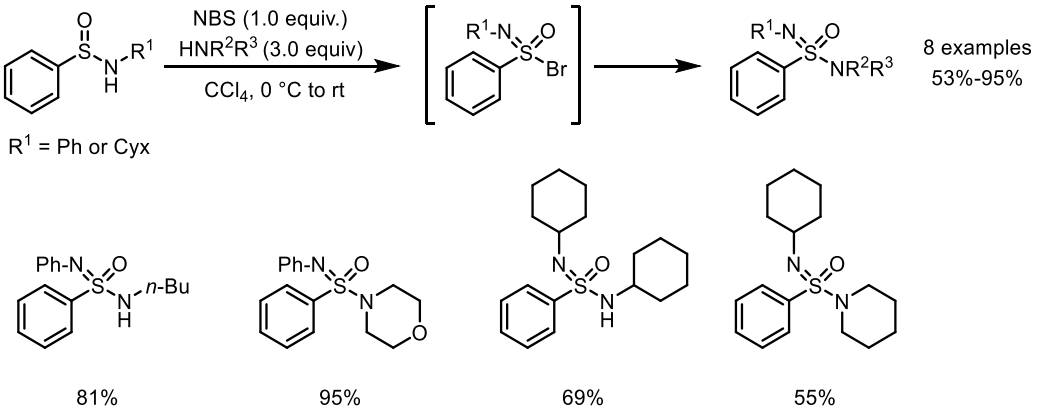


Figure 1.21. Mukaiyama's synthesis of sulfonimidamides from sulfonimidoyl bromides

The Johnson group developed several new chlorination reagents in the 1970s for the synthesis of sulfonimidoyl chlorides.[45-47] *tert*-Butyl hypochlorite (*t*-BuOCl) was found to be an effective chlorination reagent that can convert sulfinamides to sulfonimidoyl chlorides efficiently (**Figure 1.22**). Through subsequent addition of a suitable amine, a variety of *N*-Me and *N*-Ph sulfonimidamides could be obtained. Apart from *t*-BuOCl, chlorine gas and

N-chlorobenzotriazole have also been used as the chlorination reagent. In 2007, Bolm and co-workers used a milder electrophilic chlorinating agent, *N*-chlorosuccinimide (NCS), to achieve the conversion from sulfinamides to sulfonimidoyl chlorides in good yields (**Figure 1.23**).[48]

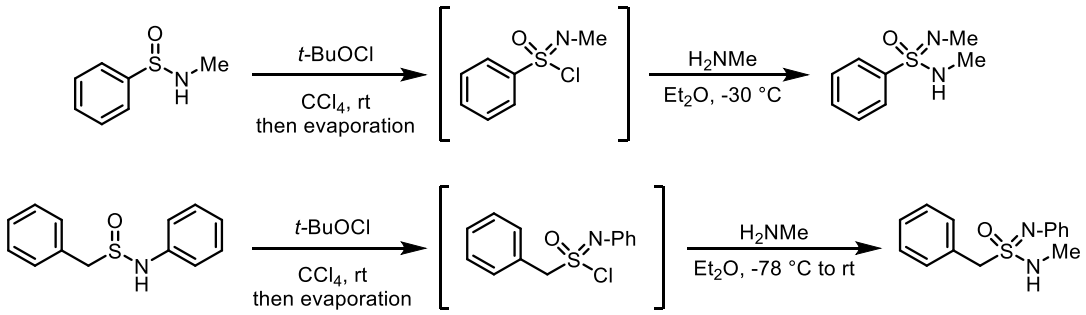


Figure 1.22. Johnson's synthesis of sulfondiimidoyl chlorides

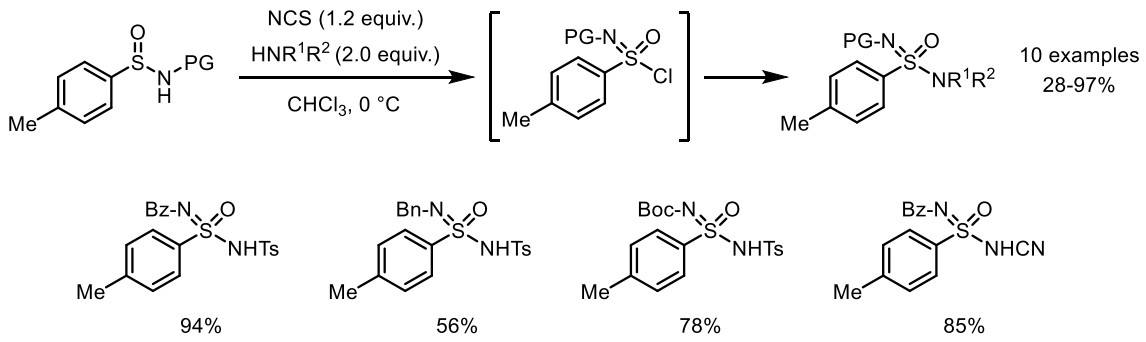


Figure 1.23. Bolm's synthesis of sulfondiimidoyl chlorides

In 1994, Yagupolskii and co-workers reported the synthesis of *N*-Tf sulfonimidamides by nucleophilic substitution of *N*-Tf sulfonimidoyl fluorides with ammonia.[49] The synthesis of *S*-CF_3-*N*-Tf sulfonimidamides were reported in 2002, using a similar method (**Figure 1.24**).[50]

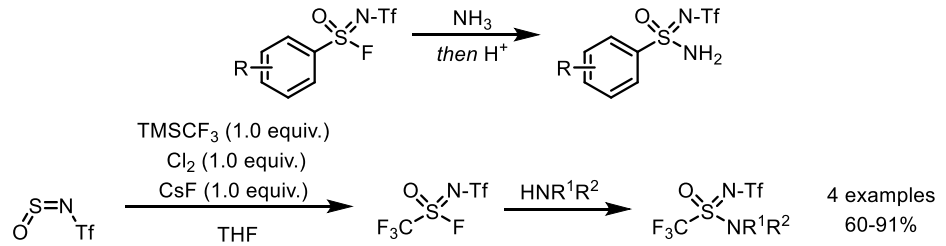


Figure 1.24. Yagupolskii's synthesis of sulfonimidamides from sulfonimidoyl fluorides

In 2015, Gibson and Chen reported a new synthesis of sulfonimidamides by the deoxychlorination of sulfonamides.[51] The sulfonimidoyl chlorides were generated *in-situ* by the reaction of TBS-protected sulfonamides with triphenyldichlorophosphorane (Ph_3PCl_2). The TBS protecting group was key to avoiding the further reaction between the sulfonimidoyl chloride intermediates and sulfonamide starting materials. The TBS group could be subsequently deprotected efficiently under acidic conditions (**Figure 1.25**).

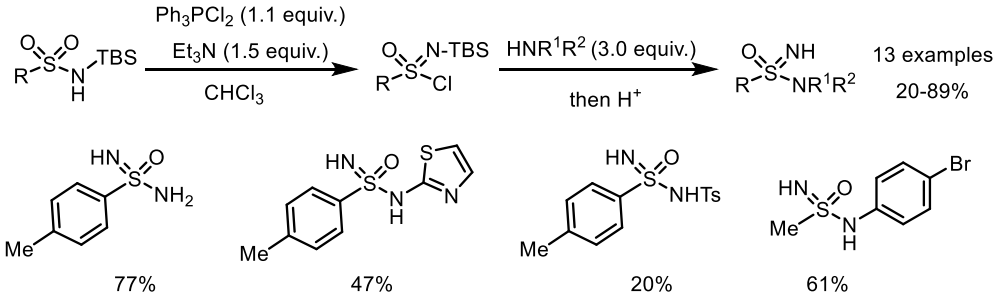


Figure 1.25. Gibson and Chen's synthesis of sulfonimidamides from sulfonamides

In 2017, the Sharpless group reported an alternative method for the synthesis of sulfonimidoyl fluorides by using the reaction of iminosulfur oxydifluorides **14** and various organolithium reagents.[37] Four sulfonimidamide examples were prepared by the nucleophilic substitution of sulfonimidoyl fluorides with amines (**Figure 1.26**). Secondary amines such as pyrrolidine can attack the sulfonimidoyl fluoride directly at 60 °C to form the corresponding sulfonimidamide, whilst anilines needed to be deprotonated before undergoing nucleophilic substitution. An important limitation of this strategy is the starting material, $S(O)F_4$ **10**, which is a highly corrosive gas requiring specialist equipment to handle. It is also not currently commercially available and needs to be synthesised from dioxygen, sulfur tetrafluoride and nitrogen dioxide at high temperature (238 °C).

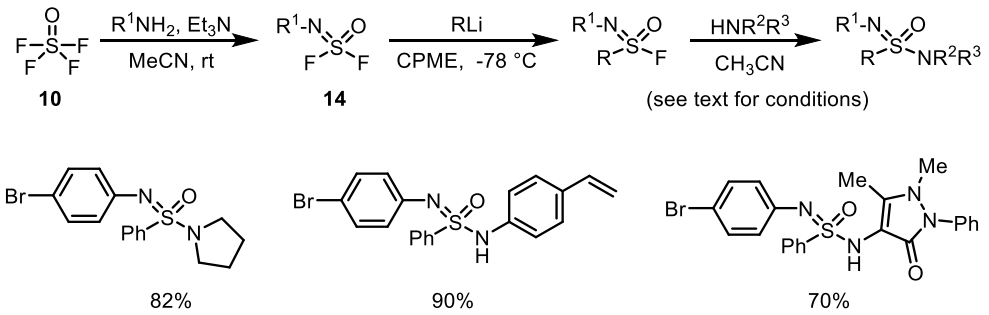


Figure 1.26. Sharpless's synthesis of sulfonimidamides from $S(O)F_4$

In the same year, the Willis group reported a one-pot synthesis of sulfonimidamides using the bench-stable reagent, *N*-sulfinyltritylamine (TrNSO).[52] Various sulfinamides were obtained *in-situ* from the reaction of TrNSO and different (hetero)aryl, alkyl and alkenyl organometallic reagents, which then underwent subsequent chlorination, amination and deprotection steps in the same pot. A broad range of sulfonimidamides were prepared from this method with modest to high yields. An analogue **15** of the COX-2 inhibitor, Celecoxib, was prepared using this methodology and its biological activity was evaluated (**Figure 1.27**).

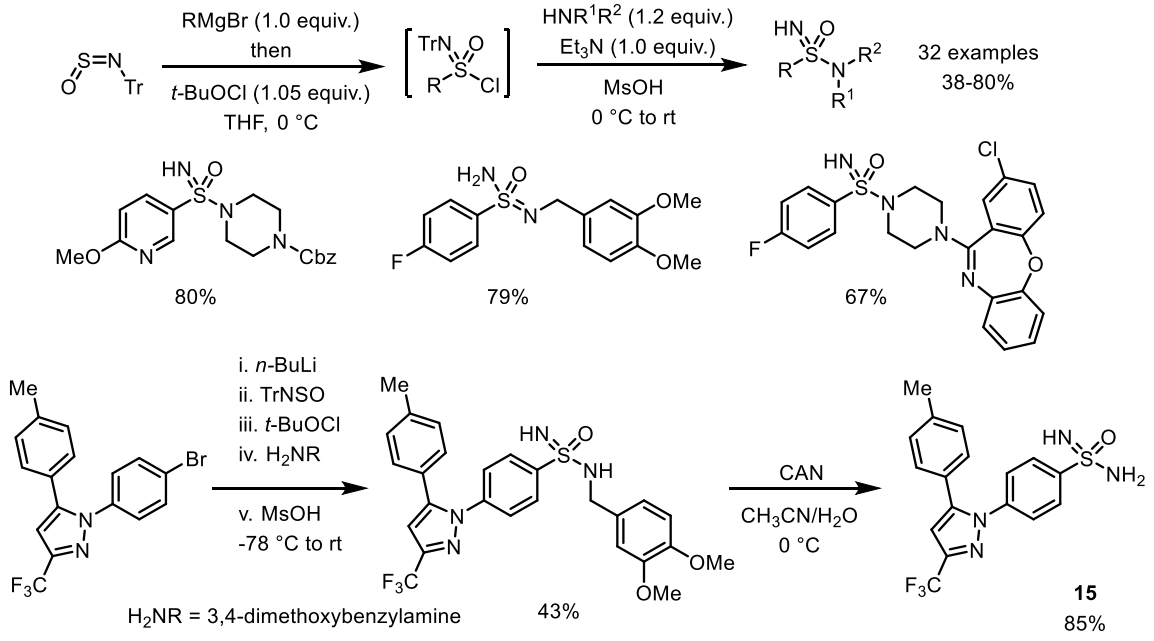


Figure 1.27. Willis' synthesis of sulfonimidamides from TrNSO

Also in 2017, the Stockman group reported a direct imination strategy to transform sulfinamides to sulfonimidamides[53] by employing similar conditions to those reported in

Bull's sulfoximine synthesis.[31] Various tertiary sulfonimidamides were prepared from tertiary sulfinamides in modest to good yields (**Figure 1.28**). When applying these conditions to primary and secondary sulfinamides, the corresponding sulfonimidate esters were obtained as the main side-products. The Bull group extended this strategy to realise the synthesis of tertiary sulfonimidamides from tertiary sulfenamides in 2019 (**Figure 1.29**),[54] although similar limitations also exist with this approach. An analogue **16** of the pharmacologically relevant sulfonamide probenecid was prepared using this methodology.

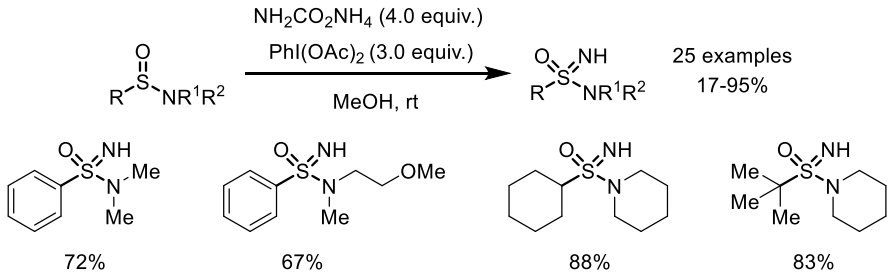


Figure 1.28. Stockman's synthesis of *N*-H sulfonimidamides from sulfinamides

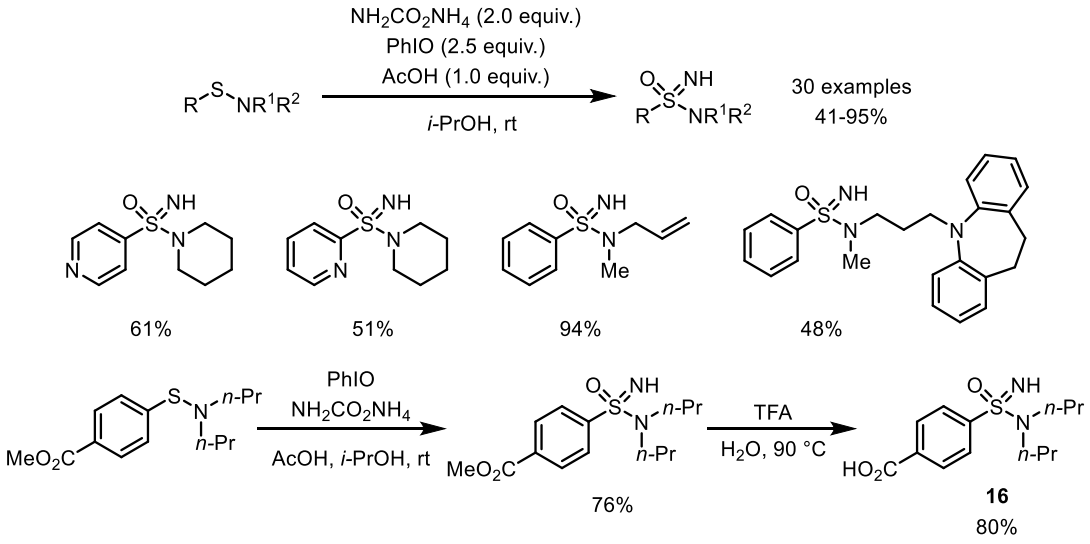


Figure 1.29. Bull's synthesis of *N*-H sulfonimidamides from sulfenamides

In 2019, the Bolm group reported a new method to synthesise *N*-Tr sulfonimidamides from the nucleophilic substitution of *N*-Tr, *S*-OBt sulfonimidates with amines.[55] The bench-stable reagent TrNSO was reacted with various (hetero)aryl diazonium salts in the presence of 1-hydroxybenzotriazole hydrate (HOBt) to generate the *N*-Tr, *S*-OBt sulfonimidates *via* a

radical process. The sulfonimidamide analogue **17** of Sildenafil was prepared using this methodology (**Figure 1.30**).

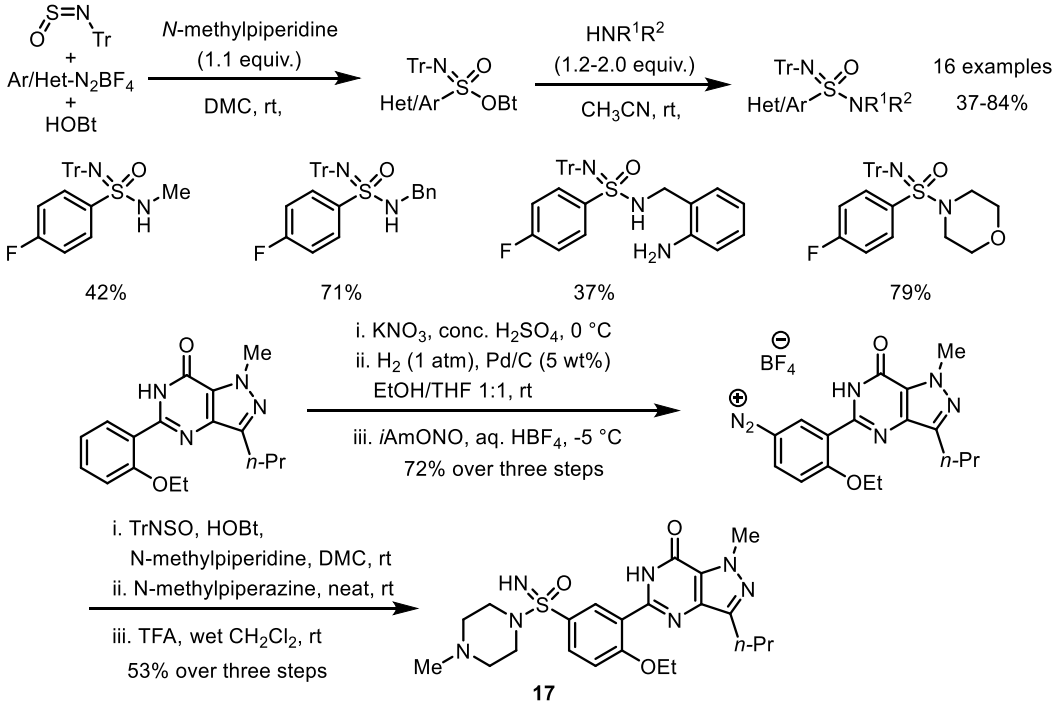


Figure 1.30. Bolm's synthesis of sulfonimidamides from TrNSO

In 2020, the Willis group reported another efficient strategy to synthesise sulfonimidamides by employing BiPhONSO **11** as the starting material. Combining BiPhONSO **11** with various organometallic reagents generates the corresponding sulfinyl nitrene intermediates **12** *in-situ*, which can be combined with amines in one-pot to give a broad range of *N*-H sulfonimidamides in good yields (**Figure 1.31**).[39]

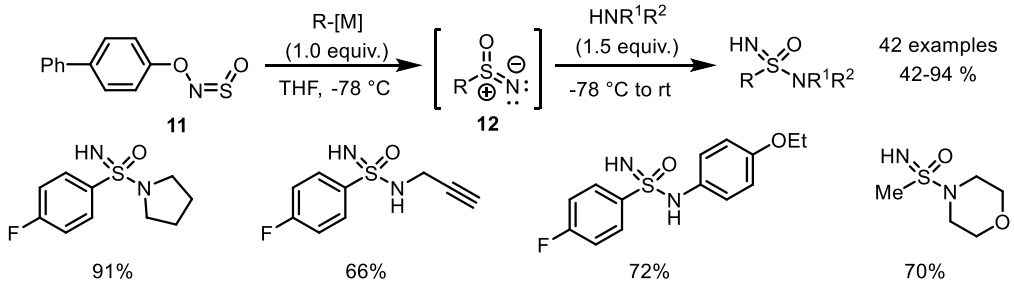


Figure 1.31. Willis' synthesis of sulfonimidamides from BiPhONSO

1.4 Synthesis of Sulfondiimines

Currently, the synthesis of sulfondiimines has only been achieved using one strategy: the double halogenation-amination of sulfides, which generates the corresponding sulfondiimines through sulfilimine intermediates (**Figure 1.32**).

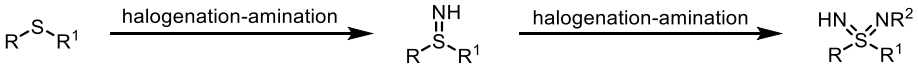


Figure 1.32. Known strategy for the synthesis of sulfondiimines

The earliest example of this method to synthesise sulfondiimines was reported by Haake and co-workers in 1970.[7] *t*-BuOCl was selected as the chlorination reagent, and several *S*,*S*-dialkyl sulfondiimines were generated in modest yields in the presence of liquid ammonia. The limitations are the lack of *S*-alkyl-*S*-aryl sulfondiimines and *S*,*S*-diaryl sulfondiimines and the low yields (**Figure 1.33**).

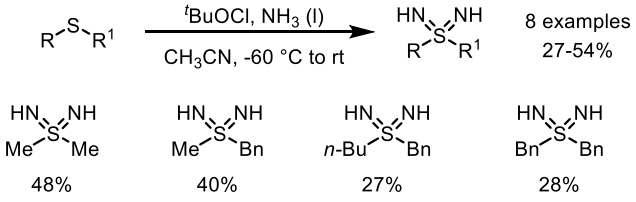


Figure 1.33. Haake's synthesis of sulfondiimines

In 1979, the Oae group reported a similar method to prepare sulfondiimines by using chloramine-T as the chlorinating reagent and TsNHNa as the amination reagent.[8] *S*,*S*-Diaryl sulfondiimines were obtained in good yields. However, *S*-alkyl-*S*-aryl sulfondiimines were generated in low yields due to the instability of the corresponding *N*-H sulfilimines. The Ts group could be removed in the presence of H_2SO_4 (**Figure 1.34**).

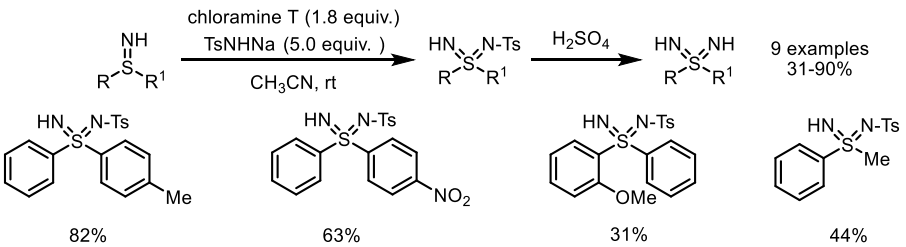


Figure 1.34. Oae's synthesis of sulfondiimines

Since 1992, the Yoshimura group reported another synthesis of *S*,*S*-diphenyl sulfondiimines by using the fluorination-amination of sulfilimines.[10-12] Selectfluor was selected as the fluorination reagent, which can convert the *N*-H sulfilimines to the *S*-fluorothiazyne **18**. *S*-fluorothiazynes **18** were then combined with various primary amines, providing *S*,*S*-diphenyl sulfondiimine examples in good yields. (**Figure 1.35**).

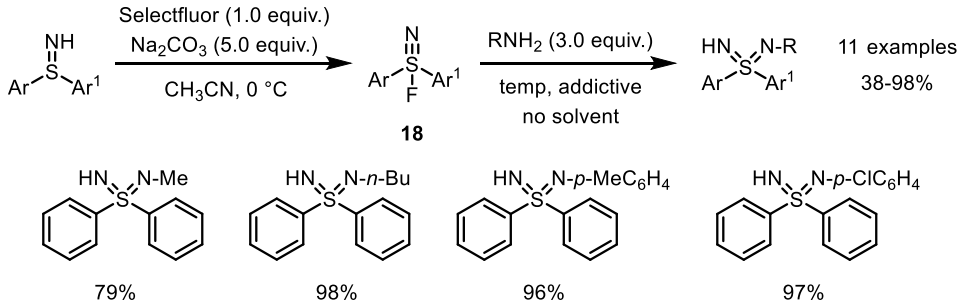


Figure 1.35. Yoshimura's synthesis of sulfondiimines

NCS was used by the Bolm group in 2012 to chlorinate sulfilimine salts.[13] The *S*-chlorothiazyne intermediate **19** formed *in-situ* was subsequently combined with various primary amines to provide a range of mono-*N*-substituted sulfondiimines. The starting *N*-H sulfilimine salts were prepared by the reaction of sulfides with MSH. However, the majority of the substrates are *S*-Me-*S*-aryl sulfondiimines, with only one *S*,*S*-diaryl sulfondiimine and one *S*,*S*-dialkyl sulfondiimine being synthesised by this method, and several examples were only obtained in low yields (**Figure 1.36**).

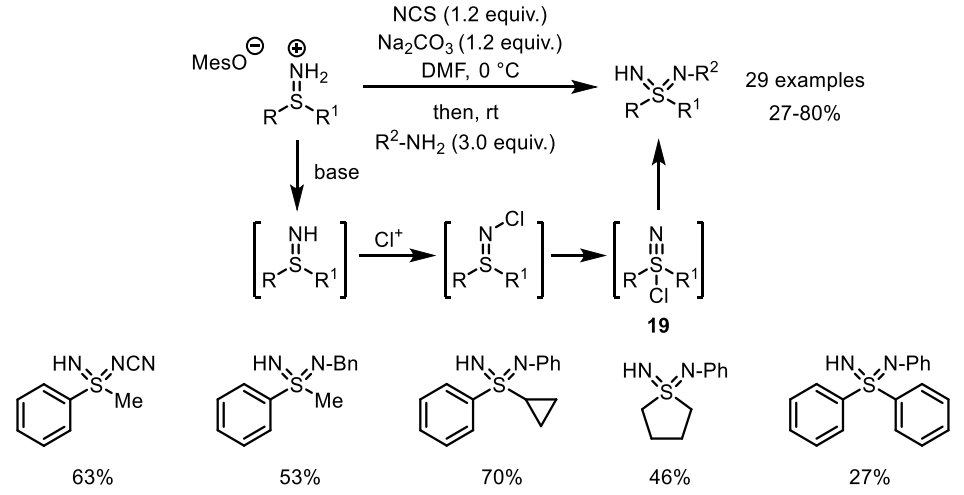


Figure 1.36. Bolm's synthesis of sulfondiimines

In conclusion, all the current methods to synthesise sulfondiimines employ sulfides as starting materials, and they convert the sulfides to corresponding sulfilimines or sulfilimine salts by a halogenation-amination strategy, generally under harsh reaction conditions. Sulfondiimines were obtained from the sulfilimines or sulfilimine salts by a second halogenation-amination sequence. There are several common limitations for this strategy: (1) the odorous nature of sulfides; (2) the generally poorer commercial availability of the sulfide starting materials; (3) harsh reaction conditions and use of explosive reagents limit the substrate scope of this method; and (4) the majority of the sulfondiimines were prepared with only modest yields (**Figure 1.37**).

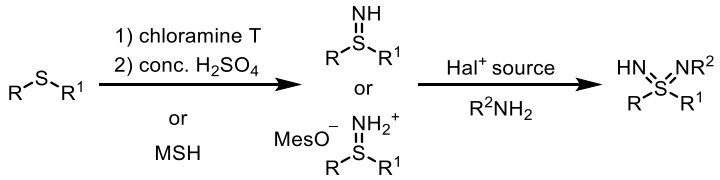


Figure 1.37. Classic strategy for the synthesis of sulfondiimines

1.5 Synthesis of Sulfondiimidamides

Sulfondiimidamides are essentially an unexplored functional group. Outside of the work presented in this thesis, there are only two reports of sulfondiimidamides in the literature.[18,19] Both of these require harsh reaction conditions and toxic reagents to synthesise the desired sulfondiimidamides. The first report is from the Laughlin group in 1968.[18] In their report, four tri-*N*-Me, *S*-alkyl sulfondiimidamides **20** were prepared in *ca*. 65% yield from the reaction of aliphatic mercaptans with methylchloramine in the presence of excess methylamine. If sulfenamide **21a** is treated with methylchloramine and dimethylamine, tetra-*N*-Me, *S*-Me sulfondiimidamide **21** could be isolated in *ca*. 20% yield (**Figure 1.38)**.

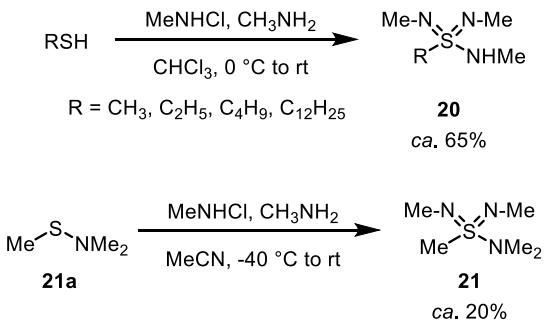


Figure 1.38. Laughlin's synthesis of sulfondiimidamides

In 1994, di-*N*-Tf primary sulfondiimidamide **24** was reported by the Yagupolskii group.[19] The highly reactive imination reagent, $TfNCl_2$ (prepared from the reaction of $TfNH_2$ and chlorine gas) was employed to convert phenyl disulfide to sulfondiimidoyl chloride **22** in 98% yield (**Figure 1.39)**. This then underwent a halogen-exchange reaction with SbF_3 to generate the di-*N*-Tf sulfondiimidoyl fluoride **23** in *ca*. 70% yield. The di-*N*-Tf primary sulfondiimidamide **24** was obtained through subsequent amination with ammonia gas.

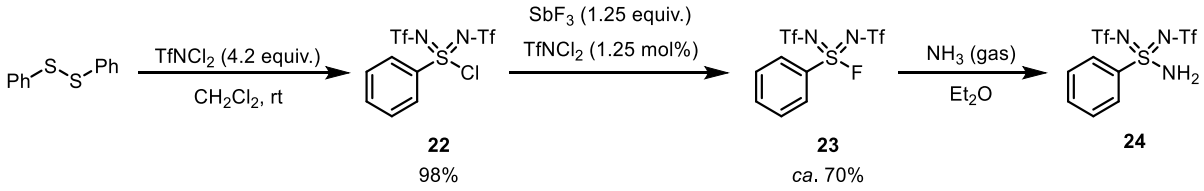


Figure 1.39. Yagupolskii's synthesis of sulfondiimidamides

Both these two methods suffer from similar limitations. They both require the use of odorous thiol or disulfide starting materials that are of limited commercial availability. The absence of other substrate examples and applications of these strategies in the literature suggests that these reactions are likely not easily generalised. As there are no derivatisation or deprotection methods disclosed this has severely limited the synthetic utility of these functional groups.

1.6 Research Aims

Sulfondiimines, as the di-aza analogues of sulfones, are highly valuable in the field of synthesis and medicinal chemistry. However, at present, sulfondiimines can only be synthesised from sulfides by two successive halogenation-amination sequences. The exploration and development of this functional group are still at its early stage due to the limitations of the current synthetic strategy. Therefore, we want to develop an efficient and robust synthesis of sulfondiimines using sulfinylamine reagents as the key starting materials (**Figure 1.40**).

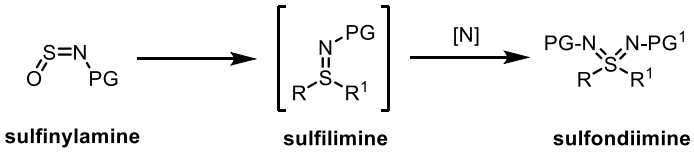


Figure 1.40. Our strategy for the synthesis of sulfondiimines

Sulfondiimidamides, as the di-aza analogues of sulfonamides, are compounds that have hardly been studied and are virtually unknown in the literature. Because there are currently no general synthetic routes, all of their chemical, physical and biological properties remain unexplored. Therefore, we also propose to develop a robust synthesis of sulfondiimidamides, again with the use of sulfinylamine reagents as starting materials (**Figure 1.41**).

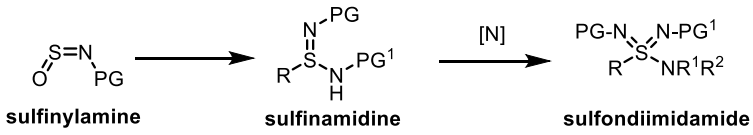


Figure 1.41. Our strategy for the synthesis of sulfondiimidamides

Chapter 2- A New Sulfondiimine Synthesis

2.1 Synthetic Strategy

Based on the limitations of the known strategies for the synthesis of sulfondiimines, we hoped to develop a new method that would avoid the use of malodorous sulfides or thiols as starting materials. In order to access a variety of highly functionalised sulfondiimines with various nitrogen substituents, we planned to generate orthogonally *N*-protected sulfondiimines. We proposed that a suitable precursor to these compounds would be a *N*-protected sulfilimine, therefore, requiring the development of a suitable imination method. Although there are reports of imination of unprotected sulfilimines, they are limited to a singular sulfilimine substrate and are unfortunately low yielding. To access the *N*-protected sulfilimines, we planned to use two different organometallic reagents as the two carbon fragments of the sulfilimine. Therefore, selecting a suitable sulfur(IV) linchpin was crucial to the success of our strategy. Due to the fact that a reagent with two different leaving groups is challenging to prepare, we chose to use a stable sulfinylamine reagent as the starting sulfur linchpin, which can be activated for nucleophilic attack in the presence of Lewis acid (**Figure 2.1**).

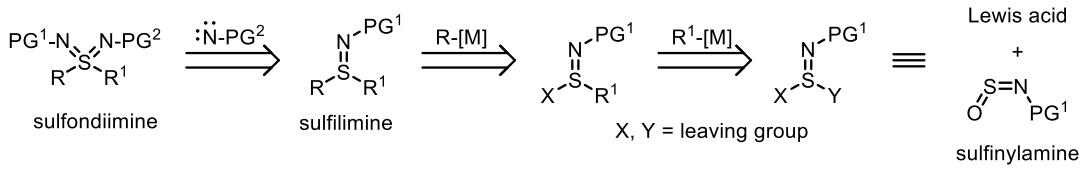


Figure 2.1. Retrosynthesis of sulfondiimines

Our strategy is shown below (**Figure 2.2**): the addition of an oxophilic Lewis acid to coordinate with a suitable sulfinylamine, followed by the addition of a Grignard reagent would lead to the formation of the proposed sulfinamide intermediate. The activated hydroxy leaving group could then be displaced in a substitution reaction through the addition of a

second Grignard reagent to give the corresponding sulfilimine. Finally, sulfondiimines and sulfoximines could be obtained *via* imination or oxidation of the sulfilimines, respectively.

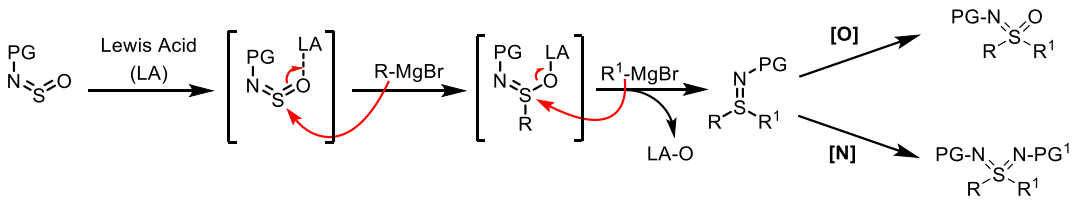


Figure 2.2. Synthetic strategies of sulfondiimines and sulfoximines

2.2 Synthesis of Sulfinylamine

Although many sulfinylamines are reported to be highly moisture sensitive,[56] which is undesirable, there are some additional requirements that we need to consider when choosing a suitable sulfinylamine reagent: firstly, the reagent needs to have sufficient reactivity while also being stable for long-term storage; secondly, the *N*-protecting group should be readily deprotected to obtain the free amine, allowing for the synthesis of varied *N*-substituted sulfondiimines; thirdly, in later findings, it was found that the *N*-protecting group of sulfilimine should be electron-rich to enable the final imination step. With these considerations in hand, it was found that *N*-sulfinyl-*tert*-octylamine (*t*-Oct-NSO) **25** was a suitable reagent, which can be easily synthesised from cheap, commercially available *t*-octylamine and thionyl chloride (**Figure 2.3**). It can be prepared in excellent yield on gram scale, is relatively moisture insensitive, retaining reactivity after storage for at least two months at -20 °C.

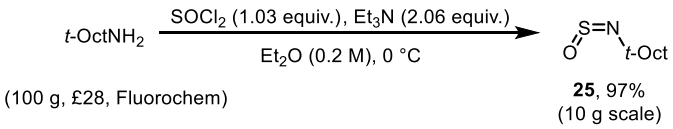


Figure 2.3. Preparation of *t*-Oct-NSO

2.3 Synthesis of Sulfilimines

In initial attempts, $BF_3{\cdot}Et_2O$ was selected as the Lewis acid to coordinate with the oxygen of the sulfinylamine. After stirring *t*-Oct-NSO **25** with $BF_3{\cdot}Et_2O$ (1.3 equiv.) in THF at 0 °C for 10 min, the first Grignard reagent (1.05 equiv.) was added at the same temperature and stirred for 1 min, before the addition of the second Grignard reagent (5.0 equiv.). The desired sulfilimine **26** was obtained in modest yield (53%). Upon isolation and characterisation of the side-products of the reaction, a complex mixture of compounds was obtained along with the product. The sulfinamide **27** resulting from simple addition to the sulfinylamine reagent was identified as the main side-product (**Figure 2.4**).

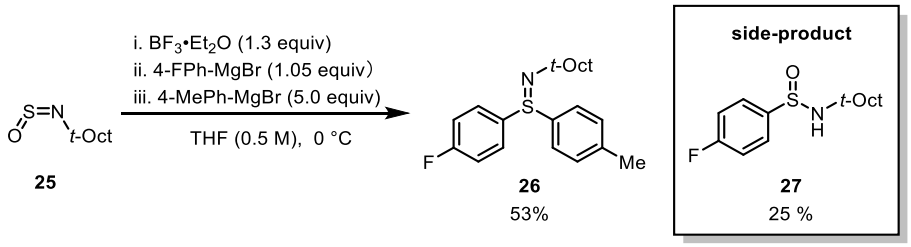


Figure 2.4. Initial synthesis of sulfilimine

Alternatively, from a mechanistic point of view, the second Grignard reagent may not only attack at the sulfur center of intermediate **28** (attack S, black arrows), but may also attack the electrophilic boron (**Figure 2.5**), hence providing an additional pathway to the sulfinamide side-product (attack B, blue arrows). We speculated that there might be a greater preference of nucleophilic addition to sulfur than silicon (attack Si, red arrows) when a silicon-based Lewis acid is employed in comparison to a boron-centred Lewis acid, due to the steric hindrance and electropositivity of the silicon-based Lewis acid. Therefore, TMSOTf and TESOTf were evaluated in place of $BF_3{\cdot}Et_2O$.

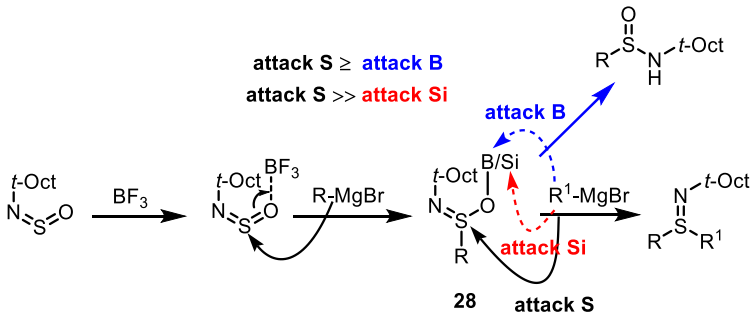
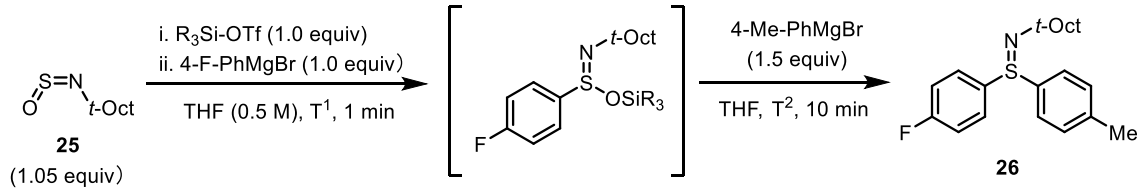


Figure 2.5. Nucleophilic attack pathways in sulfilimine synthesis

Upon optimisation (**Table 2.1**), TMSOTf was found to be the most effective among the Lewis acids explored, with the reaction kept at -78 °C to avoid decomposition (**Entries 1-4**). Modifying the temperature of the second step led to an improvement of the yield (**Entries 5-6**). Therefore, the reaction was kept at -78 °C in the first step to avoid decomposition, and then warmed up to -30 °C in the second step, forming sulfilimine **26** in 85% yield.

Table 2.1. Optimisation of one-pot sulfilimine synthesis from sulfinylamine[a]



Entry	R_3Si-OTf	T^1	T^2	Yield of 26
1	TESOTf	rt	rt	47%
2	TESOTf	0 °C	0 °C	65%
3	TESOTf	-78 °C	-78 °C	66%
4	TMSOTf	-78 °C	-78 °C	73%
5	**TMSOTf**	**-78 °C**	**-30 °C**	**85%**
6	TMSOTf	-78 °C	-15 °C	80%

a. 4-F-PhMgBr (1.0 equiv.), *t*-Oct-NSO **25** (1.05 equiv.), R_3Si-OTf (1.0 equiv.), THF (0.5 M), -78 °C, 1 min, then 4-Me-PhMgBr (1.5 equiv.), -30 °C, 10 min. Isolated yields.

2.4 Synthesis of Sulfondiimines

After realising conditions for the synthesis of *N*-*t*-Oct sulfilimine **26** in good yield, we turned our attention to converting the sulfilimines into the corresponding sulfondiimines. Although imination reactions of sulfides and sulfoxides have been well developed, with a number of

combinations of metal catalysts and imination reagents being used (**Figure 2.6**),[20] there is only one method that has been reported for the imination of sulfilimines. This uses *N*-H sulfilimine substrates and proceeds *via* a chlorination-amination strategy and was developed by the Bolm group (**Figure 2.7**).[13]

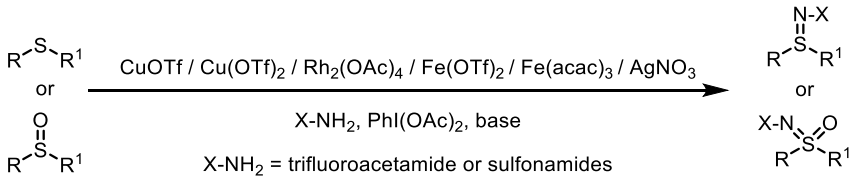


Figure 2.6. Metal-catalysed imination reactions of sulfides and sulfoxides

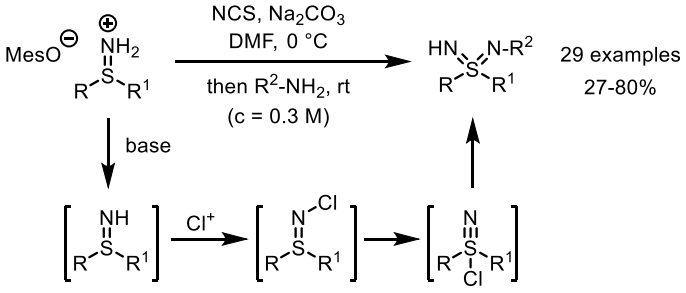
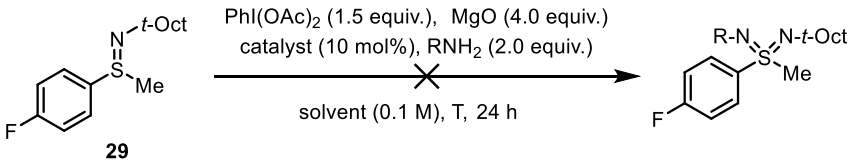


Figure 2.7. Bolm's imination method of *N*-H sulfilimines

Since there is not a general method for imination of *N*-protected sulfilimines, we planned to develop a novel metal-catalysed method to iminate the *N*-protected sulfilimines to the corresponding sulfondiimines. Taking inspiration from known methods for imination of sulfoxides,[20] we proposed the use of *in-situ* generated iminoiodinanes (PhI=NR) with sulfilimine **29** for initial reactions. Our study began by employing RNH_2 (2.0 equiv.), $PhI(OAc)_2$ (1.5 equiv.), MgO (4.0 equiv.) and various metal catalysts (10 mol%) at different temperatures. These reactions are thought to proceed through the generation of an activated [M]=NR species *in-situ* using a metal catalyst. However, none of the desired product was obtained after trying several different metal catalyst combinations, with starting material being recovered in all cases (**Table 2.2**).

Table 2.2. Initial attempt imination of sulfilimine



Entry	Catalyst	RNH_2	Solvent	T	Yield
1	$Rh_2(OAc)_4$	CF_3CONH_2	CH_2Cl_2	rt	0%
2	$Rh_2(OAc)_4$	CF_3CONH_2	CH_2Cl_2	40 °C	0%
3	$Rh_2(OAc)_4$	CF_3CONH_2	$C_2H_4Cl_2$	60 °C	0%
4	$Rh_2(OAc)_4$	$NsNH_2$	CH_2Cl_2	40 °C	0%
5	$Rh_2(OAc)_4$	$NsNH_2$	$C_2H_4Cl_2$	70 °C	0%
6	$Rh_2(OAc)_4$	$BocNH_2$	CH_2Cl_2	40 °C	0%
7	$Rh_2(OAc)_4$	NH_2COOMe	CH_2Cl_2	40 °C	0%
8	$Fe(acac)_3$	$NsNH_2$	CH_2Cl_2	40 °C	0%
9	$Fe(OTf)_2$	$NsNH_2$	CH_2Cl_2	40 °C	0%
10	$Cu(OTf)_2$	$NsNH_2$	CH_2Cl_2	40 °C	0%
11	Rh_2esp_2	$NsNH_2$	CH_2Cl_2	40 °C	0%
12	Rh_2esp_2	DPH	CF_3CH_2OH	rt	0%

From a mechanistic perspective, PhI=NR are generated *in-situ* from the reaction of RNH_2 and $PhI(OAc)_2$, with AcOH formed as a by-product (**Figure 2.8).** The presence of such an acid may protonate the sulfilimine **29** and MgO may not be basic enough to neutralise the resultant sulfilimine salt.

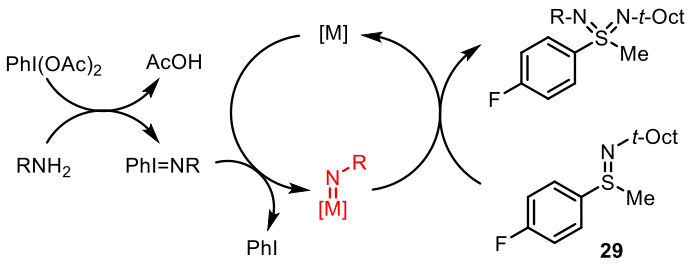
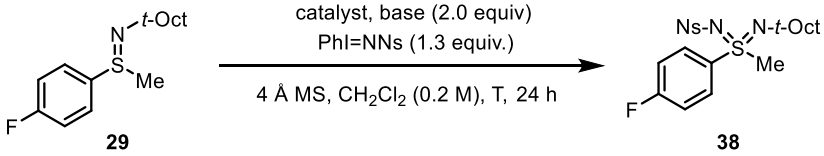


Figure 2.8. Proposed mechanism for metal-catalysed imination of sulfilimine

In order to avoid the formation of acetic acid in the reaction, PhI=NNs, a stable preformed iminoiodinane, was used instead (**Table 2.3**). A combination of $Rh_2(OAc)_4$ (5 mol%) with PhI=NNs (1.3 equiv.) and 4 Å molecular sieves in CH_2Cl_2, stirred at 40 °C for 24 h resulted in the formation of the desired sulfondiimine **38**, isolated in 13% yield (**Entry 1**). A modest yield was obtained in the presence of a base, Na_2CO_3 (**Entry 2**). When changing the catalyst

from $Rh_2(OAc)_4$ to $Rh_2(esp)_2$, a significantly improved yield of 80% was achieved (**Entry 3**). After further optimisation, we settled on optimised conditions, which involved using DBU as base (2.0 equiv.) and 2.5 mol% of $Rh_2(esp)_2$ at 40 °C (**Entry 4**). We could further reduce the catalyst loading to 0.5 mol% on a gram scale with a 78% yield being achieved (**Entry 6**). Using alternative metals such as $Fe(OTf)_2$ or $Cu(OTf)_2$ gave none of the desired sulfondiimine **38** (**Entries 7-8**).

Table 2.3. Optimisation of metal-catalysed imination reaction[a]



Entry	Catalyst	Base	T	Yield of 38
1	$Rh_2(OAc)_4$ (5.0 mol%)	-	40 °C	13%
2	$Rh_2(OAc)_4$ (5.0 mol%)	Na_2CO_3	40 °C	40%
3	$Rh_2(esp)_2$ (5.0 mol%)	Na_2CO_3	40 °C	80%
4	**$Rh_2(esp)_2$ (2.5 mol%)**	**DBU**	**40 °C**	**88%**
5	$Rh_2(esp)_2$ (2.5 mol%)	DBU	22 °C	82%
6	$Rh_2(esp)_2$ (0.5 mol%)	DBU	40 °C	78%
7	$Fe(OTf)_2$ (10 mol%)	Na_2CO_3	40 °C	0%
8	$Cu(OTf)_2$ (10 mol%)	Na_2CO_3	40 °C	0%

a. Sulfilimine **29** (1.0 equiv.), PhI=NNs (1.3 equiv.), base (2.0 equiv.), CH_2Cl_2 (0.2 M), 24 h. Isolated yields.

With an efficient method for the imination of sulfilimines now in hand, we began to vary the organometallic reagents to investigate the scope of sulfilimine and sulfondiimine synthesis. Due to the instability of electron-rich sulfilimines, the *S*,*S*-dialkyl sulfilimines and *S*-alkyl-*S*-aryl sulfilimines were used directly for the imination step after an aqueous wash and extraction. The *S*,*S*-diaryl sulfilimines were used after being purified by flash column chromatography. The yields reported in **Figure 2.9** are given over two steps, using the first Grignard reagent as the limiting reagent. A range of *N*-*t*-Oct, *N*-Ns sulfondiimines could be synthesised with modest to good yields by employing various (hetero)aryl Grignard reagents as the first nucleophilic partner, followed by a (hetero)aryl or alkyl Grignard as the second

nucleophile (**30**-**33, 38**-**42**). *S*,*S*-di(hetero)aryl sulfondiimines usually give modest yields due to the slow imination step (**30**-**37**), and the unreacted sulfilimines could be recovered. Organolithium reagents are also competent nucleophiles in the reaction (**34**, 32%), which presents an opportunity to synthesise some heteroaryl-substituted sulfondiimines (**35**, 43% and **36**, 35%). Sulfondiimine **37** containing the aryl unit of the marketed COX-2 inhibitor Celecoxib was accessed in 34% yield. Pleasingly, we found that the addition sequence of aryl and alkyl Grignard reagents could be reversed (**43**, 40%). For *S*,*S*-dialkyl sulfondiimines, low yields were obtained (**44**, 26%, **45**, 17% and **46**, 35%). This is presumed due to the instability of the corresponding sulfilimine intermediates, with decomposition occurring during the imination step.

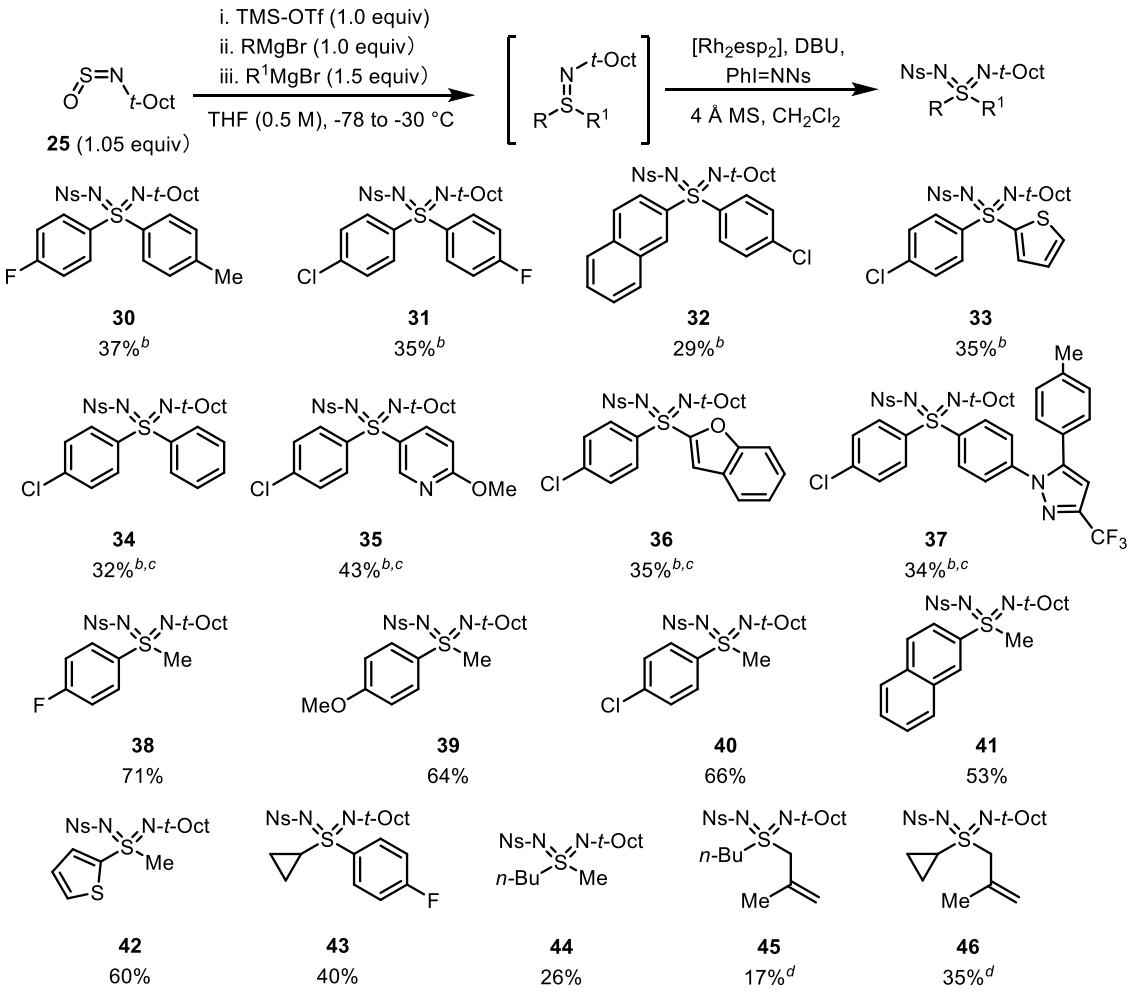


Figure 2.9. Scope of sulfondiimines[a]

a. RMgBr (1.0 equiv.), *t*-Oct-NSO **25** (1.05 equiv.), TMS-OTf (1.0 equiv.), THF (0.5 M), –78 °C, 1 min, then R^1MgBr (1.5 equiv.), –30 °C, 10 min. Aqueous work-up or flash column chromatography. PhI=NNs (1.3 equiv.), [$Rh_2(esp)_2$] (2.5 mol%), DBU (2.0 equiv.), CH_2Cl_2 (0.2 M), 40 °C, 24 h. Isolated yields. ***b***. Total of 4.5 equiv of PhI=Ns used (1.5×3), [$Rh_2(esp)_2$] (5.0 mol%), DBU (4.0 equiv.), 60 °C, 24 h. ***c***. Organolithium used as 2nd nucleophile. ***d***. Using 2-methyl-1-propenylmagnesium bromide as 2nd organometallic reagent.

2.5 Synthesis of Sulfoximines

As well as the imination of sulfilimines, we were also interested in the oxidation of sulfilimines to generate sulfoximines. Using this synthetic strategy to access sulfoximines avoids the use of thiols or sulfides, which is the common limitation for sulfoximine synthesis. Initial attempts for the oxidation of sulfilimines using *m*-CPBA only gave 26% yield (**Figure 2.10**). One possibility for this low yield is competing *N*-oxidation of this electron-rich sulfilimine.

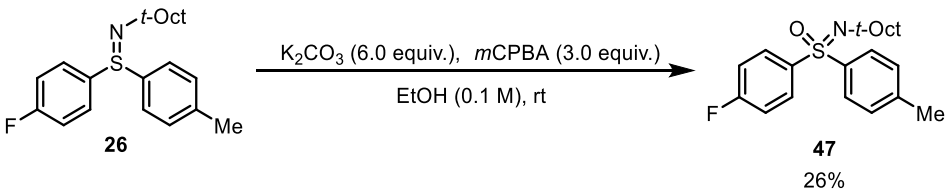


Figure 2.10. Initial synthesis of sulfoximines

Pleasingly, it was found that using *N*-methylmorpholine *N*-oxide (NMO) in combination with tetra-propylammonium perruthenate (TPAP) as a catalyst was an effective method to convert the sulfilimine **26** into sulfoximine **47** in excellent yield (**Figure 2.11**).

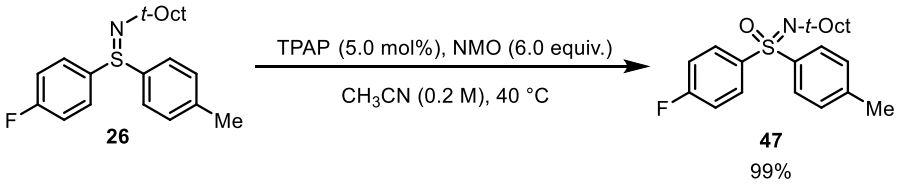


Figure 2.11. TPAP-catalysed oxidation of sulfilimines

The yields reported in **Figure 2.12** are given over two steps, using the first Grignard reagent as the limiting reagent. A board range of *S*,*S*-diaryl and *S*-aryl-*S*-alkyl sulfoximines were generated with good yield (**47-53, 57-59**). Furthermore, heteroaryl-substituted examples (**54**,

67% and **55**, 74%) and a substrate **56** containing the aryl unit of the marketed COX-2 inhibitor, Celecoxib, were well tolerated. 2-Methylphenyl-substituted sulfoximine **52** was prepared in 56% yield, demonstrating the tolerance of steric hindrance with this method. *S*,*S*-dialkyl sulfoximines were still the most challenging substrates to synthesise due to the instability of the sulfilimine intermediates (**60**, 24% and **61**, 47%).

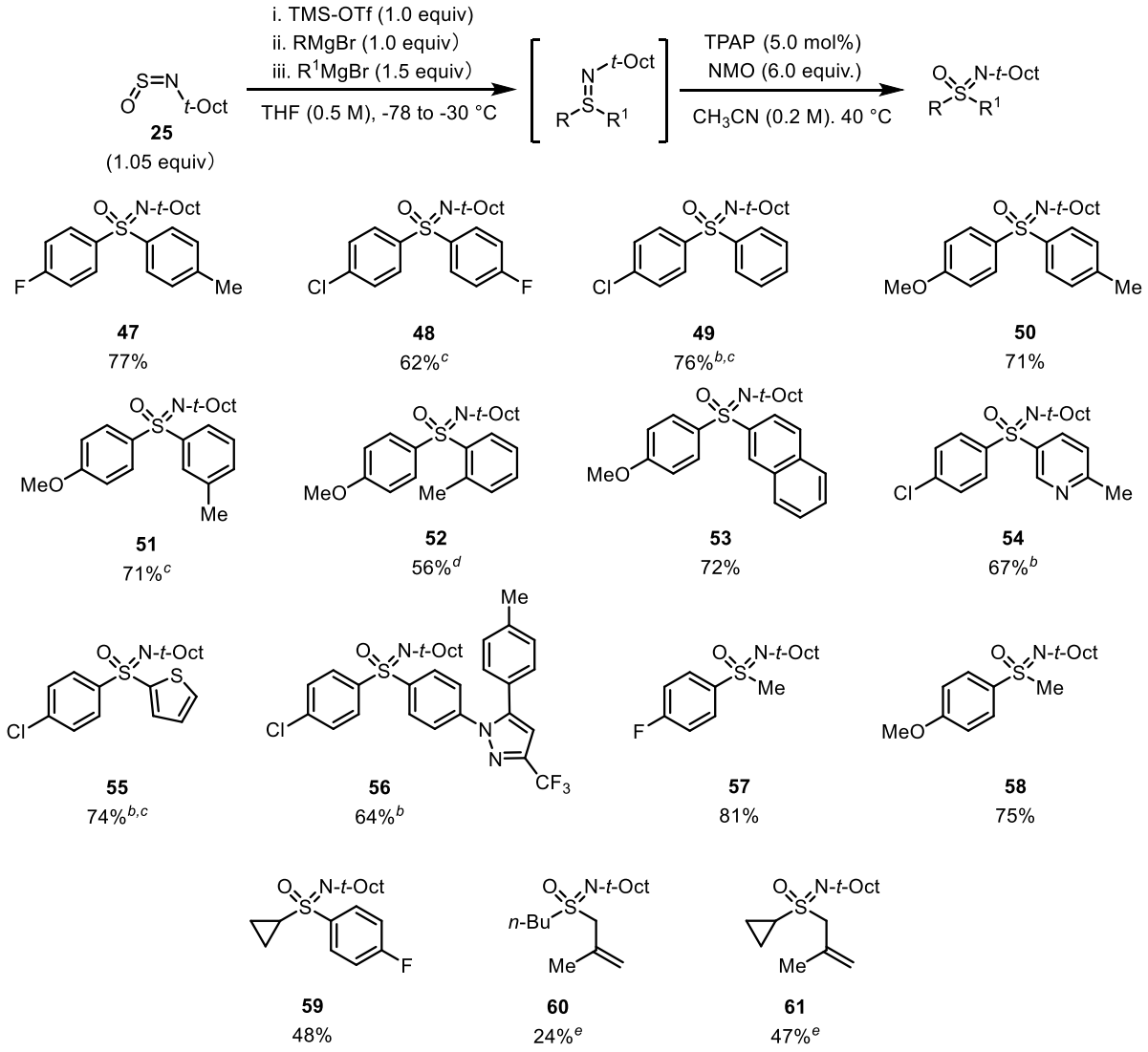


Figure 2.12. Scope of sulfoximines[a]

a. RMgBr (1.0 equiv.), *t*-Oct-NSO **25** (1.05 equiv.), TMS-OTf (1.0 equiv.), THF (0.5 M), –78 °C, 1 min, then R^1MgBr (1.5 equiv.), –30 °C, 10 min. Aqueous work-up or flash column chromatography. TPAP (5 mol%), NMO (6.0 equiv), CH_3CN (0.2 M), 40 °C. Isolated yields. ***b.*** Organolithium used as 2nd nucleophile. ***c***. 50 °C for 2nd step. ***d***. TPAP (15 mol%). ***e***. Using 2-methyl-1-propenylmagnesium bromide as 2nd organometallic reagent.

2.6 Deprotection and *N*-Functionalisation

With a broad range of *N*-*t*-Oct, *N*-Ns sulfondiimines in hand, we explored the scope of sulfondiimines that we could access through *N*-functionalisation. Therefore, the orthogonal deprotection of the nosyl and *t*-octyl groups become our immediate synthetic target (**Figure 2.13**). The nosyl group deprotection could be realized by the reaction of sulfondiimine **38** with dodecanethiol (5.0 equiv.) and DBU (4.75 equiv.), giving *N*-*t*-Oct, *N*-H sulfondiimine **62** with 89% yield. Conversely, the *t*-octyl group could be removed by treatment with TFA (0.1 M) at room temperature, generating the *N*-Ns, *N*-H sulfondiimine **63** in 97% yield. Performing the two reactions sequentially gave the di-*N*-H sulfondiimine **64** in excellent yield.

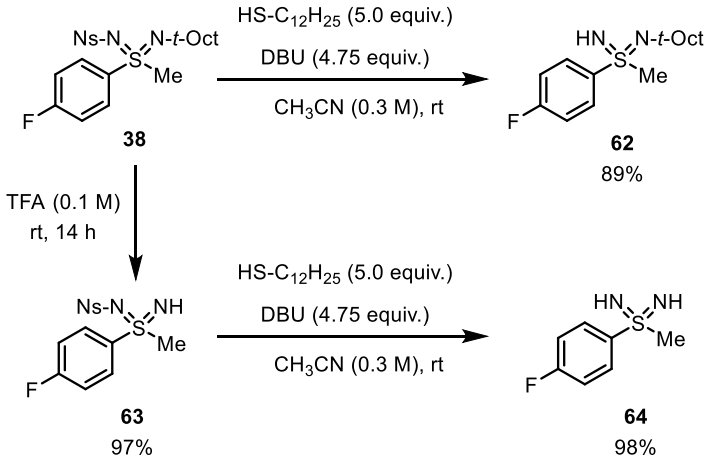


Figure 2.13. Deprotection of sulfondiimines

In an analogous manner, for the *N*-*t*-Oct sulfoximine **47**, the *t*-octyl group could be removed by treatment with TFA (0.1 M) at 60 °C to afford the *N*-H sulfoximine **65** in quantitative yield (**Figure 2.14**).

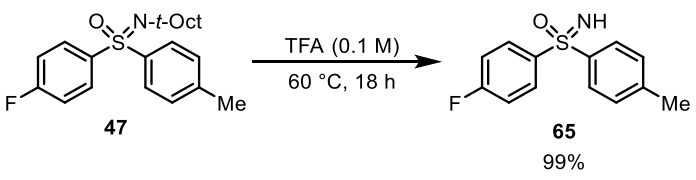


Figure 2.14. Deprotection of sulfoximine

The *N*-H sulfilimine salt **66** was also prepared in 97% yield using TfOH (5.0 equiv.) to cleave the *t*-octyl group, followed by TsOH (1.1 equiv.) to form an isolable salt (**Figure 2.15**).

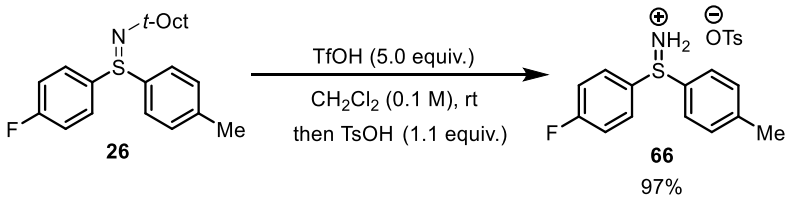


Figure 2.15. Deprotection of sulfilimine

After realising the synthesis of sulfondiimines with different protecting groups, we began to investigate different *N*-functionalisation reactions of sulfondiimines. The different electronic characters of the nosyl and *t*-octyl groups provided opportunities to functionalise the nitrogen atom with different groups. For *N*-arylation, we selected the *N*-*t*-Oct, *N*-H sulfondiimine **62** for initial reactions. Implementing traditional conditions used for Chan-Lam reaction, gave the required *N*-*t*-Oct, *N*-Ph sulfondiimine **67** in 93% yield (**Figure 2.16**). However, attempt to prepare *N*-Ph, *N*-H sulfondiimine **69** by removal of the *t*-octyl protecting group of sulfondiimine **67** with TFA gave us an unidentified mixture of compounds.

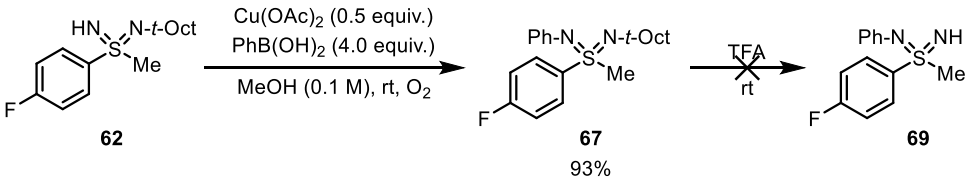


Figure 2.16. Initial attempt for the synthesis of *N*-aryl, *N*-H sulfondiimine **69**

Due to this, *N*-Ns, *N*-H sulfondiimine **63** was selected as the starting material for *N*-arylation. Using this new substrate, *N*-arylation worked efficiently under a modified Chan-Lam reaction conditions,[57] followed by deprotection with dodecanethiol (5.0 equiv.) and DBU (4.75 equiv.), generating the *N*-Ph, *N*-H sulfondiimine **69** in 67% yield over two steps (**Figure 2.17**).

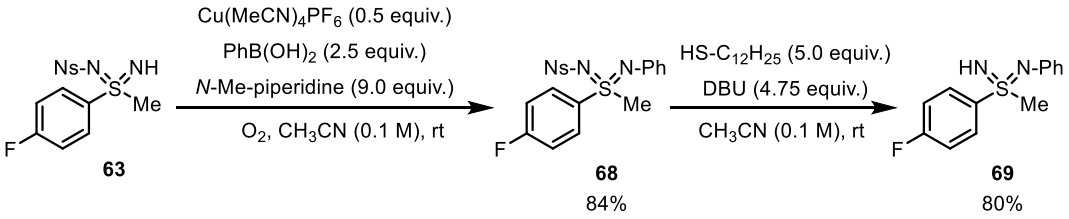


Figure 2.17. Synthesis of *N*-aryl, *N*-H sulfondiimine **69**

Due to the electron-withdrawing properties of the nosyl group, sulfondiimine **63** was easily deprotonated. The *in-situ* generated nitrogen anion could react with allyl bromide efficiently for *N*-allylation, followed by nosyl deprotection, providing the *N*-allyl, *N*-H sulfondiimine **71** in 76% yield over two steps (**Figure 2.18**).

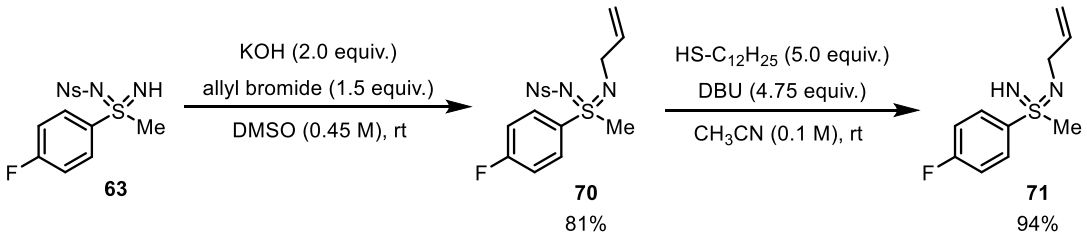


Figure 2.18. Synthesis of *N*-allyl, *N*-H sulfondiimine **71**

The *N*-*t*-Oct, *N*-H sulfondiimine **62** reacted with acetic anhydride smoothly, giving *N*-*t*-Oct, *N*-acyl derivative **72** in 99% yield. Then TFA (0.1 M) was selected to remove the *t*-octyl group, providing the *N*-acyl, *N*-H sulfondiimine **73** in 90% yield (**Figure 2.19**).

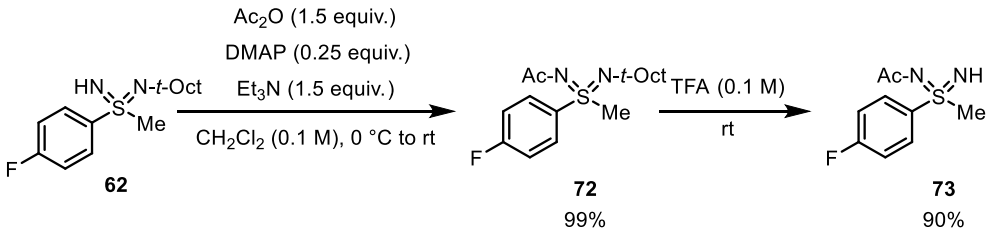


Figure 2.19. Synthesis of *N*-acyl, *N*-H sulfondiimine **73**

The *N*-urea derivative **74** was obtained in 98% yield from the reaction of sulfondiimine **62** with phenyl isocyanate under mild conditions. The *N*-urea, *N*-H sulfondiimine **75** was

generated in 86% yield after treatment with TFA (0.1 M) to remove the *t*-octyl group. These compounds are of interest due to their unique hydrogen bonding properties (**Figure 2.20**).

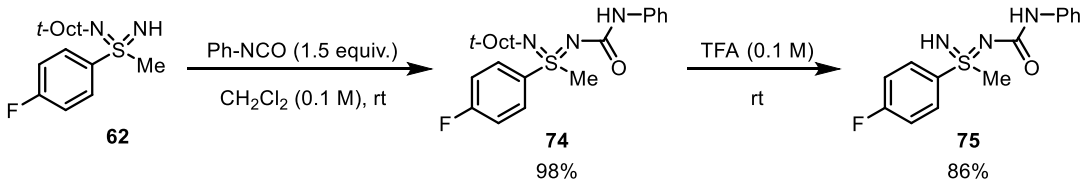


Figure 2.20. Synthesis of *N*-urea, *N*-H sulfondiimine **75**

Due to the electron-donating property of the *t*-octyl group, sulfondiimine **62** was also selected to explore reductive-amination reactions. Pleasingly, using this approach, the *N*-benzyl, *N*-H sulfondiimine **77** was obtained in 71% yield over two steps, following *t*-octyl deprotection (**Figure 2.21**).

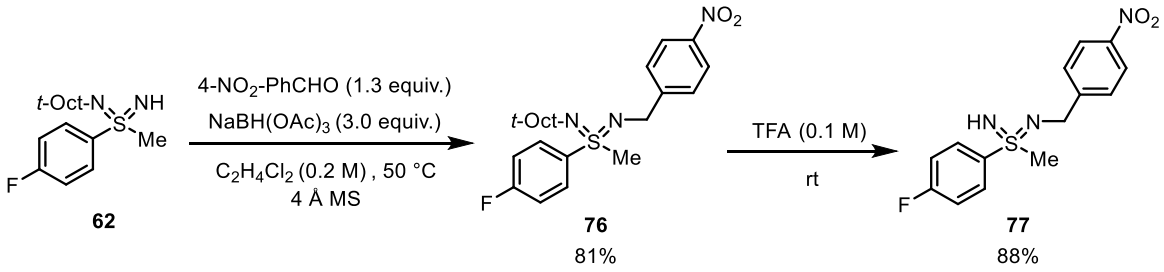


Figure 2.21. Synthesis of *N*-benzyl, *N*-H sulfondiimine **77**

2.7 Summary

We have developed a novel sulfondiimine synthesis method by combining two organometallic reagents and a sulfinylamine linchpin, followed by a rhodium-catalysed imination. The use of thiols or sulfides as the starting reagents were avoided. This methodology displays a broad substrate scope of organometallic nucleophiles, including various (hetero)aryl and alkyl derivatives. Orthogonal *N*-protecting groups were employed, allowing for flexible deprotection facilitating varied functionalization reactions. Taken together, this method provides the synthesis of the most diverse range of sulfondiimines to date, giving the possibility of further application of these interesting functional groups in pharmaceutical chemistry. The work described in this chapter has been published.[58]

Chapter 3- A New synthetic route to sulfondiimidamide

3.1 Synthetic Strategy

Sulfondiimidamides, the di-aza analogue of sulfonamides, are a relatively underexploited functional group in the literature.[18,19] One possible reason could be due to their electron-rich sulfur center, which may lead to instability at room temperature. This would mean that many of the methods to synthesise sulfonimidamides and sulfonamides cannot be extended to synthesise sulfondiimidamides. Based on the analysis of literature preparations of sulfonimidamides in **Chapter 1.3**, the nucleophilic substitution of sulfondiimidoyl halides by amines should provide a robust strategy for the synthesis of sulfondiimidamides (**Figure 3.1**). In order to prepare sulfondiimidamides with orthogonal *N*-protecting groups, the corresponding orthogonally *N*-protected sulfinamidines must in turn be synthesised.

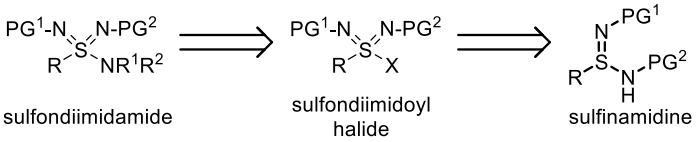


Figure 3.1. Sulfondiimidamide synthetic strategy

However, the synthesis of unsymmetrical sulfinamidines is itself also an underexplored field.[59] Our initial synthetic strategy involved a metal-catalysed imination of a sulfenamide, which itself can be prepared from the displacement reaction of an amine with a succinimide-protected thiol (**Figure 3.2**).[60] The succinimide-protected thiol can in turn be synthesised from the corresponding thiol by electrophilic amination using *N*-chlorosuccinamide (NCS).[61]

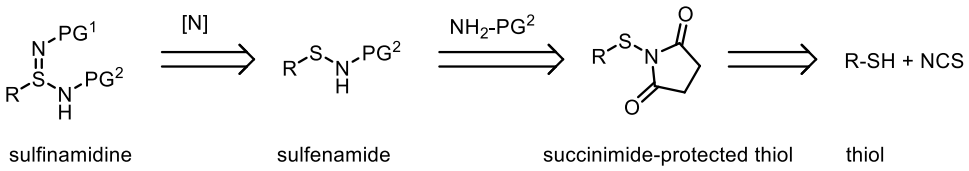


Figure 3.2. Retrosynthesis of sulfinamidines

3.2 First Generation of Sulfinamidine Synthesis

Based on our retrosynthetic analysis, we used 4-fluorobenzenethiol as the initial starting material. Amination with *N*-chlorosuccinimide proceeded smoothly to give sulfenamide **78** in 82% yield (**Figure 3.3**). Subsequent reaction of this compound with *t*-octylamine gave sulfenamide **79**, which was used directly for the next imination step, following an aqueous work-up. Imination with PhI=NNs in the presence of a $Rh_2(esp)_2$ catalyst gave the desired orthogonal *N*-protected sulfinamidine **85** in excellent yield (93% over 2 steps).

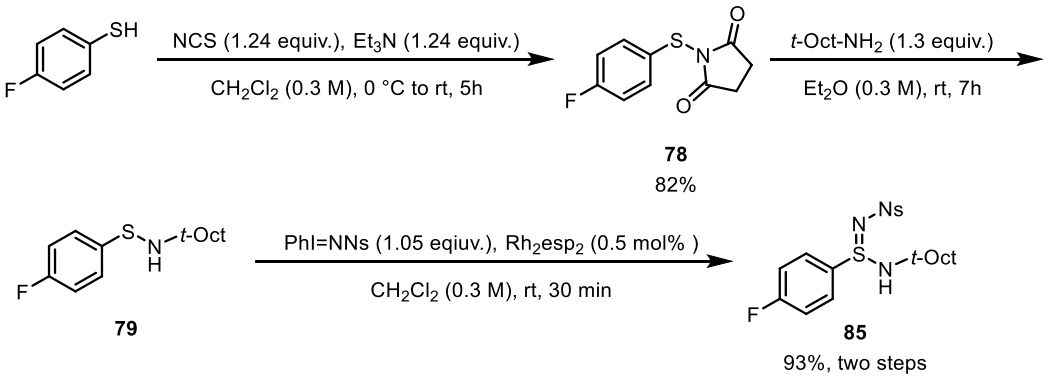


Figure 3.3. First generation of sulfinamidine synthesis

However, this sulfinamidine synthesis route has some significant limitations. Firstly, the need to use a thiol as the starting material is a severe limitation due to their instability towards oxidation, odorous nature and limited commercial availability. Secondly, at least three steps are needed (if the thiol is commercially available) to synthesise the sulfinamidine, and this usually takes in the region of two days. Thirdly, $Rh_2(esp)_2$ is an expensive catalyst, making the approach costly even when used at the low catalyst loading of 0.5 mol%.

3.3 Second Generation of Sulfinamidine Synthesis

Inspired by our sulfilimine synthetic route, we hoped to use a similar idea to prepare the orthogonal *N*-protected sulfinamidines (**Figure 3.4**). The desired sulfinamidine could be prepared by the reaction of a sulfinylamine with one amine nucleophile and one organometallic reagent. *t*-Oct-NSO **25** was again selected as the sulfinylamine starting

material due to its stability under ambient conditions whilst also maintaining sufficient reactivity.

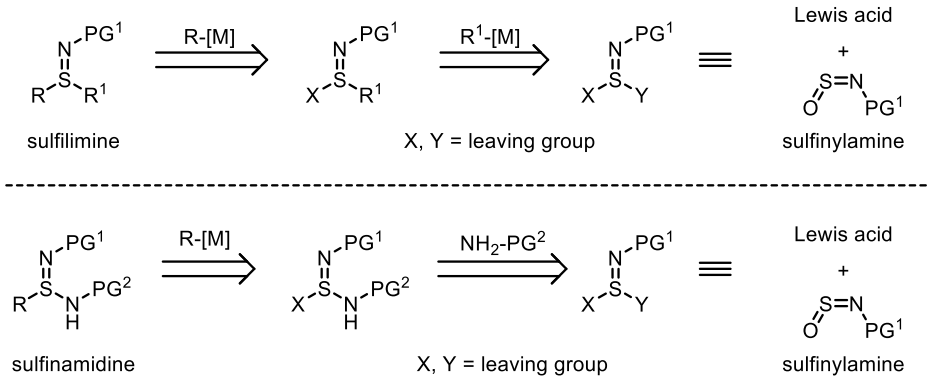


Figure 3.4. Retrosynthesis of sulfinamidines and sulfilimines from sulfinylamines

In 2001, the Zibarev group reported an effective method for sulfurdiimide synthesis, using aryl or alkyl-substituted sulfinylamines as the starting materials.[62] When reacting the various sulfinylamines with LiHMDS at low temperature, anionic species **80** were generated, which were then trapped by TMSCl to form *O*-silylated intermediate **81** This intermediate then undergoes an intramolecular Brook rearrangement to form sulfurdiimides (**Figure 3.5**).

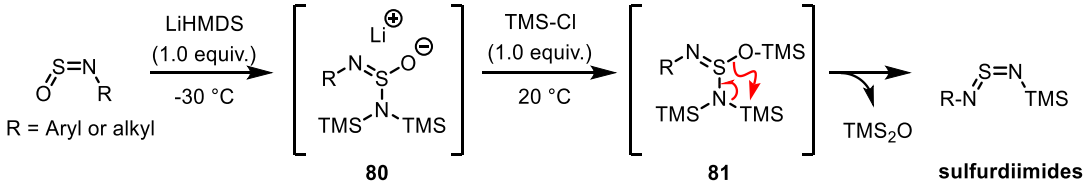


Figure 3.5. Zibarev's sulfurdiimide synthesis from sulfinylamine

Inspired by this sulfurdiimide synthesis, we proposed using LiHMDS as the amine nucleophile in combination with TMSCl as the oxophilic Lewis acid, to convert the sulfinylamine **25** to the corresponding sulfurdiimide **82**. Addition of a suitable organometallic reagent to the *in-situ* generated sulfurdiimide would give the corresponding *N*-TMS, *N*-*t*-octyl sulfinamidine. We speculated that the *N*-TMS substituent would be labile to aqueous work-up and lead to the formation of *N*-*t*-Oct primary sulfinamidine **83**. Based on our previous concerns about the stability of electron-rich sulfinamidines, we proposed

that the direct *N*-protection of the crude primary sulfinamidine **83**, for example by treatment with NsCl to give the needed *N*-*t*-Oct, *N*-Ns sulfinamidine, would be needed (**Figure 3.6**).

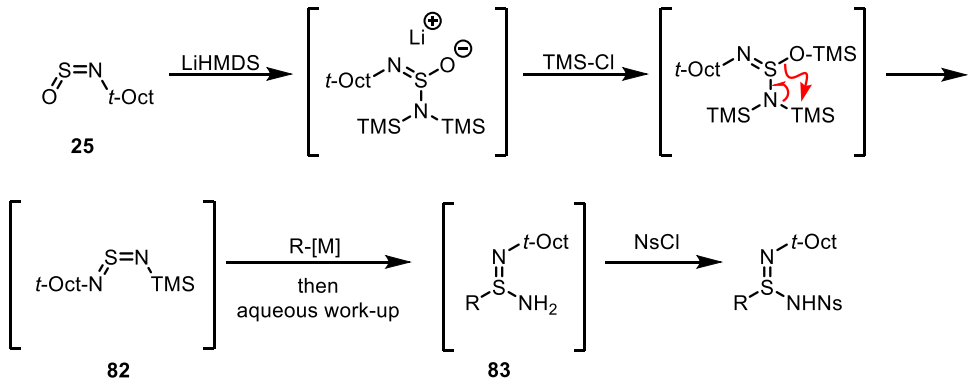


Figure 3.6. Proposed formation of sulfinamidines from *t*-Oct-NSO

Although sulfurdiimide **82** could be isolated, it was more practical to combine it directly with an organometallic reagent to deliver *N*-*t*-Oct primary sulfinamidine **83**. So, in our initial attempts, LiHMDS was added to *t*-Oct-NSO **25** in THF at -30 °C, followed by the addition of TMSCl and then 4-fluorophenyl magnesium bromide at 0 °C to give *N*-*t*-Oct primary sulfinamidine **84** after aqueous work-up (**Figure 3.7**). Subsequent nosylation of the sulfinamidine **84** generated the needed *N*-*t*-Oct, *N*-Ns sulfinamidine **85** in 87% yield.

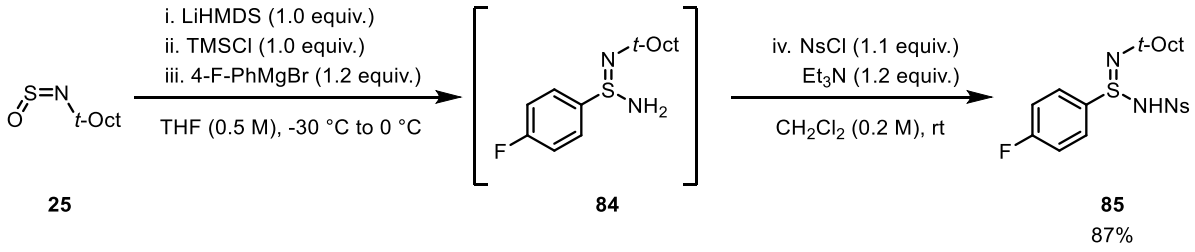


Figure 3.7. Second generation of sulfinamidine synthesis

With a convenient method for sulfinamidine synthesis in hand, we investigated the scope of this method using a variety of organometallic reagents (**Figure 3.8**). A variety of *S*-aryl sulfinamidines were obtained with generally high yields, including electronically neutral (**85**, 87%, **86**, 88% and **87**, 65%), electron-withdrawing (**88**, 67%, **89**, 88% and **92**, 86%) and electron-donating (**90**, 76% and **91**, 82%) examples. Compound **91** demonstrates sterically demanding *ortho*-substituents are well tolerated. A modest 52% yield was obtained for

product **93**, the aryl unit of which can be used to synthesise the carbon fragment of the marketed drug, Sildenafil.[63] This is likely due to the instability of the corresponding organolithium reagent. Compound **94**, which includes a fragment of the marketed COX-2 inhibitor Celecoxib, could also be prepared in 95% yield. The heteroaryl examples **95** and **96** can also be formed in good yield (80% and 75% respectively). *S*-alkyl examples were obtained in good yield as well (**97**, 84%, **98**, 61% and **99**, 72%), although the corresponding primary sulfinamidine intermediates were less stable due to the increased electron density on the sulfur atom. Alkene substrate **100** was prepared in 70% yield, providing another potential reaction site for future derivatization.

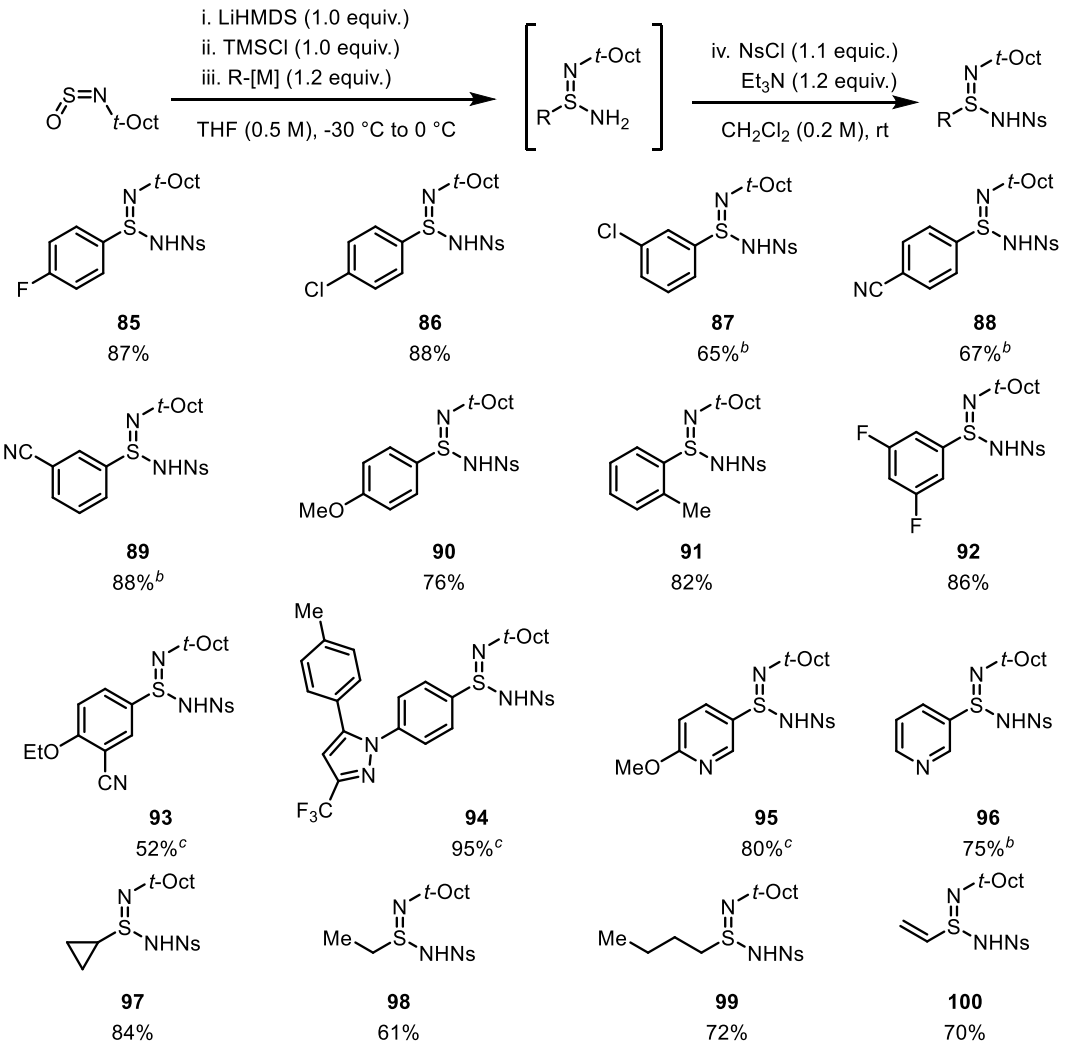
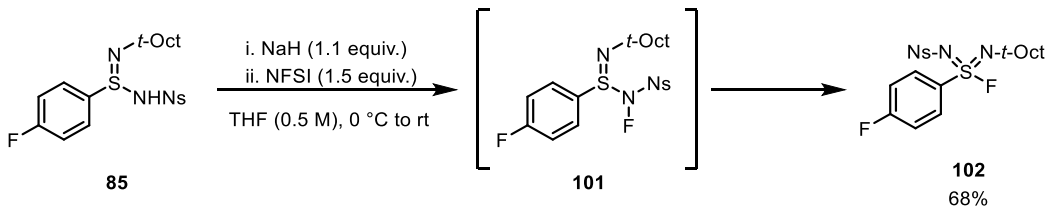


Figure 3.8. Scope of orthogonal *N*-protected sulfinamidines[a]

a. *t*-Oct-NSO **25** (1.0 equiv.), LiHMDS (1.0 equiv.), THF (0.5 M), –30 °C, 5 min, then 0 °C, 5 min. then TMSCl (1.0 equiv.), 0 °C, 10 min, then RMgBr (1.2 equiv.), 0 °C, 10 min. Aqueous work-up. Then Et_3N (1.2 equiv.), NsCl (1.1 equiv.), CH_2Cl_2, rt, 1-12 h. Isolated yields. ***b***. "Turbo Grignard" reagent (R-MgCl.LiCl) employed. ***c***. Organolithium reagent employed.

3.4 Synthesis of Sulfondiimidoyl Fluorides

With a broad range of *N*-*t*-Oct, *N*-Ns sulfinamidines in hand, we began to investigate the conversion process from sulfinamidines to sulfondiimidamides, using sulfondiimidoyl halides as intermediates. As sulfonimidoyl chlorides have been shown to be very prone to reduction, we decided to use sulfondiimidoyl fluorides as intermediates to synthesise sulfondiimidamides. Our initial attempts at electrophilic fluorination used sodium hydride as a base in combination with NFSI as the fluorine source. Deprotonation of 4-fluorophenyl-substituted sulfinamidine **85** was complete in 30 min whilst warming from 0 °C to room temperature. Subsequent addition of NFSI successfully oxidised the sulfinamidine anion to a mixture of the *N*-fluorinated product **101** and the *S*-fluorinated product **102**. After aqueous work-up, the crude mixture was allowed to stand at room temperature (open to air) for 16-20 h until all the *N*-fluorinated product **101** had isomerised to the desired *S*-fluorinated product **102** (as determined by ^{19}F NMR and TLC), generating the desired *N*-*t*-Oct, *N*-Ns sulfondiimidoyl fluoride **102** in 68% yield. This *N* to *S* migration could be followed using ^{19}F NMR spectroscopy, which demonstrates that the *S*-fluorinated product **102** is a thermodynamically stable product (**Figure 3.9**).[64] A variety of solvents (DMF, Et_2O, acetonitrile, 1,4-dioxane and ethyl acetate), fluorinating reagent (NFSI and Selectfluor), base (NaH, K_2CO_3 and Et_3N) and concentration were then evaluated, but none gave an improvement in yield (**Table 3.1**).



85 **101** **102** 68%

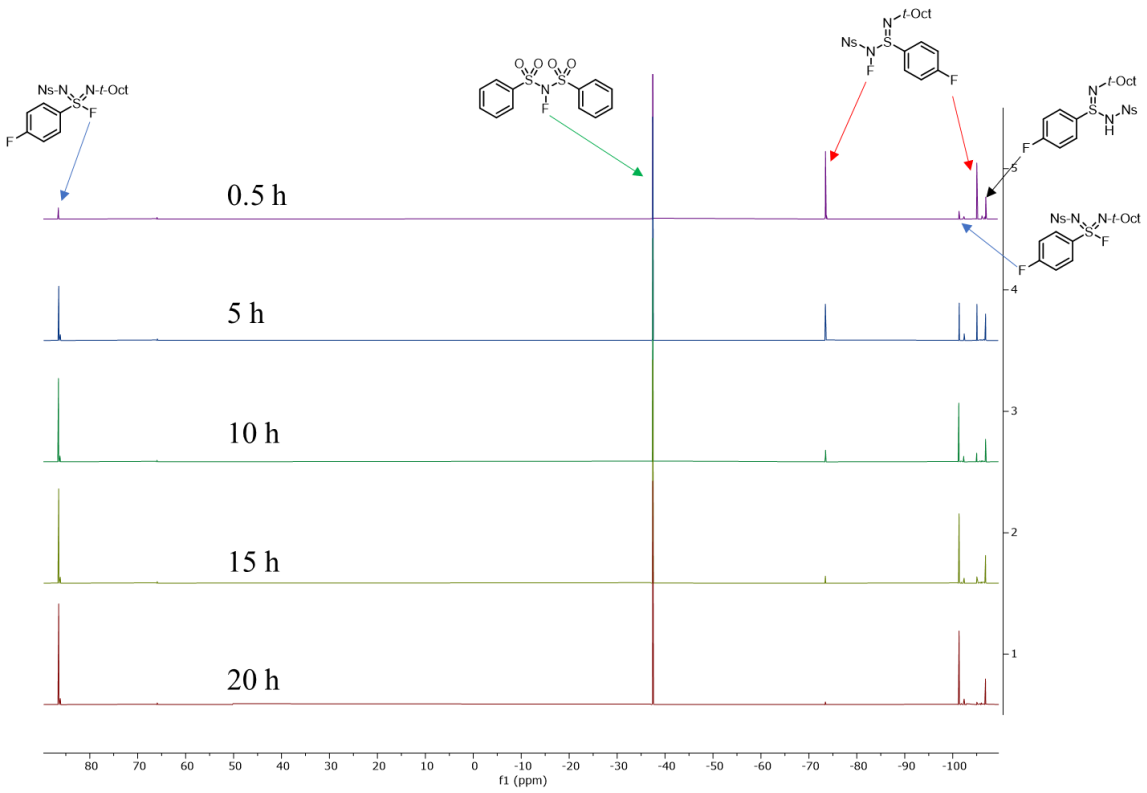
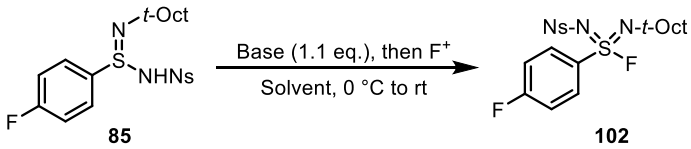


Figure 3.9. ^{19}F NMR spectra of crude mixture, analysing the isomerisation process

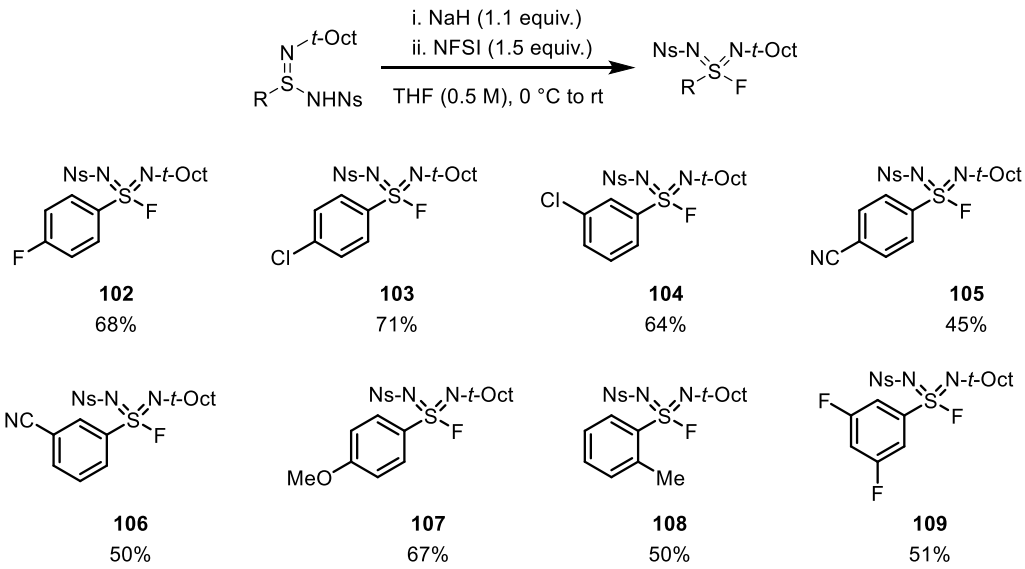
Table 3.1. Optimisation of sulfondiimidoyl fluoride 102 synthesis



Entry[a]	Solvent	Base	F^+ (eq.)	Yield
1	DMF (0.5 M)	NaH	NFSI (1.5 eq.)	57%
2	Et_2O (0.5 M)	NaH	NFSI (1.5 eq.)	10%
3	MeCN (0.5 M)	NaH	NFSI (1.5 eq.)	11%
4	1,4-dioxane (0.5 M)	NaH	NFSI (1.5 eq.)	7%
5	EtOAc (0.5 M)	NaH	NFSI (1.5 eq.)	36%
6	**THF (0.5 M)**	**NaH**	**NFSI (1.5 eq.)**	**68%**
7	THF (0.5 M)	NaH	NFSI (2.0 eq.)	66%
8	THF (0.1 M)	NaH	NFSI (2.0 eq.)	61%
9	THF (0.5 M)	NaH	NFSI (4.0 eq.)	64%
10	THF (0.5 M)	NaH	NFSI (2.0 eq.)	63%
11	THF (0.2 M)	NaH	Selectfluor (3.0 eq.)	0%[b]
12	THF (0.1 M)	K_2CO_3	NFSI (1.1 eq)	0%[b]
13	THF (0.5 M)	Et_3N	NFSI (1.5 eq.)	0%[b]
14	THF (0.5 M)	-	NFSI (1.5 eq.)	0%[b]

a. Reaction conditions: Sulfinamidine **85** (1.0 equiv.), base (1.1 equiv.), solvent, 0 °C for 5 min, then rt for 25 min. Then NFSI or Selectfluor, rt, 30 min. Aqueous work-up. 20 h. Isolated yields. ***b***. Starting material recovered.

The substrate scope of the developed fluorination is shown below (**Figure 3.10**). Aryl-substituted products were obtained in modest to good yields, including electron-neutral examples (**102**, 68%, **103**, 71% and **104**, 64%) and electron-rich examples (**107**, 67% and **108**, 50%). Electron-withdrawing examples were obtained in lower yields (**105**, 45%, **106**, 50%, **109**, 51% and **110**, 46%) due to hydrolysis and decomposition that occurred during the isomerisation of the *N*-fluorinated compound to the *S*-fluorinated compound. A similar pattern was observed for the heteroaryl examples, with more electron-rich substrates being obtained in higher yields (**112**, 60%) than the less electron-rich counterparts (**113**, 40%). Alkyl-substituted products were obtained in good to excellent yield (**114**, 93%, **115**, 70% and **116**, 91%) likely because of their more electron-rich character. In contrast to the aryl-substituted compounds, alkyl-substituted compounds could be stored at room temperature for more than 2 weeks without evidence of hydrolysis or decomposition. Alkene example **117** was also obtained in 46% yield due to decomposition. Compound **111**, which includes a fragment of the marketed COX-2 inhibitor, Celecoxib, could also be prepared in 52% yield.



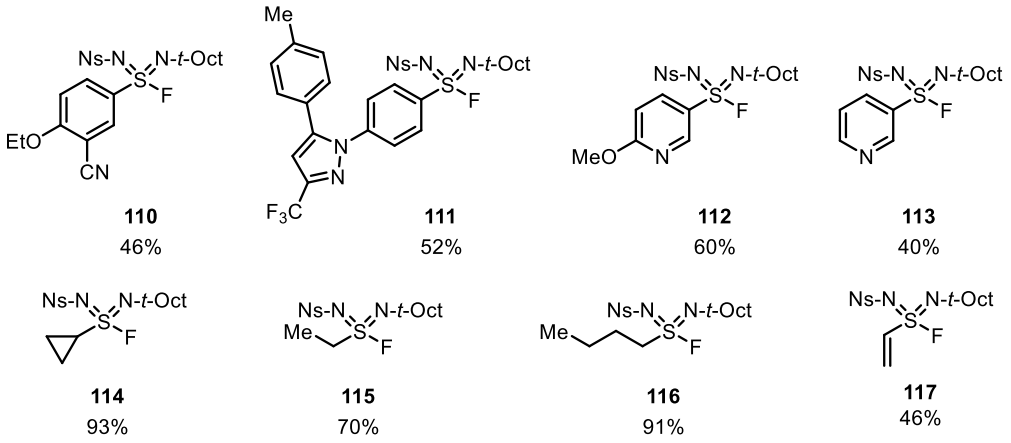


Figure 3.10. Scope of sulfondiimidoyl fluorides[a]

a. Sulfinamidine (1.0 equiv.), NaH (1.1 equiv.), THF (0.5 M), 0 °C for 5 min, then rt for 25 min. Then NFSI (1.5 equiv.), rt, 30 min. Aqueous work-up. 1-8 days. Isolated yields.

3.5 Synthesis of Sulfondiimidamides

With the corresponding sulfondiimidoyl fluorides in hand, our focus switched to the synthesis of sulfondiimidamides. Inspired by a $Ca(NTf_2)_2$-mediated amination reaction of sulfonyl fluorides reported by the Ball group (**Figure 3.11**),[65,66] we decided to use similar conditions to convert our sulfondiimidoyl fluorides into sulfondiimidamides.

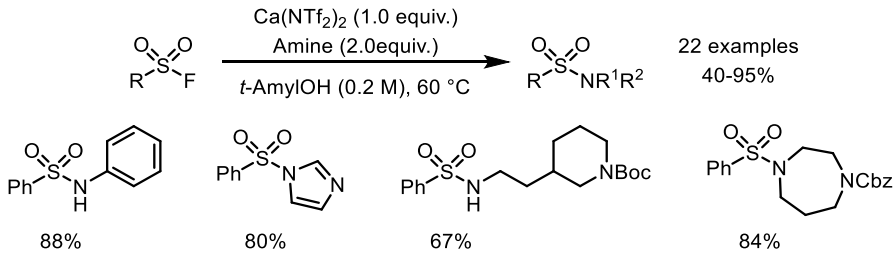
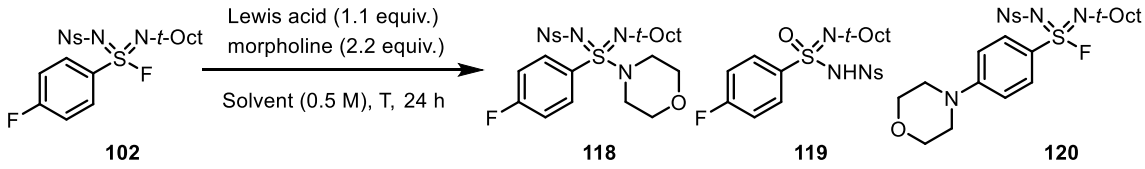


Figure 3.11. Ball's $Ca(NTf_2)_2$-mediated amination of sulfonyl fluorides

Our optimisation conditions are shown below (**Table 3.2**). Morpholine was chosen as the nucleophile, and the reaction was heated at 60 °C with different Lewis acids and solvents for 24 h. The initial attempts with $In(OTf)_3$ provided the hydrolysis product **119** in 77% yield (**Entry 1**). $Cu(OTf)_2$ also did not give any desired product, with starting material being recovered (**Entry 2**). When changing the Lewis acid to $Ca(OTf)_2$, 29% yield of the desired

product (sulfondiimidamide **118**) and 8% yield of the SN_{Ar} reaction product **120** were obtained (**Entry 3**). In a pleasant surprise, using $Ca(NTf_2)_2$ instead of $Ca(OTf)_2$ improved the yield of sulfondiimidamide **118** significantly (**Entry 4**, 93%), perhaps because triflimide salts were more soluble in the reaction than triflate salts. The related Lewis acids $Mg(NTf_2)_2$ and $Ba(NTf_2)_2$ provided modest yields (**Entries 5-6**). Calcium triflimide was then selected for further examination of solvent effects. MeOH, acetonitrile and THF were evaluated but none gave an improvement in yield (**Entries 7-9**). As expected, the 1.1 equivalents of $Ca(NTf_2)_2$ and 60 °C were essential for reactivity (**Entries 10-12**).

Table 3.2. Optimization of sulfondiimidamide 118 synthesis



102 **118** **119** **120**

Entry[a]	Lewis acid	Solvent	T	Yield of **118**	Yield of **119**	Yield of **120**
1	$In(OTf)_3$	*t*-AmylOH	60 °C	0%	77%	0%
2	$Cu(OTf)_2$	*t*-AmylOH	60 °C	0%	0%	0%
3	$Ca(OTf)_2$	*t*-AmylOH	60 °C	29%	0%	8%
4	**$Ca(NTf_2)_2$**	***t*-AmylOH**	**60 °C**	**93%**	0%	0%
5	$Mg(NTf_2)_2$	*t*-AmylOH	60 °C	55%	0%	0%
6	$Ba(NTf_2)_2$	*t*-AmylOH	60 °C	64%	0%	0%
7	$Ca(NTf_2)_2$	MeOH	60 °C	40%	0%	0%
8	$Ca(NTf_2)_2$	CH_3CN	60 °C	87%	0%	0%
9	$Ca(NTf_2)_2$	THF	60 °C	87%	0%	0%
10[b]	-	CH_3CN	60 °C	0%	0%	84%
11	$Ca(NTf_2)_2$	*t*-AmylOH	40 °C	73%	0%	0%
12	$Ca(NTf_2)_2$ (0.5 eq.)	*t*-AmylOH	60 °C	47%	0%	5%

a. Sulfondiimidoyl fluoride **102** (1.0 equiv.), Lewis acid, morpholine (2.2 equiv.), solvent (0.5 M), 24 h. Isolated yields. ***b***. DBU (2.0 equiv.) used as the additive, 15 h.

With promising conditions determined, we then explored the scope of the reaction with different sulfondiimidoyl fluorides (**Figure 3.12**). Morpholine was chosen as the amine nucleophile. Excellent yields were obtained for all aryl-substituted sulfondiimidamides, including electron-neutral (**118**, 93%, **121**, 94% and **122**, 89%), electron-withdrawing (**123**, 93%, **124**, 92%, **127**, 93% and **128**, 95%) and electron-donating (**125**, 92% and **126**, 75%)

examples. Similarly, heteroaryl examples were formed in good yield (**130**, 93% and **131**, 92%). No desired product was detected for alkenyl sulfondiimidamide **135**, indicating the alkenyl group was not compatible with this methodology, presumably due to competing addition to the alkene, although no identifiable products were isolated. Sulfondiimidamide **129**, which includes a fragment of the marketed COX-2 inhibitor, Celecoxib, could also be prepared in 88% yield.

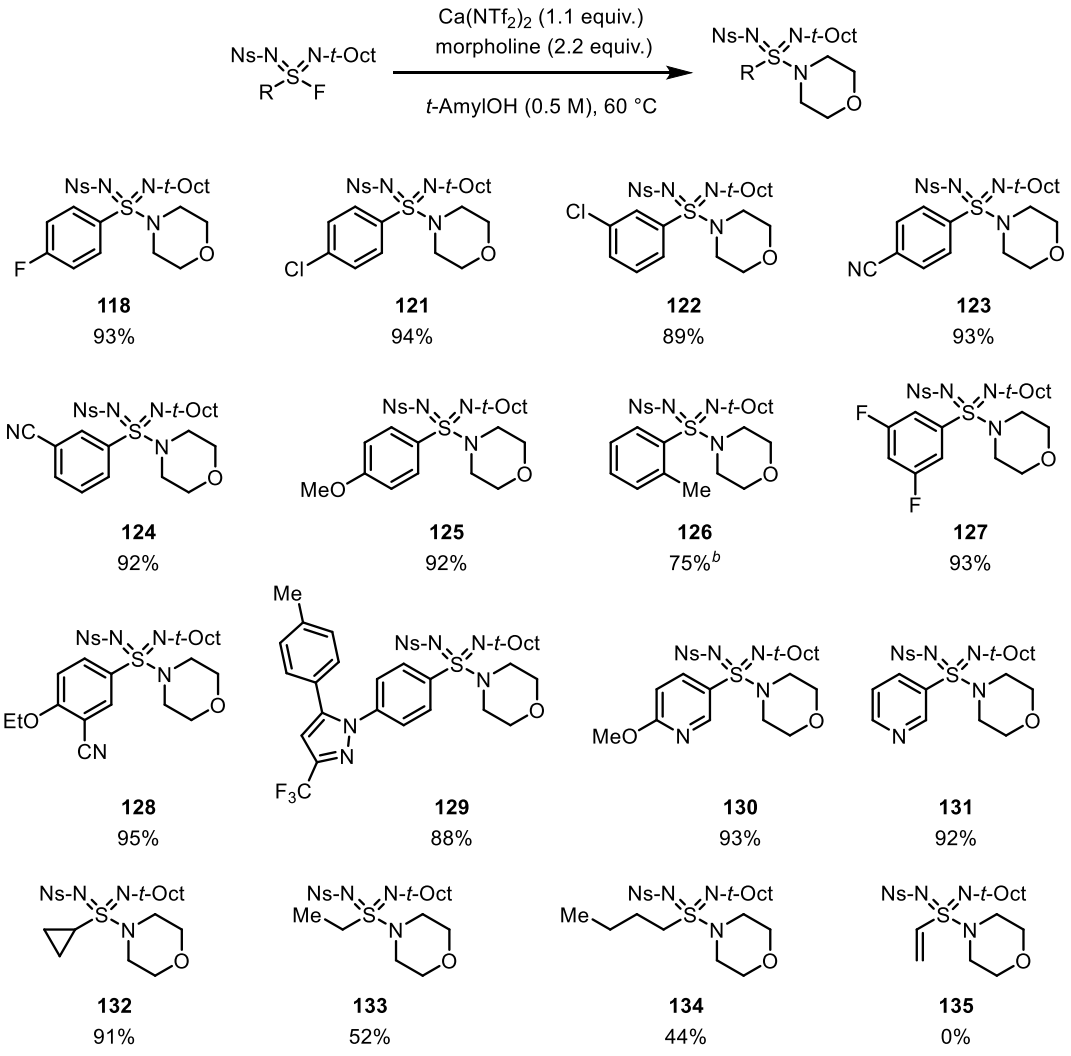


Figure 3.12. Scope of sulfondiimidamide varying the sulfondiimidoyl fluoride partner[a]

a. Sulfondiimidoyl fluoride (1.0 equiv.), morpholine (2.2 equiv.), $Ca(NTf_2)_2$ (1.1 equiv.), *t*-AmylOH (0.5 M), 60 °C, 10-36 h. Isolated yields. ***b***. Morpholine (4.0 equiv.), 75 °C.

Alkyl-substituted sulfondiimidamides showed a range of yields, with the cyclopropyl example **132** being formed in excellent yield (91%), whilst ethyl and *n*-butyl-substituted

products were isolated in more moderate yields (**133**, 52% and **134**, 44%). Interestingly, $NsNH_2$ was formed as the main side-product for these two examples. A possible mechanism is shown below (**Figure 3.13**). The reduction reaction likely occurs due to the electron-donating properties of the alkyl group, leading to the formation of *S*-ethyl sulfinamidine **98**. This in turn can be attacked by the excess of morpholine to provide new sulfinamidine **136** and $NsNH_2$. Further decomposition of sulfinamidine **136** under the reaction conditions due to the electron-rich sulfur center could explain why only $NsNH_2$ was isolated as a side-product.

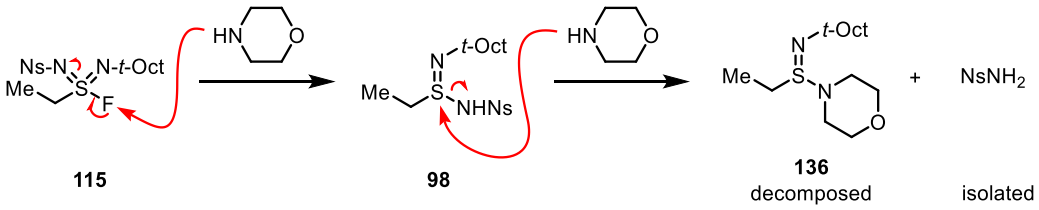


Figure 3.13. Proposed mechanism for side-product formation

The amine components were also varied to further investigate the scope of this methodology (**Figure 3.14**). A variety of cyclic secondary amines, including those containing drug fragments, worked well providing the corresponding sulfondiimidamides with excellent yields (**137**-**142**). Acyclic secondary amine was also tolerated in the reaction (**143**, 96%). The use of a chiral secondary amine resulted in the formation of two separable diastereoisomers in high yield (90% yield of a 1:1 separable mixture), providing access to enantioenriched sulfondiimidamides **144** and **145** in 45% yield for each compound after separation. Iminic and aniline nitrogen nucleophiles were also competent, as shown by examples **146** and **147** (85% and 81% yield respectively). Pleasingly, imidazole could also be used as a nucleophilic partner, as shown by example **148** in 88% yield.

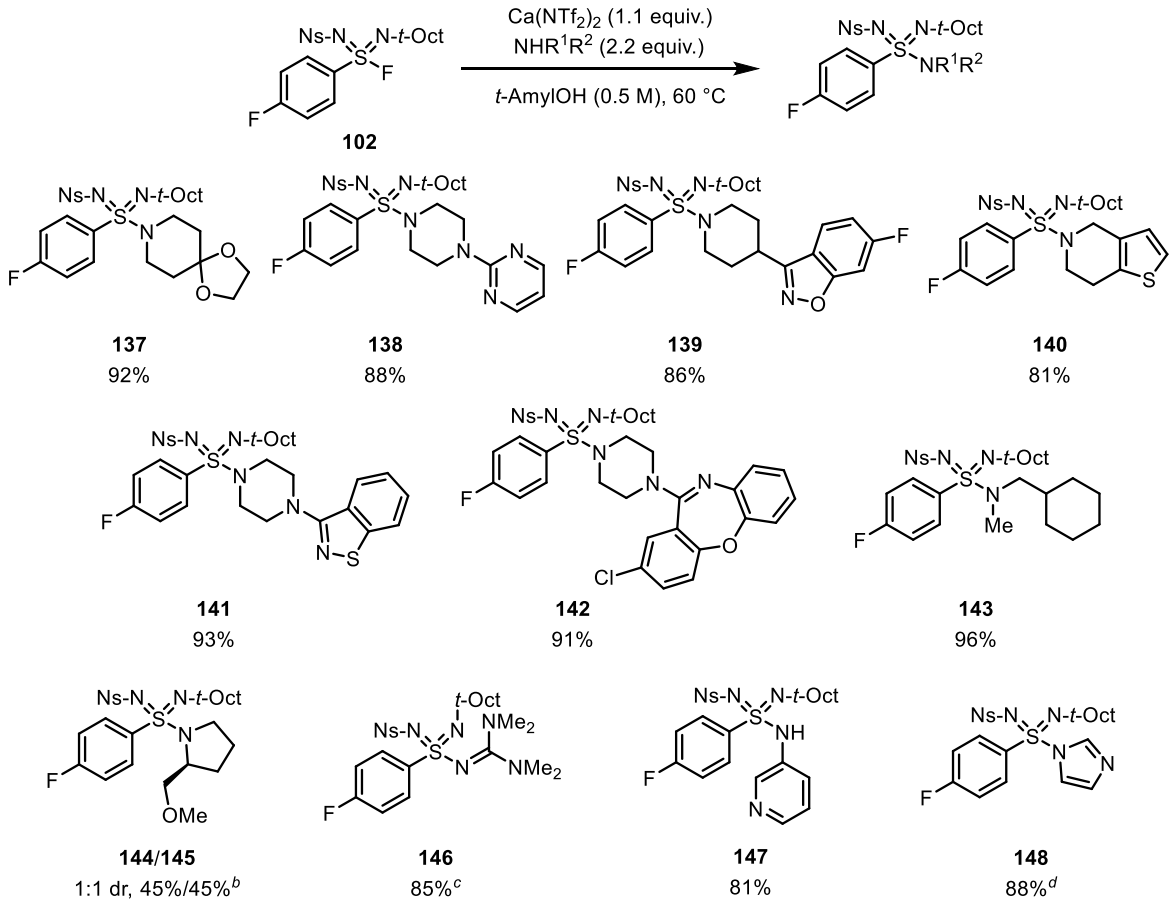


Figure 3.14. Scope of amine nucleophiles for the synthesis of sulfondiimidamides[a]

a. Sulfondiimidoyl fluoride **102** (1.0 equiv.), amine (2.2 equiv.), $Ca(NTf_2)_2$ (1.1 equiv.), *t*-AmylOH (0.5 M), 60 °C, 12-36 h. Isolated yields. ***b***. 70 °C. **c**. TMG (3.0 equiv.), 80 °C. ***d***. Imidazole (6.0 equiv.), 65 °C.

However, limitations remained in the amine scope. Firstly, secondary aryl-alkyl amines (such as indoline) did not work using the optimised conditions, likely due to the steric hindrance. Secondly, primary alkylamines (such as *n*-butylamine and benzylamine), ammonia and ammonia equivalents (such as LiHMDS, HMDS and ammonium carbamate) did not give the desired sulfondiimidamides when they were used as nucleophiles in this reaction. Thirdly, amide nucleophiles (such as acetamide and benzamide) did not work, likely due to their poor nucleophilicity.

In order to address these limitations, we planned to develop an alternative amination method. Inspired by a recent literature report on the synthesis of sulfonimidamides using

sulfonimidamide imidazolinium salt in a nucleophilic substitution (**Figure 3.15**),[67] we chose to methylate imidazole substrate **148** and then try a similar amination on this imidazolinium salt.

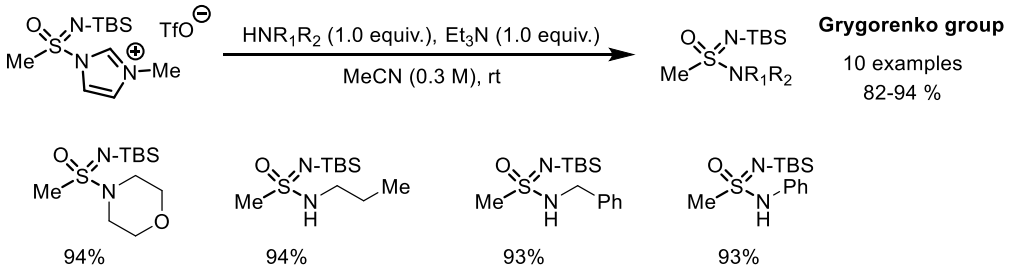


Figure 3.15. Sulfonimidamide synthesis reported by the Grygorenko group

Using MeOTf as an electrophile, the methylation of sulfondiimidamide **148** was complete as monitored by TLC after 30 min. Initially, we tried to isolate the obtained imidazolinium salt, but it was found that this imidazolinium salt was prone to hydrolysis. As a result, the imidazolinium salt was used directly *in-situ* for the amination step, providing the desired sulfondiimidamide **149** in 97% yield only 30 min after addition of *n*-butylamine (**Figure 3.16**).

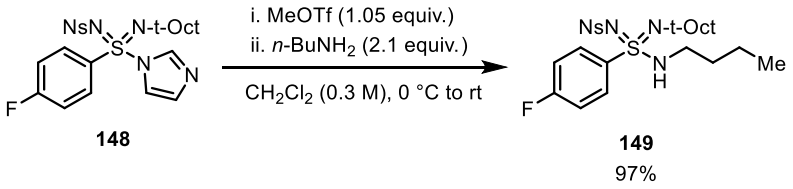


Figure 3.16. Synthesis of sulfondiimidamides from sulfondiimidamide **148**

Having established suitable conditions for this alternative amination method, we turned our attention to the scope of this reaction, particularly focusing on amines that did not work in the $Ca(NTf_2)_2$-mediated amination reaction (**Figure 3.17**). We were pleased to find that all of these amines gave the desired products in good to excellent yields using the new method. A broad range of primary alkylamines were well tolerated, including *n*-butylamine **(149**, 97%), allylamine (**150,** 80%), cyclopropylamine (**151**, 93%), and *t*-butylamine (**152**, 82%).

Various heteroaryl amine examples could also be synthesised in excellent yield (**153**, 82%, **154**, 95% and **155**, 98%). Secondary aryl-alkyl amine substrate **156** and **157** were also formed in 85% yield and 82% yield under these conditions. A carbamate nucleophile could be used in the reaction in spite of its poor nucleophilicity, allowing example **158** to be prepared in 87% yield. Pleasingly, ammonia solution could be used in these conditions to generate primary sulfondiimidamide **159** in 72% yield, which in turn could be used to synthesise a variety of other substituted sulfondiimidamides (see **Figure 3.18**). Diastereoisomers **160** and **161** were prepared in 82% yield as a 1:1 mixture, and could be separated to afford the individual enantiopure, chiral-at-sulfur compounds.

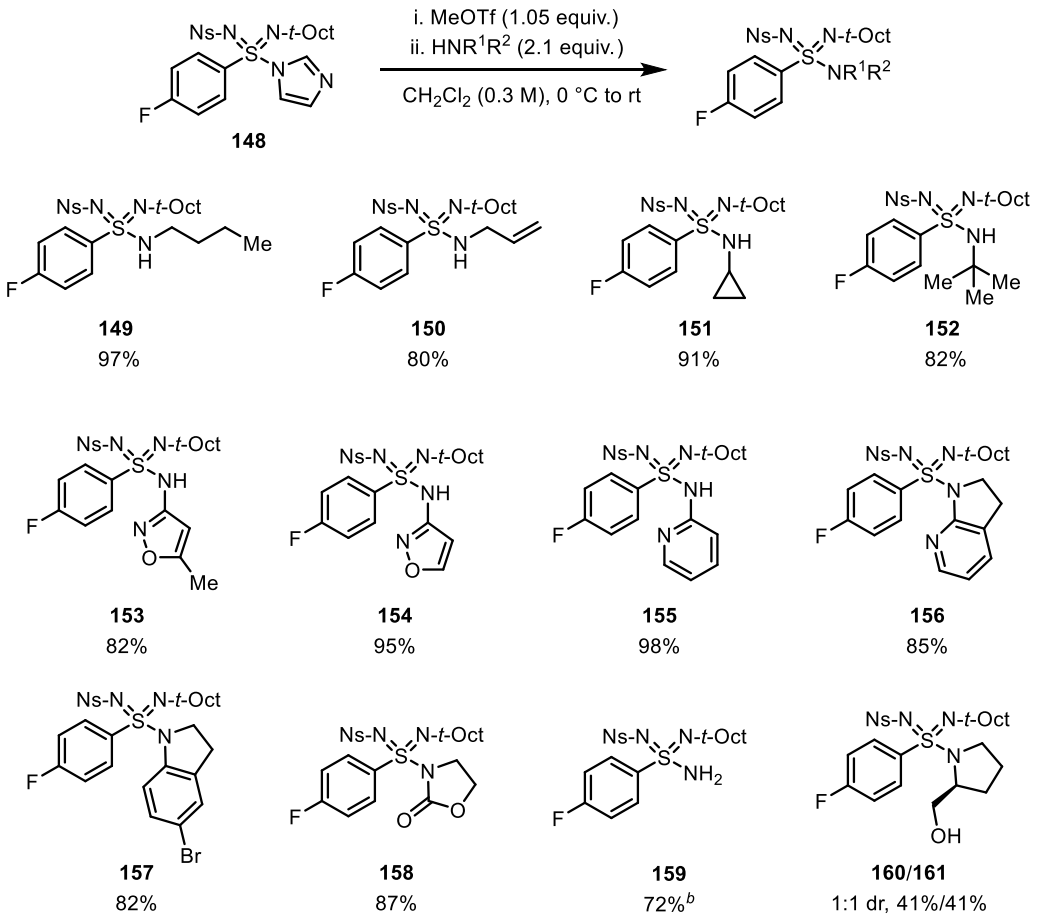


Figure 3.17. Scope of amine nucleophiles for the synthesis of sulfondiimidamides from sulfondiimidamide **148**[a]

a. Sulfondiimidamide **148** (1.0 equiv.), MeOTf (1.05 equiv.), CH_2Cl_2 (0.3 M), 0 °C, rt for 30 min, *then* amine (2.1 equiv.), rt, 30 min. ***b***. NH_3 2M in *i*-PrOH (4.0 equiv.).

Due to the fact that amide and urea functionalities are prevalent in a variety of bioactive sulfonimidamide molecules, we demonstrated that sulfondiimidamide **159** could be further functionalised (**Figure 3.18**). Stoichiometric deprotonation of **159** with sodium hydride followed by the addition of phenyl isocyanate as an electrophile enabled urea **162** to be synthesised in 82% yield, whilst acylation of sulfondiimidamide **159** with phenylacetyl chloride in the presence of triethylamine gave amide **163** in 70% yield.

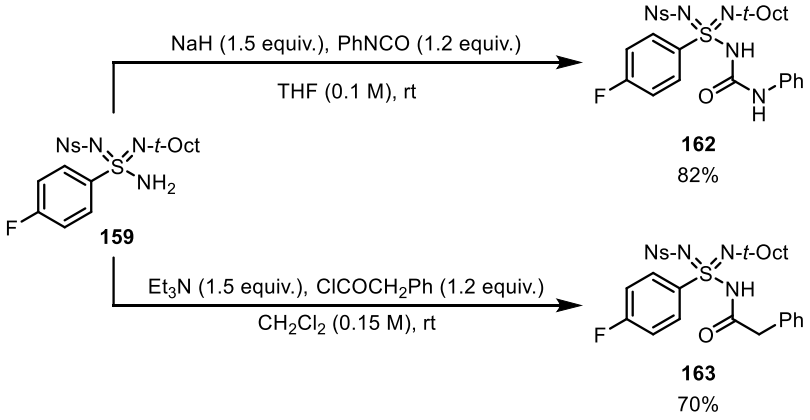


Figure 3.18. Derivatisation of sulfondiimidamide **159**

3.6 Deprotection and *N*-Functionalisation of Sulfondiimidamides

With a broad range of orthogonal *N*-protected sulfondiimidamides in hand, we next focused on the selective removal of the *t*-octyl and nosyl protecting groups. Pleasingly, treatment with 5 equivalents of TFA selectively removed the *t*-octyl group from sulfondiimidamide **118**, providing *N*-Ns, *N*-H sulfondiimidamide **164** in 95% yield (**Figure 3.19**).

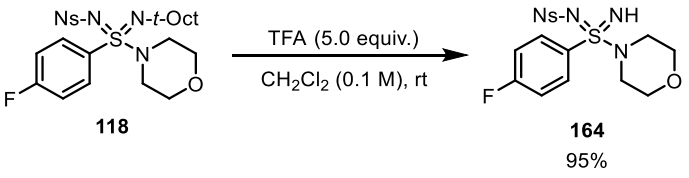
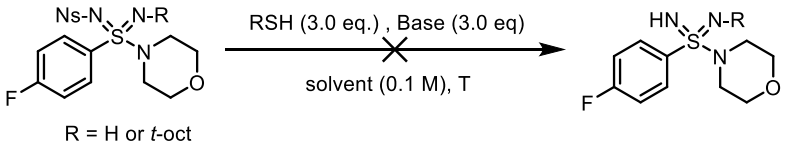


Figure 3.19. *t*-Octyl deprotection of sulfondiimidamide **118**

Initial attempts at nosyl deprotection proved challenging. Both *N*-Ns, *N*-*t*-Oct sulfondiimidamide **118** and *N*-Ns, *N*-H sulfondiimidamide **164** did not undergo nosyl

deprotection under a variety of conditions (**Table 3.3**). In most cases, a complex mixture of compounds was obtained, indicating that the electron-rich sulfondiimidamides were not particularly stable.

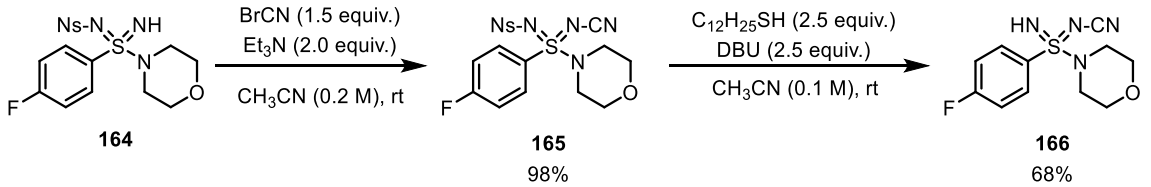
Table 3.3. Failed attempts at nosyl deprotection



R = H or *t*-oct

Entry	RSH	Base	Solvent	T	Yield
1	PhSH	K_2CO_3	CH_3CN	rt	0 %
2	PhSH	K_2CO_3	CH_3CN	0 ° C	0 %
3	PhSH	K_2CO_3	DMF	0 ° C	0 %
4	4-OMe-PhSH	K_2CO_3	DMSO	rt	0 %
5	$HOOCCH_2SH$	LiOH	DMF	0 ° C	0 %
6	$HOCH_2CH_2SH$	DBU	DMF	0 ° C	0 %
7	dodecanethiol	DBU	CH_3CN	0 ° C	0 %
8	dodecanethiol	DBU	THF	0 ° C	0 %
9	dodecanethiol	DBU	DMF	0 ° C	0 %
10	dodecanethiol	DBU	DMSO	0 ° C	0 %
11	dodecanethiol (1.1 eq.)	DBU (1.1 eq.)	CH_3CN	0 ° C	0 %

As such, we turned our attention to preparing sulfondiimidamides substituted with different electron-withdrawing groups. Due to the fact that *N*-cyano groups have been widely used in many bioactive sulfonimidamide and sulfoximine compounds,[68,69] our first synthetic target was the *N*-CN, *N*-H sulfondiimidamide **166** (**Figure 3.20**). Cyanation of sulfondiimidamide **164** with cyanogen bromide (BrCN) in the presence of triethylamine gave *N*-CN, *N*-Ns sulfondiimidamide **165** in 98% yield. Subsequent nosyl deprotection with dodecanethiol and DBU proceeded smoothly, forming *N*-CN, *N*-H sulfondiimidamide **166** in 68% yield.



164 **165** 98% **166** 68%

Figure 3.20. Cyanation and deprotection of sulfondiimidamide **164**

Other electrophiles could also be used to modify the unsubstituted imidic nitrogen of sulfondiimidamide **164** (**Figure 3.21**). Sulfonylation with methanesulfonyl chloride in the presence of triethylamine and catalytic DMAP gave doubly-sulfonylated sulfondiimidamide **167** in 81% yield, and subsequent nosyl deprotection gave the *N*-Ms, *N*-H sulfondiimidamide **168** in 71% yield. Acylation with 4-nitrobenzoyl chloride in the presence of triethylamine gave *N*-benzoyl, *N*-Ns sulfondiimidamide **169** in 94% yield, which could then be deprotected under the previously used conditions to form *N*-benzoyl, *N*-H sulfondiimidamide **170** in 69% yield.

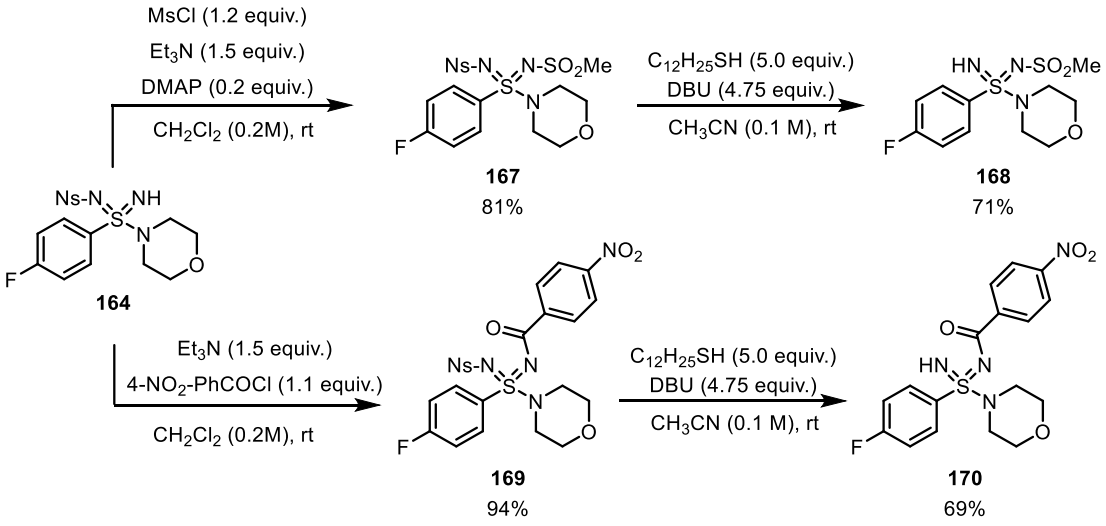
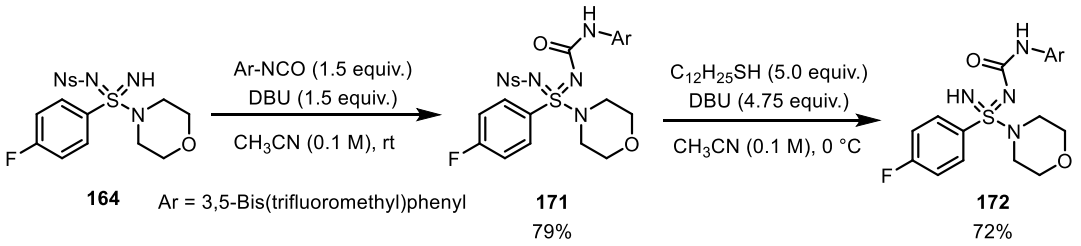


Figure 3.21. Sulfonylation and acylation of sulfondiimidamide **164**

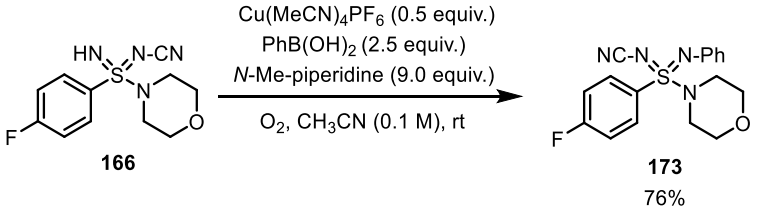
Due to the electron-withdrawing property of nosyl group, sulfondiimidamide **164** is not nucleophilic enough to react with isocyanates without first being deprotonated. By using DBU as a base followed by the addition of 3,5-bis(trifluoromethyl)phenyl isocyanate as the electrophile, *N*-urea, *N*-Ns sulfondiimidamide **171** could be formed in 79% yield (**Figure 3.22**). Deprotection of the nosyl group at 0 °C gave *N*-urea, *N*-H sulfondiimidamide **172** in 72% yield.



164 Ar = 3,5-Bis(trifluoromethyl)phenyl **171** 79% **172** 72%

Figure 3.22. Synthesis of *N*-urea, *N*-H sulfondiimidamide **172**

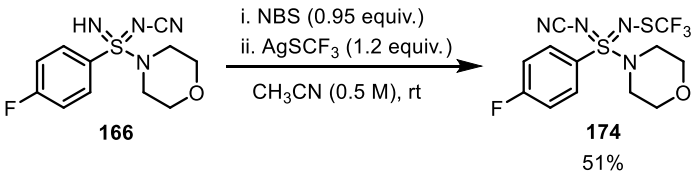
Due to the cyano group's extensive presence in bioactive sulfonimidamide compounds,[68, 69] *N*-CN, *N*-H sulfondiimidamide **166** was also selected for further derivatisation with other functional groups. Chan-Lam arylation using phenylboronic acid in the presence of *N*-methyl piperidine and $Cu(MeCN)_4PF_6$ as catalyst, gave *N*-CN, *N*-Ph sulfondiimidamide **173** in 76% yield (**Figure 3.23**).[57]



166 **173** 76%

Figure 3.23. Arylation of *N*-CN, *N*-H sulfondiimidamide **166**

Building on literature precedent from the Bolm group (using sulfonimidamides),[70] *N*-bromination of sulfondiimidamide **166** with NBS, followed by trifluoromethylthiolation with $AgSCF_3$ enabled *N*-CN, *N*-SCF_3 sulfondiimidamide **174** to be synthesised in 51% yield (**Figure 3.24**).



166 **174** 51%

Figure 3.24. Trifluoromethylthiolation of *N*-CN, *N*-H sulfondiimidamide **166**

Addition of phenyl chloroformate to sulfondiimidamide **166** in the presence of triethylamine and catalytic DMAP provided carbamate-substituted sulfondiimidamide **175** in 93% yield (**Figure 3.25**).

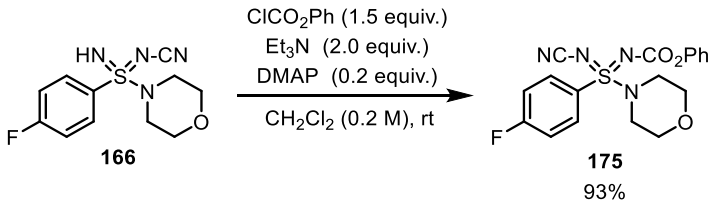


Figure 3.25. Formation of carbamate-substituted sulfondiimidamide **175**

Alkylation proved challenging due to the low nucleophilicity of the sulfondiimidamide imidic nitrogen, and reactive alkylating reagents had to be used. For example, deprotonation with DBU followed by the addition of the desired alkyl bromide generated the benzyl and propargyl-substituted sulfondiimidamides **176** and **177** in 81% and 77% yields, respectively (**Figure 3.26**).

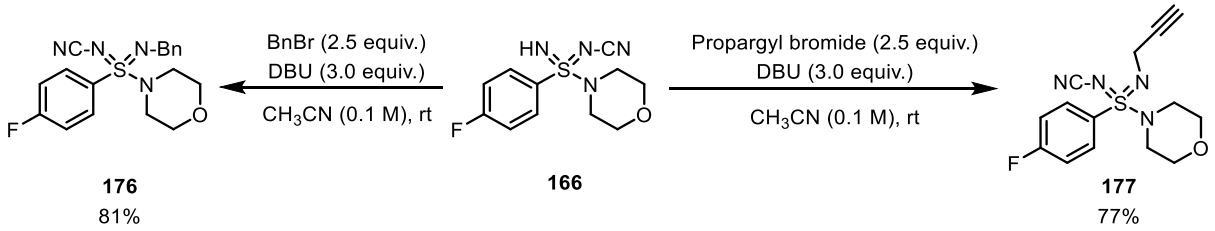


Figure 3.26. Alkylation of *N*-CN, *N*-H sulfondiimidamide **166**

3.7 Synthesis of A Celecoxib Analogue

In order to demonstrate the utility of the developed chemistry, we prepared a sulfondiimidamide analogue of the sulfonamide-containing non-steroidal anti-inflammatory drug (NSAID), Celecoxib. Given the *N*-CN substituted sulfoximines have been reported to inhibit COX-2 successfully,[6969] we choose the di-*N*-CN sulfondiimidamide analogue **183** as the synthetic target. The sulfondiimidoyl fluoride **111** could be generated from the fluorination of corresponding sulfinamidine as described in **Figure 3.10**, and the subsequent amination with diallylamine gave the *N*-*t*-octyl, *N*-Ns sulfondiimidamide **178** in 75% yield. The *t*-octyl deprotection followed by cyanation generated the *N*-CN, *N*-Ns sulfondiimidamide **180** with 86% yield (over two steps). Then a nosyl cleavage followed by another installation of an imidic CN substituent delivered the di-*N*-CN sulfondiimidamide

182 successfully (82% yield for two steps). The deallylation was achieved in the presence of $Ph(PPh_3)_4$ and barbituric acid, to provide the target analogue **183** in 93% yield.

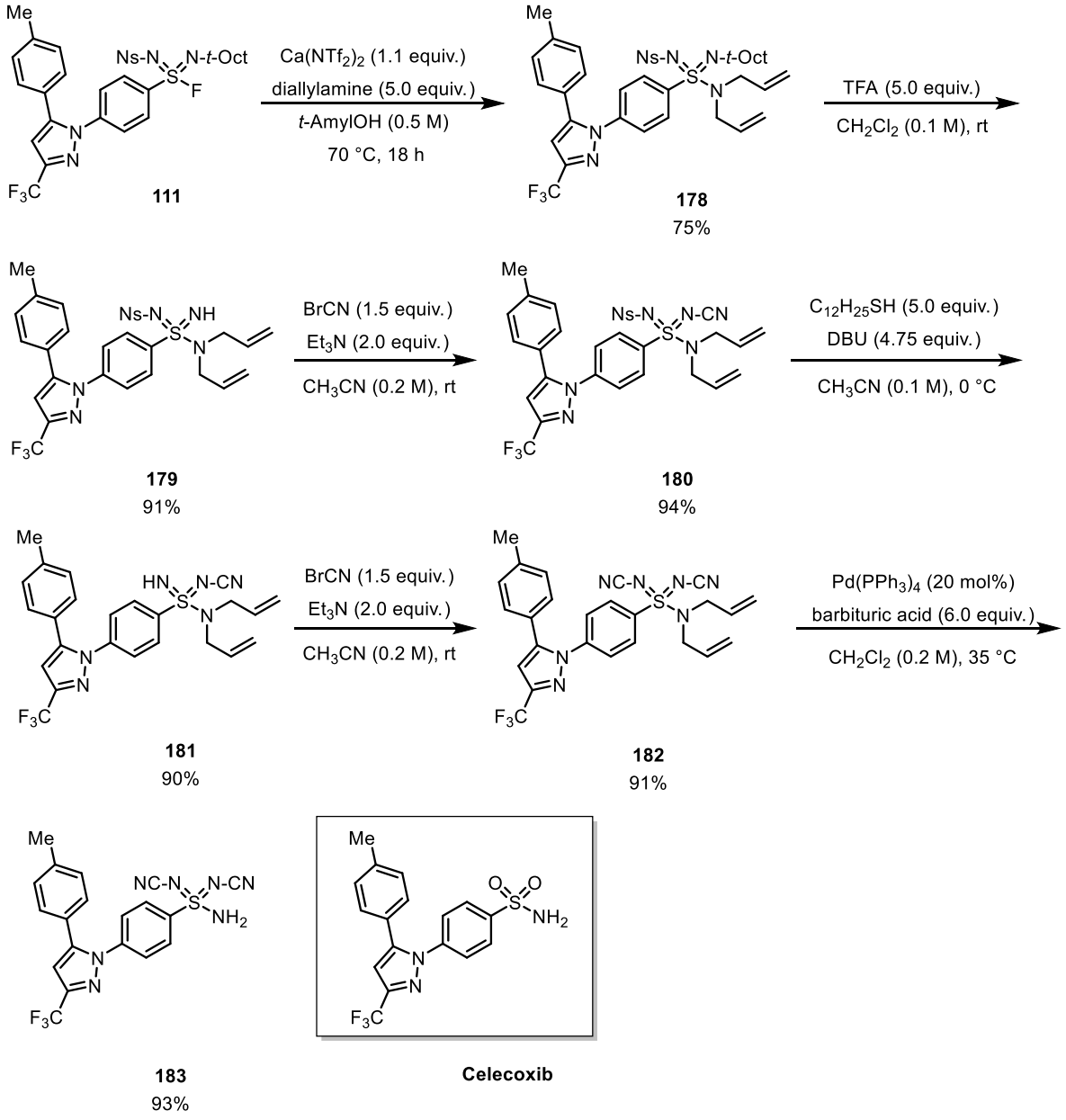


Figure 3.28. Synthesis of Celecoxib analogue **183**

3.8 Summary

In summary, we have developed an unprecedented synthesis of sulfondiimidamides from *t*-Oct-NSO. Various (hetero)aryl and alkyl organometallic reagents can be added to the *t*-Oct-NSO reagent after LiHMDS and TMSCl, generating the corresponding sulfinamidines in

good yields. Subsequent fluorination using NFSI gave modest to excellent yields of the corresponding sulfondiimidoyl fluorides. Sulfondiimidamides derived from secondary alkylamines, aniline, enamine and imidazole were obtained in high yield using $Ca(NTf_2)_2$-mediated amination. For poor yielding *N*-nucleophiles, use of the imidazole-substituted sulfondiimidamide, activated with methyl triflate, as the substrate allowed primary alkylamines, ammonia, amide and secondary alkyl-aryl amines to be installed. Deprotection of the *t*-octyl group facilitated a broad range of further functionalisation. Taken together, this method provides the first methodology for sulfondiimidamide synthesis, providing opportunities to further application of these interesting functional groups in medicinal chemistry. Furthermore, an analogue of the COX-2 inhibitor, Celecoxib, was prepared using this methodology.

Chapter 4 - Second Generation of Sulfondiimidamide Synthesis

4.1 Investigation of An Alternative Sulfinylamine Reagent

One major limitation of the synthetic route to sulfondiimidamides as described in **Chapter 3** is the requirement for strongly acidic conditions to remove the *t*-octyl group. This prevents the use of many acid-sensitive functional groups in the synthesis of *N*-functionalised sulfondiimidamides. Given the potential application of sulfondiimidamides in pharmaceutical and agrochemical research and the interest in their direct comparison to existing sulfonamide and sulfonimidamide drugs, this presents a significant challenge. A large number of drug compounds containing sulfonamide and sulfonimidamide functionalities also have basic nitrogens or other acid-sensitive functional groups. In order to address this limitation, we focused on developing a novel sulfinylamine reagent to replace *t*-Oct-NSO **25**. The new sulfinylamine reagent should meet several requirements: firstly, it should be stable under ambient conditions; secondly, it should be amenable to large-scale synthesis from cheap, commercially available starting materials; and thirdly, the *N*-protecting group should be removable under mild, acid-free conditions.

Based on these criteria, tri-*iso*propylsilyl sulfinylamine (TIPS-NSO) **185** was investigated as a potential alternative, which was carried out in collaboration with Mingyan Ding in our group. This reagent could be synthesised in a two-step protocol starting from the corresponding tri-*iso*propylsilyl chloride (TIPS-Cl). Reaction of TIPS-Cl and liquid ammonia in diethyl ether generated tri-*iso*propylsilyl amine (TIPS-NH_2) **184** as a colourless liquid in quantitative yield (**Figure 4.1**). Subsequent reaction of TIPS-NH_2 **184** with a slight excess of thionyl chloride (1.03 equiv.), in the presence of triethylamine (2.06 equiv.) at 0 °C, gave TIPS-NSO **185**, as a light-yellow liquid in quantitative yield. The reagent showed no decomposition after storage for at least two months at -20 °C.

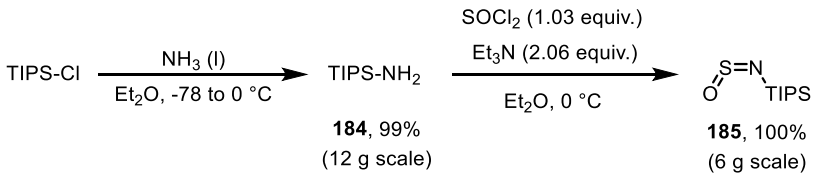


Figure 4.1. Preparation of the TIPS-NSO **185** (carried out with Mingyan Ding)

With a large amount of TIPS-NSO **185** in hand, we explored the use of this novel sulfinylamine reagent in our previously described sulfondiimidamide synthesis (**Figure 4.2**). To our delight, sulfinamidine **187** was formed in 89% yield (3.5 g scale) by using the same method previously described in **Chapter 3.3**. The subsequent fluorination reaction gave the desired sulfondiimidoyl fluoride **188** in 91% yield (compared with 68% yield for the *N*-*t*-oct, *N*-Ns sulfondiimidoyl fluoride **102**), demonstrating that the TIPS group is stable even under strongly basic conditions. $Ca(NTf_2)_2$-mediated amination gave sulfondiimidamide **189** in 73% yield, which is slightly lower than the corresponding *N*-*t*-oct, *N*-Ns sulfondiimidamide **118**, perhaps due to the increased steric hindrance of TIPS group. Deprotection of the TIPS group was achieved by treatment with TBAF solution at 0 °C in 10 min, providing *N*-H, *N*-Ns sulfondiimidamide **164** in 97% yield. The development of TIPS-NSO **185** has allowed the synthesis of *N*-H, *N*-Ns sulfondiimidamides **164** through deprotection under formally basic conditions, offering a complementary alternative to *t*-Oct-NSO derived sulfondiimidamides, therefore expanding the potential scope of substrates accessible.

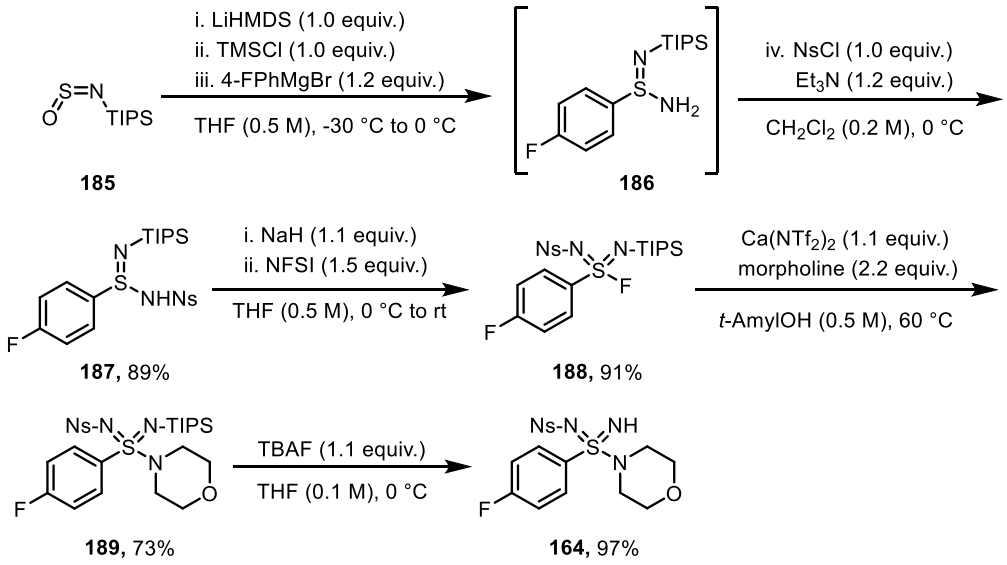


Figure 4.2. Synthesis of sulfondiimidamide **164** from TIPS-NSO

4.2 A New Strategy for Sulfondiimidamide Synthesis

Although we have already developed a robust synthesis of sulfondiimidamides *via* sulfondiimidoyl fluoride intermediates in **Chapter 3**, some limitations still exist. Firstly, several *S*-alkyl sulfondiimidamides were obtained following the $Ca(NTf_2)_2$-mediated amination step in only modest yields (eg, **133**, 52%, **134**, 44%). Secondly, four purifications using flash column chromatography are needed to obtain the *N*-H, *N*-Ns sulfondiimidamide **164** (at the sulfinamidine **85**, sulfondiimidoyl fluoride **102**, *N*-*t*-oct, *N*-Ns sulfondiimidamide **118** and *N*-H, *N*-Ns sulfondiimidamide **164** stages). When it comes to other mono-*N*-substituted sulfondiimidamides (eg, *N*-H, *N*-CN sulfondiimidamide **166**), two more steps are needed (at the *N*-CN, *N*-Ns sulfondiimidamide **165** and *N*-CN, *N*-H sulfondiimidamide **166** stages). Thirdly, the use of a strong base, NaH, in the oxidative fluorination reaction means that base-sensitive functional groups cannot be used. Lastly, the amination reaction of sulfondiimidoyl fluorides requires stoichiometric amounts of $Ca(NTf_2)_2$, which is expensive and non-ideal in terms of atom economy.

In order to address these disadvantages, an alternative synthetic strategy was envisaged. In 2020, Dr Thomas Davies and Mingyan Ding in our group developed a $PhI(OAc)_2$-promoted

amination method to prepare sulfonimidamides from primary sulfinamide counterparts, *via* nucleophilic substitution (presumed) of *in-situ* generated sulfinyl nitrenes **190** (**Figure 4.3**). This methodology utilises mild reaction conditions allowing for the synthesis of a broad range of sulfonimidamides (unpublished).

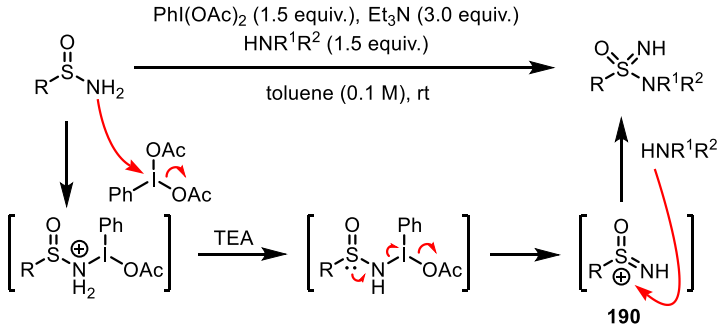


Figure 4.3. Synthesis of sulfonimidamides from primary sulfinamides

Inspired by this approach, we planned to develop a method to generate sulfondiimidamides directly from primary sulfinamidines using a combination of commercially available hypervalent iodine reagents and amines. This would allow straightforward access to various mono-*N*-substituted sulfondiimidamides. Our new strategy is shown below (**Figure 4.4**). *N*-TIPS Primary sulfinamidine **191** should be available from TIPS-NSO **185** and subsequently protected with an electron-withdrawing group (eg. nosyl) as previously described in **Chapter 4.1**. This *N*-TIPS, *N*-Ns sulfinamidine **192** should then undergo *in-situ* deprotection of the silyl group, using F^- (eg. TBAF) in one-pot, to form *N*-Ns primary sulfinamidine **193**.

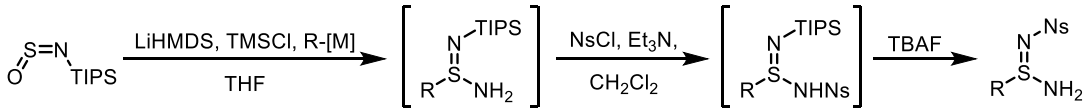


Figure 4.4. New strategy for the synthesis of primary sulfinamidines

In analogy to the reactions of primary sulfinamides, We proposed that this *N*-Ns primary sulfinamidine could be used to generate aza-sulfinyl nitrene intermediate **196** in the presence of $PhI(OAc)_2$ and base following the mechanism outlined below (**Figure 4.5**), followed by

the addition of amine nucleophiles to provide a range of sulfondiimidamides. The reactivity of **196** should mirror that of intermediate **190** generated from sulfinamides.

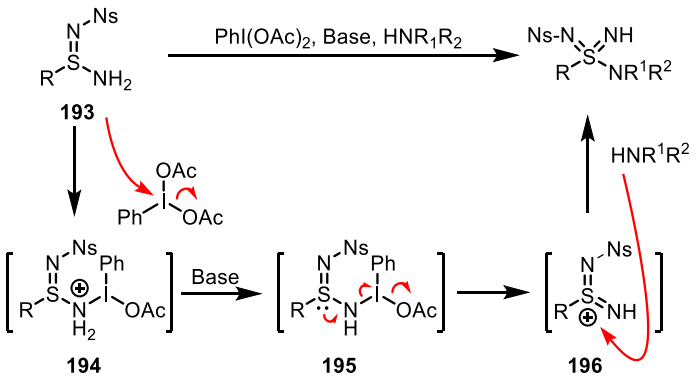


Figure 4.5. New strategy for the synthesis of sulfondiimidamides

4.3 Synthesis of Primary Sulfinamidines

Our initial attempts for synthesising *N*-Ns primary sulfinamidines followed the proposed sequence of steps shown in **Figure 4.4**. 4-Fluorophenylmagnesium bromide was selected as the organometallic reagent, which allowed the reaction to be monitored by ^{19}F NMR spectroscopy. TIPS-NSO **185** was treated with LiHMDS (1.0 equiv.) and TMSCl (1.0 equiv.) in THF, before the addition of 4-fluorophenylmagnesium bromide (1.2 equiv.), generating *N*-TIPS primary sulfinamidine **186** after aqueous work-up (**Figure 4.6**). The crude product was then protected with nosyl chloride, using triethylamine as a base in dichloromethane. The TIPS group was removed using TBAF solution at 0 °C in one-pot, giving *N*-Ns primary sulfinamidine **197** in 86% yield.

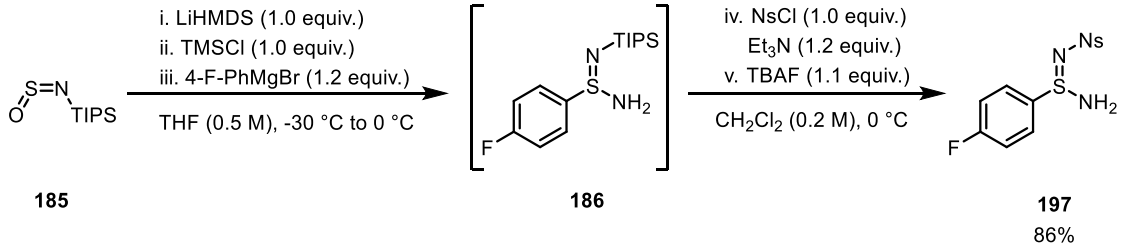
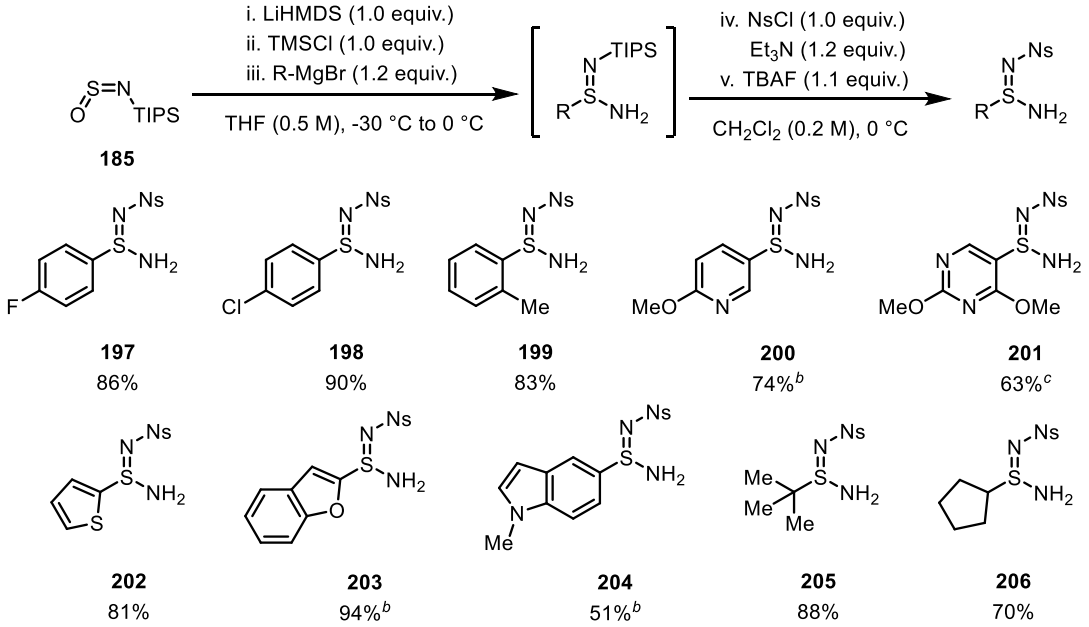
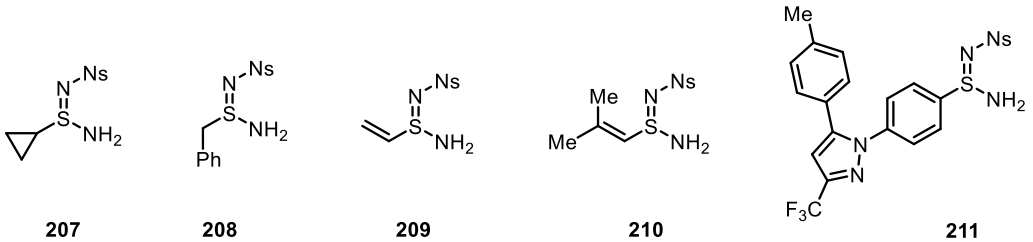


Figure 4.6. Synthesis of *N*-Ns primary sulfinamidine **197**

With the optimised reaction conditions in hand, we investigated the scope of the reaction using a variety of organometallic reagents (**Figure 4.7**). In general, *S*-aryl, *N*-Ns primary sulfinamidines were synthesised in excellent yields, including electron-withdrawing (**197**, 86% and **198**, 90%) and electron-donating (**199**, 83%) examples. This method also tolerates *ortho*-substituents as exemplified by substrate **198**. Importantly, with applications to medicinal chemistry in mind, a range of heteroaryl organometallic reagents were evaluated and all performed well, allowing the synthesis of *S*-3-pyridyl and *S*-pyrimidyl sulfinamidines (**200**, 74% and **201**, 63%). Heterocycles such as thiophene and benzofuran were incorporated in high yields (**202**, 81% and **203**, 94%). *S*-indole, *N*-Ns sulfinamidine **204** was also obtained in 51% yield. Pleasingly, this reaction was not limited to (hetero)aromatic nucleophiles, as several *S*-alkyl, *N*-Ns sulfinamidines could also be prepared in high yields, with tertiary (**205**, 88%), secondary (**206**, 70%, **207**, 82%) and primary (**208**, 79%) carbon nucleophiles all compatible. Alkenyl were also tolerated, allowing examples **209** and **210** to be formed in 82% and 40% yield, respectively. Product **211,** which includes a fragment of the marketed COX-2 inhibitor, Celecoxib, was obtained in 83% yield. Notably, all the substrates were obtained on gram scale (**Figure 4.7**).

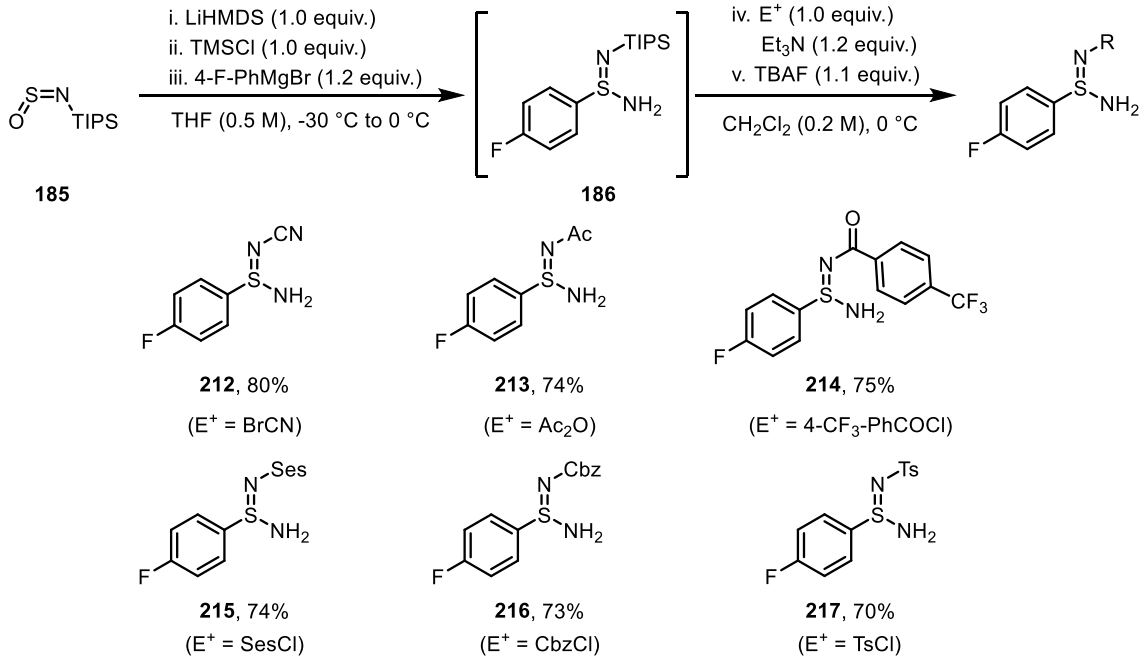




a. TIPS-NSO **185** (1.0 equiv.), LiHMDS (1.0 equiv.), THF (0.5 M), -30 °C, 5 min, then 0 °C, 5 min, then TMSCl (1.0 equiv.), 0 °C, 10 min, then RMgBr (1.2 equiv.), 0 °C, 10 min. Aqueous work-up. Then Et_3N (1.2 equiv.), NsCl (1.0 equiv.), CH_2Cl_2 (0.2 M), 0 °C, 20 min, then TBAF (1.1 equiv.), 0 °C, 10 min. Isolated yields. ***b***. Organolithium reagent employed. ***c***. "Turbo Grignard" reagent (R-MgCl·LiCl) employed.

Figure 4.7. Scope of *N*-Ns primary sulfinamidines[a]

In order to access a greater diversity of *N*-substituted sulfondiimidamides, we reacted the *N*-TIPS primary sulfinamidine intermediate **186** with a variety of electrophilic reagents (**Figure 4.8**). A range of *N*-substituted primary sulfinamidines were thus obtained on gram scales with good yields: reaction with cyanogen bromide gave *N*-CN example **212** (80%), treatment with acyl chlorides provided *N*-carbonyl examples (**213**, 74% and **214**, 75%), *N*-Ses example **215** (74%) was accessed using Ses-Cl as an electrophile, *N*-Cbz (**216**, 73%) and *N*-Ts examples (**217,** 70%) were also produced in high yields.



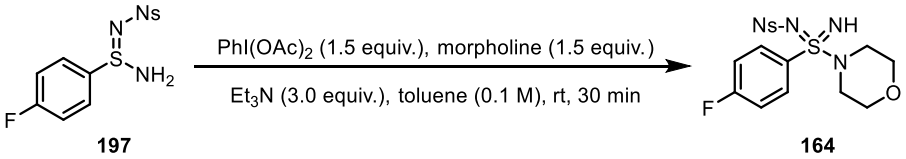
a. TIPS-NSO **185** (1.0 equiv.), LiHMDS (1.0 equiv.), THF (0.5 M), -30 °C, 5 min, then 0 °C, 5 min, then TMSCl (1.0 equiv.), 0 °C, 10 min, then 4-F-PhMgBr (1.2 equiv.), 0 °C, 10 min. Aqueous work-up. Then Et_3N (1.2 equiv.), E^+ (1.0 equiv.), CH_2Cl_2 (0.2 M), 0 °C, 20 min, then TBAF (1.1 equiv.), 0 °C, 10 min. Isolated yields.

Figure 4.8. Scope of *N*-substituted primary sulfinamidines[a]

4.4 Second Generation of Sulfondiimidamide Synthesis

Having established a convenient method to prepare various primary sulfinamidines, attention turned to the synthesis of sulfondiimidamides. Based on the previous reaction conditions developed to convert sulfinamides to sulfonimidamides within our group (**Figure 4.3**), an initial experiment was conducted with primary sulfinamidine **197** using morpholine (1.5 equiv.) as an amine nucleophile in the presence of $PhI(OAc)_2$ (1.5 equiv.) and triethylamine (3.0 equiv.), gave the desired sulfondiimidamide **164** in 93% yield after 30 min at room temperature (**Entry 1**). Some variations of the reaction condition were also investigated (**Table 4.1**). As expected, the $PhI(OAc)_2$ was essential for reactivity (**Entry 2**). Decreasing the amount of $PhI(OAc)_2$, base, or morpholine lead to lower yields (**Entries 3-6**). Increasing the equivalents of morpholine to three increased the yield of sulfondiimidamide **164** (97%, **Entry 7**). Substituting toluene with CH_3CN or CH_2Cl_2, or substituting DBU with Et_3N, resulted in diminished yields (**Entries 8-10**).

Table 4.1. Optimization of reaction conditions for the formation of sulfondiimidamide **164**



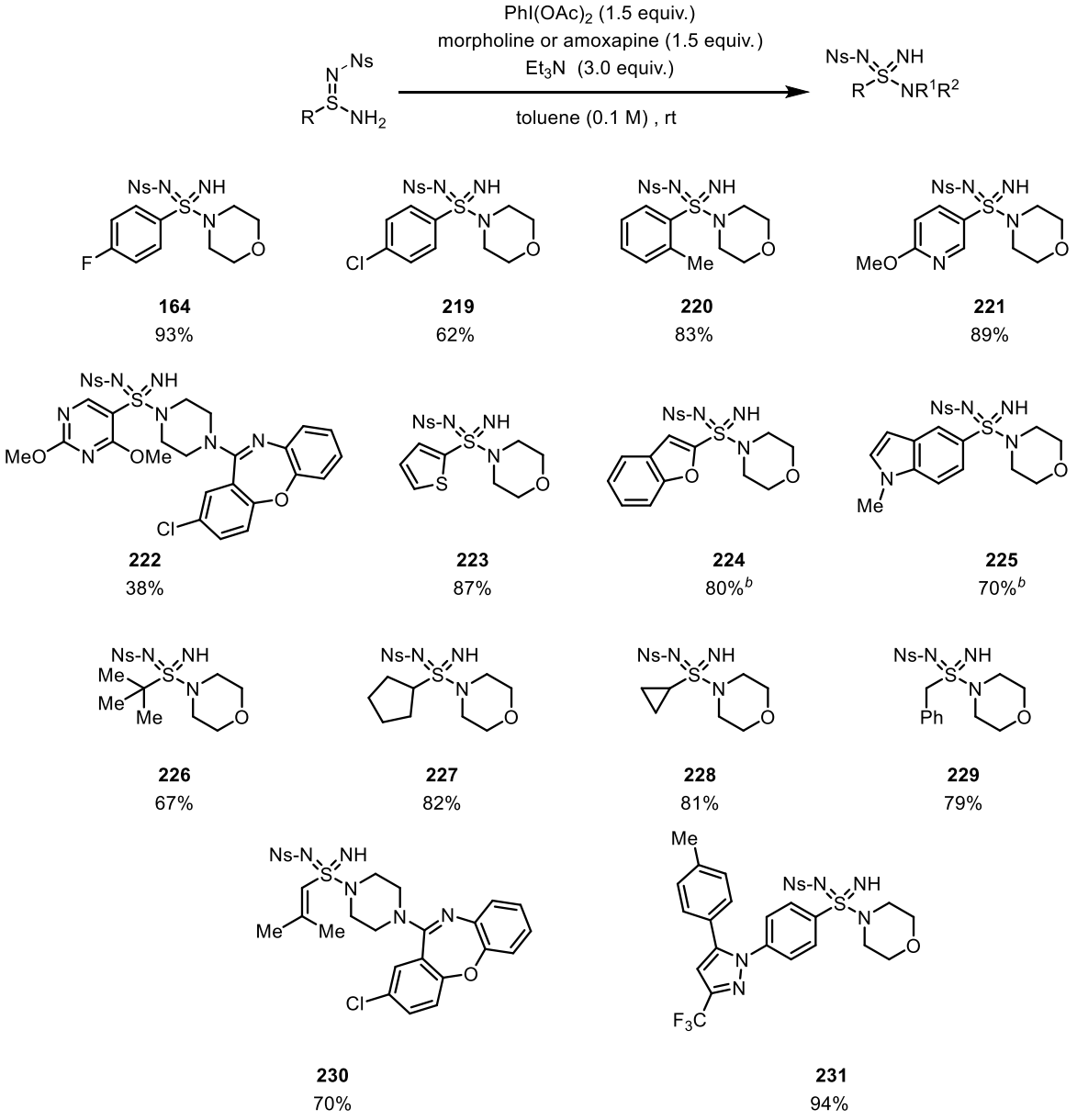
197 **164**

Entry[a]	Variation from above	yield of **164**
1	none	93%
2	no $PhI(OAc)_2$	0%
3	1.0 equiv. $PhI(OAc)_2$	75%
4	no Et_3N	76%
5	1.5 equiv. Et_3N	81%
6	1.0 equiv. morpholine	65%
7	3.0 equiv. morpholine	97%
8	DBU instead of Et_3N	69%[b]
9	CH_3CN instead of toluene	62%[b]
10	CH_2Cl_2 instead of toluene	88%[b]

a. **197** (1.0 equiv.), $PhI(OAc)_2$, base, morpholine, solvent (0.1 M), 30 min. Isolated yields. ***b***. Starting material consumed completely within 10 min.

Encouraged by this success, the sulfondiimidamide scope was then explored, initially focusing on varying the carbon component of sulfinamidines, using morpholine or amoxapine as the amine component (**Figure 4.9**). Several *S*-aryl, *N*-Ns sulfondiimidamides could be synthesised in good yields using this method, including steric and electronically varied examples (**164**, 93%, **219**, 62% and **220**, 83%). Several *S*-heteroaryl, *N*-Ns sulfondiimidamides also performed well, including 3-pyridyl (**221**, 89%), pyrimidyl (**222**, 38%), thiophene (**223**, 87%), benzofuran (**224**, 80%) and indole (**225**, 70%) examples. More electron-rich *S*-alkyl, *N*-Ns sulfinamidines were also tolerated in this method (**226,** 67%, **227,** 82%, **228,** 81% and **229,** 79%). Substrates **220** and **226** demonstrates that sterically hindered examples can be tolerated. Pleasingly, the first synthesis of *S*-vinyl sulfondiimidamide was also accomplished (**230**, 70%); this is a motif that was inaccessible using the $Ca(NTf_2)_2$-mediated amination conditions. Disappointingly, an alternative alkenyl substrate **209** did not give the desired product under the optimised reaction conditions, possibly due to competitive

Michael-addition as a side reaction. Product **231**, which includes a fragment of the marketed COX-2 inhibitor, Celecoxib, was obtained in 94% yield.

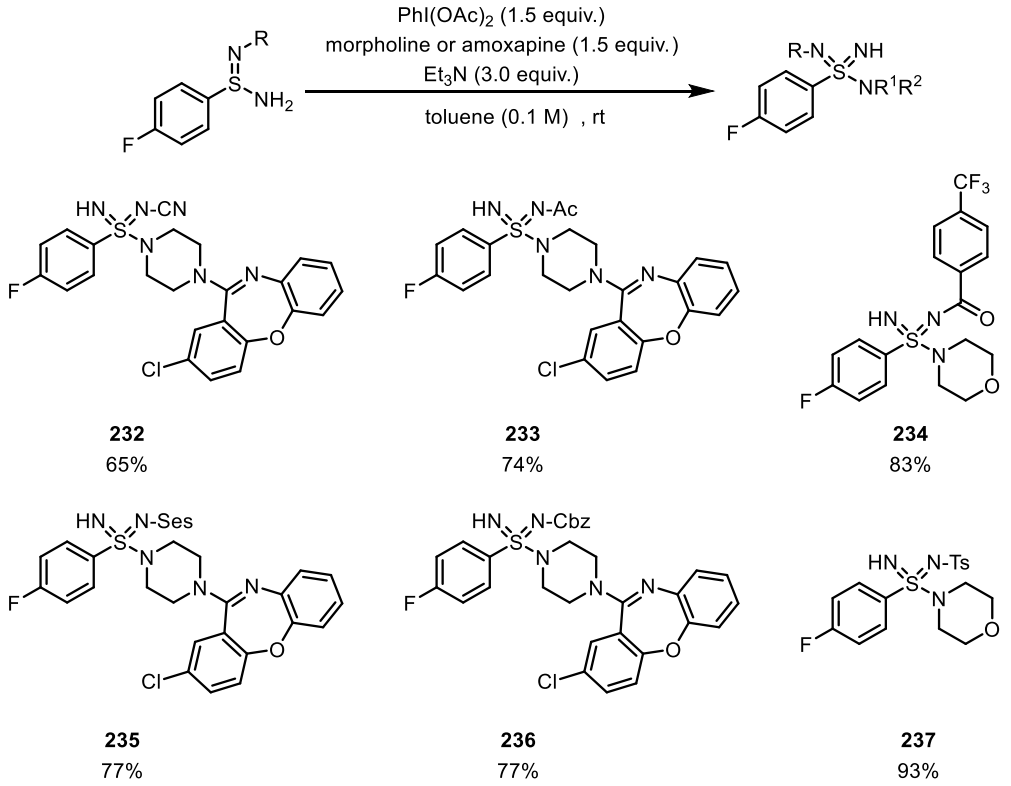


a. sulfinamidine (1.0 equiv.), $PhI(OAc)_2$ (1.5 equiv.), Et_3N (3.0 equiv.), morpholine or amoxapine (1.5 equiv.), toluene (0.1 M). Isolated yields. ***b***. $PhI(OAc)_2$ (2.0 equiv.), DBU (4.0 equiv.), morpholine (2.0 equiv.), CH_3CN (0.2 M).

Figure 4.9. Scope of sulfondiimidamides varying the organometallic reagent partners[a]

With a scope evaluated for *N*-Ns sulfondiimidamides, we turned our attention to accessing other *N*-substituted sulfondiimidamides (**Figure 4.10**). All of the *N*-substituted primary

sulfinamidines prepared in **Figure 4.8** were readily converted to the corresponding sulfondiimidamides in high yields, using morpholine or amoxapine as the amine partners: *N*-CN (**232**, 65%), *N*-carbonyl (**233**, 83% and **234**, 74%), *N*-Ses (**235**, 77%), *N*-Cbz (**236**, 77%) and *N*-Ts (**237**, 93%).

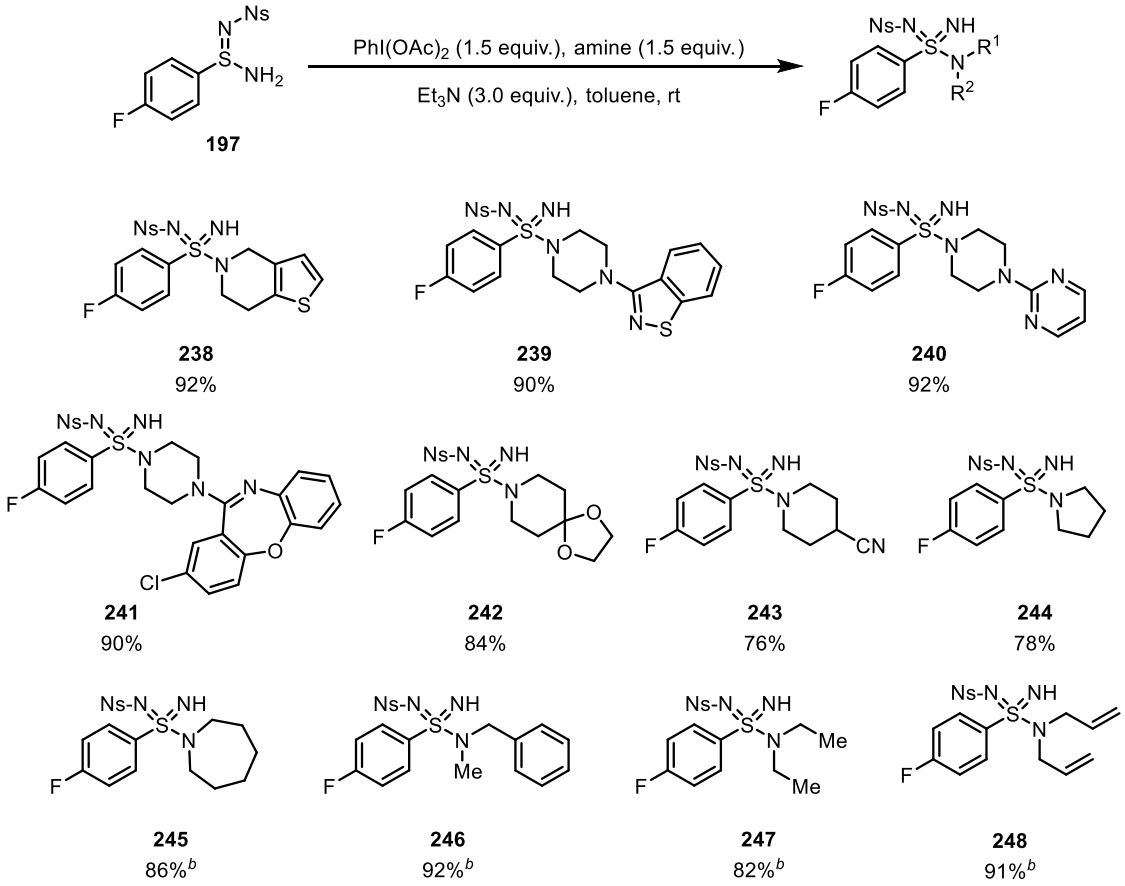


a. sulfinamidine (1.0 equiv.), $PhI(OAc)_2$ (1.5 equiv.), Et_3N (3.0 equiv.), morpholine or amoxapine (1.5 equiv.), toluene (0.1 M). Isolated yields.

Figure 4.10. Scope of *N*-substituted sulfondiimidamides[a]

The scope of the amine partners used in the reaction was then investigated (**Figure 4.11**). Cyclic secondary amines could be employed to give the corresponding sulfondiimidamides in high yields: piperidine fragments (**238,** 92%) and piperazine fragments (**239**, 90%, **240**, 92% and **241**, 90%). Examples **242** (84%) and **243** (76%) showed acetal and nitrile functionalities were also compatible. The pyrrolidine and azepane examples were also obtained with good yields (**244**, 78% and **245**, 86%). Sterically hindered acyclic secondary

amines, such as *N*-benzylmethylamine (**246**, 92%), diethylamine (**247**, 82%) and diallylamine (**248**, 91%) were also tolerated.



a. **197** (1.0 equiv.), $PhI(OAc)_2$ (1.5 equiv.), Et_3N (3.0 equiv.), amine (1.5 equiv.), toluene (0.1 M). Isolated yields. ***b***. Amine (3.0 equiv.), toluene (0.2 M).

Figure 4.11. Scope of amine nucleophiles for sulfondiimidamide synthesis[a]

4.5 Synthesis of Primary Sulfondiimidamides

However, limitations remained in the amine scope. Firstly, primary alkylamines did not work, likely due to the competing reation of $PhI(OAc)_2$ and electron-rich primary alkylamines. Secondly, electron-poor amines (such as amide, cyanamide and sulfonamide) did not work, likely due to their poor nucleophilicity. As such, we developed an alternative method that would allow additional amines to be incorporated, based on the functionalisation of sulfondiimidamide **248**. The imidic *N*-H of sulfondiimidamide **248** was converted to a

variety of functional groups (**Figure 4.12**). For example, treatment with cyanogen bromide provided *N*-Ns, *N*-CN derivative **249** in 99% yield, the diallyl group of which was removed under mild conditions using $Ph(PPh_3)_4$ and barbituric acid in dichloromethane, efficiently providing *N*-Ns, *N*-CN primary sulfondiimidamide **250** in 44% over two steps. Related two-stage procedure was also used to introduce benzyl (**252**, 40% over two steps), methyl (**254**, 38% over two steps), carbonyl (**256**, 55% over two steps) and sulfonyl (**258**, 52% over two steps) groups.

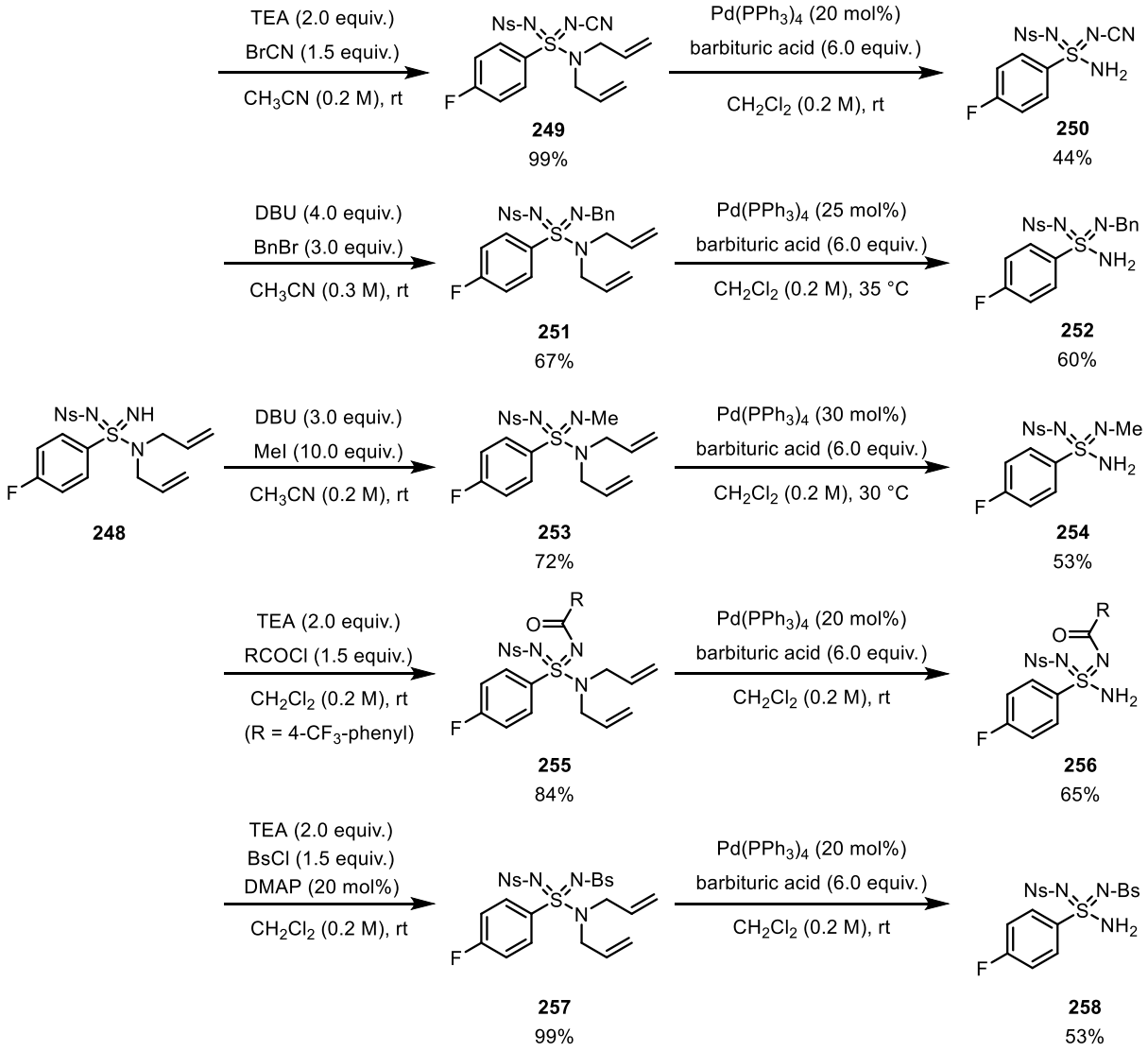


Figure 4.12. Differing *N*-substituted primary sulfondiimidamides synthesis

4.6 Second Generation of a Celecoxib Analogue Synthesis

Having developed a convenient method to prepare sulfondiimidamides, we wished to investigate its applications to complex, drug-like molecules. In **Chapter 3.7**, an eight-step route to a Celecoxib analogue **183** was described, using a $Ca(NTf_2)_2$-mediated amination as the key step to build the core sulfondiimidamide structure. We proposed a shorter route using the $PhI(OAc)_2$-promoted amination to synthesise the core sulfondiimidamide structure (**Figure 4.13**). Organolithium reagent **260** was obtained from the corresponding aryl bromide **259** *via* lithium-halogen exchange and employed in the synthesis of the *N*-CN primary sulfinamidine **262** in 86% yield. The subsequent amination with diallylamine and $PhI(OAc)_2$ gave the corresponding *N*-H, *N*-CN sulfondiimidamide **181** in 81% yield, although an increase in the stoichiometry of diallylamine (5.0 equiv.) was required. The di-*N*-CN-substituted sulfondiimidamide analogue **183** was then obtained using the cyanation and deprotection conditions developed in **Chapter 3.7**. This new route takes only 4 steps, with an overall yield of 59%.

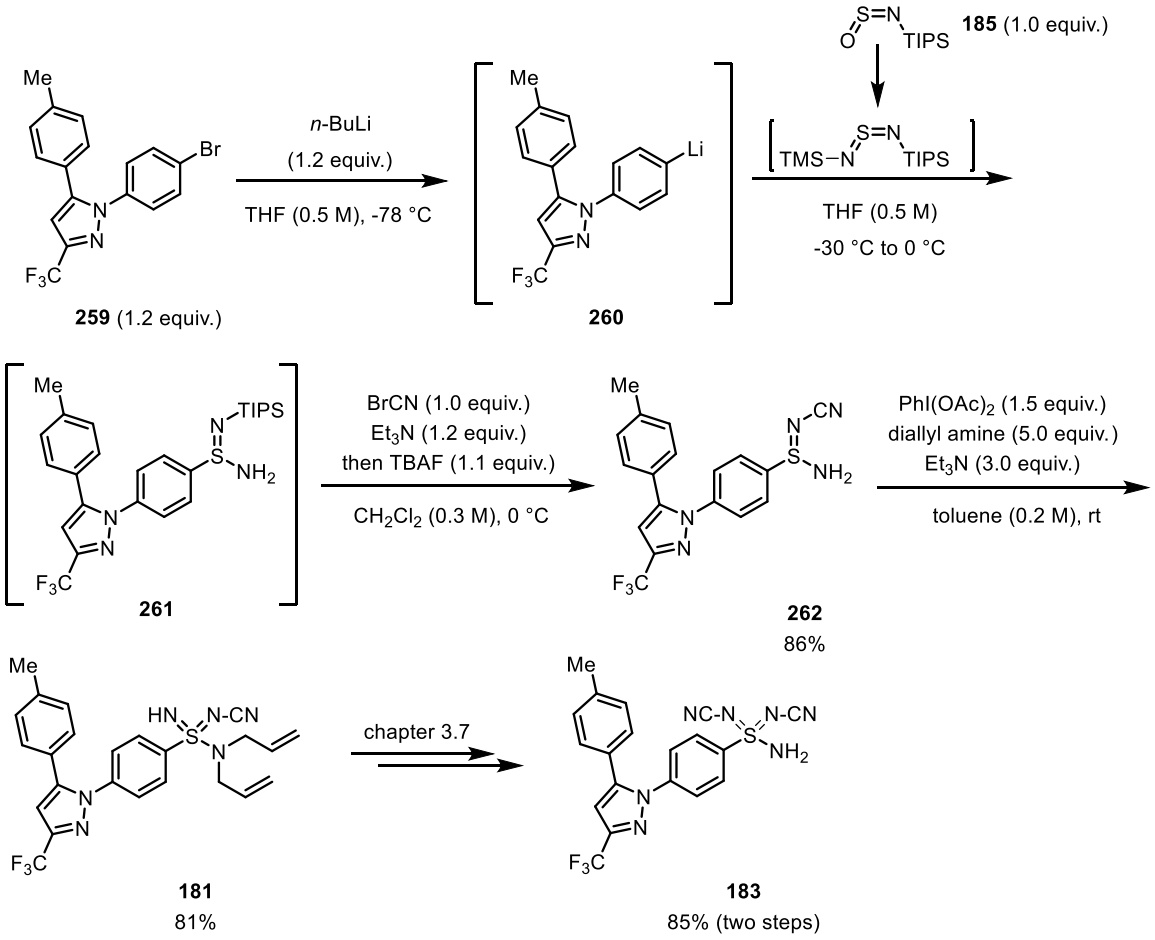


Figure 4.13. Second generation synthesis of Celecoxib analogue **183**

4.7 Synthesis of A Sildenafil Analogue

In addition to Celecoxib, we also proposed a synthesis of a sulfondiimidamide analogues of Sildenafil, which is a commercial PDE5 inhibitor featuring a sulfonamide core. The required organolithium reagent **264** was obtained from the corresponding aryl bromide **263**. In this reaction, more than two equivalents of the alkyl lithium base were required. Initially, methyl lithium was employed to deprotonate the pyrimidinone core. *n*-Butyl lithium was then used to generate the organolithium reagent, which was added to the *in-situ* generated sulfurdiimide reagent. Subsequent reaction with cyanogen bromide, and removal of the TIPS group using TBAF, gave *N*-CN primary sulfinamidine **266** in 51% yield. An increase in stoichiometry of the sulfinylamine and sulfurdiimide was required to account for the excess base in the reaction. Amination with $PhI(OAc)_2$ and *N*-methyl piperazine directly gave *N*-H,

N-CN sulfondiimidamide **267** in 62% yield (**Figure 4.14**). This Sildenafil analogue **267** was accessed using just two steps, starting from the aryl bromide **263**, thus demonstrating the utility of the developed methodology.

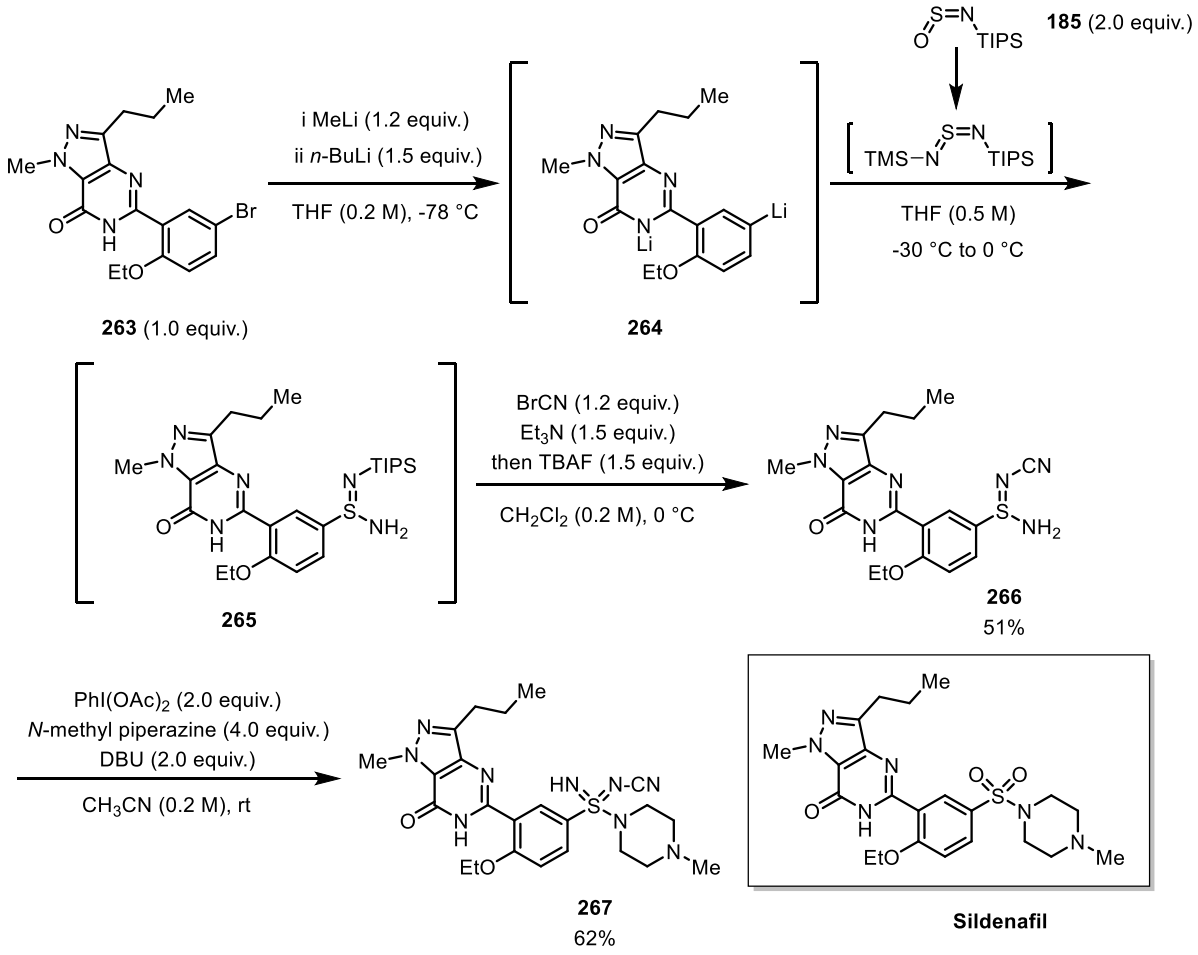


Figure 4.14. Synthesis of Sildenafil analogue **267**

4.8 Summary

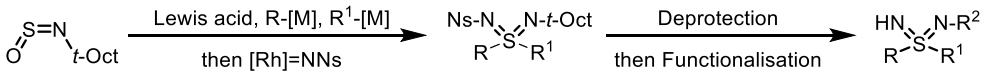
In summary, a practical and efficient method for the synthesis of primary sulfinamidines and sulfondiimidamides using TIPS-NSO as a linchpin reagent was developed. (Hetero)aryl, alkyl and alkenyl organometallic reagents were shown to be tolerated in this process, allowing a convenient access to various primary sulfinamidines. Sulfondiimidamides derived from secondary alkylamines were obtained in high yield by the $PhI(OAc)_2$-promoted amination. The further development of amination from the *S*-diallylamine-substituted

sulfondiimidamide provided an opportunity for primary alkylamine, amide, sulfonamide and cyanamide to be incorporated. Taken together, this method provides a flexible method for sulfondiimidamide synthesis and complements the earlier developed route. A novel Celecoxib derivative and an unprecedented sulfondiimidamide analogue of Sildenafil were prepared using this method.

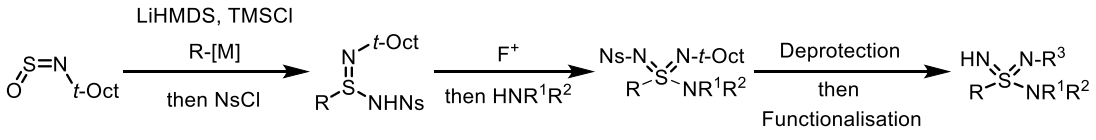
Chapter 5 - Conclusion and Future Work

This thesis demonstrates that sulfinylamines, which have been successfully employed for the effective synthesis of sulfoximines and sulfonimidamides in the past ten years, are also versatile reagents for the preparation of sulfondiimines, sulfondiimidoyl fluorides, and sulfondiimidamides. Although several sulfinylamines previously used in the literature have some common limitations, such as steric hindrance and moisture sensitivity, judicious selection of the *N*-substituent of the sulfinylamines was shown to avoid these limitations effectively.

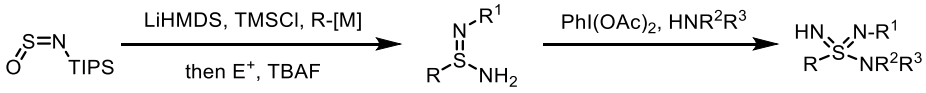
Our work began with the synthesis of sulfondiimines by combining two organometallic reagents and a sulfinylamine linchpin (*t*-Oct-NSO), followed by a rhodium-catalysed imination. The use of thiols or sulfides as the starting reagents and explosive reagents as the imination reagents were avoided. This method provides the synthesis of the most diverse range of sulfondiimines to date, providing the possibility for further application of these interesting functional groups in pharmaceutical chemistry.



t-Oct-NSO was also established as an excellent candidate for sulfondiimidamide synthesis. Orthogonally *N*-protected sulfinamidines were obtained from the reaction of *t*-Oct-NSO, organometallic reagents and NsCl. Subsequent fluorination and amination provided a broad range of sulfondiimidamides with modest to good yields. Employing this method, an analogue of the COX-2 inhibitor, Celecoxib, was prepared.



Some limitations exist in our first sulfondiimidamide synthesis, such as tedious multi-step procedures, incompatibility of acid/base-sensitive functional groups, and the requirement for stoichiometric amounts of expensive reagents. In order to address these limitations, a novel class of sulfinylamine (TIPS-NSO) and an alternative synthetic strategy was developed. Primary sulfinamidines were generated from TIPS-NSO, organometallic reagents and various electrophiles. Sulfondiimidamides were obtained in high yield through $PhI(OAc)_2$-promoted amination. A Celecoxib analogue and an unprecedented Sildenafil analogue were prepared using this method.



Future work in the group will focus on the mechanistic study of the $PhI(OAc)_2$-promoted amination, through experiment and calculations. Low temperature NMR and *in-situ* IR spectroscopy could be considered to monitor the possible reaction intermediates, which may provide insights for asymmetric sulfondiimine and sulfondiimidamide synthesis.

In general, developing transition metal-catalysed methodology for the use of aryl halides or boronic acids to replace the organometallic reagents is a crucial improvement in this field. This would further improve the substrate compatibility of these methods, and allow more analogues of sulfone and sulfonamide drugs to be prepared.

Chapter 6 - Experimental Data and Procedures

6.1 General Considerations

Handling techniques: Reactions were performed under inert nitrogen atmosphere with anhydrous solvent unless otherwise stated. All glassware was oven-dried at >100 °C and allowed to cool to room temperature under a positive pressure of nitrogen before use. Reactions were monitored by TLC until deemed complete using aluminum backed silica plates. Plates were visualised under ultraviolet light (λ_{max} = 254 nm) and/or by staining with $KMnO_4$ solution. Cooling of reaction mixtures to 0 °C was achieved using an ice-water bath. Cooling of reaction mixtures to -78 °C was achieved using a dry ice-acetone bath. 'Room temperature' refers to an ambient temperature of 21 ± 2 °C.

Reagents: Reagents were purchased from Sigma-Aldrich Chemical Co. Ltd., Alfa Aesar, Tokyo Chemical Industry UK or Fluorochem Ltd. and were used as supplied. Anhydrous solvents were purified by filtration through dried alumina columns using the University of Oxford internal solvent drying system (Innovative Technology Inc. PS-400-7) and sparged with nitrogen before use. All inert gases were sourced from the University of Oxford internal supplies and dried through $CaCl_2$ drying columns. Grignard reagents were titrated against a solution of salicylaldehyde phenylhydrazone.[71] Flash column chromatography was carried out using matrix 60 silica gel. 'Petrol' refers to the fraction of petroleum ether which boils in the range of 40-60 °C.

NMR Spectroscopy: ^{1}H-NMR spectra were obtained on a Bruker AVIII400 (400 MHz) spectrometer. ^{13}C-NMR spectra were obtained on a Bruker AVIII400 (101 MHz). ^{19}F-NMR spectra were obtained on a Bruker AVIII400 (377 MHz) spectrometer. All reported ^{1}H and ^{13}C chemical shifts (δ_H, δ_C) are referenced to the residual signal of deuterated solvents ($CDCl_3$: δ_H = 7.26 ppm, δ_C = 77.16 ppm; $(CD_3)_2SO$: δ_H = 2.50 ppm, δ_C = 39.52 ppm;

$(CD_3)_2CO$: δ_H = 2.05 ppm, δ_C = 206.26 ppm; CD_3CN: δ_H = 1.94 ppm, δ_C = 118.26 ppm; C_6D_6: δ_H = 7.16 ppm, δ_C = 128.06 ppm). ^{19}F chemical shifts (δ_F) are referenced externally to $CFCl_3$ (δ_F = 0.0 ppm). Chemical shifts (δ) are reported in parts per million (ppm) to the nearest 0.01 ppm for ^1H NMR, and 0.1 ppm for ^{13}C and ^{19}F NMR. Coupling constants (*J*) are reported in Hertz (Hz). Multiplicities are reported as follows: s (singlet), d (doublet), t (triplet), q (quartet), pent. (pentet), m (multiplet), br. (broad signal), app. (apparent).

Mass Spectroscopy: Low resolution ESI mass spectra were recorded on a Waters LCT Premier spectrometer. High resolution mass spectrometry measurements were recorded on a Bruker Daltronics MicroTOF (ESI) spectrometer or a Micromass LCT (FI) spectrometer by the internal service at Chemistry Research Laboratory, University of Oxford. Samples for mass spectra were prepared as 1 mg/mL solution in MeOH (LRMS, HRMS-ESI) or submitted neat (HRMS-FI).

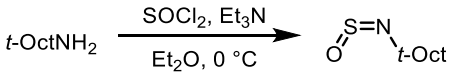
IR Spectroscopy: Infrared spectra were recorded as thin films on a Bruker Tensor 27 FT-IR spectrometer.

Melting point: Melting points were measured using a Stuart Scientific Melting Point Apparatus SMP1.

Optical rotation: Optical rotations were measured on a Schmidt Haensch UniPol L2000 polarimeter at 589 nm, 25 °C. $[\alpha]_D^T$ is expressed in deg cm^3 g^{-1} dm^{-1} and c is expressed in g/100 cm^3.

6.2 Chapter 2 Data

6.2.1 Preparation of *t*-Oct-NSO



T-Octylamine (5.17 g, 40.0 mmol, 1.00 equiv.) was dissolved in anhydrous diethyl ether (200 mL) in a 500 mL 3-necked round bottom flask. Anhydrous triethylamine (11.49 mL, 82.4 mmol, 2.06 equiv.) was added and the reaction was cooled to 0 °C. Freshly distilled thionyl chloride (2.99 mL, 41.2 mmol, 1.03 equiv.) was added dropwise. The reaction was stirred at 0 °C for 2 h. Filtration through Celite® (washed with anhydrous diethyl ether) and removal of solvent under reduced pressure afforded *t*-Oct-NSO **25** as a yellow oil (6.65 g, 38.0 mmol, 95%).

Notes

1. *t*-Oct-NSO **25** should be stored in the freezer (-20 °C) and can be used without loss of performance for at least 2 months. Prolonged contact with air or storage at room temperature should be avoided.
2. **CAUTION: Hydrolysis of sulfinylamines results in the formation of toxic sulfur dioxide gas.** Evolution of SO_2 from *t*-Oct-NSO has not been noted by the authors in the normal course of use, but avoidance of contact with water or prolonged storage at room temperature is advised.
3. *T*-Octylamine was purchased from Sigma-Aldrich and used without further purification.
4. The product may be further purified by vacuum distillation at 65 °C/5 mbar, but this was not necessary. Use of high temperatures during distillation may result in decomposition of the product.

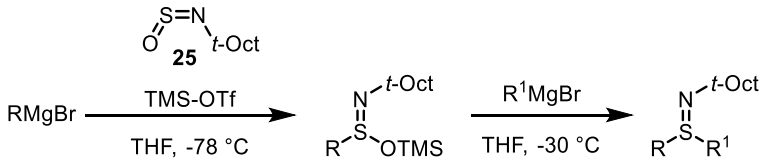
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 1.73 (s, 2H, $NC(CH_3)_2CH_2$), 1.60 (s, 6H, $NC(CH_3)_2$), 1.02 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 67.7, 55.5, 32.2, 31.5, 31.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 2888, 1382, 1252, 1152, 1073, 954;

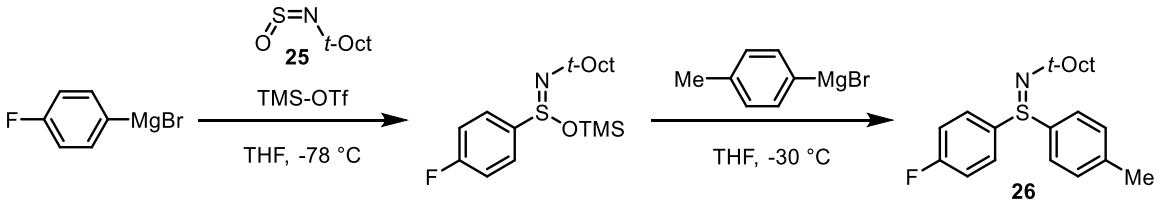
HRMS (EI^+) calcd. for $C_8H_{18}NOS^+$ $[M+H]^+$: 176.1104; found: 176.1106.

6.2.2 General Procedure A for Diaryl Sulfilimine Synthesis



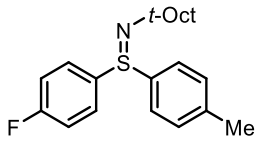
t-Oct-NSO **25** (1.05 equiv.) was dissolved in anhydrous THF (0.5 M) in an oven-dried round bottom flask. Then the mixture was cooled to -78 °C before TMSOTf (1.0 equiv.) was added and first organometallic reagent (1.0 equiv.) was added dropwise after 1 min. The reaction was stirred at -78 °C for 2 min and then the temperature was increased to -30 °C (**see note**). Second organometallic reagent (1.5 equiv.) was then added quickly. The mixture was stirred at -30 °C for 10 min. Then the reaction was quenched with sat. aq. tetrasodium EDTA solution. Ethyl acetate was added and the organic phase was separated. The aqueous phase was further extracted with ethyl acetate. The combined organic extracts were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The crude product was purified by flash column chromatography to afford diaryl sulfilimine.

Note: The reaction can be warmed from -78 °C to -30 °C through an addition of acetone to the dry ice-acetone bath over 5 min, or a quick replacement of the dry ice-acetone bath with an acetone bath at -30 °C.



t-Oct-NSO **25** (158 mg, 0.90 mmol, 1.05 equiv.) was dissolved in anhydrous THF (2 mL) in an oven-dried 25 mL round bottom flask. Then the mixture was cooled to -78 °C before TMSOTf (195 mg, 0.86 mmol, 1.0 equiv.) was added, and 4-fluorophenylmagnesium bromide (0.97 mL, 0.89 M in THF, 0.86 mmol, 1.0 equiv.) was added dropwise after 1 min. The reaction was stirred at -78 °C for 2 min and then the temperature was increased to -30 °C (**see note**). 4-Methylphenylmagnesium bromide (1.40 mL, 0.91 M in THF, 1.27 mmol, 1.5 equiv.) was then added quickly. The mixture was stirred at -30 °C for 10 min. Then the reaction was quenched with sat. aq. tetrasodium EDTA solution. Ethyl acetate (60 mL) was added and the organic phase was separated. The aqueous phase was further extracted with ethyl acetate (2 × 30 mL). The combined organic extracts were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The crude product was purified by column chromatography on silica gel (petrol/ethyl acetate with 1% Et_3N, 4:1 to 1:1 to 0:1) to afford *sulfilimine* **26** as a light-yellow oil (252 mg, 85%).

1-(4-Fluorophenyl)-1-(*p*-tolyl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ⁴-sulfanimine (26)



^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.61-7.56 (m, 2H, Ar_F-*H*), 7.47 (d, *J* = 8.2 Hz, 2H, Tol-*H*), 7.18 (d, *J* = 8.2 Hz, 2H, Tol-*H*), 7.08-7.02 (m, 2H, Ar_F-*H*), 2.33 (s, 3H, Ar_{Me}-C*H*$_3$), 1.63 (s, 2H, $NC(CH_3)_2CH_2$), 1.31 (s, 6H, $NC(CH_3)_2$), 0.95 (s, 9H, *t*-Bu-*H*);

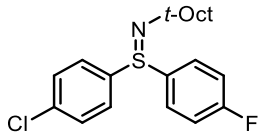
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 163.6 (d, $^1J_{CF}$ = 250.2 Hz), 141.8, 140.9 (d, $^4J_{CF}$ = 2.6 Hz), 140.4, 129.8, 128.8 (d, $^3J_{CF}$ = 8.7 Hz), 126.7, 116.1 (d, $^2J_{CF}$ = 22.2 Hz), 58.5, 58.4, 32.73, 32.70, 32.1, 31.8, 21.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -111.1 (tt, J = 9.0, 5.3 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2950, 1587, 1487, 1224, 1075, 1007, 833;

HRMS (ESI^+) calcd. for $C_{21}H_{29}FNS^+$ $[M+H]^+$: 346.1999; found: 346.1997.

1-(4-Chlorophenyl)-1-(4-fluorophenyl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (31')



Prepared according to **General Procedure A** using *t*-Oct-NSO **25** (164 mg, 0.934 mmol, 1.05 equiv.), TMSOTf (201 mg, 0.904 mmol, 1.0 equiv.), 4-chlorophenylmagnesium bromide (1.03 mL, 0.88 M in 2-methyltetrahydrofuran, 0.906 mmol, 1.0 equiv.) and 4-fluorophenylmagnesium bromide (1.42 mL, 0.96 M in THF, 1.36 mmol, 1.5 equiv.). Purification by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 7:1 to 1:1 to 0:1) afforded *sulfilimine* **31'** as a light-yellow oil (262 mg, 79%).

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.63-7.57 (m, 2H, Ar_F-*H*), 7.55 (d, J = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.35 (d, J = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.10-7.03 (m, 2H, Ar_F-*H*), 1.61 (s, 2H, $NC(CH_3)_2CH_2$), 1.29 (s, 6H, $NC(CH_3)_2$), 0.94 (s, 9H, *t*-Bu-*H*);

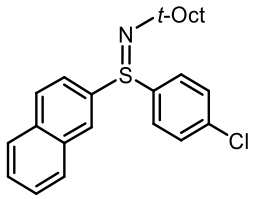
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 164.8 (d, $^1J_{CF}$ = 248.5 Hz), 146.1, 142.7 (d, $^4J_{CF}$ = 2.9 Hz), 136.7, 130.3, 129.4 (d, $^3J_{CF}$ = 8.9 Hz), 128.6, 117.2 (d, $^2J_{CF}$ = 22.9 Hz), 59.2, 59.0, 33.84, 33.79, 32.82, 32.75;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -110.1 (tt, J = 8.4, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1653, 1589, 1472, 1390, 1228, 1128, 1088, 1006, 963, 812, 736;

HRMS (ESI^+) calcd. for $C_{20}H_{26}F^{35}Cl\,NS^+$ $[M+H]^+$: 366.1453; found: 366.1446.

1-(4-Chlorophenyl)-1-(naphthalen-2-yl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (32')



Prepared according to **General Procedure A** using *t*-Oct-NSO **25** (366 mg, 2.09 mmol, 1.05 equiv.), TMSOTf (445 mg, 2.00 mmol, 1.0 equiv.), 2-naphthylmagnesium bromide (3.80 mL, 0.52 M in THF, 1.98 mmol, 1.0 equiv.) and 4-chlorophenylmagnesium bromide (3.60 mL, 0.83 M in 2-methyltetrahydrofuran, 2.99 mmol, 1.5 equiv.). Purification by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 7:1 to 5:1 to 0:1) afforded *sulfilimine* **32'** as a light-yellow oil (696 mg, 89%).

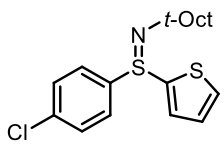
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) =8.30-8.27 (m, 1H, Ar-*H*), 7.94-7.89 (m, 1H, Ar-*H*), 7.84-7.78 (m, 2H, Ar-*H*), 7.60 (d, J = 8.5 Hz, 2H, Ar_{Cl}-*H*), 7.55-7.49 (m, 3H, Ar-*H*), 7.35 (d, J = 8.5 Hz, 2H, Ar_{Cl}-*H*), 1.71 (s, 2H, $NC(CH_3)_2CH_2$), 1.38 (s, 6H, $NC(CH_3)_2$), 0.99 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) =143.6, 141.7, 136.1, 134.0, 132.9, 129.4, 129.2, 128.7, 128.1, 127.9, 127.5, 127.1, 126.7, 123.0, 58.7, 58.3, 32.84, 32.82, 32.1, 31.8;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1474, 1389, 1210, 1132, 1092, 1011, 857, 812, 763, 750;

HRMS (ESI$^+$) calcd. for $C_{24}H_{29}N^{35}ClS^+$ $[M+H]^+$: 398.1704; found: 398.1701.

1-(4-Chlorophenyl)-1-(thiophen-2-yl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (33')



Prepared according to **General Procedure A** using *t*-Oct-NSO **25** (372 mg, 2.12 mmol, 1.05 equiv.), TMSOTf (458 mg, 2.06 mmol, 1.0 equiv.), 4-chlorophenylmagnesium bromide

(2.34 mL, 0.88 M in 2-methyltetrahydrofuran, 2.06 mmol, 1.0 equiv.) and 2-thienylmagnesium bromide (3.50 mL, 0.85 M in THF, 2.96 mmol, 1.5 equiv.). Purification by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 7:1 to 2:1 to 0:1) afforded *sulfilimine* **33'** as a light-yellow oil (627 mg, 86%).

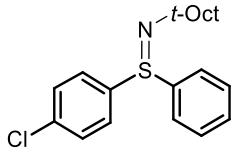
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.66 (d, J = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.43 (dd, J = 5.0, 1.3 Hz, 1H, HetAr-*H*), 7.37 (d, J = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.27-7.21 (m, 1H, HetAr-*H*), 6.97 (dd, J = 5.0, 3.7 Hz, 1H, HetAr-*H*), 1.63 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.60 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.32 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.31 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.95 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.4, 143.0, 136.4, 130.6, 129.1, 128.8, 127.4, 127.2, 58.8, 57.9, 32.5, 32.4, 31.9, 31.7;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1471, 1276, 1261, 1209, 1087, 1008, 816, 766, 706;

HRMS (ESI^+) calcd. for $C_{18}H_{25}N^{35}ClS_2^+$ $[M+H]^+$: 354.1112; found: 354.1111.

1-(4-Chlorophenyl)-1-phenyl-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (34')



Prepared according to **General Procedure A** using *t*-Oct-NSO **25** (337 mg, 1.93 mmol, 1.05 equiv.), TMSOTf (417 mg, 1.88 mmol, 1.0 equiv.), 4-chlorophenylmagnesium bromide (2.13 mL, 0.88 M in 2-methyltetrahydrofuran, 1.87 mmol, 1.0 equiv.) and phenyllithium (2.20 mL, 1.24 M in dibutyl ether, 2.73 mmol, 1.5 equiv.). Purification by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 3:1 to 1:1 to 0:1) afforded *sulfilimine* **34'** as a light-yellow oil (590 mg, 91%).

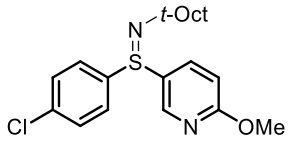
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) =7.61-7.57 (m, 2H, Ph-*H*), 7.55 (d, J = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.38- 7.30 (m, 5H, Ph-*H*/Ar_{Cl}-*H*), 1.62 (s, 2H, $NC(CH_3)_2CH_2$), 1.30 (s, 6H, $NC(CH_3)_2$), 0.94 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 144.1, 143.2, 136.1, 130.2, 129.2, 129.1, 128.0, 126.6, 58.6, 58.1, 32.6, 32.5, 31.9, 31.7;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1472, 1276, 1261, 1209, 1087, 1009, 817, 750, 702;

HRMS (ESI^+) calcd. for $C_{20}H_{27}N^{35}ClS^+$ $[M+H]^+$: 348.1547; found: 348.1544.

1-(4-Chlorophenyl)-1-(6-methoxypyridin-3-yl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (35')



Preparation of organolithium reagent

5-Bromo-2-methoxypyridine (458 mg, 2.44 mmol, 1.2 equiv.) and THF (5 mL) were added to an oven-dried reaction tube and were cooled to -78 °C. *n*-Butyllithium (1.09 mL, 2.24 M in hexanes, 2.44 mmol, 1.2 equiv.) was added dropwise and the mixture was stirred at the same temperature for 40 min.

Preparation of diaryl sulfilimine

t-Oct-NSO **25** (370 mg, 2.11 mmol, 1.05 equiv.) was dissolved in anhydrous THF (4.0 mL) in an oven-dried 25 mL round bottom flask. The mixture was cooled to -78 °C before the addition of TMSOTf (440 mg, 1.98 mmol, 1.0 equiv.). 4-Chlorophenylmagnesium bromide (2.25 mL, 0.88 M in 2-methyltetrahydrofuran, 1.98 mmol, 1.0 equiv.) was added dropwise after 1 min. The reaction was stirred at -78 °C for 2 min and then the temperature was increased to -30 °C. Then the organolithium reagent was by syringe. The mixture was stirred at -30 °C for 10 min, then warmed to room temperature and stirred for 1.5 h. The reaction was subsequently quenched with sat. aq. tetrasodium EDTA solution. Ethyl acetate (60 mL) was then added and the organic phase was separated. The aqueous phase was further extracted with ethyl acetate (2 × 30 mL). The combined extracts were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The crude product was purified by flash column

chromatography (petrol/ethyl acetate with 1% Et_3N, 4:1 to 1:1 to 0:1) to afford *sulfilimine* **35'** as a light-yellow oil (570 mg, 76%).

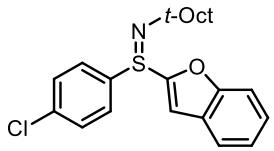
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.26 (dd, J = 2.5, 0.7 Hz, 1H, HetAr-*H*), 7.67 (dd, J = 8.7, 2.5 Hz, 1H, HetAr-*H*), 7.52 (d, J = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.31 (d, J = 8.6 Hz, 2H, Ar_{Cl}-*H*), 6.68 (dd, J = 8.7, 0.7 Hz, 1H, HetAr-*H*), 3.86 (s, 3H, OCH_3), 1.58 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.25 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.24 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.89 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.2, 145.9, 142.9, 137.0, 136.1, 133.9, 129.1, 127.5, 112.4, 58.5, 58.1, 53.9, 32.7, 32.5, 31.9, 31.7;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1587, 1473, 1362, 1276, 1261, 1010, 750;

HRMS (ESI^+) calcd. for $C_{20}H_{28}O^{35}Cl\ N_2S^+$ $[M+H]^+$: 379.1605; found: 379.1602.

1-(Benzofuran-2-yl)-1-(4-chlorophenyl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (36')



Preparation of organolithium reagent

Benzofuran (317 mg, 2.69 mmol, 1.5 equiv.) and THF (5.0 mL) were added to an oven-dried reaction tube. The reaction was cooled to 0 °C. *n*-Butyllithium (1.20 mL, 2.24 M in hexanes, 2.69 mmol, 1.5 equiv.) was added dropwise and the mixture stirred at the room temperature for 1 h.

Preparation of diaryl sulfilimine

t-Oct-NSO **25** (312 mg, 1.78 mmol, 1.05 equiv.) was dissolved in anhydrous THF (3.6 mL) in an oven-dried 25 mL round bottom flask. Then the reaction was cooled to -78 °C before TMSOTf (386 mg, 1.74 mmol, 1.0 equiv.) was added, 4-chlorophenylmagnesium bromide (1.97 mL, 0.88 M in 2-methyltetrahydrofuran, 1.73 mmol, 1.0 equiv.) was added dropwise

after 1 min. The reaction was stirred at -78 °C for 2 min and then the temperature was increased to -30 °C. Then the lithium reagent was added by syringe. The mixture was stirred at -30 °C for 10 min and then warmed to room temperature and stirred for 1.5 h. Then the reaction was quenched with saturated aqueous tetrasodium EDTA solution and poured into a 250 mL separating funnel. Ethyl acetate (60 mL) was then added and the organic phase was separated. The aqueous phase was further extracted with ethyl acetate (2 × 30 mL). The combined extracts were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 7:1 to 1:1 to 0:1) to afford *sulfilimine* **36'** as a light-yellow oil (584 mg, 87%)**.**

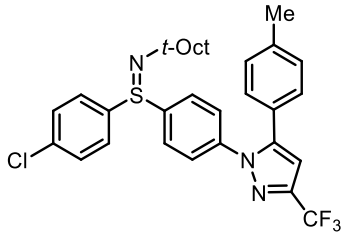
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.75 (d, J = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.57-7.52 (m, 1H, HetAr-*H*), 7.45-7.39 (m, 3H, Ar_{Cl}-*H*/HetAr-*H*), 7.32-7.27 (m, 1H, HetAr-*H*), 7.22 (app. td, J = 7.5, 1.1 Hz, 1H, HetAr-*H*), 7.04 (d, J = 1.1 Hz, 1H, HetAr-*H*), 1.68 (s, 2H, $NC(CH_3)_2CH_2$), 1.39 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.37 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.98 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 156.6, 156.4, 139.4, 136.8, 129.3, 127.6, 127.0, 126.1, 123.6, 122.0, 112.0, 109.8, 58.7, 57.8, 32.6, 32.4, 31.9, 31.8;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1472, 1444, 1276, 1261, 1010, 816, 750;

HRMS (ESI^+) calcd. for $C_{22}H_{27}O^{35}ClNS^+$ $[M+H]^+$: 388.1496; found: 388.1494.

1-(4-Chlorophenyl)-1-(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (37')



Preparation of organolithium reagent

1-(4-Bromophenyl)-5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazole (413 mg, 1.09 mmol, 1.3 equiv.) and THF (2.0 mL) were added to an oven-dried reaction tube and were cooled to -78 °C. *n*-Butyllithium (0.48 mL, 2.24 M in hexanes, 1.1 mmol, 1.3 equiv.) was added dropwise and the mixture was stirred at the same temperature for 40 min.

Preparation of diaryl sulfilimine

t-Oct-NSO **25** (155 mg, 0.89 mmol, 1.05 equiv.) was dissolved in anhydrous THF (4.0 mL) in an oven-dried 25 mL round bottom flask. The mixture was cooled to -78 °C before the addition of TMSOTf (190 mg, 0.86 mmol, 1.0 equiv.). 4-Chlorophenylmagnesium bromide (0.97 mL, 0.88 M in 2-methyltetrahydrofuran, 0.85 mmol, 1.0 equiv.) was added dropwise after 1 min. The reaction was stirred at -78 °C for 2 min and then the temperature was increased to -30 °C. Then the organolithium reagent was added by syringe. The mixture was stirred at -30 °C for 10 min, then warmed to room temperature and stirred for 1.5 h. The reaction was subsequently quenched with sat. aq. tetrasodium EDTA solution. Ethyl acetate (50 mL) was then added and the organic phase was separated. The aqueous phase was further extracted with ethyl acetate (2 × 30 mL). The combined extracts were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 3:1 to 1:1 to 0:1) to afford *sulfilimine* **37'** as a light-yellow oil (413 mg, 85%).

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.60 (d, *J* = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.56 (d, *J* = 8.6 Hz, 2H, Ar-*H*), 7.38 (d, *J* = 8.6 Hz, 2H, Ar_{Cl}-*H*), 7.36 (d, *J* = 8.6 Hz, 2H, Ar-*H*), 7.11 (d, *J* = 8.3 Hz, 2H, Tol-*H*), 7.06 (d, *J* = 8.3 Hz, 2H, Tol-*H*), 6.70 (s, 1H, HetAr-*H*), 2.35 (s, 3H, Tol-CH_3), 1.61 (s, 2H, NC$(CH_3)_2$CH_2), 1.32 (s, 6H, NC$(CH_3)_2$), 0.94 (s, 9H, *t*-Bu-*H*);

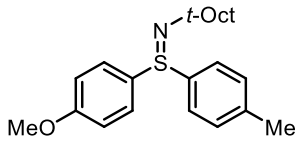
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 145.1, 143.7 (q, $^2J_{CF}$ = 38.7 Hz), 142.5, 140.8, 139.6, 136.7, 129.7, 129.5, 128.7, 128.1, 127.6, 125.92, 125.87, 125.5, 121.2 (q, $^1J_{CF}$ = 268.8 Hz), 105.9, 58.9, 58.1, 32.7, 32.5, 32.0, 31.8, 21.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -62.3 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1472, 1276, 1261, 1235, 1161, 1133, 1094, 975, 750;

HRMS (ESI^+) calcd. for $C_{31}H_{34}{}^{35}Cl\ N_3F_3S^+$ $[M+H]^+$: 572.2109; found: 572.2097.

1-(4-Methoxyphenyl)-1-(*p*-tolyl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (50')



Prepared according to **General Procedure A** using *t*-Oct-NSO **25** (208 mg, 1.19 mmol, 1.05 equiv.), TMSOTf (252 mg, 1.13 mmol, 1.0 equiv.), 4-methoxyphenylmagnesium bromide (2.30 mL, 0.48 M in THF, 1.10 mmol, 1.0 equiv.) and 4-methylphenylmagnesium bromide (1.80 mL, 0.94 M in THF, 1.69 mmol, 1.5 equiv.). Purification by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 3:1 to 1:1 to 0:1) afforded *sulfilimine* **50'** as a light-yellow oil (317 mg, 81%).

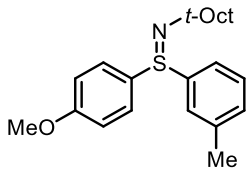
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.50 (d, J = 8.8 Hz, 2H, Ar_{OMe}-*H*), 7.46 (d, J = 8.2 Hz, 2H, Tol-*H*), 7.15 (d, J = 8.2 Hz, 2H, Tol-*H*), 6.86 (d, J = 8.8 Hz, 2H, Ar_{OMe}-*H*), 3.74 (s, 3H, OCH_3), 2.30 (s, 3H, Tol-CH_3), 1.63 (s, 2H, $NC(CH_3)_2CH_2$), 1.302 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.298 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.94 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 160.9, 142.0, 139.8, 136.4, 129.5, 128.4, 126.6, 114.3, 58.3, 58.2, 55.4, 32.62, 32.56, 32.0, 31.7, 21.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1592, 1491, 1392, 1249, 1129, 1030, 828, 730;

HRMS (ESI^+) calcd. for $C_{22}H_{32}NOS^+$ $[M+H]^+$: 358.2199; found: 358.2200.

1-(4-Methoxyphenyl)-1-(*m*-tolyl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (51')



Prepared according to **General Procedure A** using *t*-Oct-NSO **25** (305 mg, 1.74 mmol, 1.05 equiv.), TMSOTf (369 mg, 1.66 mmol, 1.0 equiv.), 4-methoxyphenylmagnesium bromide (3.45 mL, 0.48 M in THF, 1.66 mmol, 1.0 equiv.) and 3-methylphenylmagnesium chloride (3.10 mL, 0.80 M in THF, 2.48 mmol, 1.5 equiv.). Purification by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 3:1 to 1:1 to 0:1) afforded *sulfilimine* **51'** as a light-yellow oil (445 mg, 78%).

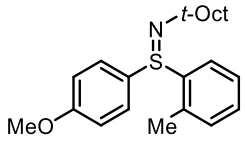
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.50 (d, J = 8.8 Hz, 2H, Ar_{OMe}-*H*), 7.43 (app. br. s, 1H, Tol-*H*), 7.35-7.30 (m, 1H, Tol-*H*), 7.21 (t, J = 7.6 Hz, 1H, Tol-*H*), 7.13-7.08 (m, 1H, Tol-*H*), 6.86 (d, J = 8.8 Hz, 2H, Ar_{OMe}-*H*), 3.74 (s, 3H, OC*H*$_3$), 2.30 (s, 3H, Tol-C*H*$_3$), 1.63 (s, 2H, NC(CH$_3$)$_2$C*H*$_2$), 1.31 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.30 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 0.93 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 160.9, 144.9, 138.8, 136.3, 130.5, 128.51, 128.46, 126.8, 123.7, 114.3, 58.3, 58.2, 55.3, 32.63, 32.56, 32.0, 31.7, 21.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1491, 1392, 1249, 1129, 1030, 828;

HRMS (ESI$^+$) calcd. for $C_{22}H_{32}NOS^+$ $[M+H]^+$: 358.2199; found: 358.2190.

1-(4-Methoxyphenyl)-1-(*o*-tolyl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (52')



Prepared according to **General Procedure A** using *t*-Oct-NSO **25** (266 mg, 1.52 mmol, 1.05 equiv.), TMSOTf (322 mg, 1.45 mmol, 1.0 equiv.), 4-methoxyphenylmagnesium bromide (3.00 mL, 0.48 M in THF, 1.44 mmol, 1.0 equiv.) and 2-methylphenylmagnesium chloride (3.00 mL, 0.73 M in THF, 2.19 mmol, 1.5 equiv.). Purification by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 3:1 to 1:1 to 0:1) afforded *sulfilimine* **52'** as a light-yellow oil (400 mg, 78%).

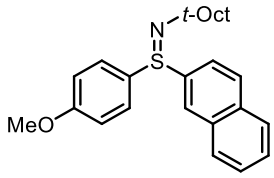
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.10 (dd, J = 7.8, 1.5 Hz, 1H, Tol-*H*), 7.34-7.29 (m, 3H, Ar_{OMe}-*H*/Tol-*H*), 7.23 (td, J = 7.4, 1.5 Hz, 1H, Tol-*H*), 7.08-7.04 (m, 1H, Tol-*H*), 6.79 (d, J = 8.9 Hz, 2H, Ar_{OMe}-*H*), 3.68 (s, 3H, OCH_3), 2.27 (s, 3H, Tol-CH_3), 1.63 (s, 2H, $NC(CH_3)_2CH_2$), 1.28 (s, 6H, $NC(CH_3)_2$), 0.93 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 160.6, 142.9, 135.3, 135.2, 130.2, 129.7, 128.7, 126.9, 126.8, 114.4, 58.4, 58.3, 55.2, 32.6, 32.3, 31.9, 31.6, 19.0;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1492, 1250, 827, 756;

HRMS (ESI^+) calcd. for $C_{22}H_{32}NOS^+$ $[M+H]^+$: 358.2199; found: 358.2196.

1-(4-Methoxyphenyl)-1-(naphthalen-2-yl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^4-sulfanimine (53')



Prepared according to **General Procedure A** using *t*-Oct-NSO **25** (358 mg, 2.04 mmol, 1.05 equiv.), TMSOTf (433 mg, 1.95 mmol, 1.0 equiv.), 4-methoxyphenylmagnesium bromide (4.05 mL, 0.48 M in THF, 1.94 mmol, 1.0 equiv.) and 2-naphthylmagnesium bromide (5.60 mL, 0.53 M in THF, 2.97 mmol, 1.5 equiv.). Purification by flash column chromatography (petrol/ethyl acetate with 1% Et_3N, 3:1 to 1:1 to 0:1) afforded *sulfilimine* **53'** as a light-yellow oil (598 mg, 78%).

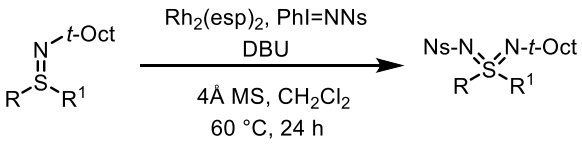
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.33-8.30 (m, 1H, Ar-*H*), 7.93-7.87 (m, 1H, Ar-*H*), 7.81-7.74 (m, 2H, Ar-*H*), 7.57 (d, J = 8.8 Hz, 2H, Ar_{OMe}-*H*), 7.51-7.45 (m, 3H, Ar-*H*), 6.87 (d, J = 8.8 Hz, 2H, Ar_{OMe}-*H*), 3.72 (s, 3H, OCH_3), 1.73 (s, 2H, $NC(CH_3)_2CH_2$), 1.40 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.39 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.99 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 161.0, 142.2, 136.0, 133.8, 132.9, 128.8, 128.6, 128.5, 127.8, 127.2, 126.8, 126.4, 123.1, 114.4, 58.5, 58.2, 55.3, 32.8, 32.6, 32.0, 31.7;

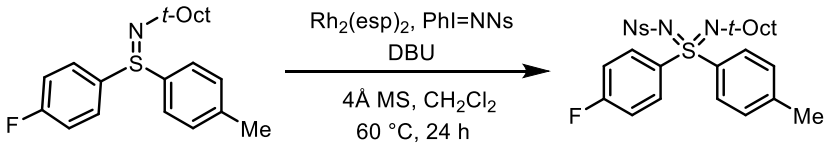
IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1591, 1492, 1382, 1249, 1129, 1029, 825, 730;

HRMS (ESI^+) calcd. for $C_{25}H_{32}NOS^+$ $[M+H]^+$: 394.2199; found: 394.2191.

6.2.3 General Procedure B for Diaryl Sulfondiimine Synthesis



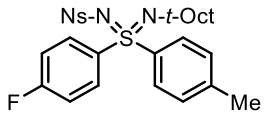
To a vial containing $Rh_2(esp)_2$ (5.0 mol%), 4 Å MS and PhI=NNs (1.5 equiv.) was added a solution of sulfilimine (1.0 equiv.) in anhydrous CH_2Cl_2 (0.2 M). DBU (4.0 equiv.) was then quickly added at room temperature and the reaction was sealed and stirred at 60 °C for 8 h. Two portions of PhI=NNs (2 × 1.5 equiv.) were subsequently added at the 8th and 16th hour. The reaction mixture was cooled to room temperature after 24 h and transferred to a round-bottom flask to separate from the 4 Å MS. The vial and 4 Å MS were washed with CH_2Cl_2 several times until no residual product was in 4 Å MS (TLC). The combined organic phase was then removed under reduced pressure. The crude product was purified by flash column chromatography to afford sulfondiimine.



To a 10 mL vial containing $Rh_2(esp)_2$ (9.0 mg, 0.012 mmol, 5.0 mol%), 4 Å MS (*c.* 0.2 g) and PhI=NNs (136 mg, 0.337 mmol, 1.5 equiv.) was added a solution of sulfilimine **26** (80 mg, 0.23 mmol, 1.0 equiv.) in anhydrous CH_2Cl_2 (1.1 mL). DBU (0.14 mL, 0.93 mmol, 4.0 equiv.) was then quickly added at room temperature and the reaction was sealed and stirred at 60 °C for 8 h. Two portions of PhI=NNs (2 × 137 mg, 0.678 mmol, 3.0 equiv.) were subsequently added at the 8th and 16th hour. The reaction mixture was cooled to room temperature after 24 h and transferred to a 100 mL round-bottom flask to separate from the 4 Å MS. The vial and 4 Å MS were washed with CH_2Cl_2 (5 × 10 mL) until no residual

product was in 4 Å MS (TLC). The combined organic phase was then removed under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate 6:1 to 4:1) to afford *sulfondiimine* **30** as a light-yellow solid (55 mg, 44%).

***N*-((4-Fluorophenyl)(*p*-tolyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (30)**



mp 169-171 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.08 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.82-7.76 (m, 2H, Ar_F-*H*), 7.72 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.60 (d, J = 8.5 Hz, 2H, Tol-*H*), 7.14 (d, J = 8.5 Hz, 2H, Tol-*H*), 7.08-6.99 (m, 2H, Ar_F-*H*), 2.37 (s, 3H, Tol-CH_3), 1.60 (d, J = 14.6 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.56 (d, J = 14.6 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.38 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.35 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.08 (s, 9H, *t*-Bu-*H*);

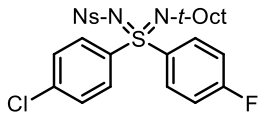
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 166.0 (d, $^1J_{CF}$ = 253.5 Hz), 150.9, 150.3, 145.0, 139.7, 139.3 (d, $^4J_{CF}$ = 3.1 Hz), 132.2 (d, $^3J_{CF}$ = 9.5 Hz), 130.8, 129.2, 128.6, 124.8, 117.2 (d, $^2J_{CF}$ = 23.1 Hz), 61.0, 58.7, 32.7, 32.6, 32.54, 32.51, 21.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.2 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 1528, 1488, 1349, 1301, 1222, 1152, 1074, 1029, 1005, 734, 612;

HRMS (ESI$^+$) calcd. for $C_{27}H_{33}FN_3O_4S_2^+$ $[M+H]^+$: 546.1891; found: 546.1885.

***N*-((4-Clorophenyl)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (31)**



Prepared according to **General Procedure B** using sulfilimine **31'** (152 mg, 0.416 mmol, 1.0 equiv.), $Rh_2(esp)_2$ (16 mg, 0.021 mmol, 5.0 mol%), PhI=NNs (3 × 262 mg, 1.95 mmol, 4.5 equiv.) and DBU (0.25 mL, 1.7 mmol, 4.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 12:1 to 4:1) afforded *sulfondiimine* **31** as a white solid (111 mg, 47% yield).

mp 191-192 °C;

R_f 0.50 (petrol/ethyl acetate, 5:1);

^{1}H NMR (400 MHz, $CDCl_3$) = 8.14 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.81-7.77 (m, 2H, Ar_F-*H*), 7.75 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.69 (d, *J* = 8.8 Hz, 2H, Ar_{Cl}-*H*), 7.34 (d, *J* = 8.8 Hz, 2H, Ar_{Cl}-*H*), 7.14-6.99 (m, 2H, Ar_F-*H*), 1.57 (s, 2H, $NC(CH_3)_2CH_2$), 1.35 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.34 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.07 (s, 9H, *t*-Bu-*H*);

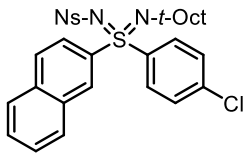
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 166.2 (d, $^1J_{CF}$ = 253.6 Hz), 150.6, 150.4, 141.8, 139.9, 138.7 (d, $^4J_{CF}$ = 3.1 Hz), 132.3 (d, $^3J_{CF}$ = 9.6 Hz), 131.0, 130.4, 128.6, 124.9, 117.4 (d, $^2J_{CF}$ = 23.1 Hz), 61.2, 58.6, 32.6, 32.52, 32.48 (2 × C);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.3 (tt, *J* = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1299, 1276, 1261, 1219, 1152, 1089, 1072, 1028, 1002;

HRMS (ESI^+) calcd. for $C_{26}H_{29}N_3F^{35}ClNaO_4S_2^+$ $[M+Na]^+$: 588.1164; found: 588.1166.

***N*-((4-Chlorophenyl)(naphthalen-2-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (32)**



Prepared according to **General Procedure B** using sulfilimine **32'** (253 mg, 0.637 mmol, 1.0 equiv.), $Rh_2(esp)_2$ (24 mg, 0.032 mmol, 5.0 mol%), PhI=NNs (3 × 397 mg, 2.95 mmol, 4.5 equiv.) and DBU (0.38 mL, 2.5 mmol, 4.0 equiv.). Purification by flash column

chromatography (petrol/ethyl acetate, 7:1 to 4:1) afforded *sulfondiimine* **32** as a white solid (125 mg, 33%).

mp 191-193 °C;

R_f 0.50 (petrol/ethyl acetate, 5:1);

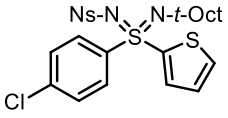
^{1}H NMR (400 MHz, $CDCl_3$) = 8.33 (d, *J* = 2.3 Hz, 1H, Ar-*H*), 7.91 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.84 (app. d, *J* = 8.1 Hz, 1H, Ar-*H*), 7.81-7.73 (m, 4H, Ar-*H*/Ar_{Cl}-*H*), 7.69-7.54 (m, 5H, Ar_{Ns}-*H*/Ar-*H*), 7.35 (d, *J* = 8.9 Hz, 2H, Ar_{Cl}-*H*), 1.66 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.60 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.44 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.39 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.12 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.2, 148.9, 140.6, 139.5, 137.4, 134.7, 132.0, 129.9, 129.8, 129.6, 129.4, 129.30, 129.27, 128.0, 127.9, 127.6, 123.5, 122.7, 60.9, 58.0, 32.2, 32.10, 32.05, 32.0;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1348, 1300, 1276, 1261, 1216, 1152, 1088, 1026, 1003, 909, 750;

HRMS (ESI^+) calcd. for $C_{30}H_{33}N_3{}^{35}ClO_4S_2^+$ $[M+H]^+$: 598.1596; found: 598.1592.

***N*-((4-Chlorophenyl)(thiophen-2-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (33)**



Prepared according to **General Procedure B** using sulfilimine **33'** (203 mg, 0.575 mmol, 1.0 equiv.), $Rh_2(esp)_2$ (21 mg, 0.028 mmol, 5.0 mol%), PhI=NNs (3 × 356 mg, 2.64 mmol, 4.5 equiv.) and DBU (0.35 mL, 2.3 mmol, 4.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 7:1 to 3:1) afforded *sulfondiimine* **33** as a light-yellow solid (128 mg, 40%).

mp 131-133 °C;

R_f 0.33 (petrol/ethyl acetate, 5:1);

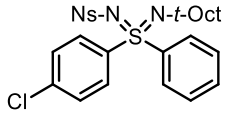
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.15 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.78 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.70 (d, *J* = 8.9 Hz, 2H, Ar_{Cl}-*H*), 7.65 (dd, *J* = 5.1, 1.3 Hz, 1H, HetAr-*H*), 7.33-7.26 (m, 3H, Ar_{Cl}-*H*/HetAr-*H*), 7.01 (dd, *J* = 5.1, 3.9 Hz, 1H, HetAr-*H*), 1.64 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.58 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.49 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.38 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.08 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 150.6, 150.4, 144.6, 142.1, 139.7, 136.6, 134.7, 130.4, 130.2, 130.0, 128.5, 124.9, 61.4, 58.6, 32.63, 32.56, 32.5, 32.1;

(ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1348, 1300, 1276, 1260, 1216, 1153, 1089, 1026, 1004, 749;

HRMS (ESI^+) calcd. for $C_{28}H_{31}N_3{}^{35}ClNaO_4S_3^+$ $[M+Na]^+$: 576.0823; found: 576.0823.

***N*-((4-Chlorophenyl)(phenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (34)**



Prepared according to **General Procedure B** using sulfilimine **34'** (251 mg, 0.723 mmol, 1.0 equiv.), $Rh_2(esp)_2$ (27 mg, 0.036 mmol, 5.0 mol%), PhI=NNs (3 × 438 mg, 3.25 mmol, 4.5 equiv.) and DBU (0.44 mL, 2.9 mmol, 4.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 7:1 to 3:1) afforded *sulfondiimine* **34** as a light-yellow solid (138 mg, 35%).

mp 145-147 °C;

R_f 0.50 (petrol/ethyl acetate = 5:1);

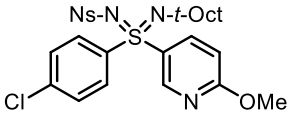
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.08 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.75-7.68 (m, 6H, Ar_{Ns}-*H*/Ph-*H*/Ar_{Cl}-*H*), 7.52-7.46 (m, 1H, Ph-*H*), 7.39-7.31 (m, 4H, Ph-*H*/Ar_{Cl}-*H*), 1.61 (d, *J* = 14.6 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.57 (d, *J* = 14.6 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.38 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.35 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.08 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.4, 149.1, 141.4, 140.7, 139.5, 132.9, 129.7, 129.3, 129.2, 128.2, 127.6, 123.7, 60.7, 57.9, 32.04, 32.0, 31.97 (2 × C);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1348, 1300, 1276, 1261, 1217, 1151, 1088, 1071, 1030, 1006;

HRMS (ESI^+) calcd. for $C_{26}H_{31}N_3{}^{35}ClO_4S_2^+$ $[M+H]^+$: 548.1439; found: 548.1441.

***N*-((4-Chlorophenyl)(6-methoxypyridin-3-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (35)**



Prepared according to **General Procedure B** using sulfilimine **35'** (230 mg, 0.608 mmol, 1.0 equiv.), $Rh_2(esp)_2$ (23 mg, 0.030 mmol, 5.0 mol%), PhI=NNs (3 × 370 mg, 2.75 mmol, 4.5 equiv.) and DBU (0.37 mL, 2.5 mmol, 4.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 7:1 to 3:1) afforded *sulfondiimine* **35** as a white solid (199 mg, 57%).

mp 197-198 °C;

R_f 0.41 (petrol/ethyl acetate, 5:1);

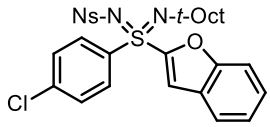
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.46 (d, *J* = 2.4 Hz, 1H, HetAr-*H*), 8.13 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.81 (dd, *J* = 8.9, 2.4 Hz, 1H, HetAr-*H*), 7.76 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.72 (d, *J* = 8.8 Hz, 2H, Ar_{Cl}-*H*), 7.35 (d, *J* = 8.8 Hz, 2H, Ar_{Cl}-*H*), 6.68 (d, *J* = 8.9 Hz, 1H, HetAr-*H*), 3.92 (s, 3H, OCH_3), 1.57 (s, 2H, $NC(CH_3)_2CH_2$), 1.37 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.35 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.06 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.4, 149.3, 149.2, 148.6, 140.6, 139.6, 137.9, 130.3, 129.46, 129.45, 127.6, 123.8, 111.5, 60.8, 57.9, 54.5, 32.03, 31.99, 31.95, 31.93;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1586, 1529, 1477, 1371, 1349, 1308, 1276, 1261, 1217, 1153, 1087, 1027, 1000, 908, 750;

HRMS (ESI^+) calcd. for $C_{26}H_{32}N_4{}^{35}ClO_5S_2^+$ $[M+H]^+$: 579.1497; found: 579.1485.

***N*-(Benzofuran-2-yl(4-chlorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (36)**



Prepared according to **General Procedure B** using sulfilimine **36'** (240 mg, 0.620 mmol, 1.0 equiv.), $Rh_2(esp)_2$ (24 mg, 0.032 mmol, 5.0 mol%), PhI=NNs (3 × 385 mg, 2.86 mmol, 4.5 equiv.) and DBU (0.38 mL, 2.6 mmol, 4.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 7:1 to 3:1) afforded *sulfondiimine* **36** as a light-yellow solid (145 mg, 40%).

mp 201-202 °C;

R$_f$ 0.44 (petrol/ethyl acetate, 5:1);

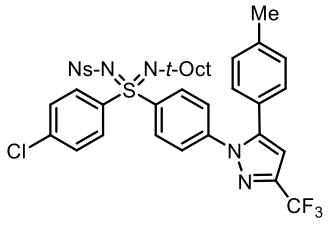
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.08 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.82 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.79 (d, J = 8.9 Hz, 2H, Ar_{Cl}-*H*), 7.71-7.66 (m, 2H, HetAr-*H*), 7.43-7.26 (m, 5H, HetAr-*H*/Ar_{Cl}-*H*), 1.63 (d, J = 14.6 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.58 (d, J = 14.6 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.47 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.38 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.09 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 156.3, 149.6, 149.2, 149.0, 140.0, 137.4, 129.6, 129.5, 128.2, 127.7, 126.1, 124.7, 123.6, 123.2, 115.6, 112.2, 60.9, 57.5, 32.2, 31.92, 31.87, 31.1;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1525, 1349, 1301, 1261, 1223, 1152, 1077, 1030, 1006, 833, 746;

HRMS (ESI$^+$) calcd. for $C_{28}H_{31}N_3{}^{35}ClO_5S_2{}^+$ $[M+H]^+$: 588.1388; found: 588.1387.

***N*-((4-Chlorophenyl)(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (37)**



Prepared according to **General Procedure B** using sulfilimine **37'** (170 mg, 0.298 mmol, 1.0 equiv.), $Rh_2(esp)_2$ (12 mg, 0.016 mmol, 5.0 mol%), PhI=NNs (3 × 181 mg, 1.34 mmol, 4.5 equiv.) and DBU (0.18 mL, 1.2 mmol, 4.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 7:1 to 3:1) afforded *sulfondiimine* **37** as a light-blue oil (93 mg, 40%).

R_f 0.56 (petrol/ethyl acetate, 5:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.11 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.78 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.75 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.66 (d, J = 8.9 Hz, 2H, Ar_{Cl}-*H*), 7.39 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.34 (d, J = 8.9 Hz, 2H, Ar_{Cl}-*H*), 7.17 (d, J = 7.9 Hz, 2H, Tol-*H*), 7.09 (d, J = 7.9 Hz, 2H, Tol-*H*), 6.73 (s, 1H, HetAr-*H*), 2.38 (s, 3H, Tol-CH_3), 1.61 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.56 (d, J = 14.6 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.38 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.34 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.07 (s, 9H, *t*-Bu-*H*);

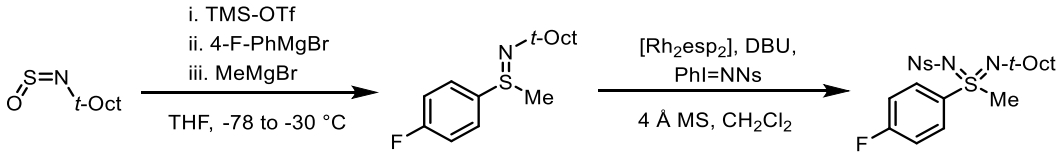
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 150.6, 150.4, 146.7, 144.4 (q, $^2J_{CF}$ = 38.2 Hz), 143.9, 142.9, 141.3, 140.7, 140.0, 131.0, 130.53, 130.49, 130.4, 130.0, 128.6, 127.2, 126.9, 124.9, 122.5 (q, $^1J_{CF}$ = 266.5 Hz), 107.0, 61.4, 58.6, 32.63, 32.59, 32.5, 32.4, 21.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -62.5 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1471, 1349, 1276, 1261, 1235, 1153, 1090, 1030, 1003, 827, 750;

HRMS (ESI^+) calcd. for $C_{37}H_{38}N_5F_3{}^{35}ClO_4S_2^+$ $[M+H]^+$: 772.2000; found: 772.1997.

6.2.4 General Procedure C for Aryl-alkyl and Dialkyl Sulfondiimine Synthesis



t-Oct-NSO **25** (240 mg, 1.37 mmol, 1.05 equiv.) was dissolved in anhydrous THF (2.7 mL) in an oven-dried 25 mL round bottom flask. The mixture was then cooled to -78 °C and

TMSOTf (297 mg, 1.34 mmol, 1.0 equiv.) was added. Then 4-fluorophenylmagnesium bromide (1.47 mL, 0.91 M in THF, 1.34 mmol, 1.0 equiv.) was added dropwise after 1 min. The reaction was stirred at -78 °C for 2 min and then the temperature was increased to -30 °C (see **note 1**). Methylmagnesium bromide (0.67 mL, 3.0 M in diethyl ether, 2.0 mmol, 1.5 equiv.) was then added quickly. The mixture was stirred at -30 °C for 10 min. Then the reaction was quenched with sat. aq. tetrasodium EDTA solution (100 mL) and poured into a 250 mL separating funnel. Ethyl acetate (80 mL) was then added and the organic phase was separated. The aqueous phase was further extracted with ethyl acetate (2 × 40 mL). The combined extracts were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude sulfilimine was dissolved in a mixture of diethyl ether (15 mL) and petroleum ether (5 mL) and acidified by a 1 M aq. solution of 4-toluenesulfonic acid (35 mL). The organic layer was discarded. The aqueous phase was washed once with a mixture of diethyl ether (5 mL) and petroleum ether (15 mL). The aqueous phase was then extracted with CH_2Cl_2 (3 × 40 mL), combined CH_2Cl_2 extracts dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford the 4-toluenesulfonic acid-sulfilimine salt (*c*. 85% yield). The sulfilimine salt was then dissolved in CH_2Cl_2 (50 mL) and treated with 1 M aq. NaOH (50 mL). The organic layer was separated and the aqueous phase was extracted with CH_2Cl_2 (2 × 50 mL). The combined organic extracts were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure to afford *sulfilimine* **29** as a light-yellow oil (300 mg, 83%).

Notes:

1. The reaction can be warmed from -78 °C to -30 °C through an addition of acetone to the dry ice-acetone bath over 5 min, or a quick replacement of the dry ice-acetone bath with an acetone bath at -30 °C.
2. Solvents were removed in a rotary evaporator below 30 °C due to instability of the

sulfilimine **29** at high temperatures.

3. After performing an acid-base workup as mentioned above, crude *S*-aryl-*S*-alkyl and *S*,*S*-dialkyl sulfilimines were used without further purification in the next step. For long-term storage, 4-toluenesulfonic acid salt would be preferred over the neutral sulfilimine due to enhanced stability.
4. EDTA solution is used to complex the magnesium salts present in the Grignard reagents, which otherwise emulsions may be formed and complicate the aqueous work-up if only water is used instead.
5. The *S*-aryl-*S*-alkyl and *S*,*S*-dialkyl sulfilimines are typically very polar and appear to be strongly basic, which often stay on the baseline of the TLC plate even when ethyl acetate is used as the eluent. When mixtures of ethyl acetate and methanol were used, the sulfilimine may travel further up the TLC plate but "streaking" is often observed. For sulfilimine **29**, 3:1 petrol/ethyl acetate can be used to observe the by-products (which are removed during the diethyl ether/petroleum ether washes).

A solution of sulfilimine **29** (300 mg, 1.11 mmol, 1.0 equiv.) in anhydrous CH_2Cl_2 (5.6 mL) was added to a 25 mL vial containing $Rh_2(esp)_2$ (21 mg, 0.028 mmol, 2.5 mol%), 4 Å MS (*c*. 0.4 g) and PhI=NNs (583 mg, 1.44 mmol, 1.3 equiv.). DBU (0.34 mL, 2.2 mmol, 2.0 equiv.) was then added at room temperature quickly and the reaction was sealed and stirred at 40 °C for 24 h. The reaction mixture was then transferred to a 100 mL round bottom flask, to separate from the 4 Å MS, washing the vial several times with CH_2Cl_2. The solvent was then removed under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) to afford *sulfondiimine* **38** as a light-yellow solid (444 mg, 71% yield over two steps).

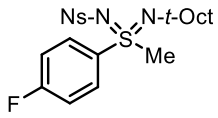
Notes:

1. The reaction is run for 24 hours as standard as some *S*,*S*-diaryl substrates need

extended reaction times, but it may be finished sooner for *S*-aryl-*S*-alkyl and *S*,*S*-dialkyl substrates.

2. The protected sulfondiimines are stable towards air and moisture and do not need any special care to be taken when handling them.

_N_-((4-Fluorophenyl)(methyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (38)



mp 153-155 °C;

R$_f$ 0.54 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.27 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.07 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.99-7.94 (m, 2H, Ar_F-*H*), 7.21-7.15 (m, 2H, Ar_F-*H*), 3.46 (s, 3H, SC*H*$_3$), 1.47 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.41 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.29 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.14 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.00 (s, 9H, *t*-Bu-*H*);

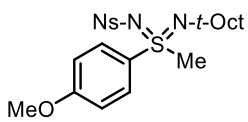
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 166.3 (d, $^1J_{CF}$ = 253.4 Hz), 151.4, 150.4, 139.6 (d, $^4J_{CF}$ = 3.1 Hz), 131.7 (d, $^3J_{CF}$ = 9.6 Hz), 128.6, 125.1, 117.4 (d, $^2J_{CF}$ = 23.0 Hz), 60.3, 58.5, 49.2, 32.6, 32.5, 32.4, 32.3;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.6 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2953, 1589, 1528, 1487, 1349, 1293, 1223, 1149, 1035, 840;

HRMS (ESI$^+$) calcd. for $C_{21}H_{29}FN_3O_4S_2^+$ $[M+H]^+$: 470.1578; found: 470.1577.

_N_-((4-Methoxyphenyl)(methyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (39)



Sulfilimine prepared according to **General Procedure C** using *t*-Oct-NSO **25** (164 mg, 0.937 mmol, 1.05 equiv.), TMSOTf (202 mg, 0.909 mmol, 1.0 equiv.), 4-methoxyphenylmagnesium bromide (1.85 mL, 0.49 M in THF, 0.907 mmol, 1.0 equiv.) and methylmagnesium bromide (0.46 mL, 3.0 M in diethyl ether, 1.4 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **39'** was generated as light-yellow oil with a crude yield of 84% (215 mg). Sulfondiimine prepared using $Rh_2(esp)_2$ (15 mg, 0.020 mmol, 2.5 mol%), PhI=NNs (400 mg, 0.990 mmol, 1.3 equiv.) and DBU (0.23 mL, 1.5 mmol, 2.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimine* **39** as a light-yellow solid (279 mg, 64% yield over two steps).

mp 117-119 °C;

R_f 0.5 (petrol/ethyl acetate, 1:1);

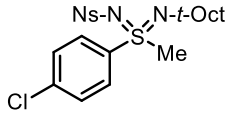
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.84 (d, J = 9.0 Hz, 2H, Ar_{OMe}-*H*), 6.94 (d, J = 9.0 Hz, 2H, Ar_{OMe}-*H*), 3.84 (s, 3H, OCH_3), 3.42 (s, 3H, SCH_3), 1.47 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.42 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.30 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.16 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.00 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 163.4, 150.2, 149.3, 133.3, 129.6, 127.6, 124.0, 114.7, 59.8, 57.8, 55.8, 49.7, 32.0, 31.9, 31.83, 31.80;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =2950, 1591, 1528, 1349, 1293, 1176, 1083, 1031, 855, 797;

HRMS (ESI^+) calcd. for $C_{22}H_{31}N_3NaO_5S_2^+$ $[M+Na]^+$: 504.1597; found: 504.1596.

***N*-((4-Chlorophenyl)(methyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (40)**



Sulfilimine prepared according to **General Procedure C** using *t*-Oct-NSO **25** (316 mg, 1.81 mmol, 1.05 equiv.), TMSOTf (381 mg, 1.71 mmol, 1.0 equiv.), 4-chlorophenylmagnesium bromide (1.95 mL, 0.88 M in 2-methyltetrahydrofuran, 1.72 mmol, 1.0 equiv.) and methylmagnesium bromide (0.85 mL, 3.0 M in diethyl ether, 2.6 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **40'** was generated as light-yellow oil with a crude yield of 78% (380 mg). Sulfondiimine prepared using $Rh_2(esp)_2$ (24 mg, 0.032 mmol, 2.5 mol%), PhI=NNs (726 mg, 1.80 mmol, 1.3 equiv.) and DBU (0.40 mL, 2.7 mmol, 2.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 7:1 to 3:1) afforded *sulfondiimine* **40** as a white solid (546 mg, 66% yield over two steps).

mp 153-155 °C

R_f 0. 6 (petrol/ethyl acetate = 2:1).

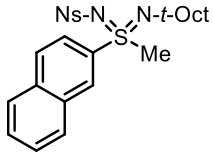
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.87 (d, J = 8.7 Hz, 2H, Ar_{Cl}-*H*), 7.45 (d, J = 8.7 Hz, 2H, Ar_{Cl}-*H*), 3.44 (s, 3H, SCH_3), 1.45 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.40 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.28 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.13 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.98 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.8, 149.3, 141.1, 139.8, 129.7, 129.0, 127.5, 124.0, 60.0, 57.6, 49.3, 31.89, 31.87, 31.73, 31.71;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1349, 1294, 1221, 1149, 1089, 1075, 1035, 1006, 968, 855;

HRMS (ESI^+) calcd. for $C_{21}H_{28}N_3Na^{35}ClO_4S_2^+$ $[M+Na]^+$: 508.1102; found: 508.1104.

***N*-(Methyl(naphthalen-2-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (41)**



Sulfilimine prepared according to **General Procedure C** using *t*-Oct-NSO **25** (249 mg, 1.42 mmol, 1.05 equiv.), TMSOTf (300 mg, 1.35 mmol, 1.0 equiv.), 2-naphthylmagnesium bromide (2.60 mL, 0.52 M in THF, 1.35 mmol, 1.0 equiv.) and methylmagnesium bromide (0.70 mL, 3.0 M in diethyl ether, 2.1 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **41'** was generated as light-yellow oil with a crude yield of 78% (318 mg). Sulfondiimine prepared using $Rh_2(esp)_2$ (20 mg, 0.026 mmol, 2.5 mol%), PhI=NNs (524 mg, 1.30 mmol, 1.3 equiv.) and DBU (0.30 mL, 2.0 mmol, 2.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) afforded *sulfondiimine* **41** as a light-yellow solid (356 mg, 53% yield over two steps).

mp 154-156 °C;

R_f 0.5 (petrol/ethyl acetate, 1.5:1);

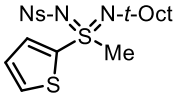
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.47 (d, *J* = 1.8 Hz, 1H, Ar-*H*), 8.16 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.04 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.96-7.84 (m, 4H, Ar-*H*), 7.67-7.57 (m, 2H, Ar-*H*), 3.52 (s, 3H, SCH_3), 1.50 (s, 2H, $NC(CH_3)_2CH_2$), 1.36 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.22 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.04 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.9, 149.1, 138.6, 134.8, 132.2, 129.7, 129.4, 129.3, 129.2, 127.91, 127.89, 127.6, 123.9, 122.1, 60.0, 57.7, 49.2, 32.0, 31.94, 31.90, 31.8;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1348, 1293, 1220, 1148, 1089, 1031, 1008, 969, 739;

HRMS (ESI^+) calcd. for $C_{25}H_{32}N_3O_4S_2^+$ $[M+H]^+$: 502.1829; found: 502.1827.

***N*-(Methyl(thiophen-2-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (42)**



Sulfilimine prepared according to **General Procedure C** using *t*-Oct-NSO **25** (295 mg, 1.69 mmol, 1.05 equiv.), TMSOTf (340 mg, 1.53 mmol, 1.0 equiv.), 2-thienylmagnesium

bromide (1.80 mL, 0.85 M in THF, 1.53 mmol, 1.0 equiv.) and methylmagnesium bromide (0.77 mL, 3.0 M in diethyl ether, 2.3 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **42'** was generated as light-yellow oil with a crude yield of 76% (300 mg). Sulfondiimine prepared using $Rh_2(esp)_2$ (22 mg, 0.029 mmol, 2.5 mol%), PhI=NNs (621 mg, 1.54 mmol, 1.3 equiv.) and DBU (0.34 mL, 2.3 mmol, 2.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 7:1 to 3:1) afforded *sulfondiimine* **42** as a white solid (414 mg, 60% yield over two steps).

mp 132-134 °C;

R$_f$ 0.42 (petrol/ethyl acetate, 3:1);

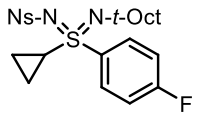
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.28 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.10 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.64 (dd, J = 5.1, 1.3 Hz, 1H, HetAr-*H*), 7.60 (dd, J = 3.9, 1.3 Hz, 1H, HetAr-*H*), 7.10 (dd, J = 5.1, 3.9 Hz, 1H, HetAr-*H*), 3.58 (s, 3H, SCH_3), 1.47 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.41 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.34 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.19 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.00 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.9, 149.4, 144.2, 134.5, 132.1, 128.6, 127.5, 124.1, 60.3, 57.6, 51.1, 31.9, 31.8, 31.6, 31.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1349, 1293, 1241, 1220, 1149, 1090, 1028, 1008, 854, 738;

HRMS (ESI$^+$) calcd. for $C_{19}H_{27}N_3NaO_4S_3^+$ $[M+Na]^+$: 480.1056; found: 480.1050.

***N*-(Cyclopropyl(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (43)**



Sulfilimine prepared according to **General Procedure C** using *t*-Oct-NSO **25** (276 mg, 1.57 mmol, 1.05 equiv.), TMSOTf (334 mg, 1.50 mmol, 1.0 equiv.), cyclopropylmagnesium bromide (1.71 mL, 0.88 M in 2-methyltetrahydrofuran, 1.50 mmol, 1.0 equiv.) and 4-

fluorophenylmagnesium bromide (2.30 mL, 0.96 M in THF, 2.21 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **43'** was generated as light-yellow oil with a crude yield of 65% (289 mg). Sulfondiimine prepared using $Rh_2(esp)_2$ (19 mg, 0.025 mmol, 2.5 mol%), PhI=NNs (531 mg, 1.31 mmol, 1.3 equiv.) and DBU (0.30 mL, 2.0 mmol, 2.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 5:1 to 3:1) afforded *sulfondiimine* **43** as a light-yellow solid (297 mg, 40% yield over two steps).

mp 87-89 °C;

R$_f$ 0.62 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.26 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.98-7.91 (m, 2H, Ar_F-*H*), 7.19-7.11 (m, 2H, Ar_F-*H*), 2.32 (tt, J = 7.6, 4.6 Hz, 1H, SC*H*), 1.71 (ddt, J = 10.5, 6.3, 4.6 Hz, 1H, SCHCH_aH_b), 1.53-1.39 (m, 3H, SCHCH$_a$$H_b$/NC(CH$_3$)$_2CH_2$), 1.36 (s, 3H, NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.14 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 1.12-1.02 (m, 2H, SCHCH_2), 0.97 (s, 9H, *t*-Bu-*H*);

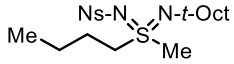
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 166.2 (d, $^1J_{CF}$ = 252.8 Hz), 151.9, 150.3, 140.3 (d, $^4J_{CF}$ = 2.8 Hz), 132.1 (d, $^3J_{CF}$ = 9.5 Hz), 128.6, 125.0, 117.2 (d, $^2J_{CF}$ = 22.5 Hz), 60.1, 58.8, 38.7, 32.8, 32.7, 32.5, 32.4, 9.5, 8.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.2 (tt, J = 8.0, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1349, 1296, 1276, 1260, 1220, 1149, 1090, 1075, 1030, 1007.

HRMS (ESI$^+$) calcd. for $C_{23}H_{30}N_3FNaO_4S_2^+$ [M+Na]$^+$: 518.1554; found: 518.1560.

***N*-(Butyl(methyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (44)**



Sulfilimine prepared according to **General Procedure C** using *t*-Oct-NSO **25** (307 mg, 1.75 mmol, 1.05 equiv.), TMSOTf (371 mg, 1.67 mmol, 1.0 equiv.), *n*-butylmagnesium chloride (0.85 mL, 1.96 M in THF, 1.7 mmol, 1.0 equiv.) and methylmagnesium bromide (0.84 mL,

3.0 M in diethyl ether, 2.5 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **44'** was generated as light-yellow oil with a crude yield of 77% (298 mg). Sulfondiimine prepared using $Rh_2(esp)_2$ (22 mg, 0.029 mmol, 2.5 mol%), PhI=NNs (690 mg, 1.71 mmol, 1.3 equiv.) and DBU (0.40 mL, 2.7 mmol, 2.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) afforded *sulfondiimine* **44** as a light-yellow solid (187 mg, 26% yield over two steps).

mp 80-82 °C;

R_f 0.35 (petrol/ethyl acetate, 2:1);

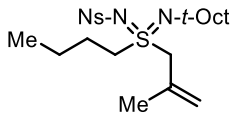
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.26 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 3.43-3.37 (m, 2H, SCH_2), 3.17 (s, 3H, SCH_3), 1.81-1.71 (m, 2H, SCH_2CH_2), 1.45-1.37 (m, 2H, $SCH_2CH_2CH_2$), 1.37 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.33 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.27 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.23 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.93-0.87 (m, 12H, *t*-Bu-*H*/*n*-Bu-CH_3);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.2, 149.3, 127.5, 123.9, 60.0, 59.3, 57.6, 44.6, 32.3, 32.0, 31.8, 31.7, 25.6, 21.4, 13.6;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1276, 1261, 1220, 1146, 1089, 1029, 1008, 750;

HRMS (ESI^+) calcd. for $C_{19}H_{33}N_3NaO_4S_2^+$ $[M+Na]^+$: 454.1805; found: 454.1798;

***N*-(Butyl(2-methylallyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (45)**



Sulfilimine prepared according to **General Procedure C** using *t*-Oct-NSO **25** (399 mg, 2.28 mmol, 1.05 equiv.), TMSOTf (486 mg, 2.19 mmol, 1.0 equiv.), *n*-butylmagnesium chloride (1.11 mL, 1.96 M in THF, 2.18 mmol, 1.0 equiv.) and 2-methyl-1-propenylmagnesium bromide (6.70 mL, 0.49 M in THF, 3.28 mmol, 1.5 equiv.). Following the general

purification method, *sulfilimine* **45'** was generated as light-yellow oil with a crude yield of 77% (454 mg). Sulfondiimine prepared using $Rh_2(esp)_2$ (31 mg, 0.041 mmol, 2.5 mol%), PhI=NNs (861 mg, 2.13 mmol, 1.3 equiv.) and DBU (0.50 mL, 3.4 mmol, 2.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 5:1 to 2:1) afforded *sulfondiimine* **45** as a yellow solid (163 mg, 16% yield over two steps).

mp 113-115 °C;

R_f 0.65 (petrol/ethyl acetate, 3:1);

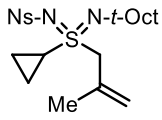
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.04 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 4.92-4.86 (m, 2H, C=CH_2), 4.16 (d, J = 19.3 Hz, 1H, SCH_aH$_b$C=CH$_2$), 3.34 (d, J = 19.3 Hz, 1H, SCH$_a$$H_b$C=CH$_2$), 2.91-2.81 (m, 1H, SC$H_aH_bCH_2$), 2.79-2.70 (m, 1H, SC$H_aH_bCH_2$), 2.00 (d, J = 14.6 Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.72 (s, 3H, SCH$_2$C=CH$_2$CH_3), 1.62 (d, J = 14.6 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.47 (s, 3H, NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.30 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 1.27-1.15 (m, 4H, SCH$_2CH_2CH_2$/SCH$_2CH_2CH_2$), 0.97 (s, 9H, *t*-Bu-*H*), 0.73-0.68 (m, *n*-Bu-CH_3);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.8, 149.1, 144.1, 127.3, 123.9, 111.9, 66.6, 52.6, 51.8, 45.4, 31.8, 31.5, 28.5, 27.6, 25.7, 21.2, 20.7, 13.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1348, 1276, 1261, 1146, 1091, 979, 910, 854, 750;

HRMS (ESI$^+$) calcd. for $C_{22}H_{38}N_3O_4S_2^+$ [M+H]$^+$: 472.2298; found: 472.2293;

***N*-(Cyclopropyl(2-methylallyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (46)**



Sulfilimine prepared according to **General Procedure C** using *t*-Oct-NSO **25** (355 mg, 2.03 mmol, 1.05 equiv.), TMSOTf (444 mg, 2.00 mmol, 1.0 equiv.), cyclopropylmagnesium bromide (2.38 mL, 0.84 M in 2-methyltetrahydrofuran, 2.00 mmol, 1.0 equiv.) and 2-

methyl-1-propenylmagnesium bromide (6.00 mL, 0.50 M in THF, 3.00 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **46'** was generated as light-yellow oil with a crude yield of 89% (455 mg). Sulfondiimine prepared using $Rh_2(esp)_2$ (33 mg, 0.044 mmol, 2.5 mol%), PhI=NNs (930 mg, 2.30 mmol, 1.3 equiv.) and DBU (0.53 mL, 3.6 mmol, 2.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) afforded *sulfondiimine* **46** as a light brown solid (315 mg, 35% yield over two steps).

mp 119-121 °C;

$\mathbf{R}_f$ 0.54 (petrol/ethyl acetate, 3:1);

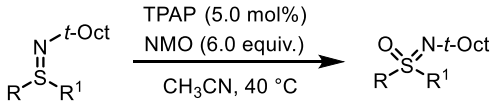
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.24 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.99 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 4.93 (s, 1H, C=C*H*$_a$H$_b$), 4.86 (s, 1H, C=CH$_a$*H*$_b$), 4.08 (d, J = 19.3 Hz, 1H, SC*H*$_a$H$_b$C=CH$_2$), 3.37 (d, J = 19.3 Hz, 1H, SCH$_a$*H*$_b$C=CH$_2$), 2.20 (tt, J = 7.7, 4.8 Hz, 1H, SC*H*), 1.97 (d, J = 14.6 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.69 (s, 3H, SCH$_2$C=CH$_2$C*H*$_3$), 1.63 (d, J = 14.6 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.49 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.29 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.23-1.16 (m, 1H, SCHC*H*$_a$H$_b$), 0.96 (s, 9H, *t*-Bu-*H*), 0.76-0.61 (m, 2H, SCHC*H*$_2$), 0.27-0.21 (m, 1H, SCHCH$_a$*H*$_b$);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.8, 149.0, 143.3, 127.2, 123.9, 111.2, 66.4, 51.8, 46.1, 31.7, 31.5, 29.6, 28.5, 27.5, 20.6, 3.9, 2.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1348, 1289, 1145, 1090, 1016, 973, 854, 768, 733;

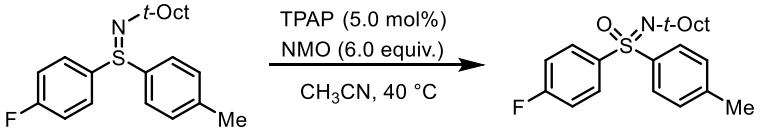
HRMS (ESI$^+$) calcd. for $C_{21}H_{34}N_3O_4S_2^+$ $[M+H]^+$: 456.1985; found: 456.1979.

6.2.5 General Procedure D for Diaryl Sulfoximine Synthesis



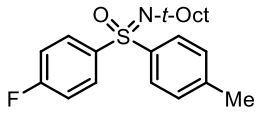
Sulfilimine (1.0 equiv.) was dissolved in anhydrous CH_3CN (0.2 M) in an oven-dried round bottom flask. Then the reaction was heated to 40 °C after TPAP (5.0 mol%) and NMO (6.0 equiv.) was added. The reaction was stirred at 40 °C for 24 h until completion of the reaction

(TLC). The reaction was quenched with water and extracted with ethyl acetate. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated. The crude product was purified by flash column chromatography to afford sulfoximine.



Sulfilimine **26** (471 mg, 1.37 mmol, 1.0 equiv.) was dissolved in anhydrous CH_3CN (7.0 mL) in an oven-dried 50 mL round bottom flask. Then the reaction was heated to 40 °C after TPAP (24 mg, 0.068 mmol, 5.0 mol%) and NMO (1.01 g, 8.63 mmol, 6.0 equiv.) was added. The reaction was stirred at 40 °C for 24 h until completion of the reaction (TLC). The reaction was quenched with water and extracted with ethyl acetate (3 × 50 mL). The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 20:1 to 10:1) to afford *sulfoximine* **47** as a colourless oil (490 mg, 99%).

(4-Fluorophenyl)(*p*-tolyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (47)



R$_f$ 0.65 (petrol / ethyl acetate = 9:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.97-7.90 (m, 2H, Ar_F-*H*), 7.80 (d, *J* = 8.3 Hz, 2H, Tol-*H*), 7.21 (d, *J* = 8.3 Hz, 2H, Tol-*H*), 7.09-7.02 (m, 2H, Ar_F-*H*), 2.36 (s, 3H, Tol-C*H*$_3$), 1.58 (s, 2H, $NC(CH_3)_2CH_2$), 1.28 (s, 6H, $NC(CH_3)_2$), 1.08 (s, 9H, *t*-Bu-*H*);

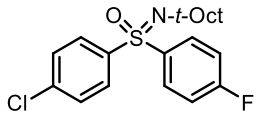
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.5 (d, $^1J_{CF}$ = 252.7 Hz), 142.8, 142.3, 142.1 (d, $^4J_{CF}$ = 3.1 Hz), 130.5 (d, $^3J_{CF}$ = 9.5 Hz), 129.6, 128.0, 115.8 (d, $^2J_{CF}$ = 22.3 Hz), 59.0, 58.8, 33.1, 33.0, 32.11, 32.07, 21.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -108.3 (tt, *J* = 8.4, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2953, 2903, 1589, 1488, 1363, 1259, 1218, 1150, 1090, 836, 813, 714;

HRMS (ESI^+) calcd. for $C_{21}H_{29}FNOS^+$ $[M+H]^+$: 362.1948; found: 362.1946.

(4-Chlorophenyl)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (48)



Prepared according to **General Procedure D** except reaction was carried out at 50 °C instead of 40 °C, using sulfilimine **31'** (140 mg, 0.384 mmol, 1.0 equiv.), TPAP (6.8 mg, 0.019 mmol, 5.0 mol%), NMO (270 mg, 2.31 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 15:1) afforded *sulfoximine* **48** as a colourless oil (113 mg, 78%).

$\mathbf{R}_f$ 0.45 (petrol/ethyl acetate, 7:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.96-7.90 (m, 2H, Ar_F-*H*), 7.85 (d, *J* = 8.7 Hz, 2H, Ar_{Cl}-*H*), 7.38 (d, *J* = 8.7 Hz, 2H, Ar_{Cl}-*H*), 7.13-7.05 (m, 2H, Ar_F-*H*), 1.58 (s, 2H, $NC(CH_3)_2CH_2$), 1.28 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.27 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.07 (s, 9H, *t*-Bu-*H*);

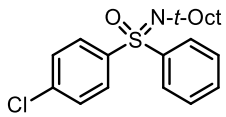
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.7 (d, $^1J_{CF}$ = 253.6 Hz), 144.3, 141.3 (d, $^4J_{CF}$ = 3.2 Hz), 138.2, 130.6 (d, $^3J_{CF}$ = 9.3 Hz), 129.4, 129.2, 116.1 (d, $^2J_{CF}$ = 22.3 Hz), 59.2, 58.7, 33.1, 33.0, 32.10, 32.05;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -107.4 (tt, *J* = 8.2, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1653, 1589, 1472, 1390, 1228, 1128, 1088, 1006, 963, 813, 736.

HRMS (ESI^+) calcd. for $C_{20}H_{26}F^{35}ClNOS^+$ $[M+H]^+$: 382.1402; found: 382.1395.

(4-Chlorophenyl)(phenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (49)



Prepared according to **General Procedure D** except reaction was carried out at 50 °C instead of 40 °C, using sulfilimine **34'** (210 mg, 0.605 mmol, 1.0 equiv.), TPAP (11 mg, 0.031 mmol, 5.0 mol%), NMO (428 mg, 3.66 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 10:1 to 6:1) afforded *sulfoximine* **49** as a colourless oil (184 mg, 84%).

R$_f$ 0.50 (petrol/ethyl acetate, 15:1);

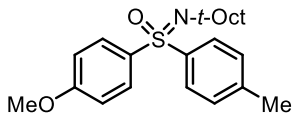
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.95-7.91 (m, 2H, Ph-*H*), 7.88 (d, *J* = 8.7 Hz, 2H, Ar_{Cl}-*H*), 7.46-7.39 (m, 3H, Ph-*H*), 7.37 (d, *J* = 8.7 Hz, 2H, Ar_{Cl}-*H*), 1.59 (s, 2H, $NC(CH_3)_2CH_2$), 1.283 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.278 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.08 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 145.3, 144.4, 138.0, 131.7, 129.5, 129.0, 128.9, 127.9, 59.1, 58.6, 33.1, 33.0, 32.1, 32.0;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1473, 1276, 1261, 1213, 1153, 1087, 1066, 1013, 827, 749, 701;

HRMS (ESI^+) calcd. for $C_{20}H_{27}O^{35}ClNS^+$ $[M+H]^+$: 364.1496; found: 364.1500.

(4-Methoxyphenyl)(*p*-tolyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (50)



Prepared according to **General Procedure D** using sulfilimine **50'** (155 mg, 0.434 mmol, 1.0 equiv.), TPAP (8.1 mg, 0.023 mmol, 5.0 mol%), NMO (310 mg, 2.65 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 7:1) afforded *sulfoximine* **50** as a colourless oil (142 mg, 88%).

R$_f$ 0.40 (petrol/ethyl acetate, 5:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.86 (d, *J* = 8.9 Hz, 2H, Ar_{OMe}-*H*), 7.80 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 7.18 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 6.87 (d, *J* = 8.9 Hz, 2H, Ar_{OMe}-*H*), 3.78 (s,

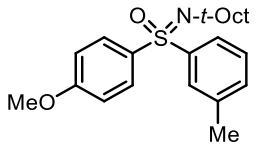
3H, OCH_3), 2.33 (s, 3H, Tol-CH_3), 1.58 (s, 2H, NC$(CH_3)_2$CH_2), 1.28 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.27 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.09 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 163.3, 145.0, 142.9, 138.9, 130.8, 130.4, 128.7, 115.0, 59.6, 59.1, 56.2, 33.8, 33.7, 32.8, 32.7, 21.6;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1594, 1492, 1387, 1251, 1151, 1091, 1027, 951, 801, 716, 673;

HRMS (ESI$^+$) calcd. for $C_{22}H_{32}NO_2S^+$ $[M+H]^+$: 374.2148; found: 374.2146.

(4-Methoxyphenyl)(*m*-tolyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (51)



Prepared according to **General Procedure D** except reaction was carried out at 50 °C instead of 40 °C, using sulfilimine **51'** (135 mg, 0.378 mmol, 1.0 equiv.), TPAP (6.9 mg, 0.019 mmol, 5.0 mol%), NMO (263 mg, 2.25 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 12:1) afforded *sulfoximine* **51** as a colourless oil (128 mg, 91%).

R$_f$ 0.46 (petrol/ethyl acetate, 9:1);

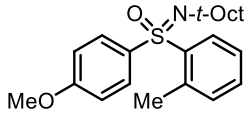
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.87 (d, *J* = 8.9 Hz, 2H, Ar_{OMe}-*H*), 7.76-7.69 (m, 2H, Tol-*H*), 7.29-7.24 (m, 1H, Tol-*H*), 7.22-7.18 (m, 1H, Tol-*H*), 6.88 (d, *J* = 8.9 Hz, 2H, Ar_{OMe}-*H*), 3.78 (s, 3H, OCH_3), 2.35 (s, 3H, Tol-CH_3), 1.59 (s, 2H, NC$(CH_3)_2$CH_2), 1.282 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.277 (s, 3H, NC$(CH_3)_a(CH_3)_b$),1.09 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 163.4, 147.7, 139.8, 138.7, 133.0, 130.9, 129.7, 128.9, 125.9, 115.0, 59.6, 59.1, 56.2, 33.8, 33.7, 32.8, 32.7, 21.6;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1594, 1493, 1386, 1252, 1151, 1090, 955, 832, 694;

HRMS (ESI$^+$) calcd. for $C_{22}H_{32}NO_2S^+$ $[M+H]^+$: 374.2148; found: 374.2140.

(4-Methoxyphenyl)(*o*-tolyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (52)



Prepared according to **General Procedure D** using sulfilimine **52'** (60 mg, 0.17 mmol, 1.0 equiv.), TPAP (9.2 mg, 0.026 mmol, 15 mol%), NMO (117 mg, 1.00 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 12:1) afforded *sulfoximine* **52** as a colourless oil (45 mg, 72%).

R$_f$ 0.50 (petrol/ethyl acetate, 9:1);

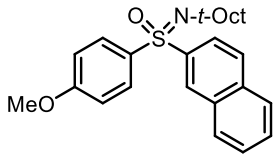
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.36 (dd, *J* = 7.6, 1.9 Hz, 1H, Tol-*H*), 7.80 (d, *J* = 9.0 Hz, 2H, Ar_{OMe}-*H*), 7.37-7.28 (m, 2H, Tol-*H*), 7.12-7.08 (m, 1H, Tol-*H*), 6.88 (d, *J* = 9.0 Hz, 2H, Ar_{OMe}-*H*), 3.81 (s, 3H, OC*H*$_3$), 2.33 (s, 3H, Tol-C*H*$_3$), 1.59 (s, 2H, NC(CH$_3$)$_2$C*H*$_2$), 1.27 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.21 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.08 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 162.0, 143.9, 137.5, 136.6, 132.6, 131.7, 130.2, 130.1, 126.1, 113.7, 59.0, 58.7, 55.6, 32.7, 32.5, 32.14, 32.07, 20.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1594, 1494, 1251, 1151, 1083, 833, 803, 759, 717;

HRMS (ESI$^+$) calcd. for $C_{22}H_{32}NO_2S^+$ [M+H]$^+$: 374.2148; found:374.2138.

(4-Methoxyphenyl)(naphthalen-2-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (53)



Prepared according to **General Procedure D** using sulfilimine **53'** (153 mg, 0.389 mmol, 1.0 equiv.), TPAP (6.9 mg, 0.019 mmol, 5.0 mol%), NMO (277 mg, 2.37 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 9:1) afforded *sulfoximine* **53** as a white solid (146 mg, 92%).

mp 106-108 °C;

R$_f$ 0.45 (petrol/ethyl acetate, 5:1);

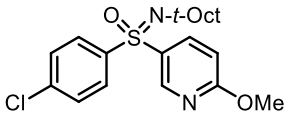
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.61-8.55 (m, 1H, Ar-*H*), 7.98-7.91 (m, 3H, Ar-*H*/Ar$_{OMe}$-*H*), 7.87 (dd, *J* = 8.7, 1.8 Hz, 1H, Ar-*H*), 7.85-7.79 (m, 2H, Ar-*H*), 7.58-7.51 (m, 2H, Ar-*H*), 6.89 (d, *J* = 9.0 Hz, 2H, Ar$_{OMe}$-*H*), 3.78 (s, 3H, OC*H*$_3$), 1.66 (d, *J* = 14.4 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.62 (d, *J* = 14.4 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.35 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.30 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.14 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 162.2, 143.5, 137.1, 134.3, 132.6, 130.1, 129.3, 128.8, 128.4, 128.2, 127.8, 127.1, 124.0, 114.0, 58.9, 58.8, 55.6, 33.3, 33.0, 32.12, 32.10;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1593, 1493, 1386, 1254, 1152, 1083, 955, 832, 748;

HRMS (ESI$^+$) calcd. for $C_{25}H_{32}NO_2S^+$ $[M+H]^+$: 410.2148; found: 410.2141.

(4-Chlorophenyl)(6-methoxypyridin-3-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (54)



Prepared according to **General Procedure D** using sulfilimine **35'** (96.6 mg, 0.256 mmol, 1.0 equiv.), TPAP (4.5 mg, 0.013 mmol, 5.0 mol%), NMO (180 mg, 1.54 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 10:1) afforded *sulfoximine* **54** as a colourless oil (88 mg, 88%).

R$_f$ 0.50 (petrol/ethyl acetate, 5:1);

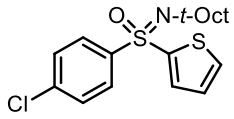
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.72 (dd, *J* = 2.5, 0.7 Hz, 1H, HetAr-*H*), 7.95 (dd, *J* = 8.8, 2.5 Hz, 1H, HetAr-*H*), 7.85 (d, *J* = 8.7 Hz, 2H, Ar$_{Cl}$-*H*), 7.38 (d, *J* = 8.7 Hz, 2H, Ar$_{Cl}$-*H*), 6.72 (dd, *J* = 8.8, 0.7 Hz, 1H, HetAr-*H*), 3.94 (s, 3H, OC*H*$_3$), 1.57 (s, 2H, NC(CH$_3$)$_2$C*H*$_2$), 1.28 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.26 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.06 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.9, 148.2, 144.4, 138.2, 138.1, 134.4, 129.3, 129.2, 111.2, 59.2, 58.6, 54.3, 33.2, 33.1, 32.1, 32.0;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1587, 1476, 1366, 1276, 1261, 1212, 1154, 1118, 1087, 1013, 823;

HRMS (ESI^+) calcd. for $C_{20}H_{28}{}^{35}ClO_2N_2S^+$ $[M+H]^+$: 395.1555; found: 395.1553.

(4-Chlorophenyl)(thiophen-2-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ⁶-sulfanone (55)



Prepared according to **General Procedure D** except reaction was carried out at 50 °C instead of 40 °C, using sulfilimine **33'** (223 mg, 0.632 mmol, 1.0 equiv.), TPAP (12 mg, 0.034 mmol, 5.0 mol%), NMO (447 mg, 3.82 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 11:1 to 6:1) afforded *sulfoximine* **55** as a colourless oil (201 mg, 87%).

$\mathbf{R}_f$ 0.50 (petrol/ethyl acetate, 15:1);

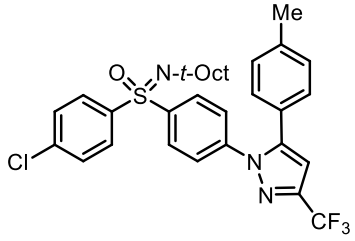
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.95 (d, J = 8.7 Hz, 2H, Ar_{Cl}-*H*), 7.50 (dd, J = 5.0, 1.3 Hz, 1H, HetAr-*H*), 7.43 (dd, J = 3.7, 1.3 Hz, 1H, HetAr-*H*), 7.39 (d, J = 8.7 Hz, 2H, Ar_{Cl}-*H*), 6.98 (dd, J = 5.0, 3.7 Hz, 1H, HetAr-*H*), 1.58 (s, 2H, $NC(CH_3)_2CH_2$), 1.334 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.329 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.08 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 148.5, 144.6, 138.1, 132.5, 131.9, 129.1, 129.0, 127.8, 59.4, 58.5, 33.1, 32.7, 32.1, 32.0;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1473, 1276, 1261, 1212, 1154, 1088, 1012, 997, 826, 750;

HRMS (ESI^+) calcd. for $C_{18}H_{25}O^{35}ClNS_2{}^+$ $[M+H]^+$: 370.1061; found: 370.1059.

(4-Chlorophenyl)(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ⁶-sulfanone (56)



Prepared according to **General Procedure D** using sulfilimine **37'** (108 mg, 0.189 mmol, 1.0 equiv.), TPAP (3.4 mg, 0.010 mmol, 5.0 mol%), NMO (137 mg, 1.17 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 10:1) afforded *sulfoximine* **56** as a colourless oil (83 mg, 75%).

R$_f$ 0.5 (petrol/ethyl acetate, 9:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.90 (d, J = 8.7 Hz, 2H, Ar_{Cl}-*H*), 7.84 (d, J = 8.7 Hz, 2H, Ar_{Cl}-*H*), 7.40 (d, J = 6.1 Hz, 2H, Ar-*H*), 7.37 (d, J = 6.1 Hz, 2H, Ar-*H*), 7.13 (d, J = 7.8 Hz, 2H, Tol-*H*), 7.07 (d, J = 7.8 Hz, 2H, Tol-*H*), 6.71 (s, 1H, HetAr-*H*), 2.37 (s, 3H, Tol-C*H*$_3$), 1.58 (s, 2H, NC(CH$_3$)$_2$C*H*$_2$), 1.28 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.27 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.06 (s, 9H, *t*-Bu-*H*);

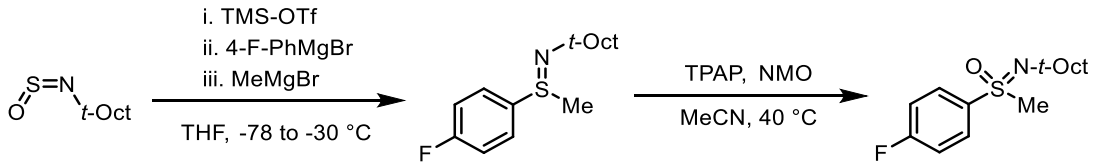
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 145.2, 144.9, 144.0 (q, $^2J_{CF}$ = 38.3 Hz), 143.8, 141.8, 139.8, 138.4, 129.7, 129.6, 129.2, 129.0, 128.8, 125.9, 125.5, 121.2 (q, $^1J_{CF}$ = 269.2 Hz), 106.2, 59.3, 58.6, 33.1, 33.0, 32.1, 32.0, 21.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -62.4 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1472, 1276, 1261, 1235, 1214, 1134, 1088, 975, 909, 750;

HRMS (ESI$^+$) calcd. for $C_{31}H_{34}O^{35}ClN_3F_3S^+$ [M+H]$^+$: 588.2058; found: 588.2055.

6.2.6 General Procedure E for Aryl-alkyl and Dialkyl Sulfoximine Synthesis



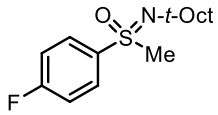
t-Oct-NSO **25** (248 mg, 1.42 mmol, 1.05 equiv.) was dissolved in anhydrous THF (3.0 mL) in an oven-dried 25 mL round bottom flask. Then the mixture was cooled to -78 °C and TMSOTf (310 mg, 1.37 mmol, 1.0 equiv.) was added. 4-Fluorophenylmagnesium bromide (1.57 mL, 0.87 M in THF, 1.37 mmol, 1.0 equiv.) was added dropwise after 1 min. The mixture was stirred at -78 °C for 2 min and then the temperature was increased to -30 °C.

Methylmagnesium bromide (0.70 mL, 3.0 M in diethyl ether, 2.1 mmol, 1.5 equiv.) was then added quickly. The mixture was stirred at -30 °C for 10 min. Then the reaction was quenched with sat. aq. tetrasodium EDTA solution and poured into a 250 mL separating funnel. Ethyl acetate (80 mL) was then added and the organic phase was separated. The aqueous phase was further extracted with ethyl acetate (2 × 40 mL). The combined extracts were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude sulfilimine was dissolved in a mixture of diethyl ether (15 mL) and petroleum ether (5 mL) and acidified by a 1 M aq. solution of 4-toluenesulfonic acid (35 mL) and the organic layer was then discarded. The aqueous phase was washed once with a mixture of diethyl ether (5 mL) and petroleum ether (15 mL). The aqueous phase was then extracted with CH_2Cl_2 (3 × 40 mL), dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to afford the *4-toluenesulfonic acid-sulfilimine salt* (*c*. 85% yield). The sulfilimine salt was then dissolved in CH_2Cl_2 (50 mL) and treated with 1M aq. NaOH solution (50 mL). The organic layer was separated and the aqueous phase was extracted with CH_2Cl_2 (2 × 50 mL). The combined organic extracts were dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford *sulfilimine* **29** as a light-yellow oil (301 mg, 82%).

(Please see notes on **General Procedure C** for further guidance.)

Sulfilimine **29** (301 mg, 1.12 mmol, 1.0 equiv.) was dissolved in anhydrous CH_3CN (6.0 mL) in an oven-dried 50 mL round bottom flask. Then the mixture was heated to 40 °C before TPAP (20 mg, 0.057 mmol, 5.0 mol%) was added, then NMO (787 mg, 6.73 mmol, 6.0 equiv.) was added. The reaction was stirred at 40 °C for 24 h until completion of the reaction (TLC). The reaction was quenched with water and extracted with ethyl acetate (3 × 50 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 5:1 to 3:1) to afford *sulfoximine* **57** as a colourless oil (315 mg, 99%).

(4-Fluorophenyl)(methyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (57)



R$_f$ 0.33 (petrol/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.97-7.89 (m, 2H, Ar_F-*H*), 7.18-7.11 (m, 2H, Ar_F-*H*), 2.97 (s, 3H, SC*H*$_3$), 1.51 (d, *J* = 14.3 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.44 (d, *J* = 14.3 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.26 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.11 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.03 (s, 9H, *t*-Bu-*H*);

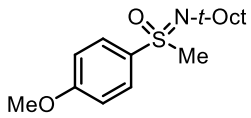
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.9 (d, $^1J_{CF}$ = 253.0 Hz), 141.8 (d, $^4J_{CF}$ = 3.2 Hz), 130.4 (d, $^3J_{CF}$ = 9.2 Hz), 116.1 (d, $^2J_{CF}$ = 22.2 Hz), 58.8, 58.3, 48.7, 32.9, 32.7, 32.0, 31.9;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -107.5 (tt, *J* = 8.5, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2956, 2903, 1589, 1491, 1363, 1226, 1150, 1090, 1077, 970, 838;

HRMS (ESI$^+$) calcd. for $C_{15}H_{25}FNOS^+$ [M+H]$^+$: 286.1635; found: 286.1637.

(4-Methoxyphenyl)(methyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (58)



Sulfilimine prepared according to **General Procedure E** using *t*-Oct-NSO **25** (135 mg, 0.770 mmol, 1.05 equiv.), TMSOTf (163 mg, 0.730 mmol, 1.0 equiv.), 4-methoxyphenylmagnesium bromide (1.5 mL, 0.49 M in THF, 0.74 mmol, 1.0 equiv.) and methylmagnesium bromide (0.37 mL, 3.0 M in diethyl ether, 1.1 mmol, 1.5 equiv.). Following the general purification method, sulfilimine **39'** was generated as light-yellow oil with a crude yield of 83% (170 mg). Sulfoximine prepared using TPAP (11 mg, 0.031 mmol, 5.0 mol%), NMO (0.42 g, 3.6 mmol, 6.0 equiv.). Purification by flash column

chromatography (petrol/ethyl acetate, 4:1 to 2:1) afforded *sulfoximine* **58** as a colourless oil (164 mg, 75% yield over two steps).

R$_f$ 0.45 (petrol/ethyl acetate, 2:1);

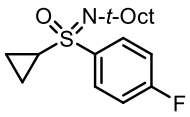
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.85 (d, J = 8.9 Hz, 2H, Ar_{OMe}-*H*), 6.96 (d, J = 8.9 Hz, 2H, Ar_{OMe}-*H*), 3.85 (s, 3H, OC*H*$_3$), 2.96 (s, 3H, SC*H*$_3$), 1.52 (d, J = 14.3 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.46 (d, J = 14.3 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.26 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.13 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.04 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 162.5, 137.4, 129.8, 114.1, 58.7, 58.4, 55.6, 48.9, 32.9, 32.7, 32.1, 31.9;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 2902, 1594, 1495, 1252, 1151, 1132, 1079, 969, 833;

HRMS (ESI$^+$) calcd. for $C_{16}H_{28}NO_2S^+$ $[M+H]^+$: 298.1835; found: 298.1836.

Cyclopropyl(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (59)



Sulfilimine prepared according to **General Procedure E** using *t*-Oct-NSO **25** (231 mg, 1.32 mmol, 1.05 equiv.), TMSOTf (290 mg, 1.31 mmol, 1.0 equiv.), cyclopropylmagnesium bromide (1.55 mL, 0.84 M in 2-methyltetrahydrofuran, 1.30 mmol, 1.0 equiv.) and 4-fluorophenylmagnesium bromide (2.00 mL, 0.96 M in THF, 1.92 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **43'** was generated as light-yellow oil with a crude yield of 78% (300 mg). Sulfoximine prepared using TPAP (18 mg, 0.050 mmol, 5.0 mol%), NMO (0.70 g, 6.0 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 5:1 to 3:1) afforded *sulfoximine* **59** as a white solid (195 mg, 48% yield over two steps).

mp 77-79 °C;

R$_f$ 0.5 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.91-7.86 (m, 2H, Ar_F-*H*), 7.17-7.11 (m, 2H, Ar_F-*H*), 2.39 (tt, *J* = 7.8, 4.8 Hz, 1H, SC*H*), 1.51 (d, *J* = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.46 (d, *J* = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.43-1.34 (m, 1H, $SCHCH_aH_b$), 1.28 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.14 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.07-0.94 (m, 11H, $SCHCH_2$/*t*-Bu-*H*), 0.80-0.70 (m, 1H, $SCHCH_aH_b$);

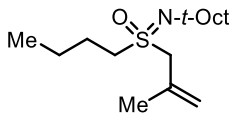
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.7 (d, $^{1}J_{CF}$ = 252.7 Hz), 142.0 (d, $^{4}J_{CF}$ = 3.3 Hz), 130.5 (d, $^{3}J_{CF}$ = 8.8 Hz), 115.9 (d, $^{2}J_{CF}$ = 22.2 Hz), 58.5, 58.4, 36.3, 33.2, 33.0, 32.1, 32.0, 6.8, 5.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -108.1 (tt, *J* = 8.5, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1490, 1276, 1261, 1226, 1149, 1114, 1077, 887, 836;

HRMS (ESI^+) calcd. for $C_{17}H_{27}ONFS^+$ $[M+H]^+$: 312.1792; found: 312.1792.

Butyl(2-methylallyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (60)



Sulfilimine prepared according to **General Procedure E** using *t*-Oct-NSO **25** (512 mg, 2.92 mmol, 1.05 equiv.), TMSOTf (605 mg, 2.72 mmol, 1.0 equiv.), *n*-butylmagnesium chloride (1.39 mL, 1.96 M in THF, 2.72 mmol, 1.0 equiv.) and 2-methyl-1-propenylmagnesium bromide (8.00 mL, 0.49 M in THF, 3.92 mmol, 1.5 equiv.). Following the general purification method, sulfilimine **45'** was generated as light-yellow oil with a crude yield of 81% (600 mg). Sulfoximine prepared using TPAP (39 mg, 0.11 mmol, 5.0 mol%), NMO (1.54 g, 13.2 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfoximine* **60** as a light-yellow oil (187 mg, 24% yield over two steps).

R_f 0.61 (petrol/ethyl acetate, 1:1);

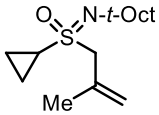
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 4.93 (s, 1H, C=CH_aH$_b$), 4.84 (s, 1H, C=CH$_a$$H_b$), 3.98 (d, J = 19.6 Hz, 1H, SCH_aH$_b$C=CH$_2$), 3.03 (d, J = 19.6 Hz, 1H, SCH$_a$$H_b$C=CH$_2$), 2.55-2.38 (m, 2H, SC$H_2CH_2$), 1.76 (d, J = 14.7 Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.70 (s, 3H, SCH$_2$C=CH$_2$CH_3), 1.68 (d, J = 14.7 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.62-1.47 (m, 2H, SCH$_2CH_2$), 1.43-1.31 (m, 5H, SCH$_2CH_2CH_2$/ NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.22 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 0.95 (s, 9H, *t*-Bu-*H*), 0.87 (t, J = 7.3 Hz, 3H, *n*-Bu-CH_3);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 145.6, 110.7, 63.6, 54.5, 53.1, 42.0, 31.9, 31.4, 29.3, 27.5, 25.9, 22.0, 20.7, 13.8;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1469, 1368, 1276, 1261, 1138, 1071, 1045, 895, 839, 763;

HRMS (ESI$^+$) calcd. for $C_{16}H_{34}NOS^+$ $[M+H]^+$: 288.2356; found: 288.2354.

Cyclopropyl(2-methylallyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfanone (61)



Sulfilimine prepared according to **General Procedure E** using *t*-Oct-NSO **25** (340 mg, 1.94 mmol, 1.05 equiv.), TMSOTf (416 mg, 1.87 mmol, 1.0 equiv.), cyclopropylmagnesium bromide (2.23 mL, 0.84 M in 2-methyltetrahydrofuran, 1.87 mmol, 1.0 equiv.) and 2-methyl-1-propenylmagnesium bromide (5.60 mL, 0.49 M in THF, 2.74 mmol, 1.5 equiv.). Following the general purification method, *sulfilimine* **46'** was generated as light-yellow oil with a crude yield of 81% (387 mg). Sulfoximine prepared using TPAP (27 mg, 0.076 mmol, 5.0 mol%), NMO (1.07 g, 9.15 mmol, 6.0 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) afforded *sulfoximine* **61** as a colourless oil (236 mg, 47% yield over two steps).

R$_f$ 0.65 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 4.96 (s, 1H, C=CH_aH$_b$), 4.78 (s, 1H, C=CH$_a$$H_b$), 3.88 (d, J = 19.8 Hz, 1H, SCH_aH$_b$C=CH$_2$), 3.05 (d, J = 19.8 Hz, 1H, SCH$_a$$H_b$C=CH$_2$), 1.88

(tt, J = 8.0, 5.0 Hz, 1H, SC*H*), 1.79 (d, J = 14.7 Hz, 1H, NC(CH_3)$_2$CH_aH$_b$), 1.65 (s, 3H, SCH_2C=CH_2CH_3), 1.64 (d, J = 14.7 Hz, 1H, NC(CH_3)$_2$C$H_a$$H_b$), 1.37 (s, 3H, NC(C$H_3$)$_a$($CH_3$)$_b$), 1.21 (s, 3H, NC($CH_3$)$_a$(C$H_3$)$_b$), 1.18-1.11 (m, 1H, SCHCH_aH$_b$), 0.93 (s, 9H, *t*-Bu-*H*), 0.65-0.54 (m, 2H, SCHCH_2), 0.52-0.44 (m, 1H, SCHC$H_a$$H_b$);

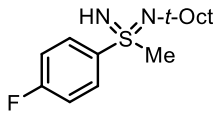
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 144.6, 110.2, 63.4, 53.3, 42.9, 31.9, 31.4, 30.1, 29.2, 27.6, 20.6, 2.7, -0.1;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1472, 1368, 1276, 1261, 1139, 1071, 1028, 896, 840, 818, 750;

HRMS (ESI^+) calcd. for $C_{15}H_{30}NOS^+$ $[M+H]^+$: 272.2043; found: 272.2043.

6.2.7 Deprotection of Sulfondiimines

1-(4-Fluorophenyl)-1-methyl-*N*-(2,4,4-trimethylpentan-2-yl)-λ^6-sulfanediimine (62)



Under an atmosphere of nitrogen, sulfondiimines **38** (1.50 g, 3.20 mmol, 1.0 equiv.) was dissolved in anhydrous CH_3CN (10 ml). 1-Dodecanethiol (3.80 ml, 15.8 mmol, 5.0 equiv.) was added at room temperature followed by DBU (2.30 mL, 15.4 mmol, 4.75 equiv.). The solution became yellow and was stirred for 20 min under nitrogen until completion of the reaction (TLC). The reaction mixture was then concentrated *in vacuo* to afford light yellow oil. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1:1 to 0:1) to afford corresponding *sulfondiimine* **62** as a colourless oil (806 mg, 89%).

R$_f$ 0.44 (ethyl acetate);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.14-8.08 (m, 2H, Ar$_F$-*H*), 7.18-7.08 (m, 2H, Ar$_F$-*H*), 3.05 (s, 3H, SCH_3), 1.97 (br. s, 1H, N*H*), 1.56 (d, J = 14.4 Hz, 1H, NC(CH_3)$_2$CH_aH$_b$), 1.52 (d, J = 14.4 Hz, 1H, NC(CH_3)$_2$C$H_a$$H_b$), 1.41 (s, 3H, NC(C$H_3$)$_a$($CH_3$)$_b$), 1.30 (s, 3H, NC($CH_3$)$_a$(C$H_3$)$_b$), 1.03 (s, 9H, *t*-Bu-*H*);

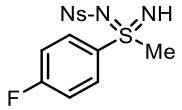
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.6 (d, $^1J_{CF}$ = 252.7 Hz), 143.0 (d, $^4J_{CF}$ = 3.1 Hz), 129.8 (d, $^3J_{CF}$ = 9.1 Hz), 115.7 (d, $^2J_{CF}$ = 22.4 Hz), 58.72, 58.70, 51.8, 33.3, 32.3, 32.08, 32.05;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -108.7 (tt, J = 8.3, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2954, 1589, 1488, 1219, 1188, 1152, 1087, 1001, 939;

HRMS (ESI^+) calcd. for $C_{15}H_{26}FN_2S^+$ $[M+H]^+$: 285.1795; found: 285.1795.

***N*-((4-Fluorophenyl)(imino)(methyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (63)**



Sulfondiimine **38** (1.00 g, 2.14 mmol, 1.0 equiv.) was mixed with TFA (21 mL) and stirred at room temperature for 14 h. The mixture was concentrated *in vacuo* then diluted with CH_2Cl_2 and basified to pH 10-11 using 1 M aq. NaOH solution. The product was extracted with CH_2Cl_2 (3 × 50 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1:1 to 1:3) to afford *sulfondiimine* **63** as a white solid (737 mg, 97%).

mp 173-175 °C;

R_f 0.37 (petrol/ethyl acetate, 1:3);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.29 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.13 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.15-8.08 (m, 2H, Ar_F-*H*), 7.29-7.24 (m, 2H, Ar_F-*H*), 3.43 (s, 3H, SCH_3), 2.71 (br. s, 1H, N*H*);

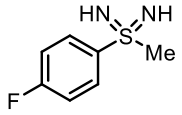
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 166.7 (d, $^1J_{CF}$ = 253.7 Hz), 151.5, 150.5, 138.5 (d, $^4J_{CF}$ = 3.2 Hz), 131.6 (d, $^3J_{CF}$ = 9.6 Hz), 129.0, 124.8, 117.4 (d, $^2J_{CF}$ = 23.1 Hz), 48.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.4 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2978, 1528, 1352, 1296, 1238, 1152, 1086, 1035, 1006, 968;

HRMS (ESI$^+$) calcd. for $C_{13}H_{13}FN_3O_4S_2^+$ [M+H]$^+$: 358.0326; found: 358.0323.

(4-Fluorophenyl)(methyl)-λ^6-sulfanediimine (64)



Under an atmosphere of nitrogen, sulfondiimines **63** (602 mg, 1.69 mmol, 1.0 equiv.) was dissolved in anhydrous CH_3CN (5.0 ml). 1-Dodecanethiol (2.00 mL, 8.35 mmol, 5.0 equiv.) was added at room temperature followed by DBU (1.20 mL, 8.02 mmol, 4.75 equiv.). The solution became yellow and was stirred for 20 min under nitrogen until completion of the reaction (TLC). The reaction mixture was concentrated *in vacuo* to afford light-yellow oil. The crude product was purified by flash column chromatography (CH_2Cl_2/MeOH, 9:1) to afford *sulfondiimine* **64** as a white solid (285 mg, 98%).

mp 103-105 °C;

R$_f$ 0.48 (CH_2Cl_2/MeOH, 9:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.17-8.08 (m, 2H, Ar_F-*H*), 7.18-7.09 (m, 2H, Ar_F-*H*), 3.09 (s, 3H, SC*H*$_3$), 2.48 (br. s, 2H, N*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.2 (d, $^1J_{CF}$ = 254.2 Hz), 140.4 (d, $^4J_{CF}$ = 3.1 Hz), 129.9 (d, $^3J_{CF}$ = 9.3 Hz), 116.1 (d, $^2J_{CF}$ = 22.4 Hz), 50.6;

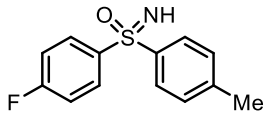
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.7 (tt, *J* = 8.5, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1490, 1227, 1057, 933, 839, 661;

HRMS (ESI$^+$) calcd. for $C_7H_{10}FN_2S^+$ [M+H]$^+$: 173.0543; found: 173.0543.

6.2.8 Deprotection of Sulfoximine

(4-Fluorophenyl)(imino)(*p*-tolyl)-λ^6-sulfanone (65)



Sulfoximine **47** (69 mg, 0.19 mmol, 1.0 equiv.) was mixed with TFA (1.5 mL) and heated to 60 °C for 18 h. The mixture was concentrated *in vacuo* then diluted with CH_2Cl_2 and basified to pH 10-11 using 1 M aq. NaOH solution. The product was extracted with CH_2Cl_2 (3 × 30 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:2) to afford *sulfoximine* **65** as a colourless oil (47 mg, 99%).

R$_f$ 0.41 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.05-8.00 (m, 2H, Ar_F-*H*), 7.89 (d, *J* = 8.4 Hz, 2H, Tol-*H*), 7.26 (d, *J* = 8.4 Hz, 2H, Tol-*H*), 7.14-7.08 (m, 2H, Ar_F-*H*), 2.90 (br. s, 1H, N*H*), 2.37 (s, 3H, Tol-CH_3);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.2 (d, $^1J_{CF}$ = 254.4 Hz), 143.7, 140.5, 139.8 (d, $^4J_{CF}$ = 3.1 Hz), 130.7 (d, $^3J_{CF}$ = 9.5 Hz), 130.0, 128.0, 116.4 (d, $^2J_{CF}$ = 22.7 Hz), 21.6;

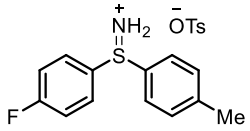
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.2 (tt, *J* = 8.3, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2981, 2888, 1588, 1489, 1382, 1229, 1130, 1094, 968, 839;

HRMS (ESI$^+$) calcd. for $C_{13}H_{13}FNOS^+$ $[M+H]^+$: 250.0696; found: 250.0695.

6.2.9 Deprotection of Sulfilimine

(4-Fluorophenyl)(*p*-tolyl)-λ^4-sulfaniminium-4-methylbenzenesulfonate (66)



In a 25 mL round bottom flask, sulfilimine **26** (225 mg, 0.652 mmol, 1.0 equiv.) was dissolved in anhydrous CH_2Cl_2 (6.5 mL). Triflic acid (0.29 mL, 3.29 mmol, 5.0 equiv.) was added and the reaction was stirred at room temperature for 1 h. The mixture was diluted with CH_2Cl_2 and basified to pH 10-11 using 1 M aq. NaOH solution. The separated aqueous phase was extracted with CH_2Cl_2 (3 × 30 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. Then the crude sulfilimine was

dissolved in CH_2Cl_2 (20 mL), $TsOH \cdot H_2O$ (123 mg, 0.715 mmol, 1.1 equiv.) was added and stirred at room temperature for 10 min until a homogeneous solution is formed. The mixture was then concentrated *in vacuo* and was purified by flash column chromatography (CH_2Cl_2/MeOH, 20:1 to 5:1) to afford *sulfiliminium salt* **66** as a waxy solid (255 mg, 97%).

R$_f$ 0.62 (CH_2Cl_2/MeOH, 5:1);

^{1}H NMR (400 MHz, CD_3OD): δ (ppm) = 7.87-7.81 (m, 2H, Ar_F-*H*), 7.70-7.76 (m, 4H, Ar_{Ts}-*H*), 7.50 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 7.45-7.39 (m, 2H, Ar_F-*H*), 7.19 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 2.44 (s, 3H, Ts-C*H*$_3$), 2.34 (s, 3H, Tol-C*H*$_3$);

^{13}C NMR (101 MHz, CD_3OD): δ (ppm) = 166.9 (d, $^1J_{CF}$ = 255.7 Hz), 146.7, 143.5, 141.6, 132.4, 132.3 (d, $^3J_{CF}$ = 9.7 Hz), 130.5, 130.0 (d, $^4J_{CF}$ = 3.2 Hz), 129.8, 129.4, 126.9, 119.0 (d, $^2J_{CF}$ = 23.3 Hz), 21.5, 21.3;

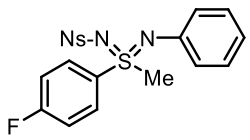
^{19}F NMR (377 MHz, CD_3OD): δ (ppm) = -105.7 (tt, *J* = 8.2, 4.7 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2981, 2361, 2341, 1589, 1494, 1227, 1177, 1122, 1034, 1011, 814;

HRMS (ESI^+) calcd. for $C_{13}H_{13}FNS^+$ $[M+H]^+$: 234.0747; found: 234.0746.

6.2.10 *N*-Functionalisation of Sulfondiimines

_N_-((4-Fluorophenyl)(methyl)(phenylimino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (68)



Sulfondiimine **63** (50 mg, 0.14 mmol, 1.0 equiv.), phenylboronic acid (45 mg, 0.37 mmol, 2.5 equiv.), $Cu(CH_3CN)_4PF_6$ (26 mg, 0.070 mmol, 0.5 equiv.), *N*-methylpiperidine (123 mg, 1.24 mmol, 9.0 equiv.) were added to an oven-dried 10 mL vial and dissolved in CH_3CN (1.4 mL) under oxygen atmosphere. The reaction was stirred at room temperature for 24 h until completion of the reaction (TLC). The reaction was quenched with water and extracted with ethyl acetate (3 × 20 mL). The combined extracts were washed with brine, dried over

anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) to afford *sulfondiimine* **68** as a white solid (51 mg, 84%).

mp 177-179 °C;

R_f 0.39 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.08-8.04 (m, 2H, Ar_F-*H*), 7.91 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.81 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.29-7.23 (m, 2H, Ar_F-*H*), 6.79-6.73 (m, 2H, Ph-*H*), 6.69-6.63 (m, 1H, Ph-*H*), 6.40-6.35 (m, 2H, Ph-*H*), 3.76 (s, 3H, SCH_3);

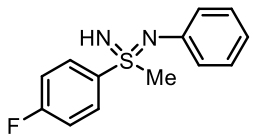
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.3 (d, $^1J_{CF}$ = 258.6 Hz), 149.4, 147.5, 142.6, 131.9 (d, $^4J_{CF}$ = 3.2 Hz), 131.1 (d, $^3J_{CF}$ = 9.7 Hz), 128.7, 128.3, 123.5, 122.1, 121.9, 117.9 (d, $^2J_{CF}$ = 23.0 Hz), 49.1;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -101.9 (tt, *J* = 8.0, 4.8 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1592, 1527, 1487, 1350, 1294, 1260, 1156, 1065, 1002, 797, 737, 691;

HRMS (ESI^+) calcd. for $C_{19}H_{17}FN_3O_4S_2^+$ $[M+H]^+$: 434.0639; found: 434.0642.

1-(4-Fluorophenyl)-1-methyl-*N*-phenyl-λ^6-sulfanediimine (69)



Under an atmosphere of nitrogen, sulfondiimines **68** (42 mg, 0.10 mmol, 1.0 equiv.) was dissolved in anhydrous CH_3CN (1.0 ml). 1-Dodecanethiol (0.12 mL, 0.50 mmol, 5.0 equiv.) was added at room temperature followed by DBU (70 µL, 0.47 mmol, 4.8 equiv.). The solution became yellow and was stirred for 20 min under nitrogen until completion of the reaction (TLC). The reaction mixture was concentrated *in vacuo* to afford light yellow oil. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1:1 to 0:1) to afford corresponding *sulfondiimine* **69** as a white solid (19 mg, 80%).

mp 122-123 °C;

R_f 0.39 (ethyl acetate);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.23-8.16 (m, 2H, Ar_F-*H*), 7.25-7.14 (m, 4H, Ar_F-*H*/Ph-*H*), 7.10-7.06 (m, 2H, Ph-*H*), 6.90 (tt, *J* = 7.5, 1.2 Hz, 1H, Ph-*H*), 3.25 (s, 3H, SC*H*$_3$), 2.17 (br. s, 1H, N*H*);

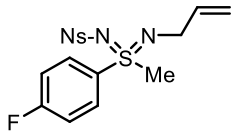
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.5 (d, $^1J_{CF}$ = 254.8 Hz), 145.8, 138.0 (d, $^4J_{CF}$ = 3.1 Hz), 130.7 (d, $^3J_{CF}$ = 9.4 Hz), 129.2, 123.2, 121.3, 116.6 (d, $^2J_{CF}$ = 22.6 Hz), 48.6;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.1 (tt, *J* = 8.3, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1590, 1486, 1390, 1254, 1153, 1081, 956, 839, 758;

HRMS (ESI^+) calcd. for $C_{13}H_{14}FN_2S^+$ $[M+H]^+$: 249.0856; found: 249.0855.

***N*-((Allylimino)(4-fluorophenyl)(methyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (70)**



In an oven-dried flask, sulfondiimine **63** (64 mg, 0.18 mmol, 1.0 equiv.) was dissolved in anhydrous DMSO (0.40 mL). KOH (21 mg, 0.37 mmol, 2.0 equiv.) was added followed by allyl bromide (35 mg, 0.29 mmol, 1.5 equiv.). The reaction mixture was stirred at room temperature for 12 h until completion of the reaction (TLC). The reaction was quenched with water and extracted with CH_2Cl_2 (3 × 20 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1:1) to afford *sulfondiimine* **70** as a light-yellow oil (58 mg, 81%).

R_f 0.35 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.30 (d, *J* = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.18 (d, *J* = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.04-7.96 (m, 2H, Ar_F-*H*), 7.41-6.94 (m, 2H, Ar_F-*H*), 5.60 (ddt, *J* = 17.0, 10.3, 5.2 Hz, 1H, SCH_2CH=CH_2), 5.05 (dq, *J* = 17.0, 1.8 Hz, 1H, SCH_2CH=CH_aH_b), 4.97

(dq, J = 10.3, 1.8 Hz, 1H, $SCH_2CH{=}CH_aH_b$), 3.59 (s, 3H, SCH_3), 3.12 (ddt, J = 15.5, 5.2, 1.7 Hz, 1H, SCH_aH_b), 2.90 (ddt, J = 15.5, 5.2, 1.7 Hz, 1H, SCH_aH_b);

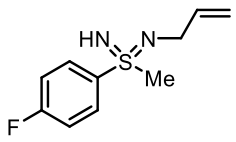
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.2 (d, $^1J_{CF}$ = 258.0 Hz), 149.7, 149.6, 135.5, 132.4 (d, $^4J_{CF}$ = 3.2 Hz), 131.3 (d, $^3J_{CF}$ = 9.7 Hz), 128.3, 124.1, 117.5 (d, $^2J_{CF}$ = 22.7 Hz), 115.6, 47.6, 46.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.7 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1390, 1153, 1084, 956;

HRMS (ESI^+) calcd. for $C_{16}H_{17}FN_3O_4S_2^+$ $[M+H]^+$: 398.0639; found: 398.0644.

***N*-Allyl-1-(4-fluorophenyl)-1-methyl-λ^6-sulfanediimine (71)**



Under an atmosphere of nitrogen, sulfondiimines **70** (45 mg, 0.11 mmol, 1.0 equiv.) was dissolved in anhydrous CH_3CN (1.1 ml). 1-Dodecanethiol (0.13 mL, 0.54 mmol, 5.0 equiv.) was added at room temperature followed by DBU (78 µL, 0.52 mmol, 4.75 equiv.). The solution became yellow and was stirred for 20 mins under nitrogen until completion of the reaction (TLC). The reaction mixture was concentrated *in vacuo* to afford light-yellow oil. The crude product was purified by flash column chromatography (CH_2Cl_2/MeOH, 15:1 to 9:1) to afford corresponding *sulfondiimine* **71** as a light-yellow oil (22 mg, 94%).

R_f 0.43 (CH_2Cl_2/MeOH = 9:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.16-8.01 (m, 2H, Ar_F-*H*), 7.23-7.17 (m, 2H, Ar_F-*H*), 5.96 (ddt, J = 17.0, 10.1, 5.6 Hz, 1H, $SCH_2CH{=}CH_2$), 5.25 (dq, J = 17.0, 1.8 Hz, 1H, $SCH_2CH{=}CH_aH_b$), 5.05 (dq, J = 10.1, 1.8 Hz, 1H, $SCH_2CH{=}CH_aH_b$), 3.68 (ddt, J = 15.2, 5.6, 1.6 Hz, 1H, SCH_aH_b), 3.53 (ddt, J = 15.2, 5.6, 1.6 Hz, 1H, SCH_aH_b), 3.12 (s, 3H, SCH_3), 2.25 (br. s, 1H, N*H*);

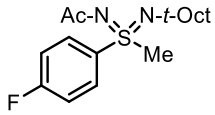
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.3 (d, $^1J_{CF}$ = 254.1 Hz), 138.5, 137.6 (d, $^4J_{CF}$ = 3.0 Hz), 130.6 (d, $^3J_{CF}$ = 9.3 Hz), 116.4 (d, $^2J_{CF}$ = 22.5 Hz), 114.8, 48.5, 45.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.7 (tt, J = 8.3, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1490, 1389, 1253, 1153, 1076, 956;

HRMS (ESI^+) calcd. for $C_{10}H_{14}FN_2S^+$ $[M+H]^+$: 213.0856; found: 213.0860.

***N*-((4-Fluorophenyl)(methyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)acetamide (72)**



Under an atmosphere of argon, sulfondiimine **62** (40 mg, 0.14 mmol, 1.0 equiv.) was dissolved in anhydrous CH_2Cl_2 (1.5 mL). Triethylamine (30 µL, 0.22 mmol, 1.5 equiv.) was added at 0°C followed by acetic anhydride (20 µL, 0.21 mmol, 1.5 equiv.) and DMAP (4.1 mg, 0.034 mmol, 0.25 equiv.). The reaction mixture was stirred at room temperature for 12 h. Sat. aq. NH_4Cl (30 mL) was added and the product was extracted with CH_2Cl_2 (3 x 10 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1.5:1) to afford *sulfondiimine* **72** as a white solid (45 mg, 99%).

mp 64-65 °C;

R_f 0.37 (petrol/ethyl acetate, 1.5:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.12-8.02 (m, 2H, Ar_F-*H*), 7.23-7.12 (m, 2H, Ar_F-*H*), 3.36 (s, 3H, SCH_3), 2.12 (s, 3H, s, 3H, $COCH_3$), 1.52 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.47 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.32 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.13 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.02 (s, 9H, *t*-Bu-*H*);

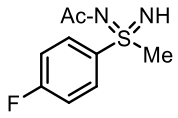
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 179.6, 166.0 (d, $^1J_{CF}$ = 251.7 Hz), 141.5 (d, $^4J_{CF}$ = 3.2 Hz), 131.6 (d, $^3J_{CF}$ = 9.1 Hz), 117.0 (d, $^2J_{CF}$ = 23.0 Hz), 59.6, 59.0, 47.9, 32.7, 32.6, 32.4, 32.2, 27.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.8 (tt, J = 8.1, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 1623, 1383, 1360, 1262, 1217, 1153, 1079, 1022, 969, 817;

HRMS (ESI^+) calcd. for $C_{17}H_{28}FN_2OS^+$ $[M+H]^+$: 327.1901; found: 327.1897.

***N*-((4-Fluorophenyl)(imino)(methyl)-λ^6-sulfaneylidene)acetamide (73)**



Sulfondiimine **72** (91 mg, 0.28 mmol, 1.0 equiv.) was mixed with TFA (2.8 mL) and stirred at room temperature for 14 h. The mixture was concentrated *in vacuo* then diluted with CH_2Cl_2 and basified to pH 10-11 using 1 M aq. NaOH solution. The product was extracted with CH_2Cl_2 (3 × 20 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (ethyl acetate, then CH_2Cl_2/MeOH, 5:1) to afford *sulfondiimine* **73** as a colourless oil (54 mg, 90%).

R$_f$ 0.28 (ethyl acetate);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.01-7.93 (m, 2H, Ar_F-*H*), 7.24-7.17 (m, 2H, Ar_F-*H*), 3.16 (s, 3H, SC*H*$_3$), 3.04 (br. s, 1H, N*H*), 2.07 (s, 3H, COC*H*$_3$);

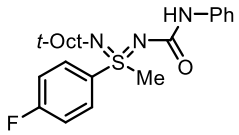
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 181.8, 165.6 (d, $^1J_{CF}$ = 255.6 Hz), 137.6 (d, $^4J_{CF}$ = 3.1 Hz), 129.7 (d, $^3J_{CF}$ = 9.4 Hz), 117.0 (d, $^2J_{CF}$ = 22.9 Hz), 45.1, 26.0;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.0 (tt, J = 8.0, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1587, 1490, 1365, 1281, 1233, 1157, 1083, 1047, 944, 818;

HRMS (ESI^+) calcd. for $C_9H_{12}FN_2OS^+$ $[M+H]^+$: 215.0649; found: 215.0648.

1-((4-Fluorophenyl)(methyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-3-phenylurea (74)



To a solution of sulfondiimine **62** (38 mg, 0.13 mmol, 1.0 equiv.) in anhydrous CH_2Cl_2 (1.3 mL), the phenyl isocyanate (26 mg, 0.22 mmol, 1.5 equiv.) was added dropwise at room temperature under argon atmosphere. The reaction was stirred at room temperature for 24 h until completion of the reaction (TLC). The reaction was quenched with water and extracted with CH_2Cl_2 (3 × 20 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) to afford *sulfondiimine* **74** as a white solid (53 mg, 98%).

mp 82-84 °C;

R$_f$ 0.56 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.15-8.08 (m, 2H, Ar_F-*H*), 7.48 (dd, *J* = 8.6, 1.2 Hz, 2H, Ph-*H*), 7.27 (dd, *J* = 8.5, 7.3 Hz, 2H, Ph-*H*), 7.24-7.18 (m, 2H, Ar_F-*H*), 6.99 (tt, *J* = 7.3, 1.2 Hz, 1H, Ph-*H*), 6.90 (br. s, 1H, N*H*), 3.43 (s, 3H, SCH_3), 1.56 (d, *J* = 14.3 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.51 (d, *J* = 14.3 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.37 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.17 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.04 (s, 9H, *t*-Bu-*H*);

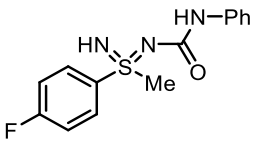
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.1 (d, $^1J_{CF}$ = 254.2 Hz), 159.2, 140.1 (d, $^4J_{CF}$ = 3.1 Hz), 139.9, 130. 2 (d, $^3J_{CF}$ = 9.4 Hz), 129.0, 122.5, 118.7, 116.4 (d, $^2J_{CF}$ = 22.8 Hz), 59.4, 58.2, 48.8, 32.1, 32.0, 31.92, 31.89;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.9. (tt, *J* = 8.5, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1650, 1506, 1389, 1217, 1153, 1088, 962, 836;

HRMS (ESI^+) calcd. for $C_{22}H_{31}FN_3OS^+$ $[M+H]^+$: 404.2166; found: 404.1273.

1-((4-Fluorophenyl)(imino)(methyl)-λ^6-sulfaneylidene)-3-phenylurea (75)



Sulfondiimine **74** (50 mg, 0.12 mmol, 1.0 equiv.) was mixed with TFA (1.2 mL) and stirred at room temperature for 3 days. The mixture was concentrated *in vacuo* then diluted with CH_2Cl_2 and basified to pH 10-11 using 1 M aq. NaOH solution. The product was extracted with CH_2Cl_2 (3 × 20 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (ethyl acetate) to afford *sulfondiimine* **75** as a light-yellow solid (31 mg, 86%).

mp 55-57 °C;

R$_f$ 0.41 (ethyl acetate);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.07-8.01 (m, 2H, Ar_F-*H*), 7.37 (dd, *J* = 8.6, 1.2 Hz, 2H, Ph-*H*), 7.26-7.18 (m, 4H, Ph-*H*/Ar_F-*H*), 7.01 (br. s, 1H, CON*H*), 7.00-6.96 (m, 1H, Ph-*H*), 3.24 (s, 3H, SCH_3), 2.87 (br. s, 1H, S=N*H*);

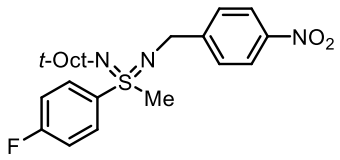
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.7 (d, $^1J_{CF}$ = 255.5 Hz), 160.3, 139.3, 138.3(d, $^4J_{CF}$ = 3.2 Hz), 130.0 (d, $^3J_{CF}$ = 9.5 Hz), 129.0, 122.8, 118.8, 117.0 (d, $^2J_{CF}$ = 22.7 Hz), 45.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.2 (tt, *J* = 8.3, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1591, 1535, 1491, 1438, 1389, 1317, 1236, 1154, 1075, 960, 832;

HRMS (ESI^+) calcd. for $C_{14}H_{15}FN_3OS^+$ $[M+H]^+$: 292.0914; found: 292.0915.

1-(4-Fluorophenyl)-1-methyl-*N*-(4-nitrobenzyl)-*N*-(2,4,4-trimethylpentan-2-yl)-λ^6-sulfanediimine (76)



Under an atmosphere of argon, sulfondiimine **62** (91 mg, 0.32 mmol, 1.0 equiv.) was dissolved in anhydrous 1,2-dichloroethane (1.5 mL). 4 Å Molecular sieves (0.1 g) were added followed by 4-nitrobenzaldehyde (71 mg, 0.47 mmol, 1.3 equiv.) and $NaBH(OAc)_3$ (199 mg, 0.940 mmol, 3.0 equiv.). The reaction mixture was stirred at 50 °C for 18 h. 1 M

aq. NaOH solution (30 mL) was added, the product was extracted with CH_2Cl_2 (3 x 30 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 4:1 to 1.5:1) to afford *sulfondiimine* **76** as a colourless oil (109 mg, 81%).

R_f 0.38 (petrol/ethyl acetate, 1.5:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.15 (d, J = 8.8 Hz, 2H, Ar-*H*), 8.08-8.01 (m, 2H, Ar_F-*H*), 7.55 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.19-7.10 (m, 2H, Ar_F-*H*), 4.33 (d, J = 16.2 Hz, 1H, NC*H*$_a$H$_b$), 4.08 (d, J = 16.2 Hz, 1H, NCH$_a$*H*$_b$), 3.15 (s, 3H, SC*H*$_3$), 1.57 (s, 2H, NC(CH$_3$)$_2$C*H*$_2$), 1.46 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.36 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.05 (s, 9H, *t*-Bu-*H*);

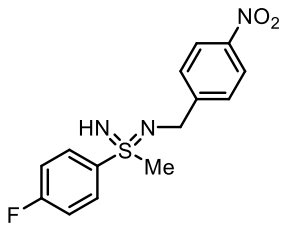
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.2 (d, $^1J_{CF}$ = 254.5 Hz), 149.1, 146.9, 137.1 (d, $^4J_{CF}$ = 2.6 Hz), 131.0 (d, $^3J_{CF}$ = 9.2 Hz), 128.3, 123.6, 116.5 (d, $^2J_{CF}$ = 22.4 Hz), 58.9, 58.5, 48.2, 46.2, 32.6, 32.3, 32.04, 32.01;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -108.2 (tt, J = 8.4, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1518, 1487, 1343, 1216, 1146, 1106, 839, 738;

HRMS (ESI$^+$) calcd. for $C_{22}H_{31}FN_3O_2S^+$ $[M+H]^+$: 420.2116; found: 420.2114.

1-(4-Fluorophenyl)-1-methyl-*N*-(4-nitrobenzyl)-λ^6-sulfanediimine (77)



Sulfondiimine **76** (45 mg, 0.11 mmol, 1.0 equiv.) was mixed with TFA (1.1 mL) and stir at room temperature for 6 h. The mixture was concentrated *in vacuo* then diluted with ethyl acetate and basified to pH 10-11 using 1 M aq. NaOH solution. The product was extracted with ethyl acetate (3 × 20 mL). The combined extracts were washed with brine, dried over

anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by flash column chromatography (CH_2Cl_2/MeOH, 20:1) to afford *sulfondiimine* **77** as a light-yellow solid (29 mg, 88%).

mp 131-133 °C;

R_f 0.36 (CH_2Cl_2/MeOH, 9:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.15 (d, J = 8.7 Hz, 2H, Ar-*H*), 8.13-8.08 (m, 2H, Ar_F-*H*), 7.55 (d, J = 8.7 Hz, 2H, Ar-*H*), 7.25-7.17 (m, 2H, Ar_F-*H*), 4.33 (d, J = 15.7 Hz, 1H, NC*H*$_a$H$_b$), 4.18 (d, J = 15.7 Hz, 1H, NCH$_a$*H*$_b$), 3.15 (s, 3H, SC*H*$_3$), 1.87 (br. s, 1H, N*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.4 (d, $^1J_{CF}$ = 254.8 Hz), 150.0, 146.8, 137.2 (d, $^4J_{CF}$ = 3.0 Hz), 130.6 (d, $^3J_{CF}$ = 9.4 Hz), 128.3, 123.7, 116.6 (d, $^2J_{CF}$ = 22.4 Hz), 48.6, 46.3;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.0 (tt, J = 8.2, 5.1 Hz);

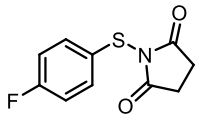
IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1516, 1344, 1153, 839;

HRMS (ESI^+) calcd. for $C_{14}H_{15}FN_3O_2S^+$ $[M+H]^+$: 308.0864; found: 308.0858.

6.3 Chapter 3 Data

6.3.1 Sulfinamidine Synthesis from Thiol

1-((4-Fluorophenyl)thio)pyrrolidine-2,5-dione (78)



To a solution of recrystallised NCS (3.31 g, 24.79 mmol, 1.24 equiv.) in dry CH_2Cl_2 (66.6 mL) in an oven-dried 250 mL round-bottom flask under nitrogen atmosphere was added 4-fluorothiophenol (2.13 mL, 20.00 mmol, 1.00 equiv.) at 0 °C. The mixture was stirred for 15 minutes turned bright yellow. Anhydrous triethylamine (3.46 mL, 24.79 mmol, 1.24 equiv.) was added dropwise at 0 °C. After stirring for 15 minutes at 0 °C the mixture was allowed to warm up to room temperature while stirring for 5 h. The reaction was quenched with sat. aq. NaCl solution (150 mL), extracted with CH_2Cl_2 (3 × 100 mL) and the combined organic layers were dried over $MgSO_4$ and concentrated. The crude residue was washed with cold Et_2O and dried under vacuum to afford the *sulfenamide* **78** as a white solid (3.78 g, 16.80 mmol, 84%).

mp 126-128 °C;

R$_f$ 0.50 (Petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.73-7.67 (m, 2H, Ar_F-*H*), 7.03-6.97 (m, 2H, Ar_F-*H*), 2.77 (s, 4H, COCH_2);

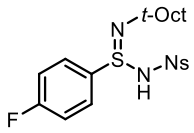
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 176.4, 164.1 (d, $^1J_{CF}$ = 252.1 Hz), 136.6 (d, $^3J_{CF}$ = 8.8 Hz), 129.2 (d, $^4J_{CF}$ = 3.5 Hz), 116.6 (d, $^2J_{CF}$ = 22.0 Hz), 28.6;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -108.7 (tt, J = 8.5, 5.3 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2160, 2030, 1714, 1585, 1486, 1305, 1221, 1146, 840, 817;

HRMS (ESI$^+$) calcd. for $C_{10}H_9FNO_2S^+$ $[M+H]^+$: 226.0333, found: 226.0336.

_N_-(_S_-(4-Fluorophenyl)-_N_-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (85)



To a suspension of sulfenamide **78** (1.35 g, 6.00 mmol, 1.00 equiv.) in Et_2O (20.0 mL) in an oven-dried 100 mL round-bottom flask was added *t*-octylamine (1.25 mL, 7.80 mmol, 1.30 equiv.) at room temperature. The mixture was stirred for 7 h and filtered. The residue was washed with Et_2O. The filtrate was washed with aqueous 1 M NaOH solution, dried over MgSO4 and concentrated under reduced pressure. The crude mixture was dissolved in anhydrous CH_2Cl_2 (20.0 mL) in an oven-dried 100 mL round-bottom flask before $Rh_2(esp)_2$ (22.7 mg, 0.03 mmol, 0.5 mol%) and PhI=NNs (2.55 g, 6.30 mmol, 1.05 equiv.) were added. The reaction was stirred at room temperature for 30 min until completion (judged by TLC). The mixture was concentrated under reduced pressure and purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 100:1 to 25:1 to 15:1) to afford *sulfinamidine* **85** as a white solid (2.53 g, 5.56 mmol, 93%).

mp 118-120 °C;

R$_f$ 0.57 (CH_2Cl_2/ethyl acetate, 15:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.21 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.96 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.67-7.47 (m, 2H, Ar_F-*H*), 7.19-6.89 (m, 2H, Ar_F-*H*), 4.48 (s, 1H, N*H*), 1.65 (d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.61 (d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.44 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.97 (s, 9H, *t*-Bu-*H*);

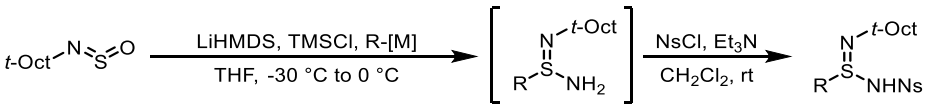
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.7 (d, $^1J_{CF}$ = 254.7 Hz), 150.2, 149.2, 133.5 (d, $^4J_{CF}$ = 3.1 Hz), 129.4 (d, $^3J_{CF}$ = 9.1 Hz), 127.3, 124.0, 116.8 (d, $^2J_{CF}$ = 22.9 Hz), 60.6, 55.6, 31.8, 31.7, 30.7, 29.1;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.7 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1490, 1349, 1290, 1145, 1088, 982, 618;

HRMS (ESI^+) calcd. for $C_{20}H_{27}FN_3O_4S_2^+$ $[M+H]^+$: 456.1422, found: 456.1421.

6.3.2 General Procedure F for Sulfinamidine Synthesis



t-Oct-NSO **25** (1.00 equiv.) was dissolved in anhydrous THF (0.5 M) in an oven-dried round-bottom flask and was purged with nitrogen gas. The mixture was cooled to -30 °C before LiHMDS solution (1.00 M in THF, 1.00 equiv.) was added. After being stirred at - 30 °C for 5 min, the reaction was warmed to 0 °C and stirred for another 5 min. TMSCl (1.00 equiv.) was added and the reaction was stirred at 0 °C for 10 min. Then the corresponding organometallic reagent (1.20 equiv.) was added. The reaction was stirred at 0 °C for 10 min before being quenched with sat. aq. tetrasodium EDTA solution. Ethyl acetate was added and the organic layer was separated. The aqueous layer was further extracted with ethyl acetate twice. The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude mixture was dissolved in anhydrous CH_2Cl_2 (0.2 M) in an oven-dried round-bottom flask. Then Et_3N (1.20 equiv.) and NsCl (1.10 equiv.) were added. The reaction was stirred at room temperature for 1 h. The reaction was then quenched with sat. aq. NaCl solution and extracted with CH_2Cl_2 three times. The combined organic layers were dried over anhydrous Na_2SO_4, filtered, concentrated under reduced pressure and purified by flash column chromatography to afford sulfinamidine.

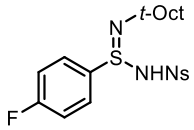
Notes:

1. *N*-*t*-oct primary sulfinamidines are sensitive to moisture and heat. For this reason, during the work-up stage volatiles were removed in a rotary evaporator with the bath temperature set to 30 °C or lower. In addition, *N*-*t*-oct primary sulfinamidines were not purified by flash column chromatography and instead were used as a crude

mixture immediately in the following nosylation step without further purification.

2. If the organometallic reagents were prepared at -78 °C, the *in-situ* generated sulfurdiimide reagent was added to the organometallic reagents at -78 °C. The reaction was then warmed to 0 °C and stirred at 0 °C for 10 min before being quenched with sat. aq. tetrasodium EDTA solution.

_N_-(_S_-(4-Fluorophenyl)-_N_-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (85)



t-Oct-NSO **25** (2.75 g, 15.68 mmol, 1.00 equiv.) was dissolved in anhydrous THF (31.4 mL) in an oven-dried 250 mL round-bottom flask and was purged with nitrogen gas. The mixture was cooled to -30 °C before LiHMDS solution (15.68 mL, 1.00 M in THF, 15.68 mmol, 1.00 equiv.) was added. After being stirred at - 30 °C for 5 min, the reaction was warmed to 0 °C and stirred for another 5 min. TMSCl (1.99 mL, 15.68 mmol, 1.00 equiv.) was added and the reaction was stirred at 0 °C for 10 min. 4-Fluorophenylmagnesium bromide solution (19.20 mL, 0.98 M in THF, 18.82 mmol, 1.20 equiv.) was then added and the reaction was stirred at 0 °C for 10 min. The reaction mixture was then quenched with sat. aq. tetrasodium EDTA solution (300 mL). Ethyl acetate (150 mL) was added and the organic layer was separated. The aqueous layer was further extracted with ethyl acetate (2 × 80 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude mixture was dissolved in anhydrous CH_2Cl_2 (78.0 mL) in an oven-dried 250 mL round-bottom flask before Et_3N (2.62 mL, 18.82 mmol, 1.20 equiv.) and NsCl (3.82 g, 17.25 mmol, 1.10 equiv.) were added. The reaction was stirred at room temperature for 1 h until completion (judged by TLC). The reaction was quenched with sat. aq. NaCl solution (250 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic

layers were dried over anhydrous Na_2SO_4, filtered, concentrated under reduced pressure and purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 30:1 to 20:1) to afford *sulfinamidine* **85** as a white solid (6.23 g, 13.69 mmol, 87%).

mp 118-120 °C;

R_f 0.57 (CH_2Cl_2/ethyl acetate, 15:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.21 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.96 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.67-7.47 (m, 2H, Ar_F-*H*), 7.19-6.89 (m, 2H, Ar_F-*H*), 4.48 (s, 1H, N*H*), 1.65 (d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.61 (d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.44 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.97 (s, 9H, *t*-Bu-*H*);

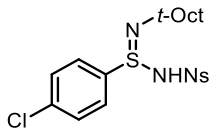
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.7 (d, $^1J_{CF}$ = 254.7 Hz), 150.2, 149.2, 133.5 (d, $^4J_{CF}$ = 3.1 Hz), 129.4 (d, $^3J_{CF}$ = 9.1 Hz), 127.3, 124.0, 116.8 (d, $^2J_{CF}$ = 22.9 Hz), 60.6, 55.6, 31.8, 31.7, 30.7, 29.1;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.7 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1490, 1349, 1290, 1145, 1088, 982, 618;

HRMS (ESI^+) calcd. for $C_{20}H_{27}FN_3O_4S_2^+$ $[M+H]^+$: 456.1422, found: 456.1421.

***N*-(S-(4-Chlorophenyl)-*N*-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (86)**



Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.27 g, 7.23 mmol, 1.00 equiv.), THF (14.5 mL), LiHMDS solution (7.23 mL, 1.00 M in THF, 7.23 mmol, 1.00 equiv.), TMSCl (0.92 mL, 7.23 mmol, 1.00 equiv.), 4-chlorophenylmagnesium bromide solution (9.85 mL, 0.88 M in 2-methyltetrahydrofuran, 8.67 mmol, 1.20 equiv.), CH_2Cl_2 (36.0 mL), Et_3N (1.21 mL, 8.68 mmol, 1.20 equiv.) and NsCl (1.76 g, 7.95 mmol, 1.10

equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 50:1 to 30:1 to 20:1) afforded *sulfinamidine* **86** as a white solid (3.01 g, 6.39 mmol, 88%).

mp 110-112 °C;

R$_f$ 0.40 (petrol/ethyl acetate, 2:1);

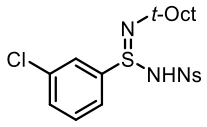
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.23 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.96 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.54 (d, J = 8.8 Hz, 2H, Ar_{Cl}-*H*), 7.39 (d, J = 8.8 Hz, 2H, Ar_{Cl}-*H*), 4.49 (s, 1H, N*H*), 1.67 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.63 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.51 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.47 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.99 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.2, 149.2, 138.7, 136.6, 129.8, 128.4, 127.3, 124.1, 60.7, 55.7, 31.81, 31.75, 30.7, 29.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1349, 1290, 1145, 1088, 982, 745, 620;

HRMS (ESI$^+$) calcd. for $C_{20}H_{27}ClN_3O_4S_2^+$ $[M+H]^+$: 472.1126, found: 472.1125.

***N*-(*S*-(3-Chlorophenyl)-*N*-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (87)**



Preparation of Grignard reagent

3-Chlorophenylmagnesium chloride lithium chloride complex solution was prepared according to the following procedure. To a solution of 1-bromo-3-chlorobenzene (1.61 g, 8.40 mmol, 1.20 equiv.) in anhydrous THF (8.4 mL) in an oven-dried 100 mL round-bottom flask was added isopropylmagnesium chloride lithium chloride complex solution (Turbo Grignard Reagent, 6.72 mL, 1.25 M in THF, 8.40 mmol, 1.20 equiv.) dropwise at 0 °C. The reaction was stirred at the same temperature for 3.5 h.

Preparation of sulfinamidine

Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.23 g, 7.00 mmol, 1.00 equiv.), THF (14.0 mL), LiHMDS solution (7.00 mL, 1.00 M in THF, 7.00 mmol, 1.00 equiv.), TMSCl (0.89 mL, 7.00 mmol, 1.00 equiv.), 3-chlorophenyl magnesium chloride lithium chloride complex solution (8.40 mmol, 1.20 equiv.), CH_2Cl_2 (35.0 mL), Et_3N (1.17 mL, 8.40 mmol, 1.20 equiv.) and NsCl (1.71 g, 7.70 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 50:1 to 30:1) afforded *sulfinamidine* **87** as a white solid (2.15 g, 4.56 mmol, 65%).

mp 104-106 °C;

R$_f$ 0.45 (CH_2Cl_2/ethyl acetate, 20:1);

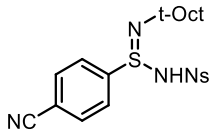
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.23 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.94 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.52-7.47 (m, 2H, Ar_{Cl}-*H*), 7.46-7.41 (m, 1H, Ar_{Cl}-*H*), 7.40-7.34 (m, 1H, Ar_{Cl}-*H*), 4.59 (s, 1H, N*H*), 1.71 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.66 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.53 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.51 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.02 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.1, 149.3, 139.8, 135.8, 132.1, 130.7, 127.3, 127.2, 125.3, 124.1, 60.9, 55.7, 31.9, 31.8, 30.9, 29.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1462, 1383, 1349, 1290, 1251, 1147, 1087, 957, 855, 732, 678;

HRMS (ESI$^+$) calcd. for $C_{20}H_{27}ClN_3O_4S_2^+$ $[M+H]^+$: 472.1126, found: 472.1125.

_N_-(_S_-(4-Cyanophenyl)-_N_-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (88)



Preparation of Grignard reagent

4-Cyanophenylmagnesium chloride lithium chloride complex solution was prepared according to the following procedure. To a solution of 4-bromobenzonitrile (1.53 g, 8.40 mmol, 1.20 equiv.) in anhydrous THF (8.4 mL) in an oven-dried 100 mL round-bottom

flask was added isopropylmagnesium chloride lithium chloride complex solution (Turbo Grignard Reagent, 6.89 mL, 1.22 M in THF, 8.40 mmol, 1.20 equiv.) dropwise at 0 °C. The reaction was stirred at room temperature for 1.5 h.

Preparation of sulfinamidine

Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.23 g, 7.00 mmol, 1.00 equiv.), THF (14.0 mL), LiHMDS solution (7.00 mL, 1.00 M in THF, 7.00 mmol, 1.00 equiv.), TMSCl (0.89 mL, 7.00 mmol, 1.0 equiv.), 4-cyanophenyl magnesium chloride lithium chloride complex solution (8.40 mmol, 1.20 equiv.), CH_2Cl_2 (35.0 mL), Et_3N (1.17 mL, 8.40 mmol, 1.20 equiv.) and NsCl (1.71 g, 7.70 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 25:1 to 15:1 to 10:1) afforded *sulfinamidine* **88** as a white solid (2.16 g, 4.68 mmol, 67%).

mp 126-128 °C;

R$_f$ 0.34 (CH_2Cl_2/ethyl acetate, 15:1);

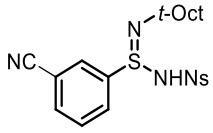
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.27 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.02 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.82 (d, J = 8.8 Hz, 2H, Ar_{CN}-*H*), 7.76 (d, J = 8.8 Hz, 2H, Ar_{CN}-*H*), 4.54 (s, 1H, N*H*), 1.68 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.64 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.51 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.46 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.00 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.9, 149.5, 143.7, 133.2, 128.0, 127.4, 124.2, 117.2, 116.0, 61.1, 55.8, 31.9, 31.8, 30.7, 29.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1349, 1289, 1144, 1087, 982, 855, 732, 618;

HRMS (ESI$^+$) calcd. for $C_{21}H_{27}N_4O_4S_2^+$ $[M+H]^+$: 463.1468, found: 463.1462.

_N_-(_S_-(3-Cyanophenyl)-_N_-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (89)



Preparation of Grignard reagent

3-Cyanophenylmagnesium chloride lithium chloride complex solution was prepared according to the following procedure. To a solution of 3-bromobenzonitrile (1.53 g, 8.40 mmol, 1.20 equiv.) in anhydrous THF (8.4 mL) in an oven-dried 100 mL round-bottom flask was added isopropylmagnesium chloride lithium chloride complex solution (Turbo Grignard Reagent) (6.83 mL, 1.23 M in THF, 8.40 mmol, 1.20 equiv.) dropwise at 0 °C. The reaction was stirred at room temperature for 2.5 h.

Preparation of sulfinamidine

Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.23 g, 7.00 mmol, 1.00 equiv.), THF (14.0 mL), LiHMDS solution (7.00 mL, 1.00 M in THF, 7.00 mmol, 1.00 equiv.), TMSCl (0.89 mL, 7.00 mmol, 1.00 equiv.), 3-cyanophenyl magnesium chloride lithium chloride complex solution (8.40 mmol, 1.20 equiv.), CH_2Cl_2 (35.0 mL), Et_3N (1.17 mL, 8.40 mmol, 1.20 equiv.) and NsCl (1.71 g, 7.70 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 25:1 to 15:1 to 10:1) afforded *sulfinamidine* **89** as a white solid (2.86 g, 6.19 mmol, 88%).

mp 102-104 °C;

R$_f$ 0.57 (CH_2Cl_2/ethyl acetate, 15:1);

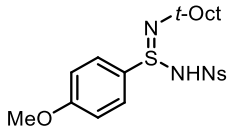
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.27 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.00 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.93-7.87 (m, 2H, Ar_{CN}-*H*), 7.78 (dt, J = 7.7, 1.3 Hz, 1H, Ar_{CN}-*H*), 7.60 (td, J = 7.7, 0.7 Hz, 1H, Ar_{CN}-*H*), 4.66 (s, 1H, N*H*), 1.69 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.65 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.51 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.47 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.01 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.9, 149.5, 140.6, 135.2, 131.4, 130.8, 130.5, 127.4, 124.2, 117.1, 114.2, 61.1, 55.7, 31.9, 31.8, 30.6, 29.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1349, 1291, 1145, 1087, 981, 855, 732, 684, 619;

HRMS (ESI$^+$) calcd. for $C_{21}H_{27}N_4O_4S_2^+$ [M+H]$^+$: 463.1468, found: 463.1463.

***N*-(*S*-(4-Methoxyphenyl)-*N*-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (90)**



Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.26 g, 7.17 mmol, 1.00 equiv.), THF (14.3 mL), LiHMDS solution (7.17 mL, 1.00 M in THF, 7.23 mmol, 1.00 equiv.), TMSCl (0.91 mL, 7.17 mmol, 1.00 equiv.), 4-methoxyphenylmagnesium bromide solution (17.20 mL, 0.50 M in THF, 8.60 mmol, 1.20 equiv.), CH_2Cl_2 (35.9 mL), Et_3N (1.20 mL, 8.60 mmol, 1.20 equiv.) and NsCl (1.75 g, 7.89 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 30:1 to 20:1 to 10:1) afforded *sulfinamidine* **90** as a white solid (2.54 g, 5.44 mmol, 76%).

mp 108-110 °C;

R$_f$ 0.2 (petrol/ethyl acetate, 2:1);

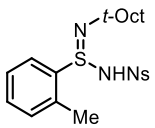
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.19 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.94 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.48 (d, J = 9.0 Hz, 2H, Ar_{OMe}-*H*), 6.88 (d, J = 9.0 Hz, 2H, Ar_{OMe}-*H*), 4.35 (s, 1H, N*H*), 3.80 (s, 3H, OCH_3), 1.68 (d, J = 15.0 Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.63 (d, J = 15.0 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.52 (s, 3H, NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.49 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 1.00 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 162.5, 150.5, 149.1, 128.7, 128.5, 127.3, 124.0, 114.9, 60.4, 55.8, 55.7, 31.83, 31.79, 30.9, 29.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1494, 1348, 1287, 1257, 1143, 1085, 1017, 980, 731, 616;

HRMS (ESI$^+$) calcd. for $C_{21}H_{30}N_3O_5S_2^+$ [M+H]$^+$: 468.1621, found: 468.1620.

4-Nitro-*N*-((*o*-tolyl)-*N*-(2,4,4-trimethylpentan)sulfinimidoyl)benzenesulfonamide (91)



Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.23 g, 7.00 mmol, 1.00 equiv.), THF (14.0 mL), LiHMDS solution (7.00 mL, 1.00 M in THF, 7.00 mmol, 1.00 equiv.), TMSCl (0.89 mL, 7.00 mmol, 1.00 equiv.), 2-methylphenylmagnesium bromide solution (13.10 mL, 0.64 M in THF, 8.40 mmol, 1.20 equiv.), CH_2Cl_2 (14.0 mL), Et_3N (1.95 mL, 14.00 mmol, 2.00 equiv.) and NsCl (2.33 g, 10.50 mmol, 1.50 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 60:1 to 30:1 to 20:1) afforded *sulfinamidine* **91** as a white solid (2.58 g, 5.72 mmol, 82%).

mp 110-112 °C;

R_f 0.36 (CH_2Cl_2/ethyl acetate, 30:1);

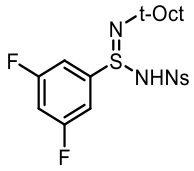
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.08 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.94 (dd, J = 7.4, 1.9 Hz, 1H, Tol-*H*), 7.75 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.38-7.29 (m, 2H, Tol-*H*), 7.09-7.05 (m, 1H, Tol-*H*), 4.49 (s, 1H, N*H*), 2.36 (s, 3H, Tol-CH_3), 1.70 (d, J = 14.9 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.65 (d, J = 14.9 Hz, 1H, NC$(CH_3)_2$C$H_a$$H_b$), 1.57 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.51 (s, 3H, NC$(CH_3)_a$$(CH_3)_b$), 0.99 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.1, 148.9, 136.6, 136.2, 132.3, 131.6, 127.2, 127.1, 125.6, 123.7, 60.8, 55.7, 31.82, 31.75, 30.5, 29.2, 19.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1348, 1286, 1143, 1088, 968, 731, 616;

HRMS (ESI$^+$) calcd. for $C_{21}H_{30}N_3O_4S_2^+$ $[M+H]^+$: 452.1672, found: 452.1669.

***N*-(*S*-(3,5-Difluorophenyl)-*N*-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (92)**



Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.02 g, 5.82 mmol, 1.00 equiv.), THF (11.6 mL), LiHMDS solution (5.82 mL, 1.00 M in THF, 5.82 mmol, 1.00 equiv.), TMSCl (0.74 mL, 5.82 mmol, 1.00 equiv.), 3,5-difluorophenylmagnesium bromide

solution (29.10 mL, 0.24 M in THF, 6.98 mmol, 1.20 equiv.), CH_2Cl_2 (29.1 mL), Et_3N (0.97 mL, 6.98 mmol, 1.20 equiv.) and NsCl (1.42 g, 6.40 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 50:1 to 25:1) afforded *sulfinamidine* **92** as a white solid (2.36 g, 4.99 mmol, 86%).

mp 110-112 °C;

R$_f$ 0.50 (CH_2Cl_2/ethyl acetate, 25:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.26 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.99 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.17-7.12 (m, 2H, Ar_F-*H*), 6.92 (tt, J = 8.3, 2.3 Hz, 1H, Ar_F-*H*), 4.68 (s, 1H, N*H*), 1.69 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.65 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.50 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.47 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.01 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 163.0 (dd, J = 255.2, 11.8 Hz), 149.9, 149.4, 142.2 (t, J = 8.5 Hz), 127.4, 124.2, 111.8-110.2 (second-order multiplet), 107.6 (t, J = 25.1 Hz), 61.1, 55.7, 31.83, 31.75, 30.6, 29.3;

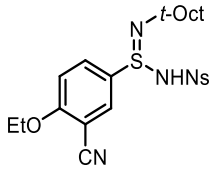
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.7 – -104.8 (second-order multiplet);

The second-order multiplet in the ^{13}C and ^{19}F NMR spectra arise due to virtual coupling;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1600, 1528, 1437, 1349, 1291, 1146, 1125, 1088, 990, 855, 731, 619;

HRMS (ESI^+) calcd. for $C_{20}H_{26}F_2N_3O_4S_2^+$ $[M+H]^+$: 474.1327, found: 474.1319.

_N_-(_S_-(3-Cyano-4-ethoxyphenyl)-_N_-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (93)



Preparation of organometallic reagent

(3-Cyano-4-ethoxyphenyl)lithium solution was prepared according to the following procedure. To a solution of 5-bromo-2-ethoxybenzonitrile (9.08 g, 40.30 mmol, 1.50 equiv.)

in anhydrous THF (40.3 mL) in an oven-dried 250 mL round-bottom flask was added *n*-butyllithium solution (16.67 mL, 2.42 M in hexanes, 40.30 mmol, 1.50 equiv.) dropwise at -78 °C. The reaction was stirred at the same temperature for 20 min.

Preparation of sulfinamidine

Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (4.73 g, 27.00 mmol, 1.00 equiv.), THF (27.0 mL), LiHMDS solution (27.00 mL, 1.00 M in THF, 27.00 mmol, 1.00 equiv.), TMSCl (3.43 mL, 27.00 mmol, 1.00 equiv.), (3-cyano-4-ethoxyphenyl)lithium solution (40.30 mmol, 1.50 equiv.), CH_2Cl_2 (135.0 mL), Et_3N (6.02 mL, 43.20 mmol, 1.60 equiv.) and NsCl (8.98 g, 40.50 mmol, 1.50 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 20:1 to 10:1) afforded *sulfinamidine* **93** as a white solid (7.11 g, 14.05 mmol, 52%).

mp 128-130 °C;

R$_f$ 0.50 (CH_2Cl_2/ethyl acetate, 9:1);

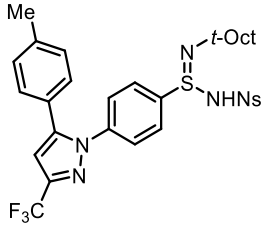
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.99 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.78-7.73 (m, 2H, Ar_{CN}-*H*), 6.99 (d, J = 8.9 Hz, 1H, Ar_{CN}-*H*), 4.54 (s, 1H, N*H*), 4.18 (qd, J = 7.0, 1.0 Hz, 2H, OC*H*$_2$), 1.67 (d, J = 15.0 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.63 (d, J = 15.0 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.50 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.49 (t, J = 7.0 Hz, 3H, OCH$_2$C*H*$_3$), 1.46 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.00 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 163.1, 150.1, 149.4, 133.2, 132.8, 129.9, 127.4, 124.2, 114.8, 113.0, 103.6, 65.9, 60.8, 55.7, 31.84, 31.76, 30.7, 29.4, 14.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1473, 1383, 1349, 1286, 1252, 1147, 1087, 956;

HRMS (ESI$^+$) calcd. for $C_{23}H_{31}N_4O_5S_2^+$ [M+H]$^+$: 507.1730, found: 507.1729.

4-Nitro-*N*-(*S*-(4-(5-(p-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)-*N*-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)benzenesulfonamide (94)



Preparation of organometallic reagent

(4-(5-(*p*-Tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)lithium solution was prepared according to the following procedure. To a solution of 1-(4-bromophenyl)-5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazole (2.42 g, 6.37 mmol, 1.20 equiv.) in anhydrous THF (12.7 mL) in an oven-dried 100 mL round-bottom flask was added *n*-butyllithium solution (2.55 mL, 2.50 M in hexanes, 6.37 mmol, 1.20 equiv.) dropwise at -78 °C. The reaction was stirred at the same temperature for 40 min.

Preparation of sulfinamidine

Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (0.91 g, 5.22 mmol, 1.00 equiv.), THF (10.4 mL), LiHMDS solution (5.22 mL, 1.00 M in THF, 5.22 mmol, 1.00 equiv.), TMSCl (0.66 mL, 5.22 mmol, 1.00 equiv.), (4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)lithium solution (6.37 mmol, 1.20 equiv.), CH_2Cl_2 (26.1 mL), Et_3N (0.89 mL, 6.37 mmol, 1.20 equiv.) and NsCl (1.27 g, 5.74 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 50:1 to 30:1 to 20:1) afforded *sulfinamidine* **94** as a white solid (3.28 g, 4.96 mmol, 95%).

mp 95-97 °C;

R$_f$ 0.45 (CH_2Cl_2/ethyl acetate, 30:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.22 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.99 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.61 (d, *J* = 8.9 Hz, 2H, Ar-*H*), 7.40 (d, *J* = 8.9 Hz, 2H, Ar-*H*), 7.15 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 7.07 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 6.71 (s, 1H, HetAr-*H*), 4.46 (s, 1H,

N*H*), 2.37 (s, 3H, Tol-C*H*$_3$), 1.66 (d, *J* = 15.0 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.62 (d, *J* = 15.0 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.50 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.44 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 0.98 (s, 9H, *t*-Bu-*H*);

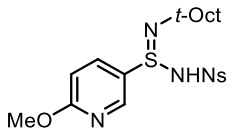
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.1, 149.3, 145.3, 144.2 (q, $^2J_{CF}$ = 38.5 Hz), 142.2, 140.0, 137.7, 129.8, 128.8, 128.0, 127.4, 125.78, 125.75, 124.1, 121.10 (q, $^1J_{CF}$ = 269.3 Hz), 106.5, 60.8, 55.8, 31.8, 31.7, 30.7, 29.2, 21.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -62.4 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1236, 1139, 1088, 969, 855, 732, 614;

HRMS (ESI$^+$) calcd. for $C_{31}H_{35}F_3N_5O_4S_2^+$ $[M+H]^+$: 662.2077, found: 662.2071.

***N*-(6-Methoxy-*N*-(2,4,4-trimethylpentan-2-yl)pyridine-3-sulfinimidoyl)-4-nitrobenzenesulfonamide (95)**



Preparation of organometallic reagent

(6-Methoxypyridin-3-yl)lithium solution was prepared according to the following procedure. To a solution of 5-bromo-2-methoxypyridine (1.74 g, 9.25 mmol, 1.20 equiv.) in anhydrous THF (18.5 mL) in an oven-dried 100 mL round-bottom flask was added *n*-butyllithium solution (3.70 mL, 2.50 M in hexanes, 9.25 mmol, 1.20 equiv.) dropwise at -78 °C. The reaction was stirred at the same temperature for 40 min.

Preparation of sulfinamidine

Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.35 g, 7.71 mmol, 1.00 equiv.), THF (15.4 mL), LiHMDS solution (7.71 mL, 1.00 M in THF, 7.71 mmol, 1.00 equiv.), TMSCl (0.98 mL, 7.71 mmol, 1.00 equiv.), (6-methoxypyridin-3-yl)lithium solution (9.25 mmol, 1.20 equiv.), CH_2Cl_2 (38.5 mL), Et_3N (1.29 mL, 9.25 mmol, 1.20 equiv.) and NsCl (1.88 g, 8.47 mmol, 1.10 equiv.). Purification by flash column chromatography

(CH_2Cl_2/ethyl acetate, 25:1 to 15:1 to 5:1) afforded *sulfinamidine* **95** as a white solid (2.89 g, 6.18 mmol, 80%).

mp 120-122 °C;

R_f 0.38 (CH_2Cl_2/ethyl acetate, 10:1);

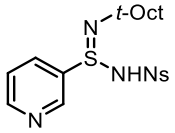
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.28 (dd, *J* = 2.7, 0.7 Hz, 1H, HetAr-*H*), 8.21 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.94 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.71 (dd, *J* = 8.9, 2.7 Hz, 1H, HetAr-*H*), 6.73 (dd, *J* = 8.9, 0.7 Hz, 1H, HetAr-*H*), 4.60 (s, 1H, N*H*), 3.91 (s, 3H, OCH_3), 1.66 (d, *J* = 15.0 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.64 (d, *J* = 15.0 Hz, 1H, NC$(CH_3)_2$C$H_a$$H_b$), 1.51 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.48 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.00 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.3, 150.2, 149.2, 146.7, 137.0, 127.3, 126.7, 124.1, 112.0, 60.7, 55.6, 54.4, 31.82, 31.76, 30.7, 29.3;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1527, 1478, 1371, 1349, 1285, 1145, 1087, 1015, 979, 732, 619;

HRMS (ESI^+) calcd. for $C_{20}H_{29}N_4O_5S_2^+$ $[M+H]^+$: 469.1574, found: 469.1570.

4-Nitro-*N*-(*N*-(2,4,4-trimethylpentan-2-yl)pyridine-3-sulfinimidoyl)benzenesulfonamide (96)



Preparation of Grignard reagent

3-Pyridylmagnesium chloride lithium chloride complex solution was prepared according to the following procedure. To a solution of 3-bromopyridine (1.32 g, 8.40 mmol, 1.20 equiv.) in anhydrous THF (8.4 mL) in an oven-dried 100 mL round-bottom flask was added isopropyl magnesium chloride lithium chloride complex solution (Turbo Grignard Reagent, 6.83 mL, 1.23 M in THF, 8.40 mmol, 1.20 equiv.) dropwise at 0 °C. The reaction was stirred

at 0 °C for 1 h. Then the mixture was warmed to room temperature and stirred for another 0.5 h.

Preparation of sulfinamidine

Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.23 g, 7.00 mmol, 1.00 equiv.), THF (14.0 mL), LiHMDS solution (7.00 mL, 1.00 M in THF, 7.00 mmol, 1.00 equiv.), TMSCl (0.89 mL, 7.00 mmol, 1.0 equiv.), 3-pyridylmagnesium chloride lithium chloride complex solution (8.40 mmol, 1.20 equiv.), CH_2Cl_2 (35.0 mL), Et_3N (1.17 mL, 8.40 mmol, 1.20 equiv.) and NsCl (1.71 g, 7.70 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 5:1 to 1:1 to 1:2) afforded *sulfinamidine* **96** as a white solid (2.31 g, 5.27 mmol, 75%).

mp 114-116 °C;

R$_f$ 0.26 (CH_2Cl_2/ethyl acetate, 1:1);

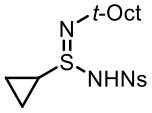
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.76 (s, 1H, HetAr-*H*), 8.67 (d, *J* = 4.8 Hz, 1H, HetAr-*H*), 8.23 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.98 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.97-7.93 (m, 1H, HetAr-*H*), 7.38 (dd, *J* = 8.3, 4.8 Hz, 1H, HetAr-*H*), 4.82 (s, 1H, N*H*), 1.70 (d, *J* = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.65 (d, *J* = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.52 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.00 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 152.4, 149.9, 149.3, 148.1, 135.3, 135.1, 127.3, 124.2, 124.1, 61.0, 55.6, 31.8, 31.7, 30.7, 29.3;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1349, 1289, 1145, 1087, 974, 731, 616;

HRMS (ESI^+) calcd. for $C_{19}H_{27}N_4O_4S_2^+$ $[M+H]^+$: 439.1368, found: 439.1469.

_N_-(_S_-Cyclopropyl-_N_-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (97)



Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.21 g, 6.91 mmol, 1.00 equiv.), THF (13.8 mL), LiHMDS solution (6.91 mL, 1.00 M in THF, 6.91 mmol, 1.00 equiv.), TMSCl (0.88 mL, 6.91 mmol, 1.00 equiv.), cyclopropylmagnesium bromide solution (9.87 mL, 0.84 M in 2-methyltetrahydrofuran, 8.29 mmol, 1.20 equiv.), CH_2Cl_2 (34.5 mL), Et_3N (1.16 mL, 8.29 mmol, 1.20 equiv.) and NsCl (1.68 g, 7.59 mmol, 1.10 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfinamidine* **97** as a white solid (2.32 g, 5.79 mmol, 84%).

mp 122-124 °C;

R$_f$ 0.44 (petrol/ethyl acetate, 1:1);

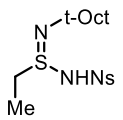
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.27 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.03 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 4.10 (s, 1H, N*H*), 2.50 (tt, J = 7.8, 4.7 Hz, 1H, SC*H*), 1.57 (d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.52 (d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.39 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.35 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.28-1.20 (m, 1H, $SCHCH_aH_b$), 0.98 (s, 9H, *t*-Bu-*H*), 0.92-0.77 (m, 2H, $SCHCH_2$), 0.63-0.55 (m, 1H, $SCHCH_aH_b$);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.8, 149.2, 127.4, 124.1, 59.6, 55.4, 31.9, 31.7, 31.1, 30.9, 28.9, 4.6, 1.7 (Note: For 2 secondary carbons in cyclopropane ring, 2 peaks were found instead of 1 due to the loss of symmetry caused by chiral sulfur atom);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1349, 1285, 1142, 1089, 981, 855, 731, 616;

HRMS (ESI$^+$) calcd. for $C_{17}H_{28}N_3O_4S_2^+$ $[M+H]^+$: 402.1516, found: 402.1514.

***N*-(*S*-Ethyl-*N*-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (98)**



Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.33 g, 7.62 mmol, 1.00 equiv.), THF (15.2 mL), LiHMDS solution (7.62 mL, 1.00 M in THF, 7.62 mmol, 1.00

equiv.), TMSCl (0.97 mL, 7.62 mmol, 1.00 equiv.), ethylmagnesium bromide solution (9.62 mL, 0.95 M in THF, 9.14 mmol, 1.20 equiv.), CH_2Cl_2 (38.1 mL), Et_3N (1.28 mL, 9.14 mmol, 1.20 equiv.) and NsCl (1.86 g, 8.38 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 20:1 to 10:1 to 5:1) afforded *sulfinamidine* **98** as a white solid (1.80 g, 4.63 mmol, 61%).

mp 122-124 °C;

R$_f$ 0.50 (CH_2Cl_2/ethyl acetate, 4:1);

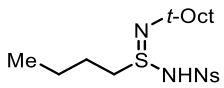
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.27 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 4.41 (s, 1H, N*H*), 3.15 (q, J = 7.4 Hz, 2H, SC*H*$_2$), 1.58 (d, J = 14.9 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.53 (d, J = 14.9 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.39 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.36 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.15 (t, J = 7.4 Hz, 3H, SCH$_2$C*H*$_3$), 0.97 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.7, 149.3, 127.3, 124.1, 59.8, 55.6, 48.8, 31.8, 31.7, 31.0, 28.8, 8.8;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1527, 1349, 1285, 1142, 1089, 979, 855, 744, 615;

HRMS (ESI$^+$) calcd. for $C_{16}H_{28}N_3O_4S_2^+$ [M+H]$^+$: 390.1516, found: 390.1518.

***N*-(*S*-Butyl-*N*-(2,4,4-trimethylpentan-2-yl)sulfinimidoyl)-4-nitrobenzenesulfonamide (99)**



Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.23 g, 7.00 mmol, 1.00 equiv.), THF (14.0 mL), LiHMDS solution (7.00 mL, 1.00 M in THF, 7.00 mmol, 1.00 equiv.), TMSCl (0.89 mL, 7.00 mmol, 1.00 equiv.), butylmagnesium chloride solution (4.29 mL, 1.96 M in THF, 8.40 mmol, 1.20 equiv.), CH_2Cl_2 (35.0 mL), Et_3N (1.17 mL, 8.40 mmol, 1.20 equiv.) and NsCl (1.71 g, 7.70 mmol, 1.10 equiv.). Purification by flash column

chromatography (CH_2Cl_2/ethyl acetate, 25:1 to 10:1) afforded *sulfinamidine* **99** as a white solid (2.11 g, 5.06 mmol, 72%).

mp 122-124 °C;

R_f 0.46 (CH_2Cl_2/ethyl acetate, 9:1);

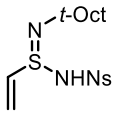
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.28 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 4.33 (s, 1H, N*H*), 3.19-3.07 (m, 2H, SC*H*$_2$), 1.58 (d, *J* = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.53 (d, *J* = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.53-1.45 (m, 2H, SCH_2CH_2), 1.39 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.37 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.36-1.29 (m, 2H, $SCH_2CH_2CH_2$), 0.98 (s, 9H, *t*-Bu-*H*), 0.82 (t, *J* = 7.3 Hz, 3H, *n*-Bu-C*H*$_3$);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.8, 149.3, 127.3, 124.1, 59.9, 55.7, 54.6, 31.8, 31.7, 31.0, 28.9, 25.9, 21.4, 13.6;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1524, 1346, 1290, 1145, 1088, 955, 919, 854, 770;

HRMS (ESI^+) calcd. for $C_{18}H_{31}N_3O_4S_2Na^+$ $[M+Na]^+$: 440.1648, found: 440.1649.

4-Nitro-*N*-(*N*-(2,4,4-trimethylpentan-2-yl)-*S*-vinylsulfinimidoyl)benzenesulfonamide (100)



Prepared according to **General Procedure F** using *t*-Oct-NSO **25** (1.31 g, 7.50 mmol, 1.00 equiv.), THF (15.0 mL), LiHMDS solution (7.50 mL, 1.00 M in THF, 7.50 mmol, 1.00 equiv.), TMSCl (0.95 mL, 7.50 mmol, 1.00 equiv.), vinylmagnesium bromide solution (10.10 mL, 0.89 M in THF, 9.00 mmol, 1.20 equiv.), CH_2Cl_2 (37.5 mL), Et_3N (1.25 mL, 9.00 mmol, 1.20 equiv.) and NsCl (1.83 g, 8.25 mmol, 1.10 equiv.). Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 20:1 to 10:1 to 5:1) afforded *sulfinamidine* **100** as a white solid (2.04 g, 5.27 mmol, 70%).

mp 92-94 °C;

R$_f$ 0.30 (CH_2Cl_2/ethyl acetate, 10:1);

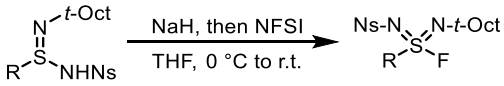
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.27 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.03 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 6.50 (dd, J = 16.0, 9.2 Hz, 1H, SC*H*), 5.99 (dd, J = 16.0, 1.4 Hz, 1H, SCH=CH_aH_b), 5.90 (dd, J = 9.2, 1.4 Hz, 1H, SCH=CH_aH_b), 4.31 (s, 1H, N*H*), 1.62 (d, J = 15.0 Hz, 1H, NC$(CH_3)_2$CH_aH_b), 1.54 (d, J = 15.0 Hz, 1H, NC$(CH_3)_2$CH_aH_b), 1.43 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.39 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 0.98 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.4, 149.3, 135.3, 127.3, 125.8, 124.1, 60.1, 55.3, 31.8, 31.7, 31.0, 29.1;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1349, 1287, 1143, 1088, 979, 855, 618;

HRMS (ESI^+) calcd. for $C_{16}H_{26}N_3O_4S_2^+$ $[M+H]^+$: 388.1359, found: 388.1361.

6.3.3 General Procedure G for Sulfondiimidoyl Fluoride Synthesis

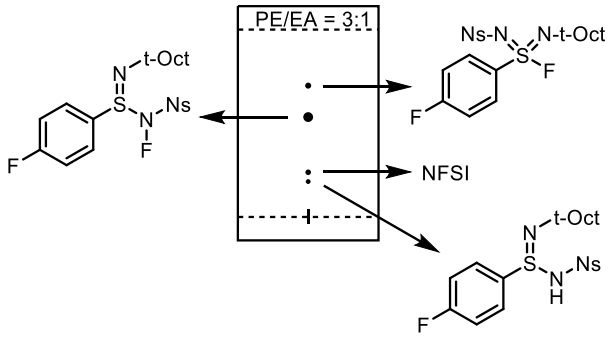


An oven-dried round-bottom flask was charged with sulfinamidine (1.00 equiv.) and NaH (60 % dispersion in mineral oil, 1.10 equiv.) at 0 °C and was purged with nitrogen gas. Anhydrous THF (0.5 M) was added. The reaction was stirred at 0 °C for 5 min before being warmed to room temperature and stirred for another 25 min. NFSI (1.50 equiv.) was then added under a positive pressure of nitrogen and the reaction was stirred at room temperature for 30 min before being quenched with sat. aq. NaCl solution. Ethyl acetate was added and the organic layer was separated. The aqueous layer was further extracted with ethyl acetate twice. The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure to give a crude solid. Diethyl ether was added to the crude solid. The resulting suspension was shaken well before being filtered. The white filter cake was washed with diethyl ether and CH_2Cl_2. The combined filtrate was concentrated under reduced pressure to give a crude product containing a mixture of *N*-fluorinated product

and *S*-fluorinated product. The crude mixture was allowed to stand at room temperature (open to air) for 1-8 days until all the *N*-fluorinated product had isomerised to the desired *S*-fluorinated product (as determined by TLC and ^{19}F NMR). The crude product was then purified by flash column chromatography to afford the sulfondiimidoyl fluoride.

Notes:

1. The time taken for the *N*-fluorinated compound to isomerize into the *S*-fluorinated compound varies from substrate to substrate. ^{19}F NMR can be used to monitor this isomerization and determine when it is complete. The chemical shifts of the fluorine atoms for *N*-fluorinated compounds in the ^{19}F NMR are present at approximately -70 ppm and the chemical shifts of the fluorine atoms for *S*-fluorinated compounds in the ^{19}F NMR are present at approximately 80 ppm. When monitoring by TLC, the *N*-fluorinated compound is usually more polar than *S*-fluorinated compound (in the eluent system of petrol and ethyl acetate).

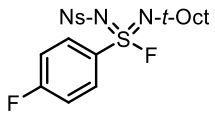


2. Sulfondiimidoyl fluorides containing electron-withdrawing substituents on carbon can be susceptible to hydrolysis when stored at room temperature. For this reason, we suggest purification of all sulfondiimidoyl fluorides should be carried out as soon as possible upon the completion of isomerization. We also recommend using purified sulfondiimidoyl fluorides in the next amination step immediately in order to maximise yield.
3. Even for different batches of the same substrate, the time taken for the *N*-fluorinated

compound to isomerize into the *S*-fluorinated compound is not identical. It is recommended to monitor the isomerization every 12 h by ^{19}F NMR or TLC.

4. Sulfondiimidoyl fluorides decompose gradually when stored in $CDCl_3$. As such, it is recommended to remove the $CDCl_3$ or other deuterated solvent immediately after the NMR experiments for longer term storage. Storing them in pure form typically reduces their decomposition rate.
5. The *in-situ* generated sulfinamidine salt forms a viscous slurry in the reaction flask. When NFSI (solid) is added, the stirring is often difficult and some solid was found to stick to the upper part of the wall of the round-bottom flask, which led to insufficient reaction of the two reagents and reduced yield. When this happens, it is recommended to add additional anhydrous THF (sulfinamidine conc. 1.0 M) to flush the adhered solids from the wall to the bottom of round-bottom flask, and the addition of THF will not lead to a decrease in yield.

4-Fluoro-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl) benzene sulfondiimidoyl fluoride (102)



An oven-dried 50 mL round-bottom flask was charged with sulfinamidine **85** (2.20 g, 4.84 mmol, 1.00 equiv.) and NaH (213 mg, 60 % dispersion in mineral oil, 5.32 mmol, 1.10 equiv.) at 0 °C and was purged with nitrogen gas. Anhydrous THF (9.70 mL) was added. The reaction was stirred at 0 °C for 5 min before being warmed to room temperature and stirred for another 25 min. NFSI (2.29 g, 7.26 mmol, 1.50 equiv.) was then added under a positive pressure of nitrogen and the reaction was stirred at room temperature for 30 min before being quenched with sat. aq. NaCl solution (250 mL). Ethyl acetate (150 mL) was added and the organic layer was separated. The aqueous layer was further extracted with ethyl acetate (2 ×

60 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure to give a crude solid. Diethyl ether (100 mL) was added to the crude solid and the resulting suspension was shaken well before being filtered. The white filter cake was washed with diethyl ether (120 mL) and CH_2Cl_2 (20 mL). The combined filtrate was concentrated under reduced pressure to give a crude product containing a mixture of *N*-fluorinated product and *S*-fluorinated product. The crude mixture was allowed to stand at room temperature (open to air) for 16-20 h until all the *N*-fluorinated product had isomerised to the desired *S*-fluorinated product (as determined by TLC and ^{19}F NMR). The crude product was then purified by flash column chromatography (petrol/ethyl acetate, 4:1) to afford *sulfondiimidoyl fluoride* **102** a pale-yellow solid (1.56 g, 3.30 mmol, 68%).

mp 57-59 °C;

R$_f$ 0.59 (petrol/ethyl acetate, 6:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.32 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.04-7.98 (m, 2H, Ar_F-*H*), 7.26-7.19 (m, 2H, Ar_F-*H*), 1.67 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.52 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.43 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.96 (s, 9H, *t*-Bu-*H*);

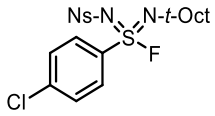
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.1 (d, $^1J_{CF}$ = 258.8 Hz), 150.0, 148.3, 134.4 (dd, $^{2,4}J_{CF}$ = 25.1, 3.3 Hz), 130.6 (d, $^3J_{CF}$ = 9.8 Hz), 128.1, 124.2, 116.9 (d, $^2J_{CF}$ = 23.1 Hz), 63.5 (d, $^3J_{CF}$ = 4.6 Hz), 56.5 (d, $^4J_{CF}$ = 3.2 Hz), 31.84, 31.79 (d, $^4J_{CF}$ = 2.7 Hz), 31.52, 31.45 (d, $^4J_{CF}$ = 6.6 Hz);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 86.5 (s), -101.4 (tt, J = 7.8, 4.7 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1532, 1492, 1348, 1240, 1163, 1089, 1075;

HRMS (ESI^+) calcd. for $C_{20}H_{25}F_2N_3O_4S_2Na^+$ $[M+Na]^+$: 496.1147, found: 496.1146.

4-Chloro-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (103)



Prepared according to **General Procedure G** using sulfinamidine **86** (707 mg, 1.50 mmol, 1.00 equiv.), THF (3.00 mL), NaH (66 mg, 60 % dispersion in mineral oil, 1.65 mmol, 1.10 equiv.) and NFSI (709 mg, 2.25 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 16 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1) afforded *sulfondiimidoyl fluoride* **103** as a white solid (520 mg, 1.06 mmol, 71%).

mp 66-68 °C;

R_f 0.55 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.32 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.92 (d, J = 8.9 Hz, 2H, Ar_{Cl}-*H*), 7.52 (d, J = 8.9 Hz, 2H, Ar_{Cl}-*H*), 1.67 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.53 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.44 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.97 (s, 9H, *t*-Bu-*H*);

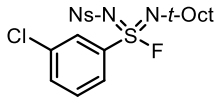
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.0, 148.2, 141.4, 136.9 (d, $^2J_{CF}$ = 25.3 Hz), 129.8, 129.0, 128.1, 124.2, 63.5 (d, $^3J_{CF}$ = 4.4 Hz), 56.5 (d, $^4J_{CF}$ = 3.4 Hz), 31.83, 31.81 (d, $^4J_{CF}$ = 2.5 Hz), 31.51, 31.46 (d, $^4J_{CF}$ = 5.9 Hz);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 86.0 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1347, 1309, 1162, 1108, 1087, 1072, 1010, 745, 610;

HRMS (ESI^+) calcd. for $C_{20}H_{25}ClFN_3O_4S_2Na^+$ $[M+Na]^+$: 512.0851, found: 512.0857.

3-Chloro-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl) benzenesulfondiimidoyl fluoride (104)



Prepared according to **General Procedure G** using sulfinamidine **87** (471 mg, 1.00 mmol, 1.00 equiv.), THF (2.00 mL), NaH (44 mg, 60 % dispersion in mineral oil, 1.10 mmol, 1.10 equiv.) and NFSI (473 mg, 1,50 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 24 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1) afforded *sulfondiimidoyl fluoride* **104** as a pale-yellow oil (313 mg, 0.64 mmol, 64%).

R$_f$ 0.70 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.29 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.02 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.87 (ddd, J = 8.1, 2.0, 1.0 Hz, 1H, Ar_{Cl}-*H*), 7.81 (t, J = 2.0 Hz, 1H, Ar_{Cl}-*H*), 7.61 (ddd, J = 8.1, 2.0, 1.0 Hz, 1H, Ar_{Cl}-*H*), 7.49 (t, J = 8.1 Hz, 1H, Ar_{Cl}-*H*), 1.68 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.51 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.47 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.97 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.0, 148.0, 139.7 (d, $^2J_{CF}$ = 25.3 Hz), 135.5, 134.5, 130.7, 128.1, 127.4, 125.7, 124.2, 63.7 (d, $^3J_{CF}$ = 4.6 Hz), 56.4 (d, $^4J_{CF}$ = 3.3 Hz), 31.84 (d, $^4J_{CF}$ = 2.8 Hz), 31.78, 31.5, 31.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 85.8 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1347, 1310. 1163, 1131, 1088, 1071, 672, 616;

HRMS (ESI^+) calcd. for $C_{20}H_{25}ClFN_3O_4S_2Na^+$ $[M+Na]^+$: 512.0851, found: 512.0854.

4-Cyanophenyl-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (105)



Prepared according to **General Procedure G** using sulfinamidine **88** (693 mg, 1.50 mmol, 1.00 equiv.), THF (3.00 mL), NaH (66 mg, 60 % dispersion in mineral oil, 1.65 mmol, 1.10 equiv.) and NFSI (709 mg, 2.25 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 24 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:1) afforded *sulfondiimidoyl fluoride* **105** as a colourless oil (325 mg, 0.68 mmol, 45%).

R$_f$ 0.50 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.34 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.14 (d, J = 8.7 Hz, 2H, Ar_{CN}-*H*), 8.08 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.87 (d, J = 8.7 Hz, 2H, Ar_{CN}-*H*), 1.66 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.52 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.47 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.43 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.95 (s, 9H, *t*-Bu-*H*);

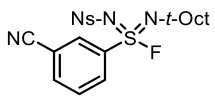
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.1, 147.9, 142.5 (d, $^2J_{CF}$ = 26.3 Hz), 133.2, 128.2, 128.1, 124.3, 118.1, 116.8, 64.0 (d, $^3J_{CF}$ = 4.6 Hz), 56.3 (d, $^4J_{CF}$ = 3.3 Hz), 31.8, 31.78, 31.5, 31.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 86.3 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1532, 1350, 1303, 1164, 1133, 1107, 1089, 1071;

HRMS (ESI^+) calcd. for $C_{21}H_{25}FN_4O_4S_2Na^+$ $[M+Na]^+$: 503.1193, found: 503.1194.

3-Cyanophenyl-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (106)



Prepared according to **General Procedure G** using sulfinamidine **89** (693 mg, 1.50 mmol, 1.00 equiv.), THF (3.00 mL), NaH (66 mg, 60 % dispersion in mineral oil, 1.65 mmol, 1.10 equiv.) and NFSI (709 mg, 2.25 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 24 h for the

completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:1) afforded *sulfondiimidoyl fluoride* **106** as a colourless oil (359 mg, 0.75 mmol, 50%).

R$_f$ 0.55 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.33 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.27-8.21 (m, 2H, Ar_{CN}-*H*), 8.07 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.96 (dt, J = 7.8, 1.3 Hz, 1H, Ar_{CN}-*H*), 7.73 (t, J = 7.8 Hz, 1H, Ar_{CN}-*H*), 1.67 (d, J = 14.8 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54 (d, J = 14.8 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.44 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.95 (s, 9H, *t*-Bu-*H*);

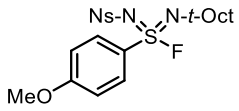
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.1, 147.8, 140.1 (d, $^2J_{CF}$ = 26.9 Hz), 137.3, 131.3, 131.1, 130.6, 128.1, 124.3, 116.6, 114.2, 64.0 (d, $^3J_{CF}$ = 4.6 Hz), 56.3 (d, $^4J_{CF}$ = 3.3 Hz), 31.8, 31.7, 31.5, 31.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 86.7 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1532, 1349, 1306, 1164, 1109, 1087, 1073;

HRMS (ESI^+) calcd. for $C_{21}H_{25}FN_4O_4S_2Na^+$ $[M+Na]^+$: 503.1193, found: 503.1188.

4-Methoxyphenyl-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (107)



Prepared according to **General Procedure G** using sulfinamidine **90** (467 mg, 1.00 mmol, 1.00 equiv.), THF (2.00 mL), NaH (44 mg, 60 % dispersion in mineral oil, 1.10 mmol, 1.10 equiv.) and NFSI (473 mg, 1.50 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 24 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:1) afforded xx *sulfondiimidoyl fluoride* **107** a colourless oil (325 mg, 0.67 mmol, 67%).

R_f 0.54 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25 (d, J = 8.7 Hz, 2H, Ar_{Ns}-*H*), 8.00 (d, J = 8.7 Hz, 2H, Ar_{Ns}-*H*), 7.84 (d, J = 9.0 Hz, 2H, Ar_{OMe}-*H*), 6.93 (d, J = 9.0 Hz, 2H, Ar_{OMe}-*H*), 3.83 (s, 3H, OC*H*$_3$), 1.65 (d, J = 14.8 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.51 (d, J = 14.8 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.48 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.43 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 0.95 (s, 9H, *t*-Bu-*H*);

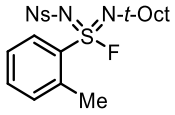
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.2, 149.7, 148.4, 129.9, 129.2 (d, $^2J_{CF}$ = 24.0 Hz), 128.0, 124.0, 114.5, 62.9 (d, $^3J_{CF}$ = 4.4 Hz), 56.4 (d, $^4J_{CF}$ = 3.2 Hz), 55.9, 31.72, 31.69 (d, $^4J_{CF}$ = 2.7 Hz), 31.5, 31.3 (d, $^4J_{CF}$ = 6.2 Hz);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 86.1 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1349, 1311, 1266, 1162, 1104, 1089;

HRMS (ESI$^+$) calcd. for $C_{21}H_{28}FN_3O_5S_2Na^+$ [M+Na]$^+$: 508.1347, found: 508.1353.

o-Tolyl-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (108)



Prepared according to **General Procedure G** using sulfinamidine **91** (451 mg, 1.00 mmol, 1.00 equiv.), THF (2.00 mL), NaH (44 mg, 60 % dispersion in mineral oil, 1.10 mmol, 1.10 equiv.) and NFSI (473 mg, 1.50 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 48 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:1) afforded *sulfondiimidoyl fluoride* **108** a white solid (235 mg, 0.50 mmol, 50%).

mp 86-88 °C;

R_f 0.63 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.26 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.98 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.98-7.95 (m, 1H, Tol-*H*), 7.53 (td, J = 7.5, 1.3 Hz, 1H, Tol-*H*), 7.38 (t, J = 7.5 Hz, 1H, Tol-*H*), 7.29 (d, J = 7.5 Hz, 1H, Tol-*H*), 2.56 (s, 3H, Tol-CH_3), 1.59 (d, J = 14.6 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.50 (d, J = 14.6 Hz, 1H, NC$(CH_3)_2$C$H_a$$H_b$), 1.47 (s, 3H, NC(C$H_3)_a$$(CH_3)_b$), 1.45 (s, 3H, NC$(CH_3)_a$(C$H_3)_b$), 0.89 (s, 9H, *t*-Bu-*H*);

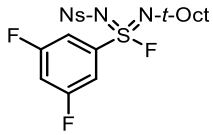
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.8, 148.1, 137.6, 137.3 (d, $^{2}J_{CF}$ = 19.5 Hz), 134.2, 133.0 (d, $^{3}J_{CF}$ = 1.8 Hz), 128.2 (d, $^{3}J_{CF}$ = 2.4 Hz), 128.1, 126.6, 124.0, 63.5 (d, $^{3}J_{CF}$ = 4.6 Hz), 56.5 (d, $^{4}J_{CF}$ = 3.0 Hz), 31.7, 31.5 (d, $^{4}J_{CF}$ = 3.1 Hz), 31.4, 31.1 (d, $^{4}J_{CF}$ = 6.6 Hz), 20.1 (d, $^{4}J_{CF}$ = 2.3 Hz);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 81.2 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1349, 1327, 1306, 1164, 1147, 1086, 1059, 686, 620;

HRMS (ESI^+) calcd. for $C_{21}H_{28}FN_3O_4S_2Na^+$ $[M+Na]^+$: 492.1397, found: 492.1389.

3,5-Difluorophenyl-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (109)



Prepared according to **General Procedure G** using sulfinamidine **92** (710 mg, 1.50 mmol, 1.00 equiv.), THF (3.00 mL), NaH (66 mg, 60 % dispersion in mineral oil, 1.65 mmol, 1.10 equiv.) and NFSI (709 mg, 2.25 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 24 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1) afforded *sulfondiimidoyl fluoride* **109** as a white solid (373 mg, 0.76 mmol, 51%).

mp 50-52 °C;

R$_f$ 0.70 (petrol/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.34 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.08 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.56-7.51 (m, 2H, Ar_F-*H*), 7.13 (tt, J = 8.2, 2.3 Hz, 1H, Ar_F-*H*), 1.68 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.49 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.45 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.97 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 162.6 (dd, $^{1,3}J_{CF}$ = 256.0, 11.8 Hz), 150.1, 147.9, 141.2 (dt, $^{2,3}J_{CF}$ = 28.4, 9.6 Hz), 128.1, 124.3, 111.7-111.3 (second-order multiplet), 110.2 (t, $^{2}J_{CF}$ = 24.9 Hz), 64.0 (d, $^{3}J_{CF}$ = 4.6 Hz), 56.3 (d, $^{4}J_{CF}$ = 3.4 Hz), 31.82, 31.80, 31.46 (d, $^{4}J_{CF}$ = 6.1 Hz), 31.45;

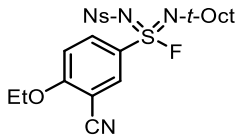
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 87.12 (s), -103.8- -103.9 (second-order multiplet);

The second-order multiplet in the ^{13}C and ^{19}F NMR spectra arise due to virtual coupling;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1604, 1533, 1349, 1299, 1166, 1131, 1106, 1086;

HRMS (ESI^+) calcd. for $C_{20}H_{24}F_3N_3O_4S_2Na^+$ $[M+Na]^+$: 514.1053, found: 514.1053.

3-Cyano-4-ethoxy-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (110)



Prepared according to **General Procedure G** using sulfinamidine **93** (3.84 g, 7.58 mmol, 1.00 equiv.), THF (15.2 mL), NaH (334 mg, 60 % dispersion in mineral oil, 8.35 mmol, 1.10 equiv.) and NFSI (3.58 g, 11.37 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 20 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 2:1) afforded *sulfondiimidoyl fluoride* **110** as a white solid (1.91 g, 3.65 mmol, 48%).

mp 120-122 °C;

R_f 0.58 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.32 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.15 (dd, J = 9.1, 2.6 Hz, 1H, Ar_{CN}-*H*), 8.11 (d, J = 2.6 Hz, 1H, Ar_{CN}-*H*), 8.06 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.09 (d, J = 9.1 Hz, 1H, Ar_{CN}-*H*), 4.26 (q, J = 7.0 Hz, 2H, OCH_2), 1.66 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54-1.49 (m, 4H, $NC(CH_3)_2CH_aH_b$/OCH_2CH_3), 1.46 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.42 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.95 (s, 9H, *t*-Bu-*H*);

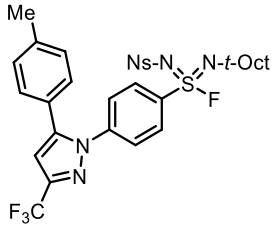
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.4, 150.0, 148.0, 133.83, 133.81, 130.2 (d, $^{2}J_{CF}$ = 26.9 Hz), 128.1, 124.2, 114.2, 112.7, 103.4, 66.3, 63.6 (d, $^{3}J_{CF}$ = 4.3 Hz), 56.3 (d, $^{4}J_{CF}$ = 3.1 Hz), 31.8, 31.7 (d, $^{4}J_{CF}$ = 2.8 Hz), 31.43, 31.37 (d, $^{4}J_{CF}$ = 6.2 Hz), 14.3;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 87.8 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1473, 1383, 1251, 1151, 1072, 955, 615;

HRMS (ESI^+) calcd. for $C_{23}H_{29}FN_4O_5S_2Na^+$ $[M+Na]^+$: 547.1456, found: 547.1456.

4-(5-(*p*-Tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (111)



Prepared according to **General Procedure G** using sulfinamidine **94** (661 mg, 1.00 mmol, 1.00 equiv.), THF (2.00 mL), NaH (44 mg, 60 % dispersion in mineral oil, 1.10 mmol, 1.10 equiv.) and NFSI (473 mg, 1.50 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 24 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:1) afforded *sulfondiimidoyl fluoride* **111** as a colourless oil (350 mg, 0.52 mmol, 52%).

R$_f$ 0.64 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.30 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.98 (d, *J* = 8.9 Hz, 2H, Ar-*H*), 7.53 (d, *J* = 8.9 Hz, 2H, Ar-*H*), 7.21 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 7.14 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 6.75 (s, 1H, HetAr-*H*), 2.40 (s, 3H, Tol-C*H*$_3$), 1.67 (d, *J* = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.53 (d, *J* = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.43 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.96 (s, 9H, *t*-Bu-*H*);

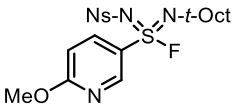
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.9, 148.1, 145.5, 144.5 (q, $^{2}J_{CF}$ = 38.8 Hz), 143.8, 140.2, 137.3 (d, $^{2}J_{CF}$ = 25.1 Hz), 130.0, 128.8, 128.6, 128.1, 125.6, 125.2, 124.2, 121.0 (q, $^{1}J_{CF}$ = 269.2 Hz), 106.9, 63.5 (d, $^{3}J_{CF}$ = 4.2 Hz), 56.3 (d, $^{4}J_{CF}$ = 2.7 Hz), 31.78 (d, $^{4}J_{CF}$ = 2.2 Hz), 31.76, 31.43, 31.35 (d, $^{4}J_{CF}$ = 5.9 Hz), 21.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 86.7 (s), -62.5 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1530, 1348, 1237, 1161, 1135, 1107, 974, 744;

HRMS (ESI^+) calcd. for $C_{31}H_{33}F_4N_5O_4S_2Na^+$ $[M+Na]^+$: 702.1802, found: 702.1799.

6-Methoxy-*N*-(4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)pyridine-3-sulfondiimidoyl fluoride (112)



Prepared according to **General Procedure G** using sulfinamidine **95** (468 mg, 1.00 mmol, 1.00 equiv.), THF (2.00 mL), NaH (44 mg, 60 % dispersion in mineral oil, 1.10 mmol, 1.10 equiv.) and NFSI (473 mg, 1.50 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 24 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:1) afforded *sulfondiimidoyl fluoride* **112** as a white solid (291 mg, 0.60 mmol, 60%).

mp 70-72 °C;

R_f 0.50 (petrol/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.69 (d, J = 2.7 Hz, 1H, HetAr-*H*), 8.29 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.08-8.05 (m, 1H, HetAr-*H*), 8.04 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 6.81 (dd, J = 9.0, 0.6 Hz, 1H, HetAr-*H*), 3.98 (s, 3H, OC*H*$_3$), 1.65 (d, J = 14.7 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.50 (d, J = 14.7 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.47 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.42 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 0.95 (s, 9H, *t*-Bu-*H*);

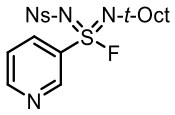
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 167.2, 149.9, 148.2, 148.1, 137.3, 128.1, 127.7 (d, $^2J_{CF}$ = 24.8 Hz), 124.1, 111.6, 63.4 (d, $^3J_{CF}$ = 4.4 Hz), 56.4 (d, $^4J_{CF}$ = 3.1 Hz), 54.8, 31.8, 31.7 (d, $^4J_{CF}$ = 2.6 Hz), 31.5, 31.4 (d, $^4J_{CF}$ = 6.3 Hz);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 88.7 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1532, 1484, 1381, 1348, 1310, 1288, 1163, 1086, 607;

HRMS (ESI$^+$) calcd. for $C_{20}H_{27}FN_4O_5S_2Na^+$ [M+Na]$^+$: 509.1299, found: 509.1307.

***N*-((4-Nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)pyridine-3-sulfondiimidoyl fluoride (113)**



Prepared according to **General Procedure G** using sulfinamidine **96** (657 mg, 1.50 mmol, 1.00 equiv.), THF (3.00 mL), NaH (66 mg, 60 % dispersion in mineral oil, 1.65 mmol, 1.10 equiv.) and NFSI (709 mg, 2.25 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 72 h for the completion of isomerization. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 25:1 to 10:1) afforded *sulfondiimidoyl fluoride* **113** as a colourless oil (275 mg, 0.60 mmol, 40%).

R_f 0.58 (CH_2Cl_2/ethyl acetate, 20:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.10 (dd, J = 2.5, 0.8 Hz, 1H, HetAr-*H*), 8.84 (dd, J = 4.9, 1.5 Hz, 1H, HetAr-*H*), 8.31-8.27 (m,1 H, HetAr-*H*), 8.29 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.03 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.50 (ddd, J = 8.3, 4.9, 0.8 Hz, 1H, HetAr-*H*), 1.66 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.52 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.43 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.94 (s, 9H, *t*-Bu-*H*);

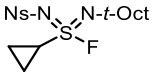
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 154.5, 150.0, 148.1, 147.9, 135.5 (d, $^2J_{CF}$ = 24.9 Hz), 135.1, 128.0, 124.2, 123.8, 63.8 (d, $^3J_{CF}$ = 4.5 Hz), 56.3 (d, $^4J_{CF}$ = 3.2 Hz), 31.8, 31.7, 31.44, 31.39;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 88.1 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1532, 1473, 1462, 1382, 1251, 1162, 1085, 954;

HRMS (ESI^+) calcd. for $C_{19}H_{25}FN_4O_4S_2Na^+$ $[M+Na]^+$: 479.1193, found: 479.1195.

_N_-((4-Nitrophenyl)sulfonyl)-_N_-(2,4,4-trimethylpentan-2-yl)cyclopropanesulfondiimidoyl fluoride (114)



Prepared according to **General Procedure G** using sulfinamidine **97** (401 mg, 1.00 mmol, 1.00 equiv.), THF (2.00 mL), NaH (44 mg, 60 % dispersion in mineral oil, 1.10 mmol, 1.10 equiv.) and NFSI (473 mg, 1.50 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 8 days for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:1) afforded *sulfondiimidoyl fluoride* **114** as a colourless oil (390 mg, 0.93 mmol, 93%).

R$_f$ 0.63 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.34 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.14 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 3.50 (tq, J = 8.3, 4.3 Hz, 1H, SC*H*), 1.55-1.47 (m, 1H, $SCHCH_aH_b$), 1.51 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.43-1.36 (m, 1H, $SCHCH_aH_b$), 1.39 (d, J = 14.7 Hz,

1H, $NC(CH_3)_2CH_aH_b$), 1.32 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.30-1.18 (m, 2H, $SCHCH_2$), 1.27 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.93 (s, 9H, *t*-Bu-*H*);

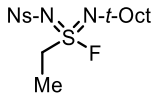
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.0, 148.7, 128.1, 124.2, 62.2 (d, $^3J_{CF}$ = 4.5 Hz), 56.5 (d, $^4J_{CF}$ = 2.5 Hz), 34.9 (d, $^2J_{CF}$ = 28.5 Hz), 31.7, 31.5, 31.4 (d, $^4J_{CF}$ = 2.7 Hz), 31.2 (d, $^4J_{CF}$ = 6.9 Hz), 8.2, 7.9 (d, $^3J_{CF}$ = 2.0 Hz) (Note: For 2 secondary carbons in cyclopropane ring, 2 peaks were found instead of 1 due to the loss of symmetry caused by chiral sulfur atom);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 86.0 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1349, 1334, 1299, 1160, 1071, 735, 686, 615;

HRMS (ESI^+) calcd. for $C_{17}H_{26}FN_3O_4S_2Na^+$ $[M+Na]^+$: 442.1241, found: 442.1241.

***N*-((4-Nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)ethanesulfondiimidoyl fluoride (115)**



Prepared according to **General Procedure G** using sulfinamidine **98** (389 mg, 1.00 mmol, 1.00 equiv.), THF (2.00 mL), NaH (44 mg, 60 % dispersion in mineral oil, 1.10 mmol, 1.10 equiv.) and NFSI (473 mg, 1.50 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 12 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 4:1) afforded *sulfondiimidoyl fluoride* **115** as a white solid (286 mg, 0.70 mmol, 70%).

mp 80-82 °C;

R_f 0.52 (petrol/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.30 (d, *J* = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.08 (d, *J* = 9.0 Hz, 2H, Ar_{Ns}-*H*), 3.90-3.69 (m, 2H, SCH_2), 1.53-1.47 (m, 4H, $NC(CH_3)_2CH_aH_b/SCH_2CH_3$),

1.36 (d, J = 14.7 Hz, 1H, NC(CH_3)$_2$C$H_a$$H_b$), 1.31 (s, 3H, NC(C$H_3$)$_a$($CH_3$)$_b$), 1.23 (s, 3H, NC($CH_3$)$_a$(C$H_3$)$_b$), 0.90 (s, 9H, *t*-Bu-*H*);

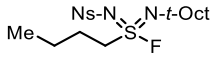
^{13}C NMR (101 MHz, $CDCl_3$): 149.8, 148.4, 128.0, 124.1, 62.1 (d, $^3J_{CF}$ = 4.7 Hz), 56.2 (d, $^4J_{CF}$ = 2.7 Hz), 52.5 (d, $^2J_{CF}$ = 17.0 Hz), 31.7, 31.39 (d, $^4J_{CF}$ = 2.7 Hz), 31.36, 31.1 (d, $^4J_{CF}$ = 6.8 Hz), 8.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 77.9 (t, J = 3.5 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1349, 1161, 1081, 1056, 739;

HRMS (ESI^+) calcd. for $C_{16}H_{26}FN_3O_4S_2Na^+$ $[M+Na]^+$: 430.1241, found: 430.1240.

N-((4-Nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)butanesulfondiimidoyl fluoride (116)



Prepared according to **General Procedure G** using sulfinamidine **99** (626 mg, 1.50 mmol, 1.00 equiv.), THF (3.00 mL), NaH (66 mg, 60 % dispersion in mineral oil, 1.65 mmol, 1.10 equiv.) and NFSI (709 mg, 2.25 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 6 days for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 7:1 to 5:1) afforded *sulfondiimidoyl fluoride* **116** as a colourless oil (593 mg, 1.36 mmol, 91%).

R$_f$ 0.47 (petrol/ethyl acetate, 8:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.34 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 8.11 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 3.88 (dddd, J = 13.8, 9.0, 6.2, 2.5 Hz, 1H, SCH_aH$_b$), 3.76 (dddd, J = 13.8, 9.0, 6.2, 4.0 Hz, 1H, SCH$_a$$H_b$), 1.93-1.84 (m, 2H, SCH$_2CH_2$), 1.58 (d, J = 14.6 Hz, 1H, NC(CH_3)$_2$CH_aH$_b$), 1.53-1.42 (m, 3H, SCH$_2$CH$_2$CH_2/NC(CH_3)$_2$CH$_a$$H_b$), 1.36 (s, 3H, NC(C$H_3$)$_a$($CH_3$)$_b$), 1.30 (s, 3H, NC($CH_3$)$_a$(C$H_3$)$_b$), 0.97 (s, 9H, *t*-Bu-*H*), 0.94 (t, J = 7.4 Hz, 3H, *n*-Bu-CH_3);

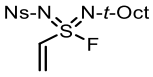
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 151.2, 149.3, 128.9, 125.4, 62.9 (d, $^3J_{CF}$ = 4.9 Hz), 57.7 (d, $^2J_{CF}$ = 14.2 Hz), 56.8 (d, $^4J_{CF}$ = 3.1 Hz), 32.2, 31.8 (d, $^4J_{CF}$ = 3.1 Hz), 31.7, 31.5 (d, $^4J_{CF}$ = 6.8 Hz), 26.7, 21.5, 13.6;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = 81.2 (t, J = 3.4 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1348, 1307, 1160, 1071, 742, 686, 614;

HRMS (ESI^+) calcd. for $C_{18}H_{30}FN_3O_4S_2Na^+$ $[M+Na]^+$: 458.1554, found: 458.1552.

***N*-((4-Nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)ethenesulfondiimidoyl fluoride (117)**



Prepared according to **General Procedure G** using sulfinamidine **100** (418 mg, 1.08 mmol, 1.00 equiv.), THF (3.60 mL), NaH (48 mg, 60 % dispersion in mineral oil, 1.20 mmol, 1.10 equiv.) and NFSI (510 mg, 1.62 mmol, 1.50 equiv.). The crude mixture of *N*-fluorinated compound and *S*-fluorinated compound was left at room temperature for 24 h for the completion of isomerization. Purification by flash column chromatography (petrol/ethyl acetate, 3:1) afforded *sulfondiimidoyl fluoride* **117** as a colourless oil (210 mg, 0.52 mmol, 48%).

R_f 0.62 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.33 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.11 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.04 (ddd, J = 16.0, 9.6, 2.3 Hz, 1H, SC*H*), 6.55 (dd, J = 16.0, 1.5 Hz, 1H, SCH=CH_aH_b), 6.25 (ddd, J = 9.6, 4.5, 1.5 Hz, 1H, SCH=CH_aH_b), 1.59 (d, J = 14.7 Hz, 1H, NC$(CH_3)_2$CH_aH_b), 1.43 (d, J = 14.7 Hz, 1H, NC$(CH_3)_2$CH_aH_b), 1.37 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.32 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 0.93 (s, 9H, *t*-Bu-*H*);

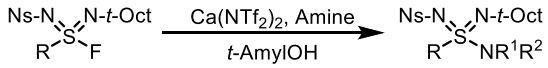
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.9, 148.3, 134.1 (d, $^2J_{CF}$ = 29.0 Hz), 130.3, 128.1, 124.2, 62.6 (d, $^3J_{CF}$ = 4.6 Hz), 56.2 (d, $^4J_{CF}$ = 3.1 Hz), 31.7, 31.6 (d, $^4J_{CF}$ = 2.7 Hz), 31.5 (d, $^4J_{CF}$ = 6.3 Hz), 31.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = 86.5 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1348, 1312, 1161, 1082, 741, 616;

HRMS (ESI^+) calcd. for $C_{16}H_{24}FN_3O_4S_2Na^+$ $[M+Na]^+$: 428.1084, found: 428.1084.

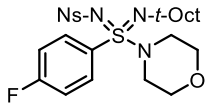
6.3.4 General Procedure H for Sulfondiimidamide Synthesis



Sulfondiimidoyl fluoride (1.00 equiv.), $Ca(NTf_2)_2$ (1.10 equiv.) and amine (2.20-6.00 equiv.) were added to an oven-dried round-bottom flask and dissolved in anhydrous *t*-AmylOH (0.5 M). The reaction was stirred at 60-80 °C until completion (judged by TLC, 10-36 h). The mixture was then diluted with CH_2Cl_2 and quenched with sat. aq. NaCl solution. The organic layer was separated and the aqueous layer was extracted with CH_2Cl_2 twice. The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography to afford the desired sulfondiimidamide product.

Note: an emulsion may form during extraction in a large-scale reaction. In this case, 0.5 M aq. HCl solution is suggested to be used in aqueous workup stage instead of sat. aq. NaCl solution to facilitate easier separation.

***N*-((4-Fluorophenyl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (118)**



Sulfondiimidoyl fluoride **102** (120 mg, 0.25 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (167 mg, 0.28 mmol, 1.10 equiv.) were added to an oven-dried 10 mL round-bottom flask and dissolved in anhydrous *t*-AmylOH (0.5 mL). Then morpholine (48 mg, 0.55 mmol, 2.20 equiv.) was added and the reaction was stirred at 60 °C for 24 h until completion (judged by TLC). The mixture was then diluted with CH_2Cl_2 (80 mL) and quenched with sat. aq. NaCl solution

(120 mL). The organic layer was separated and the aqueous layer was extracted with CH_2Cl_2 (2 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) to afford *sulfondiimidamide* **118** as a white solid (126 mg, 0.23 mmol, 93%).

Gram scale: Sulfondiimidoyl fluoride **102** (4.40 g, 9.30 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (5.86 g, 9.77 mmol, 1.05 equiv.) were added to an oven-dried 100 mL round-bottom flask and dissolved in anhydrous *t*-AmylOH (18.6 mL). Then morpholine (1.78 g, 20.43 mmol, 2.20 equiv.) was added and the reaction was stirred at 60 °C for 24 h until completion (judged by TLC). The mixture was then diluted with CH_2Cl_2 (250 mL) and quenched with 0.5 M aq. HCl solution (250 mL). The organic layer was separated and the aqueous layer was extracted with CH_2Cl_2 (2 × 100 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) to afford *sulfondiimidamide* **118** as a white solid (4.51 g, 8.35 mmol, 90%).

mp 55-57 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.19 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.84 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.71 -7.64 (m, 2H, Ar_F-*H*), 7.09-7.02 (m, 2H, Ar_F-*H*), 3.68 (app. t, J = 4.5 Hz, 4H, OC*H*$_2$), 3.11 (dt, J = 12.0, 4.5 Hz, 2H, NC*H*$_2$), 3.04 (dt, J = 12.0, 4.5 Hz, 2H, NC*H*$_2$), 1.71 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.59-1.51 (m, 4H, $NC(CH_3)_2CH_aH_b$ /$NC(CH_3)_a(CH_3)_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.05 (s, 9H, *t*-Bu-*H*);

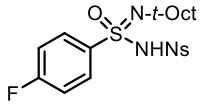
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.1 (d, $^1J_{CF}$ = 256.1 Hz), 149.5, 149.3, 133.5 (d, $^4J_{CF}$ = 3.1 Hz), 130.7 (d, $^3J_{CF}$ = 9.2 Hz), 127.5, 123.8, 116.1 (d, $^2J_{CF}$ = 22.7 Hz), 66.6, 60.3, 57.6, 47.0, 32.1, 31.92, 31.87, 31.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.1 (tt, J = 7.9, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1350, 1298, 1154, 1088, 1050, 921;

HRMS (ESI^+) calcd. for $C_{24}H_{33}FN_4O_5S_2Na^+$ $[M+Na]^+$: 563.1769, found: 563.1766.

***N*-(4-Fluoro-*N*-(2,4,4-trimethylpentan-2-yl)phenylsulfonimidoyl)-4-nitrobenzenesulfonamide (119)**



R$_f$ 0.60 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.28 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.09 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.96-7.90 (m, 2H, Ar_F-*H*), 7.19-7.11 (m, 2H, Ar_F-*H*), 6.15 (s, 1H, N*H*), 1.60 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.49 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.32 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.16 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.95 (s, 9H, *t*-Bu-*H*);

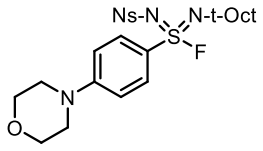
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.6 (d, $^1J_{CF}$ = 257.2 Hz), 149.8, 148.9, 137.4 (d, $^4J_{CF}$ = 3.2 Hz), 130.6 (d, $^3J_{CF}$ = 9.6 Hz), 128.2, 124.0, 116.5 (d, $^2J_{CF}$ = 22.9 Hz), 61.9, 56.1, 31.6, 31.5, 30.1, 28.2;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -103.1 (tt, J = 8.5, 4.8 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1590, 1530, 1493, 1384, 1351, 1302, 1261, 1154, 1091, 1039, 1027;

HRMS (ESI^+) calcd. for $C_{20}H_{27}FN_3O_5S_2^+$ $[M+H]^+$: 472.1371, found: 472.1371.

4-Morpholino-*N*-((4-nitrophenyl)sulfonyl)-*N*-(2,4,4-trimethylpentan-2-yl)benzenesulfondiimidoyl fluoride (120)



R$_f$ 0.62 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.19 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.87 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.58 (d, J = 9.3 Hz, 2H, Ar-*H*), 6.80 (d, J = 9.3 Hz, 2H, Ar-*H*), 3.77-3.69

(m, 4H, OCH_2), 3.29-3.21 (m, 4H, NCH_2), 1.69 (d, J = 14.6 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.55 (d, J = 14.6 Hz, 1H, NC$(CH_3)_2$C$H_a$$H_b$), 1.51 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.47 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 0.98 (s, 9H, *t*-Bu-*H*);

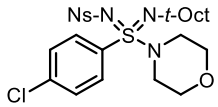
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 155.7, 150.8, 149.0, 130.4, 128.9, 125.1, 124.2 (d, $^2J_{CF}$ = 24.3 Hz), 113.7, 66.9, 63.3 (d, $^3J_{CF}$ = 4.4 Hz), 57.0 (d, $^4J_{CF}$ = 3.2 Hz), 47.5, 32.3, 32.2 (d, $^4J_{CF}$ = 2.5 Hz), 31.83, 31.77 (d, $^4J_{CF}$ = 6.4 Hz);

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = 84.9 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1590, 1530, 1349, 1332, 1304, 1247, 1161, 1089, 1053, 928;

HRMS (ESI^+) calcd. for $C_{24}H_{33}FN_4O_5S_2Na^+$ $[M+ Na]^+$: 563.1769, found: 563.1771.

***N*-((4-Chlorophenyl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (121)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **103** (88 mg, 0.18 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (119 mg, 0.20 mmol, 1.10 equiv.), morpholine (35 mg, 0.40 mmol, 2.20 equiv.) and *t*-AmylOH (0.36 mL). The reaction was stirred at 60 °C for 24 h. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:2) afforded *sulfondiimidamide* **121** as a white solid (95 mg, 0.17 mmol, 94%).

mp 128-130 °C;

R$_f$ 0.61 (petrol/ethyl acetate, 2:1);

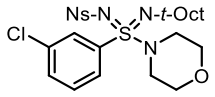
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.19 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 7.84 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 7.59 (d, J = 8.8 Hz, 2H, Ar$_{Cl}$-*H*), 7.34 (d, J = 8.8 Hz, 2H, Ar$_{Cl}$-*H*), 3.70-3.65 (m, 4H, OCH_2), 3.11 (dt, J = 12.0, 4.5 Hz, 2H, NCH_2), 3.04 (dt, J = 12.0, 4.5 Hz, 2H, NCH_2), 1.71 (d, J = 14.5 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.55 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.55 (d, J = 14.5 Hz, 1H, NC$(CH_3)_2$C$H_a$$H_b$), 1.48 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.05 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.4, 149.3, 139.4, 136.1, 129.4, 129.2, 127.5, 123.8, 66.6, 60.3, 57.5, 47.0, 32.1, 31.92, 31.86, 31.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1299, 1257, 1153, 1087, 1062, 1009, 919, 746;

HRMS (ESI^+) calcd. for $C_{24}H_{33}ClN_4O_5S_2Na^+$ $[M+Na]^+$: 579.1473, found: 579.1475.

***N*-((3-Chlorophenyl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (122)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **104** (160 mg, 0.33 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (216 mg, 0.36 mmol, 1.10 equiv.), morpholine (63 mg, 0.72 mmol, 2.20 equiv.) and *t*-AmylOH (0.65 mL). The reaction was stirred at 60 °C for 24 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **122** as a white solid (162 mg, 0.29 mmol, 89%).

mp 112-114 °C;

R_f 0.73 (petrol/ethyl acetate, 1:1);

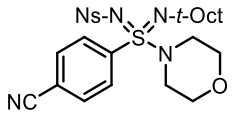
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.16 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.78 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.54 (ddd, J = 8.0, 2.0, 1.0 Hz, 1H, Ar_{Cl}-*H*), 7.43 (ddd, J = 8.0, 2.0, 1.0 Hz, 1H, Ar_{Cl}-*H*), 7.39 (t, J = 2.0 Hz, 1H, Ar_{Cl}-*H*), 7.31 (t, J = 8.0 Hz, 1H, Ar_{Cl}-*H*), 3.69-3.64 (m, 4H, OCH_2), 3.10 (dt, J = 12.0, 4.2 Hz, 2H, NCH_2), 3.03 (dt, J = 12.0, 4.2 Hz, 2H, NCH_2), 1.75 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.61 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.57 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.50 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.06 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.3, 149.1, 139.0, 135.0, 132.6, 130.2, 127.6, 127.4, 126.3, 123.8, 66.5, 60.5, 57.4, 46.9, 32.0, 31.9, 31.8, 31.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1296, 1255, 1153, 1112, 1088, 1049, 917, 733, 677;

HRMS (ESI^+) calcd. for $C_{24}H_{33}ClN_4O_5S_2Na^+$ $[M+Na]^+$: 579.1473, found: 579.1469.

***N*-((4-Cyanophenyl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (123)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **105** (200 mg, 0.42 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (275 mg, 0.46 mmol, 1.10 equiv.), morpholine (80 mg, 0.92 mmol, 2.20 equiv.) and *t*-AmylOH (0.83 mL). The reaction was stirred at 60 °C for 12 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **123** as a white solid (213 mg, 0.39 mmol, 93%).

mp 154-156 °C;

R$_f$ 0.54 (petrol/ethyl acetate, 1:1);

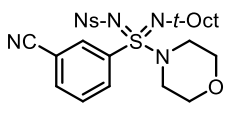
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.21 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.87 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.81 (d, J = 8.8 Hz, 2H, Ar_{CN}-*H*), 7.71 (d, J = 8.8 Hz, 2H, Ar_{CN}-*H*), 3.66 (app. t, J = 4.8 Hz, 4H, OC*H*$_2$), 3.09 (dt, J = 12.0, 4.6 Hz, 2H, NC*H*$_2$), 3.01 (dt, J = 12.0, 4.6 Hz, 2H, NC*H*$_2$), 1.69 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.52 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.46 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.02 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.4, 149.1, 142.2, 132.7, 128.5, 127.4, 123.9, 117.1, 116.2, 66.4, 60.5, 57.3, 46.9, 31.9, 31.79, 31.75, 31.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1299, 1257, 1154, 1086, 1045, 917, 733;

HRMS (ESI$^+$) calcd. for $C_{25}H_{33}N_5O_5S_2Na^+$ $[M+Na]^+$: 570.1815, found: 570.1812.

***N*-((3-Cyanophenyl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (124)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **106** (285 mg, 0.59 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (392 mg, 0.46 mmol, 1.10 equiv.), morpholine (114 mg,

1.31 mmol, 2.20 equiv.) and *t*-AmylOH (1.19 mL). The reaction was stirred at 60 °C for 12 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) afforded *sulfondiimidamide* **124** as a white solid (300 mg, 0.55 mmol, 92%).

mp 160-162 °C;

R_f 0.60 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.24 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.93-7.85 (m, 2H, Ar_{CN}-*H*), 7.87 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.80 (dt, J = 7.8, 1.3 Hz, 1H, Ar_{CN}-*H*), 7.56 (t, J = 7.8 Hz, 1H, Ar_{CN}-*H*), 3.73-3.68 (m, 4H, OCH_2), 3.12 (dt, J = 12.0, 4.6 Hz, 2H, NCH_2), 3.04 (dt, J = 12.0, 4.6 Hz, 2H, NCH_2), 1.74 (d, J = 14.7 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.59 (d, J = 14.7 Hz, 1H, NC$(CH_3)_2$C$H_a$$H_b$), 1.58 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.50 (s, 3H, NC$(CH_3)_a(CH_3)_b$), 1.06 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.6, 149.1, 139.4, 135.7, 131.73, 131.65, 130.1, 127.5, 124.1, 117.1, 113.7, 66.5, 60.8, 57.5, 47.1, 32.1, 31.91, 31.90, 31.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1385, 1350, 1298, 1257, 1154, 1088, 1064, 922;

HRMS (ESI^+) calcd. for $C_{25}H_{33}N_5O_5S_2Na^+$ $[M+Na]^+$: 570.1815, found: 570.1811.

***N*-((4-Methoxyphenyl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (125)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **107** (110 mg, 0.23 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (150 mg, 0.25 mmol, 1.10 equiv.), morpholine (44 mg, 0.51 mmol, 2.20 equiv.) and *t*-AmylOH (0.45 mL). The reaction was stirred at 60 °C for 24 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **125** as a white solid (115 mg, 0.21 mmol, 92%).

mp 132-134 °C;

R_f 0.59 (petrol/ethyl acetate, 1:1);

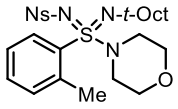
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.10 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.77 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.50 (d, *J* = 9.0 Hz, 2H, Ar_{OMe}-*H*), 6.75 (d, *J* = 9.0 Hz, 2H, Ar_{OMe}-*H*), 3.77 (s, 3H, OCH_3), 3.68-3.63 (m, 4H, OCH_2), 3.10 (dt, *J* = 12.0, 4.1 Hz, 2H, NCH_2), 3.03 (dt, *J* = 12.0, 4.1 Hz, 2H, NCH_2), 1.70 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.56 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.53 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.47 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.04 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 162.9, 149.6, 149.1, 130.0, 128.5, 127.6, 123.6, 113.9, 66.6, 59.9, 57.6, 55.7, 46.8, 32.1, 31.9, 31.8, 31.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1530, 1383, 1348, 1296, 1254, 1151, 1087, 1063, 914, 733;

HRMS (ESI^+) calcd. for $C_{25}H_{37}N_4O_6S_2^+$ $[M+H]^+$: 553.2149, found: 553.2144.

***N*-(Morpholino(o-tolyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (126)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **108** (175 mg, 0.37 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (244 mg, 0.41 mmol, 1.10 equiv.), morpholine (129 mg, 1.48 mmol, 4.00 equiv.) and *t*-AmylOH (0.75 mL). The reaction was stirred at 75 °C for 18 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) afforded *sulfondiimidamide* **126** as a white solid (149 mg, 0.28 mmol, 75%).

mp 114-116 °C;

R_f 0.46 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.09 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.08-8.05 (m, 1H, Tol-*H*), 7.71 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.36 (td, *J* = 7.5, 1.4 Hz, 1H, Tol-*H*), 7.26-7.21 (m, 1H, Tol-*H*), 7.06 (dt, *J* = 7.5, 1.4 Hz, 1H, Tol-*H*), 3.69-3.61 (m, 4H, OCH_2), 3.29 (ddd, *J* =

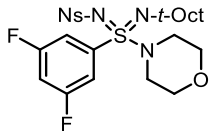
12.3, 6.0, 4.0 Hz, 2H, NCH_2), 3.16 (ddd, J = 12.3, 6.0, 4.0 Hz, 2H, NCH_2), 2.30 (s, 3H, Tol-CH_3), 1.72 (d, J = 14.5 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.66 (d, J = 14.5 Hz, 1H, NC$(CH_3)_2$CH$_a$$H_b$), 1.51 (s, 3H, NC$(CH_3)_a$$(CH_3)_b$), 1.49 (s, 3H, NC$(CH_3)_a$$(CH_3)_b$), 1.04 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.12, 149.10, 138.0, 137.0, 133.6, 132.6, 131.8, 127.5, 126.4, 123.6, 66.4, 60.4, 57.7, 45.3, 32.1, 31.9, 31.8, 31.5, 21.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1527, 1349, 1296, 1257, 1151, 1061, 1034, 919, 734;

HRMS (ESI^+) calcd. for $C_{25}H_{36}N_4O_5S_2Na^+$ $[M+Na]^+$: 559.2019, found: 559.2010.

***N*-((3,5-Difluorophenyl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (127)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **109** (310 mg, 0.63 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (417 mg, 0.70 mmol, 1.10 equiv.), morpholine (121 mg, 1.39 mmol, 2.20 equiv.) and *t*-AmylOH (1.26 mL). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) afforded *sulfondiimidamide* **127** as a white solid (328 mg, 0.59 mmol, 93%).

mp 152-154 °C;

R$_f$ 0.37 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.23 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.88 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.16-7.13 (m, 2H, Ar_F-*H*), 6.96 (tt, J = 8.2, 2.3 Hz, 1H, Ar_F-*H*), 3.69 (app. t, J = 4.7 Hz, 4H, OCH_2), 3.11 (dt, J = 12.0, 4.6 Hz, 2H, NCH_2), 3.04 (dt, J = 12.0, 4.6 Hz, 2H, NCH_2), 1.75 (d, J = 14.5 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.58 (d, J = 14.5 Hz, 1H, NC$(CH_3)_2$CH$_a$$H_b$), 1.58 (s, 3H, NC$(CH_3)_a$$(CH_3)_b$), 1.49 (s, 3H, NC$(CH_3)_a$$(CH_3)_b$), 1.06 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 162.6 (dd, $^{1,3}J_{CF}$ = 254.9, 11.7 Hz), 149.5, 149.1, 141.2 (t, $^{3}J_{CF}$ = 8.2 Hz), 127.5, 124.0, 111.6-111.3 (second-order multiplet), 108.3 (t, $^{2}J_{CF}$ = 25.1 Hz), 66.5, 60.8, 57.5, 47.0, 32.0, 31.90, 31.86, 31.5;

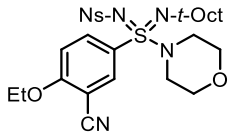
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.22- -105.24 (second-order multiplet);

Note: The second-order multiplet in the ^{13}C and ^{19}F NMR spectra arise due to virtual coupling;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1601, 1529, 1350, 1293, 1257, 1157, 1090, 1066, 920;

HRMS (ESI^+) calcd. for $C_{24}H_{32}F_2N_4O_5S_2Na^+$ $[M+Na]^+$: 581.1674, found: 581.1664.

***N*-((3-Cyano-4-ethoxyphenyl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (128)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **110** (510 mg, 0.97 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (642 mg, 1.07 mmol, 1.10 equiv.), morpholine (186 mg, 2.13 mmol, 2.20 equiv.) and *t*-AmylOH (1.94 mL). The reaction was stirred at 60 °C for 24 h. 0.5 M aq. HCl solution was used to quench the reaction (instead of sat. aq. NaCl solution) and the aqueous layers was extracted with ethyl acetate (instead of CH_2Cl_2). Purification by flash column chromatography (petrol/ethyl acetate, 1:1 to 1:2) afforded *sulfondiimidamide* **128** as a white solid (546 mg, 0.92 mmol, 95%).

mp 183-185 °C;

R_f 0.58 (petrol/ethyl acetate, 2:3);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.23 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.88 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.84-7.78 (m, 2H, Ar_{CN}-*H*), 6.92 (d, J = 8.9 Hz, 1H, Ar_{CN}-*H*), 4.19 (q, J = 7.0 Hz, 2H, OCH_2CH_3), 3.72-3.67 (m, 4H, OCH_2CH_2), 3.10 (dt, J = 12.0, 4.6 Hz, 2H, NCH_2), 3.03 (dt, J = 12.0, 4.6 Hz, 2H, NCH_2), 1.71 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.56 (d,

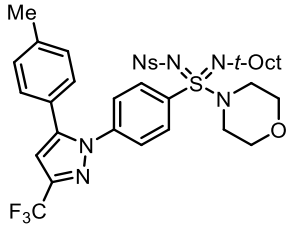
J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.55 (s, 3H, NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.51 (t, J = 7.0 Hz, 3H, OCH$_2$CH_3), 1.48 (s, 3H, NC(CH$_3$)$_a$(CH_3)$_b$), 1.05 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 163.3, 149.5, 149.3, 134.2, 134.1, 129.6, 127.5, 124.0, 114.7, 112.1, 102.8, 66.6, 66.0, 60.6, 57.6, 47.0, 32.1, 31.92, 31.89, 31.5, 14.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 1529, 1349, 1294, 1256, 1152, 1063, 920, 735;

HRMS (ESI$^+$) calcd. for $C_{27}H_{38}N_5O_6S_2^+$ [M+H]$^+$: 592.2258, found: 592.2261.

***N*-(Morpholino(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (129)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **111** (401 mg, 0.59 mmol, 1.00 equiv.), Ca(NTf$_2$)$_2$ (390 mg, 0.65 mmol, 1.10 equiv.), morpholine (112 mg, 1.29 mmol, 2.20 equiv.) and *t*-AmylOH (1.18 mL). The reaction was stirred at 60 °C for 24 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **129** as a white solid (386 mg, 0.52 mmol, 88%).

mp 165-167 °C;

R$_f$ 0.48 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.11 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 7.82 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 7.63 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.37 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.20 (d, J = 8.0 Hz, 2H, Tol-*H*), 7.12 (d, J = 8.0 Hz, 2H, Tol-*H*), 6.72 (s, 1H, HetAr-*H*), 3.65 (app. t, J = 4.5 Hz, 4H, OCH_2), 3.06 (dt, J = 11.8, 4.5 Hz, 2H, NCH_2), 2.99 (dt, J = 11.8, 4.5 Hz, 2H, NCH_2), 2.38 (s, 3H, Tol-CH_3), 1.72 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.58 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.57 (s, 3H, NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.49 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 1.04 (s, 9H, *t*-Bu-*H*);

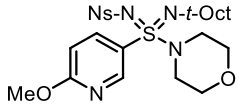
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.4, 149.3, 145.2, 144.1 (q, $^2J_{CF}$ = 38.5 Hz), 142.5, 139.9, 137.2, 129.8, 128.8, 128.7, 127.4, 125.8, 125.2, 123.8, 121.1 (q, $^1J_{CF}$ = 269.3 Hz), 106.5, 66.4, 60.4, 57.5, 46.9, 32.0, 31.81, 31.78, 31.5, 21.3;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -62.4 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1349, 1299, 1236, 1156, 1089, 1062, 918, 733;

HRMS (ESI^+) calcd. for $C_{35}H_{42}F_3N_6O_5S_2^+$ $[M+H]^+$: 747.2605, found: 747.2604.

***N*-((6-Methoxypyridin-3-yl)(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (130)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **112** (290 mg, 0.60 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (394 mg, 0.66 mmol, 1.10 equiv.), morpholine (115 mg, 1.32 mmol, 2.20 equiv.) and *t*-AmylOH (1.20 mL). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **130** as a white solid (307 mg, 0.56 mmol, 93%).

mp 140-142 °C;

R_f 0.44 (petrol/ethyl acetate, 2:1);

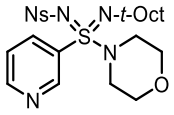
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.29 (d, *J* = 2.6 Hz, 1H, HetAr-*H*), 8.14 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.80 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.77 (dd, *J* = 8.9, 2.6 Hz, 1H, HetAr-*H*), 6.65 (d, *J* = 8.9 Hz, 1H, HetAr-*H*), 3.88 (s, 3H, OCH_3), 3.66 (app. t, *J* = 4.7 Hz, 4H, OCH_2), 3.12 (dt, *J* = 12.0, 4.5 Hz, 2H, NCH_2), 3.04 (dt, *J* = 12.0, 4.5 Hz, 2H, NCH_2), 1.69 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.52 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.45 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.02 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.2, 149.4, 149.3, 148.0, 138.4, 127.5, 126.6, 123.8, 111.0, 66.5, 60.2, 57.5, 54.4, 46.8, 32.1, 31.84, 31.80, 31.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1586, 1528, 1479, 1349, 1298, 1256, 1154, 1089, 1050, 1012, 919;

HRMS (ESI$^+$) calcd. for $C_{24}H_{35}N_5O_6S_2Na^+$ [M+Na]$^+$: 576.1921, found: 576.1915.

***N*-(Morpholino(pyridin-3-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (131)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **113** (230 mg, 0.50 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (330 mg, 0.55 mmol, 1.10 equiv.), morpholine (96 mg, 1.10 mmol, 2.20 equiv.) and *t*-AmylOH (1.00 mL). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:2) afforded *sulfondiimidamide* **131** as a white solid (240 mg, 0.46 mmol, 92%).

mp 126-128 °C;

R$_f$ 0.33 (petrol/ethyl acetate, 1:2);

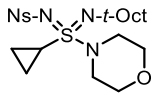
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.74 (dd, *J* = 2.5, 0.8 Hz, 1H, HetAr-*H*), 8.65 (dd, *J* = 4.8, 1.5 Hz, 1H, HetAr-*H*), 8.14 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.95 (ddd, *J* = 8.2, 2.5, 1.5 Hz, 1H, HetAr-*H*), 7.78 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.32 (ddd, *J* = 8.2, 4.8, 0.8 Hz, 1H, HetAr-*H*), 3.67-3.61 (m, 4H, OCH_2), 3.11 (dt, *J* = 12.5, 4.7 Hz, 2H, NCH_2), 3.02 (dt, *J* = 12.5, 4.7 Hz, 2H, NCH_2), 1.70 (d, *J* = 14.5 Hz, 1H, NC$(CH_3)_2$CH_aH$_b$), 1.54 (s, 3H, NC(CH_3)$_a$$(CH_3)_b$), 1.53 (d, *J* = 14.5 Hz, 1H, NC$(CH_3)_2$C$H_a$$H_b$), 1.46 (s, 3H, NC$(CH_3)_a$(C$H_3$)$_b$), 1.01 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 152.8, 149.3, 149.0, 148.5, 135.8, 134.3, 127.3, 123.9, 123.4, 66.4, 60.4, 57.3, 46.8, 32.0, 31.8, 31.7, 31.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1350, 1297, 1257, 1154, 1110, 1089, 1062, 1011, 921, 742;

HRMS (ESI$^+$) calcd. for $C_{23}H_{33}N_5O_5S_2Na^+$ [M+Na]$^+$: 546.1815, found: 546.1808.

***N*-(Cyclopropyl(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (132)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **114** (390 mg, 0.93 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (614 mg, 1.02 mmol, 1.10 equiv.), morpholine (178 mg, 2.04 mmol, 2.20 equiv.) and *t*-AmylOH (1.86 mL). The reaction was stirred at 60 °C for 24 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **132** as a white solid (413 mg, 0.85 mmol, 91%).

mp 125-127 °C;

R$_f$ 0.23 (petrol/ethyl acetate, 2:1);

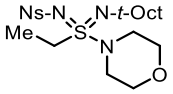
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 3.71-3.62 (m, 4H, OC*H*$_2$), 3.28 (ddd, *J* = 12.0, 6.0, 3.2 Hz, 2H, NC*H*$_2$), 3.19 (ddd, *J* = 12.0, 6.0, 3.2 Hz, 2H, NC*H*$_2$), 2.26 (tt, *J* = 7.6, 4.5 Hz, 1H, SC*H*), 1.44 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.36 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.36 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.29 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.26 (dt, *J* = 5.3, 2.7 Hz, 2H, SCHC*H*$_2$), 1.01-0.95 (m, 1H, $SCHCH_aH_b$), 0.93-0.83 (m, 10H, *t*-Bu-*H*/ $SCHCH_aH_b$);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.5, 149.2, 127.4, 123.9, 66.6, 59.5, 57.8, 47.2, 32.0, 31.7, 31.6, 31.3, 29.2, 7.6, 5.6 (Note: For 2 secondary carbons in cyclopropane ring, 2 peaks were found instead of 1 due to the loss of symmetry caused by chiral sulfur atom);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1349, 1293, 1256, 1149, 1091, 1057, 918, 733;

HRMS (ESI$^+$) calcd. for $C_{21}H_{35}N_4O_5S_2^+$ $[M+H]^+$: 487.2043, found: 487.2045.

***N*-(Ethyl(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (133)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **115** (160 mg, 0.39 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (259 mg, 0.43 mmol, 1.10 equiv.), *t*-AmylOH (0.79 mL) and morpholine (75 mg, 0.86 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 10 h. Ethyl acetate was used for extraction instead of CH_2Cl_2 because of the better aqueous

solubility of this substrate. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 20:1) afforded *sulfondiimidamide* **133** as a colourless oil (96 mg, 0.20 mmol, 52%).

R$_f$ 0.38 (petrol/ethyl acetate, 1:1);

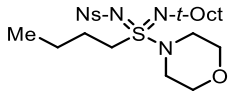
^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.30 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.07 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 3.69-3.60 (m, 4H, OC*H*$_2$), 3.60-3.47 (m, 2H, SC*H*$_2$), 3.27 (t, J = 4.6 Hz, 4H, NC*H*$_2$), 1.56 (d, J = 14.4 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.45 (d, J = 14.4 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.41 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.36 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.20 (t, J = 7.4 Hz, 3H, SCH$_2$C*H*$_3$), 1.01 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 151.3, 150.5, 128.1, 125.2, 67.5, 59.8, 58.0, 50.7, 47.8, 32.5, 32.3, 32.1, 31.8, 9.3;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 1528, 1350, 1256, 1148, 1091, 1066, 924, 739;

HRMS (ESI$^+$) calcd. for $C_{20}H_{34}N_4O_5S_2Na^+$ $[M+Na]^+$: 497.1863, found: 497.1856.

***N*-(Butyl(morpholino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (134)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **116** (216 mg, 0.50 mmol, 1.00 equiv.), Ca(NTf$_2$)$_2$ (328 mg, 0.55 mmol, 1.10 equiv.), *t*-AmylOH (1.0 mL) and morpholine (96 mg, 1.10 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 22 h. Ethyl acetate was used for extraction instead of CH_2Cl_2 because of the better aqueous solubility of this substrate. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) afforded *sulfondiimidamide* **134** as a pale-yellow oil (110 mg, 0.22 mmol, 44%).

R$_f$ 0.23 (CH_2Cl_2);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.30 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.07 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 3.69-3.59 (m, 4H, OC*H*$_2$), 3.57-3.38 (m, 2H, SC*H*$_2$), 3.29-3.23 (m, 4H,

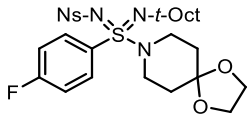
NCH_2), 1.72-1.60 (m, 1H, $SCH_2CH_aH_b$), 1.59-1.50 (m, 2H, $SCH_2CH_aH_b$/$NC(CH_3)_2CH_aH_b$), 1.45 (d, J = 14.4 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.42 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.36 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.34-1.25 (m, 2H, $SCH_2CH_2CH_2$), 1.01 (s, 9H, *t*-Bu-*H*), 0.83 (t, J = 7.4 Hz, 3H, *n*-Bu-CH_3);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 151.4, 150.5, 128.1, 125.2, 67.5, 59.9, 58.0, 55.5, 47.8, 32.5, 32.3, 32.1, 31.9, 26.5, 22.0, 13.9;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1292, 1256, 1148, 1089, 1061, 923, 743, 633;

HRMS (ESI^+) calcd. for $C_{22}H_{38}N_4O_5S_2Na^+$ $[M+Na]^+$: 525.2176, found: 525.2175.

***N*-((4-Fluorophenyl)(1,4-dioxa-8-azaspiro[4.5]decan-8-yl)((2,4,4-trimethylpentan-2-yl)imino)- λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (137)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (220 mg, 0.47 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (307 mg, 0.51 mmol, 1.10 equiv.), *t*-AmylOH (0.94 mL) and 1,4-dioxa-8-azaspiro[4.5]decane (148 mg, 1.03 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **137** as a white solid (254 mg, 0.43 mmol, 92%).

mp 86-88 °C;

R$_f$ 0.45 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.15 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.78 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.65-7.60 (m, 2H, Ar_F-*H*), 7.03-6.97 (m, 2H, Ar_F-*H*), 3.89 (s, 4H, OCH_2), 3.26 (ddd, J = 11.9, 6.5, 4.5 Hz, 2H, NCH_2), 3.19 (ddd, J = 11.9, 6.5, 4.5 Hz, 2H, NCH_2), 1.76-1.66 (m, 5H, NCH_2CH_2/ $NC(CH_3)_2CH_aH_b$), 1.58-1.52 (m, 4H, $NC(CH_3)_2CH_aH_b$/ $NC(CH_3)_a(CH_3)_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.04 (s, 9H, *t*-Bu-*H*);

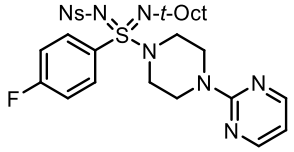
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.9 (d, $^1J_{CF}$ = 255.6 Hz), 149.6, 149.2, 134.3 (d, $^4J_{CF}$ = 3.1 Hz), 130.4 (d, $^3J_{CF}$ = 9.2 Hz), 127.5, 123.7, 116.0 (d, $^2J_{CF}$ = 22.6 Hz), 106.1, 64.6, 60.1, 57.6, 44.9, 34.9, 31.93, 31.85, 31.8, 31.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.6 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1349, 1300, 1226, 1153, 1088, 1040;

HRMS (ESI^+) calcd. for $C_{27}H_{37}FN_4O_6S_2Na^+$ $[M+Na]^+$: 619.2031, found: 619.2027.

***N*-((4-Fluorophenyl)(4-(pyrimidin-2-yl)piperazin-1-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (138)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (86 mg, 0.18 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (120 mg, 0.20 mmol, 1.10 equiv.), *t*-AmylOH (0.36 mL) and 2-(piperazin-1-yl)pyrimidine (66 mg, 0.40 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) afforded *sulfondiimidamide* **138** as a white solid (99 mg, 0.16 mmol, 88%).

mp 176-178 °C;

R_f 0.31 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25 (d, J = 4.8 Hz, 2H, HetAr-*H*), 8.17 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.84 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.69-7.63 (m, 2H, Ar_F-*H*), 7.05-6.98 (m, 2H, Ar_F-*H*), 6.50 (t, J = 4.8 Hz, 1H, HetAr-*H*), 3.90-3.82 (m, 4H, NCH_2), 3.22-3.08 (m, 4H, NCH_2), 1.72 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.58 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.57 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.51 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.06 (s, 9H, *t*-Bu-*H*);

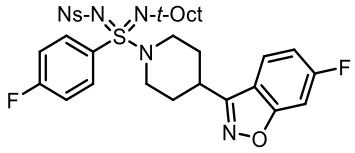
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.0 (d, $^1J_{CF}$ = 256.1 Hz), 161.3, 157.8, 149.5, 149.3, 133.7 (d, $^4J_{CF}$ = 3.1 Hz), 130.6 (d, $^3J_{CF}$ = 9.2 Hz), 127.5, 123.8, 116.1 (d, $^2J_{CF}$ = 22.7 Hz), 110.9, 60.3, 57.6, 46.7, 43.6, 32.0, 31.93, 31.87, 31.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.2 (tt, J = 8.0, 4.8 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1585, 1528, 1486, 1349, 1300, 1260, 1227, 1153, 1086, 1053, 950;

HRMS (ESI^+) calcd. for $C_{28}H_{37}FN_7O_4S_2^+$ $[M+H]^+$: 618.2327, found: 618.2319.

***N*-((4-(6-Fluorobenzo[*d*]isoxazol-3-yl)piperidin-1-yl)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (139)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (180 mg, 0.38 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (251 mg, 0.42 mmol, 1.10 equiv.), *t*-AmylOH (0.76 mL) and 6-fluoro-3-(4-piperidinyl)-1,2-benzisoxazole (184 mg, 0.84 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) afforded *sulfondiimidamide* **139** as a white solid (220 mg, 0.33 mmol, 86%).

mp 78-80 °C;

R$_f$ 0.77 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.16 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.82 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.73-7.68 (m, 2H, Ar_F-*H*), 7.54 (dd, J = 8.7, 5.0 Hz, 1H, HetAr-*H*), 7.21 (dd, J = 8.4, 2.1 Hz, 1H, HetAr-*H*), 7.07-7.01 (m, 3H, Ar_F-*H*/HetAr-*H*), 4.09-4.02 (m, 1H, NC*H*$_a$H$_b$), 3.89-3.83 (m, 1H, NCH$_a$*H*$_b$), 3.10 (tt, J = 11.0, 3.9 Hz, 1H, HetAr-C*H*), 2.83 (td, J = 11.5, 2.5 Hz, 1H, NC*H*$_a$H$_b$), 2.53 (td, J = 11.5, 2.5 Hz, 1H, NCH$_a$*H*$_b$), 2.21-2.11 (m, 2H, NCH_2CH_2), 2.09-1.92 (m, 2H, NCH_2CH_2), 1.70 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.56 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.56 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.50 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.05 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.9 (d, $^1J_{CF}$ = 255.9 Hz), 164.3 (d, $^1J_{CF}$ = 251.5 Hz), 163.9 (d, $^3J_{CF}$ = 13.5 Hz), 159.9, 149.6, 149.2, 134.2 (d, $^4J_{CF}$ = 2.3 Hz), 130.5 (d, $^3J_{CF}$

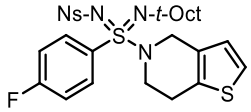
= 9.1 Hz), 127.5, 123.8, 122.0 (d, $^{3}J_{CF}$ = 11.2 Hz), 117.1, 116.1 (d, $^{2}J_{CF}$ = 22.5 Hz), 112.8 (d, $^{2}J_{CF}$ = 25.5 Hz), 97.6 (d, $^{2}J_{CF}$ = 26.9 Hz), 60.1, 57.6, 47.8, 44.9, 33.5, 31.90, 31.86, 31.8, 31.5, 30.5, 29.8 (Note: For 4 secondary carbons in piperidine ring, 4 peaks were found instead of 2 due to the loss of symmetry caused by chiral sulfur atom);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.3 (tt, *J* = 8.0, 4.9 Hz), -108.8 (td, *J* = 8.6, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1298, 1269, 1229, 1153, 1087, 1050, 913, 839, 736;

HRMS (ESI^+) calcd. for $C_{32}H_{38}F_2N_5O_5S_2^+$ $[M+H]^+$: 674.2277, found: 674.2272.

***N*-((6,7-Dihydrothieno[3,2-c]pyridin-5(4*H*)-yl)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (140)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (115 mg, 0.24 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (160 mg, 0.27 mmol, 1.10 equiv.), *t*-AmylOH (0.48 mL) and 4,5,6,7-tetrahydrothieno[3,2-*c*]pyridine (74 mg, 0.53 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 3:1) afforded *sulfondiimidamide* **140** as a pale-yellow oil (117 mg, 0.20 mmol, 81%).

R$_f$ 0.45 (petrol/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.13 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.78 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.74 -7.68 (m, 2H, Ar_F-*H*), 7.12 (d, *J* = 5.2 Hz, 1H, HetAr-*H*), 7.04-6.97 (m, 2H, Ar_F-*H*), 6.68 (d, *J* = 5.2 Hz, 1H, HetAr-*H*), 4.35 (d, *J* = 15.1 Hz, 1H, N-C*H*$_a$H$_b$-HetAr), 4.20 (d, *J* = 15.1 Hz, 1H, N-CH$_a$*H*$_b$-HetAr), 3.59 (ddd, *J* = 12.0, 6.8, 4.9 Hz, 1H, NC*H*$_a$H$_b$CH$_2$), 3.50 (dt, *J* = 12.0, 5.5 Hz, 1H, NCH$_a$*H*$_b$CH$_2$), 2.94-2.73 (m, 2H, NCH$_2$C*H*$_2$), 1.68 (d, *J* = 14.5 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.57 (d, *J* = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.54 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.46 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.06 (s, 9H, *t*-Bu-*H*);

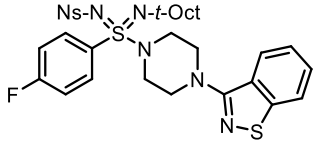
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.0 (d, $^1J_{CF}$ = 256.2 Hz), 149.5, 149.2, 135.0 (d, $^4J_{CF}$ = 3.1 Hz), 132.8, 131.1, 130.7 (d, $^3J_{CF}$ = 9.2 Hz), 127.5, 124.8, 124.2, 123.7, 116.0 (d, $^2J_{CF}$ = 22.6 Hz), 60.2, 57.6, 46.5, 44.1, 31.94, 31.90, 31.8, 31.6, 25;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.2 (tt, *J* = 8.0, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 2889, 1383, 1252, 1153, 1088, 955;

HRMS (ESI^+) calcd. for $C_{27}H_{33}FN_4O_4S_3Na^+$ $[M+Na]^+$: 615.1540, found: 615.1536.

***N*-((4-(Benzo[*d*]isothiazol-3-yl)piperazin-1-yl)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)- λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (141)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (180 mg, 0.38 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (251 mg, 0.42 mmol, 1.10 equiv.), *t*-AmylOH (0.76 mL) and 3-(piperazin-1-yl)benzo[*d*]isothiazole (184 mg, 0.84 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) afforded *sulfondiimidamide* **141** as a pale-yellow solid (238 mg, 0.35 mmol, 93%).

mp 66-68 °C;

R_f 0.54 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.20 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.86 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.81 (dt, *J* = 8.1, 1.0 Hz, 1H, HetAr-*H*), 7.79 (dt, *J* = 8.1, 1.0 Hz, 1H, HetAr-*H*), 7.75-7.70 (m, 2H, Ar_F-*H*), 7.47 (ddd, *J* = 8.1, 7.0, 1.1 Hz, 1H, HetAr-*H*), 7.34 (ddd, *J* = 8.1, 7.0, 1.1 Hz, 1H, HetAr-*H*), 7.10-7.05 (m, 2H, Ar_F-*H*), 3.60 (ddd, *J* = 12.7, 6.5, 3.3 Hz, 2H, NCH_2), 3.54 (ddd, *J* = 12.7, 6.5, 3.3 Hz, 2H, NCH_2), 3.39 (ddd, *J* = 10.0, 6.4, 3.3 Hz, 2H, NCH_2), 3.33 (ddd, *J* = 10.0, 6.4, 3.3 Hz, 2H, NCH_2), 1.75 (d, *J* = 14.5 Hz, 1H,

$NC(CH_3)_2CH_aH_b$), 1.60 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.60 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.08 (s, 9H, *t*-Bu-*H*);

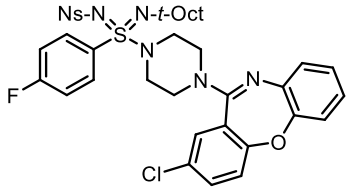
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.0 (d, $^1J_{CF}$ = 256.0 Hz), 163.0, 152.9, 149.5, 149.3, 133.8 (d, $^4J_{CF}$ = 3.1 Hz), 130.6 (d, $^3J_{CF}$ = 9.2 Hz), 127.9, 127.6, 127.5, 124.3, 123.8, 123.5, 120.8, 116.1 (d, $^2J_{CF}$ = 22.6 Hz), 60.3, 57.6, 49.9, 46.5, 32.0, 31.94, 31.87, 31.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.1 (tt, *J* = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1489, 1383, 1349, 1302, 1261, 1230, 1153, 1087, 1052, 925;

HRMS (ESI^+) calcd. for $C_{31}H_{38}FN_6O_4S_3^+$ $[M+H]^+$: 673.2095, found: 673.2093.

***N*-((4-(2-Chlorodibenzo[*b*,*f*][1,4]oxazepin-11-yl)piperazin-1-yl)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (142)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (238 mg, 0.50 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (332 mg, 0.55 mmol, 1.10 equiv.), *t*-AmylOH (1.0 mL) and Amoxapine (345 mg, 1.10 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 24 h. Purification by flash column chromatography (petrol/ethyl acetate, 5:1 to 4:1) afforded *sulfondiimidamide* **142** as a pale-yellow solid (350 mg, 0.46 mmol, 91%).

mp 68-70 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.19 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.85 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.72 -7.66 (m, 2H, Ar-*H*), 7.39 (dd, *J* = 8.6, 2.6 Hz, 1H, Ar-*H*), 7.23-7.01 (m, 8H, Ar-*H*), 3.59 (app. br. s, 4H, NCH_2), 3.25 (app. br. s, 4H, NCH_2), 1.74 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.59 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.59 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.53 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.08 (s, 9H, *t*-Bu-*H*);

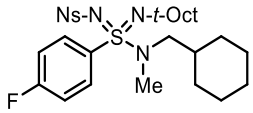
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.1 (d, $^1J_{CF}$ = 256.3 Hz), 159.5, 158.6, 151.9, 149.5, 149.3, 139.1, 133.9 (d, $^4J_{CF}$ = 2.3 Hz), 133.3, 130.6, 130.5 (d, $^3J_{CF}$ = 9.5 Hz), 128.9, 127.5, 127.1, 126.0, 125.6, 124.3, 123.9, 123.1, 120.3, 116.3 (d, $^2J_{CF}$ = 22.6 Hz), 60.4, 57.6, 47.6, 46.5, 32.02, 31.96, 31.9, 31.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.9 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 2888, 1383, 1251, 1153, 1086, 954;

HRMS (ESI^+) calcd. for $C_{37}H_{41}ClFN_6O_5S_2^+$ $[M+H]^+$: 767.2247, found: 767.2237.

***N*-(((Cyclohexylmethyl)(methyl)amino)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)- λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (143)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (153 mg, 0.32 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (213 mg, 0.36 mmol, 1.10 equiv.), *t*-AmylOH (0.65 mL) and 1-cyclohexyl-*N*-methylmethanamine (90 mg, 0.71 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 36 h. Purification by flash column chromatography (petrol/ethyl acetate, 5:1 to 4:1) afforded *sulfondiimidamide* **143** as a pale-yellow solid (180 mg, 0.31 mmol, 96%).

mp 87-89 °C;

R$_f$ 0.67 (petrol/ethyl acetate, 4:1);

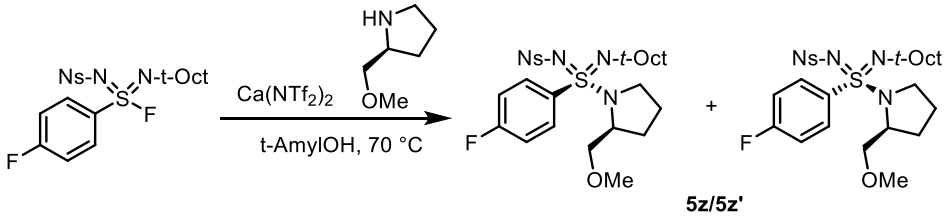
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.17 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.77 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.70-7.64 (m, 2H, Ar_F-*H*), 7.06-6.98 (m, 2H, Ar_F-*H*), 3.32 (dd, *J* = 13.0, 8.0 Hz, 1H, NCH_aH_b), 2.87 (dd, *J* = 13.0, 6.4 Hz, 1H, NCH_aH_b), 2.56 (s, 3H, NCH_3), 1.77-1.61 (m, 6H, cyclohex-*H*/$NC(CH_3)_2CH_aH_b$), 1.59-1.51 (m, 1H, cyclohex-*H*), 1.57 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.54 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.46 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.26-1.12 (m, 3H, cyclohex-*H*), 1.05 (s, 9H, *t*-Bu-*H*), 0.95-0.83 (m, 2H, cyclohex-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.8 (d, $^1J_{CF}$ = 255.4 Hz), 149.9, 149.2, 135.4 (d, $^4J_{CF}$ = 3.2 Hz), 130.7 (d, $^3J_{CF}$ = 9.2 Hz), 127.3, 123.7, 115.9 (d, $^2J_{CF}$ = 22.6 Hz), 59.9, 58.9, 57.6, 37.0, 34.7, 31.93, 31.90, 31.88, 31.7, 31.3, 31.0, 26.4, 25.9, 25.8 (Note: For 5 secondary carbons in cyclohexane ring, 5 peaks were found instead of 3 due to the loss of symmetry caused by chiral sulfur atom);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.0 (tt, J = 8.1, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 1528, 1349, 1230, 1152, 1088, 1051;

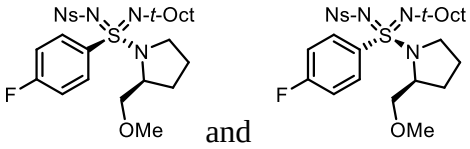
HRMS (ESI^+) calcd. for $C_{28}H_{41}FN_4O_4S_2Na^+$ $[M+Na]^+$: 603.2445, found: 603.2435.



Sulfondiimidamides **144** and **145** were prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (380 mg, 0.80 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (530 mg, 0.88 mmol, 1.10 equiv.), *t*-AmylOH (1.60 mL) and (*S*)-(+)-2-(methoxymethyl)pyrrolidine (203 mg, 1.76 mmol, 2.20 equiv.). The reaction was stirred at 70 °C for 36 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 20:1 to 15:1) afforded *diastereoisomer* **144** as a white solid (204 mg, 0.36 mmol, 45%) and *diastereoisomer* **145** as a colourless oil (206 mg, 0.36 mmol, 45%). (Sulfur stereochemistry of these two compounds remains unknown)

***N*-((*R*)-(4-Fluorophenyl)((*S*)-2-(methoxymethyl)pyrrolidin-1-yl)((2,4,4-trimethylpentan-2-yl)imino)- λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide**

***N*-((*S*)-(4-Fluorophenyl)((*S*)-2-(methoxymethyl)pyrrolidin-1-yl)((2,4,4-trimethylpentan-2-yl)imino)- λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide**



Diastereoisomer 1 (Sulfur stereochemistry is unknown)

mp 108-110 °C;

R$_f$ 0.60 (CH_2Cl_2/ethyl acetate, 15:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.08 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.82-7.75 (m, 2H, Ar_F-*H*), 7.54 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.03-6.96 (m, 2H, Ar_F-*H*), 4.32 (ddt, J = 8.0, 5.5, 2.8 Hz, 1H, NC*H*), 3.47 (dd, J = 9.3, 5.4 Hz, 1H, CH_aH$_b$OMe), 3.34 (dd, J = 9.3, 2.6 Hz, 1H, CH$_a$$H_b$OMe), 3.23-3.15 (m, 1H, NCH_aH$_b$), 3.20 (s, 3H, OCH_3), 2.73-2.67 (m, 1H, NCH$_a$$H_b$), 2.03-1.82 (m, 4H, Alk-*H*), 1.68 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.62 (s, 3H, NC(CH_3)$_a$(CH$_3$)$_b$), 1.58 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.49 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 1.04 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, (CD$_3$)$_2$CO): δ (ppm) = 165.7 (d, $^1J_{CF}$ = 252.7 Hz), 150.8, 150.0, 137.0 (d, $^4J_{CF}$ = 2.9 Hz), 132.5 (d, $^3J_{CF}$ = 9.5 Hz), 128.0, 124.5, 116.5 (d, $^2J_{CF}$ = 23.0 Hz), 75.3, 61.0, 59.9, 59.0, 58.1, 46.9, 32.6, 32.4, 32.3, 32.2, 29.7, 24.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.1 (tt, J = 8.0, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1718, 1529, 1489, 1349, 1300, 1228, 1155, 1088, 1052, 1030, 997;

HRMS (ESI$^+$) calcd. for $C_{26}H_{38}FN_4O_5S_2^+$ $[M+H]^+$: 569.2262, found: 569.2264;

$[\alpha]_D^{25}$: -126.4° (c = 1.0, $CHCl_3$).

Diastereoisomer 2 (Sulfur stereochemistry is unknown)

R$_f$ 0.46 (CH_2Cl_2/ethyl acetate, 15:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.14 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.77 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.69-7.63 (m, 2H, Ar_F-*H*), 7.00-6.94 (m, 2H, Ar_F-*H*), 4.14 (tt, J = 7.2, 3.6 Hz, 1H, NC*H*), 3.57 (dd, J = 9.2, 3.3 Hz, 1H, CH_aH$_b$OMe), 3.38 (dd, J = 9.2, 6.8 Hz, 1H, CH$_a$$H_b$OMe), 3.28 (s, 3H, OC$H_3$), 3.17-3.10 (m, 1H, NC$H_aH_b$), 3.00-2.93 (m, 1H, NH$_a$$H_b$), 1.93-1.78 (m, 3H, Alk-*H*), 1.67 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.56 (s, 3H,

NC(CH_3)$_a$(CH$_3$)$_b$), 1.55 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.47 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 1.46-1.39 (m, 1H, Alk-*H*), 1.03 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.7 (d, $^1J_{CF}$ = 255.4 Hz), 149.9, 149.1, 136.3 (d, $^4J_{CF}$ = 3.1 Hz), 130.4 (d, $^3J_{CF}$ = 9.2 Hz), 127.3, 123.7, 115.8 (d, $^2J_{CF}$ = 22.6 Hz), 75.4, 62.9, 60.1, 59.0, 57.5, 47.7, 31.9, 31.8, 31.4, 31.3, 28.8, 24.5;

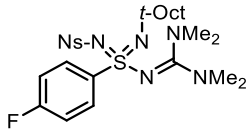
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.9 (tt, J = 8.0, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1529, 1489, 1350, 1300, 1229, 1154, 1089, 1056, 1030;

HRMS (ESI^+) calcd. for $C_{26}H_{38}FN_4O_5S_2^+$ $[M+H]^+$: 569.2262, found: 569.2256;

$[\alpha]_D^{25}$: +17.0° (c = 1.0, $CHCl_3$).

***N*-(((Bis(dimethylamino)methylene)amino)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (146)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (132 mg, 0.28 mmol, 1.00 equiv.), Ca(NTf$_2$)$_2$ (184 mg, 0.31 mmol, 1.10 equiv.), *t*-AmylOH (0.70 mL) and 1,1,3,3-tetramethylguanidine (97 mg, 0.84 mmol, 3.00 equiv.). The reaction was stirred at 80 °C for 24 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1 to 1:3) afforded *sulfondiimidamide* **146** as a colourless oil (135 mg, 0.24 mmol, 85%).

R$_f$ 0.50 (petrol/ethyl acetate, 1:2);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.12 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 7.91-7.84 (m, 4H, Ar$_{Ns}$-*H*/Ar$_F$-*H*), 6.94-6.87 (m, 2H, Ar$_F$-*H*), 2.91 (s, 12H, N(CH_3)$_2$), 1.43 (d, J = 14.4 Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.34 (d, J = 14.4 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.27 (s, 3H, NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.20 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 0.83 (s, 9H, *t*-Bu-*H*);

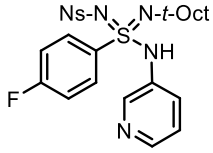
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 163.8 (d, $^1J_{CF}$ = 252.6 Hz), 161.5, 151.4, 148.7, 143.8 (d, $^4J_{CF}$ = 2.5 Hz), 129.0 (d, $^3J_{CF}$ = 8.8 Hz), 127.6, 123.3, 114.9 (d, $^2J_{CF}$ = 22.3 Hz), 59.3, 57.8, 41.1, 31.8, 31.7, 31.6, 31.3;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -108.6 (tt, J = 8.6, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1521, 1396, 1348, 1218, 1143, 1088, 1039, 729;

HRMS (ESI^+) calcd. for $C_{25}H_{38}FN_6O_4S_2^+$ $[M+H]^+$: 569.2374, found: 569.2370.

***N*-((4-Fluorophenyl)(pyridin-3-ylamino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (147)**



Prepared according to **General Procedure H** using sulfondiimidoyl fluoride **102** (146 mg, 0.31 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (205 mg, 0.34 mmol, 1.10 equiv.), *t*-AmylOH (0.62 mL) and 3-aminopyridine (64 mg, 0.68 mmol, 2.20 equiv.). The reaction was stirred at 60 °C for 30 h. Purification by flash column chromatography (petrol/ethyl acetate, 1:1) afforded *sulfondiimidamide* **147** as a pale-yellow oil (136 mg, 0.25 mmol, 81%).

R$_f$ 0.25 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.47 (dd, J = 2.7, 0.7 Hz, 1H, HetAr-*H*), 8.23-8.18 (m, 2H, Ar_F-*H*), 8.15 (dd, J = 4.8, 1.4 Hz, 1H, HetAr-*H*), 7.97 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.82 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.44 (ddd, J = 8.2, 2.7, 1.4 Hz, 1H, HetAr-*H*), 7.23-7.16 (m, 2H, Ar_F-*H*), 7.09 (ddd, J = 8.2, 4.8, 0.7 Hz, 1H, HetAr-*H*), 6.11 (br. s, 1H, N*H*), 1.41(d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.37 (d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.16 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.10 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.85 (s, 9H, *t*-Bu-*H*);

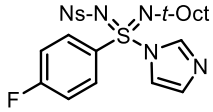
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.7 (d, $^1J_{CF}$ = 258.0 Hz), 149.5, 148.0, 143.5, 142.0, 140.2, 136.2 (d, $^4J_{CF}$ = 3.3 Hz), 131.6 (d, $^3J_{CF}$ = 9.5 Hz), 130.9, 128.2, 123.9, 123.6, 116.7 (d, $^2J_{CF}$ = 22.8 Hz), 61.6, 56.5, 31.6, 31.5, 29.3, 28.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -103.1 (tt, J = 8.0, 4.8 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1305, 1235, 1156, 1087, 733;

HRMS (ESI^+) calcd. for $C_{25}H_{31}FN_5O_4S_2^+$ $[M+H]^+$: 548.1796, found: 548.1792.

_N_-((4-Fluorophenyl)(1_H_-imidazol-1-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (148)



Sulfondiimidoyl fluoride **102** (735 mg, 1.55 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (1.02 g, 1.71 mmol, 1.10 equiv.) and imidazole (633 mg, 9.30 mmol, 6.0 equiv.) were added in an oven-dried 25 mL round-bottom flask and dissolved in anhydrous *t*-AmylOH (3.10 mL). The reaction was sealed and stirred at 65 °C for 12 h. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1 to 1:2) without an aqueous workup to afford *sulfondiimidamide* **148** as a white solid (710 mg, 1.36 mmol, 88%).

Note:

Continuous monitoring of this reaction is important as the desired product tends to hydrolyse under this reaction conditions. 12 h seems to maximise the yield with only around 5% of hydrolysed product (shown in ^{19}F NMR). Extended reaction times led to larger amounts of hydrolysed product.

mp 160-162 °C;

R$_f$ 0.62 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.20 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.04 (t, J = 1.1 Hz, 1H, HetAr-*H*), 7.77 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.61-7.57 (m, 2H, Ar_F-*H*), 7.13 (t, J = 1.5 Hz, 1H, HetAr-*H*), 7.09-7.03 (m, 3H, Ar_F-*H*/HetAr-*H*), 1.76 (d, J = 14.8 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.62 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.59 (d, J = 14.8 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.33 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.08 (s, 9H, *t*-Bu-*H*);

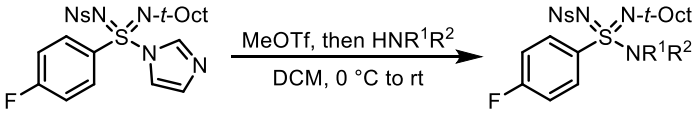
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.7 (d, $^1J_{CF}$ = 259.3 Hz), 149.8, 148.3, 137.9, 135.1 (d, $^4J_{CF}$ = 3.2 Hz), 131.6, 130.3 (d, $^3J_{CF}$ = 9.8 Hz), 127.5, 124.1, 117.6, 116.8 (d, $^2J_{CF}$ = 23.1 Hz), 63.1, 57.2, 31.9, 31.8, 31.3, 30.9;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -101.7 (tt, J = 7.7, 4.8 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1530, 1350, 1305, 1158, 1085, 1024, 735;

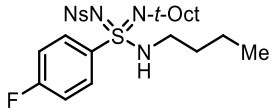
HRMS (ESI^+) calcd. for $C_{23}H_{28}FN_5O_4S_2Na^+$ $[M+Na]^+$: 544.1459, found: 544.1461.

6.3.5 General Procedure I for Sulfondiimidamide Synthesis



An oven-dried round-bottom flask containing sulfondiimidamide **148** (1.00 equiv.) was sealed and subjected to three N_2 evacuation/refill cycles before anhydrous CH_2Cl_2 (0.3 M) was added. The solution was cooled to 0 °C before MeOTf (1.05 equiv.) was added. The reaction was warmed to room temperature and stirred for 30 min. Then amine (2.10 equiv.) was added and the reaction was stirred at room temperature for another 30 min before being quenched with sat. aq. NaCl solution. CH_2Cl_2 was added and the organic layer was separated. The aqueous layers were extracted with CH_2Cl_2 twice. The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography to afford the desire sulfondiimidamide.

***N*-((Butylamino)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (149)**



An oven-dried 10 mL round-bottom flask containing sulfondiimidamide **148** (107 mg, 0.21 mmol, 1.00 equiv.) was sealed and subjected to three N_2 evacuation/refill cycles before anhydrous CH_2Cl_2 (0.70 mL) was added. The solution was cooled to 0 °C before MeOTf (25 µL, 0.22 mmol, 1.05 equiv.) was added. The reaction was warmed to room temperature and stirred for 30 min. Then *n*-butyl amine (32 mg, 0.43 mmol, 2.10 equiv.) was added and the

reaction was stirred at room temperature for another 30 min before being quenched with sat. aq. NaCl solution (50 mL). CH_2Cl_2 (20 mL) was added and the organic layer was separated. The aqueous layers were extracted with CH_2Cl_2 (2 × 20 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1) to afford *sulfondiimidamide* **149** as a white solid (105 mg, 0.20 mmol, 97%).

mp 81-83 °C;

R$_f$ 0.63 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.13 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.85-7.78 (m, 4H, Ar_{Ns}-*H*/Ar_F-*H*), 7.03- 6.97 (m, 2H, Ar_F-*H*), 5.77 (br. s, 1H, N*H*), 2.98 (dt, J = 12.2, 7.3 Hz, 1H, NHC*H*$_a$H$_b$), 2.64 (dt, J = 12.2, 7.3 Hz, 1H, NHCH$_a$*H*$_b$), 1.64 (d, J = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.56-1.43 (m, 9H, $NC(CH_3)_2CH_aH_b$/$NC(CH_3)_2$/$NHCH_2CH_2$), 1.33-1.23 (m, 2H, $NHCH_2CH_2CH_2$), 1.02 (s, 9H, *t*-Bu-*H*), 0.84 (t, J = 7.3 Hz, 3H, *n*-Bu-C*H*$_3$);

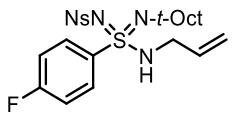
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.9 (d, $^1J_{CF}$ = 255.9 Hz), 149.3, 149.2, 135.4 (d, $^4J_{CF}$ = 2.0 Hz), 130.7 (d, $^3J_{CF}$ = 9.2 Hz), 127.7, 123.7, 116.0 (d, $^2J_{CF}$ = 22.7 Hz), 60.2, 57.6, 41.6, 31.87, 31.86, 31.6, 31.5, 31.3, 20.1, 13.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.5 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1348, 1290, 1268, 1233, 1146, 1091, 1025, 1006, 731;

HRMS (ESI^+) calcd. for $C_{24}H_{36}FN_4O_4S_2^+$ $[M+H]^+$: 527.2157, found: 527.2156.

***N*-((Allylamino)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (150)**



Prepared according to **General Procedure I** using sulfondiimidamide **148** (96 mg, 0.18 mmol, 1.00 equiv.), CH_2Cl_2 (0.60 mL), MeOTf (22 µL, 0.19 mmol, 1.05 equiv.) and

allylamine (22 mg, 0.39 mmol, 2.10 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 3:1) afforded *sulfondiimidamide* **150** as a white solid (75 mg, 0.15 mmol, 80%).

mp 95-97 °C;

R_f 0.43 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.13 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.88-7.78 (m, 2H, Ar_F-*H*), 7.81 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.05-6.98 (m, 2H, Ar_F-*H*), 6.15-5.50 (m, 2H, N*H*/C*H*=CH_aH_b), 5.22 (d, J = 17.0 Hz, 1H, CH=C*H*$_a$H$_b$), 5.14 (dd, J = 10.3, 1.3 Hz, 1H, CH=CH_aH_b), 3.74-3.57 (m, 1H, NC*H*$_a$H$_b$), 3.35 (app. br. s, 1H, NCH_a*H*$_b$), 1.67-1.37 (m, 8H, $NC(CH_3)_2CH_2$/$NC(CH_3)_2$), 1.01 (s, 9H, *t*-Bu-*H*);

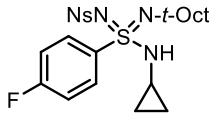
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.0 (d, $^1J_{CF}$ = 256.1 Hz), 149.3, 149.2, 135.5, 132.6, 130.7 (d, $^3J_{CF}$ = 9.3 Hz), 127.7, 123.7, 118.1, 116.1 (d, $^2J_{CF}$ = 22.7 Hz), 60.4, 57.5, 44.3, 31.9, 31.8, 31.2;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.1 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 1528, 1349, 1230, 1148, 1088, 1004, 731;

HRMS (ESI^+) calcd. for $C_{23}H_{31}FN_4O_4S_2Na^+$ $[M+Na]^+$: 533.1663, found: 533.1660.

***N*-((Cyclopropylamino)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (151)**



Prepared according to **General Procedure I** using sulfondiimidamide **148** (98 mg, 0.19 mmol, 1.00 equiv.), CH_2Cl_2 (0.62 mL), MeOTf (22 µL, 0.20 mmol, 1.05 equiv.) and cyclopropylamine (23 mg, 0.39 mmol, 2.10 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 3:1) afforded *sulfondiimidamide* **151** as a pale-yellow solid (89 mg, 0.17 mmol, 93%).

mp 88-90 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.18 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.93-7.87 (m, 2H, Ar_F-*H*), 7.85 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.09-7.02 (m, 2H, Ar_F-*H*), 6.40-5.12 (br. s, 1H, N*H*), 2.47 (app. br. s, 1H, NHC*H*), 1.66 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.58 (d, J = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.50 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.46 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.03 (s, 9H, *t*-Bu-*H*), 0.66-0.53 (m, 2H, $NHCHCH_2$), 0.50-0.41 (m, 1H, $NHCHCH_2$), 0.27 (app. br. s, 1H, $NHCHCH_2$);

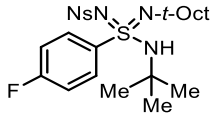
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.0 (d, $^1J_{CF}$ = 256.0 Hz), 149.4, 149.0, 136.2 (d, $^4J_{CF}$ = 2.0 Hz), 131.0 (d, $^3J_{CF}$ = 9.3 Hz), 127.7, 123.7, 115.9 (d, $^2J_{CF}$ = 22.7 Hz), 60.3, 57.3, 31.88, 31.85, 31.2, 25.0, 6.3, 1.1 (Note: For 2 secondary carbons in cyclopropane ring, 2 peaks were found instead of 1 due to the loss of symmetry caused by chiral sulfur atom);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.3 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 1383, 1252, 1149, 1088, 955;

HRMS (ESI^+) calcd. for $C_{23}H_{31}FN_4O_4S_2Na^+$ $[M+Na]^+$: 533.1663, found: 533.1656.

***N*-((*tert*-Butylamino)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (152)**



Prepared according to **General Procedure I** using sulfondiimidamide **148** (97 mg, 0.19 mmol, 1.00 equiv.), CH_2Cl_2 (0.62 mL), MeOTf (22 µL, 0.20 mmol, 1.05 equiv.) and *tert*-butylamine (29 mg, 0.39 mmol, 2.10 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 3:1) afforded *sulfondiimidamide* **152** as a white solid (80 mg, 0.15 mmol, 82%).

mp 106-108 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.22 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.98-7.94 (m, 2H, Ar_F-*H*), 7.90 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.08-7.03 (m, 2H, Ar_F-*H*), 6.06 (br. s, 1H, N*H*), 1.66-1.57 (m, 2H, $NC(CH_3)_2CH_2$), 1.48-1.23 (m, 15H, $NC(CH_3)_2$/*t*-Bu-*H*), 1.00 (s, 9H, *t*-Bu-*H*);

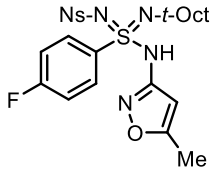
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.9 (d, $^{1}J_{CF}$ = 255.5 Hz), 149.6, 149.4, 140.2, 130.6 (d, $^{3}J_{CF}$ = 9.3 Hz), 127.5, 123.9, 115.9 (d, $^{2}J_{CF}$ = 22.6 Hz), 60.8, 57.3, 56.4, 31.9, 31.8, 31.1, 30.6;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.4 (tt, J = 8.2, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1531, 1348, 1286, 1227, 1144, 1091, 1045, 965, 744;

HRMS (ESI^+) calcd. for $C_{24}H_{35}FN_4O_4S_2Na^+$ $[M+Na]^+$: 549.1976, found: 549.1974.

***N*-((4-Fluorophenyl)((5-methylisoxazol-3-yl)amino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (153)**



Prepared according to **General Procedure I** using sulfondiimidamide **148** (113 mg, 0.22 mmol, 1.00 equiv.), CH_2Cl_2 (0.72 mL), MeOTf (26 µL, 0.23 mmol, 1.05 equiv.) and a solution of 3-amino-5-methylisoxazole (45 mg, 0.46 mmol, 2.10 equiv) in CH_2Cl_2 (0.72 mL). Purification by flash column chromatography (petrol/ethyl acetate, 3:1) afforded *sulfondiimidamide* **153** as a white solid (98 mg, 0.18 mmol, 82%).

mp 132-134 °C;

R$_f$ 0.33 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25-8.18 (m, 2H, Ar_F-*H*), 8.10 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.92 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.26-7.19 (m, 2H, Ar_F-*H*), 5.58 (d, J = 0.9 Hz, 1H, HetAr-*H*), 5.53 (br. s, 1H, N*H*), 2.21 (d, J = 0.9 Hz, 3H, HetAr-CH_3), 1.47 (d, J = 14.9

Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.41 (d, J = 14.9 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.22 (s, 3H, NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.14 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 0.93 (s, 9H, *t*-Bu-*H*);

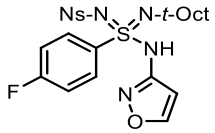
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 169.4, 165.8 (d, $^1J_{CF}$ = 257.9 Hz), 160.9, 149.5, 148.3, 135.9 (d, $^4J_{CF}$ = 3.2 Hz), 131.7 (d, $^3J_{CF}$ = 9.5 Hz), 128.4, 123.5, 116.7 (d, $^2J_{CF}$ = 22.9 Hz), 98.5, 62.0, 56.6, 31.7, 31.6, 29.3, 28.6, 12.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -103.1 (tt, J = 8.6, 4.8 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 2888, 1383, 1251, 1154, 1089, 955;

HRMS (ESI$^+$) calcd. for $C_{24}H_{31}FN_5O_5S_2^+$ [M+H]$^+$: 552.1745, found:552.1736.

***N*-((4-Fluorophenyl)(isoxazol-3-ylamino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (154)**



Prepared according to **General Procedure I** using sulfondiimidamide **148** (162 mg, 0.31 mmol, 1.00 equiv.), CH_2Cl_2 (1.03 mL), MeOTf (37 µL, 0.33 mmol, 1.05 equiv.) and 3-aminoisoxazole (55 mg, 0.65 mmol, 2.10 equiv.). Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) afforded *sulfondiimidamide* **154** as a white solid (158 mg, 0.29 mmol, 95%).

mp 118-120 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25-8.19 (m, 2H, Ar$_F$-*H*), 8.09 (d, J = 8.8 Hz, 2H, Ar$_{Ns}$-*H*), 8.05 (d, J = 1.7 Hz, 1H, HetAr-*H*), 7.91 (d, J = 8.8 Hz, 2H, Ar$_{Ns}$-*H*), 7.25-7.19 (m, 2H, Ar$_F$-*H*), 6.01 (d, J = 1.6 Hz, 1H, HetAr-*H*), 5.66 (s, 1H, N*H*), 1.45 (d, J = 14.9 Hz, 1H, NC(CH$_3$)$_2$CH_aH$_b$), 1.40 (d, J = 14.9 Hz, 1H, NC(CH$_3$)$_2$CH$_a$$H_b$), 1.19 (s, 3H, NC(C$H_3$)$_a$(CH$_3$)$_b$), 1.13 (s, 3H, NC(CH$_3$)$_a$(C$H_3$)$_b$), 0.90 (s, 9H, *t*-Bu-*H*);

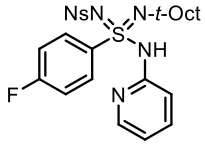
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.8 (d, $^1J_{CF}$ = 258.0 Hz), 160.3, 158.6, 149.6, 148.1, 135.7 (d, $^4J_{CF}$ = 3.2 Hz), 131.7 (d, $^3J_{CF}$ = 9.6 Hz), 128.3, 123.5, 116.7 (d, $^2J_{CF}$ = 22.9 Hz), 101.6, 62.0, 56.4, 31.6, 31.5, 29.1, 28.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.9 (tt, J = 8.1, 4.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1561, 1529, 1462, 1350, 1301, 1154, 1090, 1062, 977, 741;

HRMS (ESI^+) calcd. for $C_{23}H_{29}FN_5O_5S_2^+$ $[M+H]^+$: 538.1589, found: 538.1580.

***N*-((4-Fluorophenyl)(pyridin-2-ylamino)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (155)**



Prepared according to **General Procedure I** using sulfondiimidamide **148** (156 mg, 0.30 mmol, 1.00 equiv.), CH_2Cl_2 (1.0 mL), MeOTf (36 µL, 0.32 mmol, 1.05 equiv.) and a solution of 2-aminopyridine (59 mg, 0.63 mmol, 2.10 equiv) in CH_2Cl_2 (1.0 mL). Purification by flash column chromatography (petrol/ethyl acetate, 1:1) afforded *sulfondiimidamide* **155** as a white solid (160 mg, 0.29 mmol, 98%).

mp 128-130 °C; $\mathbf{R}_f$ 0.50 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.54-6.42 (br. s, 1H, N*H*), 8.22-8.16 (m, 2H, Ar_F-*H*), 7.98 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.92-7.82 (m, 3H, Ar_{Ns}-*H*/HetAr-*H*), 7.39 (ddd, J = 8.2, 7.3, 2.0 Hz, 1H, HetAr-*H*), 7.22-7.15 (m, 2H, Ar_F-*H*), 6.72 (ddd, J = 7.3, 5.1, 1.0 Hz, 1H, HetAr-*H*), 6.62 (dt, J = 8.2, 1.0 Hz, 1H, HetAr-*H*), 1.48 (s, 2H, $NC(CH_3)_2CH_2$), 1.25 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.18 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.95 (s, 9H, *t*-Bu-*H*);

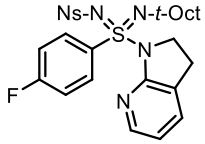
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.5 (d, $^1J_{CF}$ = 256.8 Hz), 157.3, 149.2, 149.1, 146.3, 138.2, 137.6 (d, $^4J_{CF}$ = 2.8 Hz), 131.4 (d, $^3J_{CF}$ = 9.5 Hz), 128.2, 123.3, 118.0, 117.0, 116.4 (d, $^2J_{CF}$ = 22.9 Hz), 61.6, 56.9, 31.7, 31.6, 29.4, 29.3;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -103.9 (tt, J = 8.2, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1527, 1348, 1299, 1232, 1149, 1087, 1029, 1008, 732;

HRMS (ESI^+) calcd. for $C_{25}H_{31}FN_5O_4S_2^+$ $[M+H]^+$: 548.1796, found: 548.1793.

***N*-((2,3-Dihydro-1*H*-pyrrolo[2,3-*b*]pyridin-1-yl)(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (156)**



Prepared according to **General Procedure I** using sulfondiimidamide **148** (93 mg, 0.18 mmol, 1.00 equiv.), CH_2Cl_2 (0.60 mL), MeOTf (21 µL, 0.19 mmol, 1.05 equiv.) and a solution of 2,3-dihydro-7-azaindole (45 mg, 0.38 mmol, 2.10 equiv) in CH_2Cl_2 (0.60 mL). Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **156** as a white solid (88 mg, 0.15 mmol, 85%).

mp 118-120 °C;

R$_f$ 0.40 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.09 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.83-7.78 (m, 2H, Ar_F-*H*), 7.74 (ddd, J = 5.2, 1.8, 0.9 Hz, 1H, HetAr-*H*), 7.70 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.34 (dq, J = 7.3, 1.3 Hz, 1H, HetAr-*H*), 6.96-6.89 (m, 2H, Ar_F-*H*), 6.69 (dd, J = 7.3, 5.2 Hz, 1H, HetAr-*H*), 4.51 (td, J = 10.5, 6.5 Hz, 1H, HetAr-C*H*$_a$H$_b$), 4.26 (td, J = 10.5, 7.3 Hz, 1H, HetAr-CH$_a$*H*$_b$), 3.21-3.01 (m, 2H, NC*H*$_2$), 1.63 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.57 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.49 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.35 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.02 (s, 9H, *t*-Bu-*H*);

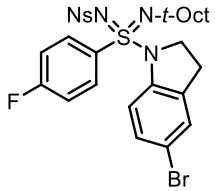
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.8 (d, $^1J_{CF}$ = 255.3 Hz), 156.3, 149.8, 149.1, 146.5, 136.6 (d, $^4J_{CF}$ = 3.1 Hz), 133.1, 130.9 (d, $^3J_{CF}$ = 9.2 Hz), 127.4, 124.4, 123.6, 117.7, 115.5 (d, $^2J_{CF}$ = 23.0 Hz), 60.7, 57.2, 51.0, 31.83, 31.81, 31.75, 31.4, 25.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.8 (tt, J = 8.1, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1415, 1349, 1301, 1230, 1152, 1088, 1043, 949, 736;

HRMS (ESI$^+$) calcd. for $C_{27}H_{33}FN_5O_4S_2^+$ [M+H]$^+$: 574.1953, found: 574.1946.

***N*-((4-Fluorophenyl)(1*H*-indol-1-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (157)**



Prepared according to **General Procedure I** using sulfondiimidamide **148** (313 mg, 0.60 mmol, 1.00 equiv.), CH_2Cl_2 (2.00 mL), MeOTf (71 µL, 0.65 mmol, 1.05 equiv.) and a solution of 5-bromoindoline (250 mg, 1.26 mmol, 2.10 equiv) in CH_2Cl_2 (2.00 mL). Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) afforded *sulfondiimidamide* **157** as a colourless oil (319 mg, 0.49 mmol, 82%).

R$_f$ 0.38 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.13-8.06 (m, 2H, Ar-*H*), 7.71-7.61 (m, 4H, Ar-*H*), 7.23 (s, 1H, Ar-*H*), 7.04 (d, *J* = 8.7 Hz, 1H, Ar-*H*), 7.00-6.93 (m, 2H, Ar-*H*), 6.73 (d, *J* = 8.6 Hz, 1H, Ar-*H*), 4.40-4.28 (m, 1H, NC*H*$_a$H$_b$), 4.18-4.07 (m, 1H, NCH$_a$*H*$_b$), 3.01 (t, *J* = 8.6 Hz, 2H, NCH$_2$C*H*$_2$), 1.66 (d, *J* = 14.7 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.63 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.54 (d, *J* = 14.6 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.35 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.06 (s, 9H, *t*-Bu-*H*).;

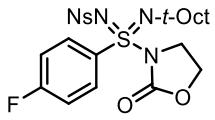
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.1 (d, $^1J_{CF}$ = 256.8 Hz), 149.4, 149.2, 140.8, 135.2 (d, $^4J_{CF}$ = 3.2 Hz), 134.4, 130.7 (d, $^3J_{CF}$ = 9.3 Hz), 130.1, 128.5, 127.3, 123.7, 116.2 (d, $^2J_{CF}$ = 22.7 Hz), 116.0, 115.9, 61.0, 57.2, 52.8, 31.89, 31.85, 31.7, 31.4, 27.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.2 (tt, *J* = 7.8, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1591, 1529, 1469, 1349, 1304, 1235, 1154, 1088, 1044;

HRMS (ESI$^+$) calcd. for $C_{28}H_{33}{}^{79}BrFN_4O_4S_2^+$ [M+H]$^+$: 651.1105, found: 651.1104; calcd. for $C_{28}H_{33}{}^{81}BrFN_4O_4S_2^+$ [M+H]$^+$: 653.1086, found: 653.1079.

***N*-((4-Fluorophenyl)(2-oxooxazolidin-3-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (158)**



Prepared according to **General Procedure D** using sulfondiimidamide **148** (156 mg, 0.30 mmol, 1.00 equiv.), CH_2Cl_2 (1.00 mL), MeOTf (36 µL, 0.31 mmol, 1.05 equiv.) and 2-oxazolidinone (55 mg, 0.63 mmol, 2.10 equiv.). The reaction was stirred at room temperature for 2 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) afforded *sulfondiimidamide* **158** as a colourless oil (141 mg, 0.26 mmol, 87%).

R$_f$ 0.41 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.20 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.86 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.85-7.80 (m, 2H, Ar_F-*H*), 7.08-7.02 (m, 2H, Ar_F-*H*), 4.36-4.28 (m, 3H, OC*H*$_2$/NC*H*$_a$H$_b$), 4.21-4.12 (m, 1H, NCH$_a$*H*$_b$), 1.73 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$C*H*$_a$H$_b$), 1.65 (d, J = 14.5 Hz, 1H, NC(CH$_3$)$_2$CH$_a$*H*$_b$), 1.58 (s, 3H, NC(C*H*$_3$)$_a$(CH$_3$)$_b$), 1.52 (s, 3H, NC(CH$_3$)$_a$(C*H*$_3$)$_b$), 1.07 (s, 9H, *t*-Bu-*H*);

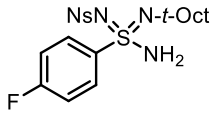
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.5 (d, $^1J_{CF}$ = 257.5 Hz), 151.9, 149.6, 148.8, 135.4 (d, $^4J_{CF}$ = 3.1 Hz), 131.0 (d, $^3J_{CF}$ = 9.7 Hz), 127.6, 124.0, 116.3 (d, $^2J_{CF}$ = 23.0 Hz), 62.2, 61.8, 57.0, 47.4, 31.9, 31.8, 31.7, 31.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -103.5 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1773, 1529, 1349, 1303, 1154, 1123, 1086, 1031, 1004, 837, 728, 647;

HRMS (ESI$^+$) calcd. for $C_{23}H_{29}FN_4O_6S_2Na^+$ [M+Na]$^+$: 563.1405, found: 563.1406.

***N*-(Amino(4-fluorophenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (159)**



An oven-dried 10 mL round-bottom flask containing sulfondiimidamide **148** (167 mg, 0.32 mmol, 1.00 equiv.) was sealed and subjected to three N_2 evacuation/refill cycles before anhydrous CH_2Cl_2 (1.07 mL) was added. The solution was cooled to 0 °C before MeOTf (38 µL, 0.34 mmol, 1.05 equiv.) was added. The reaction was warmed to room temperature and was stirred for 30 min. Then ammonia solution (0.64 mL, 2 M in ^{i}PrOH, 1.28 mmol, 4.00 equiv.) was added and the reaction was stirred at room temperature for another 30 min. The reaction was then concentrated under reduced pressure and crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) to afford *sulfondiimidamide* **159** as a white solid (108 mg, 0.23 mmol, 72%).

mp 93-95 °C;

R$_f$ 0.33 (petrol/ethyl acetate, 2:1);

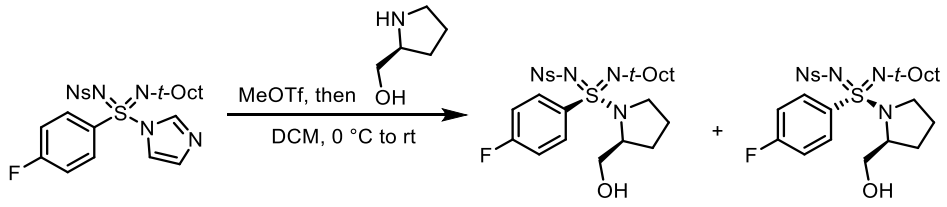
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.16 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.03-7.98 (m, 2H, Ar_F-*H*), 7.94 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.11-7.04 (m, 2H, Ar_F-*H*), 5.30 (br. s, 1H, N*H*), 3.37 (br. s, 1H, N*H*), 1.56 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.44 (d, J = 14.9 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.31 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.15 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.96 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.3 (d, $^{1}J_{CF}$ = 256.8 Hz), 149.5, 149.3, 137.4, 130.4 (d, $^{3}J_{CF}$ = 9.4 Hz), 128.0, 123.8, 116.2 (d, $^{2}J_{CF}$ = 22.7 Hz), 61.0, 56.4, 31.71, 31.70, 29.8, 28.9;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.4 (s);

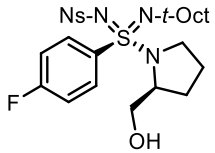
IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1281, 1153, 1096, 1059, 991, 962;

HRMS (ESI^+) calcd. for $C_{20}H_{27}FN_4O_4S_2Na^+$ $[M+Na]^+$: 493.1350, found: 493.1350.

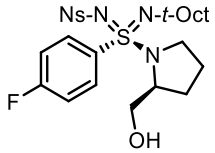


Sulfondiimidamides **160** and **161** were prepared according to **General Procedure I** using sulfondiimidamide **148** (300 mg, 0.58 mmol, 1.00 equiv.), CH_2Cl_2 (1.9 mL), MeOTf (69 µL, 0.61 mmol, 1.05 equiv.) and (*S*)-(+)-2-pyrrolidinemethanol (123 mg, 1.22 mmol, 2.10 equiv.). The reaction was stirred at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1) afforded *diastereoisomer* **160** as a white solid (132 mg, 0.24 mmol, 41%) and *diastereoisomer* **161** as a white solid (133 mg, 0.24 mmol, 41%). (Sulfur stereochemistry of these two compounds remains unknown)

***N*-((*R*)-(4-Fluorophenyl)((*S*)-2-(hydroxymethyl)pyrrolidin-1-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide**



***N*-((*S*)-(4-Fluorophenyl)((*S*)-2-(hydroxymethyl)pyrrolidin-1-yl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide**



Diastereoisomer 1 (Sulfur stereochemistry is unknown)

mp 44-46 °C;

R_f 0.53 (CH_2Cl_2/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.15 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.83-7.78 (m, 2H, Ar_F-*H*), 7.75 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.07-7.02 (m, 2H, Ar_F-*H*), 4.38 (tt, *J* = 8.4, 3.8 Hz, 1H, NC*H*), 3.84-3.04 (br. s, 1H, O*H*), 3.77 (dd, *J* = 11.0, 4.3 Hz, 1H, CH_aH$_b$OH), 3.58 (dd, *J* = 11.0, 5.3 Hz, 1H, CH$_a$$H_b$OH), 3.05 (dt, *J* = 10.0, 7.0 Hz, 1H, NCH_aH$_b$), 2.75 (ddd, *J* = 10.0, 7.0, 5.1 Hz, 1H, NCH$_a$$H_b$), 2.04-1.93 (m, 1H, NCH$_2$$H_aH_b$), 1.92-1.80 (m, 2H, NCH$_2H_a$$H_b$/ NCH$_2CH_2$$H_aH_b$), 1.76-1.67 (m, 1H, NCH$_2CH_2H_a$$H_b$), 1.65 (d, *J* = 14.5 Hz, 1H,

$NC(CH_3)_2CH_aH_b$), 1.57 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.46 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.00 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.0 (d, $^1J_{CF}$ = 256.1 Hz), 149.4, 149.3, 136.8 (d, $^4J_{CF}$ = 3.1 Hz), 131.2 (d, $^3J_{CF}$ = 9.2 Hz), 127.4, 123.8, 116.2 (d, $^2J_{CF}$ = 22.6 Hz), 65.9, 62.8, 60.3, 57.7, 46.7, 32.2, 31.9, 31.8, 31.5, 28.9, 24.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -105.3 (tt, *J* = 8.5, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1383, 1349, 1298, 1234, 1152, 1086, 1051, 969;

HRMS (ESI^+) calcd. for $C_{25}H_{36}FN_4O_5S_2^+$ $[M+H]^+$: 555.2106, found: 555.2097;

$[\alpha]_D^{25}$: -76.0° (c = 1.0, $CHCl_3$).

Diastereoisomer 2 (Sulfur stereochemistry is unknown)

mp 117-120 °C;

R_f 0.47 (CH_2Cl_2/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.20 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.87 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.76-7.71 (m, 2H, Ar_F-*H*), 7.07-7.01 (m, 2H, Ar_F-*H*), 4.30 (tt, *J* = 8.6, 4.5 Hz, 1H, NC*H*), 4.05-3.55 (br. s, 1H, O*H*), 3.71 (dd, *J* = 10.9, 7.2 Hz, 1H, CH_aH_bOH), 3.62 (dd, *J* = 10.9, 4.6 Hz, 1H, CH_aH_bOH), 3.12-3.00 (m, 2H, NCH_2), 2.04-1.94 (m, 1H, Alk-*H*), 1.78 (dt, *J* = 12.0, 6.6 Hz, 1H, Alk-*H*), 1.72-1.63 (m, 2H, Alk-*H*/$NC(CH_3)_2CH_aH_b$), 1.58 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.51 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.47 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.45-1.36 (m, 1H, Alk-*H*), 1.03 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 165.6 (d, $^1J_{CF}$ = 252.6 Hz), 150.8, 150.0, 136.8 (d, $^4J_{CF}$ = 3.1 Hz), 131.7 (d, $^3J_{CF}$ = 9.5 Hz), 128.2, 124.6, 116.5 (d, $^2J_{CF}$ = 23.0 Hz), 66.6, 65.8, 60.4, 58.2, 48.2, 32.4, 32.3, 32.0, 31.8, 29.0, 24.9;

^{19}F NMR (377 MHz, $(CD_3)_2CO$): δ (ppm) = -108.4 (tt, *J* = 8.6, 5.1 Hz);

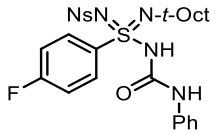
IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1529, 1489, 1350, 1299, 1265, 1230, 1152, 1087, 1047, 977;

HRMS (ESI^+) calcd. for $C_{25}H_{36}FN_4O_5S_2^+$ $[M+H]^+$: 555.2106, found: 555.2106;

$[\alpha]_D^{25}$: +37.5° (c = 1.0, $CHCl_3$).

6.3.6 *N*-Functionalisation of Primary Sulfondiimidamide

_N_-((4-Fluorophenyl)(3-phenylureido)((2,4,4-trimethylpentan-2-yl)imino)-λ⁶-sulfaneylidene)-4-nitrobenzenesulfonamide (162)



Sulfondiimidamide **159** (86 mg, 0.18 mmol, 1.00 equiv.) and NaH (11 mg, 60 % dispersion in mineral oil, 0.28 mmol, 1.50 equiv.) were added to an oven-dried 25 mL round-bottom flask at room temperature and the flask was purged with nitrogen gas. Anhydrous THF (1.80 mL) was then added. The reaction was stirred at room temperature for 15 min. Phenyl isocyanate (26 mg, 0.22 mmol, 1.20 equiv.) was then added and the reaction was stirred at room temperature for another 30 min. The reaction was quenched with sat. aq. NaCl solution (50 mL). Ethyl acetate (30 mL) was added and the organic layers was separated. The aqueous layer was further extracted with ethyl acetate (2 × 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was then purified by flash column chromatography (petrol/ethyl acetate, 3:1) to afford sulfondiimidamide **162** as a pale-yellow solid (88 mg, 0.15 mmol, 82%).

mp 146-148 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 9.33 (s, 1H，SN*H*), 8.18-8.06 (m, 5H, Ar-*H*/CON*H*), 7.87 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.48 (t, *J* = 8.8 Hz, 2H Ar_{Ns}-*H*), 7.34-7.30 (m, 2H, Ar-*H*), 7.17 (t, *J* = 7.9 Hz, 2H), 6.91 (t, *J* = 7.3 Hz, 1H, Ar-*H*), 1.53 (d, *J* = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.48 (d, *J* = 14.7 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.19 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.10 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 0.87 (s, 9H, *t*-Bu-*H*);

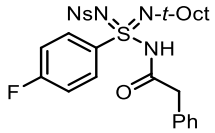
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 164.7 (d, $^1J_{CF}$ = 253.2 Hz), 154.1, 148.8, 148.4, 139.7, 137.5 (d, $^4J_{CF}$ = 2.3 Hz), 131.2 (d, $^3J_{CF}$ = 9.8 Hz), 128.4, 128.1, 123.7, 122.0, 117.9, 116.3 (d, $^2J_{CF}$ = 23.0 Hz), 60.7, 54.6, 31.19, 31.15, 28.5, 28.3;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -105.8 (tt, J = 8.7, 4.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1349, 1301, 1223, 1156, 1087, 1056, 840, 739;

HRMS (ESI^+) calcd. for $C_{27}H_{33}FN_5O_5S_2^+$ $[M+H]^+$: 590.1902; found: 590.1894.

***N*-((4-Fluorophenyl)(phenylacetamido)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (163)**



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **159** (180 mg, 0.38 mmol, 1.00 equiv.) in anhydrous CH_2Cl_2 (2.5 mL) at room temperature. Et_3N (80 µL, 0.57 mmol, 1.50 equiv.) was then added, followed by the addition of phenylacetyl chloride (70 mg, 0.46 mmol, 1.20 equiv.). After being stirred at room temperature for 30 min, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with CH_2Cl_2 (3 × 40 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) to afford *sulfondiimidamide* **163** as a white solid (158 mg, 0.27 mmol, 70%).

mp 78-80 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.13 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.95 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.88-7.83 (m, 2H, Ar_F-*H*), 7.59 (br. s, 1H, N*H*), 7.23-7.16 (m, 3H, Ph-*H*), 7.12-7.06 (m, 4H, Ph-*H*/Ar_F-*H*), 3.42 (s, 2H, Ph-CH_2), 1.56 (d, J = 15.0 Hz, 1H, $NC(CH_3)_2CH_aH_b$),

1.47 (d, J = 15.0 Hz, 1H, NC(CH_3)$_2$C$H_a$$H_b$), 1.36 (s, 3H, NC(C$H_3$)$_a$($CH_3$)$_b$), 1.13 (s, 3H, NC($CH_3$)$_a$(C$H_3$)$_b$), 0.93 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 179.3, 165.9 (d, $^1J_{CF}$ = 258.7 Hz), 149.7, 148.8, 136.6 (d, $^4J_{CF}$ = 3.3 Hz), 134.8, 130.6 (d, $^3J_{CF}$ = 9.6 Hz), 129.5, 128.6, 128.2, 127.1, 123.9, 116.9 (d, $^2J_{CF}$ = 23.0 Hz), 62.9, 56.6, 47.2, 31.8, 31.6, 29.4, 29.2;

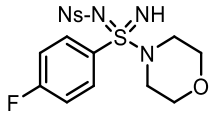
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.1 (tt, J = 7.8, 4.5 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1349, 1304, 1234, 1157, 1086;

HRMS (ESI^+) calcd. for $C_{28}H_{33}FN_4O_5S_2Na^+$ $[M+Na]^+$: 611.1769; found: 611.1768.

6.3.7 Deprotection of Sulfondiimidamide

***N*-((4-Fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (164)**



To a solution of sulfondiimidamide **118** (4.50 g, 8.33 mmol, 1.00 equiv.) in CH_2Cl_2 (83.3 mL) in an oven-dried 250 mL round-bottom flask was added TFA (3.21 mL, 41.70 mmol, 5.00 equiv.) at room temperature. The mixture was stirred at room temperature for 15 min before being concentrated *in vacuo* and diluted with ethyl acetate (200 mL). Then the mixture was basified to pH 10-11 using 1 M aq. NaOH solution (300 mL). The aqueous phase was extracted with ethyl acetate (2 × 100 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1:1 to 1:2) to afford *sulfondiimidamide* **164** as a white solid (3.39 g, 7.92 mmol, 95%).

mp 64-66 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 1:2);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.24 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.08 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.98-7.93 (m, 2H, Ar_F-*H*), 7.23-7.17 (m, 2H, Ar_F-*H*), 3.72 (t, J = 4.7 Hz, 4H, OCH_2), 3.28 (br. s, 1H, N*H*), 3.15-3.02 (m, 4H, NCH_2);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.9 (d, $^{1}J_{CF}$ = 257.8 Hz), 149.7, 149.3, 130.4 (d, $^{3}J_{CF}$ = 9.5 Hz), 129.3 (d, $^{4}J_{CF}$ = 3.2 Hz), 127.9, 124.1, 116.7 (d, $^{2}J_{CF}$ = 22.9 Hz), 66.2, 46.8;

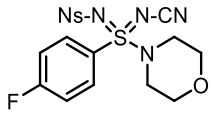
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.9 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1351, 1300, 1154, 1089, 1067, 1052, 920;

HRMS (ESI^+) calcd. for $C_{16}H_{18}FN_4O_5S_2^+$ $[M+H]^+$: 429.0697, found: 429.0695.

6.3.8 *N*-Functionalisation of Sulfondiimidamide 164

N-((Cyanoimino)(4-fluorophenyl)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (165)



To an oven-dried 250 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **164** (3.05 g, 7.13 mmol, 1.00 equiv.) in anhydrous CH_3CN (35.7 mL) at room temperature. Et_3N (1.99 mL, 14.3 mmol, 2.00 equiv.) was then added, followed by the addition of BrCN solution (2.14 mL, 5.0 M in CH_3CN, 10.7 mmol, 1.50 equiv.). After being stirred at room temperature for 30 min, the reaction mixture was quenched with sat. aq. $NaHCO_3$ solution (500 mL). The product was extracted with ethyl acetate (3 × 100 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 8:1 to 4:1) to afford *sulfondiimidamide* **165** as a white solid (3.16 g, 6.98 mmol, 98%).

mp 50-53 °C;

R_f 0.58 (CH_2Cl_2/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.38 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.22 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05-8.00 (m, 2H, Ar_F-*H*), 7.39-7.33 (m, 2H, Ar_F-*H*), 3.82 (app. t, J = 4.7 Hz, 4H, OCH_2), 3.40 (dt, J = 11.7, 4.6 Hz, 2H, NCH_2), 3.25 (dt, J = 11.7, 4.6 Hz, 2H, NCH_2);

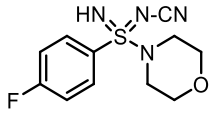
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 167.1 (d, $^1J_{CF}$ = 262.0 Hz), 150.5, 147.3, 131.6 (d, $^3J_{CF}$ = 10.1 Hz), 128.7, 127.5 (d, $^4J_{CF}$ = 3.3 Hz), 124.6, 118.1 (d, $^2J_{CF}$ = 23.1 Hz), 109.3, 65.9, 46.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -98.3 (tt, J = 7.8, 4.8 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2360, 2208, 1530, 1350, 1166, 1107, 1084, 930, 846;

HRMS (ESI^+) calcd. for $C_{17}H_{16}FN_5O_5S_2Na^+$ $[M+Na]^+$: 476.0469, found: 476.0469.

***N*-((4-Fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)cyanamide (166)**



To an oven-dried 50 mL round-bottom flask was dissolved sulfondiimidamide **165** (650 mg, 1.43 mmol, 1.00 equiv.) in anhydrous CH_3CN (14.3 mL) at room temperature. Then 1-dodecanethiol (0.86 mL, 3.58 mmol, 2.50 equiv.) was added, followed by the addition of DBU (0.54 mL, 3.58 mmol, 2.50 equiv.). After being stirred at room temperature for 15 min, the reaction was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 4:1 to 1:1 to 0:1) without an aqueous workup to afford *sulfondiimidamide* **166** as a colourless oil (278 mg, 1.04 mmol, 73%).

R$_f$ 0.38 (ethyl acetate);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.03-7.98 (m, 2H, Ar_F-*H*), 7.30-7.25 (m, 2H, Ar_F-*H*), 3.78-3.72 (m, 4H, OCH_2), 3.12-3.03 (m, 5H, NCH_2/N*H*);

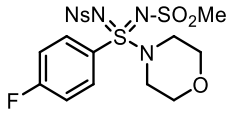
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.1 (d, $^1J_{CF}$ = 258.1 Hz), 130.9 (d, $^3J_{CF}$ = 9.5 Hz), 128.6 (d, $^4J_{CF}$ = 3.1 Hz), 117.1 (d, $^2J_{CF}$ = 22.9 Hz), 113.0, 66.2, 46.8;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.5 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2186, 1588, 1490, 1226, 1109, 924, 839;

HRMS (ESI^+) calcd. for $C_{11}H_{14}FN_4OS^+$ $[M+H]^+$: 269.0867, found: 269.0869.

***N*-((4-Fluorophenyl)((methylsulfonyl)imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (167)**



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **164** (190 mg, 0.44 mmol, 1.00 equiv.) in anhydrous CH_2Cl_2 (2.2 mL) at room temperature. Et_3N (92 µL, 0.66 mmol, 1.50 equiv.) was then added, followed by the addition of MsCl (61 mg, 0.53 mmol, 1.20 equiv.) and DMAP (11 mg, 0.09 mmol, 0.20 equiv.). After being stirred at room temperature for 30 min, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with CH_2Cl_2 (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 5:1) to afford *sulfondiimidamide* **167** as a white solid (181 mg, 0.36 mmol, 81%).

mp 56-58 °C;

R_f 0.47 (CH_2Cl_2/ethyl acetate, 5:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.23 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.96-7.91 (m, 2H, Ar_F-*H*), 7.24-7.17 (m, 2H, Ar_F-*H*), 3.73-3.68 (m, 4H, OCH_2), 3.25 (dt, *J* = 12.1, 4.8 Hz, 2H, NCH_2), 3.19 (dt, *J* = 11.0, 4.3 Hz, 2H, NCH_2), 3.15 (s, 3H, SO_2CH_3);

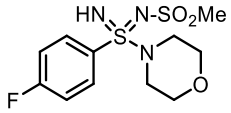
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.5 (d, $^1J_{CF}$ = 260.3 Hz), 150.0, 147.6, 131.5 (d, $^3J_{CF}$ = 9.9 Hz), 129.5 (d, $^4J_{CF}$ = 3.1 Hz), 128.2, 124.1, 117.4 (d, $^2J_{CF}$ = 23.1 Hz), 65.9, 46.4, 44.0;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -100.2 (tt, J = 8.2, 4.7 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1530, 1351, 1307, 1169, 1084, 926, 741;

HRMS (ESI^+) calcd. for $C_{17}H_{20}FN_4O_7S_3^+$ $[M+H]^+$: 507.0473, found: 507.0470.

***N*-((4-Fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)methanesulfonamide (168)**



To an oven-dried 25 mL round-bottom flask was dissolved sulfondiimidamide **167** (152 mg, 0.30 mmol, 1.00 equiv.) in anhydrous CH_3CN (3.0 mL) at room temperature. Then 1-dodecanethiol (0.36 mL, 1.50 mmol, 5.0 equiv.) was added, followed by the addition of DBU (0.21 mL, 1.43 mmol, 4.75 equiv.). After being stirred at room temperature for 15 min, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with ethyl acetate (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (ethyl acetate/MeOH, 1:0 to 9:1) to afford *sulfondiimidamide* **168** as a colourless oil (68 mg, 0.21 mmol, 71%).

R$_f$ 0.50 (ethyl acetate/MeOH, 9:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.92-7.86 (m, 2H, Ar_F-*H*), 7.12-7.06 (m, 2H, Ar_F-*H*), 3.61-3.53 (m, 4H, OCH_2), 3.15 (s, 1H, N*H*), 3.01-2.94 (m, 2H, NCH_2), 2.94-2.85 (m, 5H, NCH_2/SO_2CH_3);

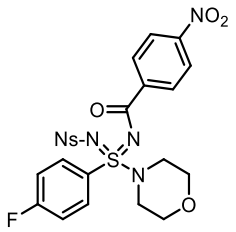
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.7 (d, $^1J_{CF}$ = 257.0 Hz), 130.3 (d, $^3J_{CF}$ = 9.4 Hz), 129.9 (d, $^4J_{CF}$ = 3.1 Hz), 116.6 (d, $^2J_{CF}$ = 22.7 Hz), 66.3, 46.9, 44.6;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -103.7 (tt, J = 8.0, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1590, 1490, 1292, 1137, 1092, 1051, 1009, 913, 725;

HRMS (ESI^+) calcd. for $C_{11}H_{17}FN_3O_3S_2^+$ $[M+H]^+$: 322.0690, found: 322.0685.

***N*-((4-Fluorophenyl)(morpholino)(((4-nitrophenyl)sulfonyl)imino)-λ^6-sulfaneylidene)-4-nitrobenzamide (169)**



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **164** (164 mg, 0.38 mmol, 1.00 equiv.) in anhydrous CH_2Cl_2 (1.9 mL) at room temperature. Et_3N (80 µL, 0.57 mmol, 1.50 equiv.) was then added, followed by the addition of 4-nitrobenzoyl chloride (78 mg, 0.42 mmol, 1.10 equiv.). After being stirred at room temperature for 1 h, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with CH_2Cl_2 (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 7:1 to 4:1) to afford *sulfondiimidamide* **169** as a white solid (207 mg, 0.36 mmol, 94%).

mp 222-224 °C;

R$_f$ 0.75 (CH_2Cl_2/ethyl acetate, 5:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.18 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.14-8.09 (m, 2H, Ar_F-*H*), 8.04-7.97 (m, 4H, Ar-*H*), 7.94 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.34-7.28 (m, 2H, Ar_F-*H*), 3.87-3.81 (m, 4H, OCH_2), 3.63-3.56 (m, 2H, NCH_2), 3.45-3.39 (m, 2H, NCH_2);

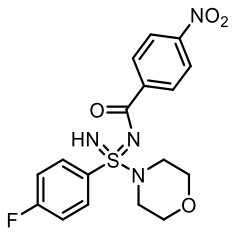
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) =169.1, 166.5 (d, $^1J_{CF}$ = 260.0 Hz), 150.5, 149.8, 147.4, 139.6, 131.6 (d, $^3J_{CF}$ = 9.9 Hz), 130.2, 129.8 (d, $^4J_{CF}$ = 3.2 Hz), 128.6, 123.9, 123.5, 117.6 (d, $^2J_{CF}$ = 23.0 Hz), 66.2, 46.2;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -100.4 (tt, J = 7.7, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1525, 1349, 1272, 1107, 1083, 1066, 936, 839, 720;

HRMS (ESI$^+$) calcd. for $C_{23}H_{21}FN_5O_8S_2^+$ $[M+H]^+$: 578.0810, found: 578.0809.

***N*-((4-Fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzamide (170)**



To an oven-dried 25 mL round-bottom flask was dissolved sulfondiimidamide **169** (202 mg, 0.35 mmol, 1.00 equiv.) in anhydrous CH_3CN (3.5 mL) at room temperature. Then 1-dodecanethiol (0.42 mL, 1.75 mmol, 5.00 equiv.) was added, followed by the addition of DBU (0.25 mL, 1.66 mmol, 4.75 equiv.). After being stirred at room temperature for 30 min, the reaction mixture was quenched with sat. aq. NaCl solution (120 mL). The product was extracted with ethyl acetate (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 1:1 to 1:2) to afford *sulfondiimidamide* **170** as colourless oil (94 mg, 0.24 mmol, 69%).

R$_f$ 0.39 (CH_2Cl_2/ethyl acetate, 1:2);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25-8.16 (m, 4H, Ar-*H*), 8.13-8.08 (m, 2H, Ar$_F$-*H*), 7.27-7.21 (m, 2H, Ar$_F$-*H*), 3.72-3.66 (m, 4H, OCH_2), 3.50 (s, 1H, N*H*), 3.13 (dt, *J* = 12.0, 4.8 Hz, 2H, NCH_2), 3.04 (dt, *J* = 12.0, 4.8 Hz, 2H, NCH_2);

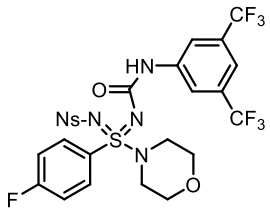
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 171.4, 166.2 (d, $^1J_{CF}$ = 252.8 Hz), 150.8, 143.3, 132.2(d, $^4J_{CF}$ = 1.7 Hz), 131.5 (d, $^3J_{CF}$ = 9.5 Hz), 130.9, 124.0, 117.1 (d, $^2J_{CF}$ = 23.0 Hz), 66.9, 47.2;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.0 (tt, *J* = 8.0, 4.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1627, 1590, 1522, 1490, 1287, 1258, 1138, 1110, 918, 721;

HRMS (ESI^+) calcd. for $C_{17}H_{18}FN_4O_4S^+$ $[M+H]^+$: 393.1027, found: 393.1024.

***N*-((((3,5-Bis(trifluoromethyl)phenyl)carbamoyl)imino)(4-fluorophenyl)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (171)**



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **164** (255 mg, 0.60 mmol, 1.00 equiv.) in anhydrous CH_3CN (6.0 mL) at room temperature. DBU (0.13 mL, 0.90 mmol, 1.50 equiv.) was then added, followed by the addition of 3,5-bis(trifluoromethyl)phenyl isocyanate (230 mg, 0.90 mmol, 1.50 equiv.). After being stirred at room temperature for 30 min, the reaction mixture was quenched with sat. aq. NaCl solution (120 mL). The product was extracted with ethyl acetate (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1:1 to 2:3) to afford *sulfondiimidamide* **171** as a white solid (322 mg, 0.47 mmol, 79%).

mp 196-198 °C;

R$_f$ 0.39 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 10.01 (s, 1H, N*H*), 8.18-8.13 (m, 2H, Ar$_F$-*H*), 8.08 (app. br. s, 4H, Ar-*H*), 7.85 (app. br. s, 2H, Ar-*H*), 7.59-7.51 (m, 3H, Ar$_F$-*H*/Ar-*H*), 3.69 (t, J = 4.5 Hz, 4H, OCH_2), 3.34-3.22 (m, 4H, NCH_2);

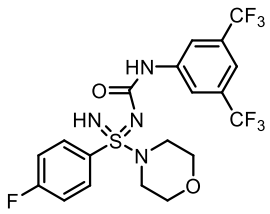
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 165.5 (d, $^1J_{CF}$ = 254.9 Hz), 154.2, 148.9, 147.5, 141.2, 131.9 (d, $^3J_{CF}$ = 10.1 Hz), 130.7 (q, $^2J_{CF}$ = 32.7 Hz), 130.1 (d, $^4J_{CF}$ = 2.8 Hz), 128.7, 123.8, 123.2 (q, $^1J_{CF}$ = 272.6 Hz), 117.2, 117.1 (d, $^2J_{CF}$ = 23.2 Hz), 114.7, 65.3, 45.6;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -62.0 (s), -103.6 (tt, J = 9.0, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1665, 1533, 1277, 1224, 1161, 1132, 1085, 940;

HRMS (ESI$^+$) calcd. for $C_{25}H_{20}F_7N_5O_6S_2Na^+$ [M+Na]$^+$: 706.0635, found: 706.0629.

1-(3,5-Bis(trifluoromethyl)phenyl)-3-((4-fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)urea (172)



To an oven-dried 25 mL round-bottom flask was dissolved sulfondiimidamide **171** (180 mg, 0.26 mmol, 1.00 equiv.) in anhydrous CH_3CN (2.6 mL) at 0 °C. Then 1-dodecanethiol (0.32 mL, 1.32 mmol, 5.00 equiv.) was added, followed by the addition of DBU (0.19 mL, 1.25 mmol, 4.75 equiv.). After being stirred at 0 °C for 30 min, the reaction mixture was quenched with sat. aq. NaCl solution (120 mL). The product was extracted with ethyl acetate (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1:1 to 1:2) to afford *sulfondiimidamide* **172** as a coluorless oil (95 mg, 0.19 mmol, 72%).

R$_f$ 0.50 (petrol/ethyl acetate, 1:2);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.07-8.02 (m, 2H, Ar_F-*H*), 7.93 (s, 2H, Ar-*H*), 7.85-7.41 (br. s, 1H, CON*H*), 7.46 (s, 1H, Ar-*H*), 7.24-7.18 (m, 2H, Ar_F-*H*), 3.71 (app. t, *J* = 4.7 Hz, 4H, OCH_2), 3.43 (s, 1H, S=N*H*), 3.10 (dt, *J* = 11.7, 4.7 Hz, 2H, NCH_2), 3.03 (dt, *J* = 11.7, 4.7 Hz, 2H, NCH_2);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.7 (d, $^1J_{CF}$ = 256.6 Hz), 158.2, 141.1, 132.2 (q, $^2J_{CF}$ = 33.1 Hz), 130.2 (d, $^3J_{CF}$ = 9.3 Hz), 130.0 (d, $^4J_{CF}$ = 2.8 Hz), 123.4 (q, $^1J_{CF}$ = 272.6 Hz), 118.5, 116.6 (d, $^2J_{CF}$ = 22.6 Hz), 115.8, 66.4, 46.6;

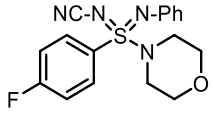
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -63.0 (s), -104.3 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1638, 1541, 1492, 1474, 1434, 1387, 1277, 1236, 1176, 1129, 924;

HRMS (ESI$^+$) calcd. for $C_{19}H_{18}F_7N_4O_2S^+$ $[M+H]^+$: 499.1033, found: 499.1029.

6.3.9 *N*-Functionalisation of Sulfondiimidamide 166

***N*-((4-Fluorophenyl)(morpholino)(phenylimino)-λ^6-sulfaneylidene)cyanamide (173)**



Sulfondiimidamide **166** (83 mg, 0.31 mmol, 1.00 equiv.), phenylboronic acid (94 mg, 0.77 mmol, 2.50 equiv.), $Cu(CH_3CN)_4PF_6$ (58 mg, 0.16 mmol, 0.50 equiv.), *N*-methylpiperidine (277 mg, 2.79 mmol, 9.00 equiv.) were dissolved in anhydrous CH_3CN (3.1 mL) in an oven-dried 25 mL round-bottom flask and under oxygen atmosphere. The reaction was stirred at room temperature for 3 h until completion (judged by TLC). Then the reaction mixture was quenched with sat. aq. NaCl solution (80 mL). The product was extracted with ethyl acetate (3 × 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 8:1 to 4:1) to afford *sulfondiimidamide* **173** as a white solid (81 mg, 0.24 mmol, 76%).

mp 107-109°C;

R_f 0.58 (CH_2Cl_2/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.07-8.02 (m, 2H, Ar_F-*H*), 7.32-7.22 (m, 6H, Ar_F-*H*/Ph-*H*), 7.07 (tt, *J* = 7.2, 1.5 Hz, 1H, Ph-*H*), 3.74-3.62 (m, 4H, OCH_2), 3.20-3.10 (m, 4H, NCH_2);

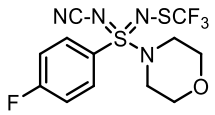
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.0 (d, $^1J_{CF}$ = 258.1 Hz), 140.6, 131.2 (d, $^3J_{CF}$ = 9.6 Hz), 129.5, 128.7 (d, $^4J_{CF}$ = 3.3 Hz), 124.1, 123.9, 117.2 (d, $^2J_{CF}$ = 22.9 Hz), 112.8, 66.0, 46.8;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.3 (tt, *J* = 8.0, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 2190, 1588, 1487, 1259, 1238, 1110, 927, 843, 759;

HRMS (ESI^+) calcd. for $C_{17}H_{18}FN_4OS^+$ $[M+H]^+$: 345.1180, found: 345.1181.

***N*-((4-Fluorophenyl)(morpholino)(((trifluoromethyl)thio)imino)-λ^6-sulfaneylidene)cyanamide (174)**



To an oven-dried 10 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **166** (170 mg, 0.63 mmol, 1.00 equiv.) in anhydrous CH_3CN (1.26 mL) at room temperature. NBS (112 mg, 0.63 mmol, 1.00 equiv.) was then added. The reaction was stirred at room temperature for 30 min, followed by the addition of a solution of $AgSCF_3$ (158 mg, 0.76 mmol, 1.20 equiv.) in anhydrous CH_3CN (1.9 mL). After being stirred at room temperature for another 30 min, the reaction mixture was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 50:1 to 20:1 to 10:1) to afford *sulfondiimidamide* **174** as a colourless oil (119 mg, 0.32 mmol, 51%).

R$_f$ 0.57 (CH_2Cl_2/ethyl acetate, 10:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.99-7.94 (m, 2H, Ar_F-*H*), 7.35-7.29 (m, 2H, Ar_F-*H*), 3.80-3.71 (m, 4H, OCH_2), 3.24-3.12 (m, 4H, NCH_2);

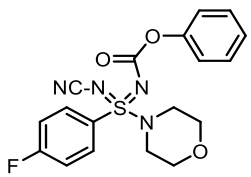
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.5 (d, $^1J_{CF}$ = 260.3 Hz), 131.5 (d, $^3J_{CF}$ = 9.9 Hz), 130.0 (q, $^1J_{CF}$ = 312.0 Hz), 127.2 (d, $^4J_{CF}$ = 3.2 Hz), 117.7 (d, $^2J_{CF}$ = 23.0 Hz), 110.6, 65.9, 46.9;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -49.8 (s), -100.1 (tt, *J* = 7.8, 4.7 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =2200, 1586, 1490, 1159, 1108, 1085, 1007, 930, 841; .

HRMS (ESI^+) calcd. for $C_{12}H_{13}F_4N_4OS_2^+$ $[M+H]^+$: 369.0461, found: 369.0467.

Phenyl ((cyanoimino)(4-fluorophenyl)(morpholino)-λ^6-sulfaneylidene)carbamate (175)



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **166** (132 mg, 0.49 mmol, 1.00 equiv.) in anhydrous CH_2Cl_2 (2.5 mL) at room temperature. Et_3N (0.14 mL, 0.98 mmol, 2.0 equiv.) was then added, followed by the addition of phenyl chloroformate (115 mg, 0.73 mmol, 1.50 equiv.) and DMAP (12 mg, 0.098 mmol, 0.20 equiv.). After being stirred at room temperature for 10 min, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with CH_2Cl_2 (3 × 40 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 8:1 to 4:1) to afford *sulfondiimidamide* **175** as a white solid (177 mg, 0.46 mmol, 93%).

mp 132-134 °C;

R$_f$ 0.50 (CH_2Cl_2/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.12-8.07 (m, 2H, Ar$_F$-*H*), 7.38-7.30 (m, 4H, Ar$_F$-*H*/Ph-*H*), 7.24-7.19 (m, 1H, Ph-*H*), 7.18-7.14 (m, 2H, Ph-*H*), 3.80 (app. t, *J* = 4.7 Hz, 4H, OC*H*$_2$), 3.39 (dt, *J* = 12.2, 5.0 Hz, 2H, NC*H*$_2$), 3.32 (dt, *J* = 12.8, 5.0 Hz, 2H, NC*H*$_2$);

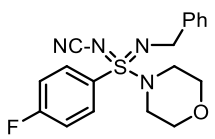
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.5 (d, $^1J_{CF}$ = 260.3 Hz), 154.5, 151.1, 131.4 (d, $^3J_{CF}$ = 9.9 Hz), 129.3, 127.6 (d, $^4J_{CF}$ = 3.0 Hz), 125.8, 121.3, 117.6 (d, $^2J_{CF}$ = 23.1 Hz), 110.4, 65.8, 46.2;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -99.8 (tt, *J* = 7.9, 4.7 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2202, 1697, 1588, 1489, 1237, 1184, 1158, 1107, 928, 838, 728;

HRMS (ESI$^+$) calcd. for $C_{18}H_{18}FN_4O_3S^+$ $[M+H]^+$: 389.1078, found: 389.1078.

***N*-((Benzylimino)(4-fluorophenyl)(morpholino)-λ^6-sulfaneylidene)cyanamide (176)**



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **166** (120 mg, 0.45 mmol, 1.00 equiv.) in anhydrous CH_3CN (4.5 mL) at room temperature. DBU (0.20 mL, 1.35 mmol, 3.00 equiv.) was then added, followed by the addition of BnBr (192 mg, 1.12 mmol, 2.50 equiv.). The reaction was stirred at room temperature for 3 h until completion (judged by TLC). The reaction was quenched with sat. aq. NaCl solution (120 mL). The product was extracted with ethyl acetate (3 × 40 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 9:1 to 4:1) to afford *sulfondiimidamide* **176** as a colourless oil (131 mg, 0.37 mmol, 81%).

R_f 0.63 (CH_2Cl_2/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.00-7.95 (m, 2H, Ar_F-*H*), 7.47-7.42 (m, 2H, Ph-*H*), 7.38-7.32 (m, 2H, Ar_F-*H*), 7.30-7.24 (m, 3H, Ph-*H*), 4.56 (d, *J* = 14.4 Hz, 1H, Ph-CH_aH$_b$), 4.38 (d, *J* = 14.4 Hz, 1H, Ph-CH$_a$$H_b$), 3.65 (ddd, *J* = 11.8, 6.3, 3.2 Hz, 2H, OCH_2), 3.57 (ddd, *J* = 11.8, 6.3, 3.2 Hz, 2H, OCH_2), 3.03 (ddd, *J* = 11.9, 6.5, 3.2 Hz, 2H, NCH_2), 2.93 (ddd, *J* = 11.9, 6.5, 3.2 Hz, 2H, NCH_2);

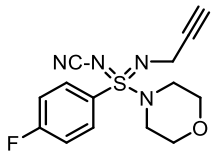
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.8 (d, $^1J_{CF}$ = 257.5 Hz), 139.4, 130.8 (d, $^3J_{CF}$ = 9.5 Hz), 128.7 (d, $^4J_{CF}$ = 3.2 Hz), 128.5, 127.8, 127.2, 116.9 (d, $^2J_{CF}$ = 22.7 Hz), 113.3, 65.9, 46.8, 46.3;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.9 (tt, *J* = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2187, 1586, 1489, 1185, 1110, 928, 838;

HRMS (ESI^+) calcd. for $C_{18}H_{20}FN_4OS^+$ $[M+H]^+$: 359.1336, found: 359.1336.

***N*-((4-Fluorophenyl)(morpholino)(prop-2-yn-1-ylimino)-λ^6-sulfaneylidene)cyanamide (177)**



To an oven-dried 10 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **166** (54.9 mg, 0.20 mmol, 1.00 equiv.) in anhydrous CH_3CN (2.1 mL) at room temperature. DBU (92 µL, 0.62 mmol, 3.00 equiv.) was then added, followed by the addition of propargyl bromide solution (76 mg, 80% wt in toluene, 0.51 mmol, 2.50 equiv.). The reaction was stirred at room temperature for 16 h until completion (judged by TLC). The reaction was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with ethyl acetate (3 × 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 10:1 to 4:1) to afford *sulfondiimidamide* **177** as a white solid (48.3 mg, 0.16 mmol, 77%).

mp 128-131 °C;

R$_f$ 0.54 (CH_2Cl_2/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.99-7.94 (m, 2H, Ar$_F$-*H*), 7.30-7.24 (m, 2H, Ar$_F$-*H*), 4.14 (dd, *J* = 17.4, 2.5 Hz, 1H, NC*H*$_a$H$_b$CCH), 4.02 (dd, *J* = 17.4, 2.5 Hz, 1H, NCH$_a$*H*$_b$CCH), 3.78-3.72 (m, 4H, OC*H*$_2$), 3.17 (dt, *J* = 11.9, 4.8 Hz, 2H, NC*H*$_2$), 3.07 (dt, *J* = 11.3, 4.2 Hz, 2H, NC*H*$_2$), 2.28 (t, *J* = 2.5 Hz, 1H, NCH$_2$CC*H*);

^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.0 (d, $^1J_{CF}$ = 257.9 Hz), 131.0 (d, $^3J_{CF}$ = 9.6 Hz), 128.4 (d, $^4J_{CF}$ = 3.2 Hz), 117.1 (d, $^2J_{CF}$ = 22.8 Hz), 112.9, 81.2, 71.5, 66.1, 47.0, 31.8;

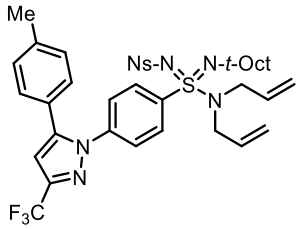
^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -102.5 (tt, *J* = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2190, 1586, 1489, 1260, 1188, 1110, 928;

HRMS (ESI$^+$) calcd. for $C_{14}H_{16}FN_4OS^+$ [M+H]$^+$: 307.1023, found: 307.1021.

6.3.10 Synthesis of A Celecoxib Analogue

_N_-((Diallylamino)(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)((2,4,4-trimethylpentan-2-yl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (178)



Sulfondiimidoyl fluoride **111** (370 mg, 0.54 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (356 mg, 0.59 mmol, 1.10 equiv.) were added to an oven-dried 10 mL round-bottom flask and dissolved in anhydrous *t*-AmylOH (1.10 mL). Then diallyl amine (262 mg, 2.70 mmol, 5.00 equiv.) was added and the reaction was stirred at 70 °C for 18 h. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 4:1) without an aqueous workup to afford *sulfondiimidamide* **178** as a white solid (306 mg, 0.40 mmol, 75%).

mp 140-142 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.09 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.74 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.66 (d, *J* = 8.8 Hz, 2H, Ar-*H*), 7.33 (d, *J* = 8.8 Hz, 2H, Ar-*H*), 7.19 (d, *J* = 8.5 Hz, 2H, Tol-*H*), 7.12 (d, *J* = 8.5 Hz, 2H, Tol-*H*), 6.73 (s, 1H, HetAr-*H*), 5.51 (dddd, *J* = 16.3, 10.2, 7.5, 5.9 Hz, 2H, NCH_2CH=CH_2), 5.14-5.04 (m, 4H, NCH_2CH=CH_2), 3.94 (dd, *J* = 15.1, 5.9 Hz, 2H, NCH_aH_bCH=CH_2), 3.74 (dd, *J* = 15.1, 7.6 Hz, 2H, NCH_aH_bCH=CH_2), 2.38 (s, 3H, Tol-CH_3), 1.72 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.61 (d, *J* = 14.5 Hz, 1H, $NC(CH_3)_2CH_aH_b$), 1.59 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.50 (s, 3H, $NC(CH_3)_a(CH_3)_b$), 1.06 (s, 9H, *t*-Bu-*H*);

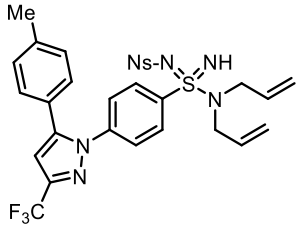
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 149.6, 149.2, 145.2, 144.2 (q, $^2J_{CF}$ = 38.5 Hz), 142.2, 141.3, 139.9, 132.5, 129.8, 128.9, 128.8, 127.3, 125.9, 125.2, 123.7, 121.1 (q, $^1J_{CF}$ = 269.4 Hz), 120.0, 106.4, 60.3, 57.5, 50.1, 31.88, 31.85, 31.5, 31.4, 21.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -62.4 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1530, 1473, 1382, 1237, 1155, 1089, 1012, 954;

HRMS (ESI^+) calcd. for $C_{37}H_{44}F_3N_6O_4S_2^+$ $[M+H]^+$: 757.2812, found: 757.2802.

***N*-((Diallylamino)(imino)(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (179)**



To a solution of sulfondiimidamide **178** (275 mg, 0.36 mmol, 1.00 equiv.) in CH_2Cl_2 (3.60 mL) in an oven-dried 25 mL round-bottom flask was added TFA (0.14 mL, 1.82 mmol, 5.00 equiv.) at room temperature. The mixture was stirred at room temperature for 15 min before being concentrated *in vacuo* and diluted with ethyl acetate (50 mL). Then the mixture was basified to pH 10-11 using 1 M aq. NaOH solution (60 mL). The aqueous phase was extracted with ethyl acetate (2 × 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 4:1 to 2:1) to afford *sulfondiimidamide* **179** as a colourless oil (212 mg, 0.33 mmol, 91%).

R$_f$ 0.54 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.21 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.00 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.93 (d, *J* = 8.9 Hz, 2H, Ar-*H*), 7.41 (d, *J* = 8.9 Hz, 2H, Ar-*H*), 7.17 (d, *J* = 8.2 Hz, 2H, Tol-*H*), 7.12 (d, *J* = 8.2 Hz, 2H, Tol-*H*), 6.89 (s, 1H, HetAr-*H*), 5.60 (ddt, *J* = 16.6, 10.2, 6.3 Hz, 2H, NCH_2CH=CH_2), 5.22-5.06 (m, 4H, NCH_2CH=CH_2), 3.91 (ddt, *J* = 15.5, 6.2, 1.6 Hz, 2H, NCH_aH_bCH=CH_2), 3.84 (ddt, *J* = 15.5, 6.4, 1.3 Hz, 2H, NCH_aH_bCH=CH_2), 3.70 (s, 1H, N*H*), 2.32 (s, 3H, Tol-CH_3);

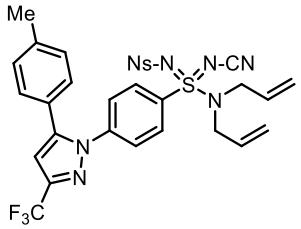
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 150.6, 150.4, 146.6, 144.2 (q, $^2J_{CF}$ = 38.1 Hz), 143.8, 140.8, 139.9, 133.3, 130.4, 129.9, 129.2, 128.8, 126.8, 126.7, 125.0, 122.5 (q, $^1J_{CF}$ = 268.2 Hz), 120.0, 107.1 (q, $^3J_{CF}$ = 2.1 Hz), 50.6, 21.4;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -62.7 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1473, 1462, 1382, 1239, 1154, 1088, 1011, 954;

HRMS (ESI^+) calcd. for $C_{29}H_{28}F_3N_6O_4S_2^+$ $[M+H]^+$: 645.1560, found: 645.1555.

***N*-((Cyanoimino)(diallylamino)(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (180)**



To an oven-dried 50 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **179** (800 mg, 1.24 mmol, 1.00 equiv.) in anhydrous CH_3CN (6.2 mL) at room temperature. Et_3N (0.35 mL, 2.50 mmol, 2.00 equiv.) was then added, followed by the addition of BrCN solution (0.37 mL, 5.0 M in CH_3CN, 1.85 mmol, 1.50 equiv.). After being stirred at room temperature for 10 min, the reaction mixture was quenched with sat. aq. $NaHCO_3$ solution (100 mL). The product was extracted with ethyl acetate (3 × 60 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) to afford *sulfondiimidamide* **180** as a pale-yellow oil (780 mg, 1.17 mmol, 94%).

R_f 0.51 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.30 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.16 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.95 (d, *J* = 9.0 Hz, 2H, Ar-*H*), 7.57 (d, *J* = 9.0 Hz, 2H, Ar-*H*), 7.18 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 7.10 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 6.73 (s, 1H, HetAr-*H*), 5.66 (ddt, *J* =

16.8, 10.2, 6.6 Hz, 2H, $NCH_2CH{=}CH_2$), 5.30-5.20 (m, 4H, $NCH_2CH{=}CH_2$), 4.05 (dd, *J* = 15.5, 6.4 Hz, 2H, $NCH_aH_bCH{=}CH_2$), 3.94 (dd, *J* = 15.5, 6.8 Hz, 2H, $NCH_aH_bCH{=}CH_2$), 2.36 (s, 3H, Tol-CH_3);

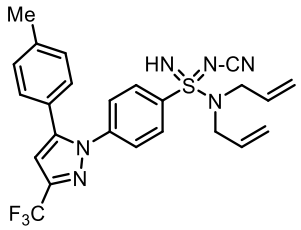
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 150.1, 147.3, 145.6, 144.51, 144.50 (q, $^2J_{CF}$ = 38.7 Hz), 140.2, 133.9, 130.1, 129.9, 129.2, 128.6, 128.4, 125.6, 125.3, 124.3, 121.8, 120.8 (q, $^1J_{CF}$ = 269.4 Hz), 109.4, 107.0, 50.1, 21.2;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -62.5 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2360, 2208, 1531, 1473, 1462, 1382, 1239, 1162, 1081, 954;

HRMS (ESI^+) calcd. for $C_{30}H_{27}F_3N_7O_4S_2^+$ $[M+H]^+$: 670.1513, found: 670.1522.

***N,N*-diallyl-*N*'-cyano-4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)benzenesulfondiimidamide (181)**



To an oven-dried 50 mL round-bottom flask was dissolved sulfondiimidamide **180** (463 mg, 0.69 mmol, 1.00 equiv.) in anhydrous CH_3CN (6.90 mL) at 0 °C. Then 1-dodecanethiol (0.83 mL, 3.47 mmol, 5.00 equiv.) was added, followed by the addition of DBU (0.50 mL, 3.28 mmol, 4.75 equiv.). After being stirred at 0 °C for 5 min, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with ethyl acetate (3 × 60 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) to afford *sulfondiimidamide* **181** as a pale-yellow oil (301 mg, 0.62 mmol, 90%).

R_f 0.40 (petrol/ethyl acetate, 3:2);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.02 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.51 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.20 (d, J = 8.2 Hz, 2H, Tol-*H*), 7.16 (d, J = 8.2 Hz, 2H, Tol-*H*), 6.92 (s, 1H, HetAr-*H*), 5.65 (ddt, J = 17.2, 10.1, 6.3 Hz, 2H, NCH_2CH=CH_2), 5.24-5.14 (m, 4H, NCH_2CH=CH_2), 3.98-3.83 (m, 5H, NCH_2CH=CH_2/N*H*), 2.34 (s, 3H, Tol-CH_3);

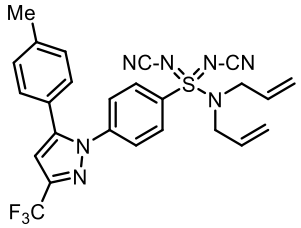
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 146.7, 144.2 (q, $^{2}J_{CF}$ = 37.8 Hz), 144.0, 140.8, 139.1, 133.1, 130.4, 129.9, 129.4, 127.0, 126.6, 122.4 (q, $^{1}J_{CF}$ = 268.2 Hz), 120.1, 114.0, 107.1 (q, $^{3}J_{CF}$ = 2.1 Hz), 50.6, 21.3;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -62.8 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2188, 1495, 1471, 1373, 1235, 1160, 1133, 1097, 974, 808;

HRMS (ESI^+) calcd. for $C_{24}H_{24}F_3N_6S^+$ $[M+H]^+$: 485.1730, found: 485.1732.

***N,N*-diallyl-*N*'-cyano-*N*''-cyano-4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)benzenesulfondiimidamide (182)**



To an oven-dried 50 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **181** (1.26 g, 2.60 mmol, 1.00 equiv.) in anhydrous CH_3CN (13.0 mL) at room temperature. Et_3N (0.73 mL, 5.24 mmol, 2.00 equiv.) was then added, followed by the addition of BrCN solution (0.78 mL, 5.0 M in CH_3CN, 3.90 mmol, 1.50 equiv.). After being stirred at room temperature for 20 min, the reaction mixture was quenched with sat. aq. $NaHCO_3$ solution (200 mL). The product was extracted with ethyl acetate (3 × 80 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 50:1 to 20:1) to afford *sulfondiimidamide* **182** as a pale-yellow oil (1.21 g, 2.38 mmol, 91%).

R_f 0.57 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.97 (d, *J* = 9.0 Hz, 2H, Ar-*H*), 7.63 (d, *J* = 9.0 Hz, 2H, Ar-*H*), 7.22 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 7.13 (d, *J* = 8.0 Hz, 2H, Tol-*H*), 6.75 (s, 1H, HetAr-*H*), 5.67 (ddt, *J* = 16.8, 10.1, 6.6 Hz, 2H, NCH_2CH=CH_2), 5.37-5.23 (m, 4H, NCH_2CH=CH_2), 3.98 (d, *J* = 6.6 Hz, 4H, NCH_2CH=CH_2), 2.39 (s, 3H, Tol-CH_3);

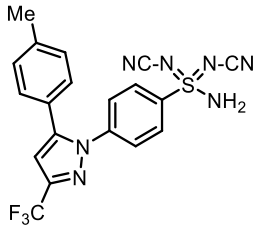
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 145.8, 145.1, 144.9 (q, $^2J_{CF}$ = 38.9 Hz), 140.5, 132.0, 130.1, 129.7, 129.4, 128.8, 125.9, 125.4, 122.5, 120.9 (q, $^1J_{CF}$ = 269.4 Hz), 109.0, 107.3 (q, $^3J_{CF}$ = 2.2 Hz), 50.1, 21.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -62.6 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2204, 1592, 1471, 1372, 1236, 1161, 1135, 1096, 973, 888;

HRMS (ESI^+) calcd. for $C_{25}H_{23}F_3N_7S^+$ $[M+H]^+$: 510.1682, found: 510.1677.

_N_'-cyano-_N_''-cyano-4-(5-(_p_-tolyl)-3-(trifluoromethyl)-1_H_-pyrazol-1-yl)benzenesulfondiimidamide (183)



Sulfondiimidamide **182** (426 mg, 0.84 mmol, 1.00 equiv.), 1,3-dimethylbarbituric acid (783 mg, 5.02 mmol, 6.00 equiv.), $Pd(PPh_3)_4$ (194 mg, 0.17 mmol, 0.20 equiv.) were dissolved in anhydrous, degassed CH_2Cl_2 (4.20 mL) in an oven-dried 25 mL round-bottom flask and under nitrogen atmosphere. The reaction was stirred at room temperature for 2 h. The crude product was purified by flash column chromatography (ethyl acetate/ethanol, 1:0 to 3:1) without an aqueous workup to afford *sulfondiimidamide* **183** as a white solid (336 mg, 0.78 mmol, 93%).

mp 208-210 °C;

R_f 0.50 (ethyl acetate/ethanol, 4:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.01 (d, J = 8.7 Hz, 2H, Ar-*H*), 7.52 (d, J = 8.7 Hz, 2H, Ar-*H*), 7.20 (s, 4H, Tol-*H*), 7.11 (s, 1H, HetAr-*H*), 4.80-2.90 (m, 2H, NH_2), 2.30 (s, 3H, Tol-CH_3);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 145.4, 144.8, 142.4 (q, $^{2}J_{CF}$ = 37.7 Hz), 141.1, 139.3, 129.6, 128.8, 127.1, 125.8, 125.4, 121.4 (q, $^{1}J_{CF}$ = 269.0 Hz), 116.5, 106.1, 20.9;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -61.0 (s);

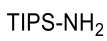
IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2162, 1472, 1377, 1238, 1162, 1053, 1025, 1006, 821;

HRMS (ESI^+) calcd. for $C_{19}H_{15}F_3N_7S^+$ $[M+H]^+$: 430.1056, found: 430.1055.

6.4 Chapter 4 Data

6.4.1 Preparation of TIPS-NSO

Triisopropylsilyl amine (184)



Triisopropylsilyl chloride (13.50 g, 70.0 mmol, 1.00 equiv.) was dissolved in anhydrous diethyl ether (140 mL) in an oven-dried 500 mL round-bottom flask. The reaction mixture was cooled to -78 °C. Anhydrous ammonia gas was bubbled through this solution for 2 h, resulting in the formation of a white precipitate. The reaction was then warmed to 0 °C and stirred for another 3 h to remove excess ammonia. Filtration over anhydrous Na_2SO_4 (washed with diethyl ether) and removal of solvent under reduced pressure afforded triisopropylsilyl amine **184** as a colourless oil (12.0 g, 69.4 mmol, 99%).

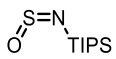
^{1}H NMR (400 MHz, C_6D_6): δ (ppm) = 1.05-1.00 (m, 18H, Si(CH(C*H*$_3$)$_2$)$_3$), 0.95-0.85 (m, 3H, Si(C*H*(CH$_3$)$_2$)$_3$), -0.12 (s, 2H, N*H*$_2$);

^{13}C NMR (101MHz, C_6D_6): δ (ppm) = 18.4, 12.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2864, 1546, 1463, 1382, 1245, 1011, 882, 817, 658;

HRMS (ESI$^+$) calcd. for $C_9H_{24}NSi^+$ $[M+H]^+$: 174.1673; mass not found.

Triisopropylsilyl Sulfinylamine (185)



Triisopropylsilyl amine **184** (5.20 g, 30.0 mmol, 1.00 equiv.) was dissolved in anhydrous diethyl ether (600 mL) in an oven-dried 1 L round-bottom flask. The reaction was cooled to 0 °C and anhydrous Et_3N (8.41 mL, 61.8 mmol, 2.06 equiv.) was added. Freshly distilled thionyl chloride (2.25 mL, 30.9 mmol, 1.03 equiv.) was then added dropwise. The reaction was stirred at 0 °C for 1.5 h. Filtration over Na_2SO_4 (washed with diethyl ether) and removal

of solvent under reduced pressure afforded tri-*iso*propylsilyl sulfinylamine **185** as a pale-yellow oil (6.56 g, 30.0 mmol, 100%).

Notes:

1. TIPS-NSO should be stored in the freezer (-20 °C) and can be used without loss of performance for at least 1 month.
2. **CAUTION: Hydrolysis of sulfinylamines results in the formation of toxic sulfur dioxide gas.** Evolution of SO_2 from TIPS-NSO has not been observed in the normal course of use, but avoidance of contact with water or prolonged storage at room temperature is advised.
3. During the workup stage diethyl ether was removed in a rotary evaporator with the bath temperature set to 30 °C or lower.

^{1}H NMR (400 MHz, C_6D_6): δ (ppm) = 1.19-0.96 (m, 21H, TIPS-*H*);

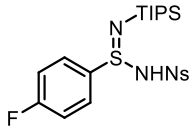
^{13}C NMR (101MHz, C_6D_6): δ (ppm) = 18.0, 12.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2980, 1463, 1385, 1308, 1128, 882, 682, 664;

HRMS (ESI^+) calcd. for $C_9H_{22}NOSSi^+$ $[M+H]^+$: 220.1186; mass not found.

6.4.2 Sulfondiimidamide 164 Synthesis from TIPS-NSO

N-(*S*-(4-Fluorophenyl)-*N*-(triisopropylsilyl)sulfinimidoyl)-4-nitrobenzenesulfonamide (187)



Triisopropylsilyl sulfinylamine **185** (1.73 g, 7.90 mmol, 1.00 equiv.) was dissolved in anhydrous THF (15.8 mL) in an oven-dried 250 mL round-bottom flask and was purged with nitrogen gas. The mixture was cooled to -30 °C before LiHMDS solution (7.90 mL, 1.00 M in THF, 7.90 mmol, 1.00 equiv.) was added. After being stirred at - 30 °C for 5 min, the reaction was warmed to 0 °C and stirred for another 5 min. TMSCl (1.00 mL, 7.90 mmol,

1.00 equiv.) was added and the reaction was stirred at 0 °C for 10 min. 4-Fluorophenylmagnesium bromide solution (10.53 mL, 0.90 M in THF, 9.48 mmol, 1.20 equiv.) was then added and the reaction was stirred at 0 °C for 10 min. The reaction mixture was then quenched with sat. aq. tetrasodium EDTA solution (250 mL). Ethyl acetate (150 mL) was added and the organic layer was separated. The aqueous layer was further extracted with ethyl acetate (2 × 80 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude mixture was dissolved in anhydrous CH_2Cl_2 (39.5 mL) in an oven-dried 250 mL round-bottom flask at 0 °C before Et_3N (1.32 mL, 9.48 mmol, 1.20 equiv.) and NsCl (1.75 g, 7.90 mmol, 1.00 equiv.) were added. The reaction was stirred at 0 °C for 20 min and then was quenched with sat. aq. NaCl solution (150 mL) and extracted with CH_2Cl_2 (3 × 80 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered, concentrated under reduced pressure and purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 100:1 to 30:1 to 20:1) to afford *sulfinamidine* **187** as a white solid (3.52 g, 7.05 mmol, 89%).

mp 148-150 °C;

R$_f$ 0.64 (CH_2Cl_2/ethyl acetate, 25:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.18 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.87 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.63-7.58 (m, 2H, Ar_F-*H*), 7.13-7.07 (m, 2H, Ar_F-*H*), 4.53 (s, 1H, N*H*), 1.32-1.20 (m, 3H, Si(C*H*$(CH_3)_2)_3$), 1.13-1.06 (m, 18H, Si(CH(C*H*$_3)_2)_3$);

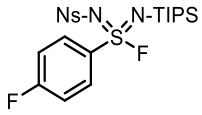
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 164.7 (d, $^1J_{CF}$ = 254.8 Hz), 150.3, 149.2, 136.6 (d, $^4J_{CF}$ = 3.2 Hz), 128.8 (d, $^3J_{CF}$ = 9.1 Hz), 127.4, 123.8, 116.8 (d, $^2J_{CF}$ = 22.7 Hz), 17.94, 17.90, 12.0 (Note: For dimethyl carbons in tri-*iso*propylsilyl group, NSi (CH$\mathbf{(CH_3)_2}$)$_3$, 2 peaks were found instead of 1 due to the loss of symmetry caused by chiral sulfur atom);

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -106.7 (tt, J = 8.1, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1490, 1389, 1347, 1299, 1227, 1149, 1088, 954,786, 608;

HRMS (ESI$^+$) calcd. for $C_{21}H_{31}FN_3O_4S_2Si^+$ $[M+H]^+$: 500.1504, found: 500.1504;

4-Fluoro-*N*-((4-nitrophenyl)sulfonyl)-*N*-(triisopropylsilyl)benzenesulfondiimidoyl fluoride (188)



An oven-dried 50 mL round-bottom flask was charged with sulfinamidine **187** (998 mg, 2.00 mmol, 1.00 equiv.) and NaH (88 mg, 60 % dispersion in mineral oil, 2.20 mmol, 1.10 equiv.) at 0 °C and was purged with nitrogen gas. Anhydrous THF (4.00 mL) was added. The reaction was stirred at 0 °C for 5 min before being warmed to room temperature and stirred for another 25 min. NFSI (945 mg, 3.00 mmol, 1.50 equiv.) was then added under a positive pressure of nitrogen and the reaction was stirred at room temperature for 30 min before being quenched with sat. aq. NaCl solution (150 mL). Ethyl acetate (100 mL) was added and the organic layer was separated. The aqueous layer was further extracted with ethyl acetate (2 × 40 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure to give a crude solid. Diethyl ether (150 ml) was added to the crude solid and the resulting suspension was shaken well before being filtered. The white filter cake was washed with diethyl ether (80 ml) and CH_2Cl_2 (80 ml). The combined filtrate was concentrated under reduced pressure to give a crude product. The crude product was then purified by flash column chromatography (petrol/ethyl acetate, 6:1) to afford *sulfondiimidoyl fluoride* **188** as a colourless oil (941 mg, 1.82 mmol, 91%).

R$_f$ 0.42 (petrol/ethyl acetate, 6:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.27 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.00-7.94 (m, 4H, Ar_{Ns}-*H*/Ar_F-*H*), 7.34-7.28 (m, 2H, Ar_F-*H*), 1.23-1.13 (m, 3H, Si(C*H*$(CH_3)_2)_3$), 1.05 (d, J = 2.9 Hz, 9H, Si(CH(C*H*$_3)_a(CH_3)_b)_3$), 1.03 (d, J = 2.9 Hz, 9H, Si(CH$(CH_3)_a$(C*H*$_3)_b)_3$);

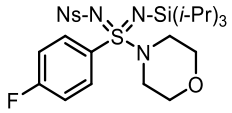
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 167.0 (d, $^{1}J_{CF}$ = 256.4 Hz), 151.1, 148.8, 136.2 (dd, $^{2,4}J_{CF}$ = 28.5, 3.1 Hz), 131.3 (d, $^{3}J_{CF}$ = 10.2 Hz), 128.8, 125.3, 118.0 (d, $^{2}J_{CF}$ = 23.5 Hz), 18.3, 18.2, 13.4 (d, $^{4}J_{CF}$ = 1.9 Hz) (Note: For dimethyl carbons in tri-*iso*propylsilyl group, NSi (CH(***CH$_3$***)***$_2$***)$_3$, 2 peaks were found instead of 1 due to the loss of symmetry caused by chiral sulfur atom);

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = 87.6 (s), -103.3 (tt, J = 8.7, 4.8 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1403, 1348, 1251, 1163, 1113, 1090, 855, 683, 614;

HRMS (ESI^+) calcd. for $C_{21}H_{29}F_2N_3O_4S_2SiNa^+$ $[M+Na]^+$: 540.1229, found: 540.1228.

***N*-((4-Fluorophenyl)(morpholino)((triisopropylsilyl)imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (189)**



Sulfondiimidoyl fluoride **188** (305 mg, 0.59 mmol, 1.00 equiv.), $Ca(NTf_2)_2$ (389 mg, 0.65 mmol, 1.10 equiv.) were added to an oven-dried 10 mL round-bottom flask and dissolved in anhydrous *t*-AmylOH (1.18 mL). Then morpholine (113 mg, 1.30 mmol, 2.20 equiv.) was added and the reaction was stirred at 60 °C for 45 h until completion (judged by TLC). The mixture was then diluted with ethyl acetate (100 mL) and quenched with sat. aq. NaCl solution (250 mL). The organic layer was separated and the aqueous layer was extracted with ethyl acetate (2 × 100 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) to afford *sulfondiimidamide* **189** as a colourless oil (252 mg, 0.43 mmol, 73%).

R$_f$ 0.41 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.26 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.04 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.87-7.82 (m, 2H, Ar_F-*H*), 7.18-7.12 (m, 2H, Ar_F-*H*), 3.71-3.66 (m, 4H,

OCH_2), 3.15 (dt, J = 11.8, 4.6 Hz, 2H, NCH_aH$_b$), 3.03 (dt, J = 11.8, 4.6 Hz, 2H, NCH$_a$$H_b$), 1.07-0.96 (m, 21H, TIPS-*H*);

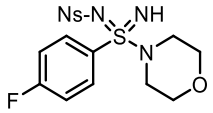
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.2 (d, $^1J_{CF}$ = 256.3 Hz), 149.8, 149.4, 135.8 (d, $^4J_{CF}$ = 3.2 Hz), 130.2 (d, $^3J_{CF}$ = 9.2 Hz), 127.6, 123.8, 116.3 (d, $^2J_{CF}$ = 22.6 Hz), 66.3, 46.5, 18.3, 13.2;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.7 (tt, J = 8.0, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1374, 1297, 1153, 1086, 1064, 1011, 922, 738, 680;

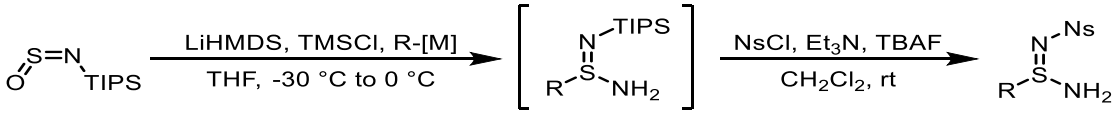
HRMS (ESI^+) calcd. for $C_{25}H_{37}FN_4O_5S_2SiNa^+$ $[M+Na]^+$: 607.1851, found: 607.1849.

***N*-((4-Fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (164)**



To a solution of sulfondiimidamide **189** (222 mg, 0.38 mmol, 1.00 equiv.) in anhydrous THF (3.80 mL) in an oven-dried 25 mL round-bottom flask was added TBAF solution (0.42 mL, 1.00 M in THF, 0.42 mmol, 1.10 equiv.) at 0 °C. After being stirred at 0 °C for 10 min, the reaction mixture was quenched with sat. aq. NaCl solution (120 mL). The product was extracted with ethyl acetate (3 × 60 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 2:1) to afford *sulfondiimidamide* **164** as a white solid (158 mg, 0.37 mmol, 97%).

6.4.3 General Procedure J for Primary Sulfinamidine Synthesis



An oven-dried round-bottom flask containing TIPS-NSO **185** (1.00 equiv.) was sealed and subjected to three N_2 evacuation/refill cycles before pre-sparged anhydrous THF (TIPS-NSO

conc. 0.5 M) was added. The solution was cooled to -30 °C and then LiHMDS solution (1.00 M in THF, 1.00 equiv.) was added. The reaction was stirred at -30 °C for 5 min before being warmed to 0 °C and stirred for 5 min at the same temperature. TMSCl (1.00 equiv.) was then added and the reaction was stirred at 0 °C for 10 min. Subsequently, the corresponding organometallic reagent (1.20 equiv.) was added. The reaction was stirred at 0 °C for another 10 min before being diluted with ethyl acetate and quenched with sat. aq. tetrasodium EDTA solution. The aqueous layer was separated and extracted with ethyl acetate three times. The combined organic extracts were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. This crude mixture was then dissolved in anhydrous CH_2Cl_2 (TIPS-NSO conc. 0.2 M) and cooled to 0 °C. Et_3N (1.20 equiv.) and NsCl (1.00 equiv.) were then added. The reaction was stirred at 0 °C for 20 min prior to the addition of TBAF solution (1.00 M in THF, 1.10 equiv.) at the same temperature. The reaction was stirred for 10 min at 0 °C. Then primary sulfinamidines were isolated following different work-up procedures (**Work-up Procedure J1**-**J3**).

Work-up Procedure J1:

Addition of TBAF solution to the reaction mixture resulted in the precipitation of a solid (Ns-protected primary sulfinamidine). This solid was isolated by filtration and was then washed with a cold solution of ethyl acetate and Et_2O (1:2). The filtered solid sulfinamidine was pure by ^1H NMR and kept as clean material, whilst sat. aq. NaCl solution was added to the combined filtrate. The aqueous phase was extracted with ethyl acetate three times. The combined organic extracts were then dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The resulting primary sulfinamidine was then purified by flash column chromatography with the appropriate solvent system.

Work-up Procedure J2:

If the addition of TBAF solution to the reaction mixture did not result in the precipitation of a solid, the reaction was then diluted with ethyl acetate and quenched with sat. aq. NaCl solution. The aqueous phase was separated and extracted with ethyl acetate three times. The combined organic extracts were then dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure to give a solid. This solid was purified by filtration and washed with cold Et_2O. The filtered solid sulfinamidine was pure by ^1H NMR and kept as clean material, whilst the combined filtrates were then concentrated under reduced pressure. The remaining material was then purified by flash column chromatography with the appropriate solvent system.

Work-up Procedure J3:

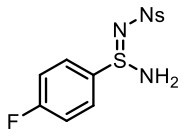
If the addition of TBAF solution to the reaction mixture did not result in the precipitation of a solid, the reaction was then diluted with ethyl acetate and quenched with sat. aq. NaCl solution. The aqueous phase was separated and extracted with ethyl acetate three times. The combined organic layers were then dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure to give an oil. The primary sulfinamidine was then purified by flash column chromatography with the appropriate solvent system.

Notes:

1. TIPS-protected primary sulfinamidines may be sensitive to moisture and heat, and may decompose slightly at room temperature. For this reason, during the work-up stage volatiles are removed in a rotary evaporator with the bath temperature set to 30 °C or lower. Additionally, crude TIPS-protected primary sulfinamidines should immediately be used in the following step without further purification.
2. If the organometallic reagents were prepared at -78 °C, the *in-situ* generated sulfurdiimide reagent was added to the organometallic reagents at -78 °C. The reaction was then warmed to 0 °C and stirred at 0 °C for 10 min before being

quenched with sat. aq. tetrasodium EDTA solution.

***N*-(Amino(4-fluorophenyl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (197)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 4-fluorophenylmagnesium bromide solution (7.50 mL, 0.80 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **197** was isolated and purified according to **Work-up Procedure J2**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 1:1) afforded the desired product as a white solid (1.48 g, 4.31 mmol, 86%).

mp 145-147 °C;

R$_f$ 0.35 (CH_2Cl_2/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.34 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.83-7.77 (m, 2H, Ar_F-*H*), 7.49-7.43 (m, 2H, Ar_F-*H*), 7.12 (s, 2H, N*H*$_2$);

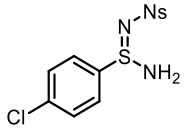
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 163.9 (d, $^1J_{CF}$ = 250.2 Hz), 150.5, 148.8, 134.8 (d, $^4J_{CF}$ = 2.8 Hz), 129.5 (d, $^3J_{CF}$ = 9.4 Hz), 127.3, 124.3, 116.6 (d, $^2J_{CF}$ = 22.9 Hz);

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -108.9 (tt, J = 8.9, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1521, 1487, 1353, 1276, 1230, 1139, 1085, 975, 835, 783, 730;

HRMS (ESI$^+$) calcd. for $C_{12}H_{11}FN_3O_4S_2^+$ $[M+H]^+$: 344.0170, found: 344.0171.

***N*-(Amino(4-chlorophenyl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (198)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 4-chlorophenylmagnesium bromide solution (6.00 mL, 1.00 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **198** was isolated and purified according to **Work-up Procedure J2**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 1:1) afforded the desired product as a white solid (1.61 g, 4.48 mmol, 90%).

mp 174-176 °C;

R$_f$ 0.47 (CH_2Cl_2/ethyl acetate, 2:1);

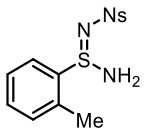
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.34 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.75 (d, J = 9.0 Hz, 2H, Ar_{Cl}-*H*), 7.68 (d, J = 9.0 Hz, 2H, Ar_{Cl}-*H*), 7.16 (s, 2H, N*H*$_2$);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.4, 148.8, 137.8, 136.8, 129.5, 128.7, 127.3, 124.3;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1520, 1475, 1393, 1350, 1271, 1149, 1080, 968, 832;

HRMS (ESI$^+$) calcd. for $C_{12}H_{11}ClN_3O_4S_2^+$ $[M+H]^+$: 359.9874, found: 359.9874.

***N*-(Amino(*o*-tolyl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (199)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 2-methylphenylmagnesium bromide solution (7.69 mL, 0.78 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N

(0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **199** was isolated and purified according to **Work-up Procedure J2**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 1:1) afforded the desired product as a white solid (1.41 g, 4.16 mmol, 83%).

mp 168-170 °C;

R$_f$ 0.46 (CH_2Cl_2/ethyl acetate, 2:1);

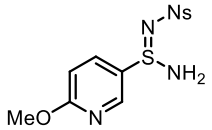
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.31 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06-7.97 (m, 3H, Ar_{Ns}-*H*/Tol-*H*), 7.52-7.41 (m, 2H, Tol-*H*), 7.34 (ddd, J = 7.1, 1.9, 1.0 Hz, 1H, Tol-*H*), 6.90 (s, 2H, NH_2), 2.39 (s, 3H, Tol-CH_3);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.7, 148.7, 137.6, 135.9, 131.9, 131.3, 127.2, 127.0, 125.0, 124.2, 18.5;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1530, 1474, 1382, 1351, 1267, 1152, 1084, 967;

HRMS (ESI$^+$) calcd. for $C_{13}H_{14}N_3O_4S_2^+$ $[M+H]^+$: 340.0425, found: 340.0421.

***N*-(Amino(6-methoxypyridin-3-yl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (200)**



Preparation of organometallic reagent

(6-Methoxypyridin-3-yl)lithium solution was prepared according to the following procedure. To a solution of 5-bromo-2-methoxypyridine (1.13 g, 6.00 mmol, 1.20 equiv.) in anhydrous THF (12.0 mL) in an oven-dried 100 mL round-bottom flask was added *n*-butyllithium solution (2.40 mL, 2.50 M in hexanes, 6.00 mmol, 1.20 equiv.) dropwise at -78 °C. The reaction was stirred at the same temperature for 40 min.

Preparation of sulfinamidine

Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), (6-methoxypyridin-3-yl)lithium solution (6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **200** was isolated and purified according to **Work-up Procedure J2**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 2:1 to 1:1) afforded the desired product as a white solid (1.31 g, 3.68 mmol, 74%).

mp 158-160 °C;

R$_f$ 0.27 (CH_2Cl_2/ethyl acetate, 2:1);

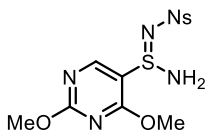
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.44 (dd, J = 2.7, 0.7 Hz, 1H, HetAr-*H*), 8.33 (d, J = 9.0 Hz, 2H, Ar$_{Ns}$-*H*), 8.05 (d, J = 9.0 Hz, 2H, Ar$_{Ns}$-*H*), 7.98 (dd, J = 8.9, 2.7 Hz, 1H, HetAr-*H*), 7.15 (s, 2H, NH_2), 7.02 (dd, J = 8.9, 0.7 Hz, 1H, HetAr-*H*), 3.90 (s, 3H, HetAr-OCH_3);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 165.5, 150.5, 148.8, 146.1, 137.6, 128.1, 127.2, 124.3, 111.5, 54.1;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1587, 1518, 1475, 1380, 1353, 1280, 1145, 1085, 966, 856, 831, 785;

HRMS (ESI$^+$) calcd. for $C_{12}H_{13}N_4O_5S_2^+$ $[M+H]^+$: 357.0322, found: 357.0323.

***N*-(Amino(2,4-dimethoxypyrimidin-5-yl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (201)**



Preparation of Grignard reagent

(2,4-Dimethoxypyrimidin-5-yl)magnesium chloride lithium chloride complex solution was prepared according to the following procedure. To a solution of 5-bromo-2,4-dimethoxypyrimidine (1.31 g, 6.00 mmol, 1.20 equiv.) in anhydrous THF (3.0 mL) in an oven-dried 100 mL round-bottom flask was added *iso*-propylmagnesium chloride lithium chloride complex solution (Turbo Grignard Reagent, 4.80 mL, 1.25 M in THF, 6.00 mmol, 1.20 equiv.) dropwise at 0 °C. The reaction was stirred at the same temperature for 1 h.

Preparation of sulfinamidine

Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), (2,4-dimethoxypyrimidin-5-yl)magnesium chloride lithium chloride complex solution (6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **201** was isolated and purified according to **Work-up Procedure J3**. Flash column chromatography (petrol/ethyl acetate, 1:2 to 1:4 to 1:10) afforded the desired product as a white solid (1.21 g, 3.13 mmol, 63%).

mp 170-172 °C;

R$_f$ 0.60 (ethyl acetate);

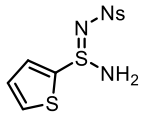
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.72 (s, 1H, HetAr-*H*), 8.31 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.96 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.08 (s, 2H, N*H*$_2$), 3.94 (s, 3H, HetAr-C*H*$_3$), 3.88 (s, 3H, HetAr-C*H*$_3$);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 166.5, 166.3, 157.5, 150.4, 148.7, 127.2, 124.1, 113.4, 55.5, 54.9;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2160, 1740, 1591, 1523, 1470, 1386, 1349, 1279, 1143, 1087, 949;

HRMS (ESI$^+$) calcd. for $C_{12}H_{14}N_5O_6S_2^+$ $[M+H]^+$: 388.0380, found: 388.0379.

***N*-(Amino(thiophen-2-yl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (202)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 2-thienylmagnesium bromide solution (6.00 mL, 1.00 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **202** was isolated and purified according to **Work-up Procedure J1**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 1:1) afforded the desired product as a white solid (1.34 g, 4.05 mmol, 81%).

mp 162-164 °C;

R$_f$ 0.41 (petrol/ethyl acetate, 1:2);

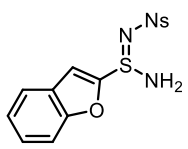
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.35 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.96 (dd, J = 5.1, 1.4 Hz, 1H, HetAr-*H*), 7.42 (dd, J = 3.8, 1.4 Hz, 1H, HetAr-*H*), 7.38 (s, 2H, N*H*$_2$), 7.21 (dd, J = 5.1, 3.8 Hz, 1H, HetAr-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.3, 148.8, 140.2, 133.9, 131.3, 128.8, 127.2, 124.3;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1535, 1477, 1431, 1401, 1351, 1294, 1143, 1086, 966, 850, 787, 728;

HRMS (ESI$^+$) calcd. for $C_{10}H_{10}N_3O_4S_3^+$ $[M+H]^+$: 331.9828, found: 331.9828.

***N*-(Amino(benzofuran-2-yl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (203)**



Preparation of organometallic reagent

2-Lithiobenzofuran solution was prepared according to the following procedure. To a solution of benzofuran (850 mg, 7.20 mmol, 1.20 equiv.) in anhydrous THF (14.4 mL) in an oven-dried 100 mL round-bottom flask was added *n*-butyllithium solution (2.88 mL, 2.50 M in hexanes, 7.20 mmol, 1.20 equiv.) dropwise at 0 °C. The reaction was stirred at the same temperature for 1 h.

Preparation of sulfinamidine

Prepared according to **General Procedure J** using TIPS-NSO **185** (1.31 g, 6.00 mmol, 1.00 equiv.), THF (12.0 mL), LiHMDS solution (6.00 mL, 1.00 M in THF, 6.00 mmol, 1.00 equiv.), TMSCl (0.76 mL, 6.00 mmol, 1.00 equiv.), 2-lithiobenzofuran solution (7.20 mmol, 1.20 equiv.), CH_2Cl_2 (30.0 mL), Et_3N (1.00 mL, 7.20 mmol, 1.20 equiv.), NsCl (1.33 g, 6.00 mmol, 1.00 equiv.) and TBAF solution (6.60 mL, 1.00 M in THF, 6.60 mmol, 1.10 equiv.). The primary sulfinamidine **203** was isolated and purified according to **Work-up Procedure J1**. Filtration afforded the desired product as a white solid (2.05 g, 5.62 mmol, 94%).

mp 188-190 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 1:2);

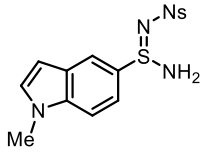
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.32 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.77 (ddd, J = 7.8, 1.3, 0.7 Hz, 1H, HetAr-*H*), 7.66-7.61 (m, 1H, HetAr-*H*), 7.57 (s, 2H, NH_2), 7.50-7.42 (m, 2H, HetAr-*H*), 7.35 (ddd, J = 8.1, 7.2, 1.0 Hz, 1H, HetAr-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 156.3, 150.1, 149.3, 148.8, 127.3, 127.1, 126.3, 124.23, 124.19, 122.8, 112.0, 111.9;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1701, 1529, 1349, 1275, 1137, 1080, 980;

HRMS (ESI$^+$) calcd. for $C_{14}H_{12}N_3O_5S_2^+$ $[M+H]^+$: 366.0213, found: 366.0213.

***N*-(Amino(1-methyl-1*H*-indol-5-yl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (204)**



Preparation of organometallic reagent

(1-methylindole-5-yl)lithium solution was prepared according to the following procedure. To a solution of 5-bromo-1-methylindole (1.26 g, 6.00 mmol, 1.20 equiv.) in anhydrous THF (12.0 mL) in an oven-dried 100 mL round-bottom flask was added *n*-butyllithium solution (2.40 mL, 2.50 M in hexanes, 6.00 mmol, 1.20 equiv.) dropwise at -78 °C. The reaction was stirred at the same temperature for 1 h.

Preparation of sulfinamidine

Prepared according to **General Procedure J** using TIPS-NSO (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), (1-methylindole-5-yl)lithium solution (6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **204** was isolated and purified according to **Work-up Procedure J1**. Filtration afforded the desired product as a yellow solid (0.96 g, 2.54 mmol, 51%).

mp 162-164 °C;

R$_f$ 0.57 (CH_2Cl_2/ethyl acetate, 1:1);

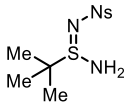
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.32 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.98 (d, J = 2.0 Hz, 1H, HetAr-*H*), 7.63 (d, J = 8.8 Hz, 1H, HetAr-*H*), 7.52-7.42 (m, 2H, HetAr-*H*), 6.91 (s, 2H, NH_2), 6.59 (dd, J = 3.1, 0.8 Hz, 1H, HetAr-*H*), 3.83 (s, 3H, HetAr-CH_3);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.9, 148.6, 137.5, 132.1, 128.5, 127.8, 127.2, 124.2, 119.5, 118.8, 110.8, 101.6, 32.8;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2160, 2031, 1529, 1348, 1290, 1140, 1084, 974, 732;

HRMS (ESI^+) calcd. for $C_{15}H_{15}N_4O_4S_2^+$ $[M+H]^+$: 379.0529, found: 379.0526.

***N*-(Amino(*tert*-butyl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (205)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.31 g, 6.00 mmol, 1.00 equiv.), THF (12.0 mL), LiHMDS solution (6.00 mL, 1.00 M in THF, 6.00 mmol, 1.00 equiv.), TMSCl (0.76 mL, 6.00 mmol, 1.00 equiv.), *tert*-butylmagnesium chloride solution (7.58 mL, 0.95 M in THF, 7.20 mmol, 1.20 equiv.), CH_2Cl_2 (30.0 mL), Et_3N (1.00 mL, 7.20 mmol, 1.20 equiv.), NsCl (1.33 g, 6.00 mmol, 1.00 equiv.) and TBAF solution (6.60 mL, 1.00 M in THF, 6.60 mmol, 1.10 equiv.).

The primary sulfinamidine **205** was isolated and purified according to **Work-up Procedure J1**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 1:1) afforded the desired product as a white solid (1.61 g, 5.28 mmol, 88%).

mp 174-176 °C;

R_f 0.45 (CH_2Cl_2/ethyl acetate, 2:1);

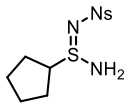
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.32 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.98 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 6.19 (s, 2H, NH_2), 1.15 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.8, 148.5, 127.3, 124.1, 57.0, 22.7;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1350, 1289, 1145, 1084, 972, 853, 733, 683, 624;

HRMS (ESI^+) calcd. for $C_{10}H_{15}N_3O_4S_2Na^+$ $[M+Na]^+$: 328.0396, found: 328.0397.

***N*-(Amino(cyclopentyl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (206)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), cyclopentylmagnesium bromide solution (3.11 mL, 1.93 M in Et_2O, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **206** was isolated and purified according to **Work-up Procedure J3**. Flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 1:1) afforded the desired product as a white solid (1.11 g, 3.50 mmol, 70%).

mp 154-156 °C;

R$_f$ 0.40 (CH_2Cl_2/ethyl acetate, 1:1);

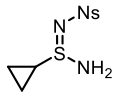
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.32 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.98 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 6.32 (s, 2H, N*H*$_2$), 3.55 (tt, J = 8.3, 5.7 Hz, 1H, SC*H*), 1.92-1.75 (m, 2H, Alkyl-*H*), 1.74-1.60 (m, 2H, Alkyl-*H*), 1.60-1.46 (m, 4H, Alkyl-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 151.0, 148.5, 127.2, 124.1, 62.0, 27.5, 27.2, 25.0, 24.8 (Note: For 4 secondary carbons in cyclopentane ring, 4 peaks were found instead of 2 due to the loss of symmetry caused by chiral sulfur atom);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1538, 1382, 1350, 1291, 1143, 1085, 970, 853, 732, 683, 620;

HRMS (ESI$^+$) calcd. for $C_{11}H_{15}N_3O_4S_2Na^+$ $[M+Na]^+$: 340.0396, found: 340.0397.

***N*-(Amino(cyclopropyl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (207)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), cyclopropylmagnesium bromide solution (6.00 mL, 1.00 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N

(0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **207** was isolated and purified according to **Work-up Procedure J2**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 1:1 to 0:1) afforded the desired product as a white solid (1.19 g, 4.12 mmol, 82%).

mp 154-156°C;

R$_f$ 0.38 (CH_2Cl_2/ethyl acetate, 1:1);

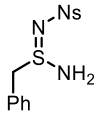
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.32 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.97 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 6.45 (s, 2H, N*H*$_2$), 2.62 (tt, J = 7.8, 4.6 Hz, 1H, SC*H*), 1.11-1.01 (m, 1H, Alkyl-*H*), 0.96-0.83 (m, 2H, Alkyl-*H*), 0.73-0.61 (m, 1H, Alkyl-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.9, 148.6, 127.2, 124.2, 29.7, 3.8, 1.8 (Note: For 2 secondary carbons in cyclopropane ring, 2 peaks were found instead of 1 due to the loss of symmetry caused by chiral sulfur atom);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1382, 1350, 1284, 1146, 1088, 983, 855, 735, 682, 616;

HRMS (ESI$^+$) calcd. for $C_9H_{12}N_3O_4S_2^+$ $[M+H]^+$: 290.0264, found: 290.0266.

***N*-(Amino(benzyl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (208)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), benzylmagnesium bromide solution (7.89 mL, 0.76 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **208** was isolated and purified according to **Work-up Procedure J1**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 2:1 to 1:2) afforded the desired product as a white solid (1.34 g, 3.95 mmol, 79%).

mp 157-159 °C;

R_f 0.37 (CH_2Cl_2/ethyl acetate, 1:1);

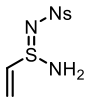
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.13 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.68 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.28-7.21 (m, 5H, Bn-*H*), 6.55 (s, 2H, N*H*$_2$), 4.43 (d, J = 12.6 Hz, 1H, Bn-C*H*$_a$H$_b$), 4.32 (d, J = 12.6 Hz, 1H, Bn-CH$_a$*H*$_b$);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.6, 148.3, 130.9, 129.8, 128.4, 128.3, 126.8, 123.9, 57.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1381, 1354, 1283, 1139, 1087, 971, 685, 617;

HRMS (ESI^+) calcd. for $C_{13}H_{14}N_3O_4S_2^+$ $[M+H]^+$: 340.0420, found: 340.0421.

***N*-(Amino(vinyl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (209)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.31 g, 6.00 mmol, 1.00 equiv.), THF (12.0 mL), LiHMDS solution (6.00 mL, 1.00 M in THF, 6.00 mmol, 1.00 equiv.), TMSCl (0.76 mL, 6.00 mmol, 1.00 equiv.), vinylmagnesium bromide solution (8.00 mL, 0.90 M in THF, 7.20 mmol, 1.20 equiv.), CH_2Cl_2 (30.0 mL), Et_3N (1.00 mL, 7.20 mmol, 1.20 equiv.), NsCl (1.33 g, 6.00 mmol, 1.00 equiv.) and TBAF solution (6.60 mL, 1.00 M in THF, 6.60 mmol, 1.10 equiv.).

The primary sulfinamidine **209** was isolated and purified according to **Work-up Procedure J1**. Filtration and flash column chromatography (CH_2Cl_2/ethyl acetate, 2:1 to 1:1) afforded the desired product as a white solid (1.35 g, 4.91 mmol, 82%).

mp 174-176 °C;

R_f 0.36 (CH_2Cl_2/ethyl acetate, 2:1);

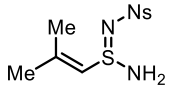
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.33 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.01 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 6.82-6.64 (m, 3H, N*H*$_2$/SC*H*=CH_2), 6.03 (d, J = 9.2 Hz, 1H, SCH=C*H*$_a$H$_b$), 5.98 (d, J = 15.9 Hz, 1H, SCH=CH$_a$*H*$_b$);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.8, 148.7, 136.0, 127.2, 125.0, 124.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1525, 1351, 1284, 1142, 1084, 971, 855, 734, 623;

HRMS (ESI$^+$) calcd. for $C_8H_{10}N_3O_4S_2^+$ $[M+H]^+$: 276.0107, found: 276.0109.

***N*-(Amino(2-methylprop-1-en-1-yl)-λ^4-sulfaneylidene)-4-nitrobenzenesulfonamide (210)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 2-methyl-1-propenylmagnesium bromide solution (13.30 mL, 0.45 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **210** was isolated and purified according to **Work-up Procedure J2**. Filtration and flash column chromatography (petrol/ethyl acetate, 1:2 to 1:4) afforded the desired product as a white solid (607 mg, 2.00 mmol, 40%).

mp 145-147 °C;

R$_f$ 0.42 (petrol/ethyl acetate, 1:4);

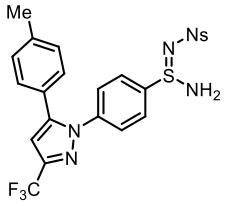
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.32 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.97 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 6.54 (s, 2H, N*H*$_2$), 6.27-6.21 (m, 1H, SC*H*=C$(CH_3)_2$), 1.82 (d, J = 1.4 Hz, 3H, SCH=C(C*H*$_3$)$_2$), 1.78 (d, J = 1.2 Hz, 3H, SC*H*=C(C*H*$_3$)$_2$);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 151.1, 148.6, 146.5, 127.1, 125.1, 124.1, 24.3, 19.8;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1349, 1265, 1155, 1086, 982, 784, 688;

HRMS (ESI^+) calcd. for $C_{10}H_{14}N_3O_4S_2^+$ $[M+H]^+$: 304.0420, found: 304.0420.

***N*-(Amino(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)-λ⁴-sulfaneylidene)-4-nitrobenzenesulfonamide (211)**



Preparation of organometallic reagent

(4-(5-(*p*-Tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)lithium solution was prepared according to the following procedure. To a solution of 1-(4-bromophenyl)-5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazole (2.28 g, 6.00 mmol, 1.20 equiv.) in anhydrous THF (12.0 mL) in an oven-dried 100 mL round-bottom flask was added *n*-butyllithium solution (2.40 mL, 2.50 M in hexanes, 6.00 mmol, 1.20 equiv.) dropwise at -78 °C. The reaction was stirred at the same temperature for 40 min.

Preparation of sulfinamidine

Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), (4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)lithium solution (6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), NsCl (1.11 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **211** was isolated and purified according to **Work-up Procedure J3**. Flash column chromatography (CH_2Cl_2/ethyl acetate, 5:1 to 3:1) afforded the desired product as a white solid (2.28 g, 4.15 mmol, 83%).

mp 207-209 °C;

R$_f$ 0.54 (CH_2Cl_2/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.34 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.07 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.81 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.58 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.25-7.14 (m, 7H, Tol-*H*/NH_2/HetAr-*H*), 2.31 (s, 3H, Tol-CH_3);

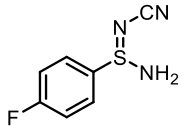
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 150.4, 148.8, 145.3, 142.4 (q, $^2J_{CF}$ = 37.7 Hz), 141.3, 139.1, 138.9, 129.4, 128.8, 128.0, 127.3, 126.4, 125.3, 124.3, 121.3 (q, $^1J_{CF}$ = 269.0 Hz), 106.2, 20.8;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -60.9 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1474, 1381, 1351, 1279, 1237, 1141, 1085, 969, 786, 613;

HRMS (ESI^+) calcd. for $C_{23}H_{19}F_3N_5O_4S_2^+$ $[M+H]^+$: 550.0825, found: 550.0828.

***N*-cyano-*S*-4-fluorobenzene primary sulfinamidine (212)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 4-fluorophenylmagnesium bromide solution (7.00 mL, 0.86 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), BrCN solution (1.00 mL, 5.0 M in CH_3CN, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **212** was isolated and purified according to **Work-up Procedure J3**. Flash column chromatography (CH_2Cl_2/ethyl acetate, 2:1 to 1:1) afforded the desired product as a white solid (734 mg, 4.01 mmol, 80%).

mp 92-94 °C;

R$_f$ 0.29 (CH_2Cl_2/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 7.90-7.83 (m, 2H, Ar_F-*H*), 7.53-7.46 (m, 2H, Ar_F-*H*), 7.10 (s, 2H, NH_2);

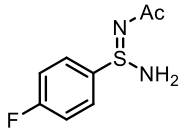
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 164.0 (d, $^{1}J_{CF}$ = 250.3 Hz), 134.7 (d, $^{4}J_{CF}$ = 2.8 Hz), 129.7 (d, $^{3}J_{CF}$ = 9.3 Hz), 119.7, 116.6 (d, $^{2}J_{CF}$ = 22.8 Hz);

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -108.7 (tt, *J* = 8.6, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2163, 1588, 1486, 1462, 1383, 1230, 1158, 1085, 1014, 953, 793;

HRMS (ESI^+) calcd. for $C_7H_7FN_3S^+$ $[M+H]^+$: 184.0339, found: 184.0342.

***N*-(Amino(4-fluorophenyl)-λ^4-sulfaneylidene)acetamide (213)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 4-fluorophenylmagnesium bromide solution (7.00 mL, 0.86 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), Ac_2O (0.47 mL, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **213** was isolated and purified according to **Work-up Procedure J1**. Filtration and Flash column chromatography (CH_2Cl_2/ethyl acetate, 1:3 to 1:10) afforded the desired product as a white solid (740 mg, 3.70 mmol, 74%).

mp 156-158 °C;

R_f 0.33 (CH_2Cl_2/ethyl acetate, 1:3);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 7.89-7.83 (m, 2H, Ar_F-*H*), 7.45-7.38 (m, 2H, Ar_F-*H*), 6.28 (s, 2H, NH_2), 1.91 (s, 3H, COCH_3);

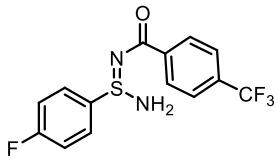
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 180.3, 163.5 (d, $^{1}J_{CF}$ = 248.7 Hz), 135.7 (d, $^{4}J_{CF}$ = 2.9 Hz), 129.5 (d, $^{3}J_{CF}$ = 9.1 Hz), 116.2 (d, $^{2}J_{CF}$ = 22.6 Hz), 25.1;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -109.8 (tt, J = 8.7, 5.3 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1595, 1541, 1490, 1473, 1462, 1382, 1252, 1155, 1073, 956, 836;

HRMS (ESI^+) calcd. for $C_8H_{10}FN_2OS^+$ $[M+H]^+$: 201.0492, found: 201.0496.

***N*-(Amino(4-fluorophenyl)-λ^4-sulfaneylidene)-4-(trifluoromethyl)benzamide (214)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 4-fluorophenylmagnesium bromide solution (7.00 mL, 0.86 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), 4-(trifluoromethyl)benzoyl chloride (0.47 mL, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.). The primary sulfinamidine **214** was isolated and purified according to **Work-up Procedure J1**. Filtration and Flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) afforded the desired product as a white solid (1.24 g, 3.76 mmol, 75%).

mp 170-172 °C;

R$_f$ 0.38 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.24 (d, J = 7.9 Hz, 2H, Ar-*H*), 8.03-7.96 (m, 2H, Ar_F-*H*), 7.78 (d, J = 7.9 Hz, 2H, Ar-*H*), 7.51-7.43 (m, 2H, Ar_F-*H*), 6.60 (s, 2H, N*H*$_2$);

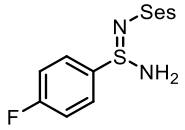
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 173.3, 163.7 (d, $^1J_{CF}$ = 249.3 Hz), 140.9, 135.2 (d, $^4J_{CF}$ = 2.9 Hz), 130.7 (q, $^2J_{CF}$ = 31.6 Hz), 129.7 (d, $^3J_{CF}$ = 9.1 Hz), 129.0, 124.9 (q, $^3J_{CF}$ = 3.8 Hz), 124.2 (q, $^1J_{CF}$ = 272.2 Hz), 116.4 (d, $^2J_{CF}$ = 22.9 Hz);

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -61.2 (s), -109.3 (tt, J = 8.7, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1597, 1541, 1473, 1383, 1252, 1162, 1070, 955, 829;

HRMS (ESI^+) calcd. for $C_{14}H_{11}F_4N_2OS^+$ $[M+H]^+$: 331.0523, found: 331.0524.

***N*-(Amino(4-fluorophenyl)-λ^4-sulfaneylidene)-2-(trimethylsilyl)ethane-1-sulfonamide (215)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 4-fluorophenylmagnesium bromide solution (7.00 mL, 0.86 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), 2-(trimethylsilyl)ethanesulfonyl chloride (1.00 g, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.). The primary sulfinamidine **215** was isolated and purified according to **Work-up Procedure J3**. Flash column chromatography (petrol/ethyl acetate, 1:1 to 1:2) afforded the desired product as a white solid (1.19 g, 3.70 mmol, 74%).

mp 126-128 °C;

R$_f$ 0.35 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 7.91-7.86 (m, 2H, Ar_F-*H*), 7.51-7.45 (m, 2H, Ar_F-*H*), 6.86 (s, 2H, N*H*$_2$), 2.86 (dd, J = 9.5, 8.3 Hz, 2H, SO_2CH_2), 1.01-0.85 (m, 2H, SO_2CH_2 CH_2), 0.01 (s, 9H, TMS-*H*);

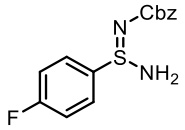
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 163.8 (d, $^1J_{CF}$ = 249.5 Hz), 135.9 (d, $^4J_{CF}$ = 2.8 Hz), 129.6 (d, $^3J_{CF}$ = 9.2 Hz), 116.4 (d, $^2J_{CF}$ = 22.8 Hz), 50.8, 10.6, -1.9;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -109.6 (tt, J = 8.6, 5.3 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1489, 1473, 1462, 1383, 1251, 1155, 1120, 1083, 957, 831;

HRMS (ESI$^+$) calcd. for $C_{11}H_{20}FN_2O_2S_2Si^+$ $[M+H]^+$: 323.0714, found: 323.0714.

Benzyl-(amino(4-fluorophenyl)-λ^4-sulfaneylidene)carbamate (216)



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.10 g, 5.00 mmol, 1.00 equiv.), THF (10.0 mL), LiHMDS solution (5.00 mL, 1.00 M in THF, 5.00 mmol, 1.00 equiv.), TMSCl (0.64 mL, 5.00 mmol, 1.00 equiv.), 4-fluorophenylmagnesium bromide solution (7.00 mL, 0.86 M in THF, 6.00 mmol, 1.20 equiv.), CH_2Cl_2 (25.0 mL), Et_3N (0.84 mL, 6.00 mmol, 1.20 equiv.), benzyl chloroformate (853 mg, 5.00 mmol, 1.00 equiv.) and TBAF solution (5.50 mL, 1.00 M in THF, 5.50 mmol, 1.10 equiv.).

The primary sulfinamidine **216** was isolated and purified according to **Work-up Procedure J2**. Filtration and flash column chromatography (petrol/ethyl acetate, 1:1 to 1:3) afforded the desired product as a white solid (1.07 g, 3.66 mmol, 73%).

mp 122-124 °C;

R$_f$ 0.42 (petrol/ethyl acetate, 1:2);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 7.90-7.84 (m, 2H, Ar_F-*H*), 7.46-7.39 (m, 2H, Ar_F-*H*), 7.37-7.26 (m, 5H, Ph-*H*), 6.50 (s, 2H, N*H*$_2$), 5.06 (d, *J* = 12.6 Hz, 1H, Bn-C*H*$_a$H$_b$), 5.01 (d, *J* = 12.6 Hz, 1H, Bn-CH$_a$*H*$_b$);

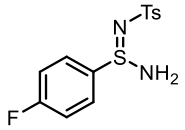
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 163.6 (d, $^1J_{CF}$ = 249.1 Hz), 163.4, 138.0, 135.7 (d, $^4J_{CF}$ = 2.8 Hz), 129.6 (d, $^3J_{CF}$ = 9.1 Hz), 128.3, 127.6, 127.5, 116.2 (d, $^2J_{CF}$ = 22.6 Hz), 66.1;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -109.8 (tt, *J* = 8.6, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1624, 1491, 1461, 1382, 1252, 1156, 1086, 955, 831;

HRMS (ESI$^+$) calcd. for $C_{14}H_{14}FN_2O_2S^+$ $[M+H]^+$: 293.0755, found: 293.0756.

***N*-(Amino(4-fluorophenyl)-λ^4-sulfaneylidene)-4-methylbenzenesulfonamide (217)**



Prepared according to **General Procedure J** using TIPS-NSO **185** (1.31 g, 6.00 mmol, 1.00 equiv.), THF (12.0 mL), LiHMDS solution (6.00 mL, 1.00 M in THF, 6.00 mmol, 1.00 equiv.), TMSCl (0.76 mL, 6.00 mmol, 1.00 equiv.), 4-fluorophenylmagnesium bromide solution (3.60 mL, 2.00 M in THF, 7.20 mmol, 1.20 equiv.), CH_2Cl_2 (30.0 mL), Et_3N (1.00 mL, 7.20 mmol, 1.20 equiv.), TsCl (1.14 g, 6.00 mmol, 1.00 equiv.) and TBAF solution (6.60 mL, 1.00 M in THF, 6.60 mmol, 1.10 equiv.).

The primary sulfinamidine **217** was isolated and purified according to **Work-up Procedure J2**. Filtration and flash column chromatography (petrol/ethyl acetate, 1:1 to 1:2) afforded the desired product as a white solid (1.31 g, 4.20 mmol, 70%).

mp 158-160°C;

R$_f$ 0.47 (petrol/ethyl acetate, 1:2);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 7.80-7.74 (m, 2H, Ar_F-*H*), 7.69 (d, *J* = 8.2 Hz, 2H, Tol-*H*), 7.48-7.41 (m, 2H, Ar_F-*H*), 7.30 (d, *J* = 8.2 Hz, 2H, Tol-*H*), 6.96 (s, 2H, NH_2), 2.34 (s, 3H, Tol-CH_3);

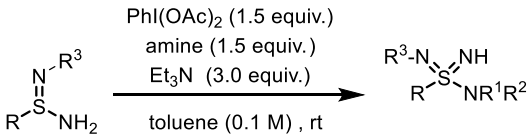
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 163.8 (d, $^1J_{CF}$ = 249.8 Hz), 142.3, 141.0, 135.4 (d, $^4J_{CF}$ = 2.8 Hz), 129.5 (d, $^3J_{CF}$ = 9.4 Hz), 129.2, 125.7, 116.4 (d, $^2J_{CF}$ = 23.0 Hz), 20.9;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -109.4 (tt, *J* = 8.7, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1596, 1487, 1462, 1383, 1252, 1145, 1086, 967, 814;

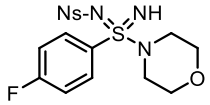
HRMS (ESI$^+$) calcd. for $C_{13}H_{14}FN_2O_2S_2^+$ [M+H]$^+$: 313.0475, found: 313.0474.

6.4.4 General Procedure K for Sulfondiimidamide Synthesis



An oven-dried round-bottom flask containing primary sulfinamidine (1.00 equiv.) and $PhI(OAc)_2$ (1.50 equiv.) was sealed and subjected to three N_2 evacuation/refill cycles before pre-sparged anhydrous toluene (sulfinamidine conc. 0.1 M) was added. Et_3N (3.00 equiv.) was added to the solution, followed immediately by the addition of amine (1.50 equiv.). The reaction mixture was then stirred at room temperature for the specified time. Once judged complete by TLC, the reaction was diluted with ethyl acetate and quenched with sat. aq. NaCl solution. The aqueous phase was extracted with ethyl acetate three times. The combined organic layers were then dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The sulfondiimidamide was purified by flash column chromatography with the appropriate solvent system.

***N*-((4-Fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (164)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 30 min. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 5:1 to 3:1) afforded *sulfondiimidamide* **164** as a white solid (200 mg, 0.47 mmol, 93%).

mp 64-66 °C;

R$_f$ 0.50 (petrol/ethyl acetate, 1:2);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.21 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.96-7.89 (m, 2H, Ar_F-*H*), 7.21-7.13 (m, 2H, Ar_F-*H*), 3.67 (t, J = 4.7 Hz, 4H, OCH_2), 3.32 (s, 1H, N*H*), 3.13-2.98 (m, 4H, NCH_2);

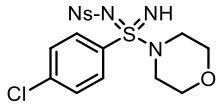
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.7 (d, $^1J_{CF}$ = 257.8 Hz), 149.6, 149.2, 130.3 (d, $^3J_{CF}$ = 9.5 Hz), 129.3 (d, $^4J_{CF}$ = 3.2 Hz), 127.9, 124.0, 116.6 (d, $^2J_{CF}$ = 22.9 Hz), 66.1, 46.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -103.0 (tt, J = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1351, 1300, 1154, 1089, 1067, 1052, 920;

HRMS (ESI^+) calcd. for $C_{16}H_{18}FN_4O_5S_2^+$ $[M+H]^+$: 429.0697, found: 429.0695.

***N*-((4-Chlorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (219)**



Following **General Procedure K**, sulfinamidine **198** (180 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 24 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 5:1 to 3:1) afforded *sulfondiimidamide* **219** as a white solid (138 mg, 0.31 mmol, 62%).

mp 150-152 °C;

R$_f$ 0.50 (CH_2Cl_2/ethyl acetate, 3:1);

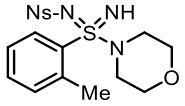
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.31 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.03 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.84 (d, J = 8.8 Hz, 2H, Ar_{Cl}-*H*), 7.68 (d, J = 8.8 Hz, 2H, Ar_{Cl}-*H*), 5.50 (s, 1H, N*H*), 3.60-3.49 (m, 4H, OCH_2), 2.97-2.83 (m, 4H, NCH_2);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 149.1, 149.0, 138.5, 133.7, 129.5, 129.3, 127.9, 124.1, 65.4, 45.9;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1532, 1383, 1260, 1157, 1083, 954, 776, 623;

HRMS (ESI$^+$) calcd. for $C_{16}H_{18}ClN_4O_5S_2^+$ $[M+H]^+$: 445.0402, found: 445.0402.

***N*-(Imino(morpholino)(*o*-tolyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (220)**



Following **General Procedure K**, sulfinamidine **199** (170 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 2 h. Purification by flash column chromatography (petrol/ethyl acetate, 1:2 to 1:3) afforded *sulfondiimidamide* **220** as a colourless oil (176 mg, 0.42 mmol, 83%).

R$_f$ 0.54 (CH_2Cl_2/ethyl acetate, 2:1);

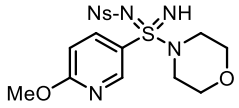
^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.16 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.99 (dd, J = 8.5, 1.4 Hz, 1H, Tol-*H*), 7.95 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.47 (td, J = 7.4, 1.4 Hz, 1H, Tol-*H*), 7.32-7.26 (m, 2H, Tol-*H*), 3.74-3.44 (m, 5H, OCH_2/N*H*), 3.14-3.02 (m, 4H, NCH_2), 2.56 (s, 3H, Tol-CH_3);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 150.5, 149.9, 139.5, 135.2, 134.6, 134.5, 131.2, 128.7, 127.1, 124.9, 66.6, 45.7, 20.9;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1382, 1350, 1297, 1259, 1151, 1069, 954, 770;

HRMS (ESI$^+$) calcd. for $C_{17}H_{21}N_4O_5S_2^+$ $[M+H]^+$: 425.0948, found: 425.0948.

***N*-(Imino(6-methoxypyridin-3-yl)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (221)**



Following **General Procedure K**, sulfinamidine **200** (178 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room

temperature for 2 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **221** as a white solid (196 mg, 0.44 mmol, 89%).

mp 152-154 °C;

R$_f$ 0.42 (CH_2Cl_2/ethyl acetate, 2:1);

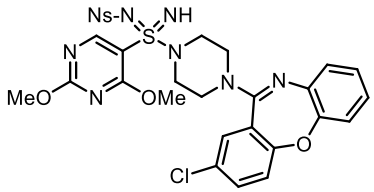
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.58 (dd, *J* = 2.7, 0.7 Hz, 1H, HetAr-*H*), 8.31 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06-8.01 (m, 3H, Ar_{Ns}-*H*/HetAr-*H*), 6.98 (dd, *J* = 8.9, 0.7 Hz, 1H, HetAr-*H*), 6.00-5.00 (br. s, 1H, N*H*), 3.92 (s, 3H, HetAr-OCH_3), 3.61-3.51 (m, 4H, OCH_2), 3.00-2.89 (m, 4H, NCH_2);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 166.2, 149.1, 149.0, 147.8, 138.5, 128.0, 124.4, 124.1, 111.1, 65.4, 54.3, 45.8;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1521, 1474, 1462, 1381, 1255, 1155, 1087, 955;

HRMS (ESI^+) calcd. for $C_{16}H_{20}N_5O_6S_2^+$ $[M+H]^+$: 442.0850, found: 442.0851.

***N*-((4-(2-Chlorodibenzo[*b*,*f*][1,4]oxazepin-11-yl)piperazin-1-yl)(2,4-dimethoxypyrimidin-5-yl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (222)**



Following **General Procedure K**, sulfinamidine **201** (194 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and amoxapine (235 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 12 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 2:3) afforded *sulfondiimidamide* **222** as a pale-yellow oil (131 mg, 0.19 mmol, 38%).

R$_f$ 0.57 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.78 (s, 1H, HetAr-*H*), 8.21 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.96 (d, *J* = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.48 (dd, *J* = 8.7, 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.36 (d, *J* = 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.26 (d, *J* = 8.7 Hz, 1H, Ar_{Cl}-*H*), 7.15-6.98 (m, 4H Ar-*H*), 3.98 (s,

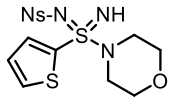
3H, HetAr-OCH_3), 3.96 (s, 3H, HetAr-OCH_3), 3.57 (s, 1H, N*H*), 3.50 (app. s, 4H, NCH_2), 3.39 (app. s, 4H, NCH_2);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 168.3, 167.9, 163.7, 160.3, 159.5, 152.6, 150.6, 150.2, 140.9, 134.0, 131.2, 129.9, 128.9, 127.7, 126.9, 125.8, 125.6, 124.9, 123.7, 121.2, 113.3, 56.5, 55.7, 48.0, 46.3;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1572, 1550, 1528, 1470, 1384, 1303, 1155, 1109, 1090, 1005, 936, 797;

HRMS (ESI^+) calcd. for $C_{29}H_{28}ClN_8O_7S_2^+$ $[M+H]^+$: 699.1205, found: 699.1200.

***N*-(Imino(morpholino)(thiophen-2-yl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (223)**



Following **General Procedure K**, sulfinamidine **202** (165 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (petrol/ethyl acetate, 1:2 to 1:5) afforded *sulfondiimidamide* **223** as a white solid (180 mg, 0.43 mmol, 87%).

mp 146-148 °C;

R$_f$ 0.44 (petrol/ethyl acetate, 1:3);

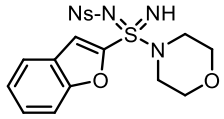
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.33 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.06 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.01 (dd, J = 5.1, 1.3 Hz, 1H, HetAr-*H*), 7.56 (dd, J = 3.9, 1.3 Hz, 1H, HetAr-*H*), 7.20 (dd, J = 5.1, 3.9 Hz, 1H, HetAr-*H*), 5.54 (s, 1H, N*H*), 3.62-3.51 (m, 4H, OCH_2), 2.94 (t, J = 4.8 Hz, 4H, NCH_2);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 149.2, 149.0, 135.2, 135.0, 133.4, 128.4, 128.0, 124.2, 65.3, 46.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1531, 1397, 1352, 1321, 1260, 1153, 1069, 955, 915, 700;

HRMS (ESI$^+$) calcd. for $C_{14}H_{16}N_4O_5S_3Na^+$ [M+Na]$^+$: 439.0175, found: 439.0174.

***N*-(Benzofuran-2-yl(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (224)**



Following **General Procedure K**, sulfinamidine **203** (183 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (322 mg, 1.00 mmol, 2.00 equiv.), CH_3CN (2.5 mL), DBU (0.30 mL, 2.00 mmol, 4.00 equiv.) and morpholine (87 µL, 1.00 mmol, 2.00 equiv.) were combined at room temperature for 30 min. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 7:1 to 3:1) afforded *sulfondiimidamide* **224** as a white solid (179 mg, 0.40 mmol, 80%).

mp 166-168 °C;

R$_f$ 0.56 (CH_2Cl_2/ethyl acetate, 4:1);

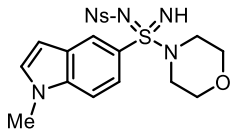
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.18 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.00 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.79-7.72 (m, 1H, HetAr-*H*), 7.62-7.56 (m, 2H, HetAr-*H*), 7.47 (ddd, J = 8.2, 7.1, 1.3 Hz, 1H, HetAr-*H*), 7.38-7.32 (m, 1H, HetAr-*H*), 5.98 (br. s, 1H, N*H*), 3.66-3.56 (m, 4H, OCH_2), 3.24 (ddd, J = 12.2, 5.5, 3.8 Hz, 2H, NCH_2), 3.17 (ddd, J = 12.0, 5.7, 3.8 Hz, 2H, NCH_2).

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 155.4, 149.0, 148.3, 146.9, 127.94, 127.91, 125.5, 124.4, 123.9, 123.2, 115.4, 112.1, 65.6, 46.0.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1350, 1303, 1159, 1085, 1069, 1052, 926;

HRMS (ESI$^+$) calcd. for $C_{18}H_{19}N_4O_6S_2^+$ [M+H]$^+$: 451.0741, found: 451.0740.

***N*-(Imino(1-methyl-1*H*-indol-5-yl)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (225)**



Following **General Procedure K**, sulfinamidine **204** (189 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (322 mg, 1.00 mmol, 2.00 equiv.), CH_3CN (2.5 mL), DBU (0.30 mL, 2.00 mmol, 4.00 equiv.) and morpholine (87 µL, 1.00 mmol, 2.00 equiv.) were combined at room temperature for 30 min. Purification by flash column chromatography (petrol/ethyl acetate, 1:3 to 1:5) afforded *sulfondiimidamide* **225** as a yellow oil (161 mg, 0.35 mmol, 70%).

R$_f$ 0.33 (petrol/ethyl acetate, 1:3);

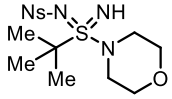
^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.12 (dd, *J* = 2.0, 0.6 Hz, 1H, HetAr-*H*), 8.09 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.96 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.64 (dd, *J* = 8.9, 2.0 Hz, 1H, HetAr-*H*), 7.44 (d, *J* = 8.9 Hz, 1H, HetAr-*H*), 7.28 (d, *J* = 3.2 Hz, 1H, HetAr-*H*), 6.56 (dd, *J* = 3.2, 0.8 Hz, 1H, HetAr-*H*), 3.78 (s, 3H, indole-C*H*3), 3.58-3.47 (m, 5H, N*H*/OCH_2), 2.97 (ddd, *J* = 11.9, 5.9, 3.6 Hz, 2H, NCH_2), 2.91 (ddd, *J* = 11.8, 6.0, 3.5 Hz, 2H, NCH_2);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 150.5, 150.3, 139.6, 133.3, 128.7, 128.6, 124.8, 124.5, 123.0, 121.0, 110.9, 103.3, 66.7, 47.2, 33.6;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1348, 1297, 1150, 1056, 917, 855;

HRMS (ESI^+) calcd. for $C_{19}H_{22}N_5O_5S_2^+$ $[M+H]^+$: 464.1057, found: 464.1057.

***N*-(*Tert*-butyl(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (226)**



Following **General Procedure K**, sulfinamidine **205** (153 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 5 h. Purification by flash column chromatography (petrol/ethyl acetate, 1:2 to 1:4) afforded *sulfondiimidamide* **226** as a colourless oil (132 mg, 0.33 mmol, 67%).

R$_f$ 0.33 (petrol/ethyl acetate, 1:2);

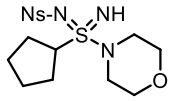
^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.30 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.08 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 3.73-3.61 (m, 4H, OCH_2), 3.53-3.41 (m, 4H, NCH_2), 3.25 (s, 1H, N*H*), 1.32 (s, 9H, *t*-Bu-*H*);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 151.1, 150.5, 128.4, 125.0, 67.9, 67.6, 49.8, 24.1;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1350, 1295, 1258, 1148, 1089, 1038, 934, 746, 610;

HRMS (ESI^+) calcd. for $C_{14}H_{22}N_4O_5S_2Na^+$ $[M+Na]^+$: 413.0924, found: 413.0923.

***N*-(cyclopentyl(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (227)**



Following **General Procedure K**, sulfinamidine **206** (159 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 3:2 to 2:3) afforded *sulfondiimidamide* **227** as a colourless oil (165 mg, 0.41 mmol, 82%).

R$_f$ 0.40 (CH_2Cl_2/ethyl acetate, 1:1);

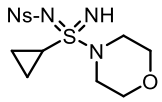
^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.27 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.03 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 3.75 (dddd, J = 16.2, 8.6, 7.4, 2.2 Hz, 1H, SC*H*), 3.55 (dt, J = 11.6, 4.7 Hz, 2H, OCH_2), 3.48 (dt, J = 11.6, 4.7 Hz, 2H, OCH_2), 3.24 (s, 1H, N*H*), 3.22 (t, J = 4.7 Hz, 4H, NCH_2), 1.92-1.75 (m, 4H, Alkyl-*H*), 1.66-1.46 (m, 4H, Alkyl-*H*);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 151.0, 150.5, 128.5, 125.0, 67.2, 64.2, 47.7, 28.8, 27.9, 26.5, 26.2 (Note: For 4 secondary carbons in cyclopentane ring, 4 peaks were found instead of 2 due to the loss of symmetry caused by chiral sulfur atom);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1527, 1382, 1350, 1296, 1258, 1149, 1090, 1051, 935;

HRMS (ESI^+) calcd. for $C_{15}H_{22}N_4O_5S_2Na^+$ $[M+Na]^+$: 425.0924, found: 425.0924.

***N*-(cyclopropyl(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (228)**



Following **General Procedure K**, sulfinamidine **207** (145 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 24 h. Purification by flash column chromatography (ethyl acetate) afforded *sulfondiimidamide* **228** as pale-yellow solid (152 mg, 0.41 mmol, 81%).

mp 130-132 °C;

R$_f$ 0.38 (ethyl acetate);

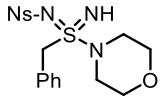
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.36 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.08 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 4.58 (s, 1H, N*H*), 3.56 (ddd, J = 11.6, 6.2, 3.2 Hz, 2H, OCH_2), 3.49 (ddd, J = 11.6, 6.2, 3.2 Hz, 2H, OCH_2), 3.20 (ddd, J = 12.0, 6.2, 3.2 Hz, 2H, NCH_2), 3.13 (ddd, J = 12.0, 6.2, 3.2 Hz, 2H, NCH_2), 2.89-2.81 (m, 1H, SC*H*), 1.06-0.93 (m, 4H, Alkyl-*H*);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 149.7, 149.1, 127.9, 124.1, 65.6, 46.2, 29.1, 5.1, 4.7 (Note: For 2 secondary carbons in cyclopropane ring, 2 peaks were found instead of 1 due to the loss of symmetry caused by chiral sulfur atom);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1524, 1351, 1296, 1148, 1090, 1073, 920, 770, 609;

HRMS (ESI$^+$) calcd. for $C_{13}H_{19}N_4O_5S_2^+$ $[M+H]^+$: 375.0791, found: 375.0792.

***N*-(benzyl(imino)(morpholino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (229)**



Following **General Procedure K**, sulfinamidine **208** (170 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol,

3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 3:2 to 2:3) afforded *sulfondiimidamide* **229** as a white solid (171 mg, 0.40 mmol, 81%).

mp 102-104 °C;

R$_f$ 0.44 (CH_2Cl_2/ethyl acetate, 1:1);

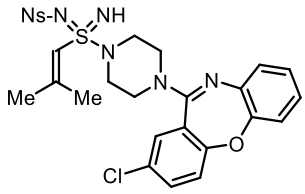
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.26 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.94 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.44-7.30 (m, 5H, Bn-*H*), 4.68 (d, J = 13.8 Hz, 1H, Bn-C*H*$_a$H$_b$), 4.61 (d, J = 13.8 Hz, 1H, Bn-CH$_a$*H*$_b$), 4.60 (s, 1H, N*H*), 3.56 (ddd, J = 11.5, 6.4, 3.0 Hz, 2H, OC*H*$_2$), 3.47 (ddd, J = 11.5, 6.4, 3.0 Hz, 2H, OC*H*$_2$), 3.23 (ddd, J = 12.4, 6.5, 3.0 Hz, 2H, NC*H*$_2$), 3.12 (ddd, J = 12.4, 6.5, 3.0 Hz, 2H, NC*H*$_2$);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 149.6, 148.9, 131.9, 128.7, 128.1, 128.0, 127.6, 123.9, 65.7, 58.3, 46.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1528, 1382, 1352, 1292, 1256, 1146, 1060, 746;

HRMS (ESI$^+$) calcd. for $C_{17}H_{21}N_4O_5S_2^+$ $[M+H]^+$: 425.0948, found: 425.0948.

***N*-((4-(2-chlorodibenzo[*b*,*f*][1,4]oxazepin-11-yl)piperazin-1-yl)(imino)(2-methylprop-1-en-1-yl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (230)**



Following **General Procedure K**, sulfinamidine **210** (152 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and amoxapine (235 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 3 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:2 to 2:3) afforded *sulfondiimidamide* **230** as a pale-yellow oil (215 mg, 0.35 mmol, 70%).

R$_f$ 0.55 (petrol/ethyl acetate, 1:1);

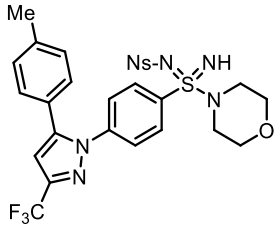
^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.27 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.45 (dd, J = 8.7, 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.33 (d, J = 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.24 (d, J = 8.7 Hz, 1H, Ar_{Cl}-*H*), 7.14-6.98 (m, 4H, Ar-*H*), 5.96 (d, J = 1.4 Hz, 1H, SC*H*=C$(CH_3)_2$), 3.60-3.38 (app. s, 4H, NCH_2), 3.44 (s, 1H, N*H*), 3.35-3.04 (app. s, 4H, NCH_2), 2.07 (d, J = 1.3 Hz, 3H, SCH=C(C$H_3)_2$), 1.86 (d, J = 1.4 Hz, 3H, SCH=C(C$H_3)_2$);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 160.2, 159.4, 159.0, 152.6, 150.8, 150.6, 140.9, 134.0, 131.1, 129.9, 128.9, 127.7, 126.9, 125.8, 125.5, 125.0, 123.7, 121.2, 121.0, 47.6, 46.1, 27.2, 20.2;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) =1603, 1587, 1559, 1526, 1471, 1349, 1299, 1151, 1089, 1048, 1010;

HRMS (ESI^+) calcd. for $C_{27}H_{28}ClN_6O_5S_2^+$ $[M+H]^+$: 615.1246, found: 615.1241.

***N*-(Imino(morpholino)(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (231)**



Following **General Procedure B**, sulfinamidine **211** (275 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 2 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 10:1 to 5:1) afforded *sulfondiimidamide* **231** as a colourless oil (297 mg, 0.47 mmol, 94%).

R$_f$ 0.43 (CH_2Cl_2/ethyl acetate, 7:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.23 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.04 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.89 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.47 (d, J = 8.8 Hz, 2H, Ar-*H*), 7.17 (d, J = 8.1 Hz, 2H, Tol-*H*), 7.12 (d, J = 8.1 Hz, 2H, Tol-*H*), 6.90 (s, 1H, HetAr-*H*), 3.70 (s, 1H, N*H*), 3.60-3.50 (m, 4H, OCH_2), 3.00-2.94 (m, 4H, NCH_2), 2.32 (s, 3H, Tol-CH_3);

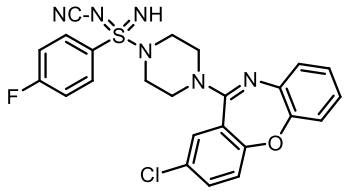
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 150.7, 150.3, 146.6, 144.2 (q, $^2J_{CF}$ = 38.1 Hz), 144.1, 140.8, 134.9, 130.4, 129.9, 129.6, 128.8, 126.7, 126.6, 125.1, 122.4 (q, $^1J_{CF}$ = 268.2 Hz), 107.2 (q, $^3J_{CF}$ = 1.7 Hz), 66.7, 47.4, 21.3;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -62.8 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1529, 1472, 1381, 1237, 1154, 1088, 1069, 969;

HRMS (ESI^+) calcd. for $C_{27}H_{26}F_3N_6O_5S_2^+$ $[M+H]^+$: 635.1353, found: 635.1351.

***N*-((4-(2-Chlorodibenzo[*b*,*f*][1,4]oxazepin-11-yl)piperazin-1-yl)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)cyanamide (232)**



Following **General Procedure K**, sulfinamidine **212** (92 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and amoxapine (235 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 14 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 3:1 to 2:1) afforded *sulfondiimidamide* **232** as a pale-yellow solid (160 mg, 0.32 mmol, 65%).

mp 168-170 °C;

R$_f$ 0.60 (CH_2Cl_2/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.08-8.00 (m, 2H, Ar_F-*H*), 7.59 (dd, *J* = 8.7, 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.58-7.49 (m, 2H, Ar_F-*H*), 7.45 (d, *J* = 2.7 Hz, 1H, Ar_{Cl}-*H*), 7.36 (d, *J* = 8.7 Hz, 1H, Ar_{Cl}-*H*), 7.16 (dd, *J* = 7.8, 1.5 Hz, 1H, Ar-*H*), 7.12-6.97 (m, 3H, Ar-*H*), 5.84 (s, 1H, N*H*), 3.55 (app. s, 4H, NCH_2), 3.18 (app. s, 4H, NCH_2).

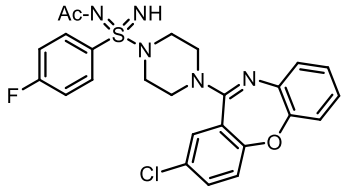
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 165.1 (d, $^1J_{CF}$ = 253.4 Hz), 158.7, 157.8, 151.2, 139.5, 133.2, 130.9 (d, $^3J_{CF}$ = 9.8 Hz), 130.4 (d, $^4J_{CF}$ = 2.7 Hz), 129.7, 128.8, 126.5, 125.8, 124.6, 124.1, 123.1, 120.2, 116.9 (d, $^2J_{CF}$ = 23.0 Hz), 113.4, 46.3, 45.7;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -104.9 (tt, J = 8.9, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2185, 2031, 1588, 1486, 1470, 1363, 1157, 1021, 871;

HRMS (ESI^+) calcd. for $C_{24}H_{21}ClFN_6OS^+$ $[M+H]^+$: 495.1165, found: 495.1163.

***N*-((4-(2-Chlorodibenzo[*b*,*f*][1,4]oxazepin-11-yl)piperazin-1-yl)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)acetamide (233)**



Following **General Procedure K**, sulfinamidine **213** (100 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and amoxapine (235 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 4 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 2:1 to 1:2) afforded *sulfondiimidamide* **233** as a colourless oil (190 mg, 0.37 mmol, 74%).

R$_f$ 0.55 (CH_2Cl_2/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.05-8.00 (m, 2H, Ar_F-*H*), 7.43 (dd, J = 8.7, 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.33-7.25 (m, 3H, Ar_F-*H*/Ar_{Cl}-*H*), 7.22 (d, J = 8.7 Hz, 1H, Ar_{Cl}-*H*), 7.12-6.97 (m, 4H, Ar-*H*), 3.70-3.35 (br. s, 1H, N*H*), 3.48 (app. s, 4H, NCH_2), 3.11 (app. s, 4H, NCH_2), 2.04 (s, 3H, COCH_3);

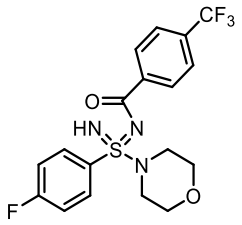
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 179.9, 166.1 (d, $^1J_{CF}$ = 252.3 Hz), 160.2, 159.4, 152.6, 140.9, 133.9, 132.3 (d, $^4J_{CF}$ = 3.1 Hz), 131.2 (d, $^3J_{CF}$ = 9.5 Hz), 131.1, 129.9, 127.7, 126.8, 125.7, 125.5, 123.7, 121.1, 117.1 (d, $^2J_{CF}$ = 23.0 Hz), 47.8, 46.5, 27.1;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -107.7 (tt, J = 8.7, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1558, 1488, 1471, 1363, 1240, 1155, 1101, 934, 833;

HRMS (ESI$^+$) calcd. for $C_{25}H_{24}ClFN_5O_2S^+$ [M+H]$^+$: 512.1318, found: 512.1318.

***N*-((4-Fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)-4-(trifluoromethyl)benzamide (234)**



Following **General Procedure K**, sulfinamidine **214** (165 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 4 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:2 to 2:3 to 1:2) afforded *sulfondiimidamide* **234** as a colourless oil (172 mg, 0.41 mmol, 83%).

R$_f$ 0.50 (petrol/ethyl acetate, 2:3);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.28 (dq, J = 8.7, 0.9 Hz, 2H, Ar-*H*), 8.16-8.11 (m, 2H, Ar$_F$-*H*), 7.73 (d, J = 8.7 Hz, 2H, Ar-*H*), 7.38-7.30 (m, 2H, Ar$_F$-*H*), 3.76-3.49 (br. s, 1H, N*H*), 3.65 (t, J = 4.7 Hz, 4H, OCH_2), 3.13-3.00 (m, 4H, NCH_2).

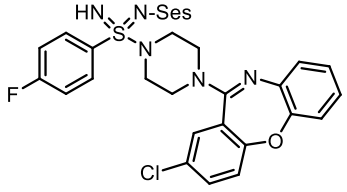
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 172.5, 166.4 (d, $^1J_{CF}$ = 252.8 Hz), 141.2, 133.3 (q, $^2J_{CF}$ = 32.0 Hz), 131.7 (d, $^4J_{CF}$ = 3.0 Hz), 131.5 (d, $^3J_{CF}$ = 9.6 Hz), 130.4, 126.0 (q, $^3J_{CF}$ = 3.8 Hz), 125.2 (q, $^1J_{CF}$ = 271.8 Hz), 117.2 (d, $^2J_{CF}$ = 22.9 Hz), 67.0, 47.2;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -63.2 (s), -107.3 (tt, J = 8.6, 5.1 Hz).

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1620, 1491, 1383, 1312, 1285, 1257, 1129, 1111, 1065, 1015, 921;

HRMS (ESI$^+$) calcd. for $C_{18}H_{18}F_4N_3O_2S^+$ [M+H]$^+$: 416.1050, found: 416.1050.

***N*-((4-(2-Chlorodibenzo[*b*,*f*][1,4]oxazepin-11-yl)piperazin-1-yl)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-2-(trimethylsilyl)ethane-1-sulfonamide (235)**



Following **General Procedure K**, sulfinamidine **215** (161 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and amoxapine (235 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1) afforded *sulfondiimidamide* **235** as a pale-yellow oil (245 mg, 0.39 mmol, 77%).

R$_f$ 0.40 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.08-8.03 (m, 2H, Ar_F-*H*), 7.44 (dd, *J* = 8.7, 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.36-7.30 (m, 2H, Ar_F-*H*), 7.28 (d, *J* = 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.23 (d, *J* = 8.7 Hz, 1H, Ar_{Cl}-*H*), 7.12-6.97 (m, 4H, Ar-*H*), 3.60 (s, 1H, N*H*), 3.53 (app. s, 4H, NCH_2), 3.17 (app. s, 4H, NCH_2), 3.06-3.01 (m, 2H, SO_2CH_2), 1.06-0.99 (m, 2H, $SO_2CH_2CH_2$), 0.00 (s, 9H, TMS-*H*);

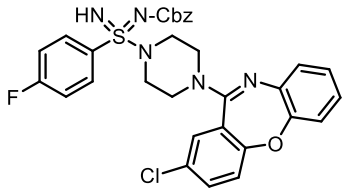
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.4 (d, $^1J_{CF}$ = 253.2 Hz), 160.2, 159.4, 152.6, 140.9, 134.0, 132.9 (d, $^4J_{CF}$ = 3.0 Hz), 131.5 (d, $^3J_{CF}$ = 9.6 Hz), 131.1, 129.9, 127.7, 126.8, 125.8, 125.5, 123.7, 121.2, 117.2 (d, $^2J_{CF}$ = 23.0 Hz), 53.3, 47.7, 47.0, 11.3, -1.9;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -107.0 (tt, *J* = 8.6, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1471, 1383, 1304, 1250, 1132, 1092, 1008, 833;

HRMS (ESI^+) calcd. for $C_{28}H_{34}ClFN_5O_3S_2Si^+$ $[M+H]^+$: 634.1539, found: 634.1534.

Benzyl((4-(2-chlorodibenzo[*b*,*f*][1,4]oxazepin-11-yl)piperazin-1-yl)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)carbamate (236)



Following **General Procedure K**, sulfinamidine **216** (146 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and amoxapine (235 mg, 0.75 mmol, 1.50 equiv.) were combined at room

temperature for 1 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) afforded *sulfondiimidamide* **236** as a pale-yellow oil (232mg, 0.38 mmol, 77%).

R$_f$ 0.65 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.05-7.97 (m, 2H, Ar_F-*H*), 7.39 (dd, *J* = 8.6, 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.35-7.24 (m, 7H, Ar-*H*), 7.21-7.17 (m, 2H, Ar-*H*), 7.10-6.96 (m, 4H, Ar-*H*), 5.08 (s, 2H, Bn-CH_2), 3.77-3.28 (br. s, 1H, N*H*), 3.43 (app. s, 4H, NCH_2), 3.09 (app. s, 4H, NCH_2);

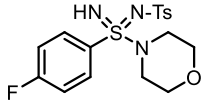
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.1 (d, $^1J_{CF}$ = 253.0 Hz), 160.1, 159.4, 159.3, 152.6, 140.8, 138.4, 133.9, 132.0 (d, $^4J_{CF}$ = 3.0 Hz), 131.3 (d, $^3J_{CF}$ = 9.5 Hz), 131.0, 129.8, 129.4, 128.72, 128.70, 127.7, 126.8, 125.7, 125.4, 123.7, 121.1, 117.1 (d, $^2J_{CF}$ = 22.8 Hz), 67.8, 47.7, 46.7;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -107.1 (tt, *J* = 8.4, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1662, 1588, 1470, 1239, 1102, 1008, 933, 905;

HRMS (ESI^+) calcd. for $C_{31}H_{28}ClFN_5O_3S^+$ $[M+H]^+$: 604.1580, found: 604.1578.

***N*-((4-Fluorophenyl)(imino)(morpholino)-λ^6-sulfaneylidene)-4-methylbenzenesulfonamide (237)**



Following **General Procedure K**, sulfinamidine **217** (156 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and morpholine (66 µL, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 2:1) afforded *sulfondiimidamide* **237** as a colourless oil (185 mg, 0.47 mmol, 93%).

R*f* 0.44 (CH_2Cl_2/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 7.94-7.89 (m, 2H, Ar_F-*H*), 7.73 (d, *J* = 8.3 Hz, 2H, Tol-*H*), 7.29-7.22 (m, 4H, Ar_F-*H*/Tol-*H*), 3.62-3.25 (br. s, 1H, N*H*), 3.54 (ddd, *J* = 11.8, 5.9,

3.7 Hz, 2H, OCH_2), 3.49 (ddd, J = 11.6, 7.6, 3.6 Hz, 2H, OCH_2), 2.98-2.84 (m, 4H, NCH_2), 2.35 (s, 3H, Tol-CH_3);

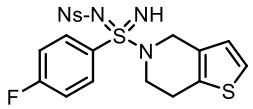
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.3 (d, $^1J_{CF}$ = 253.2 Hz), 143.7, 142.2, 131.5 (d, $^3J_{CF}$ = 9.7 Hz), 131.4 (d, $^4J_{CF}$ = 2.9 Hz), 130.2, 127.4, 117.1 (d, $^2J_{CF}$ = 23.1 Hz), 66.6, 47.4, 21.4;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -106.8 (tt, J = 8.6, 5.2 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1473, 1462, 1383, 1252, 1151, 1087, 1071, 954;

HRMS (ESI^+) calcd. for $C_{17}H_{21}FN_3O_3S_2^+$ $[M+H]^+$: 398.1003, found: 398.0997.

***N*-((6,7-Dihydrothieno[3,2-*c*]pyridin-5(4*H*)-yl)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (238)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and 4,5,6,7-tetrahydrothieno[3,2-*c*]pyridine (104 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 12:1) afforded *sulfondiimidamide* **238** as a pale-yellow oil (221 mg, 0.46 mmol, 92%).

R$_f$ 0.60 (CH_2Cl_2/ethyl acetate, 10:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.11 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.01 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.00-7.96 (m, 2H, Ar_F-*H*), 7.27-7.21 (m, 2H, Ar_F-*H*), 7.05 (d, J = 5.1 Hz, 1H, HetAr-*H*), 6.56 (d, J = 5.1 Hz, 1H, HetAr-*H*), 4.09 (dt, J = 14.9, 1.8 Hz, 1H, N-CH_aH$_b$-HetAr), 3.91 (dt, J = 14.9, 1.8 Hz, 1H, N-C$H_a$$H_b$-HetAr), 3.85 (s, 1H, N*H*), 3.68-3.59 (m, 1H, NCH_aH$_b$CH_2), 3.18 (ddd, J = 12.4, 7.4, 5.1 Hz, 1H, NC$H_a$$H_bCH_2$), 2.81-2.67 (m, 2H, NC$H_2CH_2$);

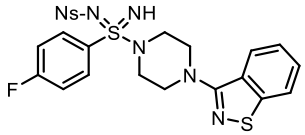
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.3 (d, $^1J_{CF}$ = 253.7 Hz), 150.3, 149.9, 133.6, 132.8 (d, $^4J_{CF}$ = 3.0 Hz), 131.5, 131.1 (d, $^3J_{CF}$ = 9.7 Hz), 128.7, 125.9, 124.8, 124.7, 117.3 (d, $^2J_{CF}$ = 23.0 Hz), 47.4, 45.1, 25.6;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -106.2 (tt, J = 8.6, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1526, 1382, 1349, 1299, 1236, 1151, 1088, 1049, 968, 734;

HRMS (ESI^+) calcd. for $C_{19}H_{18}FN_4O_4S_3^+$ $[M+H]^+$: 481.0469, found: 481.0467.

***N*-((4-(Benzo[*d*]isothiazol-3-yl)piperazin-1-yl)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (239)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and 3-(piperazin-1-yl)benzo[*d*]isothiazole (165 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 12:1 to 7:1) afforded *sulfondiimidamide* **239** as a pale-yellow oil (253 mg, 0.45 mmol, 90%).

R$_f$ 0.54 (CH_2Cl_2/ethyl acetate, 10:1);

^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ (ppm) = 8.30 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.18 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.13-8.08 (m, 2H, Ar_F-*H*), 7.98-7.90 (m, 2H, Ar_F-*H*), 7.50 (ddd, J = 8.2, 7.0, 1.0 Hz, 1H, HetAr-*H*), 7.40-7.33 (m, 3H, HetAr-*H*), 4.35 (s, 1H, N*H*), 3.57-3.48 (m, 4H, NCH_2), 3.36 (t, J = 4.9 Hz, 4H, NCH_2);

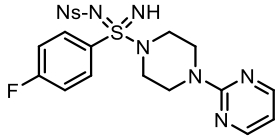
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 166.2 (d, $^1J_{CF}$ = 253.9 Hz), 163.7, 153.4, 150.5, 150.3, 132.1 (d, $^4J_{CF}$ = 3.0 Hz), 131.5 (d, $^3J_{CF}$ = 9.7 Hz), 128.8, 128.6, 128.3, 125.0, 124.7, 124.6, 121.4, 117.1 (d, $^2J_{CF}$ = 23.0 Hz), 50.0, 46.9;

^{19}F NMR (377 MHz, $(CD_3)_2CO$): δ (ppm) = -106.2 (tt, J = 9.1, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1528, 1489, 1383, 1350, 1263, 1087, 1056, 891, 731;

HRMS (ESI$^+$) calcd. for $C_{23}H_{22}FN_6O_4S_3^+$ [M+H]$^+$: 561.0843, found: 561.0842.

***N*-((4-Fluorophenyl)(imino)(4-(pyrimidin-2-yl)piperazin-1-yl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (240)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), PhI(OAc)$_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et$_3$N (0.21 mL, 1.50 mmol, 3.00 equiv.) and 2-(piperazin-1-yl)pyrimidine (123 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (petrol/ethyl acetate, 1:1 to 1:3) afforded *sulfondiimidamide* **240** as a colourless oil (233 mg, 0.46 mmol, 92%).

R$_f$ 0.31 (petrol/ethyl acetate, 1:2);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.26 (d, J = 4.8 Hz, 2H, HetAr-*H*), 8.23 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 8.04 (d, J = 8.9 Hz, 2H, Ar$_{Ns}$-*H*), 7.95-7.91 (m, 2H, Ar$_F$-*H*), 7.27-7.22 (m, 2H, Ar$_F$-*H*), 6.54 (t, J = 4.8 Hz, 1H, HetAr-*H*), 3.78-3.69 (m, 5H, NC*H*$_2$/N*H*), 3.08-3.02 (m, 4H, NC*H*$_2$);

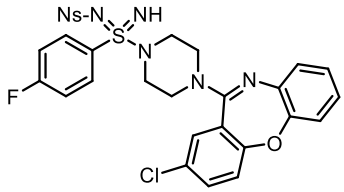
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.5 (d, $^1J_{CF}$ = 253.9 Hz), 162.2, 158.8, 150.6, 150.3, 131.7 (d, $^4J_{CF}$ = 3.2 Hz), 131.6 (d, $^3J_{CF}$ = 9.9 Hz), 128.8, 125.0, 117.3 (d, $^2J_{CF}$ = 23.1 Hz), 111.6, 47.0, 43.8;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -106.4 (tt, J = 8.6, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1585, 1528, 1488, 1448, 1352, 1303, 1154, 1088, 1049, 950;

HRMS (ESI$^+$) calcd. for $C_{20}H_{21}FN_7O_4S_2^+$ [M+H]$^+$: 506.1075, found: 506.1073.

***N*-((4-(2-chlorodibenzo[*b*,*f*][1,4]oxazepin-11-yl)piperazin-1-yl)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (241)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and amoxapine (235 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 2 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) afforded *sulfondiimidamide* **241** as a pale-yellow oil (293 mg, 0.45 mmol, 90%).

R$_f$ 0.68 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $(CD_3)_2CO$): δ (ppm) = 8.31 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.17 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.11-8.04 (m, 2H, Ar_F-*H*), 7.48 (dd, J = 8.7, 2.6 Hz, 1H, Ar_{Cl}-*H*), 7.36-7.27 (m, 4H, Ar_F-*H*/Ar_{Cl}-*H*), 7.14-7.04 (m, 3H, Ar-*H*), 7.00 (ddd, J = 7.8, 6.8, 2.3 Hz, 1H, Ar-*H*), 4.32 (s, 1H, N*H*), 3.58 (app. s, 4H, NCH_2), 3.29 (app. s, 4H, NCH_2).

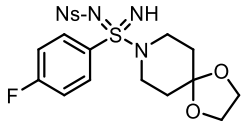
^{13}C NMR (101 MHz, $(CD_3)_2CO$): δ (ppm) = 166.2 (d, $^1J_{CF}$ = 253.9 Hz), 160.1, 159.0, 152.5, 150.6, 150.4, 140.6, 133.8, 132.3 (d, $^4J_{CF}$ = 3.0 Hz), 131.6 (d, $^3J_{CF}$ = 9.7 Hz), 130.9, 129.6, 128.9, 127.8, 126.5, 125.6, 125.4, 124.8, 123.8, 121.0, 117.1 (d, $^2J_{CF}$ = 23.0 Hz), 47.5, 46.8;

^{19}F NMR (377 MHz, $(CD_3)_2CO$): δ (ppm) = -106.2 (tt, J = 8.5, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1528, 1472, 1382, 1241, 1151, 1087, 731;

HRMS (ESI^+) calcd. for $C_{29}H_{25}ClFN_6O_5S_2^+$ $[M+H]^+$: 655.0995, found: 655.0993.

***N*-((4-Fluorophenyl)(imino)(1,4-dioxa-8-azaspiro[4.5]decan-8-yl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (242)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and 1,4-dioxa-8-azaspiro[4.5]decane (107 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 4:1 to 2:1) afforded *sulfondiimidamide* **242** as a pale-yellow solid (203 mg, 0.42 mmol, 84%).

mp 122-124 °C;

R$_f$ 0.57 (CH_2Cl_2/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.23 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.02 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.96-7.91 (m, 2H, Ar_F-*H*), 7.29-7.22 (m, 2H, Ar_F-*H*), 3.82 (app. s, 4H, OCH_2), 3.63 (s, 1H, N*H*), 3.13 (t, J = 5.8 Hz, 4H, NCH_2), 1.67-1.56 (m, 4H, NCH_2CH_2);

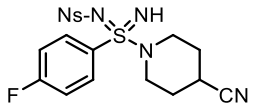
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.3 (d, $^1J_{CF}$ = 253.8 Hz), 150.6, 150.3, 132.5 (d, $^4J_{CF}$ = 3.0 Hz), 131.3 (d, $^3J_{CF}$ = 9.6 Hz), 128.8, 125.0, 117.3 (d, $^2J_{CF}$ = 23.1 Hz), 106.4, 65.1, 45.7, 35.0;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -106.4 (tt, J = 8.8, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1587, 1530, 1471, 1382, 1230, 1153, 1084, 1037, 964;

HRMS (ESI^+) calcd. for $C_{19}H_{22}FN_4O_6S_2^+$ $[M+H]^+$: 485.0959, found: 485.0951.

***N*-((4-Cyanopiperidin-1-yl)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (243)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and piperidine-4-carbonitrile (83 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl

acetate, 10:1 to 4:1) afforded *sulfondiimidamide* **243** as a white solid (171 mg, 0.38 mmol, 76%).

mp 154-156 °C;

R$_f$ 0.50 (CH_2Cl_2/ethyl acetate, 5:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.32 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.04 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.95-7.89 (m, 2H, Ar_F-*H*), 7.47-7.41 (m, 2H, Ar_F-*H*), 5.41 (s, 1H, N*H*), 3.31-3.17 (m, 2H, alkyl-*H*), 2.93 (tt, J = 8.5, 4.0 Hz, 1H, CN-C*H*), 2.88-2.77 (m, 2H, alkyl-*H*), 1.93-1.83 (m, 2H, alkyl-*H*), 1.69 (ddd, J = 13.1, 8.5, 3.6 Hz, 1H, alkyl-*H*), 1.62 (ddd, J = 12.5, 8.5, 3.6 Hz, 1H, alkyl-*H*);

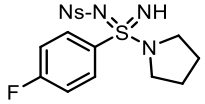
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 164.7 (d, $^1J_{CF}$ = 252.6 Hz), 149.12, 149.10, 132.1 (d, $^4J_{CF}$ = 2.8 Hz), 130.5 (d, $^3J_{CF}$ = 9.8 Hz), 128.0, 124.1, 121.5, 116.4 (d, $^2J_{CF}$ = 23.0 Hz), 44.3, 43.7, 27.5, 27.5, 24.4 (Note: For 4 secondary carbons in piperidine ring, 4 peaks were found instead of 2 due to the loss of symmetry caused by chiral sulfur atom);

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -105.8 (tt, J = 8.7, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1526, 1381, 1347, 1294, 1146, 1087, 1055, 952, 836;

HRMS (ESI^+) calcd. for $C_{18}H_{19}FN_5O_4S_2^+$ $[M+H]^+$: 452.0857, found: 452.0856.

***N*-((4-Fluorophenyl)(imino)(pyrrolidin-1-yl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (244)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and pyrrolidine (53 mg, 0.75 mmol, 1.50 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (CH_2Cl_2/ethyl acetate, 10:1 to 5:1) afforded *sulfondiimidamide* **244** as a white solid (160 mg, 0.39 mmol, 78%).

mp 124-126 °C;

R$_f$ 0.50 (CH_2Cl_2/ethyl acetate, 9:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.22 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 8.00 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.99-7.95 (m, 2H, Ar_F-*H*), 7.27-7.21 (m, 2H, Ar_F-*H*), 3.65 (s, 1H, N*H*), 3.24-3.17 (m, 2H, NCH_2), 3.16-3.09 (m, 2H, NCH_2), 1.73-1.67 (m, 4H, NCH_2CH_2);

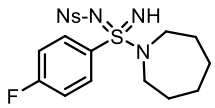
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.3 (d, $^1J_{CF}$ = 253.4 Hz), 150.6, 150.5, 133.7 (d, $^4J_{CF}$ = 3.1 Hz), 131.5 (d, $^3J_{CF}$ = 9.7 Hz), 128.8, 124.9, 117.2 (d, $^2J_{CF}$ = 23.1 Hz), 49.3, 25.9;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -106.9 (tt, J = 8.7, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1521, 1381, 1348, 1293, 1234, 1148, 1083, 954, 849, 616;

HRMS (ESI^+) calcd. for $C_{16}H_{18}FN_4O_4S_2^+$ $[M+H]^+$: 413.0748, found: 413.0747.

***N*-(Azepan-1-yl(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (245)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (2.5 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and azepane (150 mg, 1.50 mmol, 3.00 equiv.) were combined at room temperature for 15 min. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 2:3) afforded *sulfondiimidamide* **245** as a colourless oil (190 mg, 0.43 mmol, 86%).

R$_f$ 0.50 (petrol/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.21 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.99 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.93-7.88 (m, 2H, Ar_F-*H*), 7.23-7.17 (m, 2H, Ar_F-*H*), 3.53 (s, 1H, N*H*), 3.35 (ddd, J = 13.8, 7.0, 4.7 Hz, 2H, NCH_aH$_b$), 3.26 (ddd, J = 13.8, 6.9, 4.5 Hz, 2H, NCH_aH_b), 1.71-1.49 (m, 8H, alkyl-*H*);

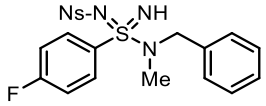
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.0 (d, $^1J_{CF}$ = 253.1 Hz), 150.7, 150.4, 135.7 (d, $^4J_{CF}$ = 3.1 Hz), 130.9 (d, $^3J_{CF}$ = 9.8 Hz), 128.7, 124.9, 117.1 (d, $^2J_{CF}$ = 23.0 Hz), 49.5, 29.6, 27.1;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -107.2 (tt, J = 8.5, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1528, 1489, 1350, 1300, 1235, 1151, 1088, 1046, 1009;

HRMS (ESI^+) calcd. for $C_{18}H_{22}FN_4O_4S_2^+$ $[M+H]^+$: 441.1061, found: 441.1054.

***N*-((benzyl(methyl)amino)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (246)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (2.5 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and *N*-benzylmethylamine (182 mg, 1.50 mmol, 3.00 equiv.) were combined at room temperature for 10 min. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) afforded *sulfondiimidamide* **246** as a colourless oil (213 mg, 0.46 mmol, 92%).

R$_f$ 0.46 (petro/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.20 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.04 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.03-7.98 (m, 2H, Ar_F-*H*), 7.34-7.28 (m, 7H, Ar_F-*H*/Bn-*H*), 4.29 (d, J = 14.2 Hz, 1H, Bn-C*H*$_a$H$_b$), 4.21 (d, J = 14.2 Hz, 1H, Bn-CH$_a$*H*$_b$), 3.80 (s, 1H, N*H*), 2.55 (s, 3H, NC*H*$_3$);

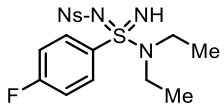
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.3 (d, $^1J_{CF}$ = 253.6 Hz), 150.5, 150.3, 136.7, 133.2 (d, $^4J_{CF}$ = 3.0 Hz), 131.3 (d, $^3J_{CF}$ = 9.7 Hz), 129.5, 129.3, 128.8, 128.7, 125.0, 117.3 (d, $^2J_{CF}$ = 23.1 Hz), 54.6, 35.5;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -106.4 (tt, J = 8.4, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2361, 1589, 1528, 1490, 1350, 1301, 1153, 1088, 1051;

HRMS (ESI^+) calcd. for $C_{20}H_{20}FN_4O_4S_2^+$ $[M+H]^+$: 463.0905, found: 463.0907.

***N*-((Diethylamino)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (247)**



Following **General Procedure K**, sulfinamidine **197** (172 mg, 0.50 mmol, 1.00 equiv.), $PhI(OAc)_2$ (242 mg, 0.75 mmol, 1.50 equiv.), toluene (2.5 mL), Et_3N (0.21 mL, 1.50 mmol, 3.00 equiv.) and diethylamine (110 mg, 1.50 mmol, 3.00 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (petrol/ethyl acetate, 2:1 to 2:3) afforded *sulfondiimidamide* **247** as a colourless oil (170 mg, 0.41 mmol, 82%).

R$_f$ 0.40 (CH_2Cl_2/ethyl acetate, 15:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.20 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.97 (d, J = 9.0 Hz, 2H, Ar_{Ns}-*H*), 7.94-7.89 (m, 2H, Ar_F-*H*), 7.23-7.17 (m, 2H, Ar_F-*H*), 3.43 (s, 1H, N*H*), 3.35-3.19 (m, 4H, NCH_2), 1.05 (t, J = 7.1 Hz, 6H, NCH_2CH_3);

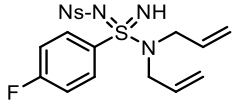
^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.1 (d, $^1J_{CF}$ = 253.1 Hz), 150.53, 150.47, 136.4 (d, $^4J_{CF}$ = 3.1 Hz), 131.1 (d, $^3J_{CF}$ = 9.6 Hz), 128.7, 124.9, 117.1 (d, $^2J_{CF}$ = 23.1 Hz), 43.1, 14.3;

^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -107.3 (tt, J = 8.6, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1526, 1489, 1382, 1349, 1298, 1235, 1151, 1087, 1045, 1003, 766, 613;

HRMS (ESI$^+$) calcd. for $C_{16}H_{20}FN_4O_4S_2^+$ $[M+H]^+$: 415.0905, found: 415.0904.

***N*-((Diallylamino)(4-fluorophenyl)(imino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (248)**



Following **General Procedure K**, sulfinamidine **197** (343 mg, 1.00 mmol, 1.00 equiv.), $PhI(OAc)_2$ (483 mg, 1.50 mmol, 1.50 equiv.), toluene (5.0 mL), Et_3N (0.42 mL, 3.00 mmol,

3.00 equiv.) and diallyl amine (292 mg, 3.00 mmol, 3.00 equiv.) were combined at room temperature for 1 h. Purification by flash column chromatography (petrol/ethyl acetate, 3:1 to 1:1) afforded *sulfondiimidamide* **248** as a pale-yellow oil (400 mg, 0.91 mmol, 91%).

R$_f$ 0.40 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.21 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.01-7.93 (m, 4H, Ar_{Ns}-*H*/Ar_F-*H*), 7.24-7.18 (m, 2H, Ar_F-*H*), 5.63 (ddt, J = 16.6, 10.1, 6.3 Hz, 2H, NCH_2CH=CH_2), 5.23-5.09 (m, 4H, NCH_2CH=CH_2), 3.93-3.77 (m, 4H, NCH_2CH=CH_2), 3.63 (s, 1H, N*H*);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 166.2 (d, $^1J_{CF}$ = 253.5 Hz), 150.6, 150.3, 136.1 (d, $^4J_{CF}$ = 3.1 Hz), 133.5, 131.3 (d, $^3J_{CF}$ = 9.8 Hz), 128.8, 125.0, 119.9, 117.2 (d, $^2J_{CF}$ = 23.0 Hz), 50.5;

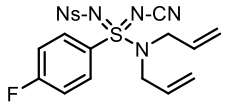
^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -106.9 (tt, J = 8.4, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1526, 1491, 1350, 1294, 1233, 1150, 1089, 1007, 744;

HRMS (ESI^+) calcd. for $C_{18}H_{20}FN_4O_4S_2^+$ $[M+H]^+$: 439.0905, found: 439.0895.

6.4.5 Synthesis of Primary Sulfondiimidamides

N-((Cyanoimino)(diallylamino)(4-fluorophenyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (249)



To an oven-dried 50 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **248** (573 mg, 1.31 mmol, 1.00 equiv.) in anhydrous CH_3CN (6.5 mL) at room temperature. Et_3N (0.37 mL, 2.65 mmol, 2.00 equiv.) was then added, followed by the addition of BrCN solution (0.39 mL, 5.0 M in CH_3CN, 1.95 mmol, 1.50 equiv.). After being stirred at room temperature for 20 min, the reaction mixture was quenched with sat. aq. $NaHCO_3$ solution (100 mL). The product was extracted with ethyl acetate (3 × 50 mL). The

combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) to afford *sulfondiimidamide* **249** as a colourless oil (598 mg, 1.29 mmol, 99%).

R_f 0.40 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.34 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.18 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.05-7.99 (m, 2H, Ar_F-*H*), 7.33-7.26 (m, 2H, Ar_F-*H*), 5.68 (ddt, J = 16.9, 10.1, 6.7 Hz, 2H, NCH_2CH=CH_2), 5.32-5.21 (m, 4H, NCH_2CH=CH_2), 4.05 (dd, J = 14.9, 6.5 Hz, 2H, NCH_aH_bCH=CH_2), 3.94 (dd, J = 15.3, 6.8 Hz, 2H, NCH_aH_bCH=CH_2);

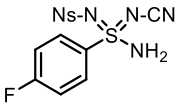
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.7 (d, $^1J_{CF}$ = 261.2 Hz), 150.3, 147.5, 131.4 (d, $^3J_{CF}$ = 10.0 Hz), 130.8 (d, $^4J_{CF}$ = 3.2 Hz), 130.2, 128.5, 124.4, 122.0, 117.7 (d, $^2J_{CF}$ = 23.3 Hz), 109.6, 50.2;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -99.2 (tt, J = 7.8, 4.7 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2206, 1530, 1350, 1216, 1165, 1082, 939, 744;

HRMS (ESI^+) calcd. for $C_{19}H_{19}FN_5O_4S_2^+$ $[M+H]^+$: 464.0857, found: 464.0858.

***N*-(Amino(cyanoimino)(4-fluorophenyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (250)**



Sulfondiimidamide **249** (250 mg, 0.54 mmol, 1.00 equiv.), 1,3-dimethylbarbituric acid (505 mg, 3.24 mmol, 6.00 equiv.), $Pd(PPh_3)_4$ (125 mg, 0.11 mmol, 0.20 equiv.) were dissolved in anhydrous, degassed CH_2Cl_2 (2.70 mL) in an oven-dried 25 mL round-bottom flask and under nitrogen atmosphere. After being stirred at room temperature for 1.5 h, the reaction mixture was quenched with 0.2 M aq. Na_2CO_3 solution (80 mL). The product was extracted with ethyl acetate (3 × 40 mL). The combined organic layers were dried over anhydrous

Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (ethyl acetate/ethanol, 10:1 to 4:1) to afford *sulfondiimidamide* **250** as a colourless oil (90 mg, 0.23 mmol, 44%).

R$_f$ 0.50 (ethyl acetate/ethanol, 5:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.21 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.88 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.87-7.83 (m, 2H, Ar_F-*H*), 7.27-7.21 (m, 2H, Ar_F-*H*), 3.99 (s, 1H, N*H*).

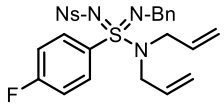
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 163.6 (d, $^1J_{CF}$ = 249.3 Hz), 150.5, 148.5, 141.2 (d, $^4J_{CF}$ = 2.9 Hz), 129.0 (d, $^3J_{CF}$ = 9.2 Hz), 127.9, 123.6, 116.3, 115.2 (d, $^2J_{CF}$ = 22.6 Hz).

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -109.1 (tt, J = 9.5, 5.4 Hz).

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2166, 1473, 1383, 1252, 1152, 1056, 1026, 1007, 955.

HRMS (ESI^-) calcd. for $C_{13}H_9FN_5O_4S_2^-$ $[M-H]^-$: 382.0085, found: 382.0082.

***N*-((Benzylimino)(diallylamino)(4-fluorophenyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (251)**



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **248** (300 mg, 0.68 mmol, 1.00 equiv.) in anhydrous CH_3CN (2.20 mL) at room temperature. DBU (0.41 mL, 2.74 mmol, 4.00 equiv.) was then added, followed by the addition of BnBr (350 mg, 2.05 mmol, 3.00 equiv.). After being stirred at room temperature for 20 h, the reaction was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with ethyl acetate (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) to afford *sulfondiimidamide* **251** as a pale-yellow oil (240 mg, 0.45 mmol, 67%).

R$_f$ 0.40 (petrol/ethyl acetate, 4:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.06 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.00-7.96 (m, 2H, Ar_F-*H*), 7.93 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.34-7.28 (m, 4H, Ar_F-*H*/Bn-*H*), 7.27-7.21 (m, 1H, Bn-*H*), 7.16-7.10 (m, 2H, Bn-*H*), 5.54 (dddd, J = 17.1, 10.2, 7.1, 6.1 Hz, 2H, NCH_2CH=CH_2), 5.22-5.11 (m, 4H, NCH_2CH=CH_2), 4.20 (d, J = 15.1 Hz, 1H, Bn-CH_aH_b), 4.11 (d, J = 15.1 Hz, 1H, Bn-CH_aH_b), 3.96 (dd, J = 15.6, 6.2 Hz, 2H, NCH_aH_bCH=CH_2), 3.76 (dd, J = 15.1, 7.2 Hz, 2H, NCH_aH_bCH=CH_2);

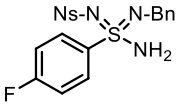
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.2 (d, $^1J_{CF}$ = 256.6 Hz), 149.3, 149.0, 139.5, 134.5 (d, $^4J_{CF}$ = 3.1 Hz), 131.9, 130.8 (d, $^3J_{CF}$ = 9.4 Hz), 128.3, 127.9, 127.0, 126.9, 123.6, 120.2, 116.3 (d, $^2J_{CF}$ = 22.7 Hz), 49.2, 46.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.3 (tt, J = 8.1, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1590, 1528, 1489, 1350, 1302, 1154, 1089, 1056, 930;

HRMS (ESI^+) calcd. for $C_{25}H_{26}FN_4O_4S_2^+$ $[M+H]^+$: 529.1374, found: 529.1373.

***N*-(Amino(benzylimino)(4-fluorophenyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (252)**



Sulfondiimidamide **251** (260 mg, 0.49 mmol, 1.00 equiv.), 1,3-dimethylbarbituric acid (459 mg, 2.94 mmol, 6.00 equiv.), $Pd(PPh_3)_4$ (142 mg, 0.12 mmol, 0.25 equiv.) were dissolved in anhydrous, degassed CH_2Cl_2 (2.50 mL) in an oven-dried 25 mL round-bottom flask and under nitrogen atmosphere. After being stirred at 35 °C for 12 h, the reaction mixture was quenched with 0.2 M aq. Na_2CO_3 solution (60 mL). The product was extracted with ethyl acetate (3 × 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:2 to 2:3) to afford *sulfondiimidamide* **252** as a pale-yellow solid (132 mg, 0.29 mmol, 60%).

mp 122-124 °C;

R_f 0.60 (ethyl acetate/ethanol, 1:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.19 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.04-7.99 (m, 2H, Ar_F-*H*), 7.98 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.30-7.25 (m, 3H, Ar_F-*H*/Bn-*H*), 7.18-7.09 (m, 4H, Bn-*H*), 6.69-1.87 (br. s, 2H, NH_2), 4.17 (d, J = 14.1 Hz, 1H, Bn-CH_aH$_b$), 4.04 (d, J = 14.1 Hz, 1H, Bn-CH$_a$$H_b$);

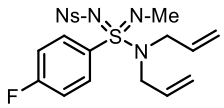
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.6 (d, $^1J_{CF}$ = 257.5 Hz), 149.6, 148.9, 135.6, 133.7 (d, $^4J_{CF}$ = 3.1 Hz), 130.5 (d, $^3J_{CF}$ = 9.5 Hz), 128.9, 128.3, 128.1, 128.0, 124.0, 116.6 (d, $^2J_{CF}$ = 22.8 Hz), 46.4;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -103.4 (tt, J = 8.0, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1527, 1492, 1350, 1282, 1236, 1151, 1092, 1025, 1009, 967;

HRMS (ESI^+) calcd. for $C_{19}H_{18}FN_4O_4S_2^+$ $[M+H]^+$: 449.0748, found: 449.0744.

***N*-((Diallylamino)(4-fluorophenyl)(methylimino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (253)**



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **248** (387 mg, 0.88 mmol, 1.00 equiv.) in anhydrous CH_3CN (4.40 mL) at room temperature. DBU (0.40 mL, 2.64 mmol, 3.00 equiv.) was then added, followed by the addition of MeI (0.55 mL, 8.83 mmol, 10.00 equiv.). After being stirred at room temperature for 18 h, the reaction was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with ethyl acetate (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) to afford *sulfondiimidamide* **253** as a colourless oil (288 mg, 0.64 mmol, 72%).

R_f 0.48 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.17 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.95 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.88-7.83 (m, 2H, Ar_F-*H*), 7.10-7.04 (m, 2H, Ar_F-*H*), 5.52 (dddd, J = 17.1, 10.2, 7.0, 6.1 Hz, 2H, $NCH_2C\mathit{H}{=}CH_2$), 5.18-5.09 (m, 4H, $NCH_2CH{=}C\mathit{H}_2$), 3.90 (dd, J = 15.5, 6.2 Hz, 2H, $NC\mathit{H}_aH_bCH{=}CH_2$), 3.74 (dd, J = 15.3, 7.0 Hz, 2H, $NCH_a\mathit{H}_bCH{=}CH_2$), 2.61 (s, 3H, N-$C\mathit{H}_3$);

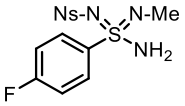
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 165.2 (d, $^1J_{CF}$ = 256.6 Hz), 149.4, 149.3, 134.6 (d, $^4J_{CF}$ = 3.2 Hz), 132.0, 130.7 (d, $^3J_{CF}$ = 9.3 Hz), 128.0, 123.7, 120.1, 116.3 (d, $^2J_{CF}$ = 22.7 Hz), 49.0, 29.7;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -104.6 (tt, J = 8.0, 5.1 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1528, 1490, 1350, 1301, 1231, 1154, 1089, 1052, 1010;

HRMS (ESI^+) calcd. for $C_{19}H_{22}FN_4O_4S_2^+$ $[M+H]^+$: 453.1061, found: 453.1061.

***N*-(Amino(4-fluorophenyl)(methylimino)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (254)**



Sulfondiimidamide **253** (180 mg, 0.40 mmol, 1.00 equiv.), 1,3-dimethylbarbituric acid (374 mg, 2.40 mmol, 6.00 equiv.), $Pd(PPh_3)_4$ (139 mg, 0.12 mmol, 0.30 equiv.) were dissolved in anhydrous, degassed CH_2Cl_2 (2.00 mL) in an oven-dried 25 mL round-bottom flask and under nitrogen atmosphere. After being stirred at 30 °C for 16 h, the reaction mixture was quenched with 0.2 M aq. Na_2CO_3 solution (60 mL). The product was extracted with ethyl acetate (3 × 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 1:1 to 1:2) to afford *sulfondiimidamide* **254** as a pale-yellow solid (79 mg, 0.21 mmol, 53%).

mp 116-118 °C;

R_f 0.44 (ethyl acetate/ethanol, 1:2);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.24 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.95-7.70 (m, 5H, Ar_{Ns}-*H*/Ar_F-*H*/N*H*), 7.40-7.29 (m, 2H, Ar_F-*H*), 4.94 (s, 1H, N*H*), 2.31 (s, 3H, N-CH_3);

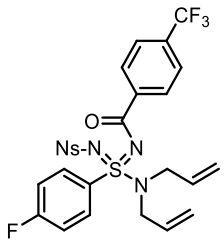
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 164.3 (d, $^1J_{CF}$ = 251.6 Hz), 149.3, 148.9, 134.6 (d, $^4J_{CF}$ = 3.8 Hz), 130.3 (d, $^3J_{CF}$ = 9.7 Hz), 127.8, 123.9, 116.1 (d, $^2J_{CF}$ = 22.9 Hz), 26.9;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -106.9 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1528, 1489, 1350, 1299, 1236, 1154, 1091, 1034, 1009;

HRMS (ESI^+) calcd. for $C_{13}H_{14}FN_4O_4S_2^+$ $[M+H]^+$: 373.0435, found: 373.0433.

***N*-((Diallylamino)(4-fluorophenyl)(((4-nitrophenyl)sulfonyl)imino)-λ^6-sulfaneylidene)-4-(trifluoromethyl)benzamide (255)**



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **248** (285 mg, 0.65 mmol, 1.00 equiv.) in anhydrous CH_2Cl_2 (3.3 mL) at room temperature. Et_3N (0.18 mL, 1.29 mmol, 2.00 equiv.) was then added, followed by the addition of 4-(trifluoromethyl)benzoyl chloride (204 mg, 0.98 mmol, 1.50 equiv.). After being stirred at room temperature for 3 h, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with CH_2Cl_2 (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 3:1 to 2:1) to afford *sulfondiimidamide* **255** as a white solid (335 mg, 0.55 mmol, 84%).

mp 138-140 °C;

R_f 0.41 (petrol/ethyl acetate, 3:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.12-8.06 (m, 2H, Ar_F-*H*), 7.97 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.91 (d, *J* = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.83 (d, *J* = 8.1 Hz, 2H, Ar_{CF3}-*H*), 7.57 (d, *J* = 8.1 Hz, 2H, Ar_{CF3}-*H*), 7.30-7.22 (m, 2H, Ar_F-*H*), 5.82 (ddt, *J* = 16.5, 9.9, 6.6 Hz, 2H, NCH_2CH=CH_2), 5.31-5.22 (m, 4H, NCH_2CH=CH_2), 4.16 (dd, *J* = 15.6, 6.6 Hz, 2H, NCH_aH_bCH=CH_2), 4.05 (dd, *J* = 15.6, 6.6 Hz, 2H, NCH_aH_bCH=CH_2);

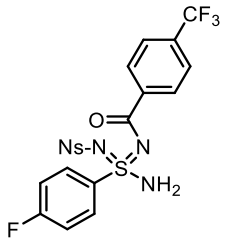
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 169.6, 166.2 (d, $^{1}J_{CF}$ = 259.2 Hz), 149.5, 147.5, 137.6, 134.3 (q, $^{2}J_{CF}$ = 32.7 Hz), 132.3 (d, $^{4}J_{CF}$ = 3.1 Hz), 131.6, 131.5 (d, $^{3}J_{CF}$ = 9.7 Hz), 129.4, 128.6, 125.2 (q, $^{3}J_{CF}$ = 3.7 Hz), 123.74, 123.68 (q, $^{1}J_{CF}$ = 272.6 Hz), 120.9, 117.3 (d, $^{2}J_{CF}$ = 23.1 Hz), 50.6;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -63.1 (s), -101.4 (tt, *J* = 8.0, 4.9 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2981, 2888, 1633, 1586, 1528, 1382, 1277, 1249, 1164, 1126, 1065;

HRMS (ESI^+) calcd. for $C_{26}H_{23}F_4N_4O_5S_2^+$ $[M+H]^+$: 611.1041, found: 611.1039.

***N*-(Amino(4-fluorophenyl)(((4-nitrophenyl)sulfonyl)imino)-λ^6-sulfaneylidene)-4-(trifluoromethyl)benzamide (256)**



Sulfondiimidamide **255** (230 mg, 0.38 mmol, 1.00 equiv.), 1,3-dimethylbarbituric acid (356 mg, 2.28 mmol, 6.00 equiv.), $Pd(PPh_3)_4$ (88 mg, 0.076 mmol, 0.20 equiv.) were dissolved in anhydrous, degassed CH_2Cl_2 (1.90 mL) in an oven-dried 25 mL round-bottom flask and under nitrogen atmosphere. After being stirred at room temperature for 1 h, the reaction mixture was quenched with 0.2 M aq. Na_2CO_3 solution (60 mL). The product was extracted with ethyl acetate (3 × 40 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude solid was washed with cold CH_2Cl_2 to afford *sulfondiimidamide* **256** as a white solid (131 mg, 0.25 mmol, 65%).

mp 218-220 °C;

R_f 0.40 (ethyl acetate);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.10 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 8.04-7.98 (m, 2H, Ar_F-*H*), 7.91 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.83 (d, J = 8.1 Hz, 2H, Ar_{CF3}-*H*), 7.60 (d, J = 8.1 Hz, 2H, Ar_{CF3}-*H*), 7.29-7.22 (m, 2H, Ar_F-*H*), 3.60 (s, 1H, N*H*);

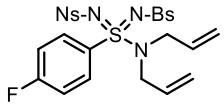
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 169.1, 163.4 (d, $^1J_{CF}$ = 248.5 Hz), 151.3, 148.1, 141.58, 141.57 (d, $^4J_{CF}$ = 3.5 Hz), 130.4 (q, $^2J_{CF}$ = 31.5 Hz), 129.4 (d, $^3J_{CF}$ = 9.1 Hz), 128.8, 128.1, 124.4 (q, $^3J_{CF}$ = 3.6 Hz), 124.2 (q, $^1J_{CF}$ = 272.6 Hz), 123.3, 114.8 (d, $^2J_{CF}$ = 22.5 Hz);

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -61.2 (s), -110.0 (tt, J = 8.9, 5.4 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2981, 2888, 1531, 1462, 1382, 1318, 1251, 1149, 1088, 1068, 1015;

HRMS (ESI^-) calcd. for $C_{20}H_{13}F_4N_4O_5S_2^-$ $[M-H]^-$: 529.0269, found: 529.0259.

4-Bromo-*N*-((diallylamino)(4-fluorophenyl)(((4-nitrophenyl)sulfonyl)imino)-λ^6-sulfaneylidene)benzenesulfonamide (257)



To an oven-dried 25 mL round-bottom flask under nitrogen atmosphere was dissolved sulfondiimidamide **248** (300 mg, 0.68 mmol, 1.00 equiv.) in anhydrous CH_2Cl_2 (3.4 mL) at room temperature. Et_3N (0.19 mL, 1.36 mmol, 2.00 equiv.) was then added, followed by the addition of benzenesulfonyl chloride (0.13 mL, 1.02 mmol, 1.50 equiv.) and DMAP (17 mg, 0.14 mmol, 0.20 equiv.). After being stirred at room temperature for 16 h, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with CH_2Cl_2 (3 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) to afford *sulfondiimidamide* **257** as a pale-yellow oil (390 mg, 0.67 mmol, 99%).

R_f 0.39 (petrol/ethyl acetate, 2:1);

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.19 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 8.00 (d, J = 8.9 Hz, 2H, Ar_{Ns}-*H*), 7.81-7.74 (m, 2H, Ar_F-*H*), 7.57-7.51 (m, 2H, Ar_{Bs}-*H*), 7.47-7.41 (m, 1H, Ar_{Bs}-*H*), 7.34-7.27 (m, 2H, Ar_{Bs}-*H*), 7.10-7.04 (m, 2H, Ar_F-*H*), 5.72 (ddt, J = 17.0, 10.3, 6.7 Hz, 2H, NCH_2CH=CH_2), 5.26-5.14 (m, 4H, NCH_2CH=CH_2), 4.05 (dd, J = 15.4, 6.7 Hz, 2H, NCH_aH_bCH=CH_2), 3.95 (dd, J = 15.4, 6.9 Hz, 2H, NCH_aH_bCH=CH_2);

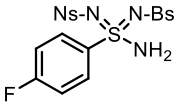
^{13}C NMR (101 MHz, $CDCl_3$): δ (ppm) = 166.1(d, $^1J_{CF}$ = 259.7 Hz), 149.7, 147.5, 141.9, 132.5, 131.8 (d, $^3J_{CF}$ = 9.9 Hz), 131.0, 130.7 (d, $^4J_{CF}$ = 3.2 Hz), 128.6, 128.3, 126.3, 123.8, 121.3, 116.8 (d, $^2J_{CF}$ = 23.1 Hz), 50.5;

^{19}F NMR (377 MHz, $CDCl_3$): δ (ppm) = -100.7 (tt, J = 8.0, 5.0 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1589, 1529, 1489, 1350, 1327, 1308, 1167, 1068;

HRMS (ESI^+) calcd. for $C_{24}H_{24}FN_4O_6S_3^+$ $[M+H]^+$: 579.0837, found: 579.0830.

***N*-(Amino(((4-bromophenyl)sulfonyl)imino)(4-fluorophenyl)-λ^6-sulfaneylidene)-4-nitrobenzenesulfonamide (258)**



Sulfondiimidamide **257** (355 mg, 0.61 mmol, 1.00 equiv.), 1,3-dimethylbarbituric acid (571 mg, 3.66 mmol, 6.00 equiv.), $Pd(PPh_3)_4$ (141 mg, 0.12 mmol, 0.20 equiv.) were dissolved in anhydrous, degassed CH_2Cl_2 (3.00 mL) in an oven-dried 25 mL round-bottom flask and under nitrogen atmosphere. After being stirred at room temperature for 3 h, the reaction mixture was quenched with 0.2 M aq. Na_2CO_3 solution (60 mL). The product was extracted with ethyl acetate (3 × 40 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (ethyl acetate/ethanol, 100:1 to 20:1 to 10:1) to afford *sulfondiimidamide* **258** as a pale-yellow oil (160 mg, 0.32 mmol, 53%).

R_f 0.50 (ethyl acetate/ethanol, 10:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 8.16 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.82 (d, J = 8.8 Hz, 2H, Ar_{Ns}-*H*), 7.79-7.74 (m, 2H, Ar_F-*H*), 7.57-7.53 (m, 2H, Ar_{Bs}-*H*), 7.43-7.38 (m, 1H, Ar_{Bs}-*H*), 7.35-7.29 (m, 2H, Ar_{Bs}-*H*), 7.16-7.10 (m, 2H, Ar_F-*H*), 3.56 (s, 1H, N*H*);

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 163.3 (d, $^1J_{CF}$ = 248.8 Hz), 151.0, 148.2, 145.0, 141.4 (d, $^4J_{CF}$ = 2.7 Hz), 130.6, 129.2 (d, $^3J_{CF}$ = 9.3 Hz), 128.0, 127.9, 126.1, 123.3, 114.7 (d, $^2J_{CF}$ = 22.5 Hz);

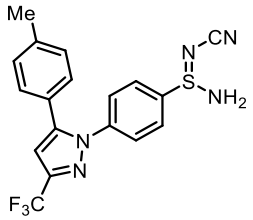
^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -109.8 (tt, J = 9.2, 5.4 Hz);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 1588, 1528, 1491, 1350, 1283, 1149, 1087, 1029, 1008, 996;

HRMS (ESI^+) calcd. For $C_{18}H_{16}FN_4O_6S_3^+$ $[M+H]^+$: 499.0211, found: 499.0207.

6.4.6 Second Generation of A Celecoxib Analogue Synthesis

N-cyano-*S*-(4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl primary sulfinamidine (262)



Preparation of organometallic reagent

(4-(5-(*p*-Tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)lithium solution was prepared according to the following procedure. To a solution of 1-(4-bromophenyl)-5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazole (6.84 g, 18.00 mmol, 1.20 equiv.) in anhydrous THF (36.0 mL) in an oven-dried 100 mL round-bottom flask was added *n*-butyllithium solution (7.20 mL, 2.50 M in hexanes, 18.00 mmol, 1.20 equiv.) dropwise at -78 °C. The reaction was stirred at the same temperature for 40 min.

Preparation of sulfinamidine

TIPS-NSO **185** (3.29 g, 15.00 mmol, 1.00 equiv.) was dissolved in anhydrous THF (30.0 mL) in an oven-dried 250 mL round-bottom flask and was purged with nitrogen gas. The mixture was cooled to -30 °C before LiHMDS solution (15.00 mL, 1.00 M in THF, 15.00 mmol, 1.00 equiv.) was added. After being stirred at - 30 °C for 5 min, the reaction was warmed to 0 °C and stirred for another 5 min. TMSCl (1.90 mL, 15.00 mmol, 1.00 equiv.) was added and the reaction was stirred at 0 °C for 10 min. Then the reaction solution was added to the (4-(5-(*p*-Tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)phenyl)lithium solution (18.00 mmol, 1.20 equiv.) at - 78 °C and stirred at 0 °C for 10 min. The reaction mixture was then quenched with sat. aq. tetrasodium EDTA solution (300 mL). Ethyl acetate (150 mL) was added and the organic layer was separated. The aqueous layer was further extracted with ethyl acetate (2 × 80 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. This crude mixture was then dissolved in anhydrous CH_2Cl_2 (50.0 mL) in an oven-dried 250 mL round-bottom flask and cooled to 0 °C. Then Et_3N (2.51 mL, 18.00 mmol, 1.20 equiv.) and BrCN solution (3.00 mL, 5.0 M in CH_3CN, 15.00 mmol, 1.00 equiv.) were added. The reaction was stirred at 0 °C for 20 min prior to the addition of TBAF solution (16.50 mL, 1.00 M in THF, 16.50 mmol, 1.10 equiv.) at the same temperature. The reaction was stirred for another 10 min. The reaction was then quenched with sat. aq. $NaHCO_3$ solution (250 mL) and extracted with ethyl acetate (3 × 100 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered, concentrated under reduced pressure and purified by flash column chromatography (CH_2Cl_2/ethyl acetate, 2:1 to 1:1 to 1:2) to afford *sulfinamidine* **262** as a pale-yellow oil (5.03 g, 12.93 mmol, 86%).

R$_f$ 0.50 (CH_2Cl_2/ethyl acetate, 1:1);

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 7.88 (d, *J* = 8.8 Hz, 2H, Ar-*H*), 7.61 (d, *J* = 8.8 Hz, 2H, Ar-*H*), 7.23-7.16 (m, 7H, Tol-*H*/HetAr-*H*/N*H*$_2$), 2.31 (s, 3H, Tol-C*H*$_3$);

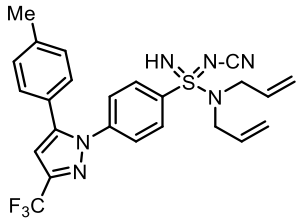
^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 145.3, 142.3 (q, $^2J_{CF}$ = 37.7 Hz), 141.4, 139.1, 138.8, 129.5, 128.8, 128.2, 126.3, 125.4, 121.3 (q, $^1J_{CF}$ = 268.6 Hz), 119.7, 106.2, 20.8;

^{19}F NMR (377 MHz, $(CD_3)_2SO$): δ (ppm) = -60.9 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2152, 1496, 1472, 1374, 1236, 1161, 1134, 1097, 975;

HRMS (ESI^+) calcd. for $C_{18}H_{15}F_3N_5S^+$ $[M+H]^+$: 390.0995, found: 390.0988.

***N*,*N*-Diallyl-*N*'-cyano-4-(5-(*p*-tolyl)-3-(trifluoromethyl)-1*H*-pyrazol-1-yl)benzenesulfondiimidamide (181)**



An 100 mL oven-dried round-bottom flask containing primary sulfinamidine **262** (105 mg, 0.27 mmol, 1.00 equiv.) and $PhI(OAc)_2$ (130 mg, 0.40 mmol, 1.50 equiv.) was sealed and subjected to three N_2 evacuation/refill cycles before pre-sparged anhydrous toluene (1.35 mL) was added. Et_3N (113 µL, 0.81 mmol, 3.00 equiv.) was added to the solution, followed immediately by the addition of diallyl amine (130 mg, 1.34 mmol, 5.00 equiv.). After being stirred at room temperature for 40 min, the reaction mixture was quenched with sat. aq. NaCl solution (50 mL). The product was extracted with ethyl acetate (2 × 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petrol/ethyl acetate, 2:1 to 1:1) to afford *sulfondiimidamide* **181** as a pale-yellow oil (106 mg, 0.22 mmol, 81%).

R$_f$ 0.40 (petrol/ethyl acetate, 3:2);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.03 (d, *J* = 8.9 Hz, 2H, Ar-*H*), 7.52 (d, *J* = 8.9 Hz, 2H, Ar-*H*), 7.21 (d, *J* = 8.2 Hz, 2H, Tol-*H*), 7.17 (d, *J* = 8.2 Hz, 2H, Tol-*H*), 6.93 (s, 1H, HetAr-*H*), 5.65 (ddt, *J* = 16.6, 10.2, 6.3 Hz, 2H, NCH_2CH=CH_2), 5.28-5.12 (m, 4H,

$NCH_2CH=CH_2$), 3.94 (ddt, *J* = 15.0, 6.1, 1.7 Hz, 2H, $NCH_2CH=CH_2$), 3.87 (ddt, *J* = 15.9, 6.4, 1.7 Hz, 2H, $NCH_2CH=CH_2$), 3.82 (s, 1H, N*H*), 2.35 (s, 3H, Tol-CH_3);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 146.7, 144.2 (q, $^2J_{CF}$ = 37.8 Hz), 144.1, 140.9, 139.2, 133.2, 130.4, 129.9, 129.5, 127.1, 126.7, 122.5 (q, $^1J_{CF}$ = 268.2 Hz), 120.1, 114.0, 107.1, 50.7, 21.3;

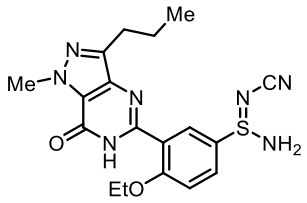
^{19}F NMR (377 MHz, CD_3CN): δ (ppm) = -62.9 (s);

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2188, 1495, 1471, 1373, 1235, 1160, 1133, 1097, 974, 808;

HRMS (ESI^+) calcd. for $C_{24}H_{24}F_3N_6S^+$ $[M+H]^+$: 485.1730, found: 485.1735.

6.4.7 Synthesis of A Sildenafil Analogue

N-Cyano-*S*-(4-Ethoxy-3-(1-methyl-7-oxo-3-propyl-6,7-dihydro-1*H*-pyrazolo[4,3-*d*]pyrimidin-5-yl)-phenyl) primary sulfinamidine (266)



Preparation of organometallic reagent

(4-Ethoxy-3-(1-methyl-7-oxo-3-propyl-6,7-dihydro-1*H*-pyrazolo[4,3-*d*]pyrimidin-5-yl)-phenyl) lithium solution was prepared according to the following procedure. To a solution of 5-(5-Bromo-2-ethoxyphenyl)-1-methyl-3-propyl-1*H*-pyrazolo[4,3-*d*]pyrimidin-7(6H)-one (3.90 g, 10.00 mmol, 1.00 equiv.) in anhydrous THF (50.0 mL) in an oven-dried 250 mL round-bottom flask was added methyllithium solution (7.50 mL, 1.60 M in Et_2O, 12.00 mmol, 1.20 equiv.) dropwise at -78 °C. The reaction was stirred at the same temperature for 10 min. Then *n*-butyllithium solution (6.00 mL, 2.50 M in hexanes, 15.00 mmol, 1.50 equiv.) was added dropwise at -78 °C. The reaction was stirred at the same temperature for 40 min.

Preparation of sulfinamidine

Tri-*iso*propylsilyl sulfinylamine **185** (4.38 g, 20.00 mmol, 2.00 equiv.) was dissolved in anhydrous THF (40.0 mL) in an oven-dried 250 mL round-bottom flask and was purged with nitrogen gas. The mixture was cooled to -30 °C before LiHMDS solution (20.00 mL, 1.00 M in THF, 20.00 mmol, 2.00 equiv.) was added. After being stirred at - 30 °C for 5 min, the reaction was warmed to 0 °C and stirred for another 5 min. TMSCl (2.54 mL, 20.00 mmol, 2.00 equiv.) was added and the reaction was stirred at 0 °C for 10 min. Then the reaction solution was added to the (4-Ethoxy-3-(1-methyl-7-oxo-3-propyl-6,7-dihydro-1*H*-pyrazolo[4,3-*d*]pyrimidin-5-yl)-phenyl) lithium solution (10.00 mmol, 1.00 equiv.) at - 78 °C and stirred at 0 °C for 10 min. The reaction mixture was then quenched with sat. aq. tetrasodium EDTA solution (400 mL). Ethyl acetate (200 mL) was added and the organic layer was separated. The aqueous layer was further extracted with ethyl acetate (2 × 100 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. This crude mixture was then dissolved in anhydrous CH_2Cl_2 (50.0 mL) in an oven-dried 250 mL round-bottom flask and cooled to 0 °C. Then Et_3N (2.09 mL, 15.00 mmol, 1.50 equiv.) and BrCN solution (2.40 mL, 5.0 M in CH_3CN, 12.00 mmol, 1.20 equiv.) were added. The reaction was stirred at 0 °C for 20 min prior to the addition of TBAF solution (15.00 mL, 1.00 M in THF, 15.00 mmol, 1.50 equiv.) at the same temperature. The reaction was stirred for another 10 min and resulted in the precipitation of a white solid (primary sulfinamidine). This white solid was purified by filtration and being washed with cold CH_2Cl_2. Sat. aq. NaCl solution (200 mL) was added to the combined filtrates. The aqueous phase was extracted with CH_2Cl_2 (2 × 80 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered, concentrated under reduced pressure and purified by flash column chromatography. Filtration and flash column chromatography (ethyl acetate/ethanol, 50:1 to 5:1) afforded the desired product **266** as a white solid (2.03 g, 5.09 mmol, 51%).

mp 162-164 °C;

R$_f$ 0.50 (ethyl acetate/methanol, 25:1);

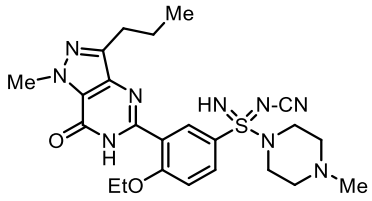
^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ (ppm) = 12.19 (s, 1H, CON*H*), 7.98 (d, *J* = 2.6 Hz, 1H, Ar-*H*), 7.88 (dd, *J* = 8.9, 2.6 Hz, 1H, Ar-*H*), 7.40 (d, *J* = 9.0 Hz, 1H, Ar-*H*), 7.07 (s, 2H, N*H*$_2$), 4.20 (q, *J* = 7.0 Hz, 2H, OC*H*$_2$), 4.16 (s, 3H, HetAr-C*H*$_3$), 2.78 (t, *J* = 7.5 Hz, 2H, HetAr-C*H*$_2$), 1.79-1.68 (m, 2H, HetAr-CH$_2$C*H*$_2$), 1.34 (t, *J* = 6.9 Hz, 3H, OCH$_2$C*H*$_3$), 0.93 (t, *J* = 7.4 Hz, 3H, HetAr-CH$_2$CH$_2$C*H*$_3$).

^{13}C NMR (101 MHz, $(CD_3)_2SO$): δ (ppm) = 159.0, 153.8, 148.4, 145.0, 137.8, 130.6, 129.6, 129.1, 124.4, 123.7, 119.9, 113.7, 64.8, 37.9, 27.1, 21.7, 14.3, 13.8.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2154, 2030, 1686, 1463, 1392, 1248, 1152, 1078, 954;

HRMS (ESI$^+$) calcd. for $C_{18}H_{22}N_7O_2S^+$ $[M+H]^+$: 400.1550, found: 400.1550.

***N*-((4-Ethoxy-3-(1-methyl-7-oxo-3-propyl-6,7-dihydro-1*H*-pyrazolo[4,3-*d*]pyrimidin-5-yl)phenyl)(imino)(4-methylpiperazin-1-yl)-λ^6-sulfaneylidene)cyanamide (267)**



An 25 mL oven-dried round-bottom flask containing primary sulfinamidine **266** (399 mg, 1.00 mmol, 1.00 equiv.) and PhI(OAc)$_2$ (644 mg, 2.00 mmol, 2.00 equiv.) was sealed and subjected to three N_2 evacuation/refill cycles before pre-sparged anhydrous CH_3CN (5.0 mL) was added. DBU (0.30 mL, 2.0 mmol, 2.00 equiv.) was added to the solution, followed immediately by the addition of *N*-methyl piperazine (401 mg, 4.00 mmol, 4.00 equiv.). After being stirred at room temperature for 30 min, the reaction mixture was quenched with sat. aq. NaCl solution (100 mL). The product was extracted with ethyl acetate (2 × 50 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by flash column chromatography (ethyl

acetate/ethanol, 4:1 to 1:1 to 1:4 to 1:100 with 2% Et_3N) to afford *sulfondiimidamide* **267** as a pale-yellow oil (306 mg, 0.62 mmol, 62%).

R_f 0.18 (ethyl acetate/ethanol, 1:5);

^{1}H NMR (400 MHz, CD_3CN): δ (ppm) = 8.57 (d, *J* = 2.6 Hz, 1H, Ar-*H*), 7.96 (dd, *J* = 8.9, 2.6 Hz, 1H, Ar-*H*), 7.81-4.34 (br. s, 2H, CON*H*/S=N*H*), 7.26 (d, *J* = 9.0 Hz, 1H, Ar-*H*), 4.26 (q, *J* = 6.9 Hz, 2H, OCH_2), 4.08 (s, 3H, HetAr-CH_3), 3.07 (app. s, 4H, NCH_2), 2.78 (t, *J* = 7.4 Hz, 2H, HetAr-CH_2), 2.37 (app. s, 4H, NCH_2), 2.14 (s, 3H, NCH_3), 1.85-1.66 (m, 2H, HetAr-CH_2CH_2), 1.45 (t, *J* = 6.9 Hz, 3H, OCH_2CH_3), 0.94 (t, *J* = 7.3 Hz, 3H, HetAr-CH_2CH_2CH_3);

^{13}C NMR (101 MHz, CD_3CN): δ (ppm) = 161.4, 154.3, 148.0, 146.8, 138.9, 132.8, 131.5, 127.0, 125.4, 122.9, 114.8, 114.3, 67.1, 54.8, 47.4, 45.7, 38.6, 28.4, 22.8, 14.8, 14.4;

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2187, 1689, 1596, 1489, 1467, 1394, 1277, 1219, 1128, 1028, 908, 726;

HRMS (ESI^+) calcd. for $C_{23}H_{32}N_9O_2S^+$ $[M+H]^+$: 498.2394, found: 498.2388.

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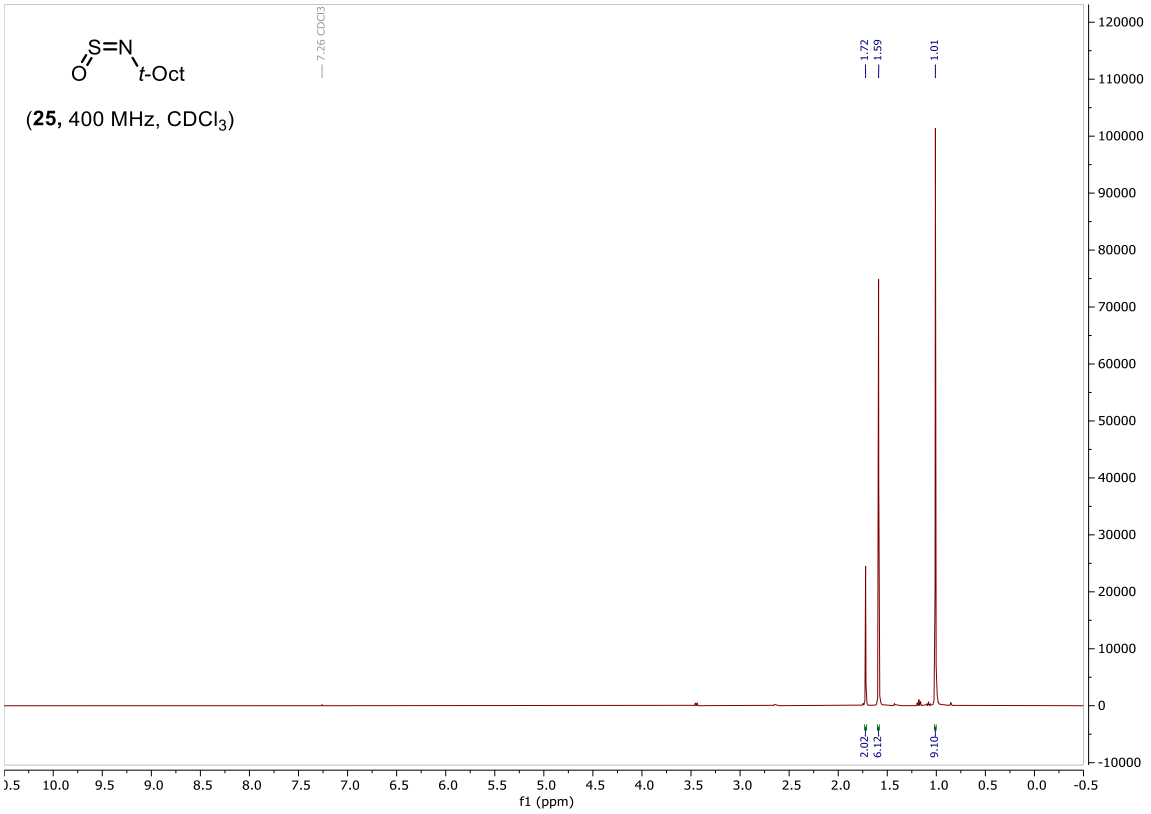
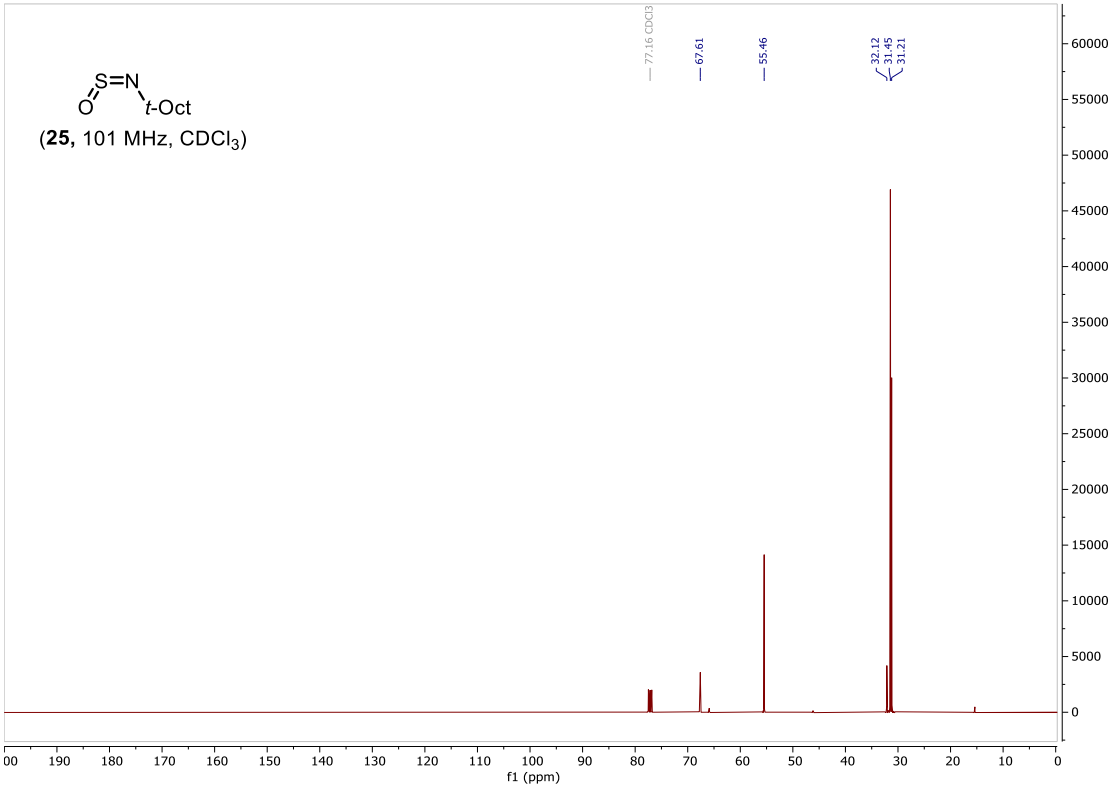
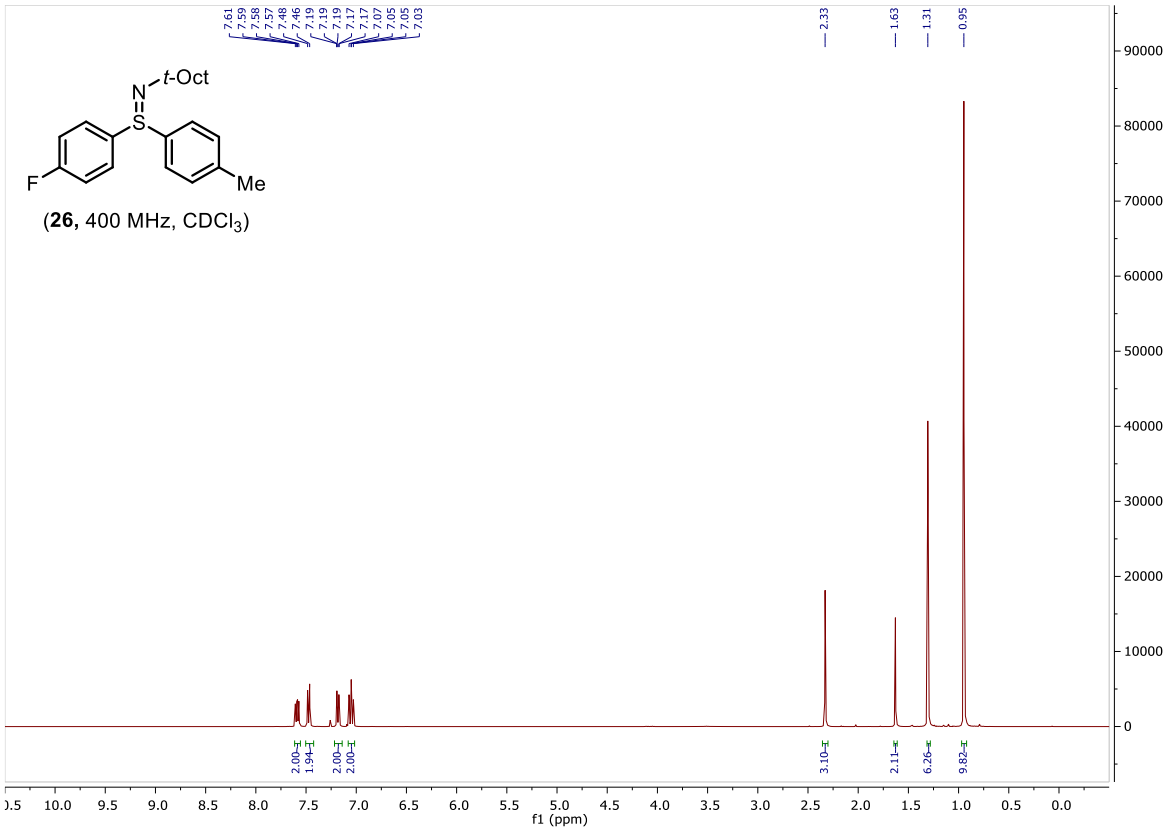
NMR Spectra

Chapter 2 NMR Spectra



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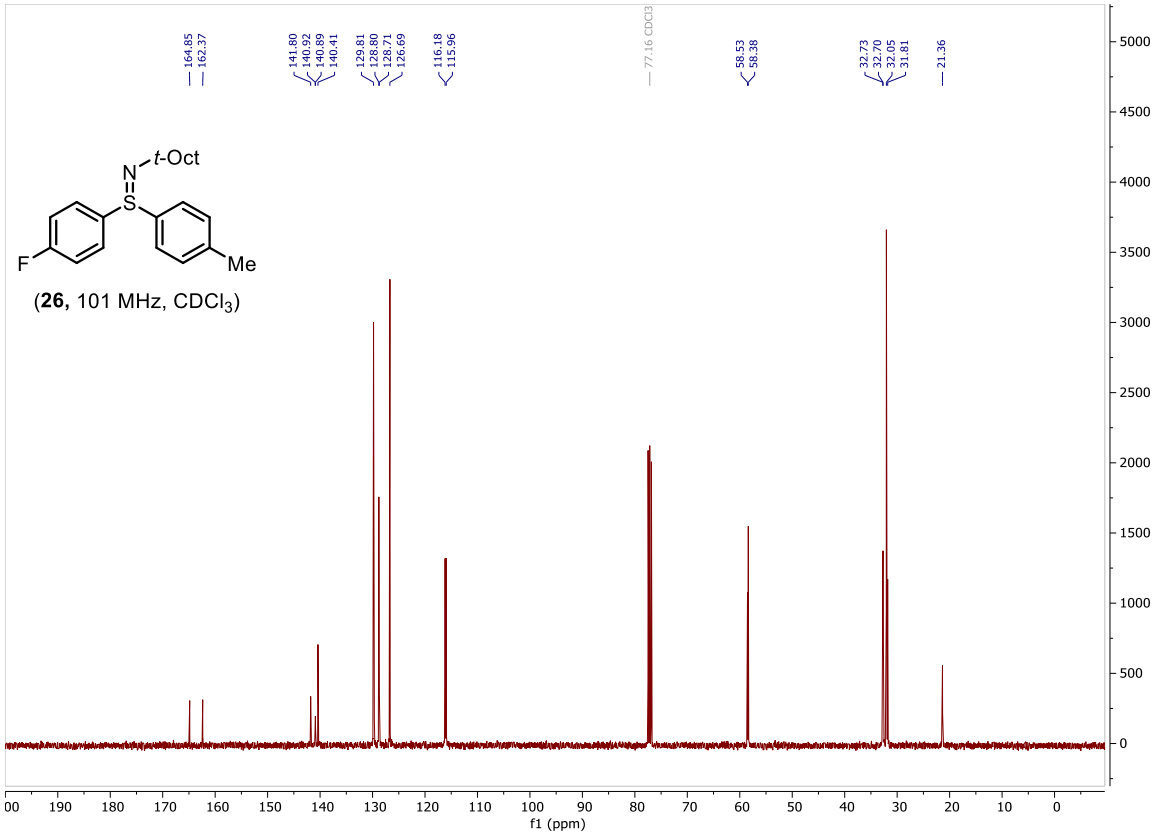
7.46
7.19
7.19
7.17
7.17
7.07
7.05
7.05
7.03
2.33
1.63
1.31
0.95
t-Oct
N
S
F
Me
(26, 400 MHz, CDCl3)
2.00
1.94
2.00
2.00
3.10
2.11
6.26
9.82
f1 (ppm)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116.18
115.96
77.16 CDCl3
58.53
58.38
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N
S
F
Me
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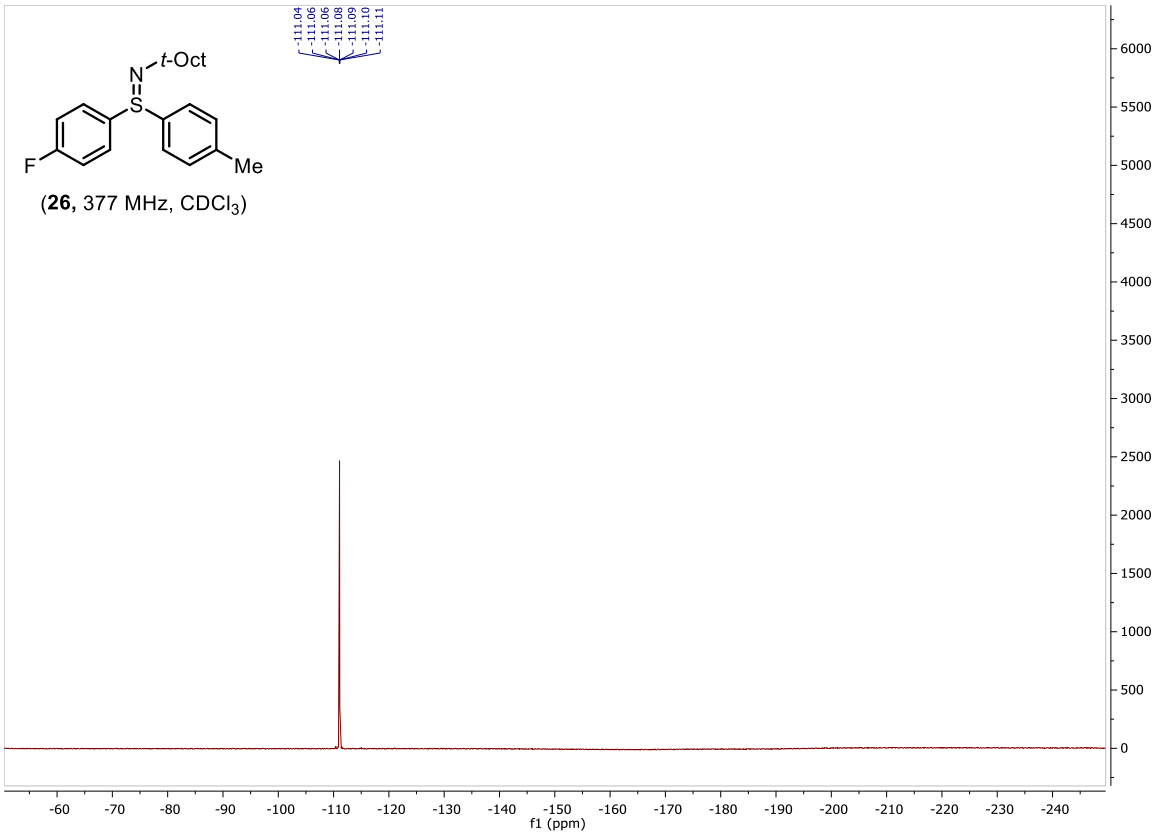
f1 (ppm)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-111.06
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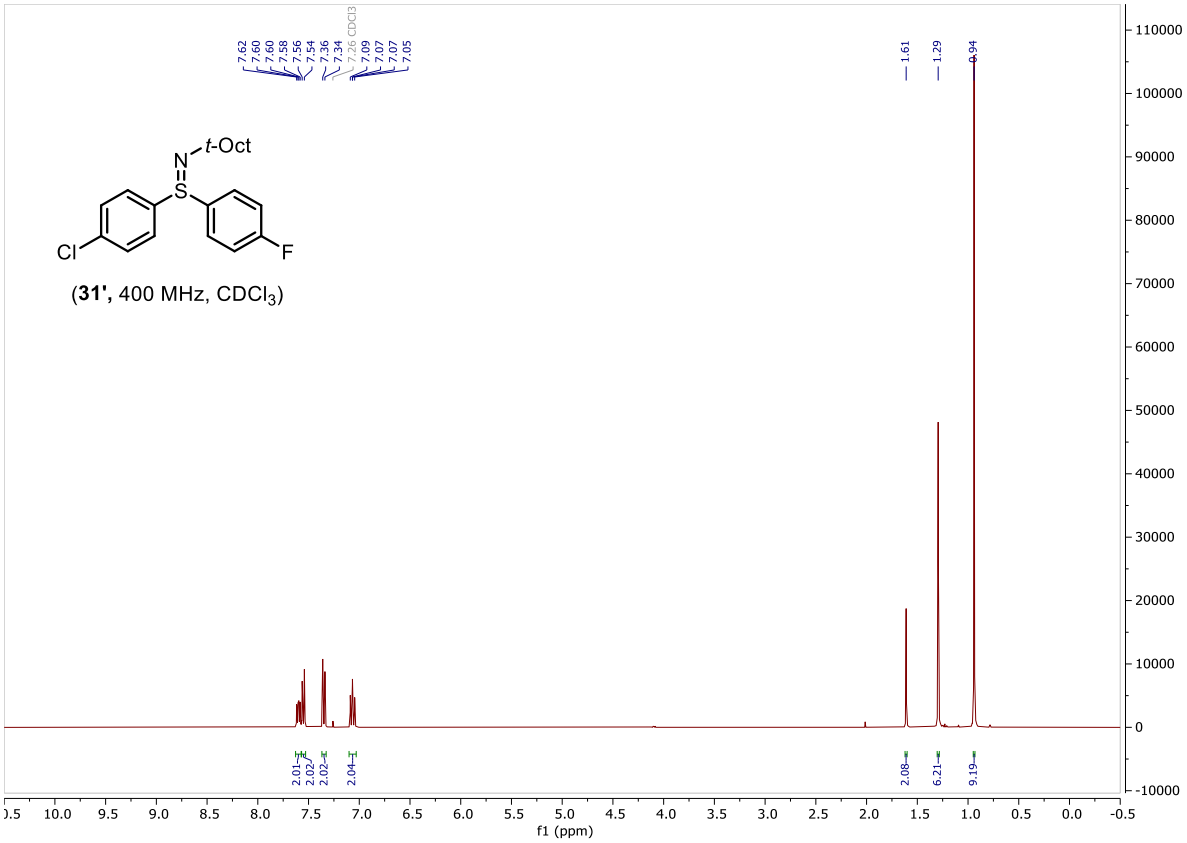
t-Oct
N
S
F
Me
(26, 377 MHz, CDCl3)
f1 (ppm)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7.60
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7.56
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7.34
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7.07
7.07
7.05
1.61
1.29
0.94
t-Oct
N
S
Cl
F
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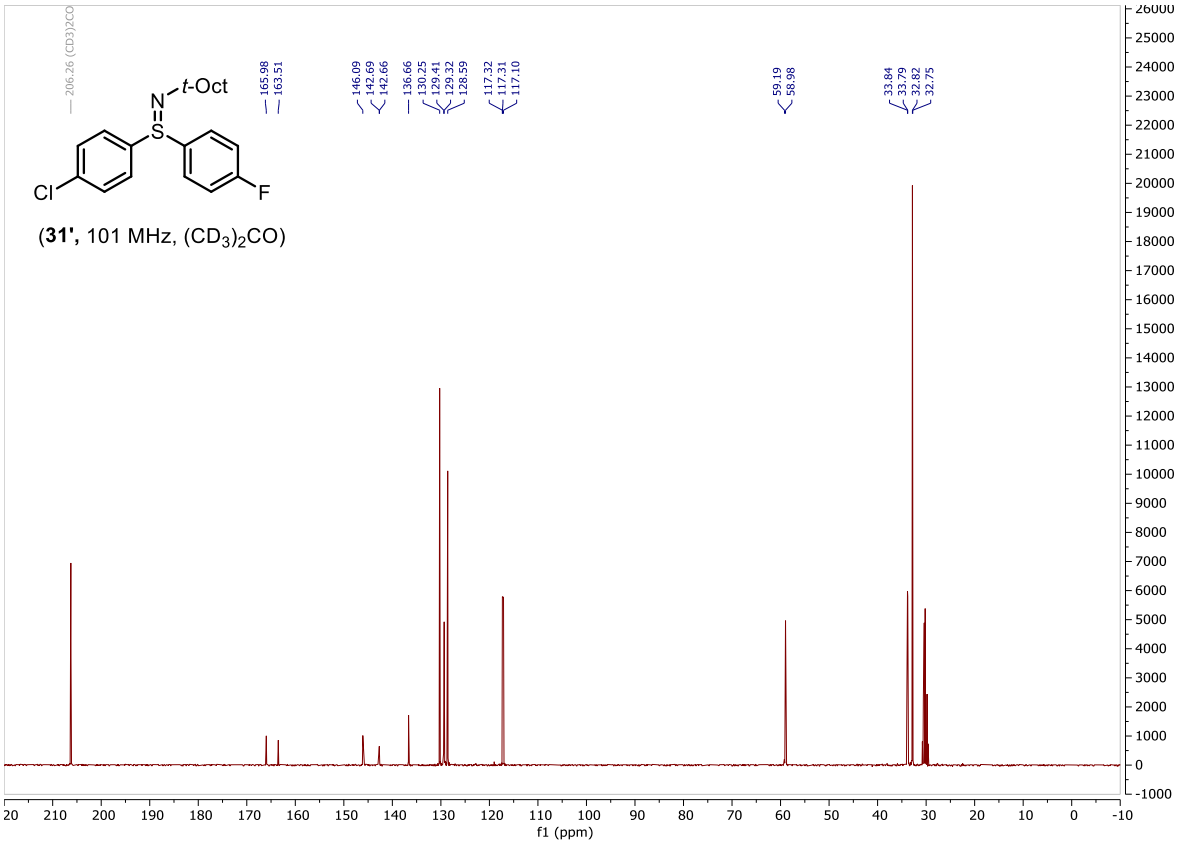
2.02
2.02
2.04
2.08
6.21
9.19
f1 (ppm)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117.32
117.31
117.10
59.19
58.98
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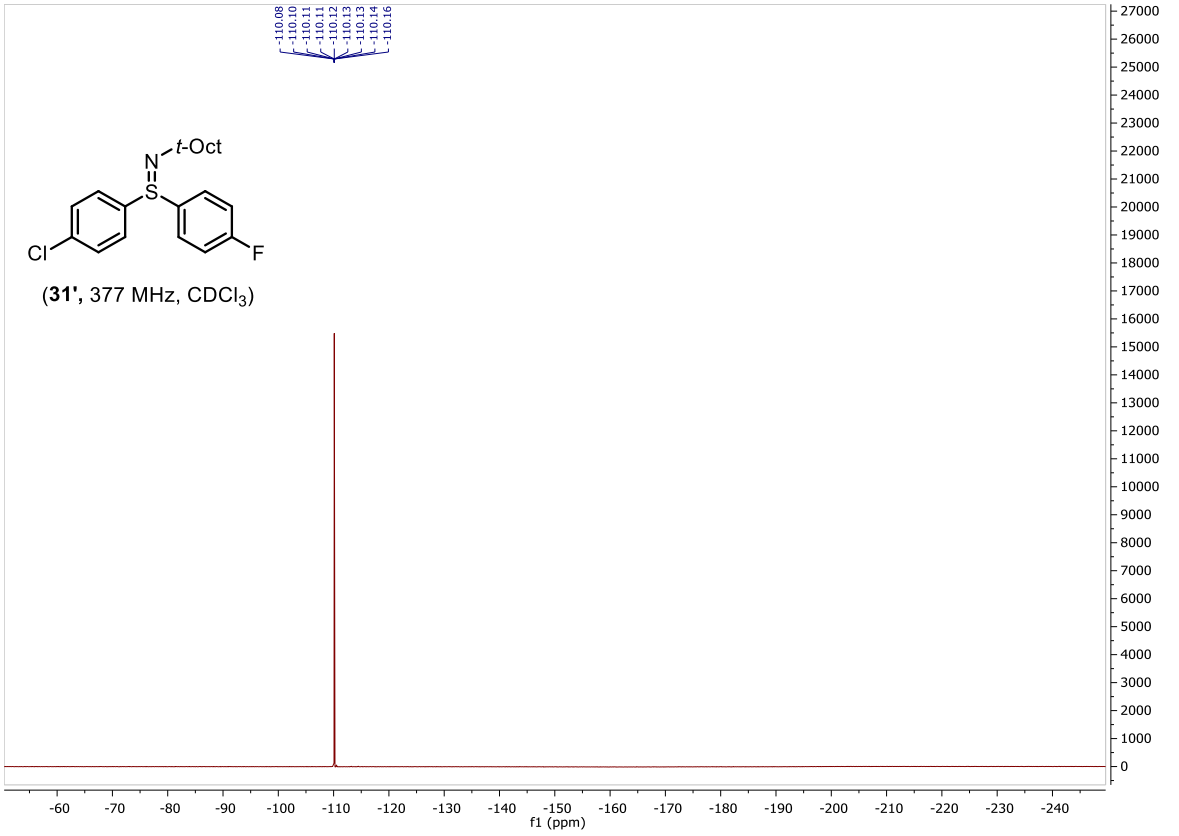
S
Cl
F
(31', 101 MHz, (CD3)2CO)
f1 (ppm)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S
Cl
F
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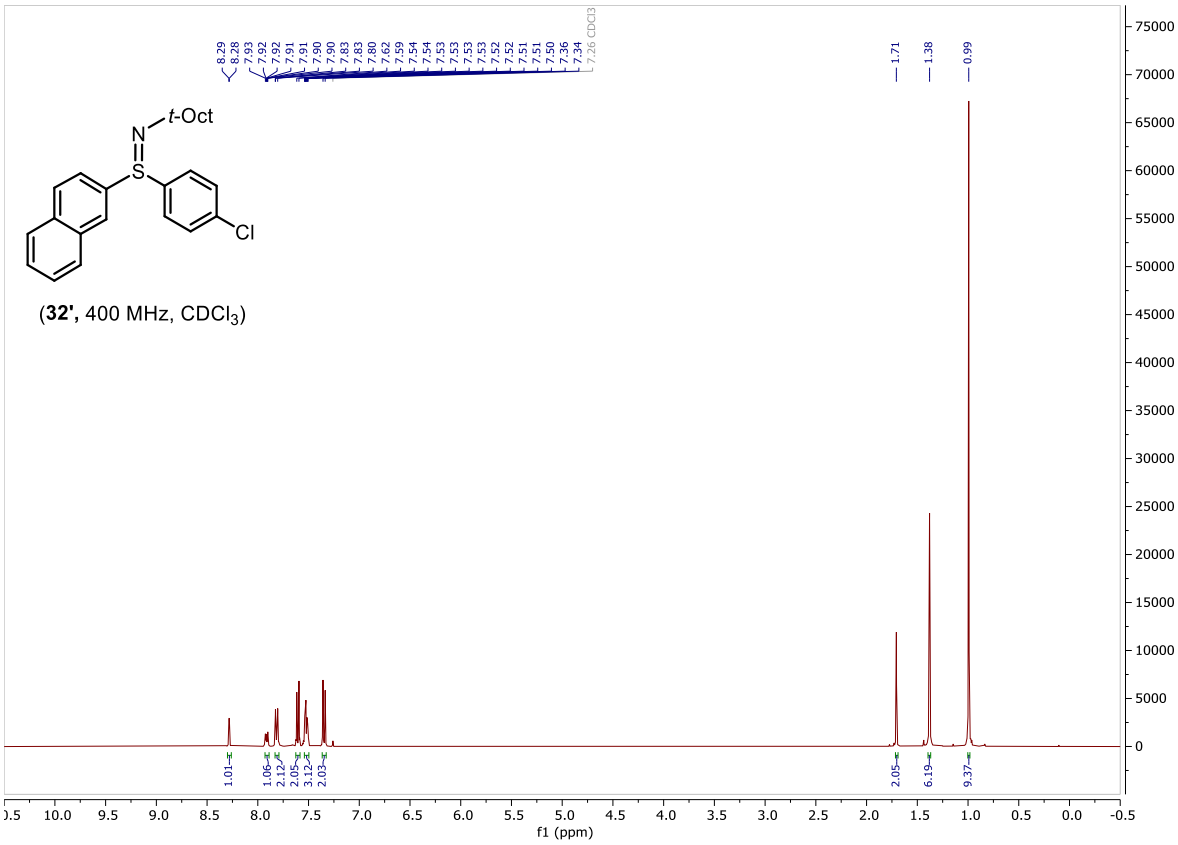
f1 (ppm)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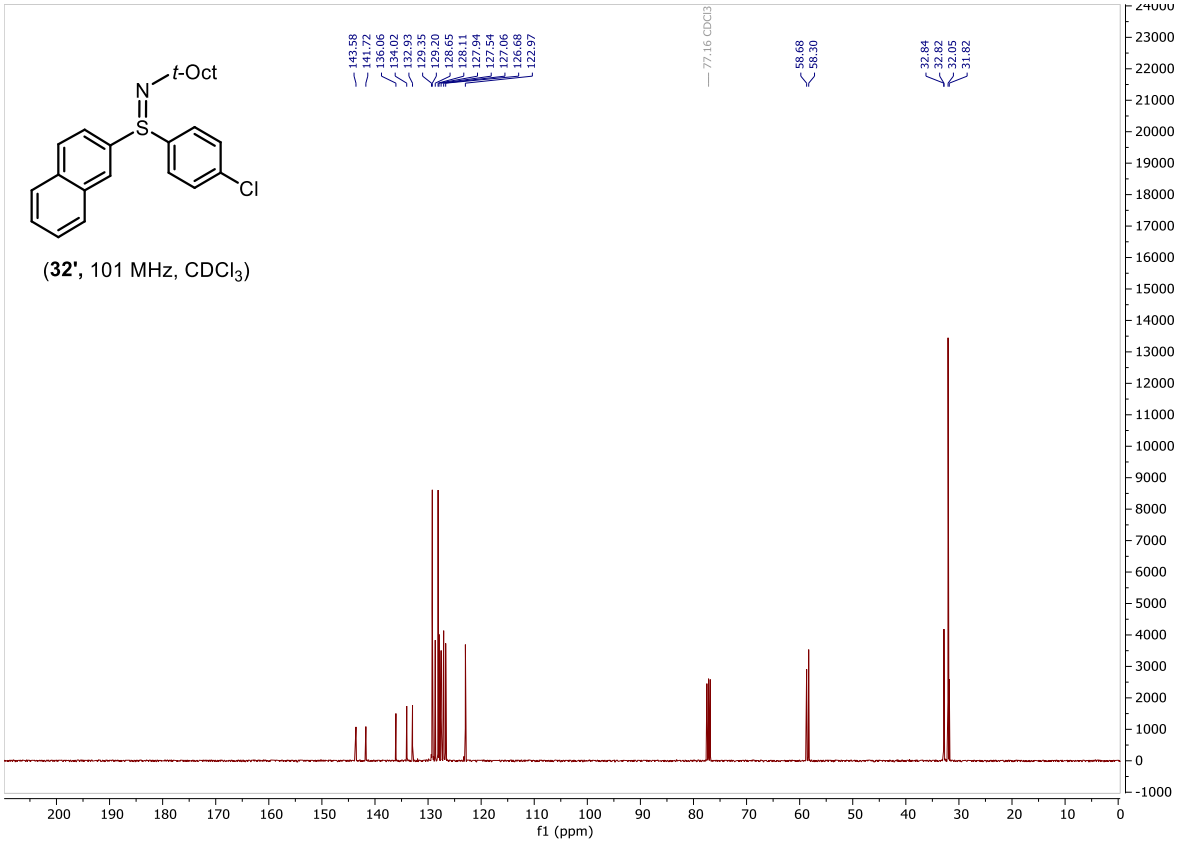
f1 (ppm)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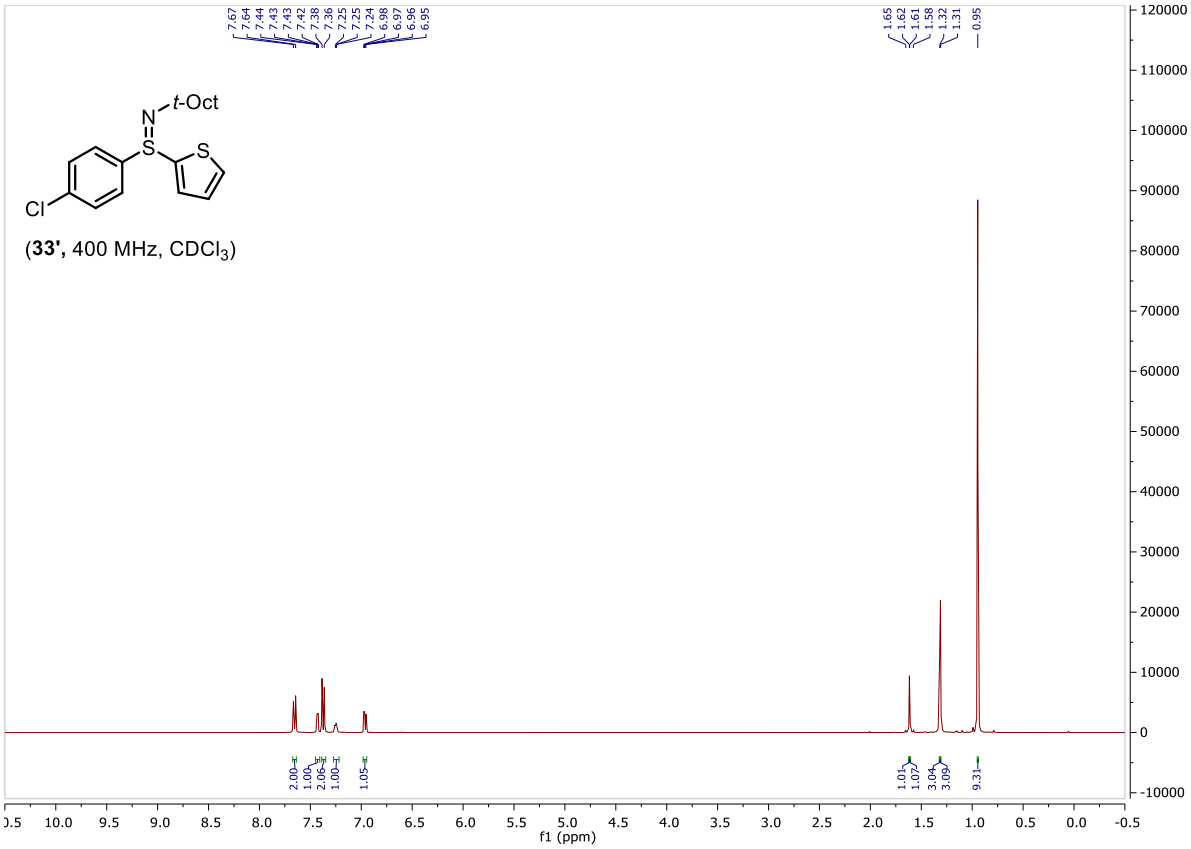
f1 (ppm)



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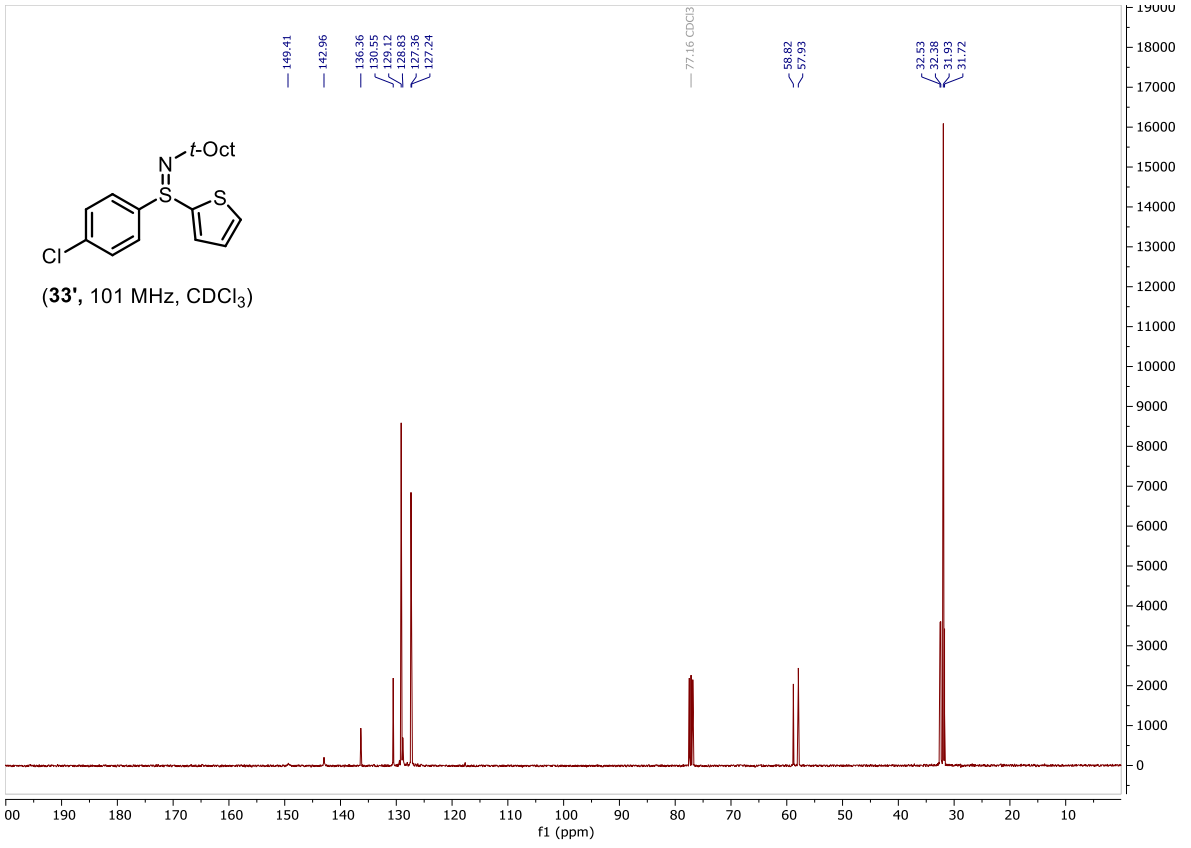

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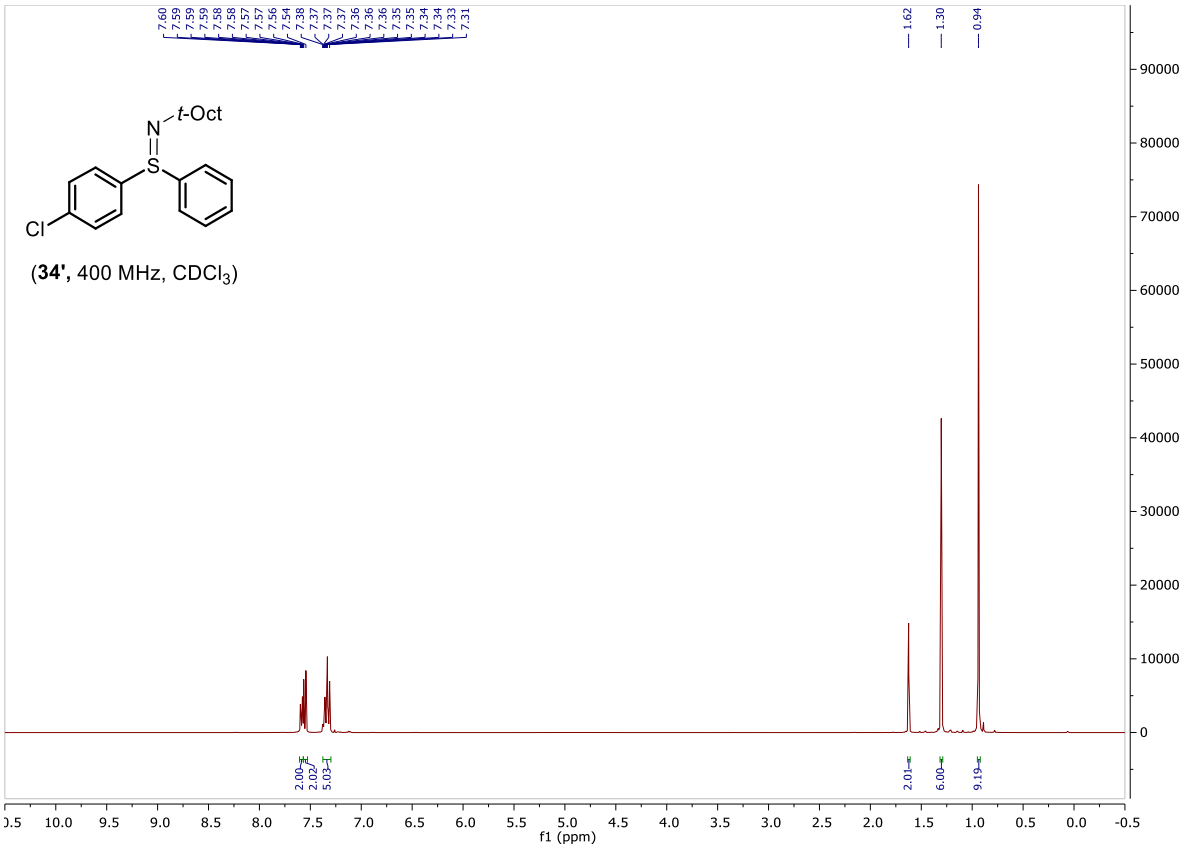

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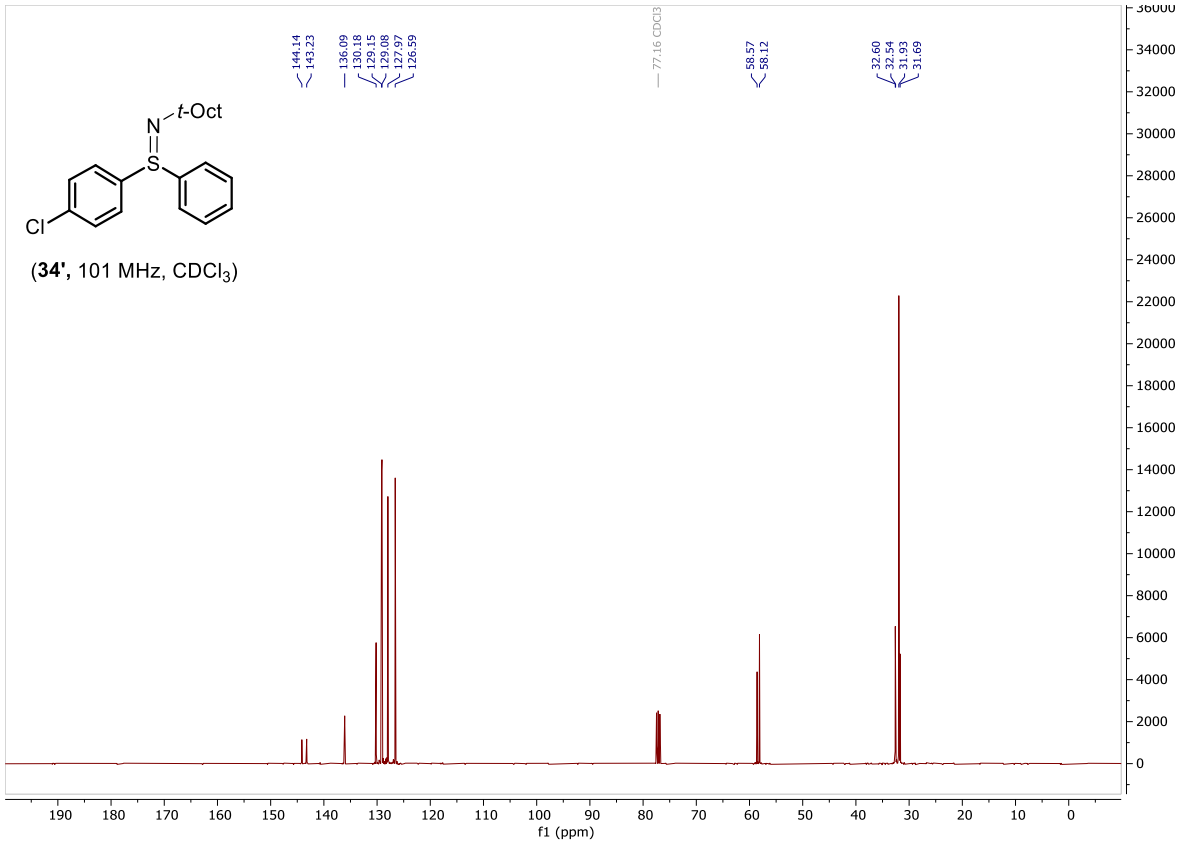

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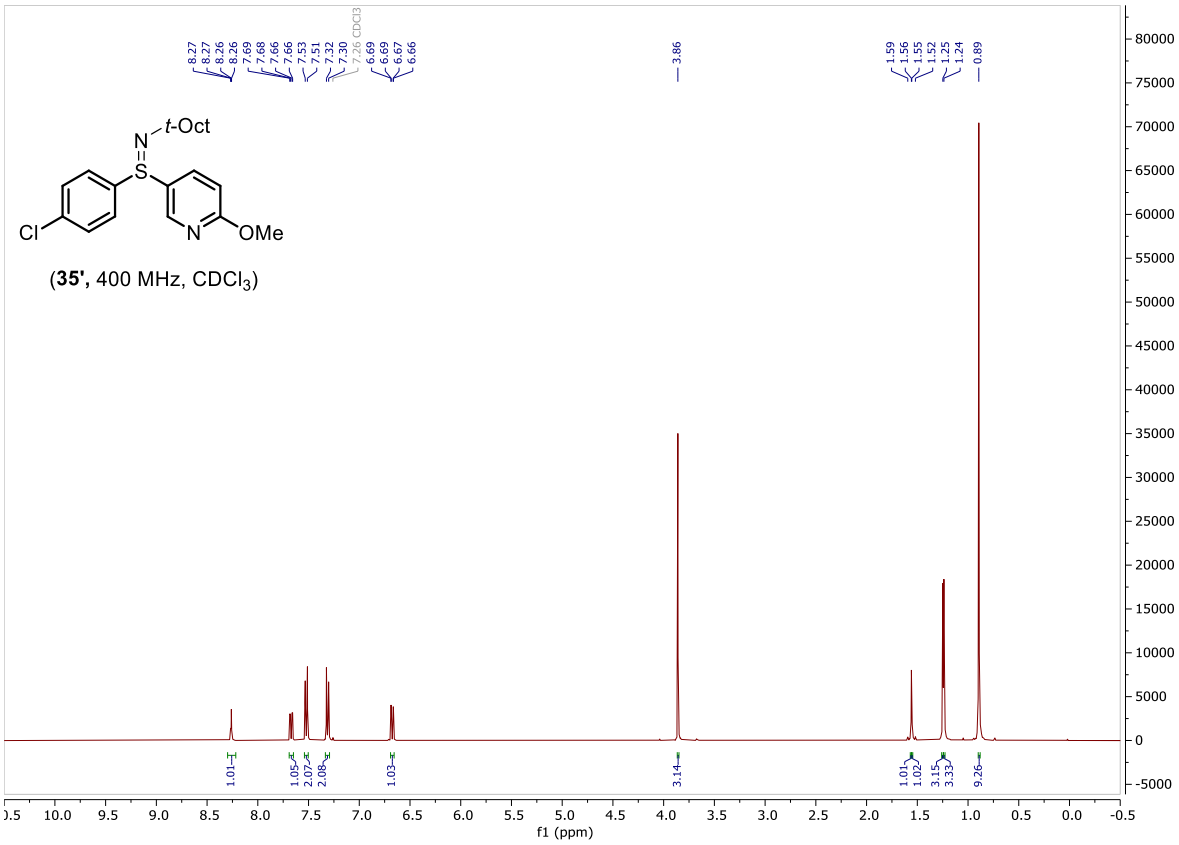

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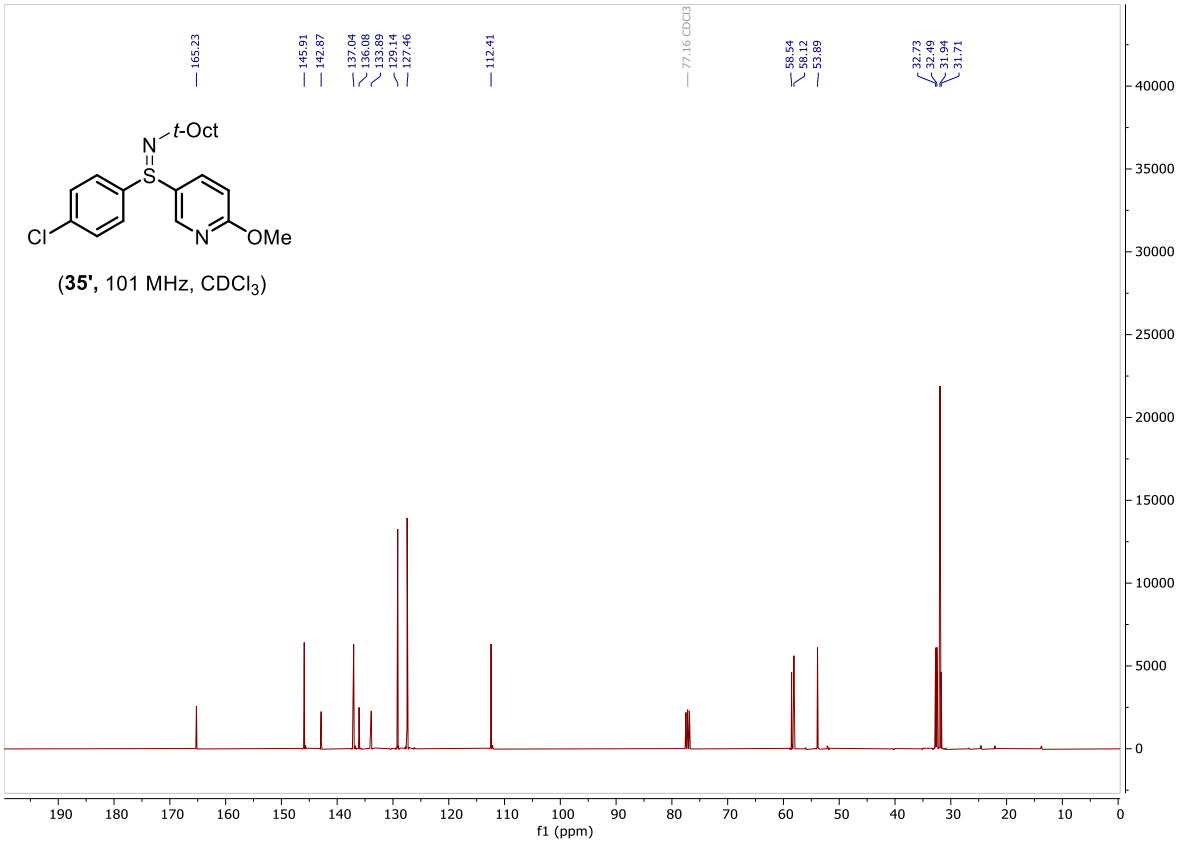

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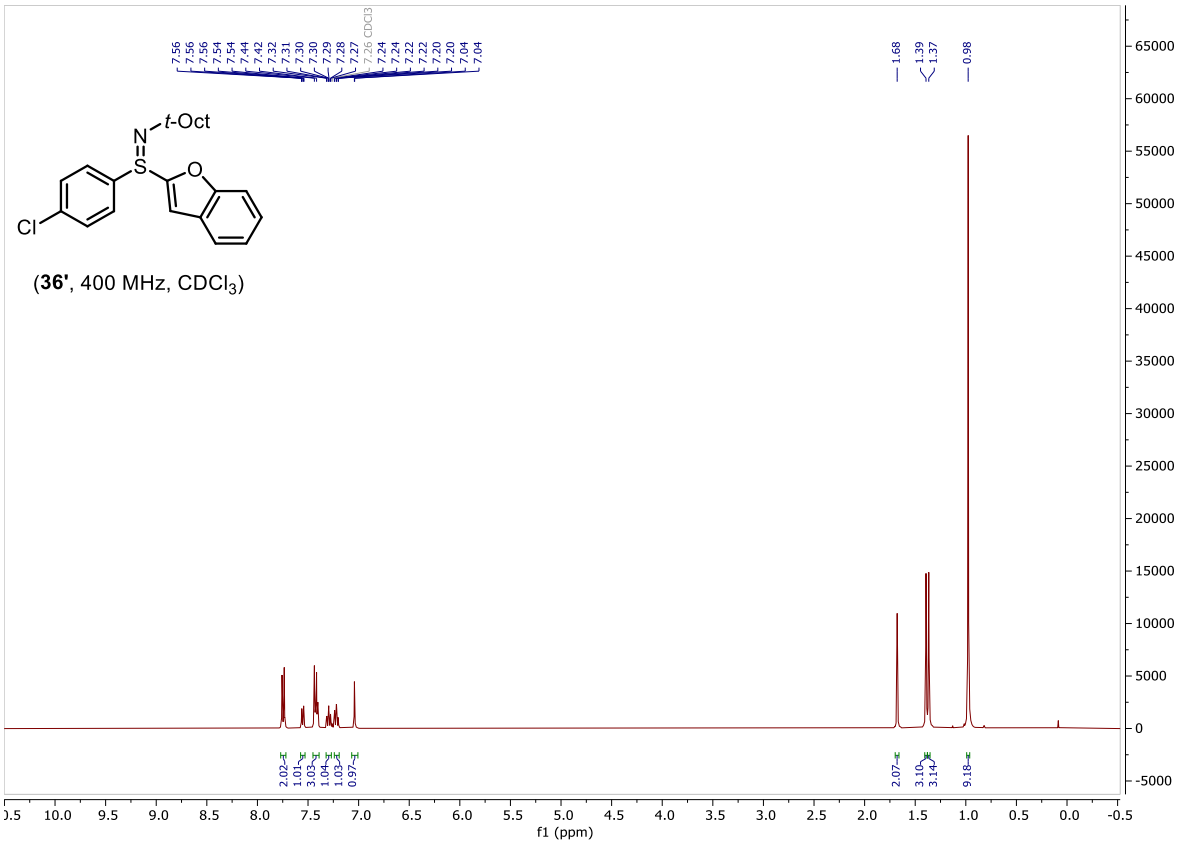

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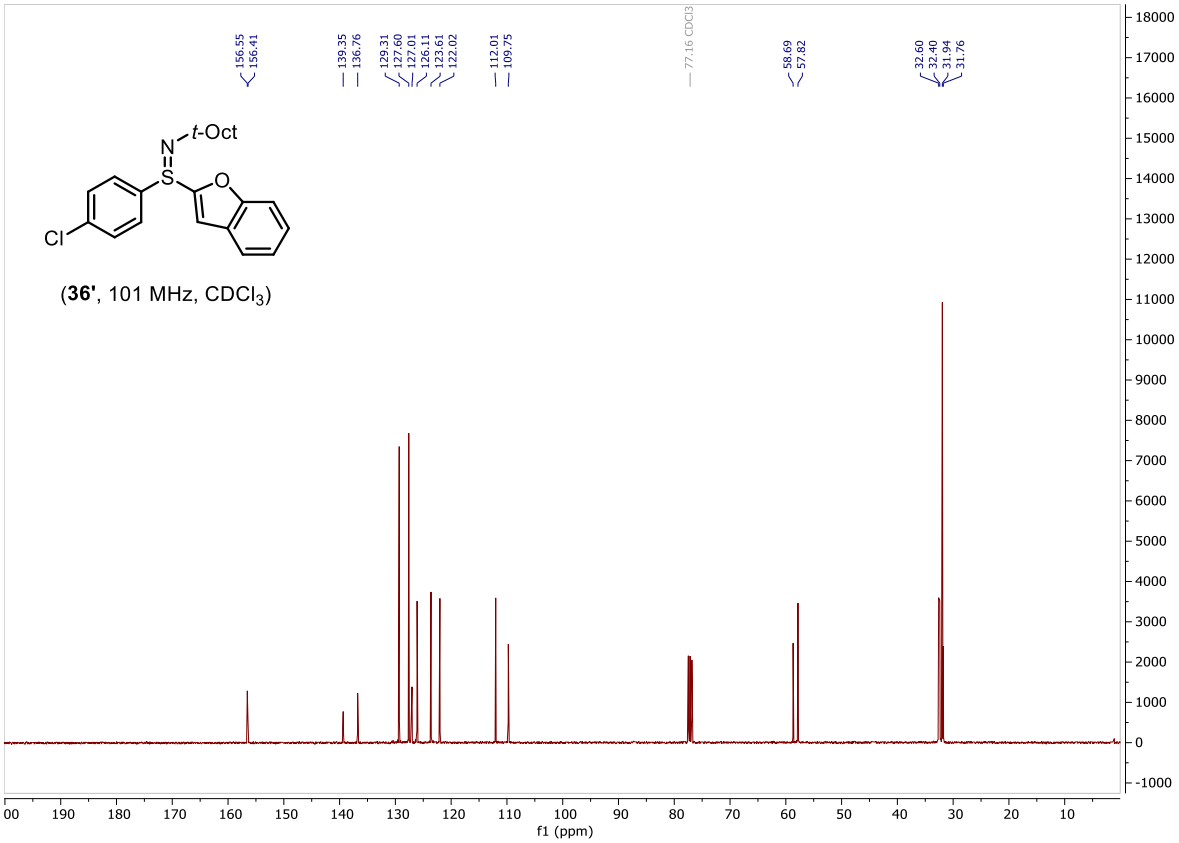

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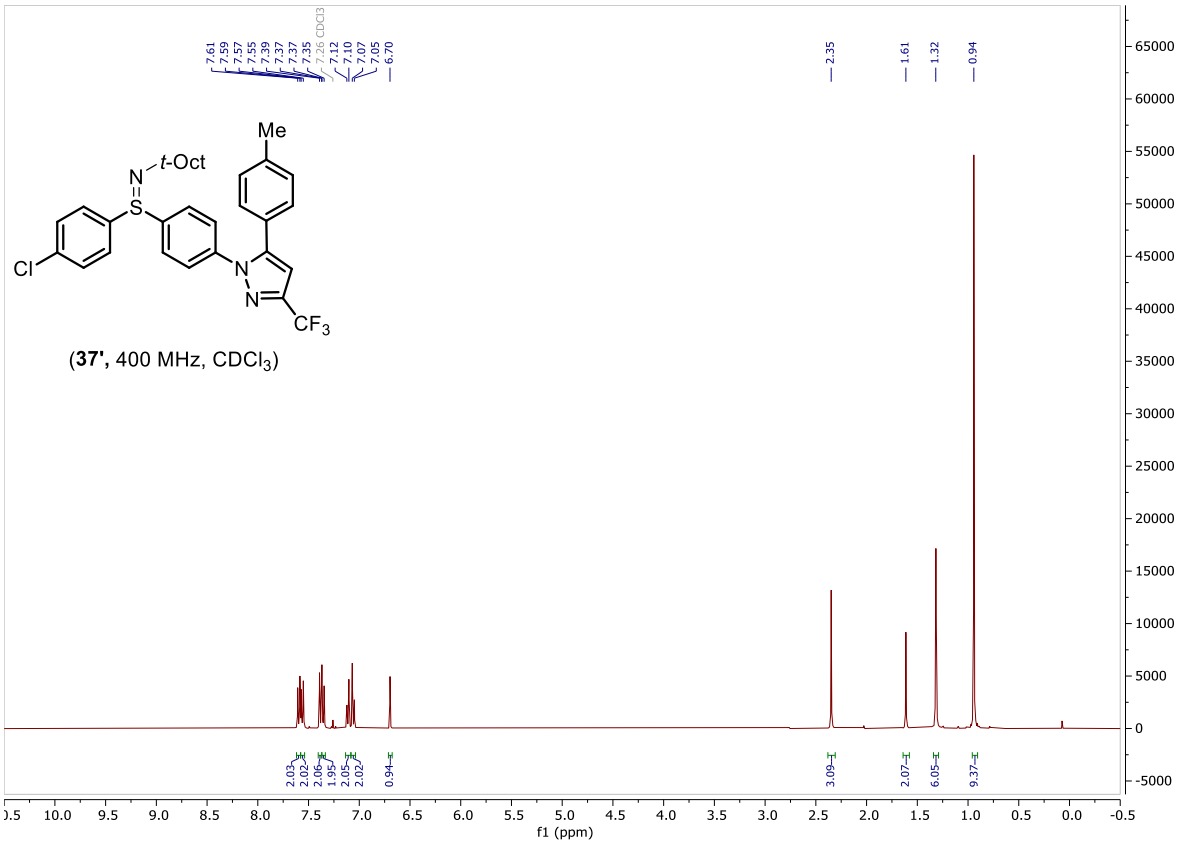

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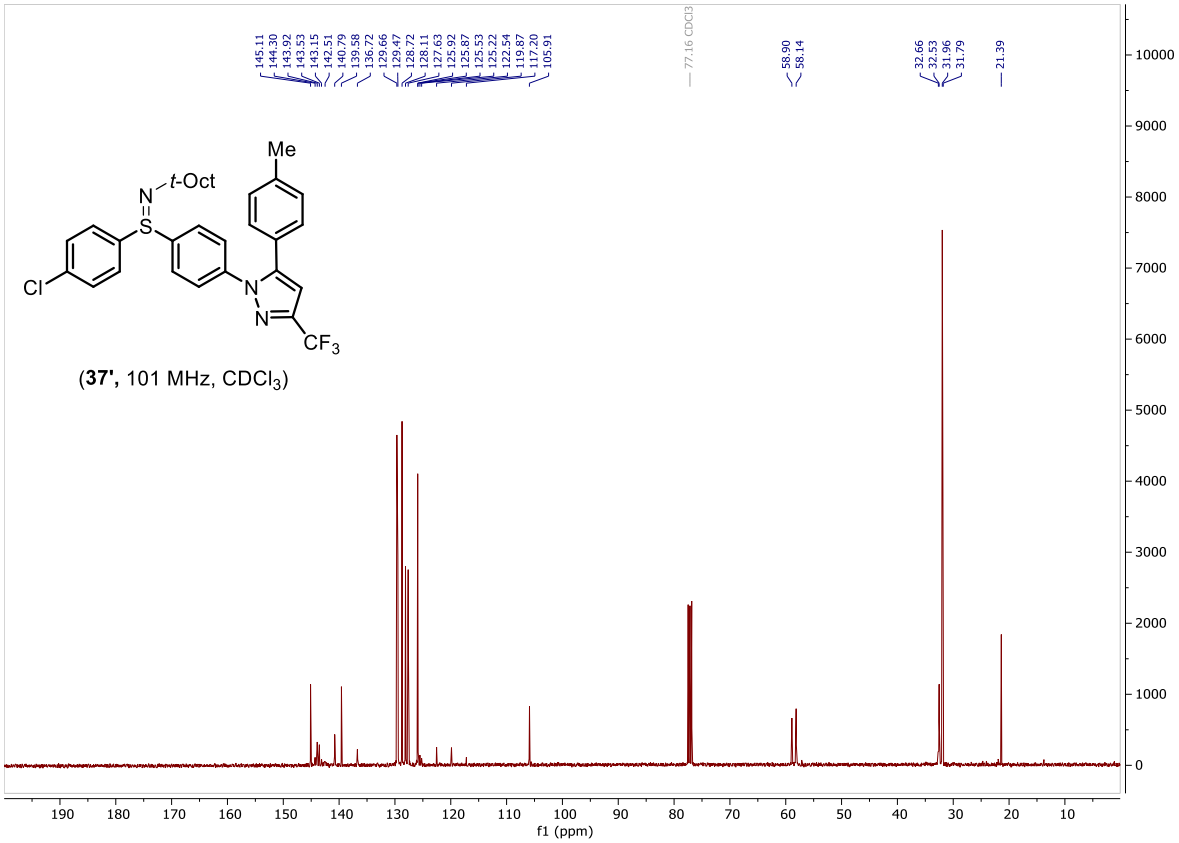

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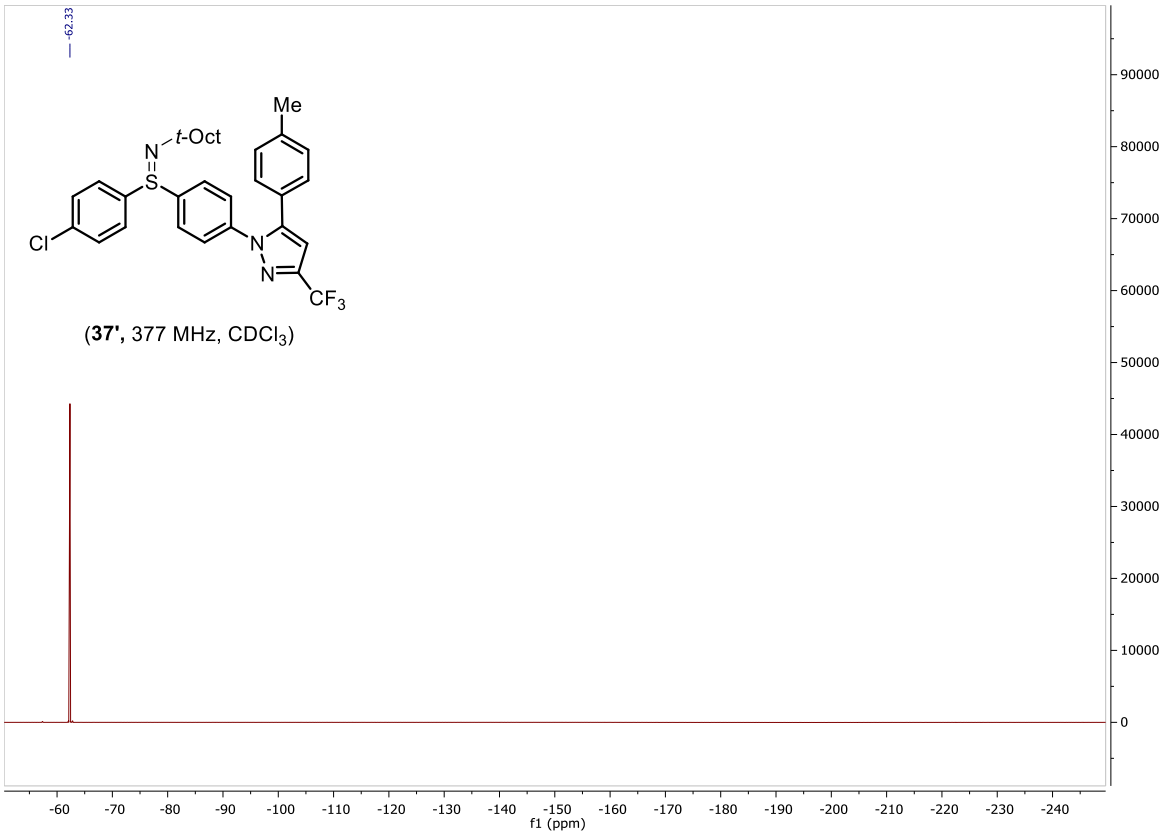

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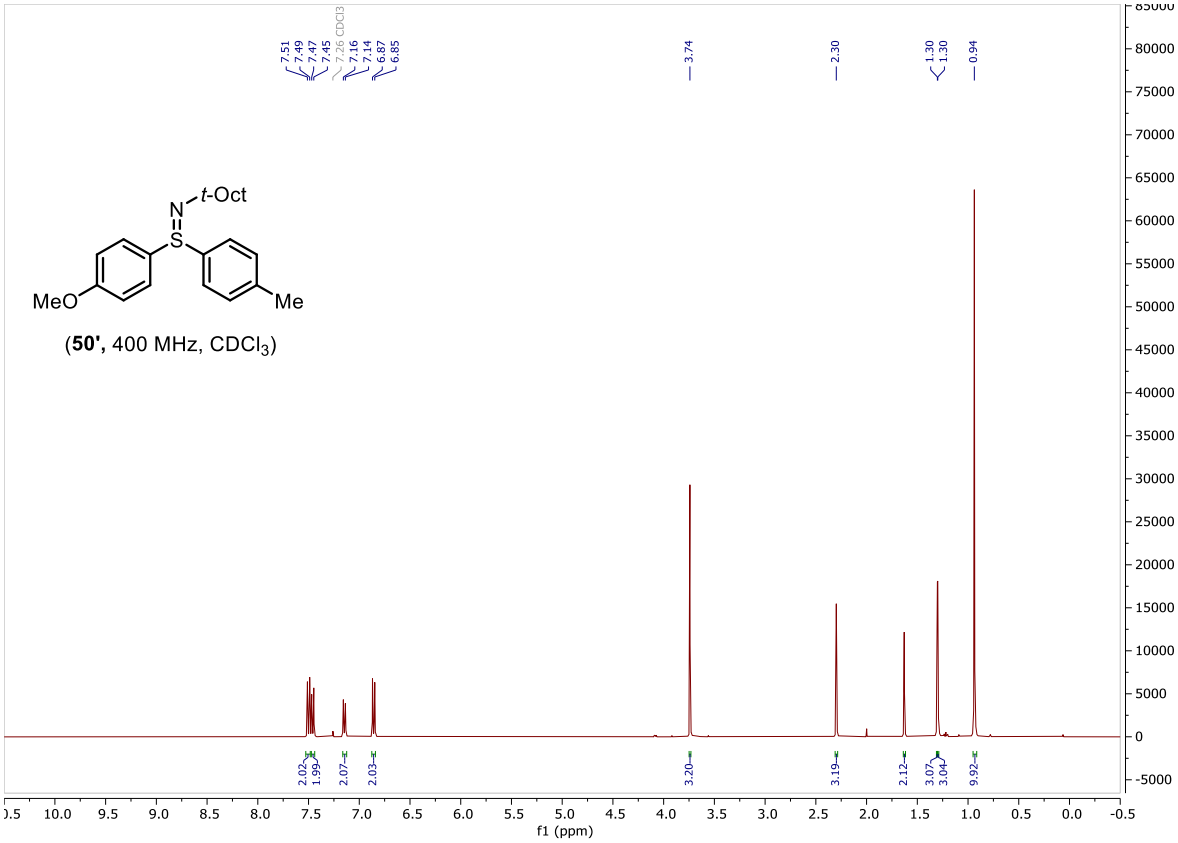

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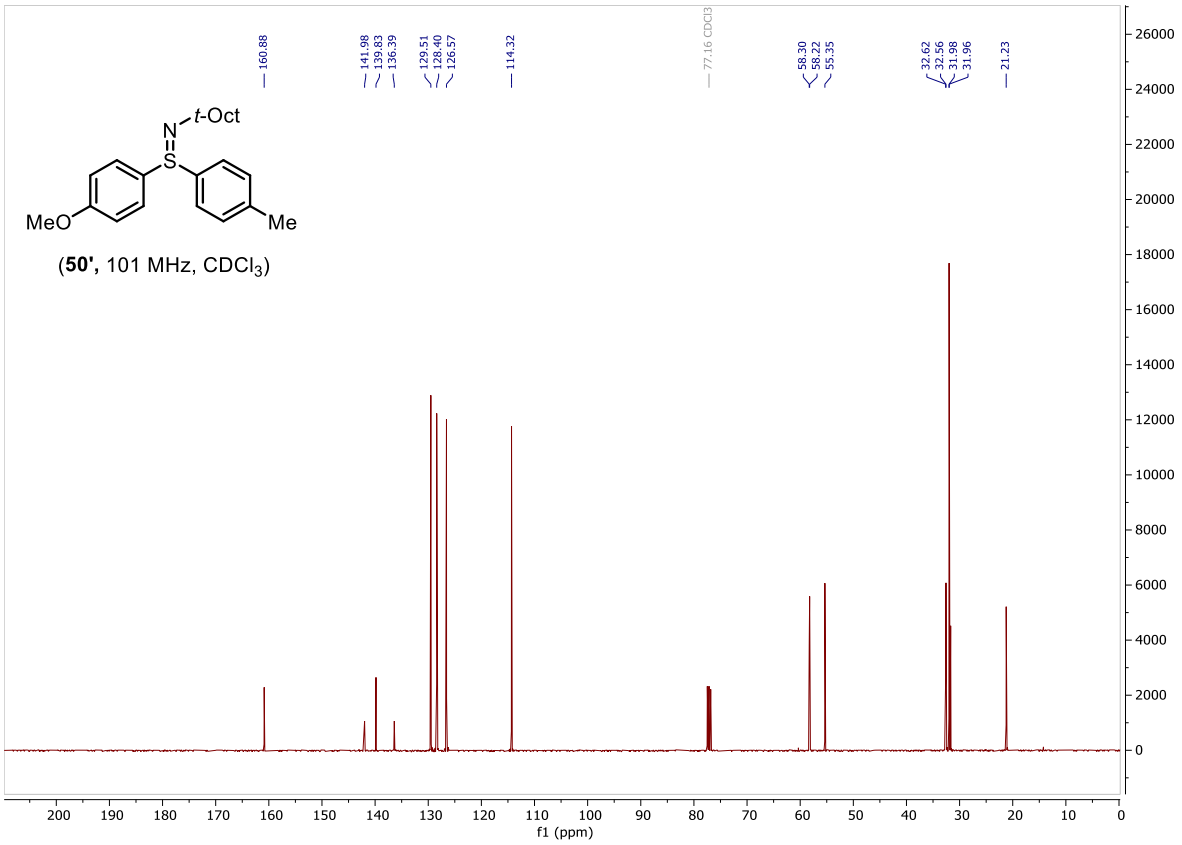

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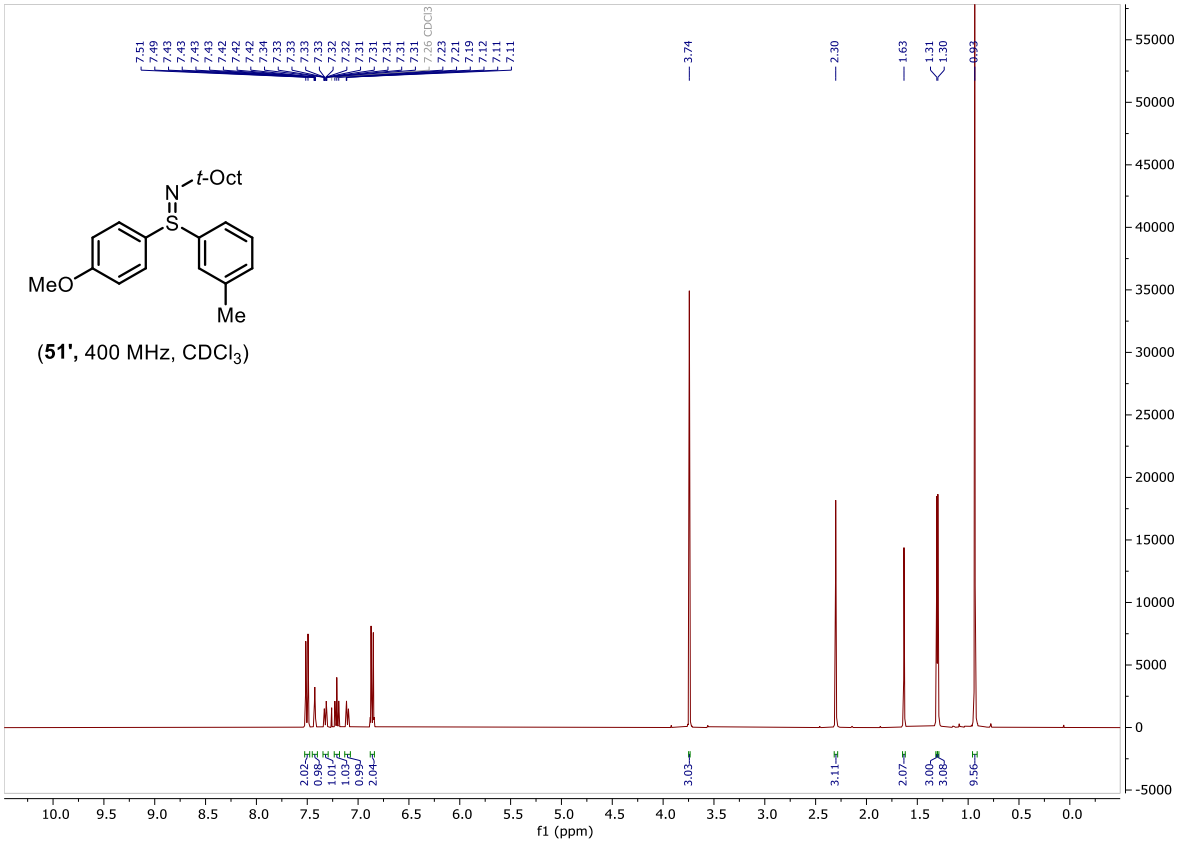

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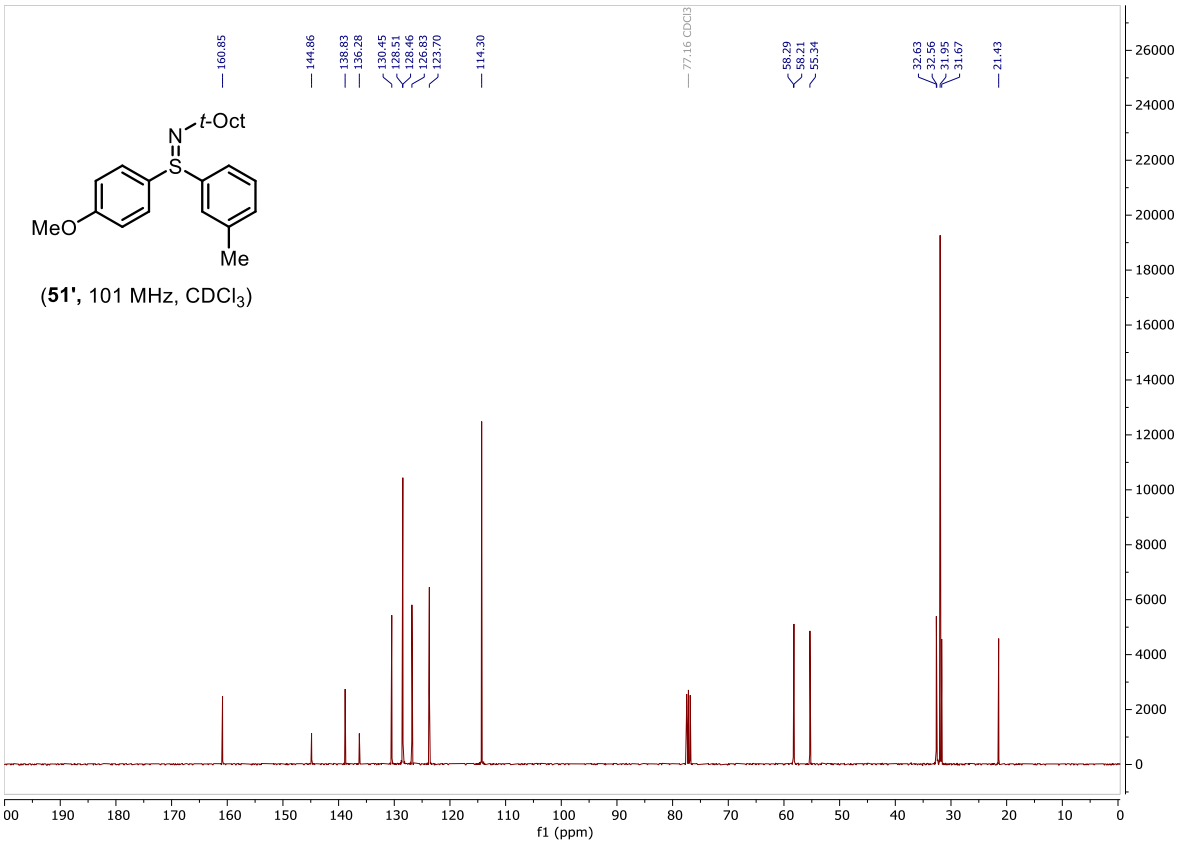

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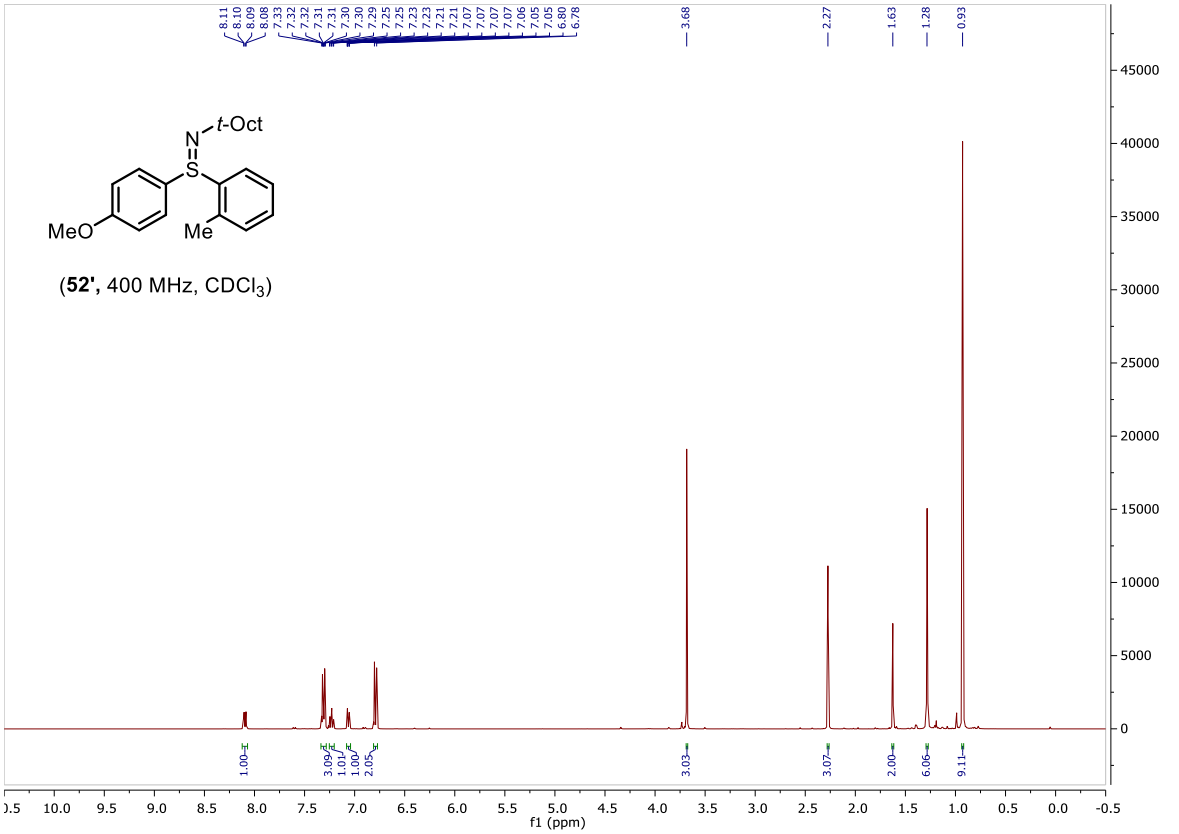

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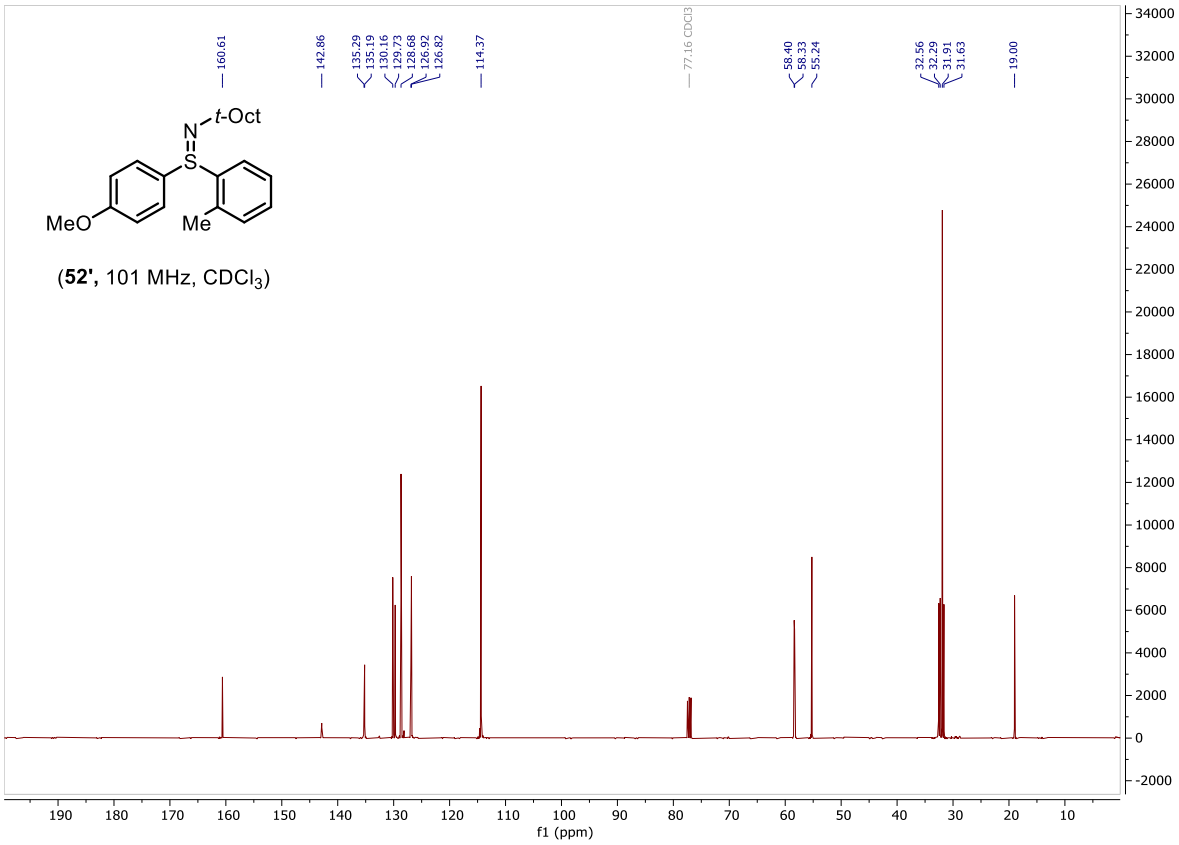

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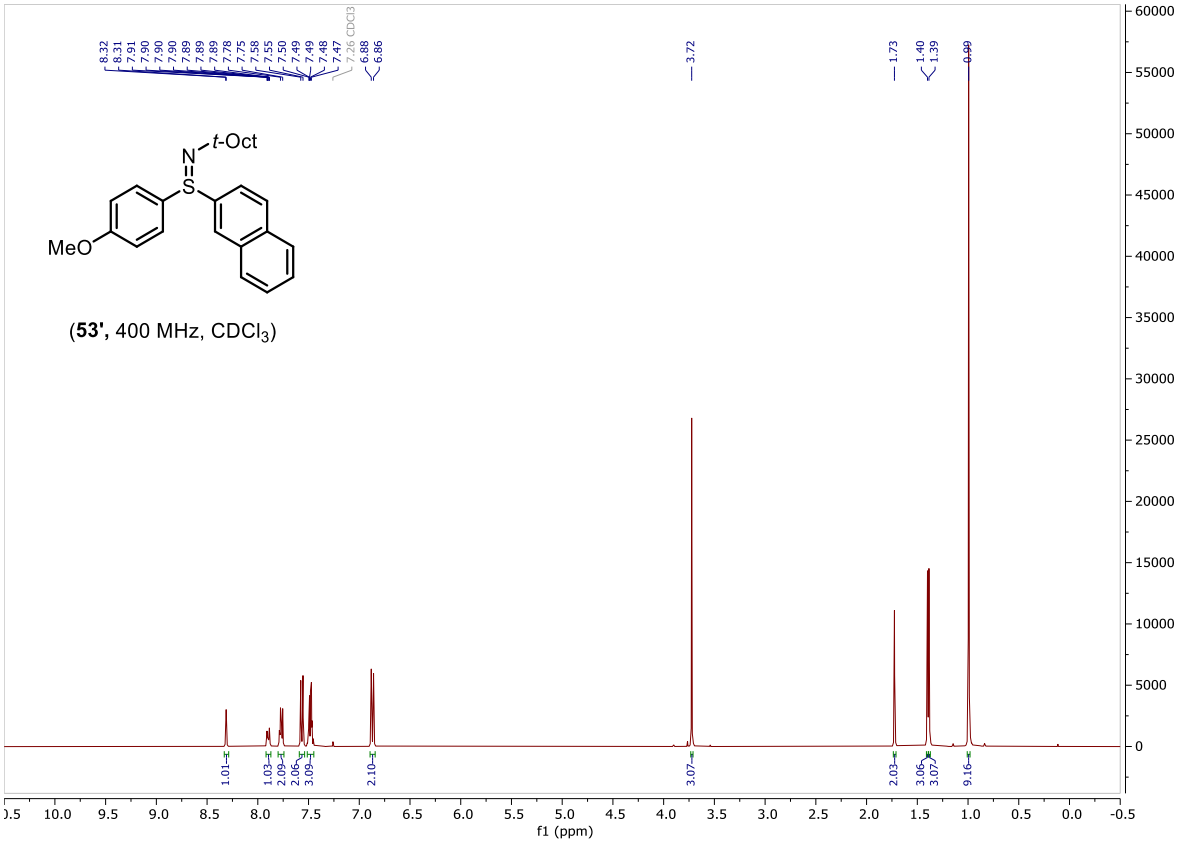

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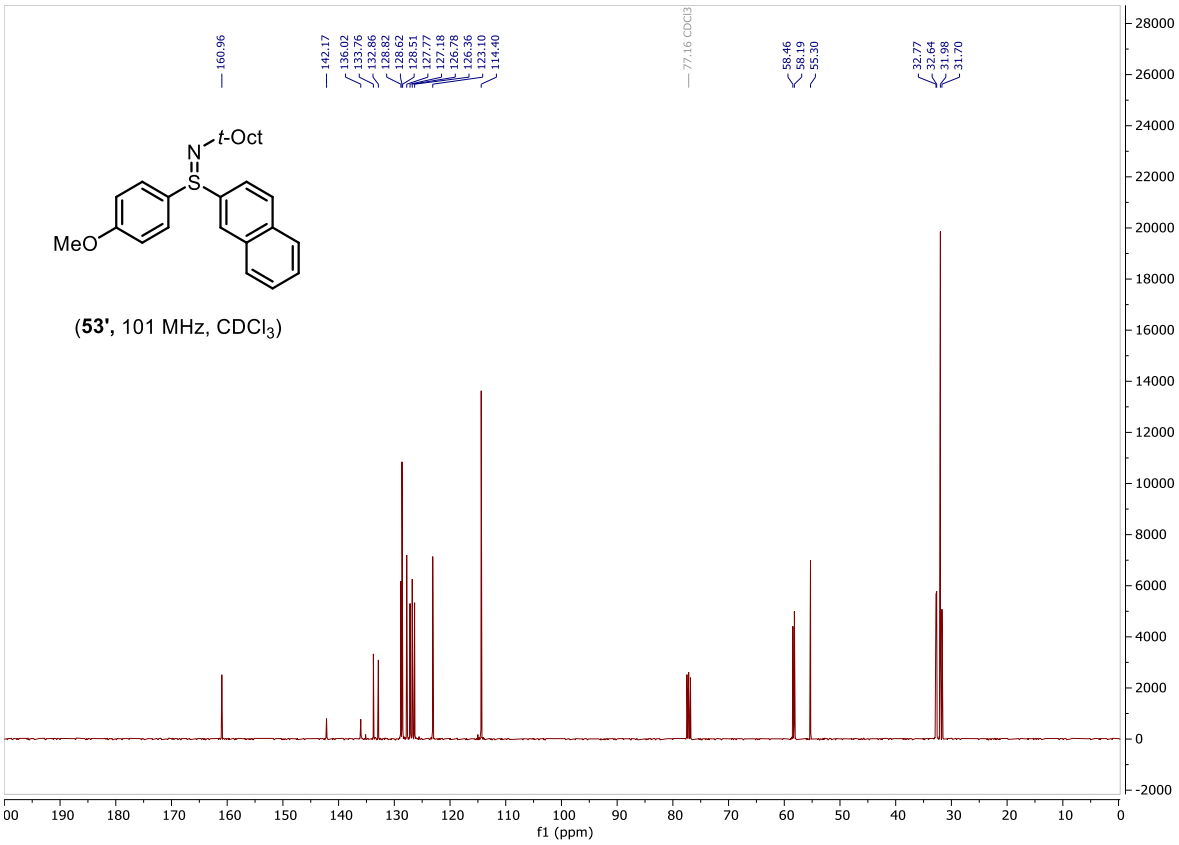

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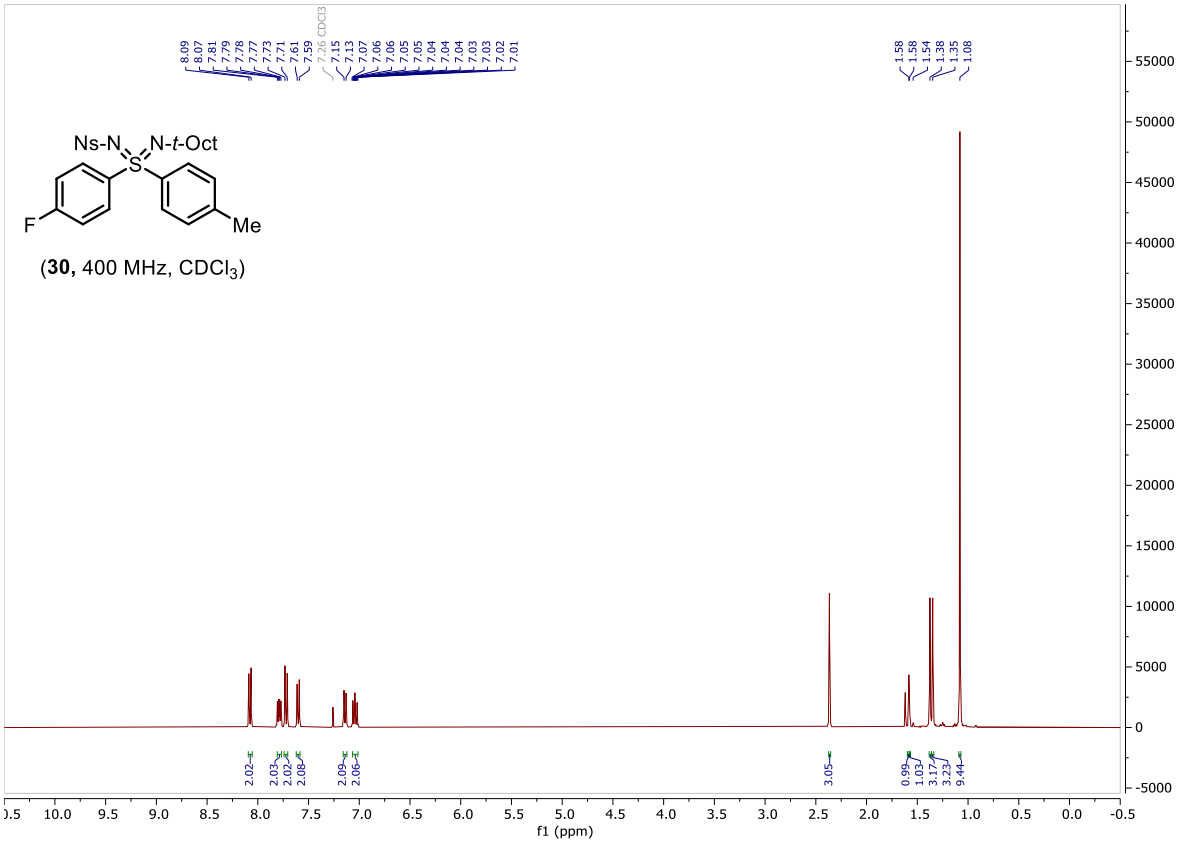

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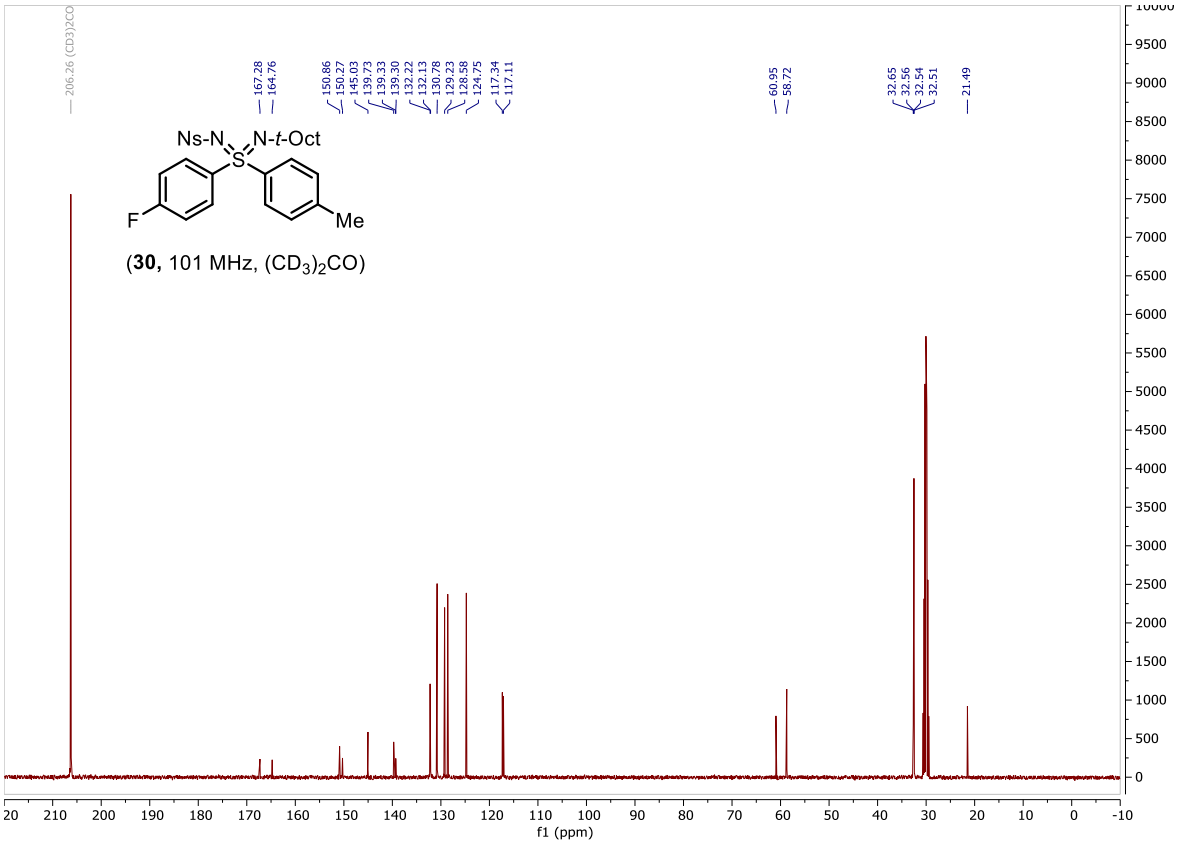
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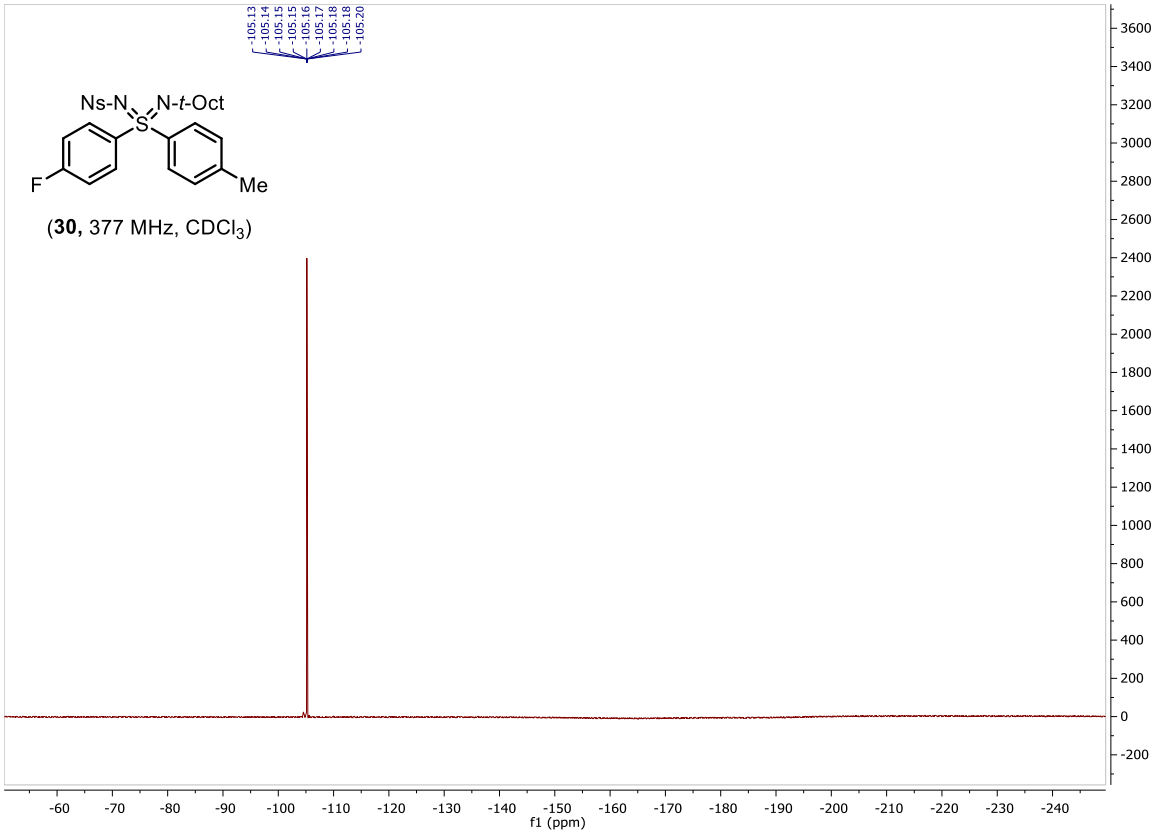
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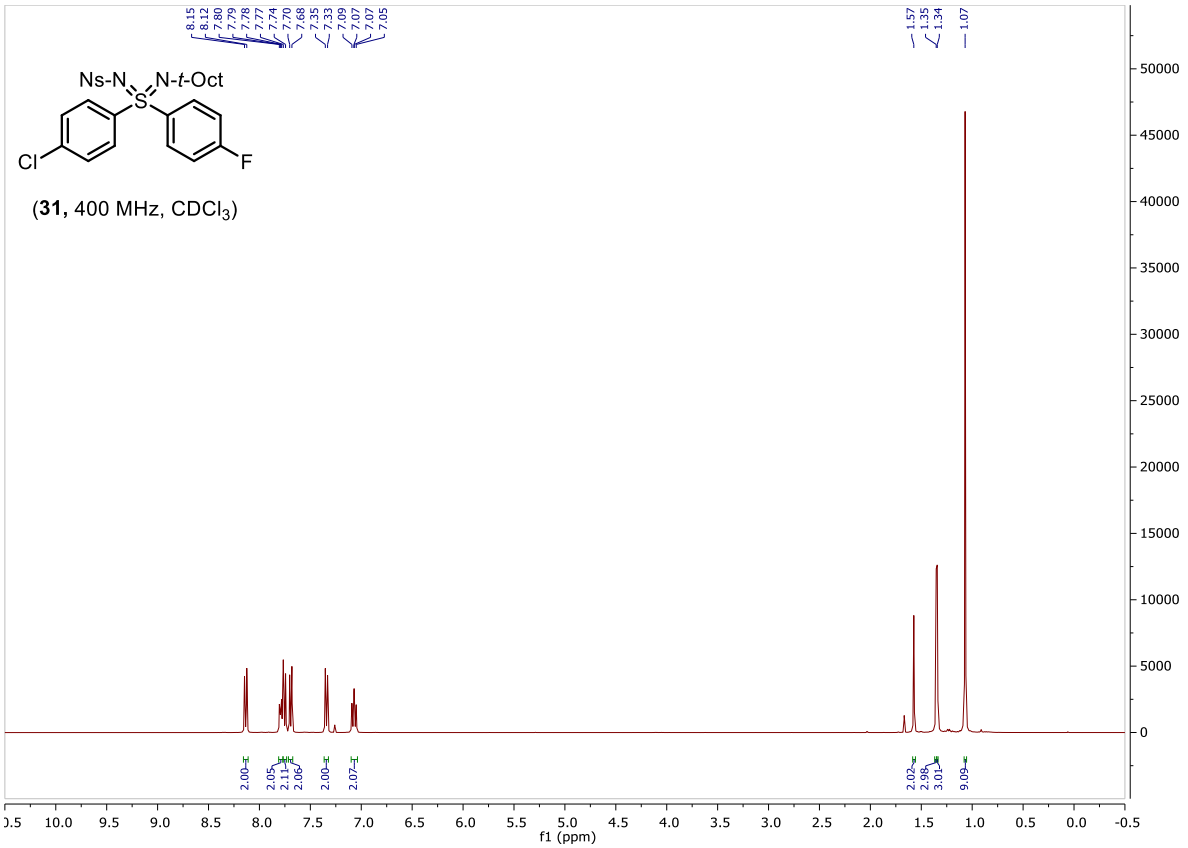
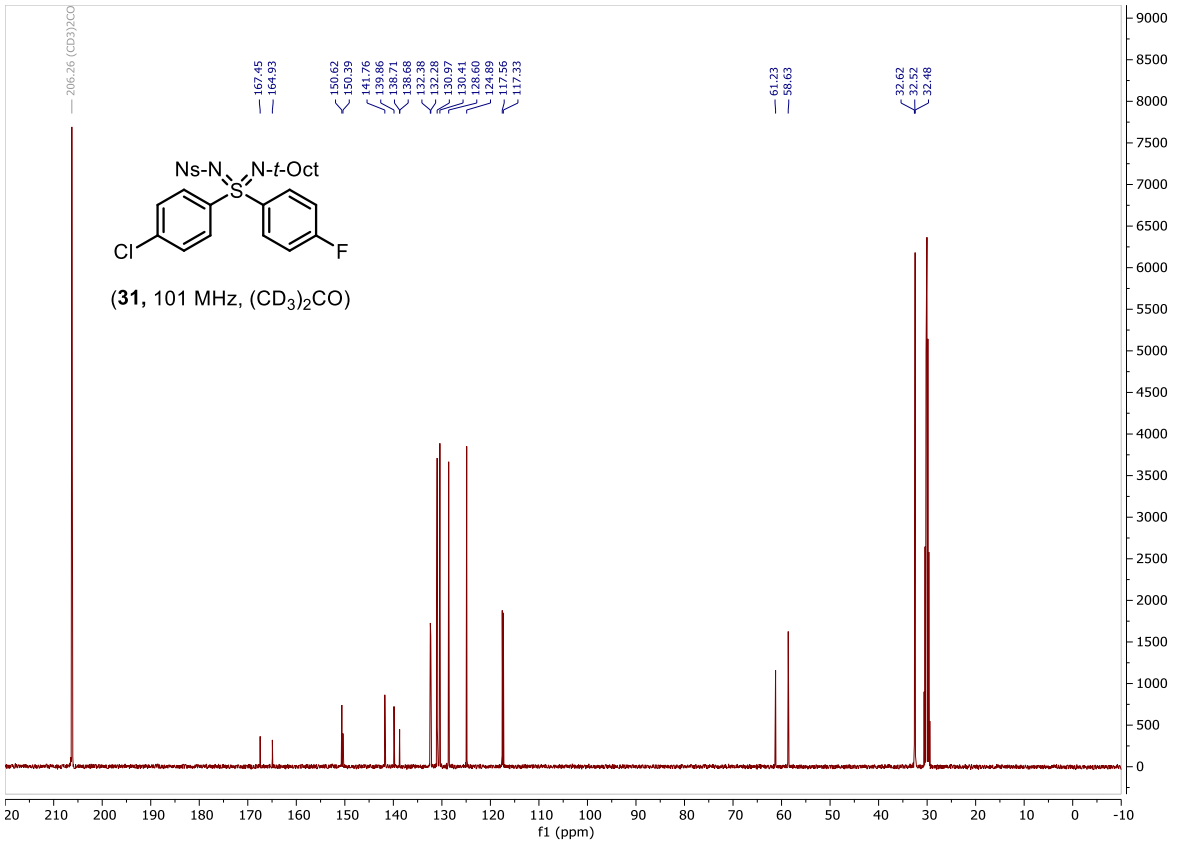
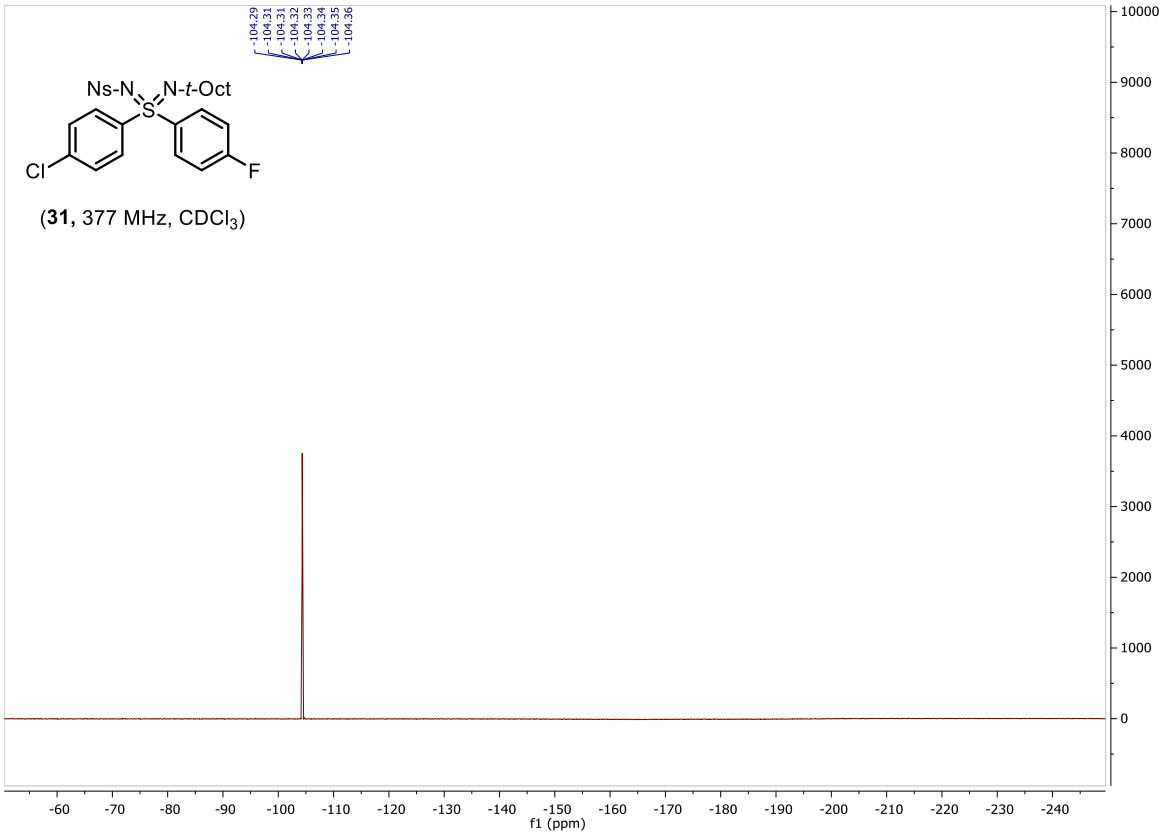
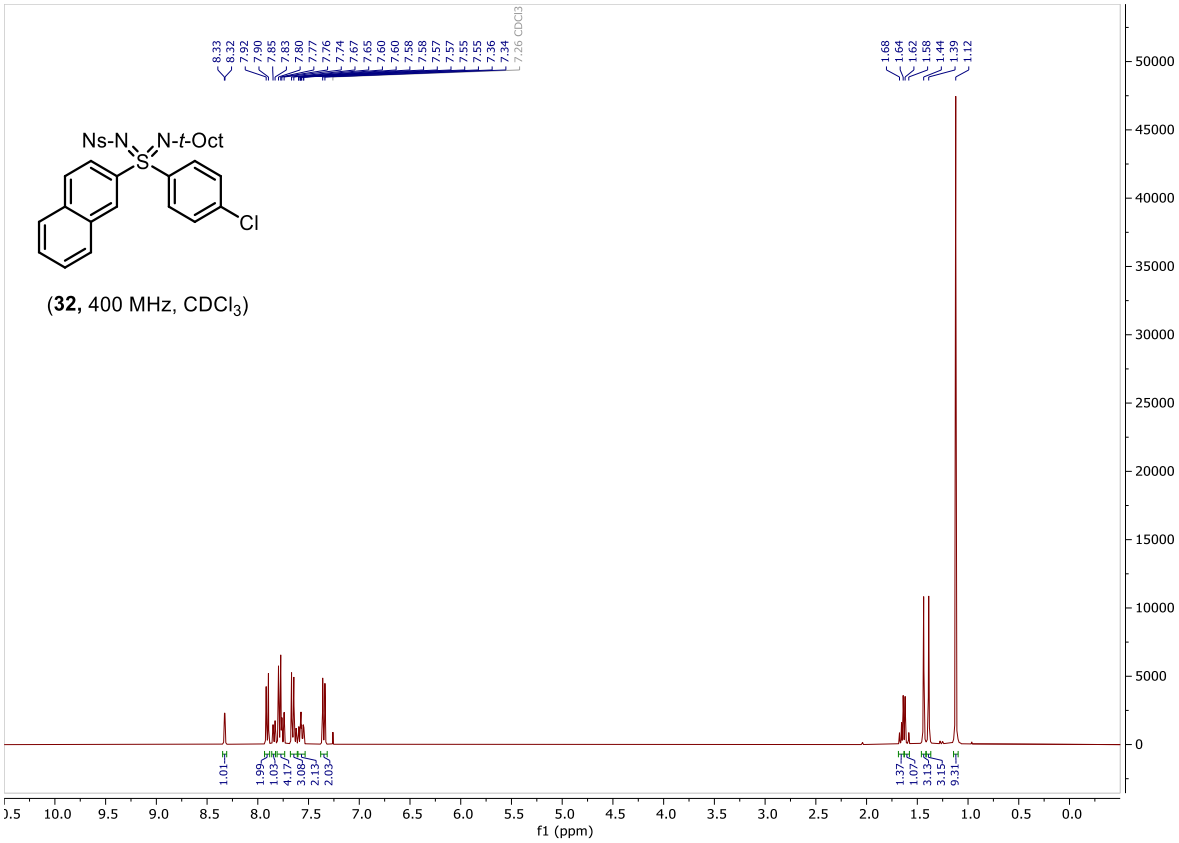
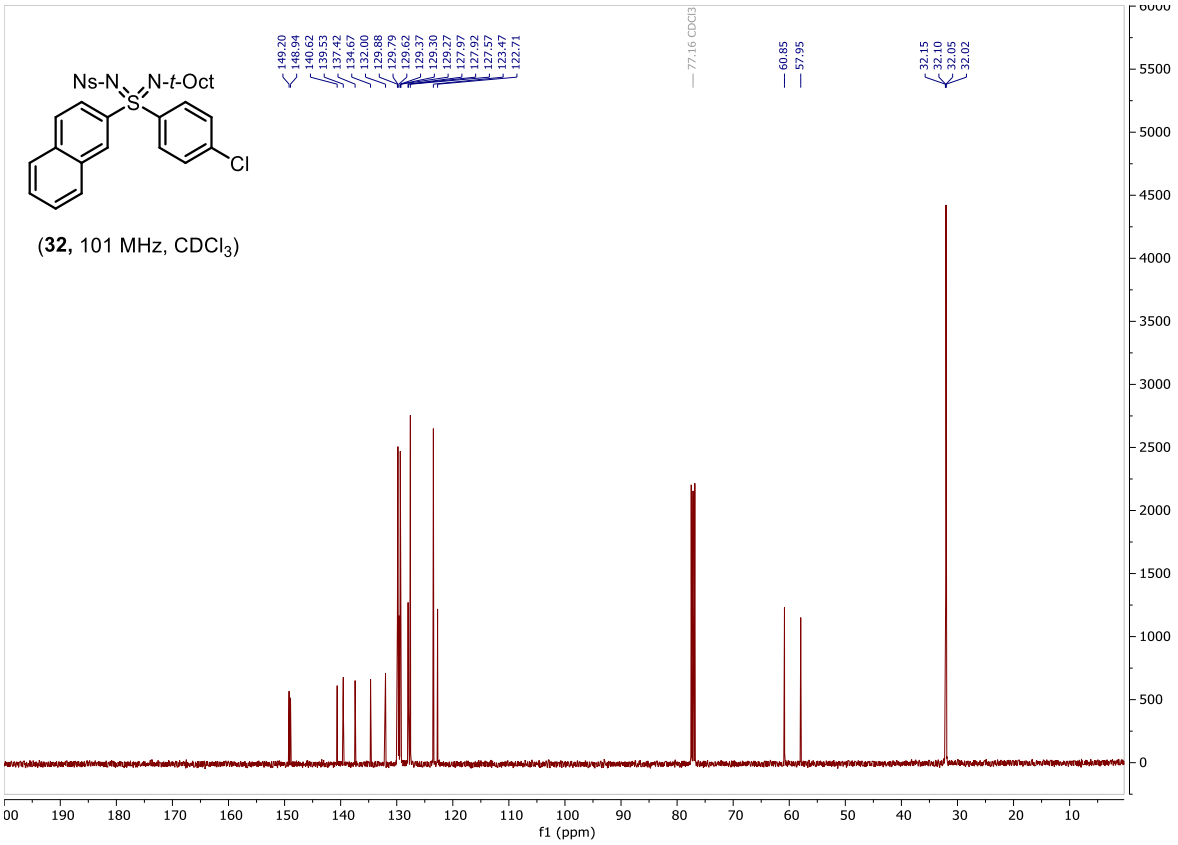

8.15
8.12
7.80
7.79
7.78
7.77
7.74
7.70
7.68
7.35
7.33
7.09
7.07
7.07
7.05
1.57
1.35
1.34
1.07
Ns-N
N-t-Oct
S
Cl
F
(31, 400 MHz, CDCl3)
2.00
2.05
2.11
2.06
2.00
2.07
2.02
2.98
3.01
9.09
f1 (ppm)

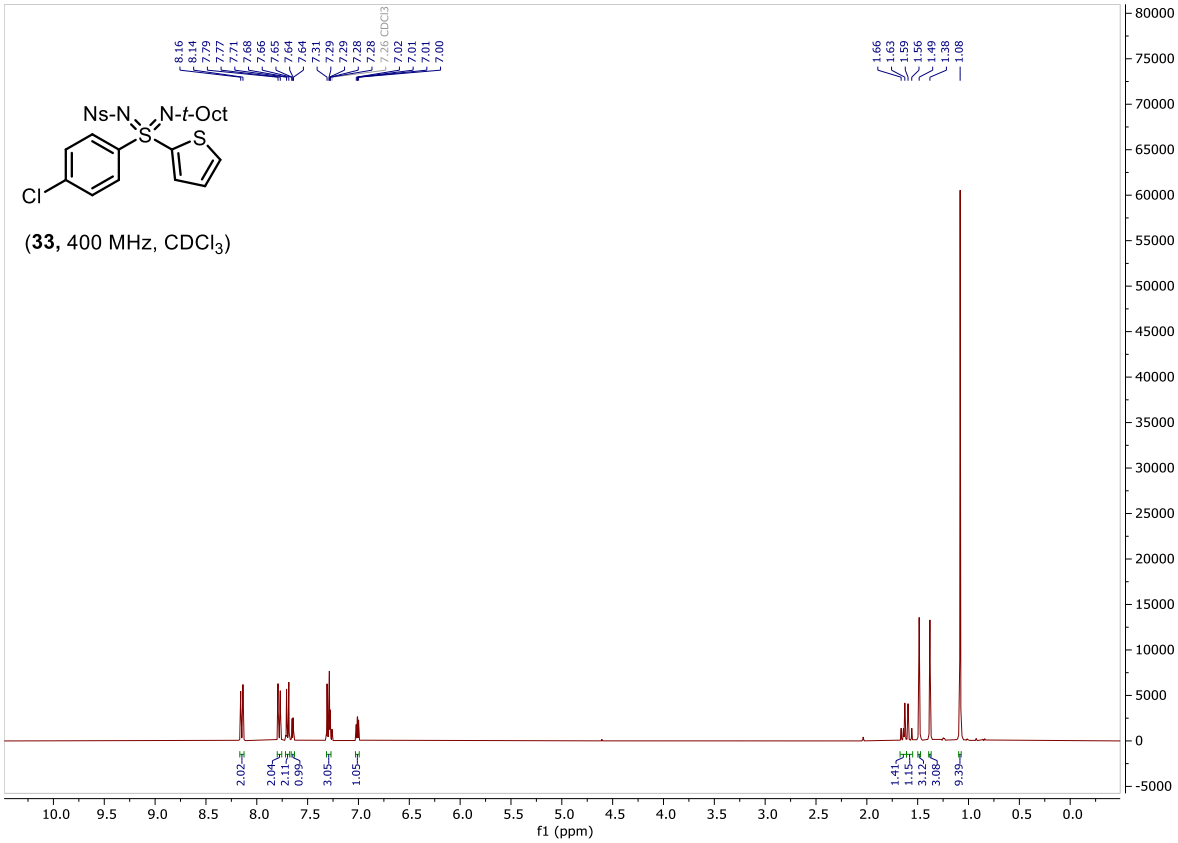

206.26 (CD3)2CO
167.45
164.93
150.62
150.39
141.76
139.86
138.71
138.68
132.38
132.28
130.97
130.41
128.60
124.89
117.56
117.33
61.23
58.63
32.62
32.52
32.48
Ns-N
N-t-Oct
S
Cl
F
(31, 101 MHz, (CD3)2CO)
f1 (ppm)


-104.29
-104.31
-104.31
-104.31
-104.32
-104.33
-104.34
-104.35
-104.36
Ns-N
S
N-t-Oct
Cl
F
(31, 377 MHz, CDCl3)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
-220
-230
-240
f1 (ppm)

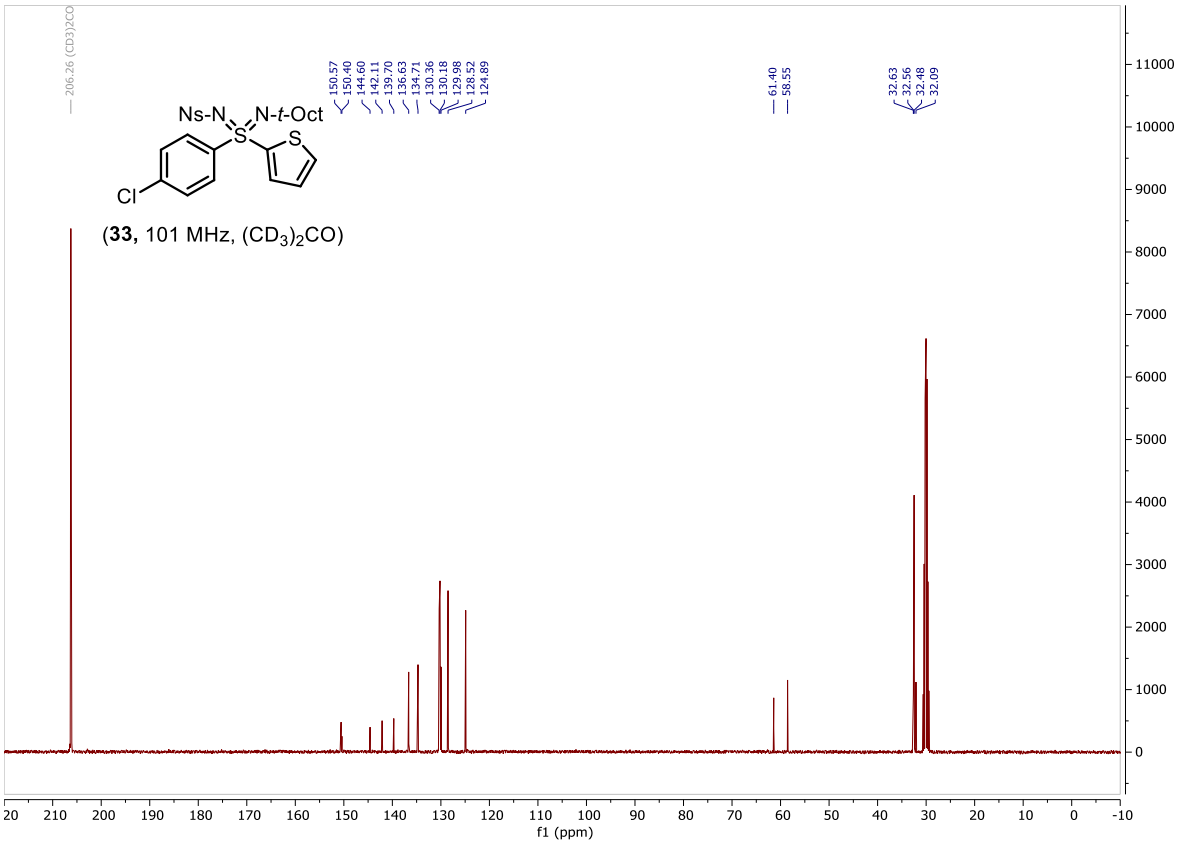

8.33
8.32
7.92
7.90
7.85
7.83
7.80
7.77
7.76
7.74
7.67
7.65
7.60
7.60
7.58
7.58
7.57
7.57
7.55
7.55
7.36
7.34
7.26 CDCl3
1.68
1.64
1.62
1.58
1.44
1.39
1.12
Ns-N
S
N-t-Oct
Cl
(32, 400 MHz, CDCl3)
1.01
1.99
1.03
4.17
3.08
2.13
2.03
1.37
1.07
3.13
3.15
9.31
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



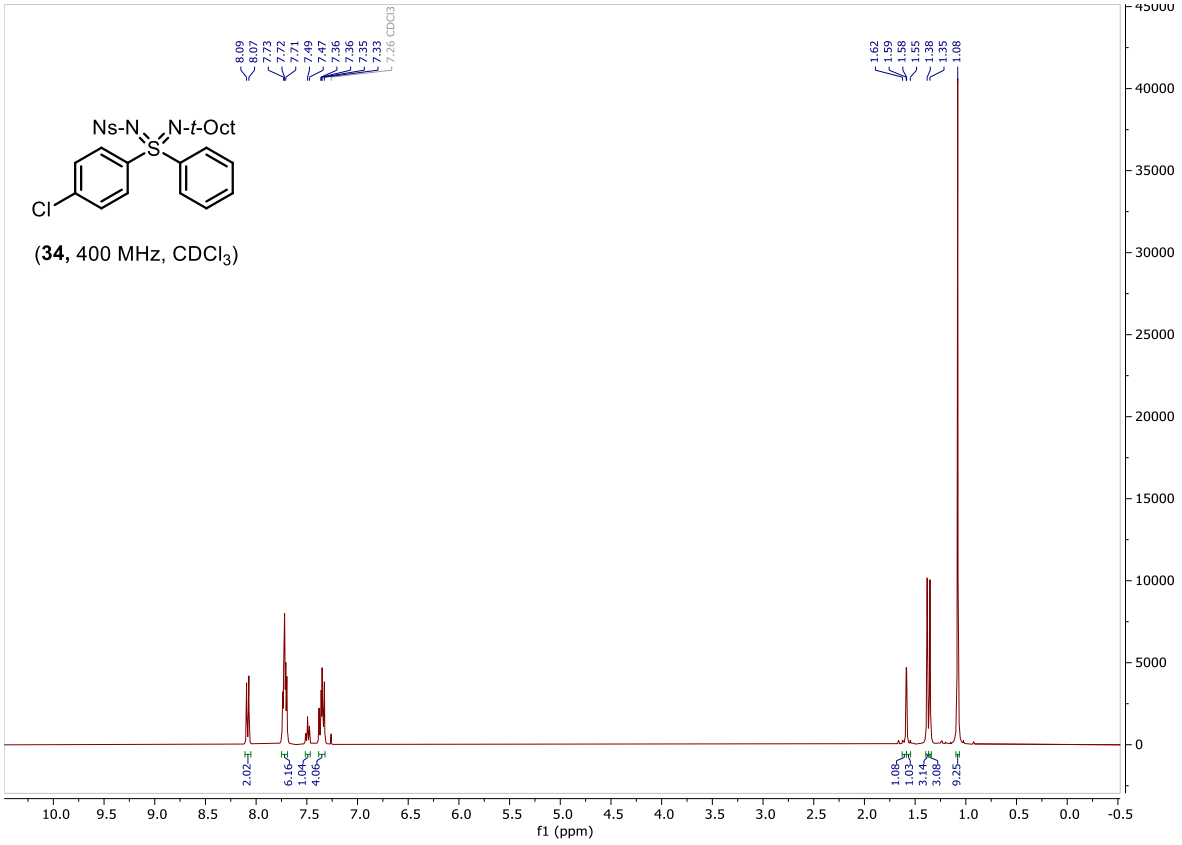
(**32,** 101 MHz, $CDCl_3$)



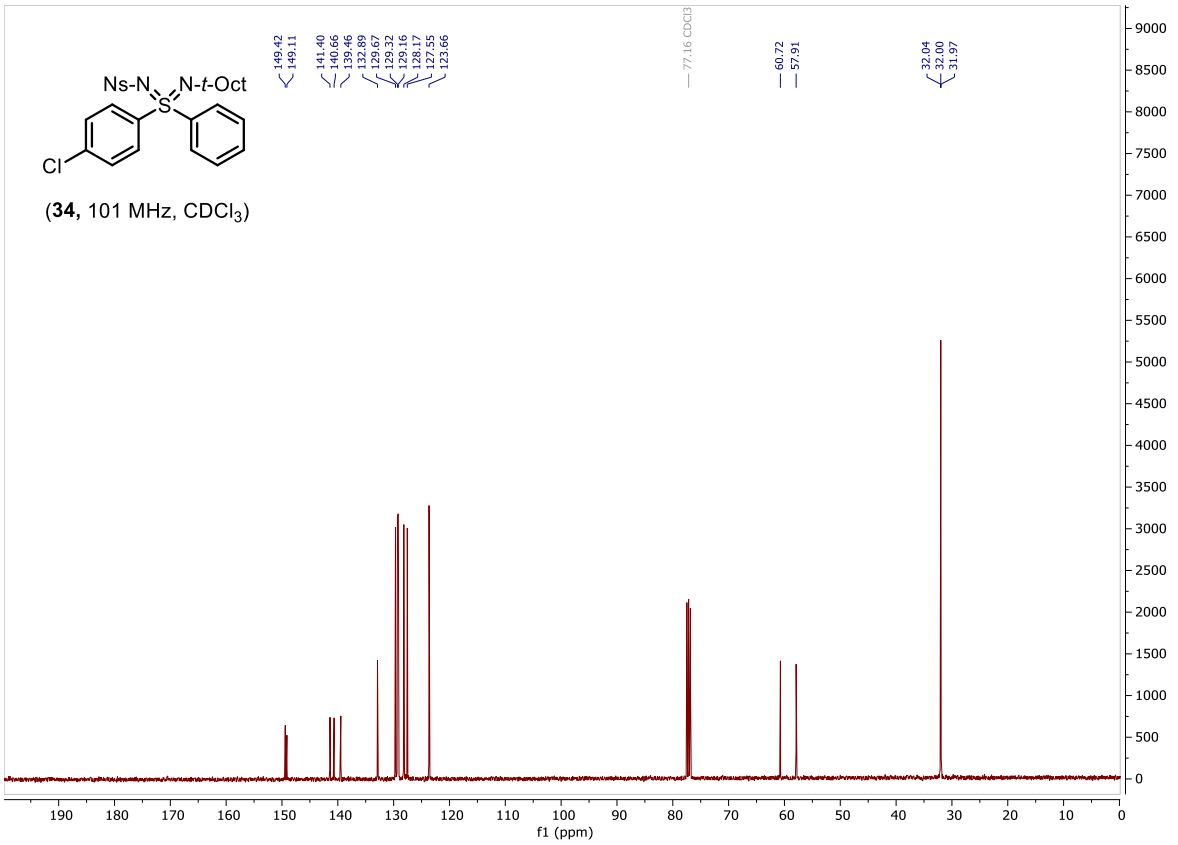
(**33,** 400 MHz, $CDCl_3$)



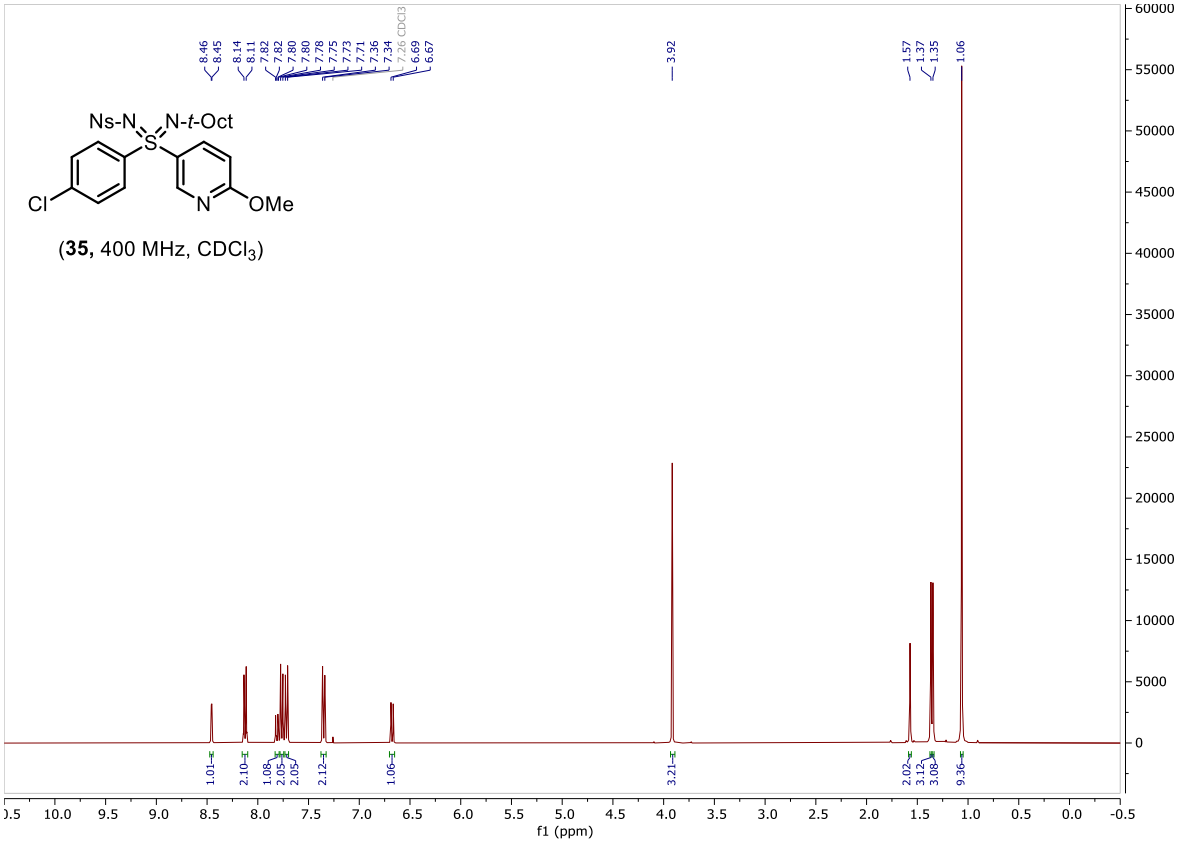
(**33,** 101 MHz, $(CD_3)_2CO$)



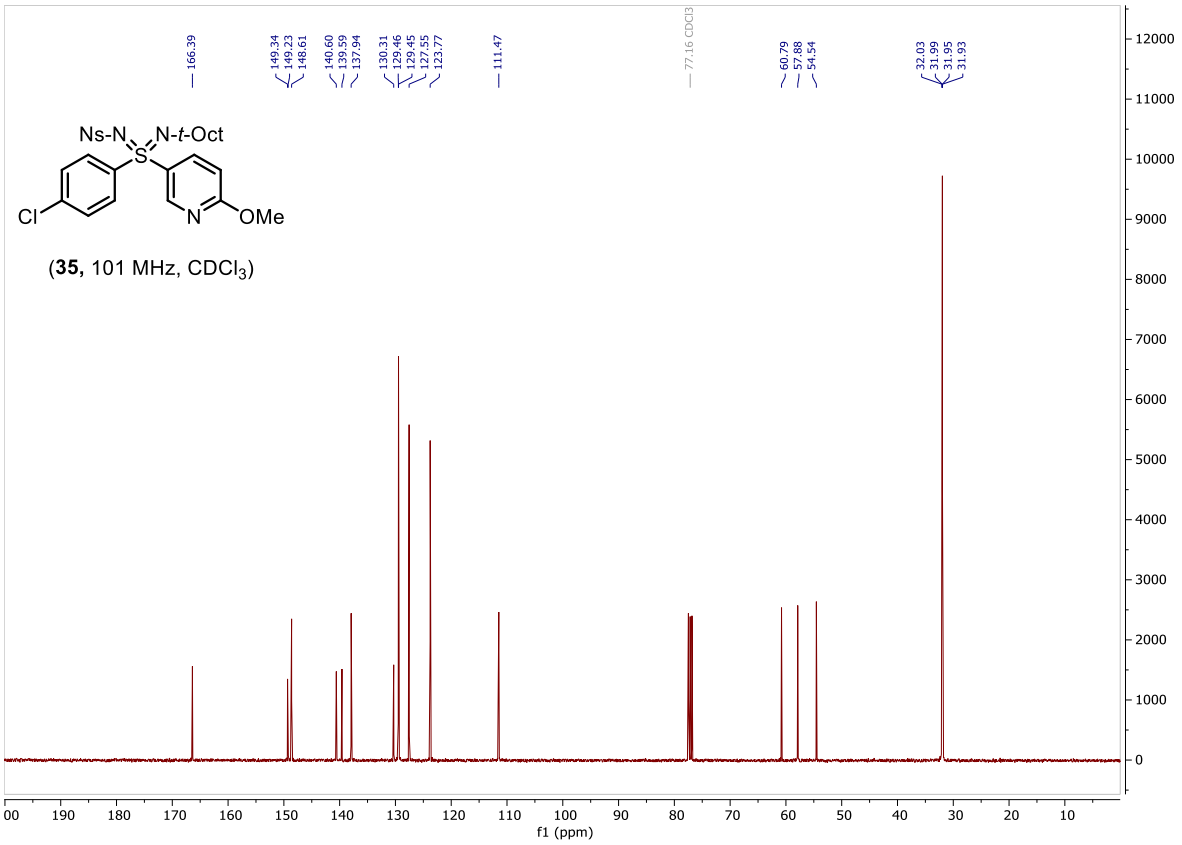
(**34,** 400 MHz, $CDCl_3$)



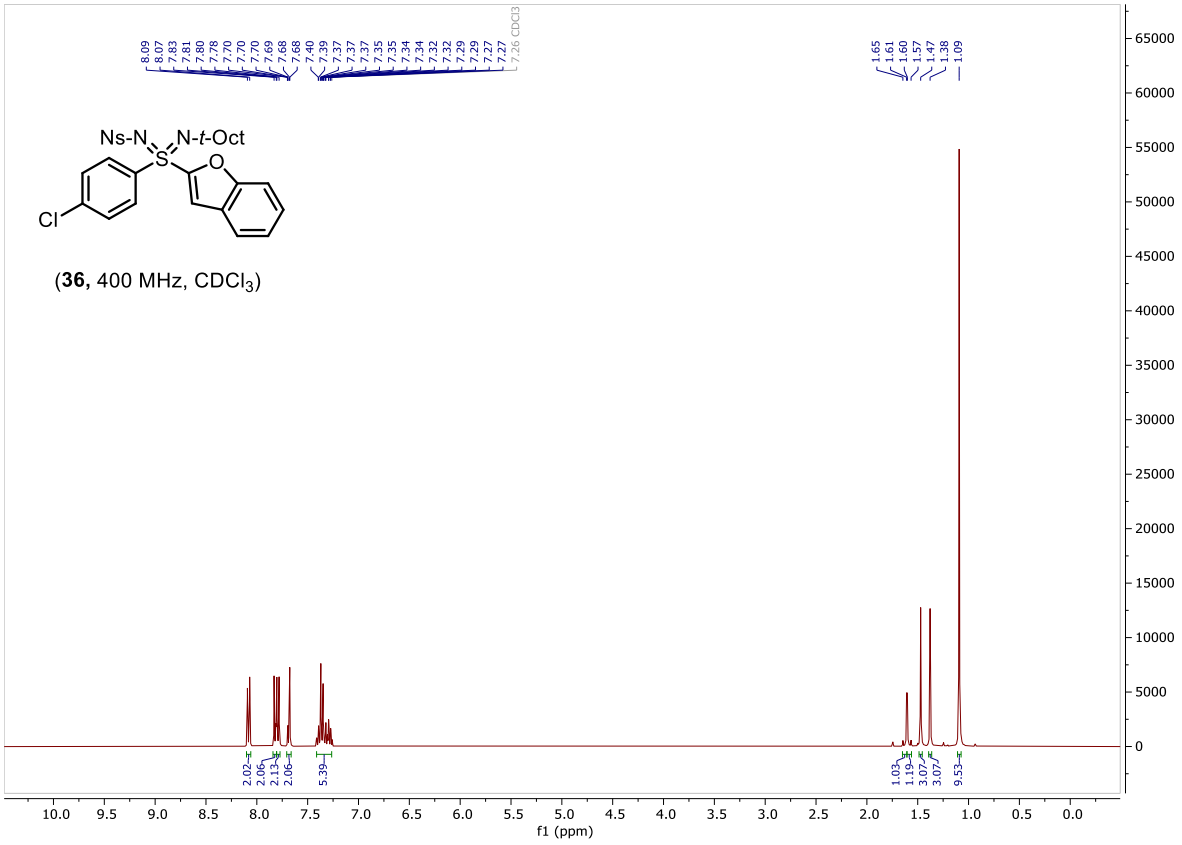
(**34,** 101 MHz, $CDCl_3$)



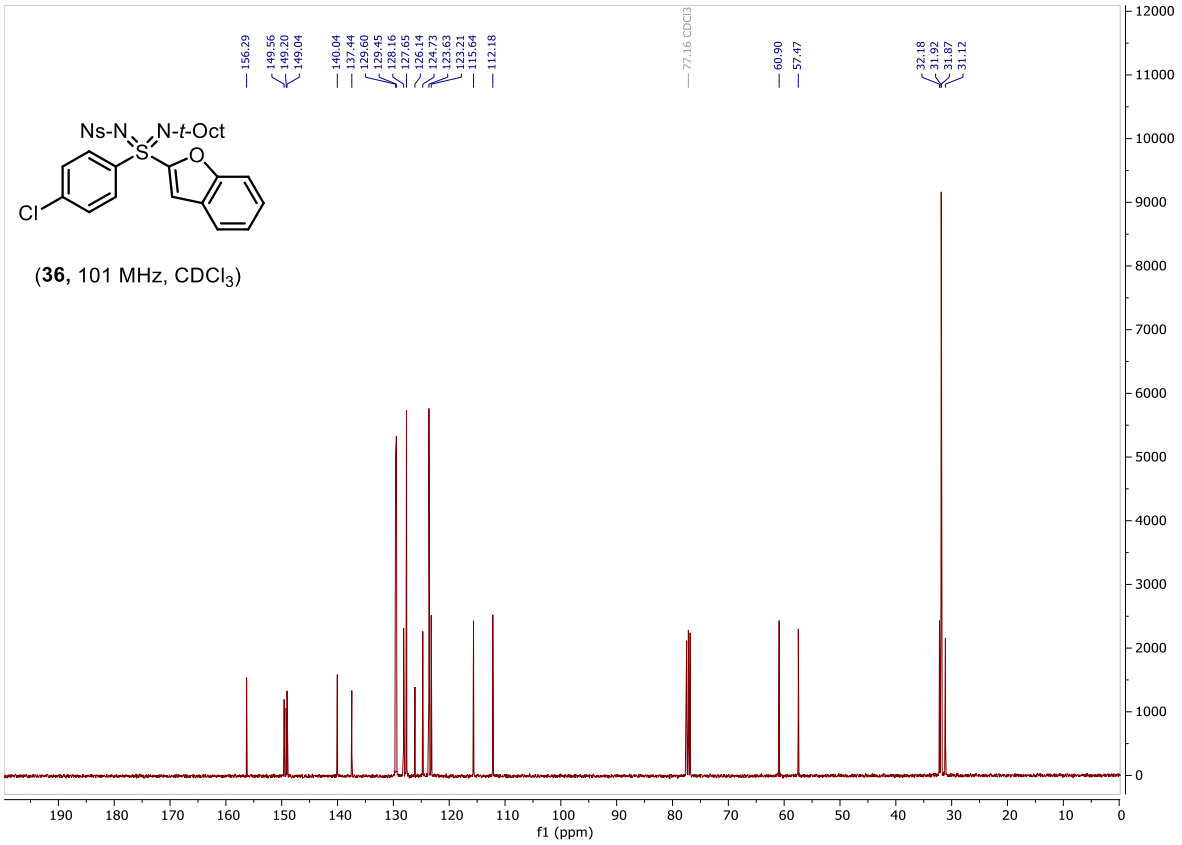
(**35,** 400 MHz, $CDCl_3$)



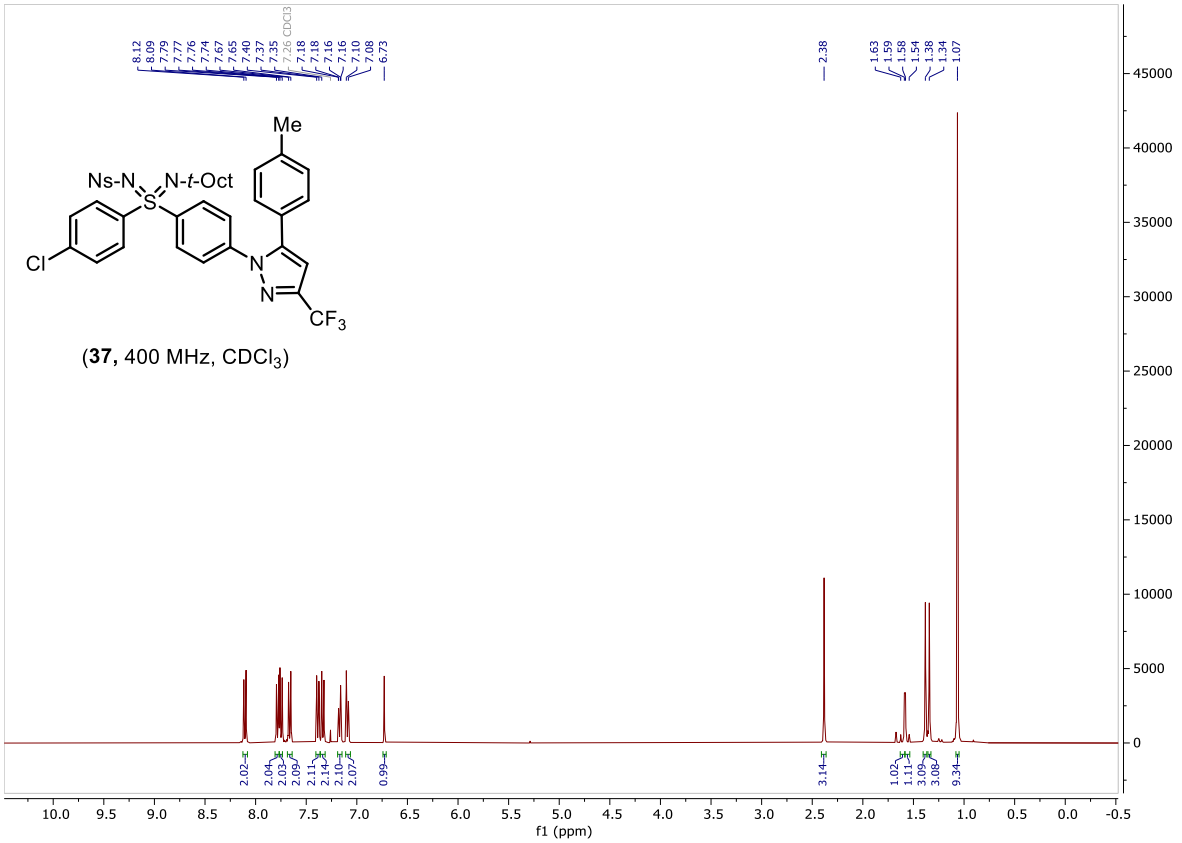
(**35,** 101 MHz, $CDCl_3$)



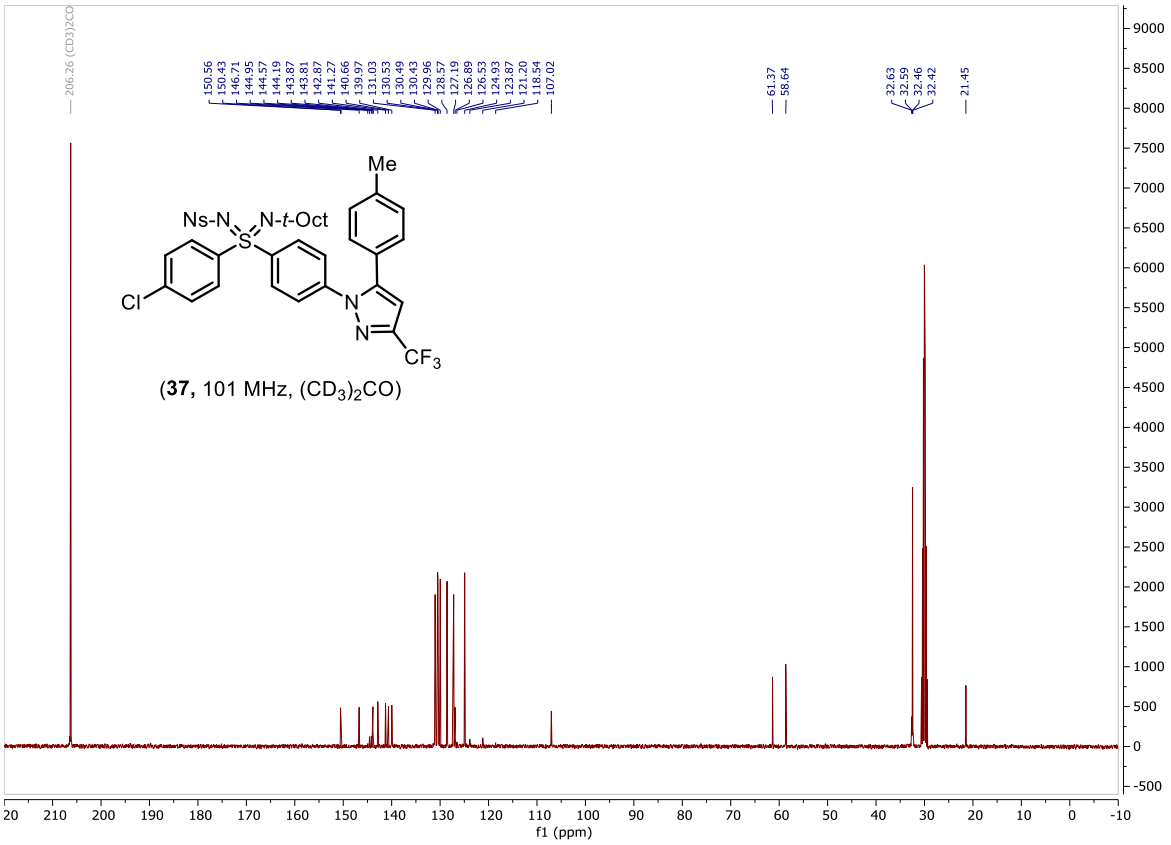
(**36,** 400 MHz, $CDCl_3$)



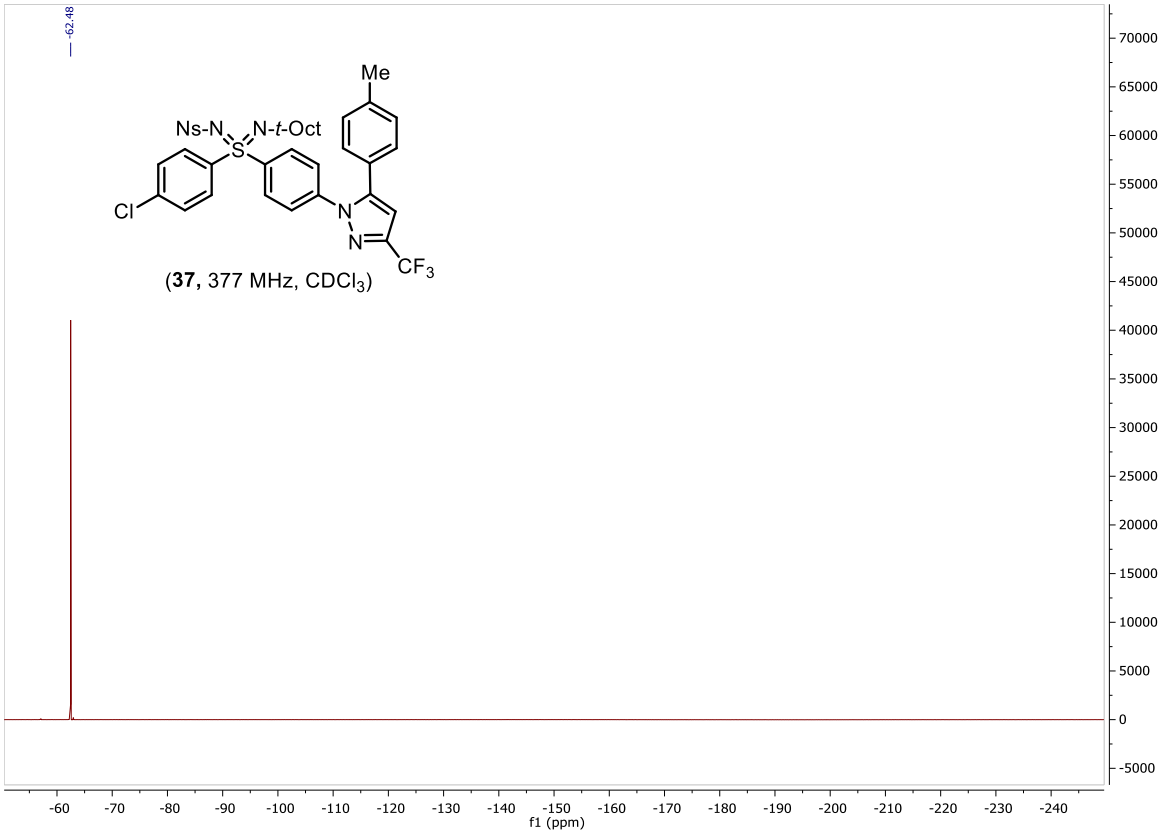
(**36,** 101 MHz, $CDCl_3$)



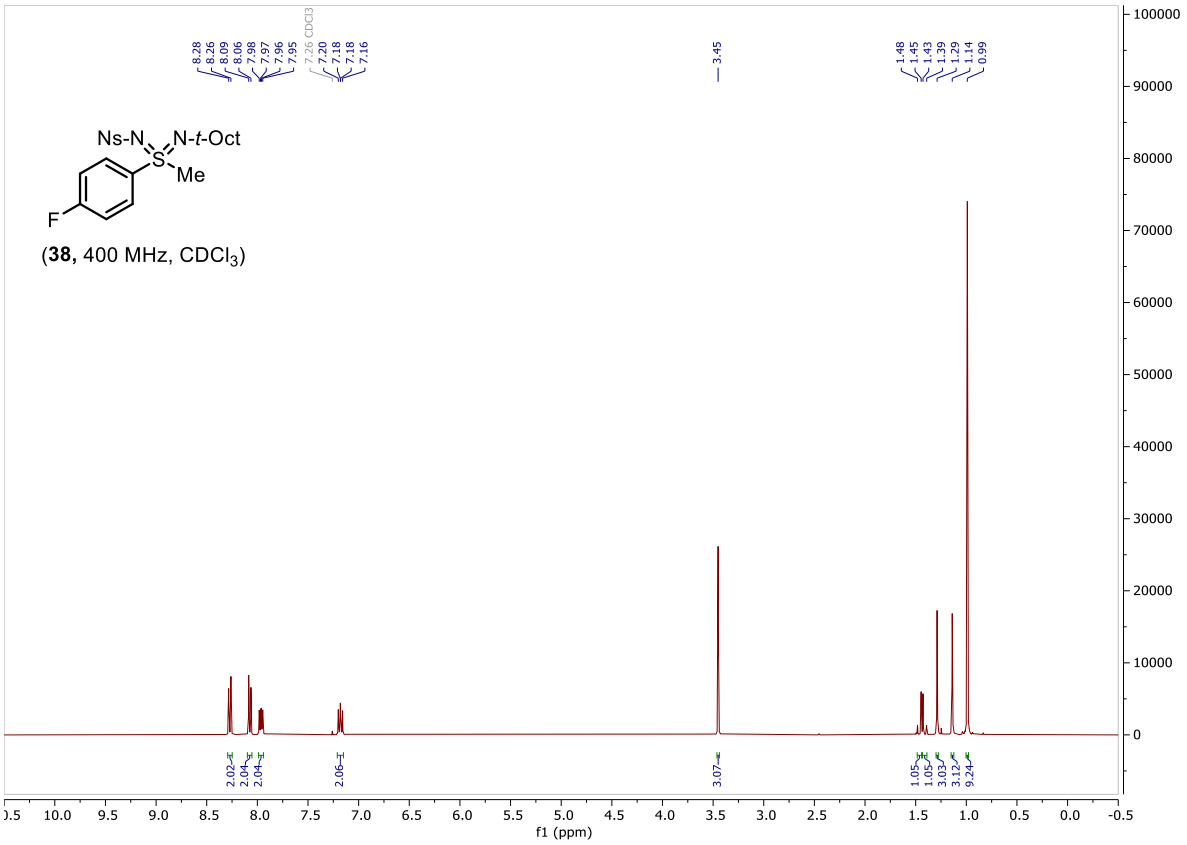
(**37,** 400 MHz, $CDCl_3$)



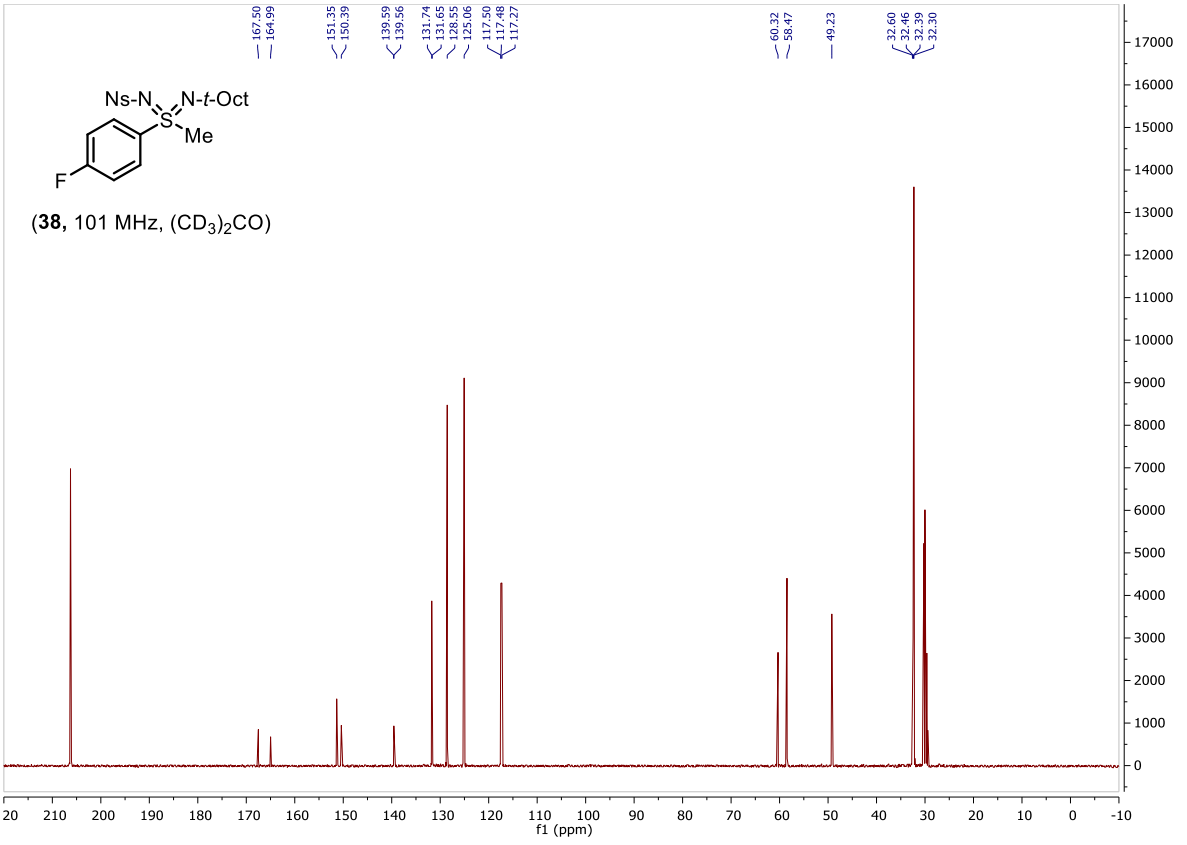
(**37**, 101 MHz, $(CD_3)_2CO$)



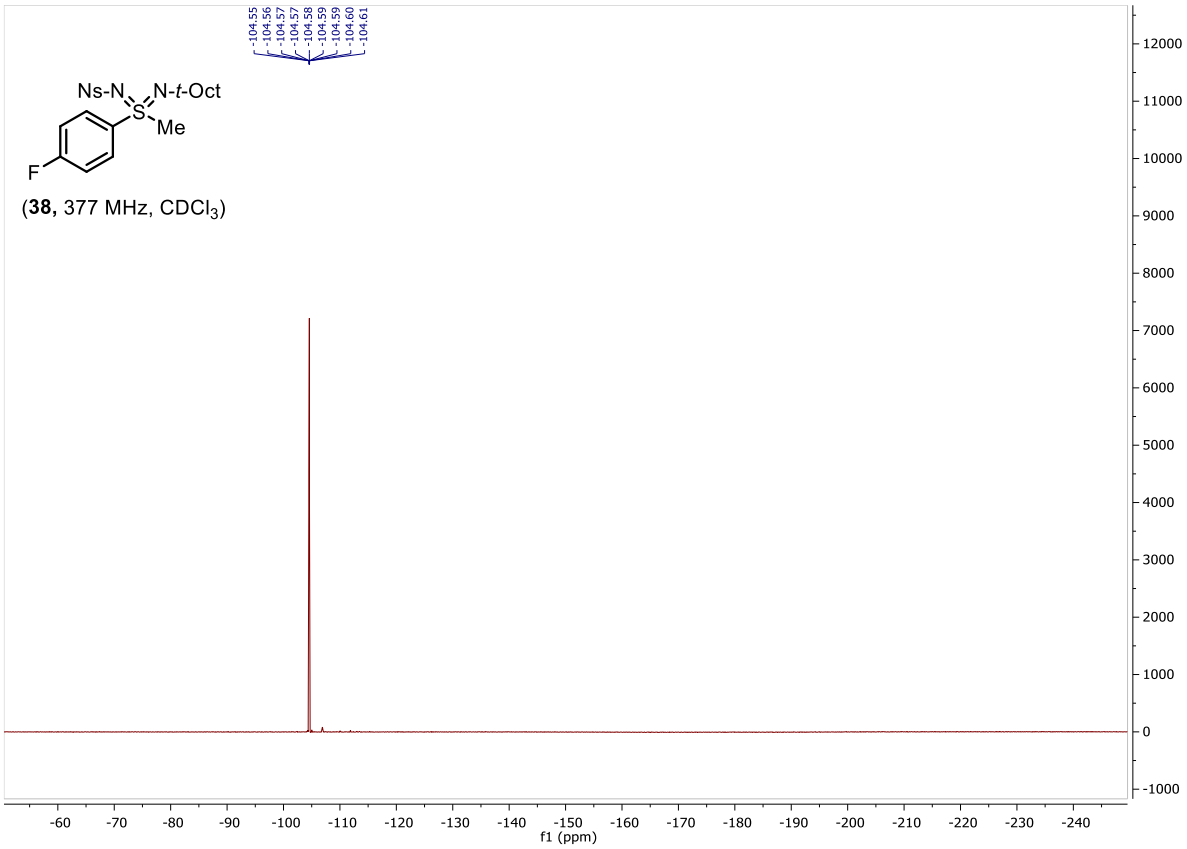
(**37**, 377 MHz, $CDCl_3$)



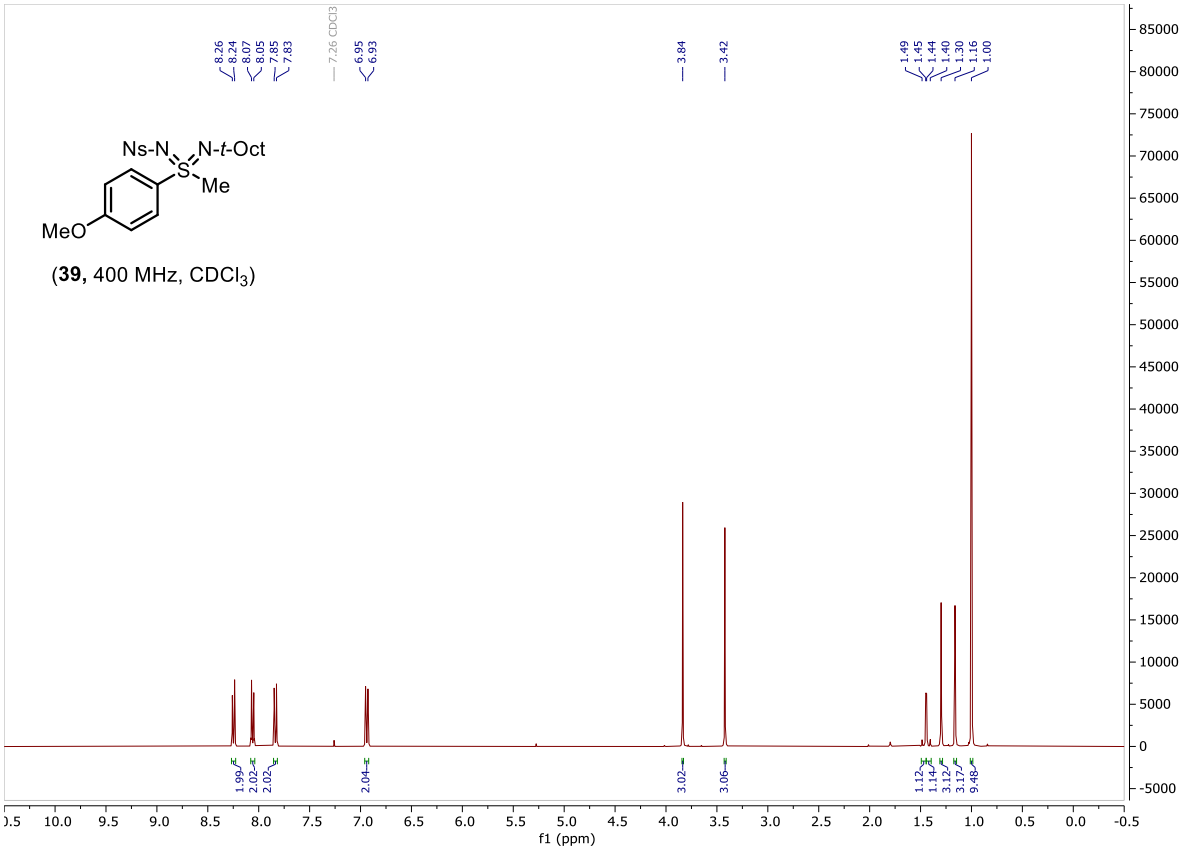
(**38,** 400 MHz, $CDCl_3$)



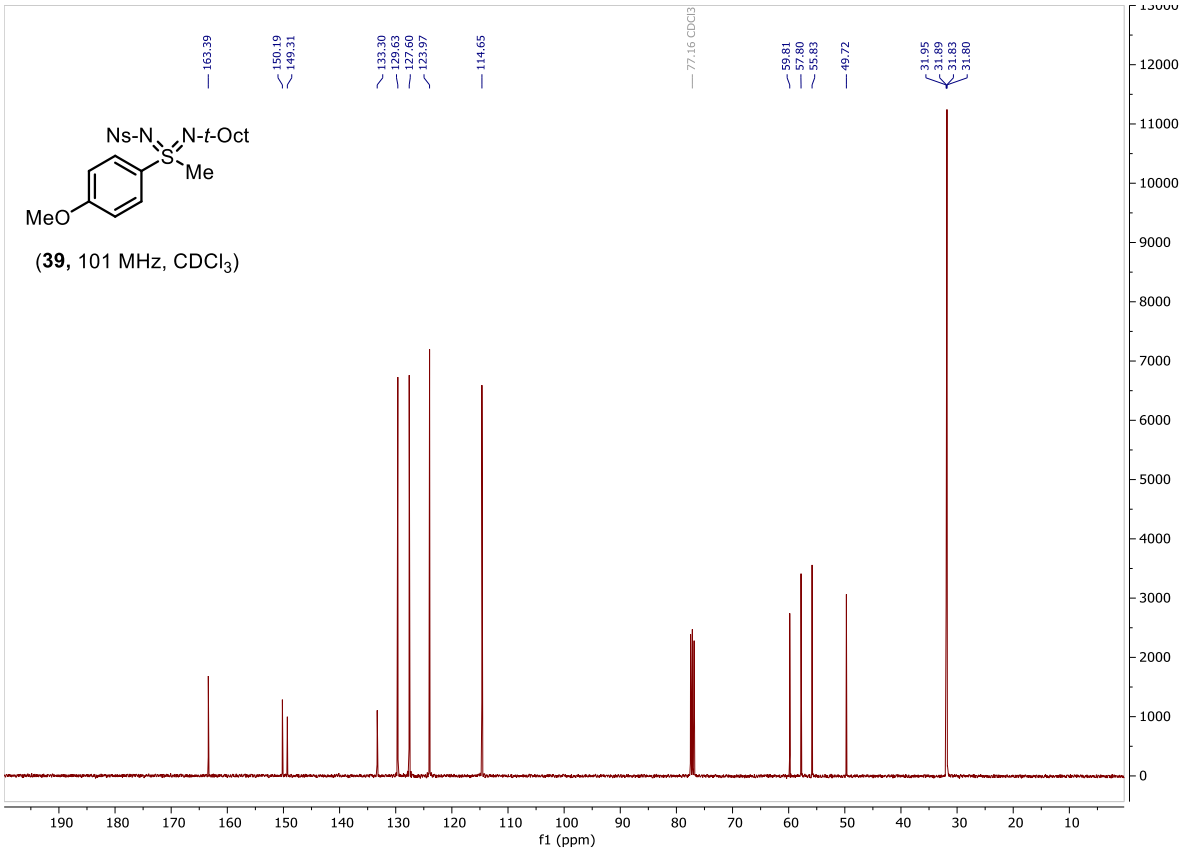
(**38,** 101 MHz, $(CD_3)_2CO$)



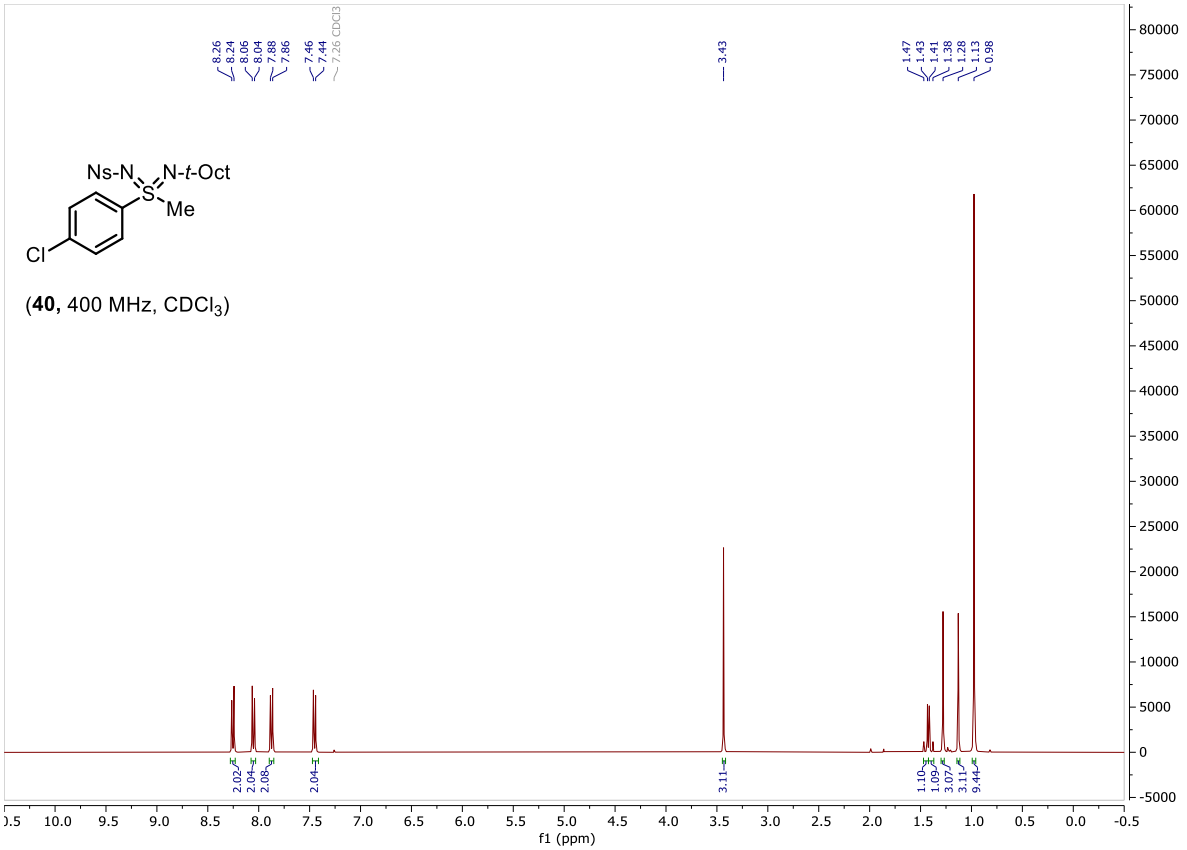
(**38,** 377 MHz, $CDCl_3$)



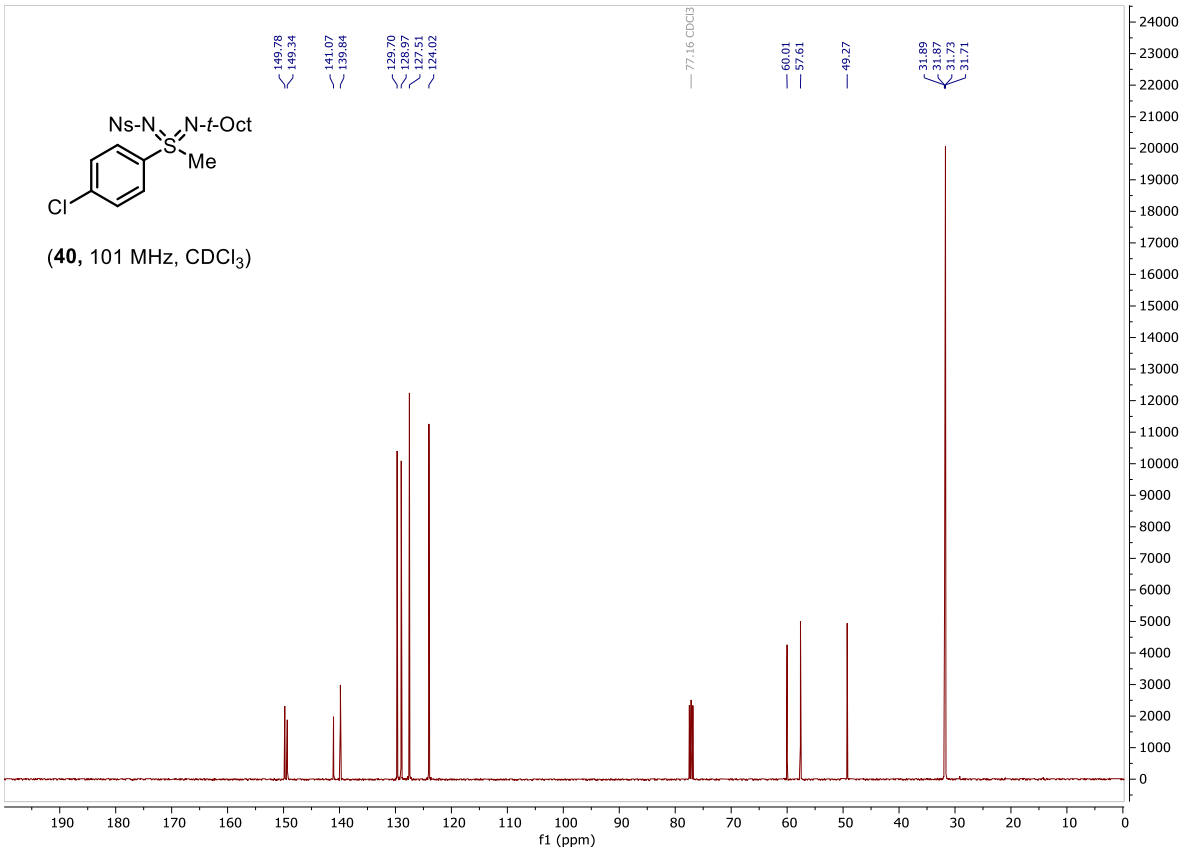
(**39,** 400 MHz, $CDCl_3$)



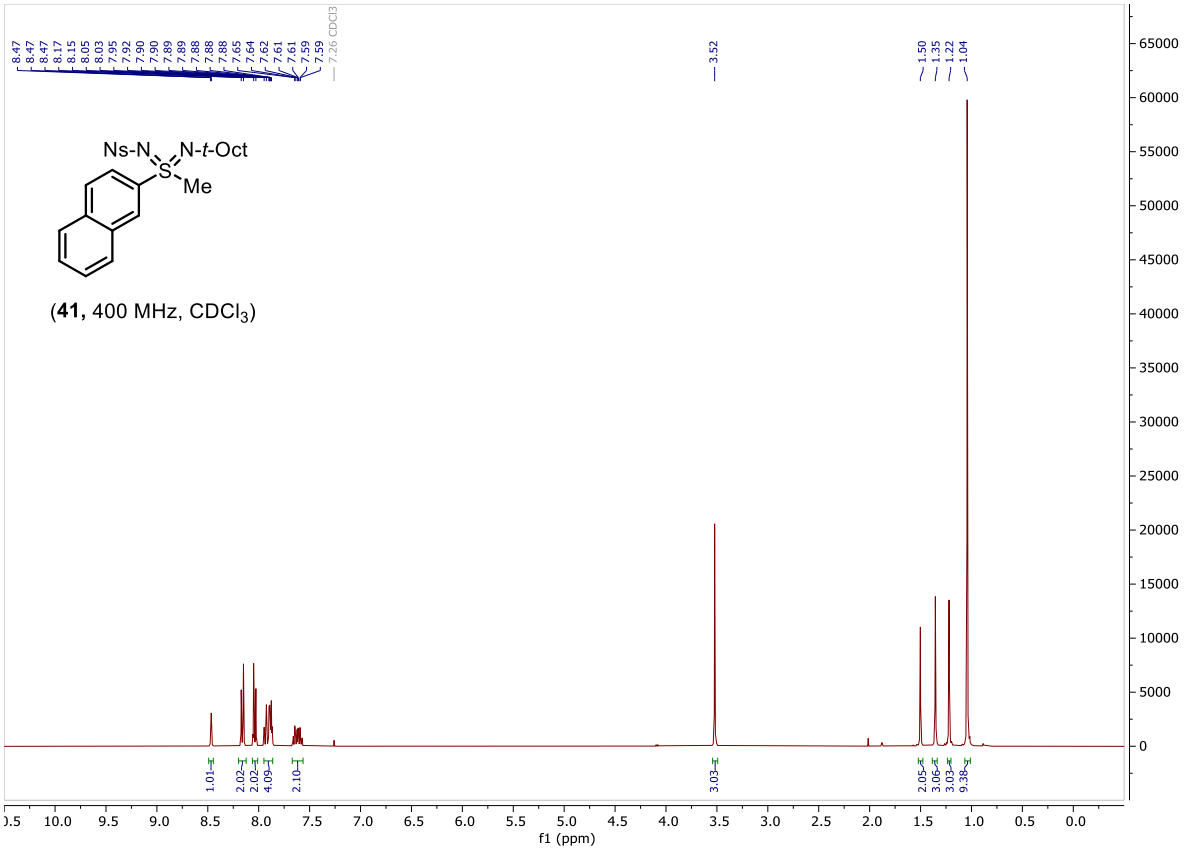
(**39,** 101 MHz, $CDCl_3$)



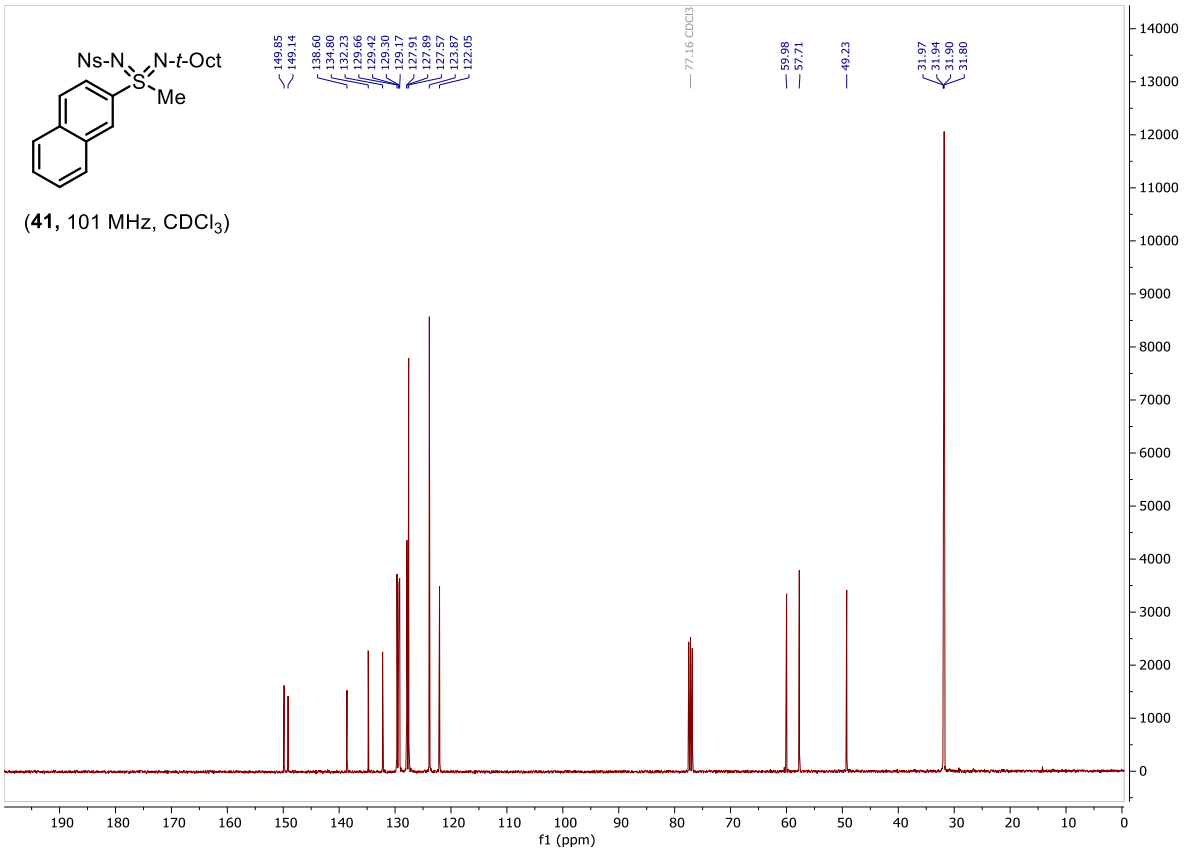
(**40,** 400 MHz, $CDCl_3$)



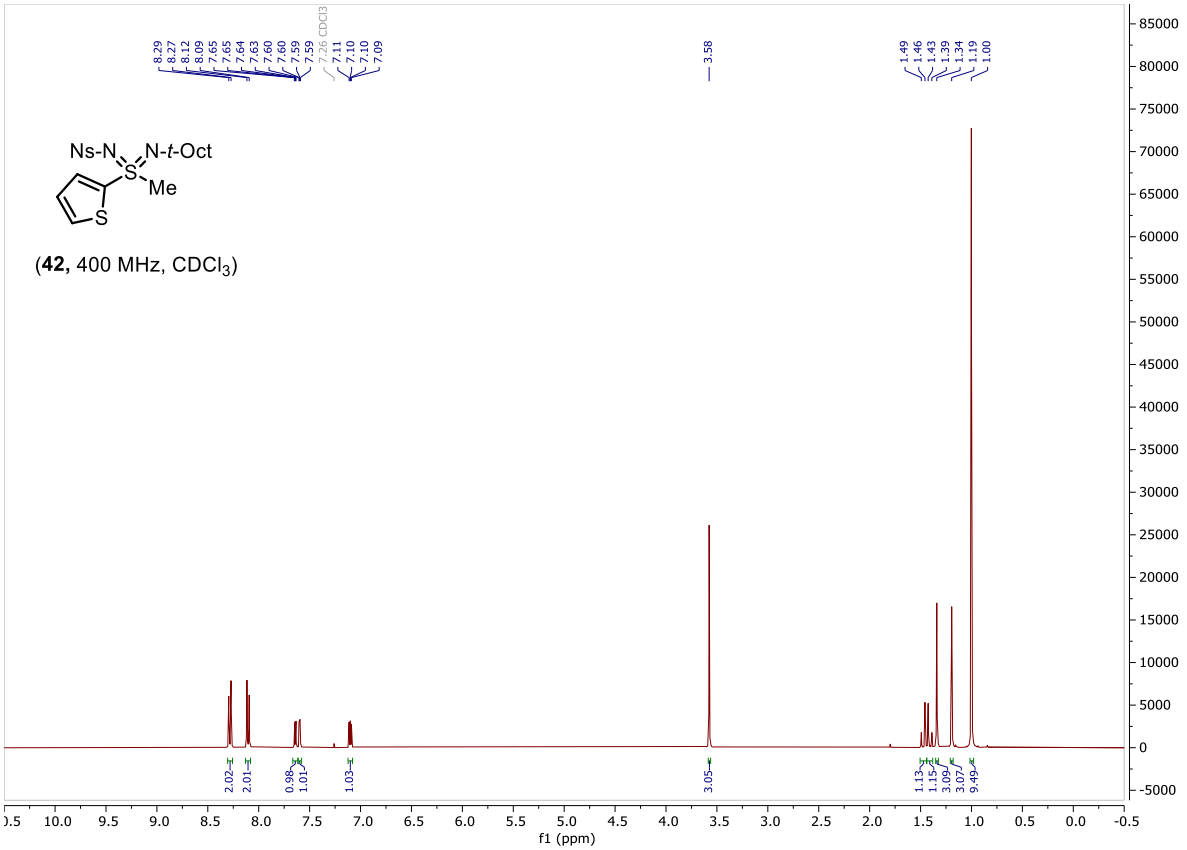
(**40,** 101 MHz, $CDCl_3$)



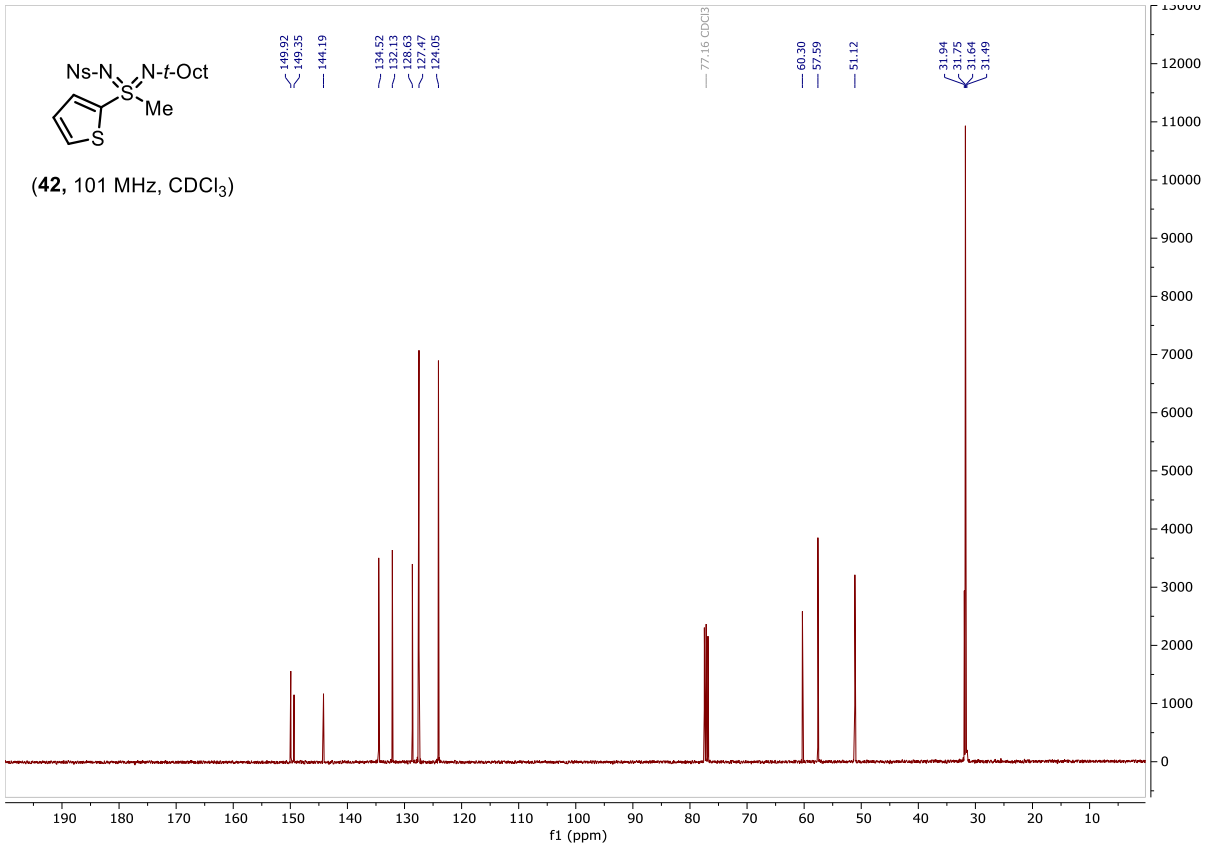
(**41,** 400 MHz, $CDCl_3$)



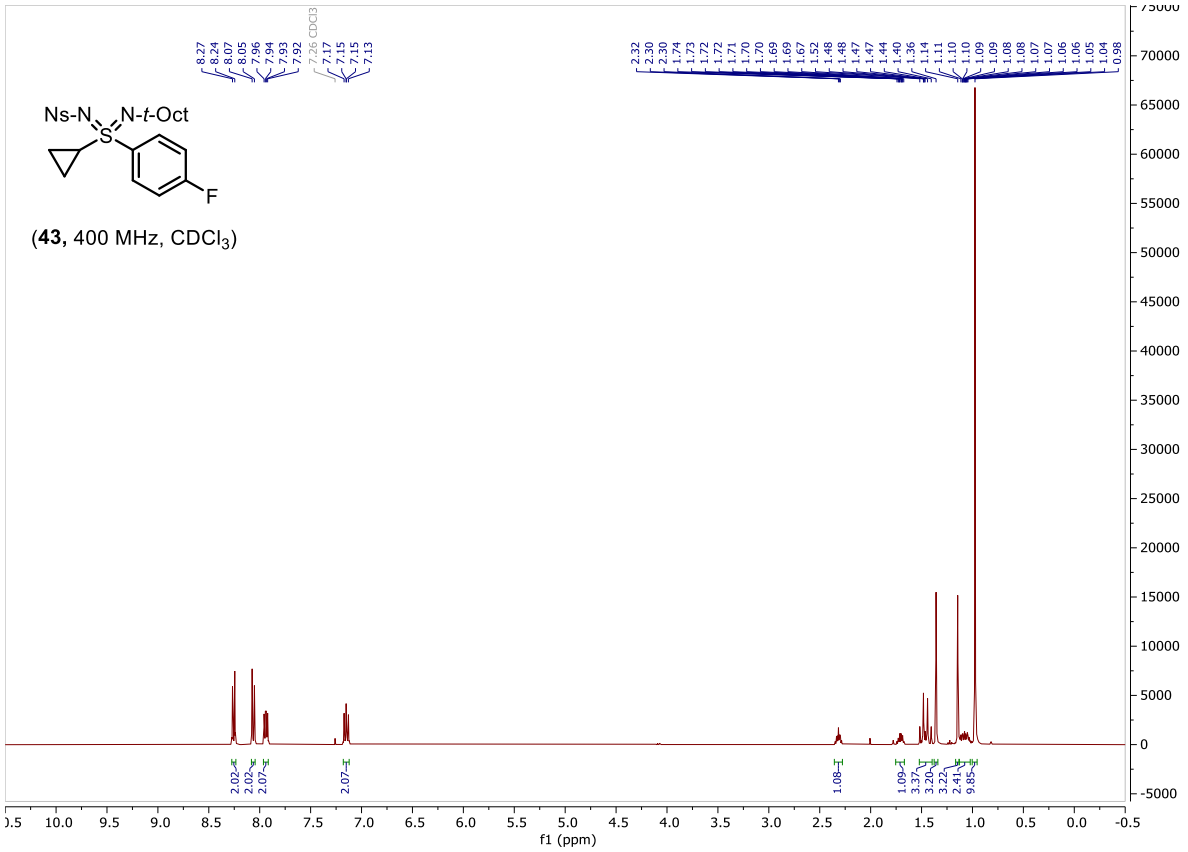
(**41,** 101 MHz, $CDCl_3$)



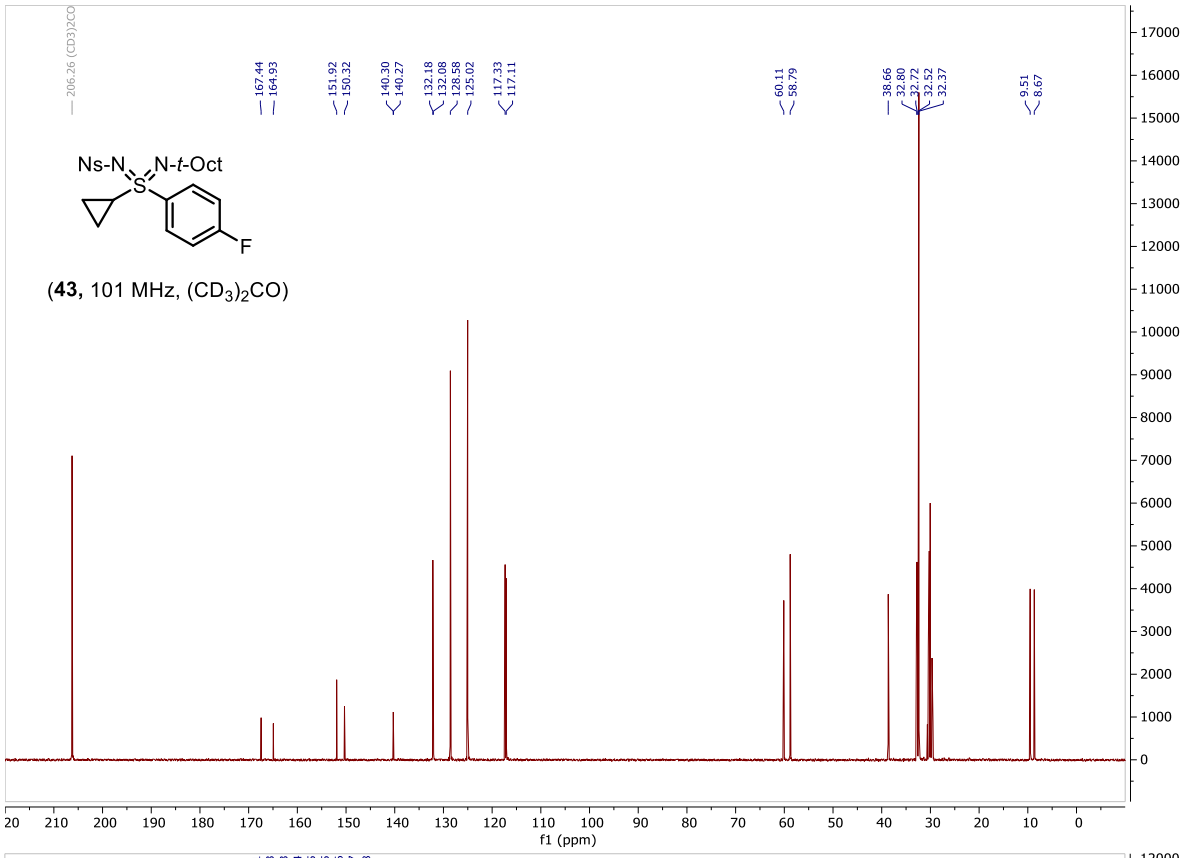
(**42,** 400 MHz, $CDCl_3$)



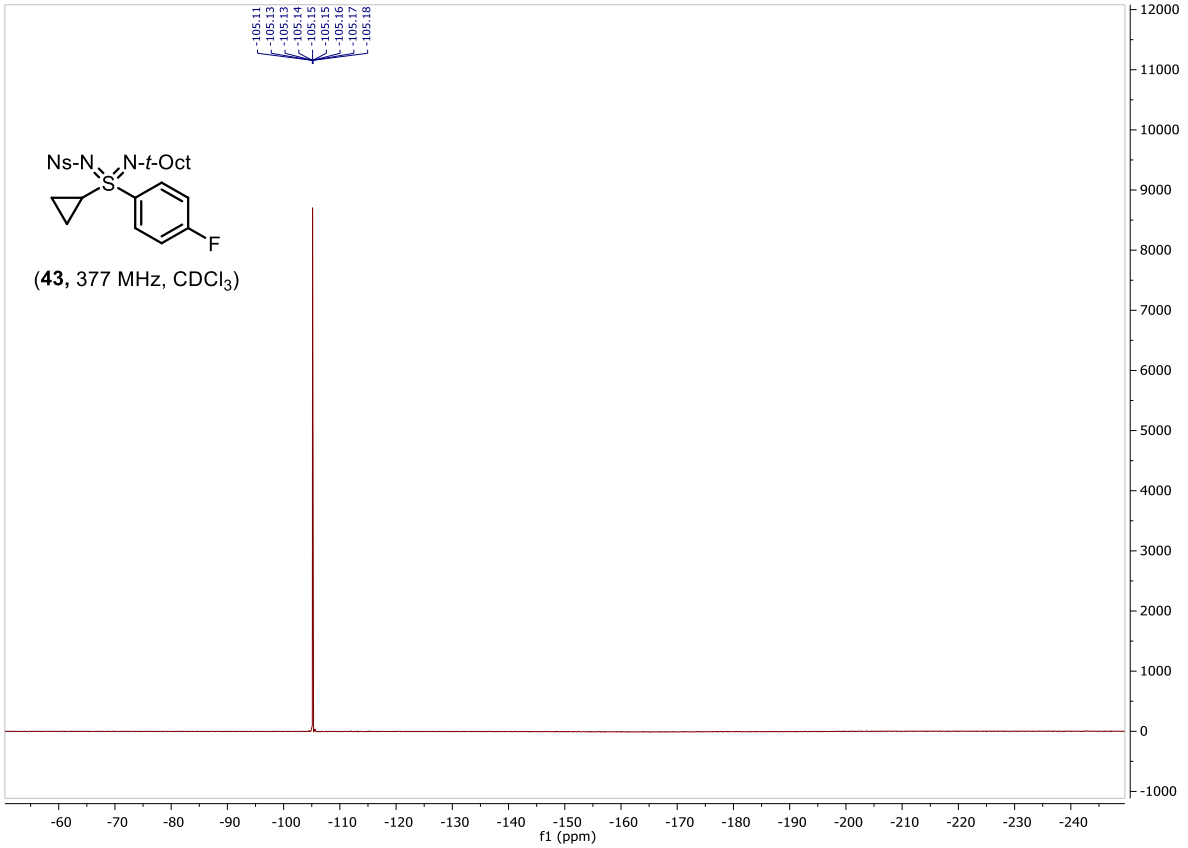
(**42,** 101 MHz, $CDCl_3$)



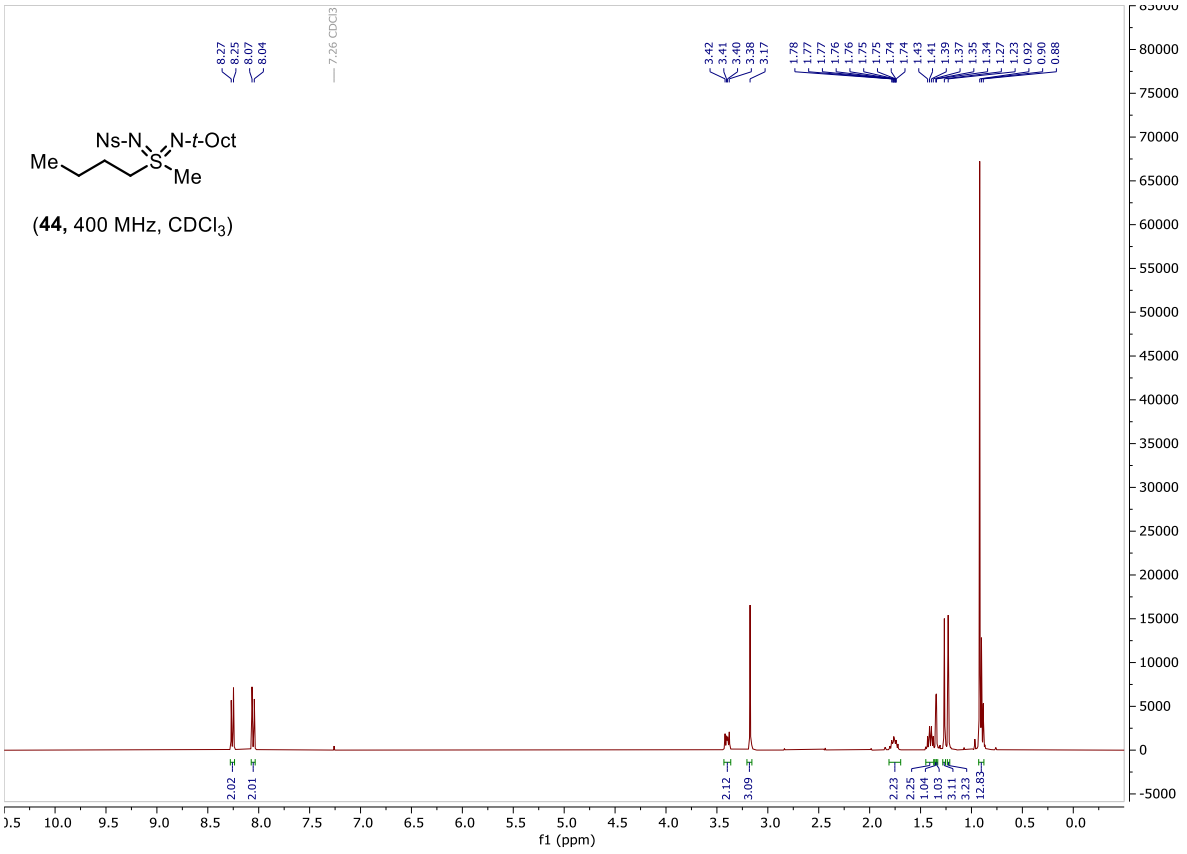
(**43,** 400 MHz, $CDCl_3$)

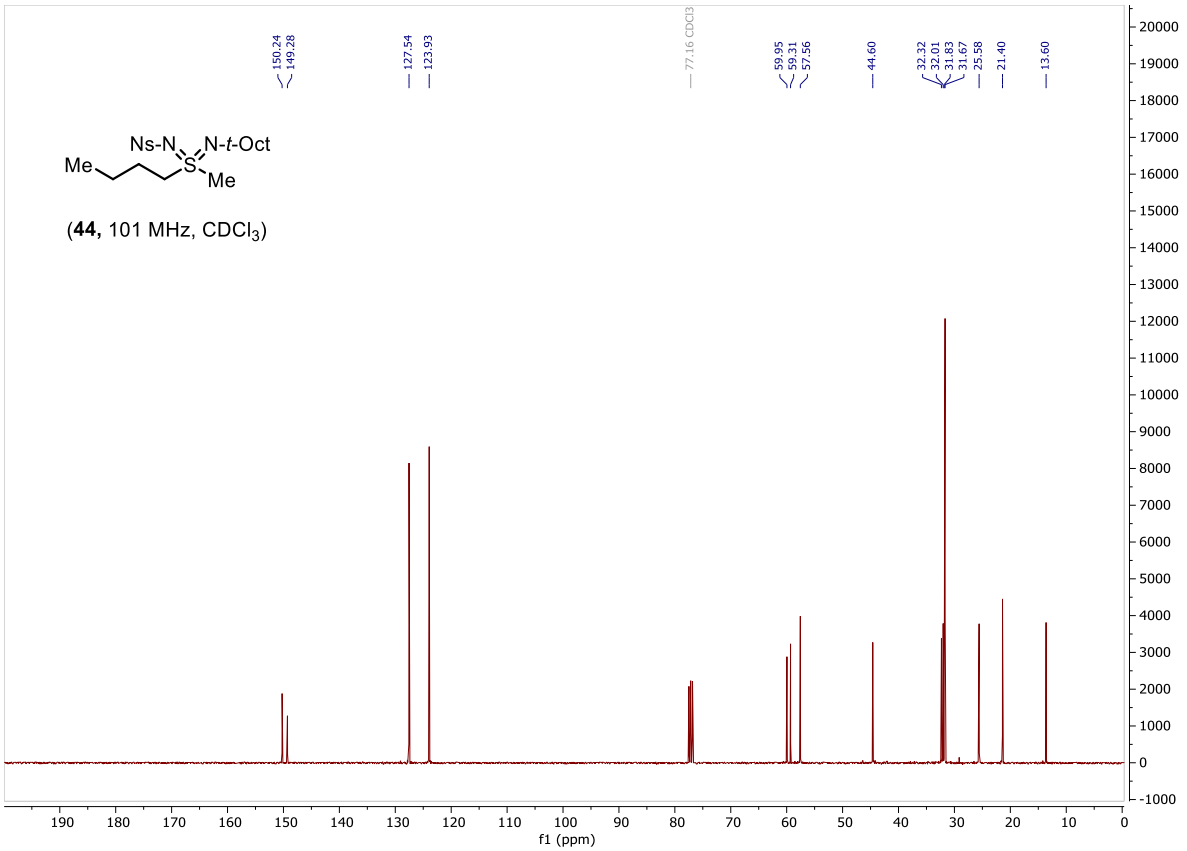


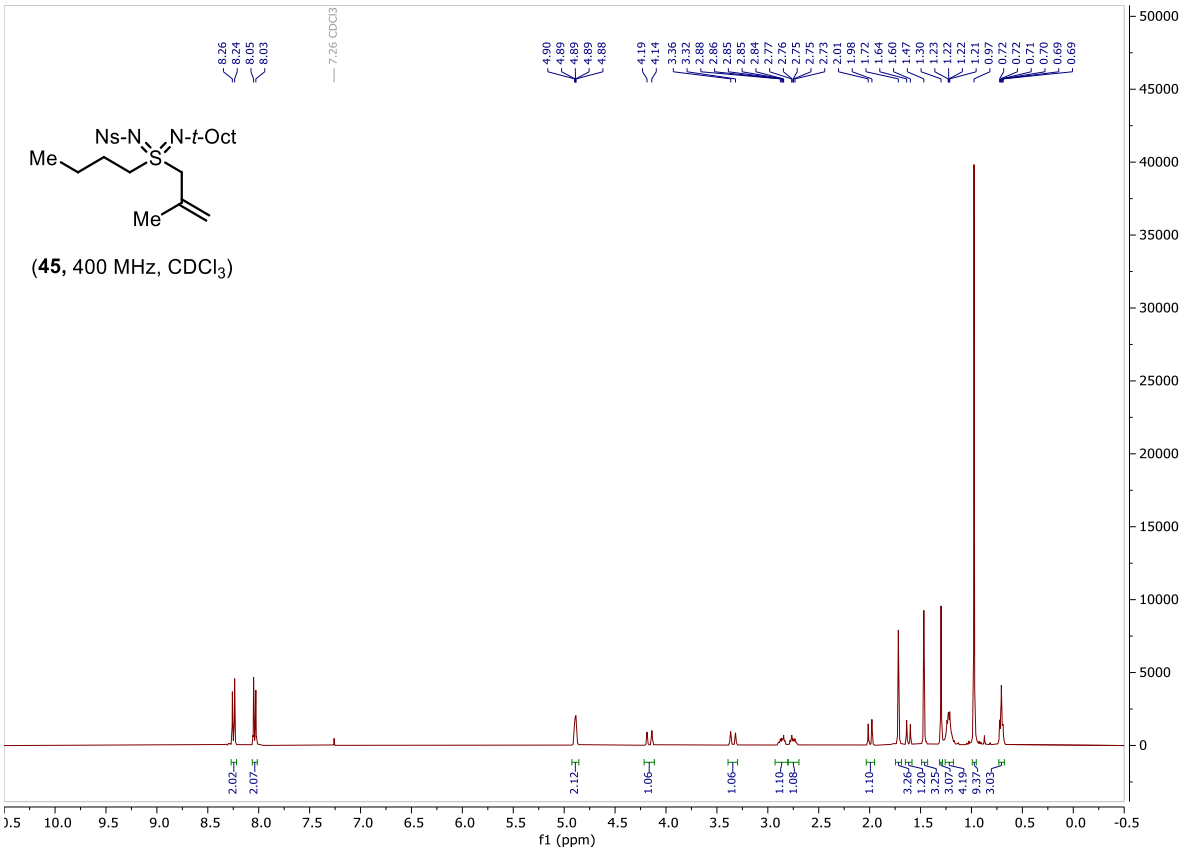
(**43,** 101 MHz, $(CD_3)_2CO$)

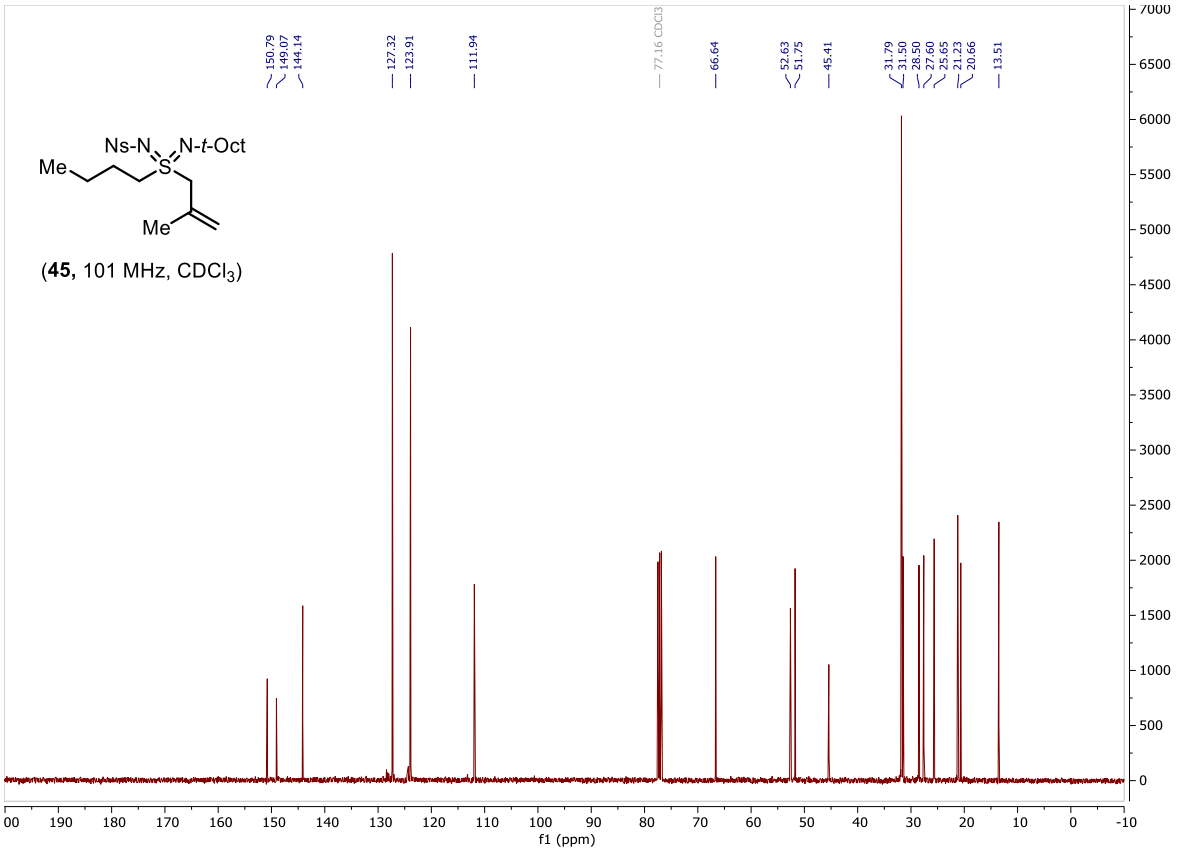


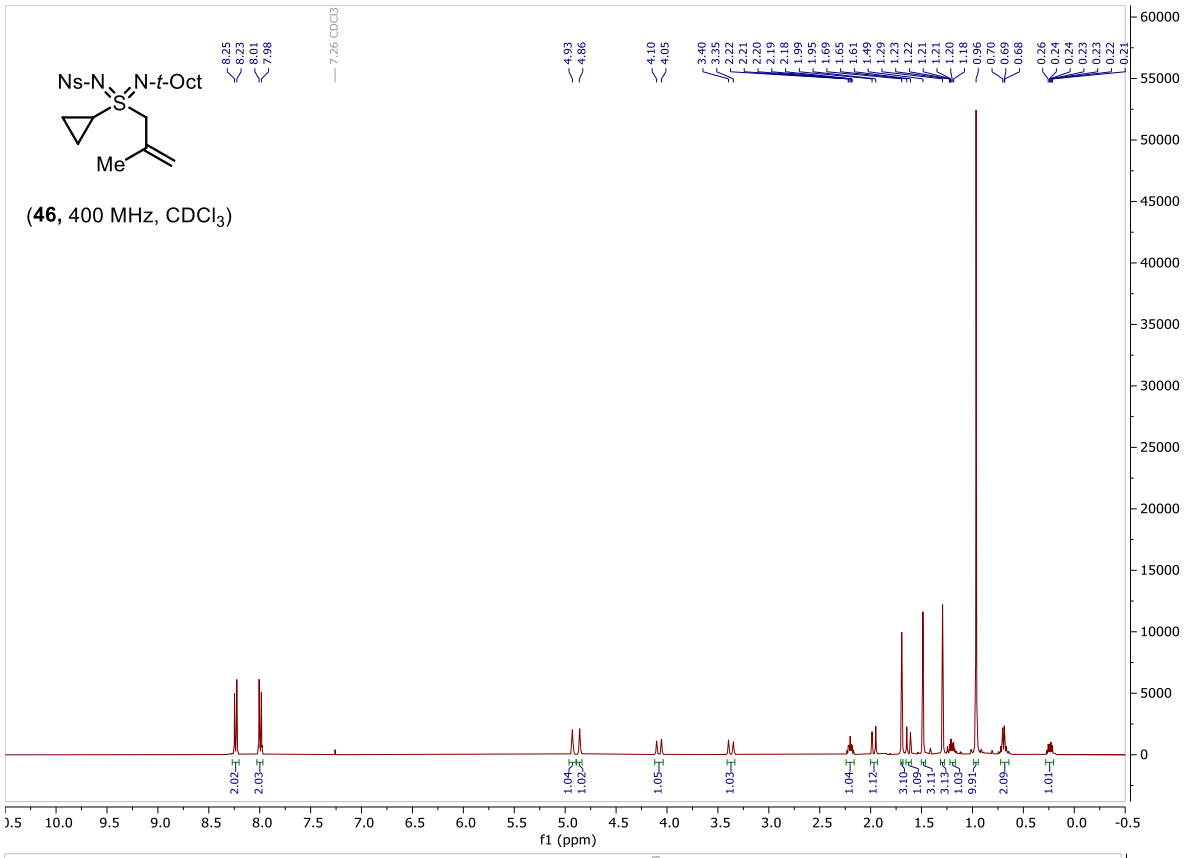
(**43,** 377 MHz, $CDCl_3$)

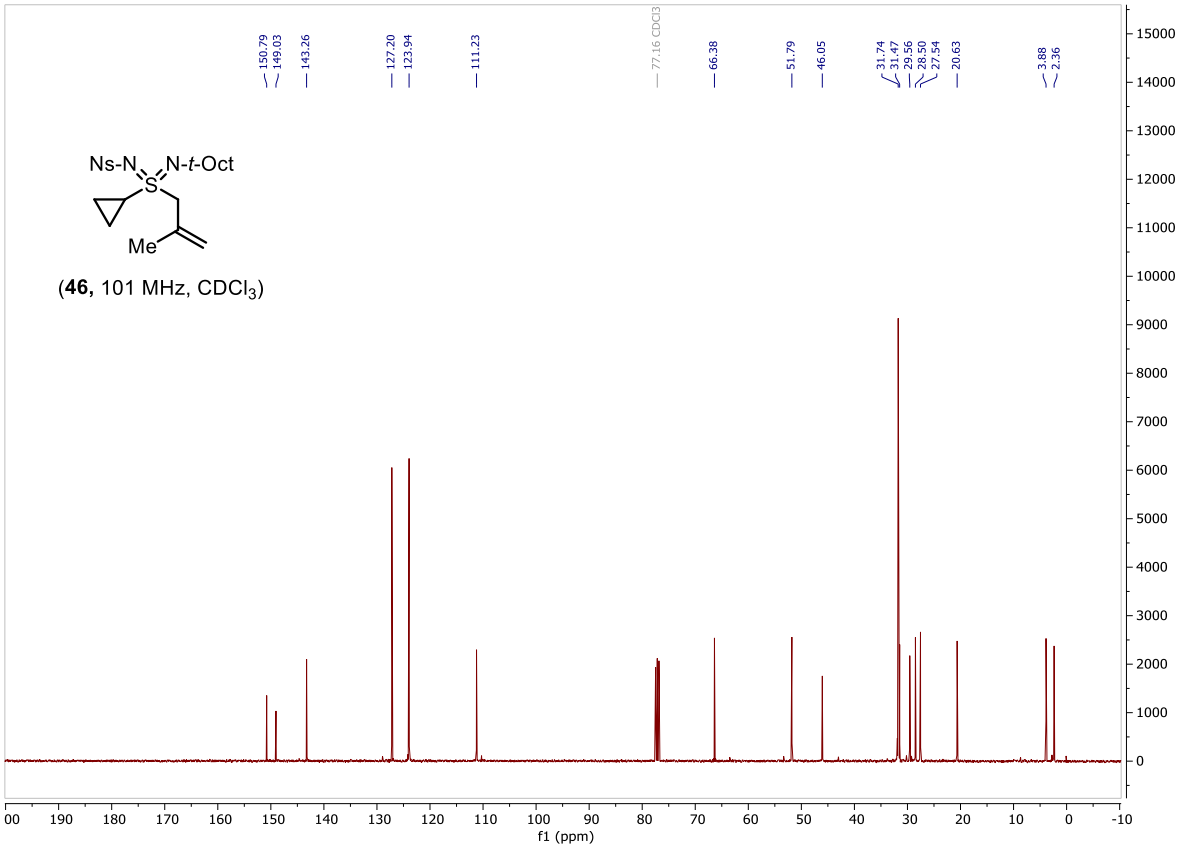

Ns-N
N-t-Oct
Me
S
Me
(44, 400 MHz, CDCl3)
f1 (ppm)

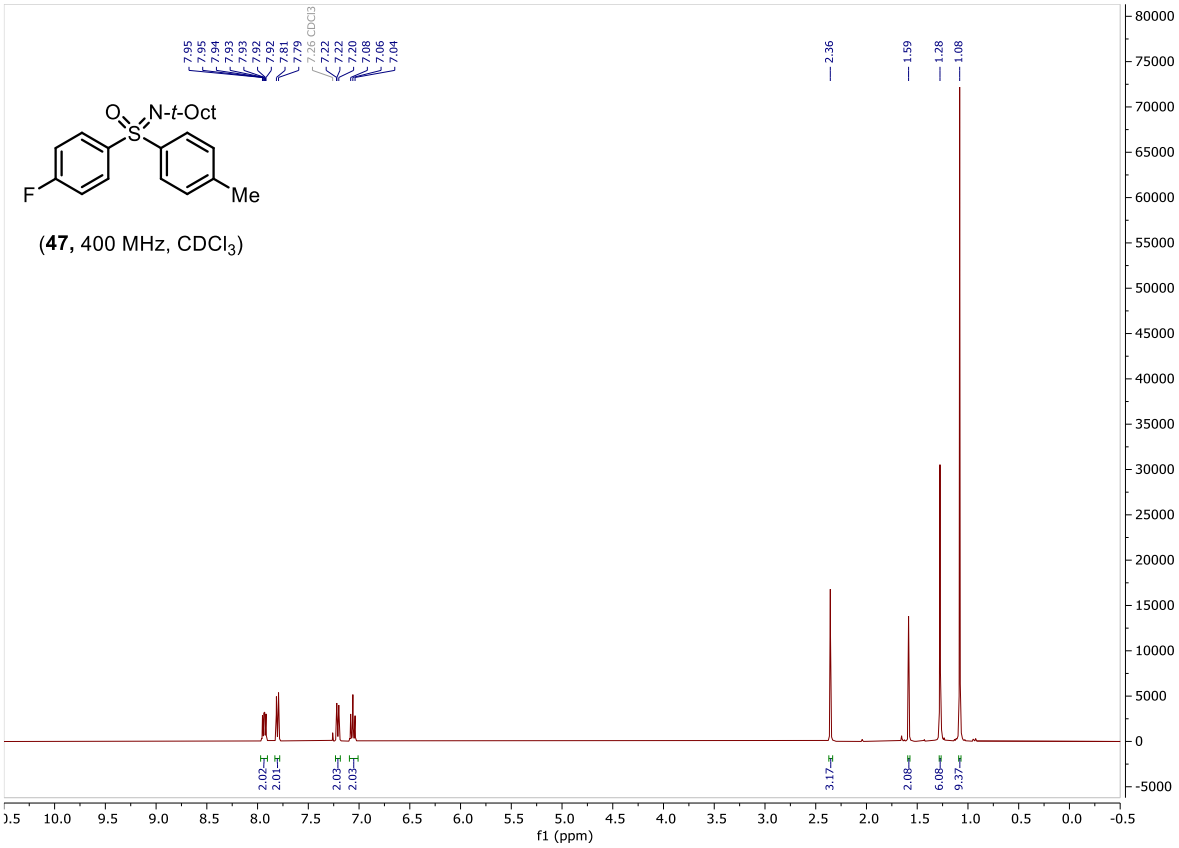

Ns-N
N-t-Oct
Me
S
Me
(44, 101 MHz, CDCl3)
f1 (ppm)


Ns-N
N-t-Oct
Me
S
Me
(45, 400 MHz, CDCl3)
f1 (ppm)

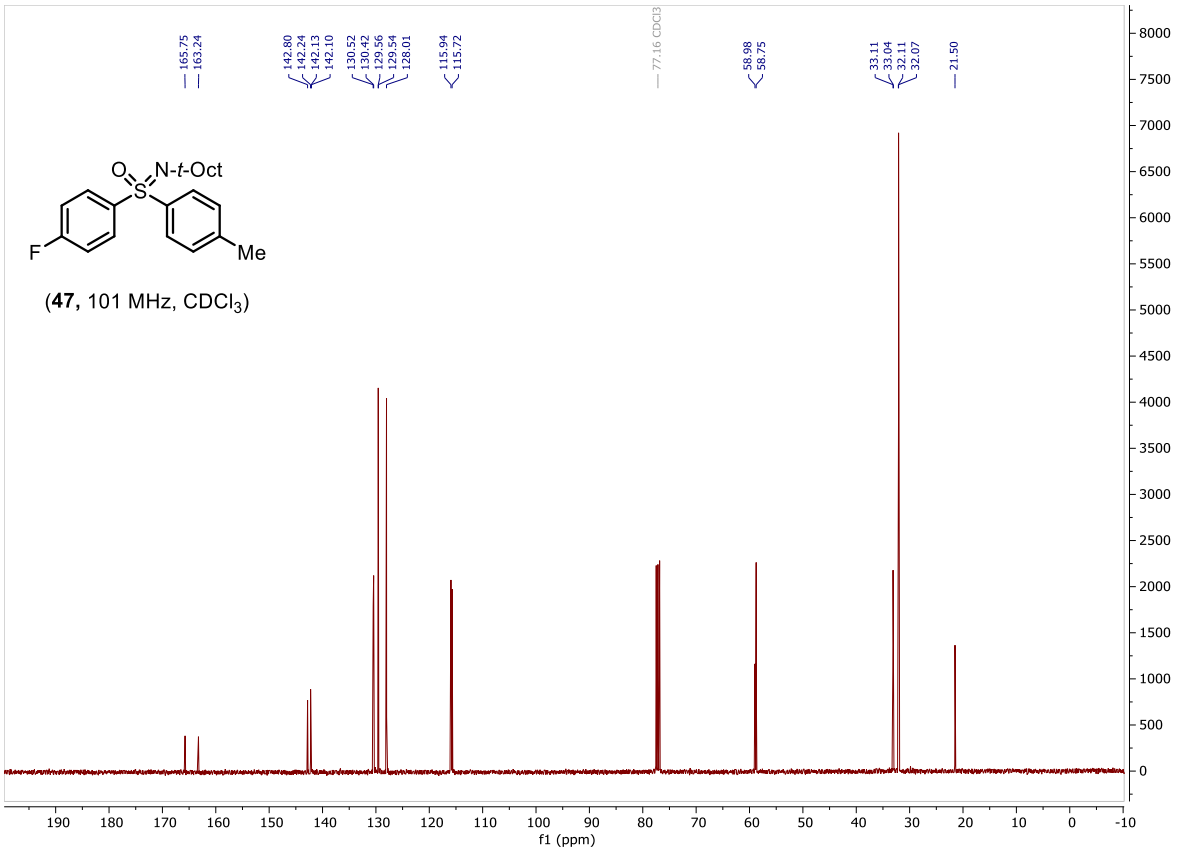

Ns-N
N-t-Oct
Me
S
Me
(45, 101 MHz, CDCl3)
f1 (ppm)


Ns-N
N-t-Oct
S
Me
(46, 400 MHz, CDCl3)
f1 (ppm)

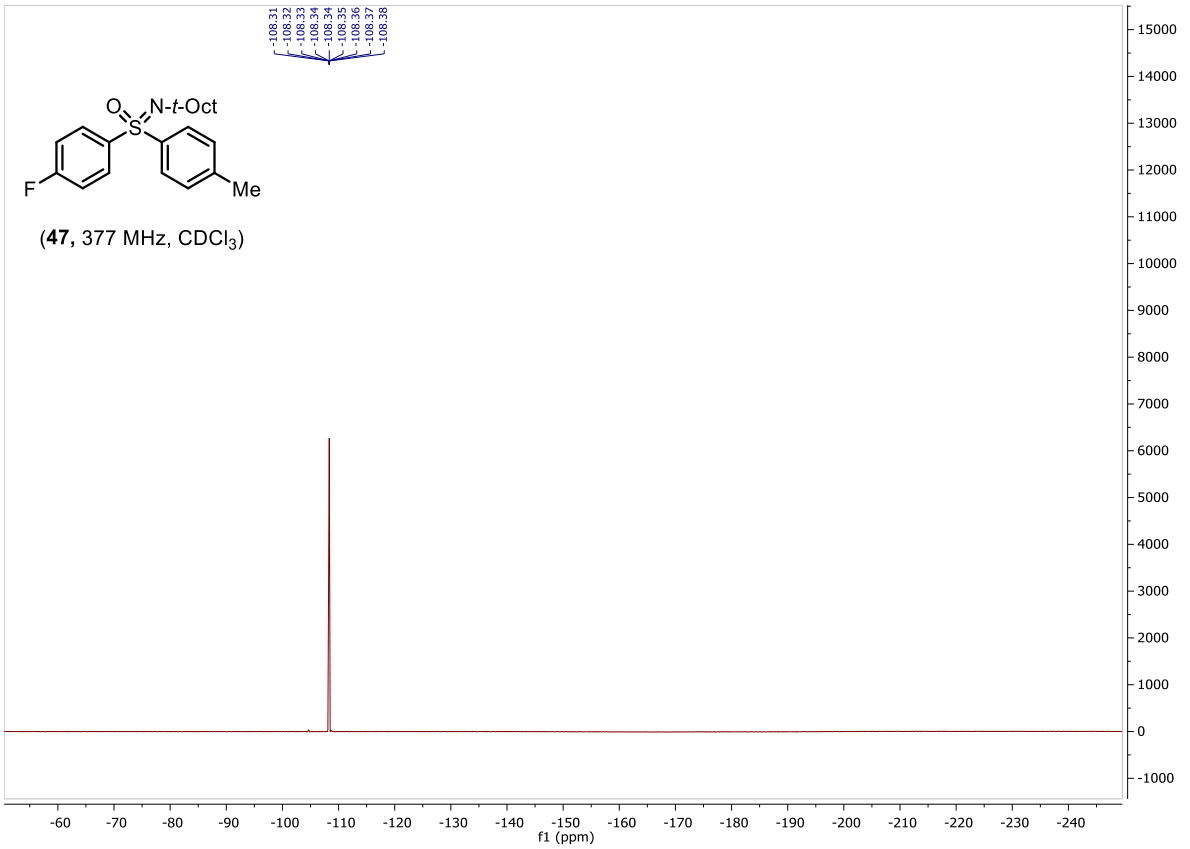

Ns-N
N-t-Oct
S
Me
(46, 101 MHz, CDCl3)
f1 (ppm)

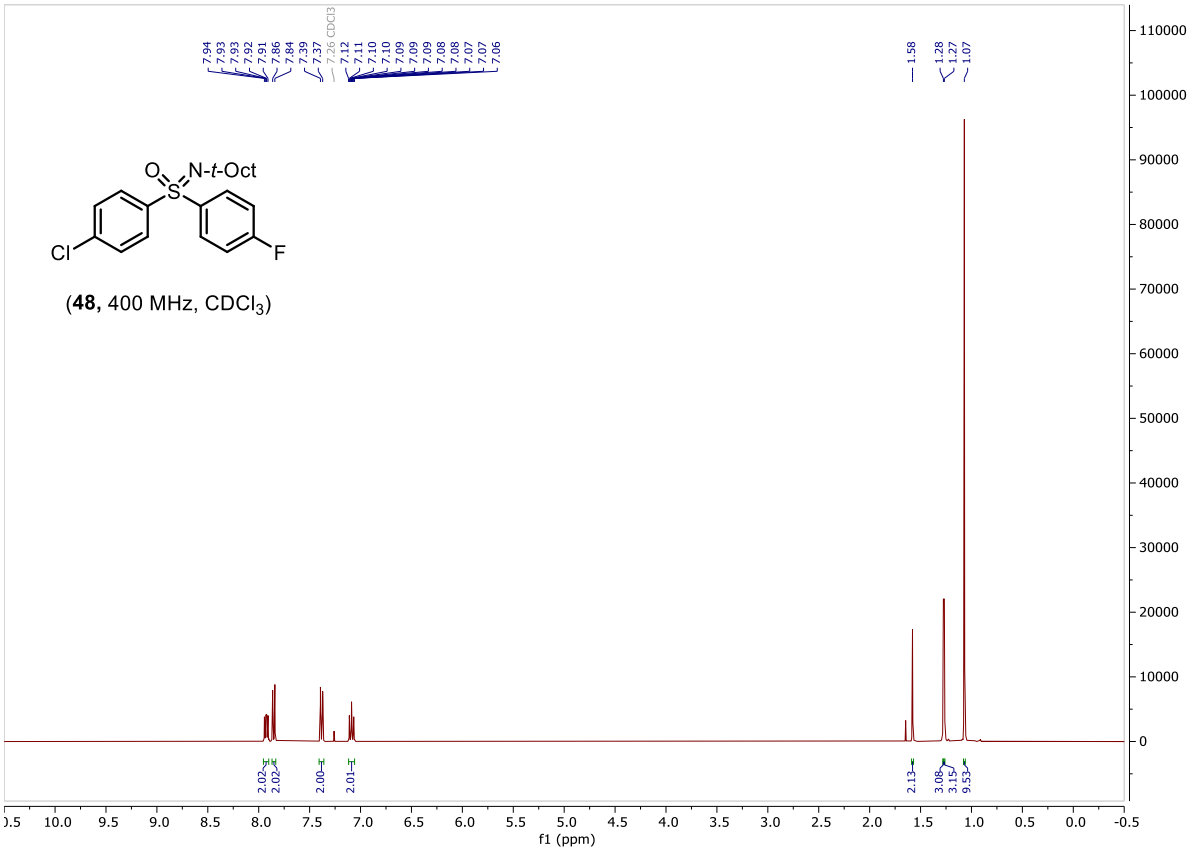


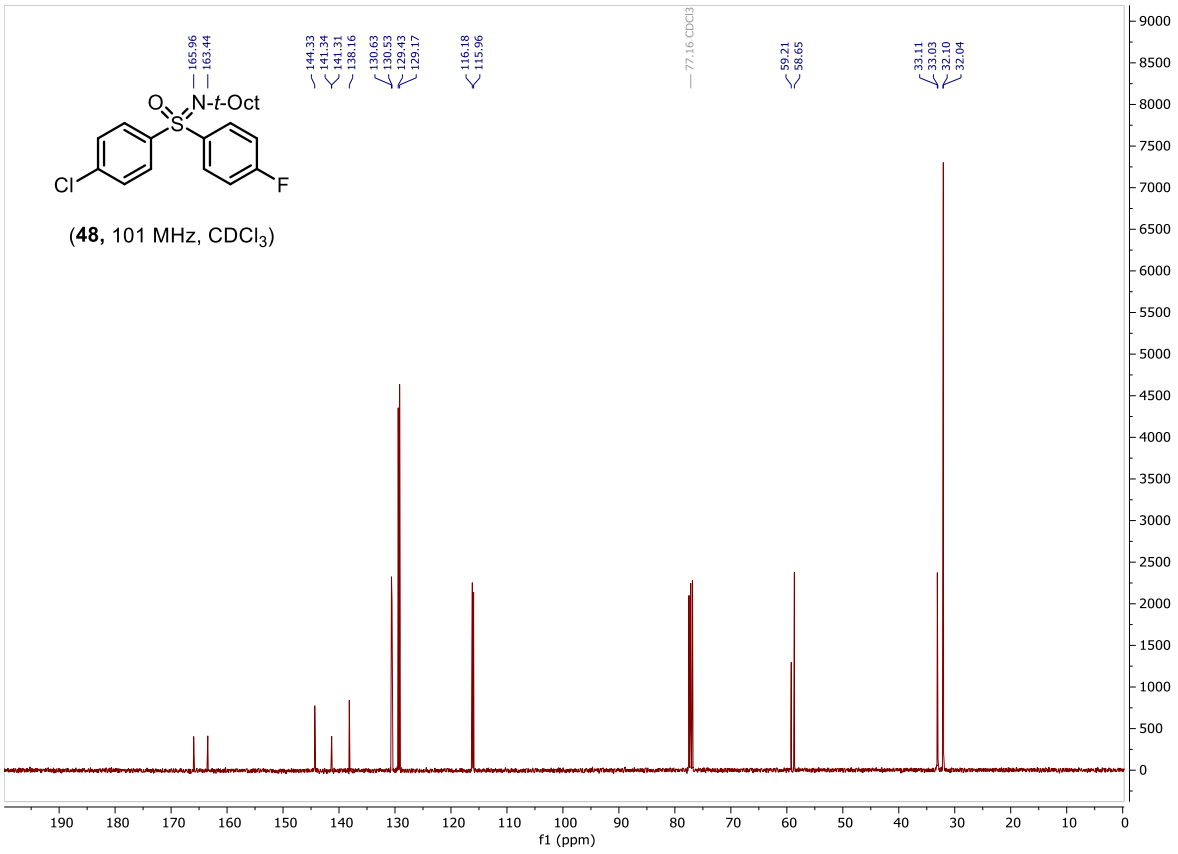
(**47**, 400 MHz, $CDCl_3$)

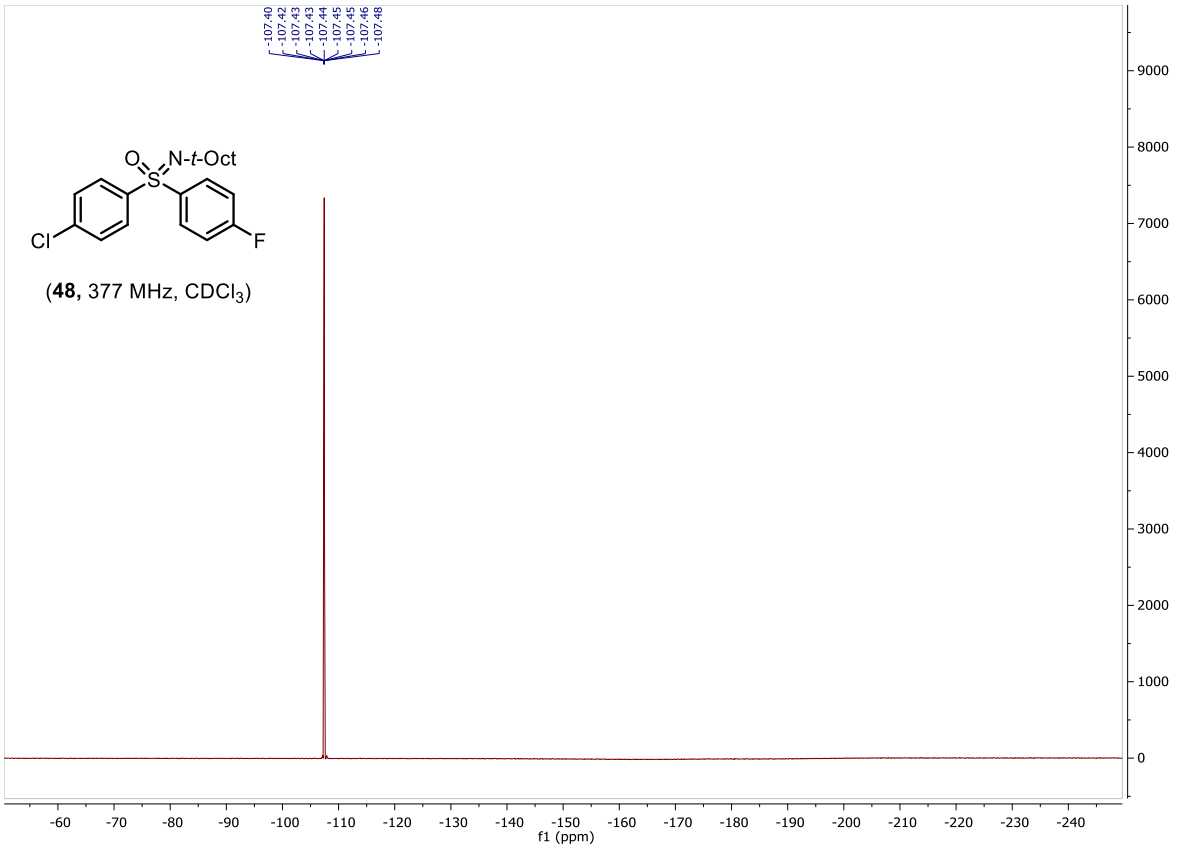


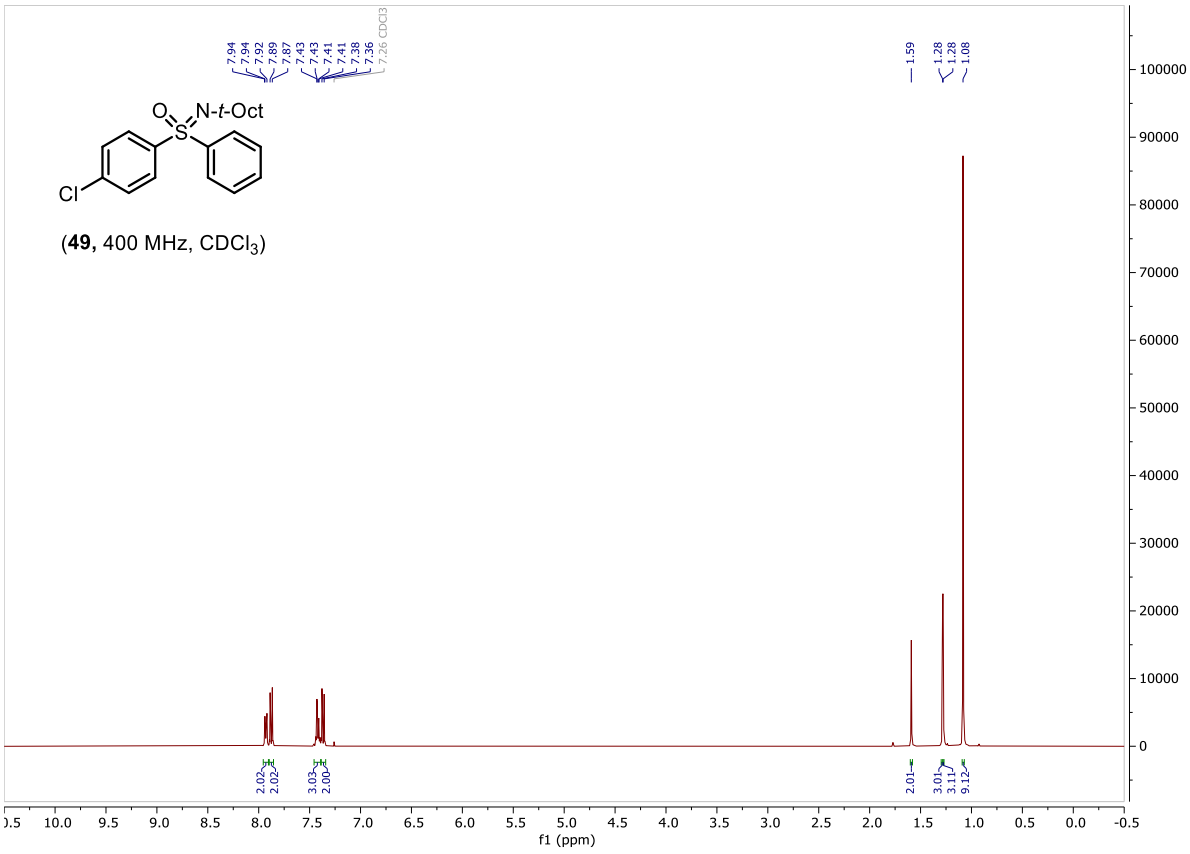
(**47**, 101 MHz, $CDCl_3$)

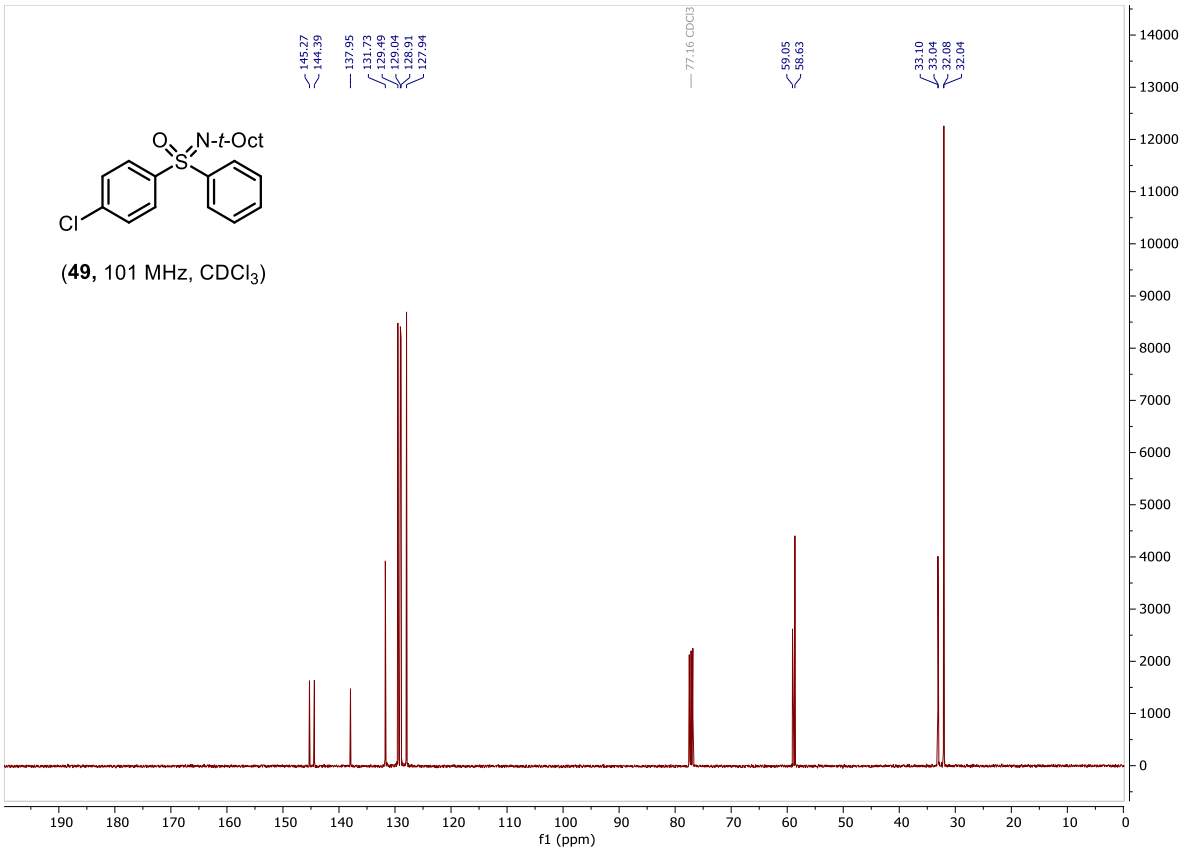

-108.31
-108.32
-108.33
-108.34
-108.34
-108.35
-108.36
-108.37
-108.38
O
S
N-t-Oct
F
Me
(47, 377 MHz, CDCl3)
f1 (ppm)

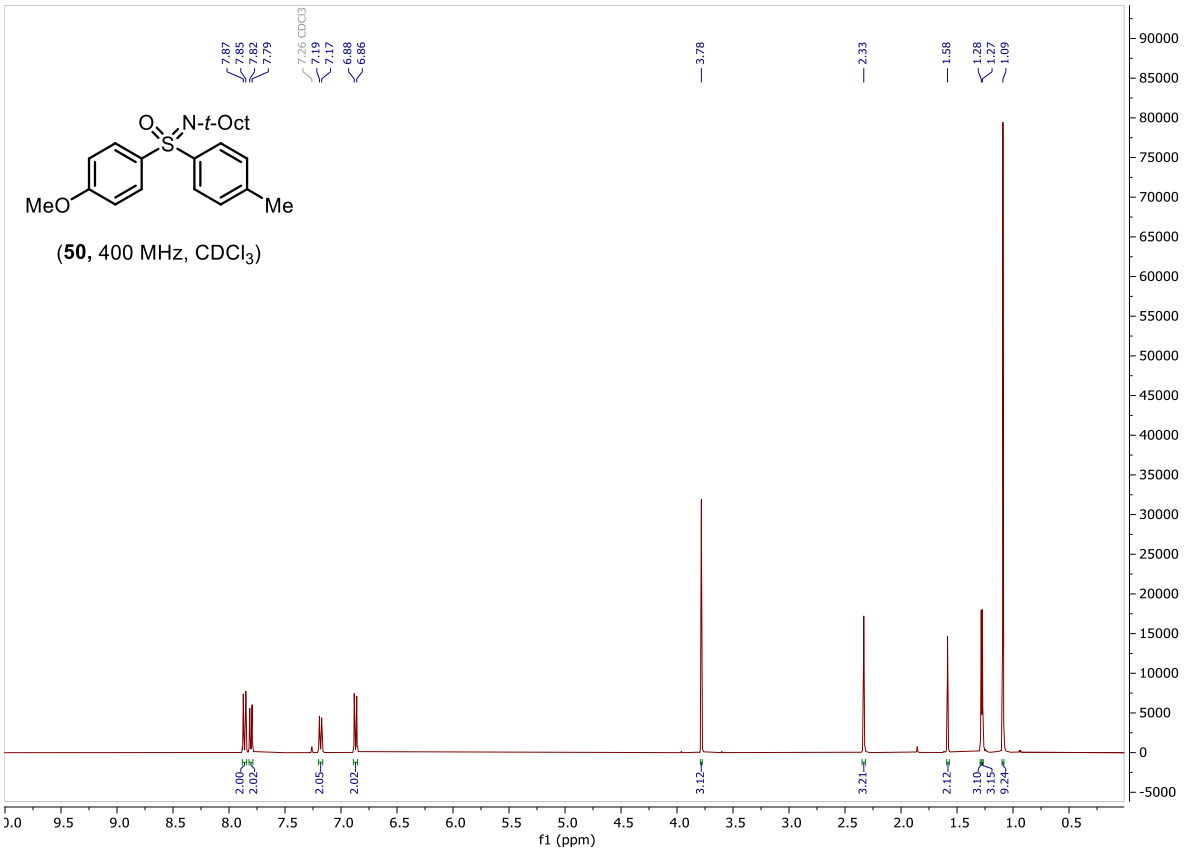

7.94
7.93
7.93
7.92
7.91
7.86
7.84
7.39
7.37
7.26 CDCl3
7.12
7.11
7.10
7.10
7.09
7.09
7.09
7.08
7.08
7.07
7.07
7.06
1.58
1.28
1.27
1.07
O
S
N-t-Oct
Cl
F
(48, 400 MHz, CDCl3)
2.02
2.02
2.00
2.01
2.13
3.08
3.15
9.53
f1 (ppm)


165.96
163.44
144.33
141.34
141.31
138.16
130.63
130.53
129.43
129.17
116.18
115.96
77.16 CDCl3
59.21
58.65
33.11
33.03
32.10
32.04
O
S
N-t-Oct
Cl
F
(48, 101 MHz, CDCl3)
f1 (ppm)

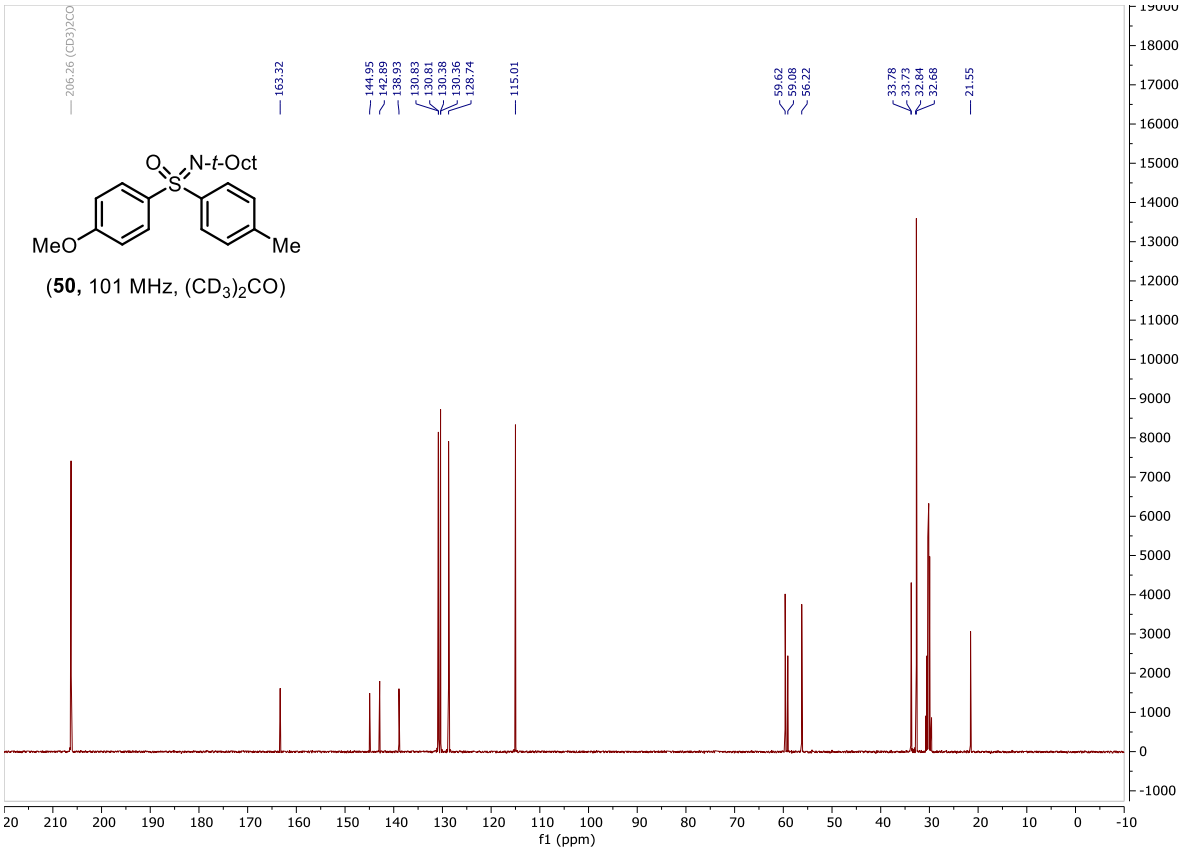

-107.40
-107.42
-107.43
-107.43
-107.44
-107.45
-107.45
-107.46
-107.48
O
S
N-t-Oct
Cl
F
(48, 377 MHz, CDCl3)
f1 (ppm)


7.94
7.94
7.92
7.89
7.87
7.43
7.43
7.41
7.41
7.38
7.36
7.26 CDCl3
1.59
1.28
1.28
1.08
O
S
N-t-Oct
Cl
(49, 400 MHz, CDCl3)
2.02
2.02
3.03
2.00
2.01
3.01
3.11
9.12
f1 (ppm)

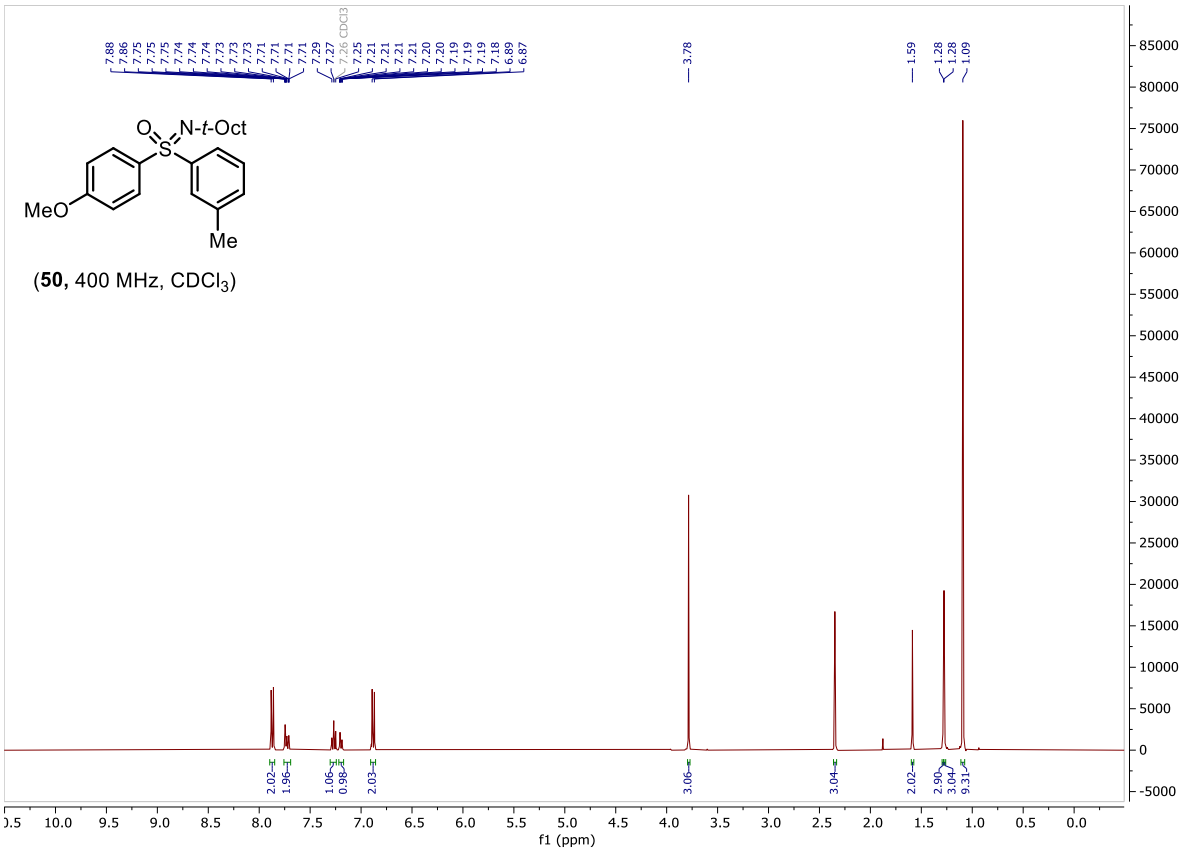

145.27
144.39
137.95
131.73
129.49
129.04
128.91
127.94
77.16 CDCl3
59.05
58.63
33.10
33.04
32.08
32.04
O
S
N-t-Oct
Cl
(49, 101 MHz, CDCl3)
f1 (ppm)



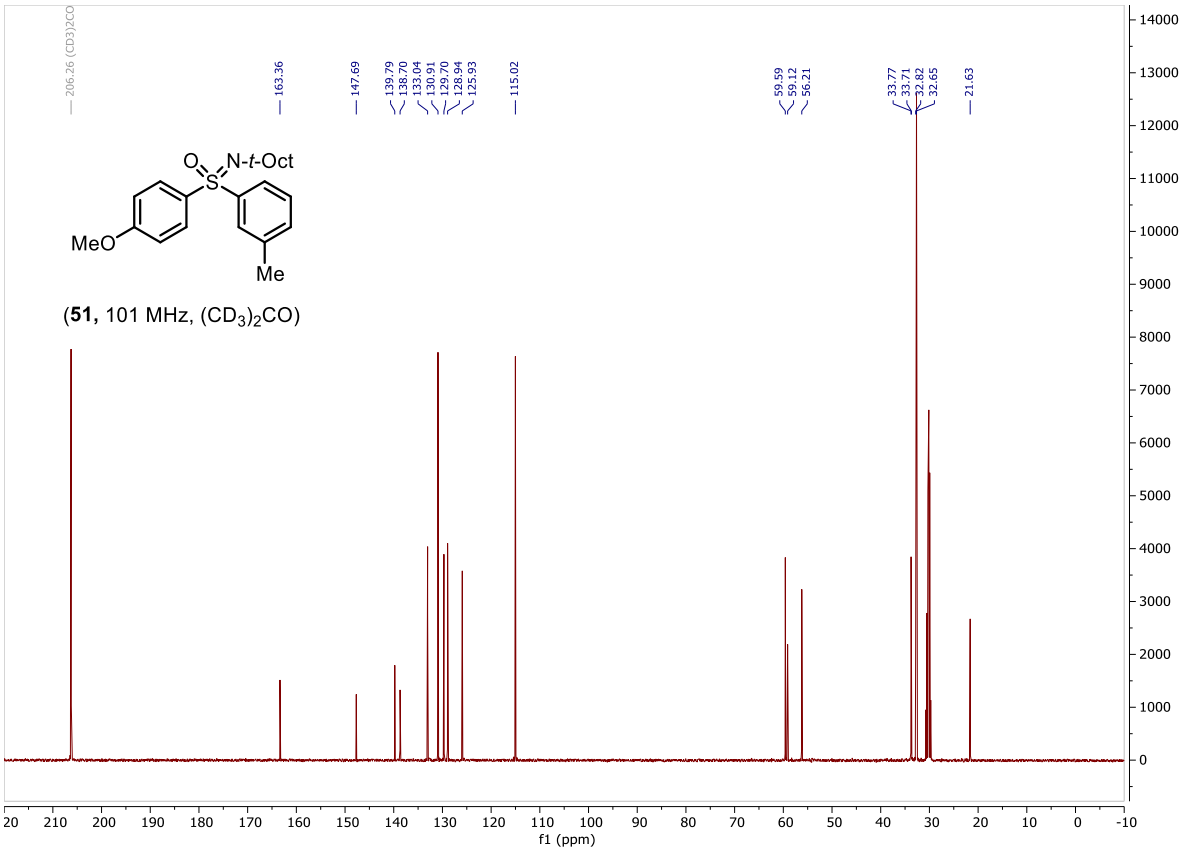
(**50,** 400 MHz, $CDCl_3$)



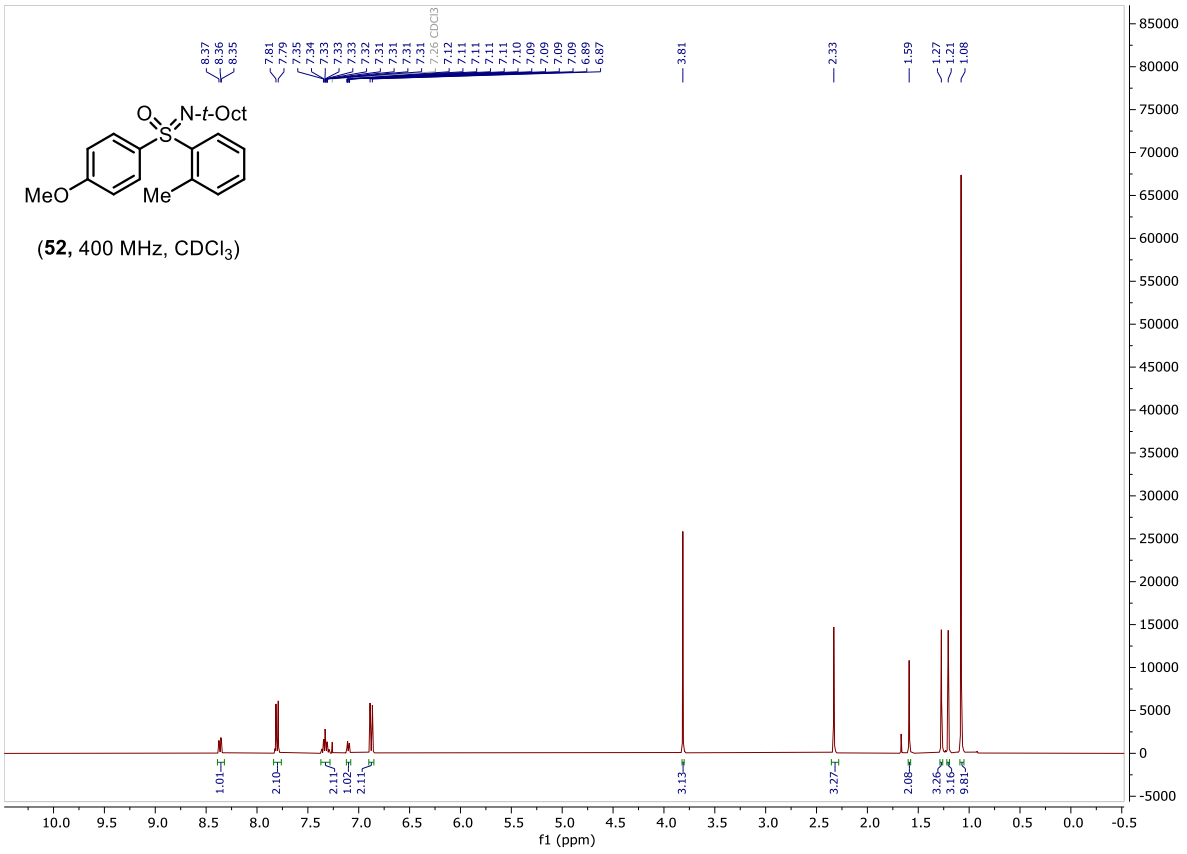
(**50,** 101 MHz, $(CD_3)_2CO$)

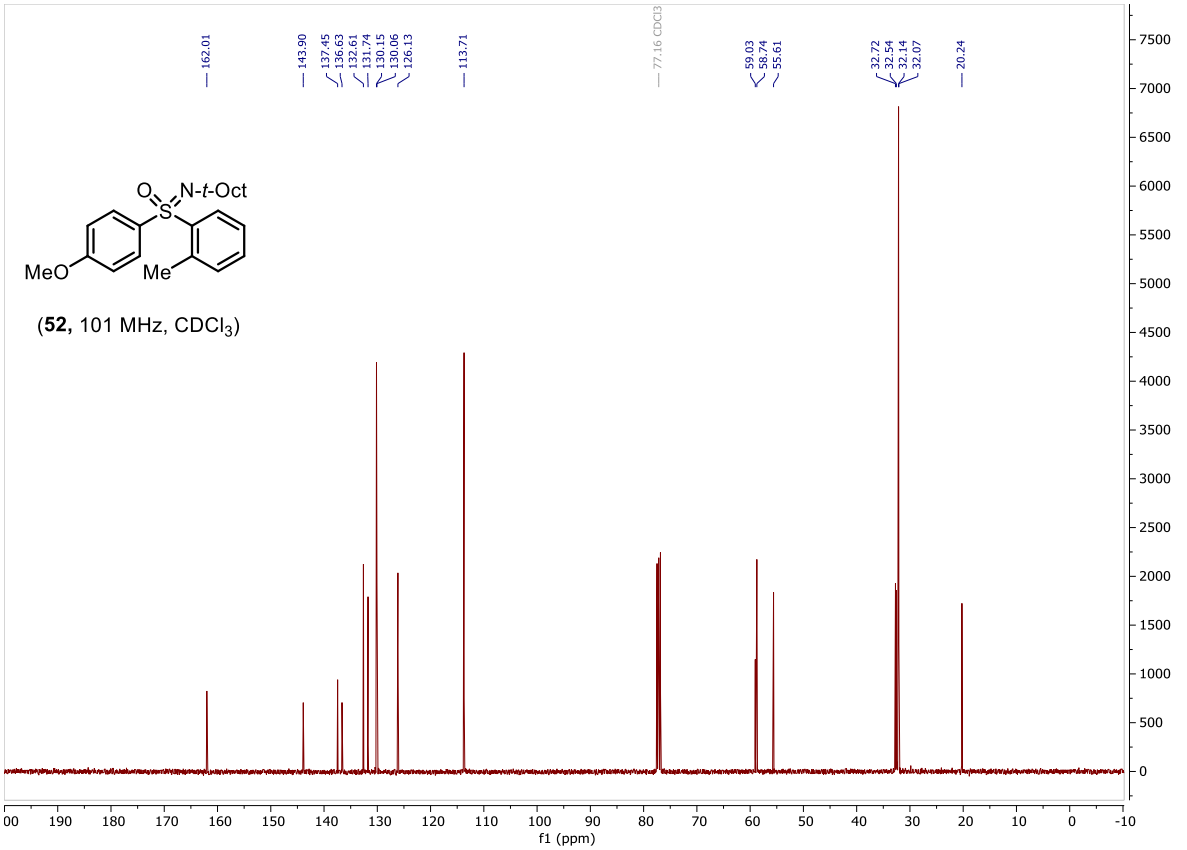


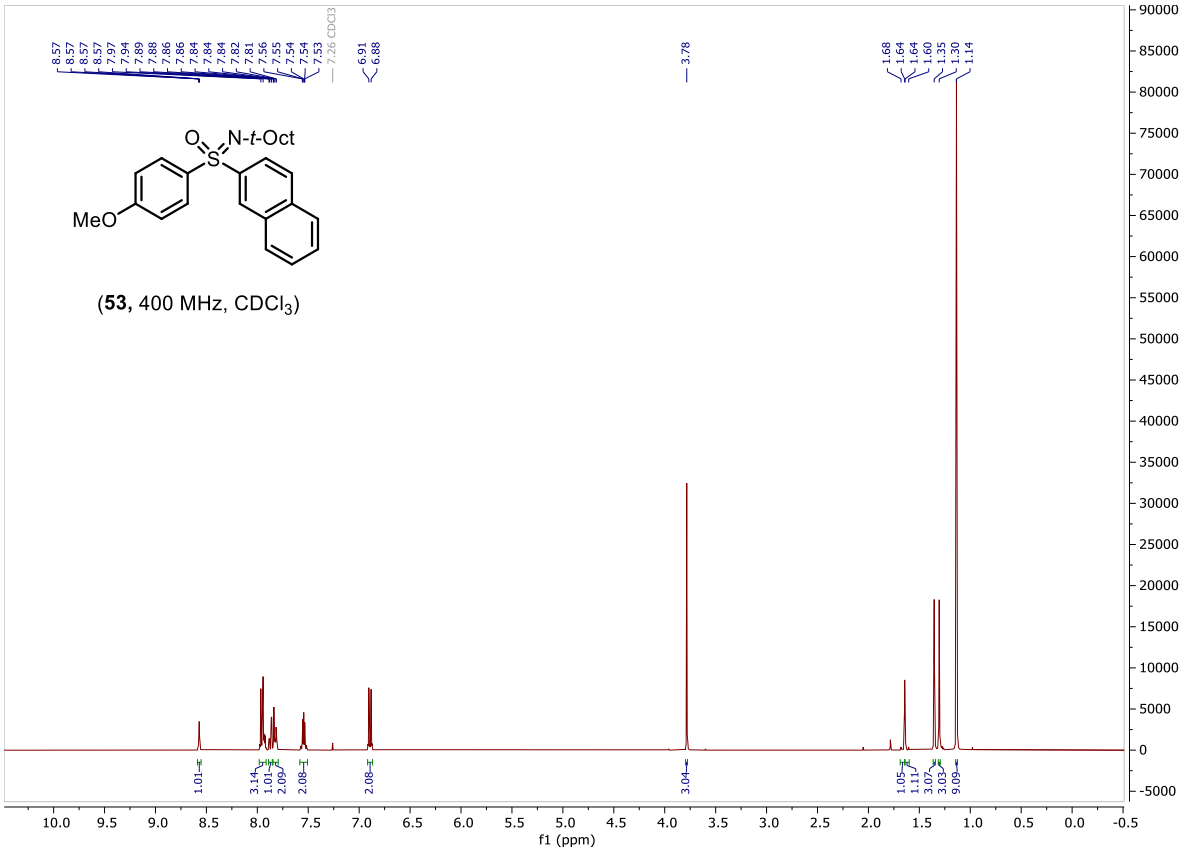
(**50,** 400 MHz, $CDCl_3$)



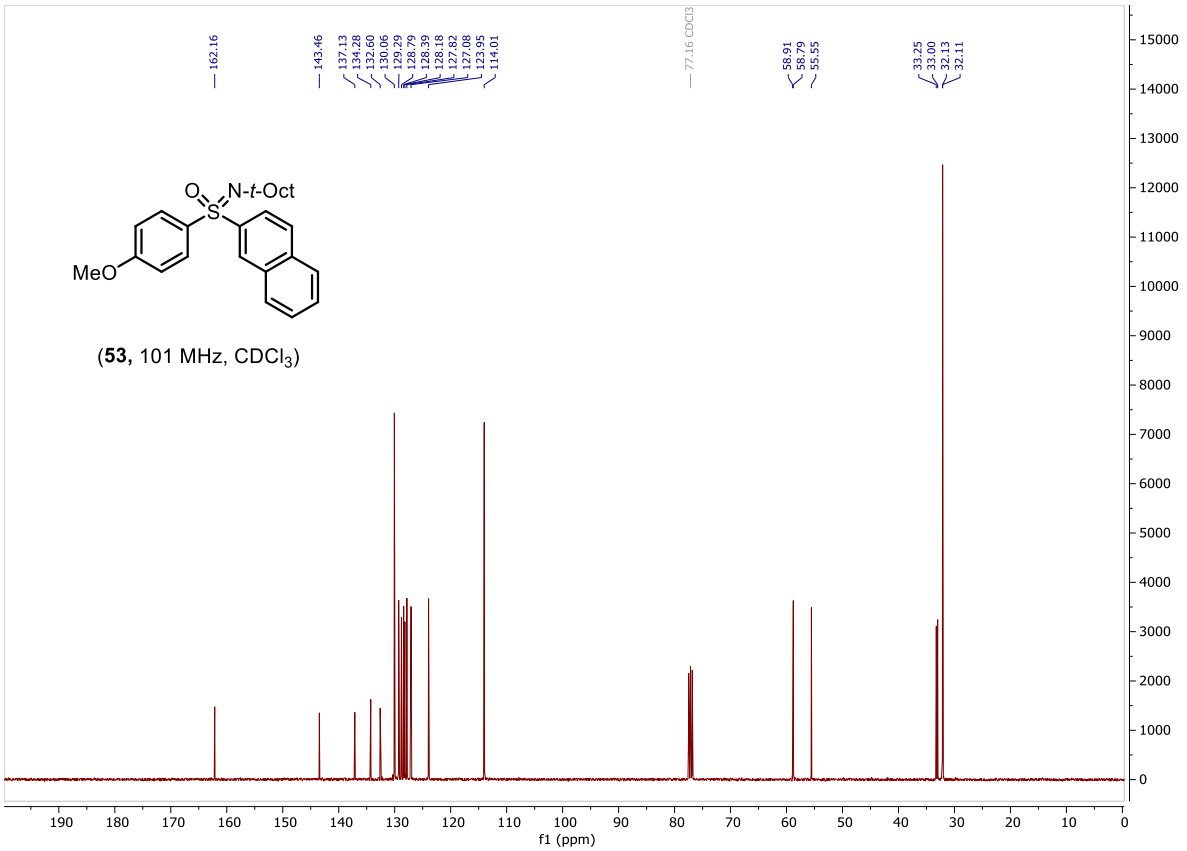
(**51,** 101 MHz, $(CD_3)_2CO$)


8.37
8.36
8.35
7.81
7.79
7.35
7.34
7.33
7.33
7.33
7.32
7.31
7.31
7.31
7.31
7.26 CDCl3
7.12
7.11
7.11
7.11
7.11
7.10
7.09
7.09
7.09
7.09
7.09
6.89
6.87
3.81
2.33
1.59
1.27
1.21
1.08
O
N-t-Oct
S
MeO
Me
(52, 400 MHz, CDCl3)
1.01
2.10
2.11
2.11
1.02
2.11
3.13
3.27
2.08
3.26
3.16
9.81
f1 (ppm)

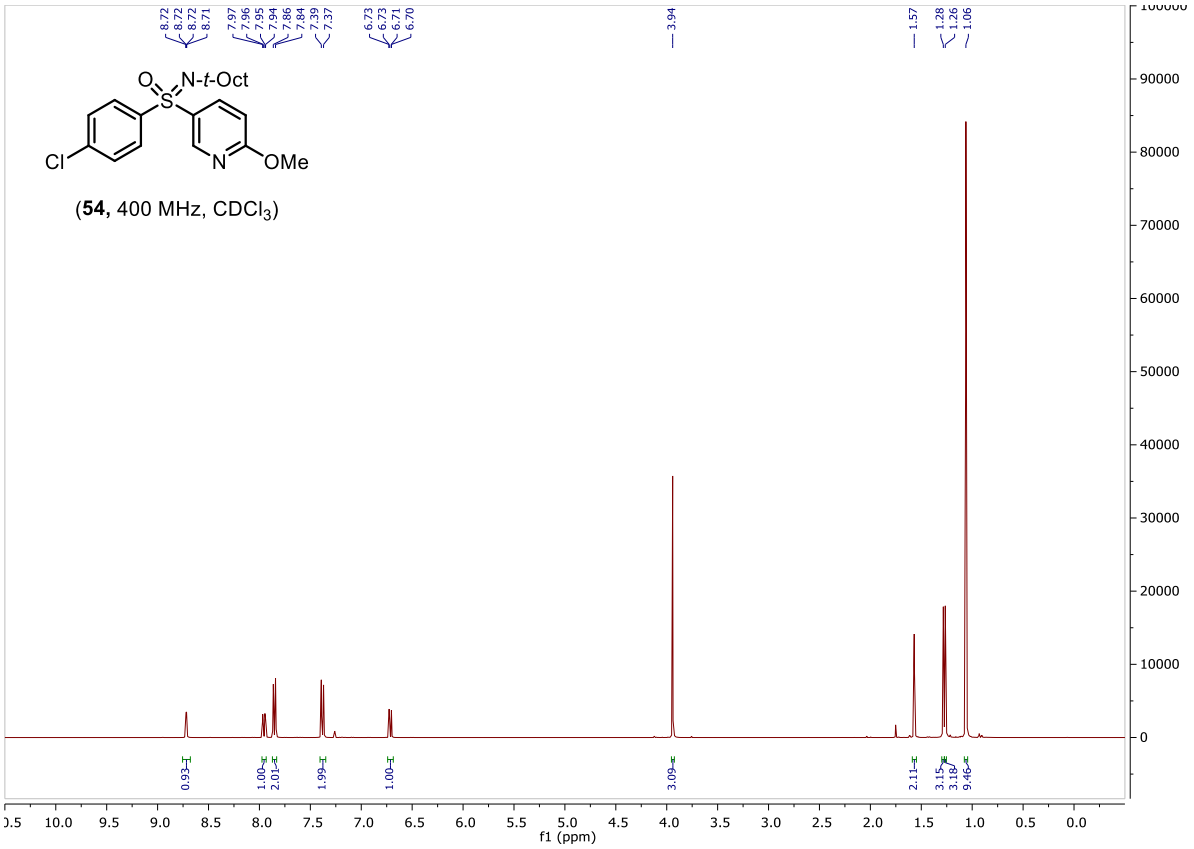

162.01
143.90
137.45
136.63
132.61
131.74
130.15
130.06
126.13
113.71
77.16 CDCl3
59.03
58.74
55.61
32.72
32.54
32.14
32.07
20.24
O
N-t-Oct
S
MeO
Me
(52, 101 MHz, CDCl3)
f1 (ppm)



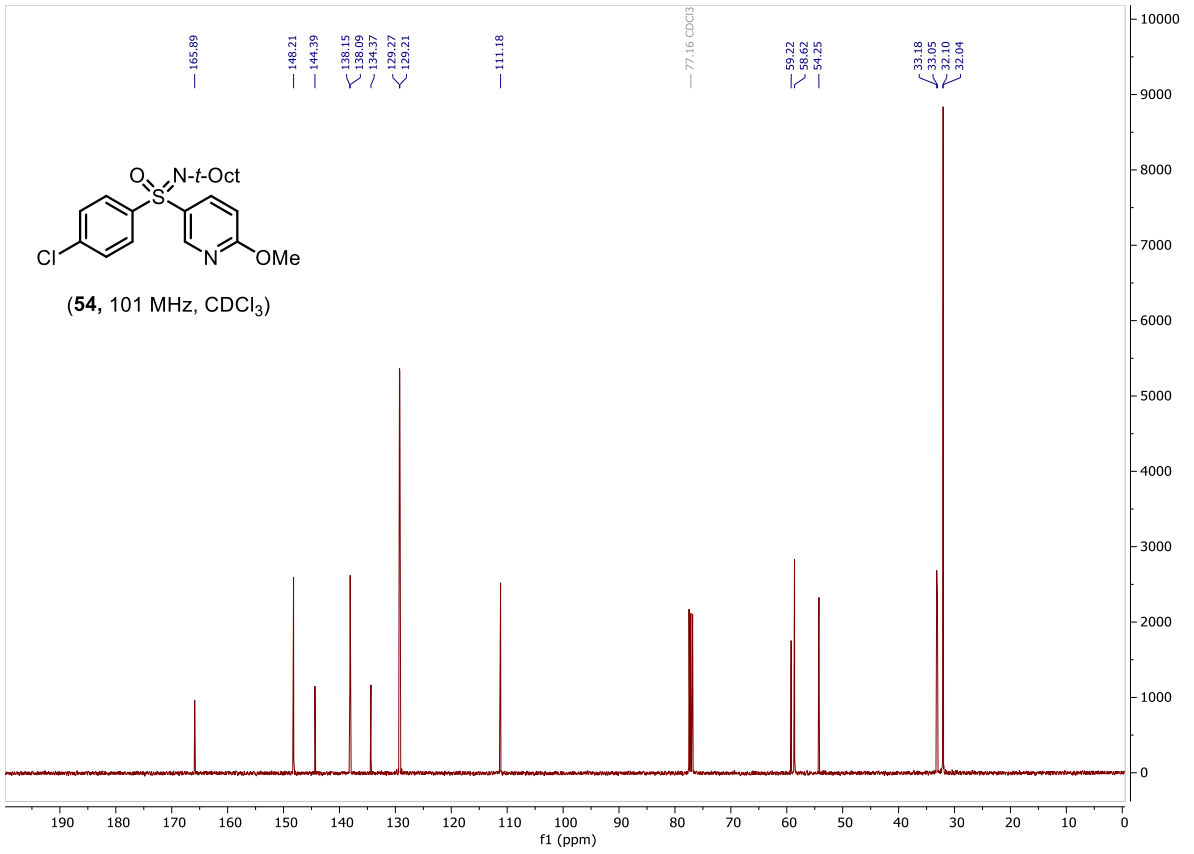
(**53,** 400 MHz, $CDCl_3$)



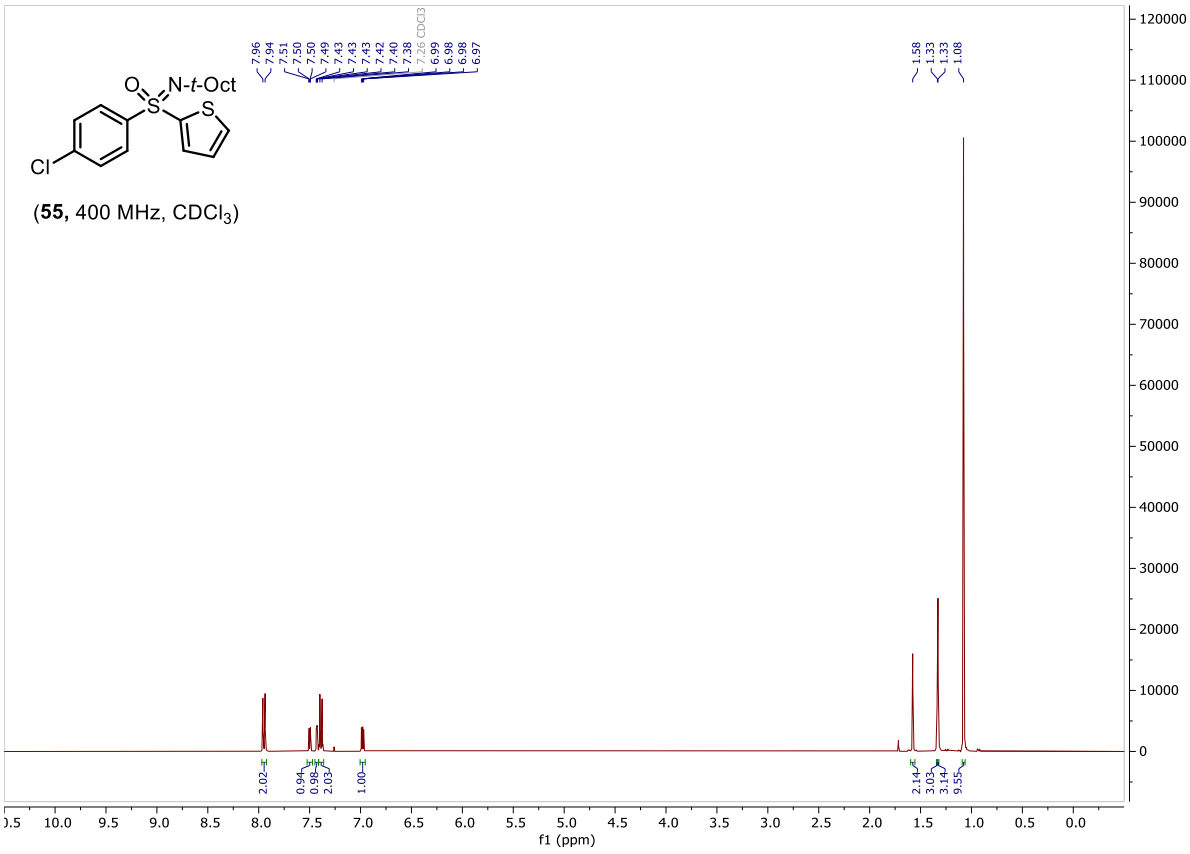
(**53,** 101 MHz, $CDCl_3$)



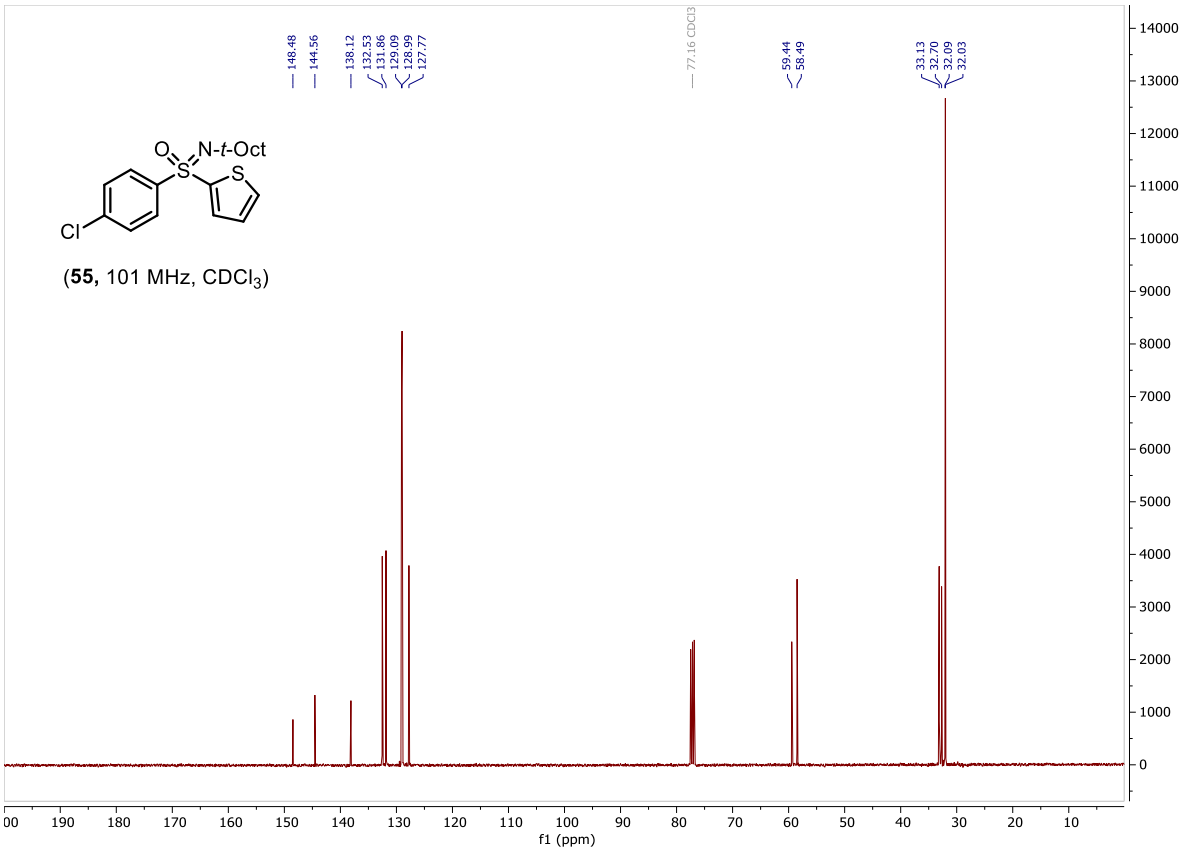
(**54,** 400 MHz, $CDCl_3$)



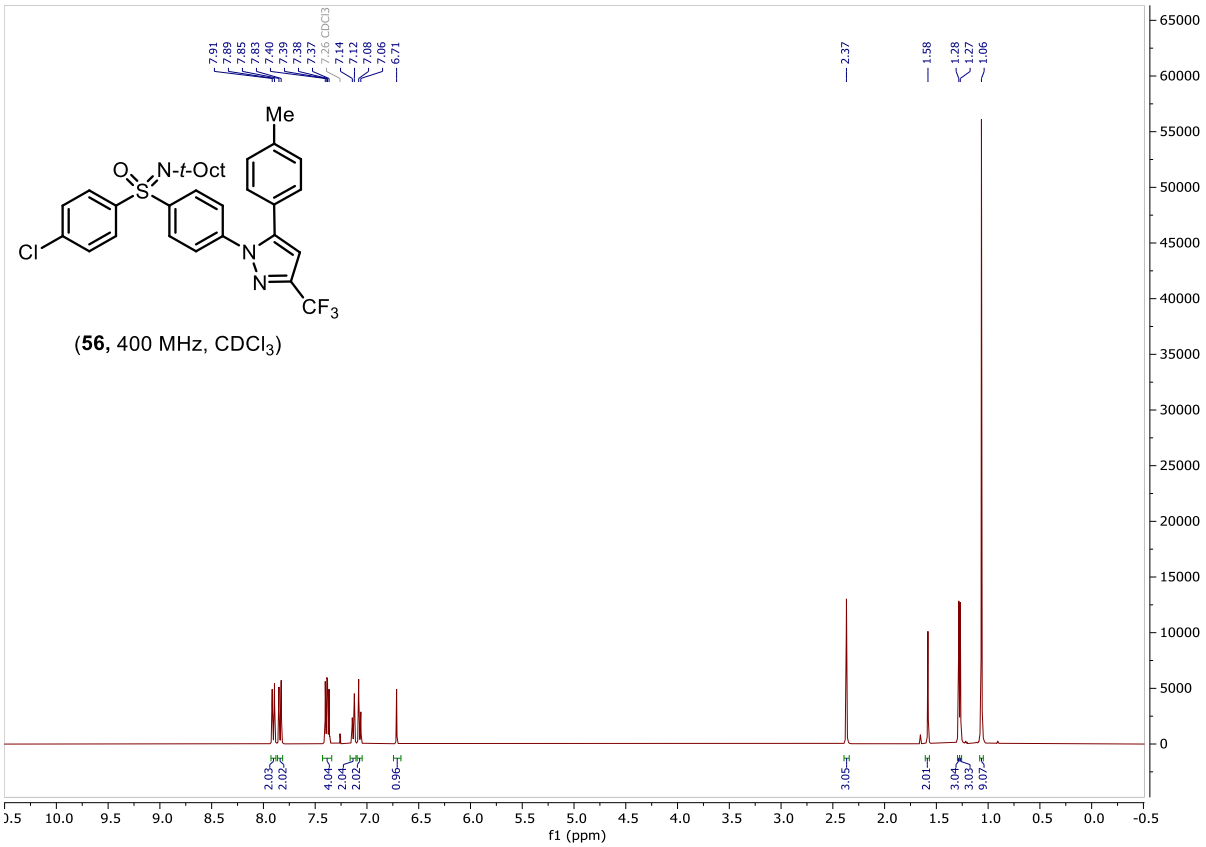
(**54,** 101 MHz, $CDCl_3$)



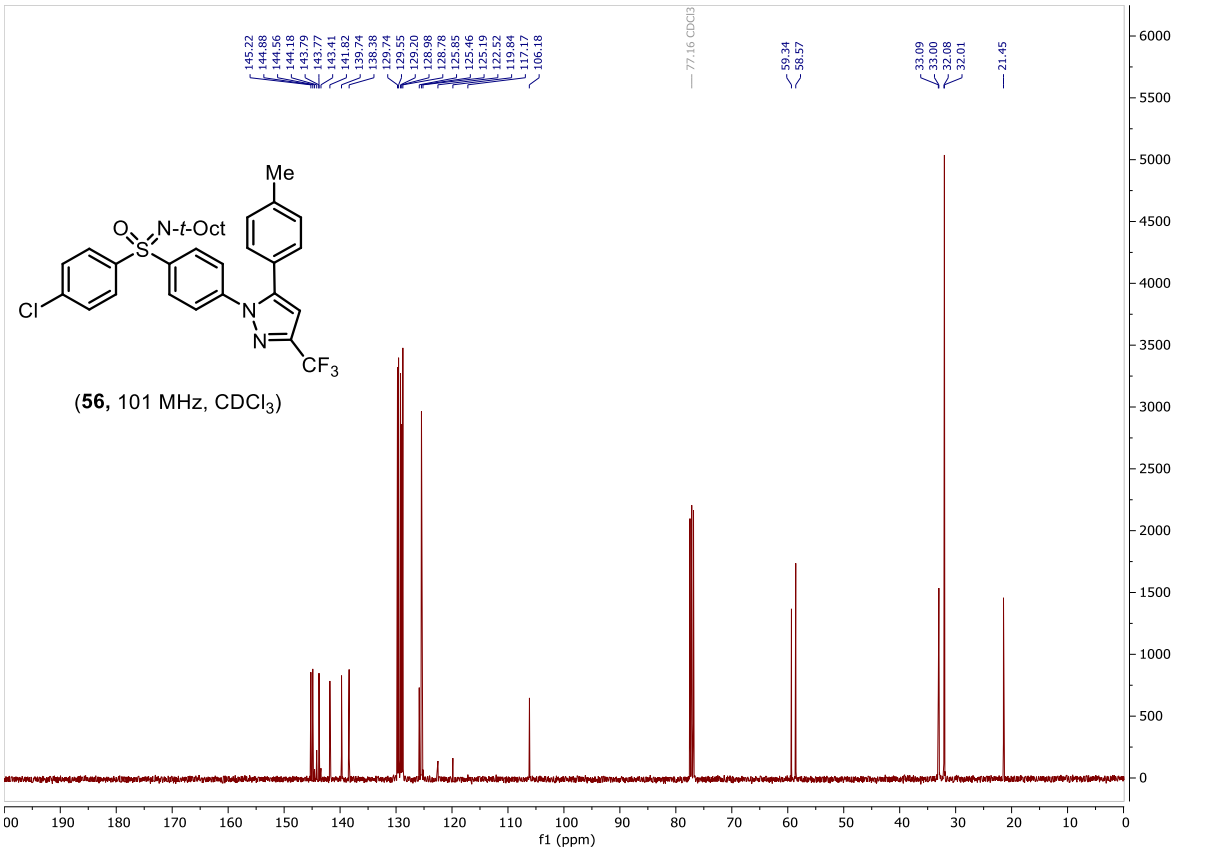
(**55,** 400 MHz, $CDCl_3$)



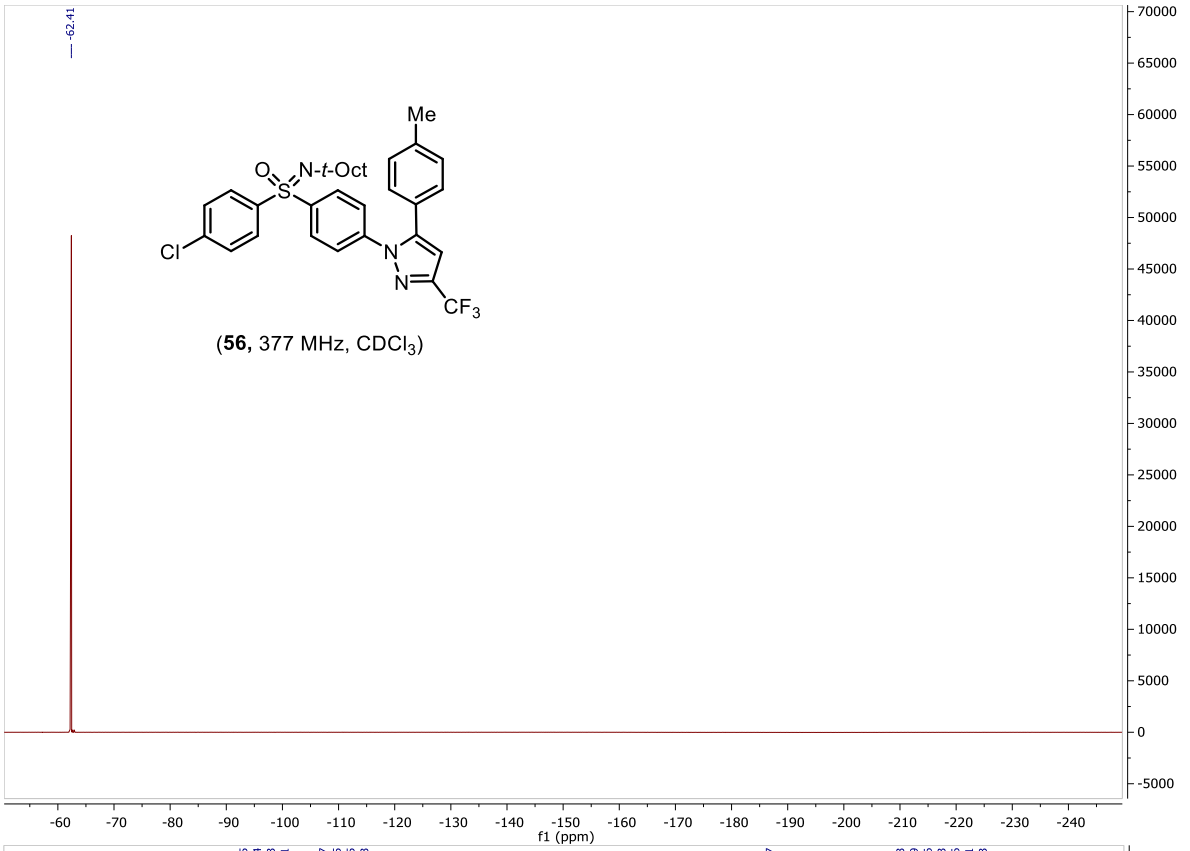
(**55,** 101 MHz, $CDCl_3$)



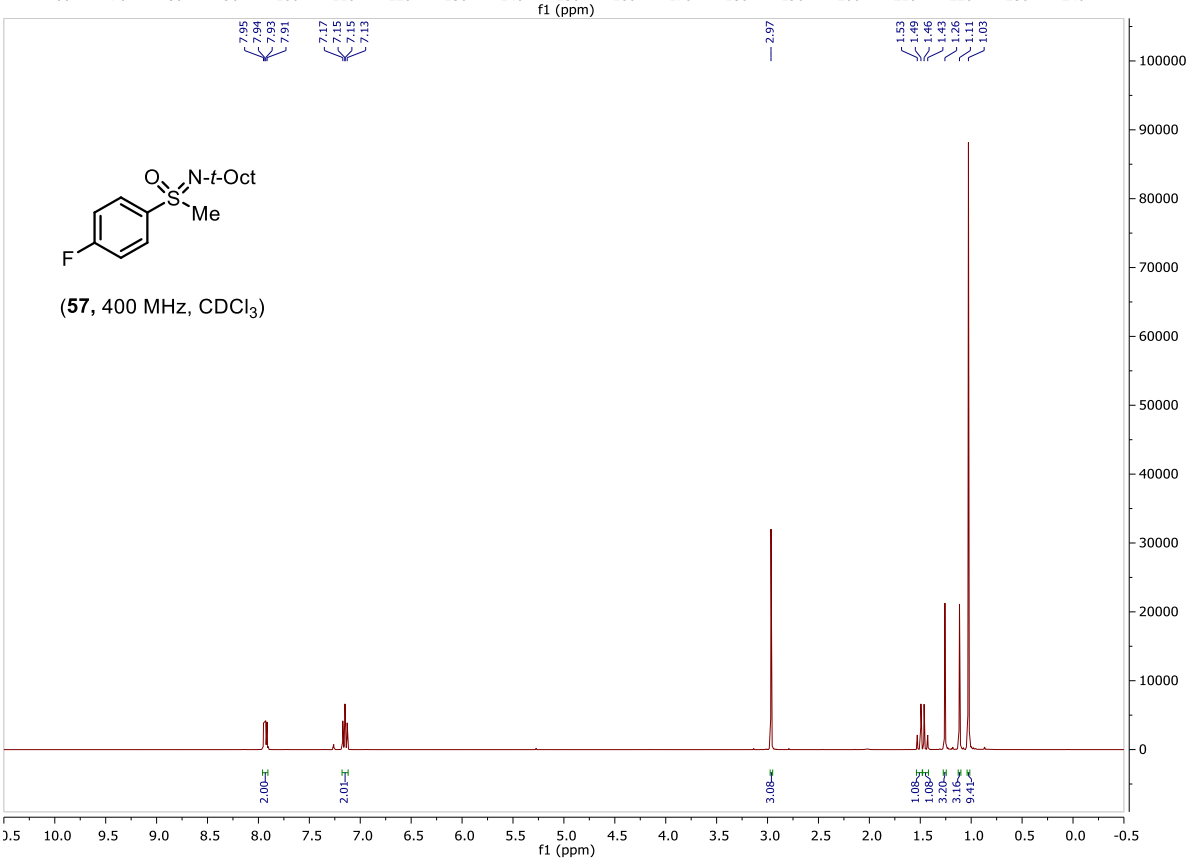
(**56,** 400 MHz, $CDCl_3$)



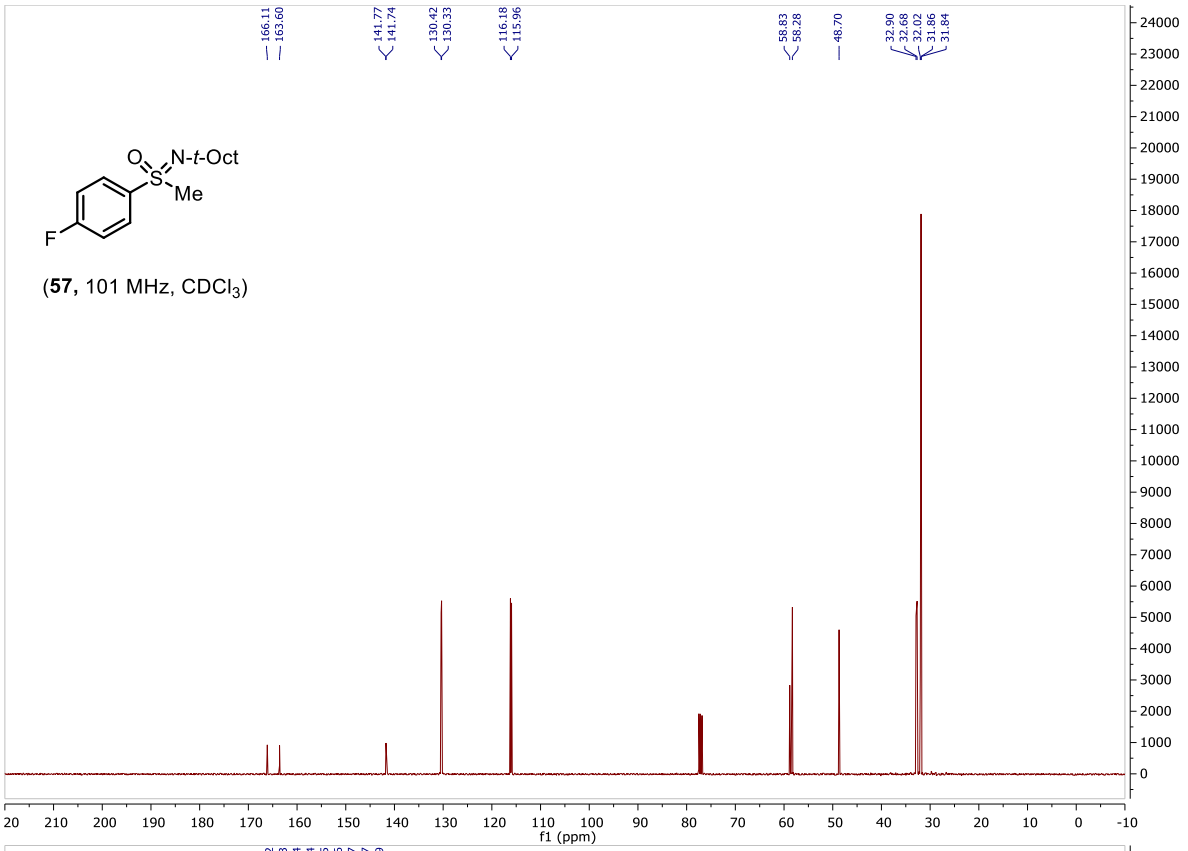
(**56,** 101 MHz, $CDCl_3$)



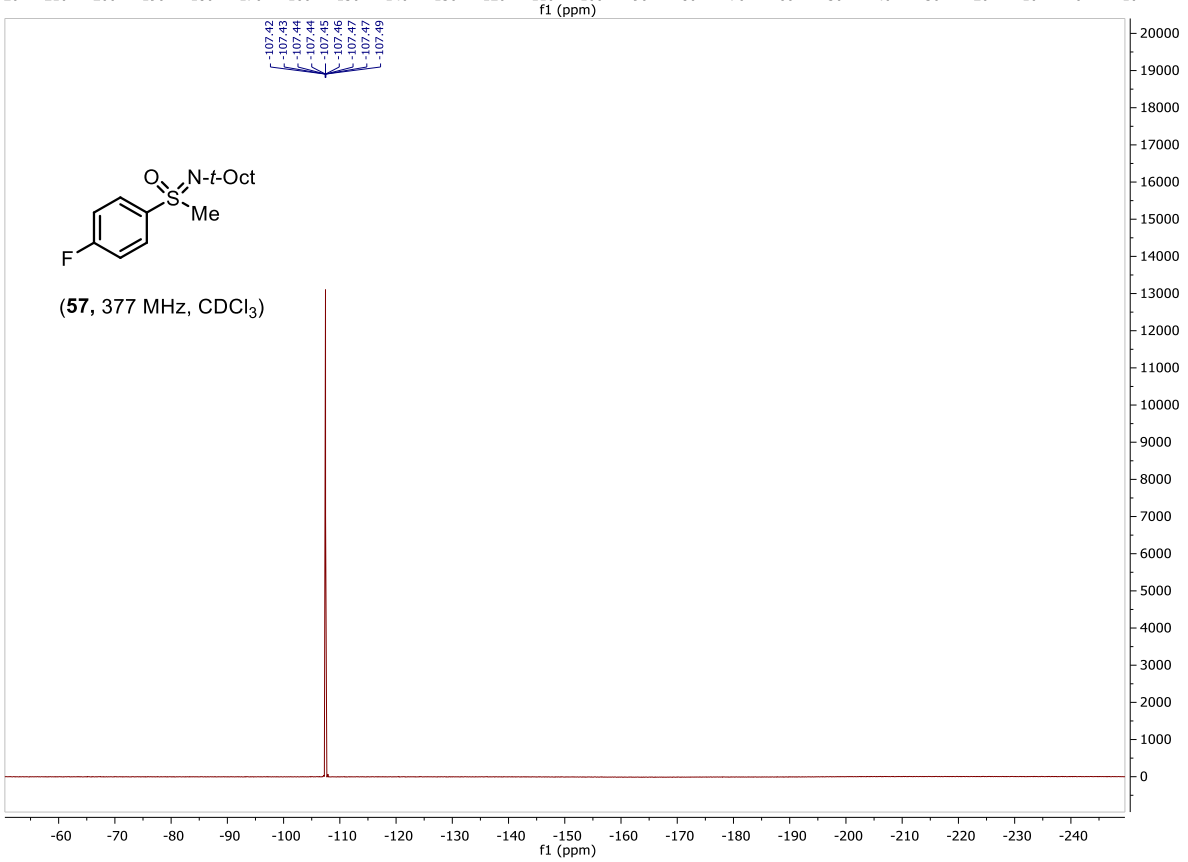
(**56,** 377 MHz, $CDCl_3$)



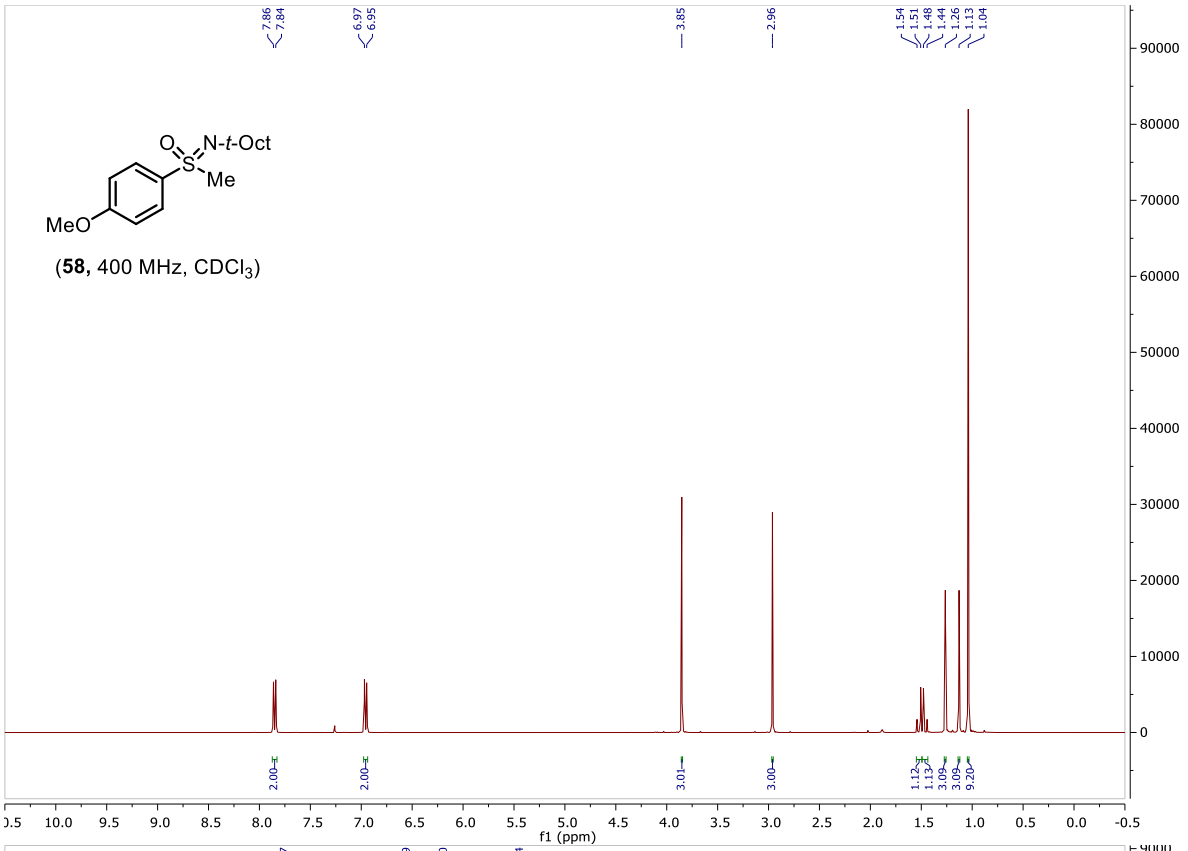
(**57,** 400 MHz, $CDCl_3$)



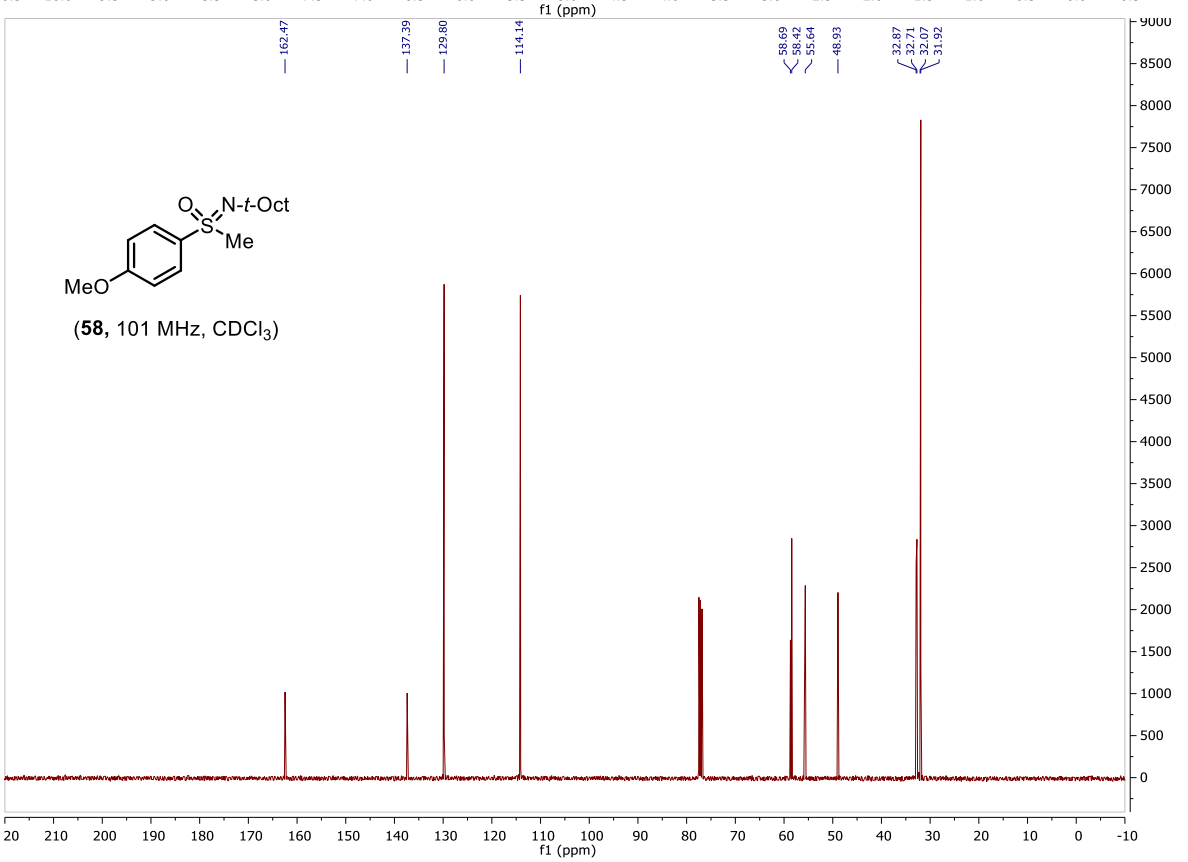
(**57,** 101 MHz, $CDCl_3$)



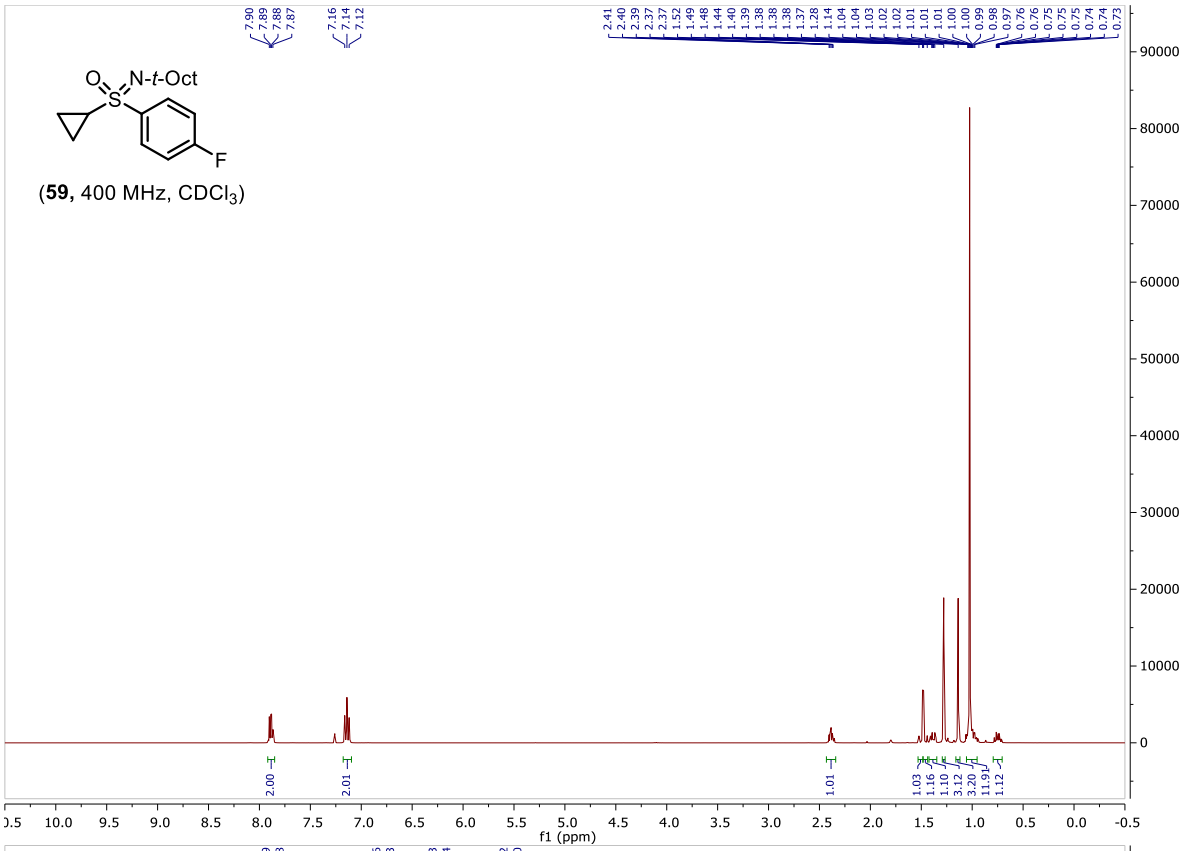
(**57,** 377 MHz, $CDCl_3$)



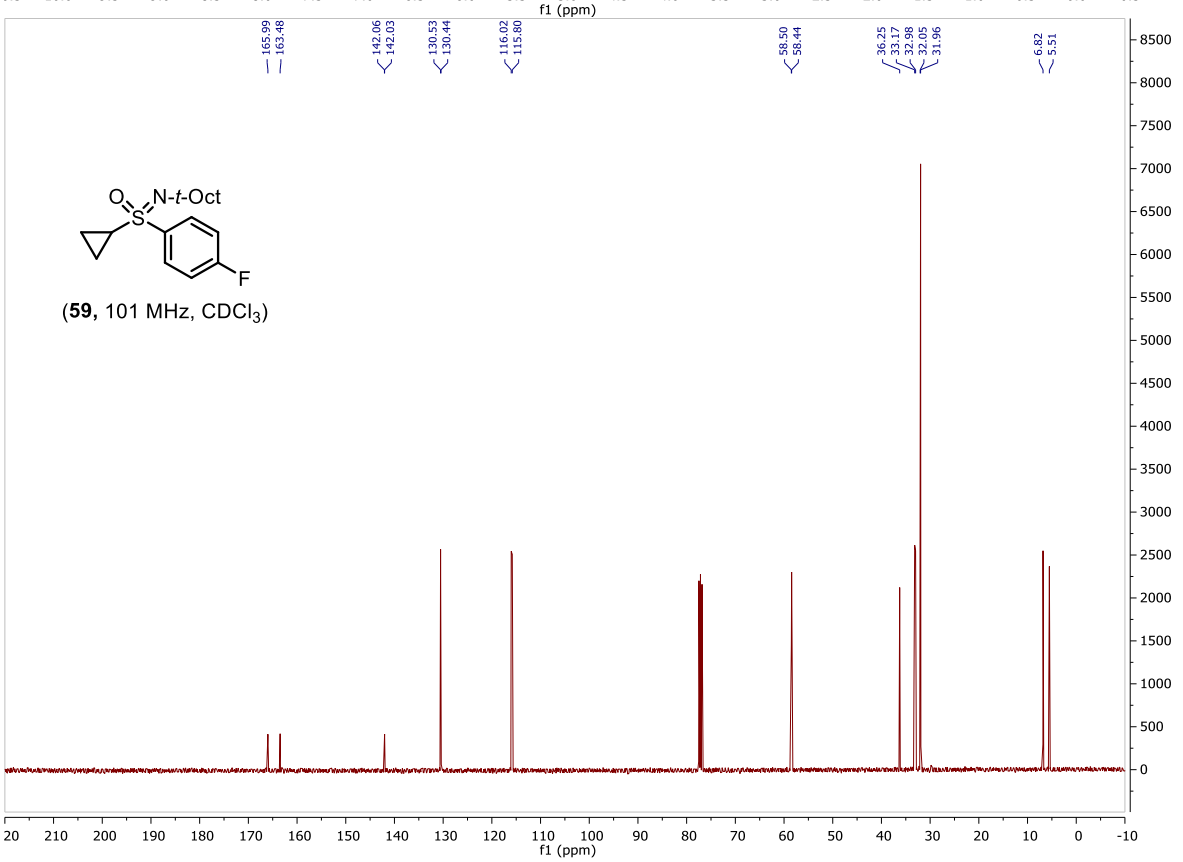
(**58,** 400 MHz, $CDCl_3$)



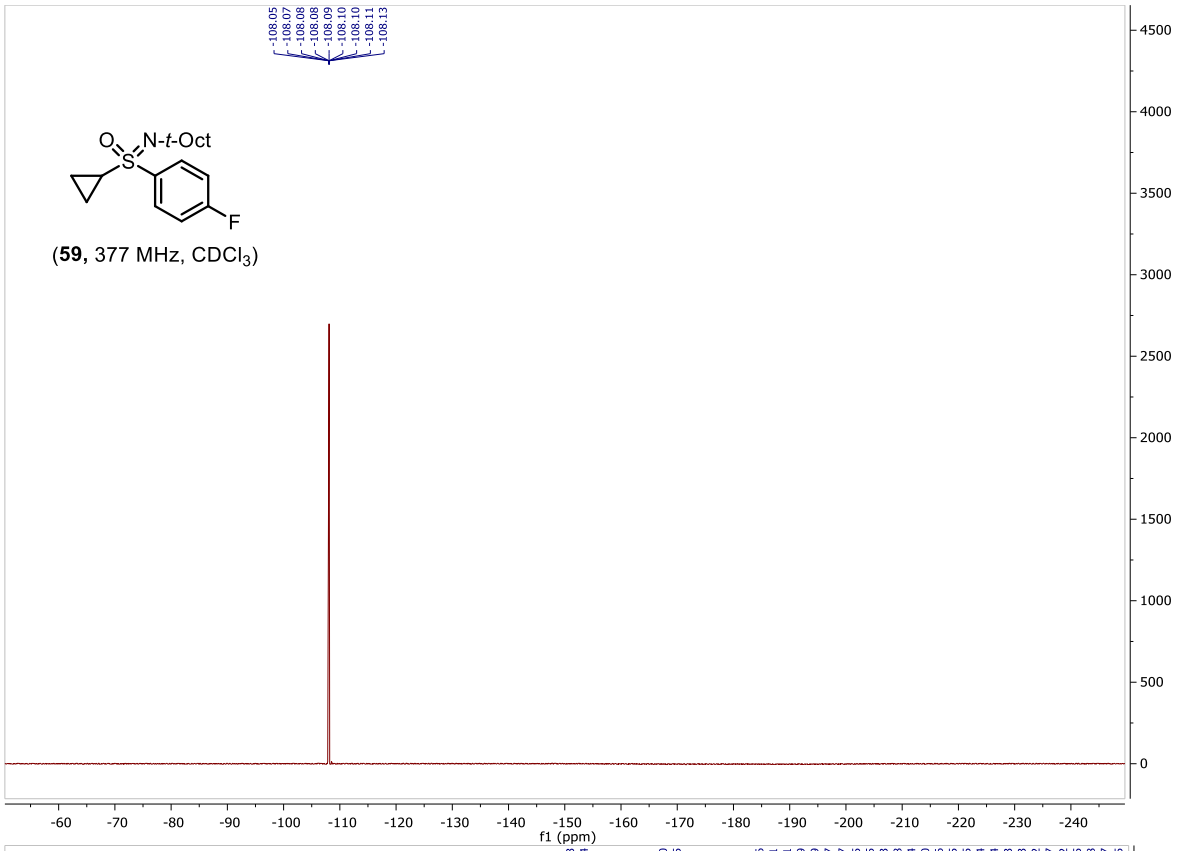
(**58,** 101 MHz, $CDCl_3$)



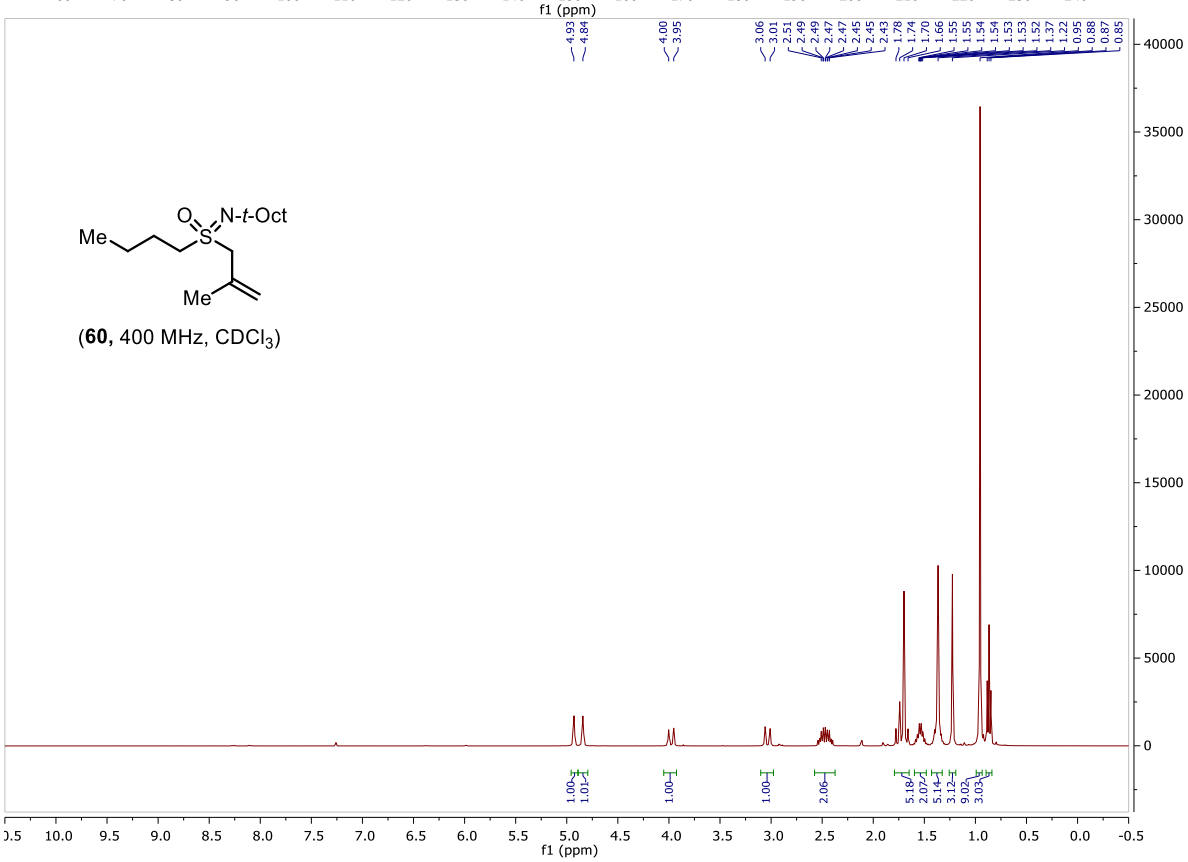
(**59**, 400 MHz, $CDCl_3$)



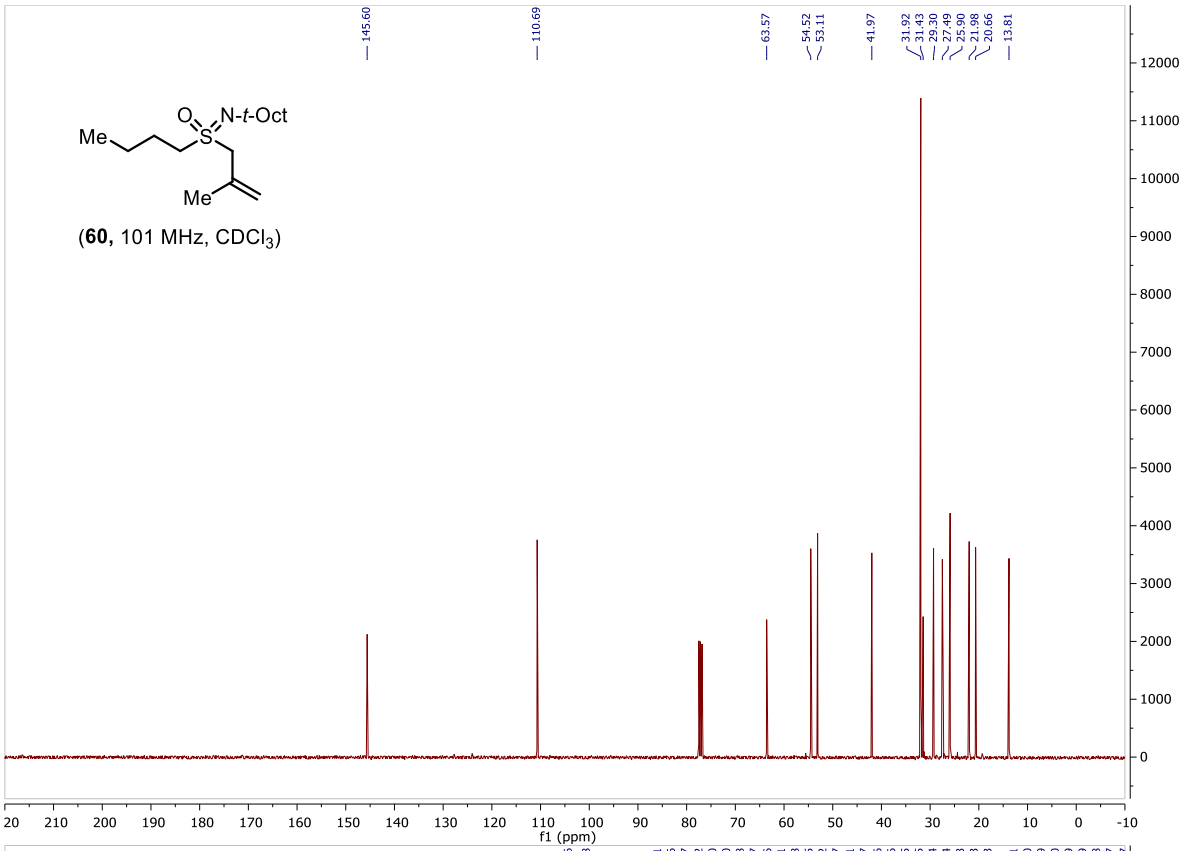
(**59**, 101 MHz, $CDCl_3$)



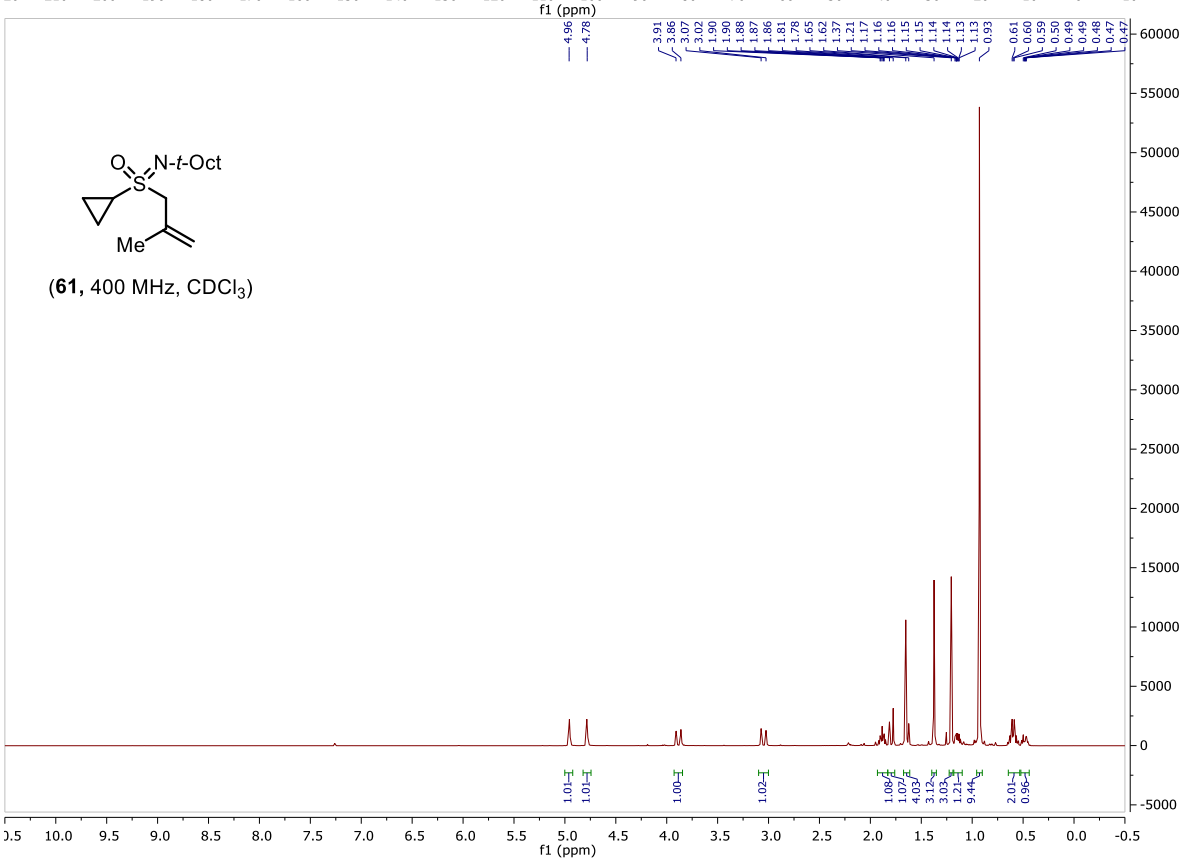
(**59,** 377 MHz, $CDCl_3$)



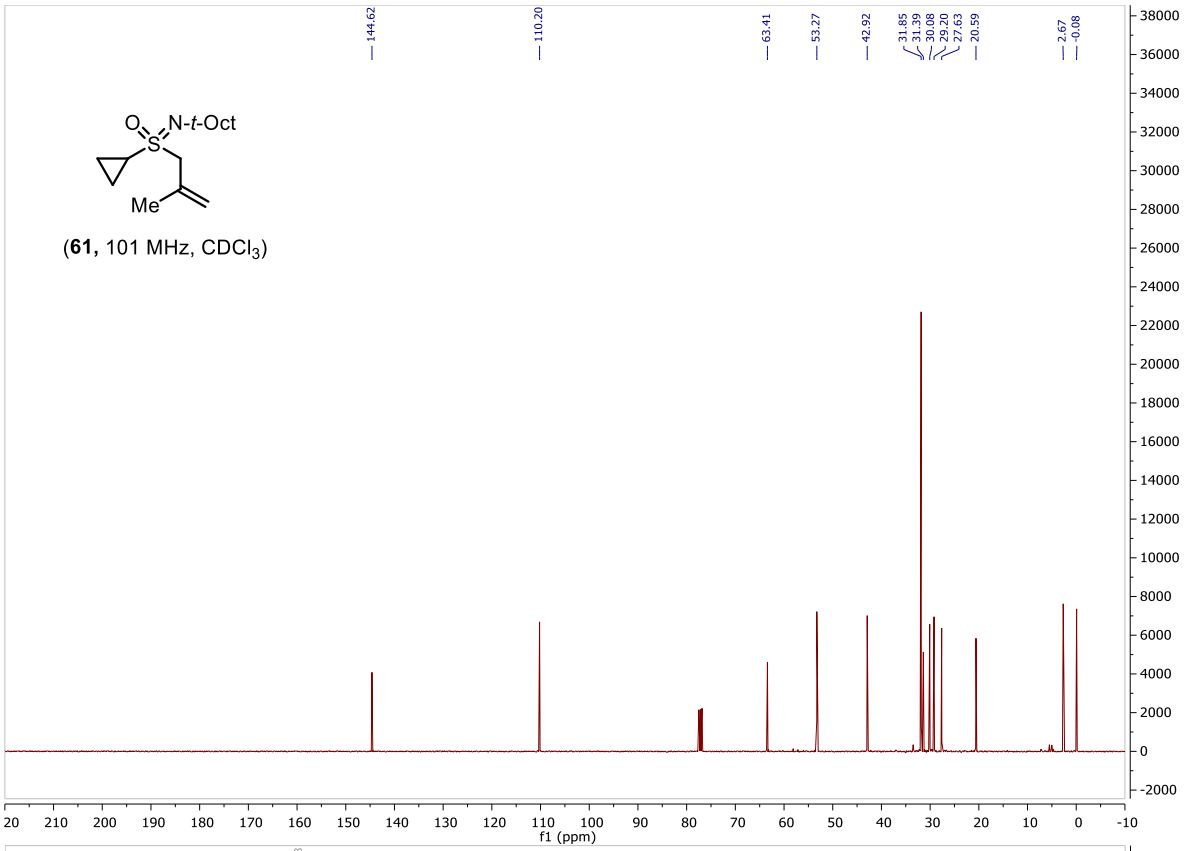
(**60,** 400 MHz, $CDCl_3$)



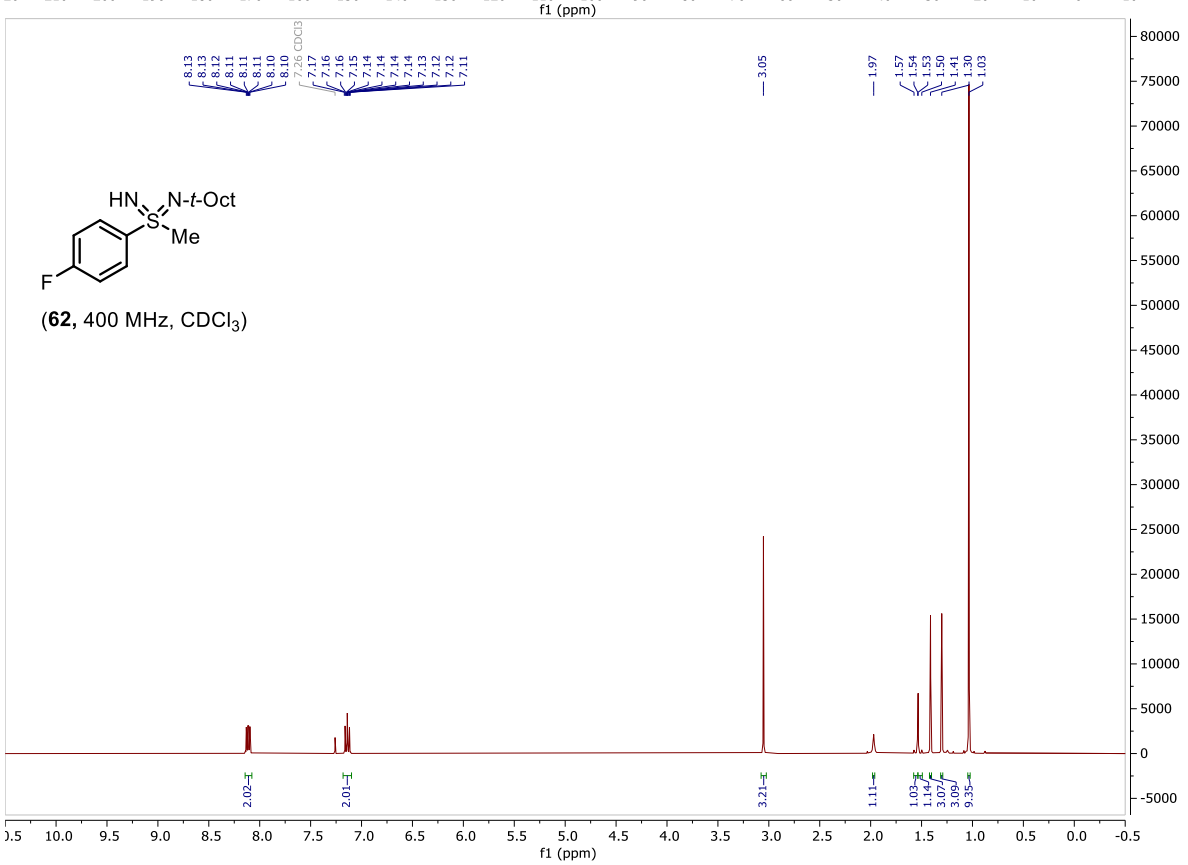
(**60,** 101 MHz, $CDCl_3$)



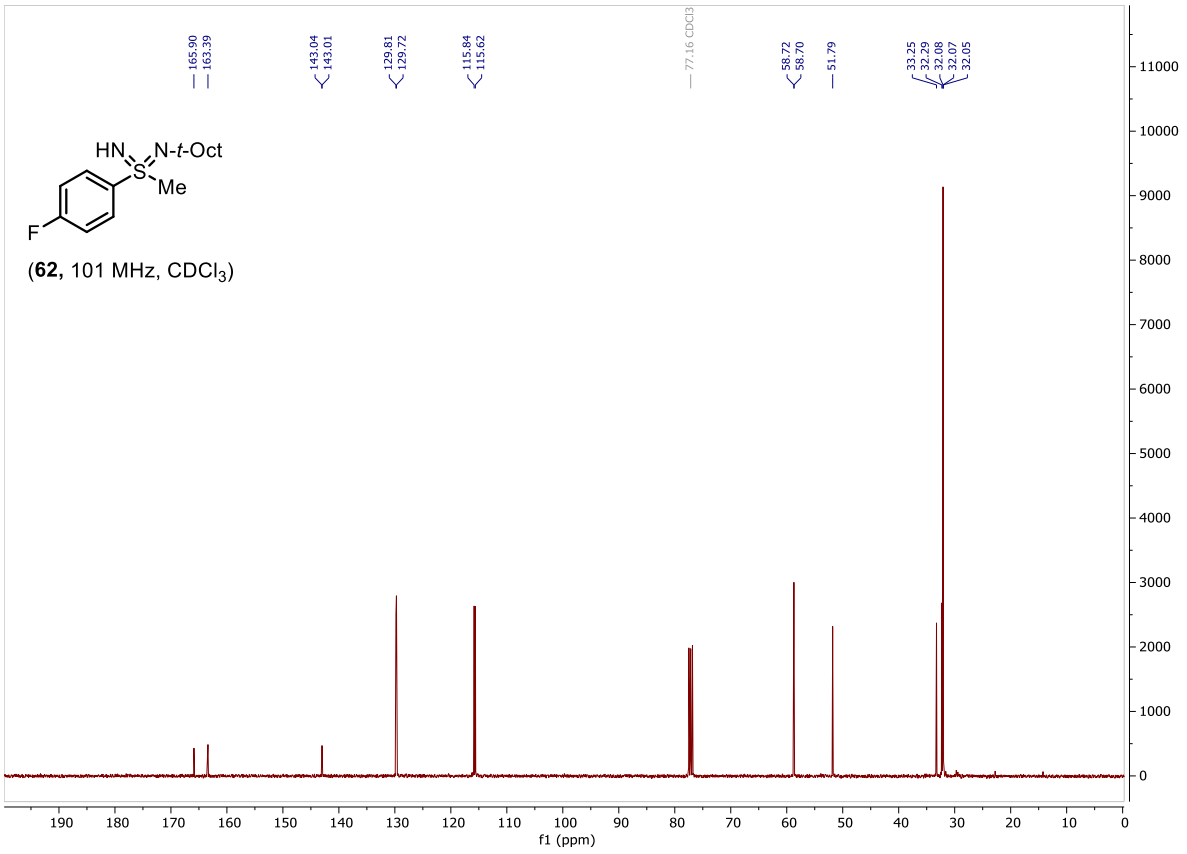
(**61,** 400 MHz, $CDCl_3$)



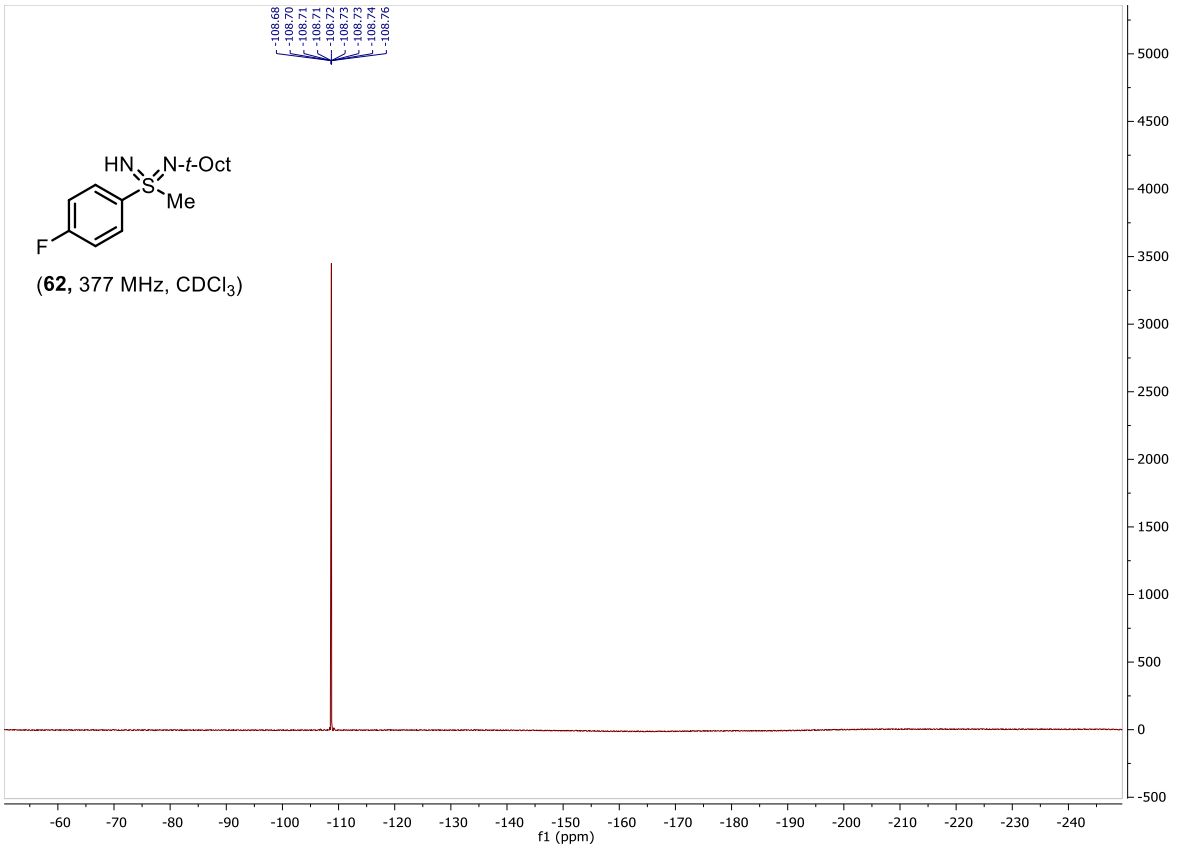
(**61,** 101 MHz, $CDCl_3$)



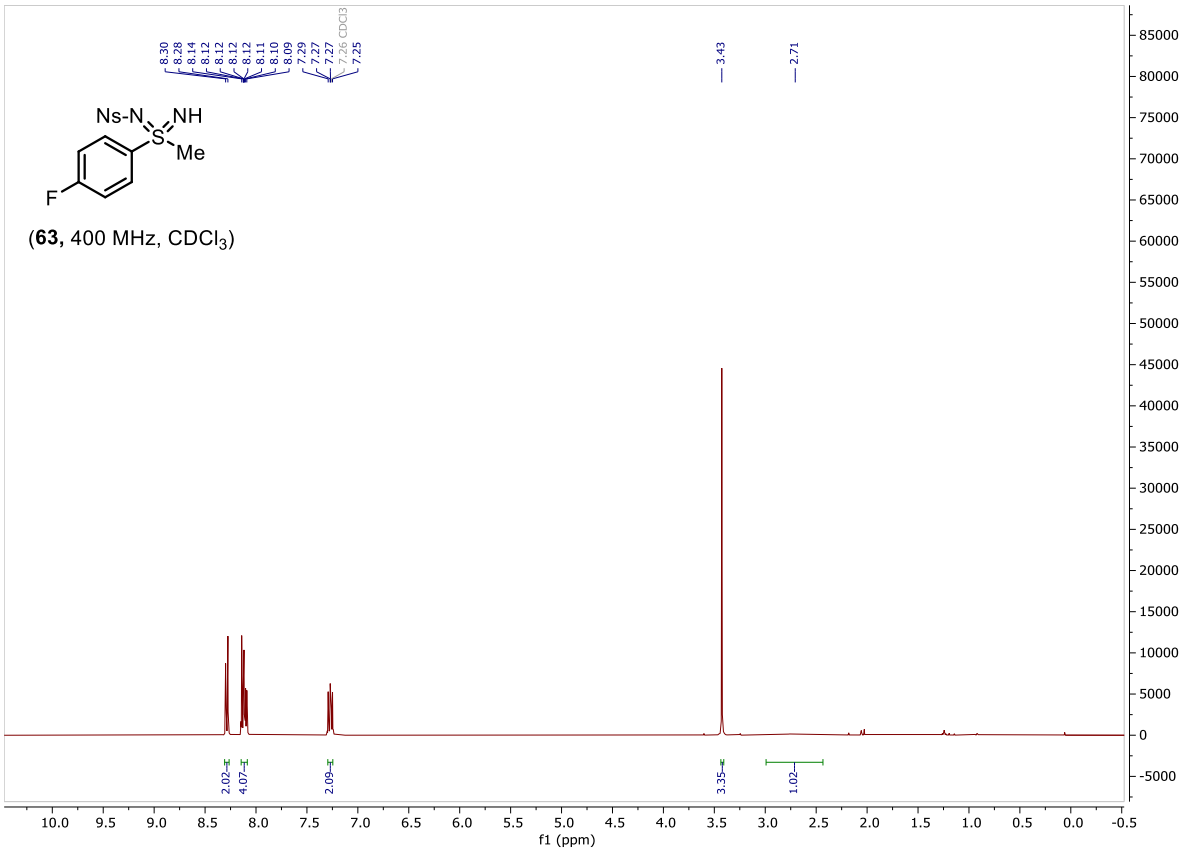
(**62,** 400 MHz, $CDCl_3$)



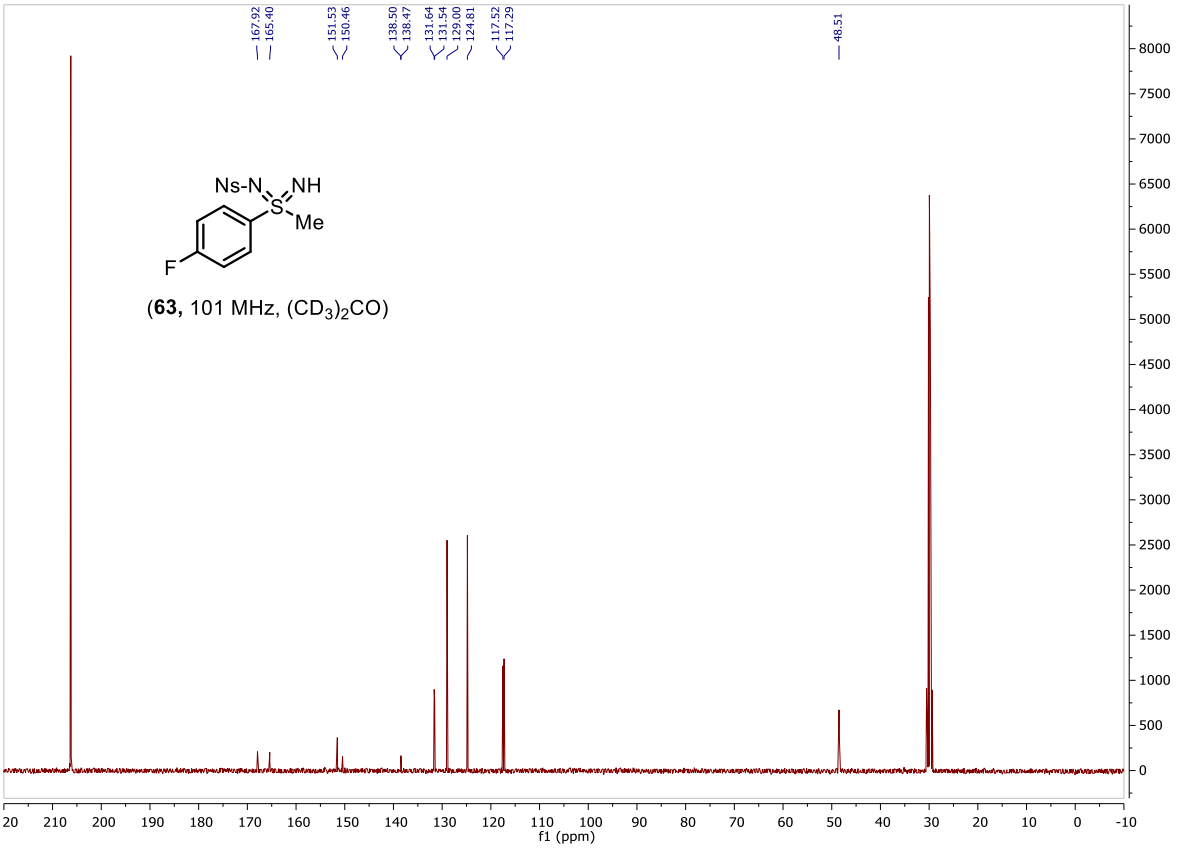
(**62,** 101 MHz, $CDCl_3$)



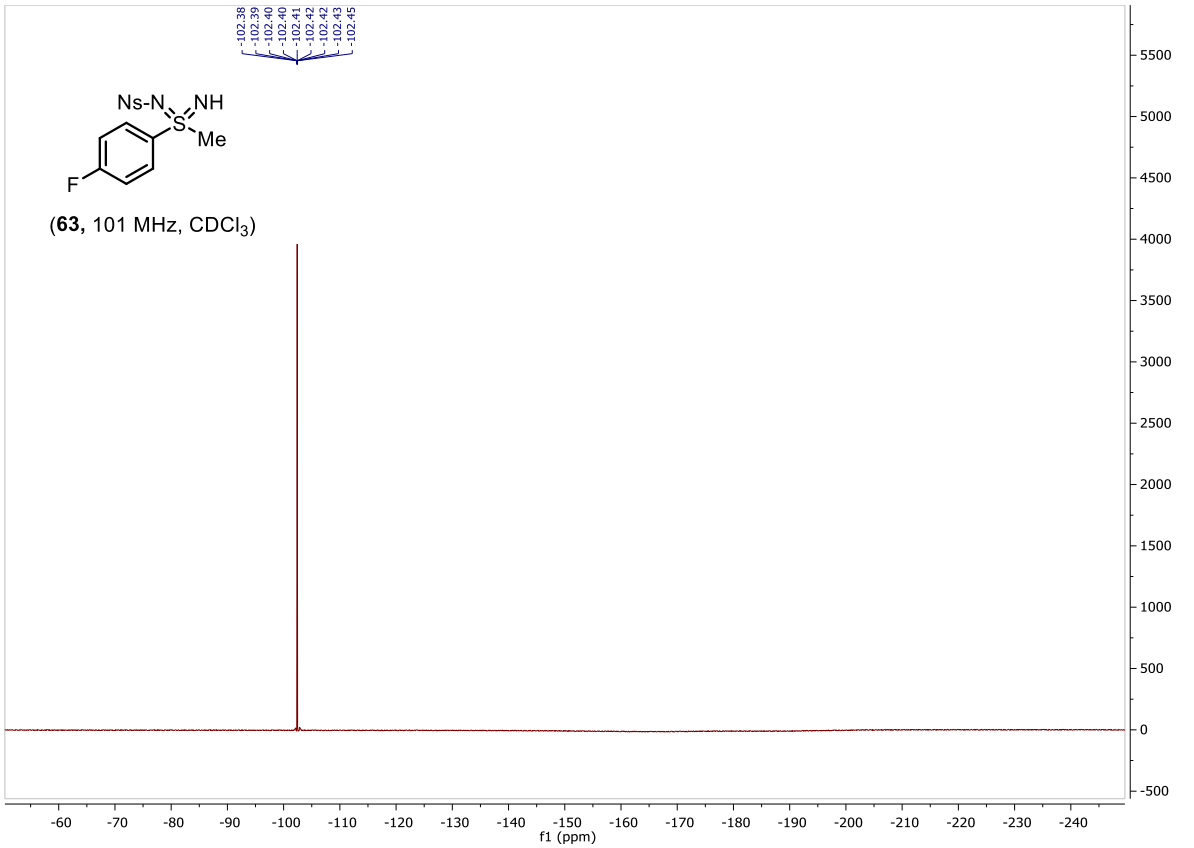
(**62,** 377 MHz, $CDCl_3$)



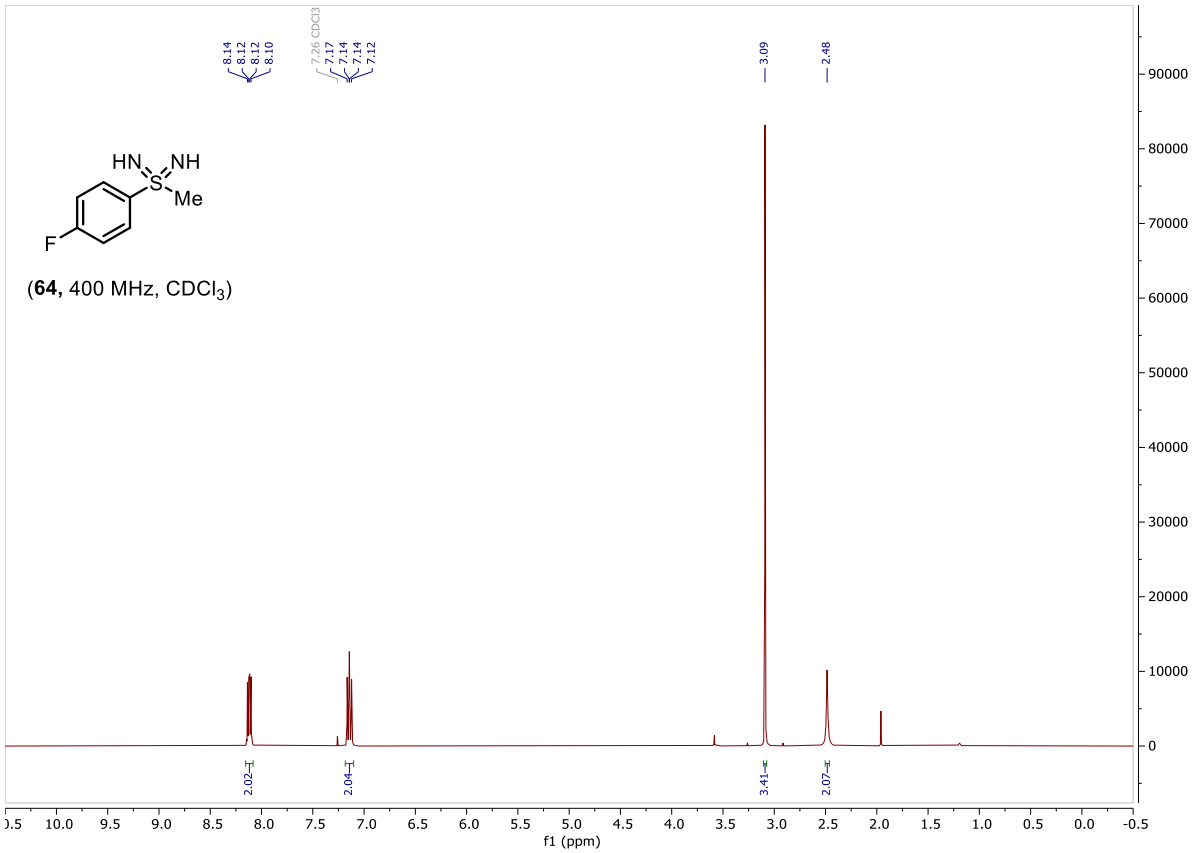
(**63,** 400 MHz, $CDCl_3$)



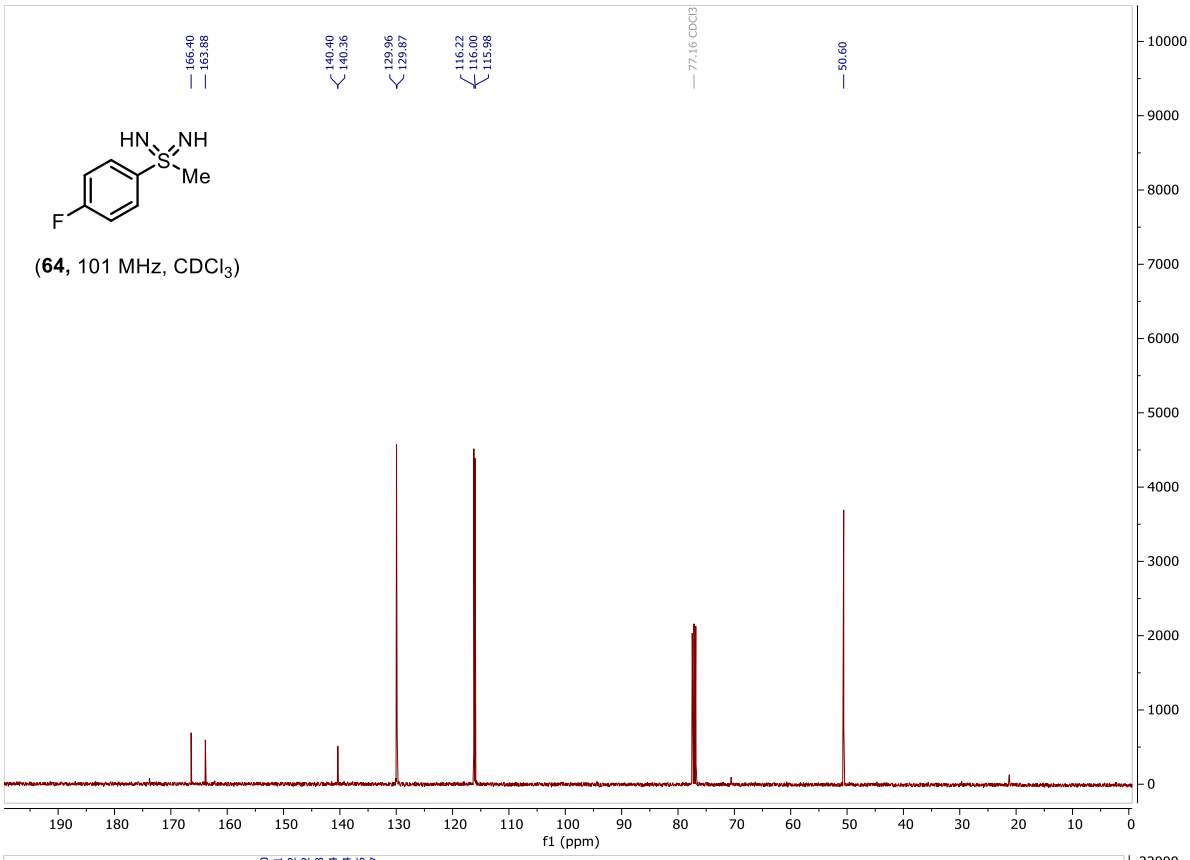
(**63,** 101 MHz, $(CD_3)_2CO$)



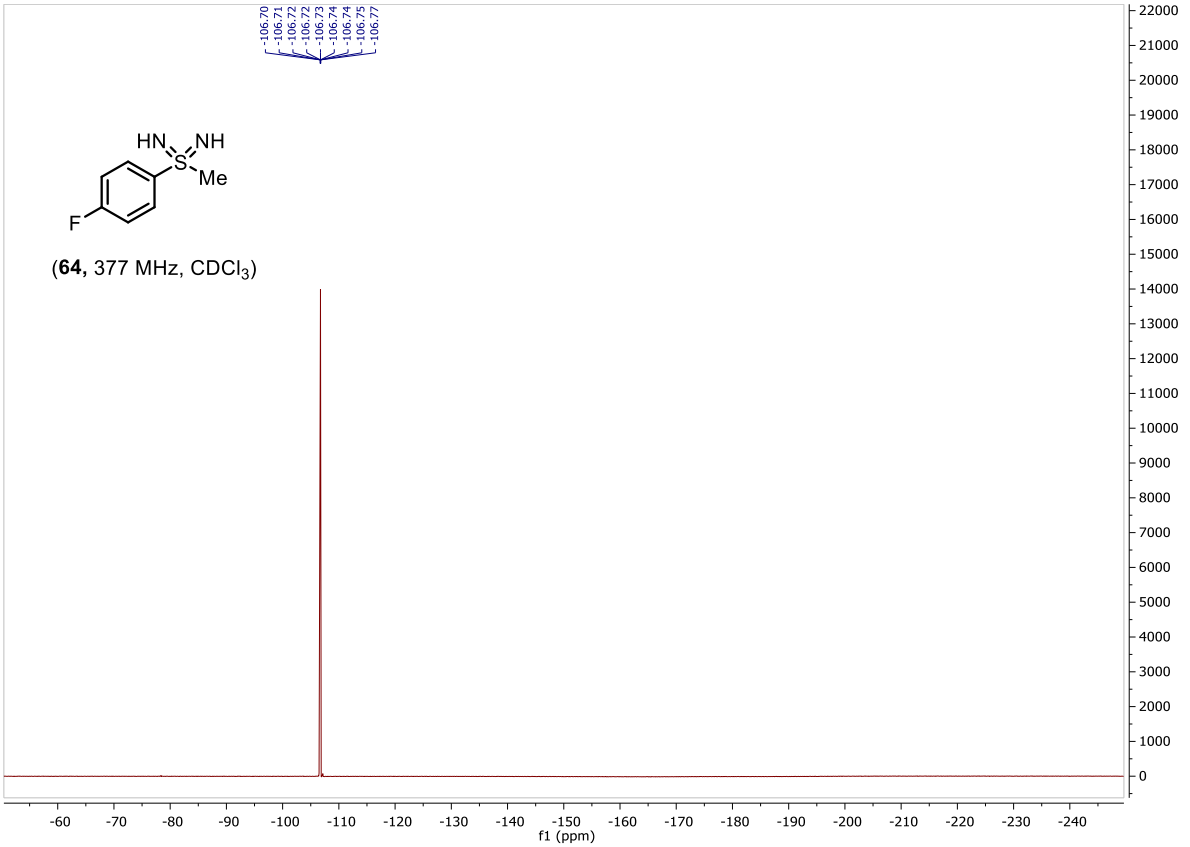
(**63,** 101 MHz, $CDCl_3$)



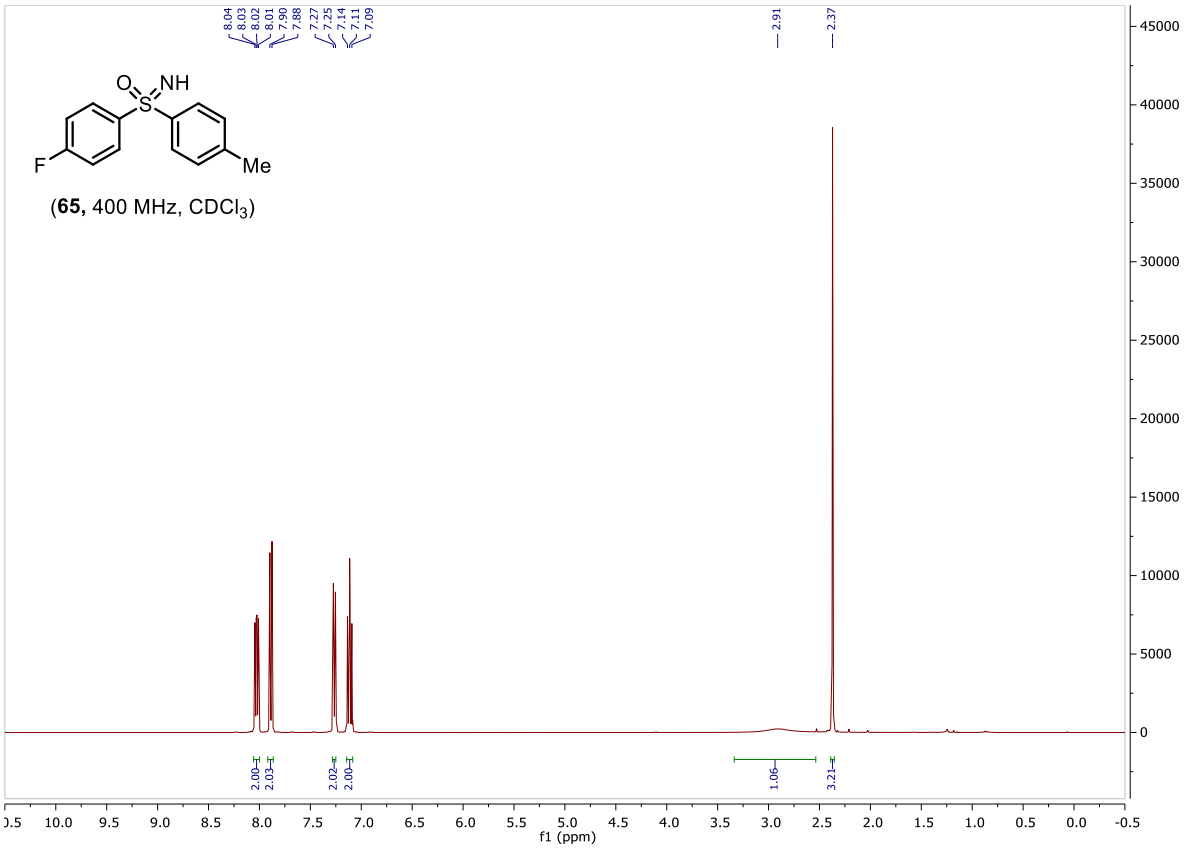
(**64,** 400 MHz, $CDCl_3$)



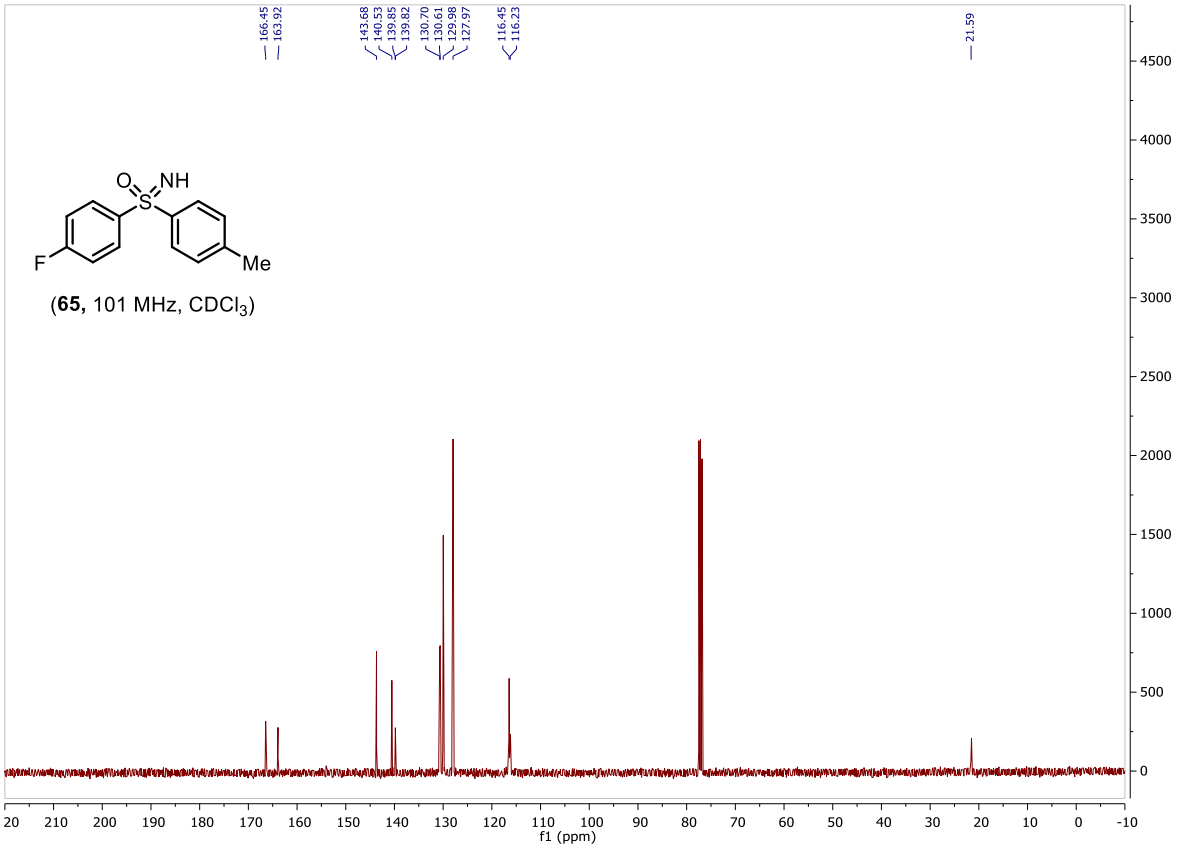
(**64,** 101 MHz, $CDCl_3$)



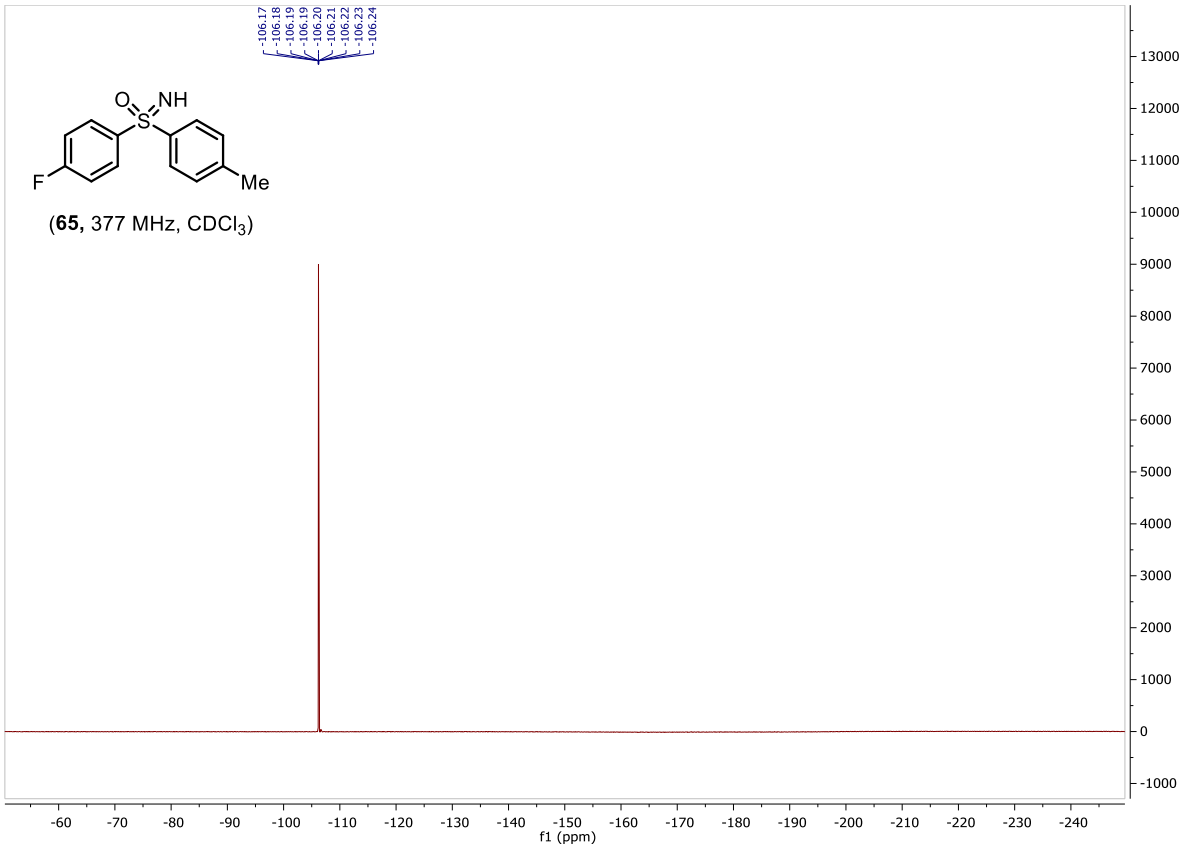
(**64,** 377 MHz, $CDCl_3$)

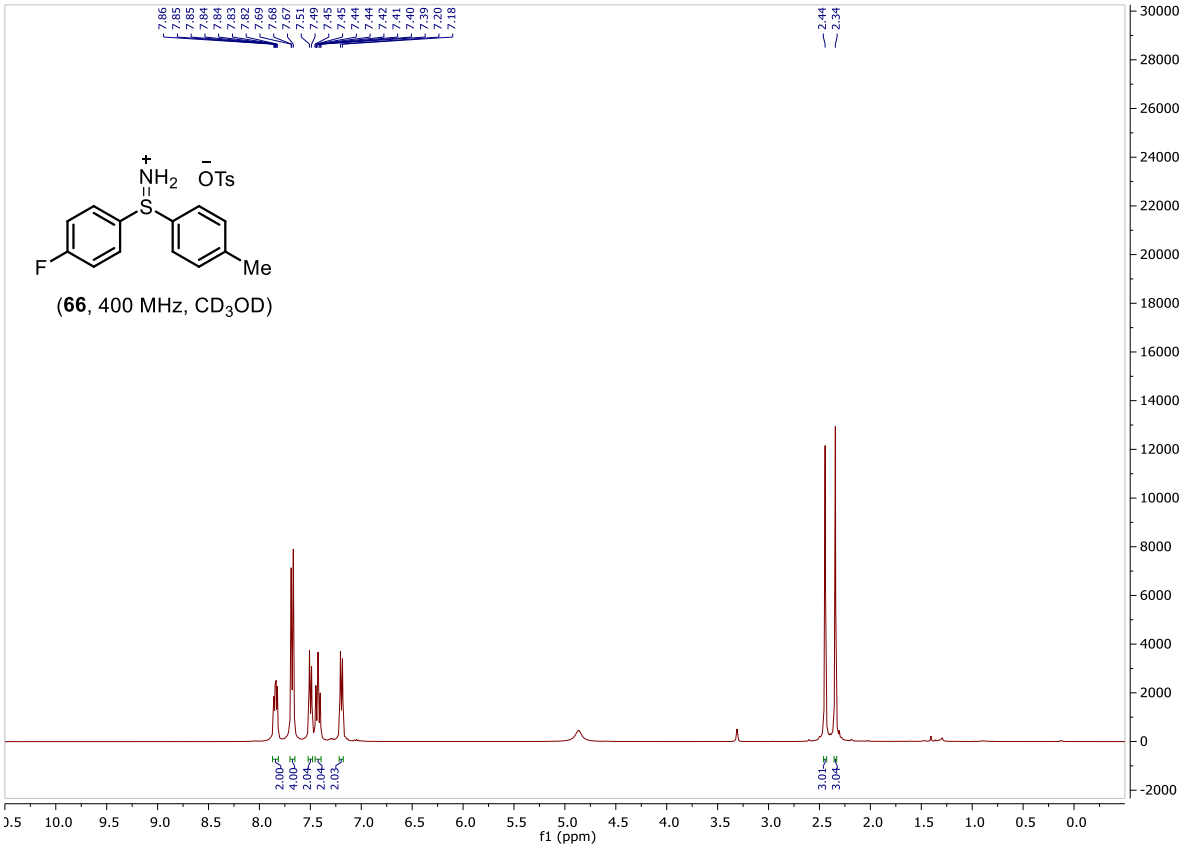


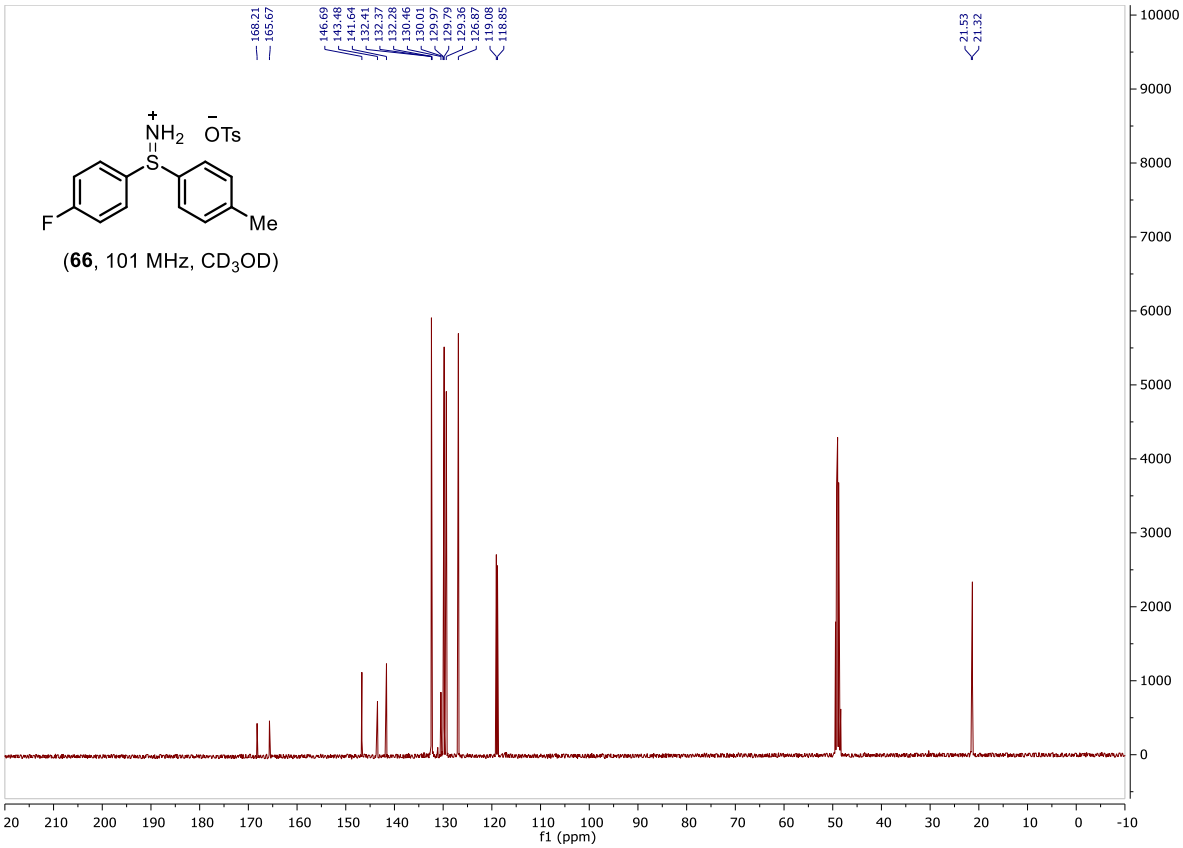
(**65,** 400 MHz, $CDCl_3$)

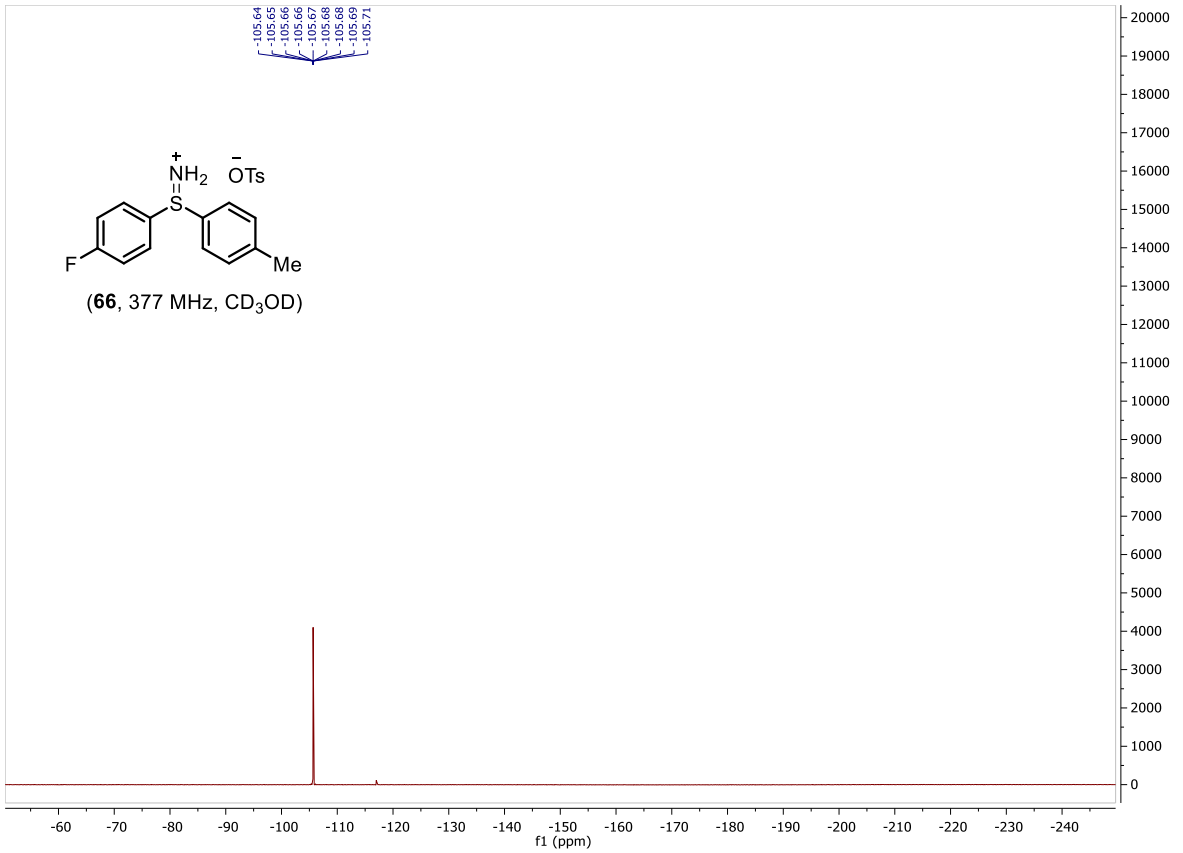


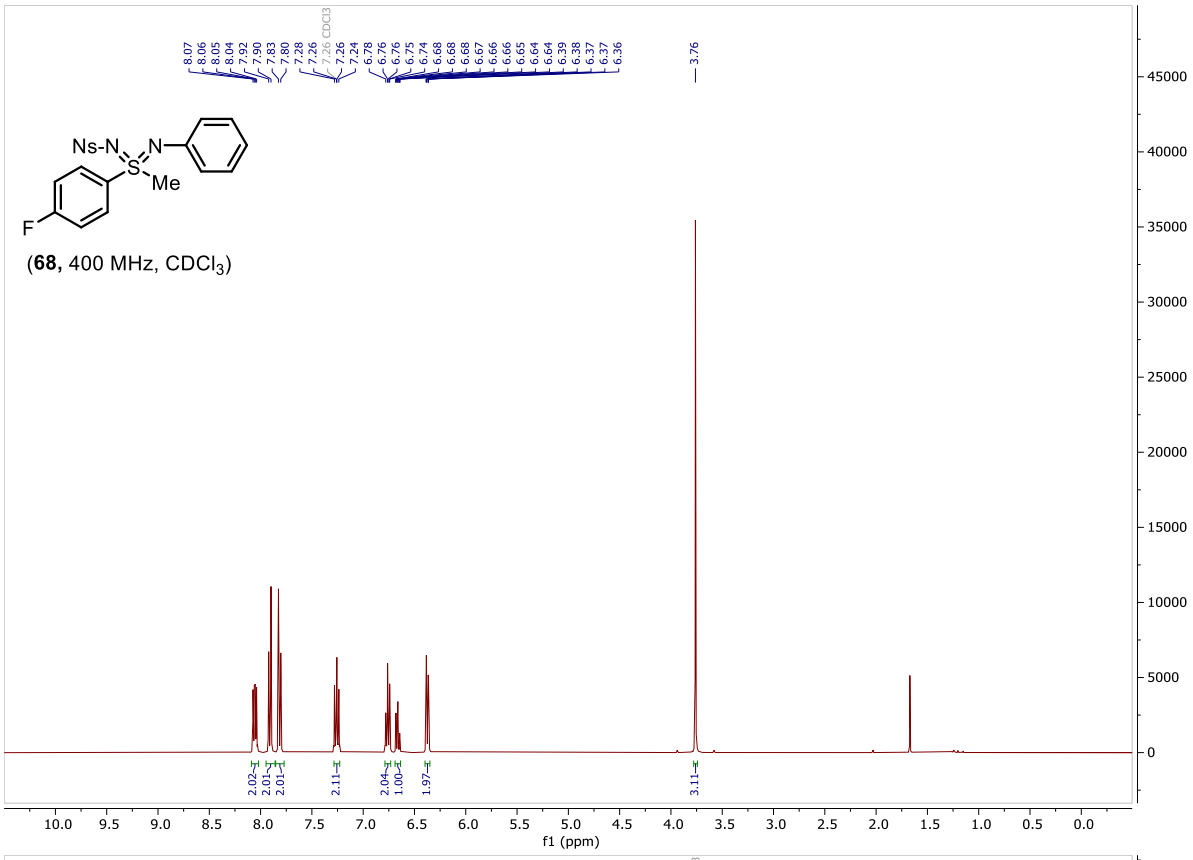
(**65,** 101 MHz, $CDCl_3$)

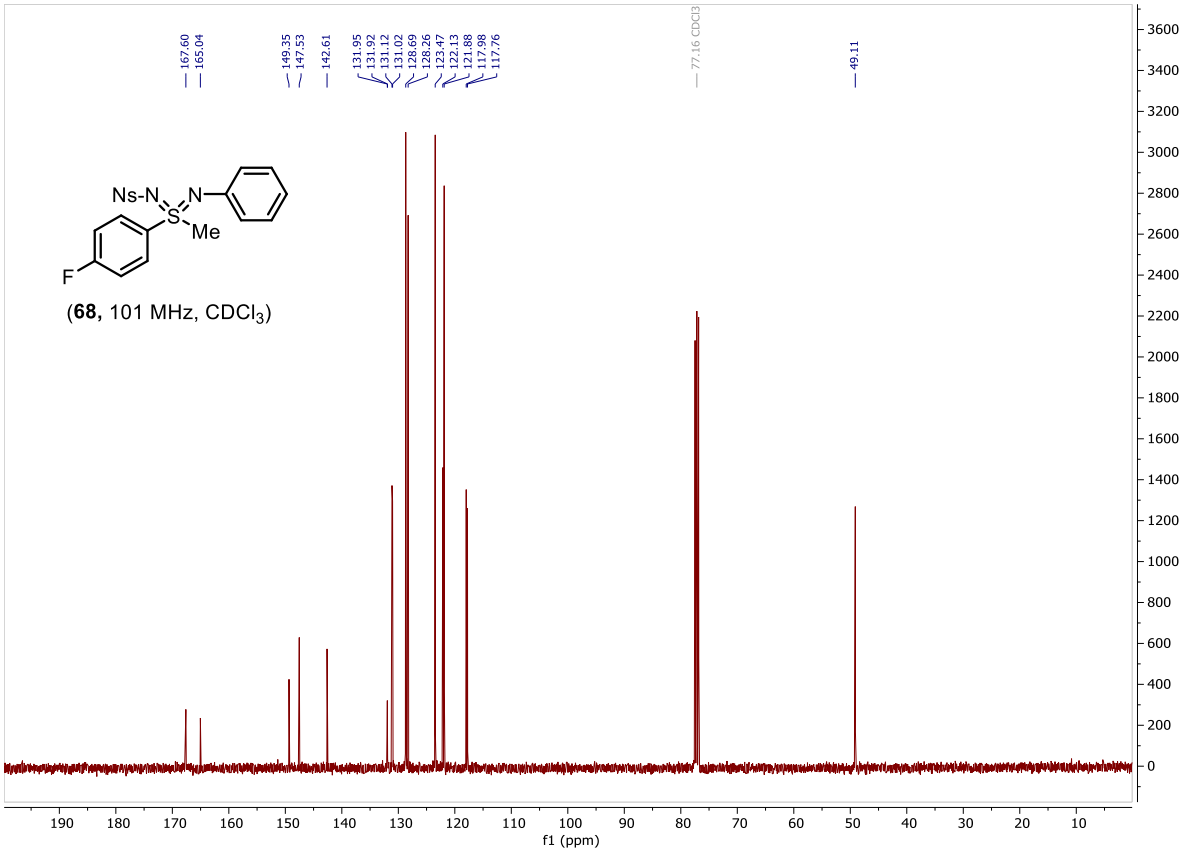

-106.17
-106.18
-106.19
-106.19
-106.20
-106.21
-106.22
-106.23
-106.24
O
NH
S
F
Me
(65, 377 MHz, CDCl3)
f1 (ppm)

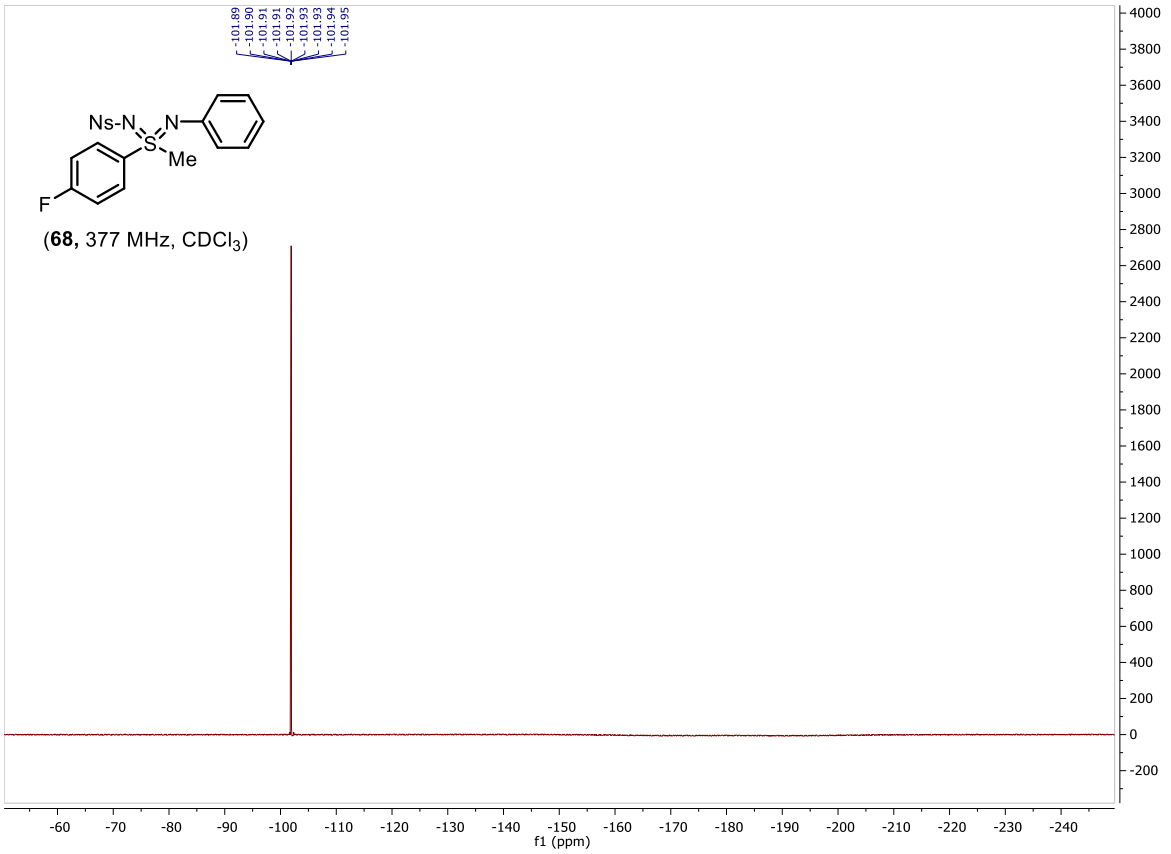

7.86
7.85
7.85
7.84
7.84
7.83
7.82
7.69
7.68
7.67
7.51
7.49
7.45
7.45
7.44
7.44
7.42
7.41
7.40
7.39
7.20
7.18
2.44
2.34
NH2
OTs
S
F
Me
(66, 400 MHz, CD3OD)
2.00
4.00
2.04
2.04
2.03
3.01
3.04
f1 (ppm)


168.21
165.67
146.69
143.48
141.64
132.41
132.37
132.28
130.46
130.01
129.97
129.79
129.36
126.87
119.08
118.85
21.53
21.32
NH2
OTs
S
F
Me
(66, 101 MHz, CD3OD)
f1 (ppm)

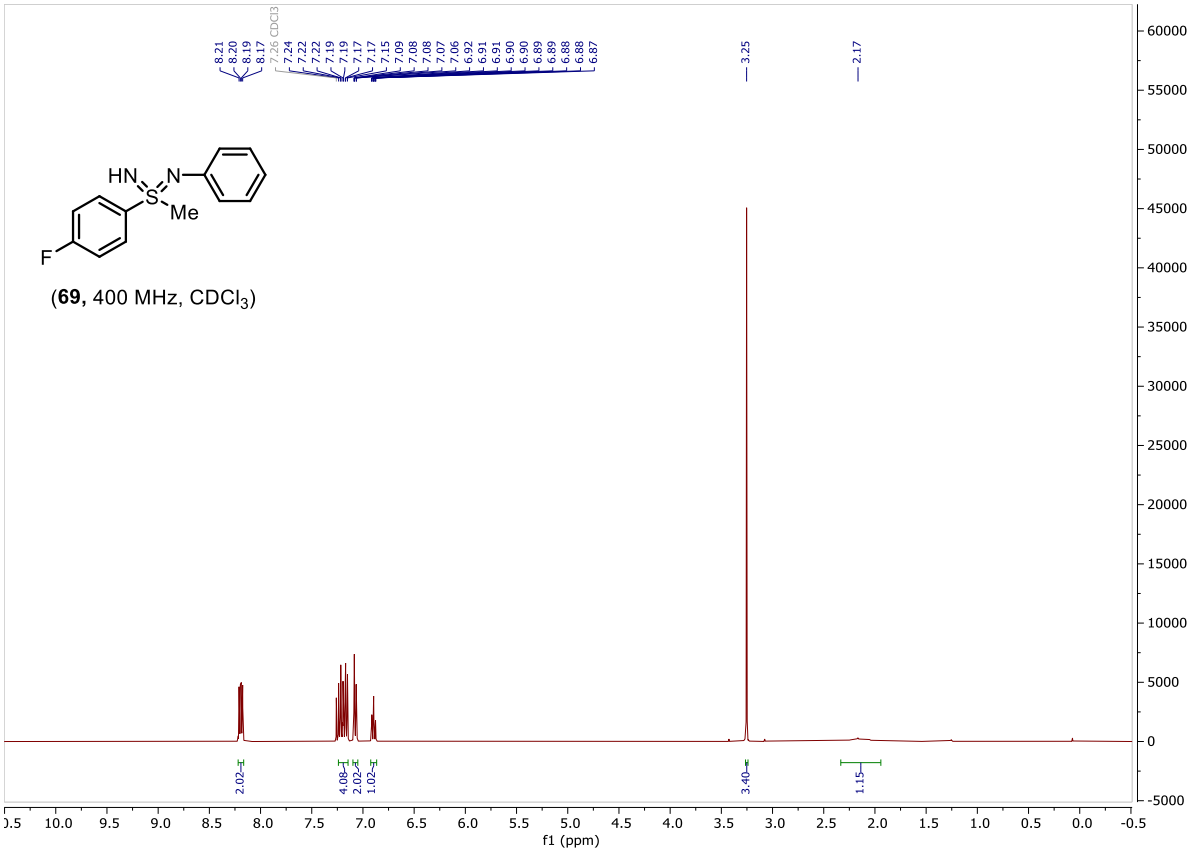

-105.64
-105.65
-105.66
-105.66
-105.67
-105.68
-105.68
-105.69
-105.71
NH2
OTs
S
F
Me
(66, 377 MHz, CD3OD)
f1 (ppm)


Ns-N
N
S
Me
F
(68, 400 MHz, CDCl3)
f1 (ppm)

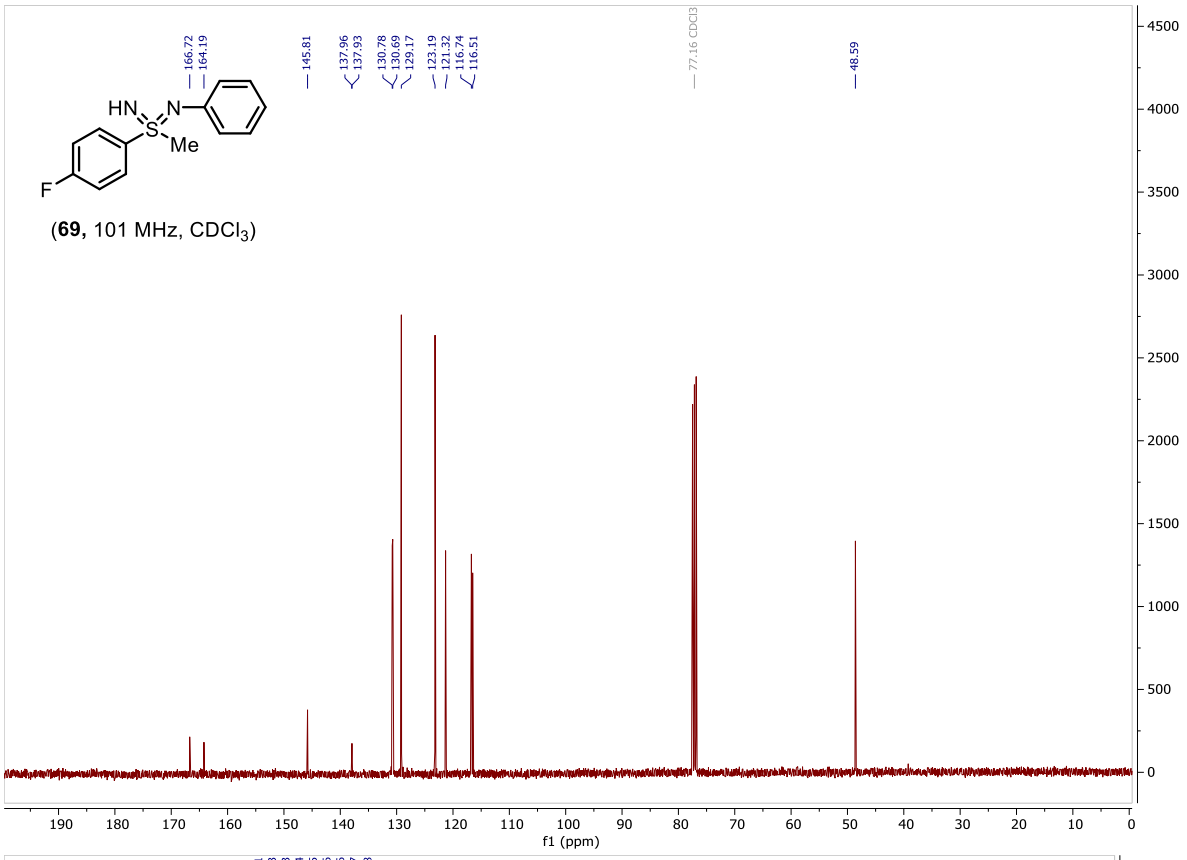

Ns-N
N
S
Me
F
(68, 101 MHz, CDCl3)
f1 (ppm)

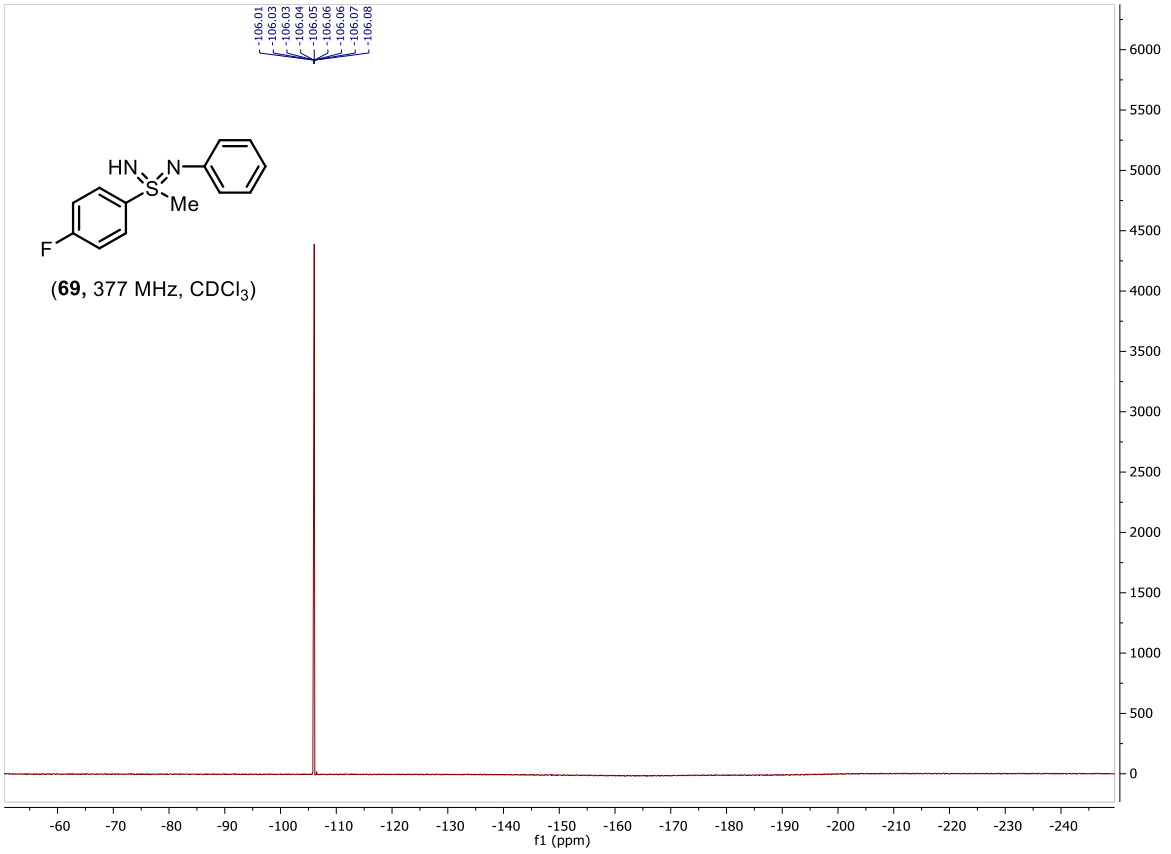


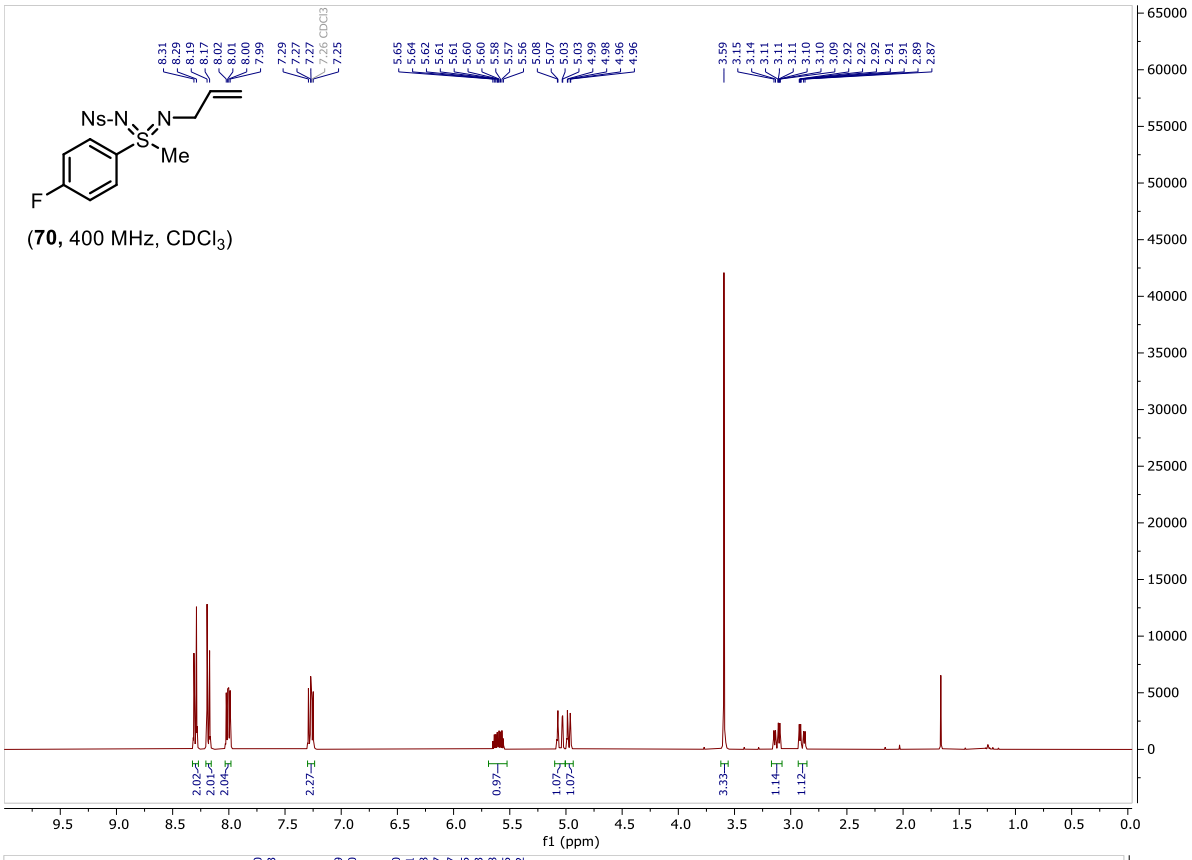
(**68,** 377 MHz, $CDCl_3$)

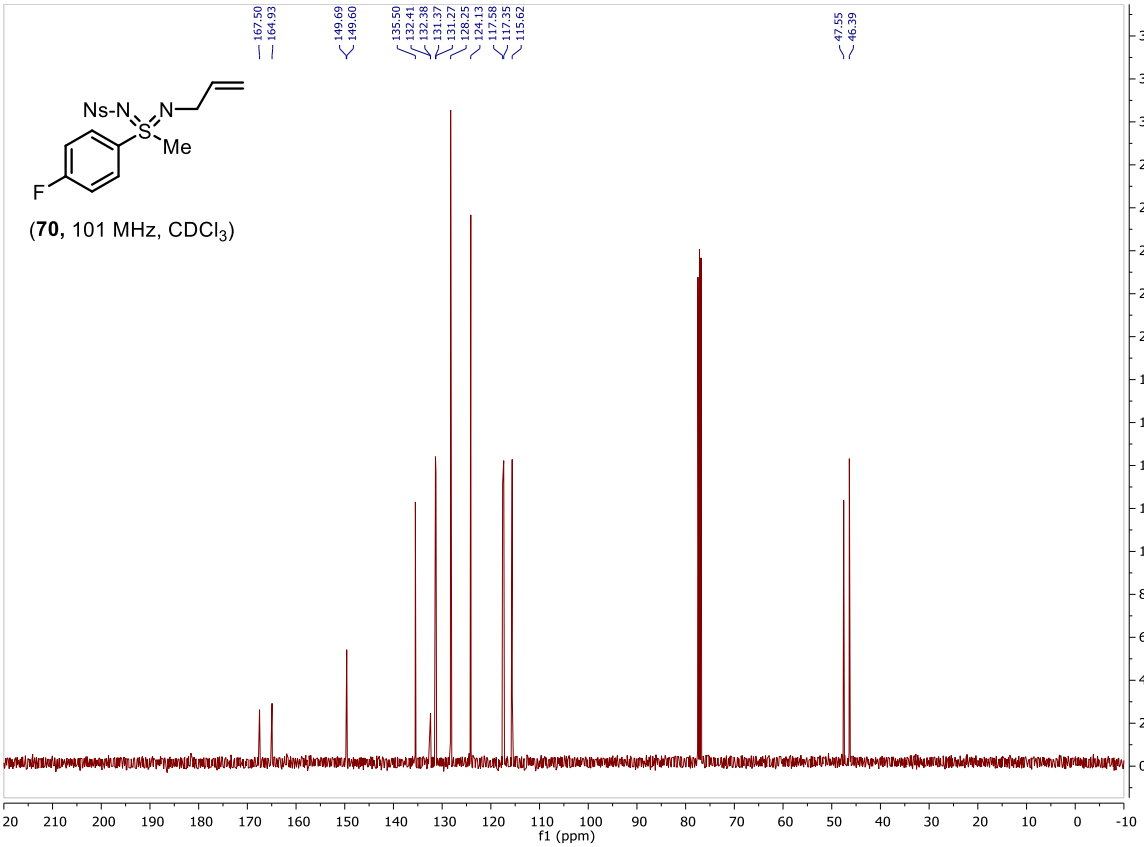


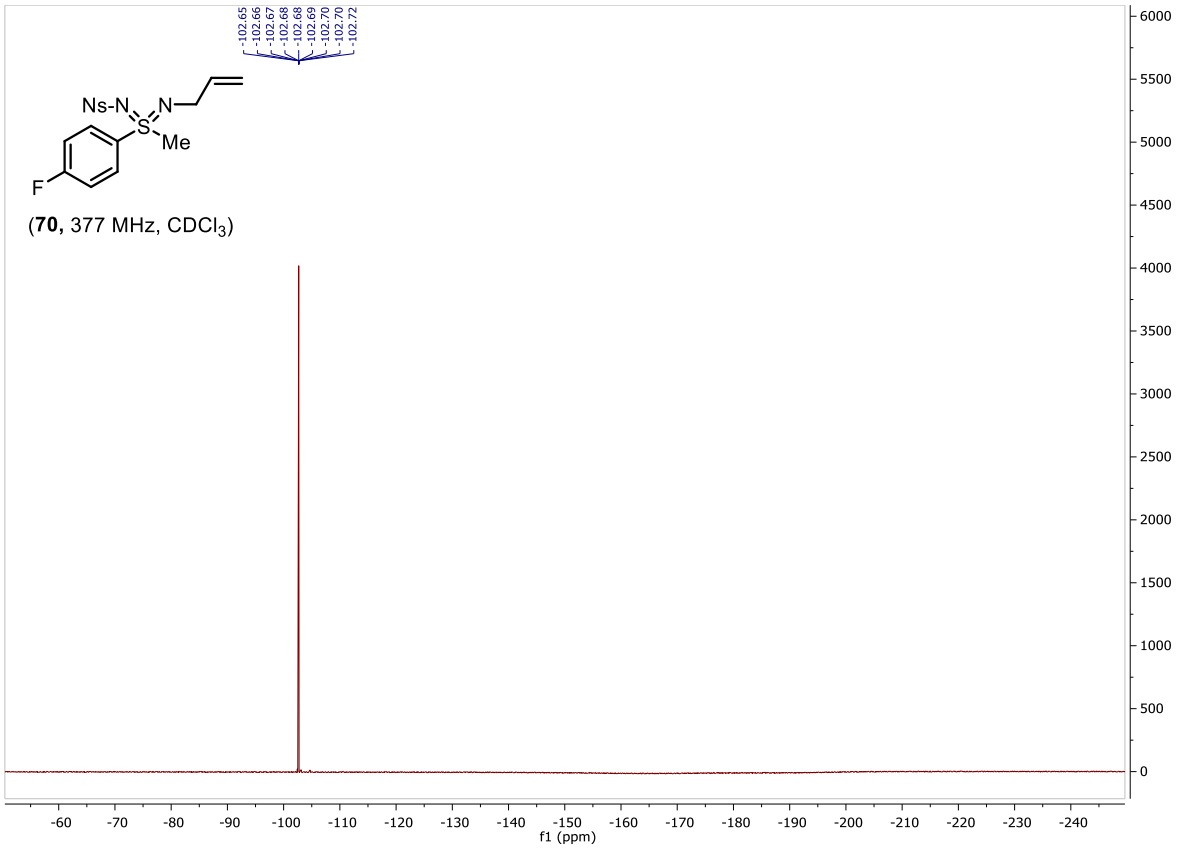
(**69,** 400 MHz, $CDCl_3$)

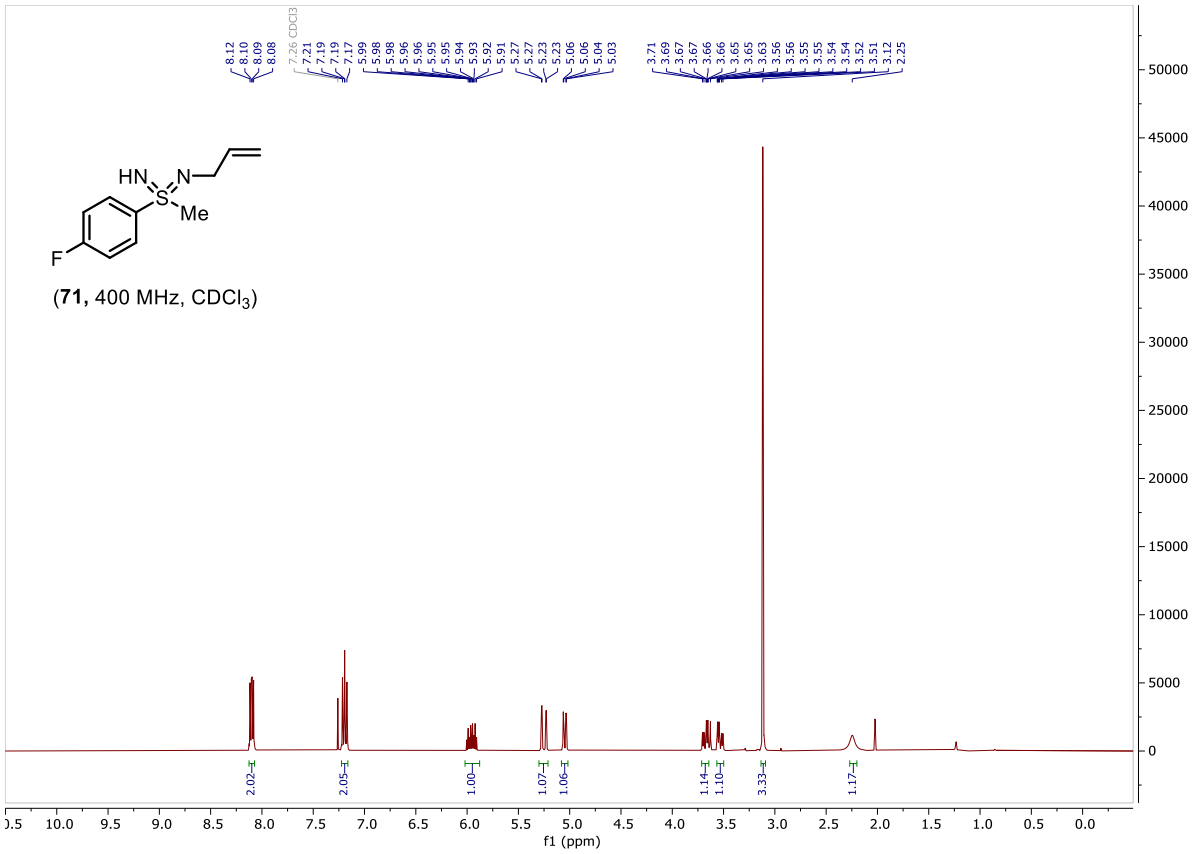

166.72
164.19
145.81
137.96
137.93
130.78
130.69
129.17
123.19
121.32
116.74
116.51
77.16 CDCl3
48.59
HN
N
S
Me
F
(69, 101 MHz, CDCl3)
f1 (ppm)

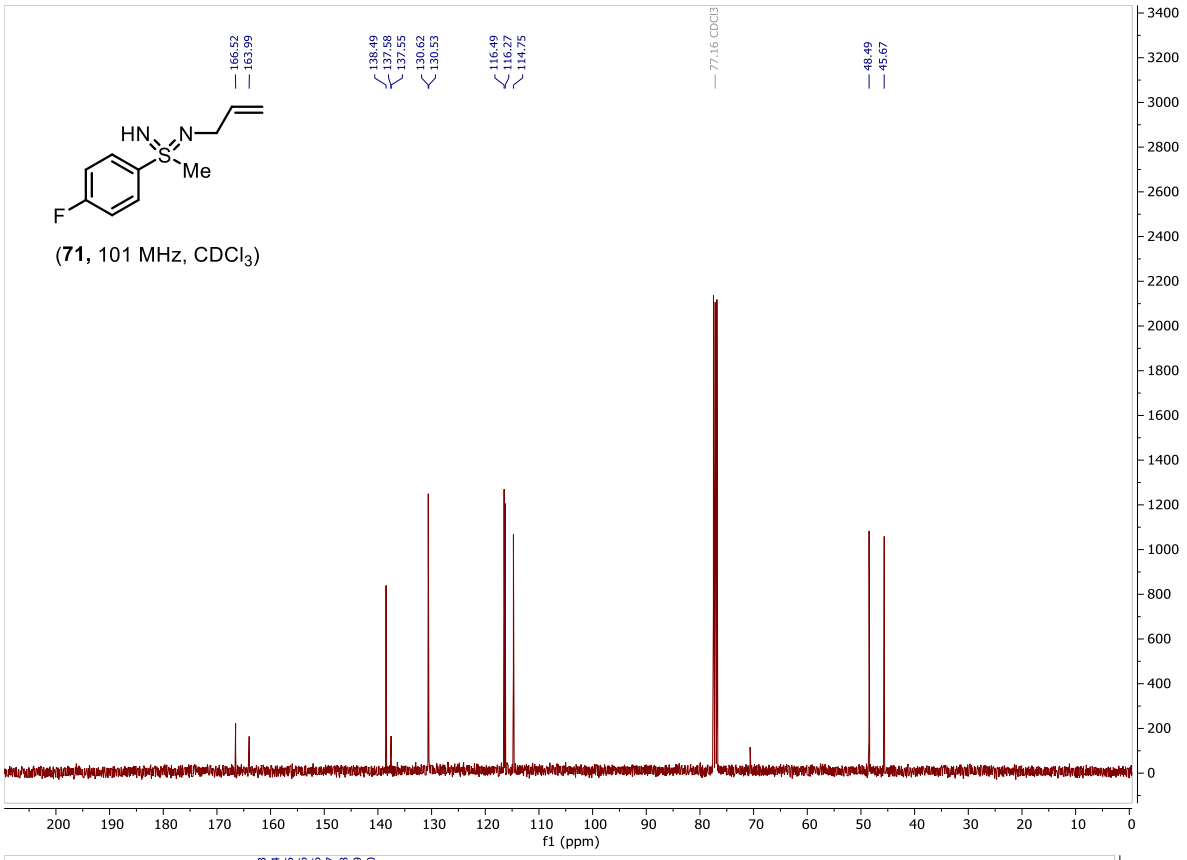

106.01
106.03
106.03
106.04
106.05
106.06
106.06
106.07
106.08
HN
N
S
Me
F
(69, 377 MHz, CDCl3)
f1 (ppm)

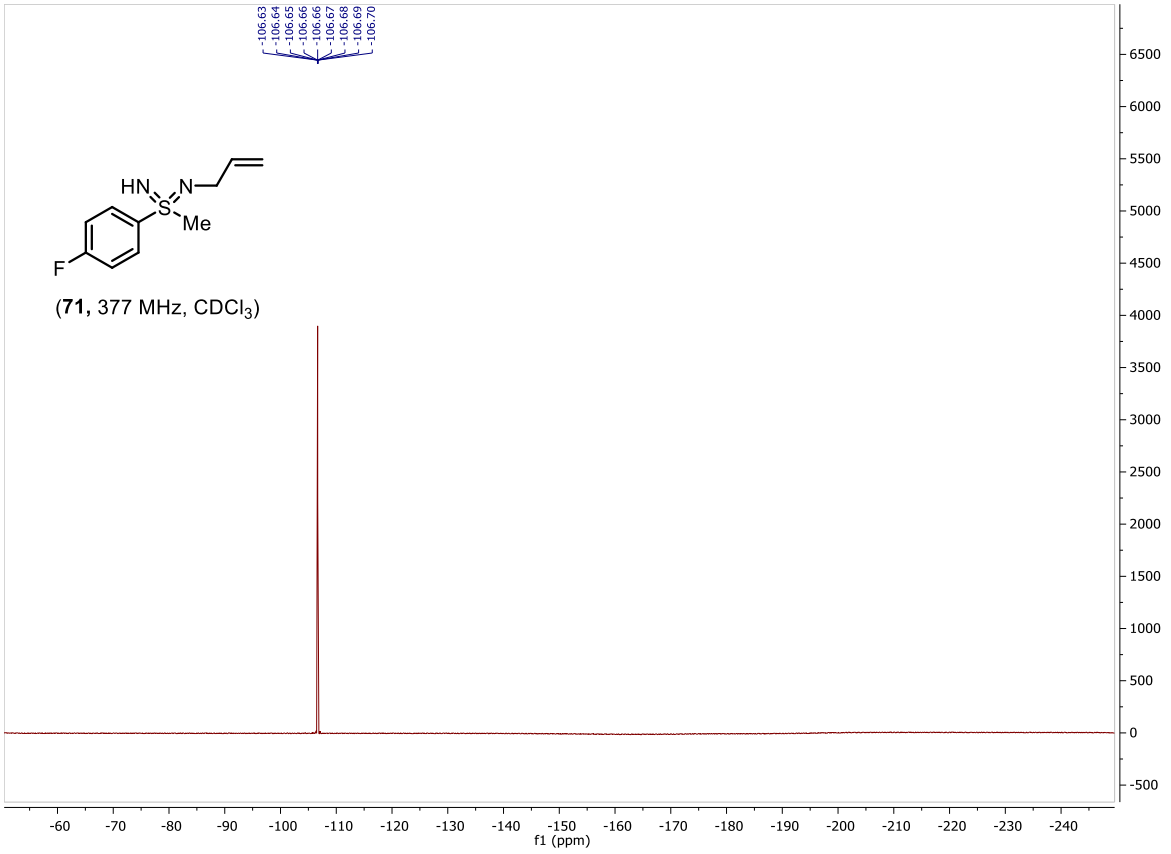

Ns-N
N
S
Me
F
(70, 400 MHz, CDCl3)
f1 (ppm)

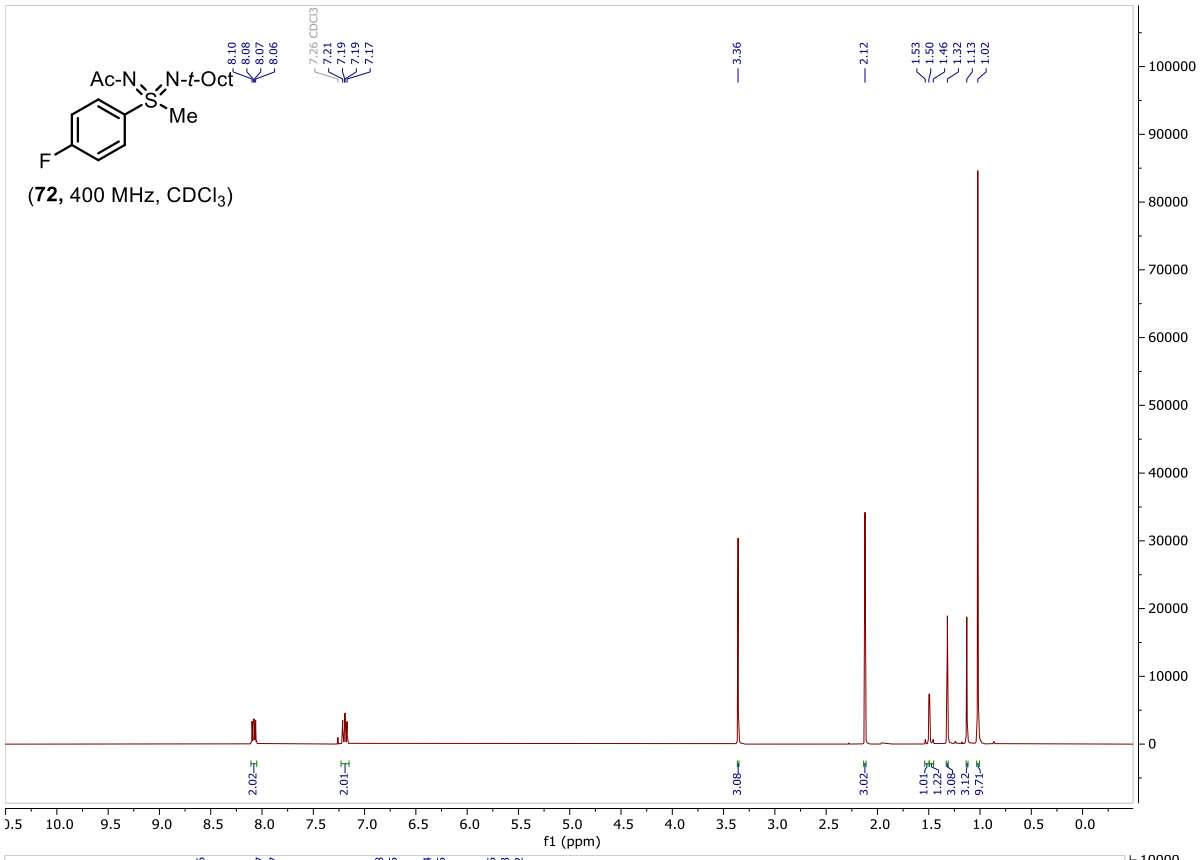

Ns-N
N
S
Me
F
(70, 101 MHz, CDCl3)
f1 (ppm)

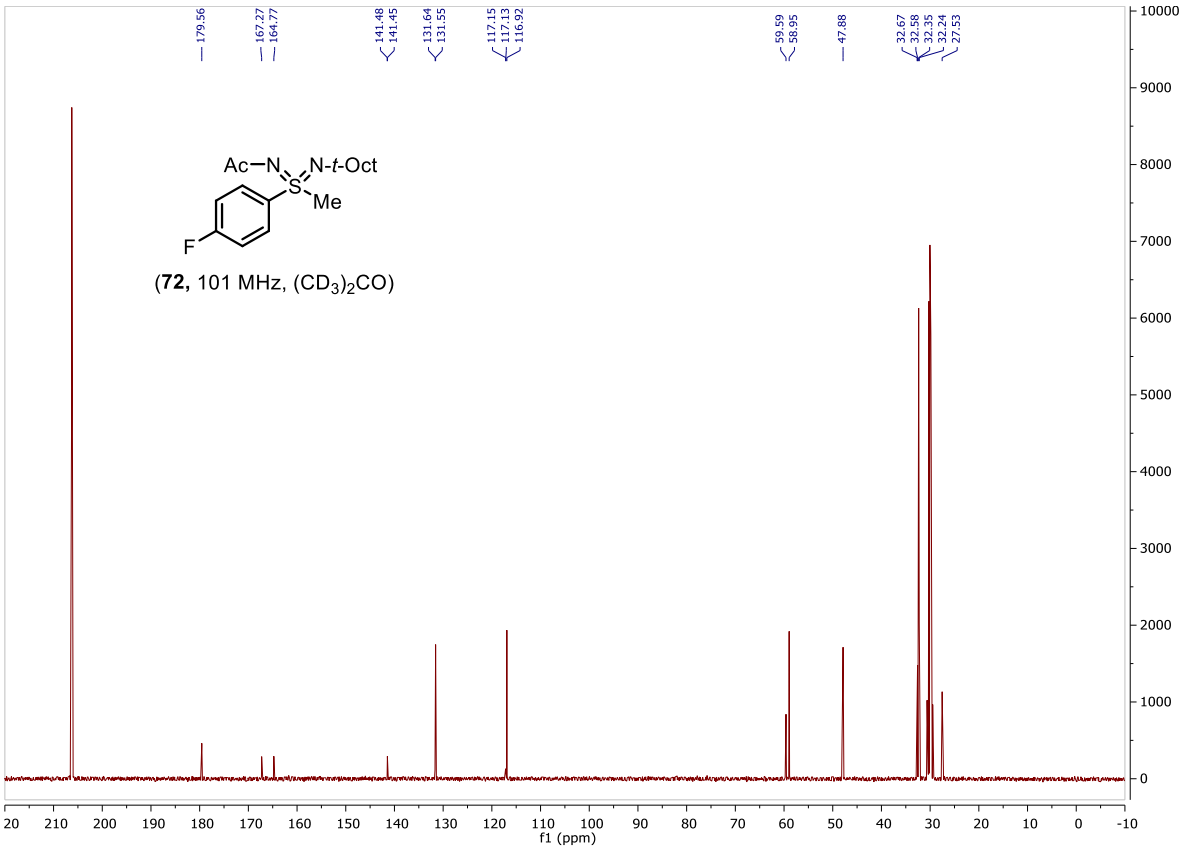

-102.65
-102.66
-102.67
-102.68
-102.68
-102.69
-102.70
-102.70
-102.72
Ns-N
N
S
Me
F
(70, 377 MHz, CDCl3)
f1 (ppm)

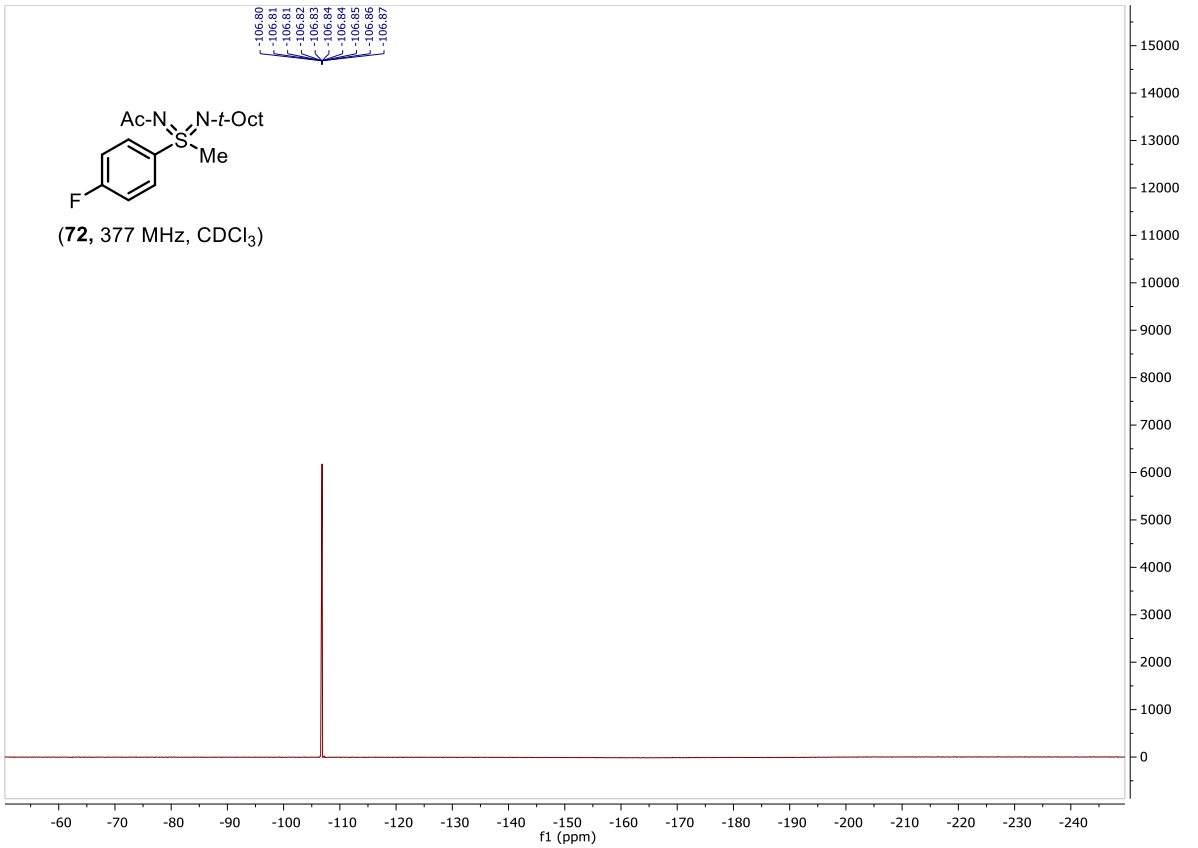

8.12
8.10
8.09
8.08
7.26 CDCl3
7.21
7.19
7.19
7.17
5.99
5.98
5.98
5.96
5.96
5.95
5.95
5.94
5.93
5.92
5.91
5.27
5.27
5.23
5.23
5.06
5.06
5.04
5.03
3.71
3.69
3.67
3.67
3.66
3.66
3.65
3.65
3.63
3.56
3.56
3.55
3.55
3.54
3.54
3.52
3.51
3.12
2.25
HN
N
S
Me
F
(71, 400 MHz, CDCl3)
2.02
2.05
1.00
1.07
1.06
1.14
1.10
3.33
1.17
f1 (ppm)


166.52
163.99
138.49
137.58
137.55
130.62
130.53
116.49
116.27
114.75
77.16 CDCl3
48.49
45.67
HN
N
S
Me
F
(71, 101 MHz, CDCl3)
f1 (ppm)

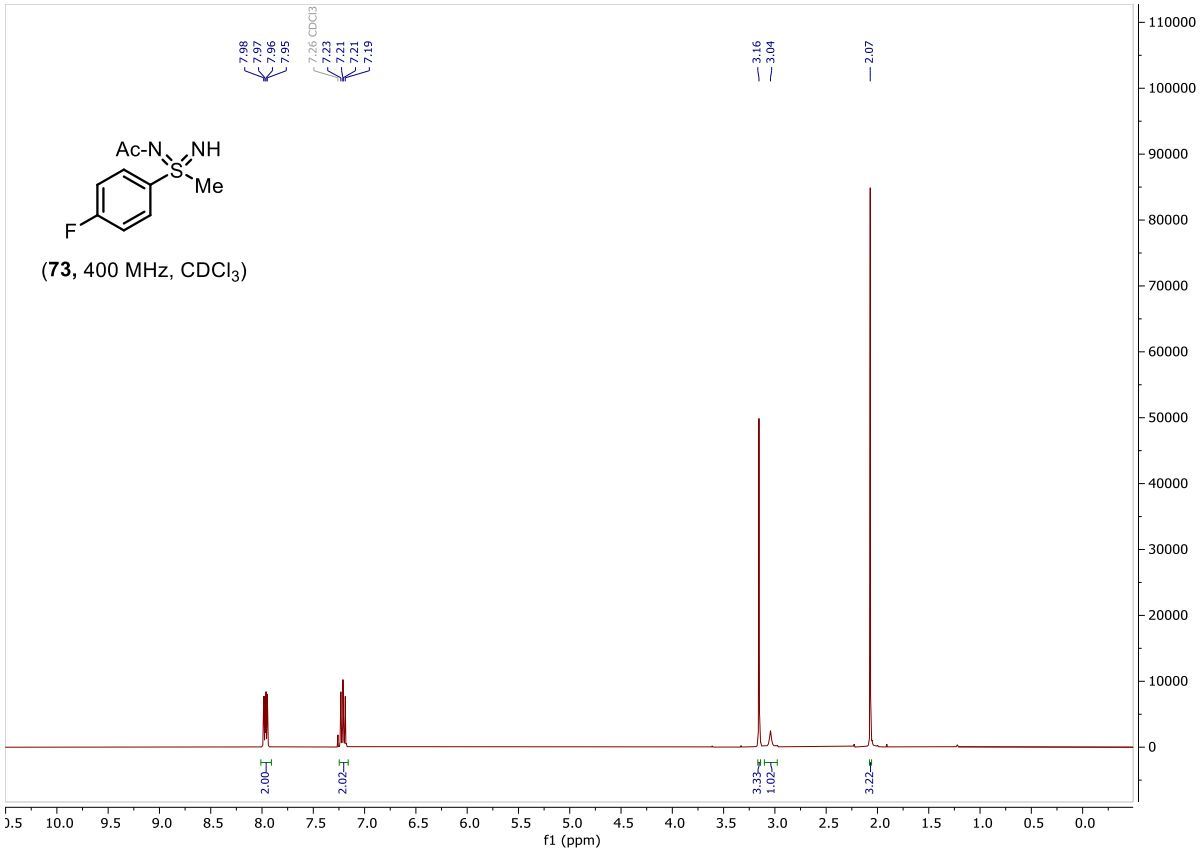

106.63
106.64
106.65
106.66
106.66
106.67
106.68
106.69
106.70
HN
N
S
Me
F
(71, 377 MHz, CDCl3)
f1 (ppm)


Ac-N
N-t-Oct
S
Me
F
(72, 400 MHz, CDCl3)
8.10
8.08
8.07
8.06
7.26 CDCl3
7.21
7.19
7.19
7.17
3.36
2.12
1.53
1.50
1.46
1.32
1.13
1.02
2.02
2.01
3.08
3.02
1.01
1.22
3.08
3.12
9.71
f1 (ppm)

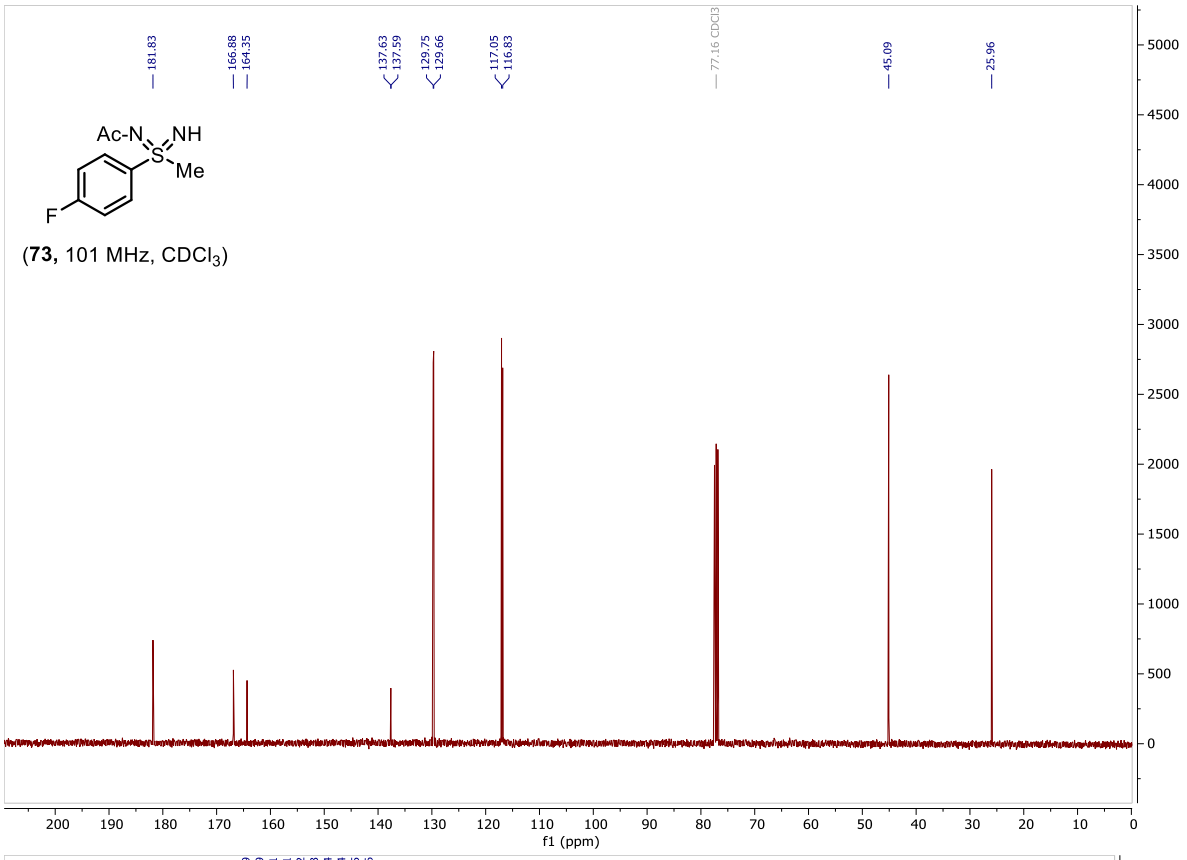

179.56
167.27
164.77
141.48
141.45
131.64
131.55
117.15
117.13
116.92
59.59
58.95
47.88
32.67
32.58
32.35
32.24
27.53
Ac—N
N-t-Oct
S
Me
F
(72, 101 MHz, (CD3)2CO)
f1 (ppm)



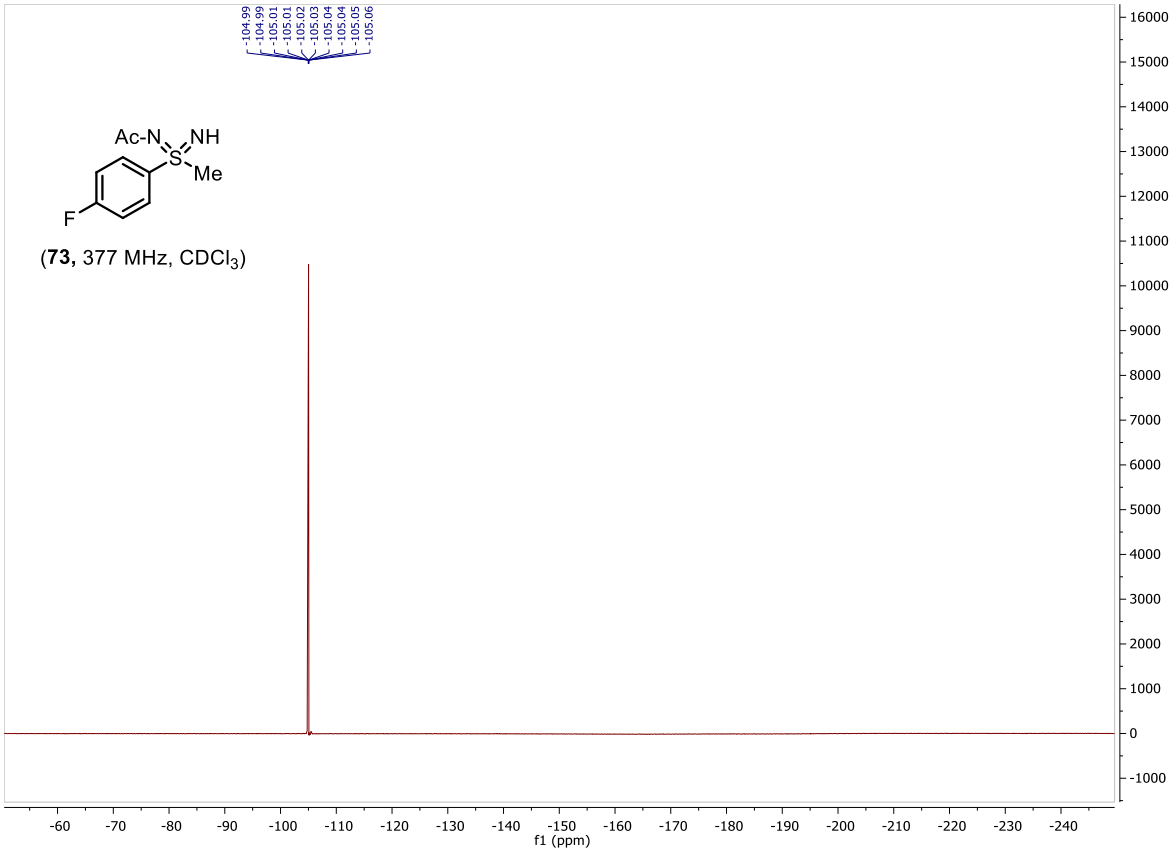
(**72,** 377 MHz, $CDCl_3$)



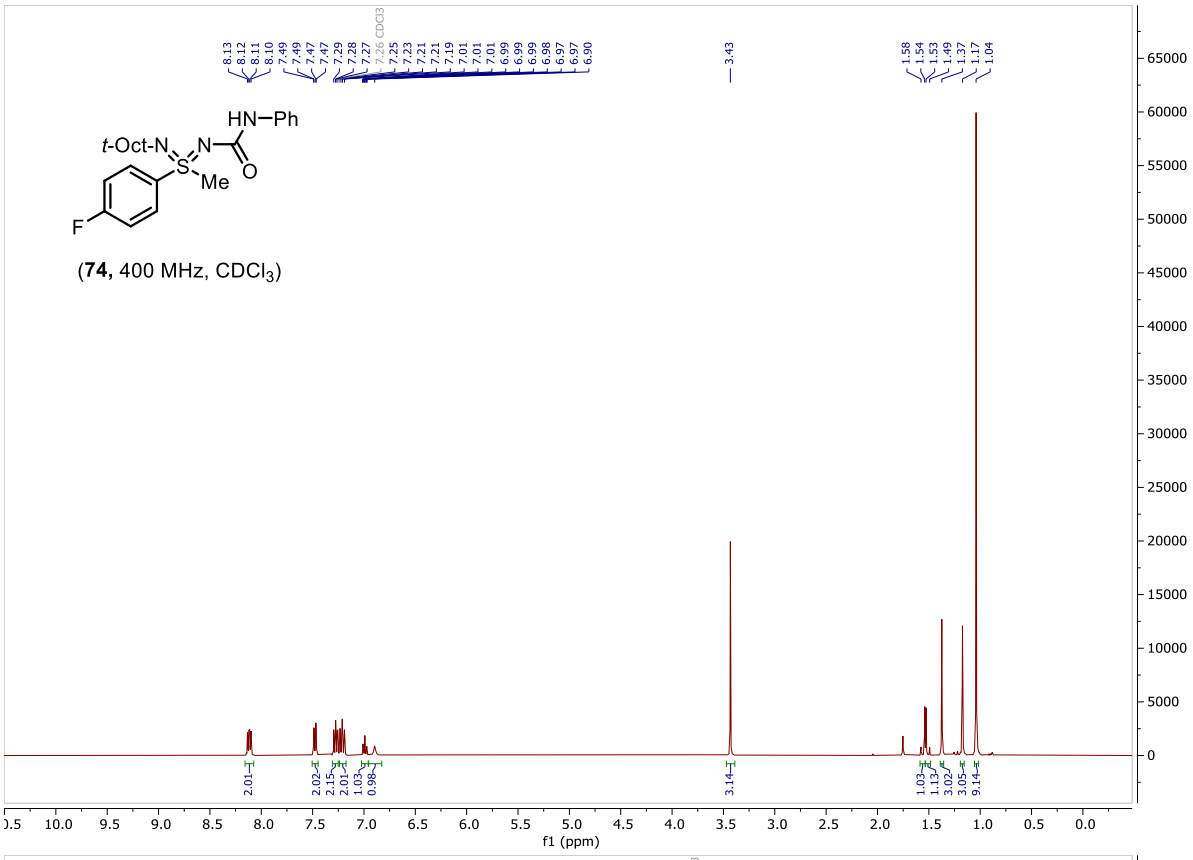
(**73,** 400 MHz, $CDCl_3$)



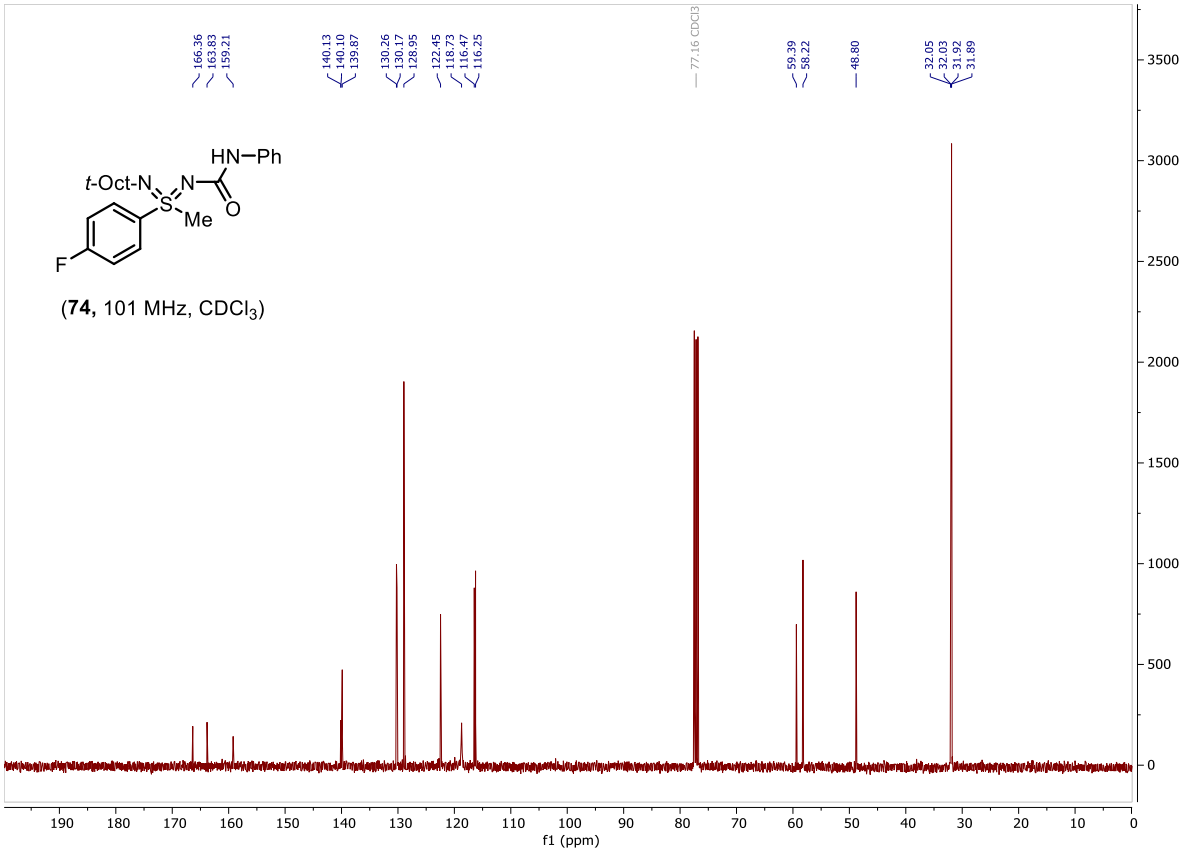
(**73,** 101 MHz, $CDCl_3$)



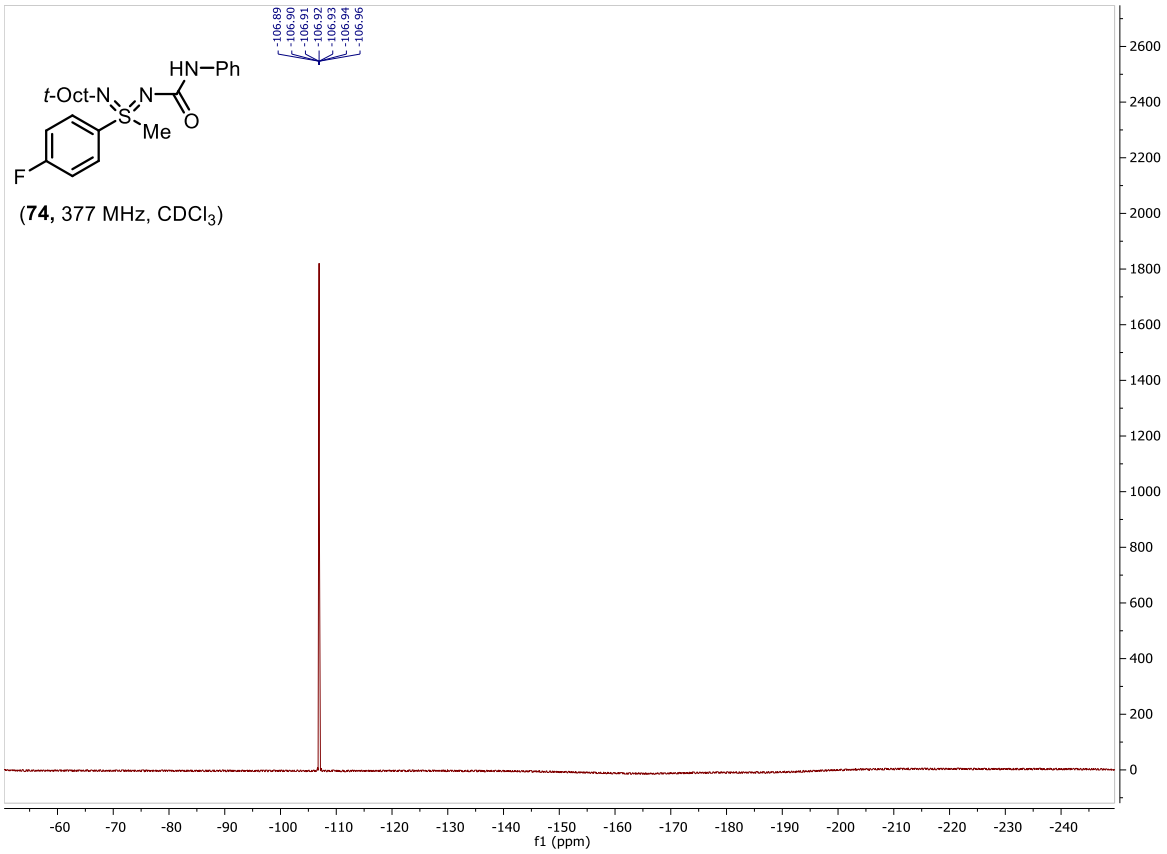
(**73,** 377 MHz, $CDCl_3$)



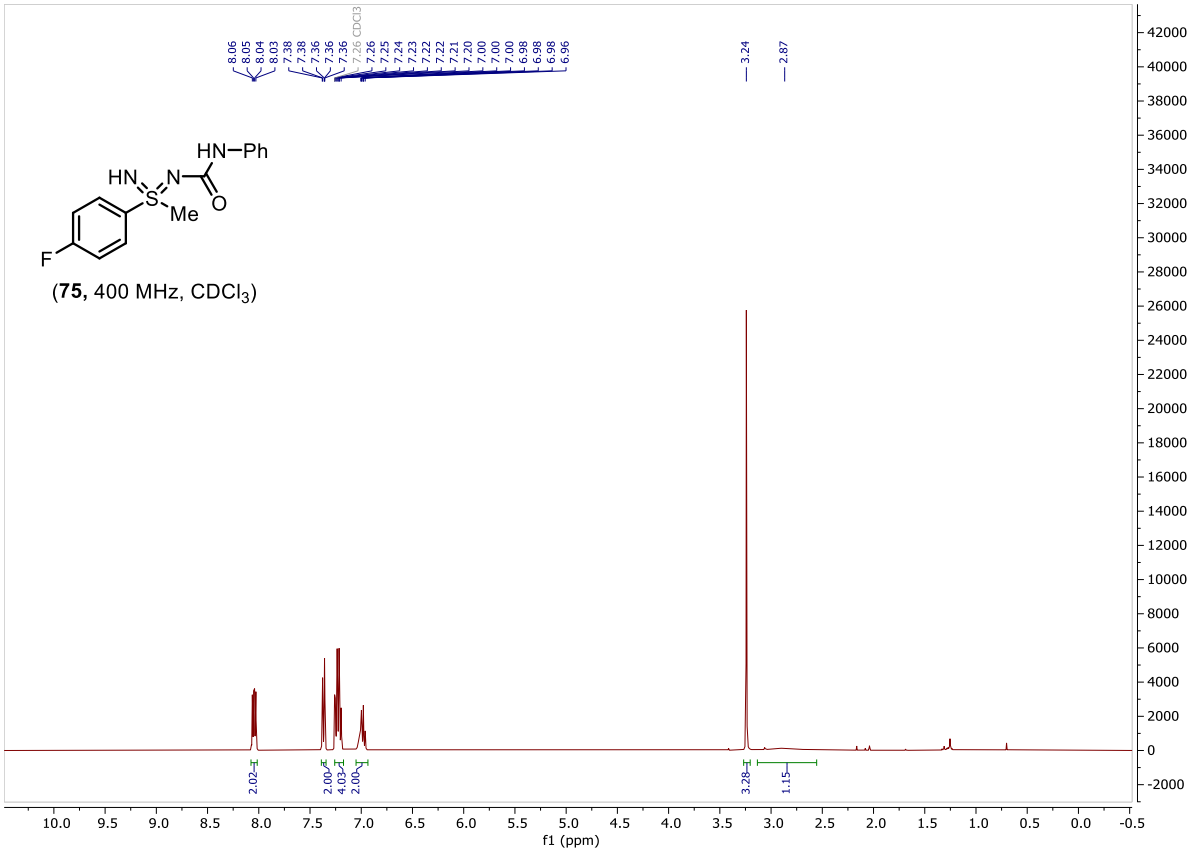
(**74,** 400 MHz, $CDCl_3$)



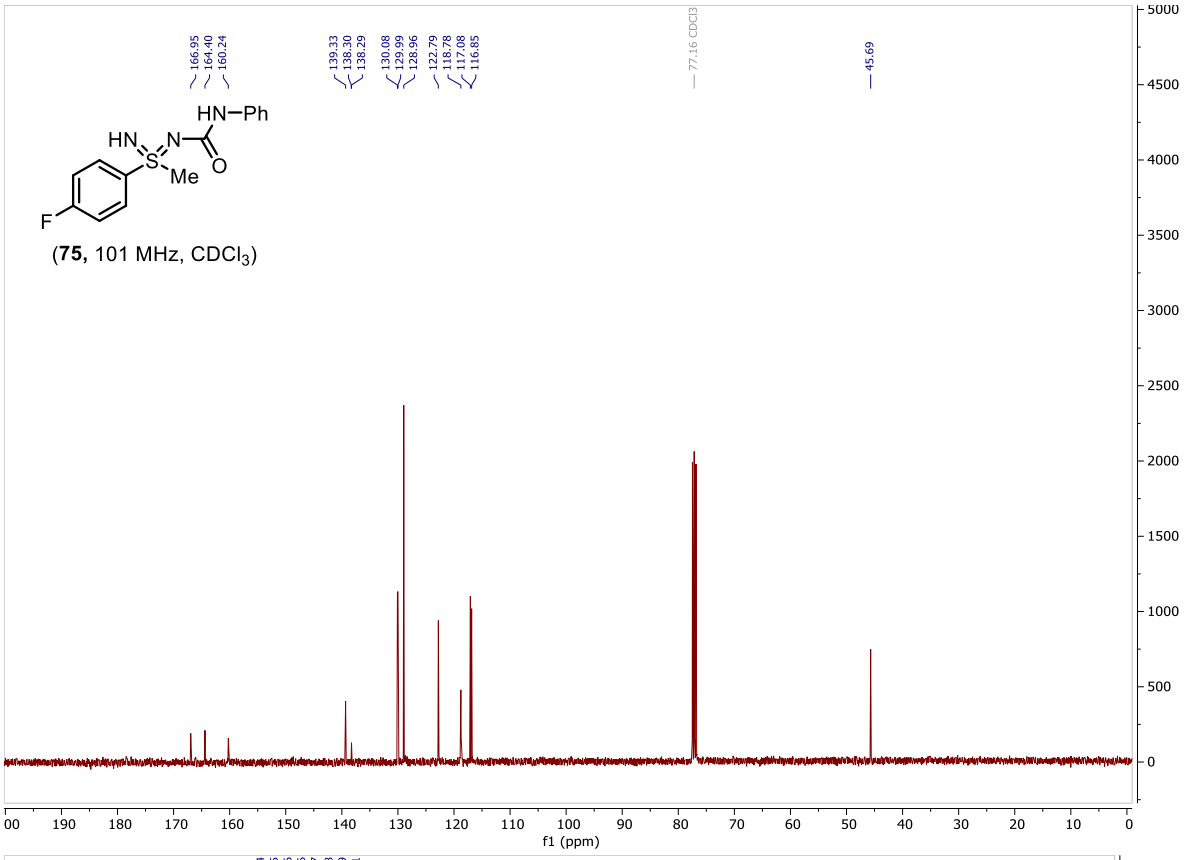
(**74,** 101 MHz, $CDCl_3$)

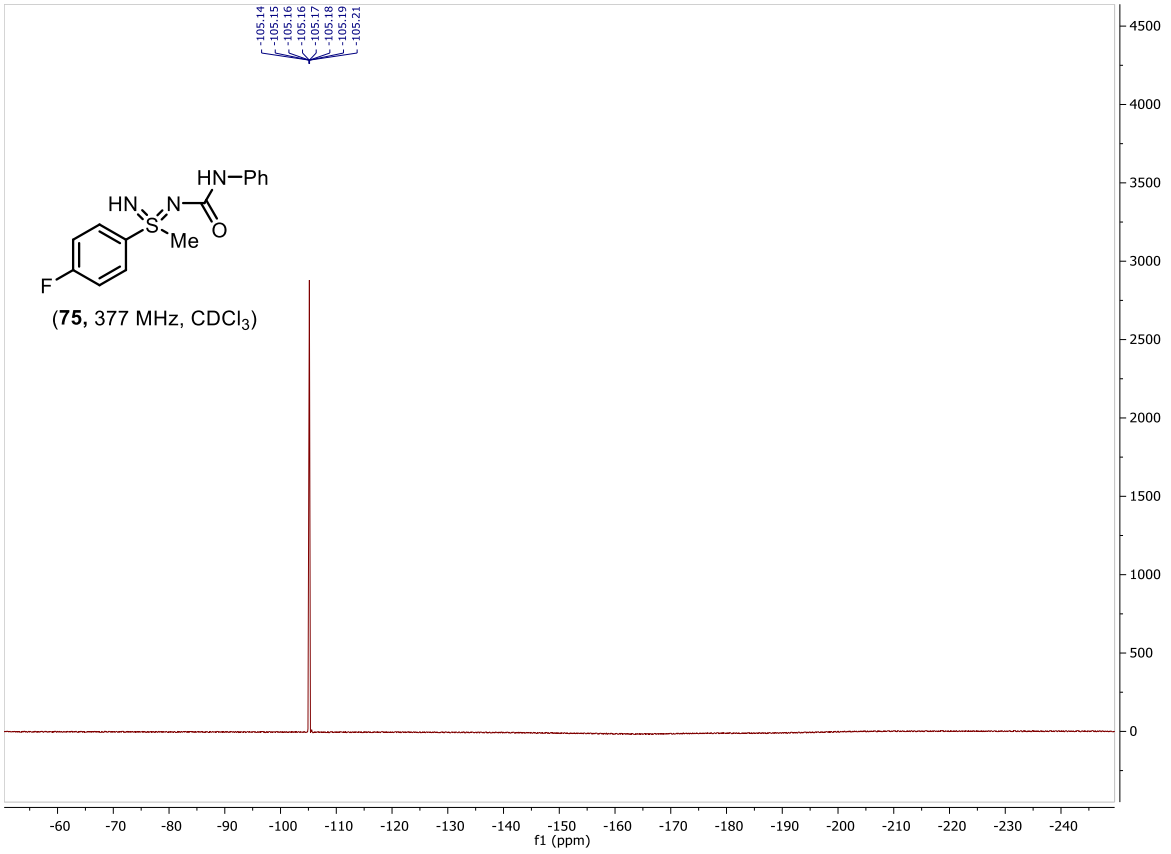


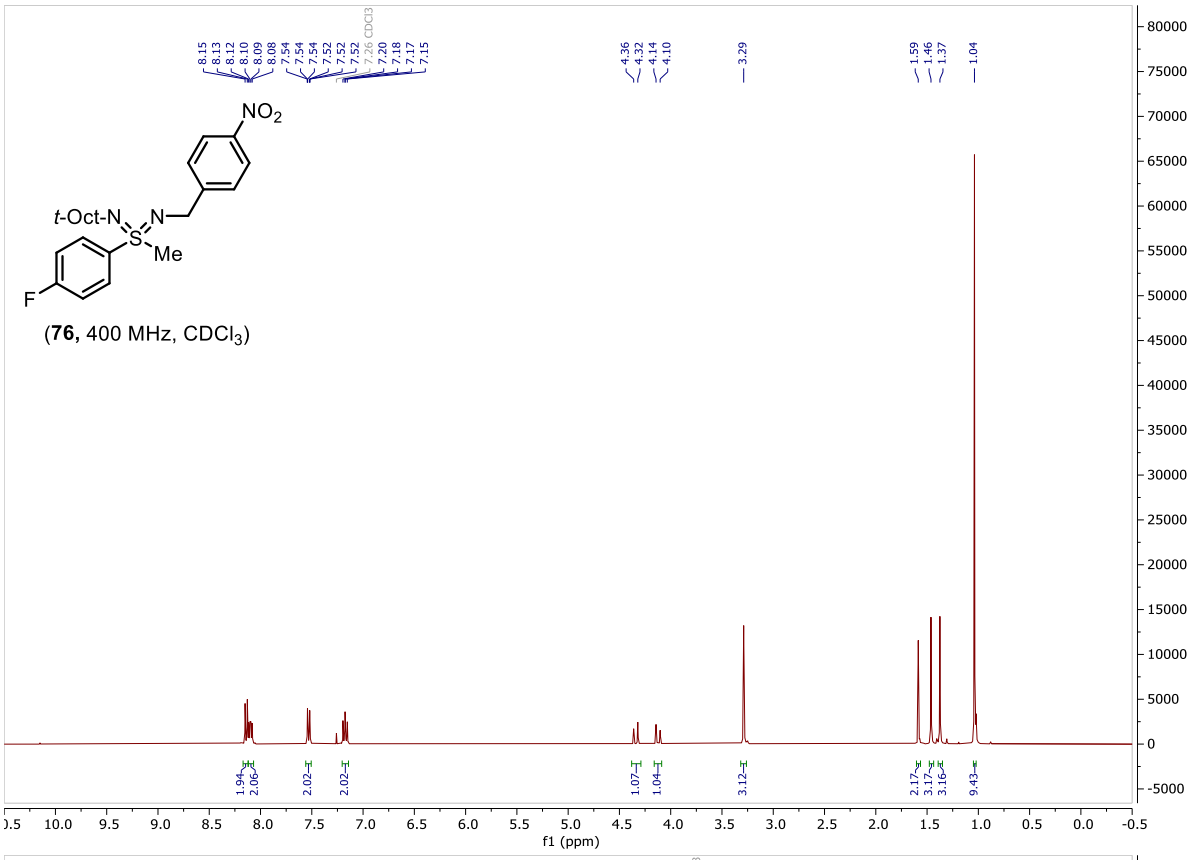
(**74,** 377 MHz, $CDCl_3$)



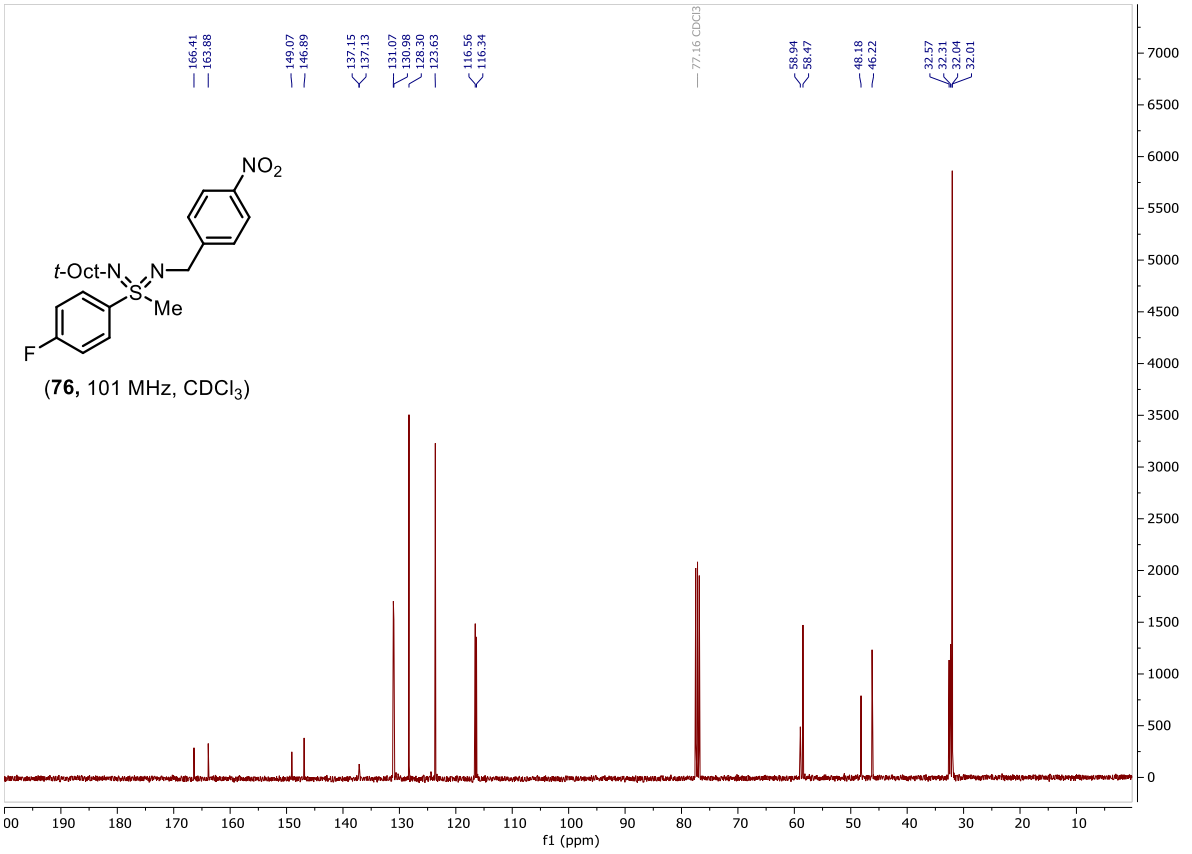
(**75,** 400 MHz, $CDCl_3$)


166.95
164.40
160.24
139.33
138.30
138.29
130.08
129.99
128.96
122.79
118.78
117.08
116.85
77.16 CDCl3
45.69
HN–Ph
HN
N
S
Me
O
F
(75, 101 MHz, CDCl3)
f1 (ppm)

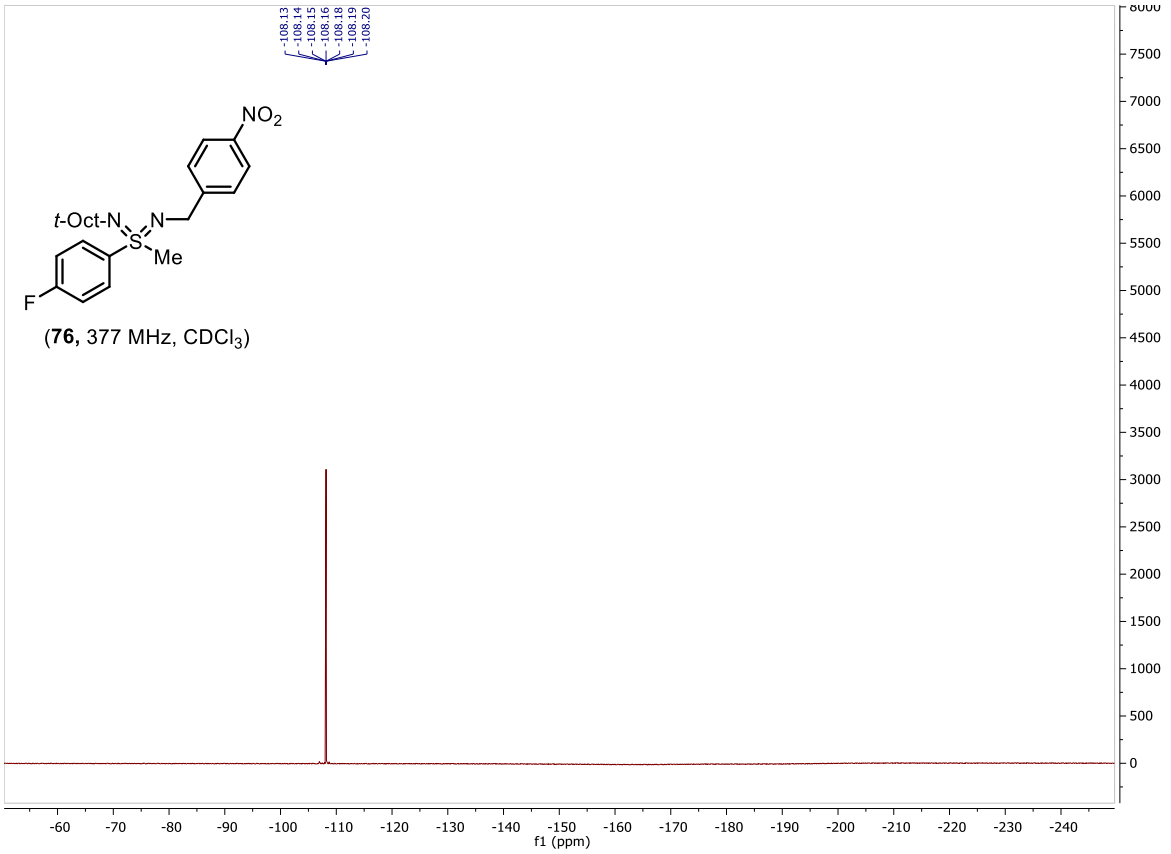

105.14
105.15
105.16
105.16
105.17
105.18
105.19
105.21
HN–Ph
HN
N
S
Me
O
F
(75, 377 MHz, CDCl3)
f1 (ppm)



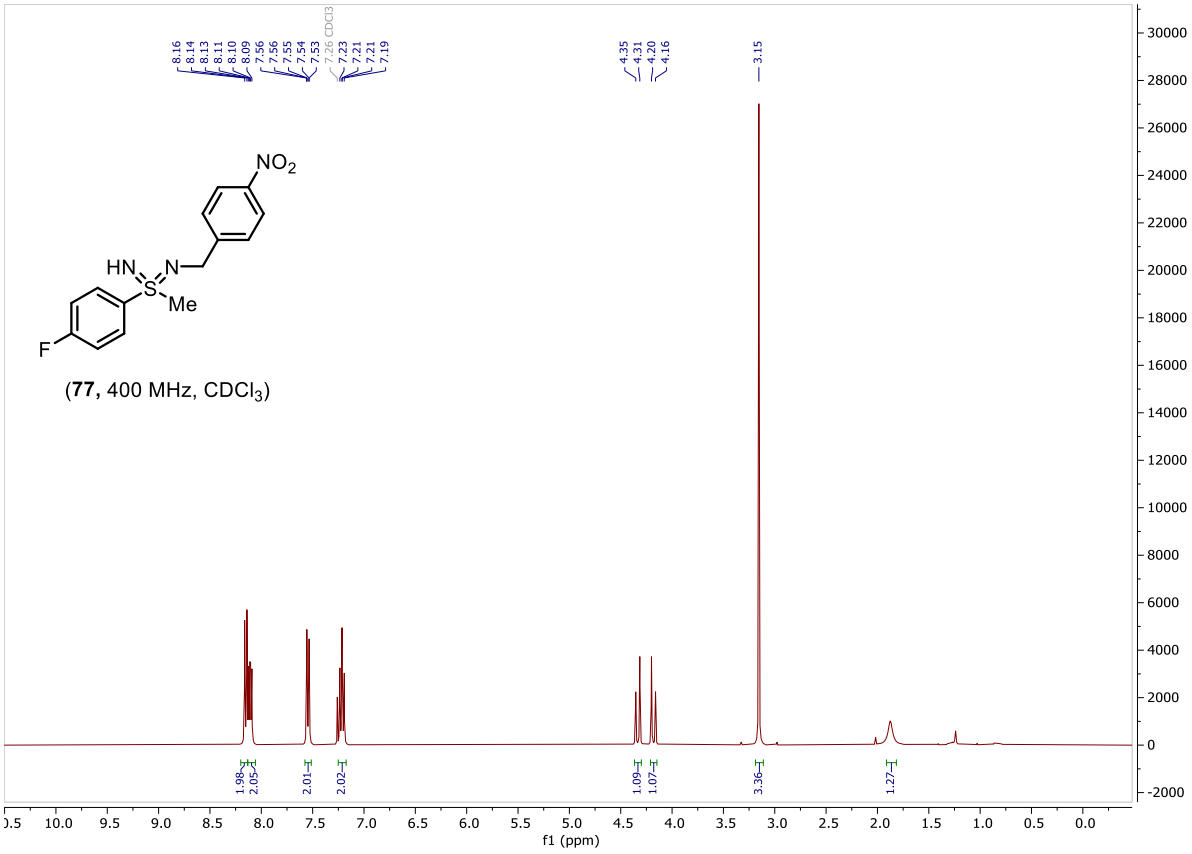
(**76,** 400 MHz, $CDCl_3$)



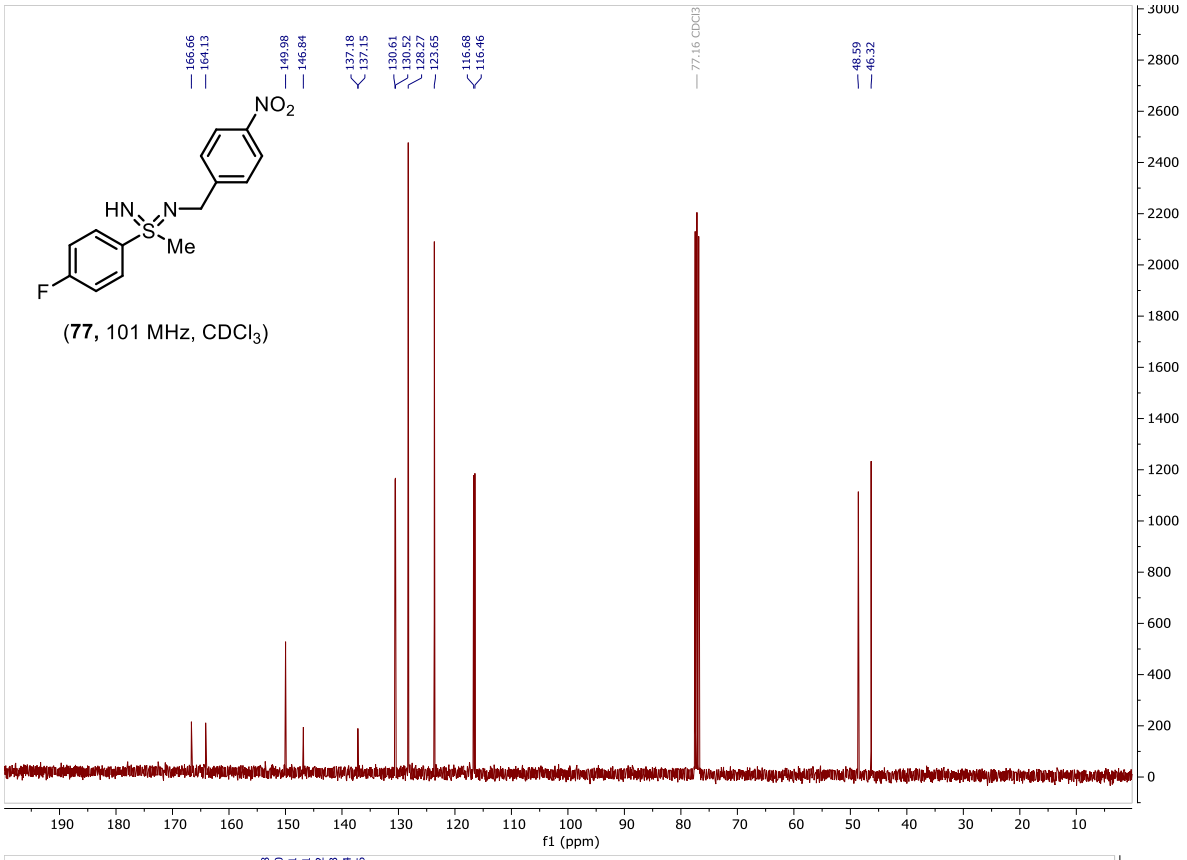
(**76,** 101 MHz, $CDCl_3$)



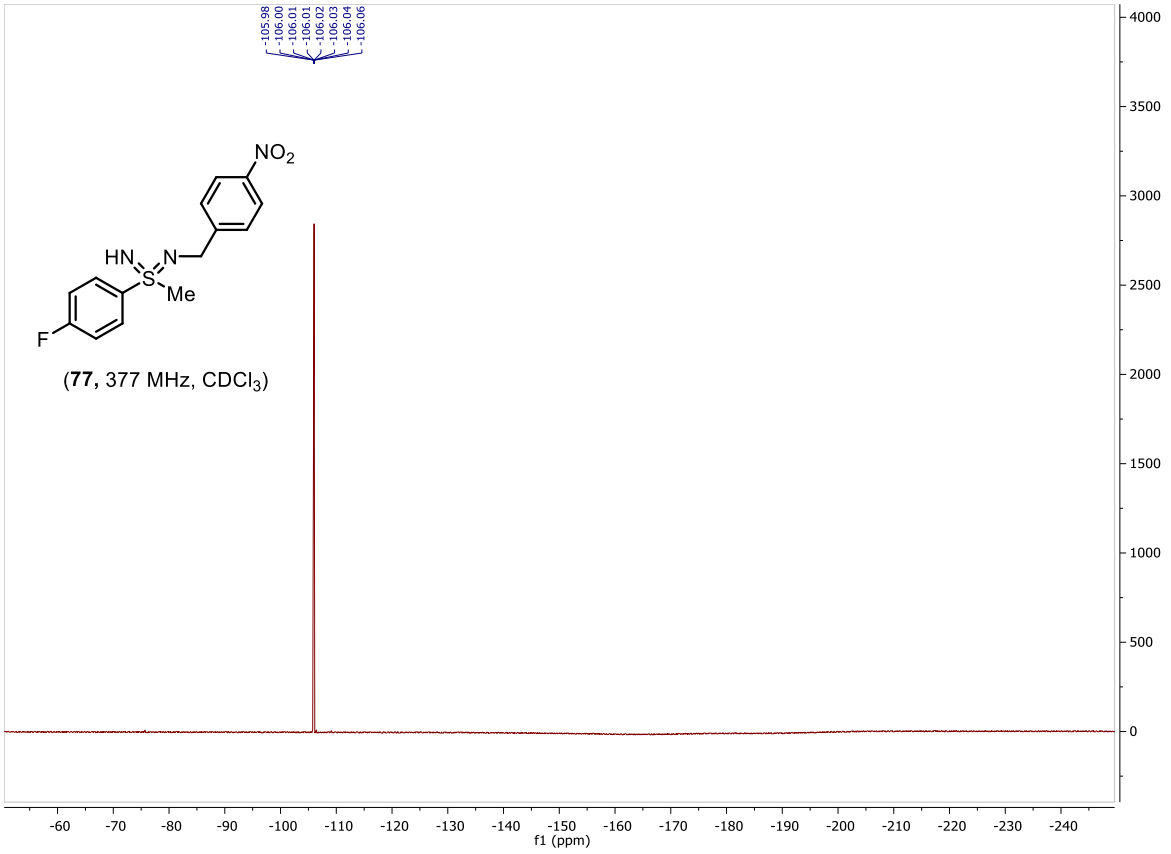
(**76,** 377 MHz, $CDCl_3$)



(**77,** 400 MHz, $CDCl_3$)

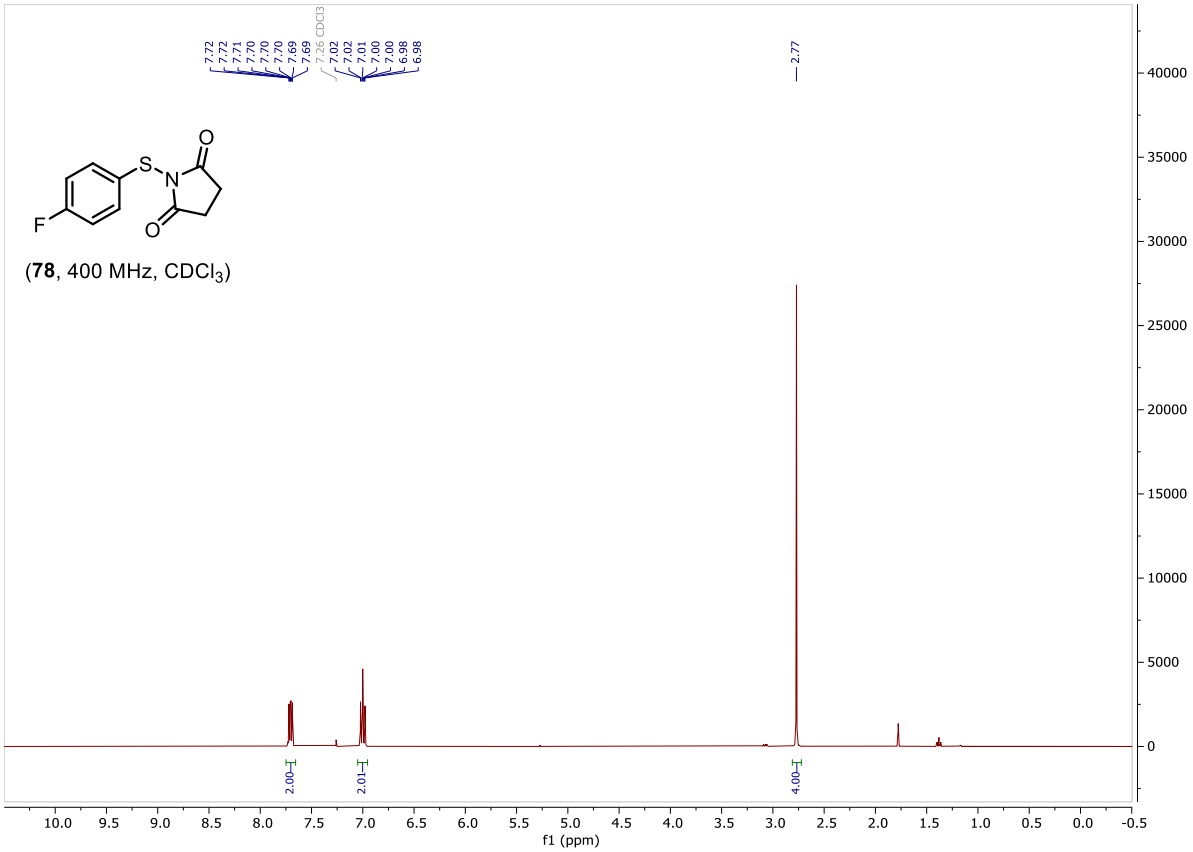


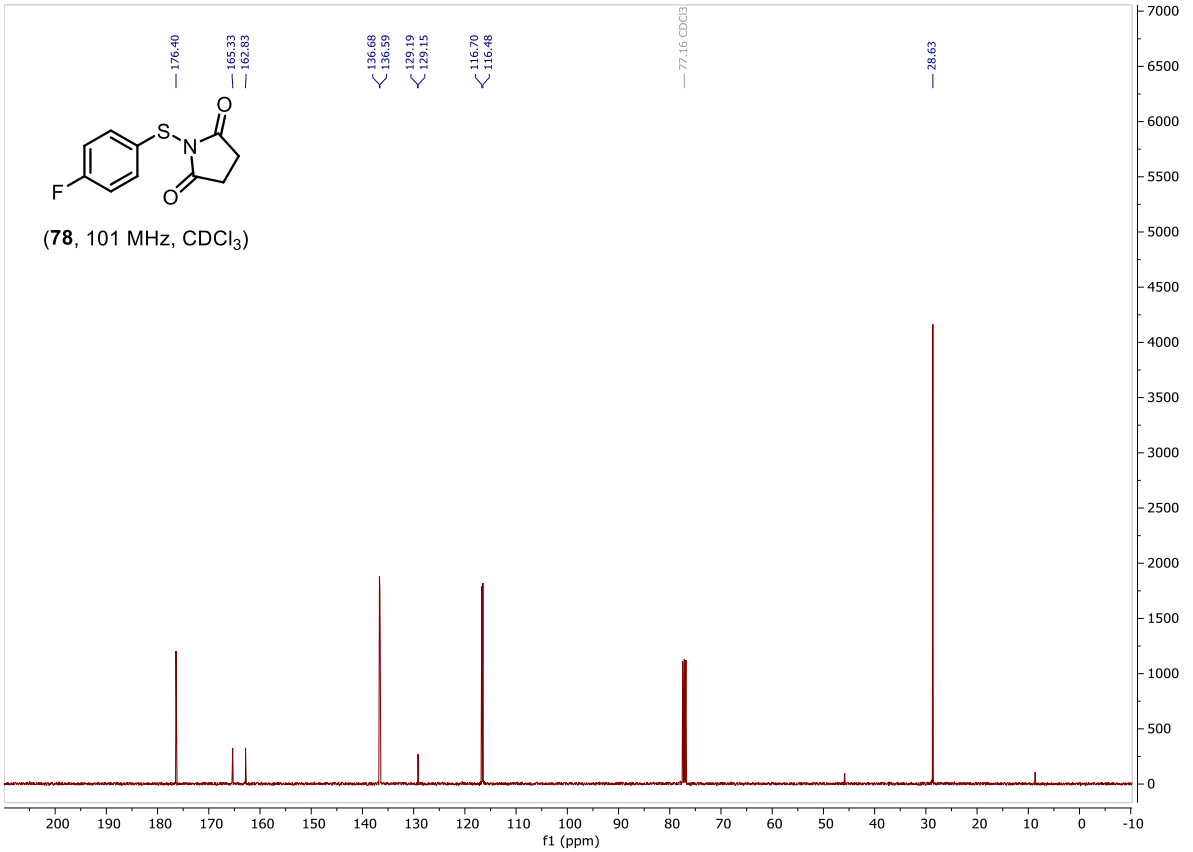
(**77,** 101 MHz, $CDCl_3$)

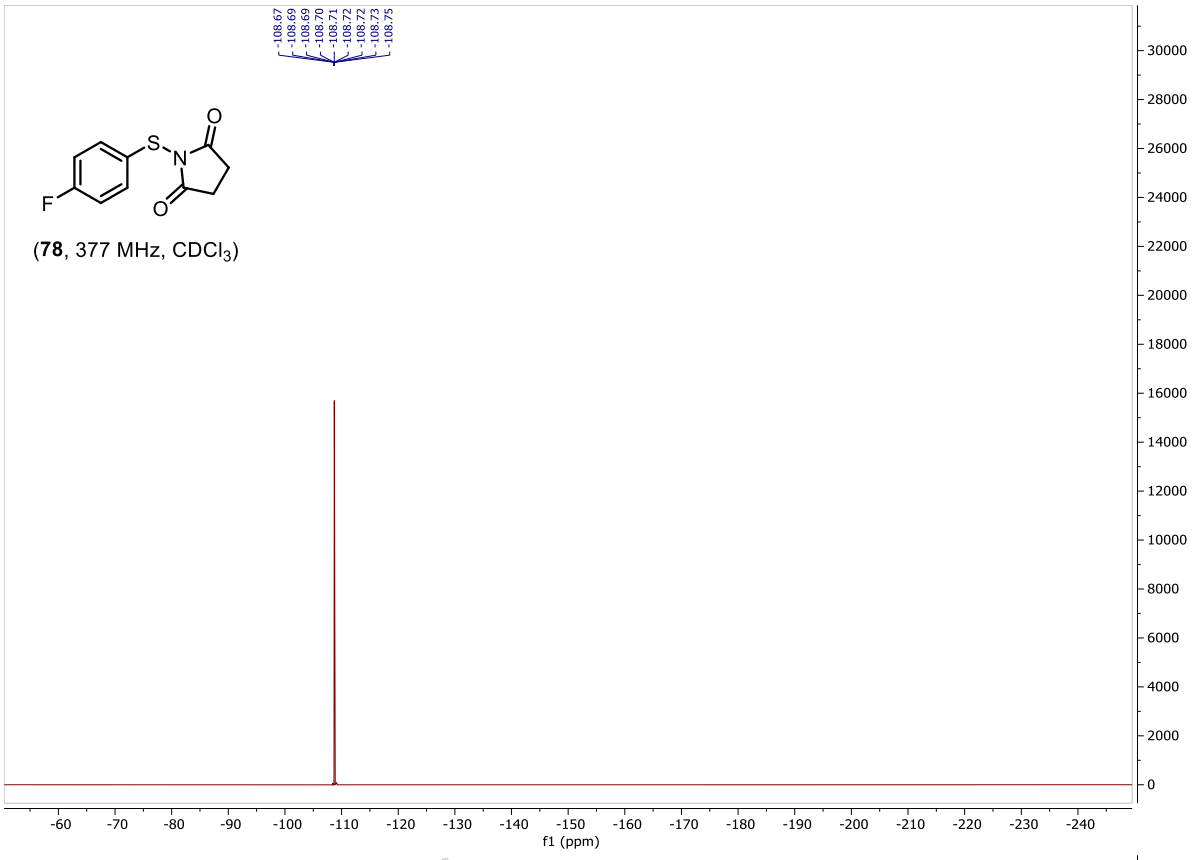


(**77,** 377 MHz, $CDCl_3$)

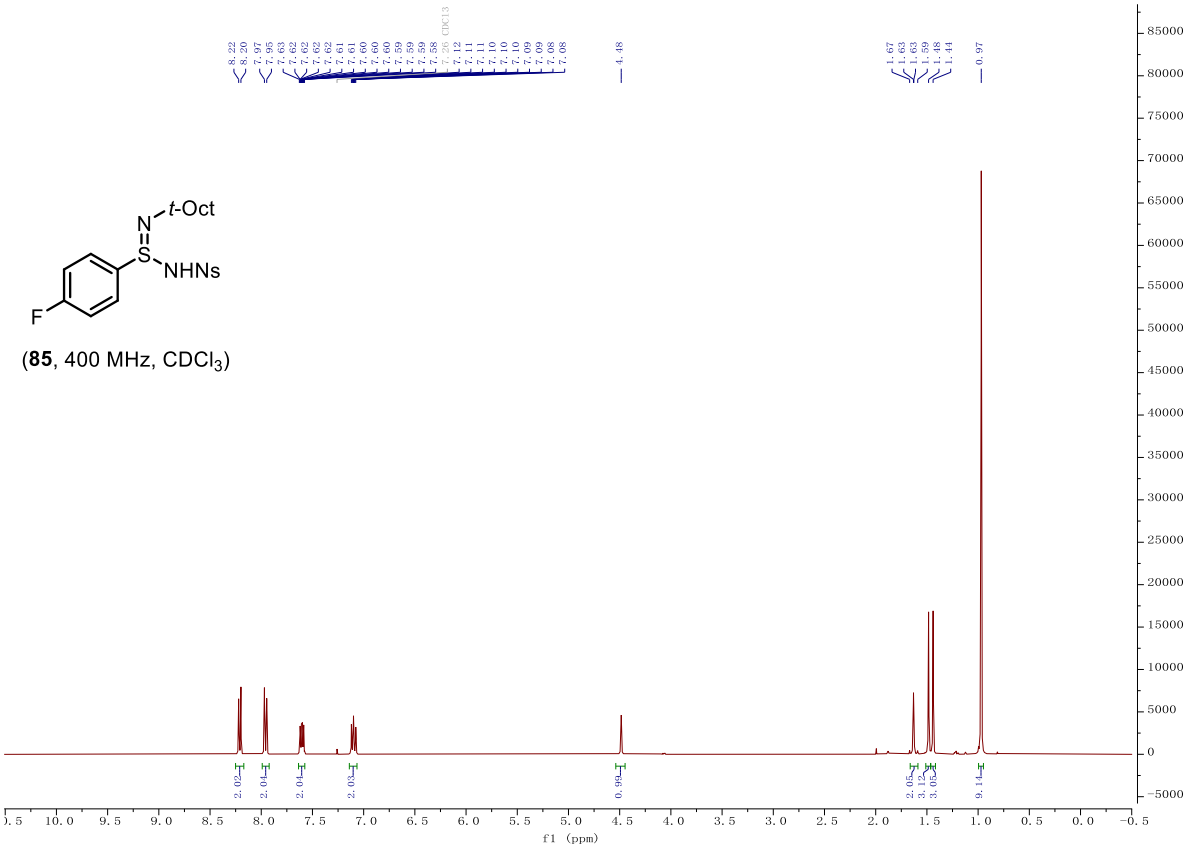
Chapter 3 NMR Spectra



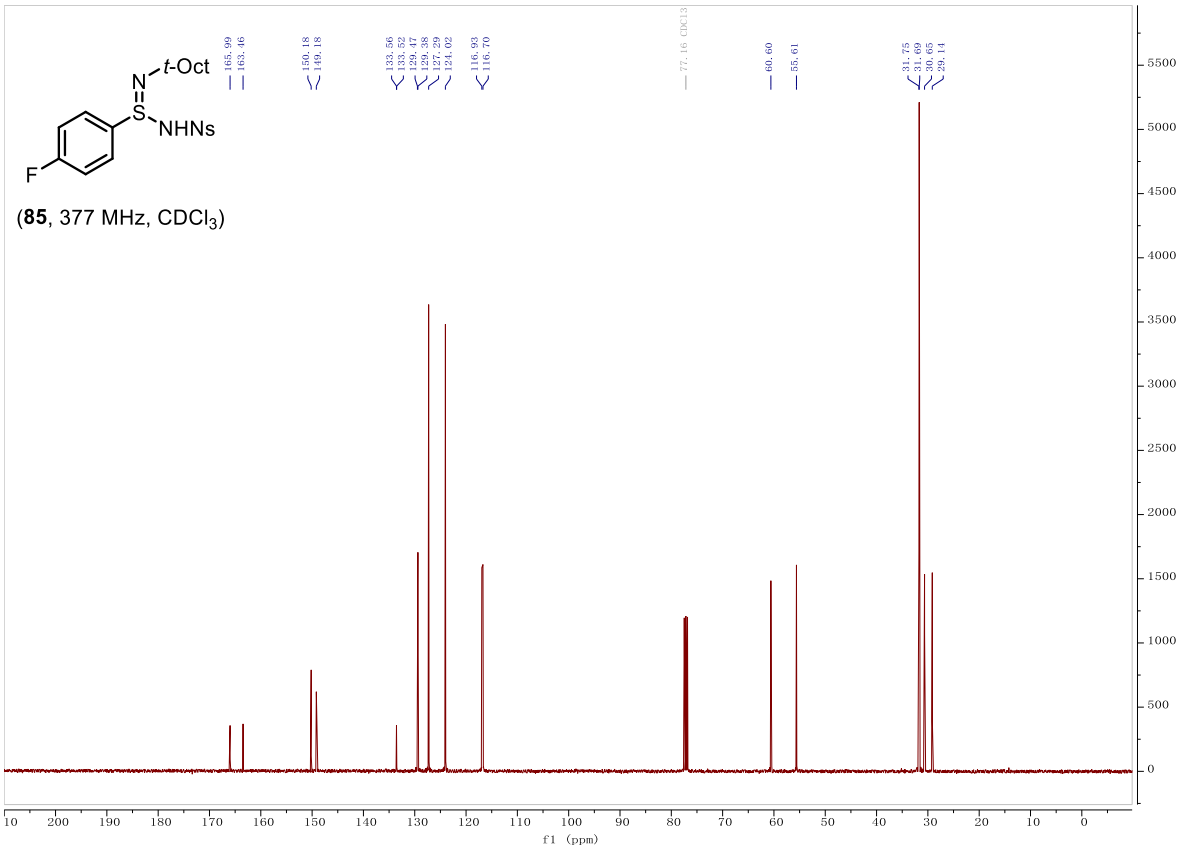


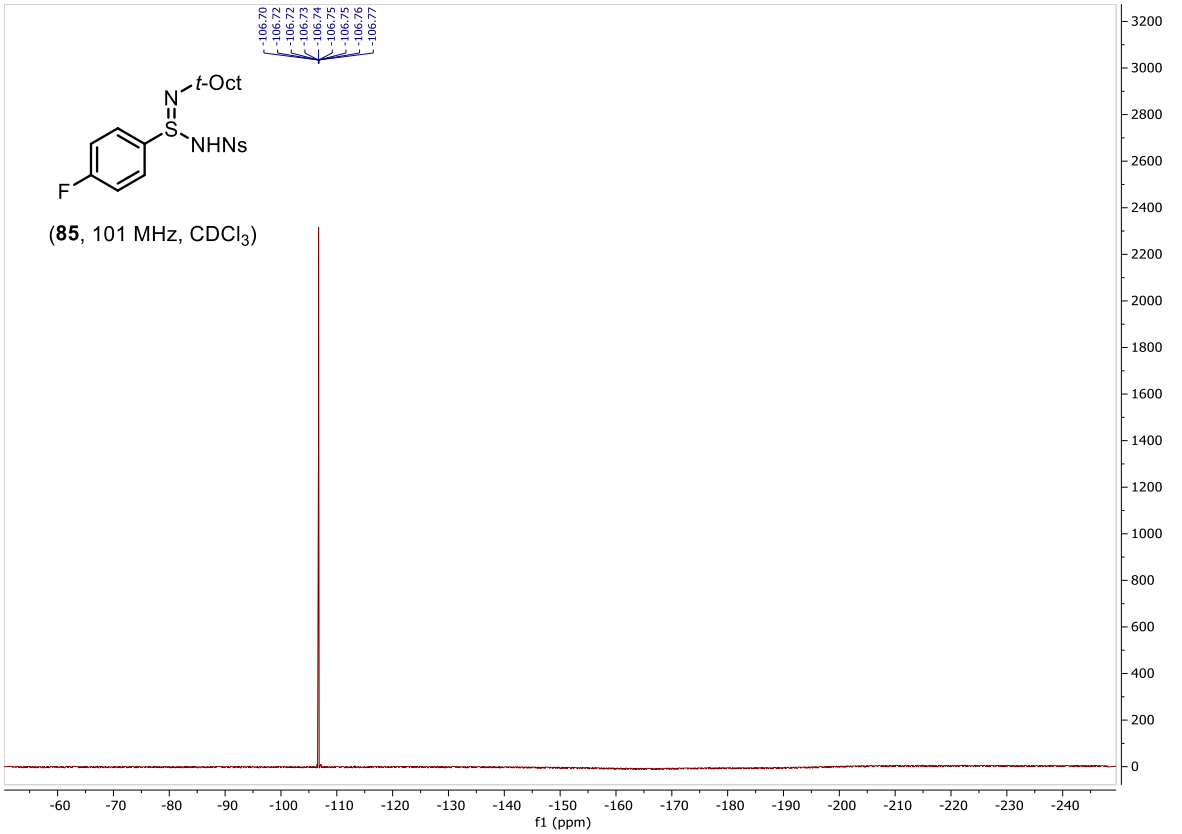


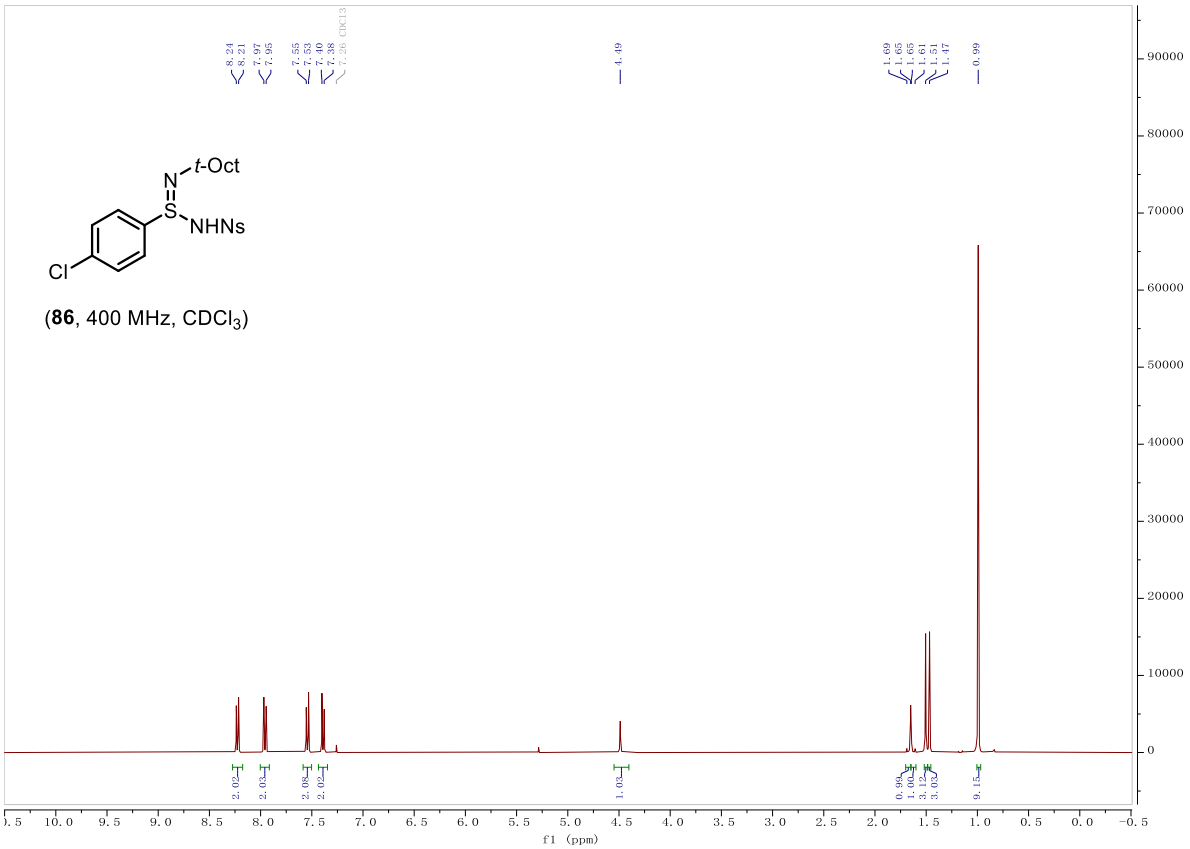
(**78**, 377 MHz, $CDCl_3$)



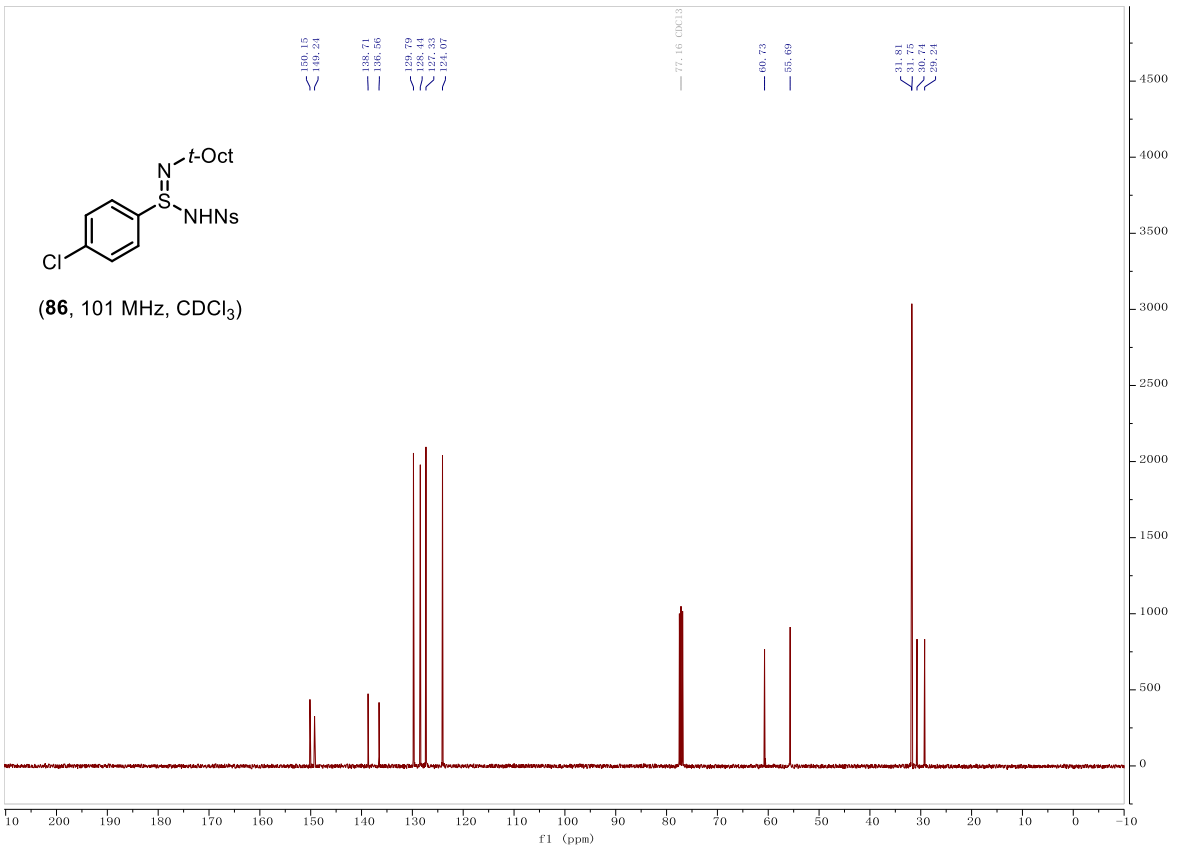
(**85**, 400 MHz, $CDCl_3$)


t-Oct
N
S
NHNs
F
(85, 377 MHz, CDCl3)
165.99
163.46
150.18
149.18
133.56
133.52
129.47
129.38
127.29
124.02
116.93
116.70
77.16 CDCl3
60.60
55.61
31.75
31.69
30.65
29.14
f1 (ppm)

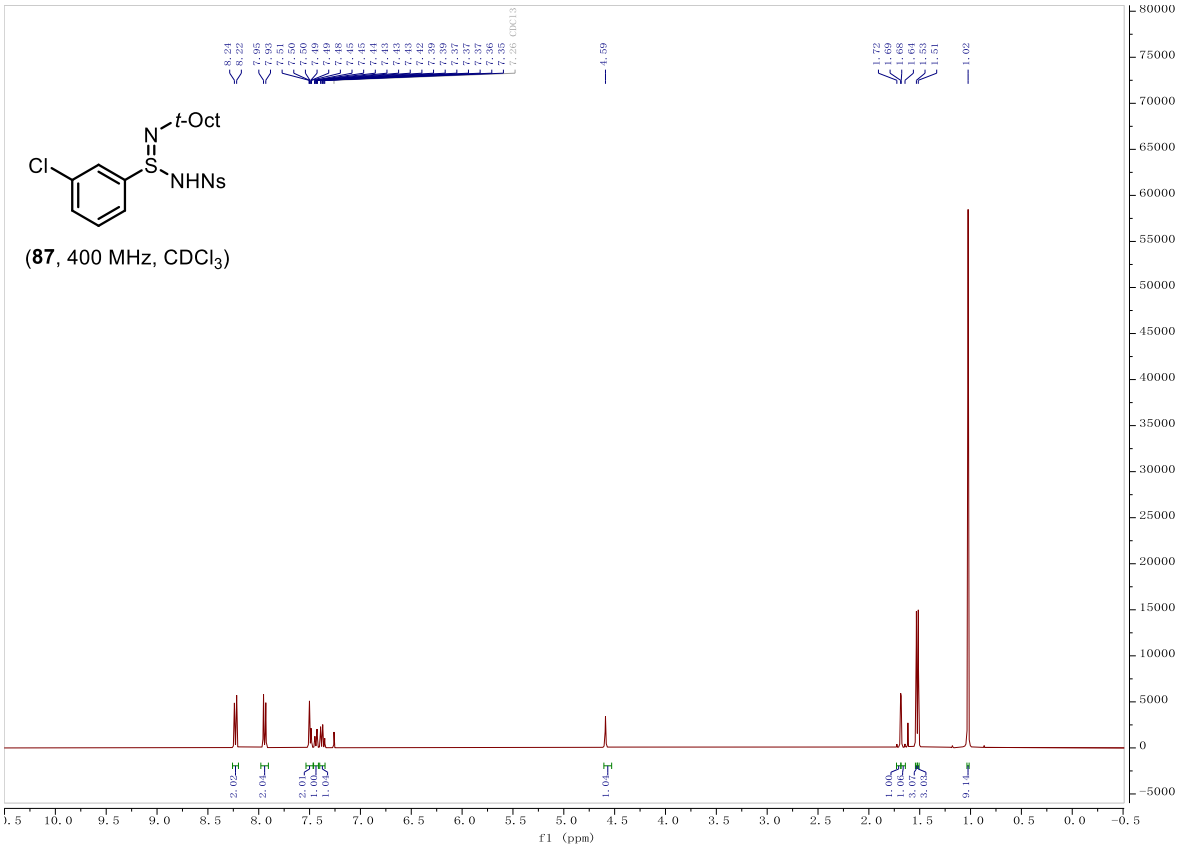

t-Oct
N
S
NHNs
F
(85, 101 MHz, CDCl3)
-106.70
-106.72
-106.72
-106.73
-106.74
-106.75
-106.75
-106.76
-106.77
f1 (ppm)



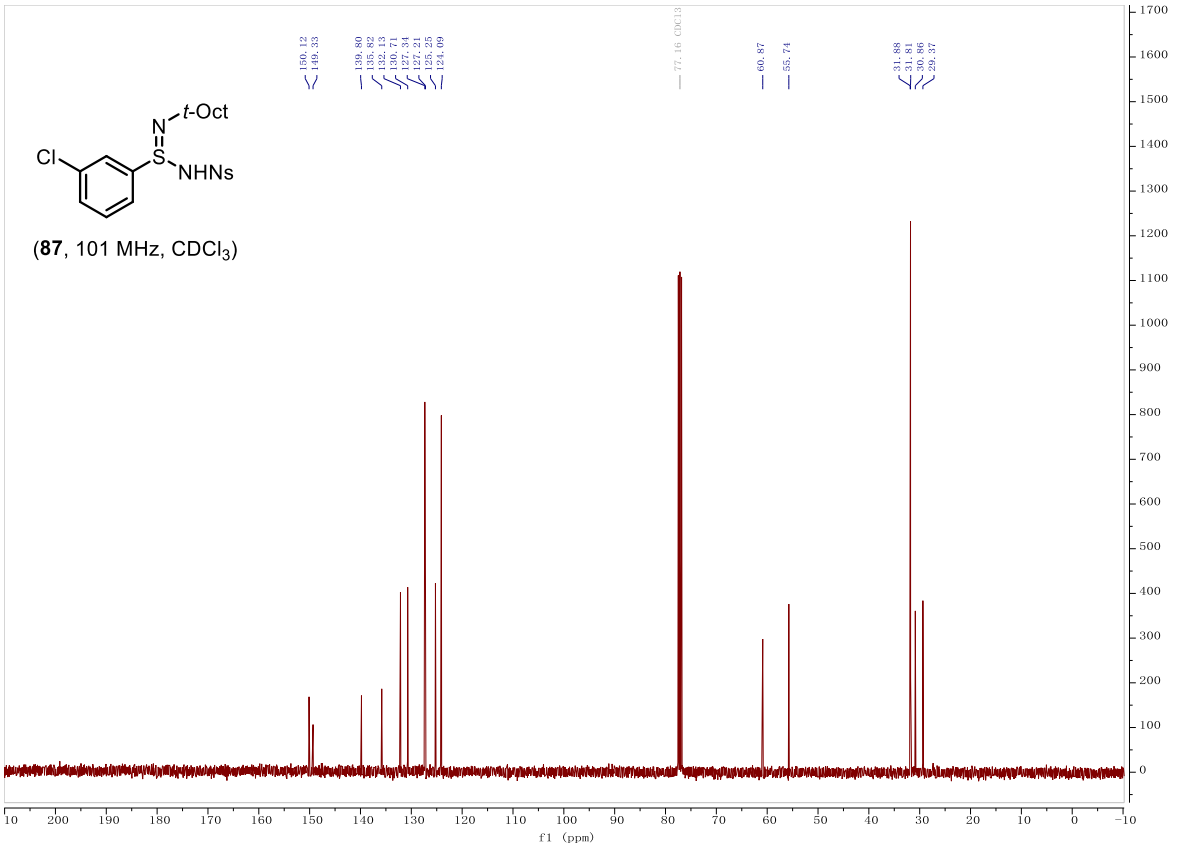
(**86**, 400 MHz, $CDCl_3$)



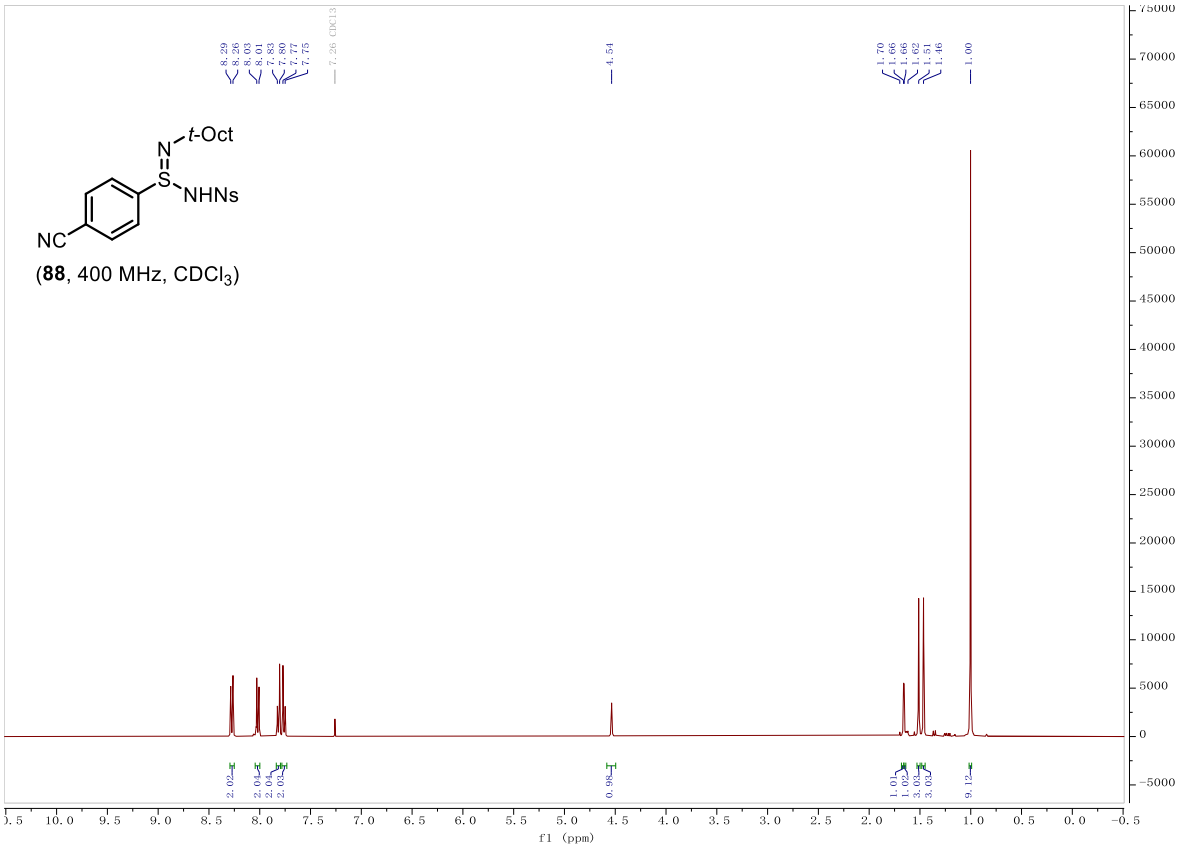
(**86**, 101 MHz, $CDCl_3$)

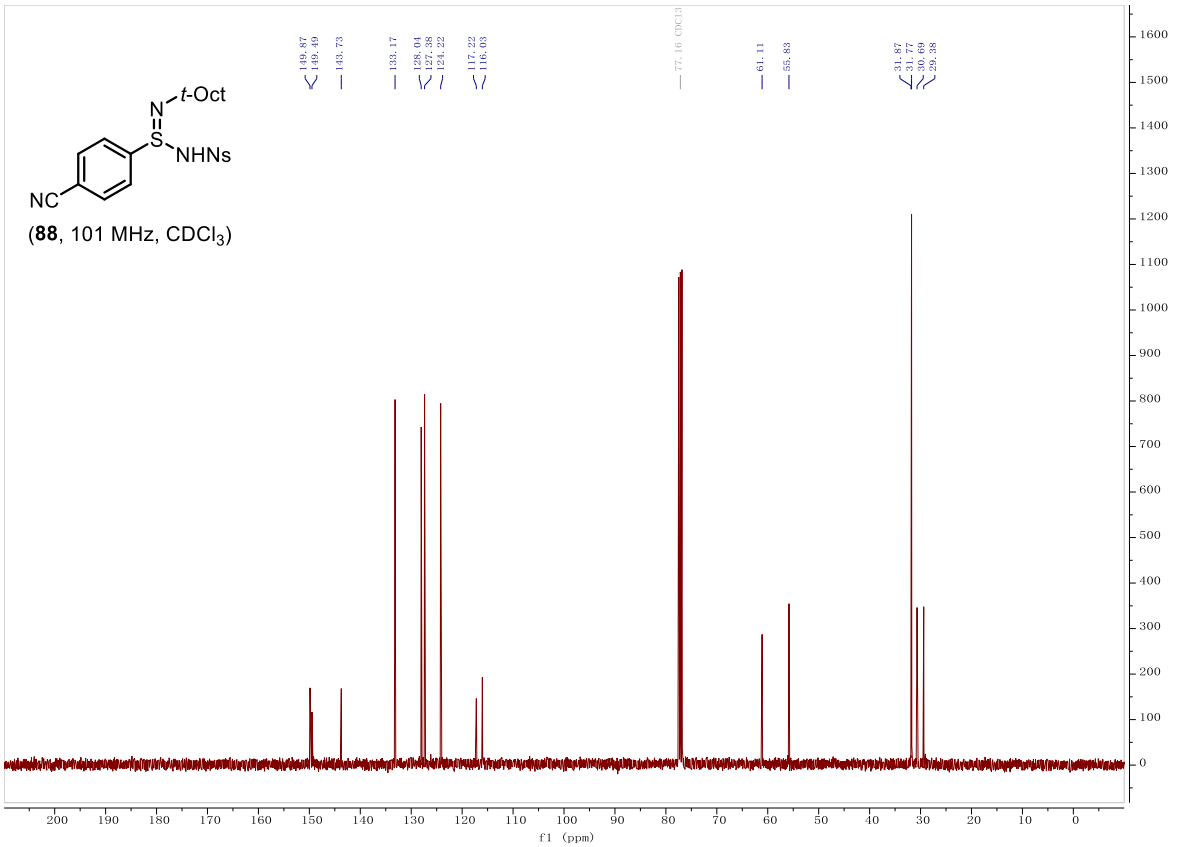


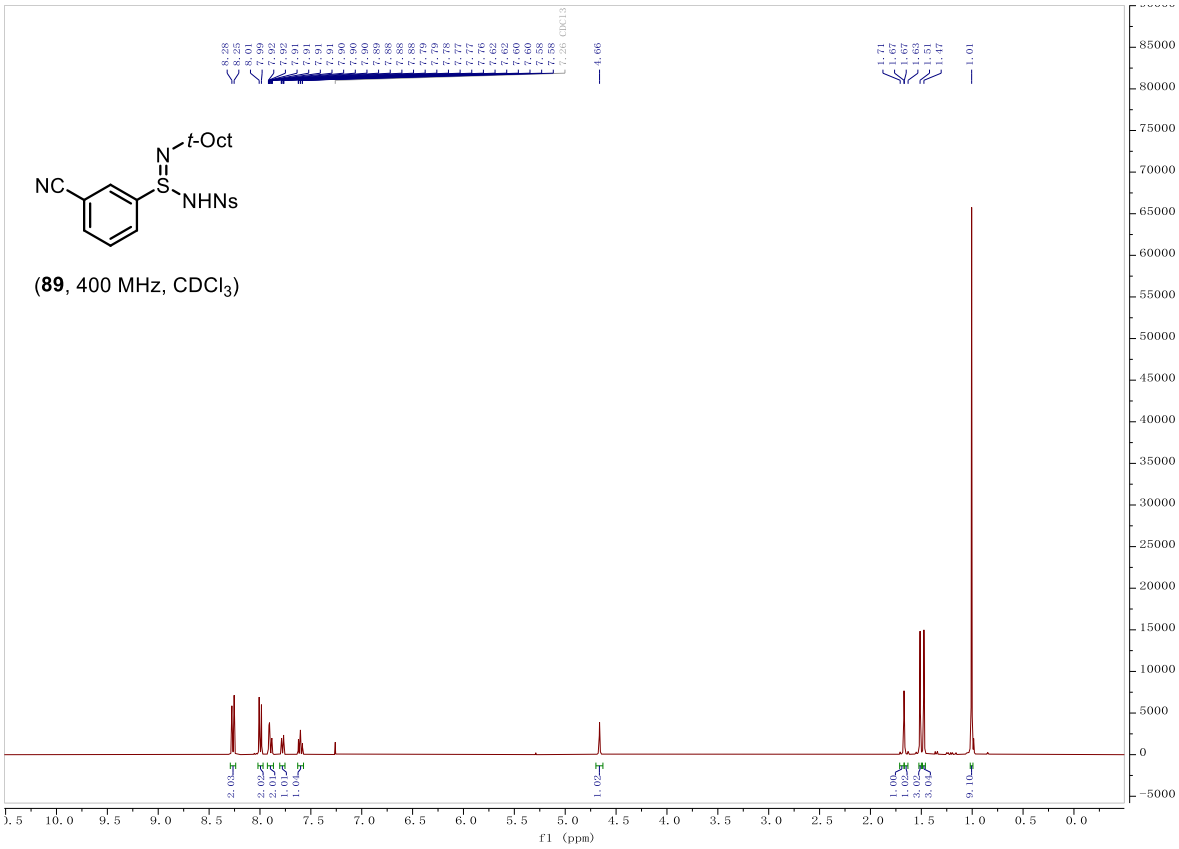
(**87**, 400 MHz, $CDCl_3$)

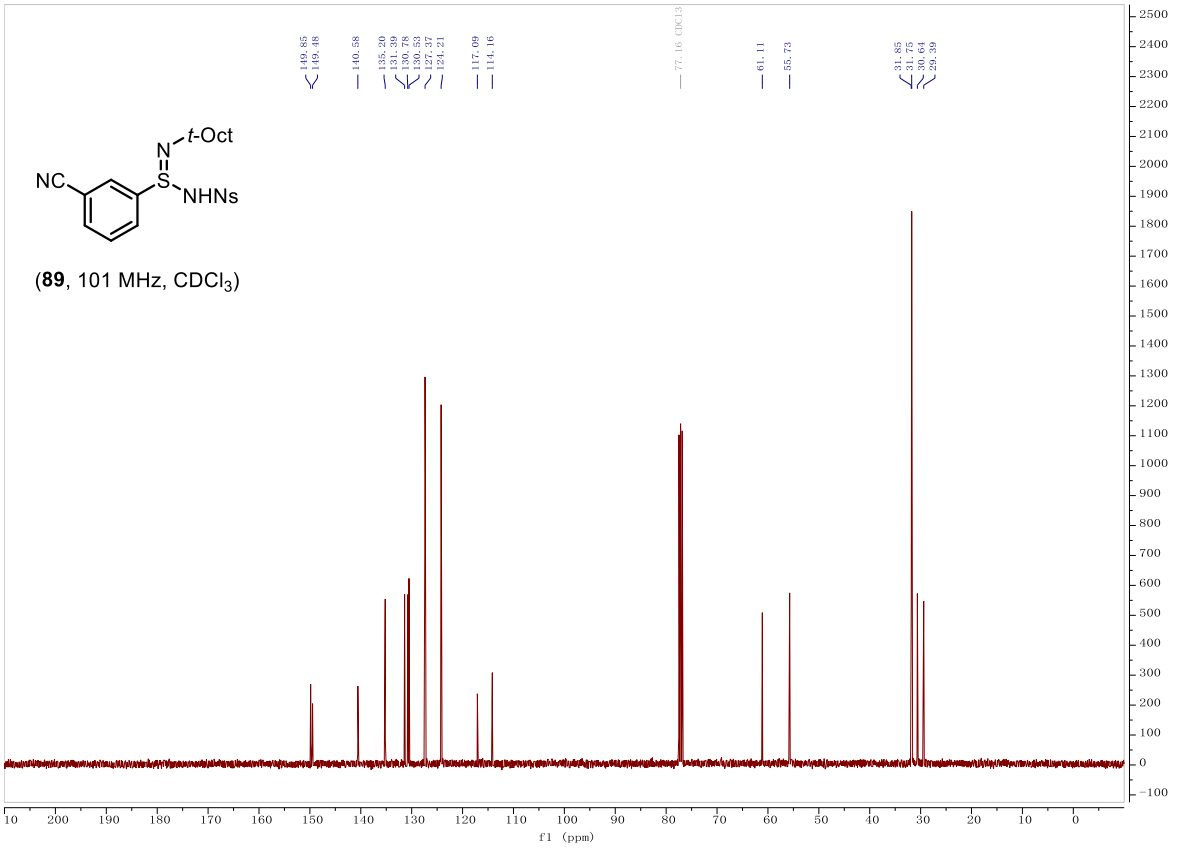


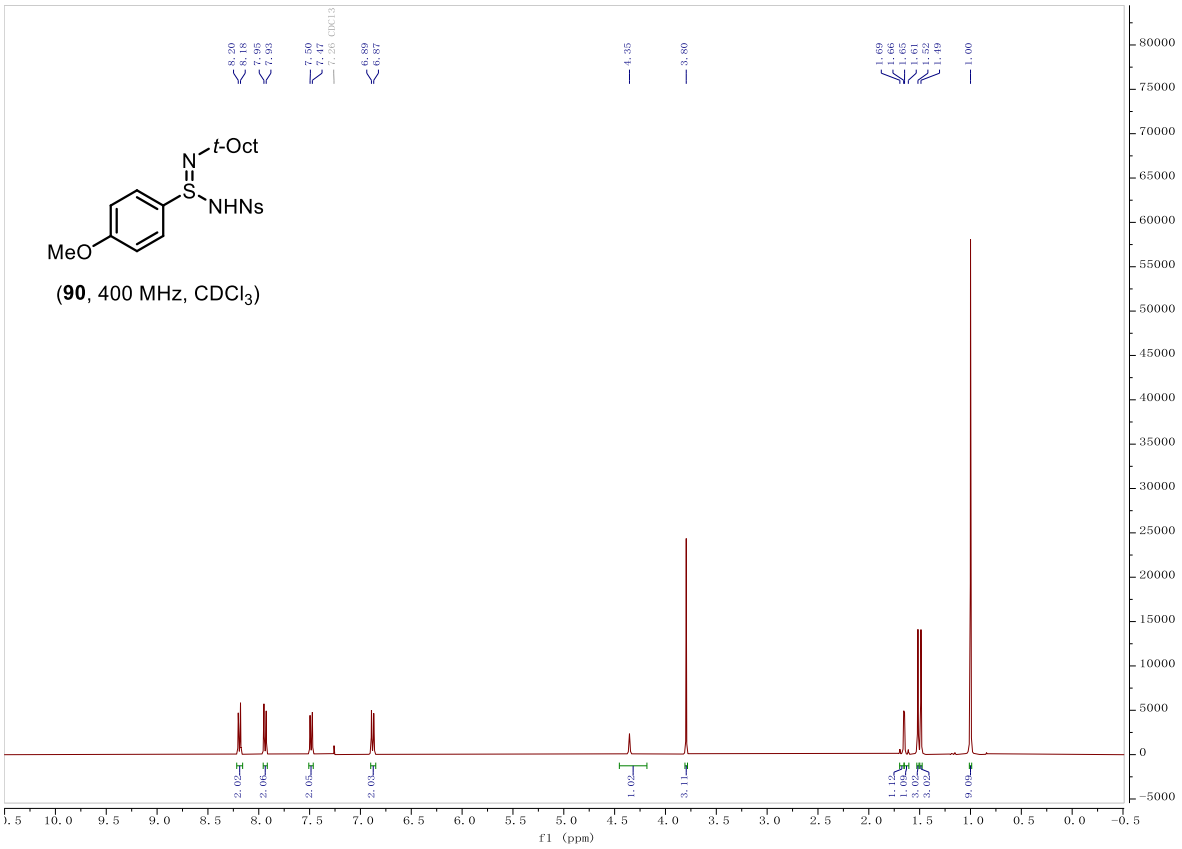
(**87**, 101 MHz, $CDCl_3$)

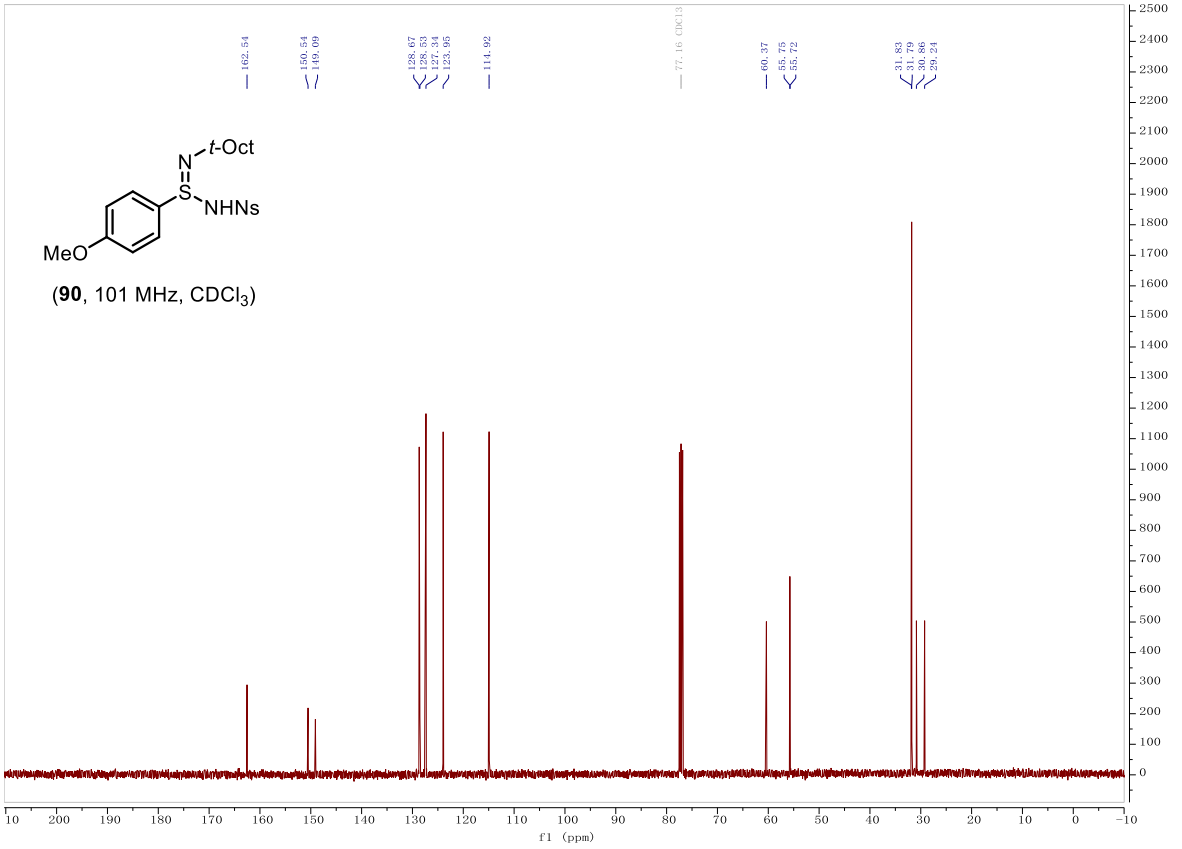

8.29
8.26
8.03
8.01
7.83
7.80
7.77
7.75
7.26 CDCl3
4.54
1.70
1.66
1.66
1.62
1.51
1.46
1.00
t-Oct
N
S
NHNs
NC
(88, 400 MHz, CDCl3)
f1 (ppm)

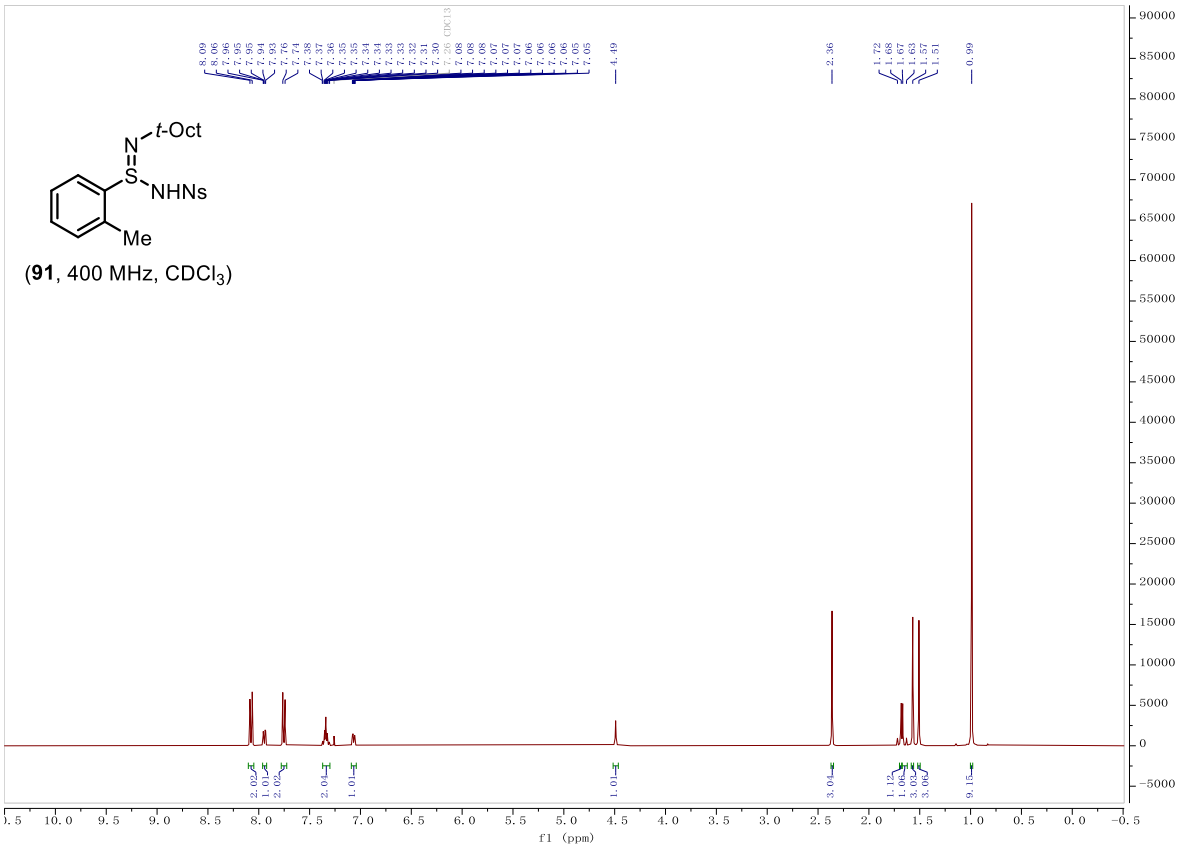

149.87
149.49
143.73
133.17
128.04
127.38
124.22
117.22
116.03
77.16 CDCl3
61.11
55.83
31.87
31.77
30.69
29.38
t-Oct
N
S
NHNs
NC
(88, 101 MHz, CDCl3)
f1 (ppm)

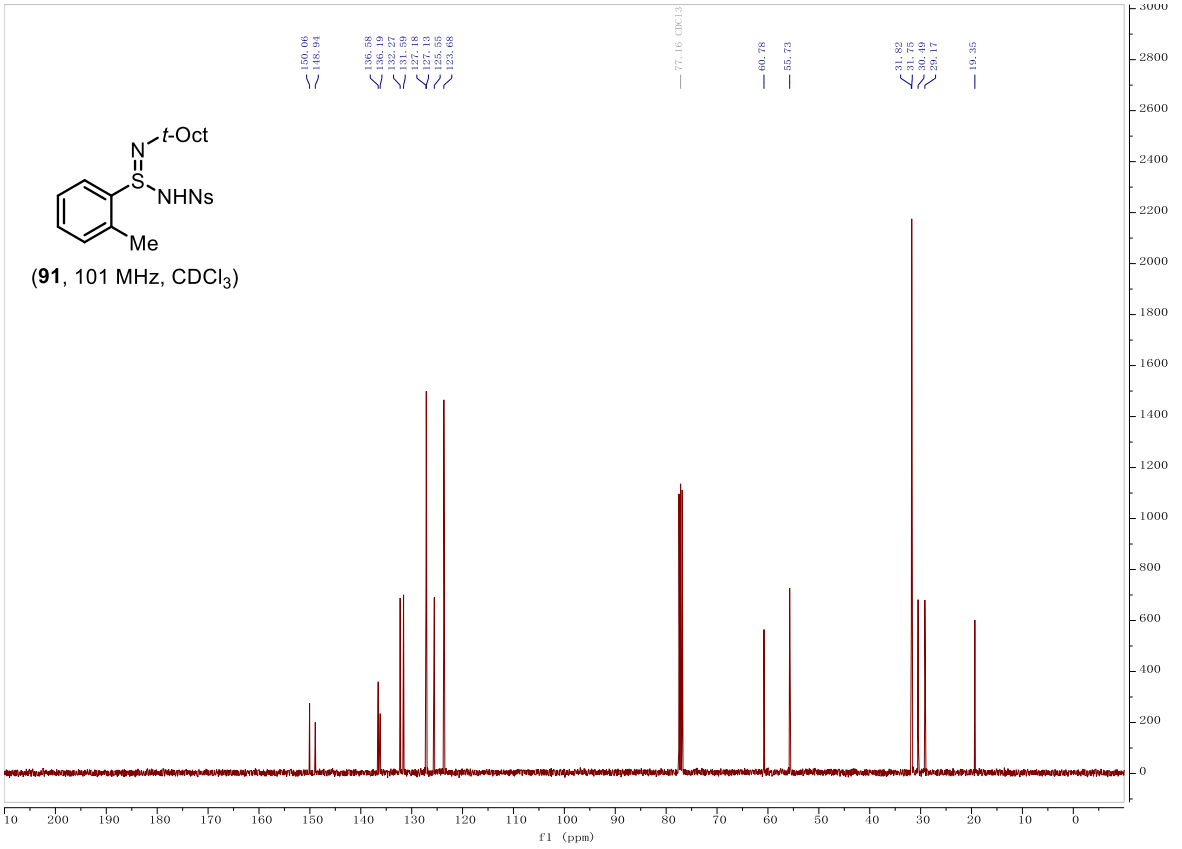

t-Oct
N
S
NC
NHNs
(89, 400 MHz, CDCl3)
f1 (ppm)

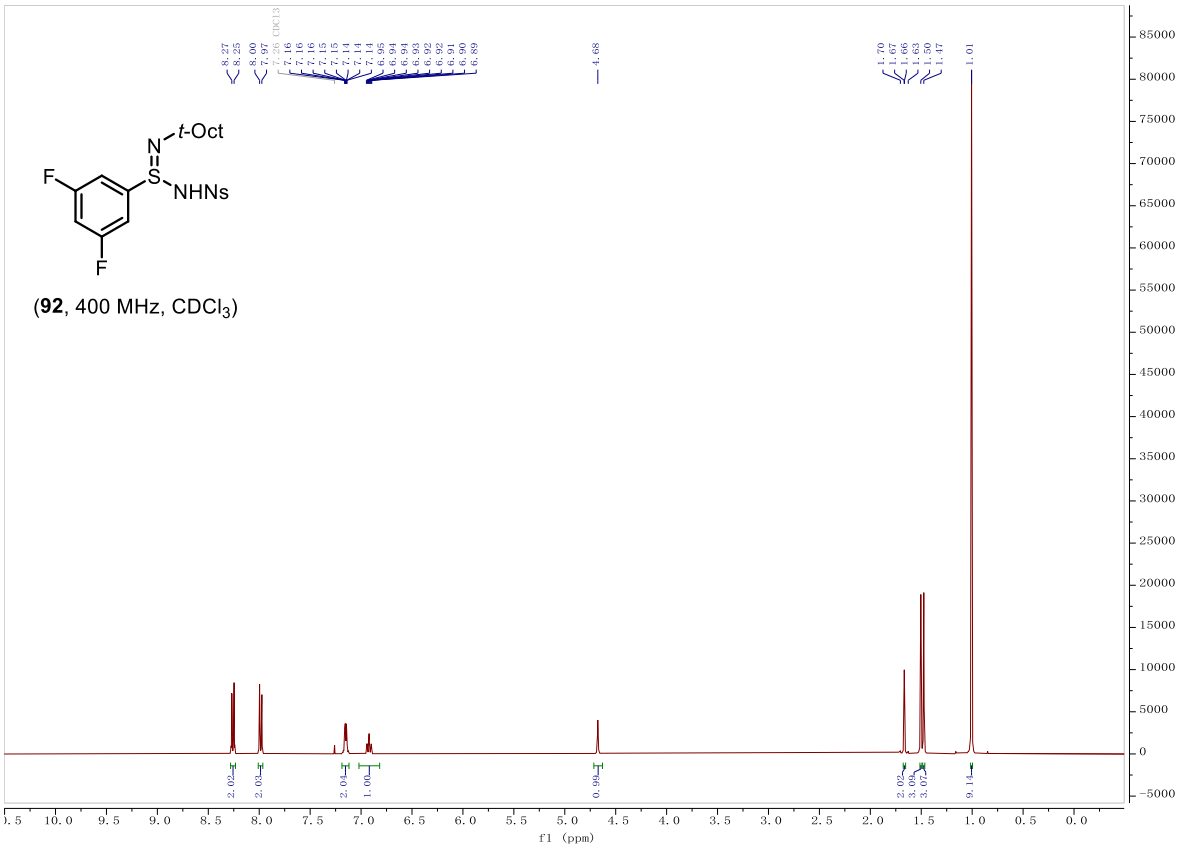

t-Oct
N
S
NC
NHNs
(89, 101 MHz, CDCl3)
f1 (ppm)


8.20
8.18
7.95
7.93
7.50
7.47
7.26 CDCl3
6.89
6.87
4.35
3.80
1.69
1.66
1.65
1.61
1.52
1.49
1.00
t-Oct
N
S
NHNs
MeO
(90, 400 MHz, CDCl3)
f1 (ppm)

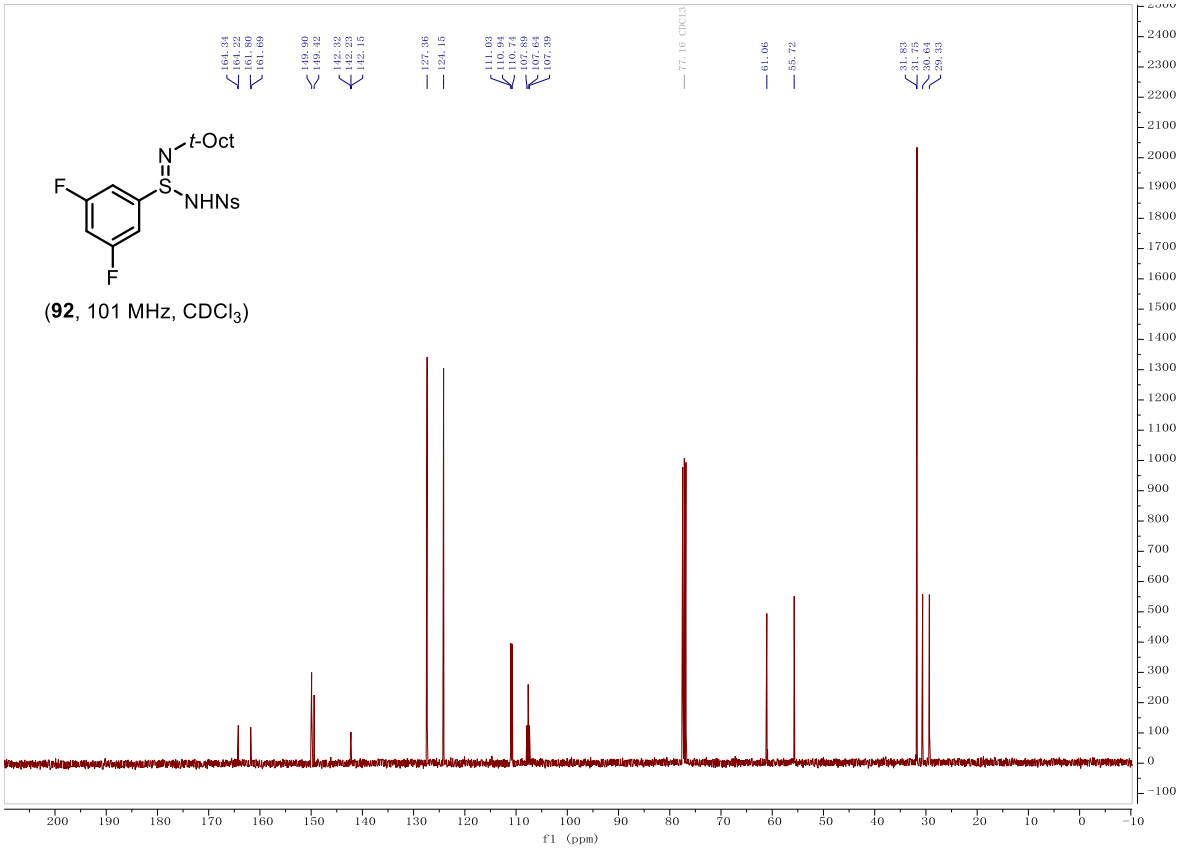

162.54
150.54
149.09
128.67
128.53
127.34
123.95
114.92
77.16 CDCl3
60.37
55.75
55.72
31.83
31.79
30.86
29.24
t-Oct
N
S
NHNs
MeO
(90, 101 MHz, CDCl3)
f1 (ppm)


t-Oct
N
S
NHNs
Me
(91, 400 MHz, CDCl3)
f1 (ppm)

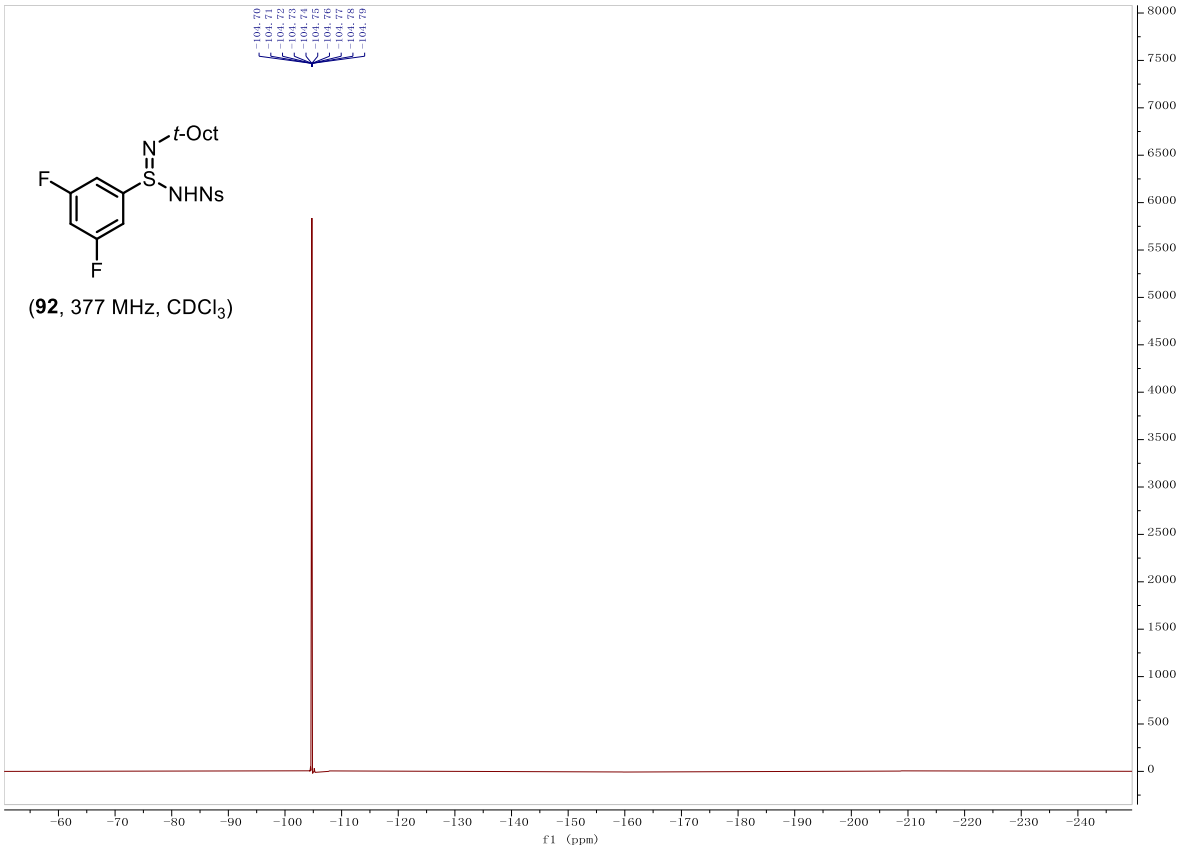

t-Oct
N
S
NHNs
Me
(91, 101 MHz, CDCl3)
f1 (ppm)

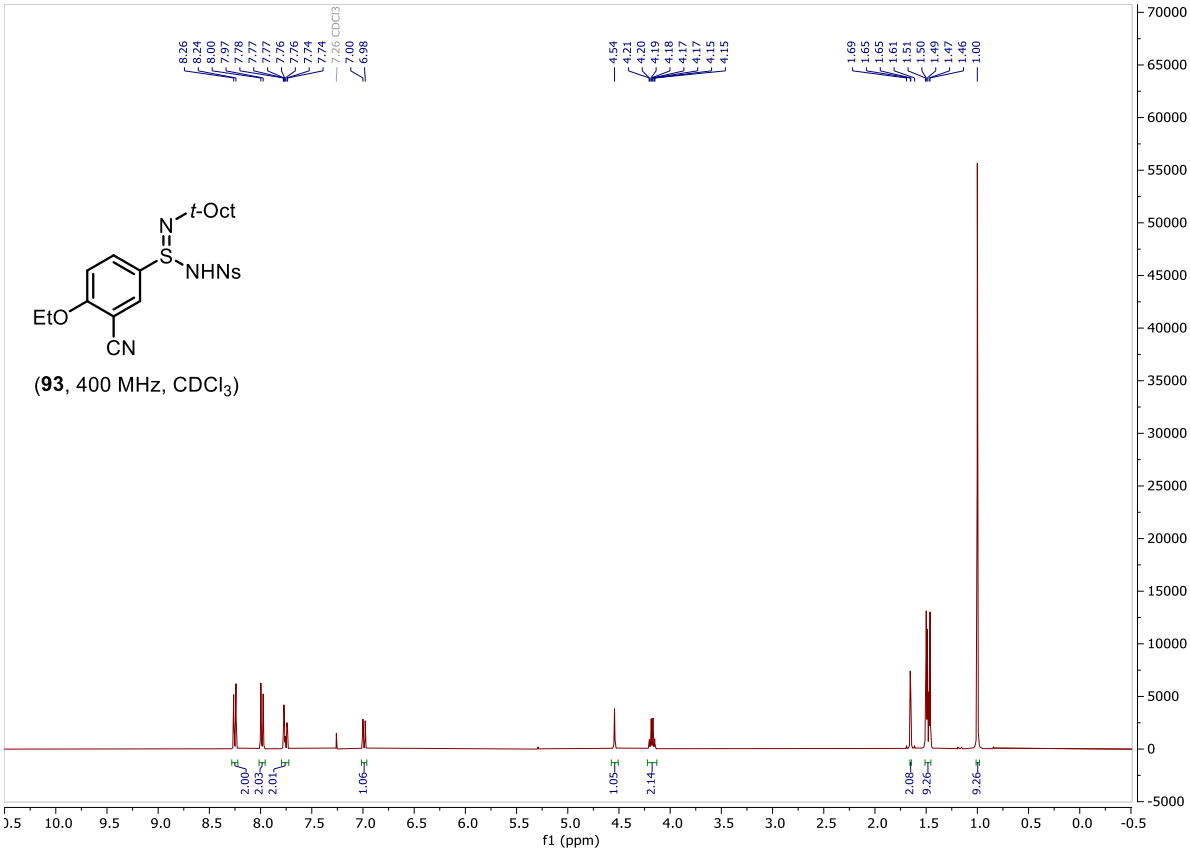


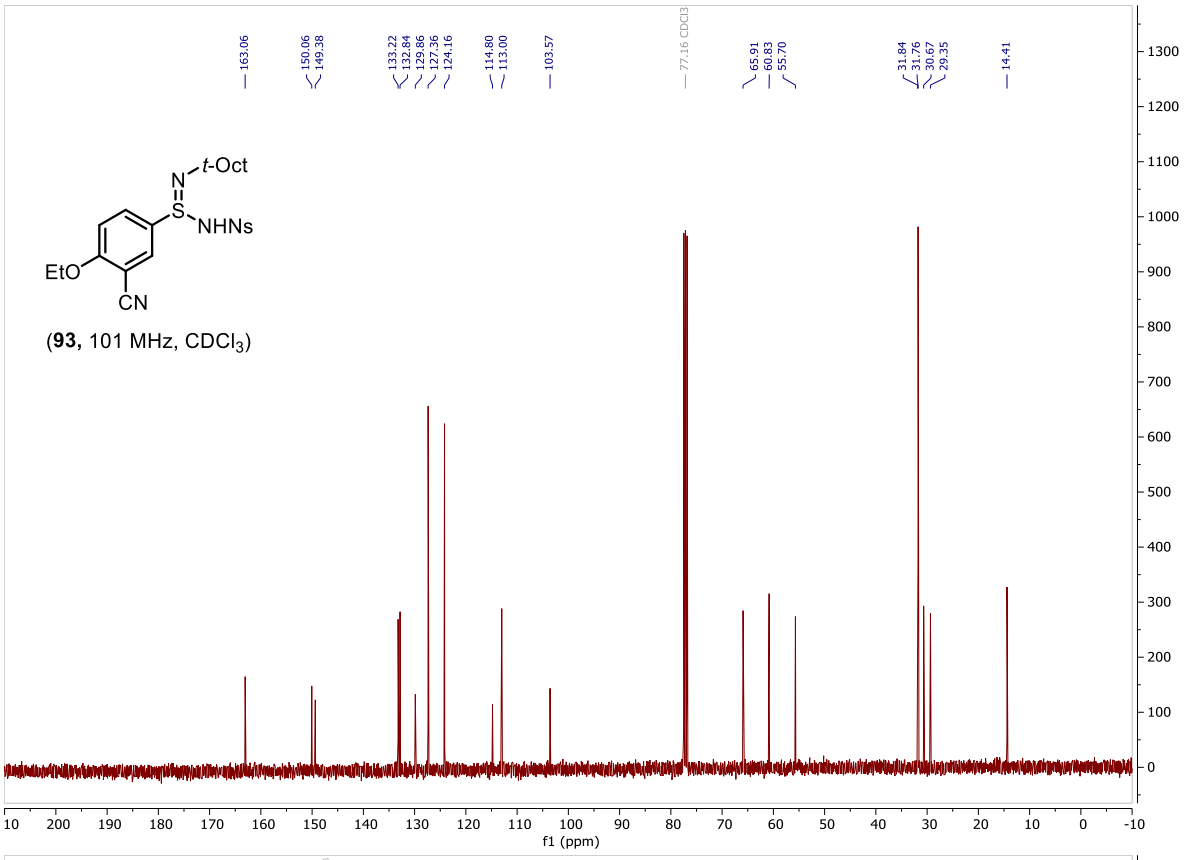
(**92**, 400 MHz, $CDCl_3$)



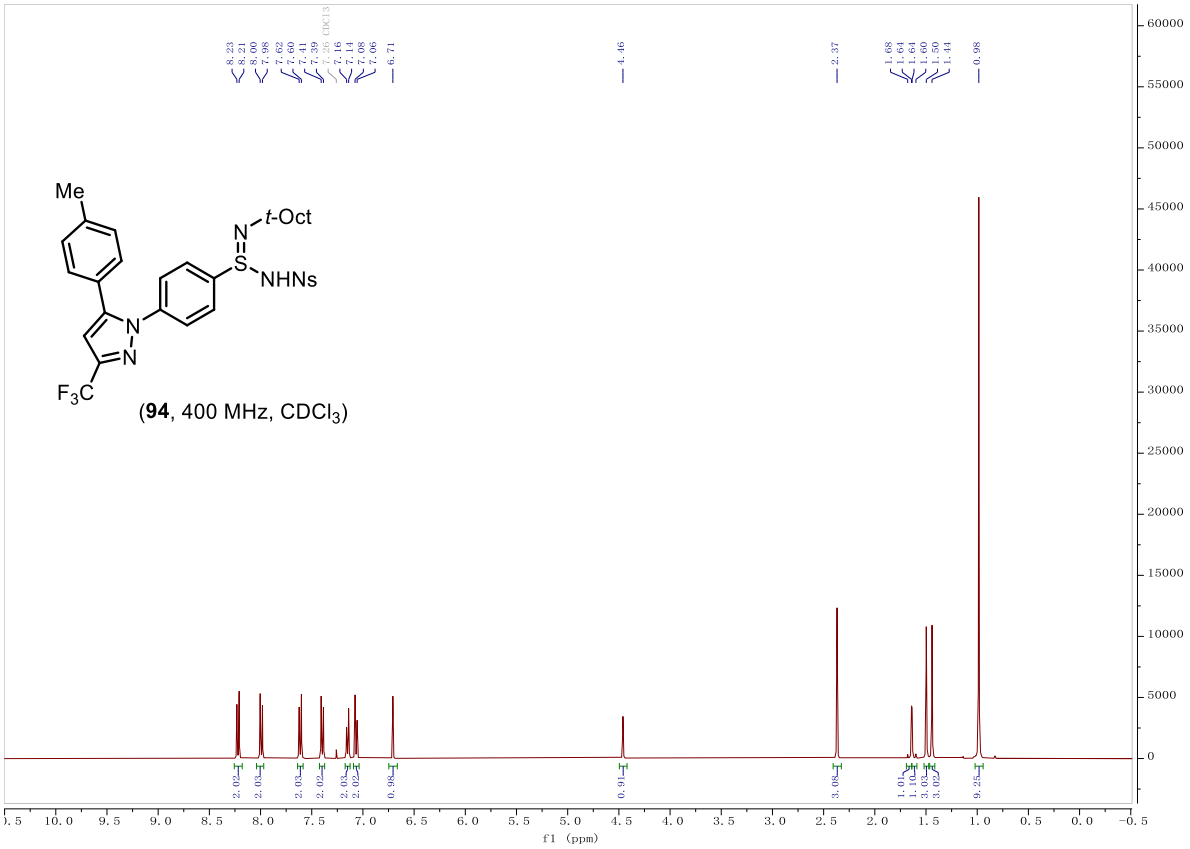
(**92**, 101 MHz, $CDCl_3$)


t-Oct
N
S
NHNs
F
F
(92, 377 MHz, CDCl3)
f1 (ppm)

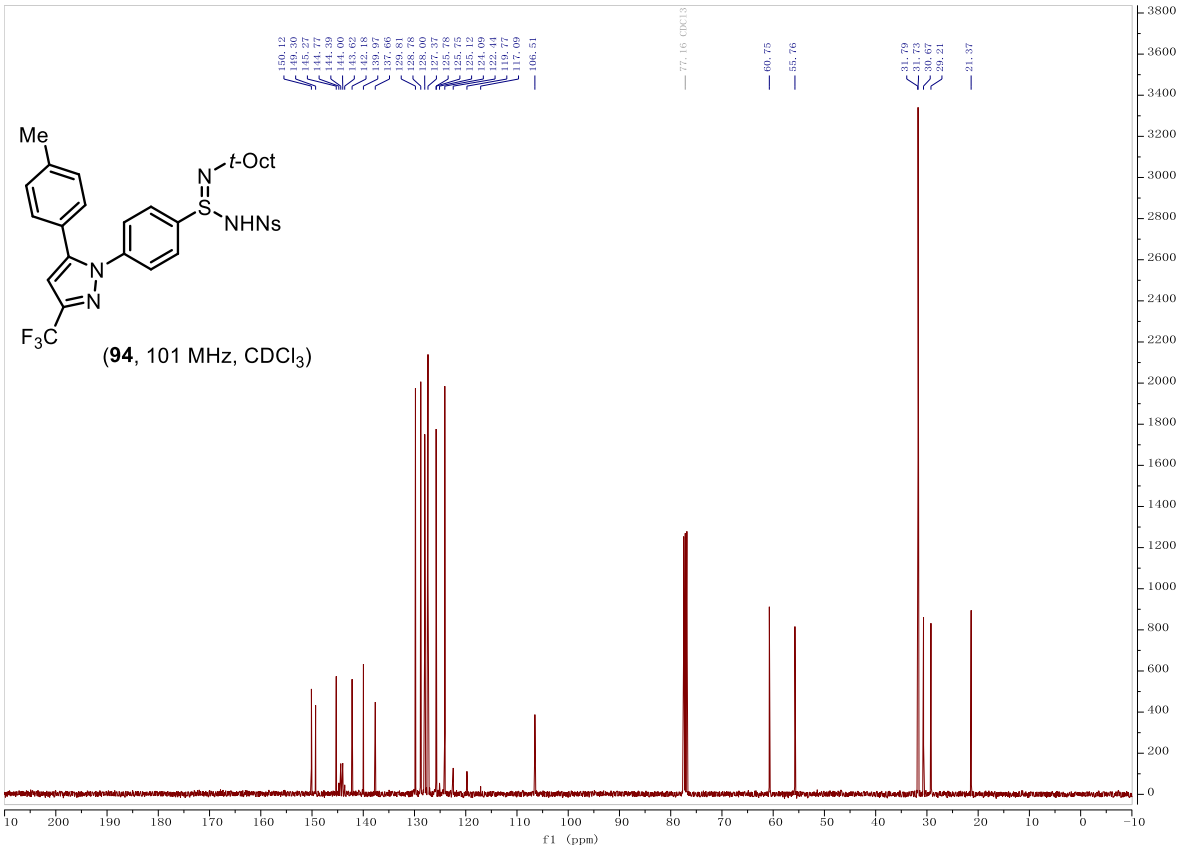

t-Oct
N
S
NHNs
EtO
CN
(93, 400 MHz, CDCl3)
f1 (ppm)

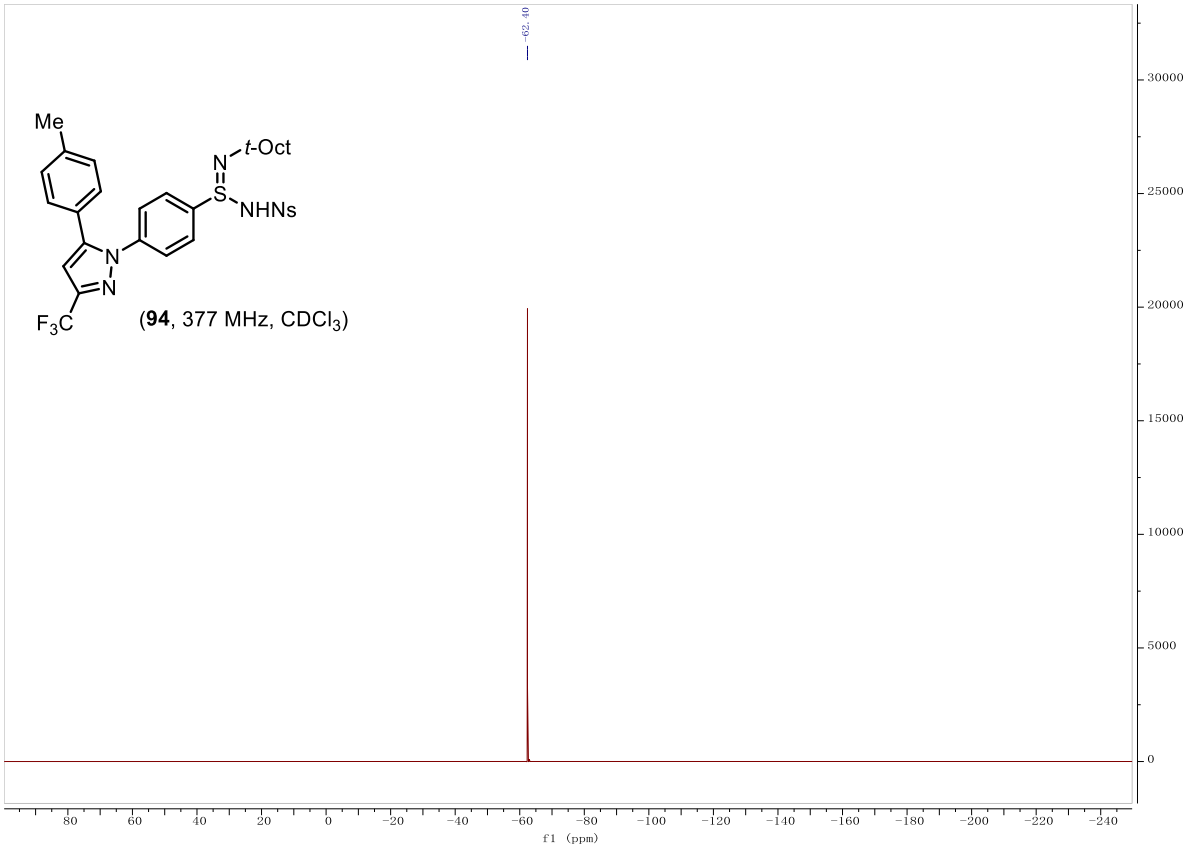


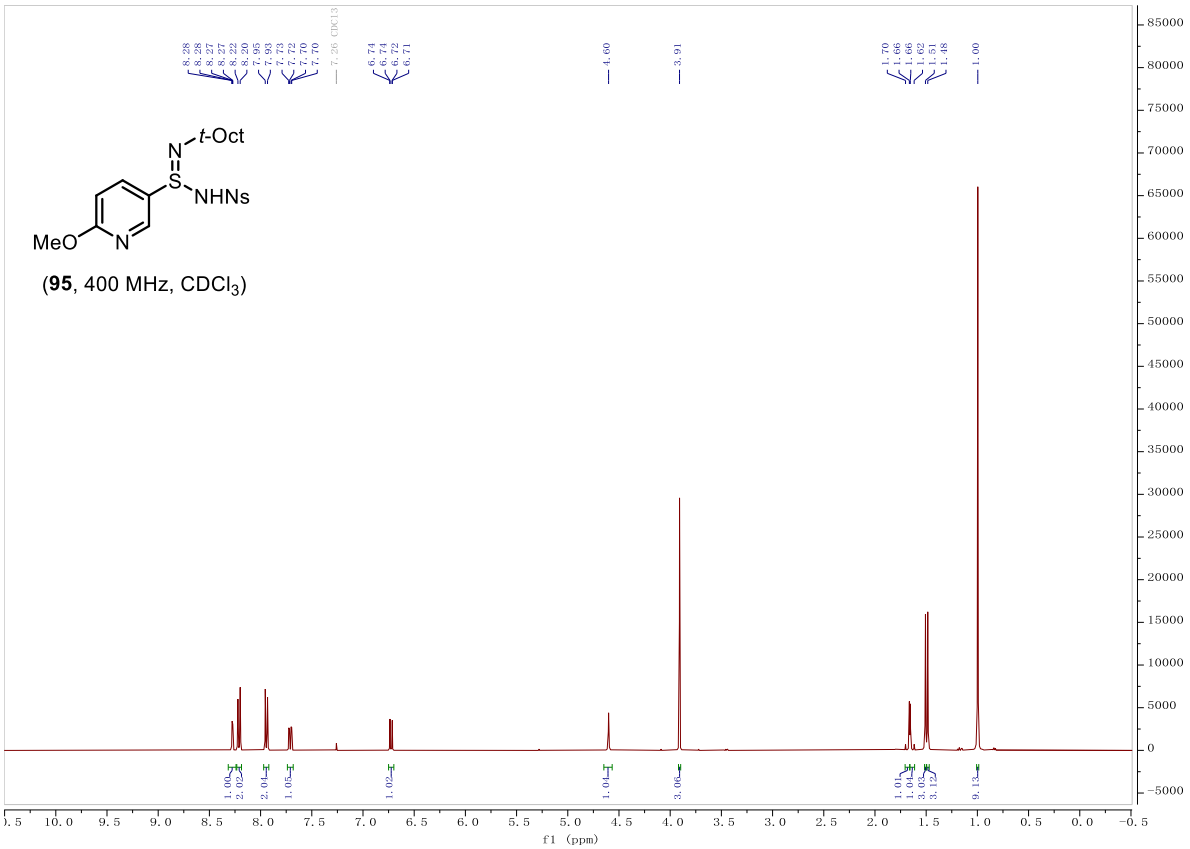
(**93,** 101 MHz, $CDCl_3$)

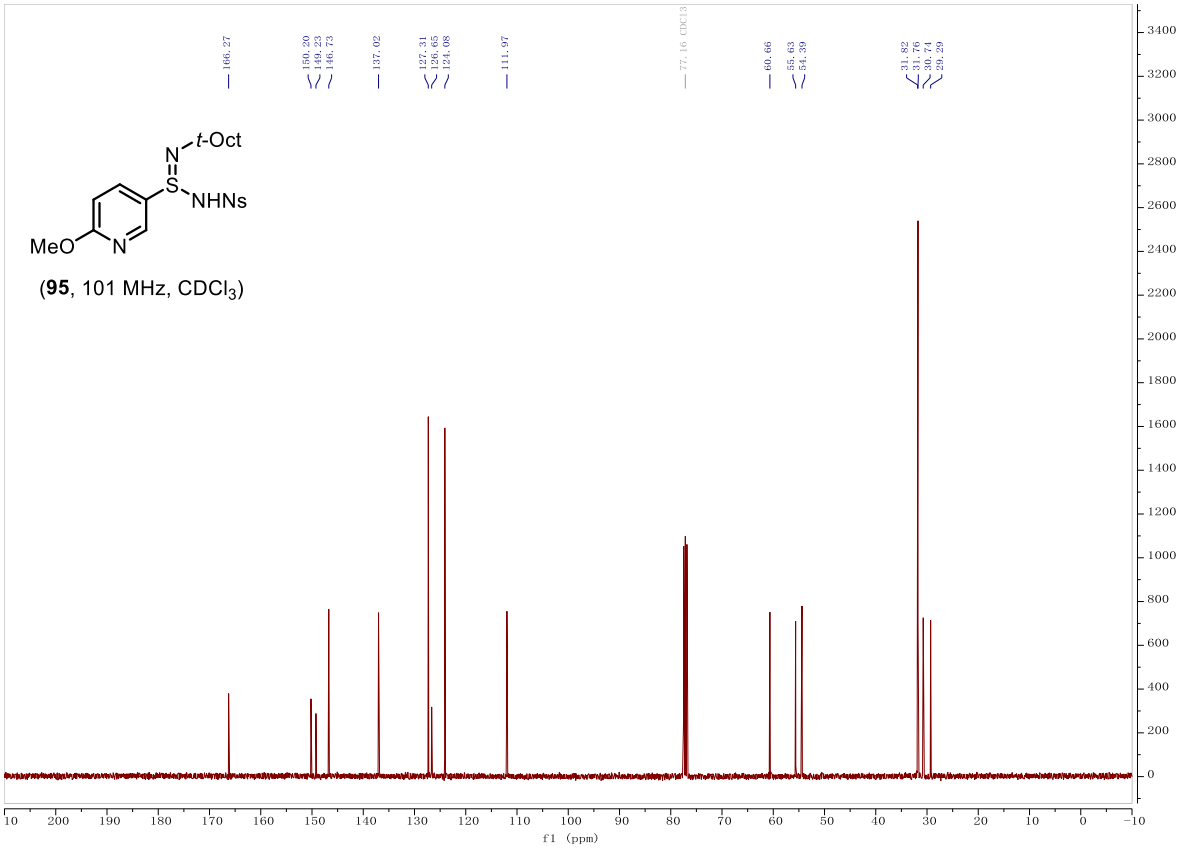


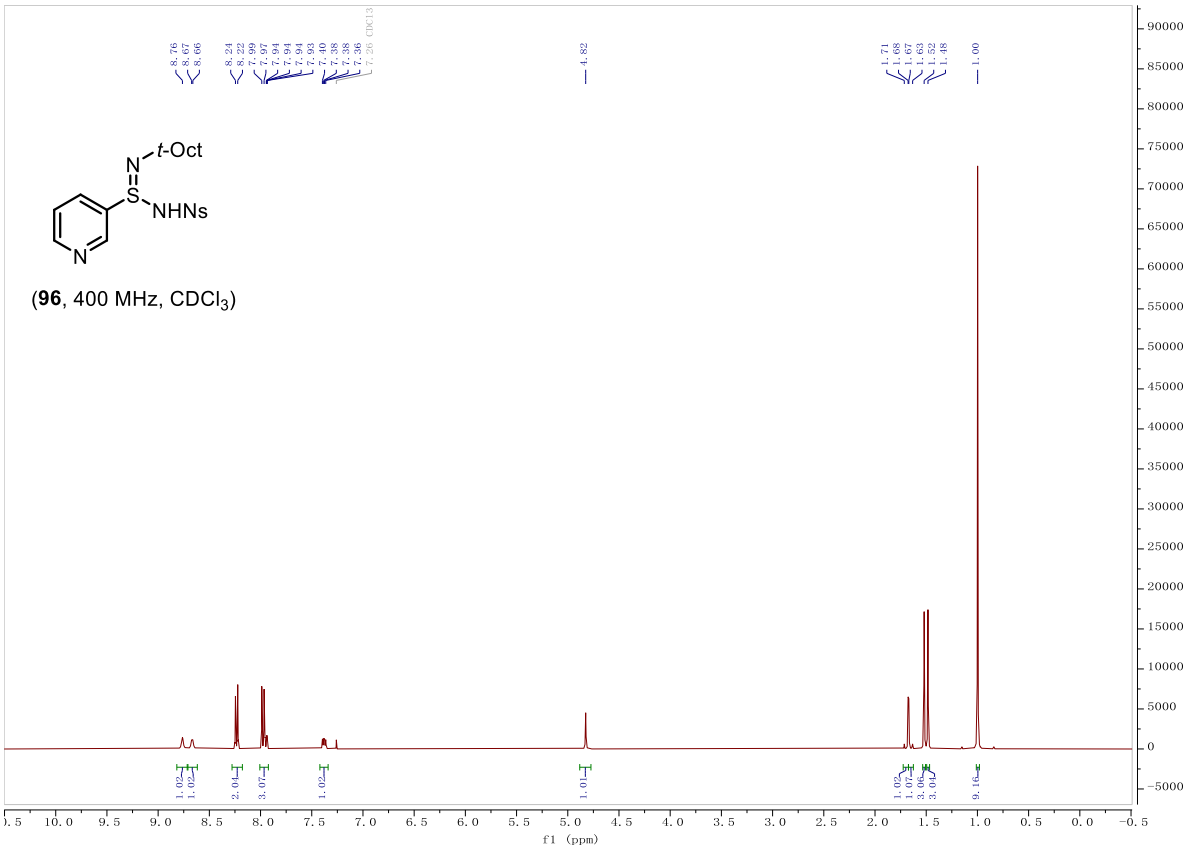
(**94**, 400 MHz, $CDCl_3$)

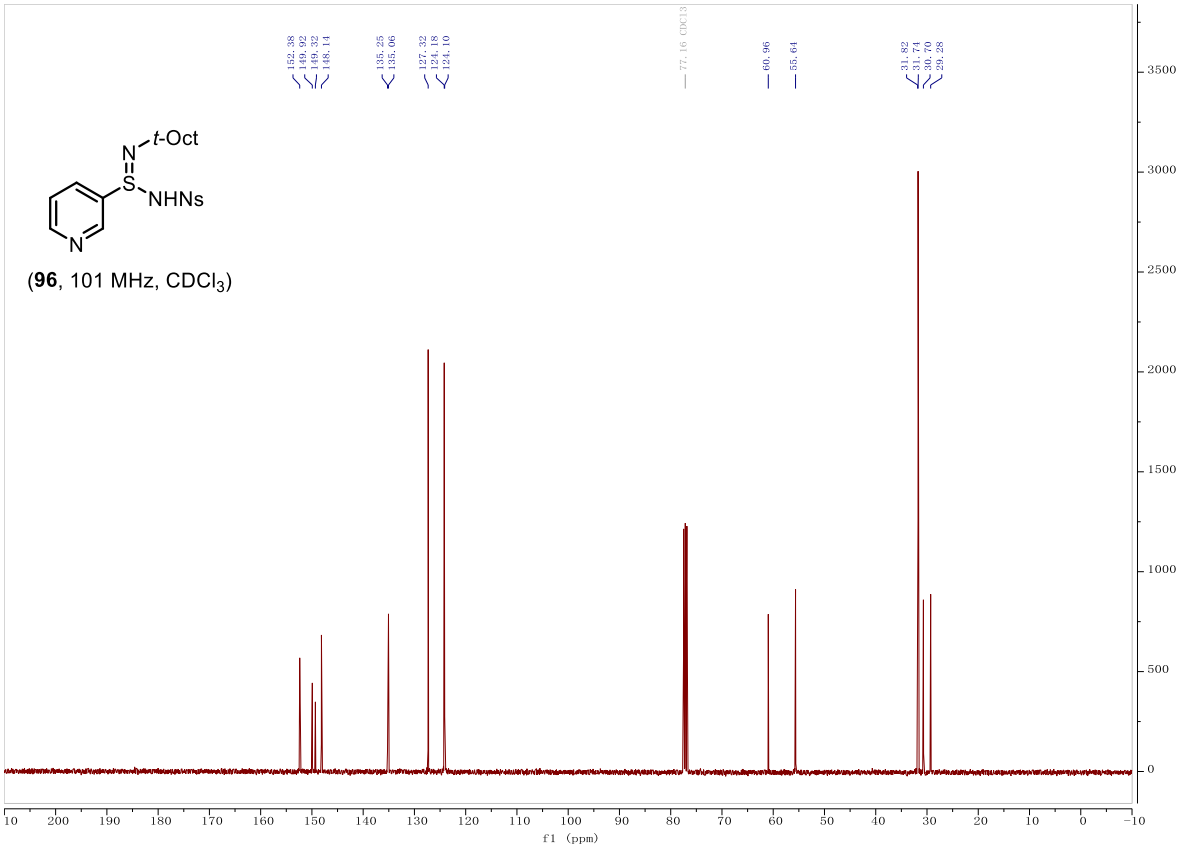

Me
t-Oct
N
S
NHNs
N
N
F3C
(94, 101 MHz, CDCl3)
150.12
140.30
145.27
144.77
144.39
144.00
143.62
142.18
139.97
137.66
129.81
128.78
128.00
127.37
125.78
125.75
125.12
124.09
122.44
119.77
117.09
106.51
77.16 CDCl3
60.75
55.76
31.79
31.73
30.67
29.21
21.37
f1 (ppm)

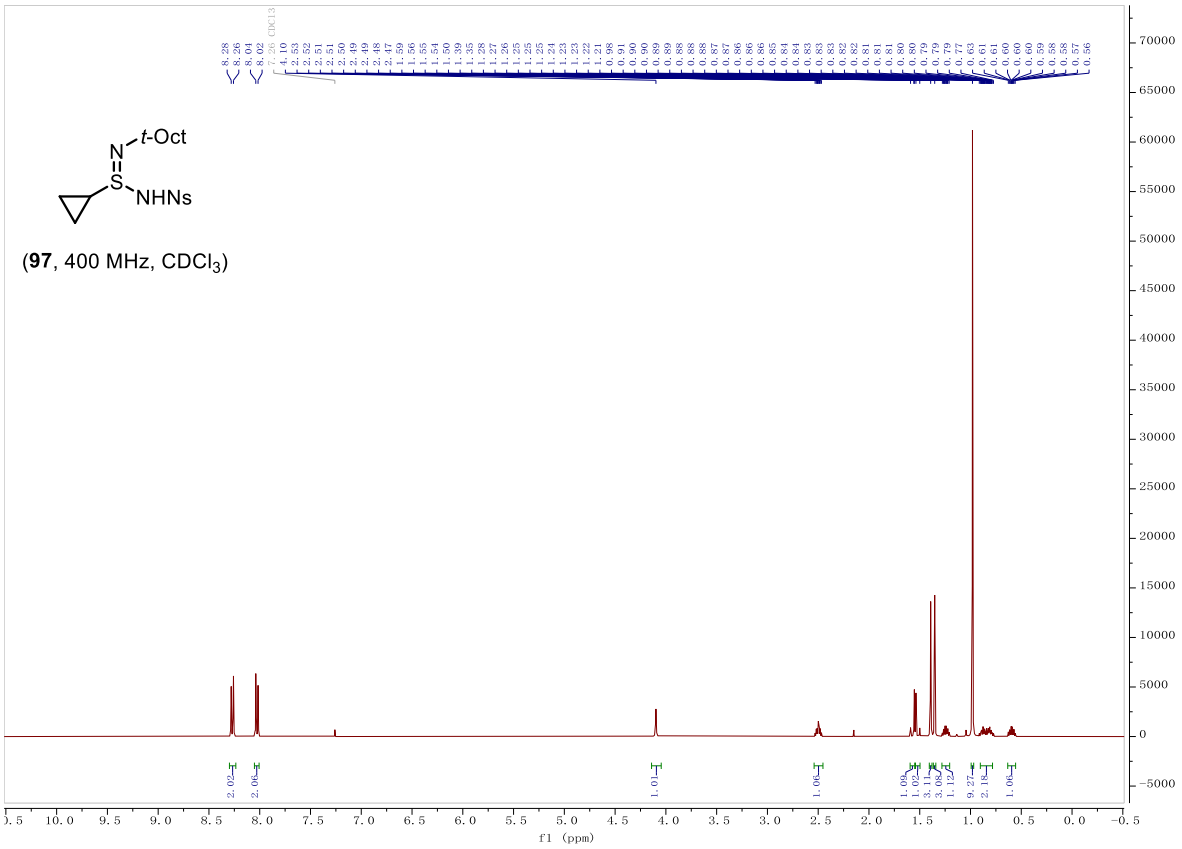

Me
t-Oct
N
S
NHNs
N
N
F3C
(94, 377 MHz, CDCl3)
-62.40
f1 (ppm)

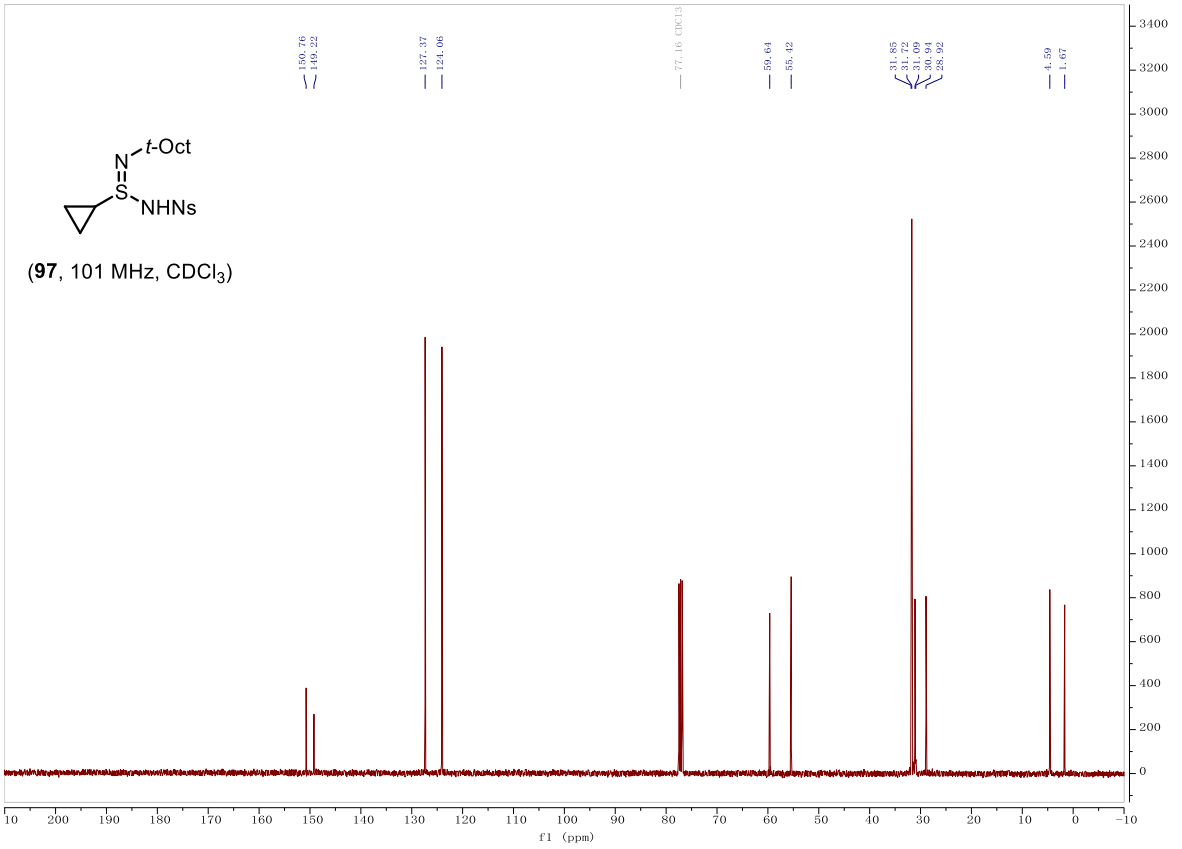

8.28
8.26
8.27
8.27
8.22
8.20
7.95
7.93
7.73
7.72
7.70
7.70
7.26 CDCl3
6.74
6.74
6.72
6.71
4.60
3.91
1.70
1.66
1.65
1.62
1.51
1.48
1.00
t-Oct
N
S
NHNs
MeO
N
(95, 400 MHz, CDCl3)
1.00
2.02
2.04
1.05
1.02
1.04
3.06
1.01
1.04
3.03
3.12
9.13
f1 (ppm)

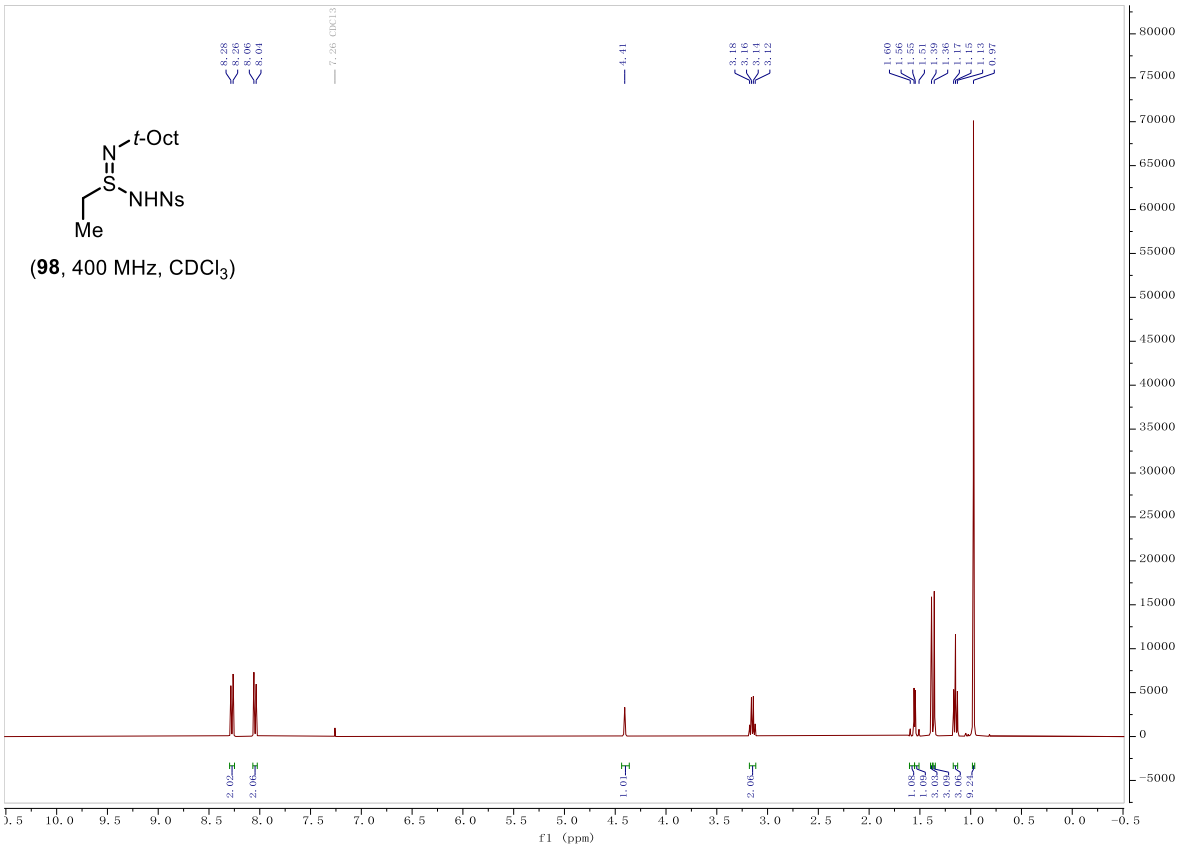

166.27
150.20
149.23
146.73
137.02
127.81
126.65
124.08
111.97
77.16 CDCl3
60.66
55.63
54.39
31.82
31.76
30.74
29.29
t-Oct
N
S
NHNs
MeO
N
(95, 101 MHz, CDCl3)
f1 (ppm)


t-Oct
N
S
NHNs
N
(96, 400 MHz, CDCl3)
f1 (ppm)

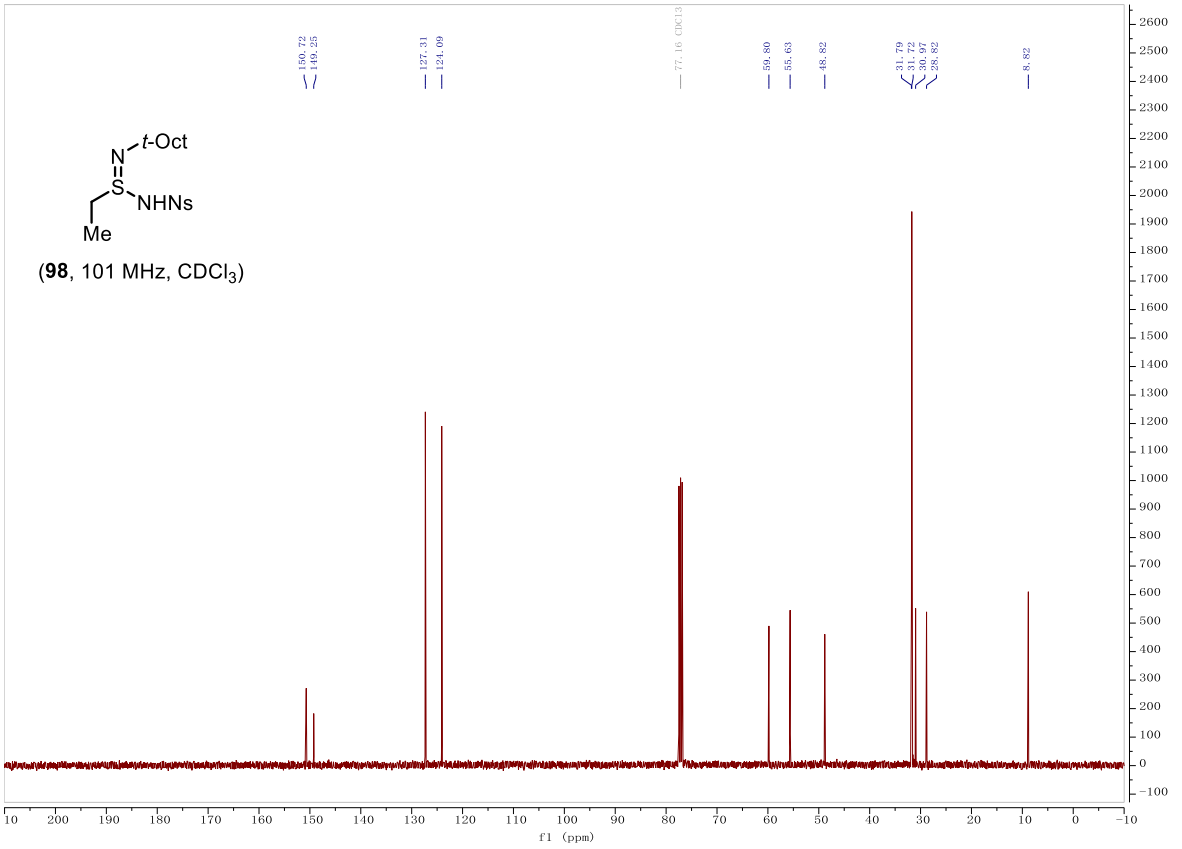

t-Oct
N
S
NHNs
N
(96, 101 MHz, CDCl3)
f1 (ppm)


t-Oct
N
S
NHNs
(97, 400 MHz, CDCl3)
f1 (ppm)

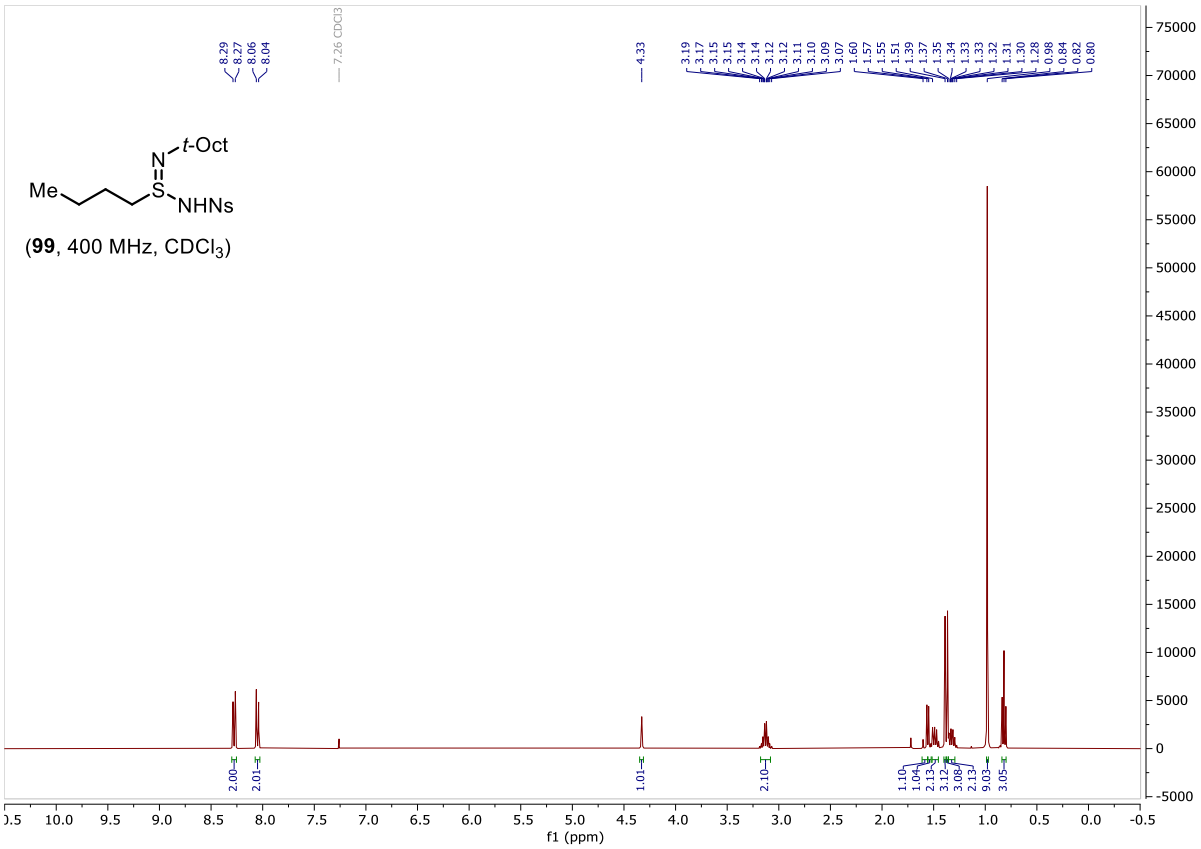

t-Oct
N
S
NHNs
(97, 101 MHz, CDCl3)
f1 (ppm)

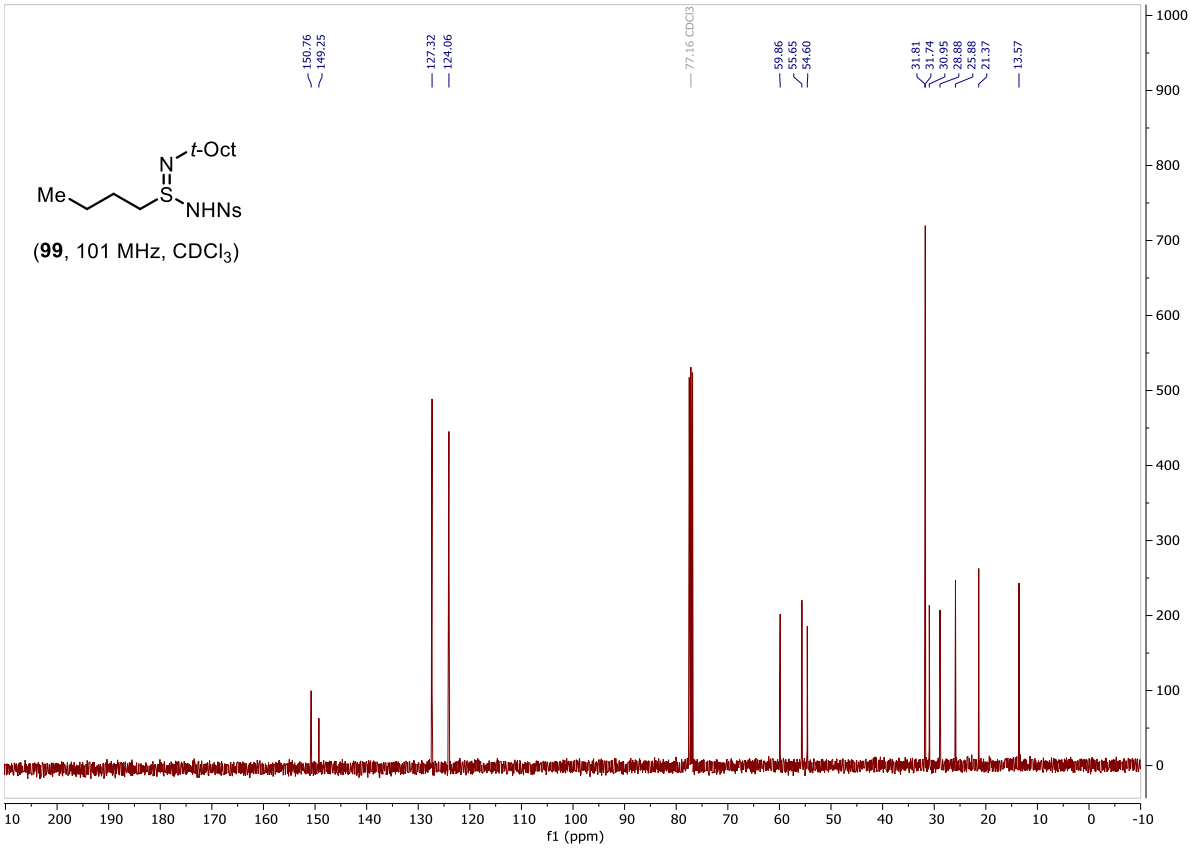


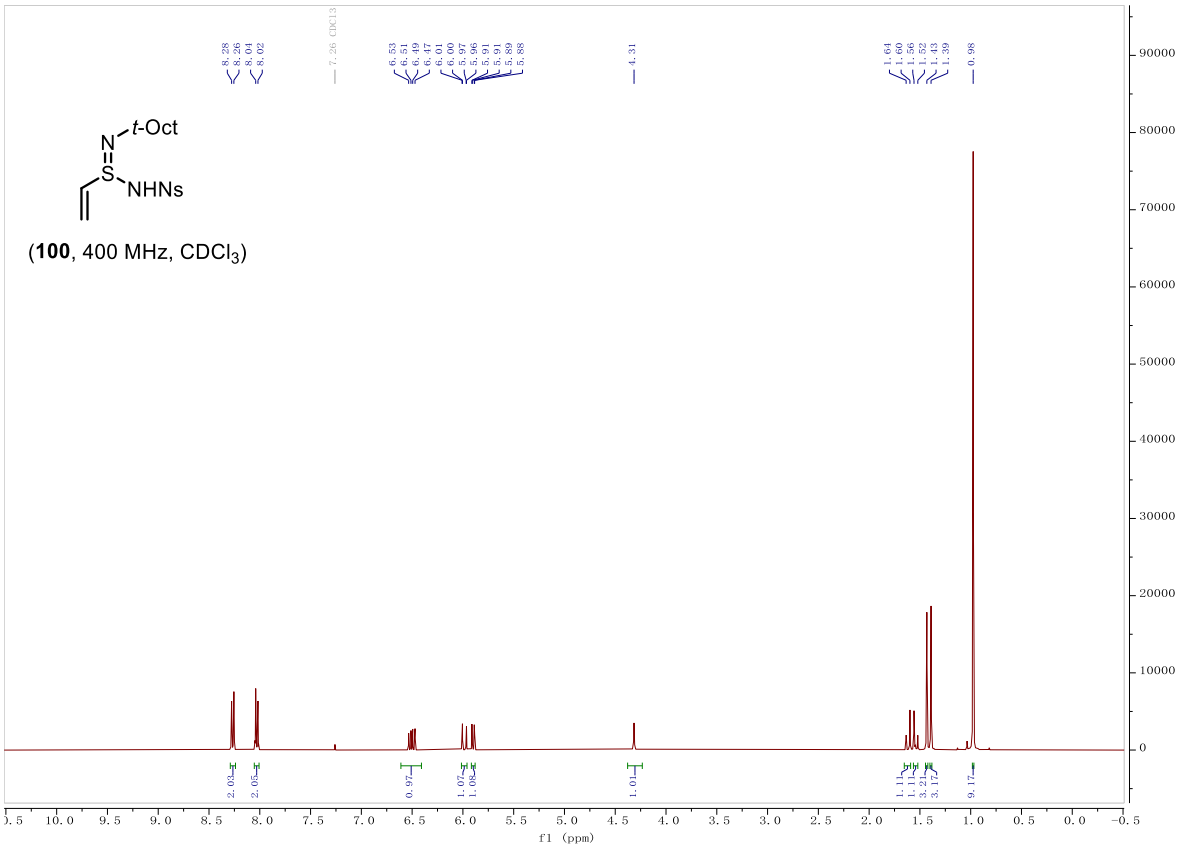
(**98**, 400 MHz, $CDCl_3$)

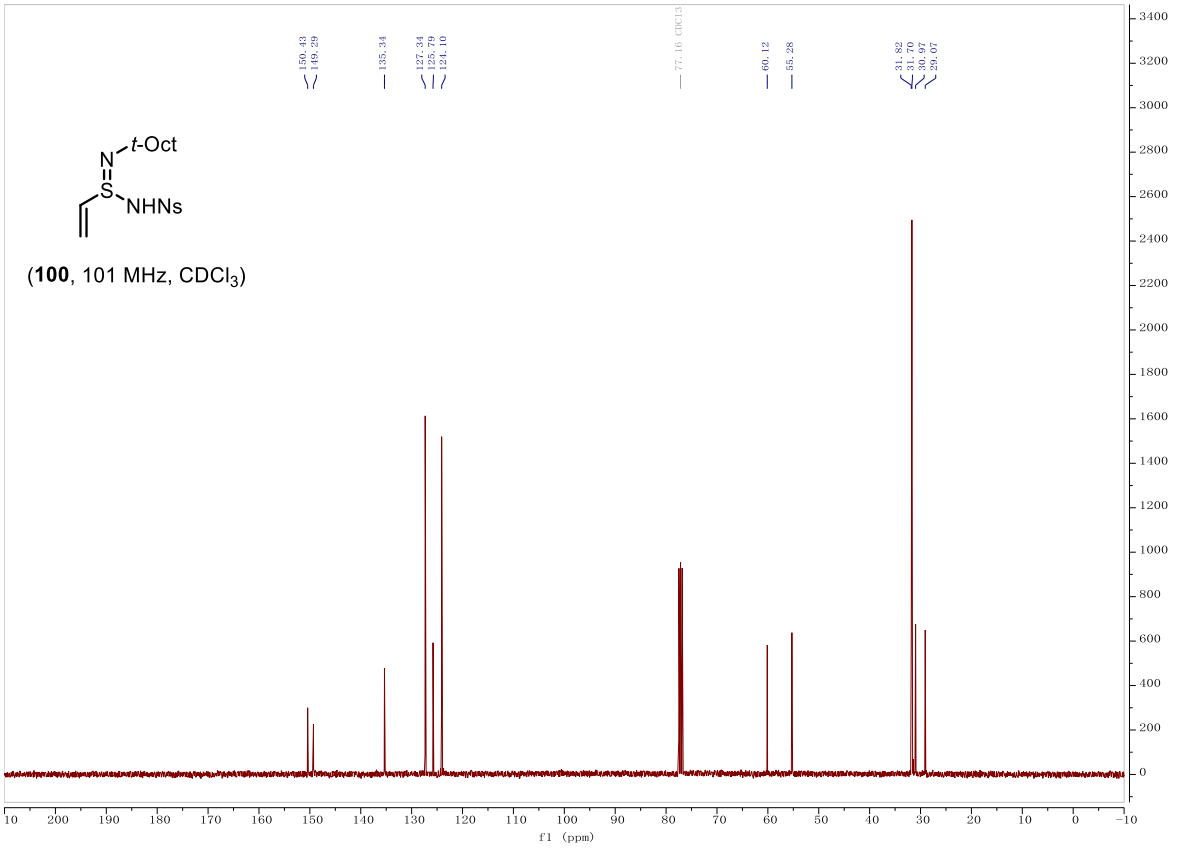


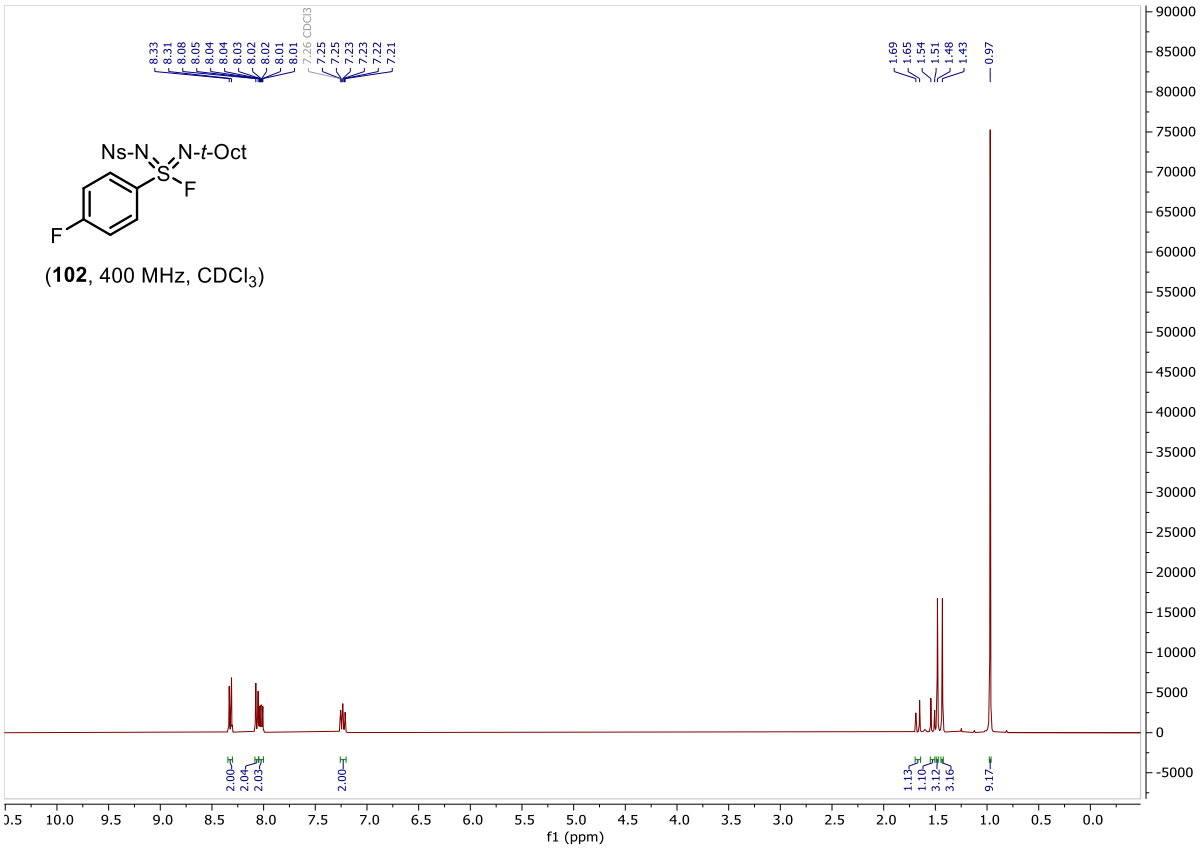
(**98**, 101 MHz, $CDCl_3$)

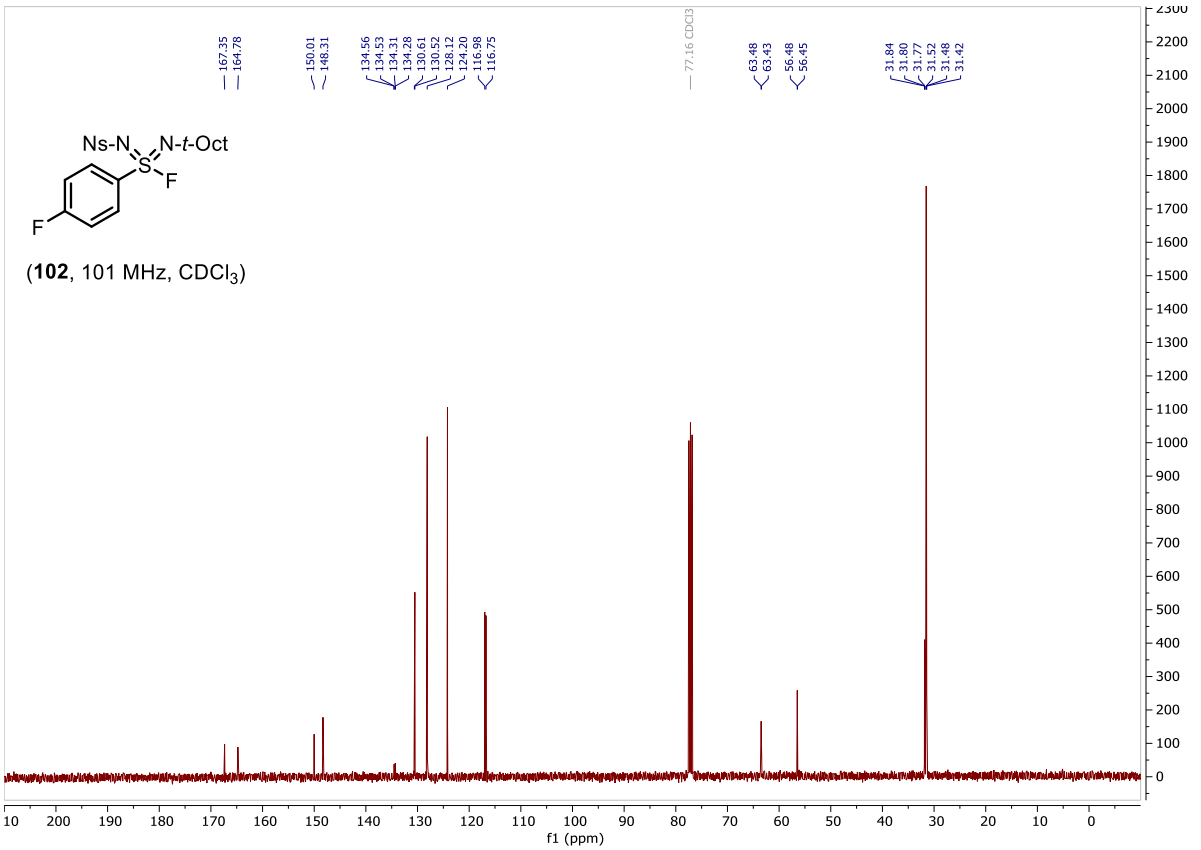

8.29
8.27
8.06
8.04
7.26 CDCl3
4.33
3.19
3.17
3.15
3.15
3.14
3.14
3.12
3.12
3.11
3.10
3.09
3.07
1.60
1.57
1.55
1.51
1.39
1.37
1.35
1.34
1.33
1.33
1.32
1.31
1.30
1.28
0.98
0.84
0.82
0.80
t-Oct
N
S
Me
NHNs
(99, 400 MHz, CDCl3)
2.00
2.01
1.01
2.10
1.10
1.04
2.13
3.12
3.08
2.13
9.03
3.05
f1 (ppm)

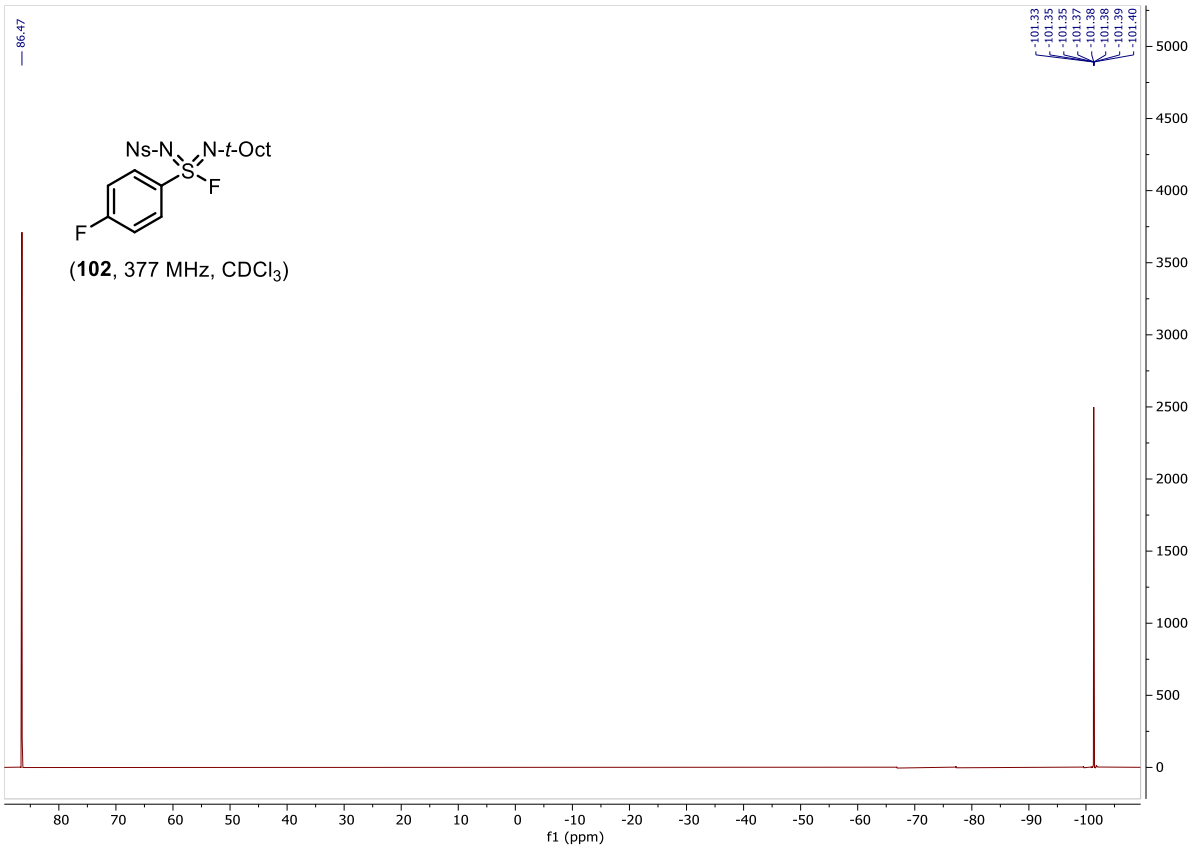

150.76
149.25
127.32
124.06
77.16 CDCl3
59.86
55.65
54.60
31.81
31.74
30.95
28.88
25.88
21.37
13.57
t-Oct
N
S
Me
NHNs
(99, 101 MHz, CDCl3)
f1 (ppm)

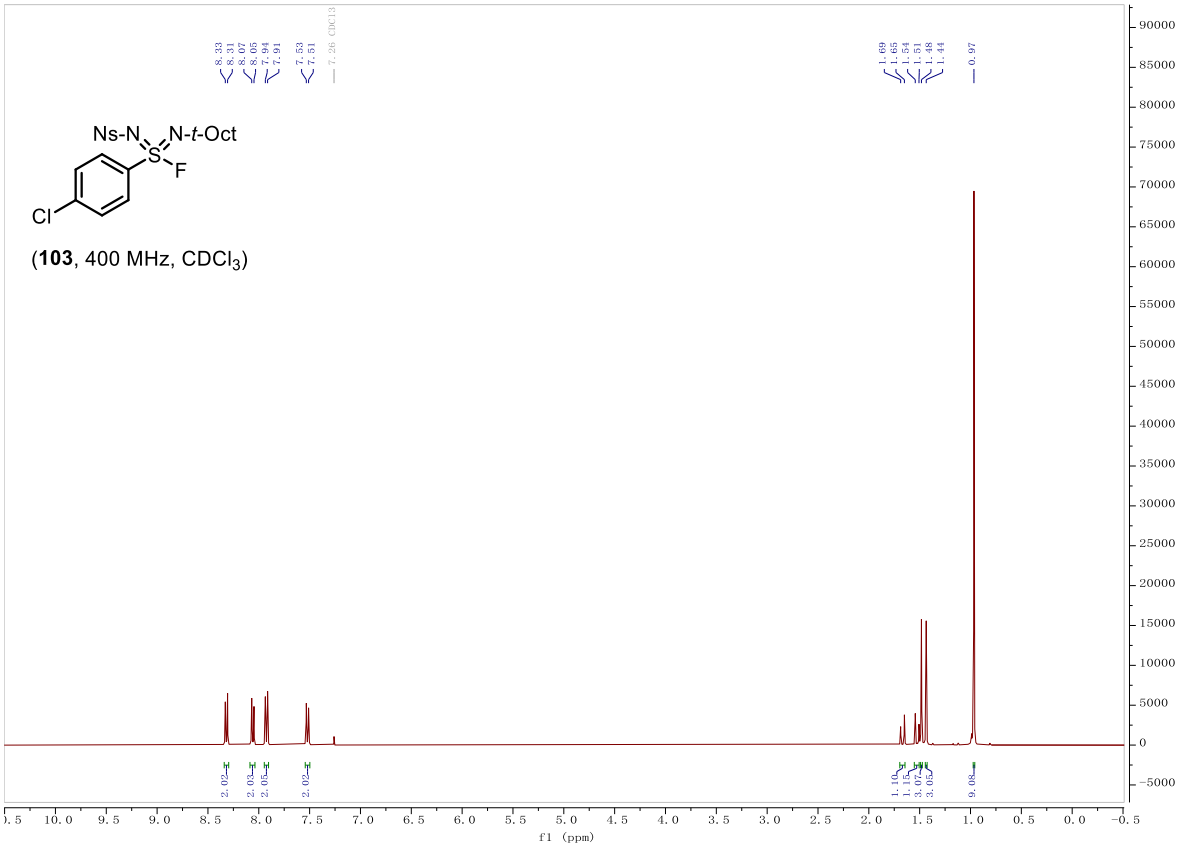

8.28
8.26
8.04
8.02
7.26 CDCl3
6.53
6.51
6.49
6.47
6.01
6.00
5.97
5.96
5.91
5.91
5.89
5.88
4.31
1.64
1.60
1.56
1.52
1.43
1.39
0.98
t-Oct
N
S
NHNs
(100, 400 MHz, CDCl3)
f1 (ppm)

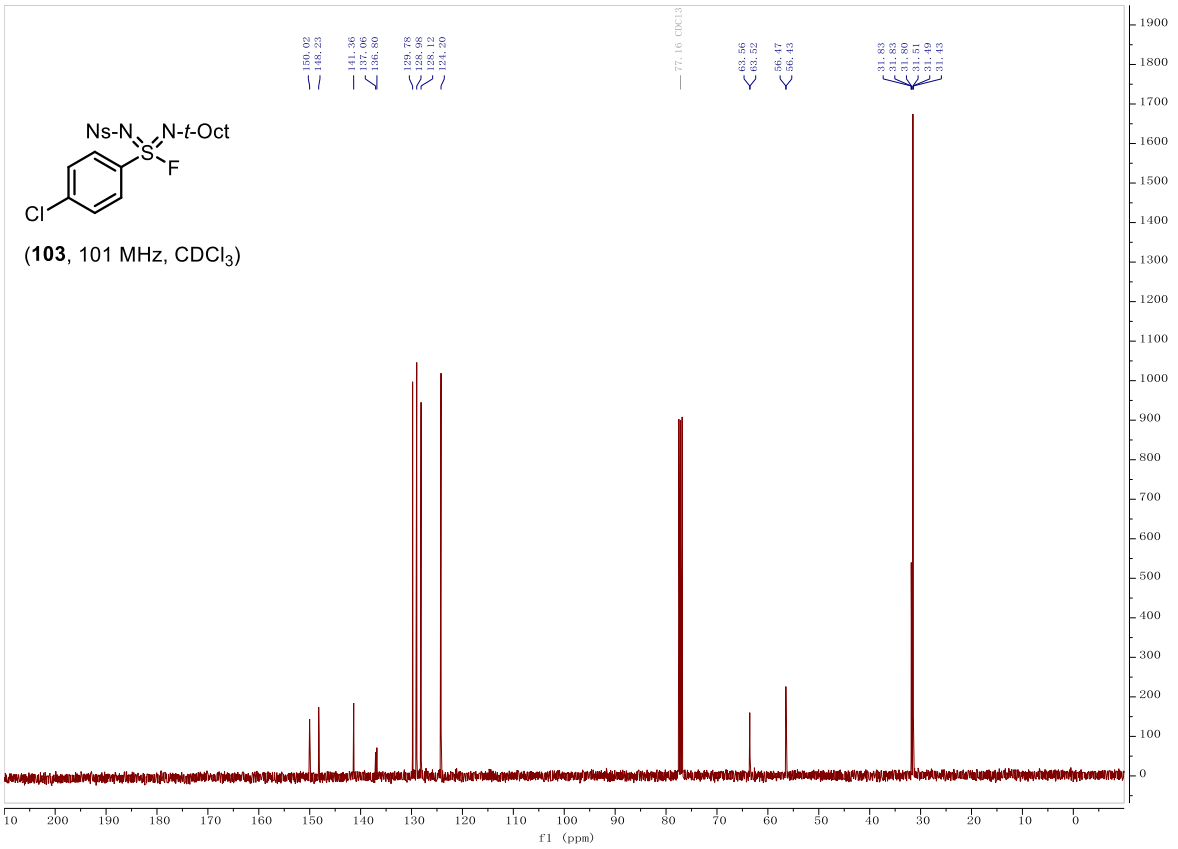

150.43
149.29
135.34
127.34
125.79
124.10
77.16 CDCl3
60.12
55.28
31.82
31.70
30.97
29.07
t-Oct
N
S
NHNs
(100, 101 MHz, CDCl3)
f1 (ppm)


Ns-N
N-t-Oct
S
F
F
(102, 400 MHz, CDCl3)
f1 (ppm)

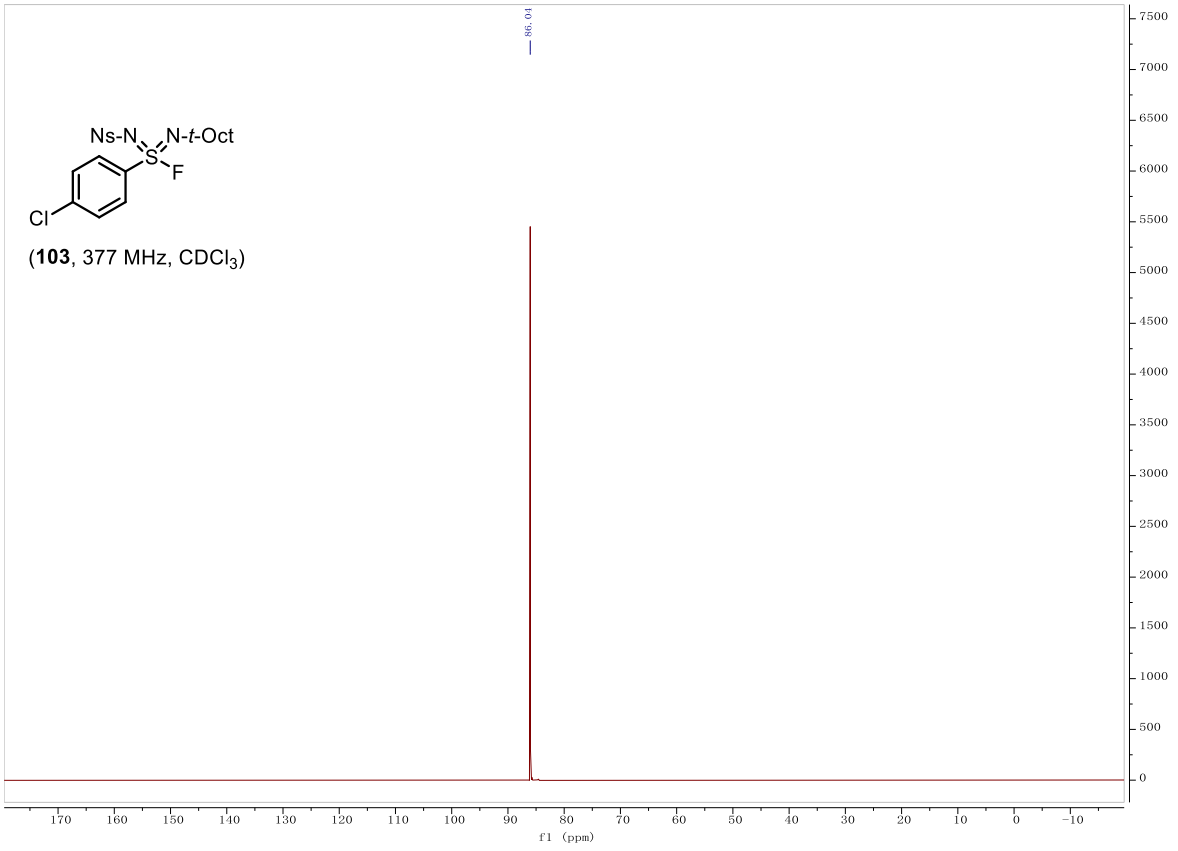

Ns-N
N-t-Oct
S
F
F
(102, 101 MHz, CDCl3)
f1 (ppm)


Ns-N
N-t-Oct
S
F
F
(102, 377 MHz, CDCl3)
f1 (ppm)

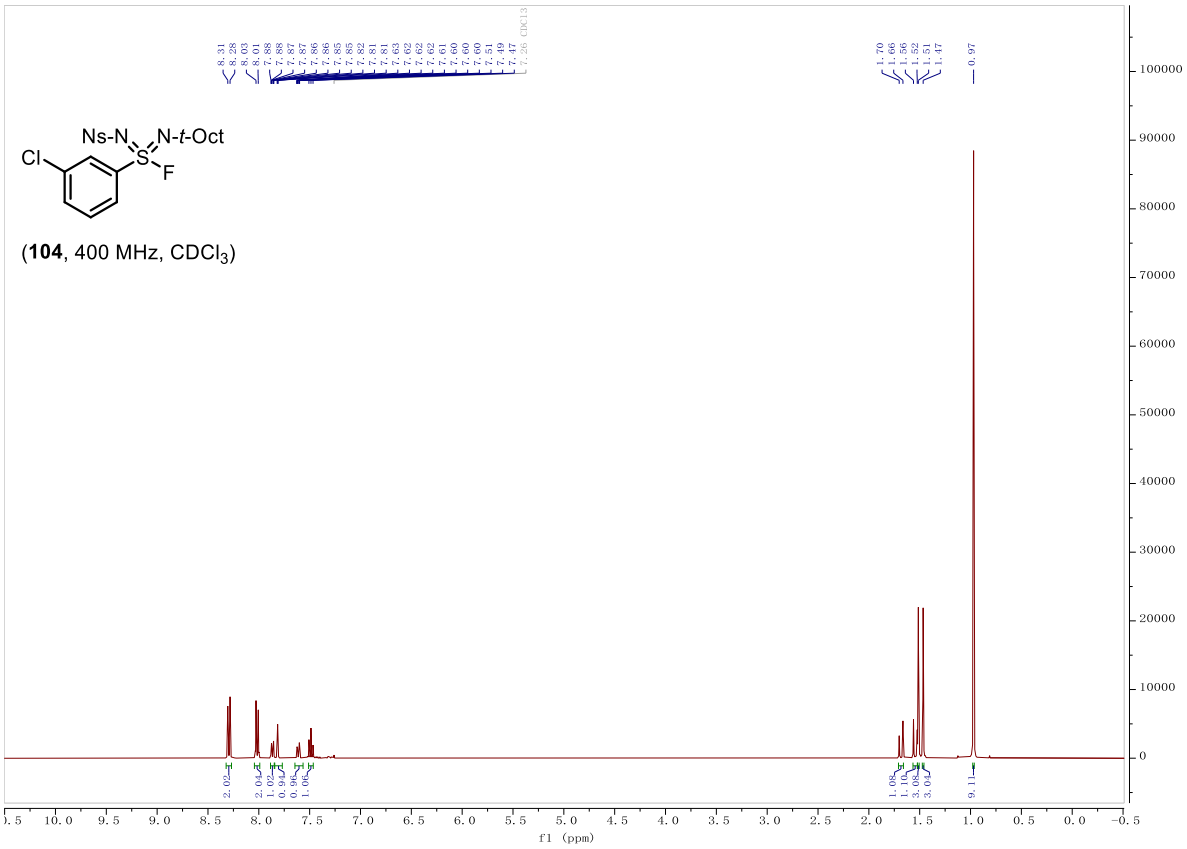

Ns-N
N-t-Oct
S
F
Cl
(103, 400 MHz, CDCl3)
f1 (ppm)



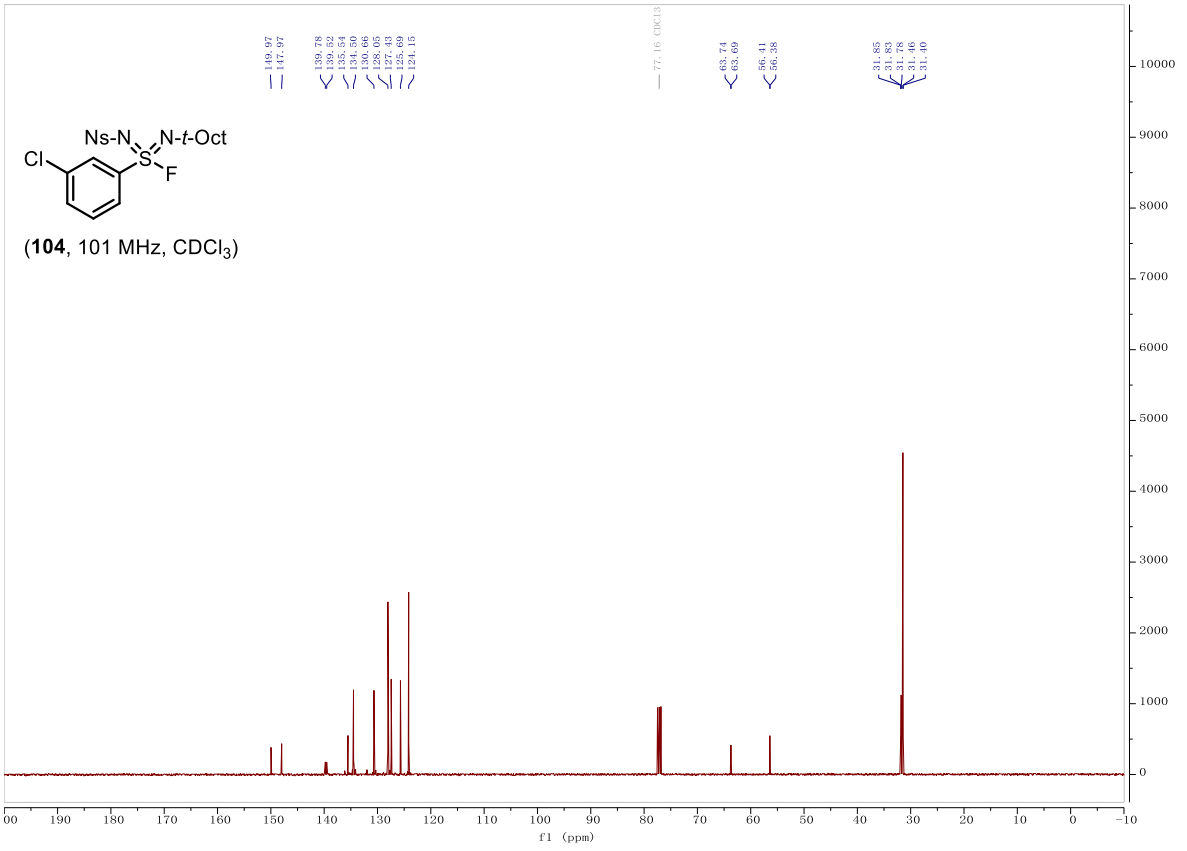
(**103**, 101 MHz, $CDCl_3$)



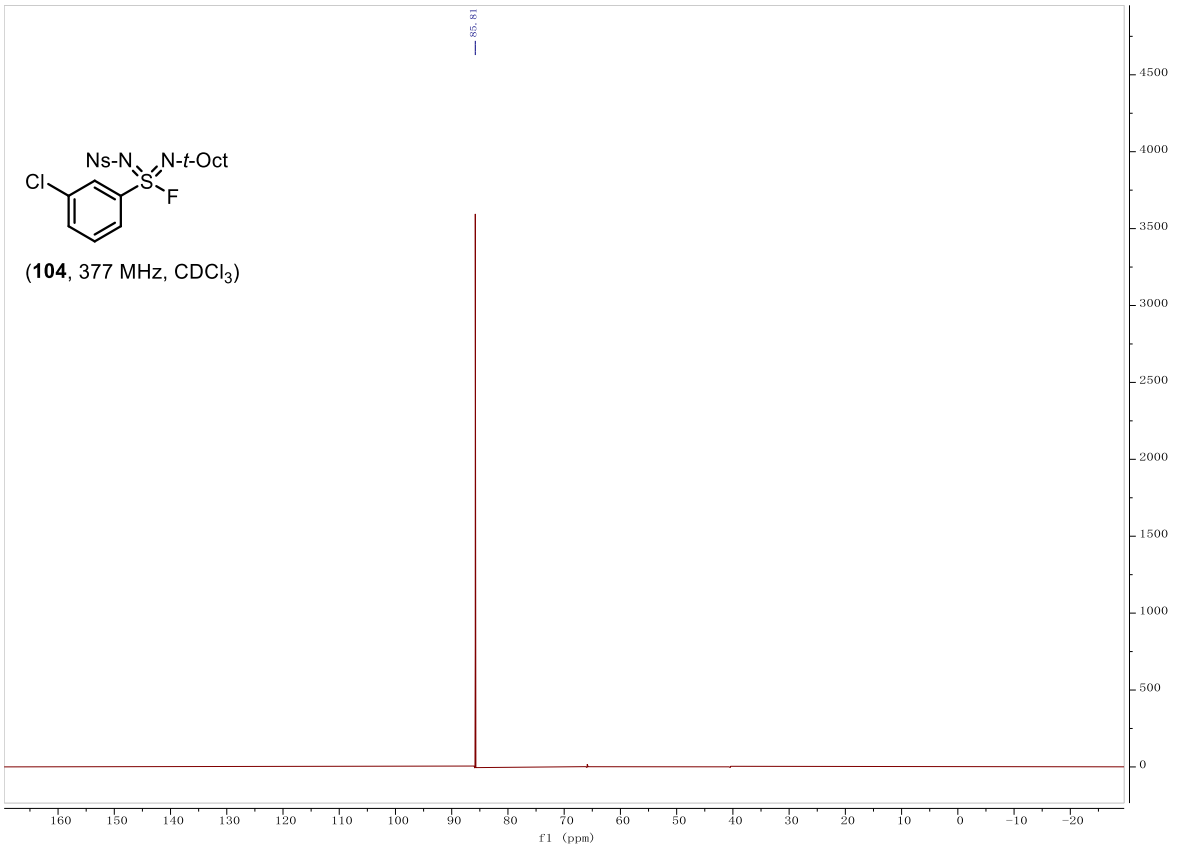
(**103**, 377 MHz, $CDCl_3$)

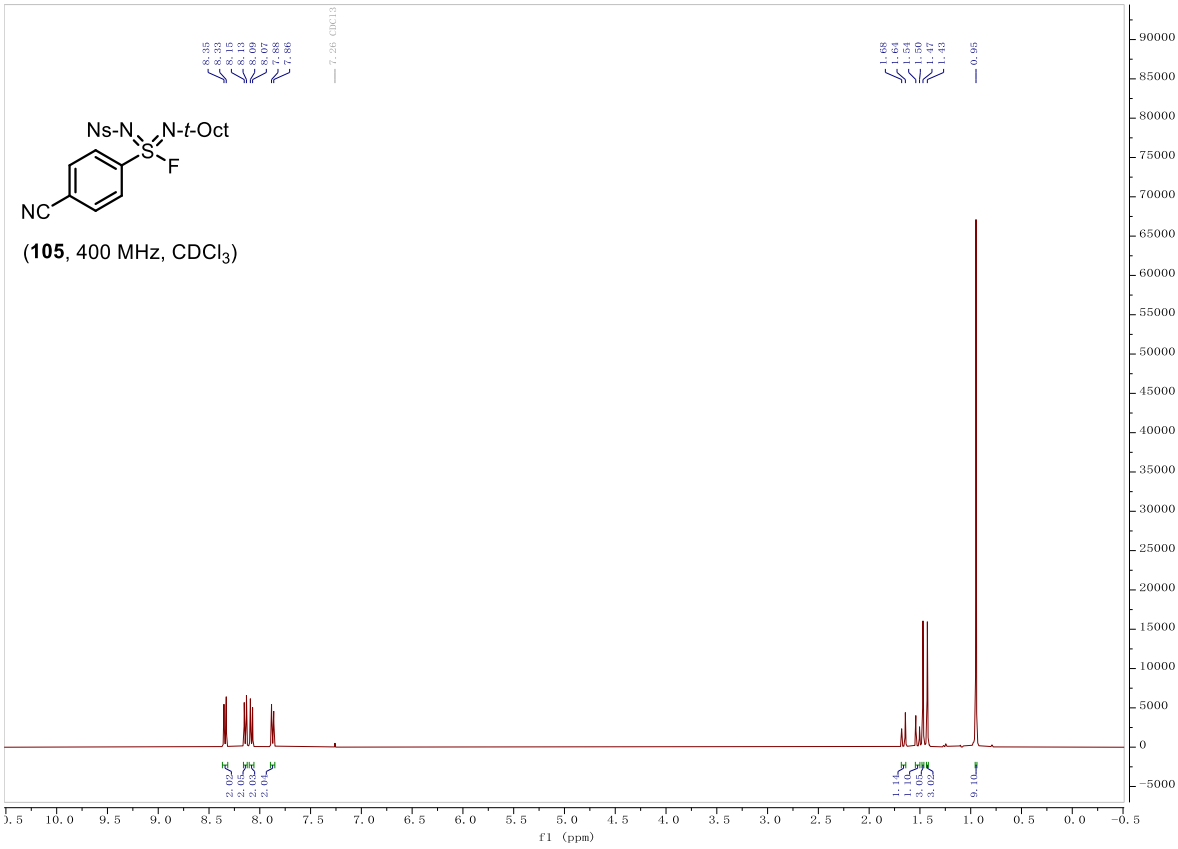


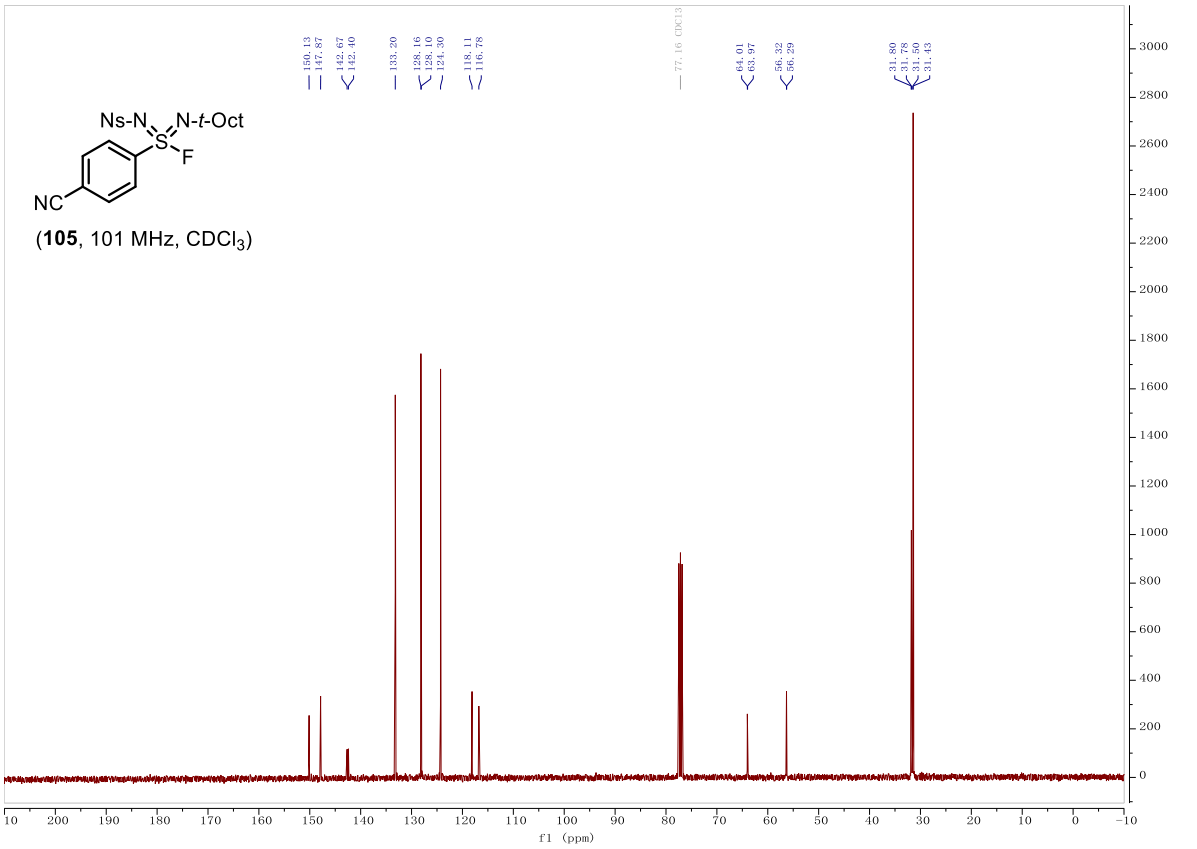
(**104**, 400 MHz, $CDCl_3$)



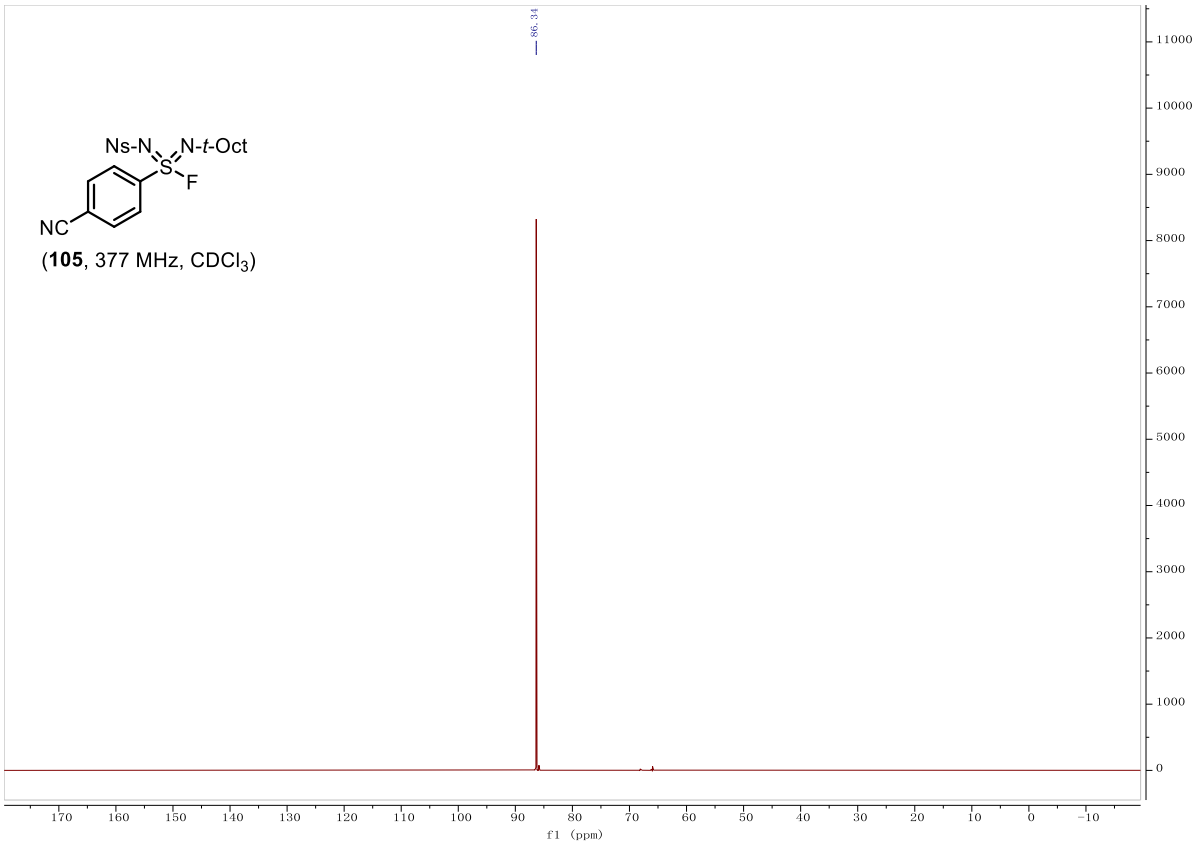
(**104**, 101 MHz, $CDCl_3$)


Ns-N
N-t-Oct
S
F
Cl
(104, 377 MHz, CDCl3)
85.81
f1 (ppm)

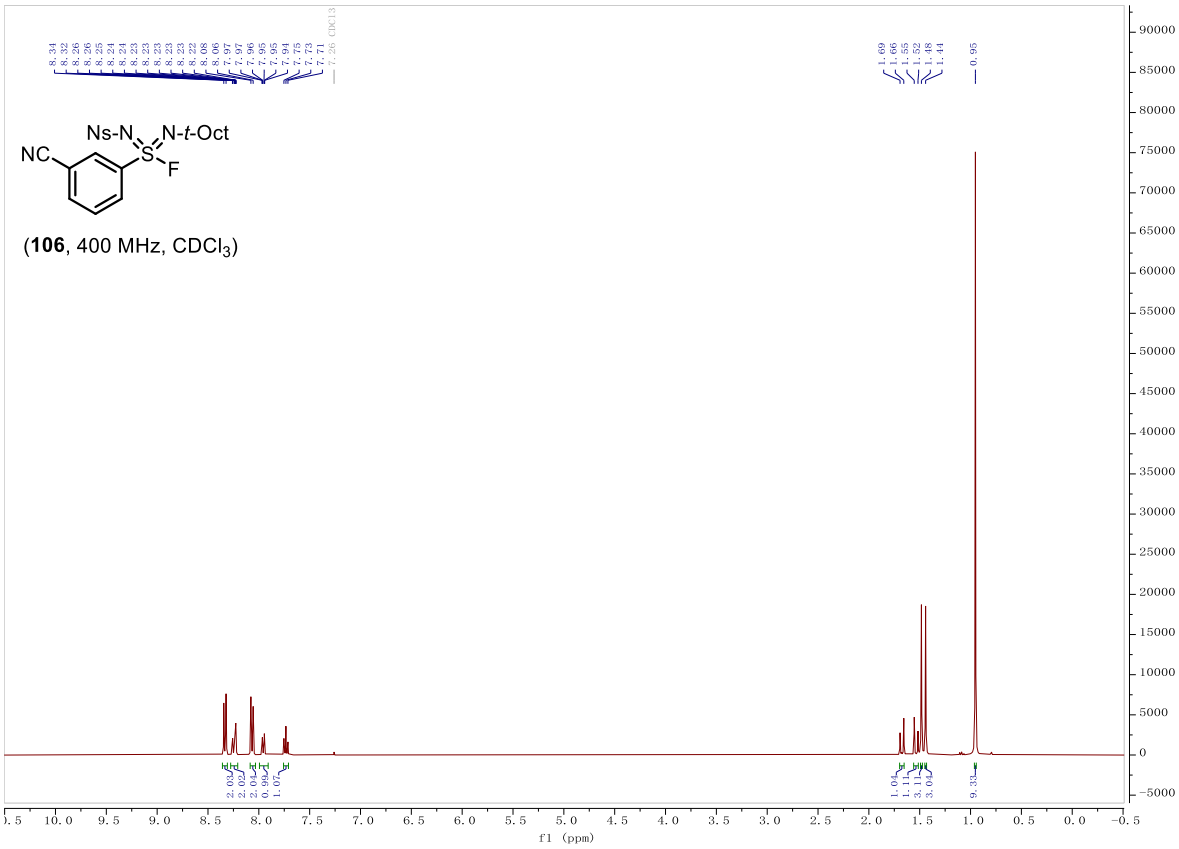

Ns-N
N-t-Oct
S
F
NC
(105, 400 MHz, CDCl3)
8.35
8.33
8.15
8.13
8.09
8.07
7.88
7.86
7.26 CDCl3
1.68
1.64
1.54
1.50
1.47
1.43
0.95
f1 (ppm)



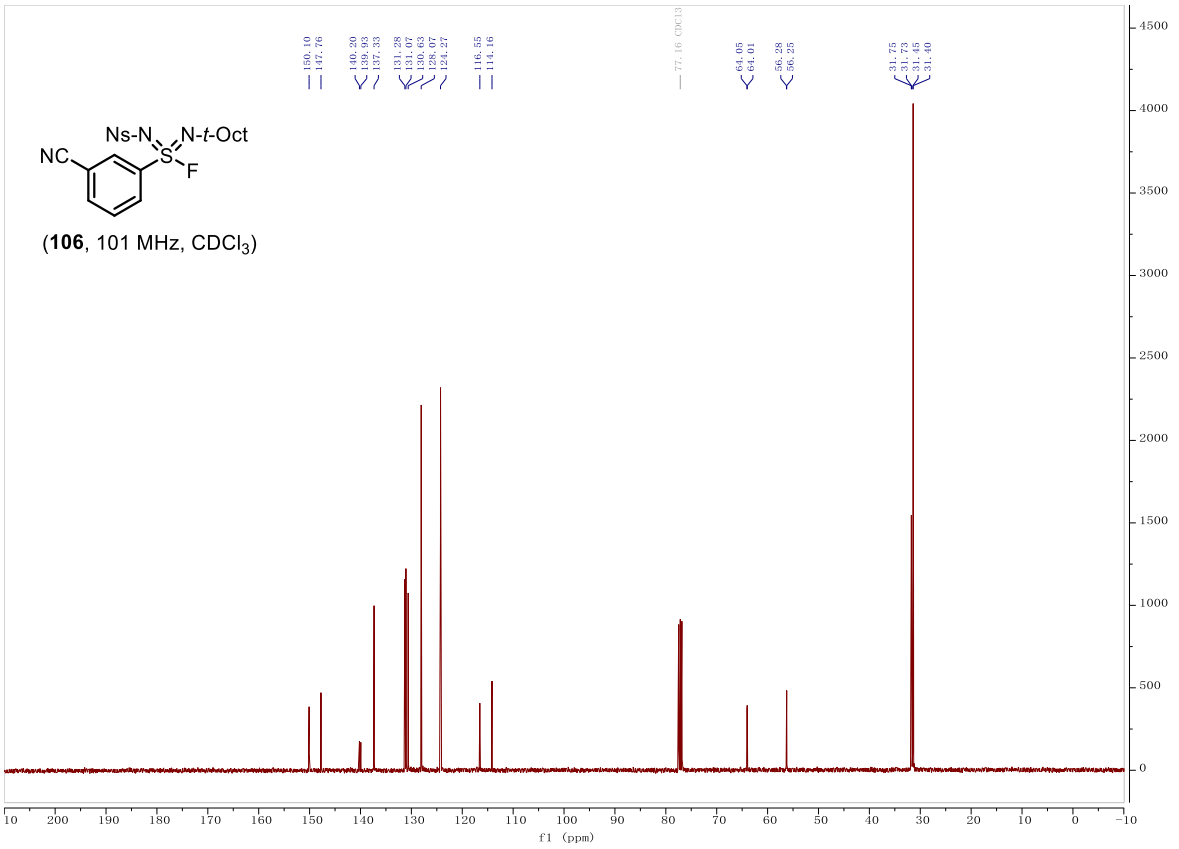
(**105**, 101 MHz, $CDCl_3$)



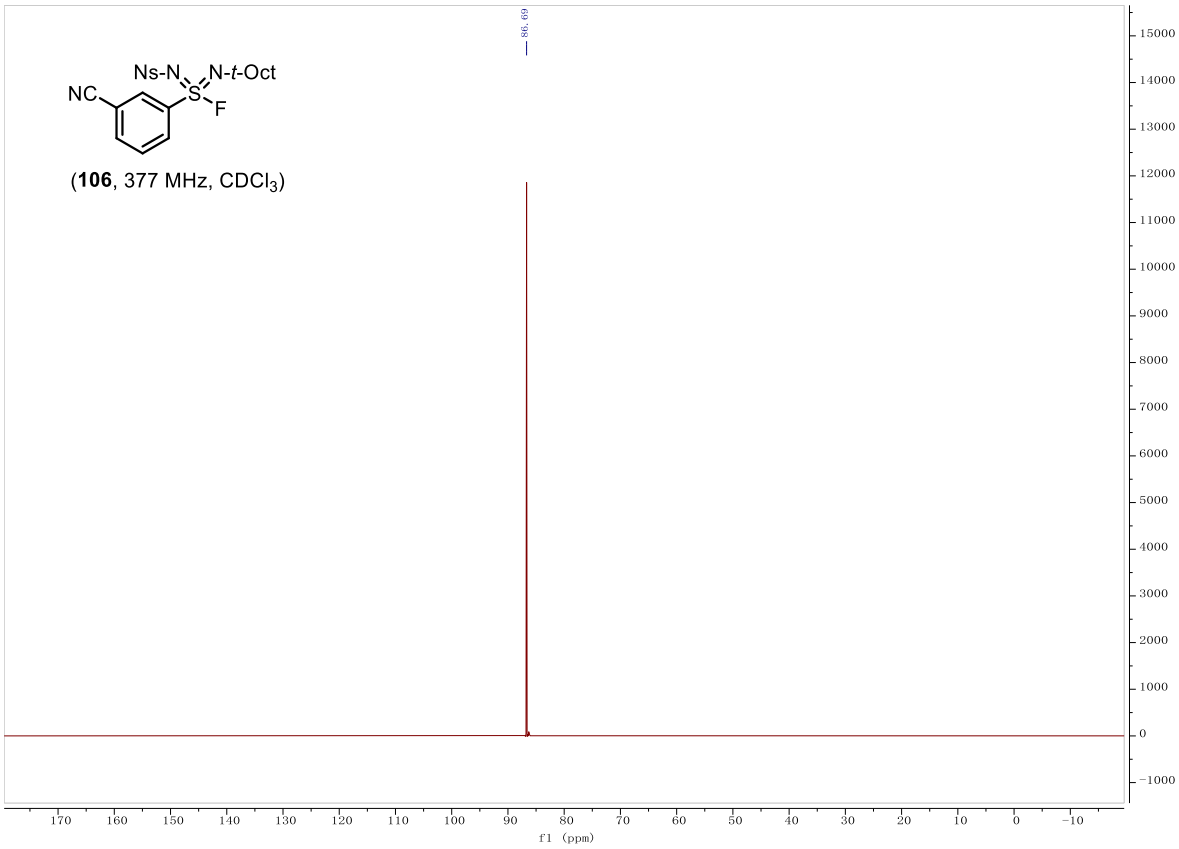
(**105**, 377 MHz, $CDCl_3$)

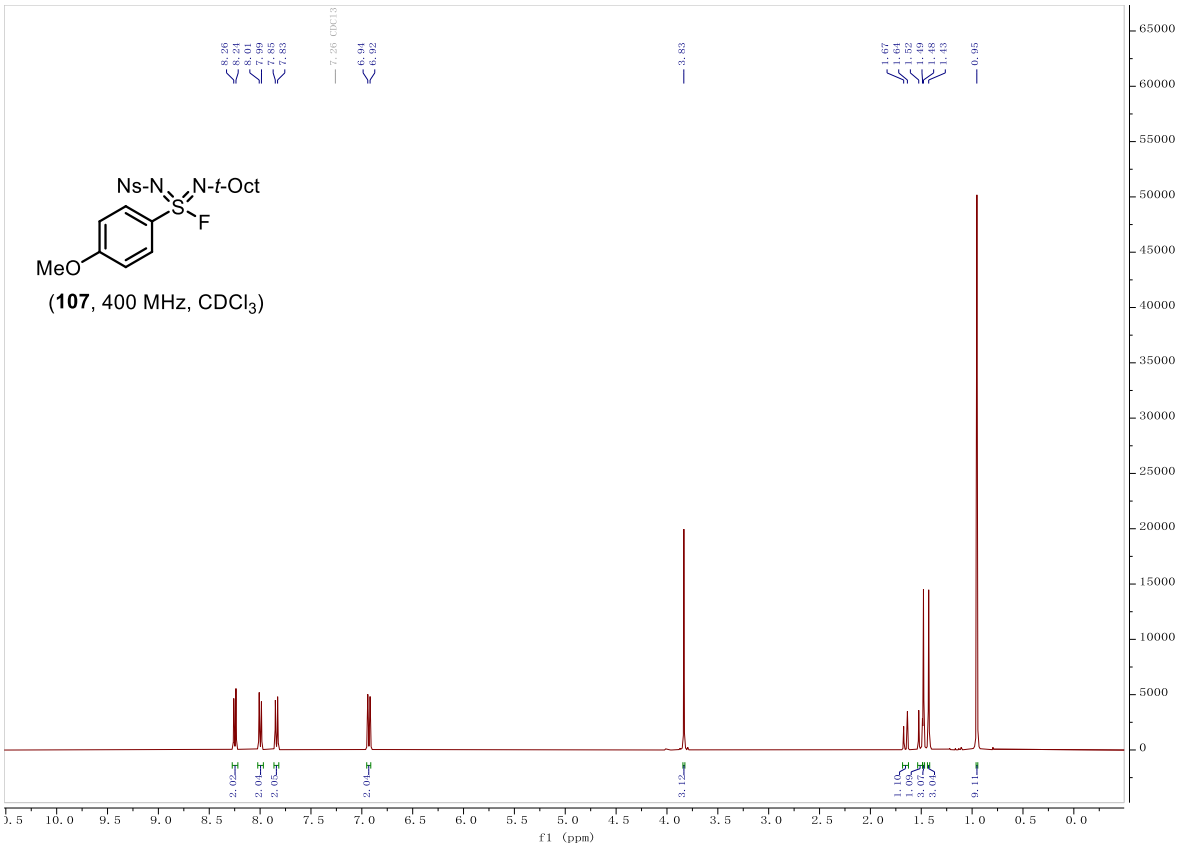


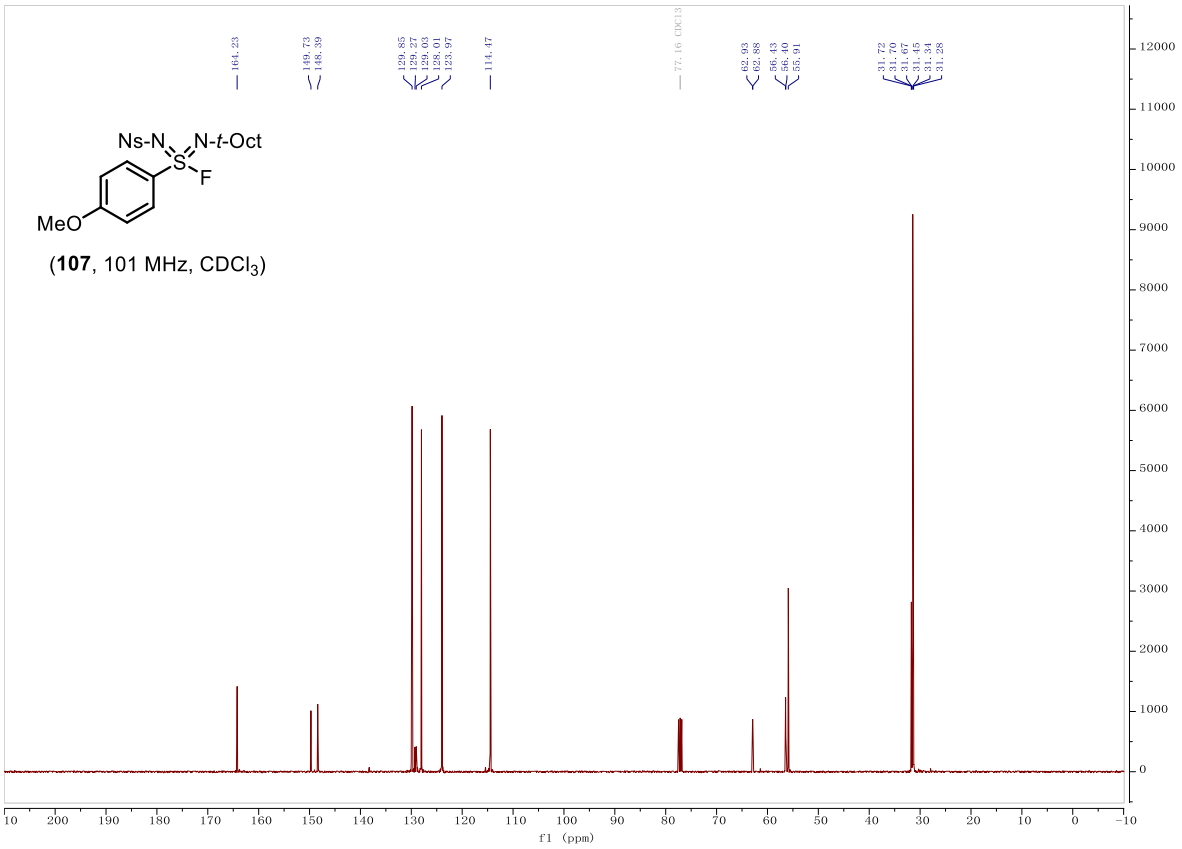
(**106**, 400 MHz, $CDCl_3$)

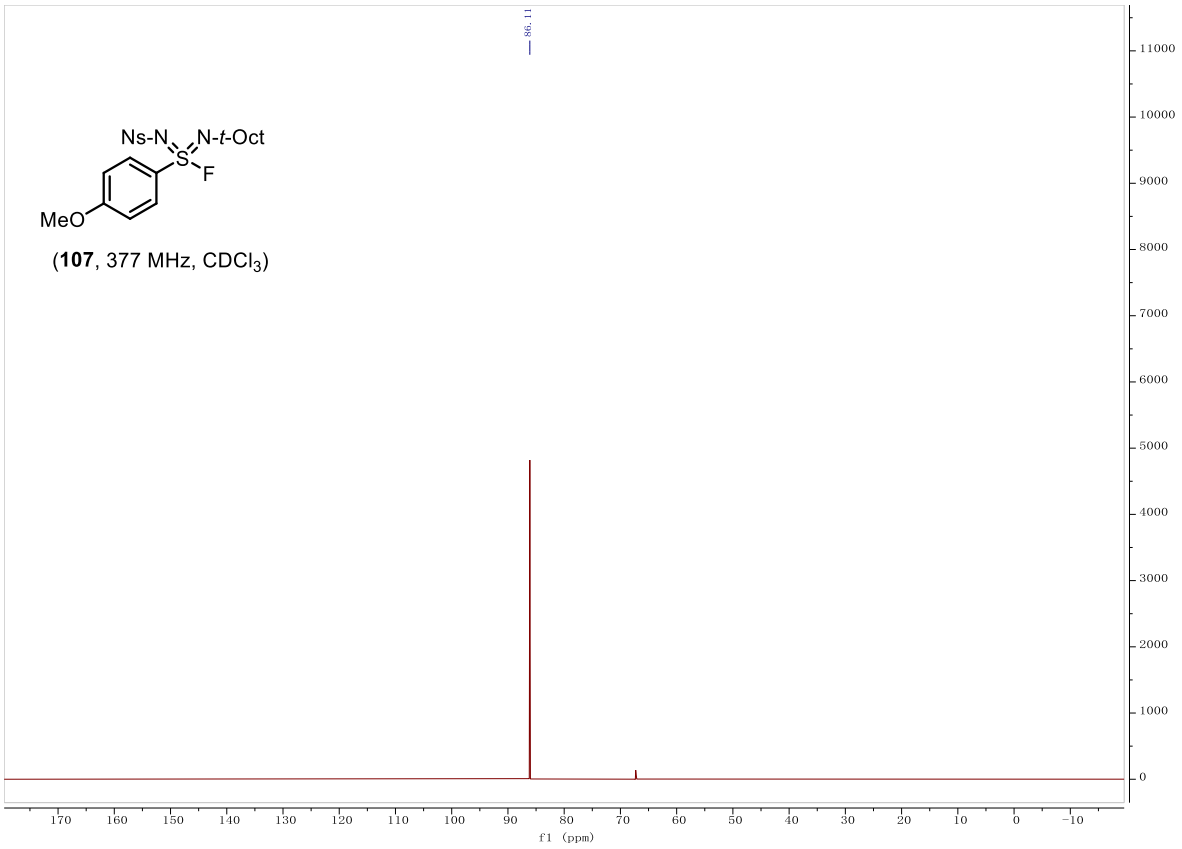


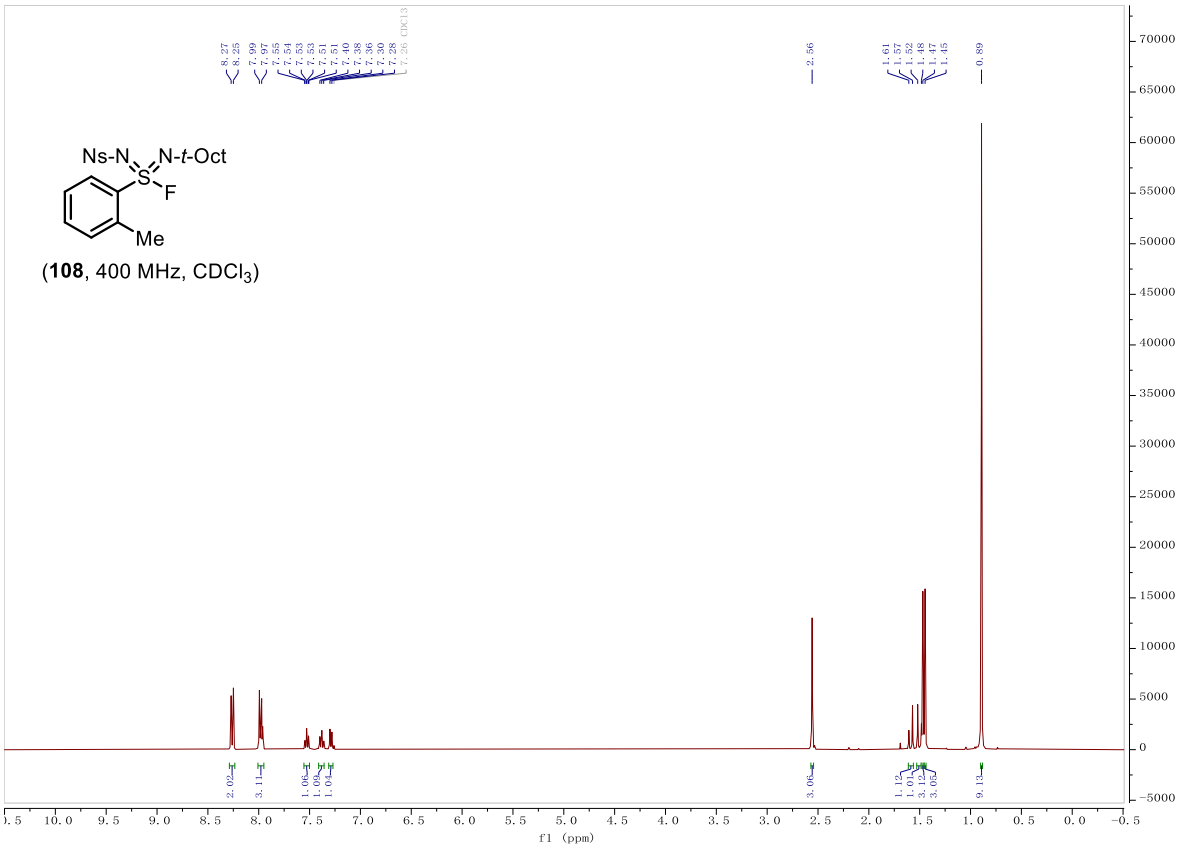
(**106**, 101 MHz, $CDCl_3$)


Ns-N
N-t-Oct
NC
S
F
(106, 377 MHz, CDCl3)
86.69
f1 (ppm)

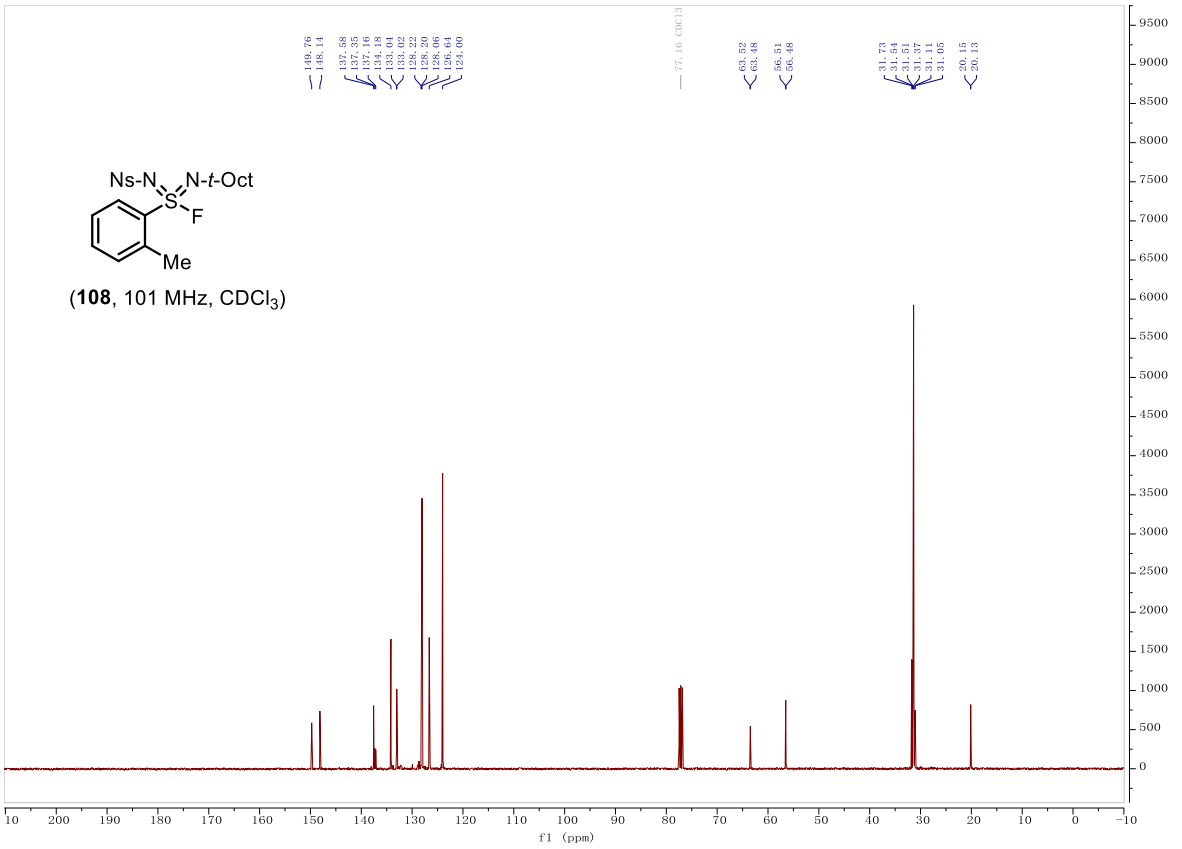

Ns-N
N-t-Oct
S
F
MeO
(107, 400 MHz, CDCl3)
8.26
8.24
8.01
7.99
7.85
7.83
7.26 CDCl3
6.94
6.92
3.83
1.67
1.64
1.52
1.49
1.48
1.43
0.95
2.02
2.04
2.05
2.04
3.12
1.10
1.08
3.07
3.04
9.11
f1 (ppm)


Ns-N
N-t-Oct
S
F
MeO
(107, 101 MHz, CDCl3)
164.23
149.73
148.39
129.85
129.27
129.03
128.01
123.97
114.47
77.16 CDCl3
62.93
62.88
56.43
56.40
25.91
31.72
31.70
31.67
31.45
31.34
31.28
f1 (ppm)

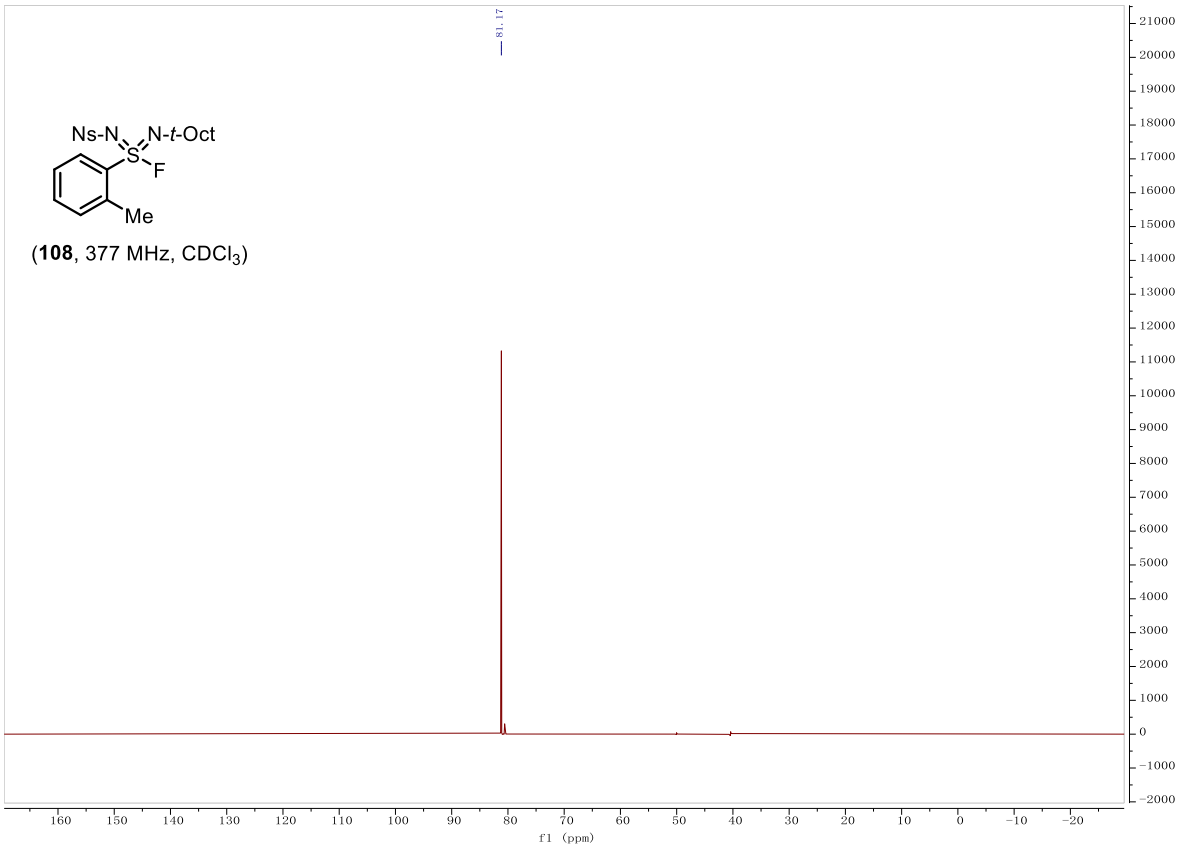

Ns-N
N-t-Oct
S
F
MeO
(107, 377 MHz, CDCl3)
86.11
f1 (ppm)



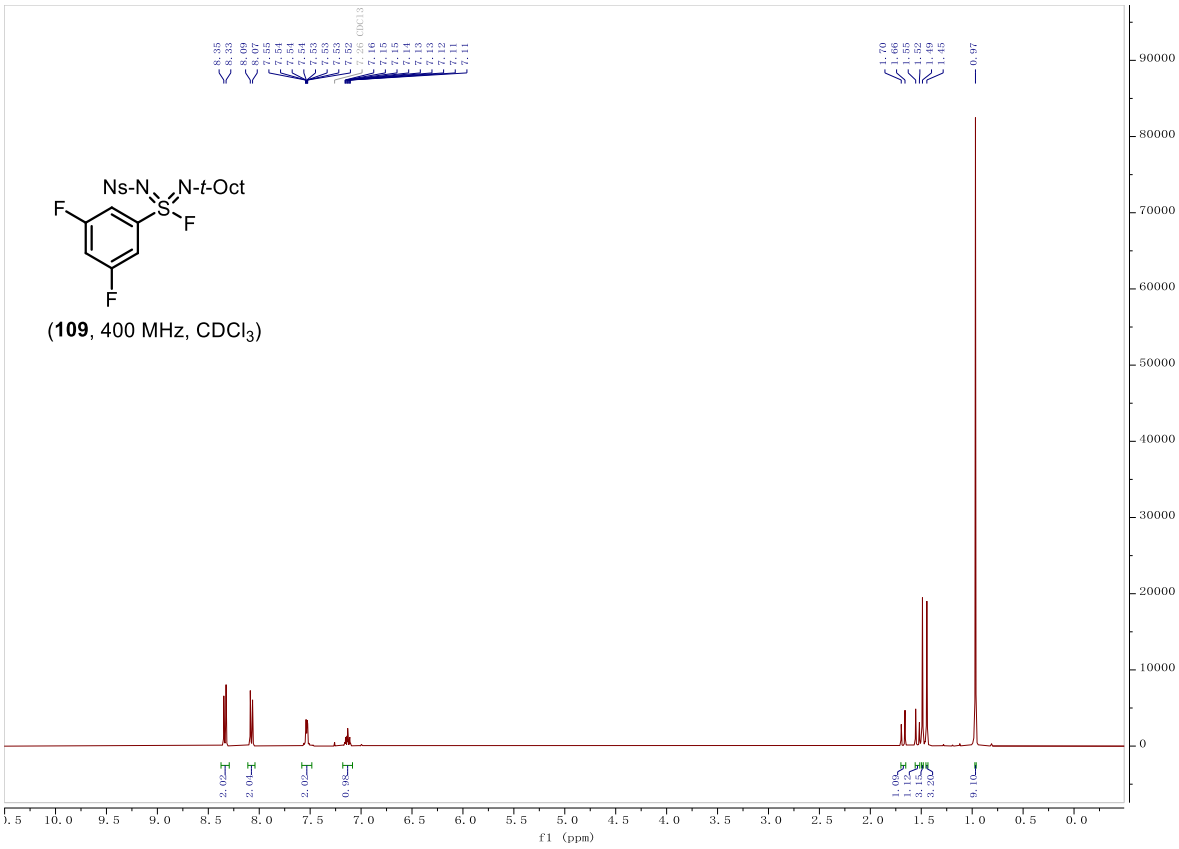
(**108**, 400 MHz, $CDCl_3$)



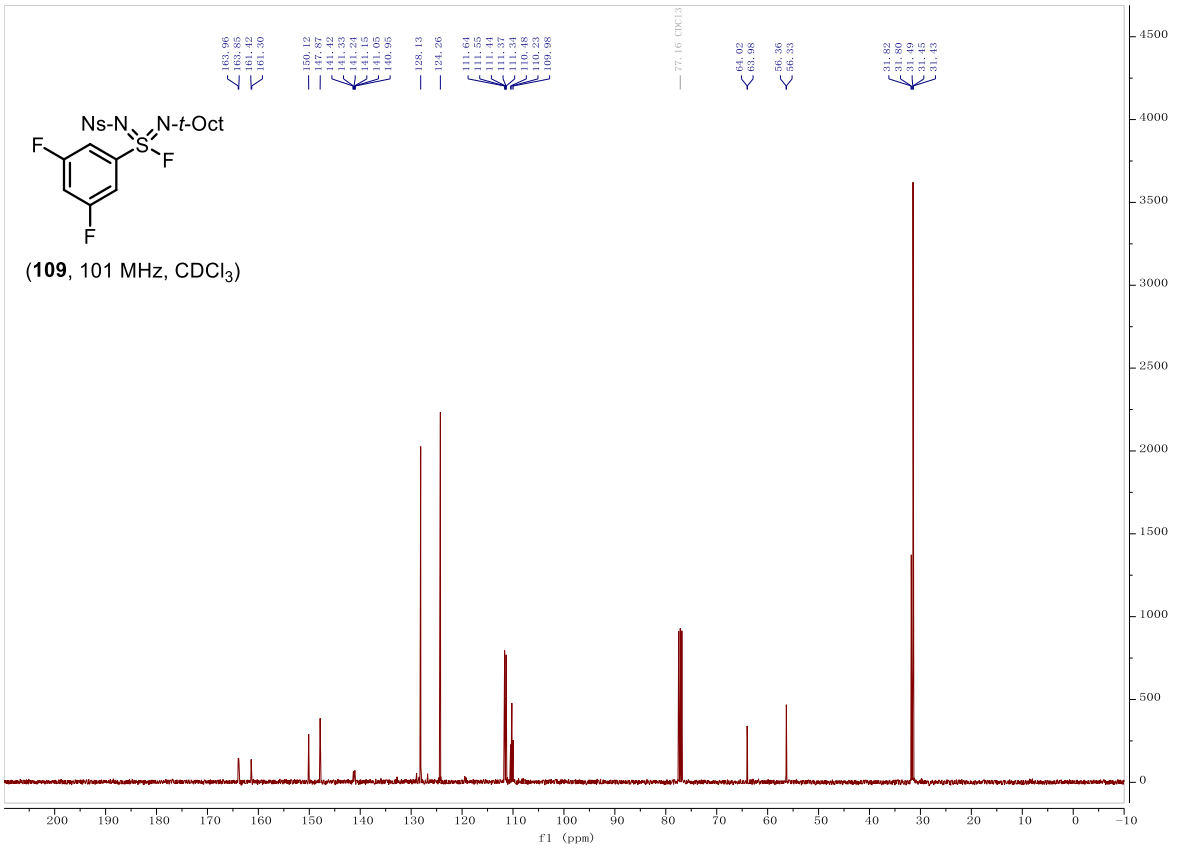
(**108**, 101 MHz, $CDCl_3$)



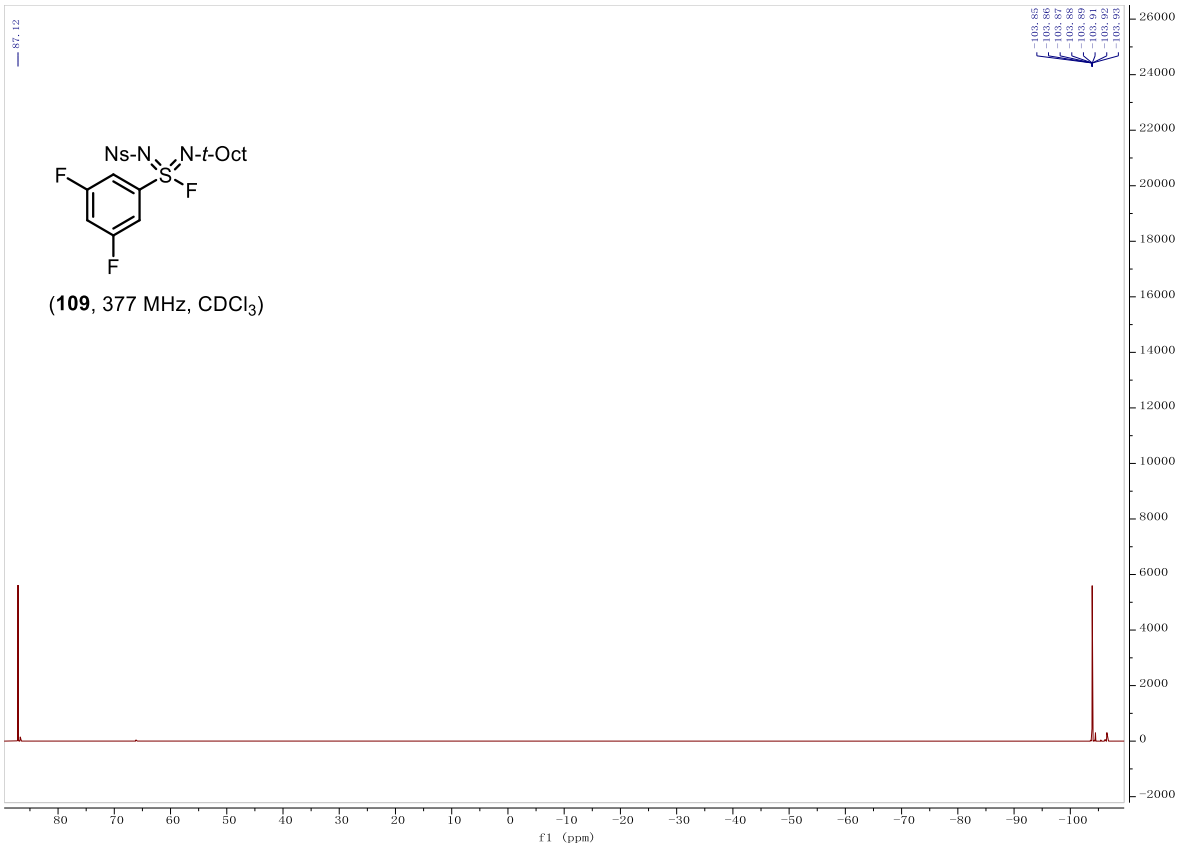
(**108**, 377 MHz, $CDCl_3$)



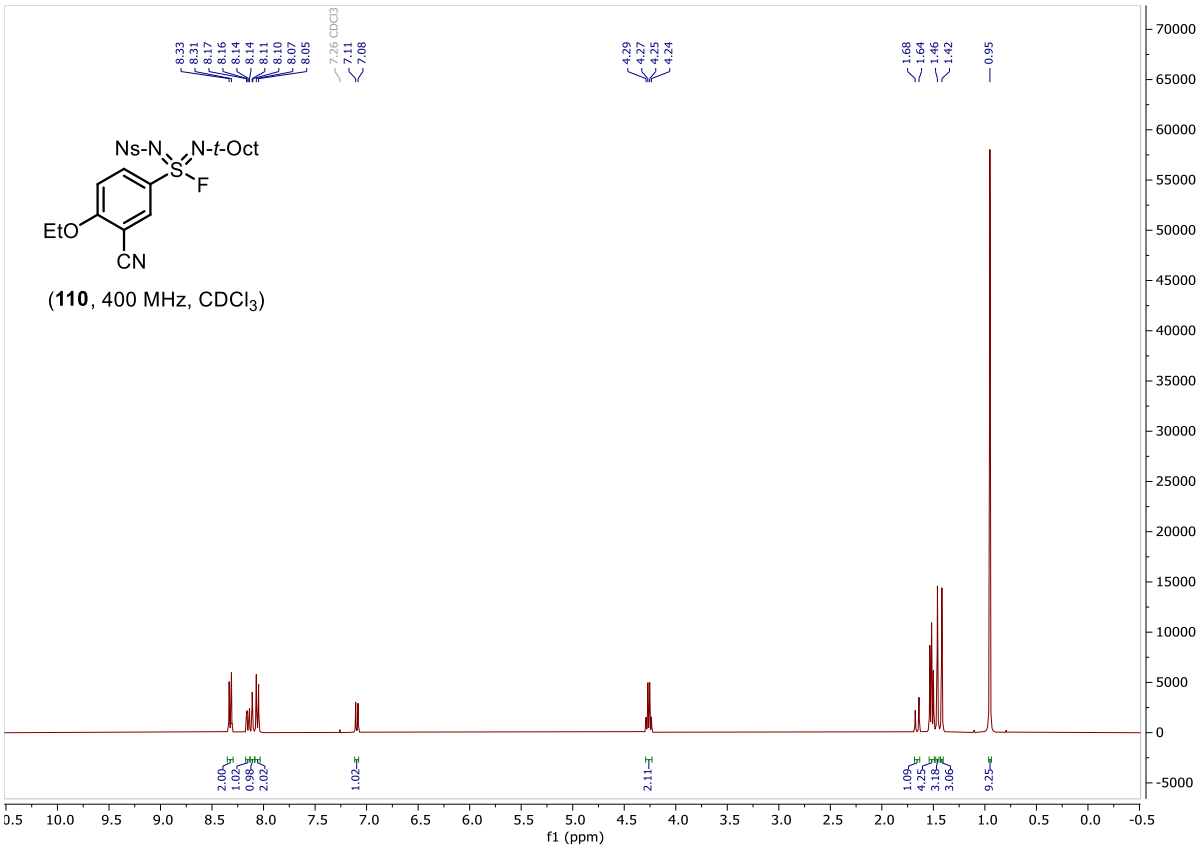
(**109**, 400 MHz, $CDCl_3$)

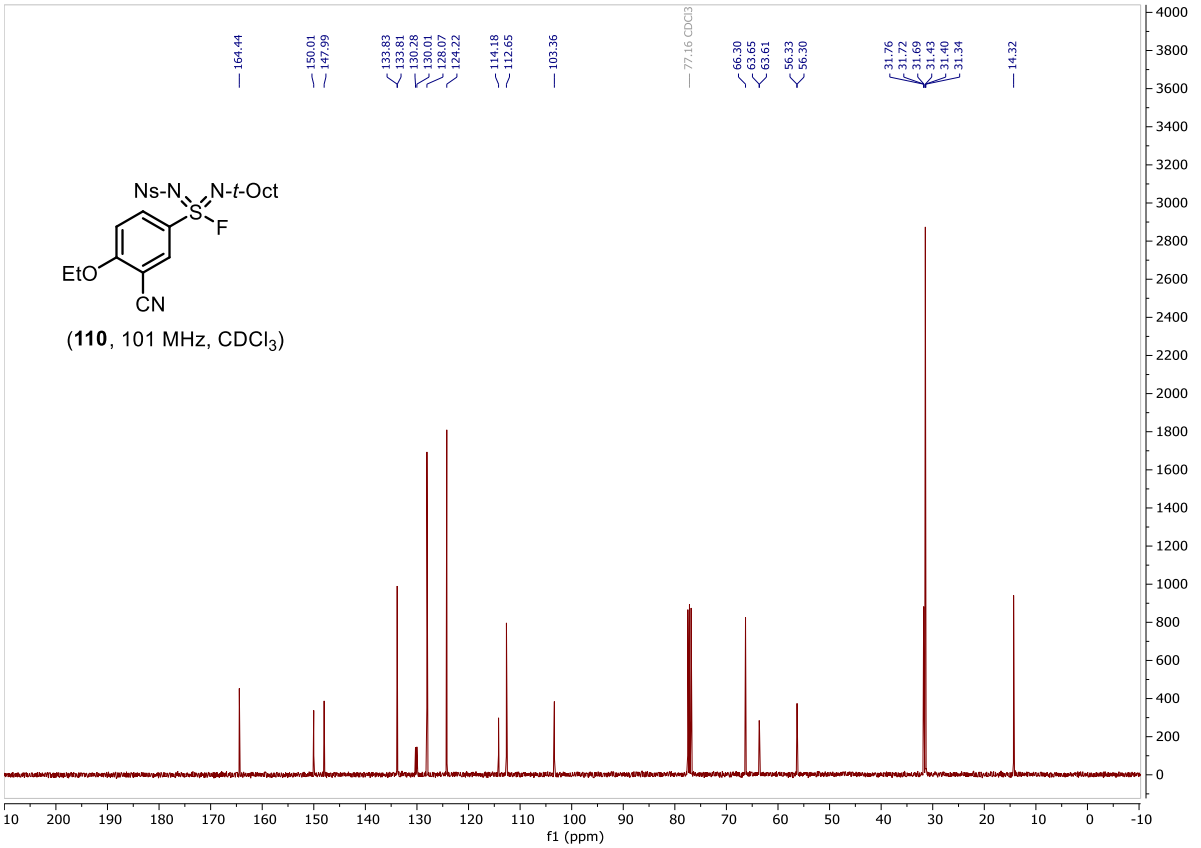


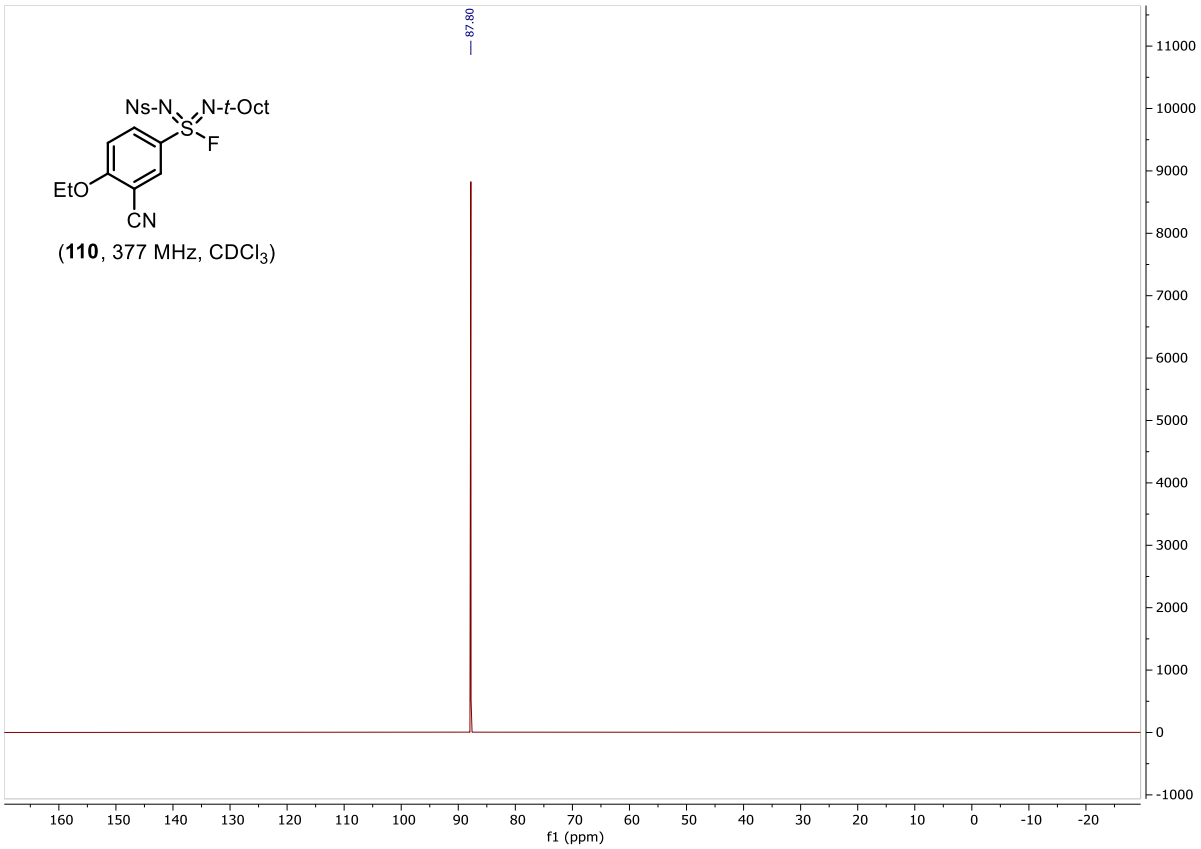
(**109**, 101 MHz, $CDCl_3$)

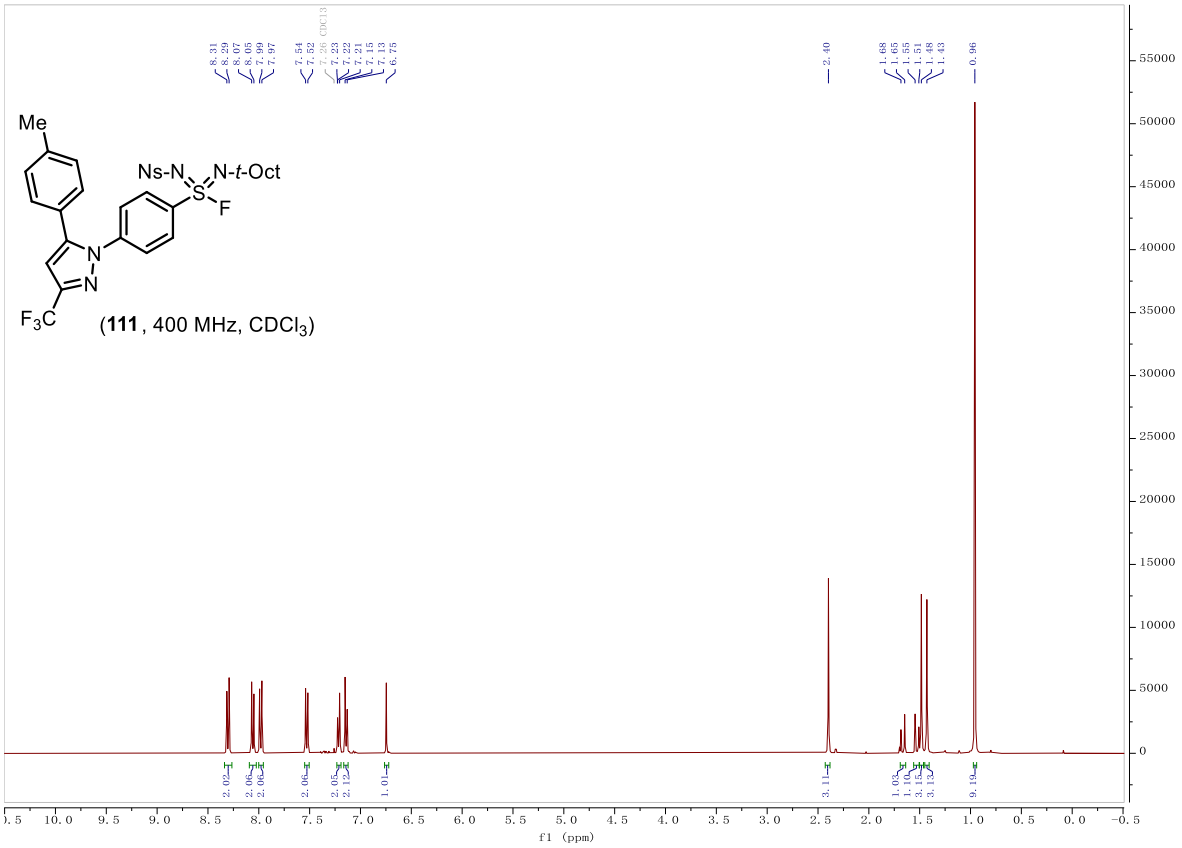


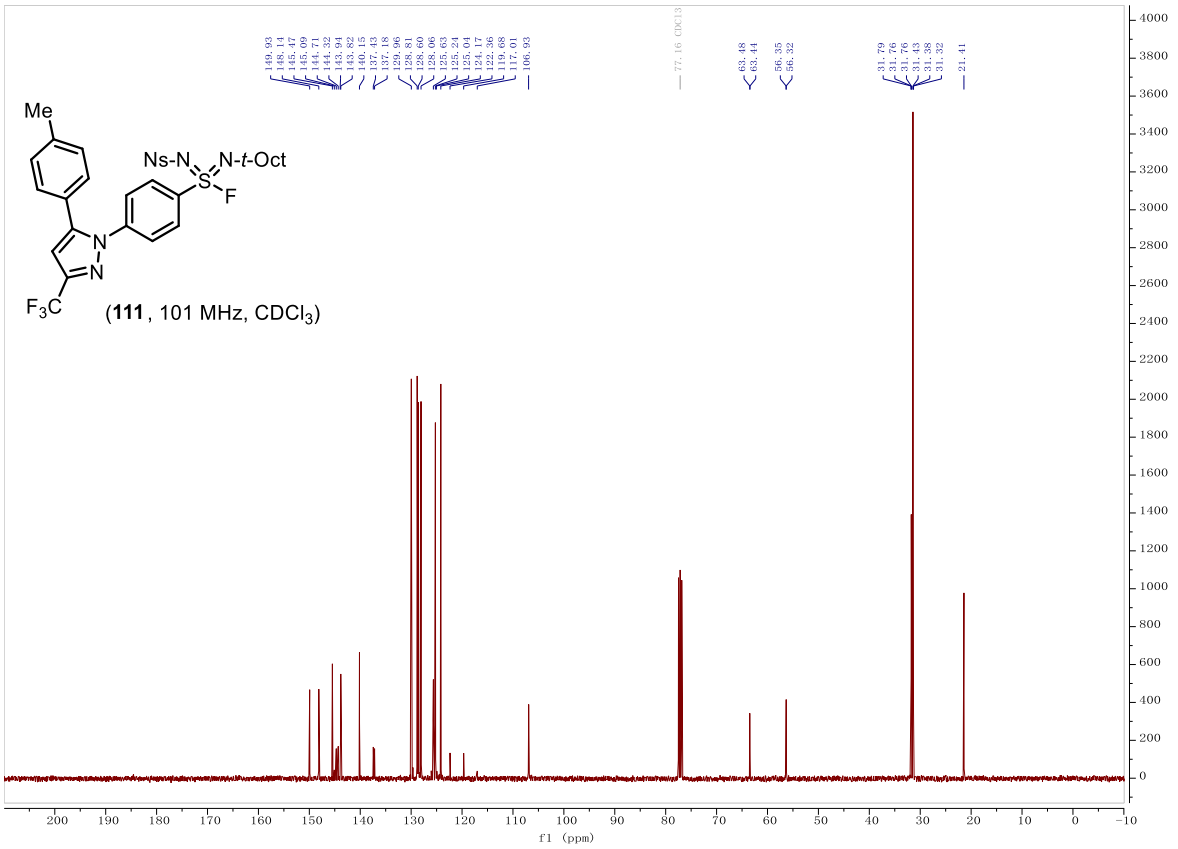
(**109**, 377 MHz, $CDCl_3$)

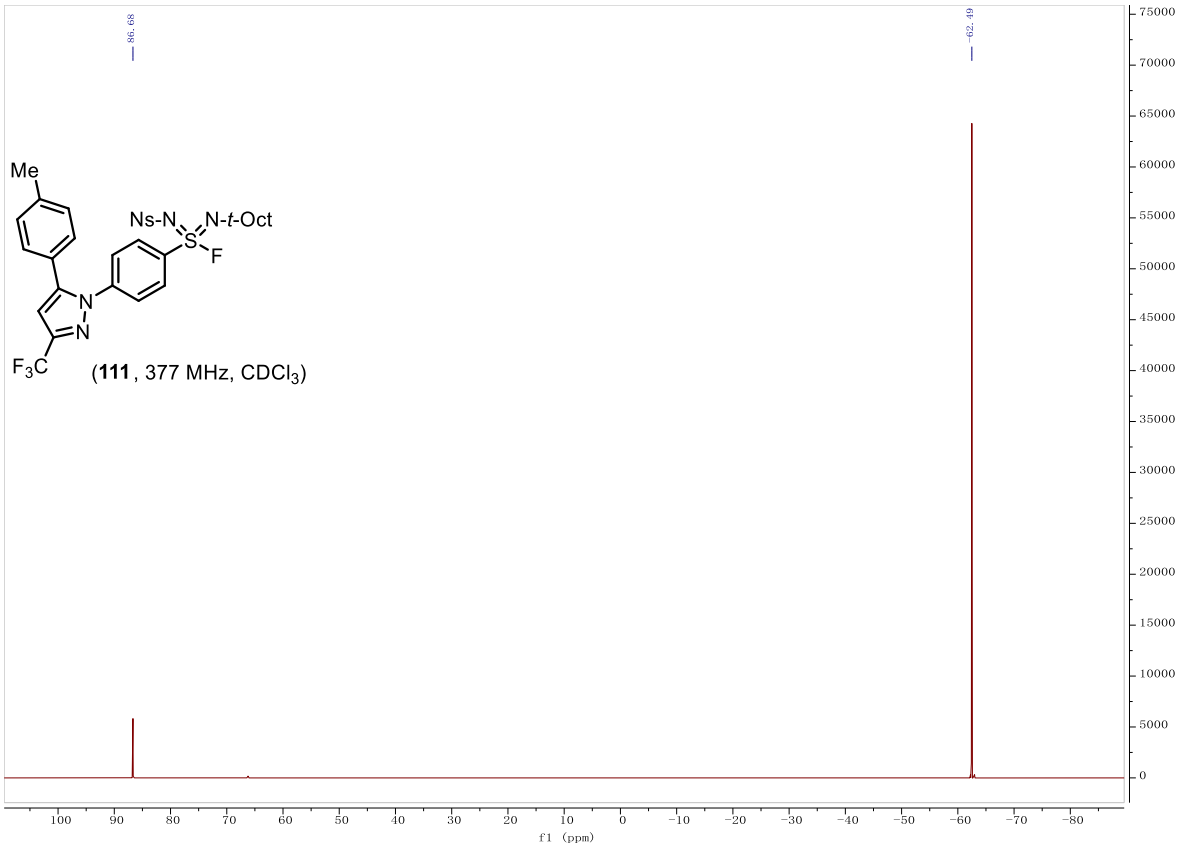

Ns-N
N-t-Oct
S
F
EtO
CN
(110, 400 MHz, CDCl3)
f1 (ppm)

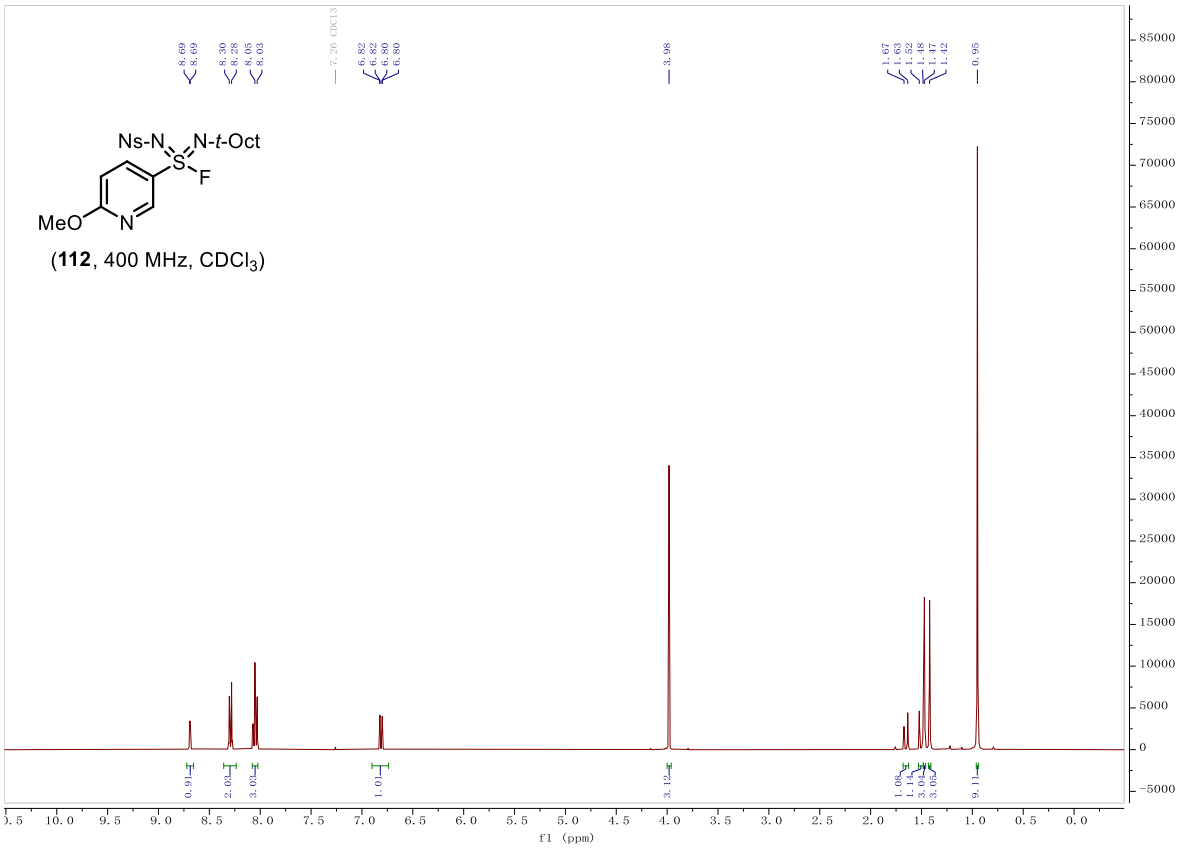

Ns-N
N-t-Oct
S
F
EtO
CN
(110, 101 MHz, CDCl3)
f1 (ppm)

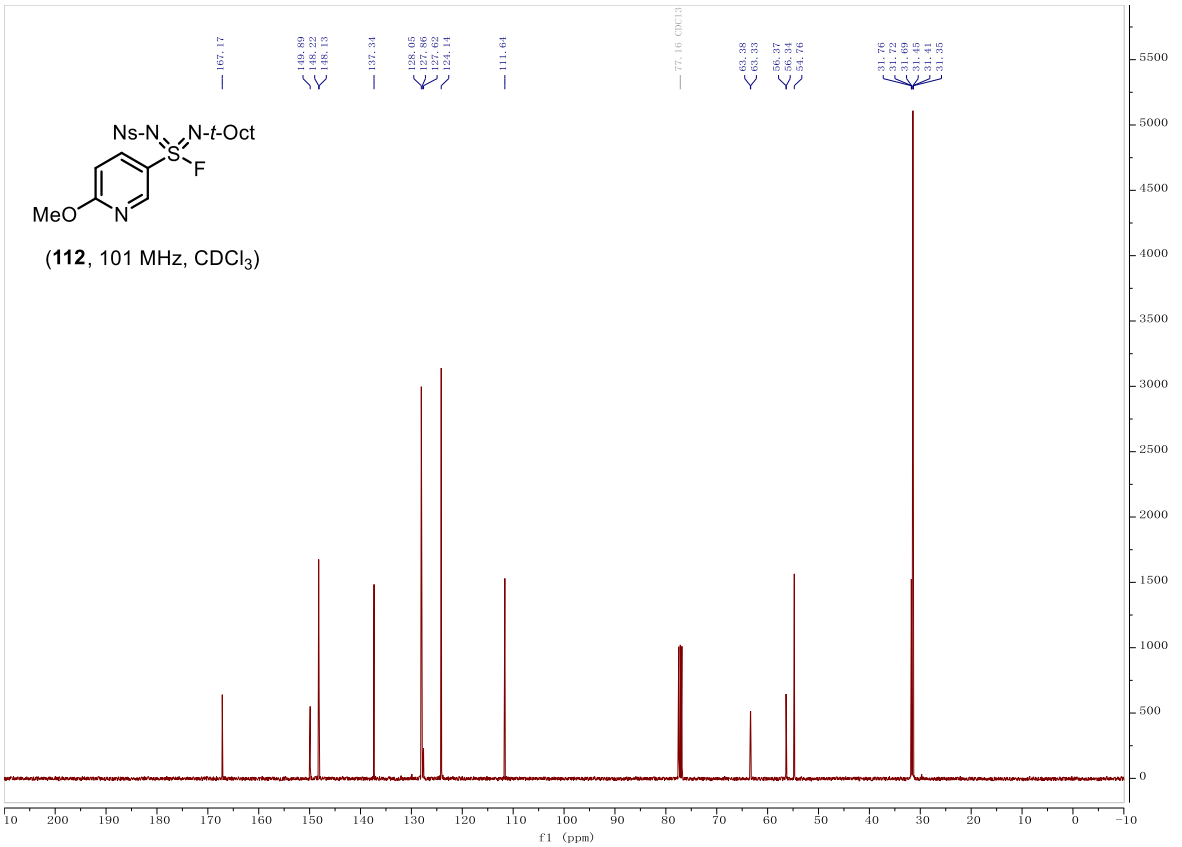

Ns-N
N-t-Oct
S
F
EtO
CN
(110, 377 MHz, CDCl3)
87.80
f1 (ppm)

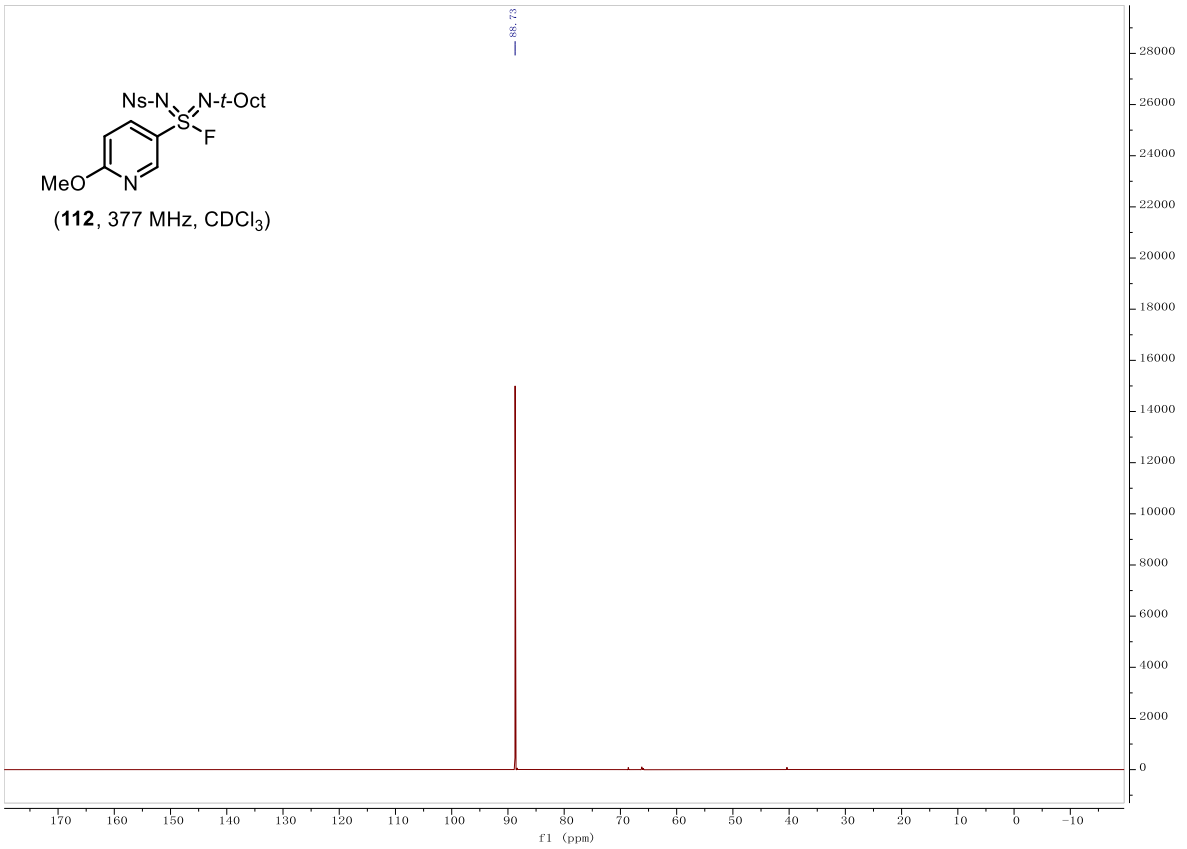

Me
Ns-N
N-t-Oct
S
F
N
N
F3C
(111, 400 MHz, CDCl3)
8.31
8.29
8.07
8.05
7.99
7.97
7.54
7.52
7.23
7.22
7.21
7.15
7.13
6.75
2.40
1.68
1.65
1.55
1.51
1.48
1.43
0.96
f1 (ppm)

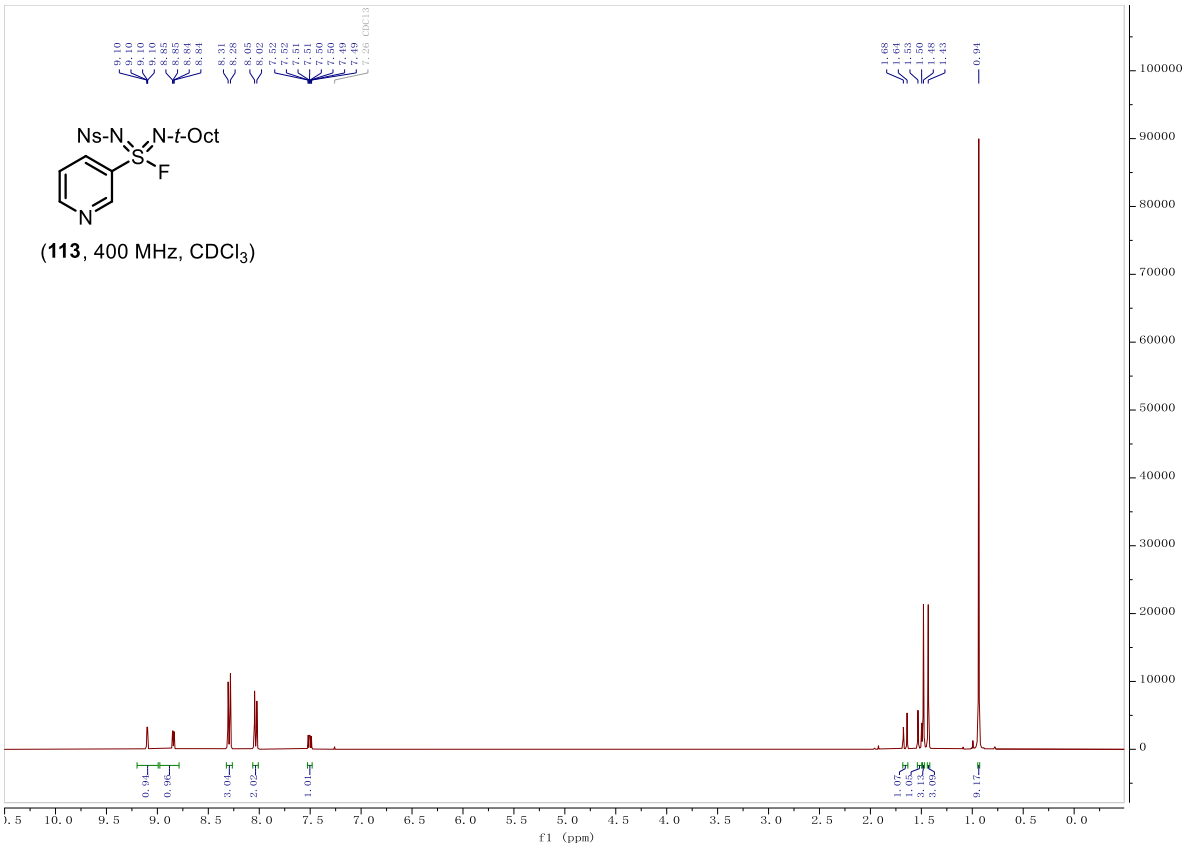

Me
Ns-N
N-t-Oct
S
F
N
N
F3C
(111, 101 MHz, CDCl3)
f1 (ppm)

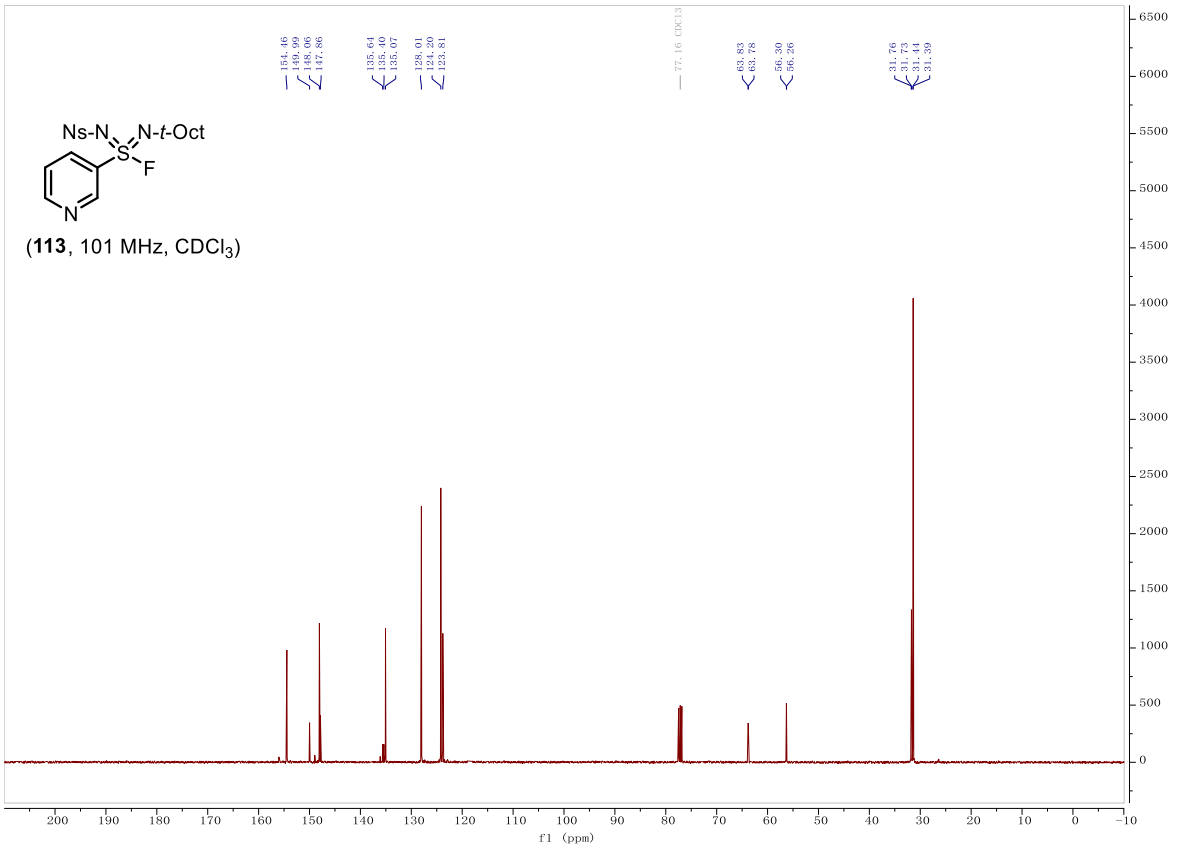

Me
Ns-N
N-t-Oct
S
F
N
N
F3C
(111, 377 MHz, CDCl3)
f1 (ppm)


Ns-N
N-t-Oct
S
F
MeO
N
(112, 400 MHz, CDCl3)
f1 (ppm)

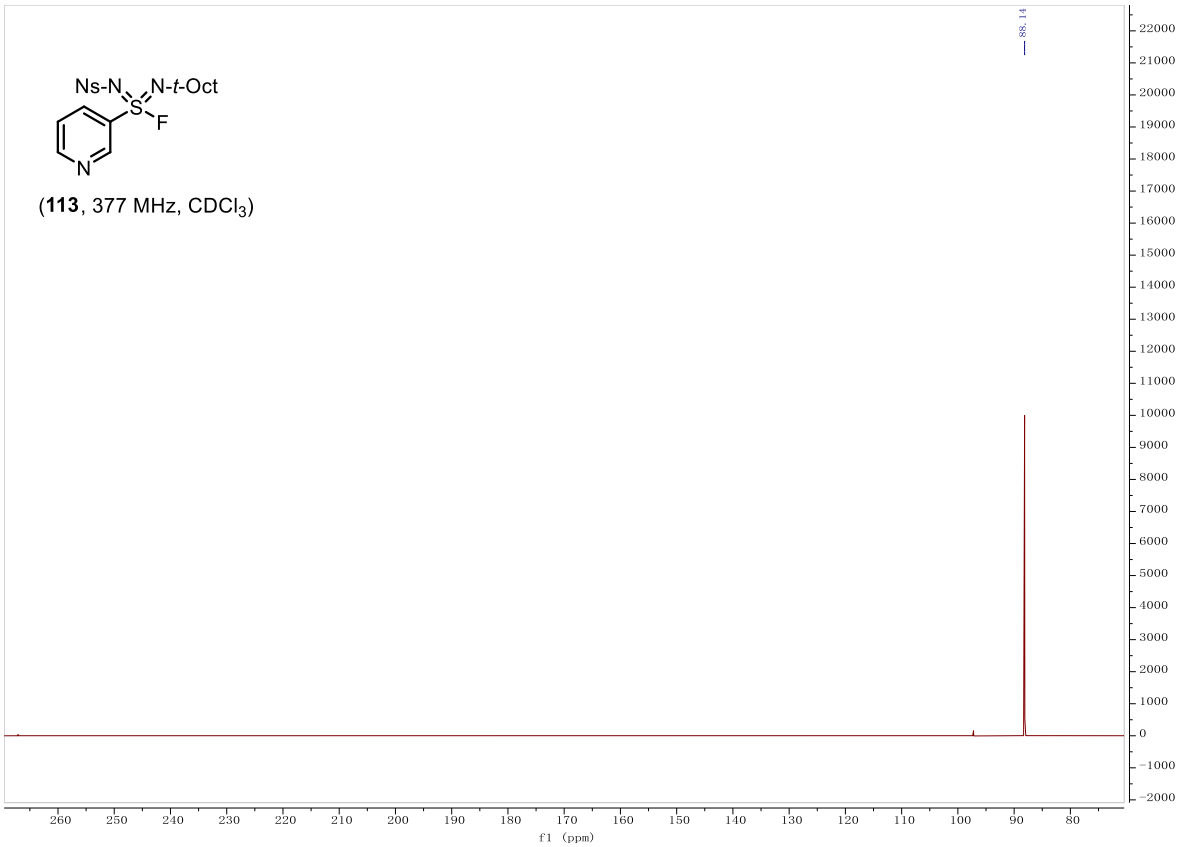

Ns-N
N-t-Oct
S
F
MeO
N
(112, 101 MHz, CDCl3)
f1 (ppm)


Ns-N
N-t-Oct
S
F
MeO
N
(112, 377 MHz, CDCl3)
88.73
f1 (ppm)

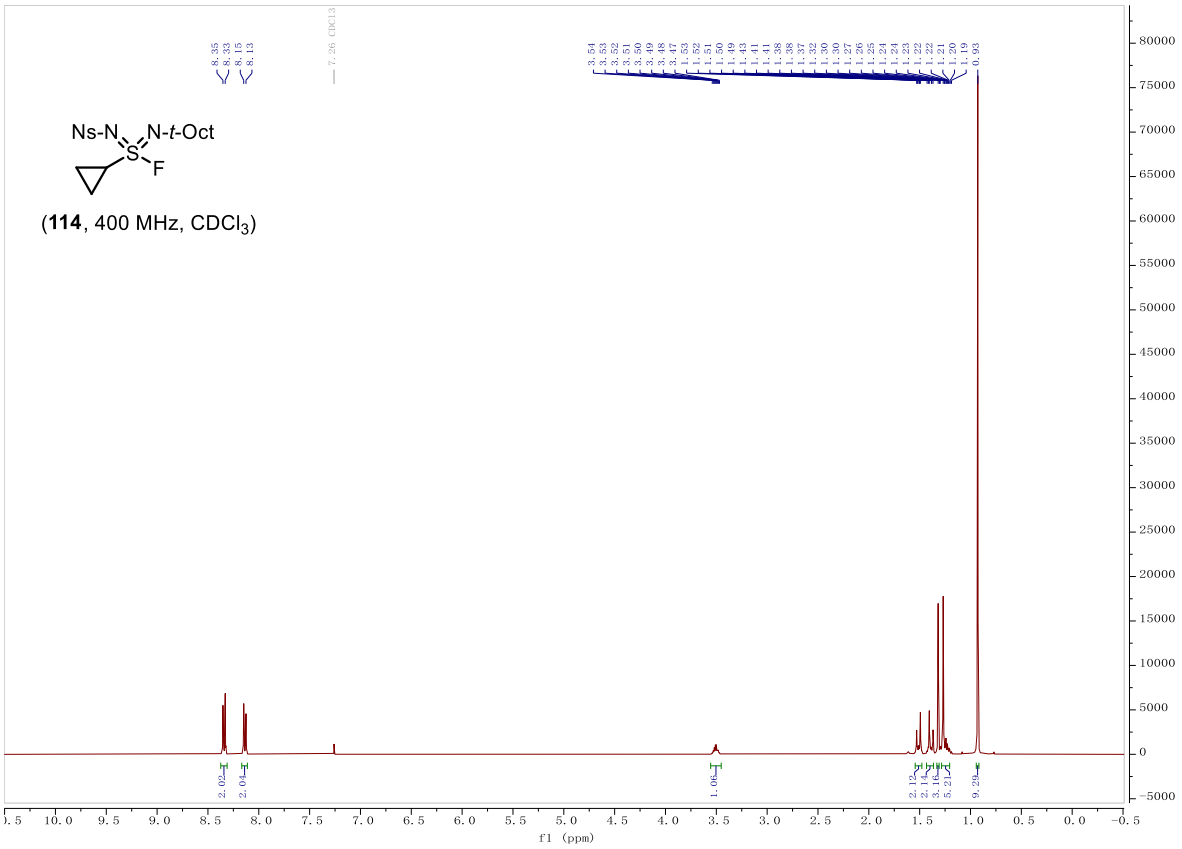

Ns-N
N-t-Oct
S
F
N
(113, 400 MHz, CDCl3)
9.10
8.85
8.84
8.31
8.28
8.05
8.02
7.52
7.51
7.50
7.49
7.26 CDCl3
1.68
1.64
1.53
1.50
1.48
1.43
0.94
0.94
0.96
3.04
2.02
1.01
1.07
1.05
3.13
3.09
9.17
f1 (ppm)

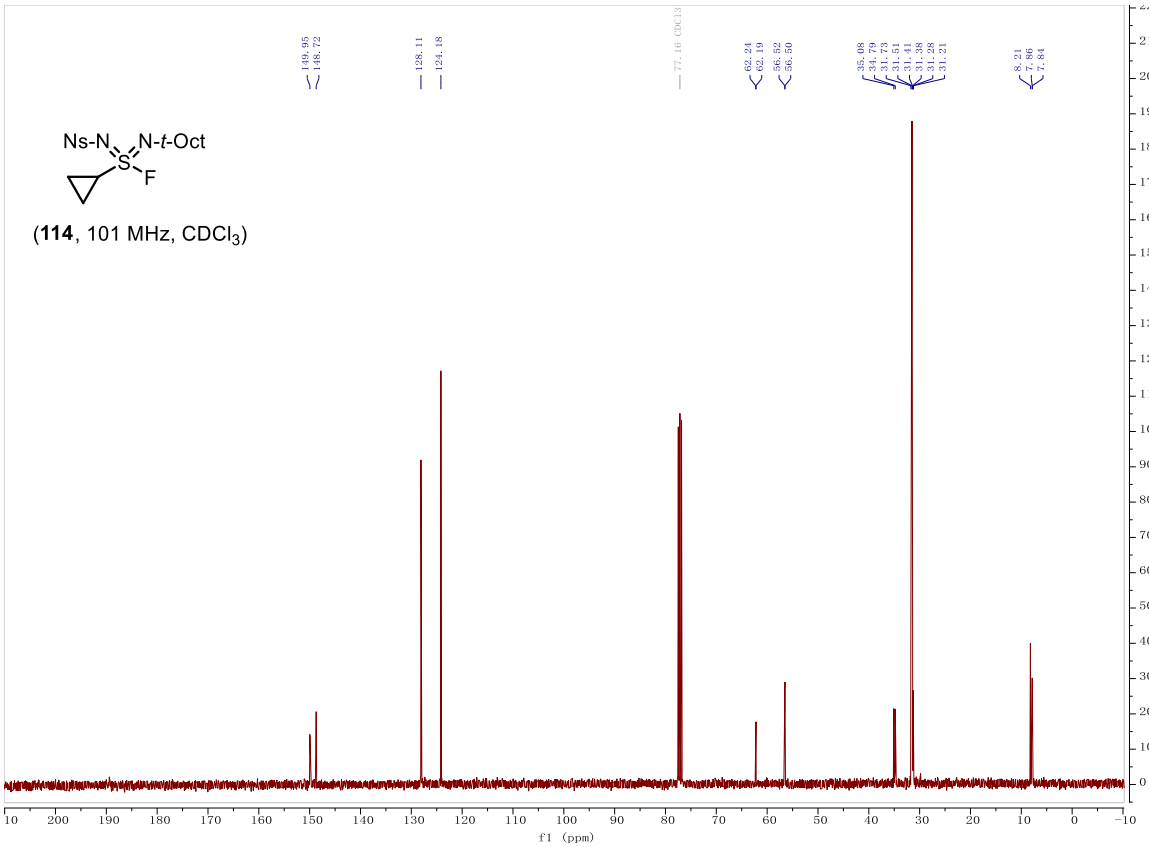


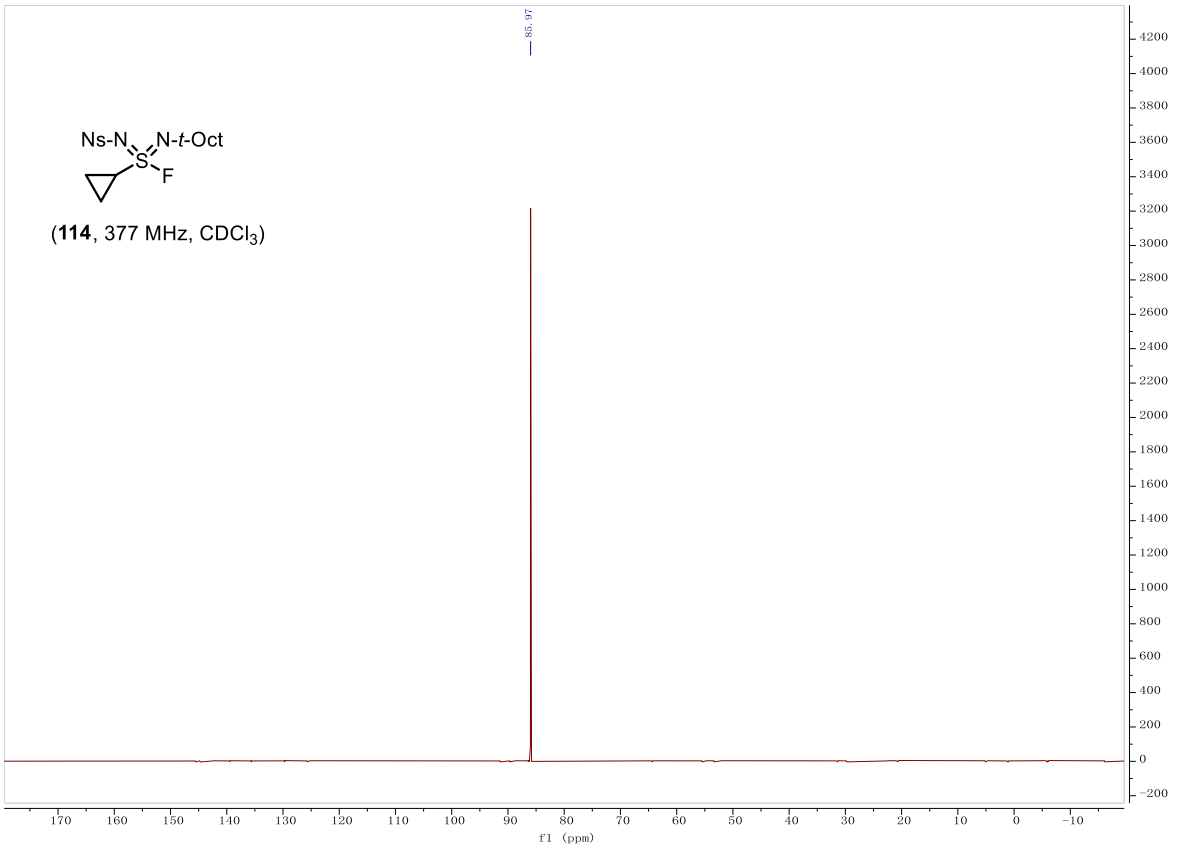
(**113**, 101 MHz, $CDCl_3$)

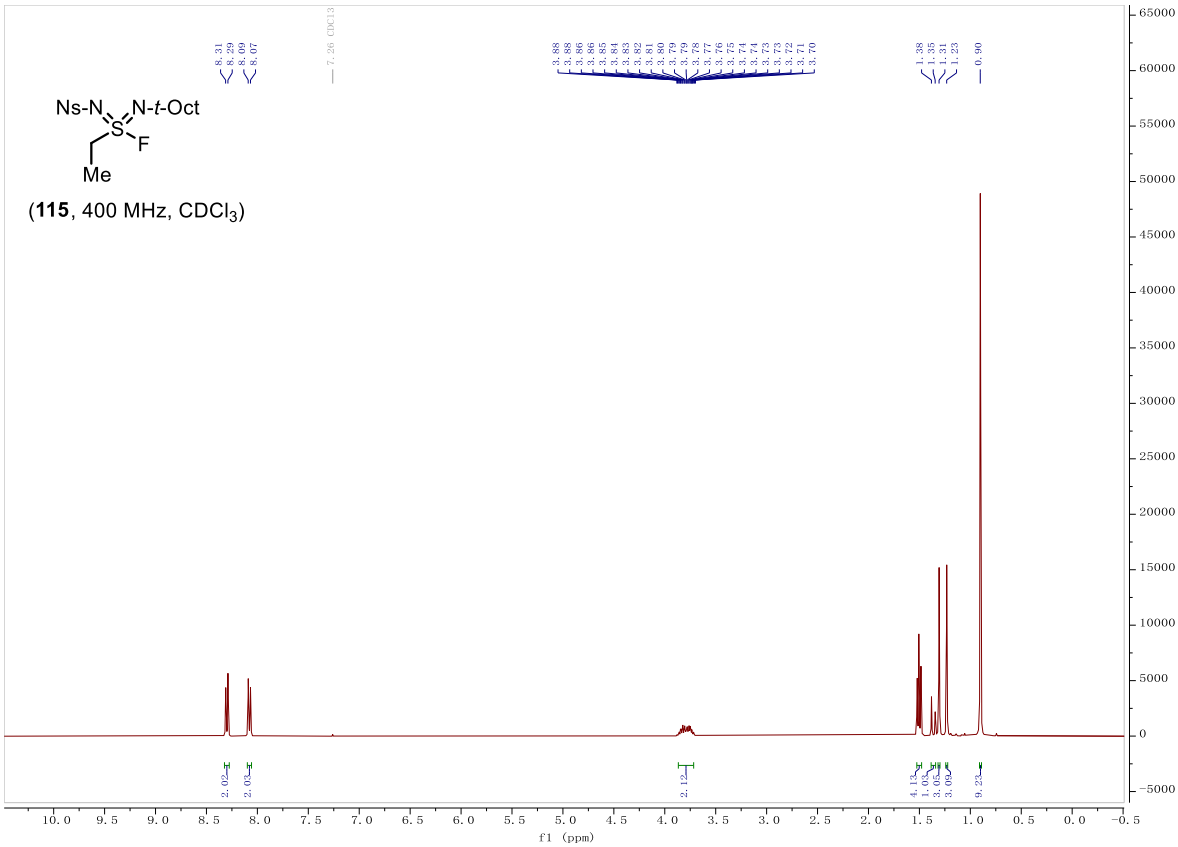


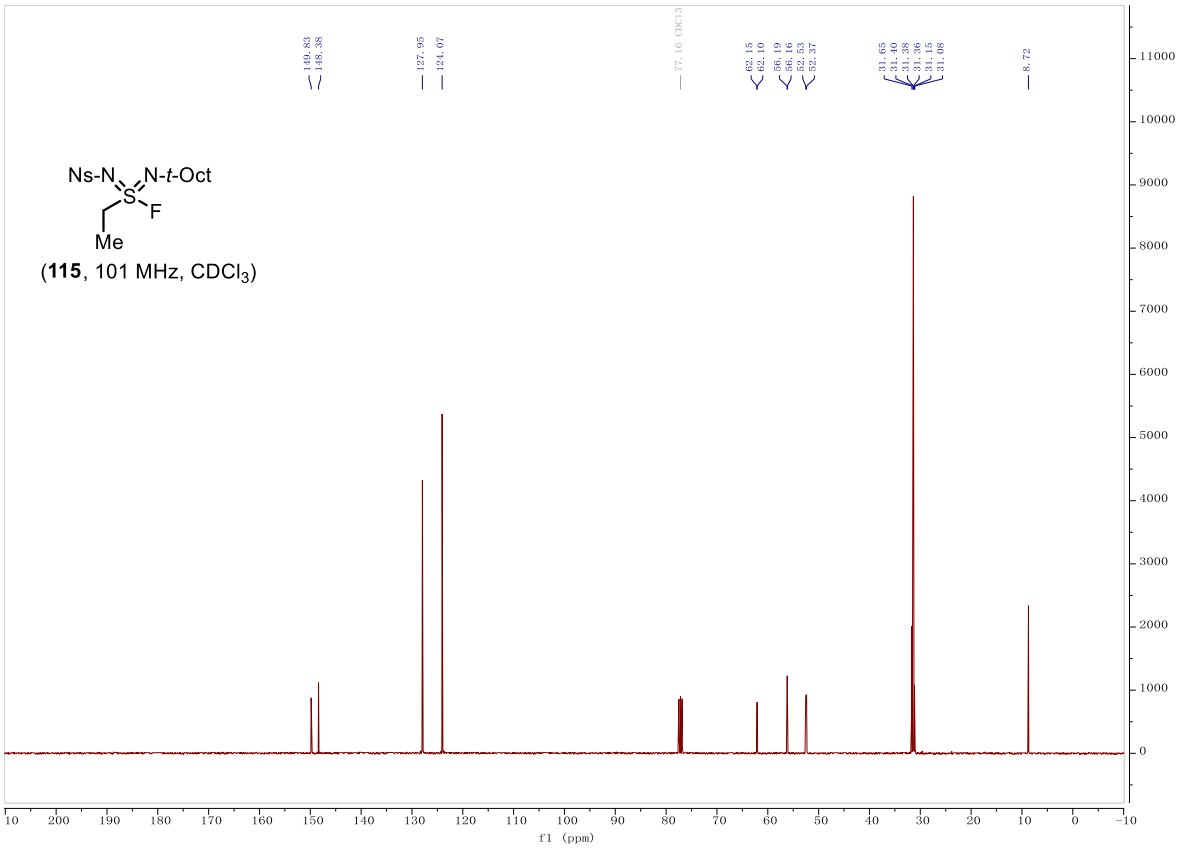
(**113**, 377 MHz, $CDCl_3$)

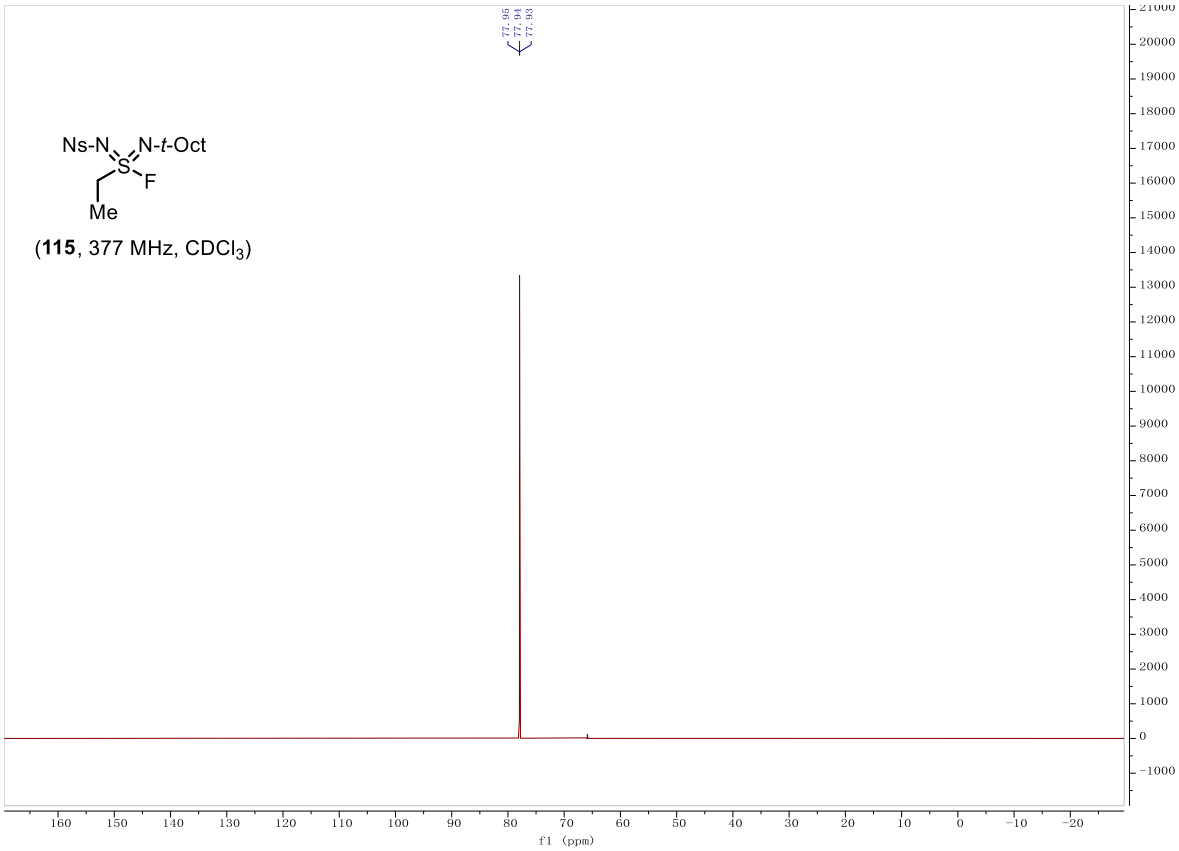

Ns-N
N-t-Oct
S
F
(114, 400 MHz, CDCl3)
f1 (ppm)

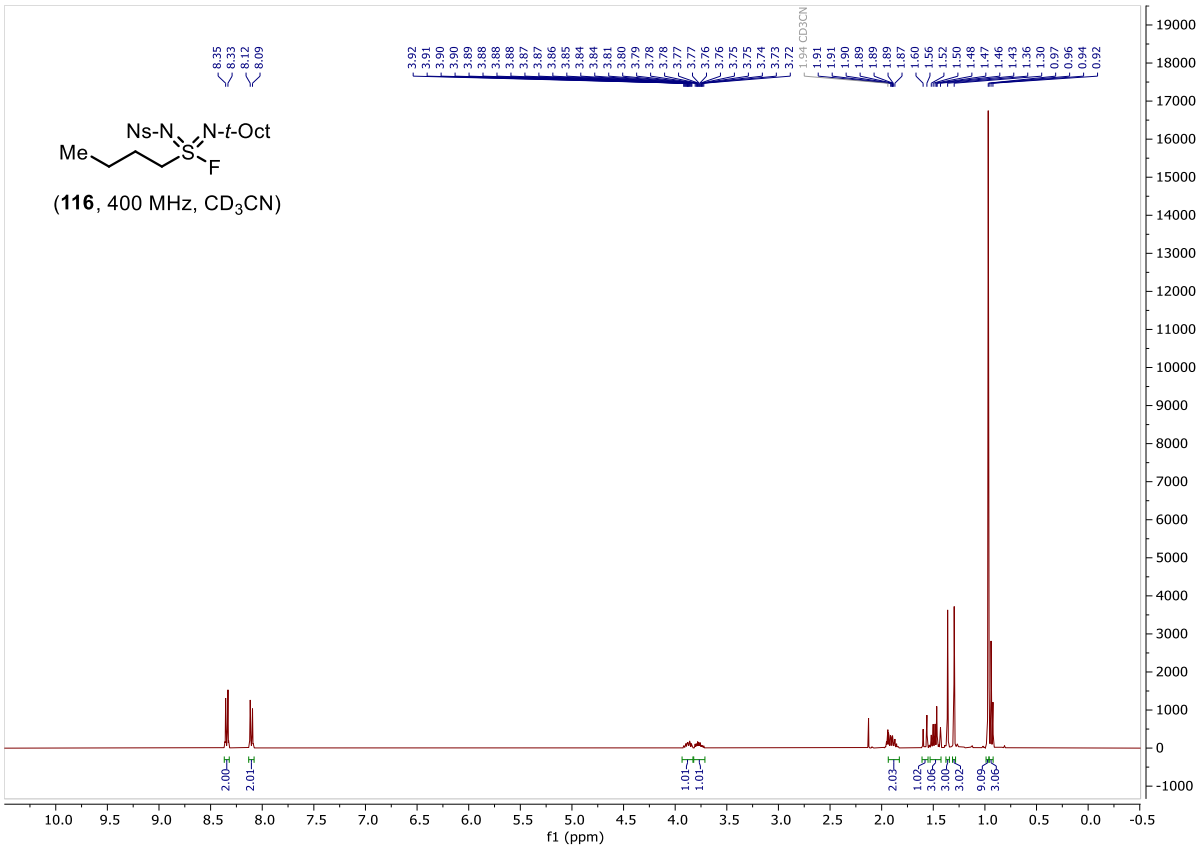

Ns-N
N-t-Oct
S
F
(114, 101 MHz, CDCl3)
f1 (ppm)

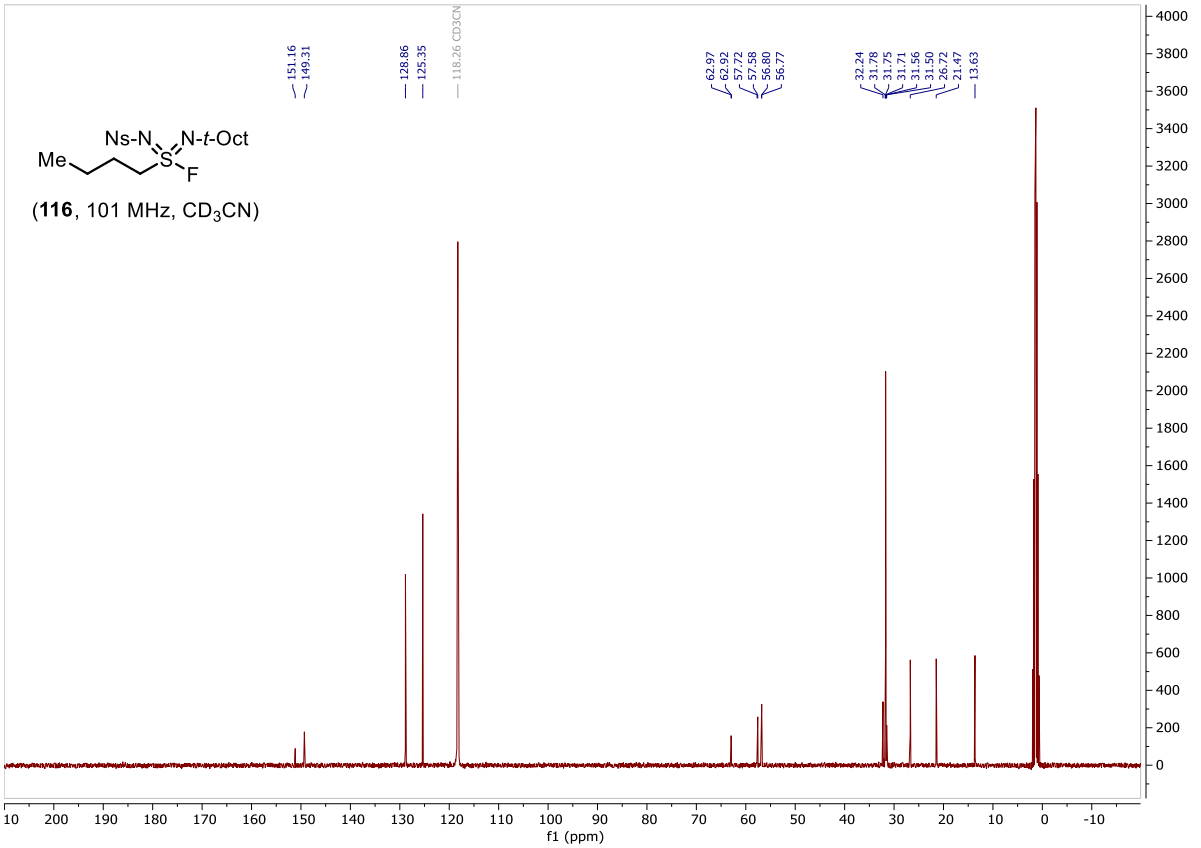

Ns-N
N-t-Oct
S
F
(114, 377 MHz, CDCl3)
85.97
f1 (ppm)

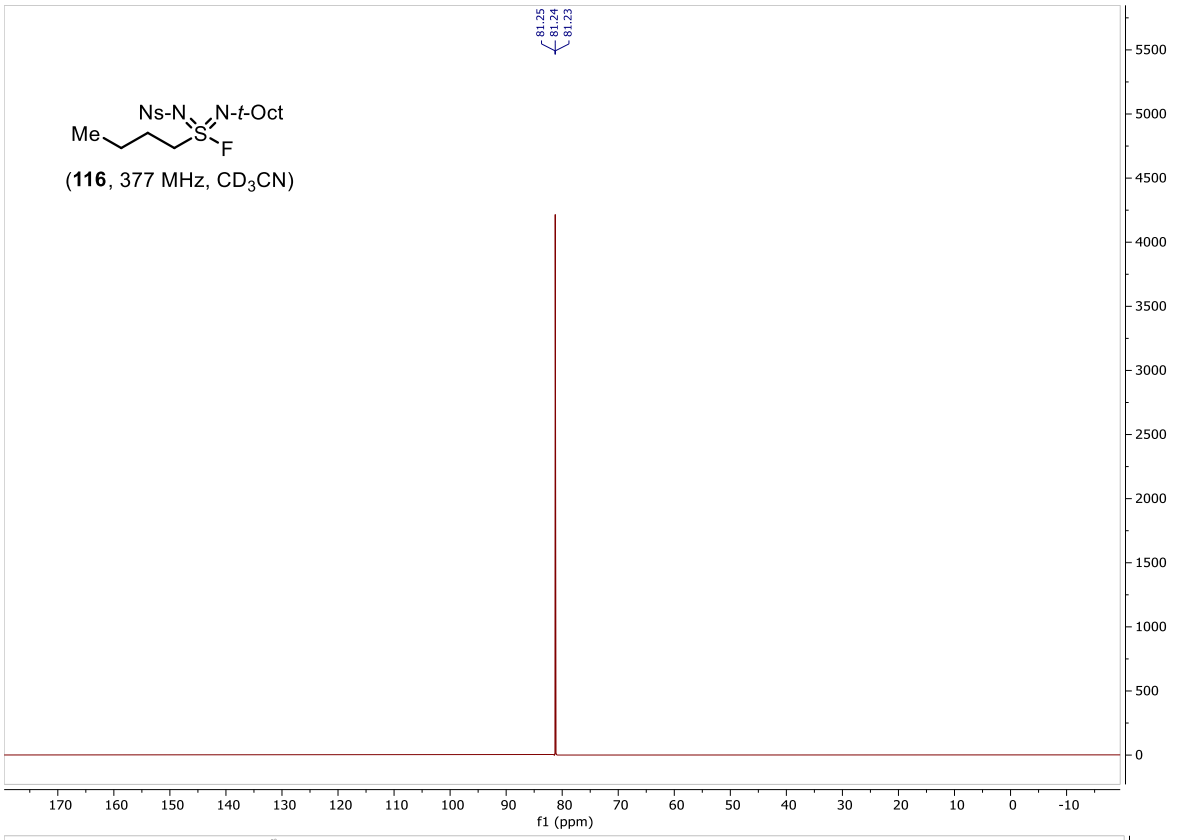

Ns-N
N-t-Oct
S
F
Me
(115, 400 MHz, CDCl3)
8.31
8.29
8.09
8.07
7.26 CDCl3
3.88
3.86
3.85
3.84
3.83
3.82
3.81
3.80
3.79
3.78
3.77
3.76
3.75
3.74
3.73
3.72
3.71
3.70
1.38
1.35
1.31
1.23
0.90
2.02
2.04
2.12
4.13
1.05
3.04
3.09
9.23
f1 (ppm)

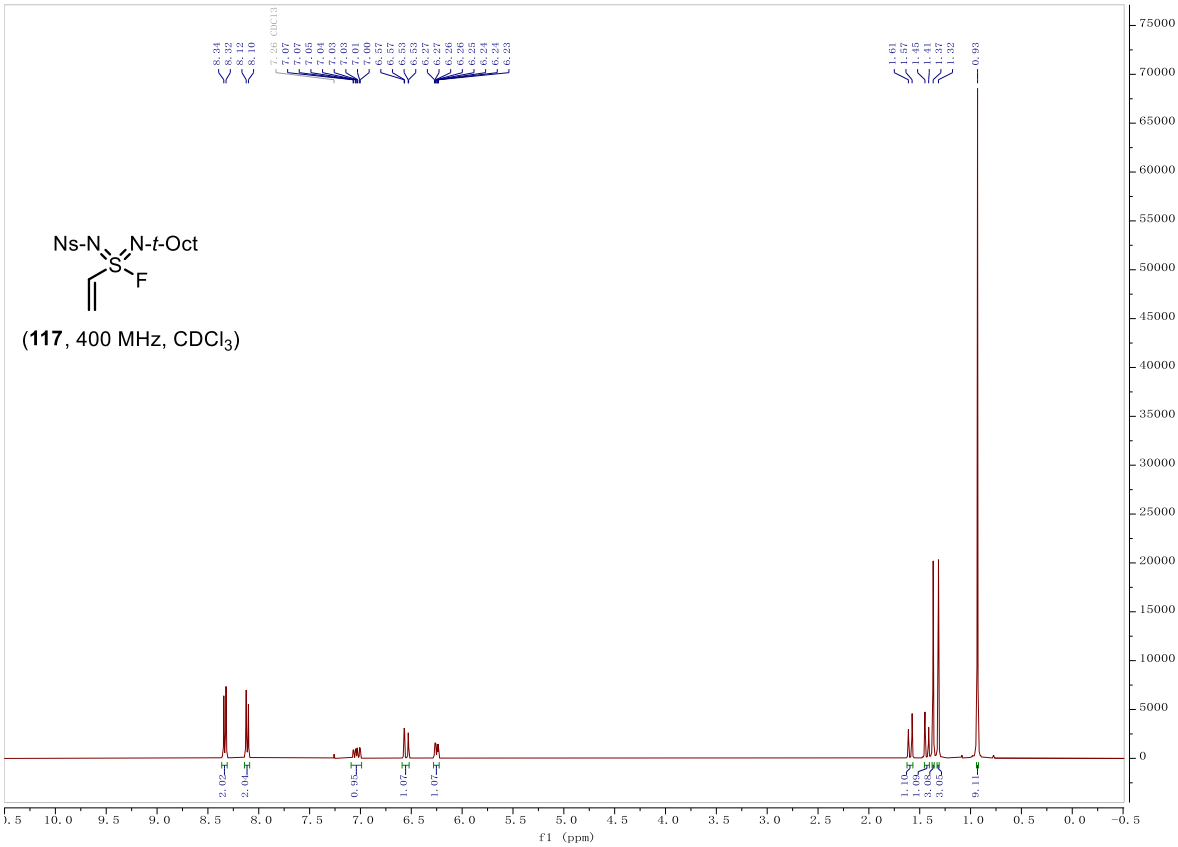

149.83
148.38
127.95
124.07
77.16 CDCl3
62.15
62.10
56.19
56.16
52.53
52.37
31.65
31.40
31.38
31.36
31.15
31.08
8.72
Ns-N
N-t-Oct
S
F
Me
(115, 101 MHz, CDCl3)
f1 (ppm)

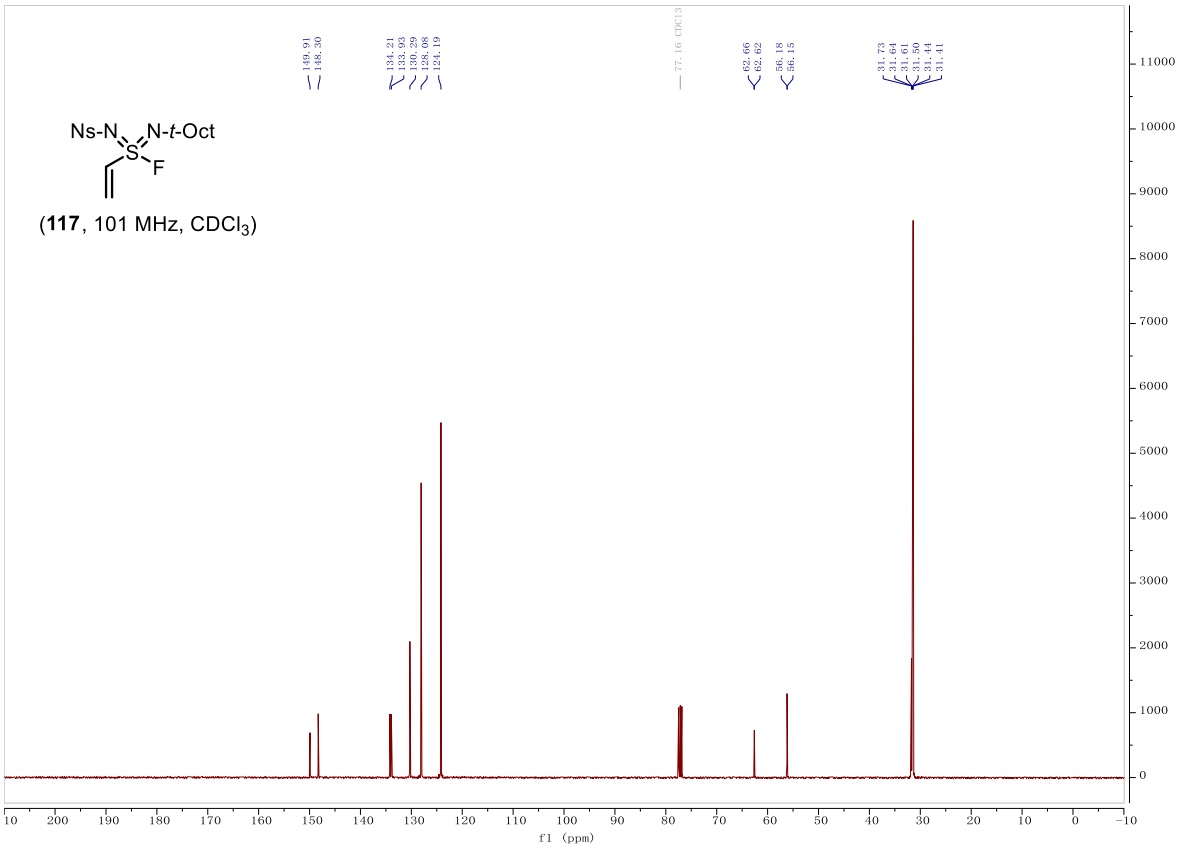

77.95
77.94
77.93
Ns-N
N-t-Oct
S
F
Me
(115, 377 MHz, CDCl3)
f1 (ppm)

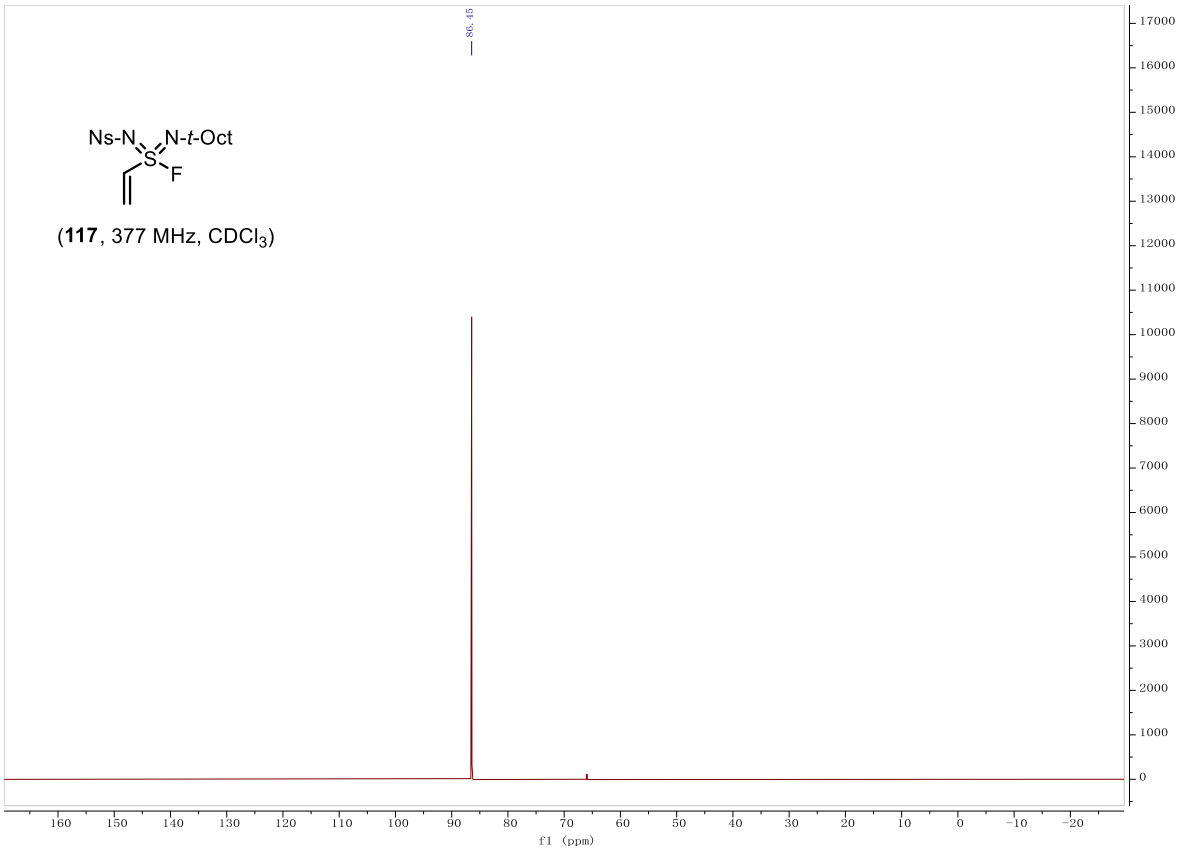

Ns-N
N-t-Oct
Me
S
F
(116, 400 MHz, CD3CN)
f1 (ppm)

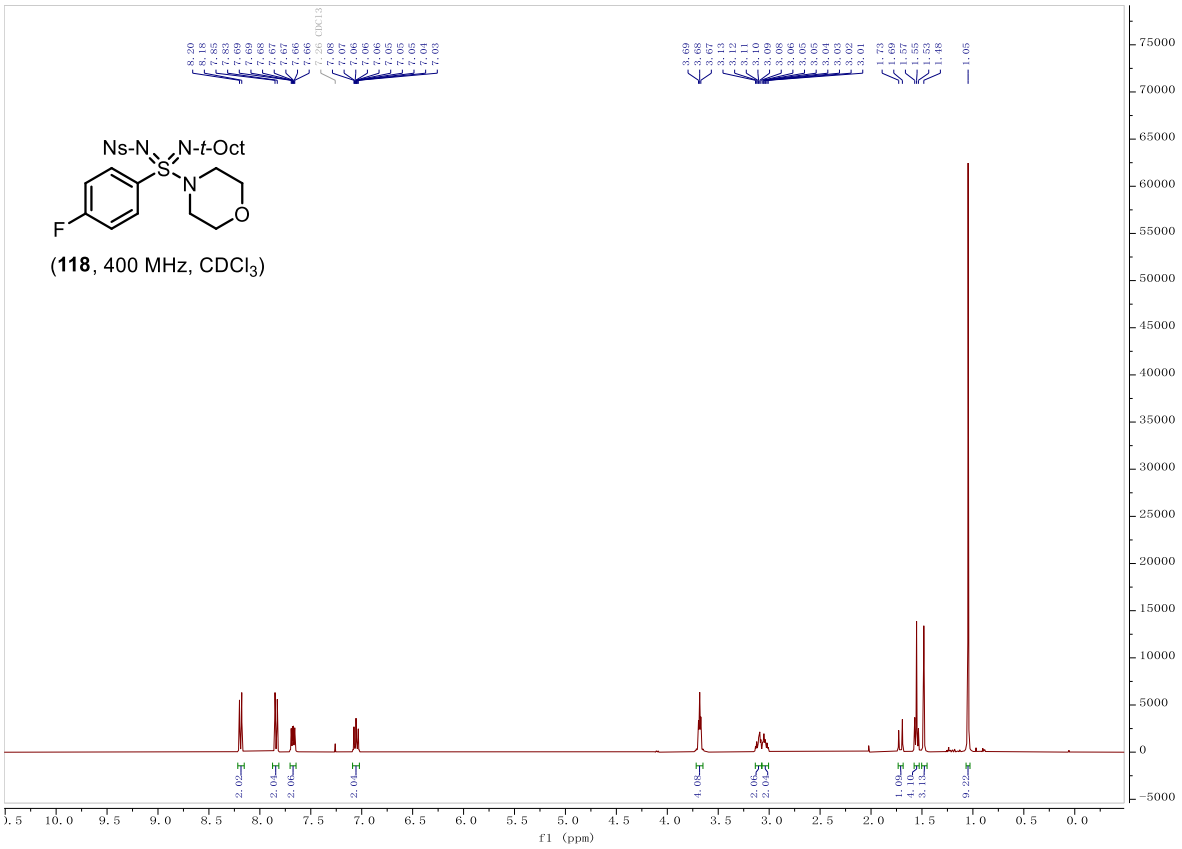

Ns-N
N-t-Oct
Me
S
F
(116, 101 MHz, CD3CN)
f1 (ppm)


81.25
81.24
81.23
Ns-N
N-t-Oct
Me
S
F
(116, 377 MHz, CD3CN)
f1 (ppm)

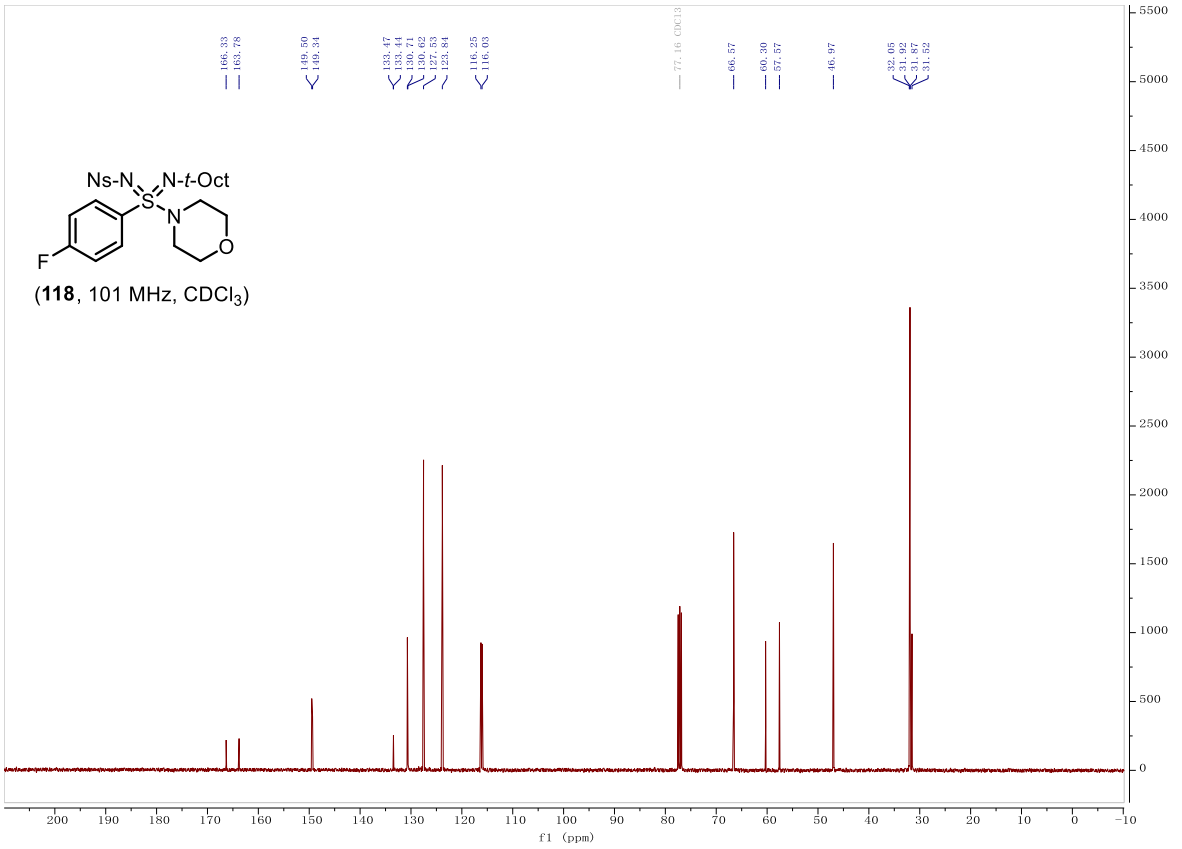

Ns-N
N-t-Oct
S
F
(117, 400 MHz, CDCl3)
f1 (ppm)


149.91
148.30
134.21
133.93
130.29
128.08
124.19
77.16 CDCl3
62.66
62.62
56.18
56.15
31.73
31.64
31.61
31.50
31.44
31.41
Ns-N
N-t-Oct
S
F
(117, 101 MHz, CDCl3)
f1 (ppm)

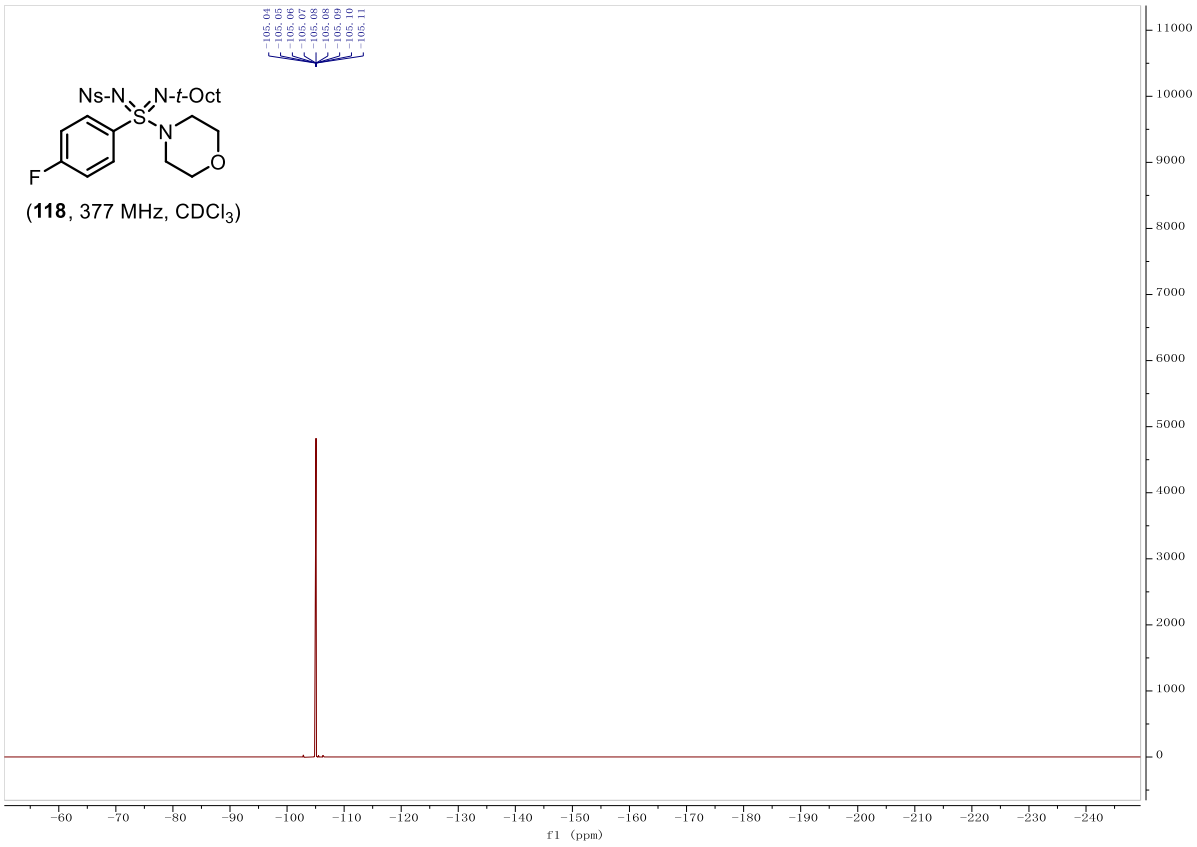

86.45
Ns-N
N-t-Oct
S
F
(117, 377 MHz, CDCl3)
f1 (ppm)

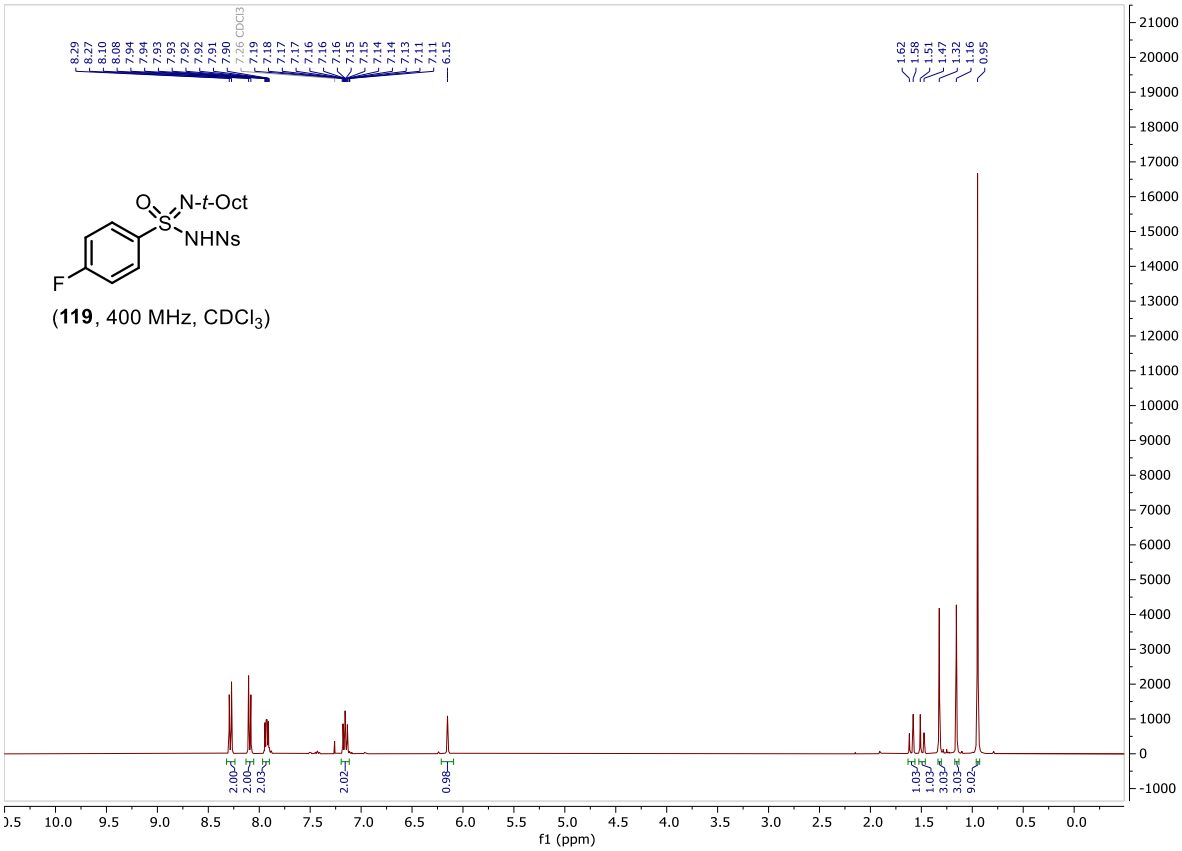


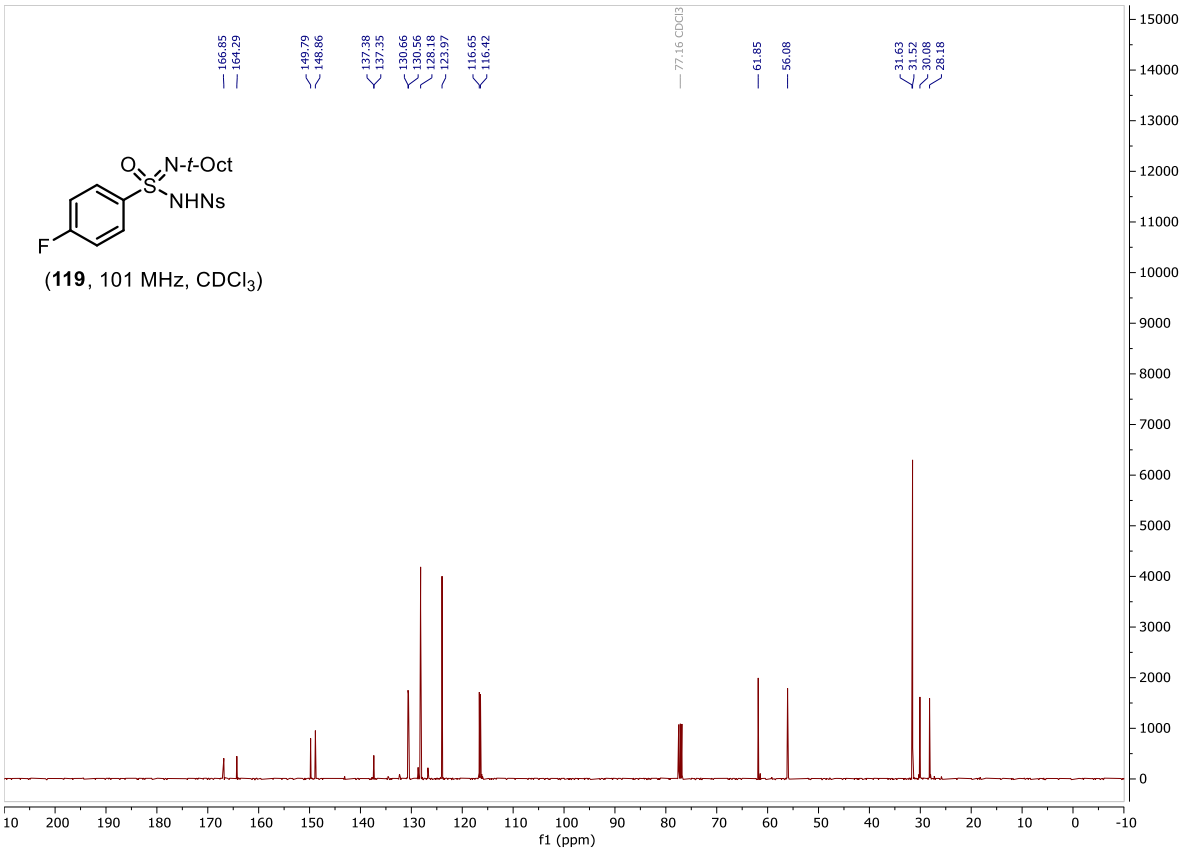
(**118**, 400 MHz, $CDCl_3$)



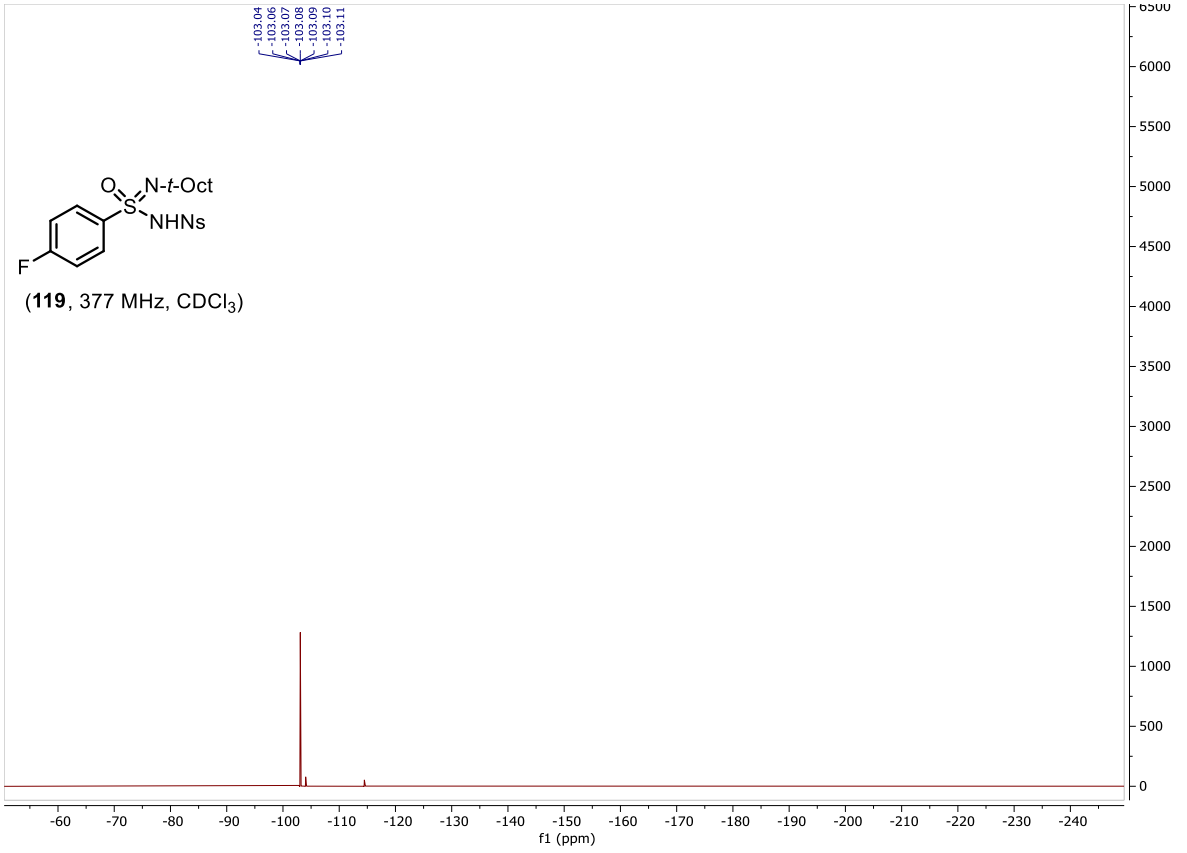
(**118**, 101 MHz, $CDCl_3$)


Ns-N
N-t-Oct
S
N
O
F
(118, 377 MHz, CDCl3)
f1 (ppm)

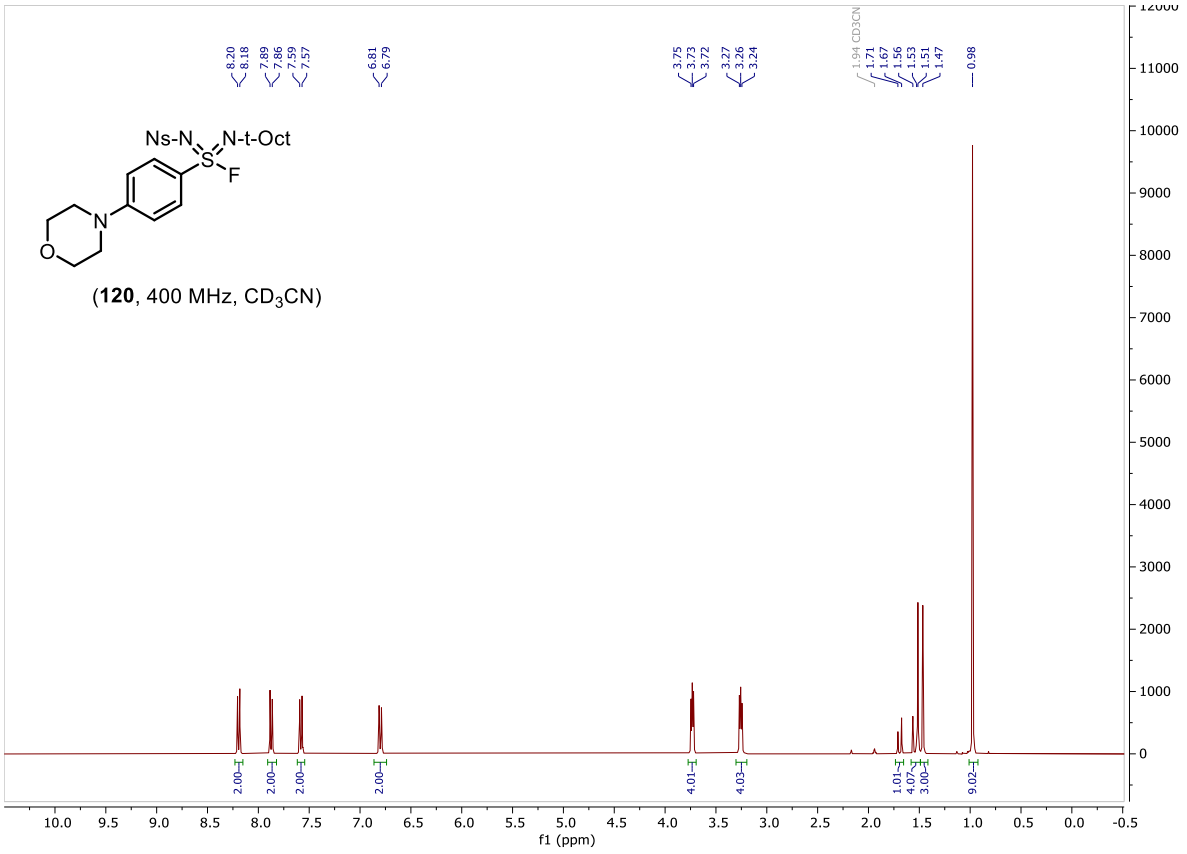

O
N-t-Oct
S
NHNs
F
(119, 400 MHz, CDCl3)
f1 (ppm)



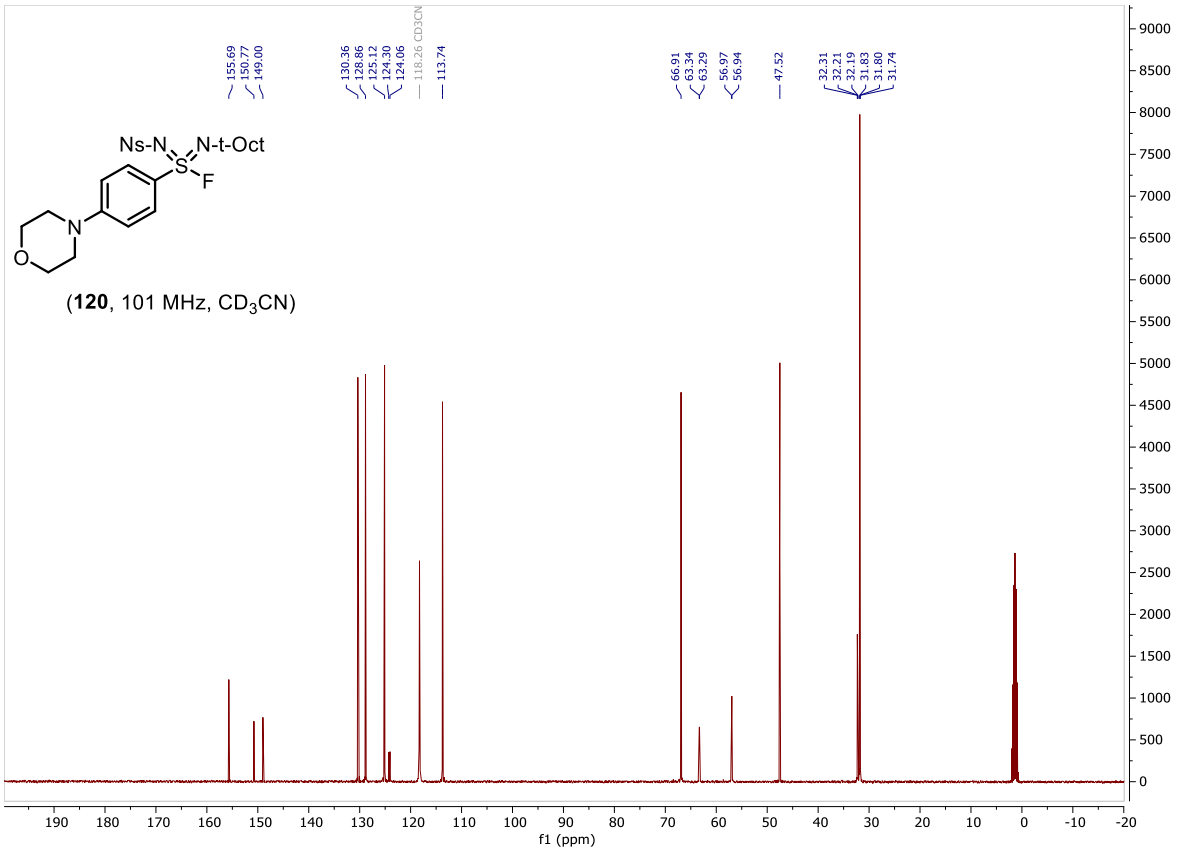
(**119**, 101 MHz, $CDCl_3$)



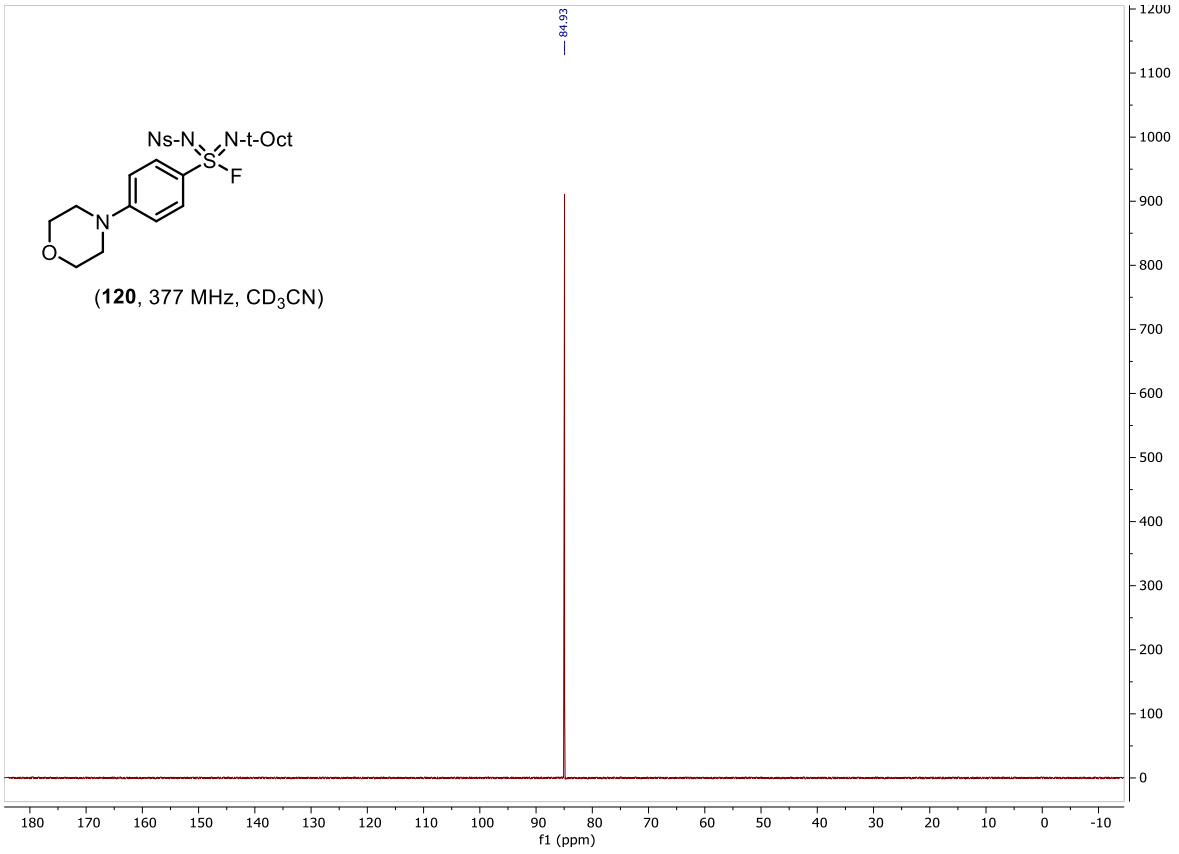
(**119**, 377 MHz, $CDCl_3$)



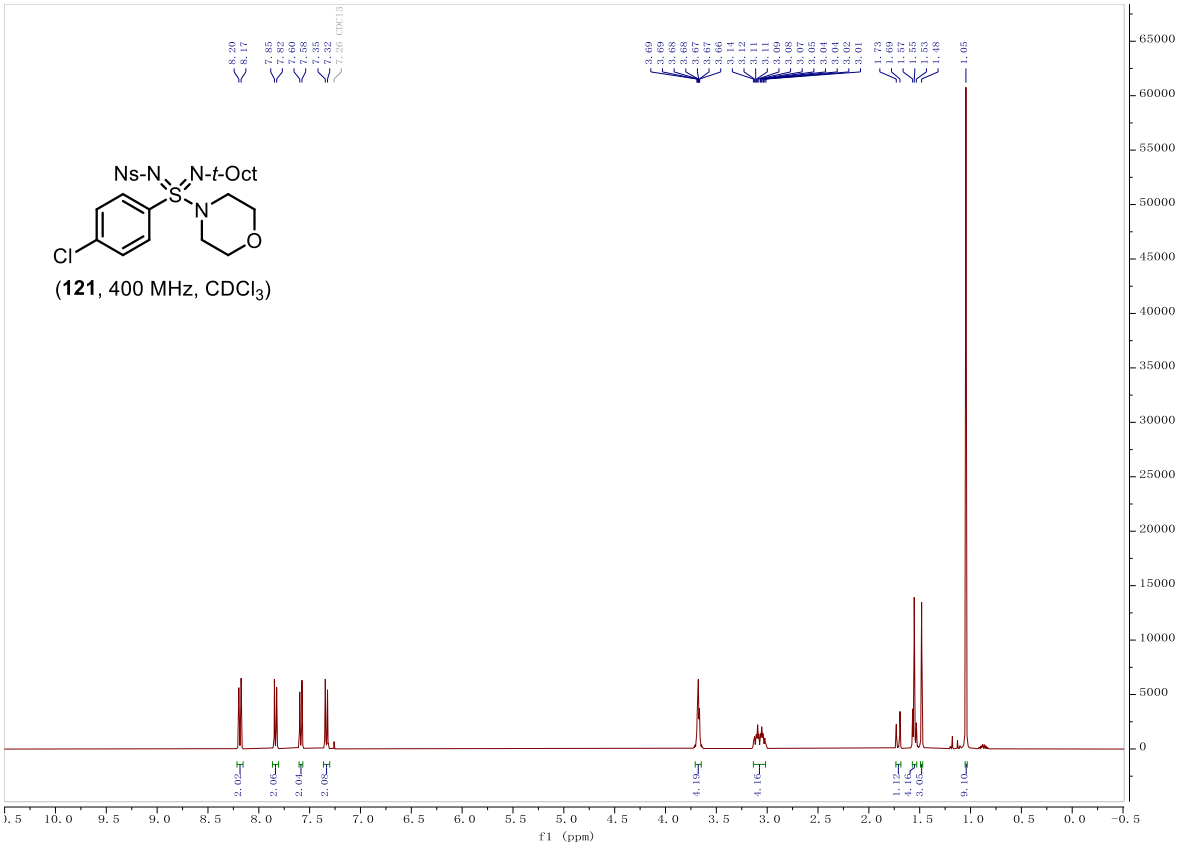
(**120**, 400 MHz, CD_3CN)



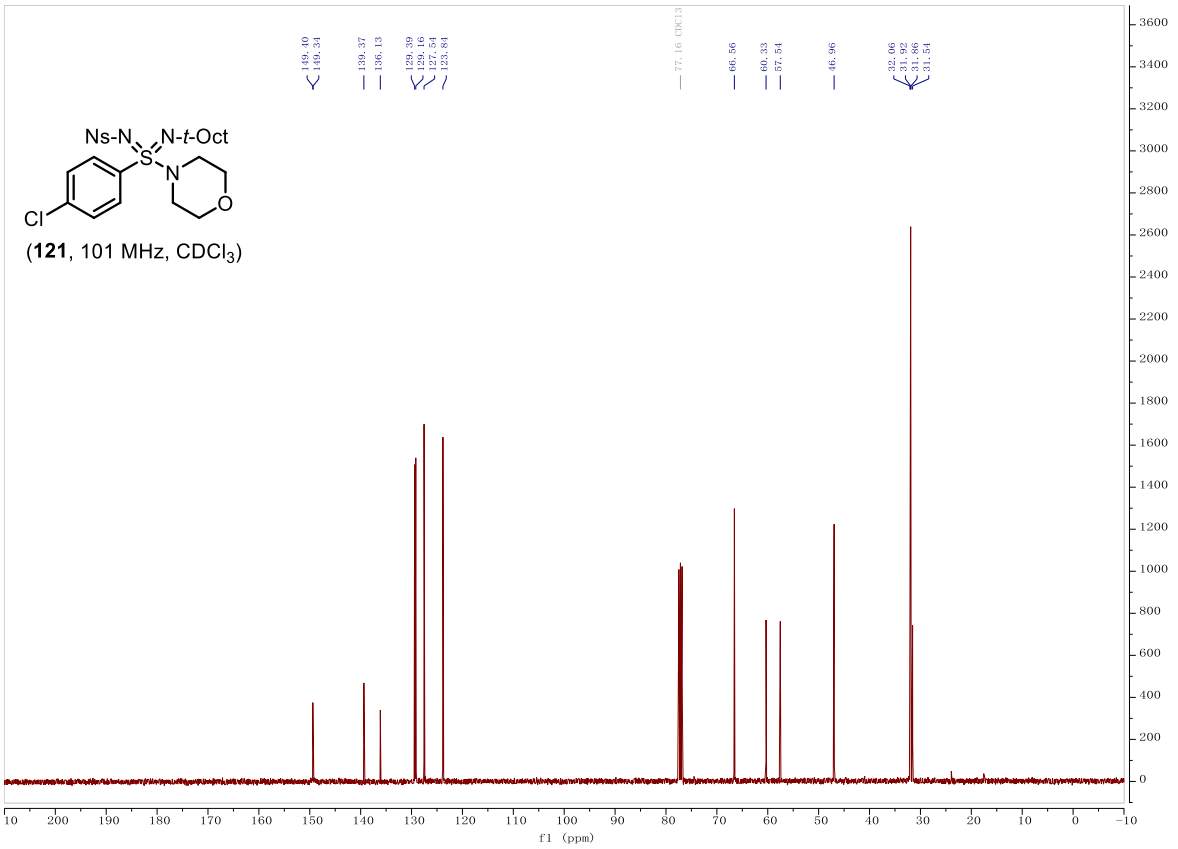
(**120**, 101 MHz, CD_3CN)



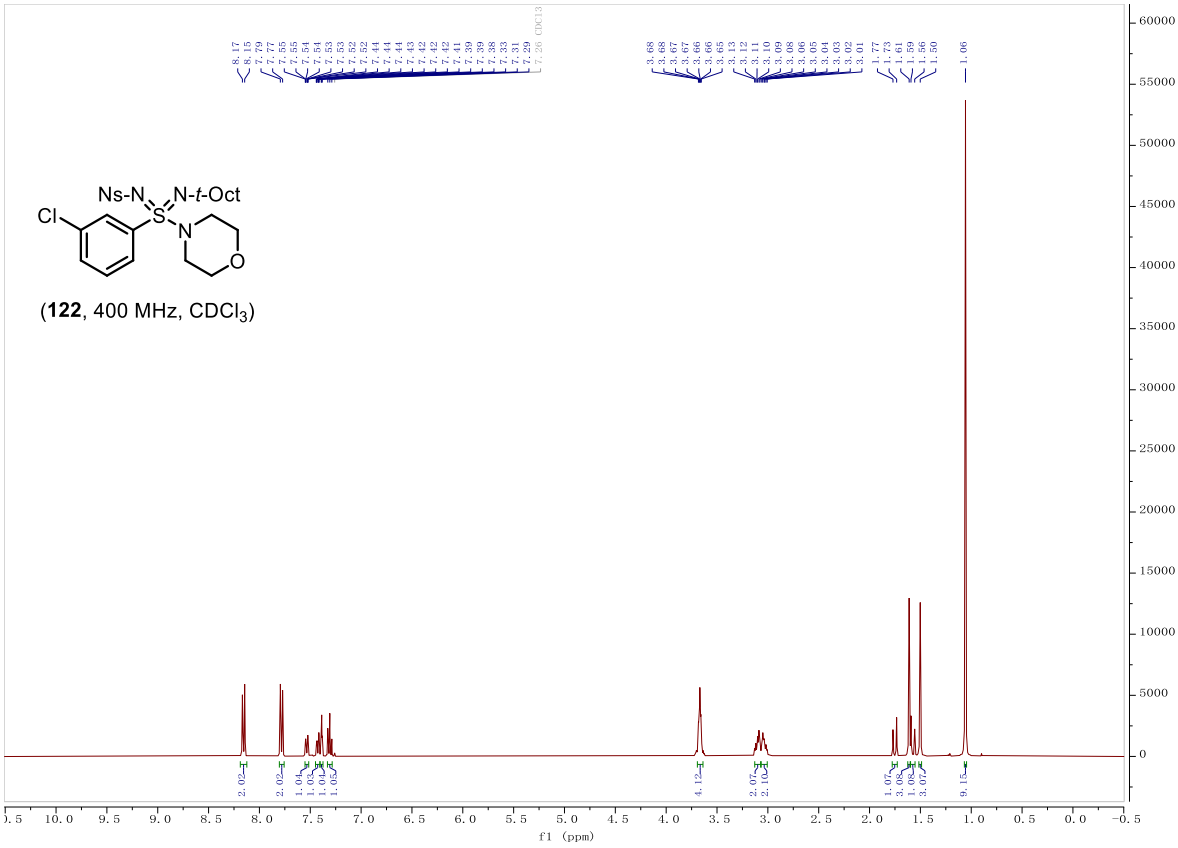
(**120**, 377 MHz, CD_3CN)



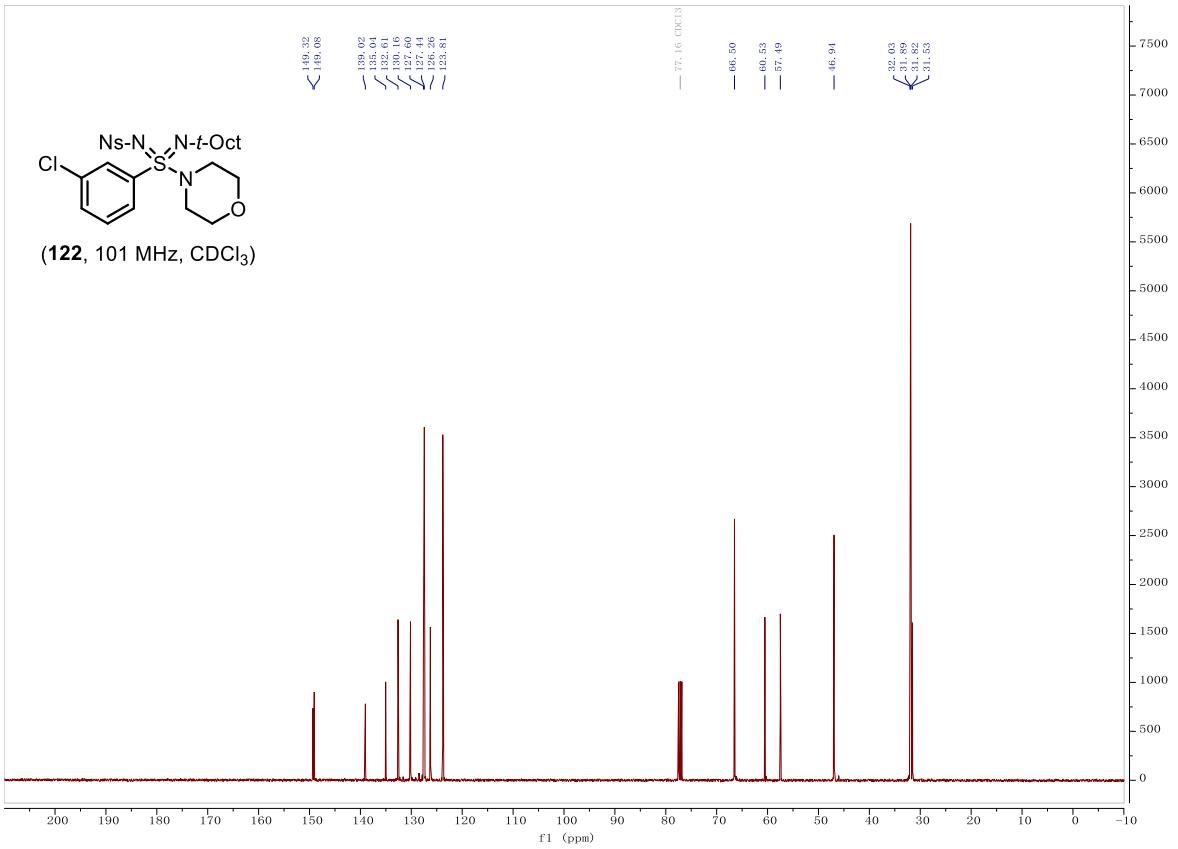
(**121**, 400 MHz, $CDCl_3$)

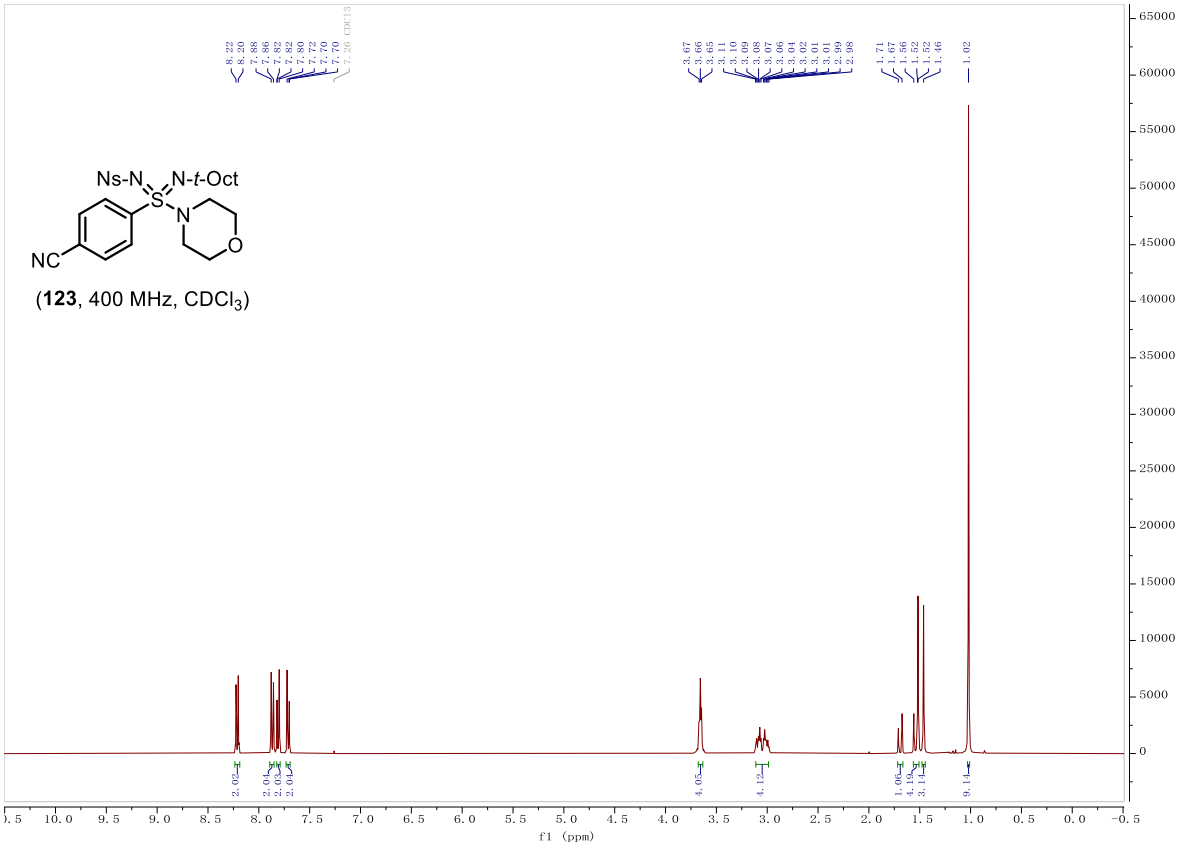


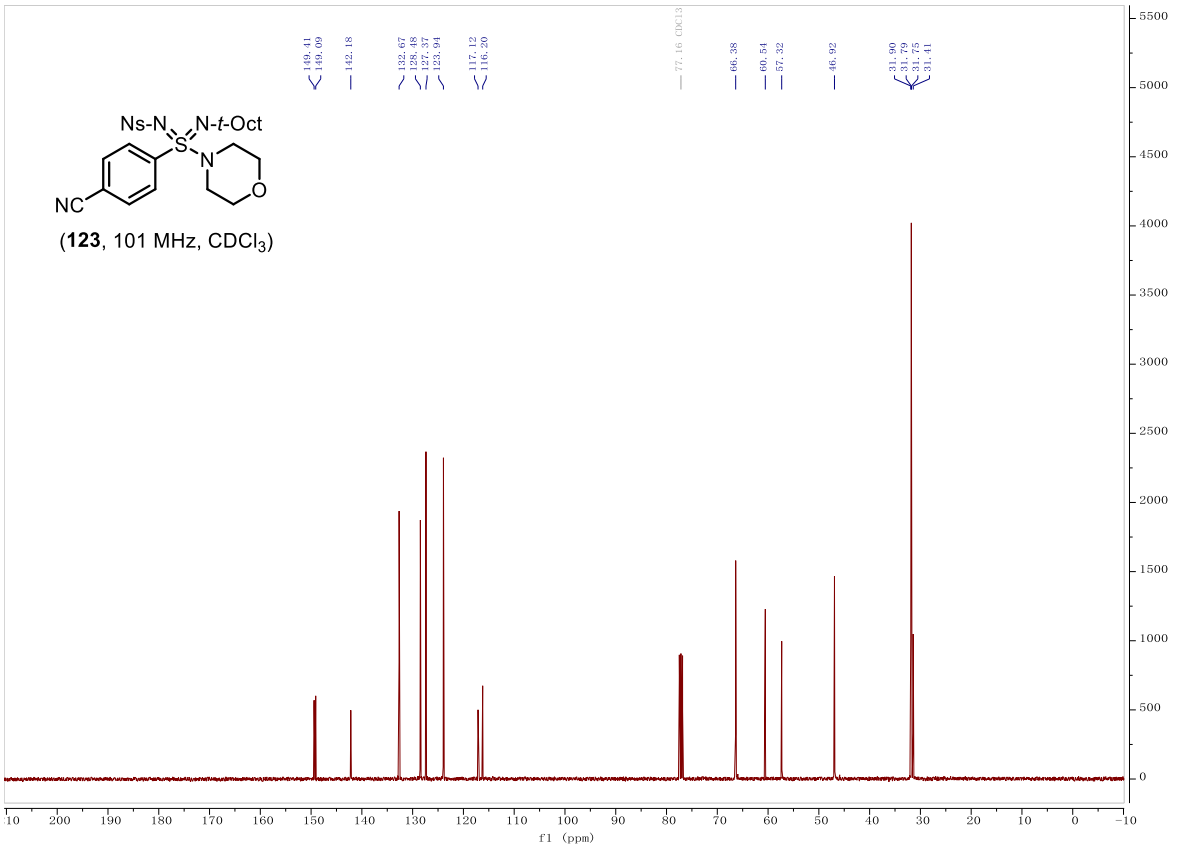
(**121**, 101 MHz, $CDCl_3$)

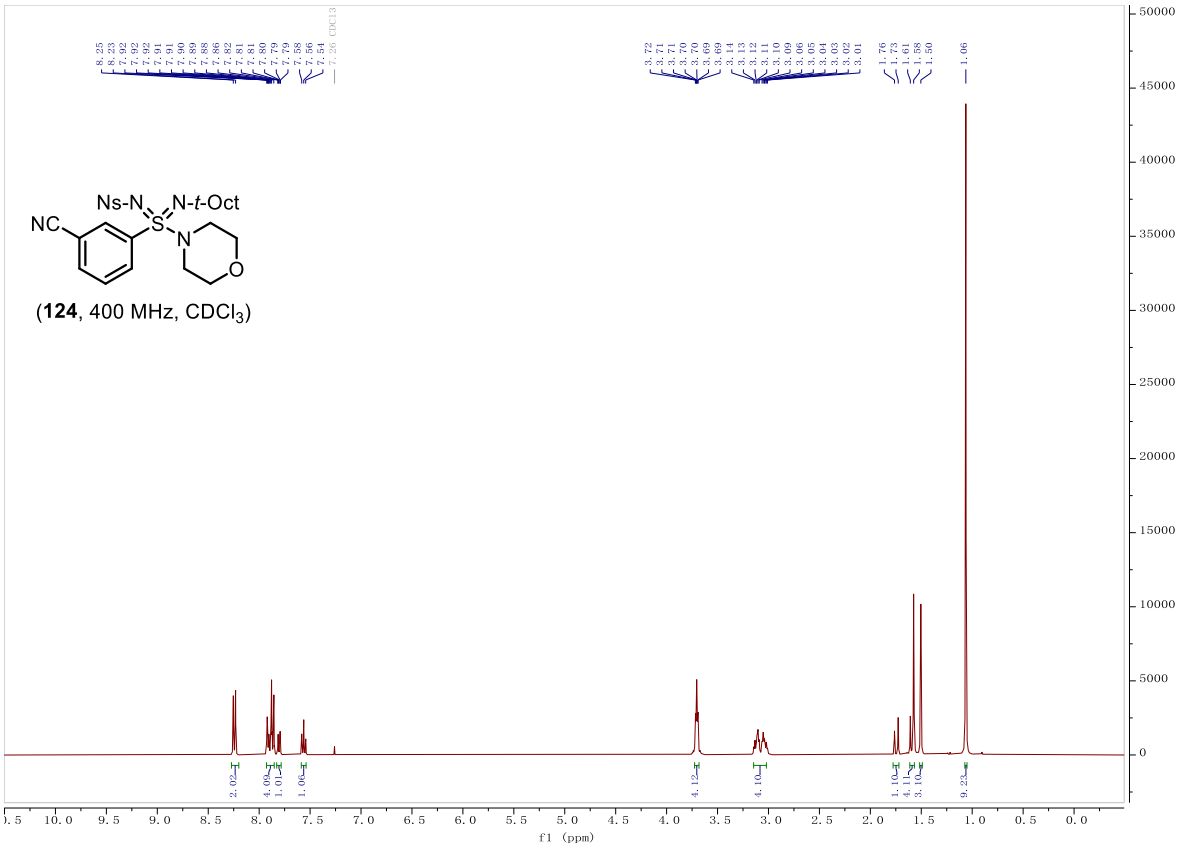


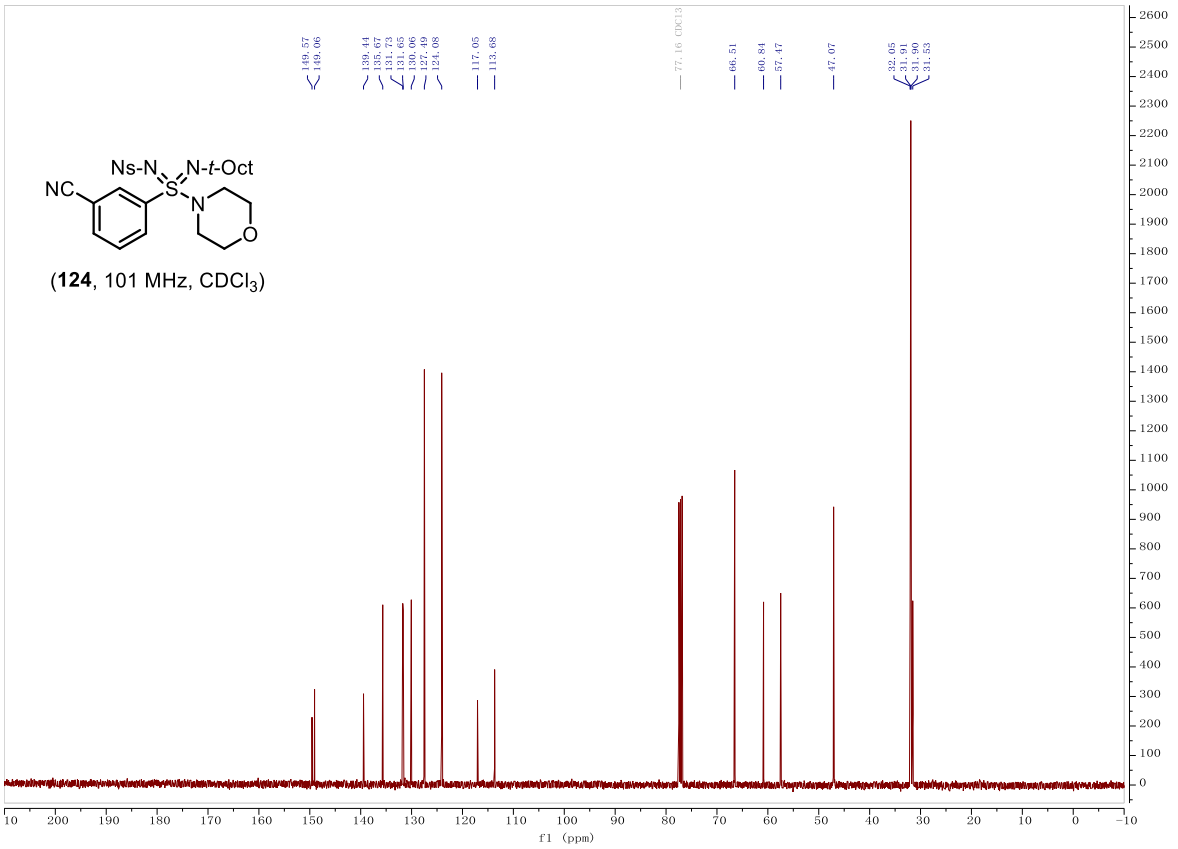
(**122**, 400 MHz, $CDCl_3$)

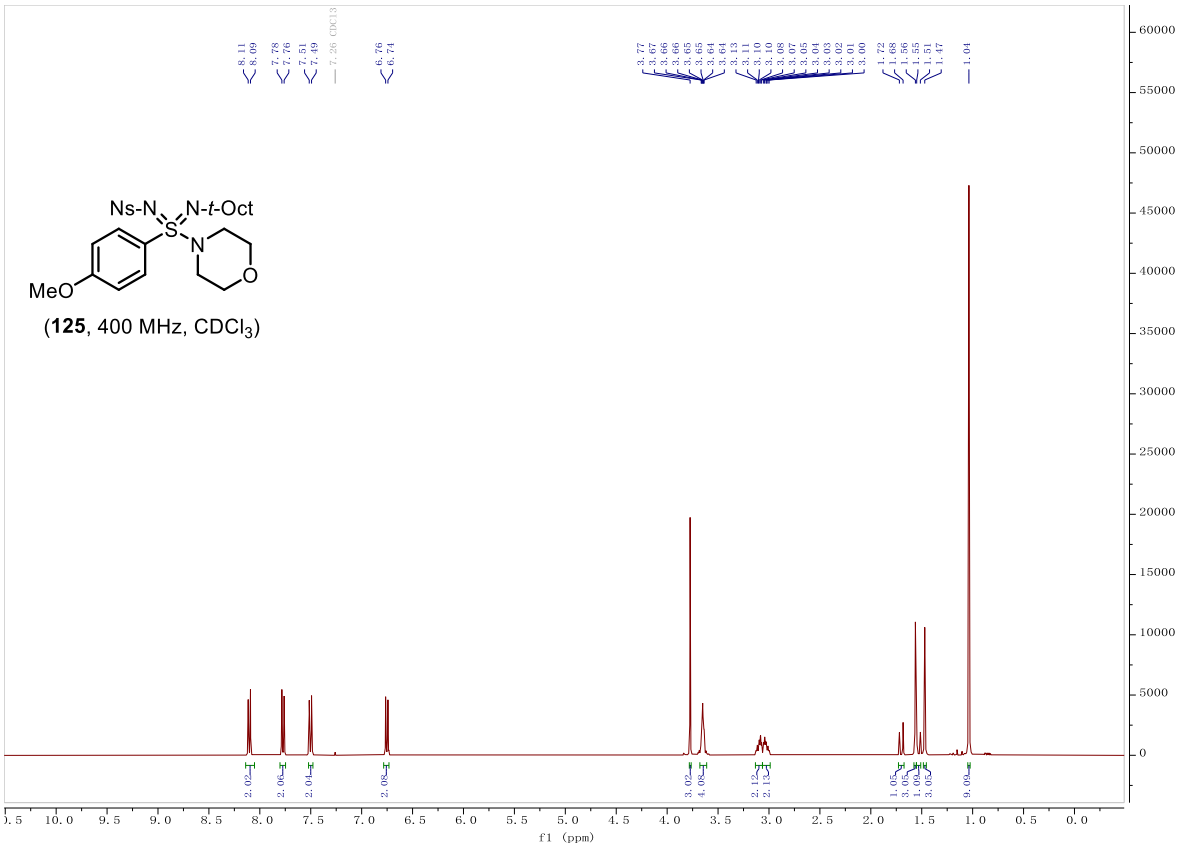

Ns-N
N-t-Oct
Cl
S
N
O
(122, 101 MHz, CDCl3)
149.32
149.08
139.02
135.04
132.61
130.16
127.60
127.44
126.26
123.81
77.16 CDCl3
66.50
60.53
57.49
46.94
32.03
31.89
31.82
31.53
f1 (ppm)

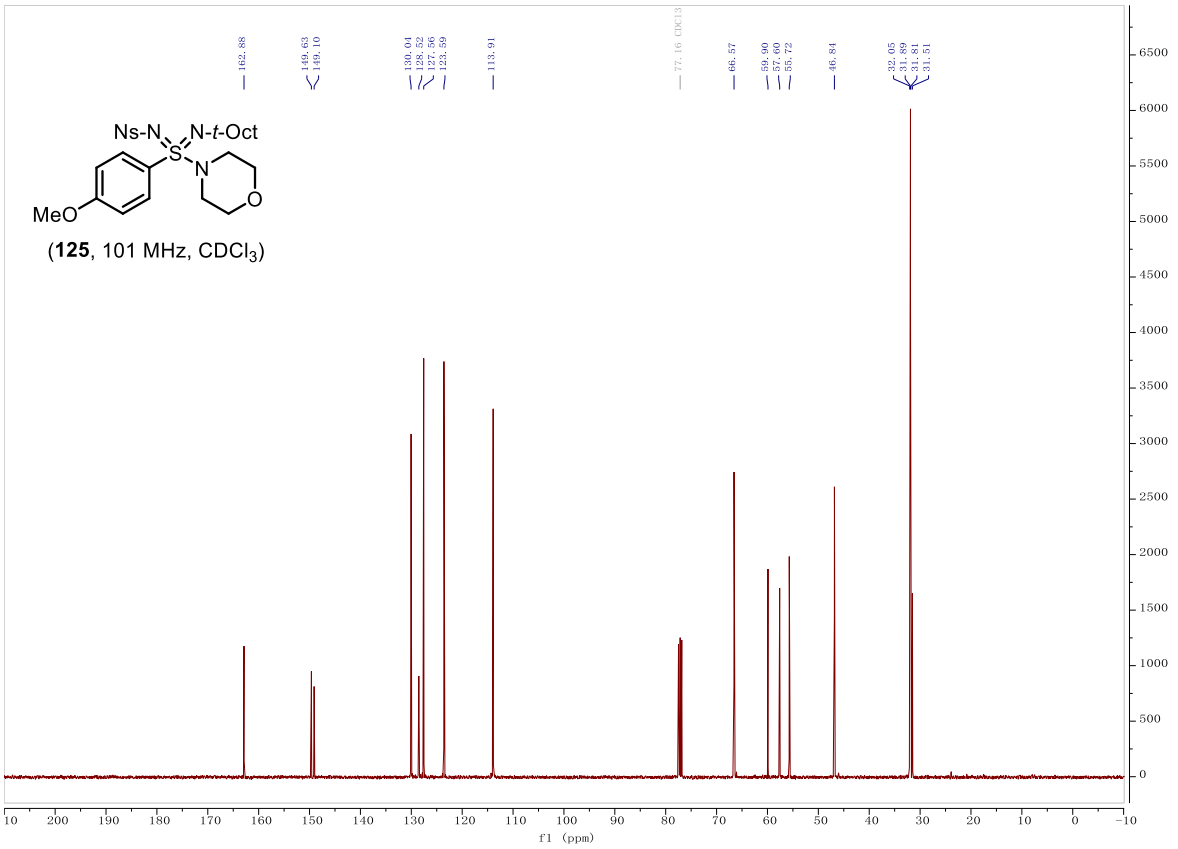

Ns-N
N-t-Oct
NC
S
N
O
(123, 400 MHz, CDCl3)
8.22
8.20
7.88
7.86
7.82
7.80
7.72
7.70
7.70
7.26 CDCl3
3.67
3.66
3.65
3.11
3.10
3.09
3.08
3.07
3.06
3.04
3.02
3.01
3.01
2.99
2.98
1.71
1.67
1.56
1.52
1.52
1.46
1.02
2.02
2.04
2.03
2.04
4.05
4.12
1.06
4.00
3.14
9.14
f1 (ppm)


Ns-N
N-t-Oct
S
N
O
NC
(123, 101 MHz, CDCl3)
149.41
149.09
142.18
132.67
128.48
127.37
123.94
117.12
116.20
77.16 CDCl3
66.38
60.54
57.32
46.92
31.90
31.79
31.75
31.41
f1 (ppm)

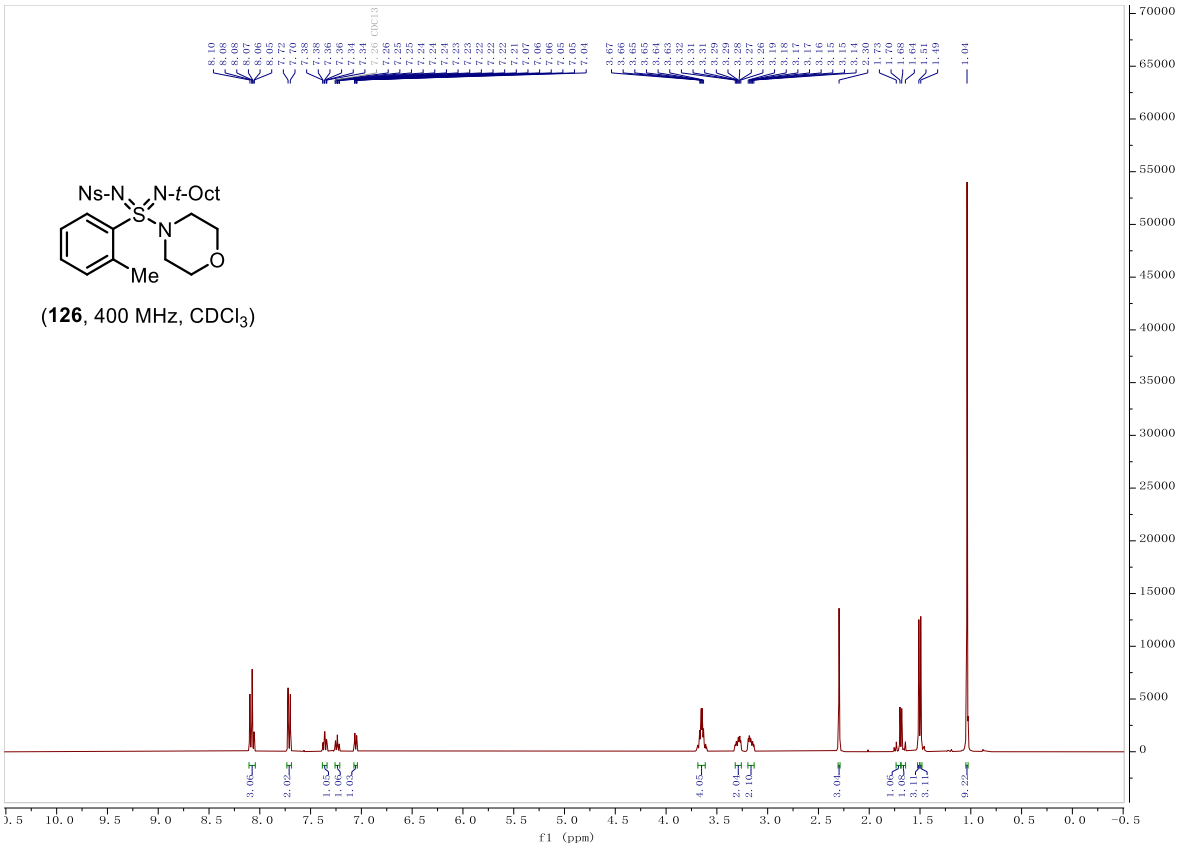

Ns-N
N-t-Oct
S
N
O
NC
(124, 400 MHz, CDCl3)
8.25
8.23
7.92
7.92
7.92
7.91
7.91
7.90
7.89
7.88
7.86
7.82
7.81
7.81
7.80
7.79
7.79
7.58
7.56
7.54
7.26 CDCl3
3.72
3.71
3.71
3.70
3.70
3.69
3.69
3.14
3.13
3.12
3.11
3.10
3.09
3.06
3.05
3.04
3.03
3.02
3.01
1.76
1.73
1.61
1.58
1.50
1.06
2.02
4.09
1.01
1.06
4.12
4.10
1.10
4.11
3.10
9.23
f1 (ppm)


Ns-N
N-t-Oct
NC
S
N
O
(124, 101 MHz, CDCl3)
f1 (ppm)

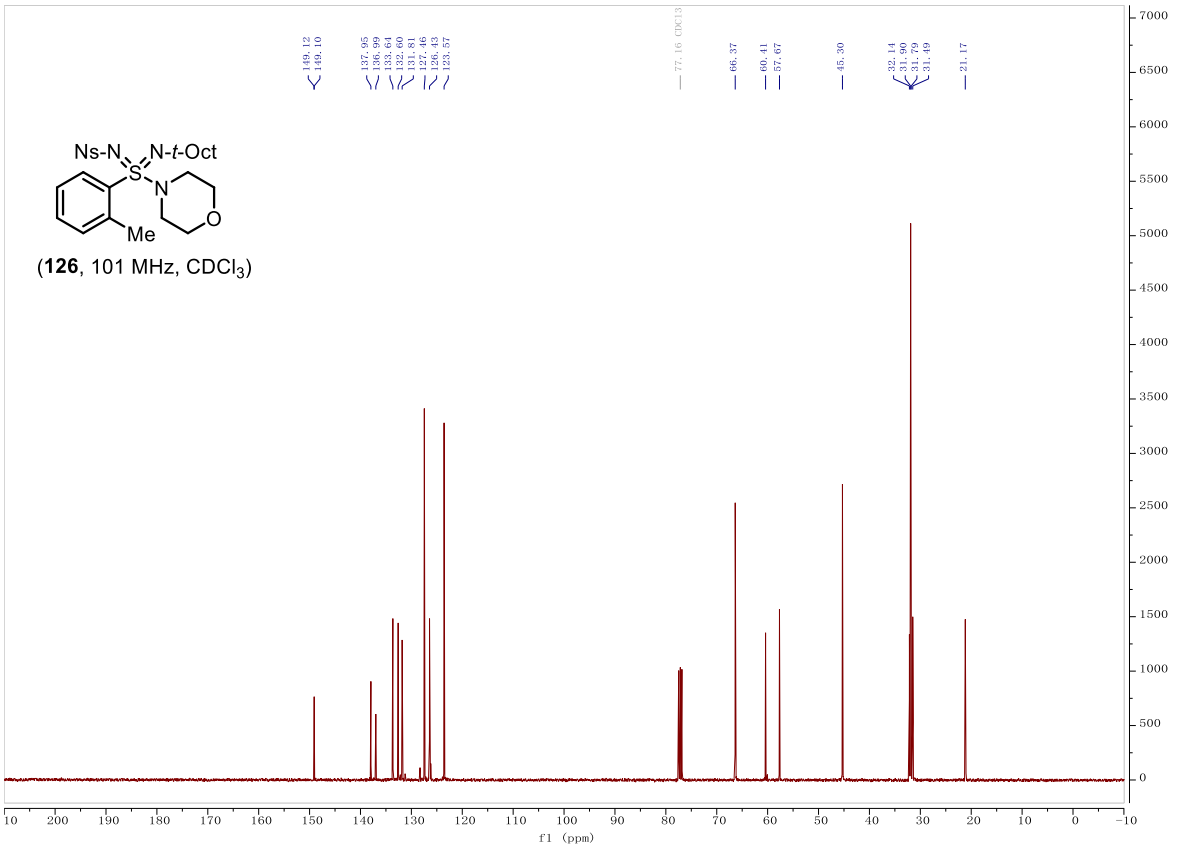

Ns-N
N-t-Oct
MeO
S
N
O
(125, 400 MHz, CDCl3)
f1 (ppm)



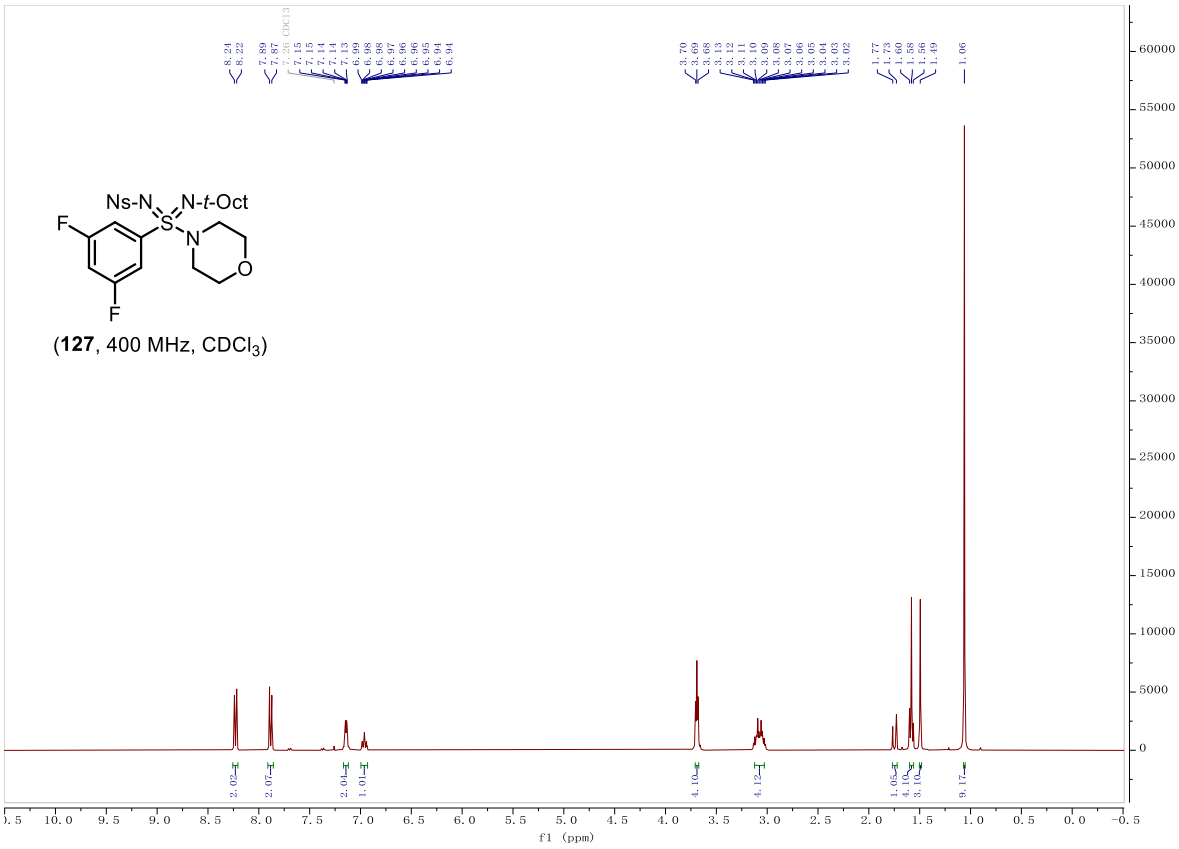
(**125**, 101 MHz, $CDCl_3$)



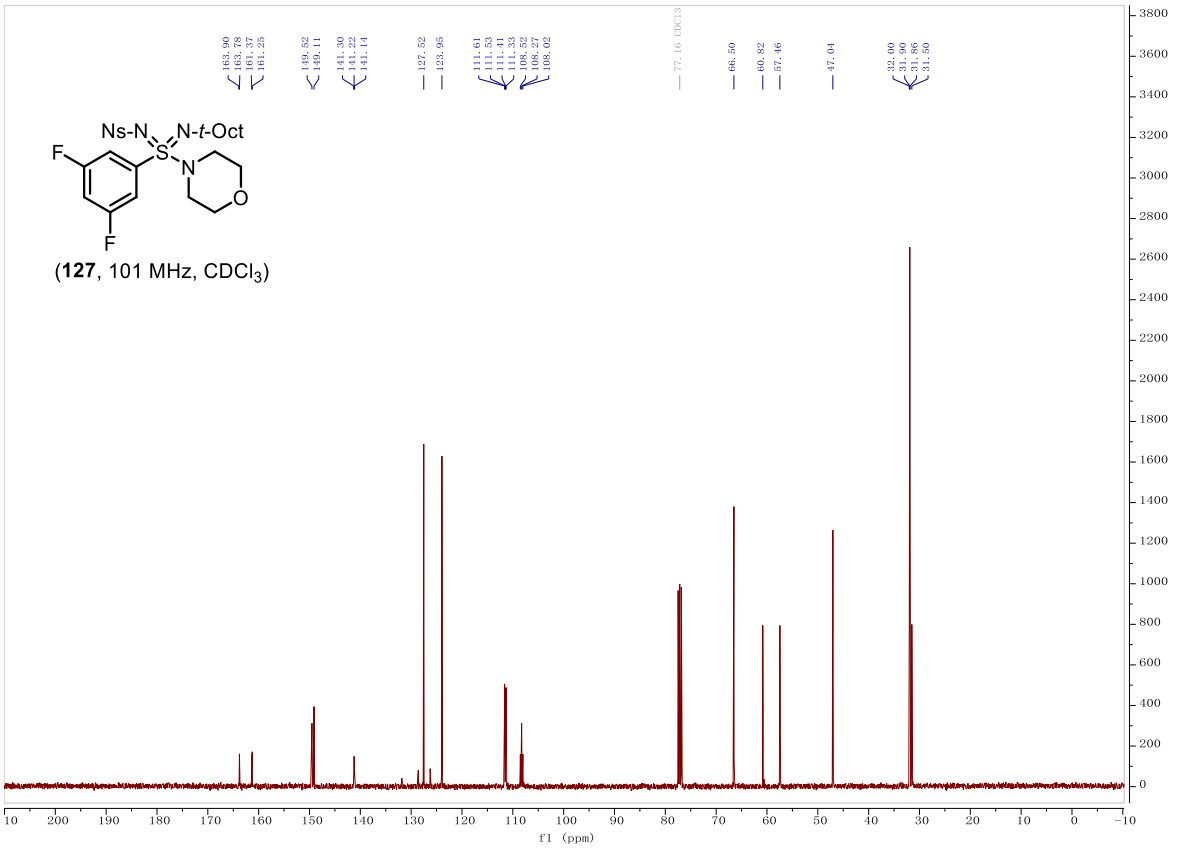
(**126**, 400 MHz, $CDCl_3$)

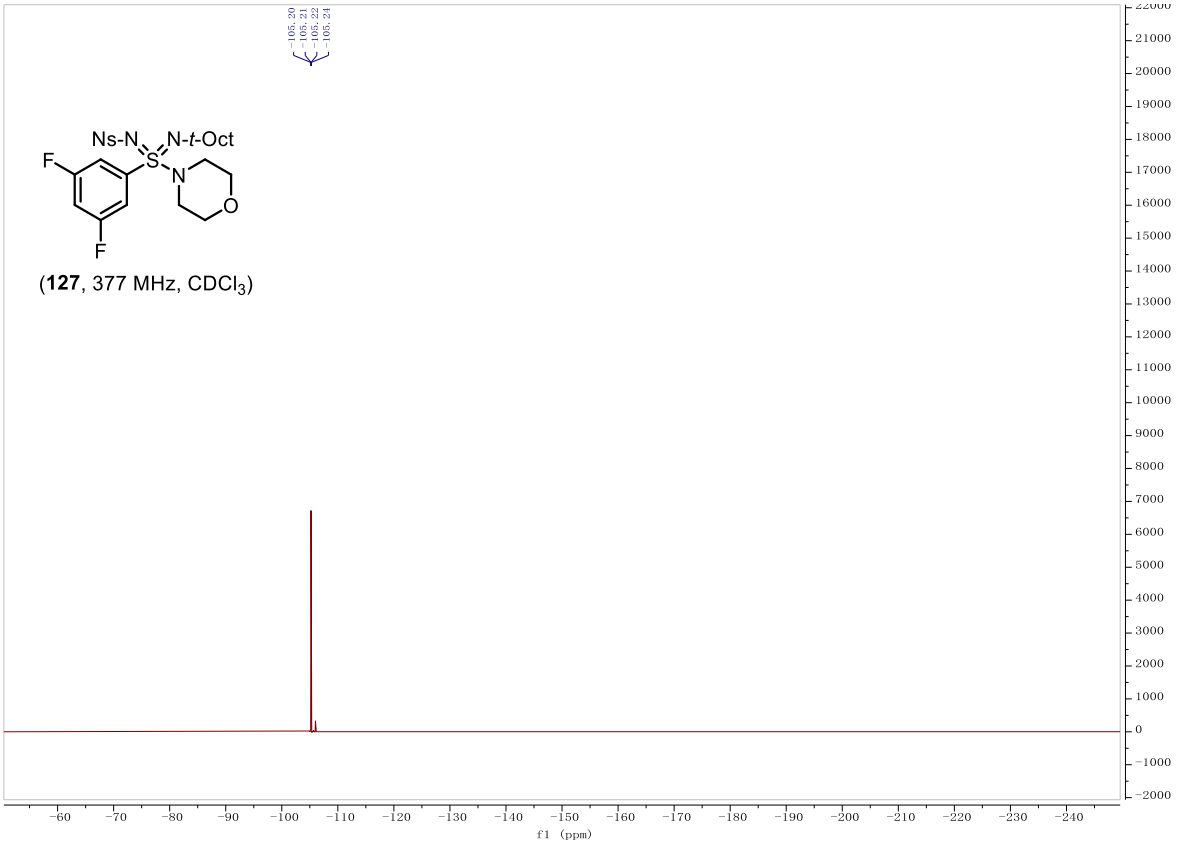


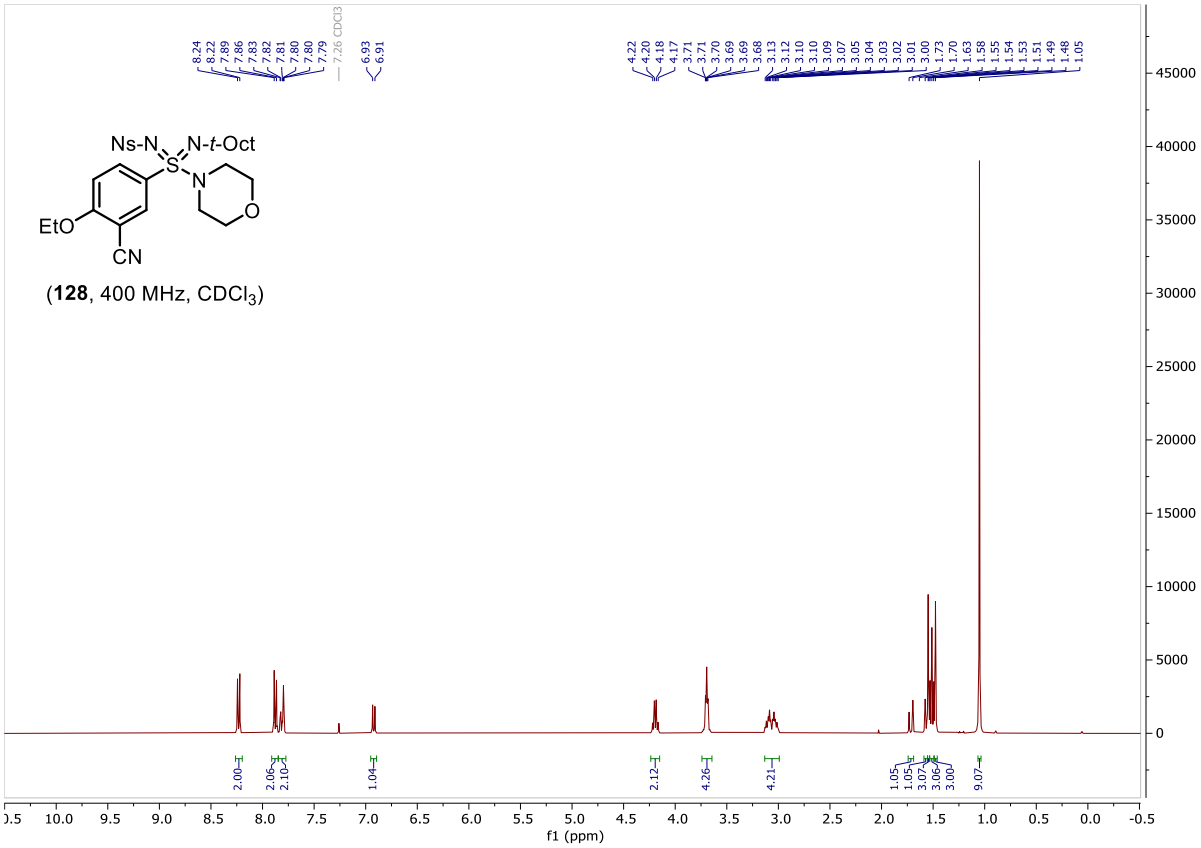
(**126**, 101 MHz, $CDCl_3$)

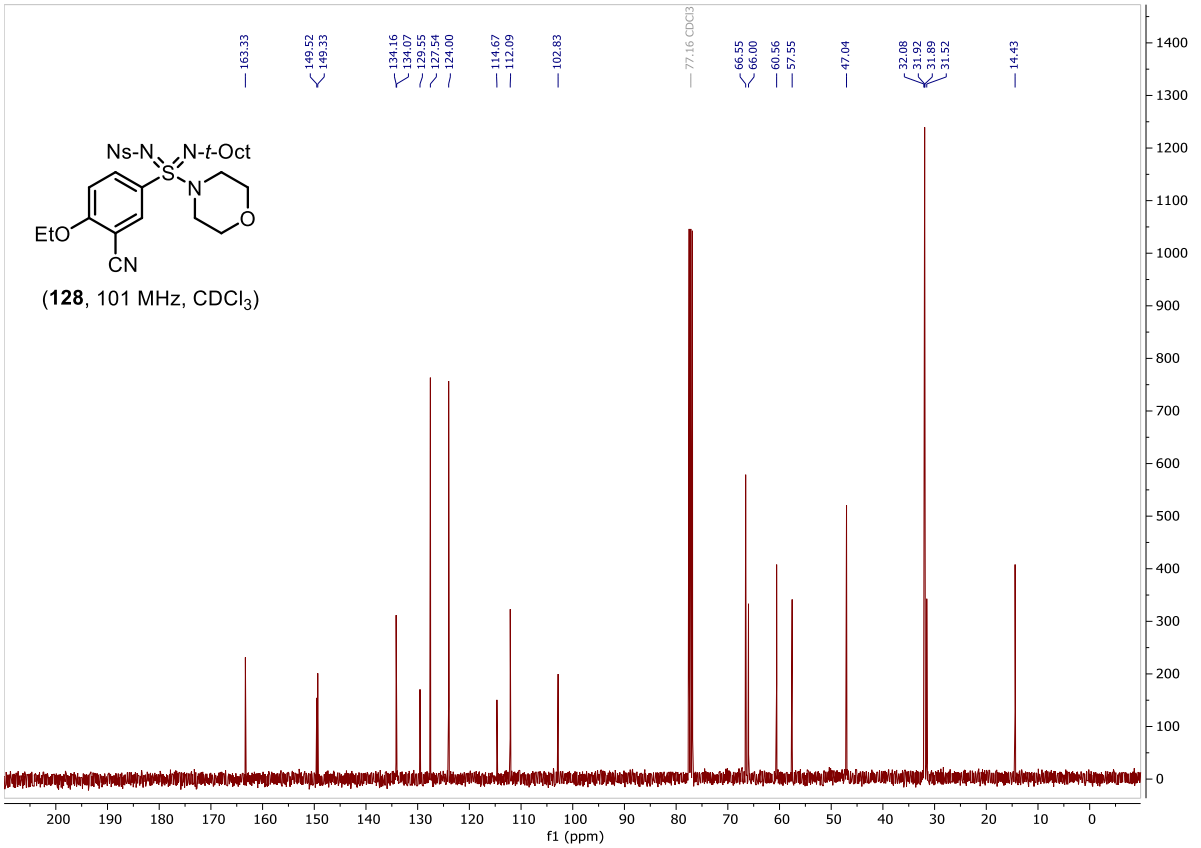


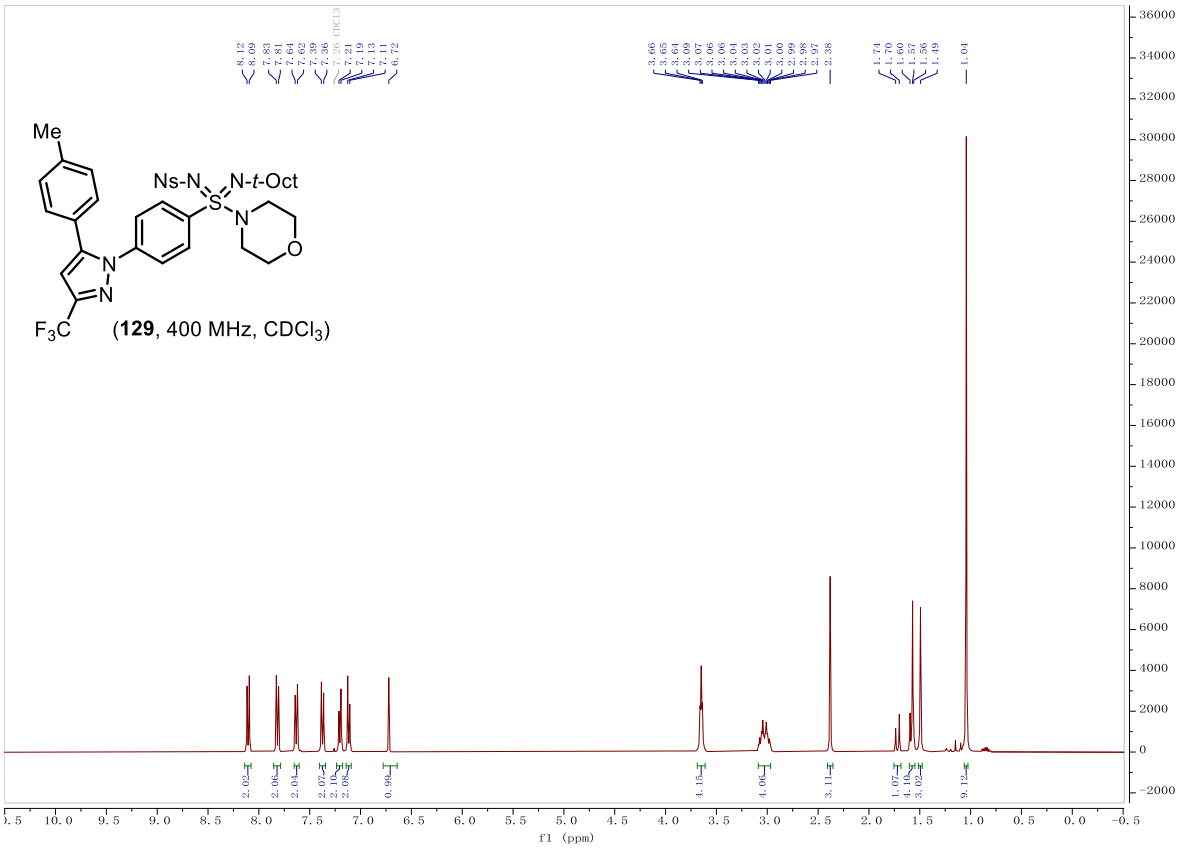
(**127**, 400 MHz, $CDCl_3$)

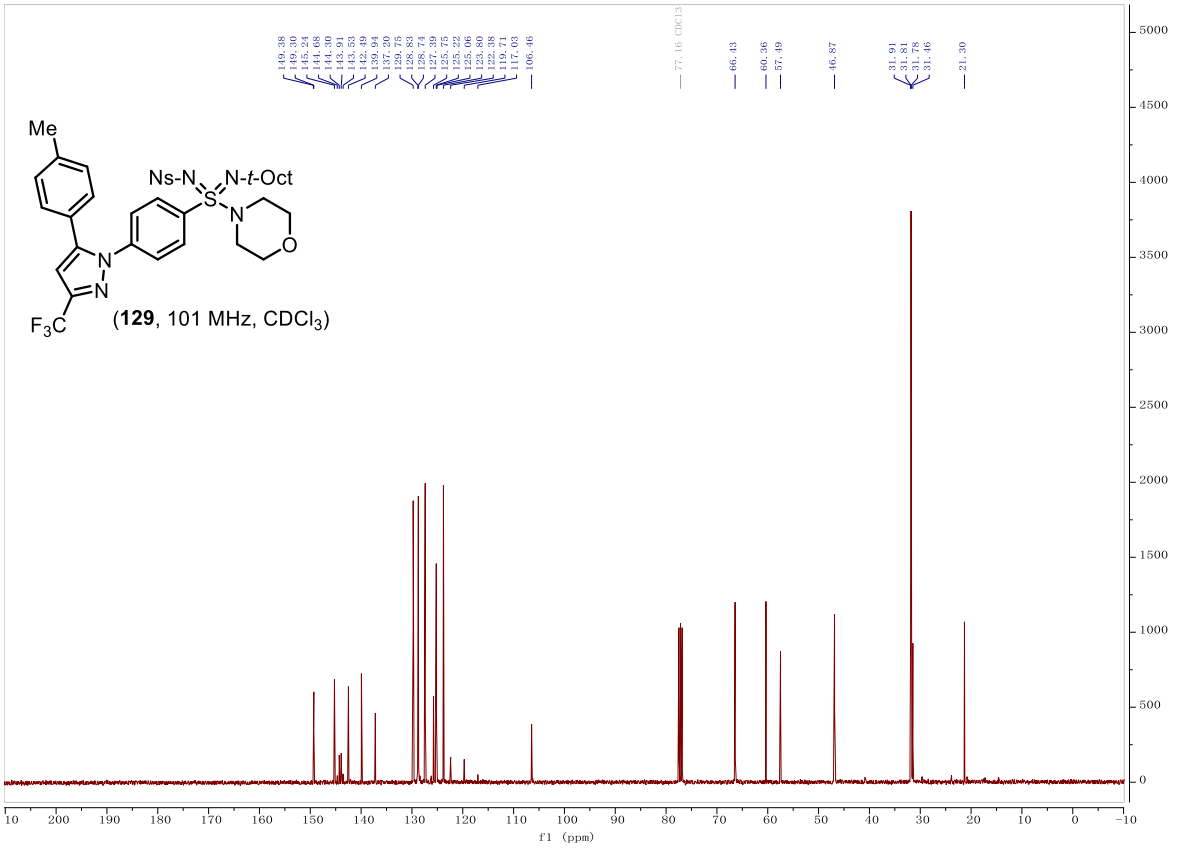

Ns-N
N-t-Oct
S
N
O
F
F
(127, 101 MHz, CDCl3)
f1 (ppm)

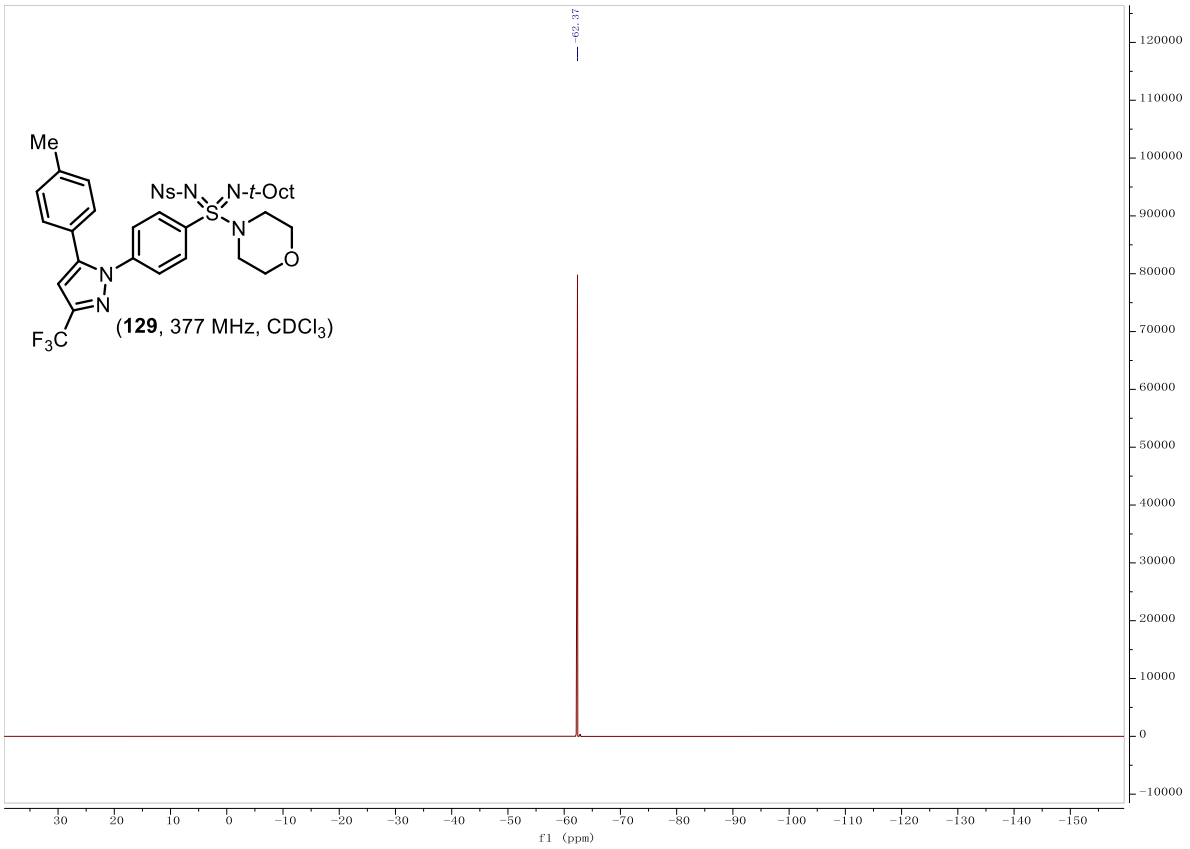

Ns-N
N-t-Oct
S
N
O
F
F
(127, 377 MHz, CDCl3)
f1 (ppm)

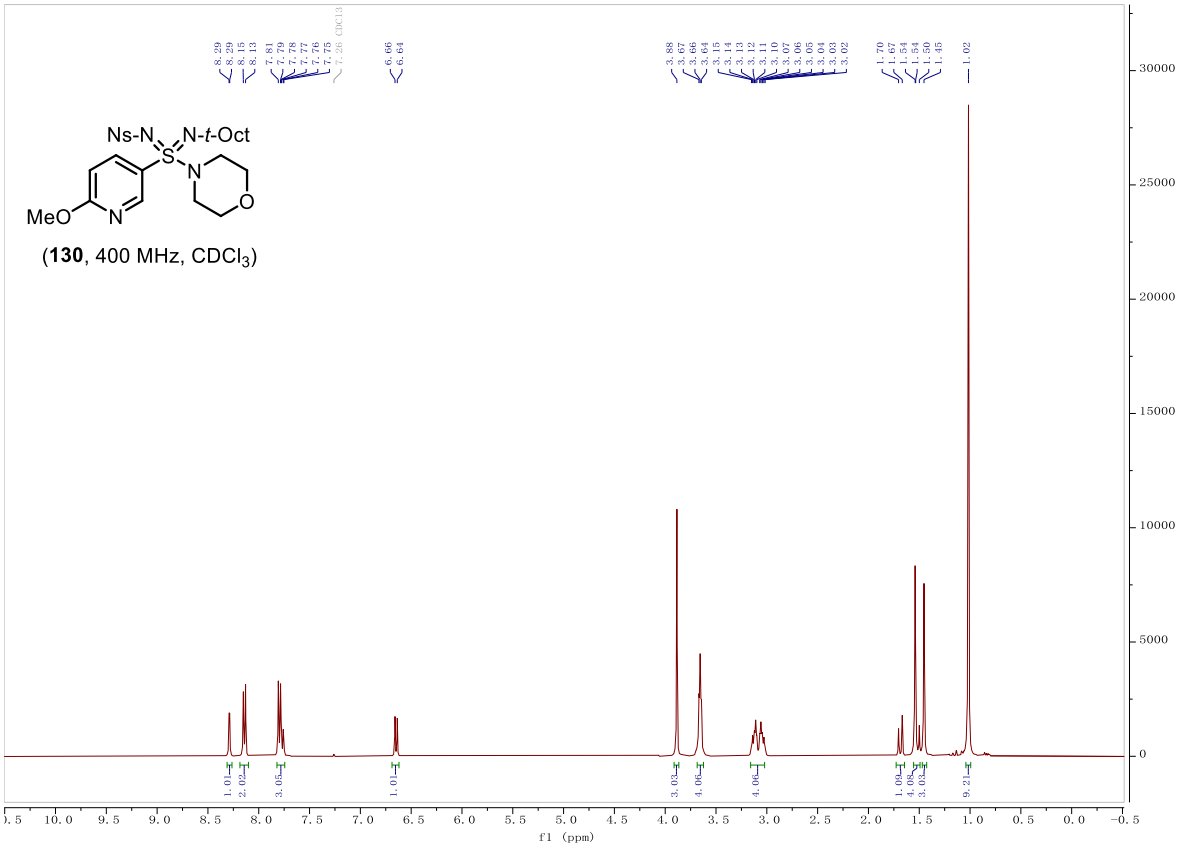

Ns-N
N-t-Oct
S
N
O
EtO
CN
(128, 400 MHz, CDCl3)
f1 (ppm)

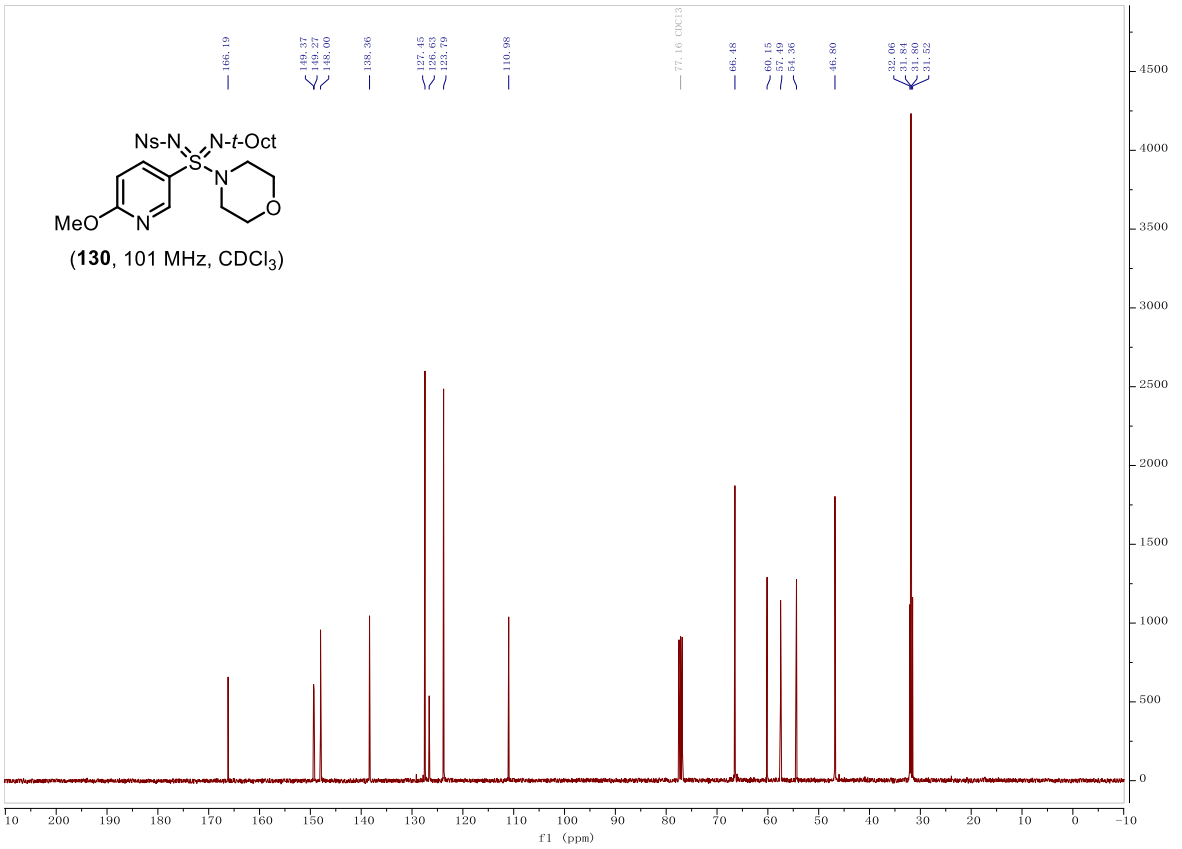

Ns-N
N-t-Oct
S
N
O
EtO
CN
(128, 101 MHz, CDCl3)
f1 (ppm)

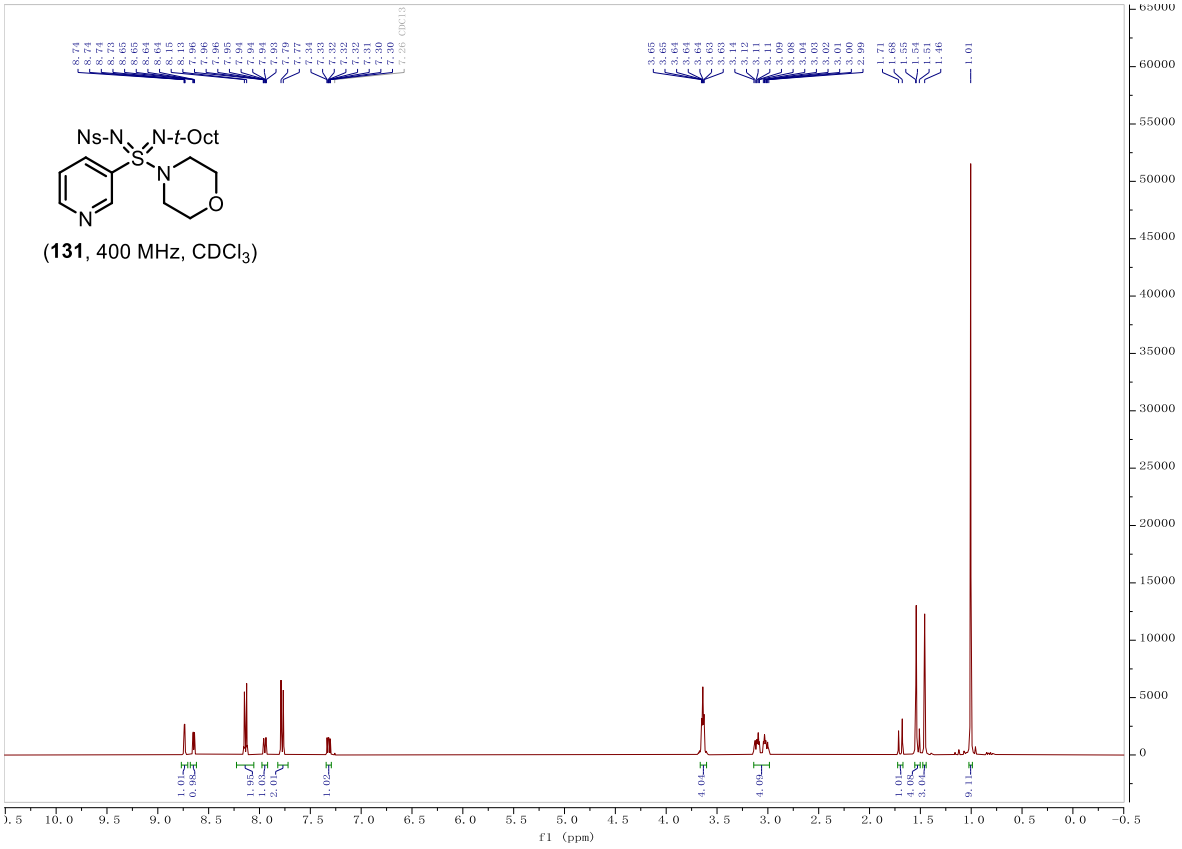

Me
Ns-N
N-t-Oct
S
N
O
N
N
F3C
(129, 400 MHz, CDCl3)
f1 (ppm)

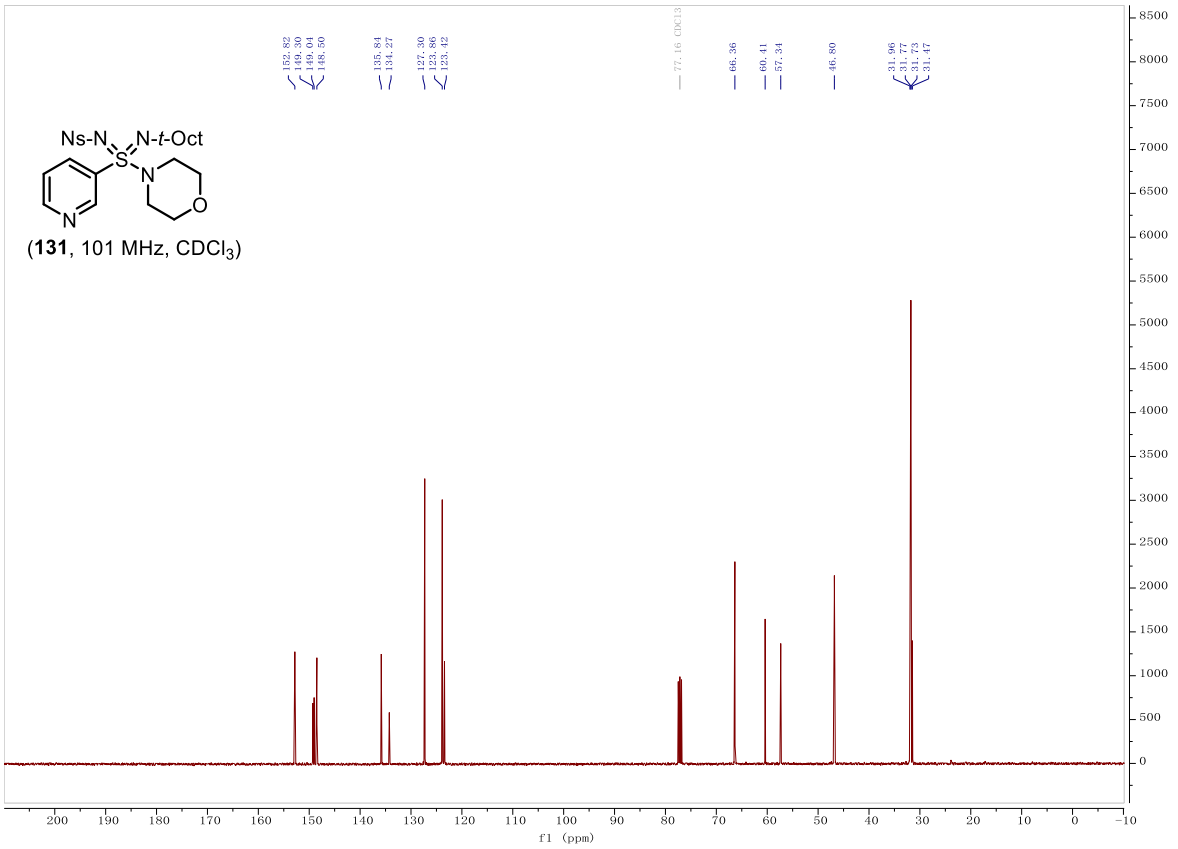

Me
Ns-N
N-t-Oct
S
N
O
N
N
F3C
(129, 101 MHz, CDCl3)
f1 (ppm)

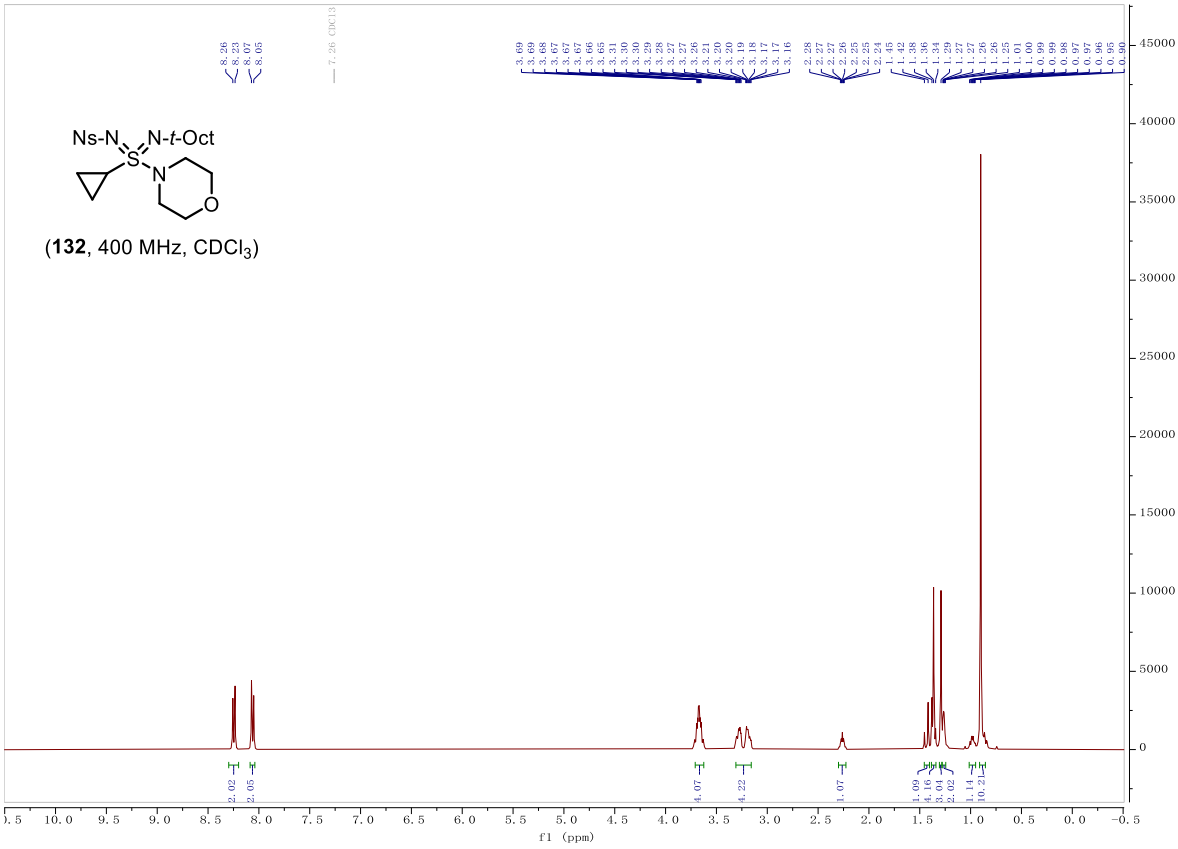

Me
Ns-N
N-t-Oct
S
N
O
N
N
F3C
(129, 377 MHz, CDCl3)
-62.37
f1 (ppm)

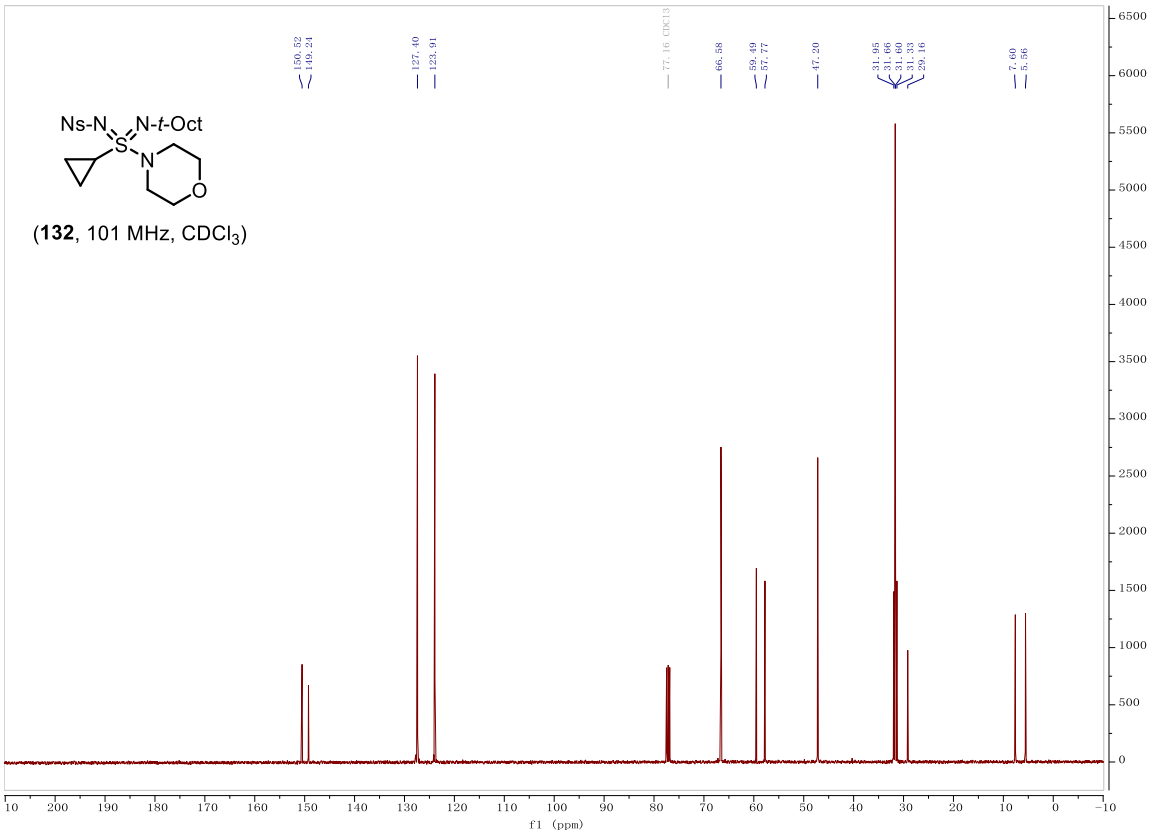

Ns-N
N-t-Oct
S
N
O
MeO
N
(130, 400 MHz, CDCl3)
f1 (ppm)

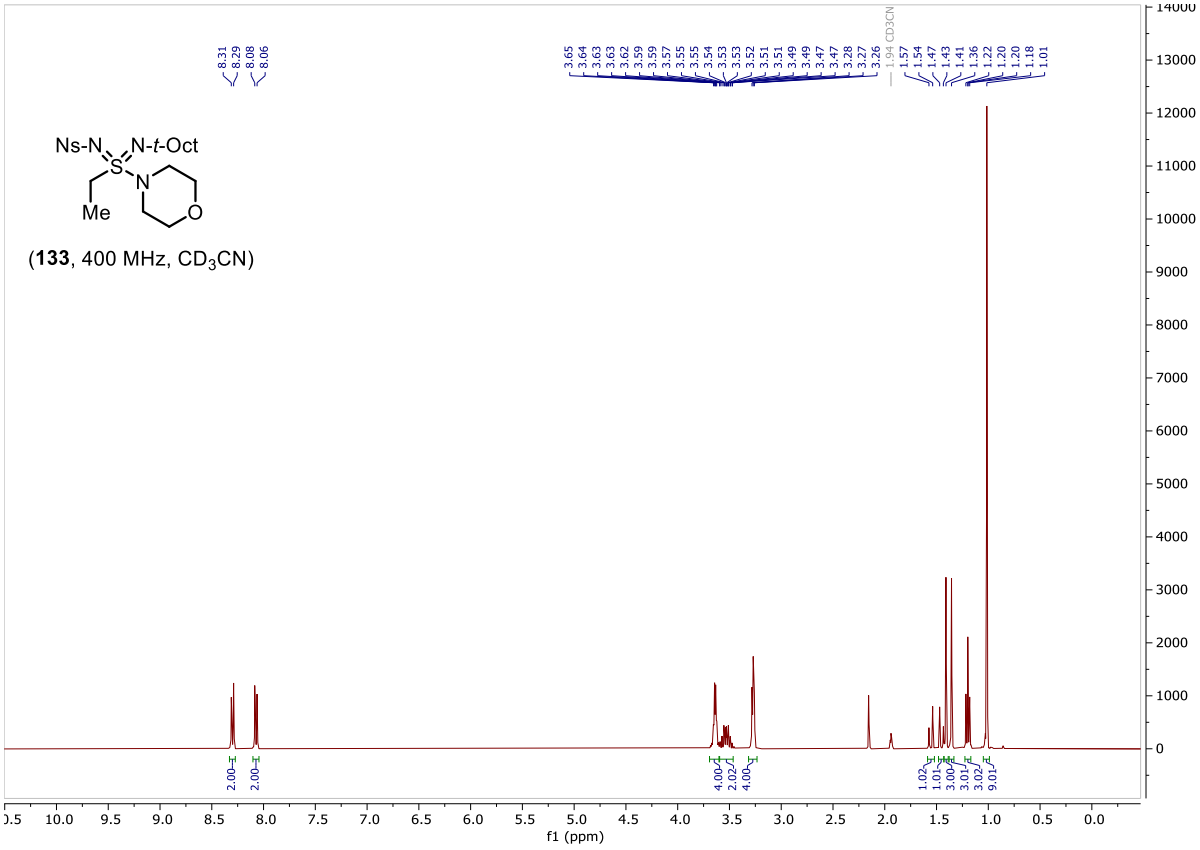

Ns-N
N-t-Oct
S
N
MeO
N
O
(130, 101 MHz, CDCl3)
166.19
149.37
149.27
148.00
138.36
127.45
126.63
123.79
110.98
77.16 CDCl3
66.48
60.15
57.49
54.36
46.80
32.06
31.84
31.80
31.52
f1 (ppm)

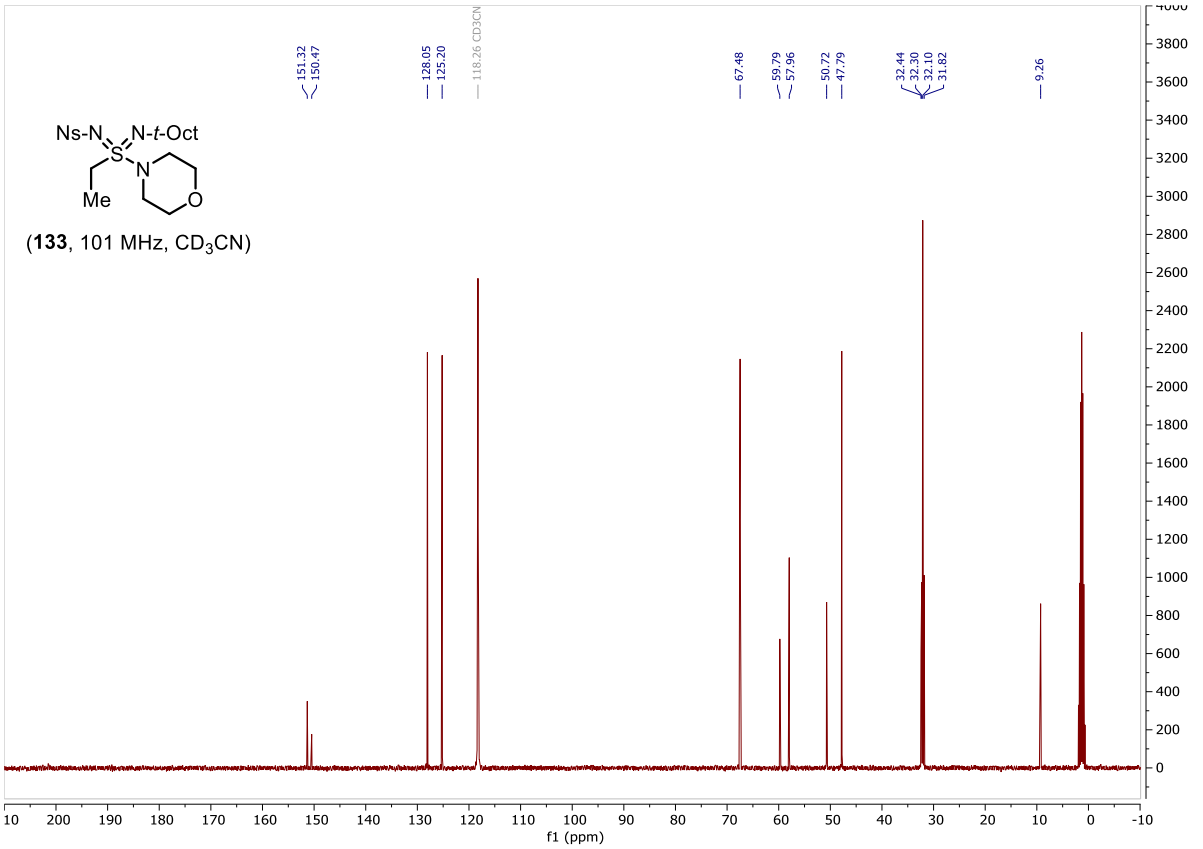

Ns-N
N-t-Oct
S
N
O
N
(131, 400 MHz, CDCl3)
f1 (ppm)

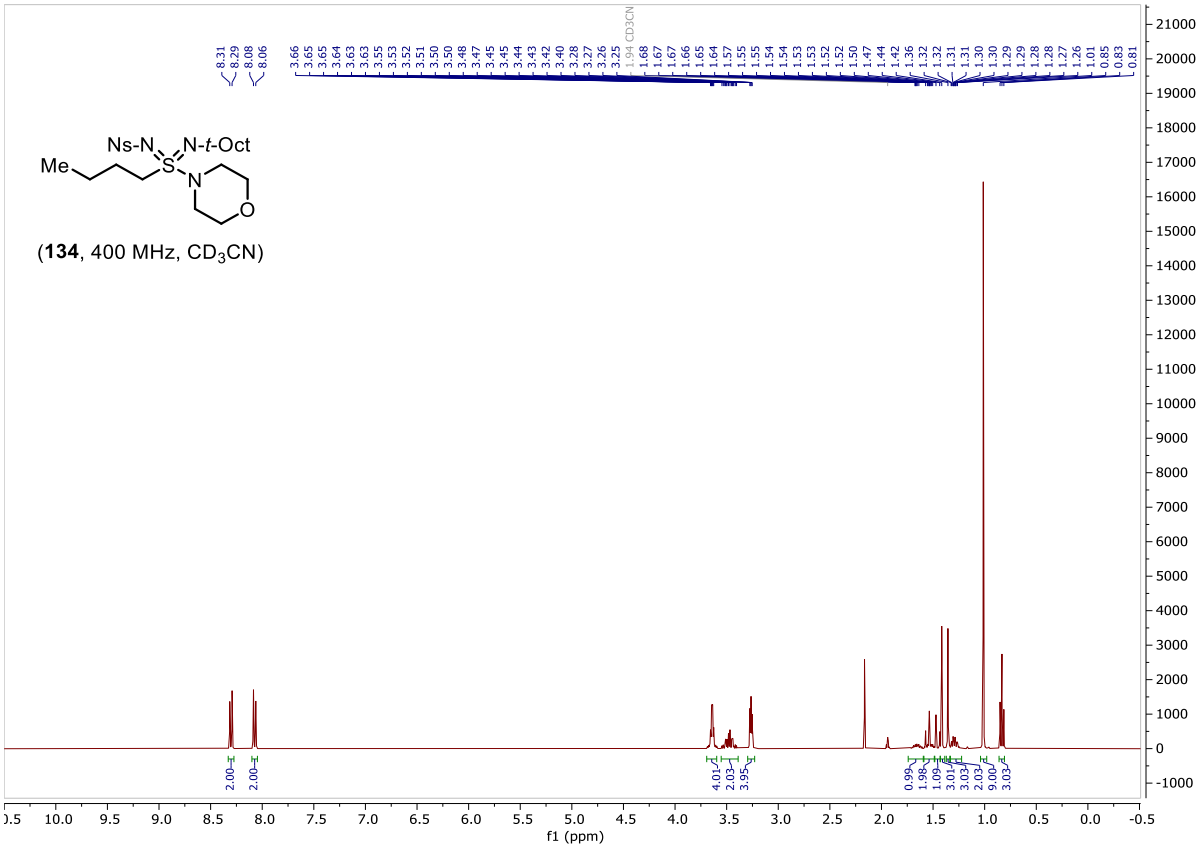

Ns-N
N-t-Oct
S
N
O
N
(131, 101 MHz, CDCl3)
162.82
149.30
146.04
148.90
135.84
134.27
127.30
123.86
123.42
77.16 CDCl3
66.36
60.41
57.34
46.80
31.96
31.77
31.73
31.47
f1 (ppm)

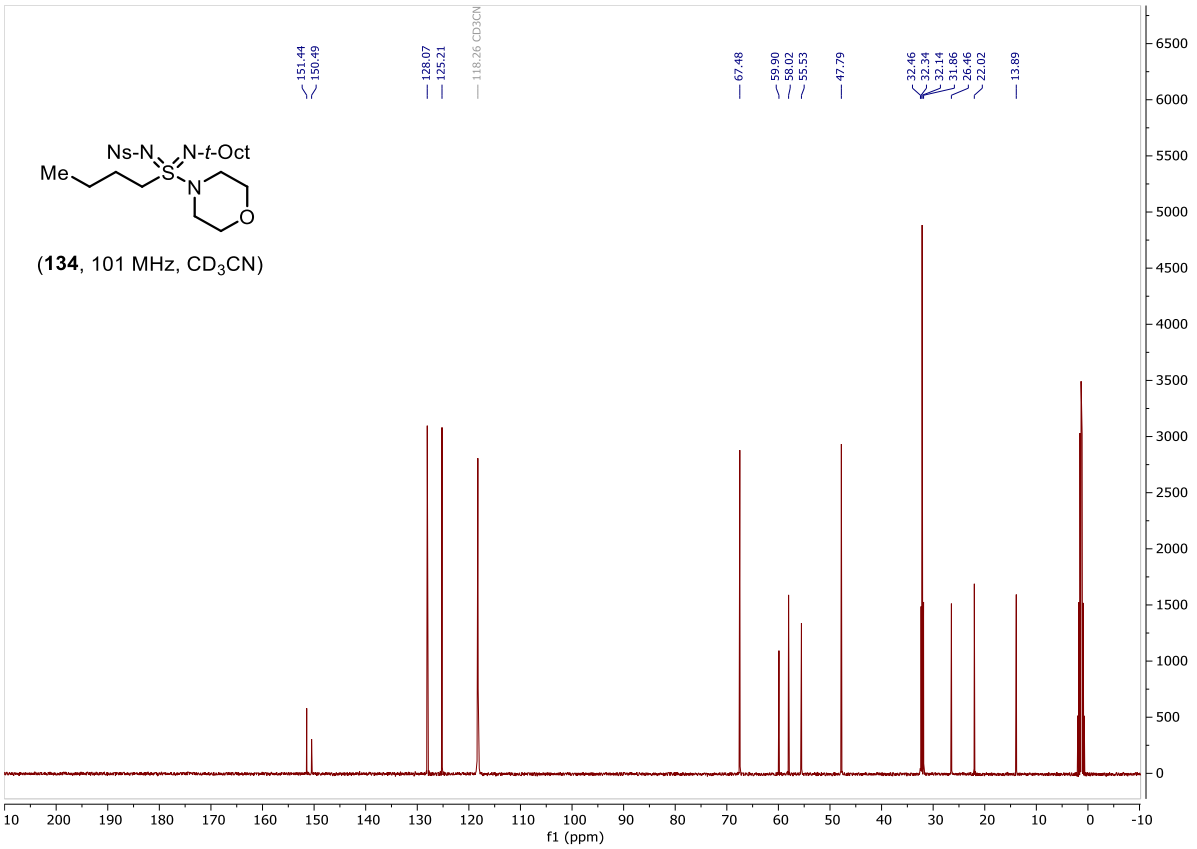

Ns-N
N-t-Oct
S
N
O
(132, 400 MHz, CDCl3)
8.26
8.23
8.07
8.05
7.26 CDCl3
2.02
2.05
4.07
4.22
1.07
4.16
3.04
2.02
10.21
f1 (ppm)

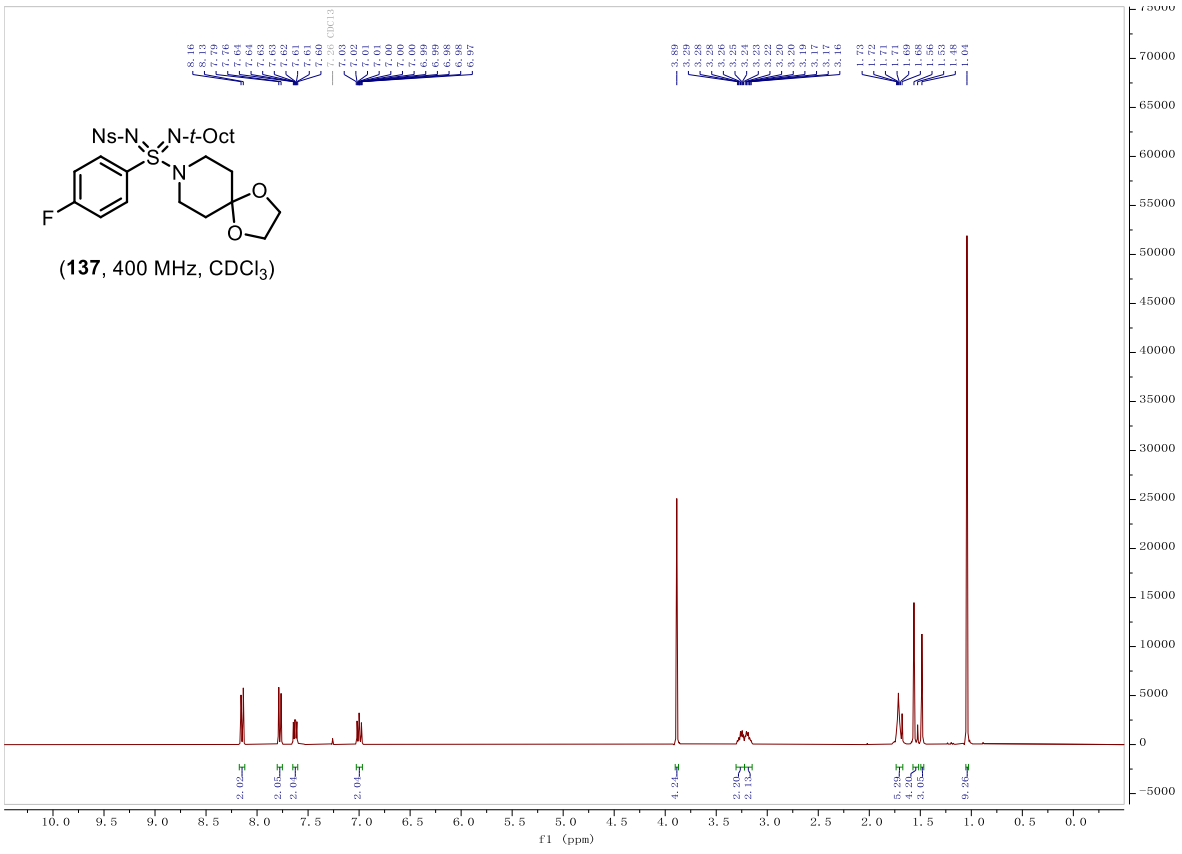

Ns-N
N-t-Oct
S
N
O
(132, 101 MHz, CDCl3)
150.52
149.24
127.40
123.91
77.16 CDCl3
66.58
59.49
57.77
47.20
31.95
31.66
31.60
31.33
29.46
7.60
5.56
f1 (ppm)

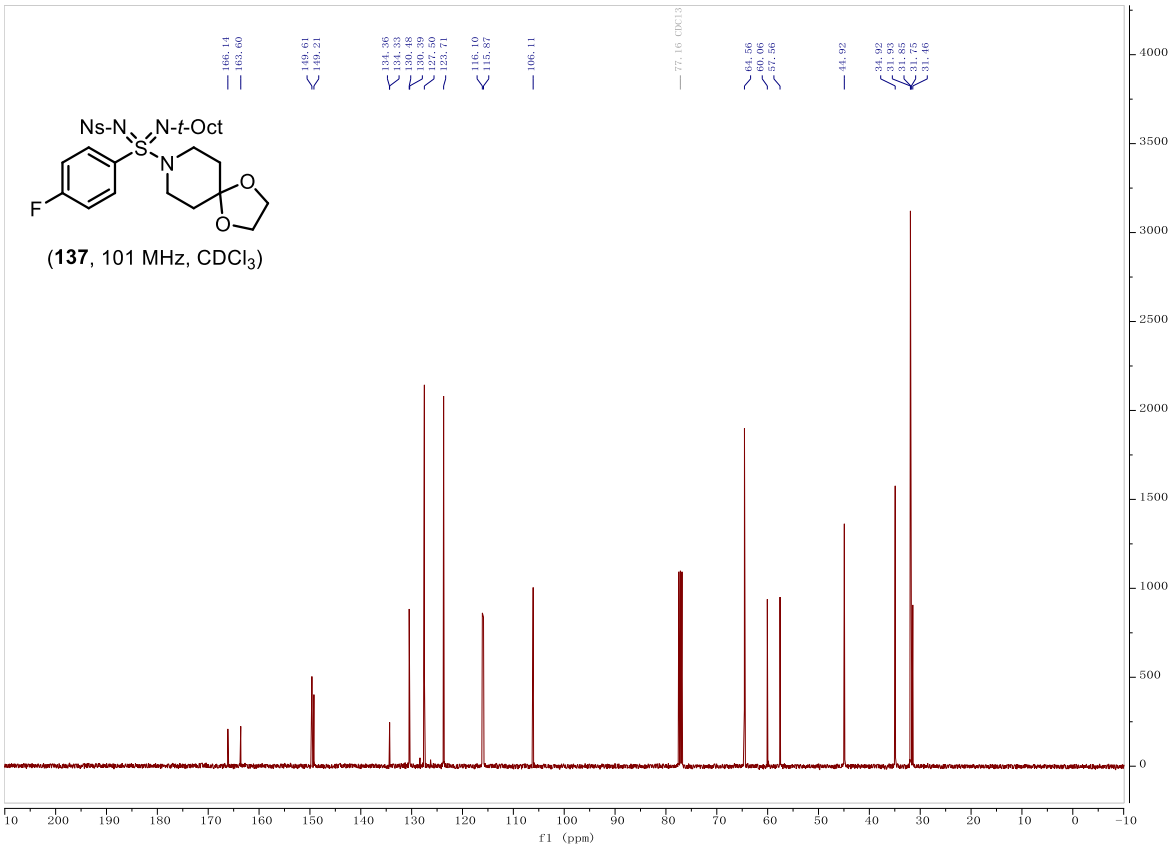

Ns-N
N-t-Oct
S
N
Me
O
(133, 400 MHz, CD3CN)
8.31
8.29
8.08
8.06
1.94 CD3CN
f1 (ppm)


Ns-N
N-t-Oct
S
N
Me
O
(133, 101 MHz, CD3CN)
151.32
150.47
128.05
125.20
118.26 CD3CN
67.48
59.79
57.96
50.72
47.79
32.44
32.30
32.10
31.82
9.26
f1 (ppm)

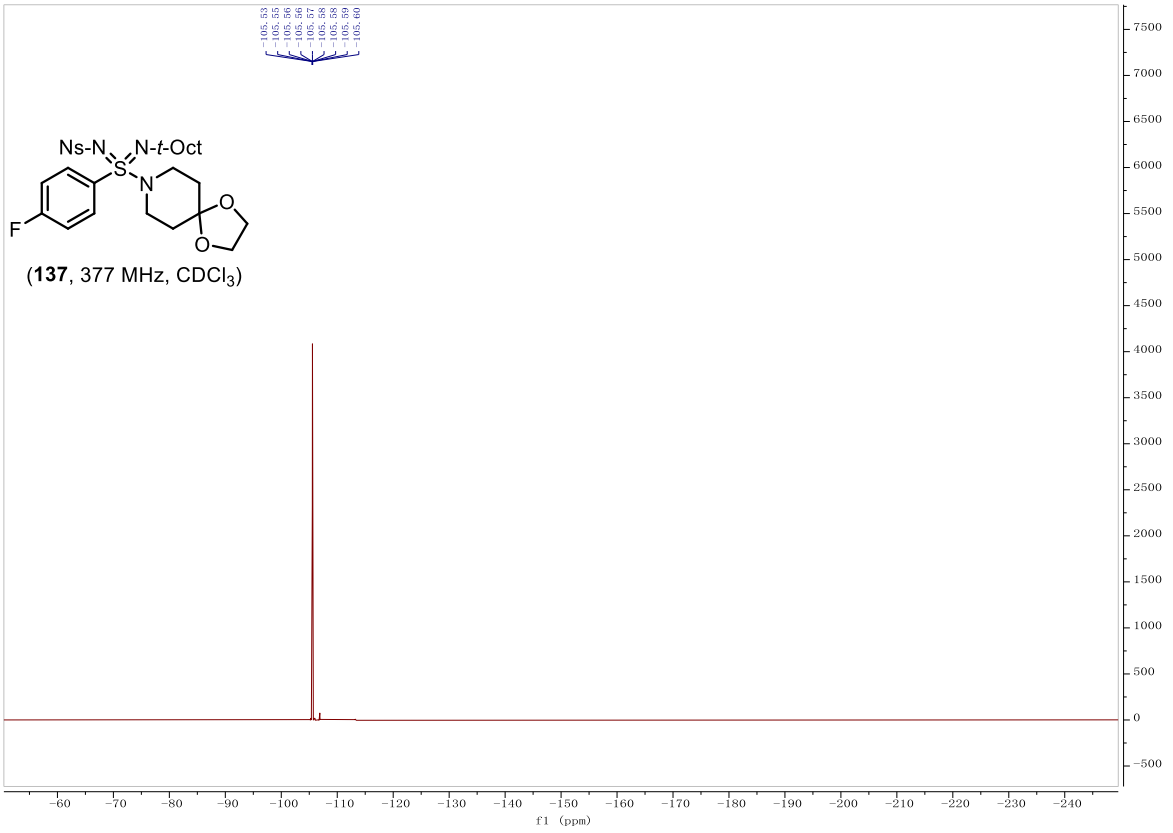

Ns-N
N-t-Oct
Me
S
N
O
(134, 400 MHz, CD3CN)
8.31
8.29
8.08
8.06
3.94 CD3CN
2.00
2.00
4.01
2.03
3.95
0.99
1.98
1.09
3.01
3.03
2.03
9.00
3.03
f1 (ppm)


Ns-N
N-t-Oct
Me
S
N
O
(134, 101 MHz, CD3CN)
151.44
150.49
128.07
125.21
118.26 CD3CN
67.48
59.90
58.02
55.53
47.79
32.46
32.34
32.14
31.86
26.46
22.02
13.89
f1 (ppm)

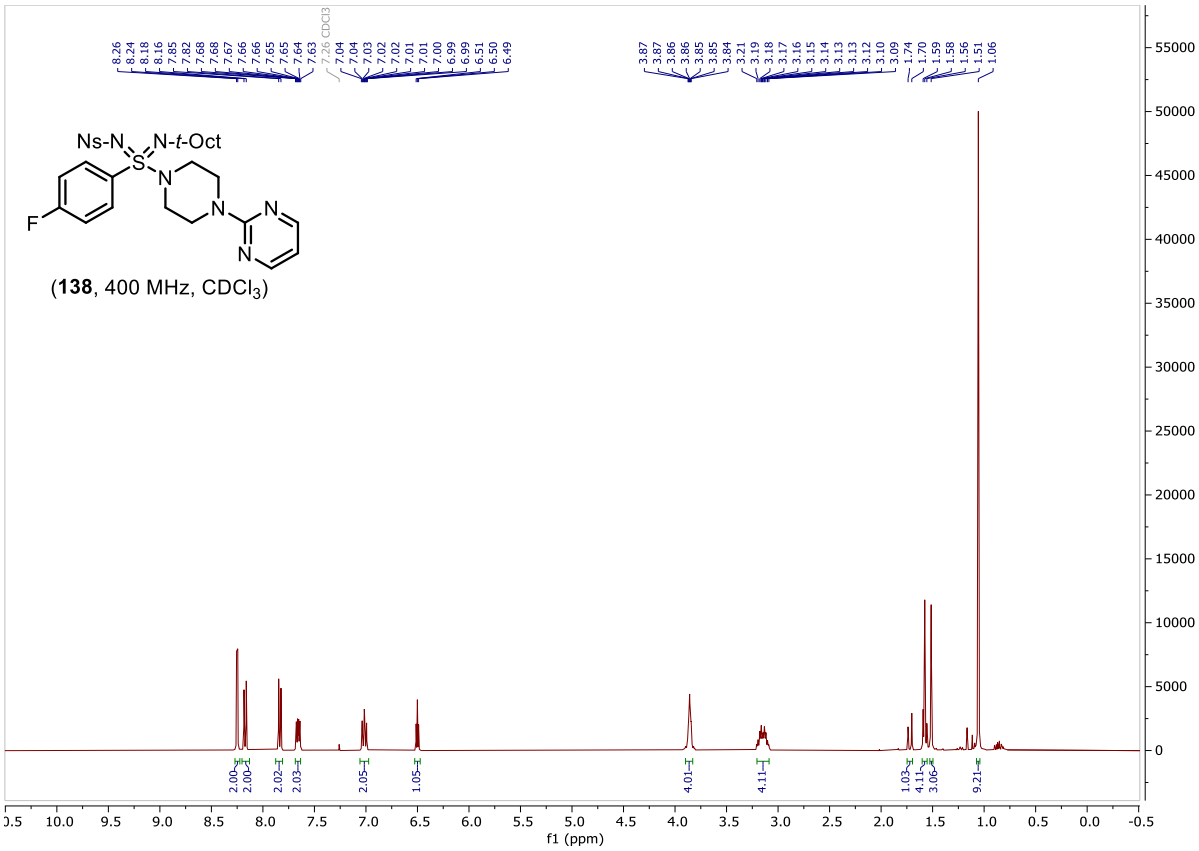

Ns-N
N-t-Oct
F
S
N
O
O
(137, 400 MHz, CDCl3)
7.26 CDCl3
f1 (ppm)



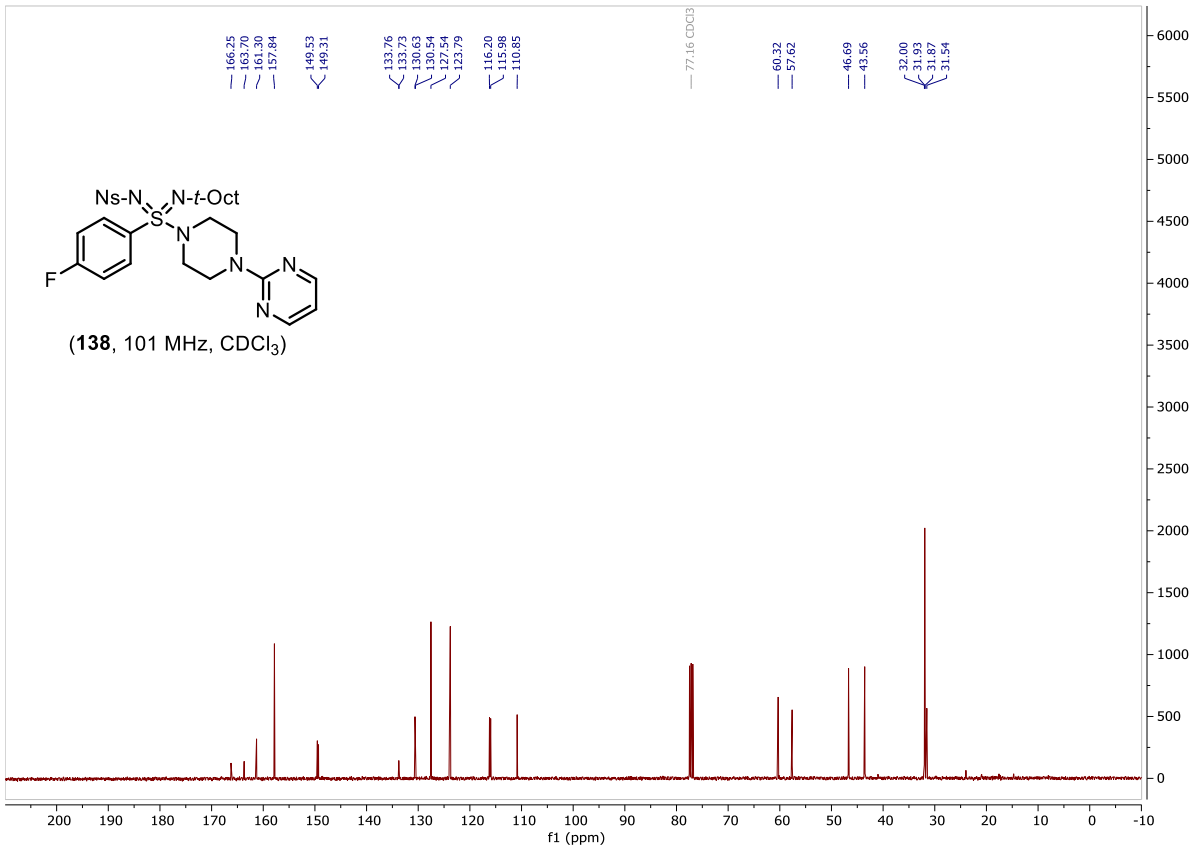
(**137**, 101 MHz, $CDCl_3$)



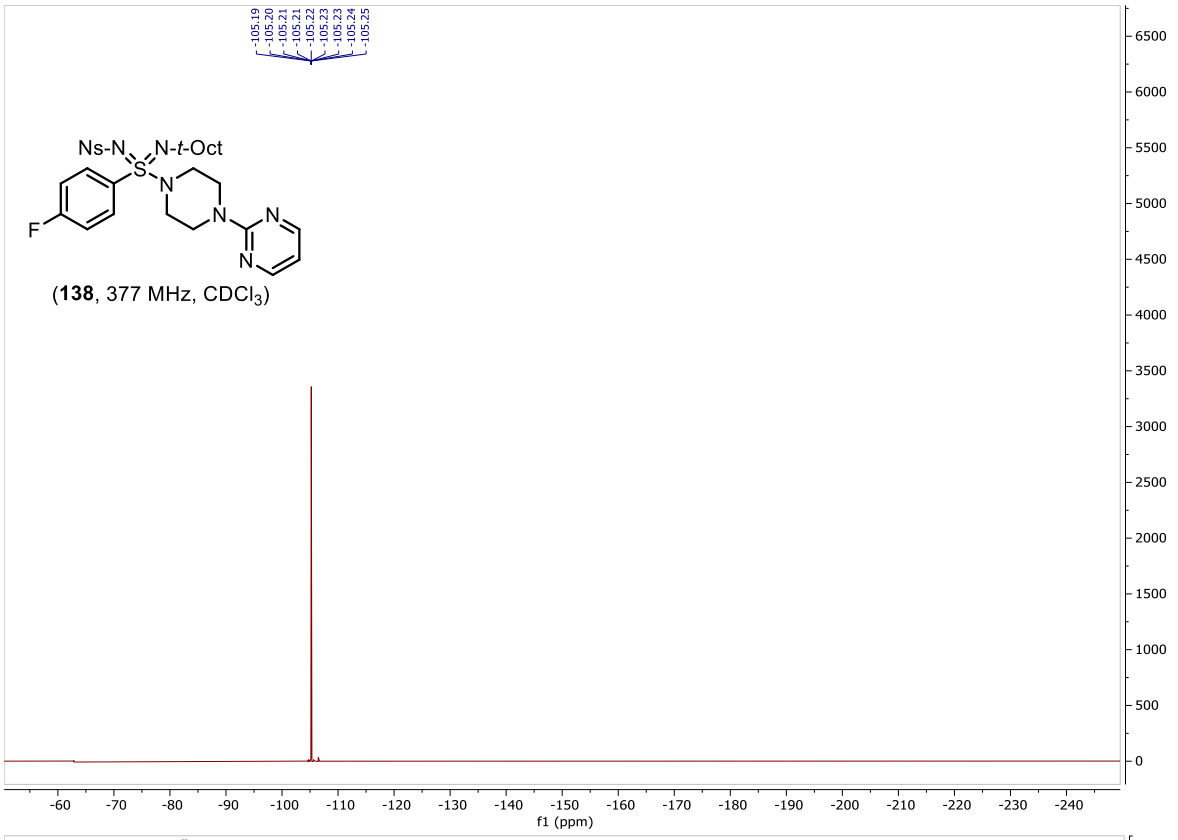
(**137**, 377 MHz, $CDCl_3$)



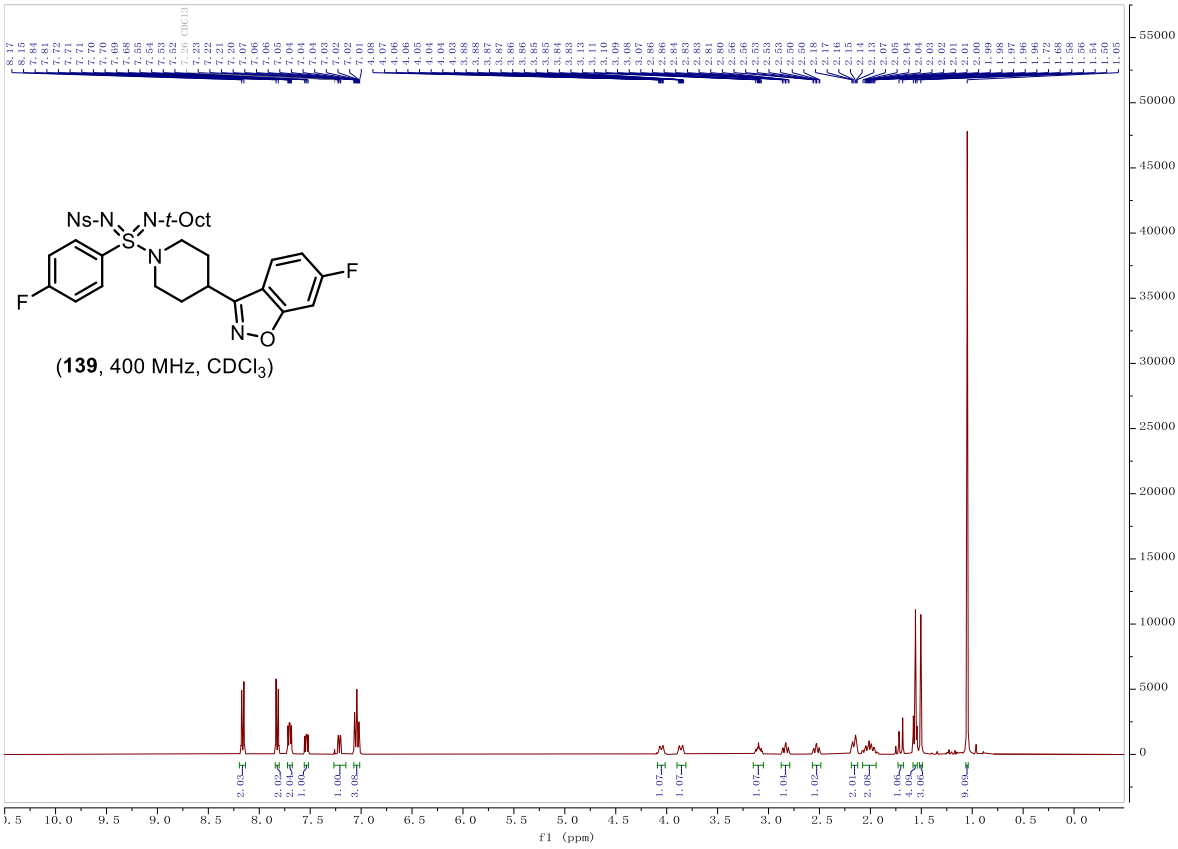
(**138**, 400 MHz, $CDCl_3$)



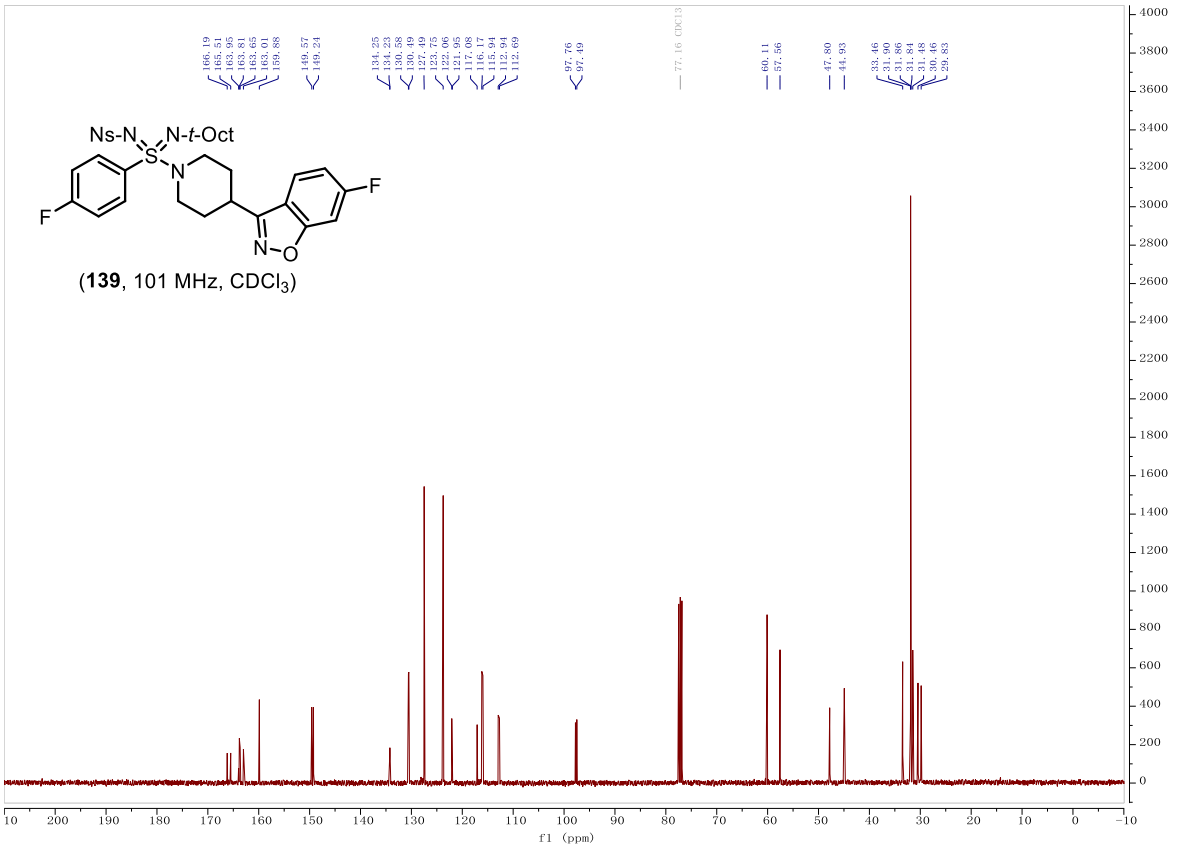
(**138**, 101 MHz, $CDCl_3$)



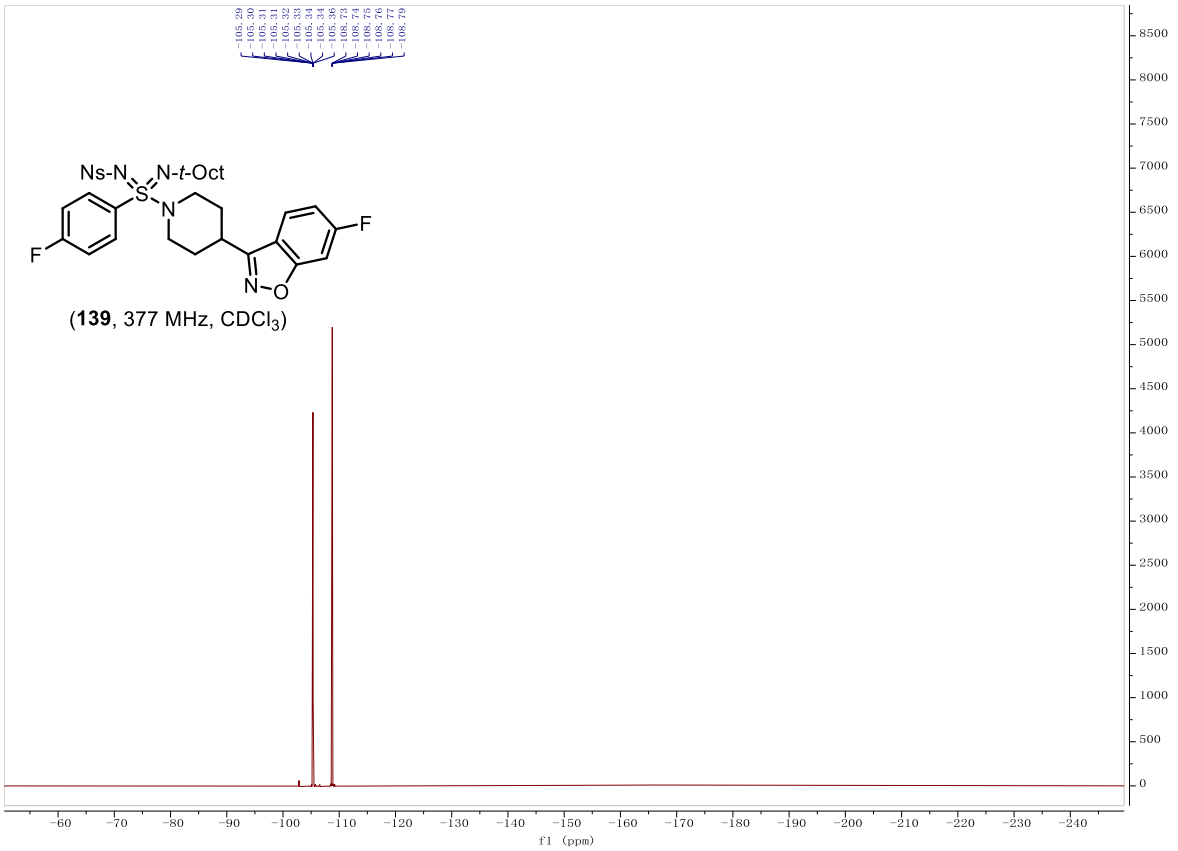
(**138**, 377 MHz, $CDCl_3$)



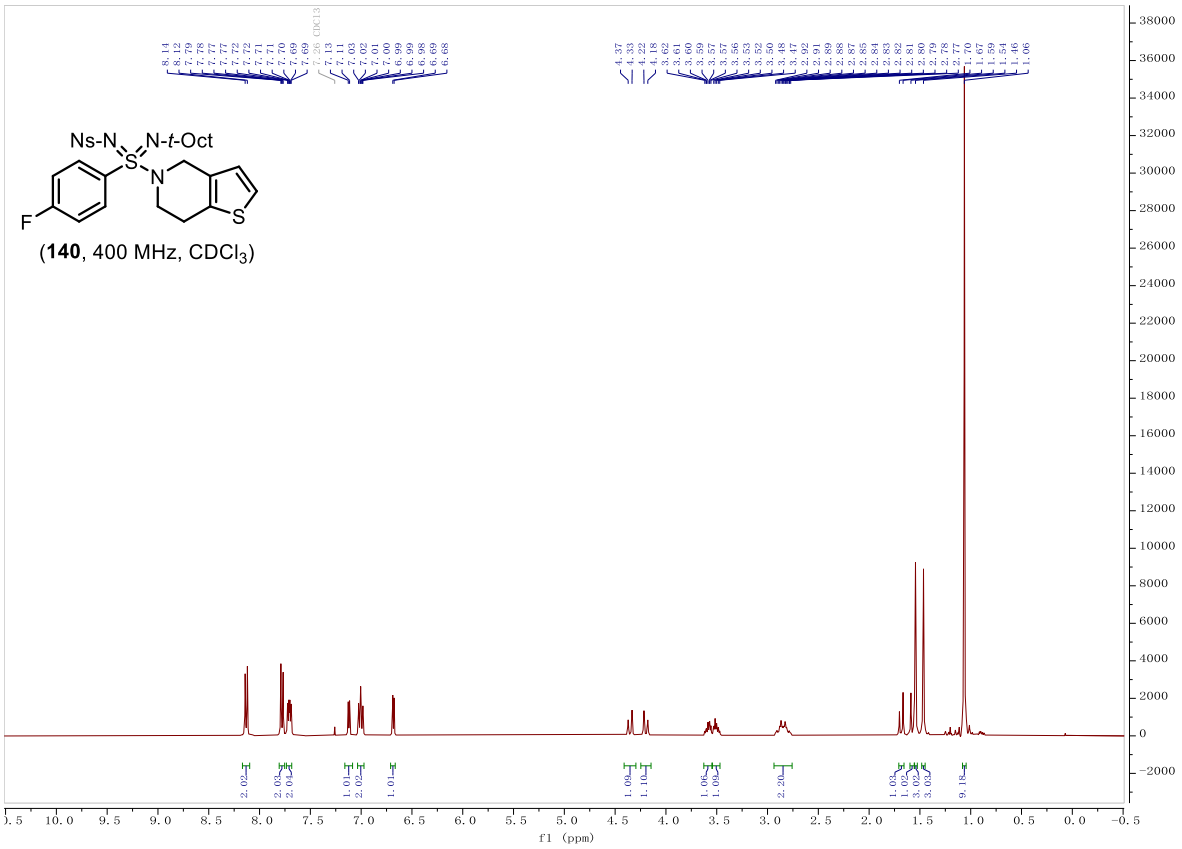
(**139**, 400 MHz, $CDCl_3$)



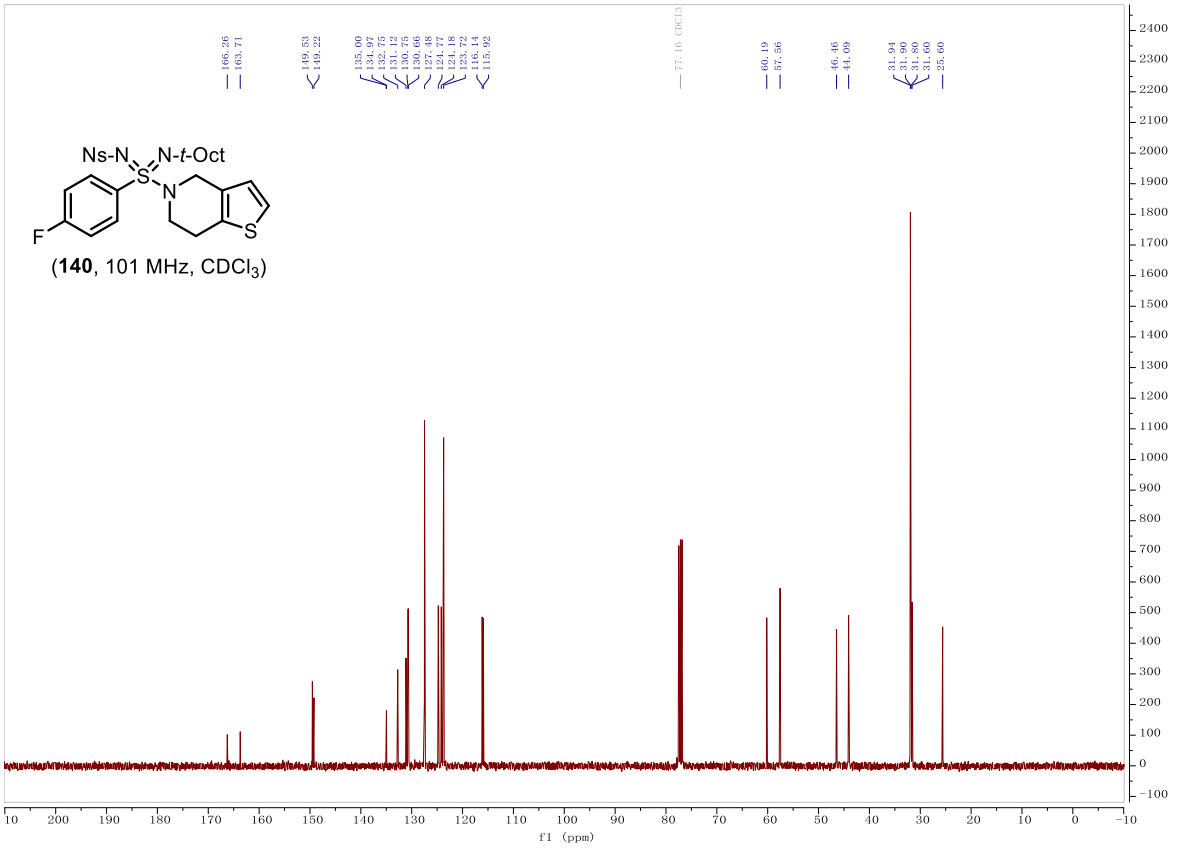
(**139**, 101 MHz, $CDCl_3$)



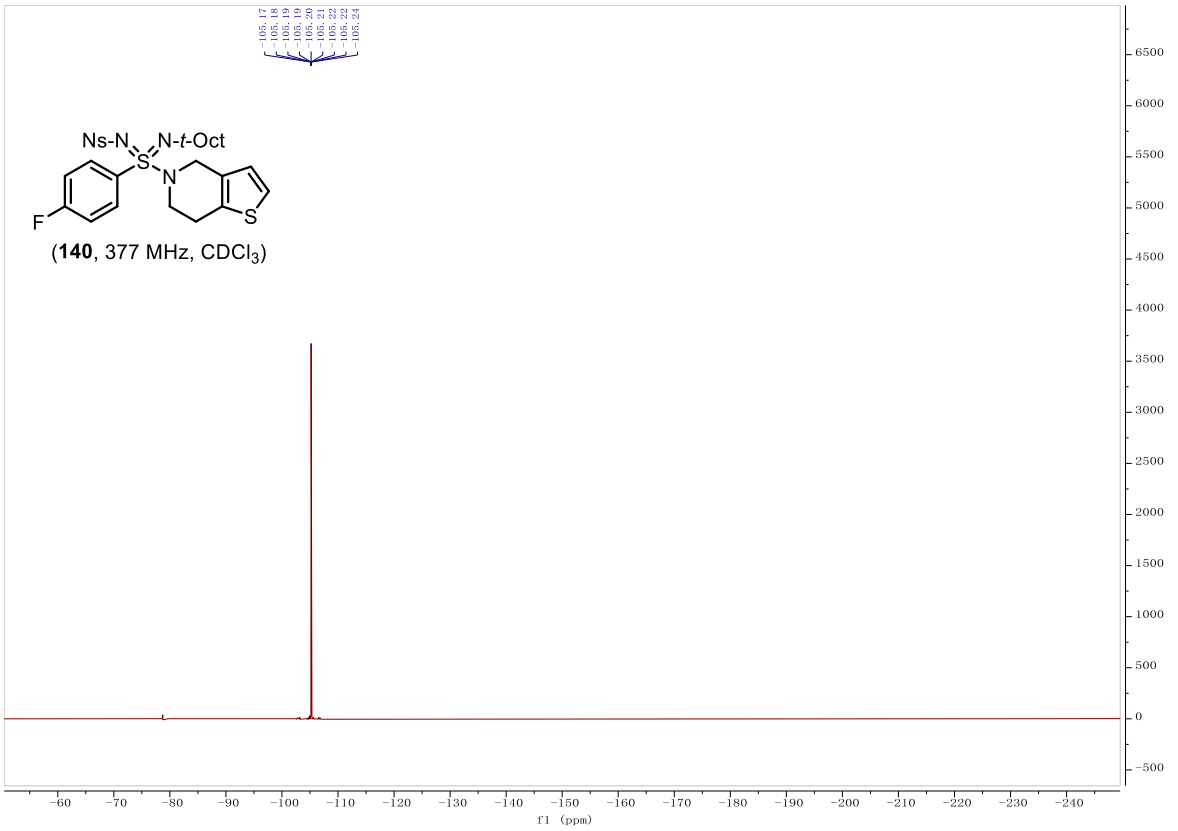
(**139**, 377 MHz, $CDCl_3$)



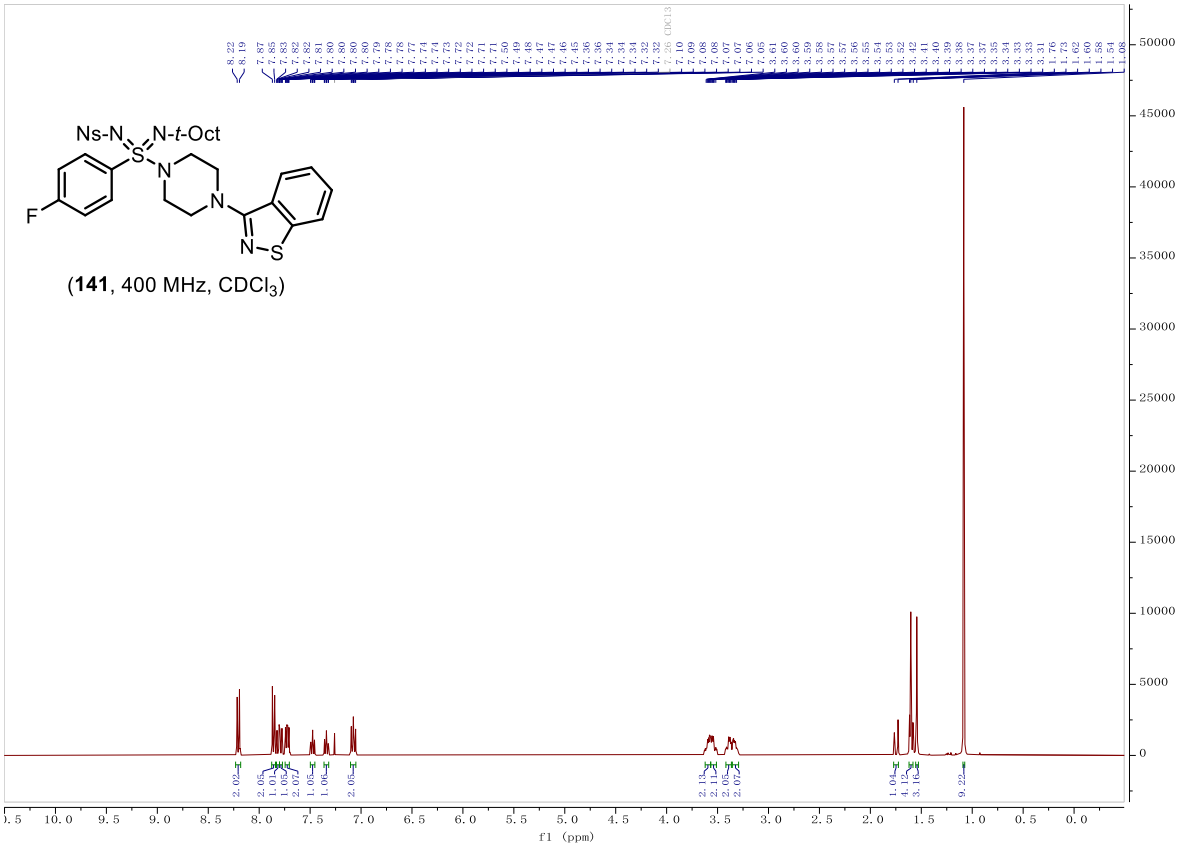
(**140**, 400 MHz, $CDCl_3$)



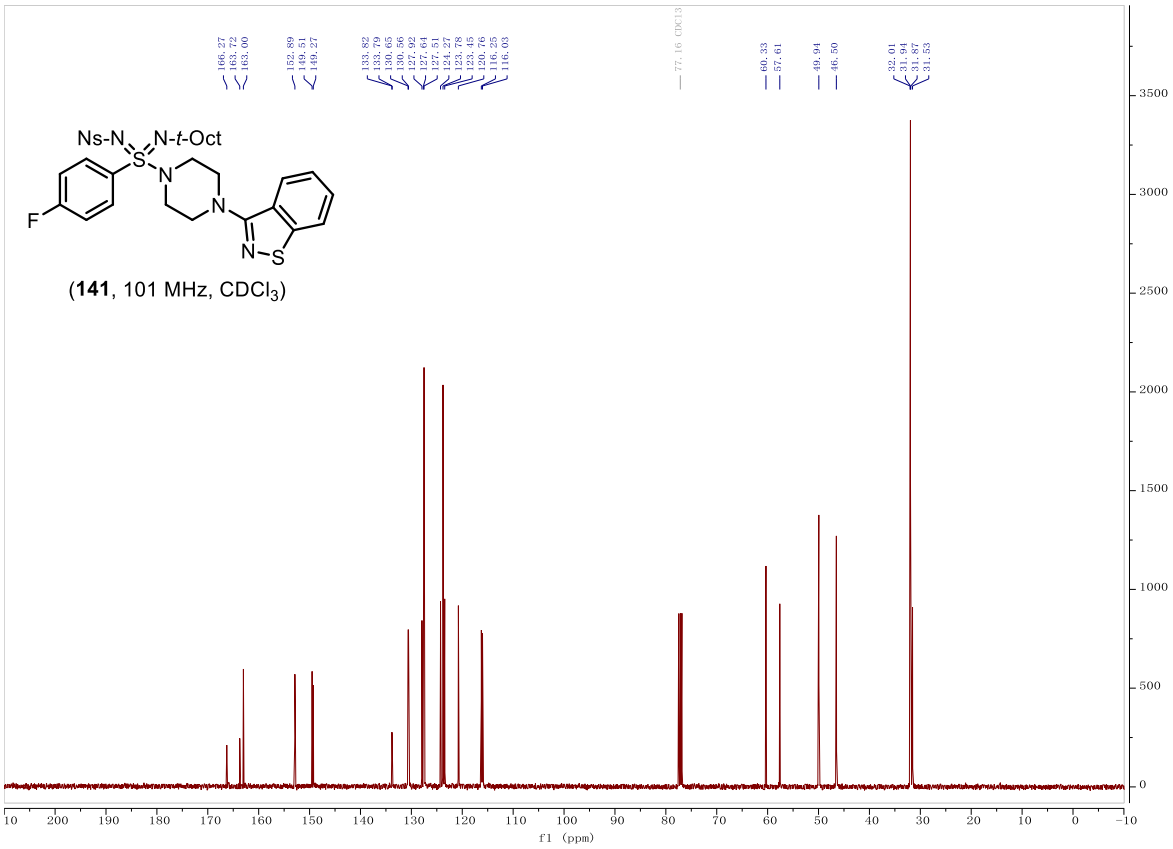
(**140**, 101 MHz, $CDCl_3$)

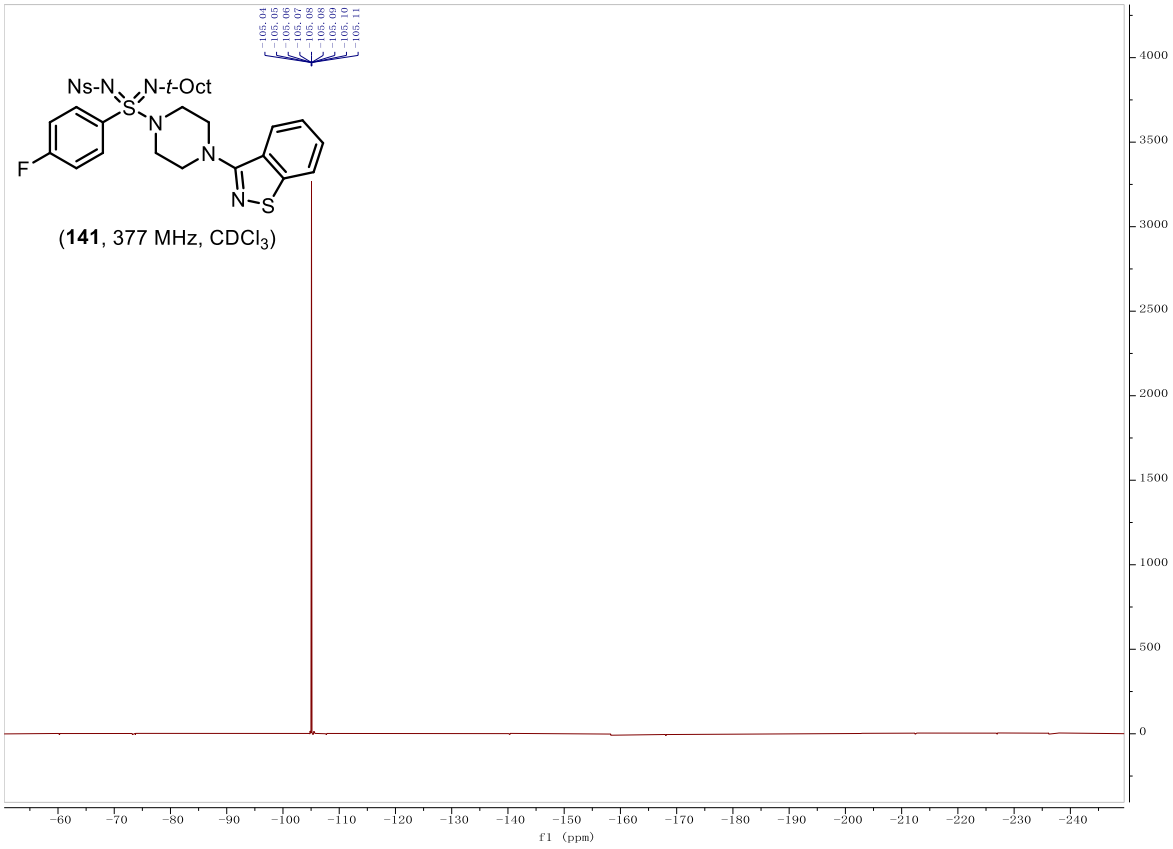


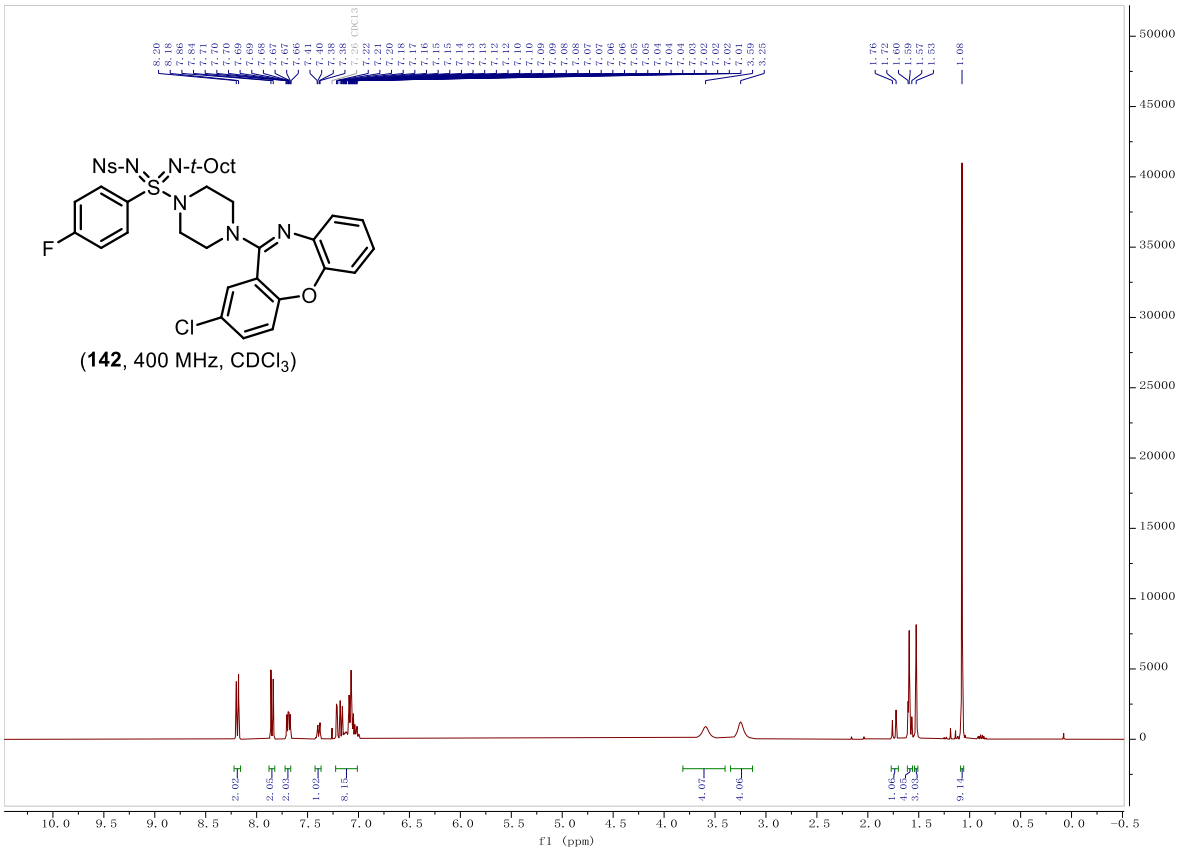
(**140**, 377 MHz, $CDCl_3$)



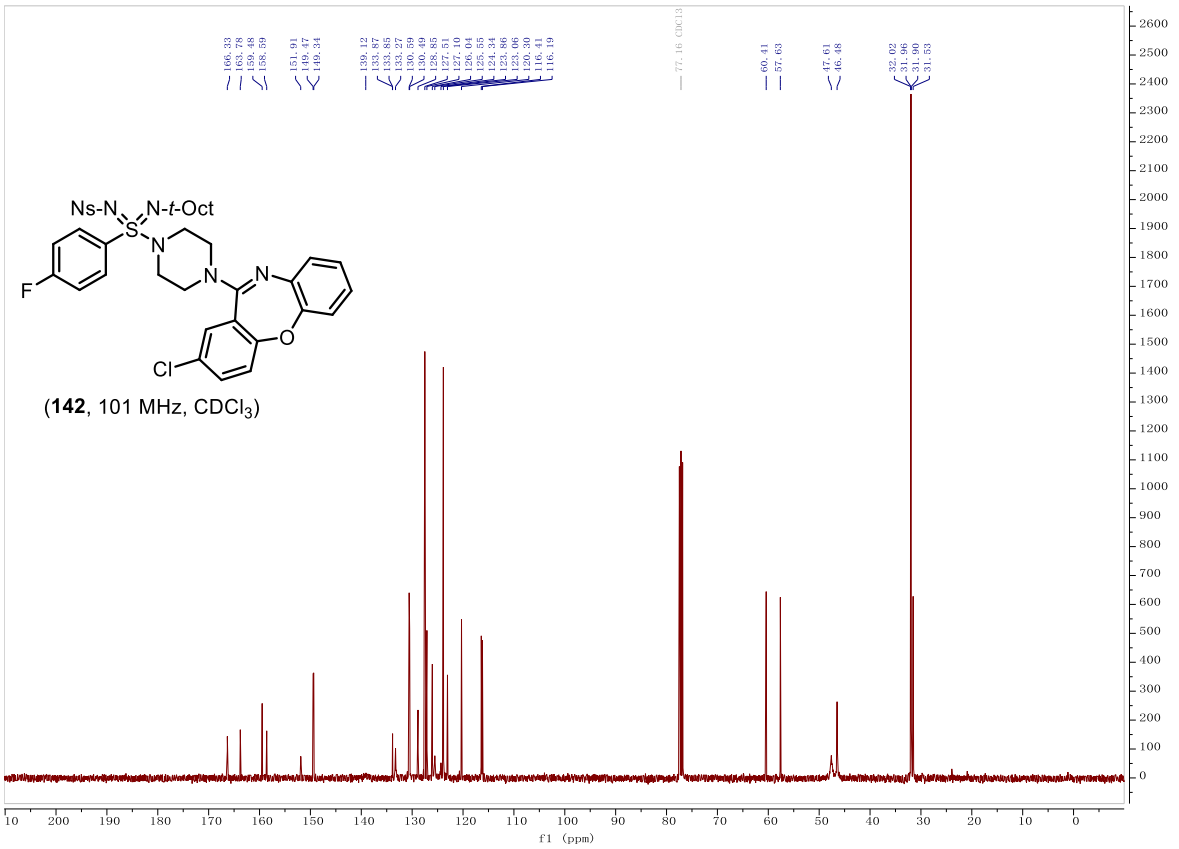
(**141**, 400 MHz, $CDCl_3$)


Ns-N
N-t-Oct
S
N
N
F
N
S
(141, 101 MHz, CDCl3)
166.27
163.72
163.06
152.89
149.51
149.27
133.82
133.79
130.65
130.56
127.92
127.64
127.51
124.27
123.78
123.45
120.76
116.25
116.03
77.16 CDCl3
60.33
57.61
49.94
46.50
32.01
31.94
31.87
31.53
f1 (ppm)

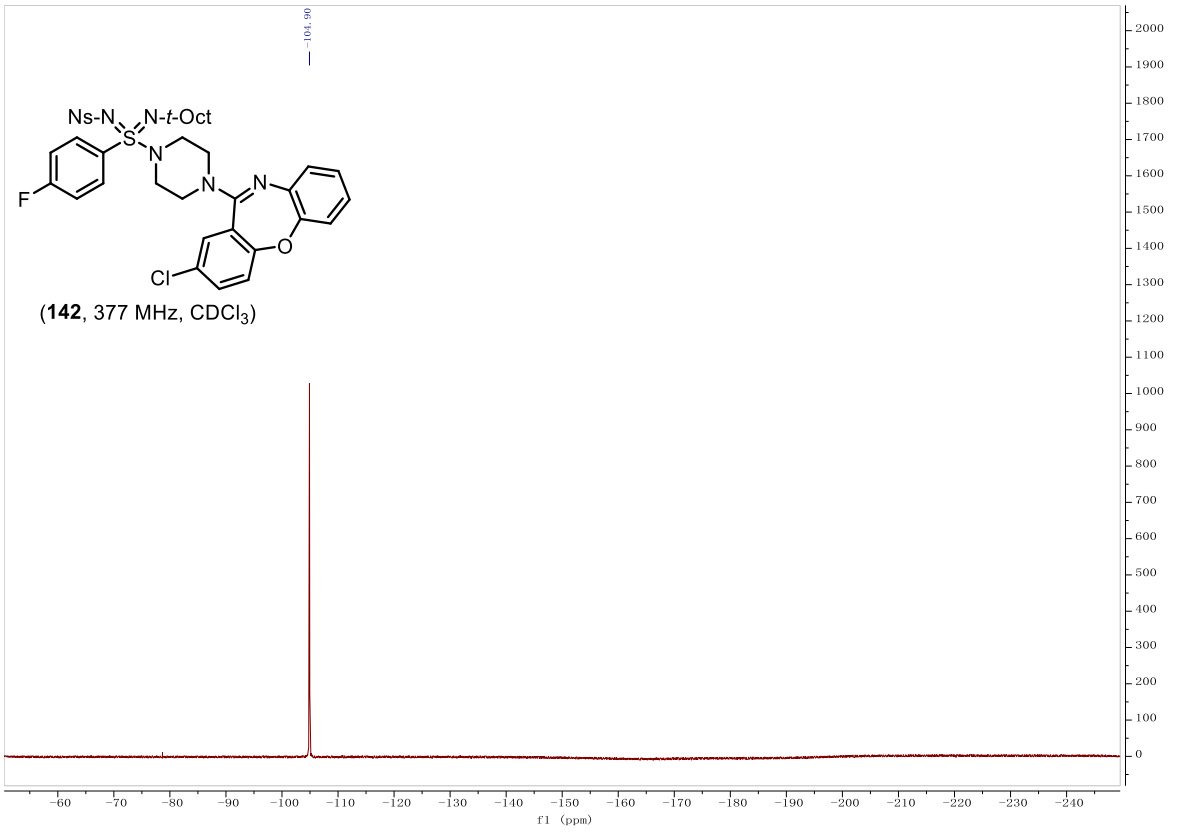

105.04
105.05
105.06
105.07
105.08
105.08
105.09
105.10
105.11
Ns-N
N-t-Oct
S
N
N
F
N
S
(141, 377 MHz, CDCl3)
f1 (ppm)



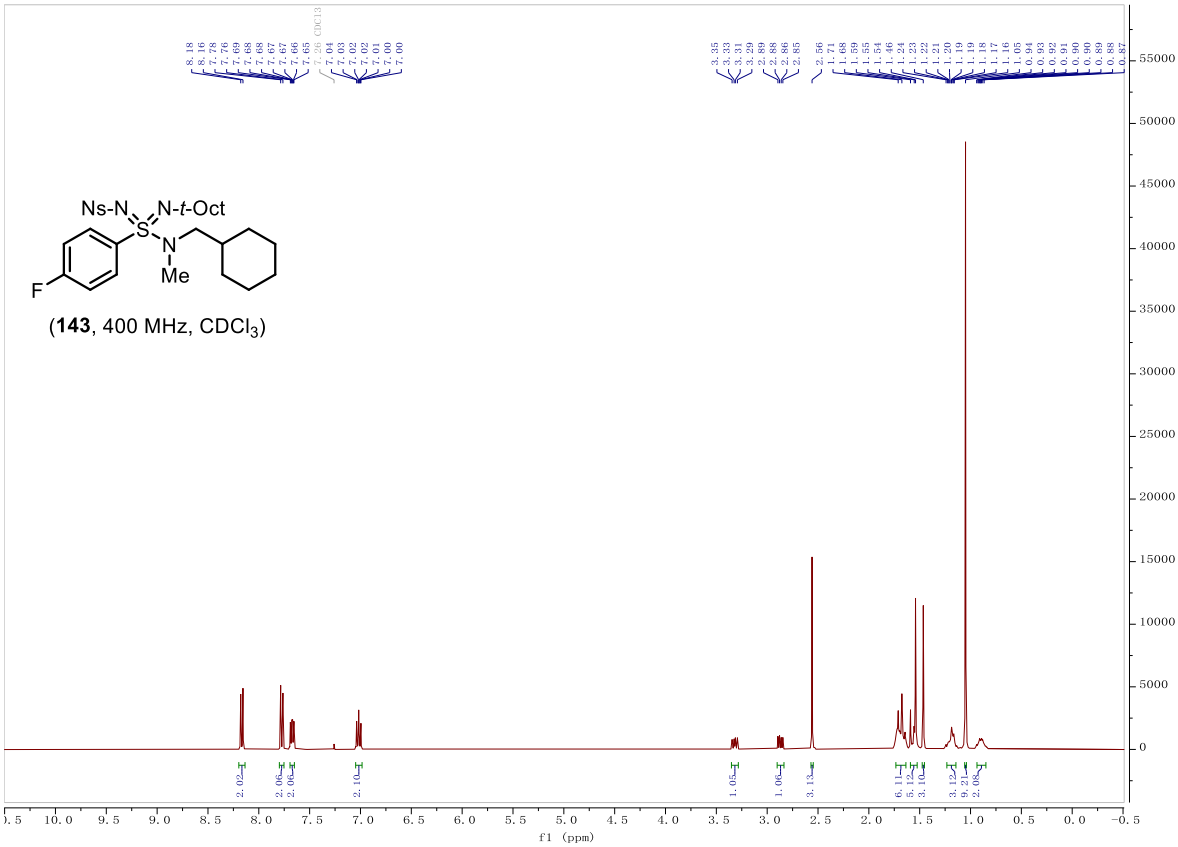
(**142**, 400 MHz, $CDCl_3$)



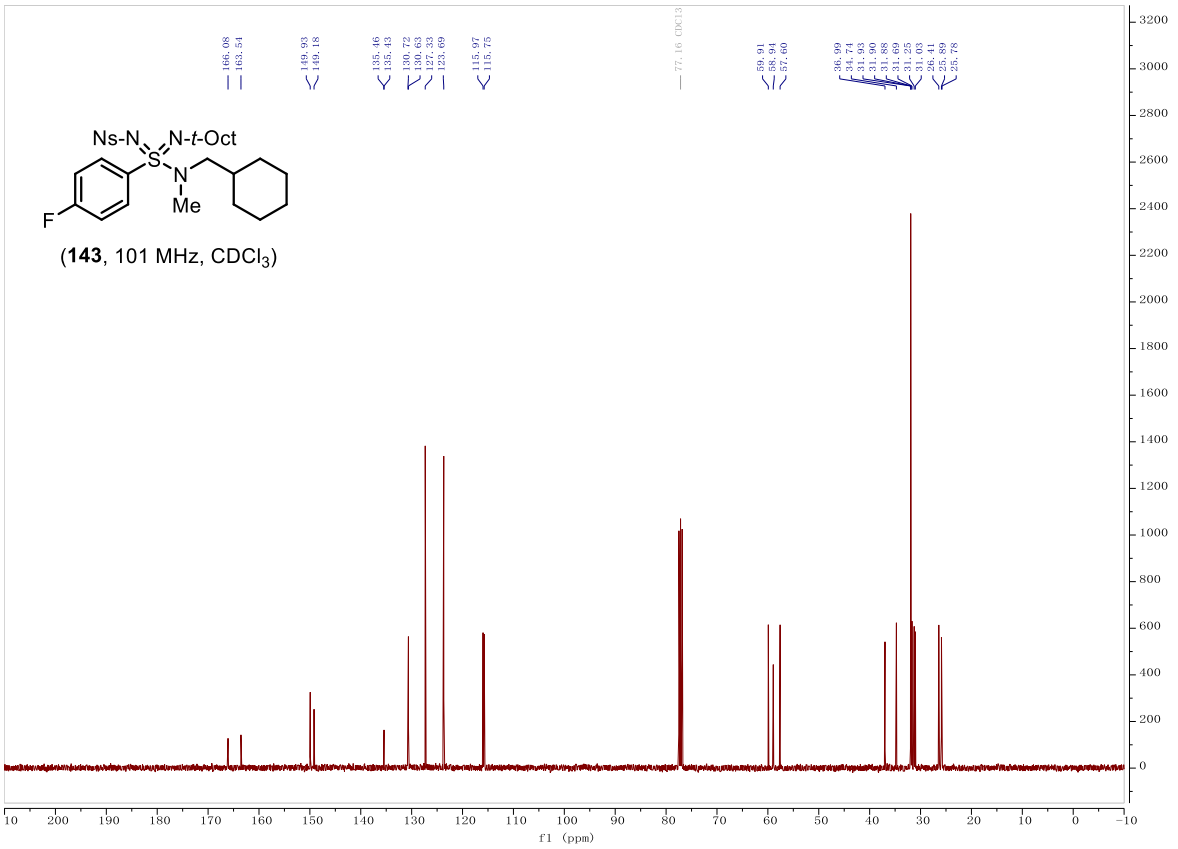
(**142**, 101 MHz, $CDCl_3$)

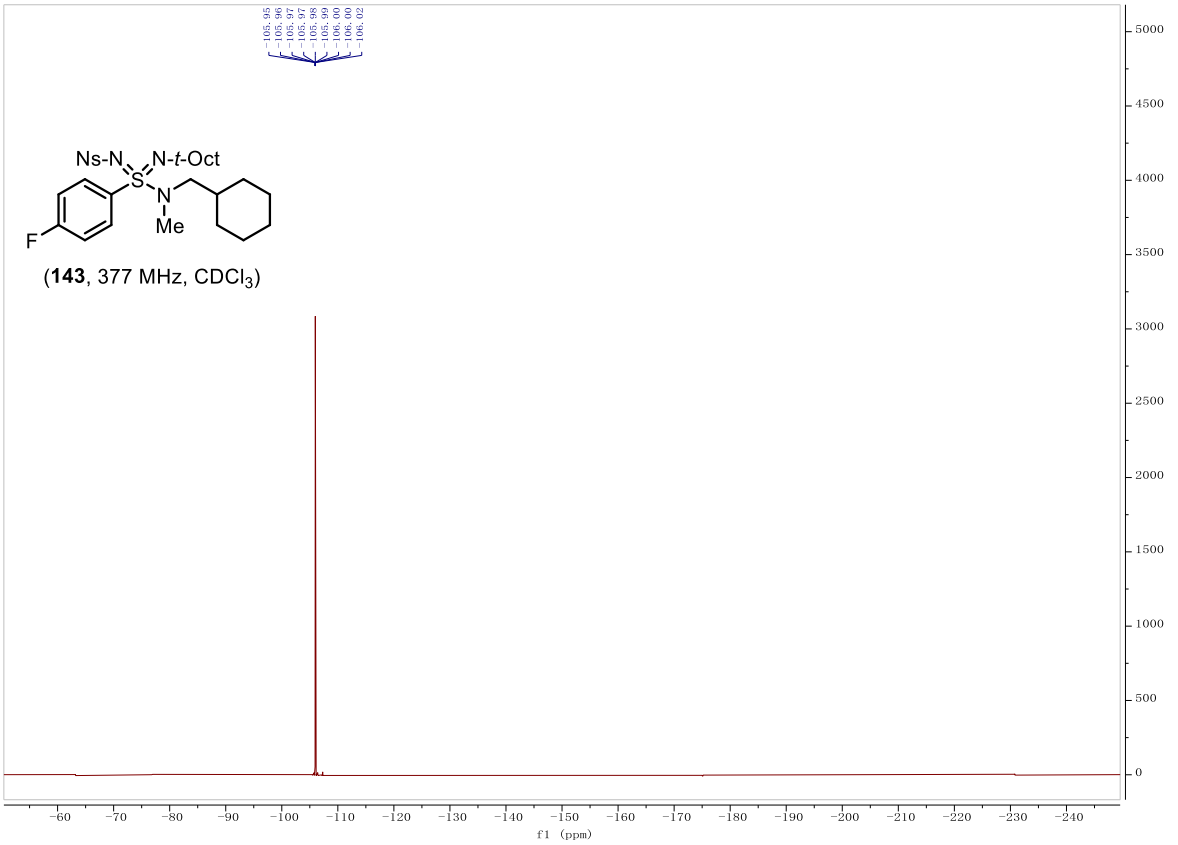


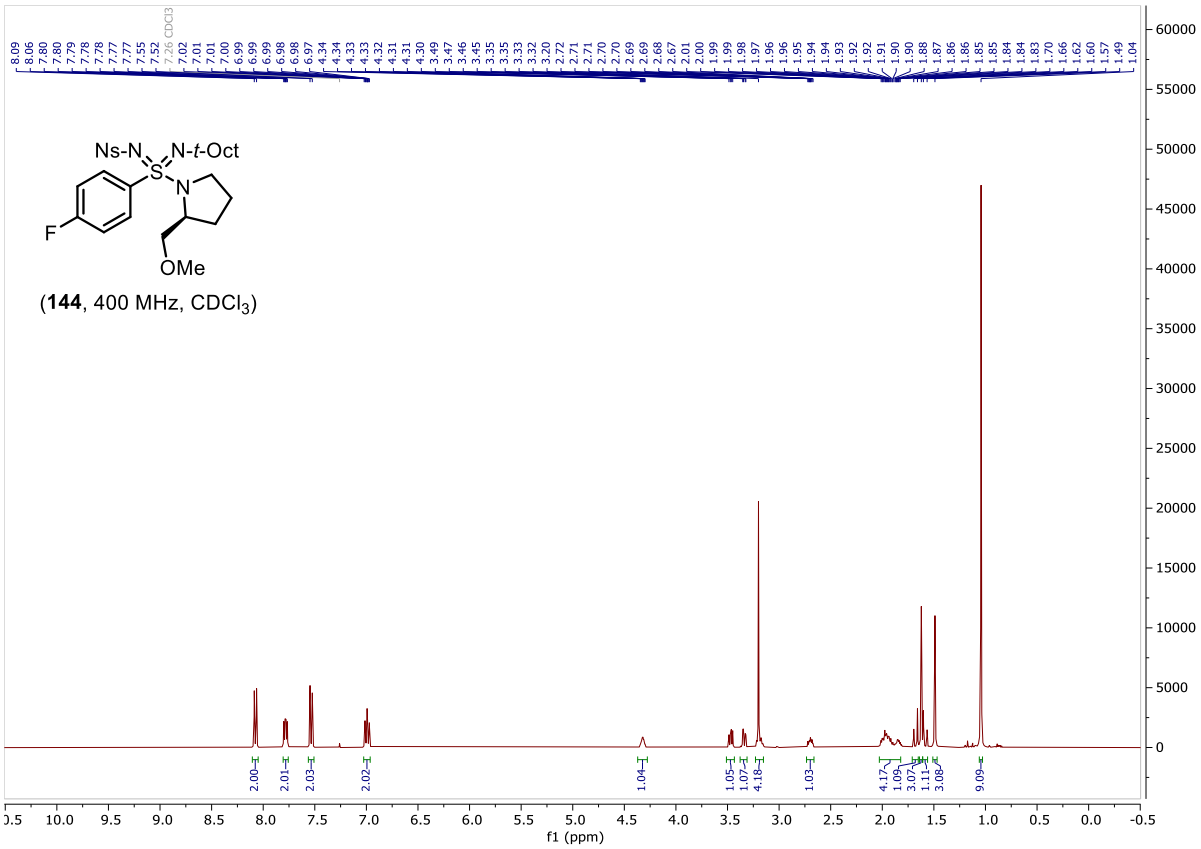
(**142**, 377 MHz, $CDCl_3$)



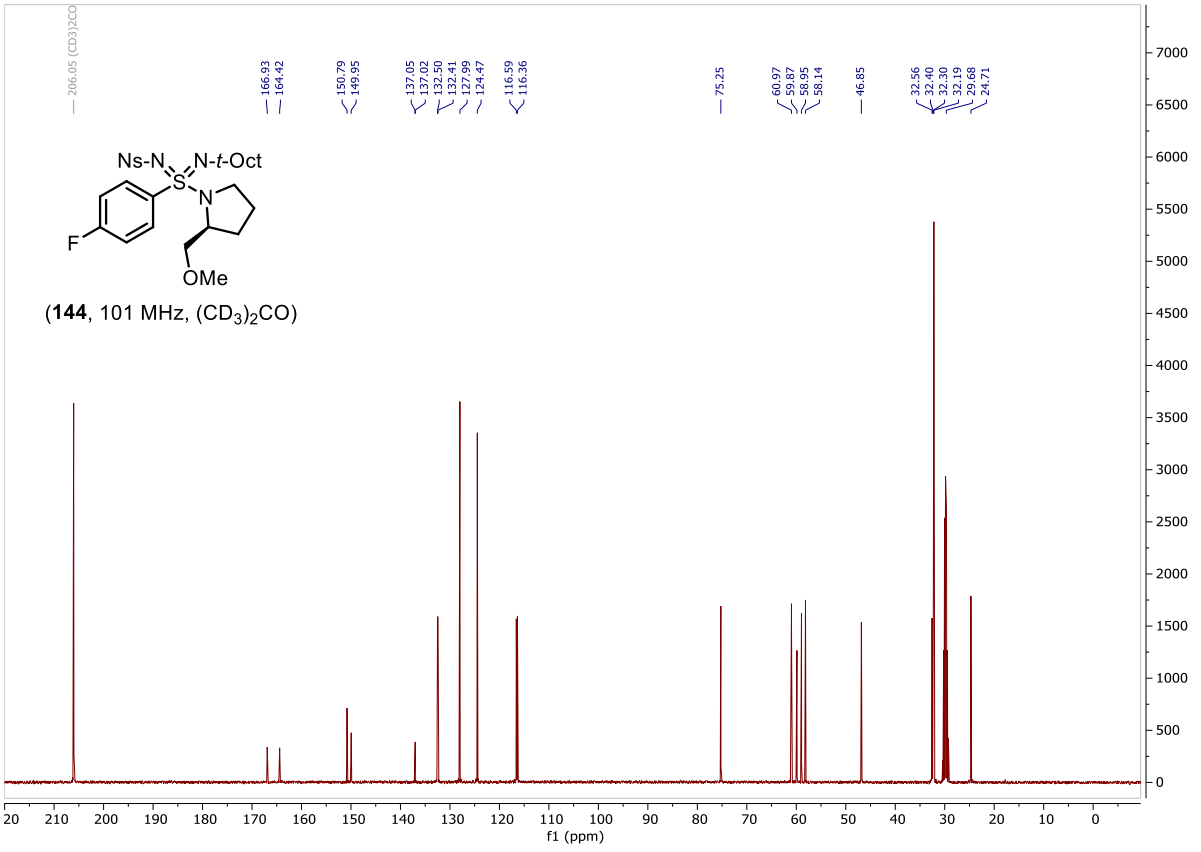
(**143**, 400 MHz, $CDCl_3$)


Ns-N
N-t-Oct
S
N
Me
F
(143, 101 MHz, CDCl3)
f1 (ppm)

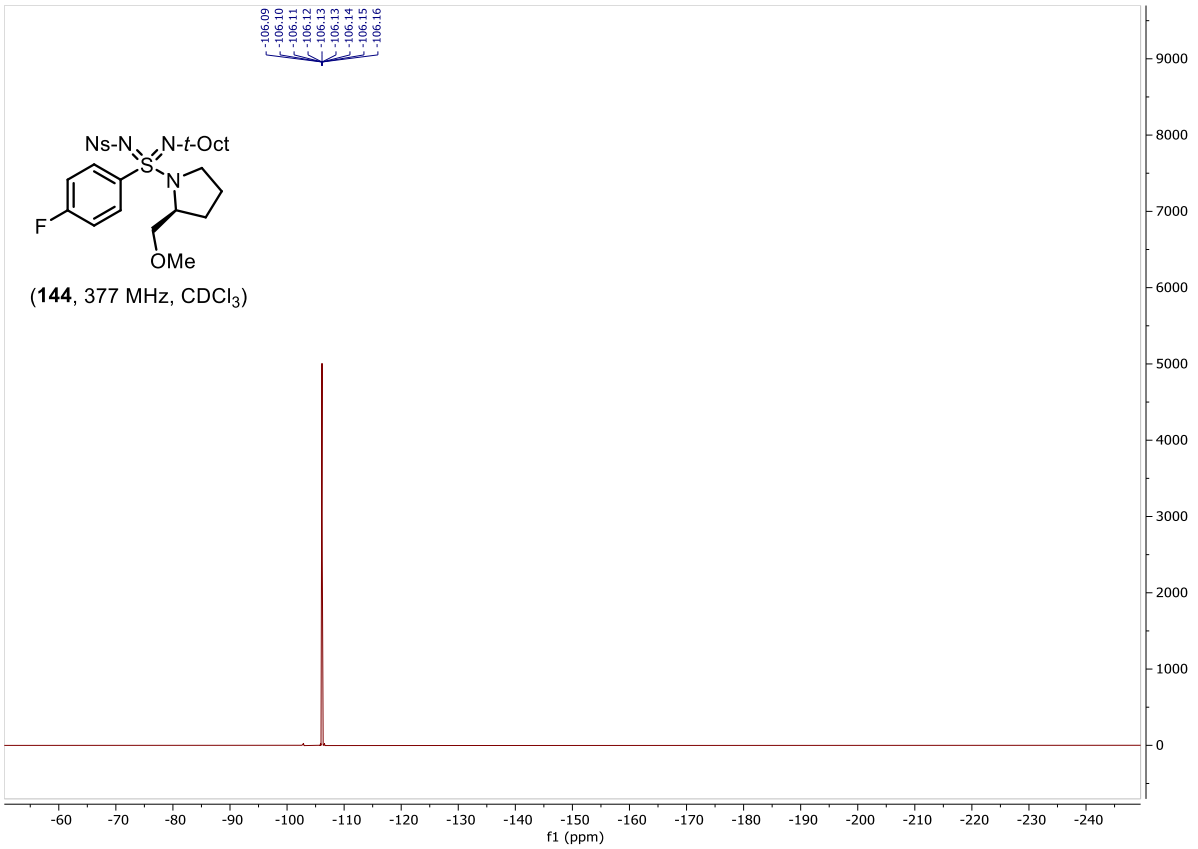

Ns-N
N-t-Oct
S
N
Me
F
(143, 377 MHz, CDCl3)
f1 (ppm)



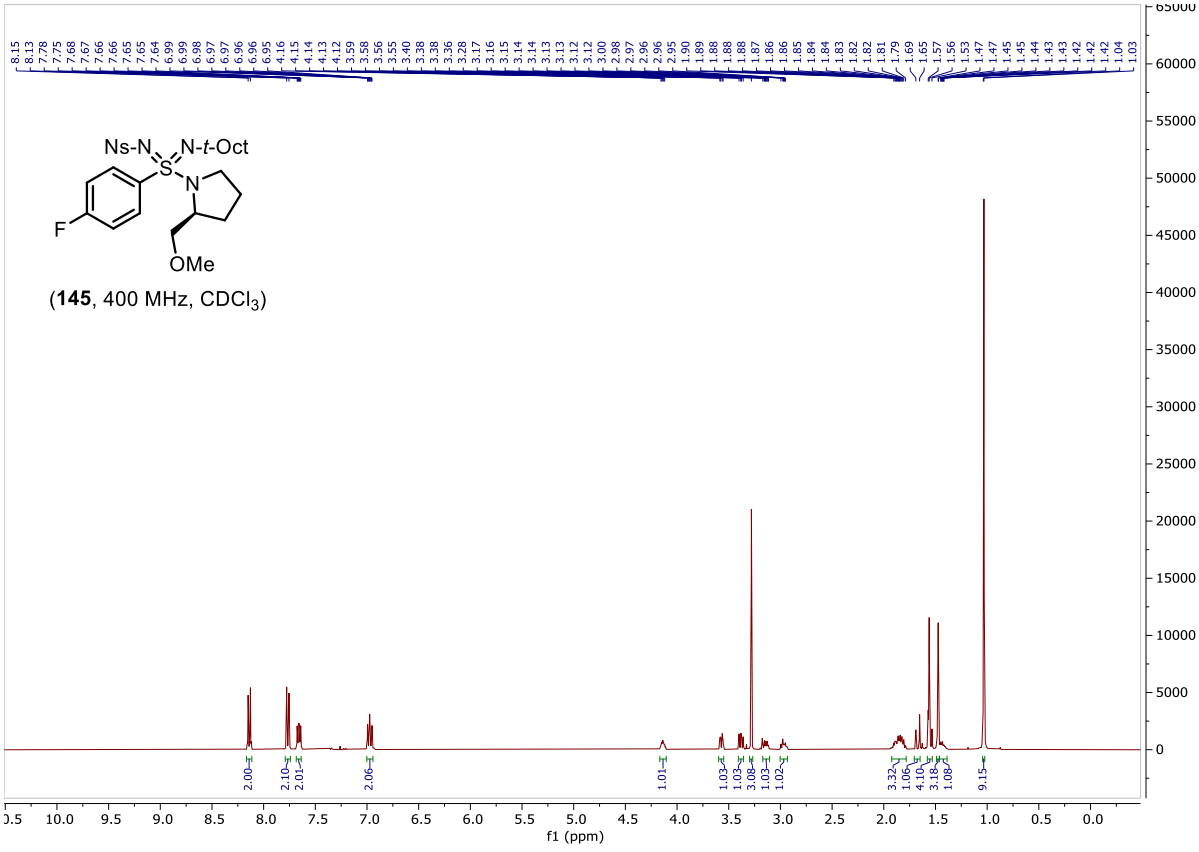
(**144**, 400 MHz, $CDCl_3$)



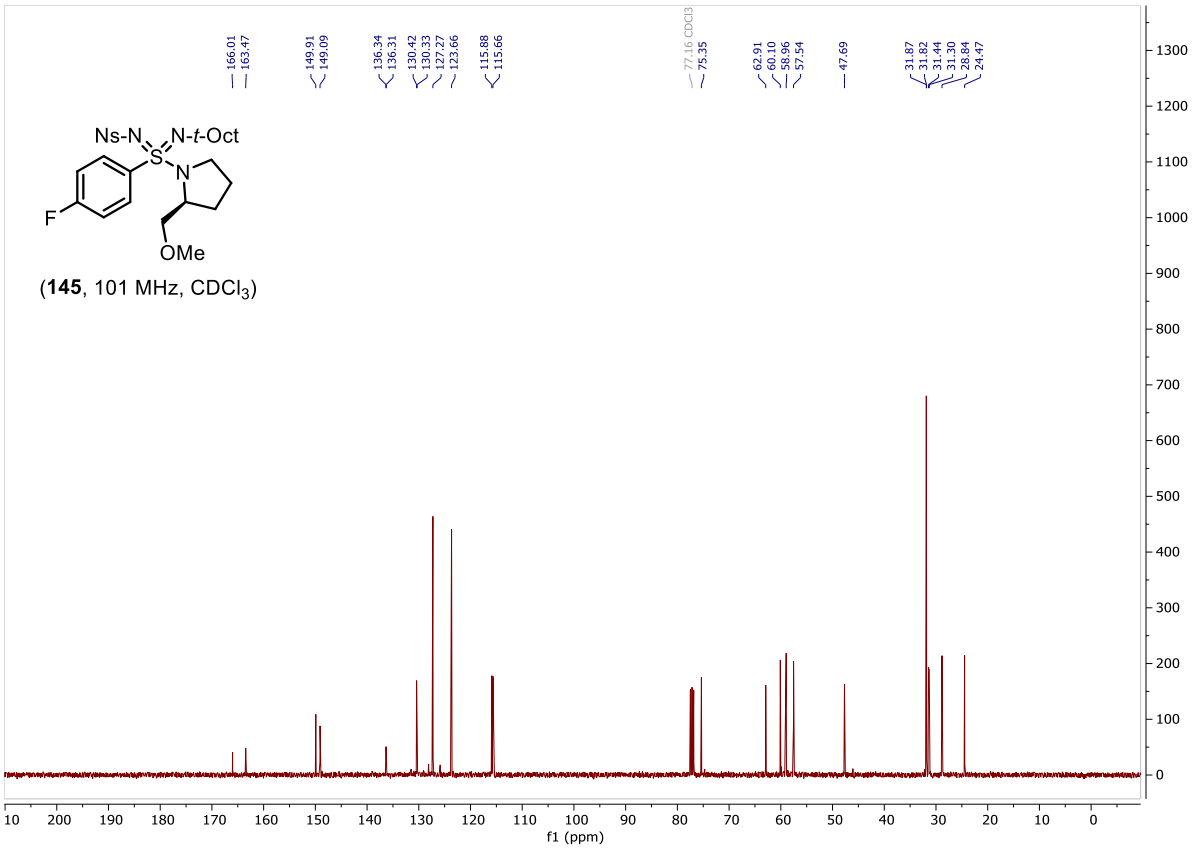
(**144**, 101 MHz, $(CD_3)_2CO$)



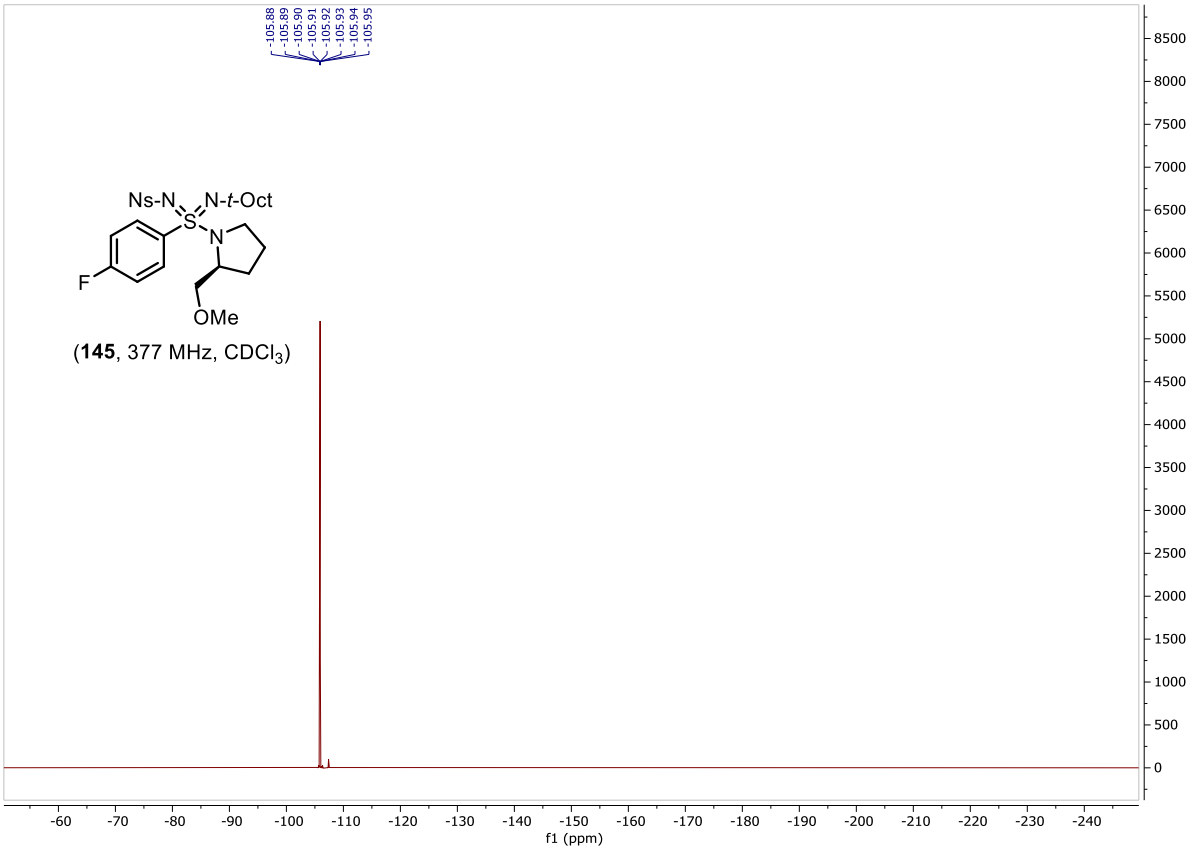
(**144**, 377 MHz, $CDCl_3$)



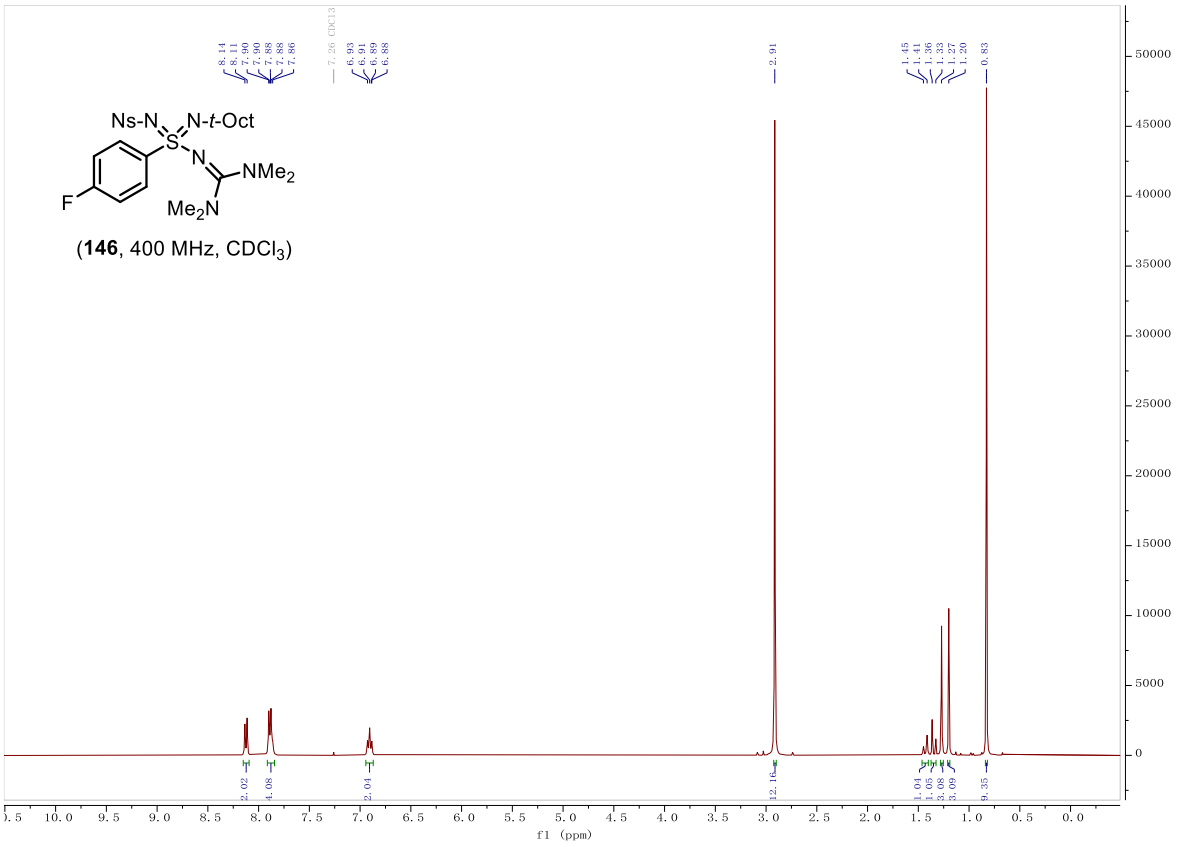
(**145**, 400 MHz, $CDCl_3$)

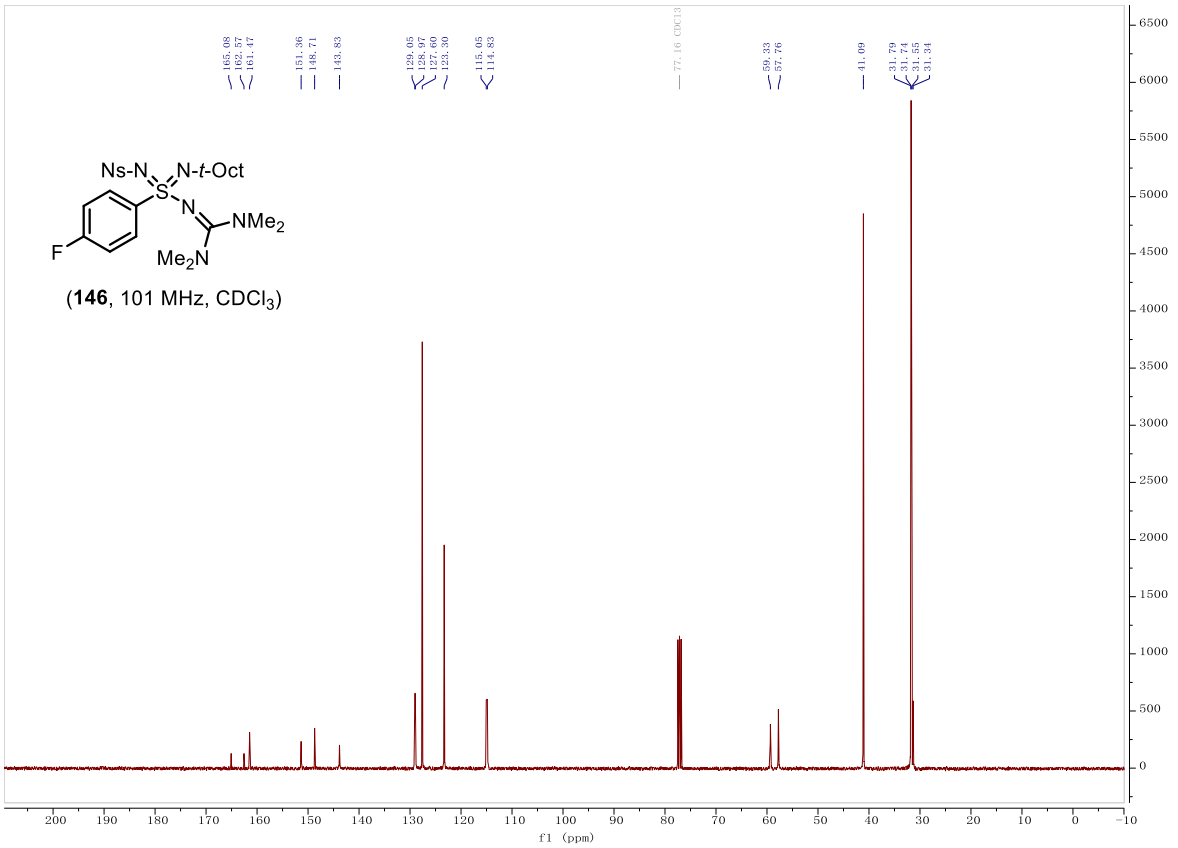


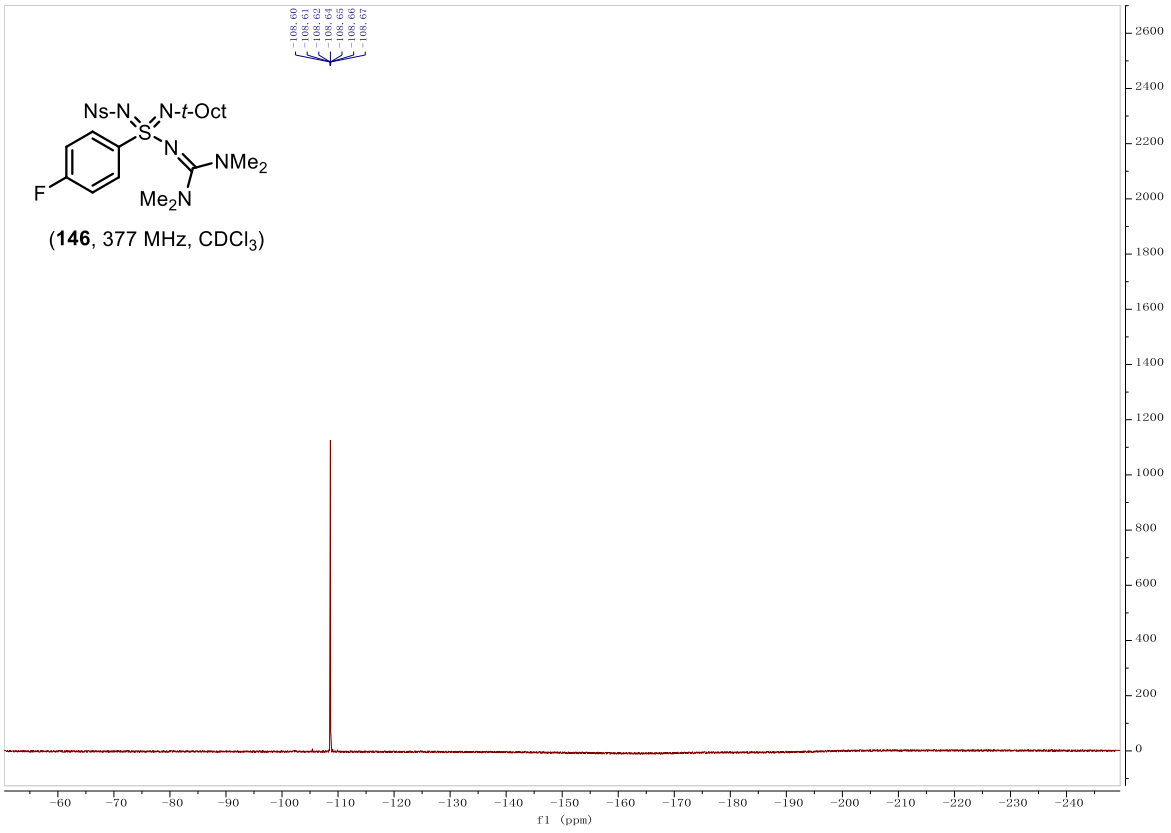
(**145**, 101 MHz, $CDCl_3$)



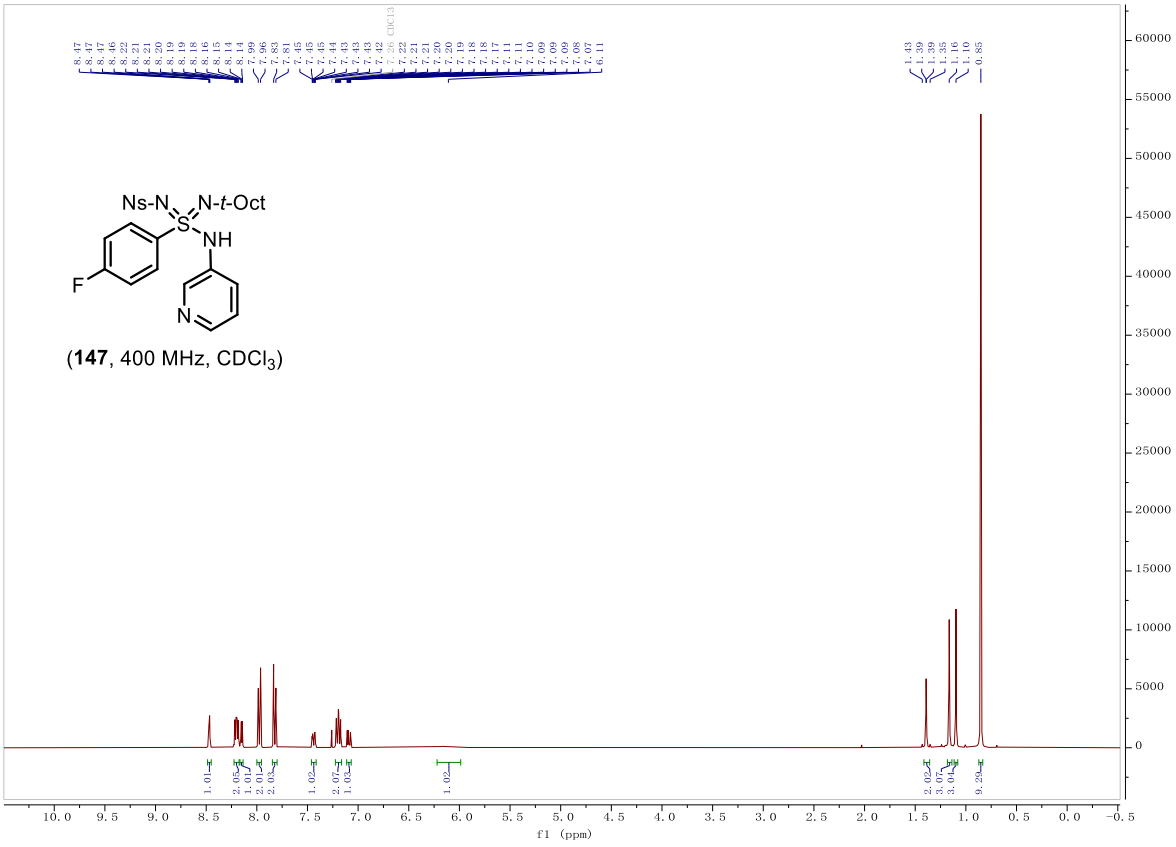
(**145**, 377 MHz, $CDCl_3$)


Ns-N
N-t-Oct
S
N
NMe2
F
Me2N
(146, 400 MHz, CDCl3)
f1 (ppm)

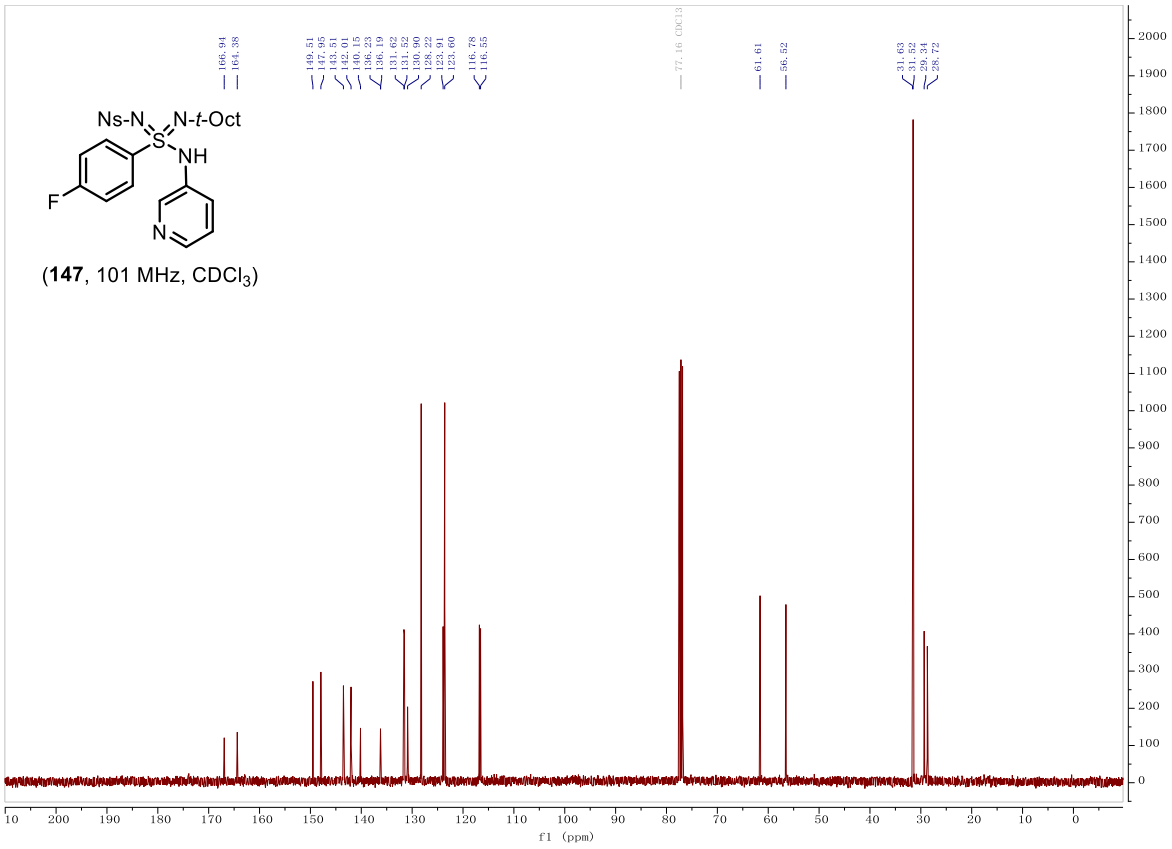

Ns-N
N-t-Oct
S
N
NMe2
F
Me2N
(146, 101 MHz, CDCl3)
f1 (ppm)

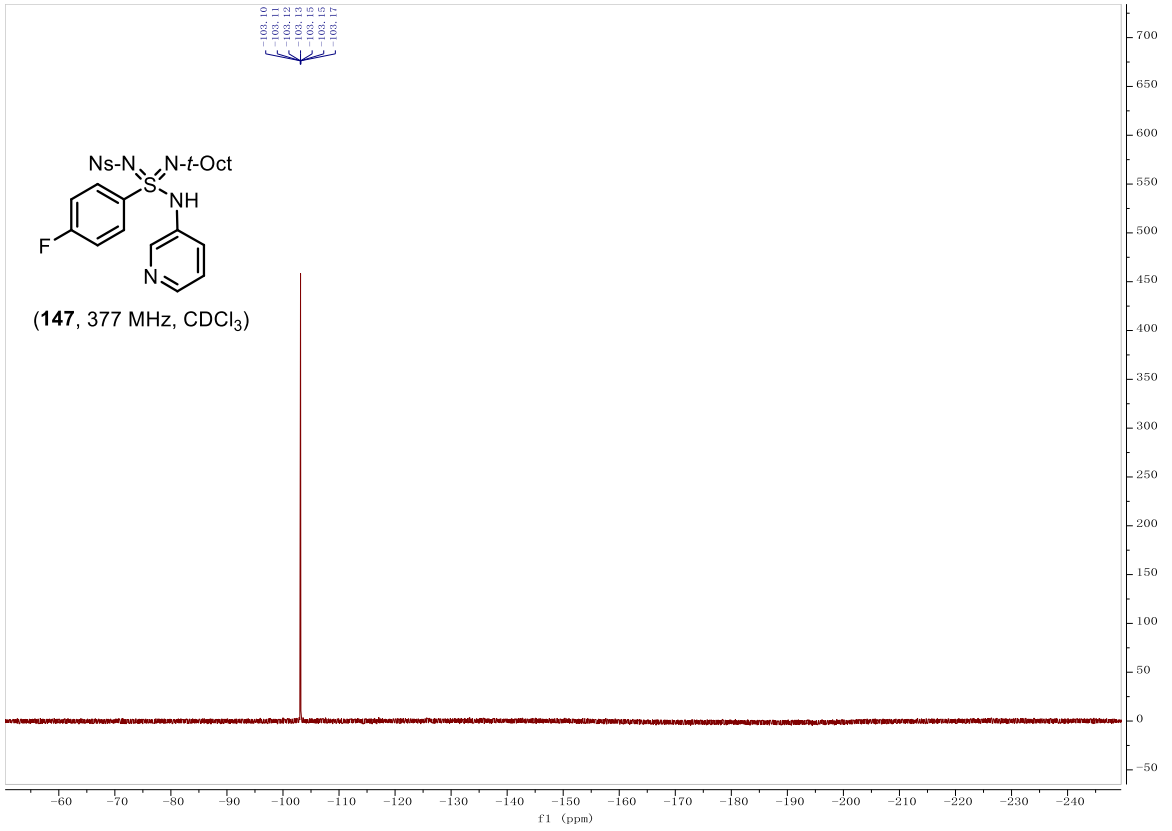


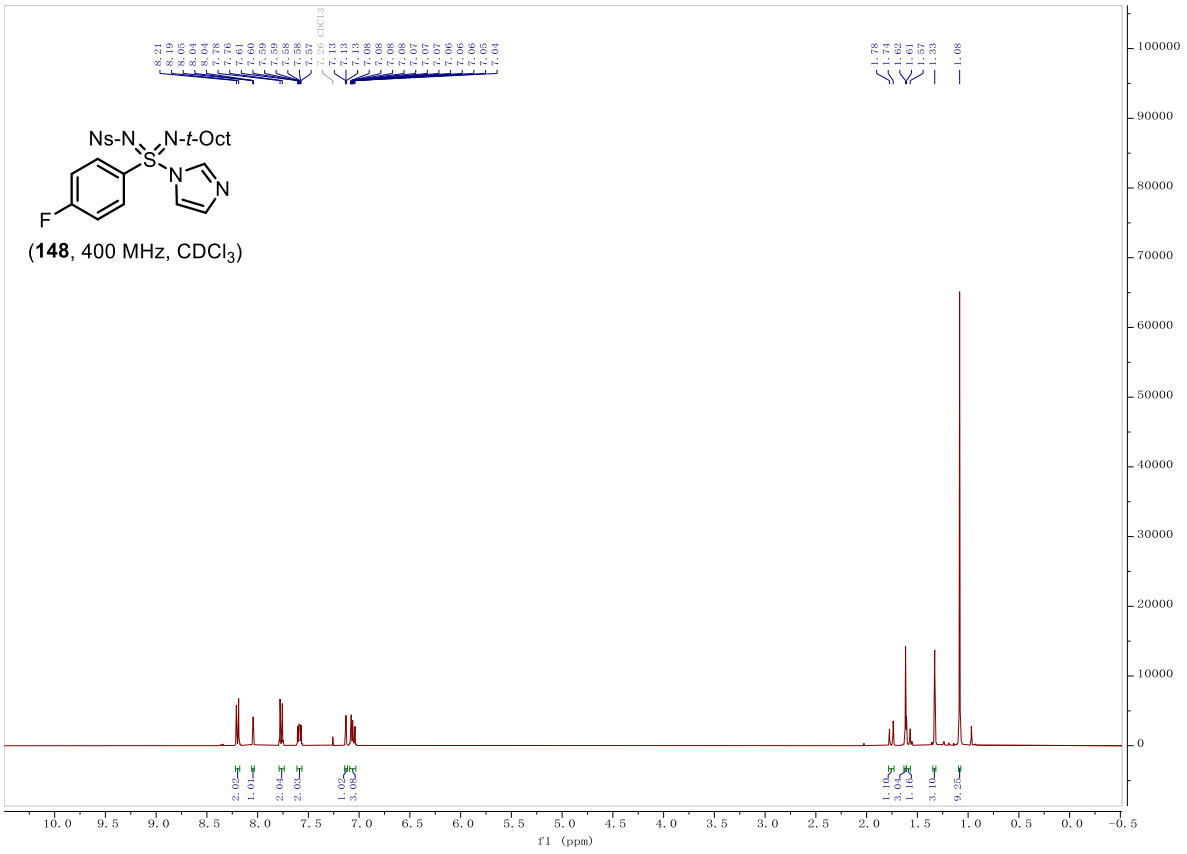
(**146**, 377 MHz, $CDCl_3$)



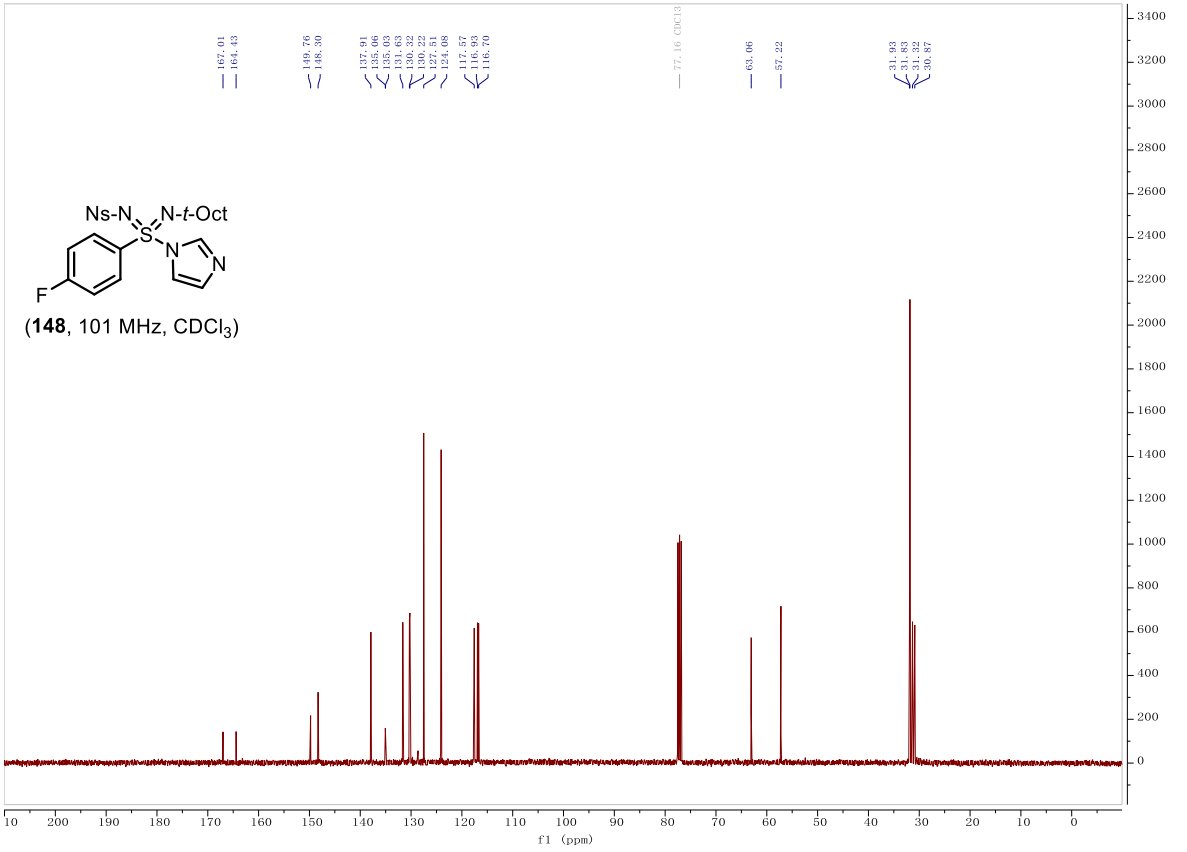
(**147**, 400 MHz, $CDCl_3$)


Ns-N
N-t-Oct
S
NH
F
N
(147, 101 MHz, CDCl3)
166.94
164.38
149.51
147.95
143.51
142.01
140.15
136.23
136.19
131.62
131.52
130.90
128.22
123.91
123.60
116.78
116.55
77.16 CDCl3
61.61
56.52
31.63
31.52
29.34
28.72
f1 (ppm)

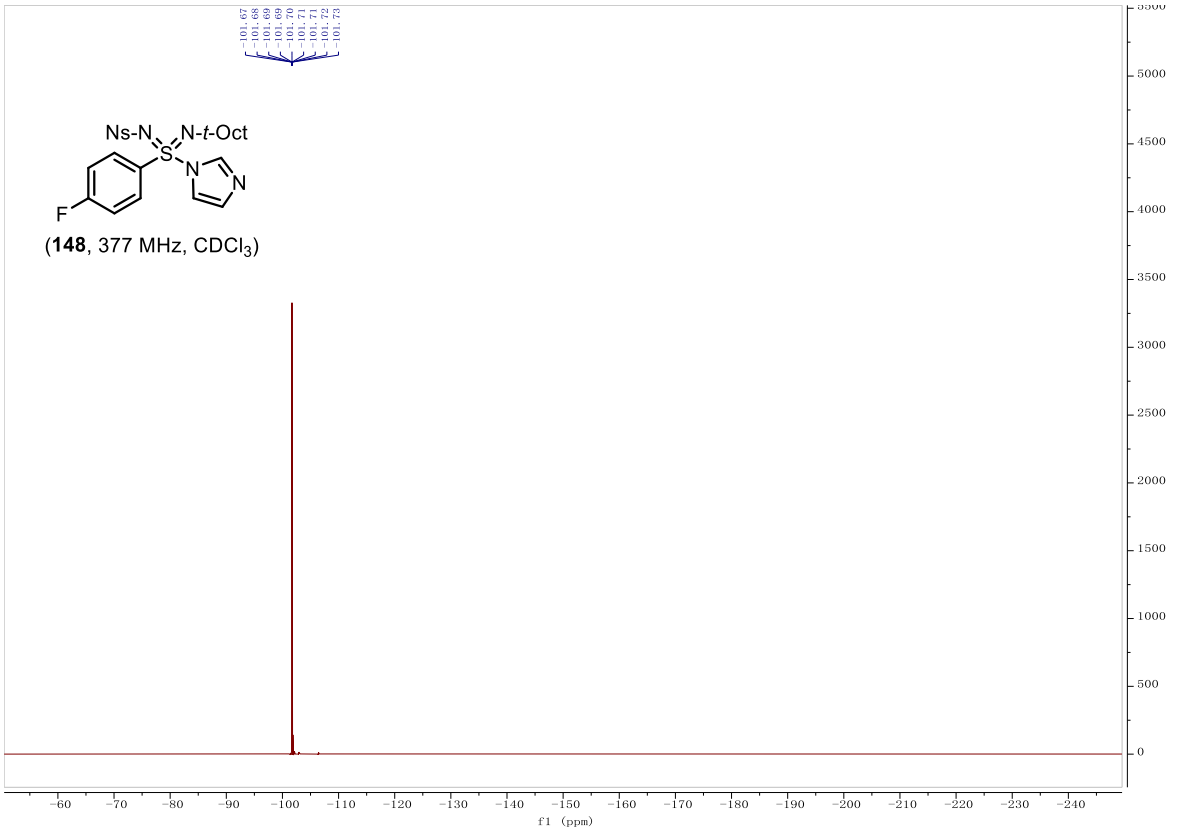

Ns-N
N-t-Oct
S
NH
F
N
(147, 377 MHz, CDCl3)
103.10
103.11
103.12
103.13
103.15
103.15
103.17
f1 (ppm)

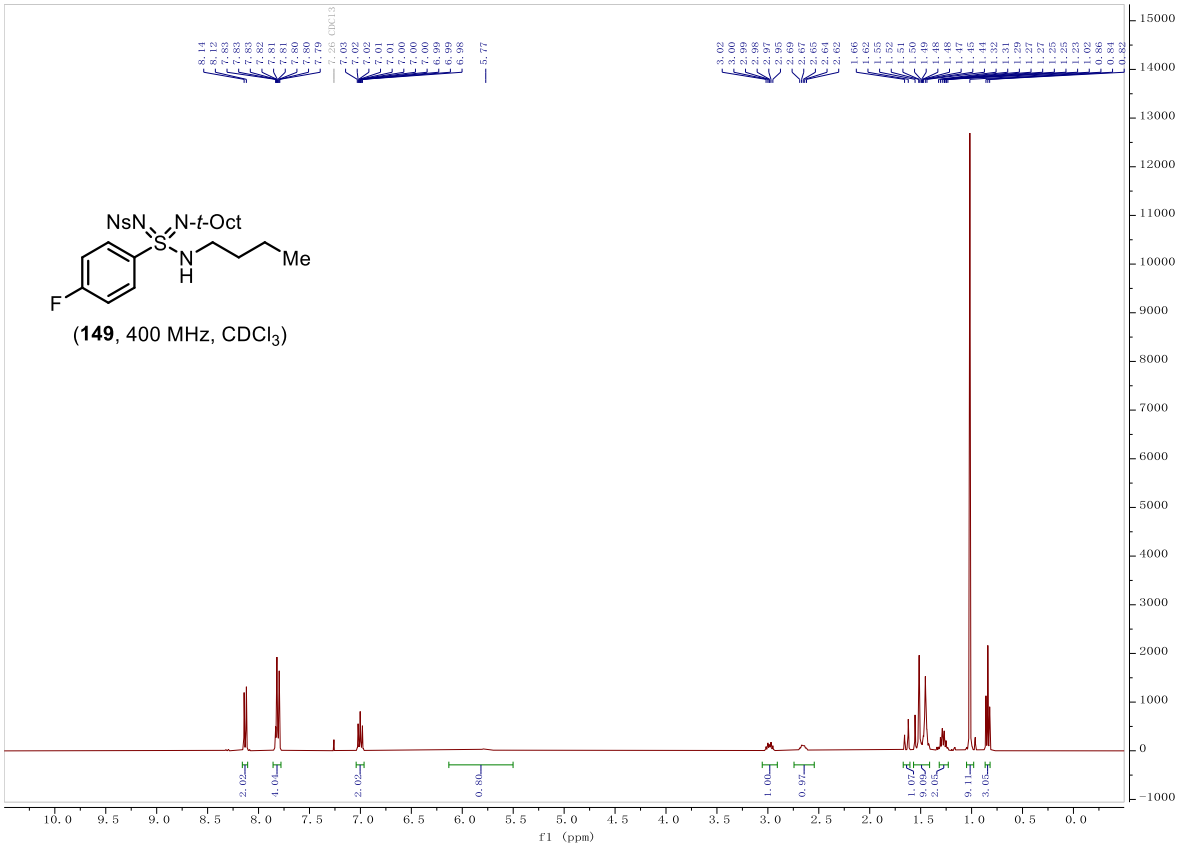


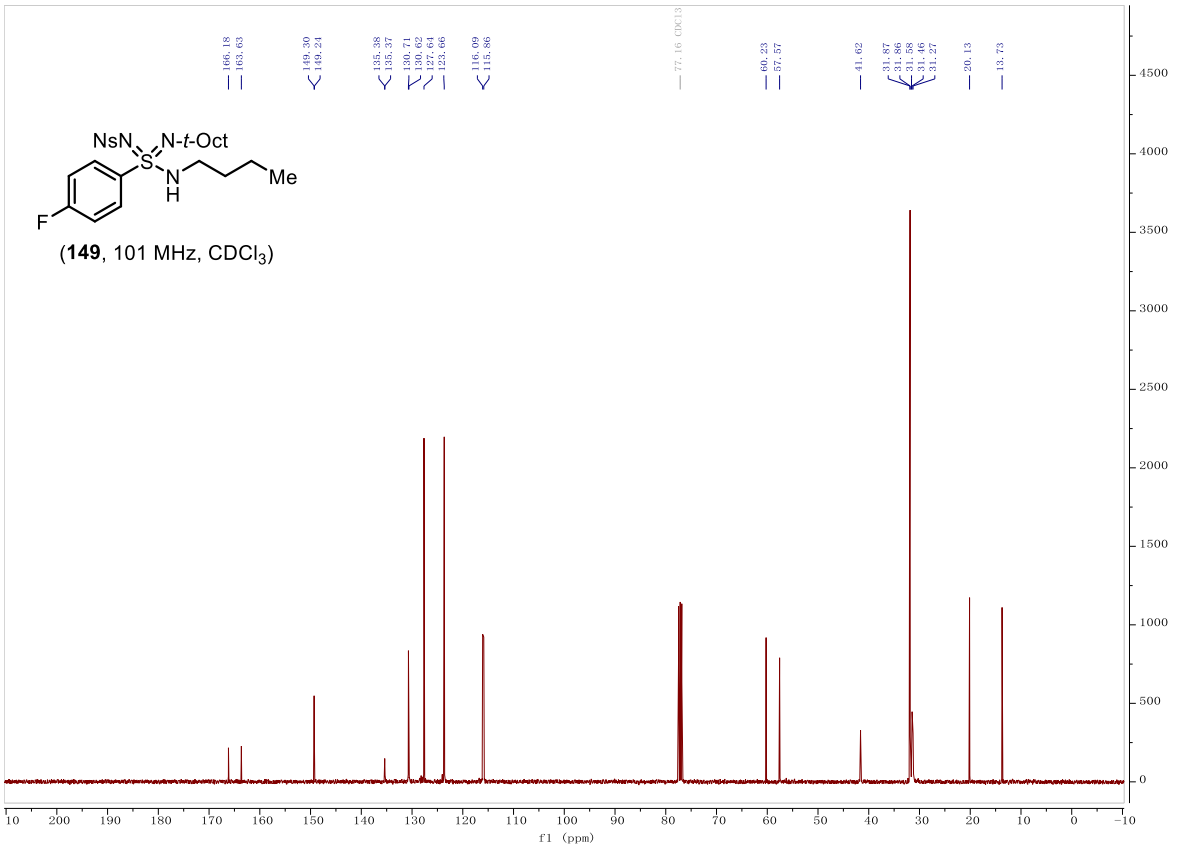
(**148**, 400 MHz, $CDCl_3$)



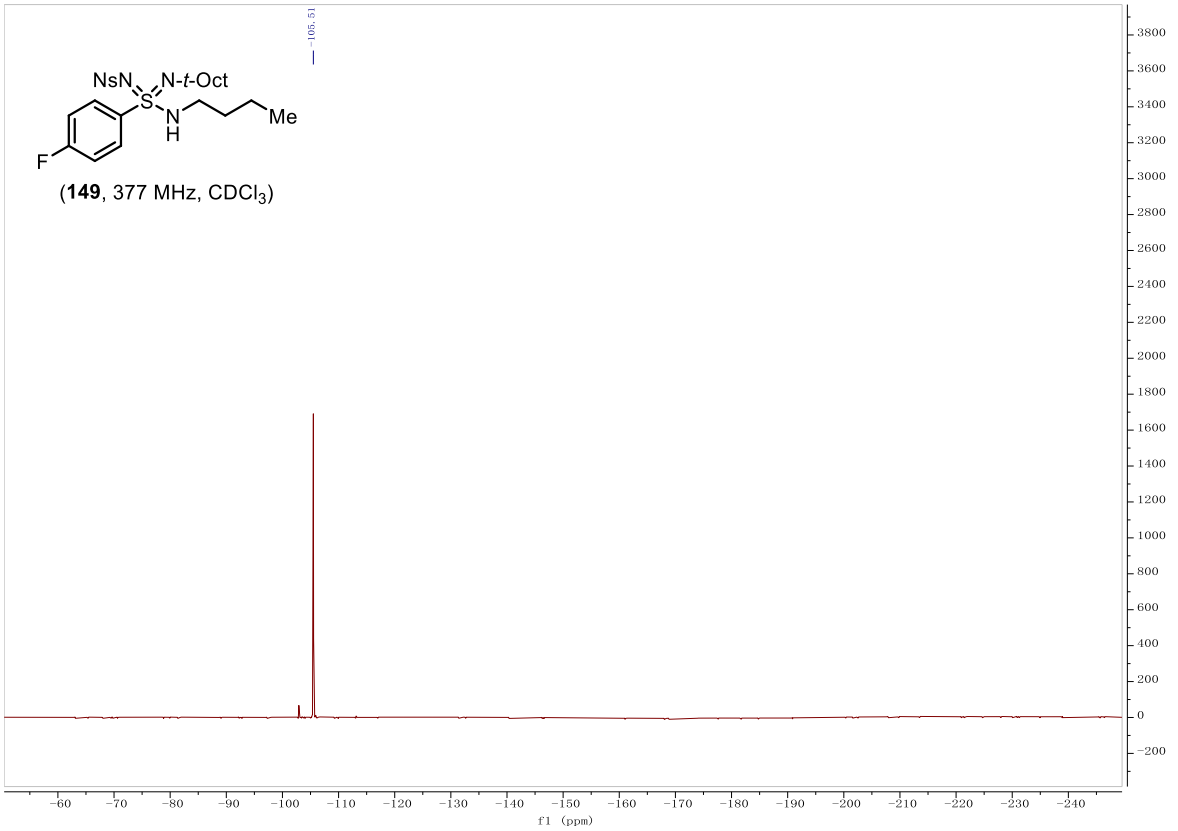
(**148**, 101 MHz, $CDCl_3$)


Ns-N
N-t-Oct
S
N
N
F
(148, 377 MHz, CDCl3)
f1 (ppm)

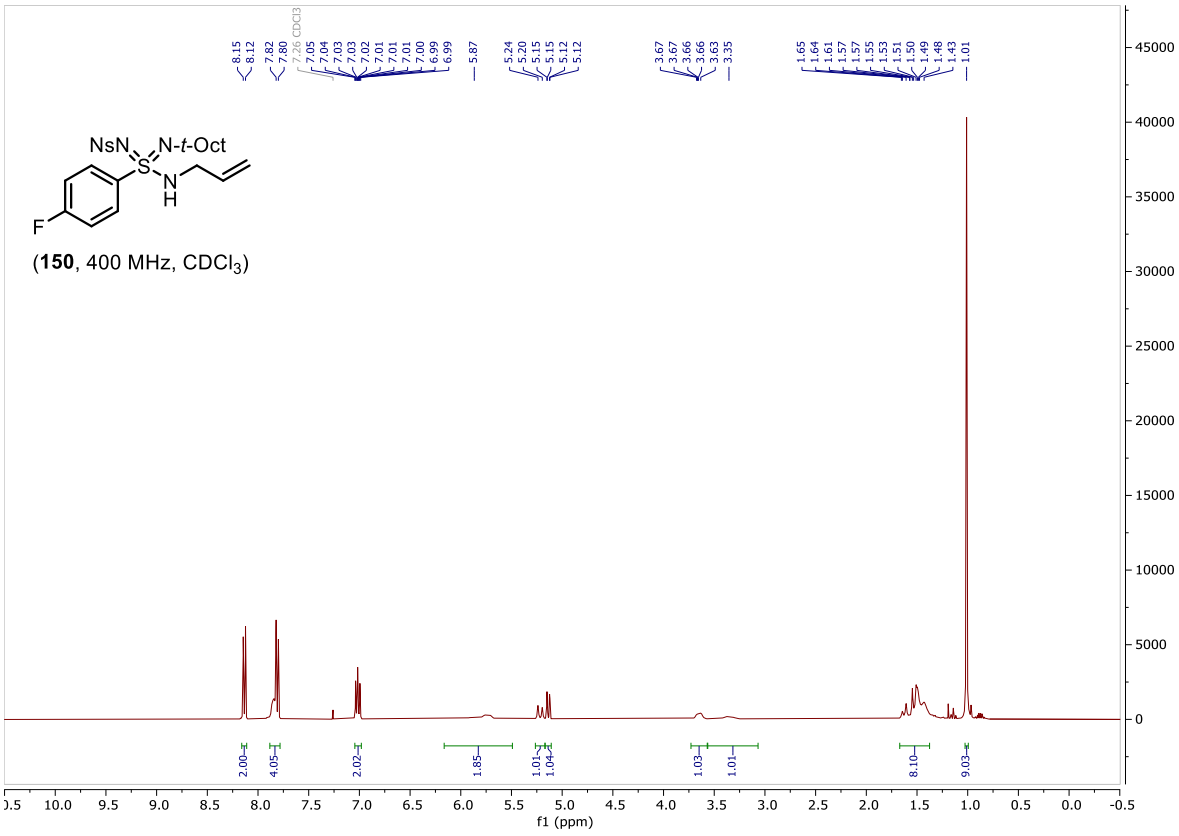

NsN
N-t-Oct
S
N
H
Me
F
(149, 400 MHz, CDCl3)
f1 (ppm)

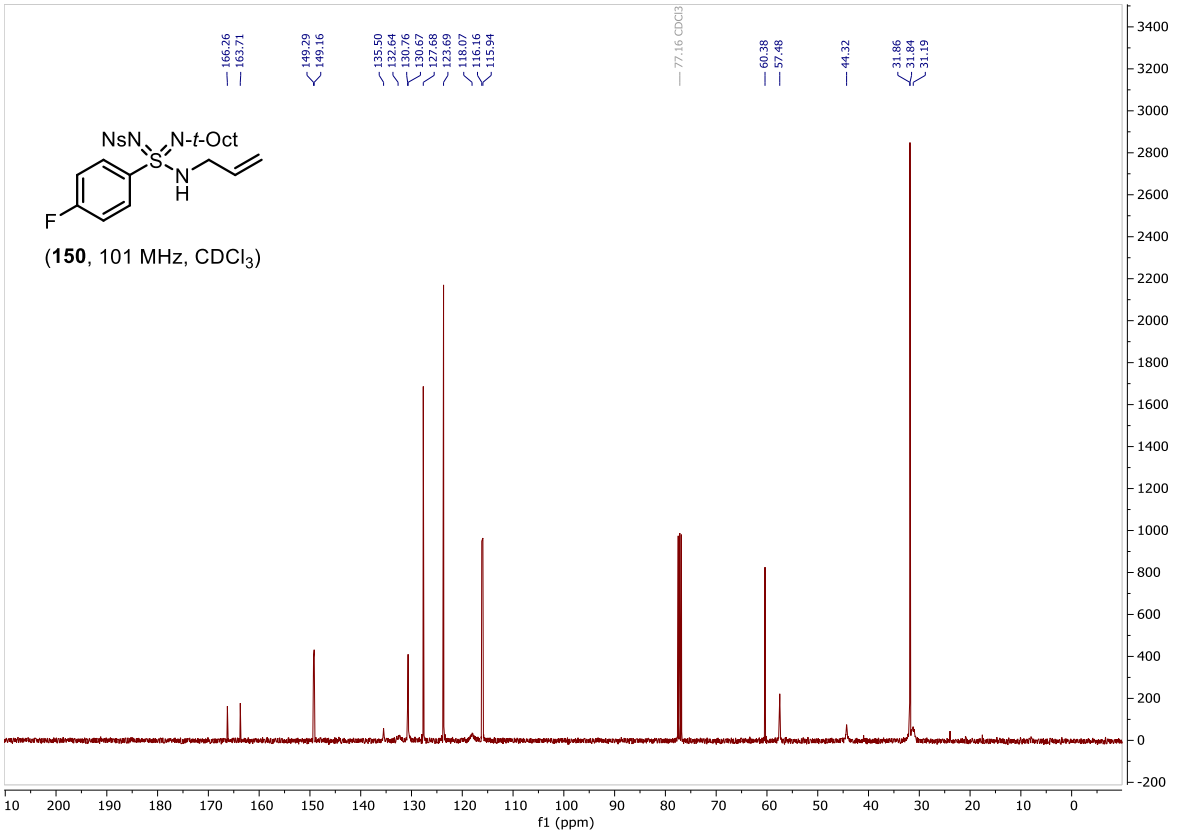


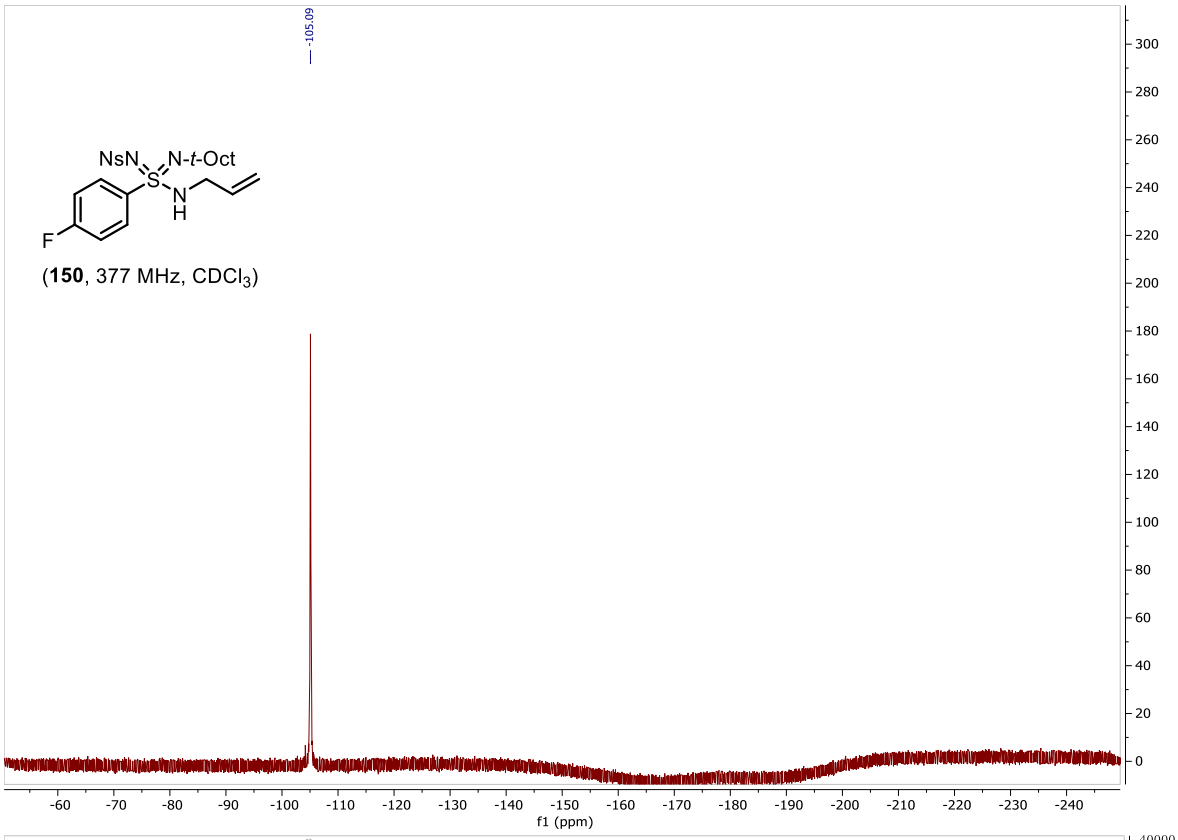
(**149**, 101 MHz, $CDCl_3$)



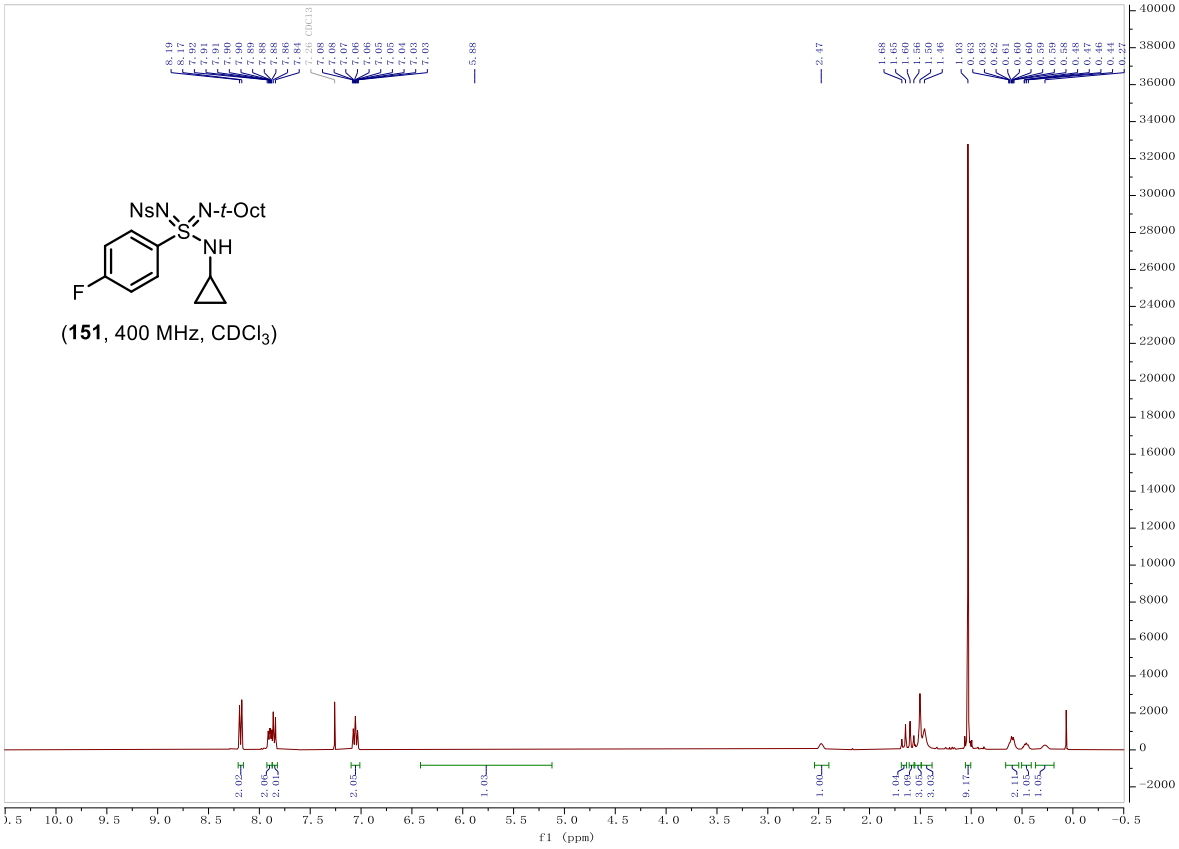
(**149**, 377 MHz, $CDCl_3$)


NsN
N-t-Oct
S
N
H
F
(150, 400 MHz, CDCl3)
f1 (ppm)

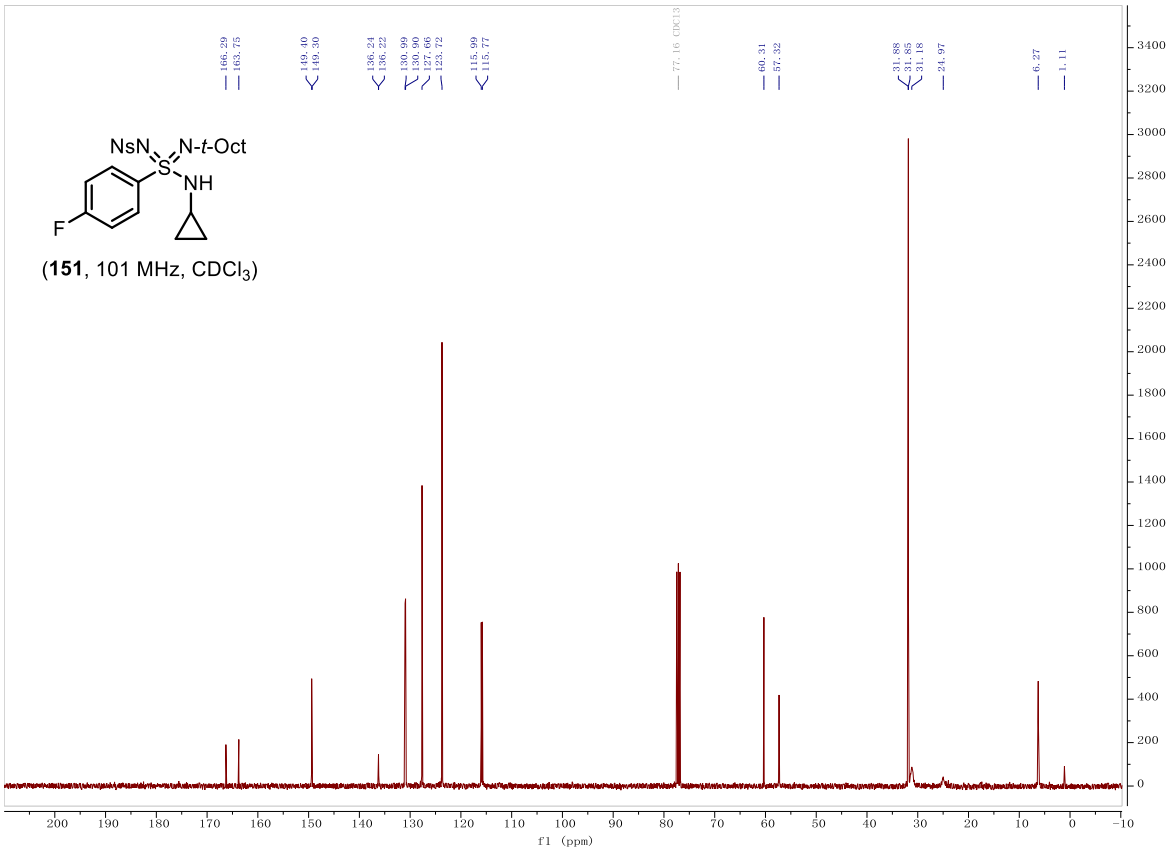

NsN
N-t-Oct
S
N
H
F
(150, 101 MHz, CDCl3)
f1 (ppm)



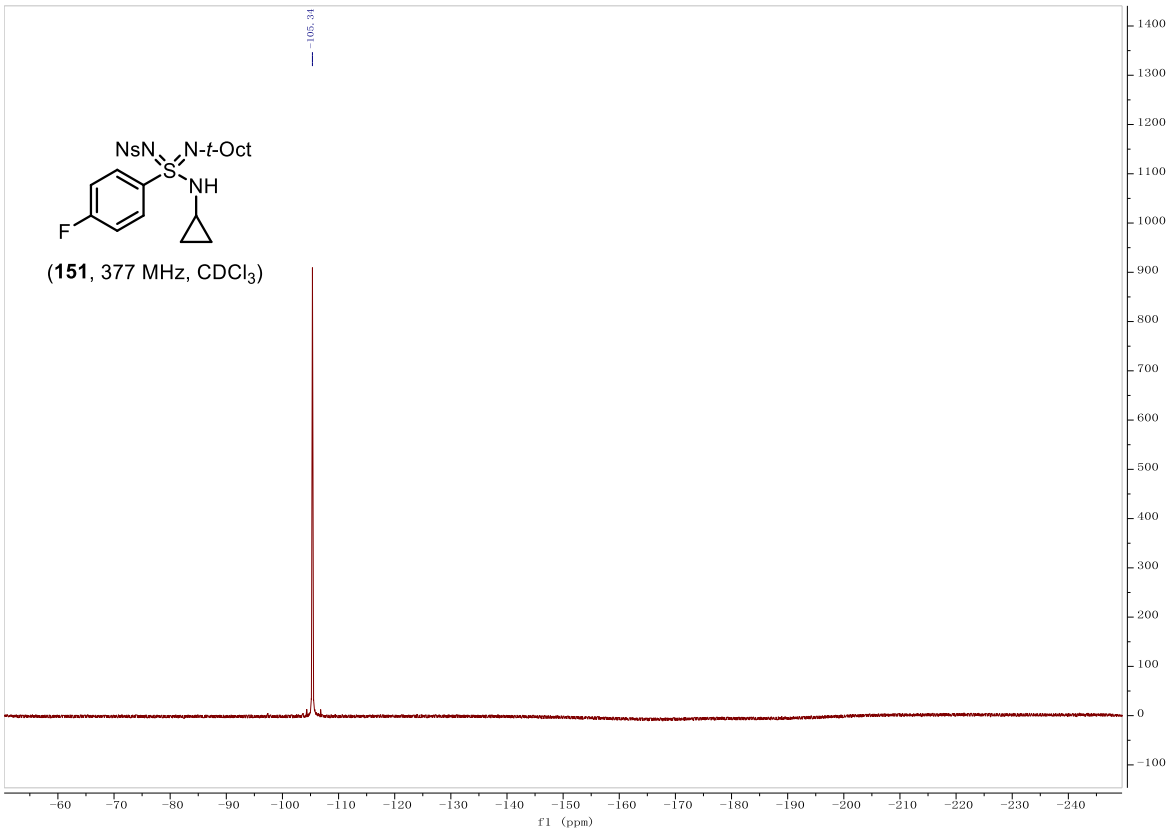
(**150**, 377 MHz, $CDCl_3$)



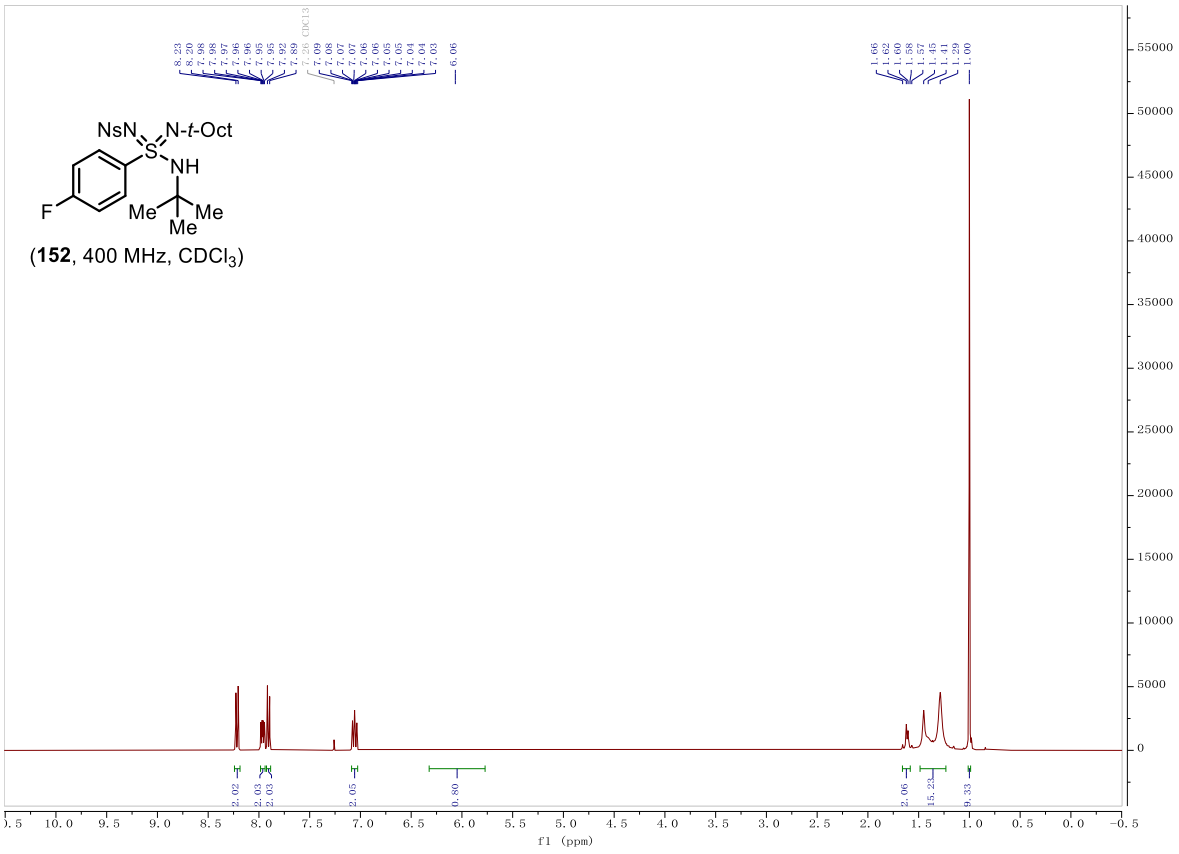
(**151**, 400 MHz, $CDCl_3$)



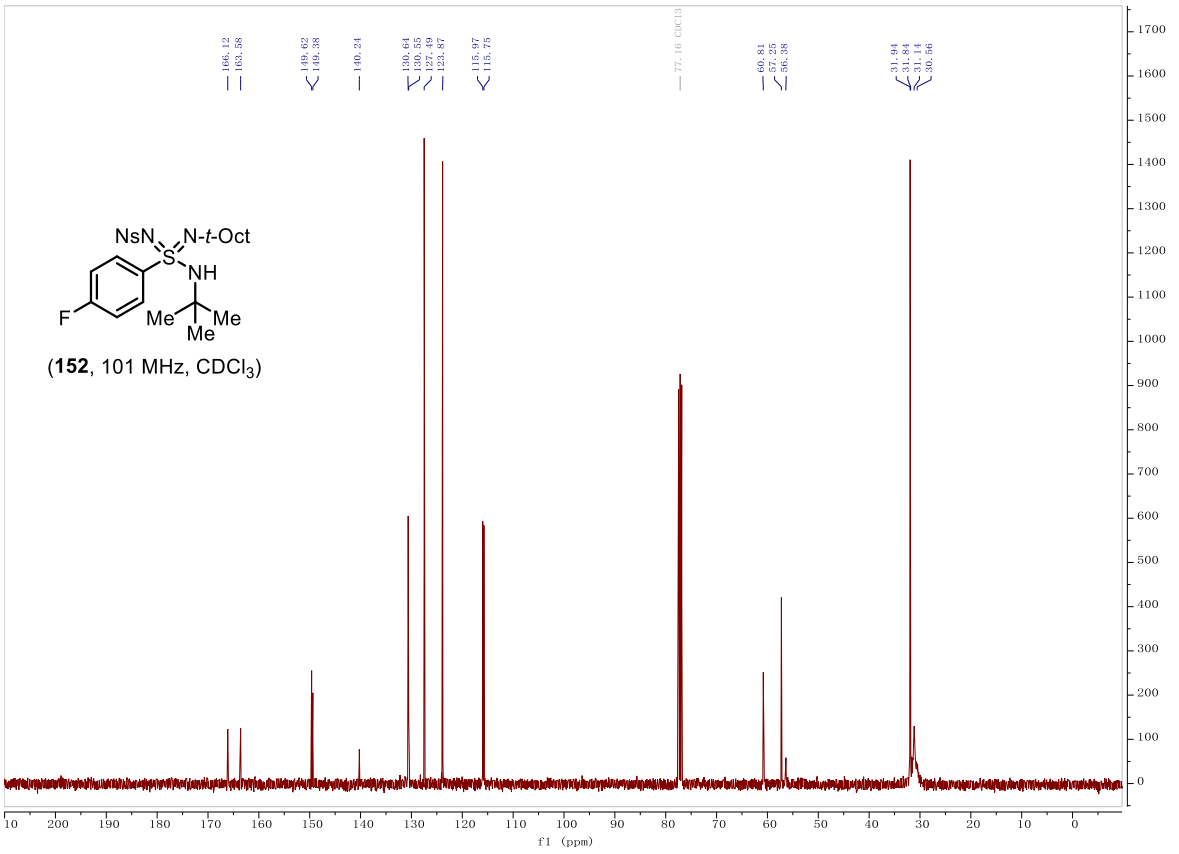
(**151**, 101 MHz, $CDCl_3$)



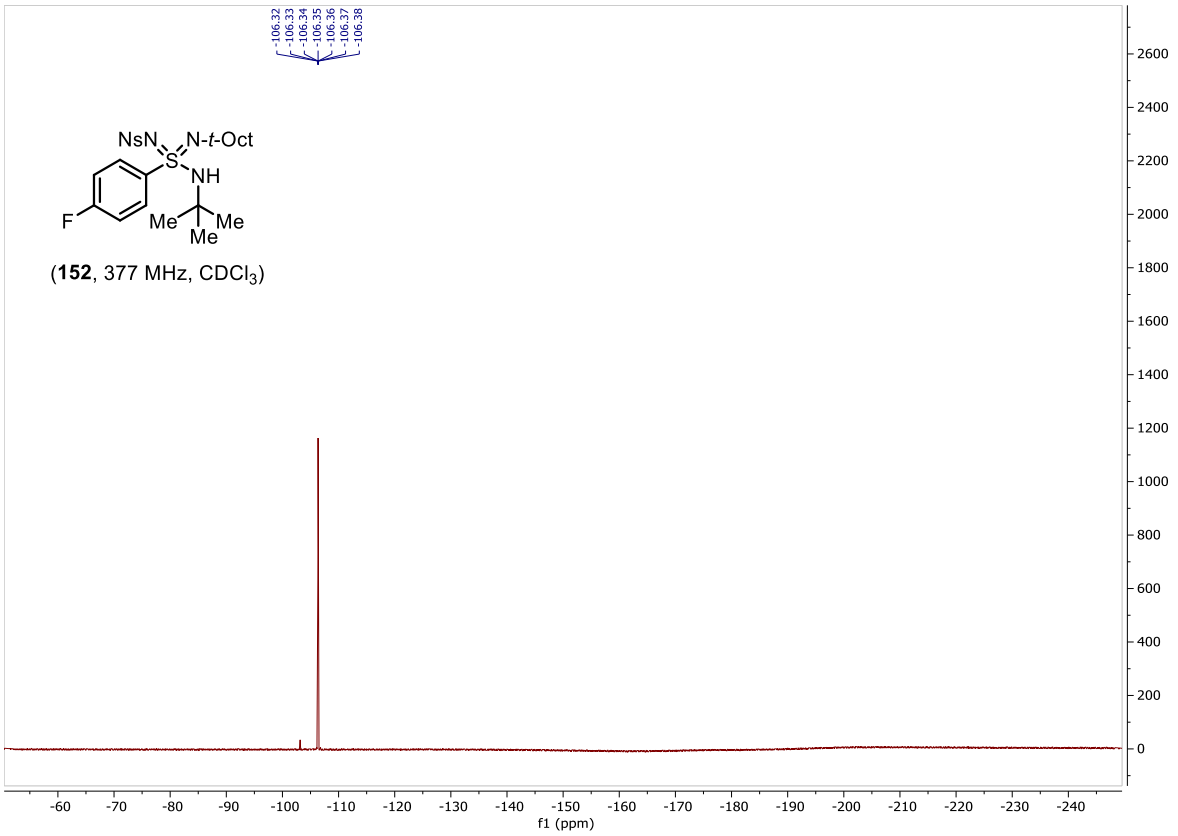
(**151**, 377 MHz, $CDCl_3$)



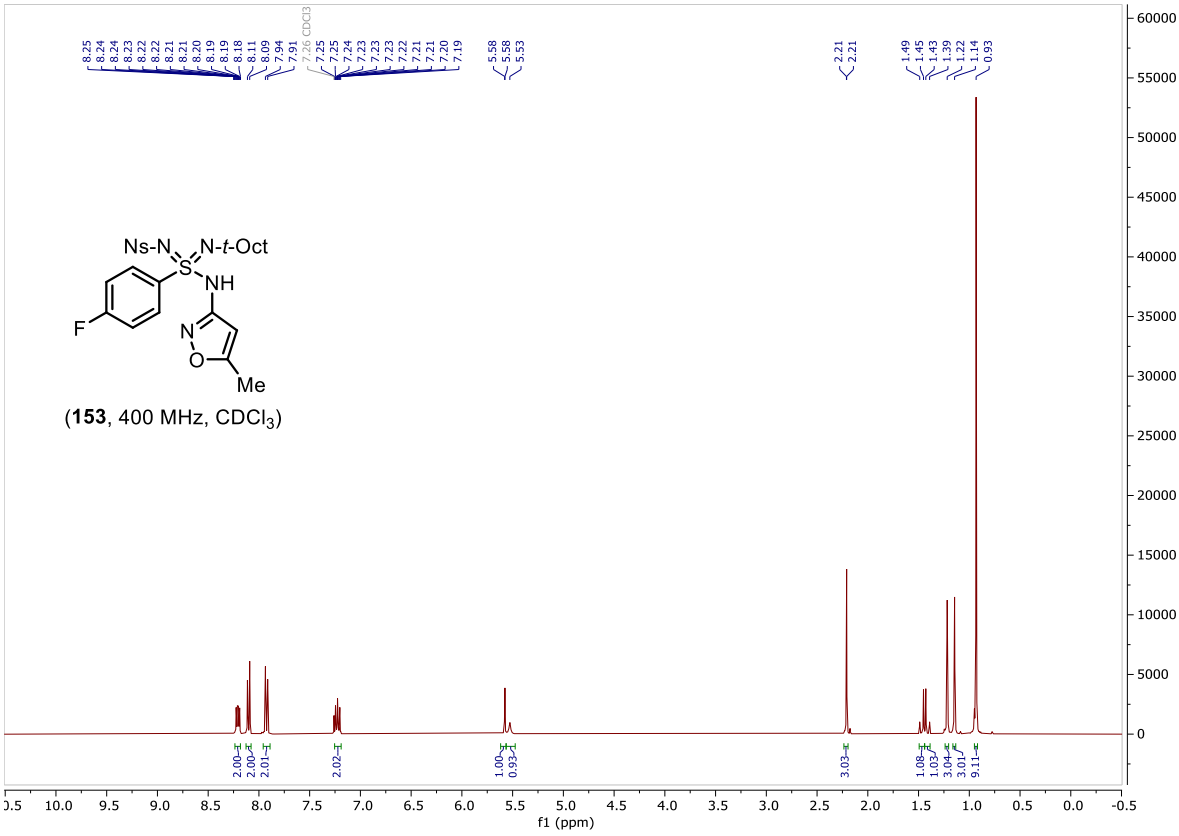
(**152**, 400 MHz, $CDCl_3$)



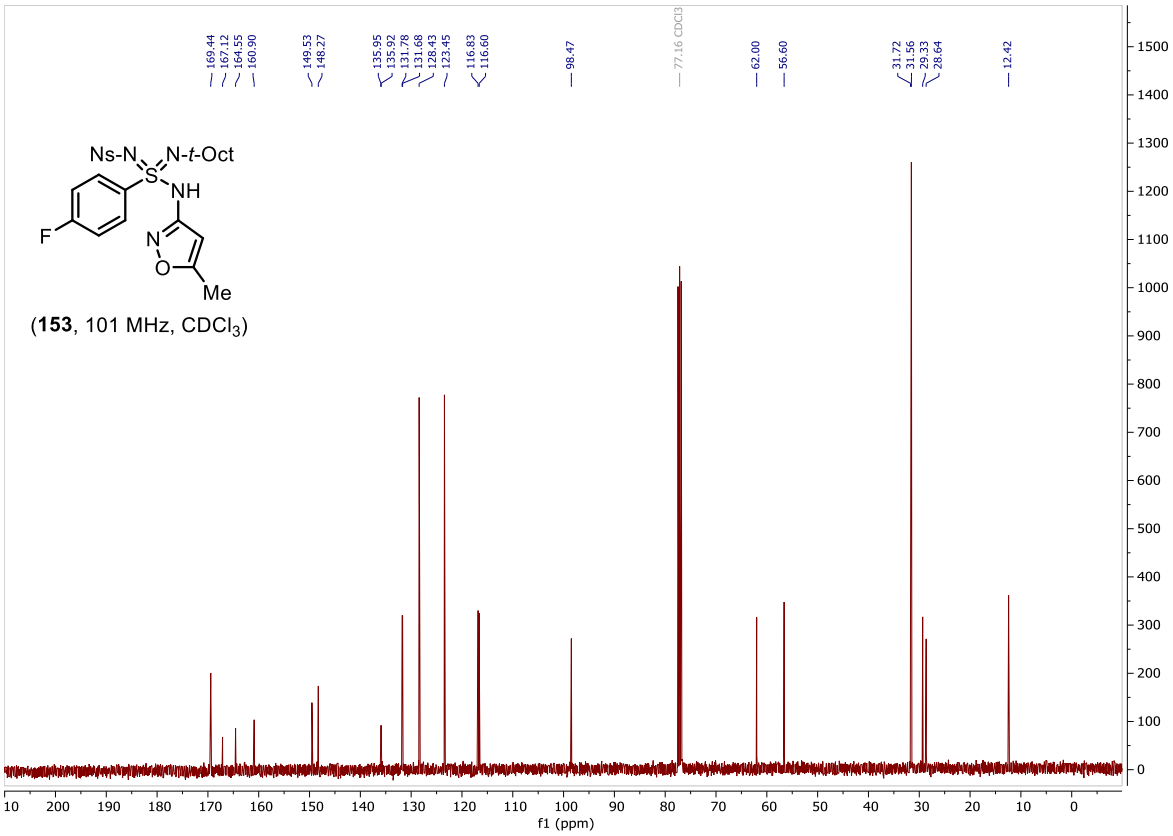
(**152**, 101 MHz, $CDCl_3$)



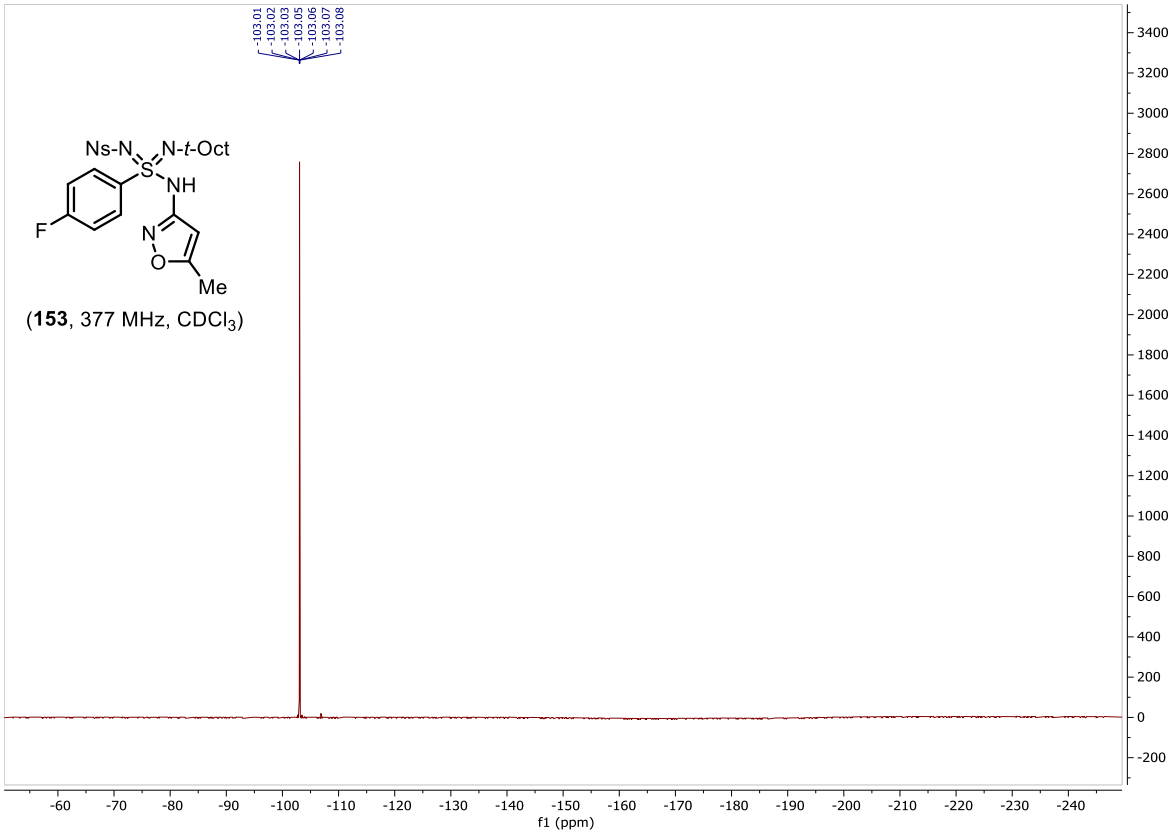
(**152**, 377 MHz, $CDCl_3$)



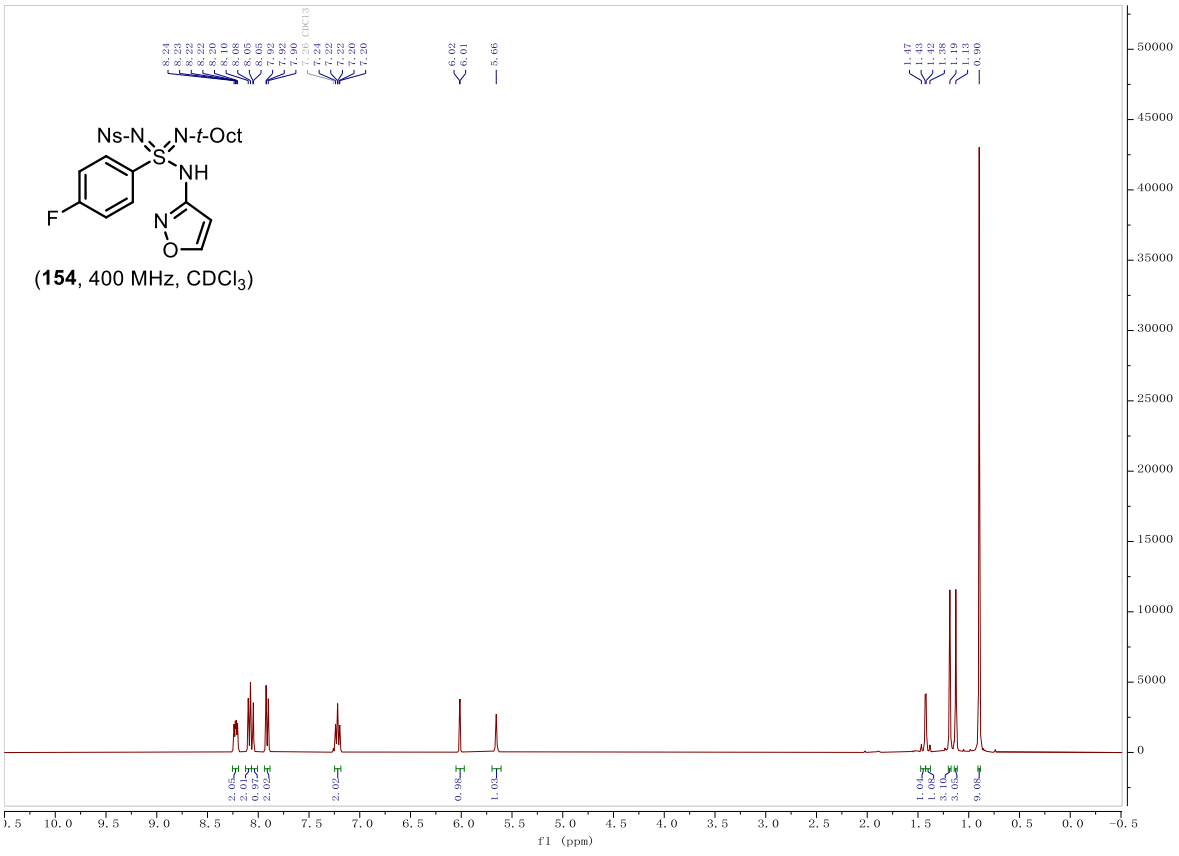
(**153**, 400 MHz, $CDCl_3$)



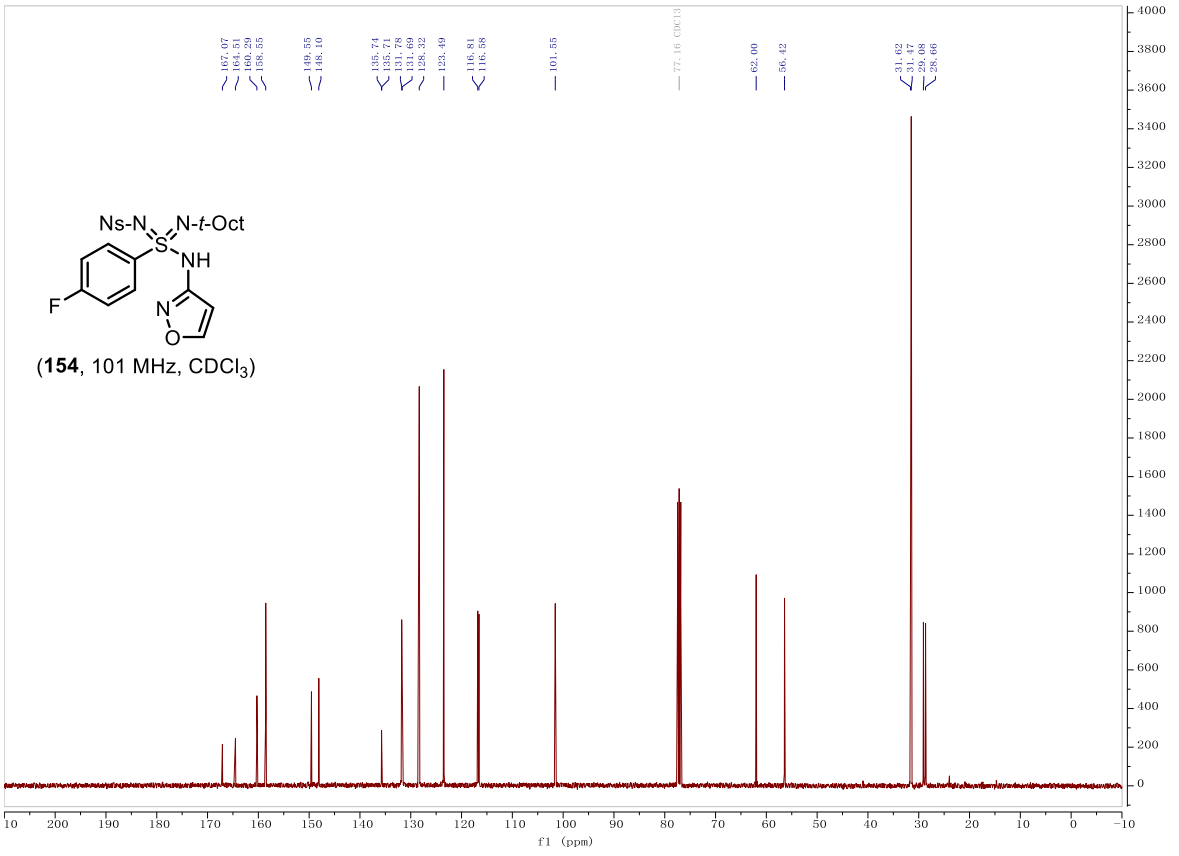
(**153**, 101 MHz, $CDCl_3$)



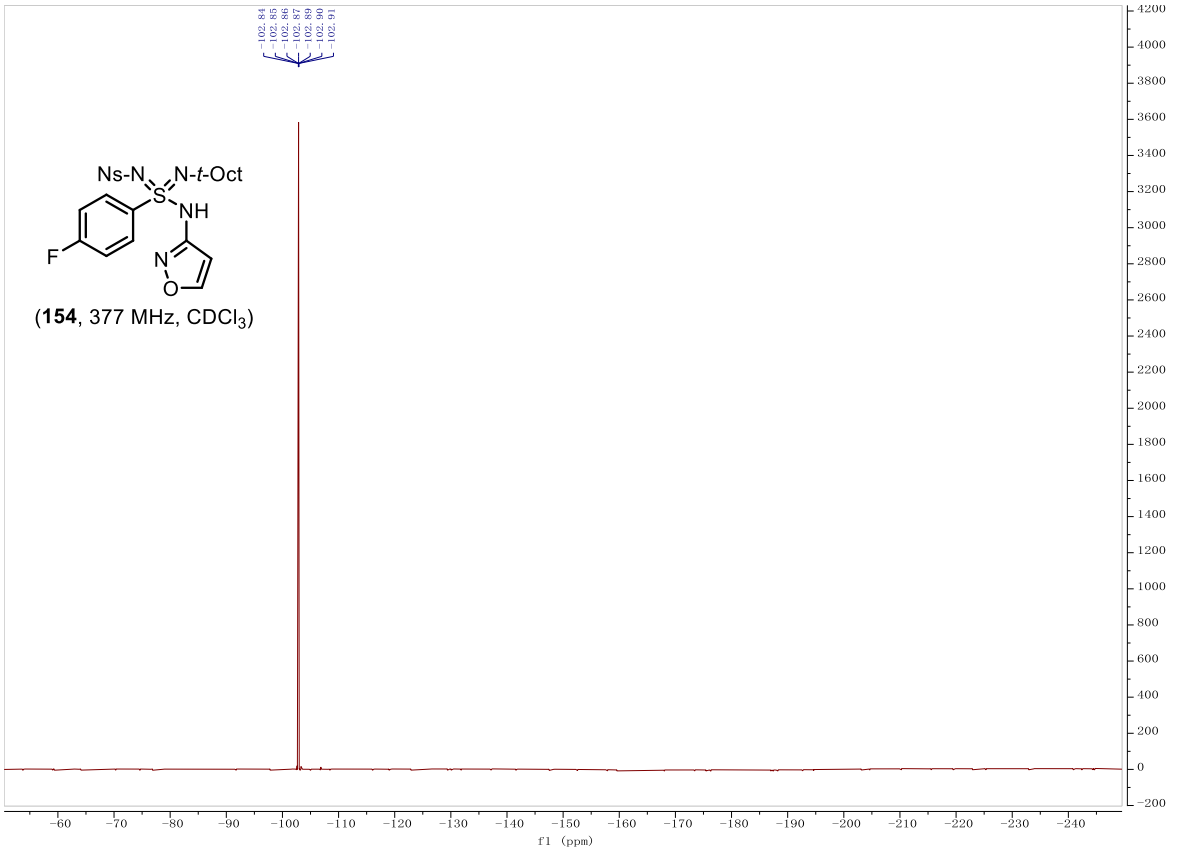
(**153**, 377 MHz, $CDCl_3$)



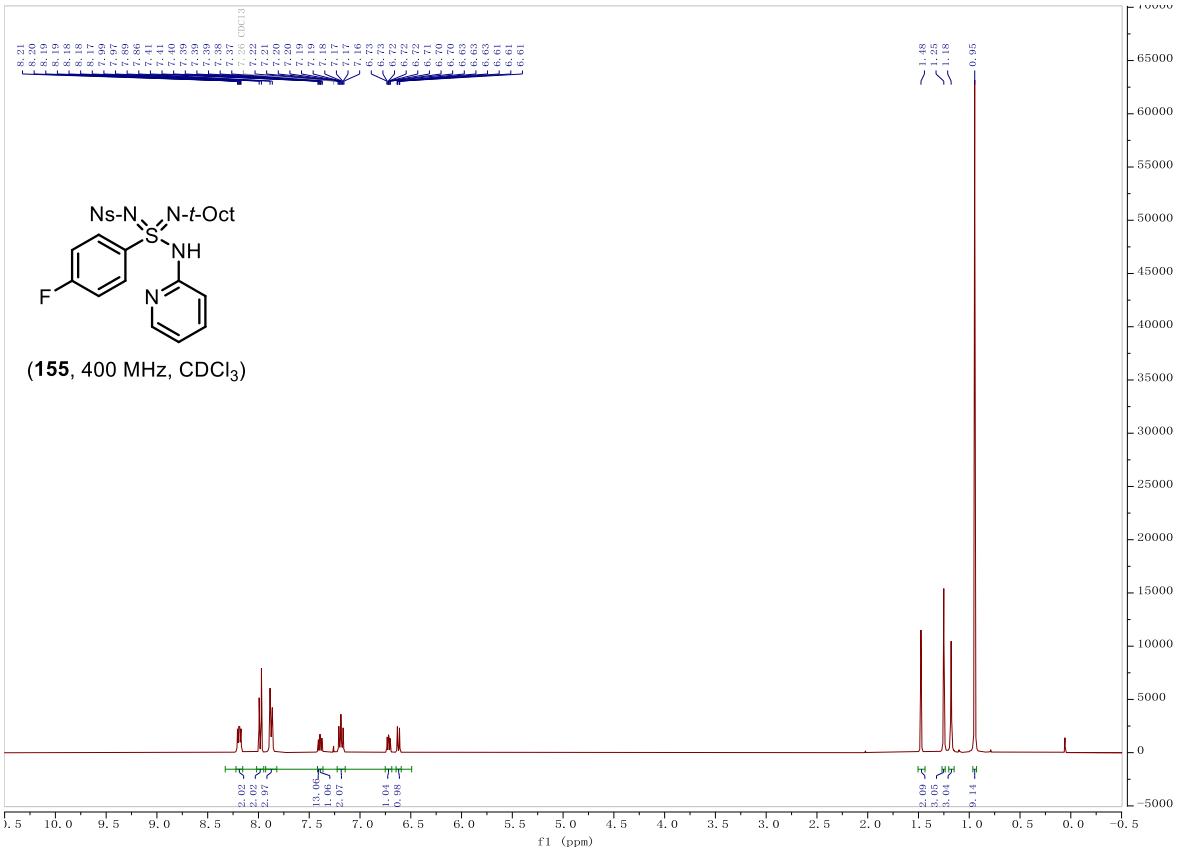
(**154**, 400 MHz, $CDCl_3$)



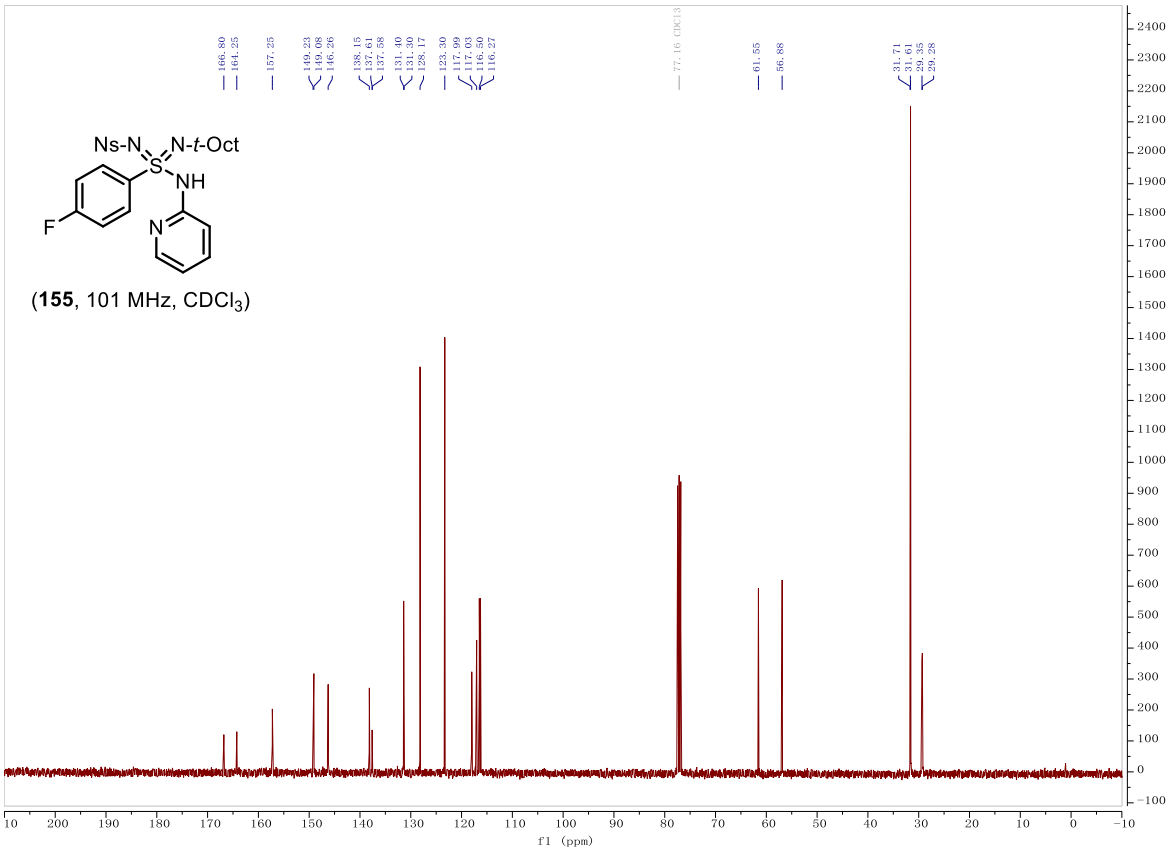
(**154**, 101 MHz, $CDCl_3$)



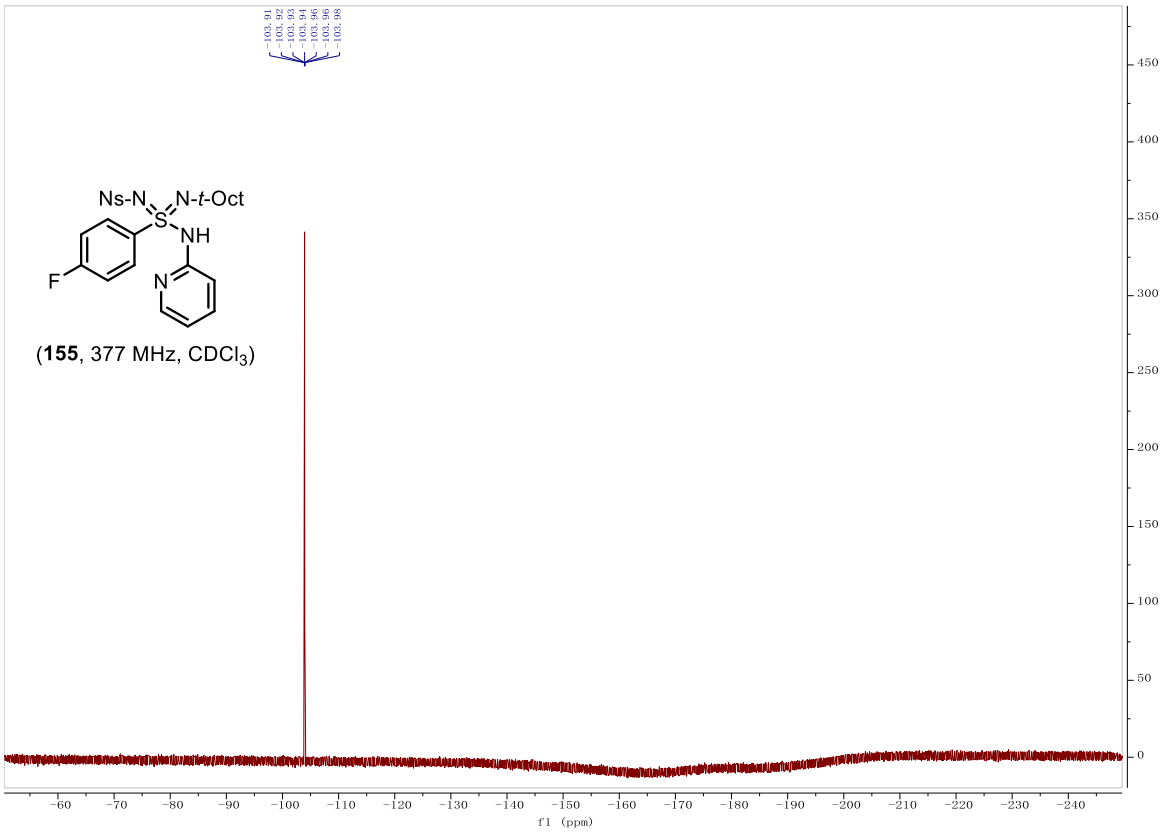
(**154**, 377 MHz, $CDCl_3$)



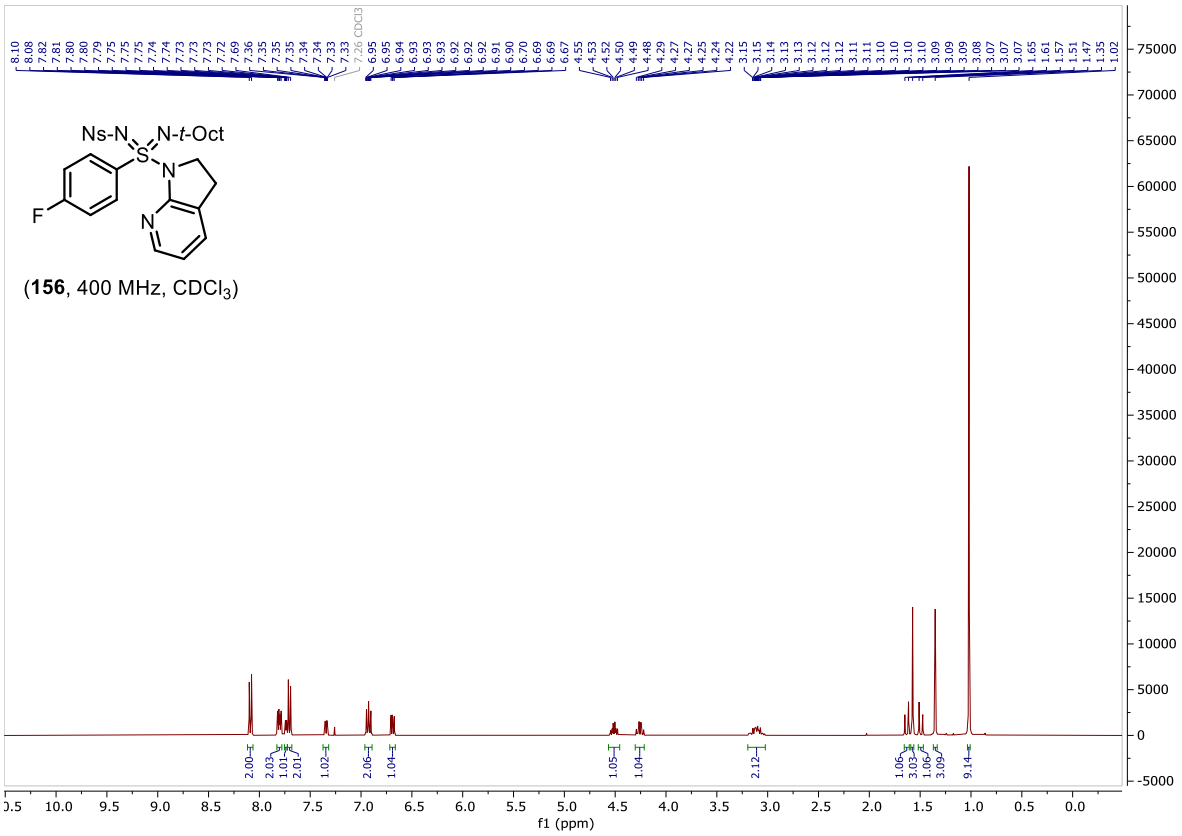
(**155**, 400 MHz, $CDCl_3$)

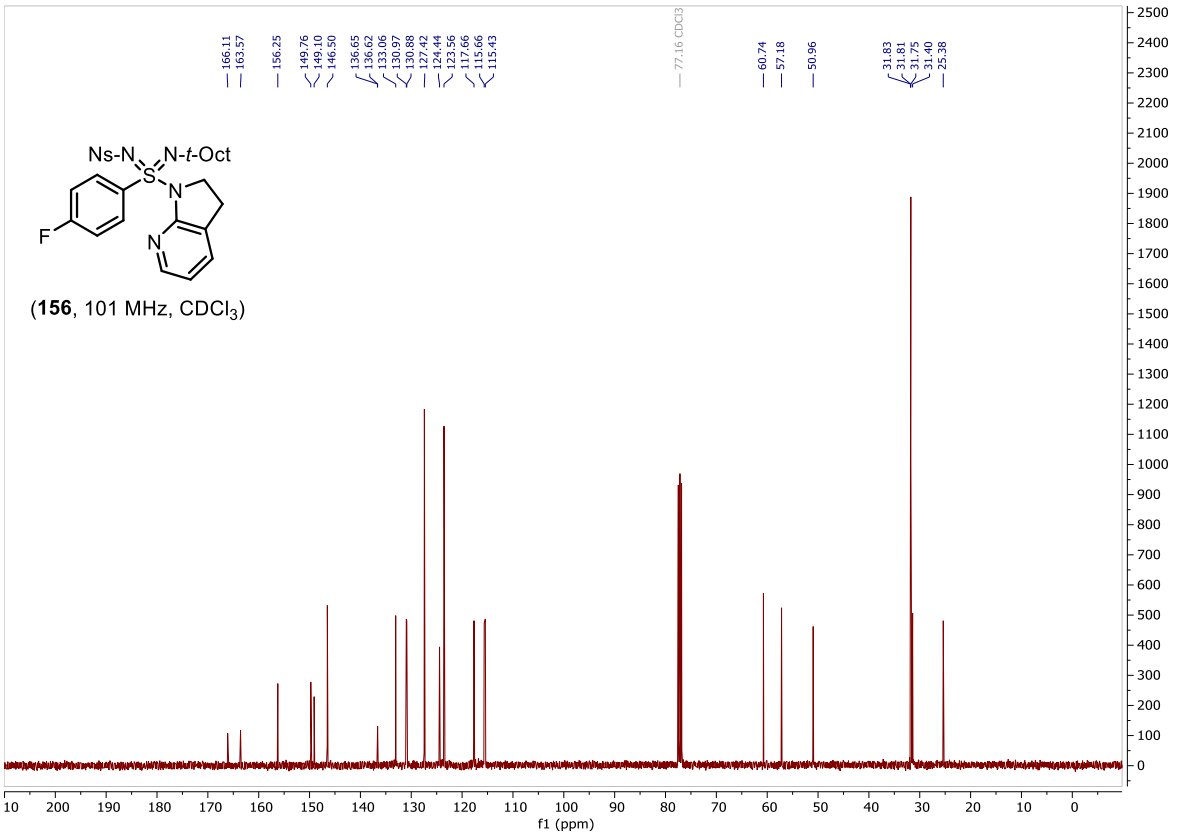


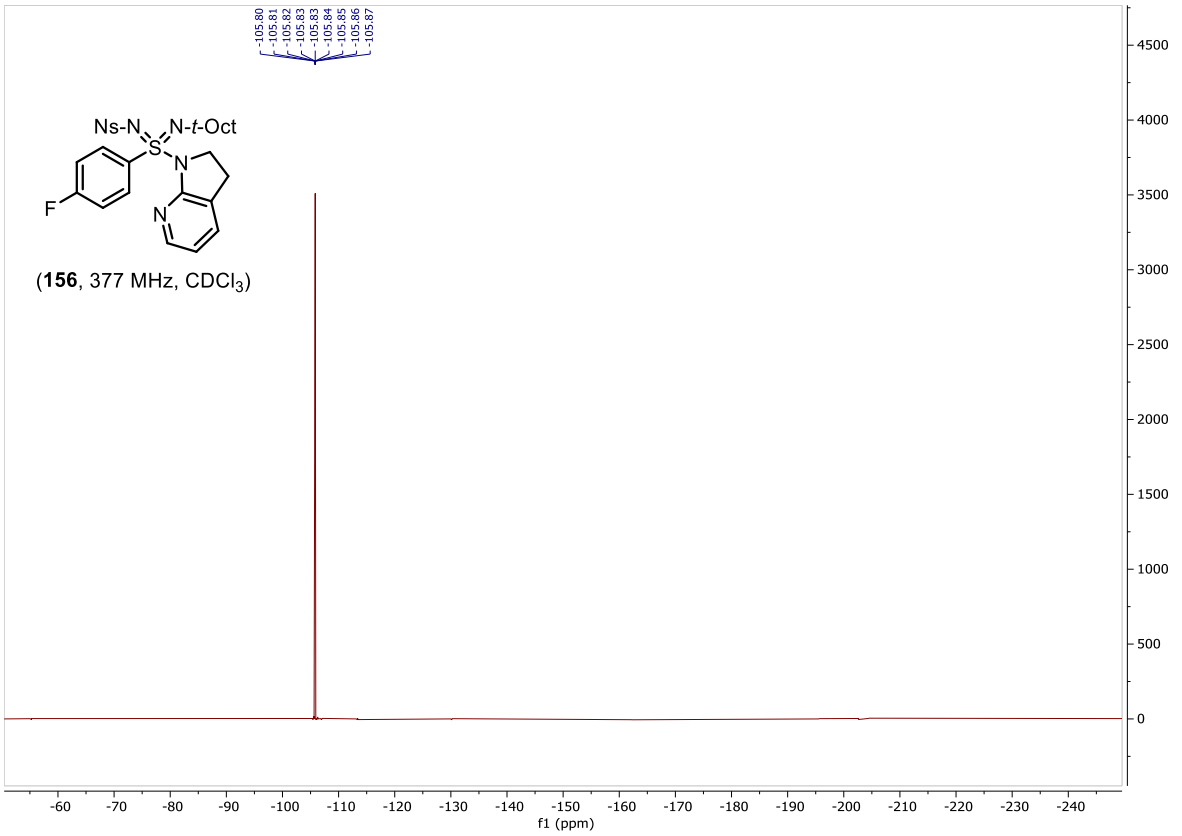
(**155**, 101 MHz, $CDCl_3$)



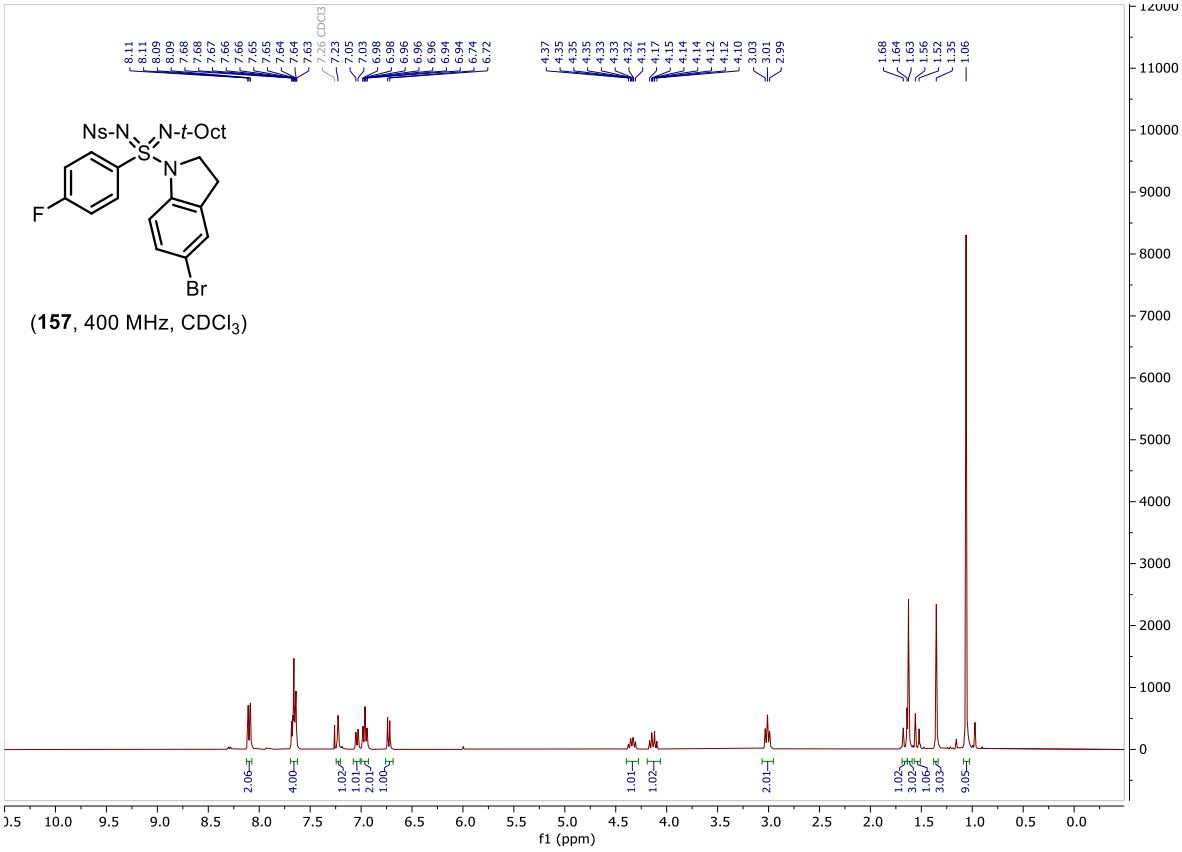
(**155**, 377 MHz, $CDCl_3$)


Ns-N
N-t-Oct
S
N
F
N
(156, 400 MHz, CDCl3)
f1 (ppm)

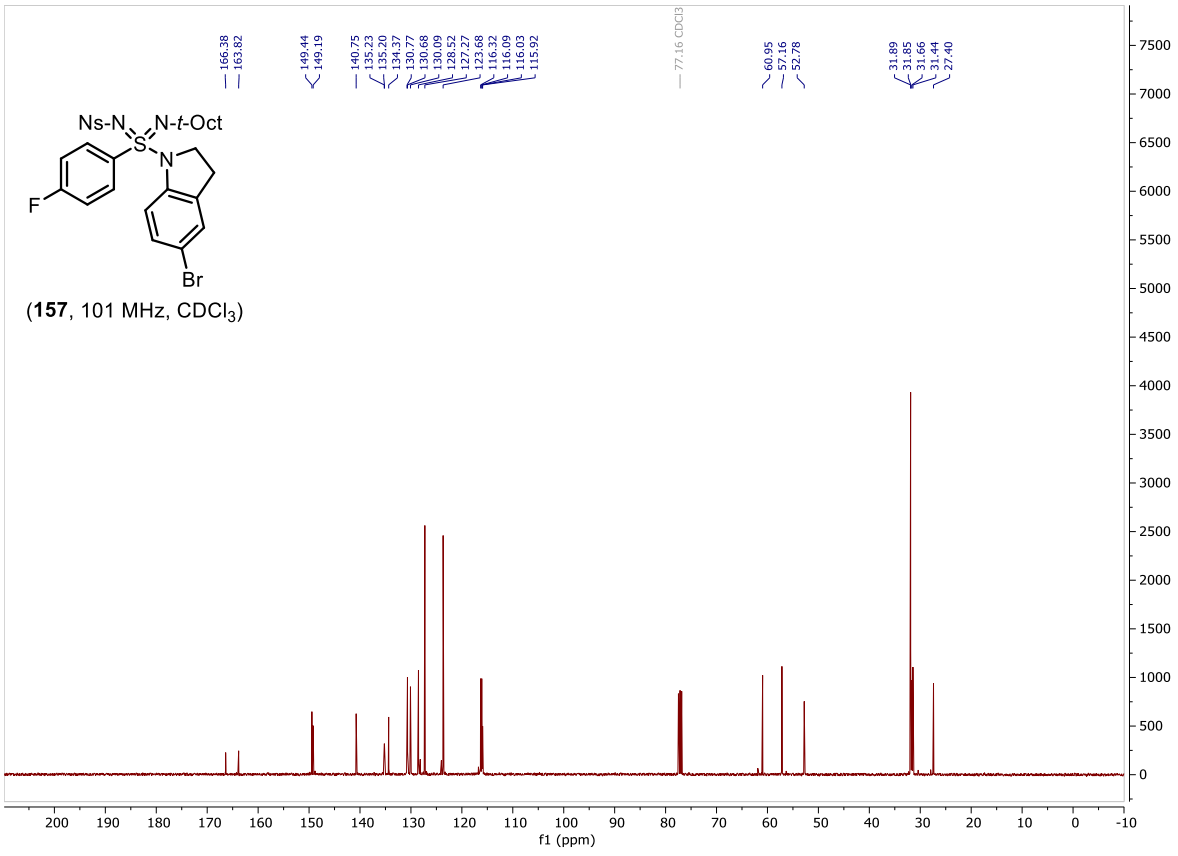

Ns-N
N-t-Oct
S
N
F
N
(156, 101 MHz, CDCl3)
f1 (ppm)



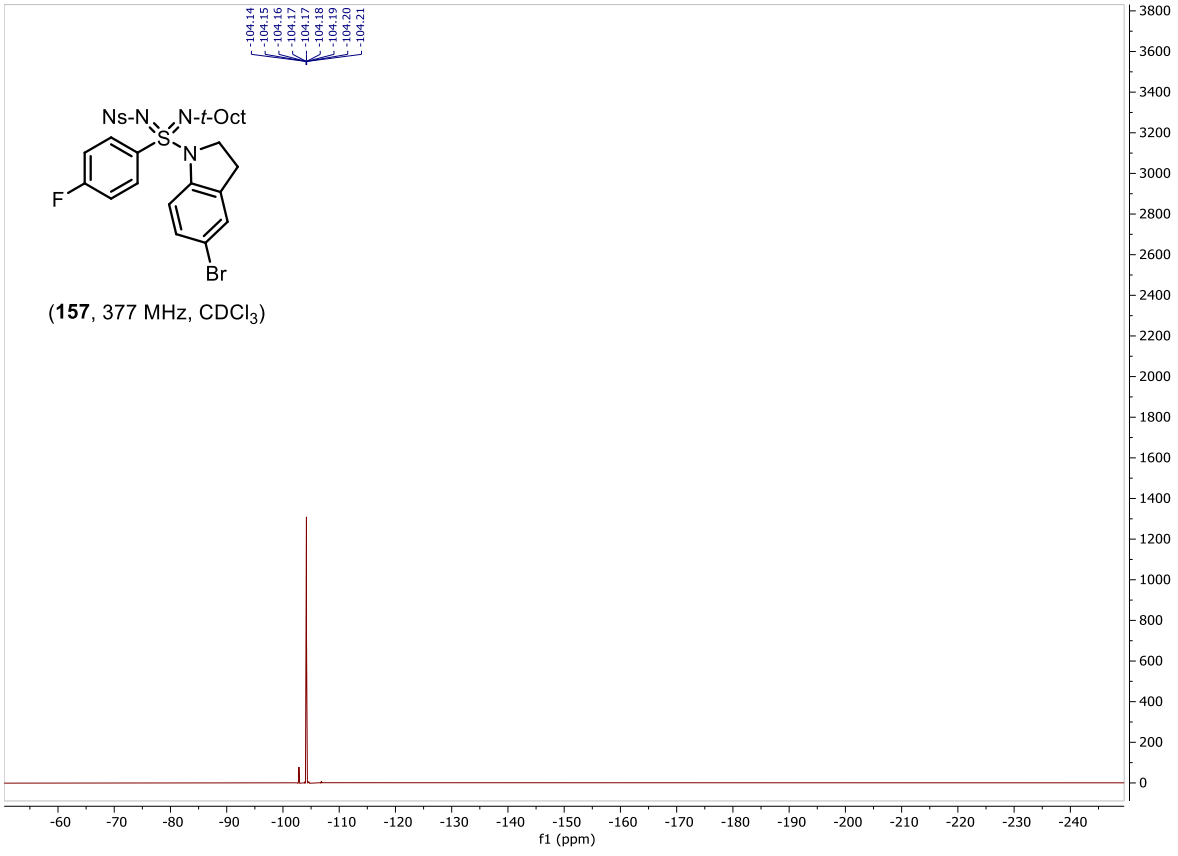
(**156**, 377 MHz, $CDCl_3$)



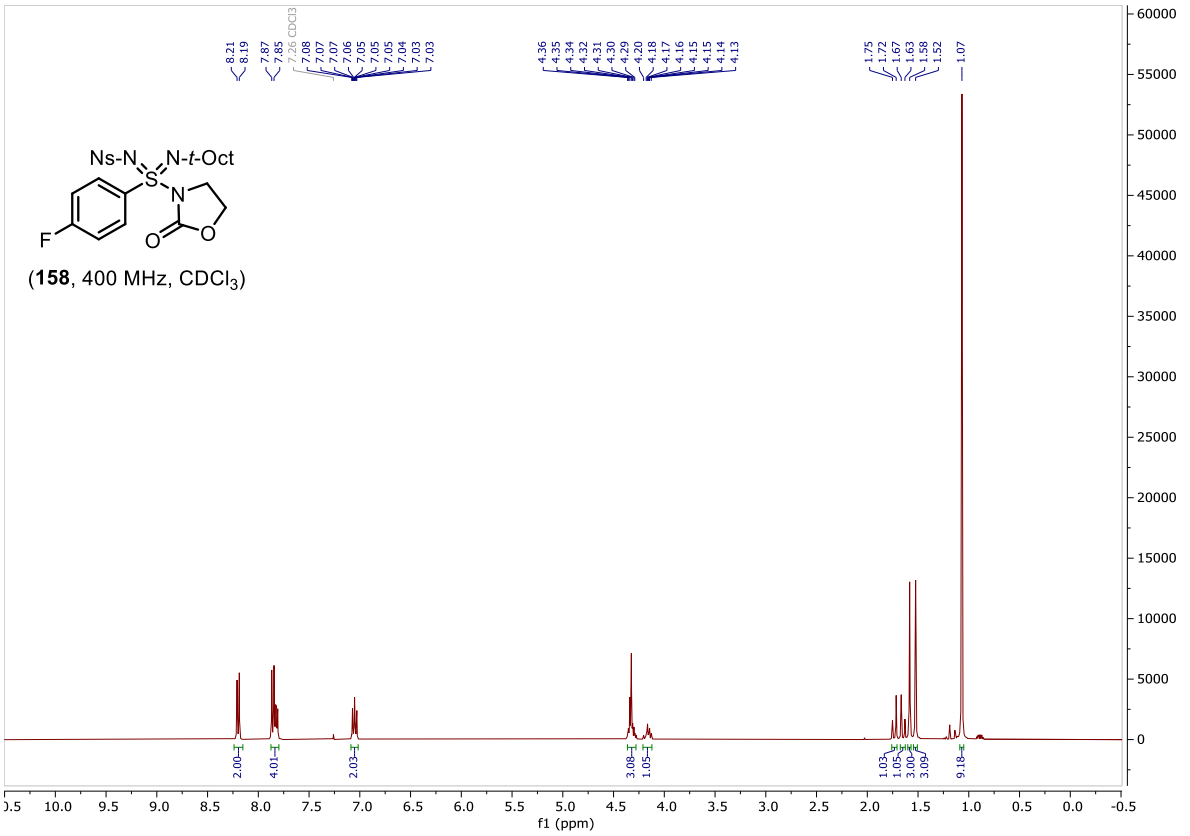
(**157**, 400 MHz, $CDCl_3$)



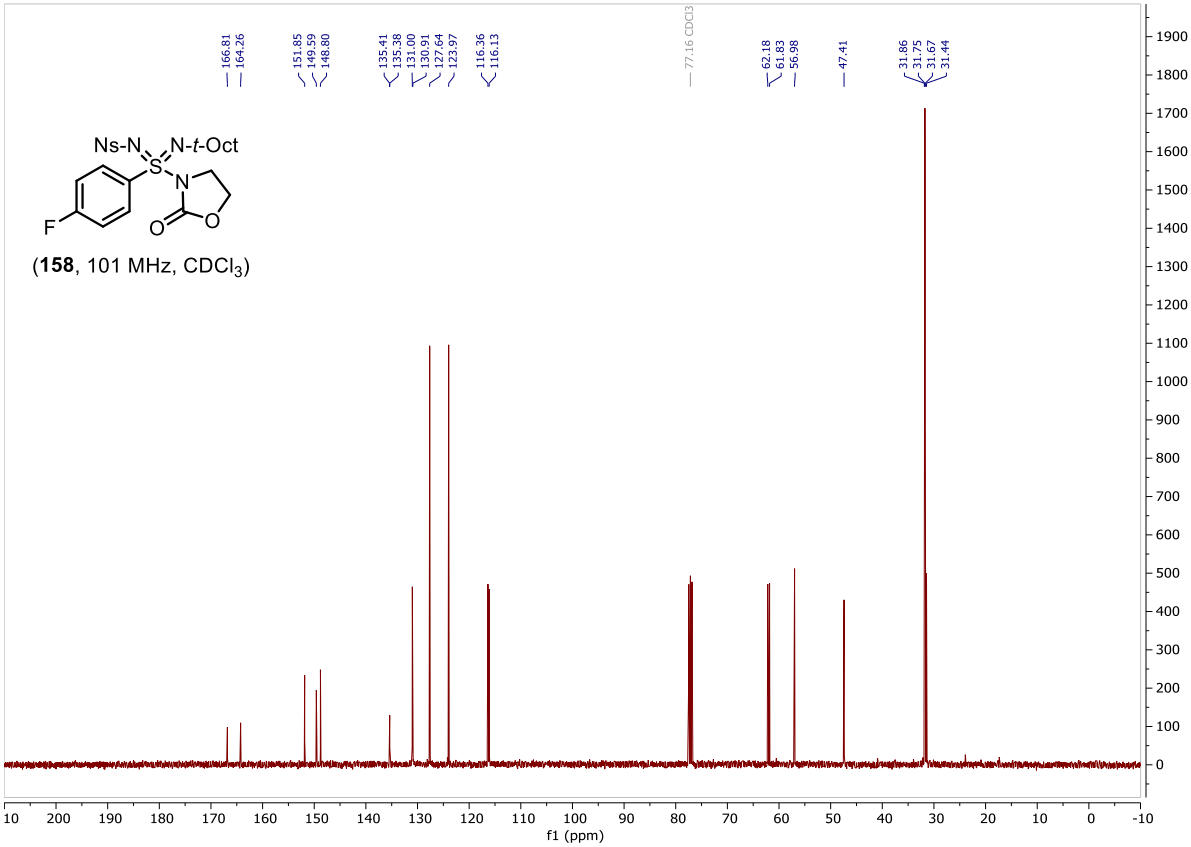
(**157**, 101 MHz, $CDCl_3$)



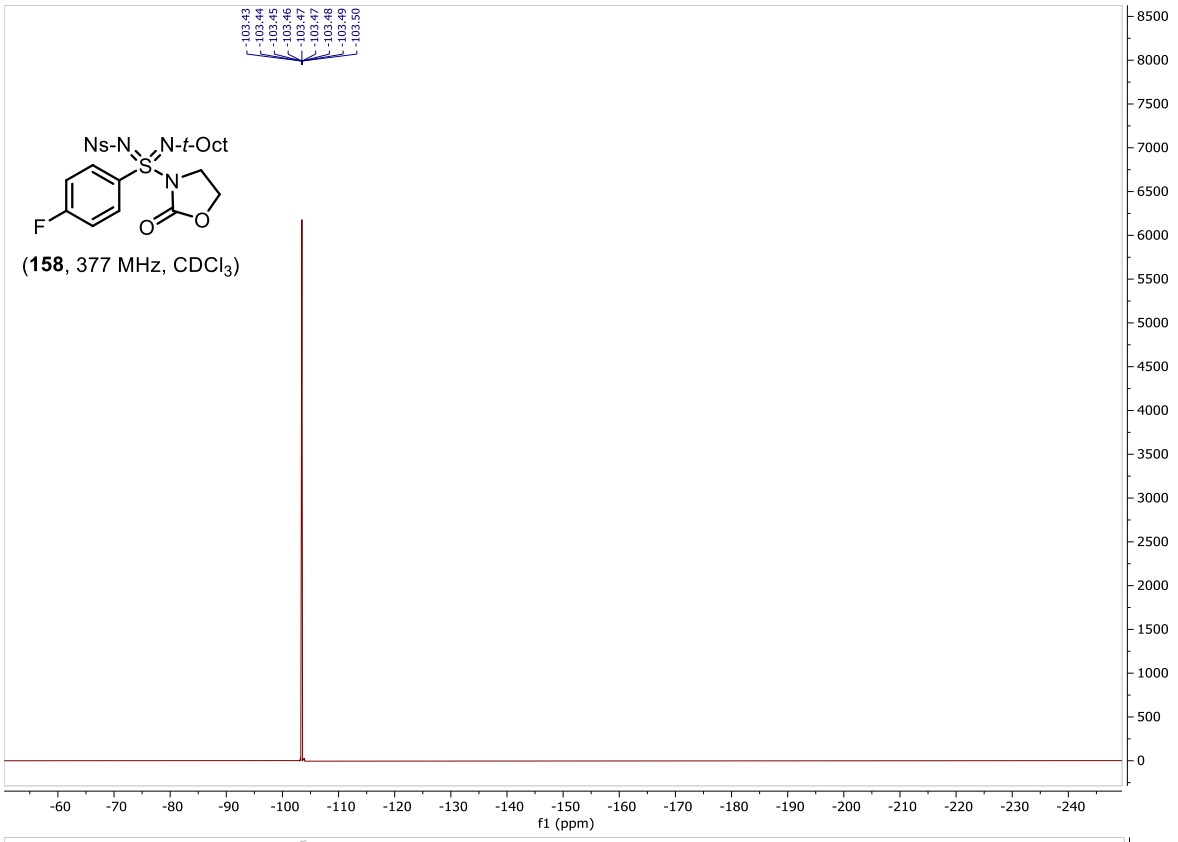
(**157**, 377 MHz, $CDCl_3$)



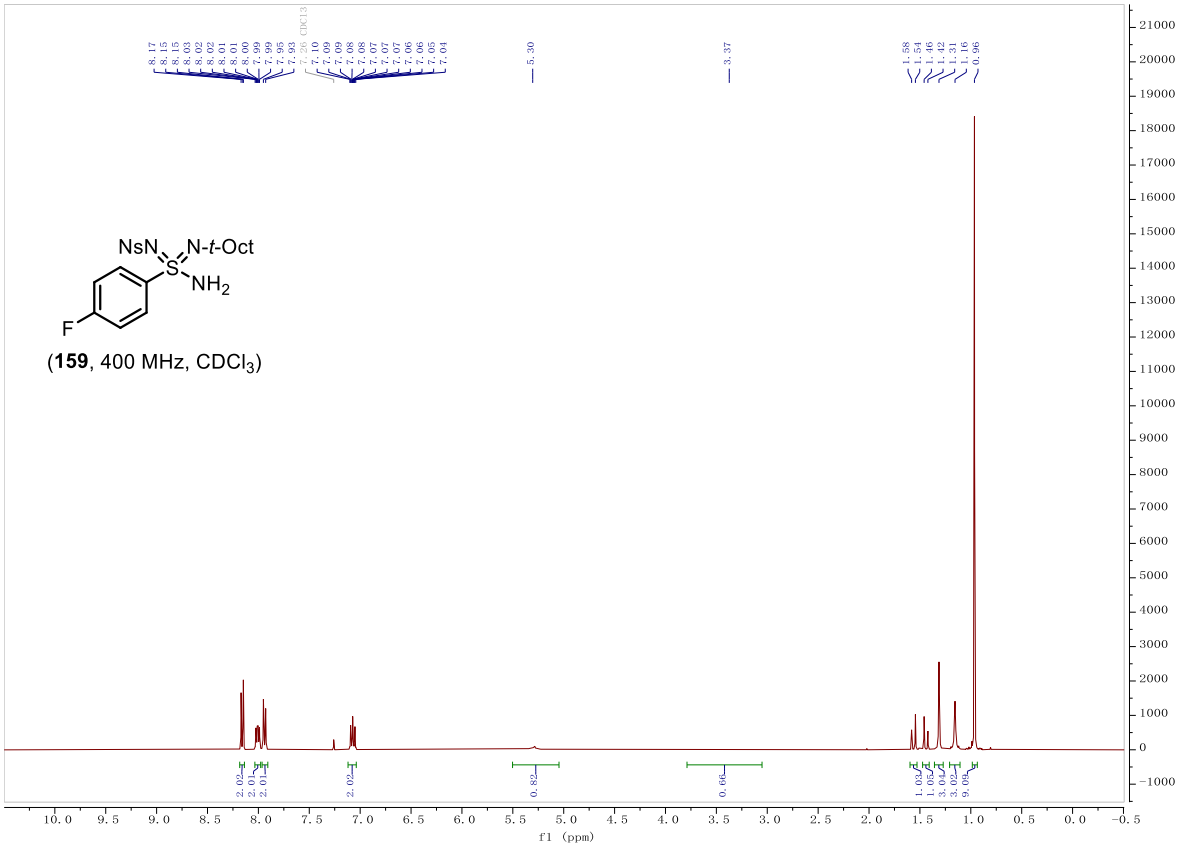
(**158**, 400 MHz, $CDCl_3$)



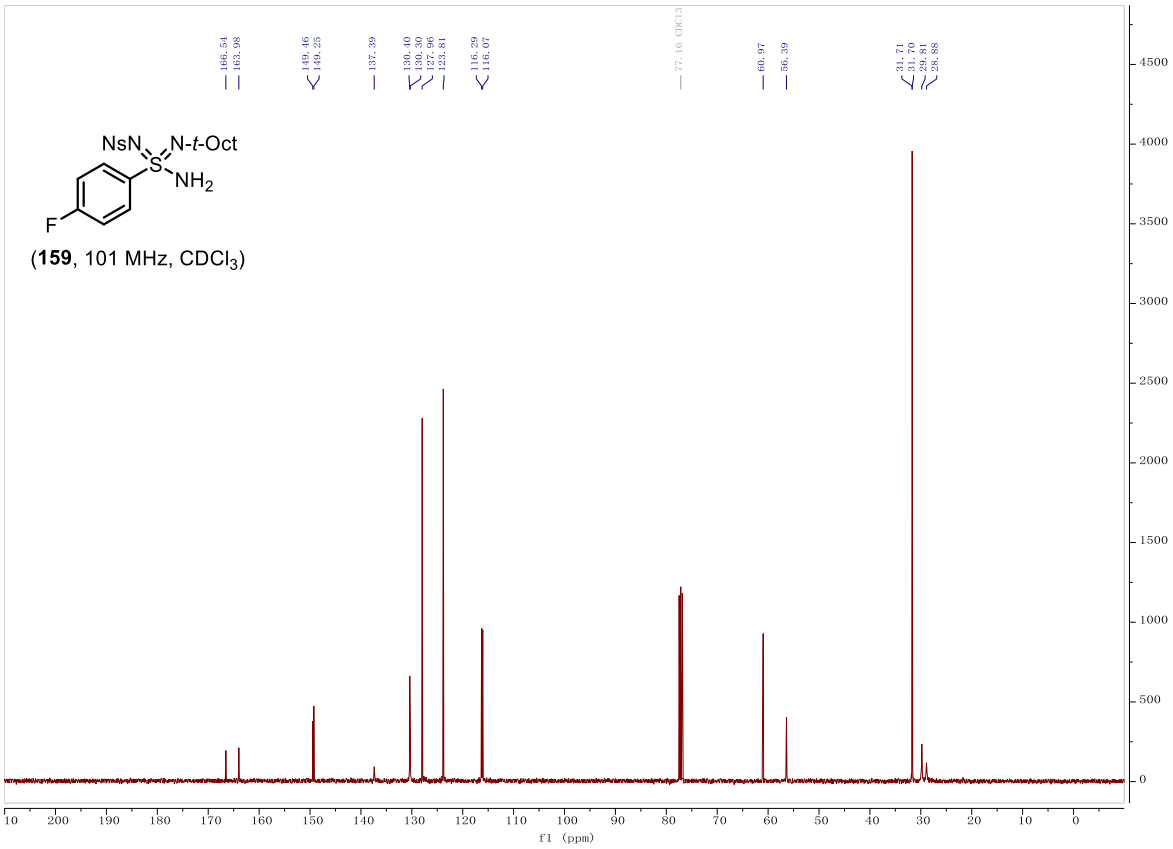
(**158**, 101 MHz, $CDCl_3$)



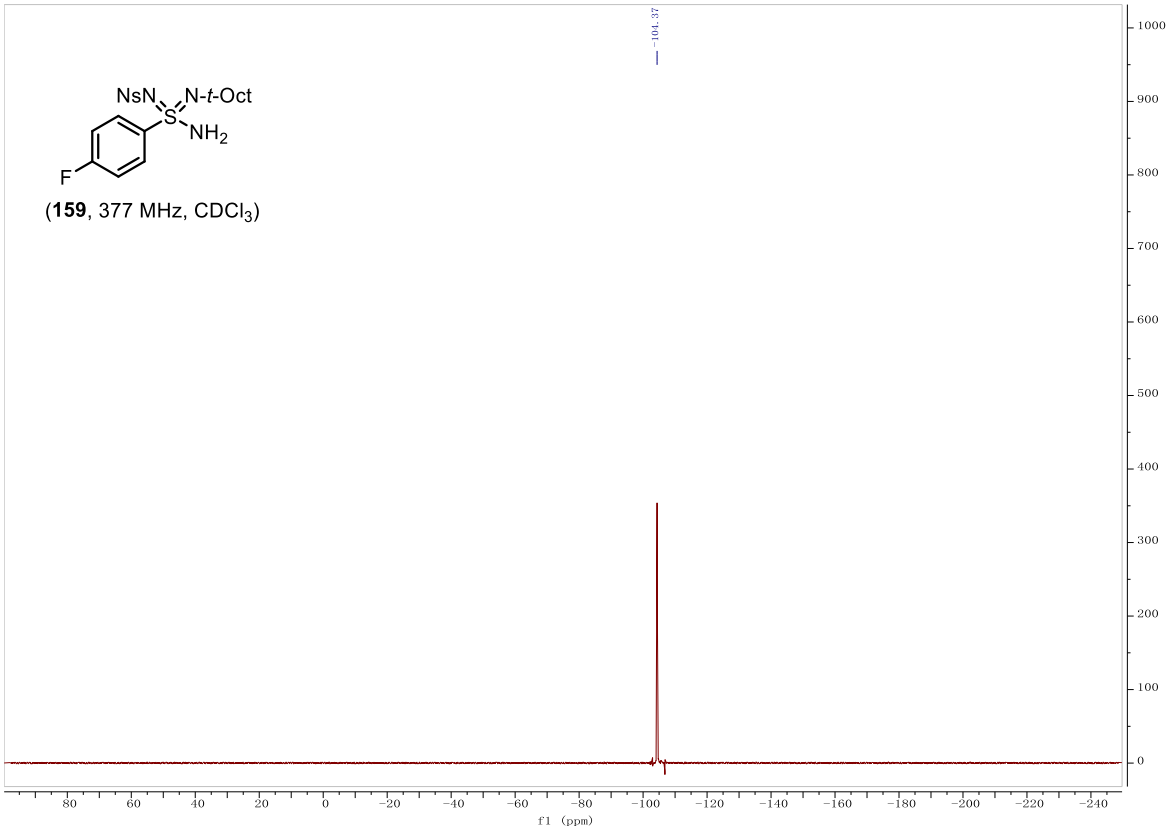
(**158**, 377 MHz, $CDCl_3$)



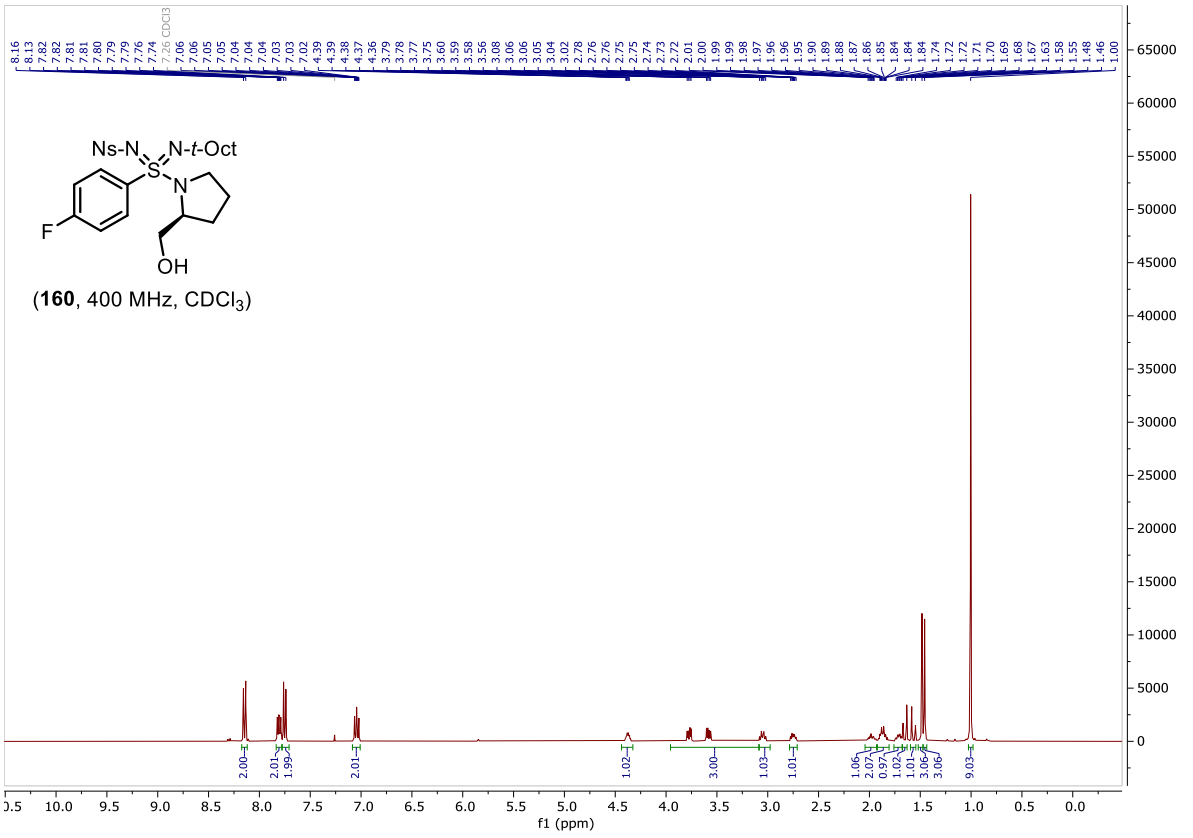
(**159**, 400 MHz, $CDCl_3$)



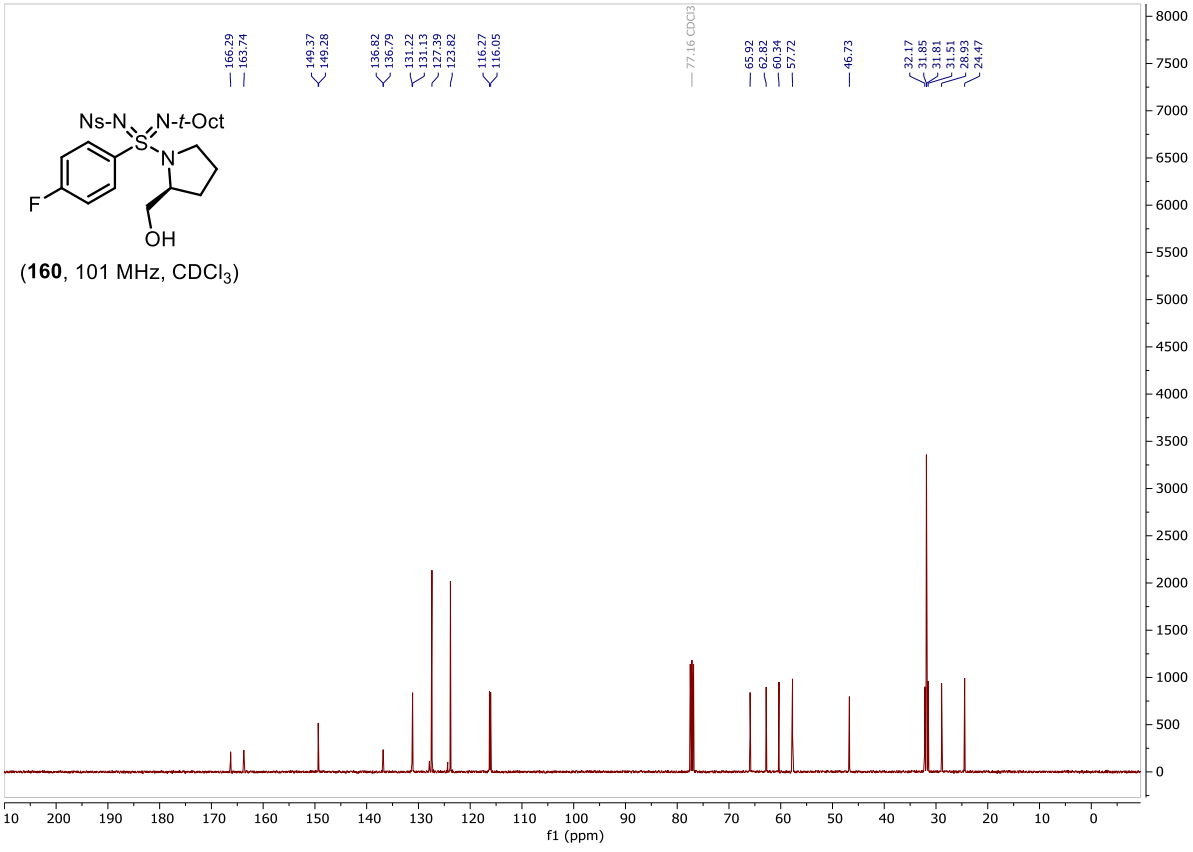
(**159**, 101 MHz, $CDCl_3$)



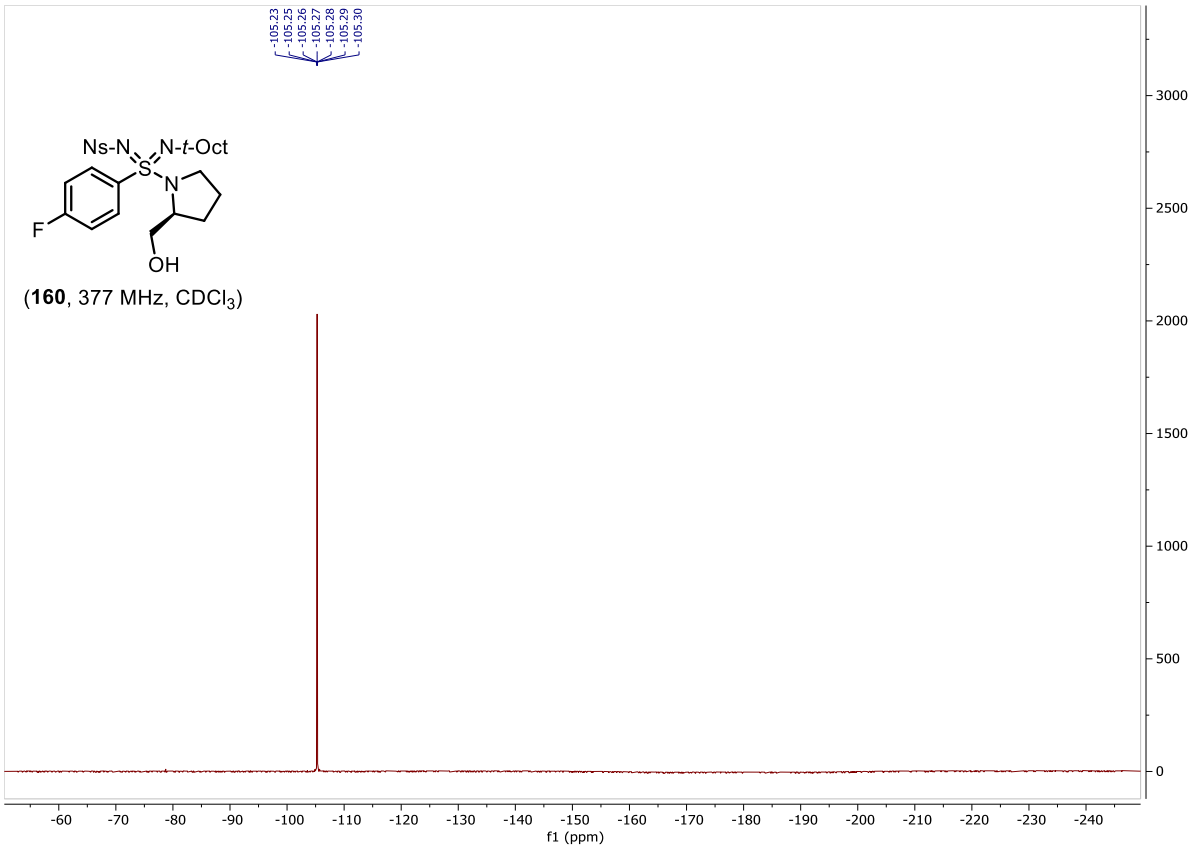
(**159**, 377 MHz, $CDCl_3$)



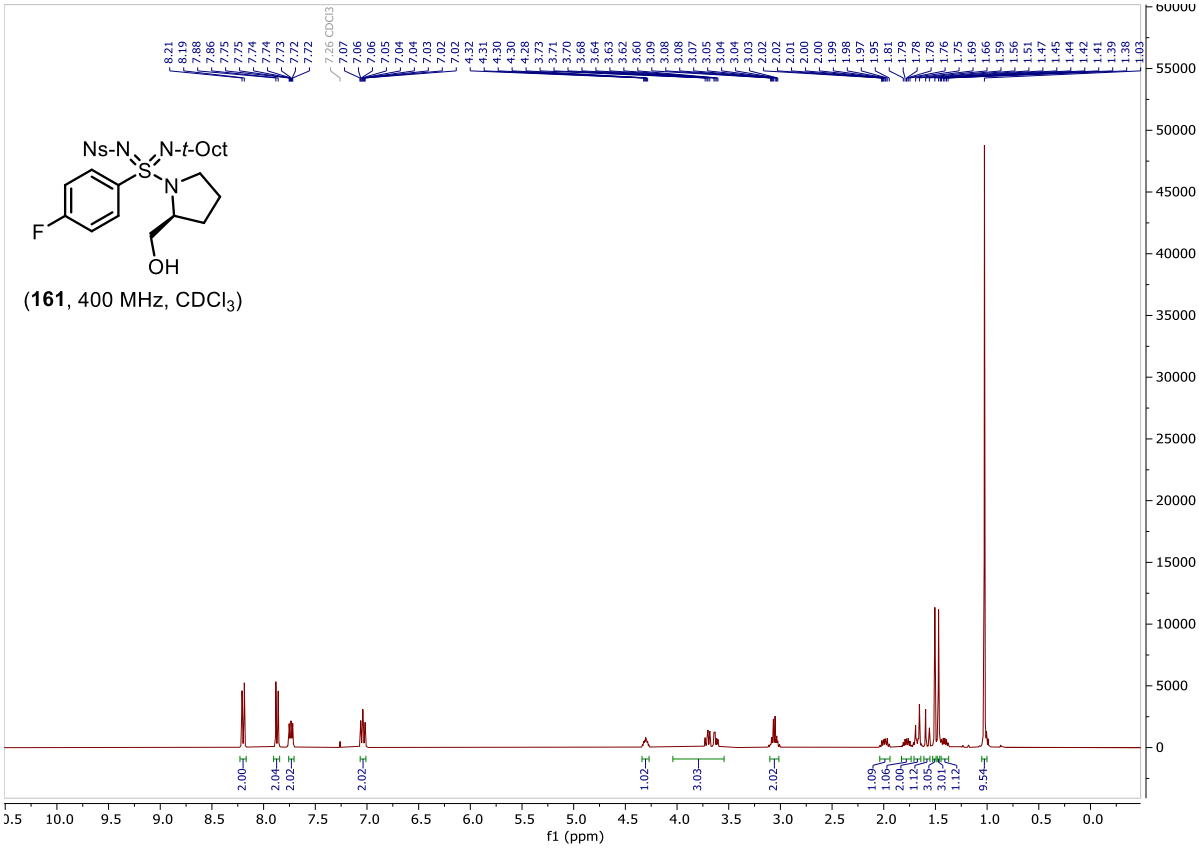
(**160**, 400 MHz, $CDCl_3$)



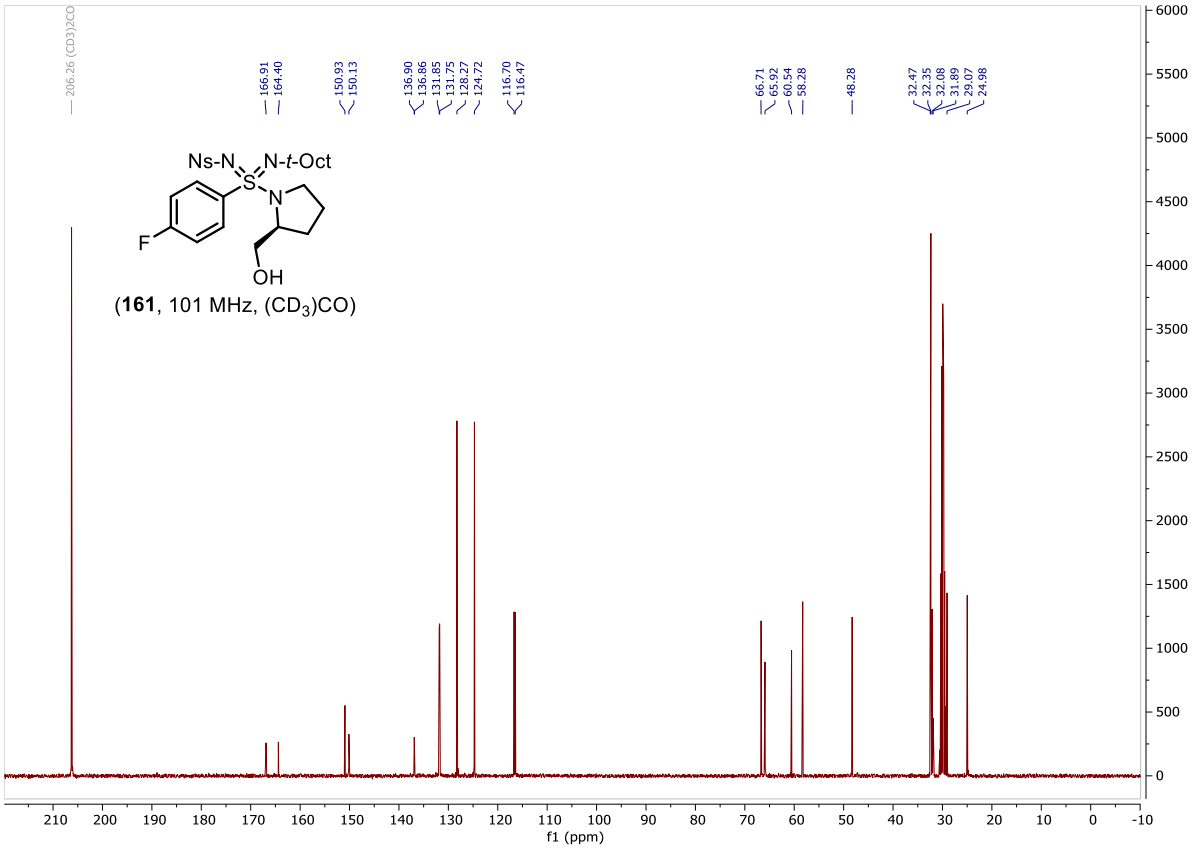
(**160**, 101 MHz, $CDCl_3$)



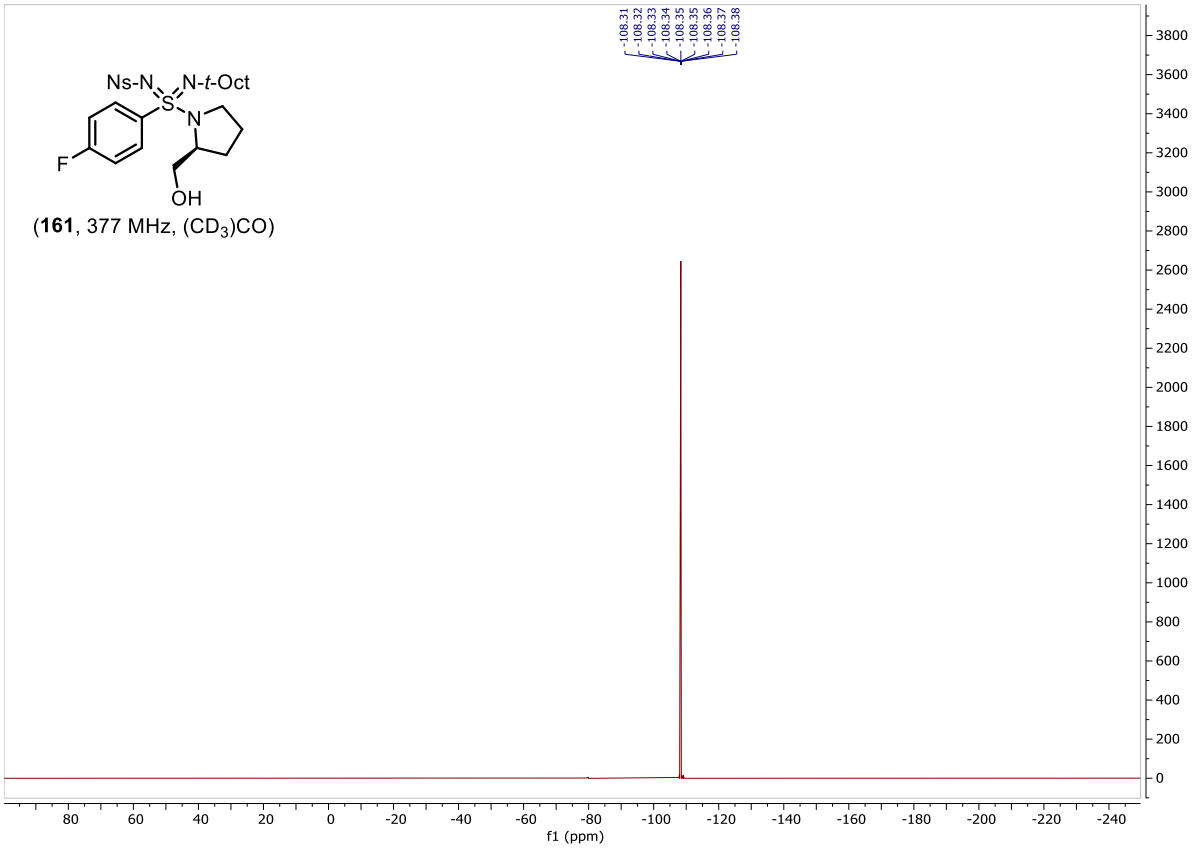
(**160**, 377 MHz, $CDCl_3$)



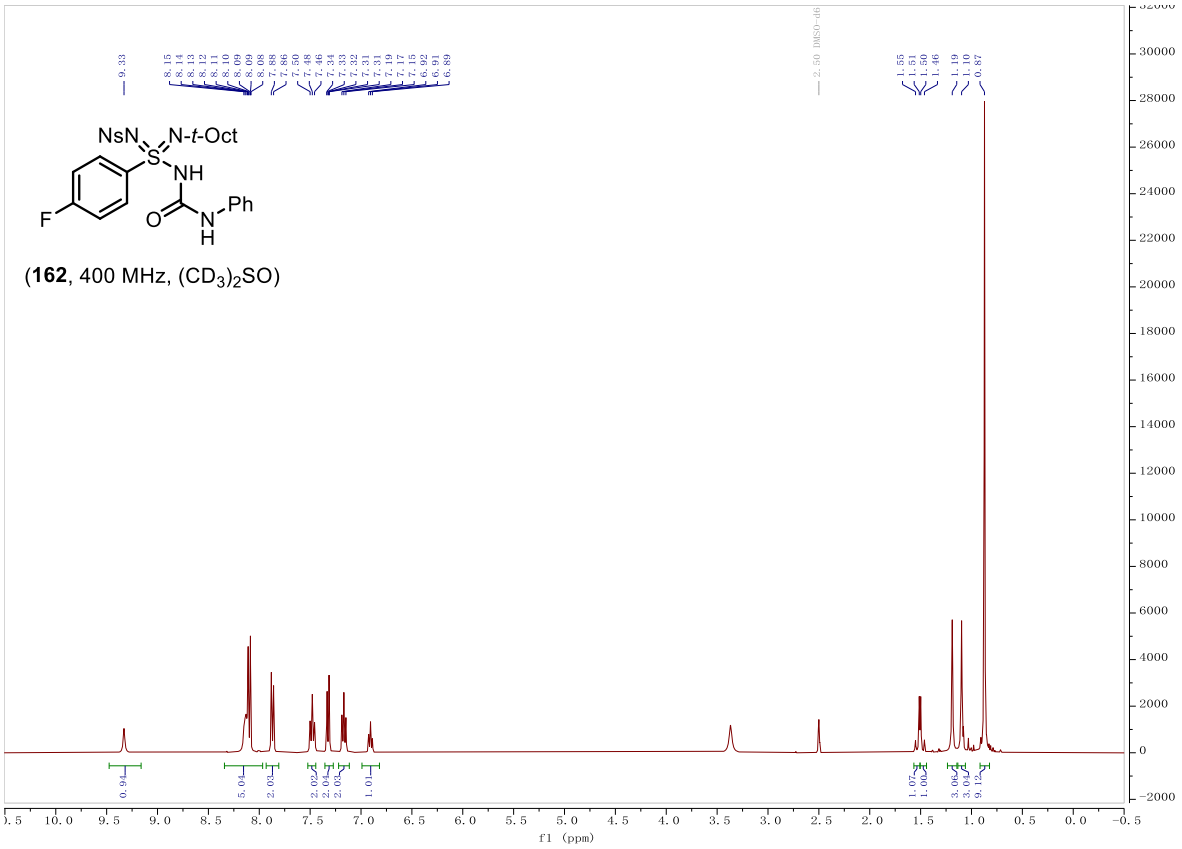
(**161**, 400 MHz, $CDCl_3$)



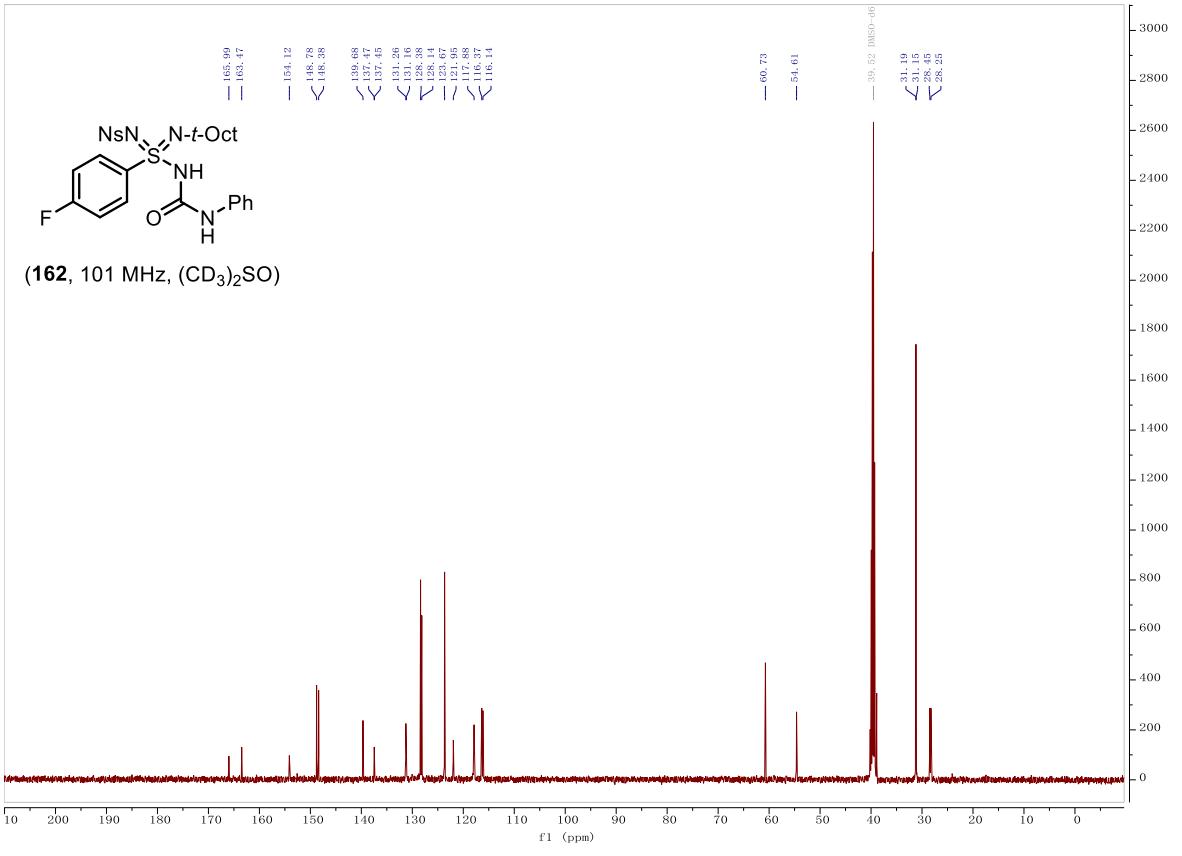
(**161**, 101 MHz, $(CD_3)CO$)



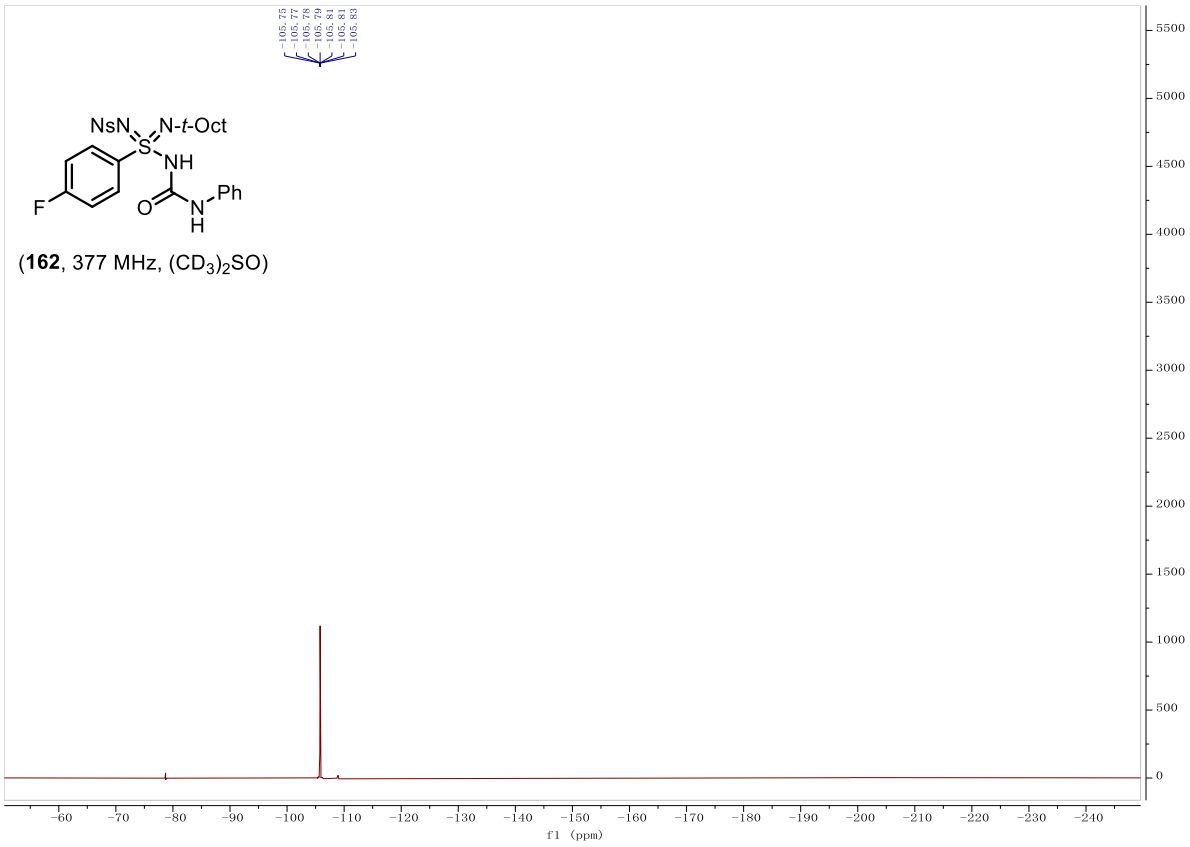
(**161**, 377 MHz, $(CD_3)CO$)



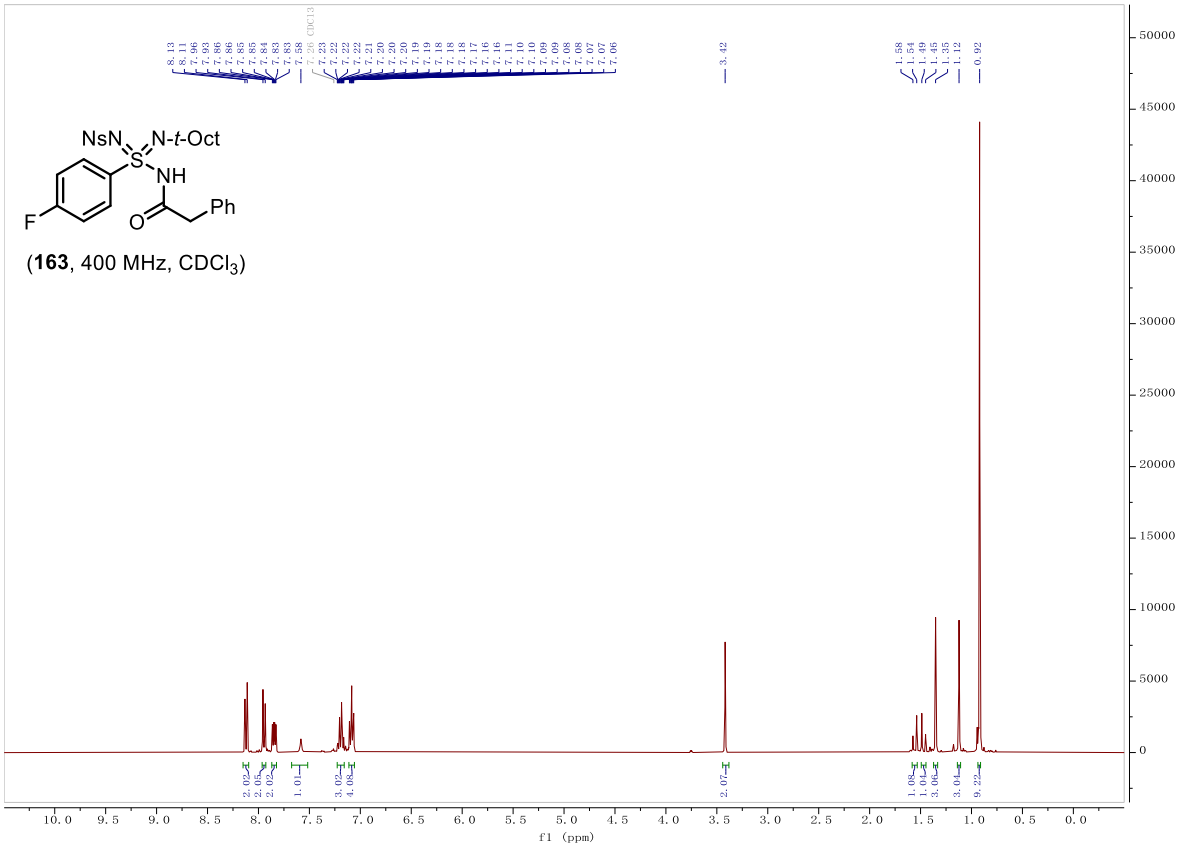
(**162**, 400 MHz, $(CD_3)_2SO$)



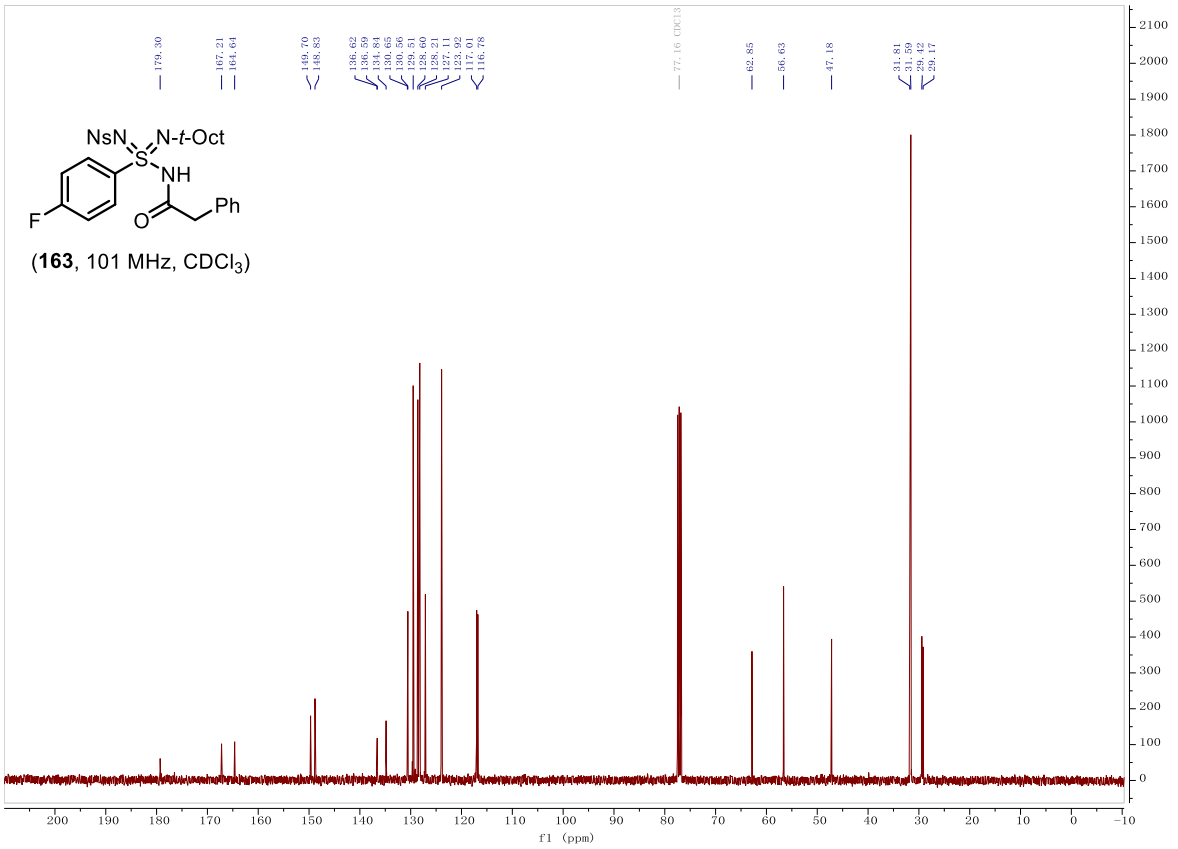
(**162**, 101 MHz, $(CD_3)_2SO$)



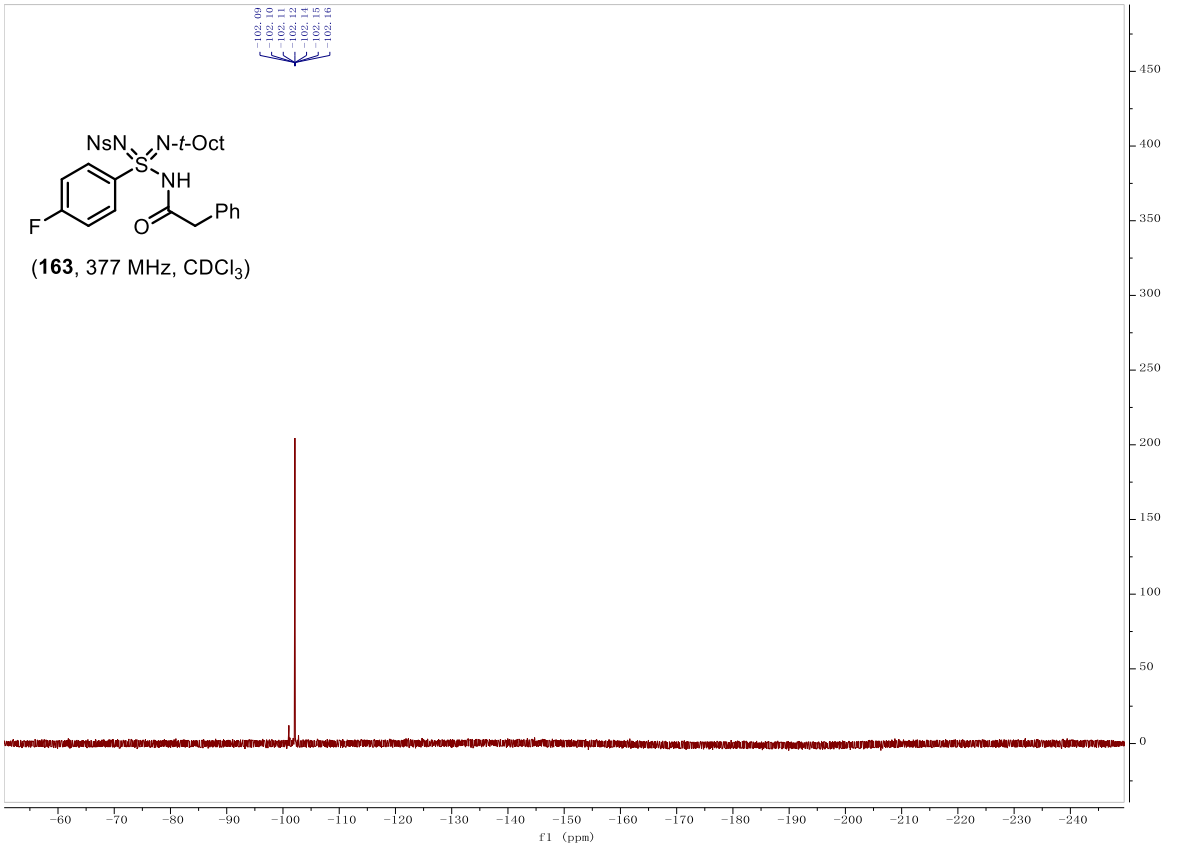
(**162**, 377 MHz, $(CD_3)_2SO$)



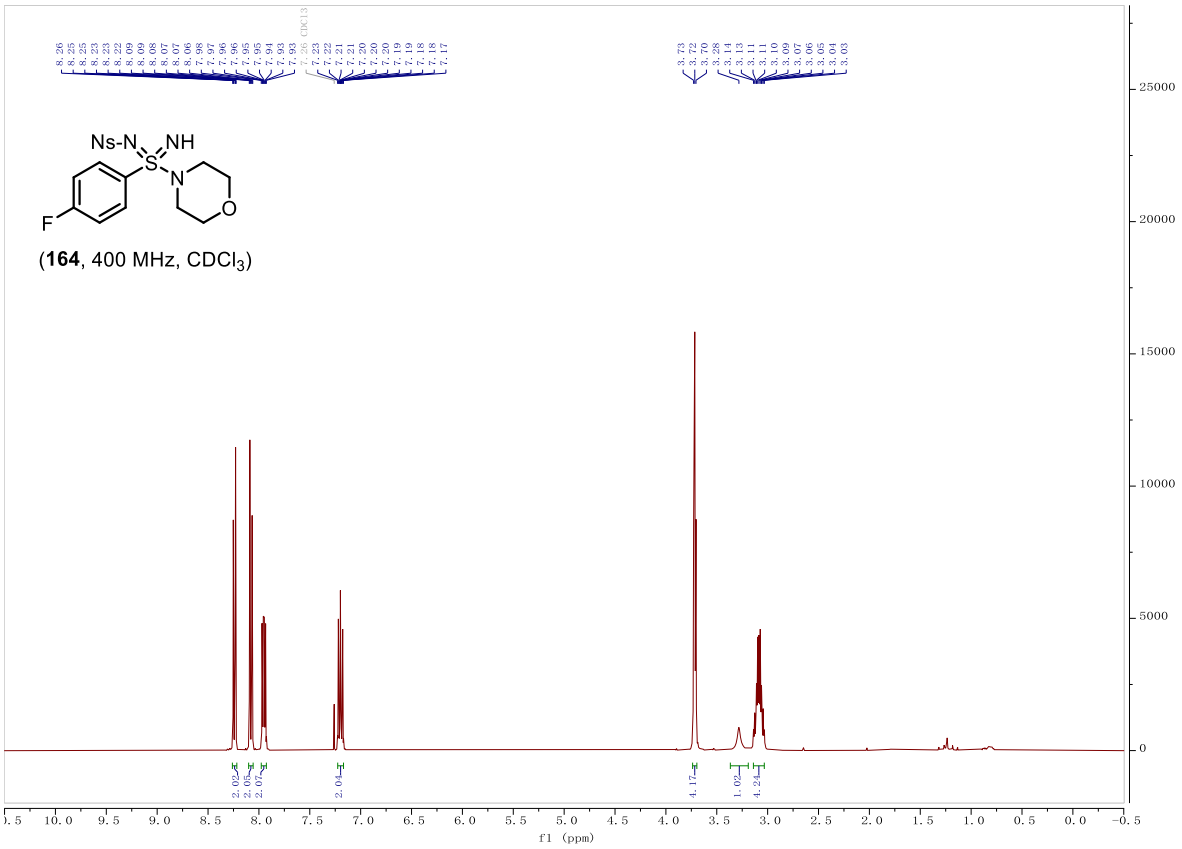
(**163**, 400 MHz, $CDCl_3$)



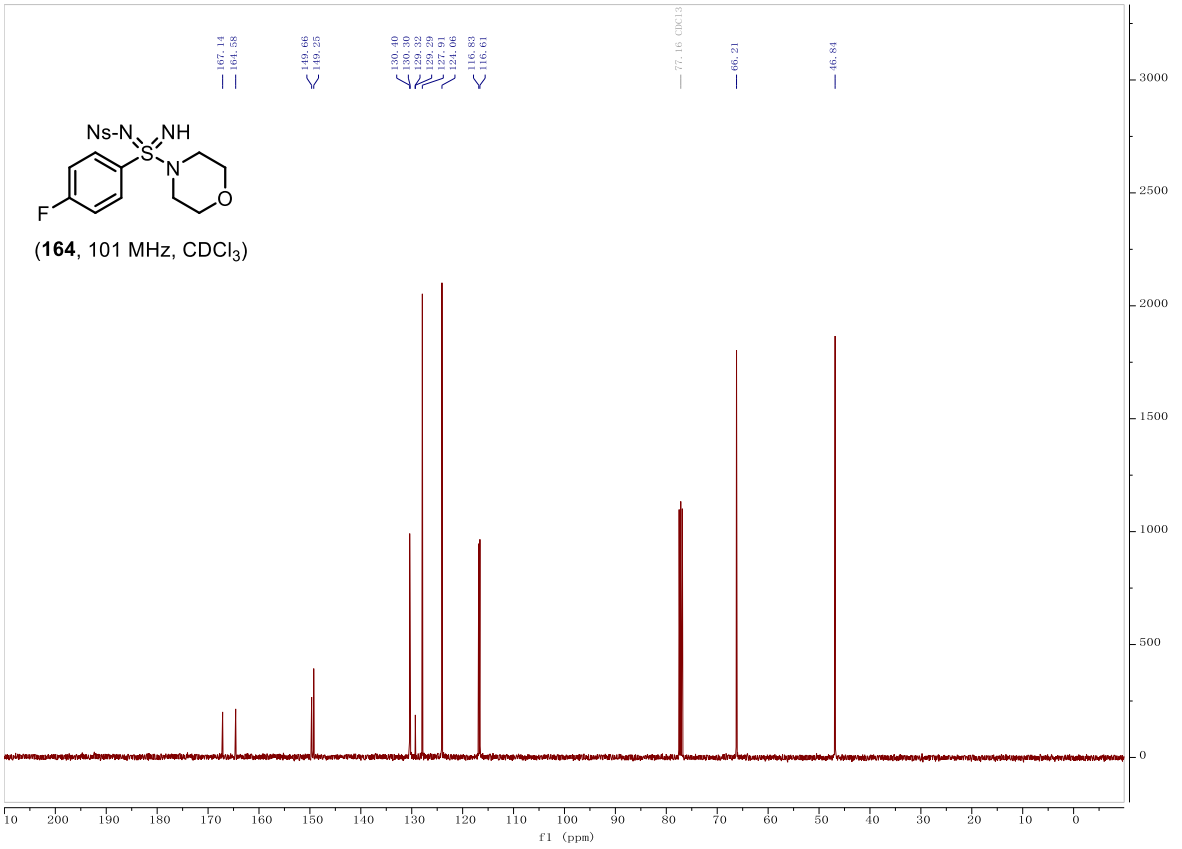
(**163**, 101 MHz, $CDCl_3$)



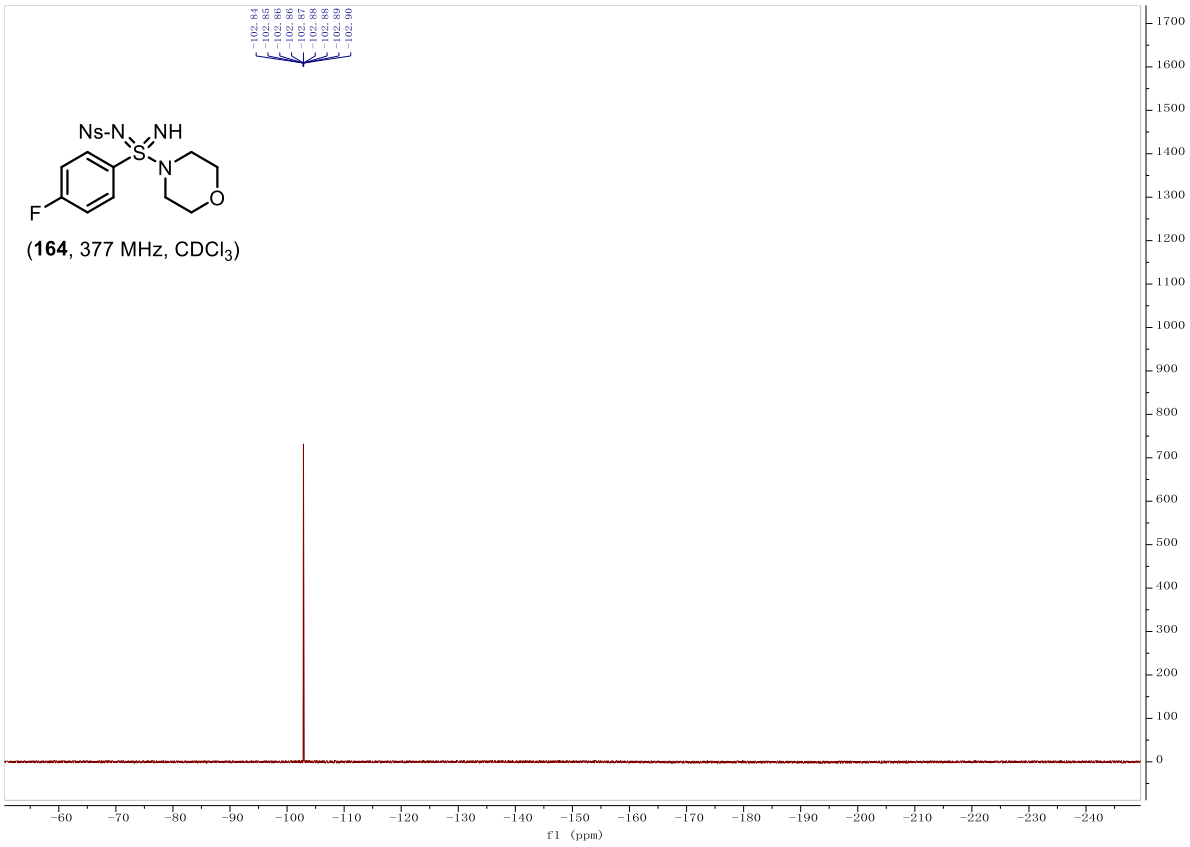
(**163**, 377 MHz, $CDCl_3$)



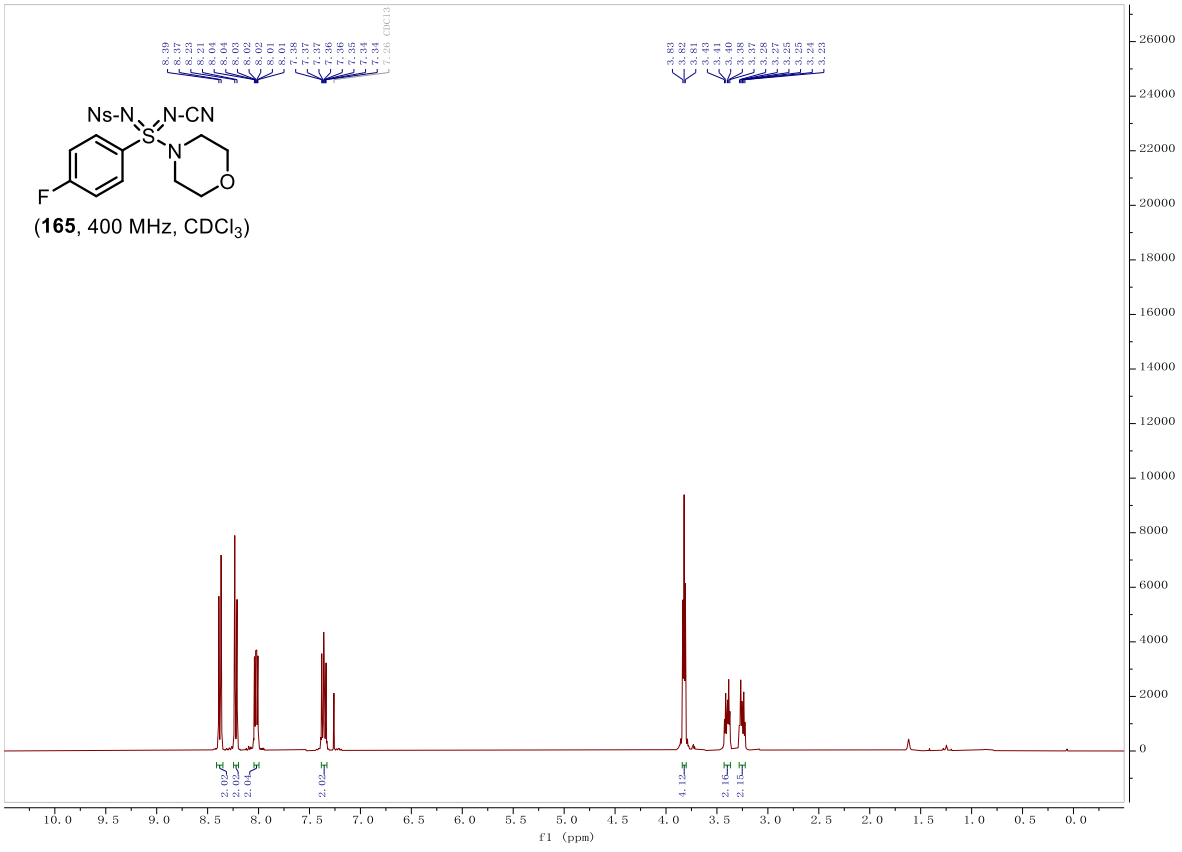
(**164**, 400 MHz, $CDCl_3$)



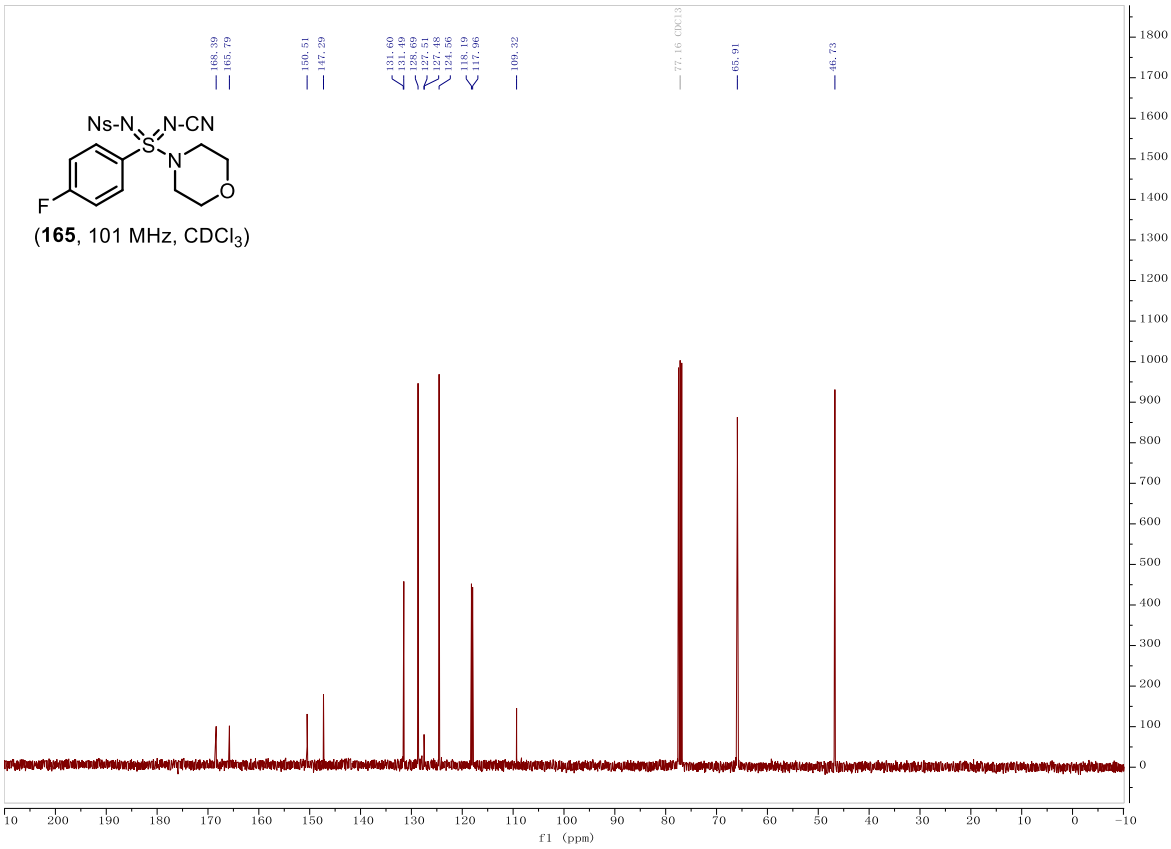
(**164**, 101 MHz, $CDCl_3$)



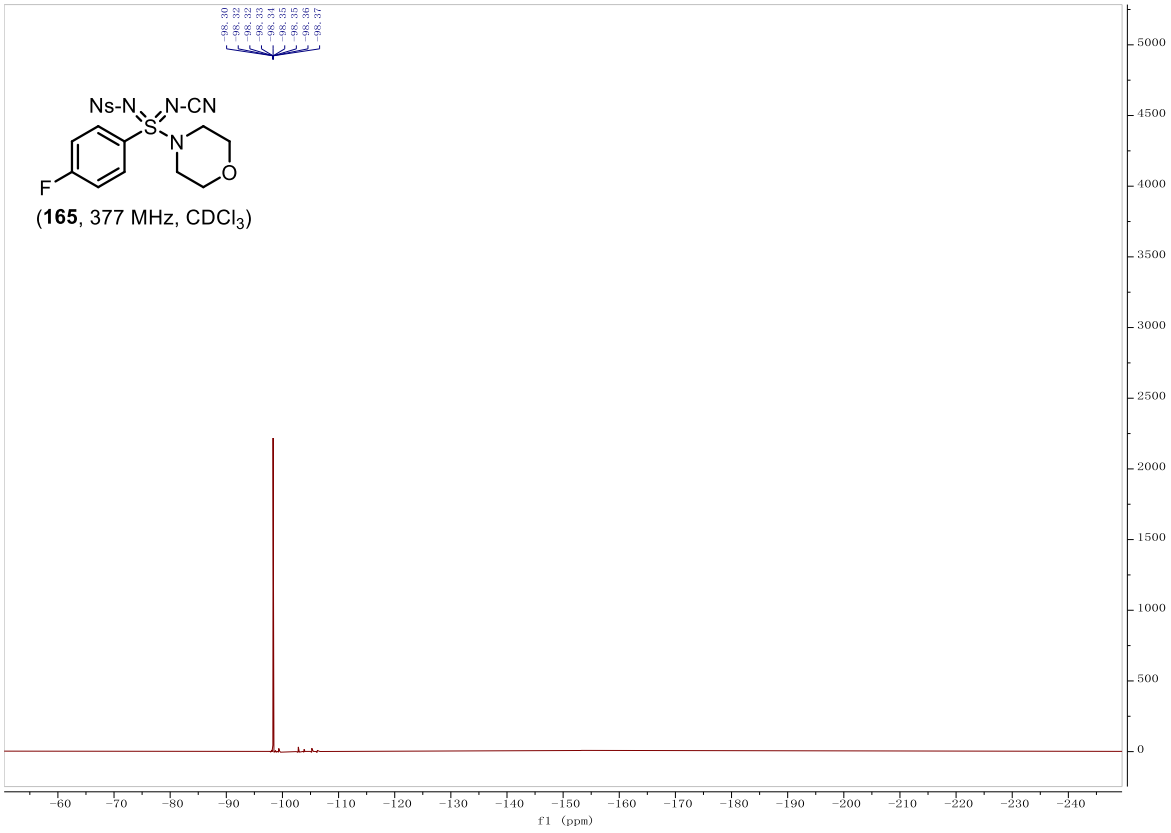
(**164**, 377 MHz, $CDCl_3$)



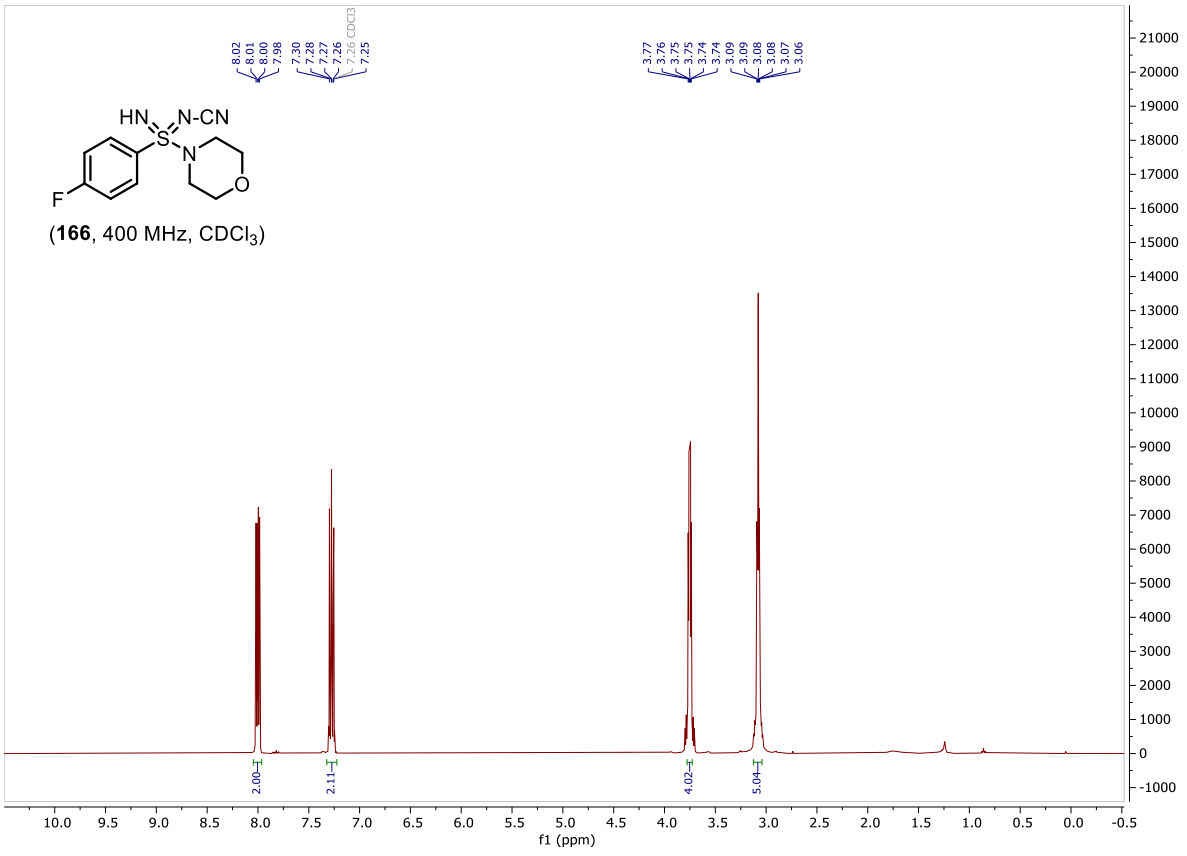
(**165**, 400 MHz, $CDCl_3$)

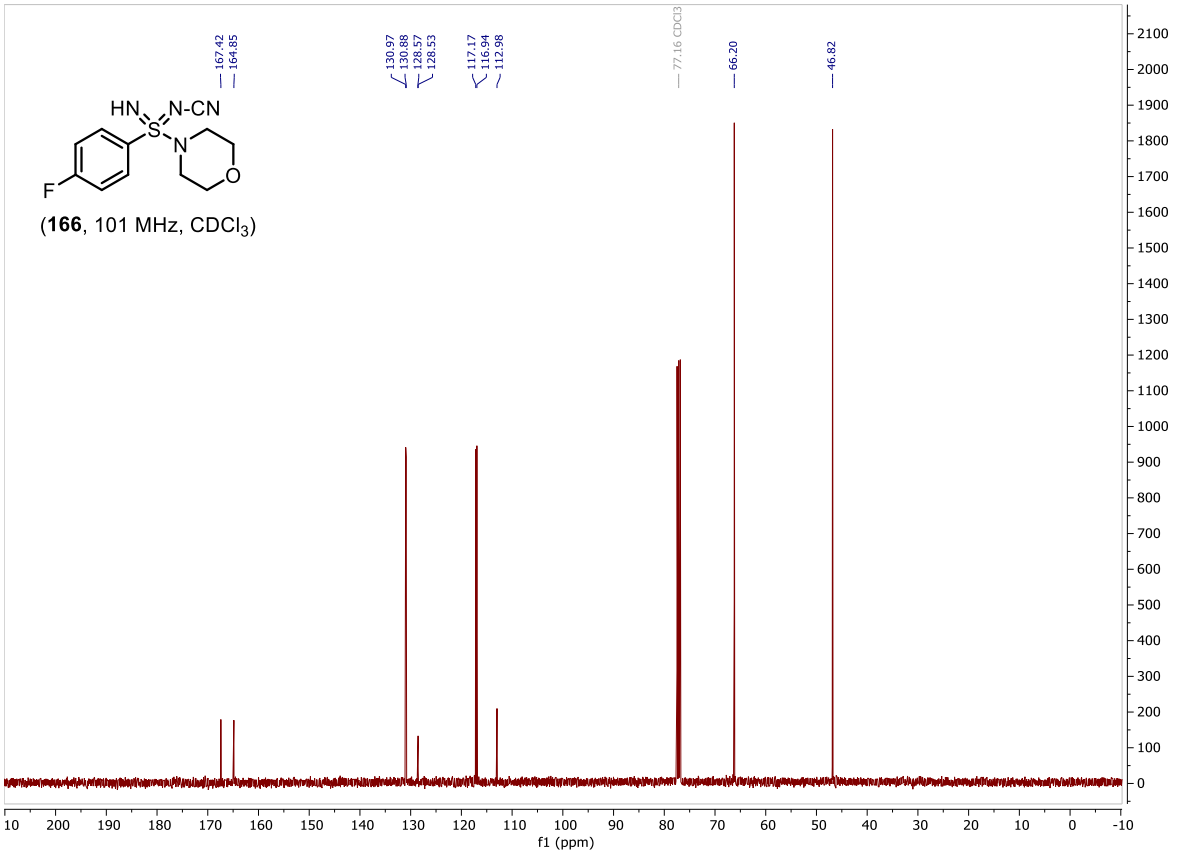


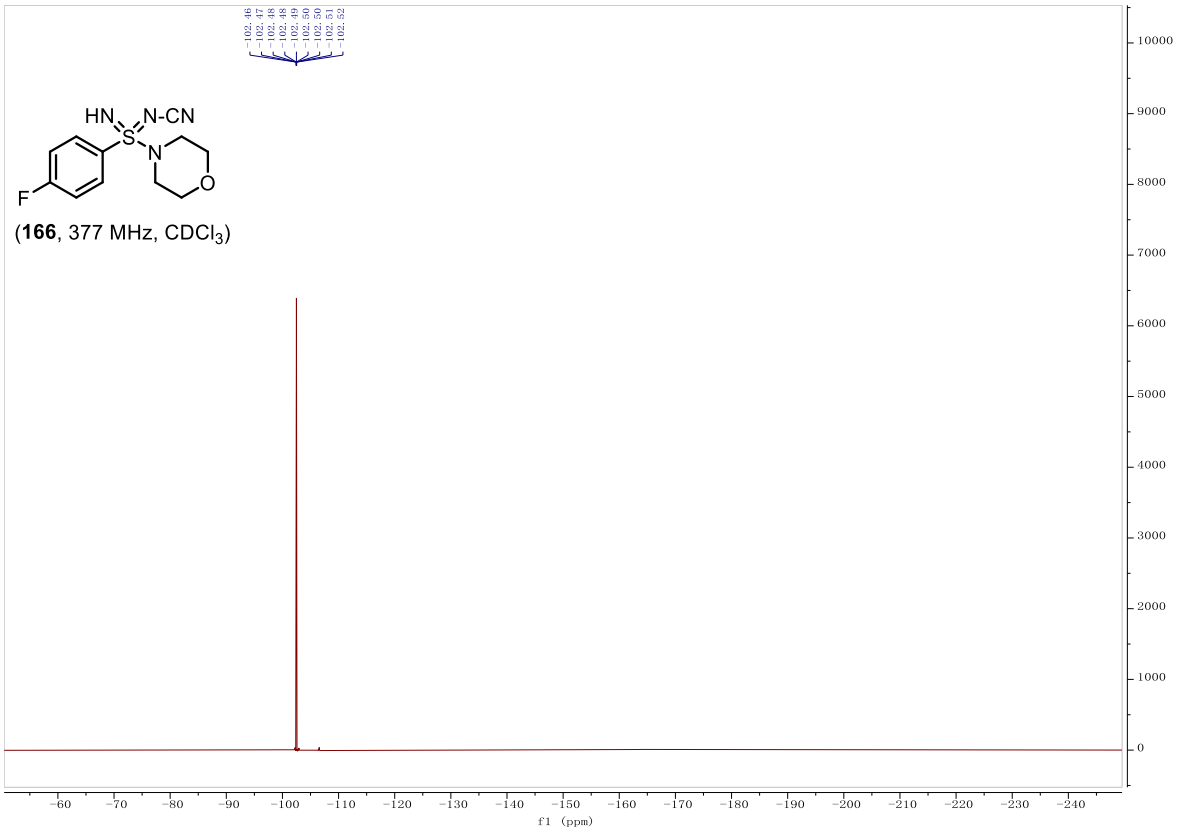
(**165**, 101 MHz, $CDCl_3$)

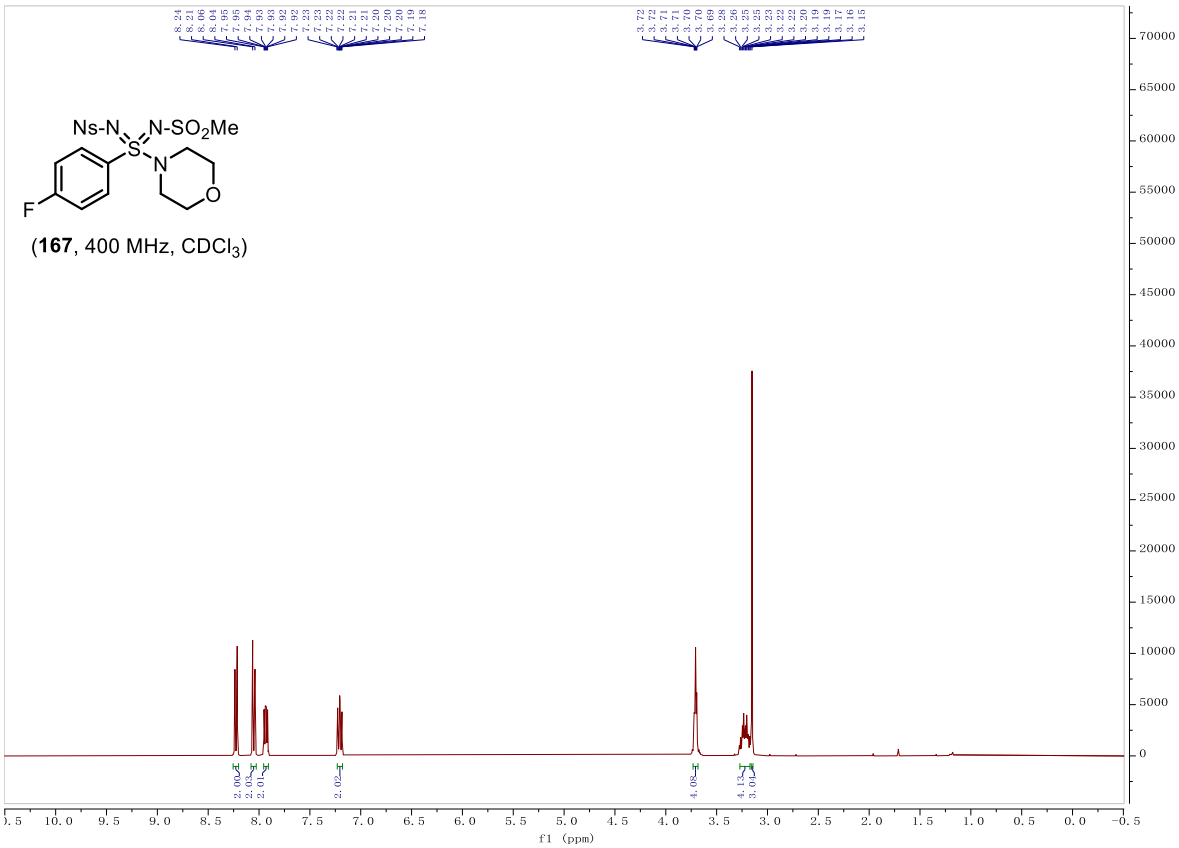


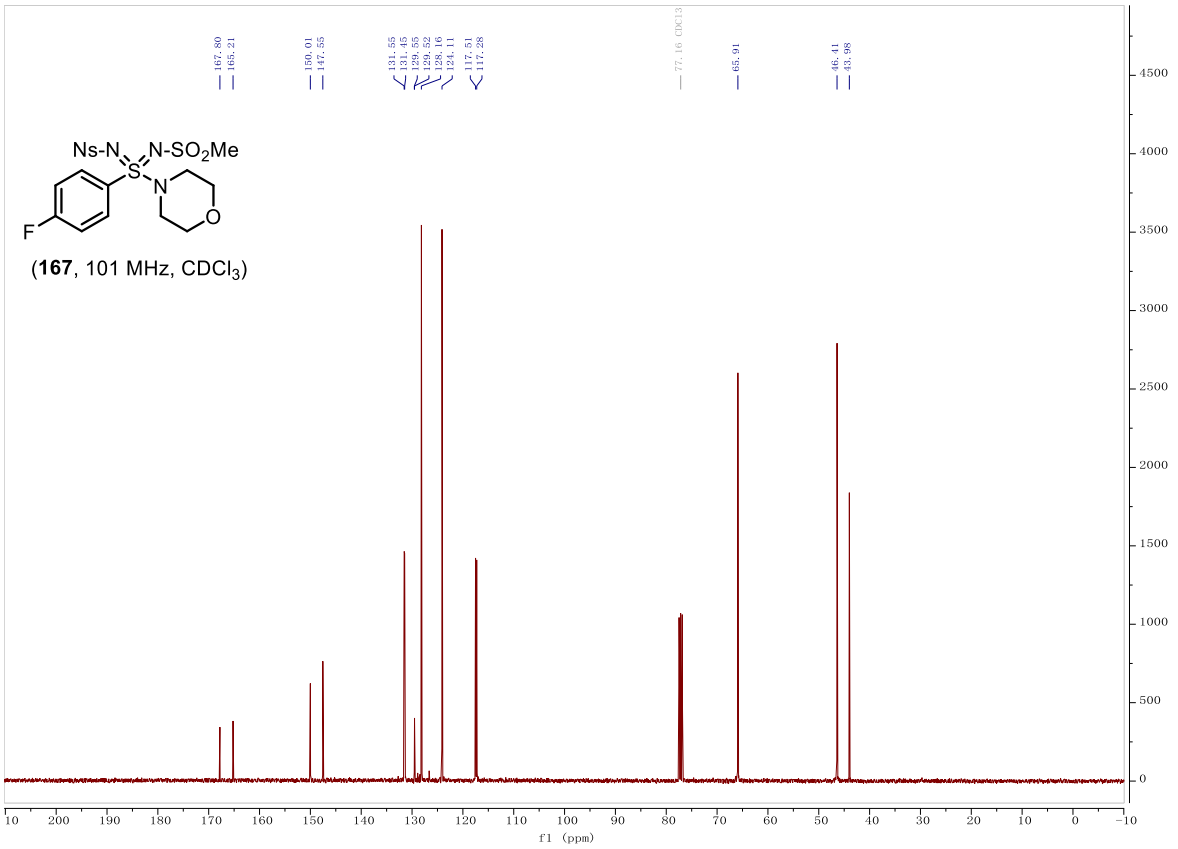
(**165**, 377 MHz, $CDCl_3$)

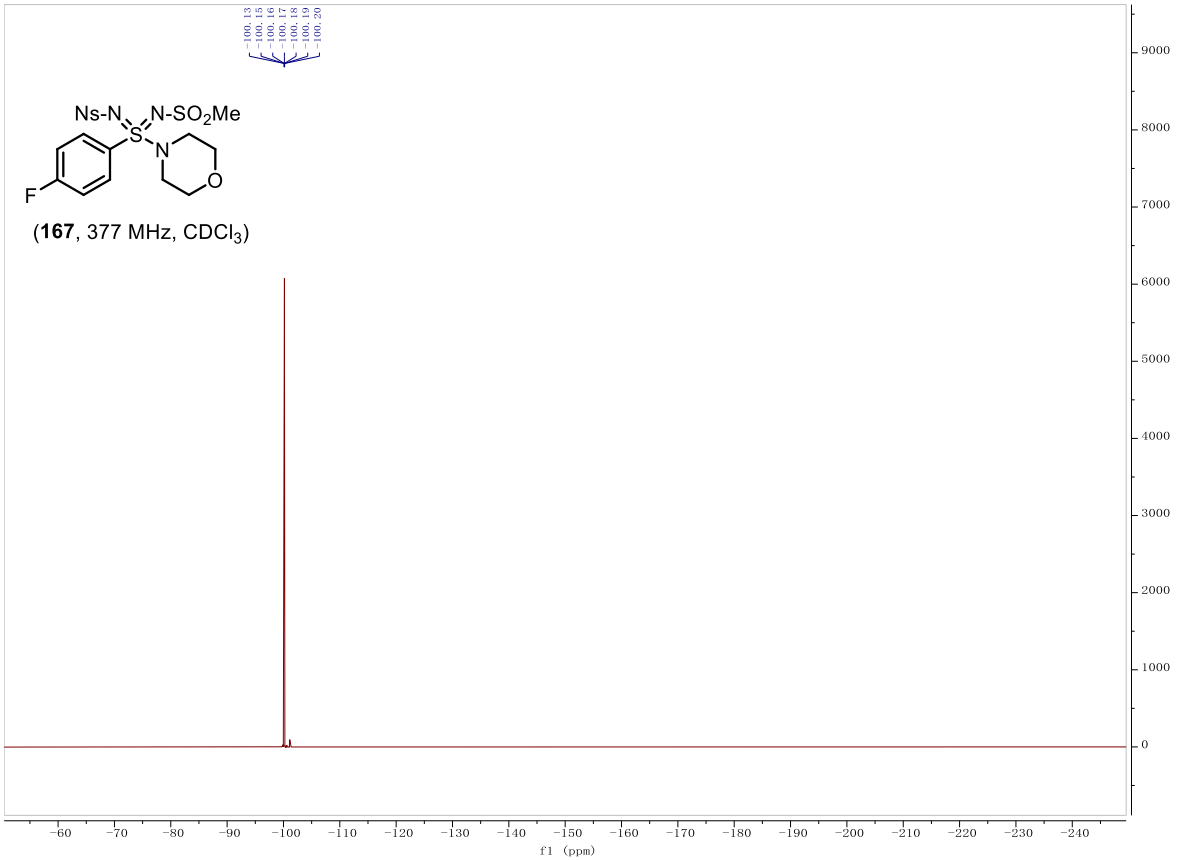

HN
N-CN
S
N
O
F
(166, 400 MHz, CDCl3)
8.02
8.01
8.00
7.98
7.30
7.28
7.27
7.26
7.25
CDCl3
3.77
3.76
3.75
3.75
3.74
3.74
3.09
3.09
3.08
3.08
3.07
3.06
2.00
2.11
4.02
5.04
f1 (ppm)

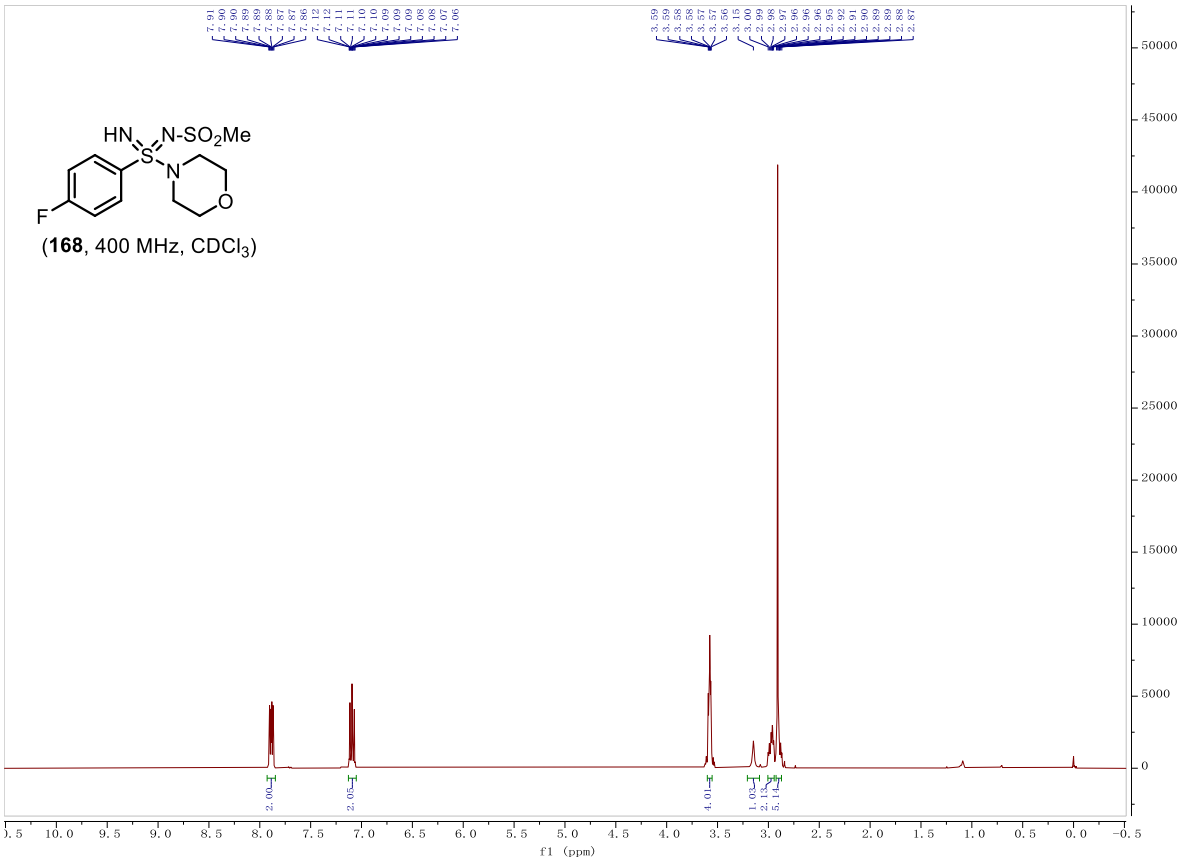

HN
N-CN
S
N
O
F
(166, 101 MHz, CDCl3)
167.42
164.85
130.97
130.88
128.57
128.53
117.17
116.94
112.98
77.16 CDCl3
66.20
46.82
f1 (ppm)

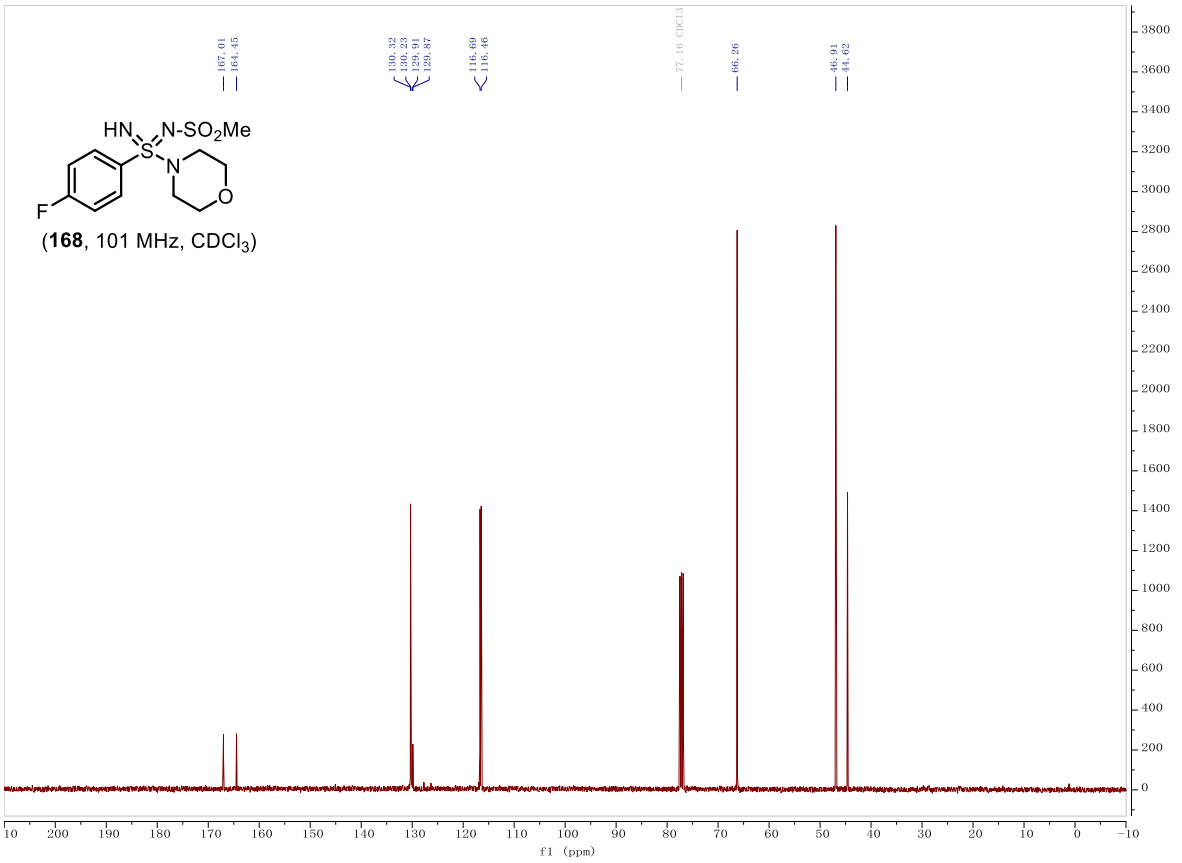

HN
N-CN
S
N
O
F
(166, 377 MHz, CDCl3)
f1 (ppm)

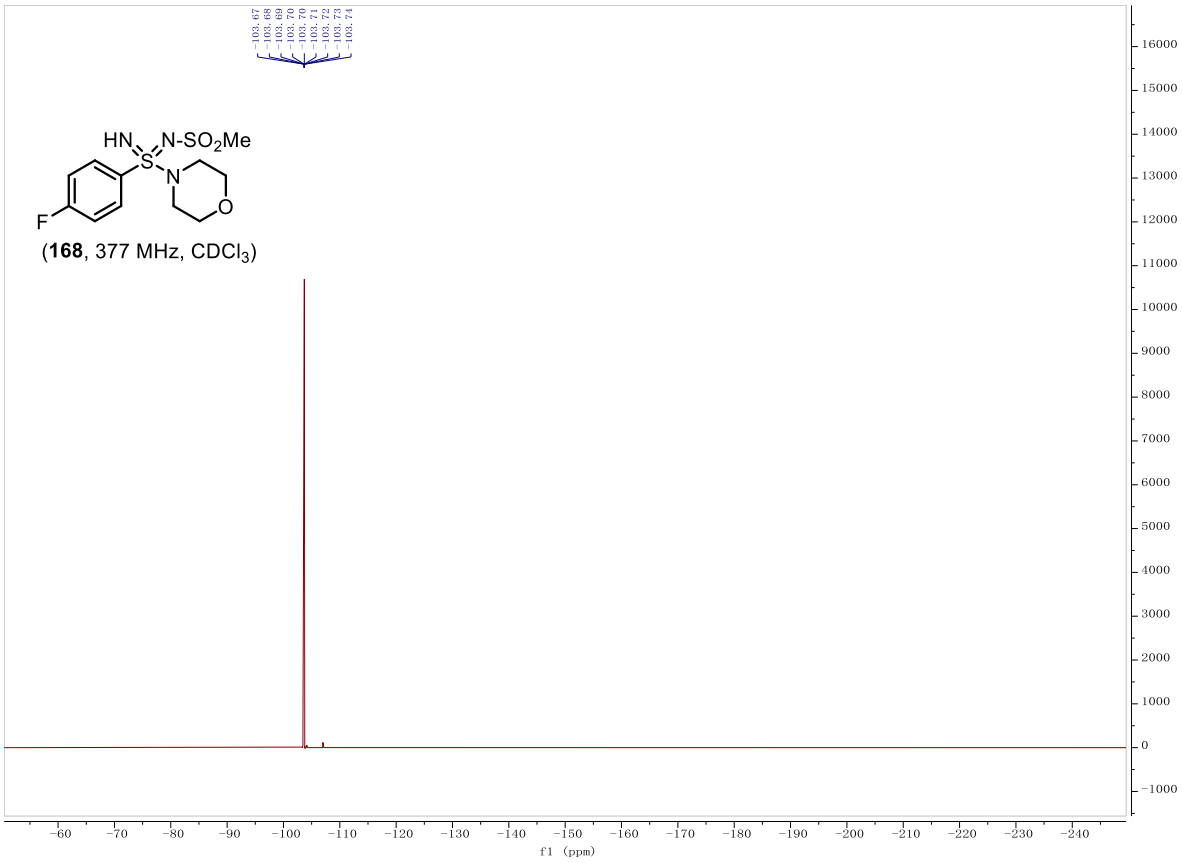

Ns-N
N-SO2Me
S
N
O
F
(167, 400 MHz, CDCl3)
f1 (ppm)

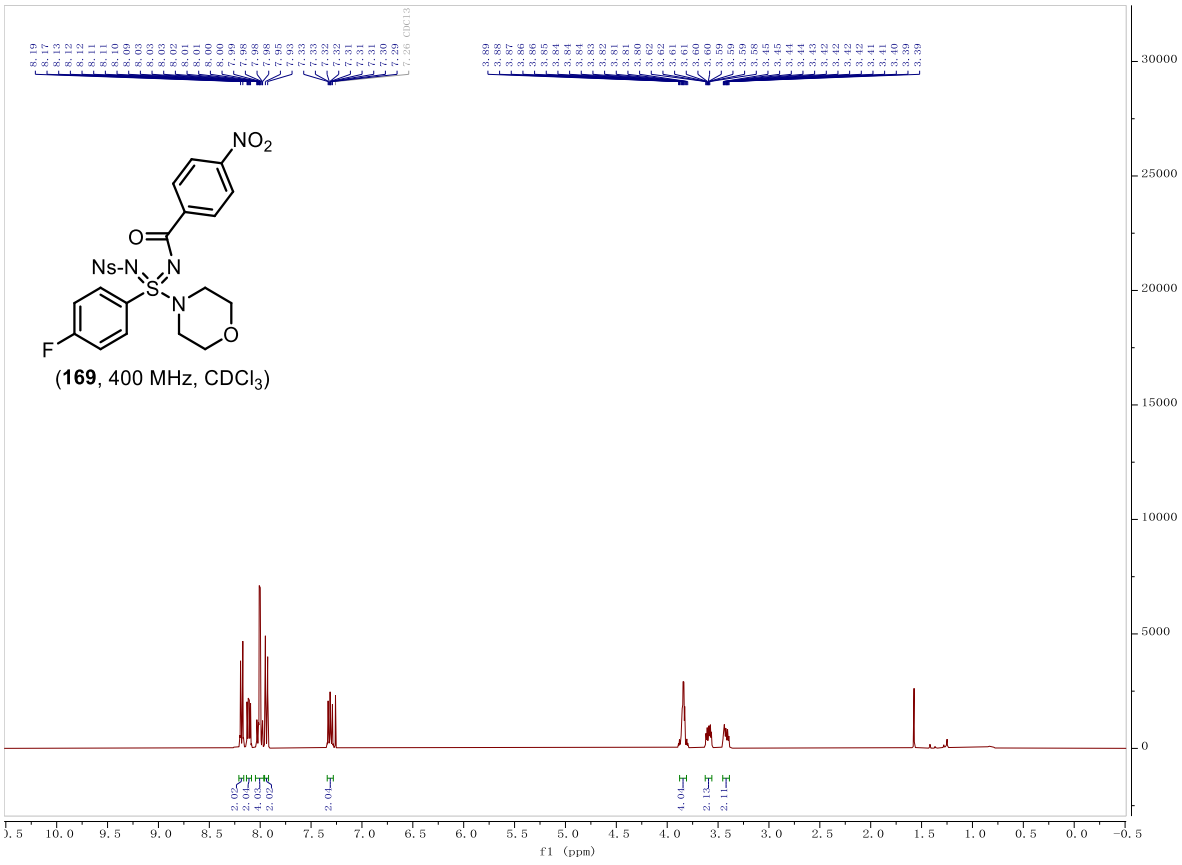

167.80
165.21
150.01
147.55
131.55
131.45
129.55
129.52
128.16
124.11
117.51
117.28
77.16 CDCl3
65.91
46.41
43.98
Ns-N
N-SO2Me
S
N
O
F
(167, 101 MHz, CDCl3)
f1 (ppm)

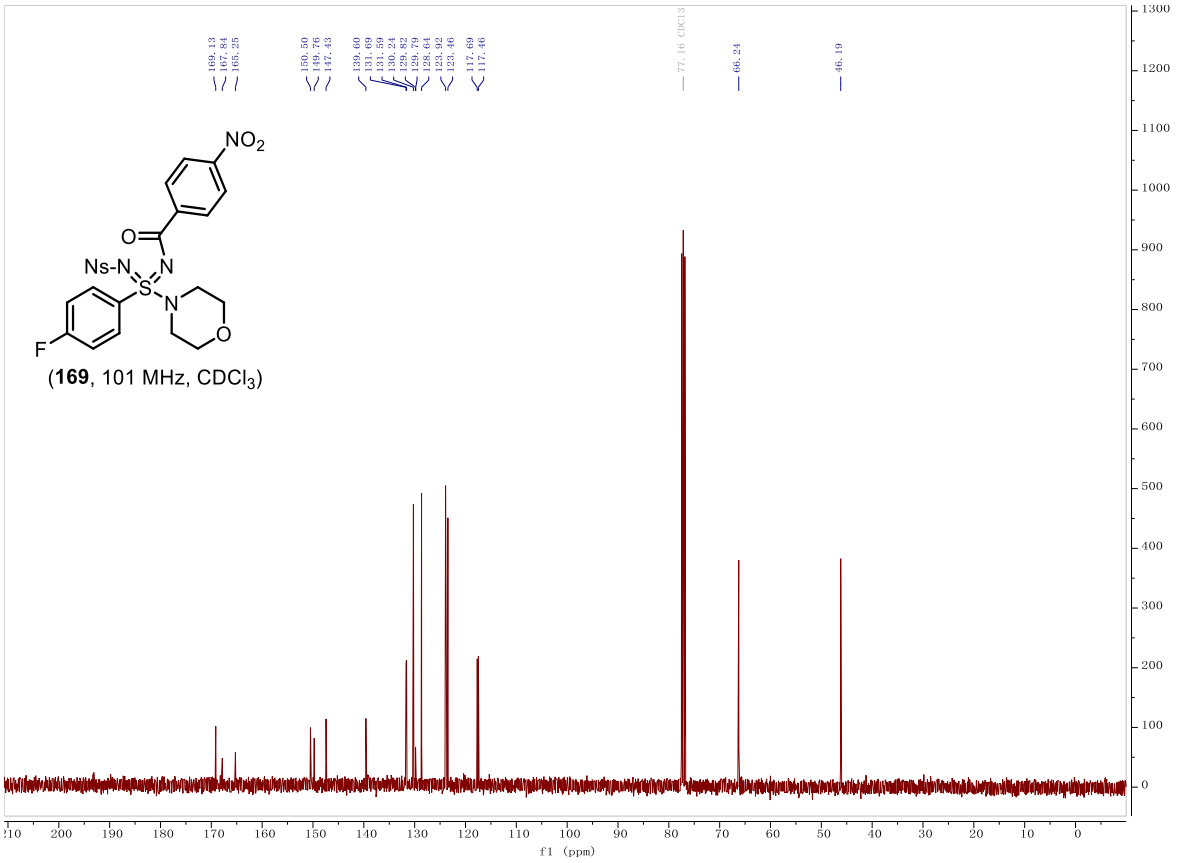

100.13
100.15
100.16
100.17
100.18
100.19
100.20
Ns-N
N-SO2Me
S
N
O
F
(167, 377 MHz, CDCl3)
f1 (ppm)

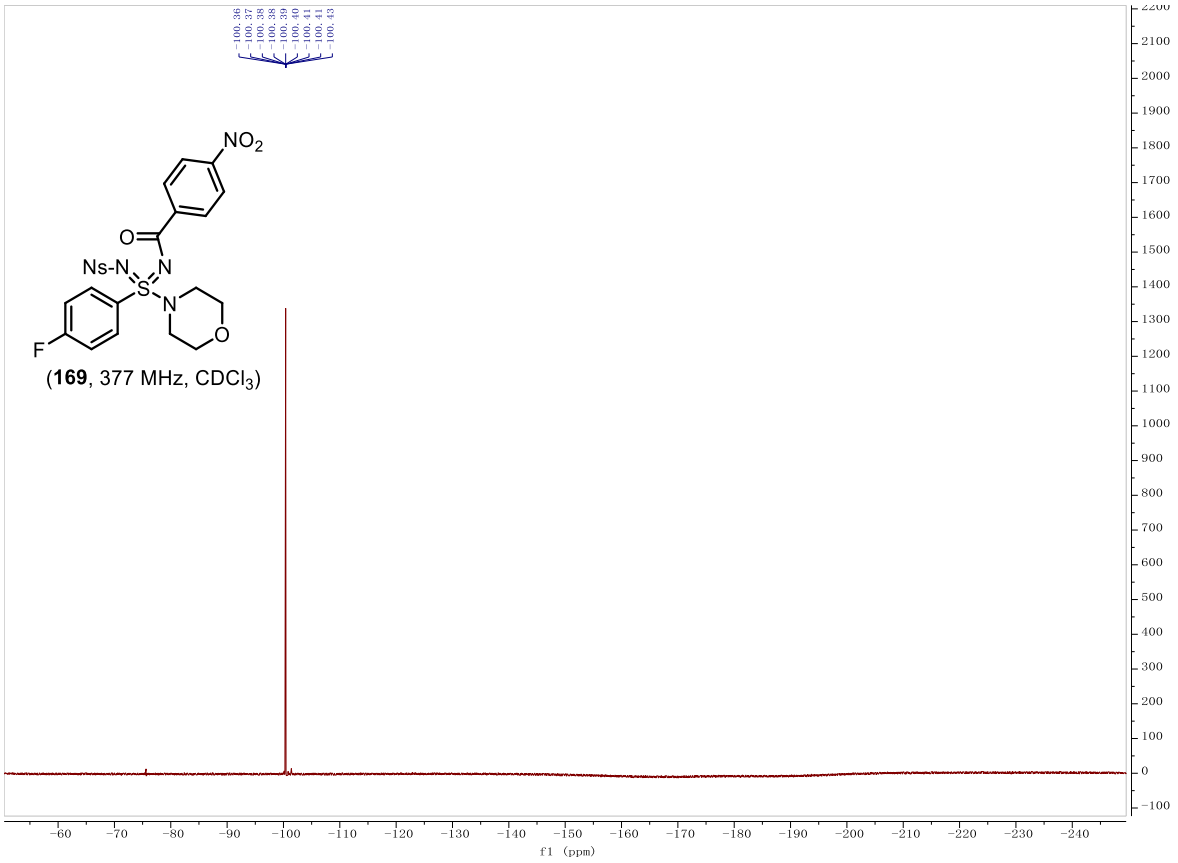

HN
N-SO2Me
S
N
O
F
(168, 400 MHz, CDCl3)
f1 (ppm)

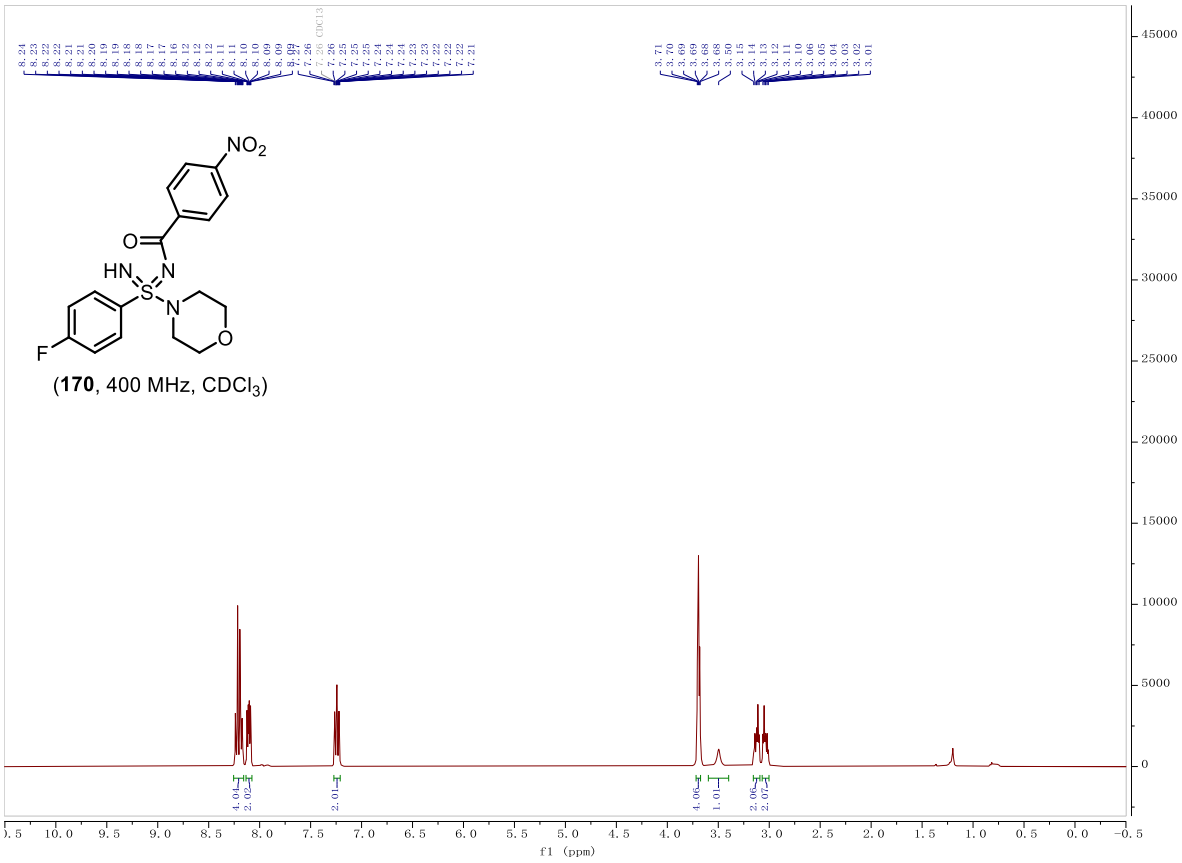

HN
N-SO2Me
S
N
O
F
(168, 101 MHz, CDCl3)
f1 (ppm)

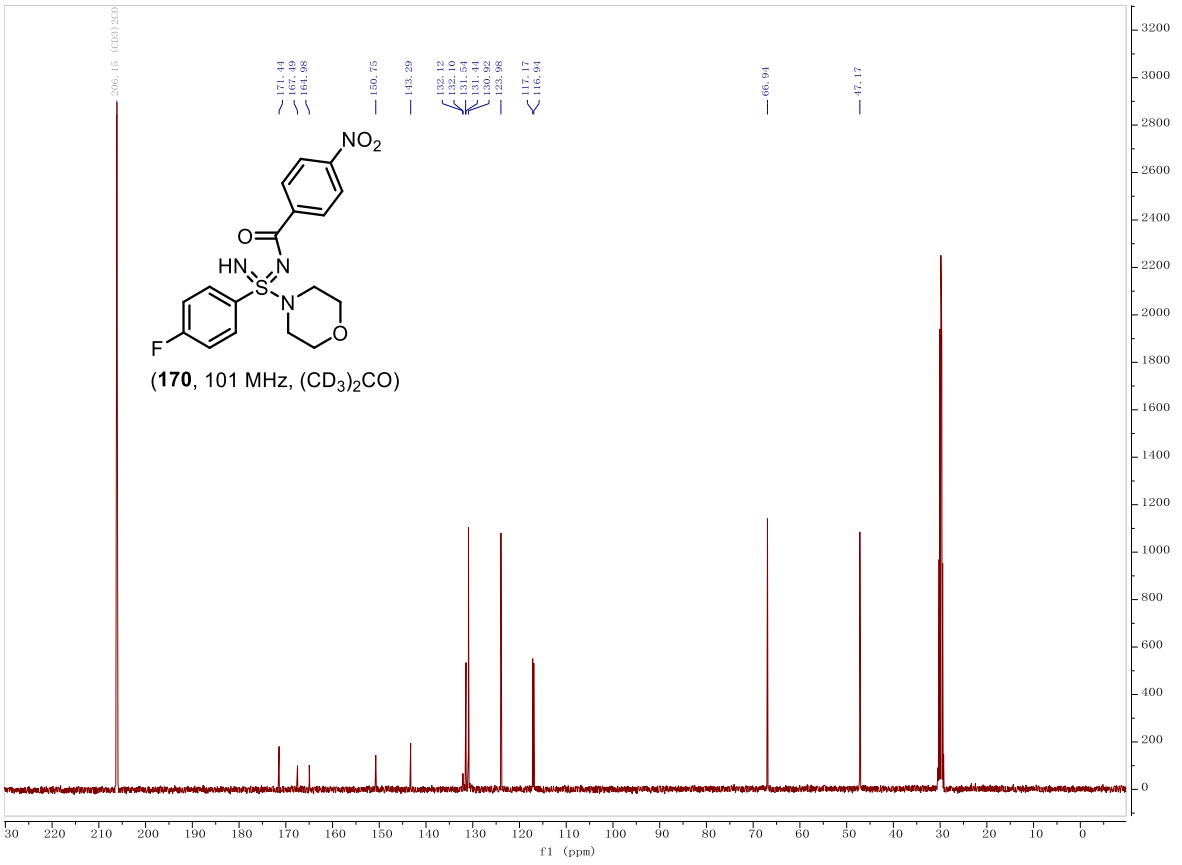

HN
N-SO2Me
S
N
O
F
(168, 377 MHz, CDCl3)
f1 (ppm)

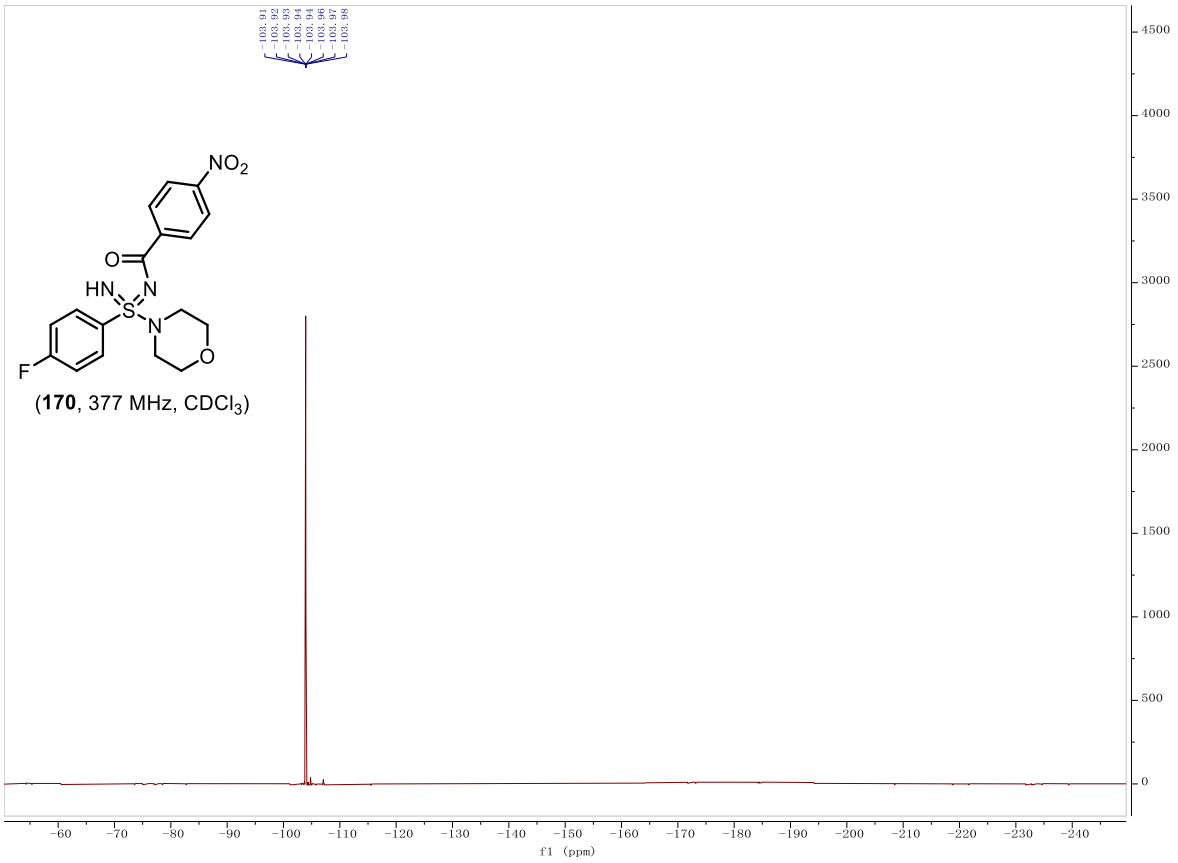

NO2
O
Ns-N
N
S
N
O
F
(169, 400 MHz, CDCl3)
f1 (ppm)

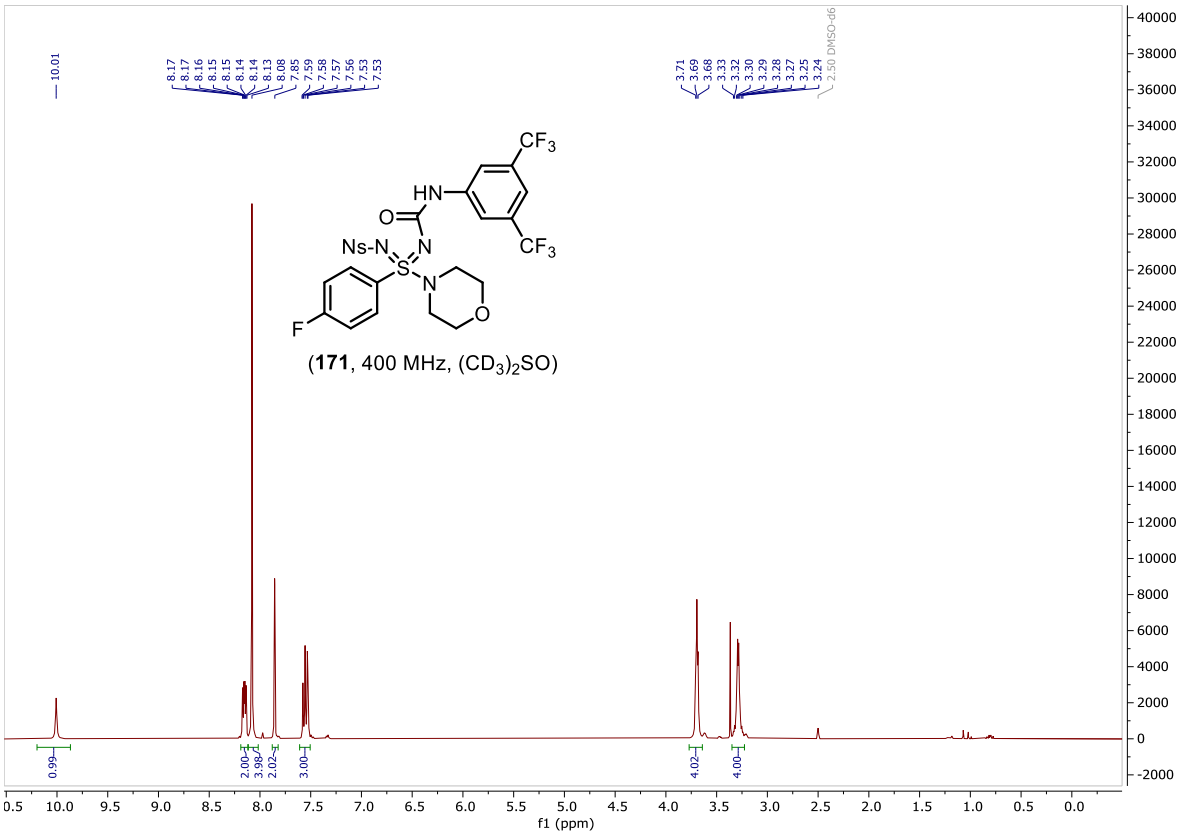

169.13
167.84
165.25
150.50
149.76
147.43
139.60
131.69
131.59
130.24
129.82
129.79
128.64
123.92
123.46
117.69
117.46
77.16 CDCl3
66.24
46.19
NO2
O
Ns-N
N
S
N
O
F
(169, 101 MHz, CDCl3)
f1 (ppm)

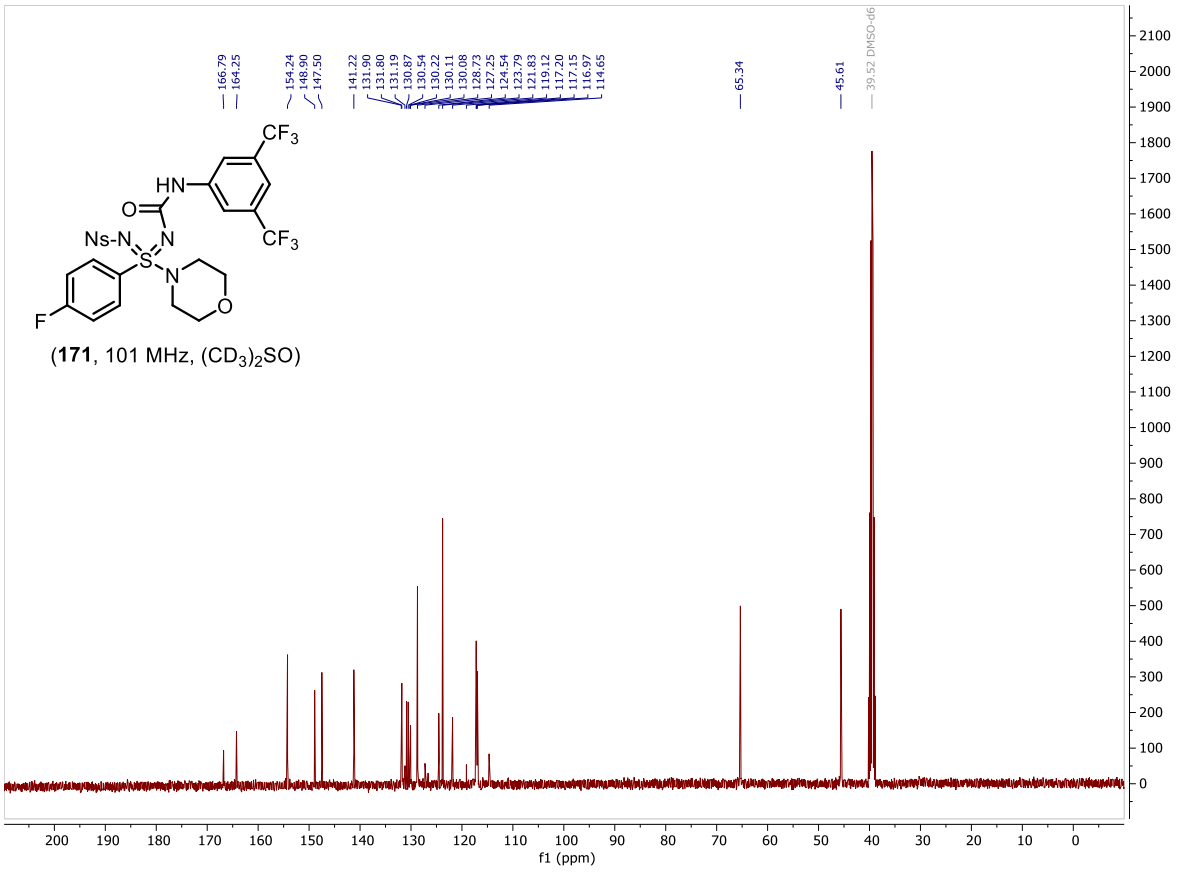

100.36
100.37
100.38
100.38
100.39
100.40
100.41
100.41
100.43
NO2
O
Ns-N
N
S
N
O
F
(169, 377 MHz, CDCl3)
f1 (ppm)


NO2
O
HN
N
S
N
O
F
(170, 400 MHz, CDCl3)
f1 (ppm)

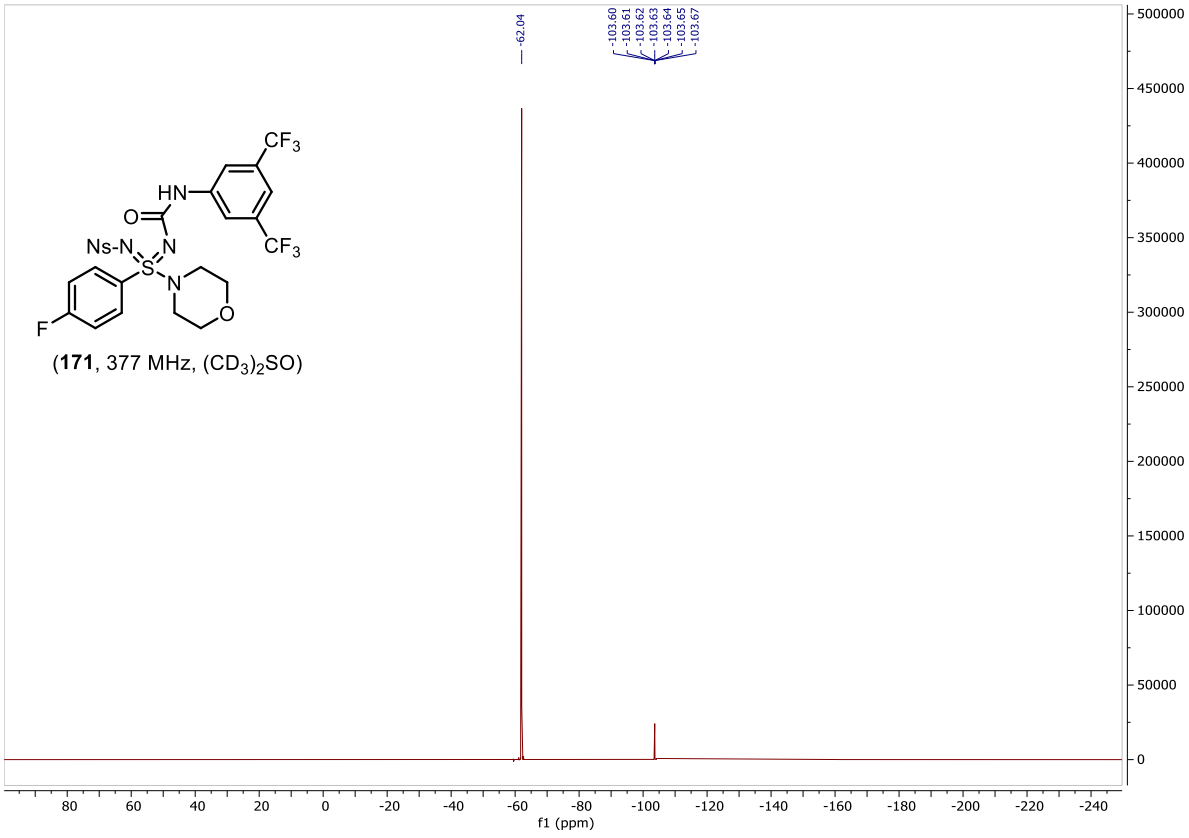

NO2
O
HN
N
S
N
O
F
(170, 101 MHz, (CD3)2CO)
f1 (ppm)


NO2
O
HN
N
S
N
O
F
(170, 377 MHz, CDCl3)
f1 (ppm)

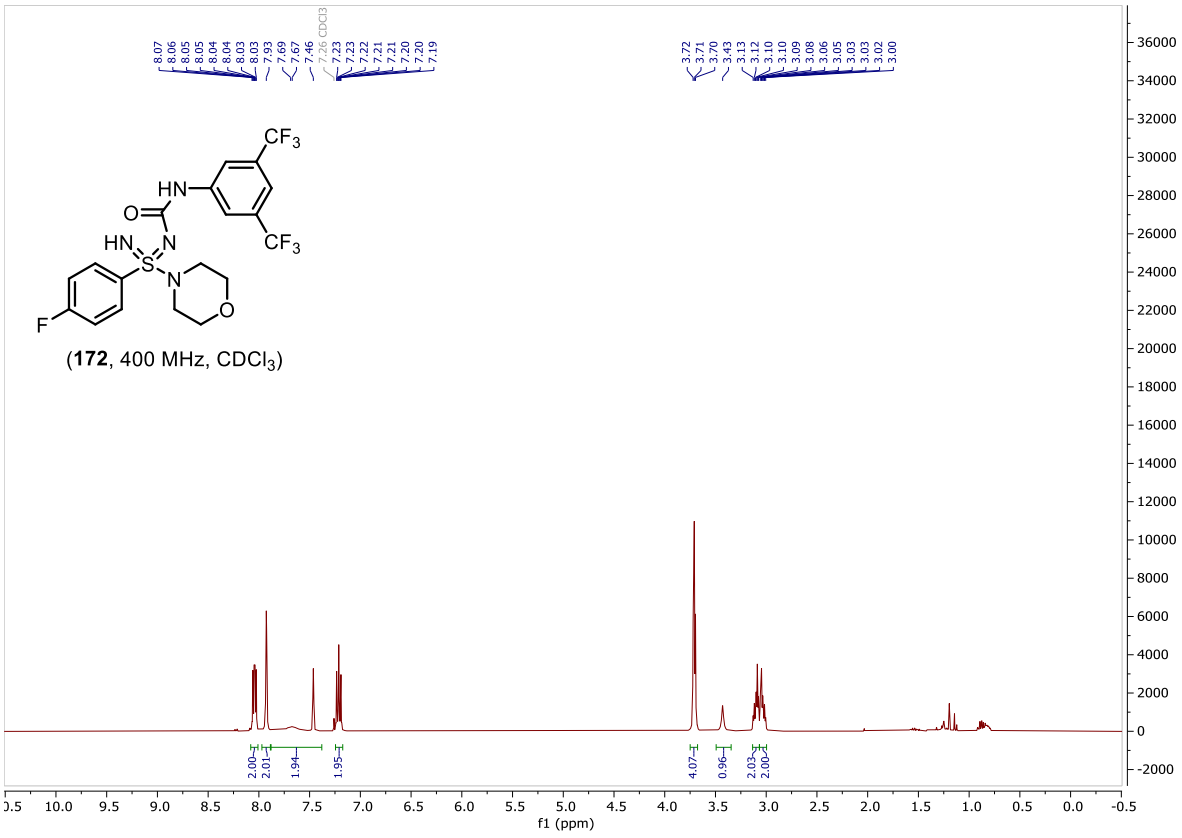

CF3
HN
O
Ns-N
N
S
N
O
F
CF3
(171, 400 MHz, (CD3)2SO)
f1 (ppm)



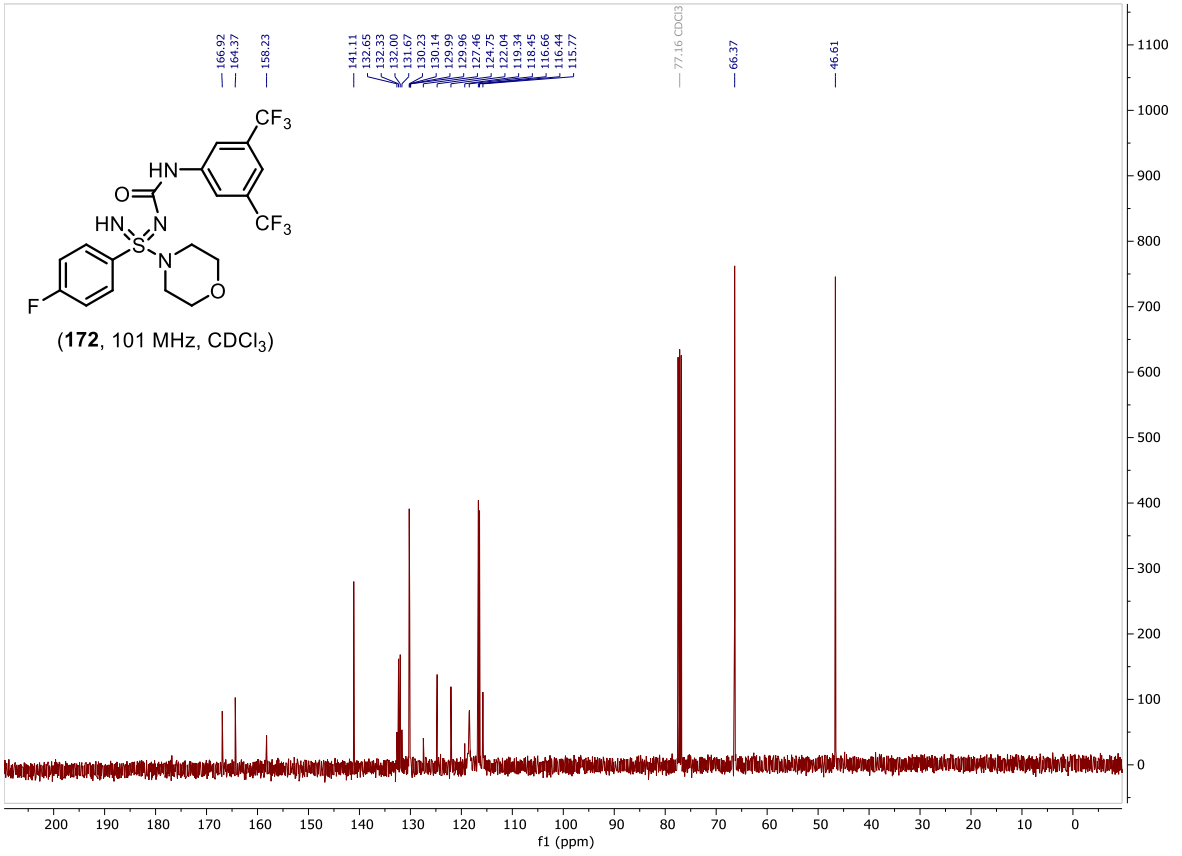
(**171**, 101 MHz, $(CD_3)_2SO$)



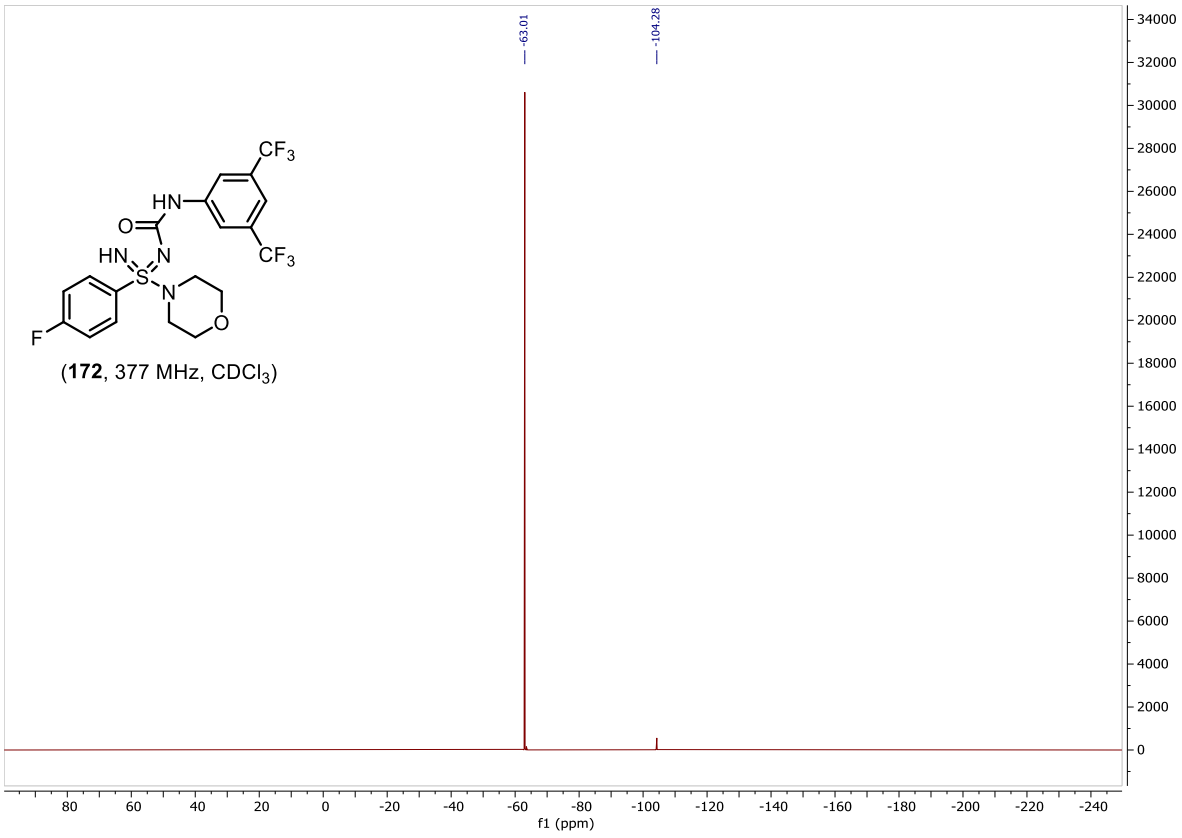
(**171**, 377 MHz, $(CD_3)_2SO$)



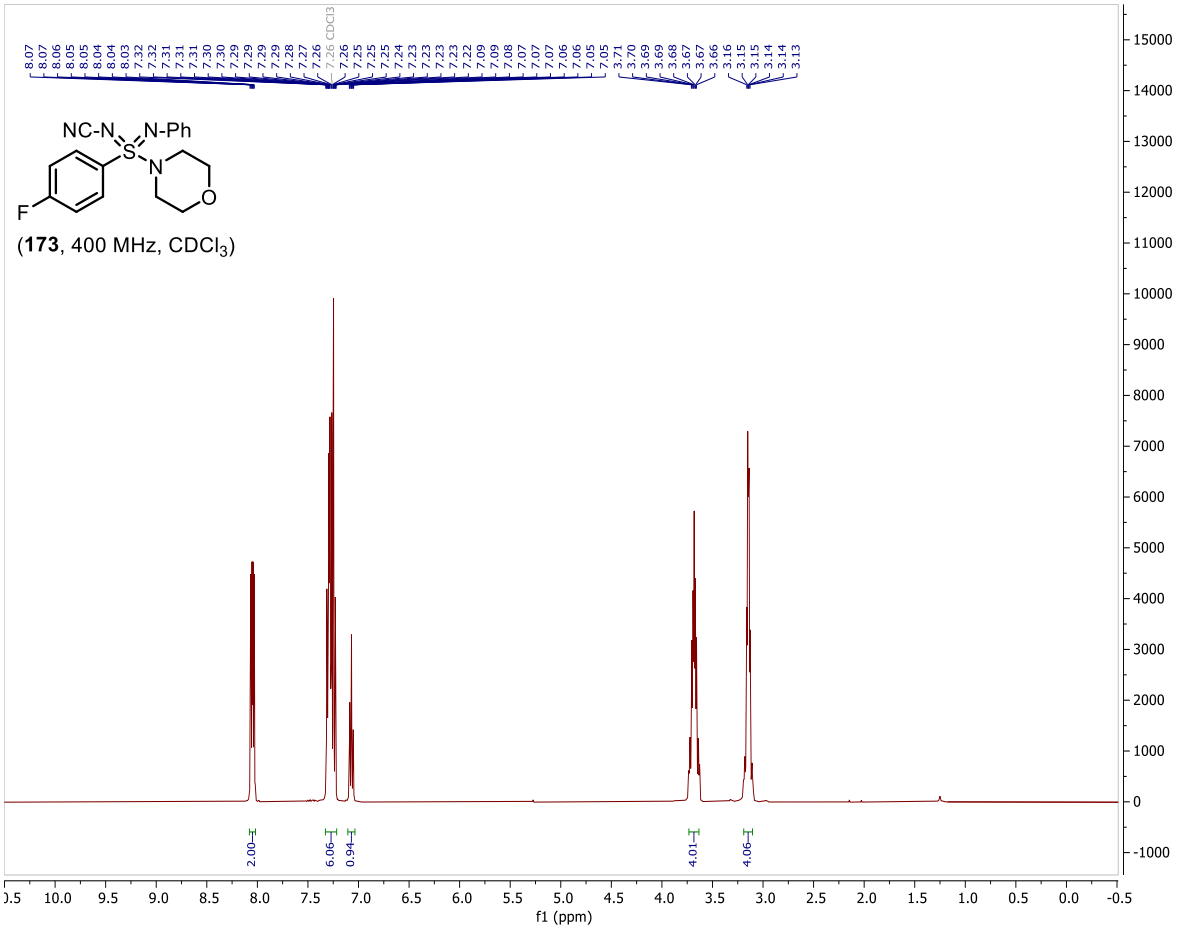
(**172**, 400 MHz, $CDCl_3$)



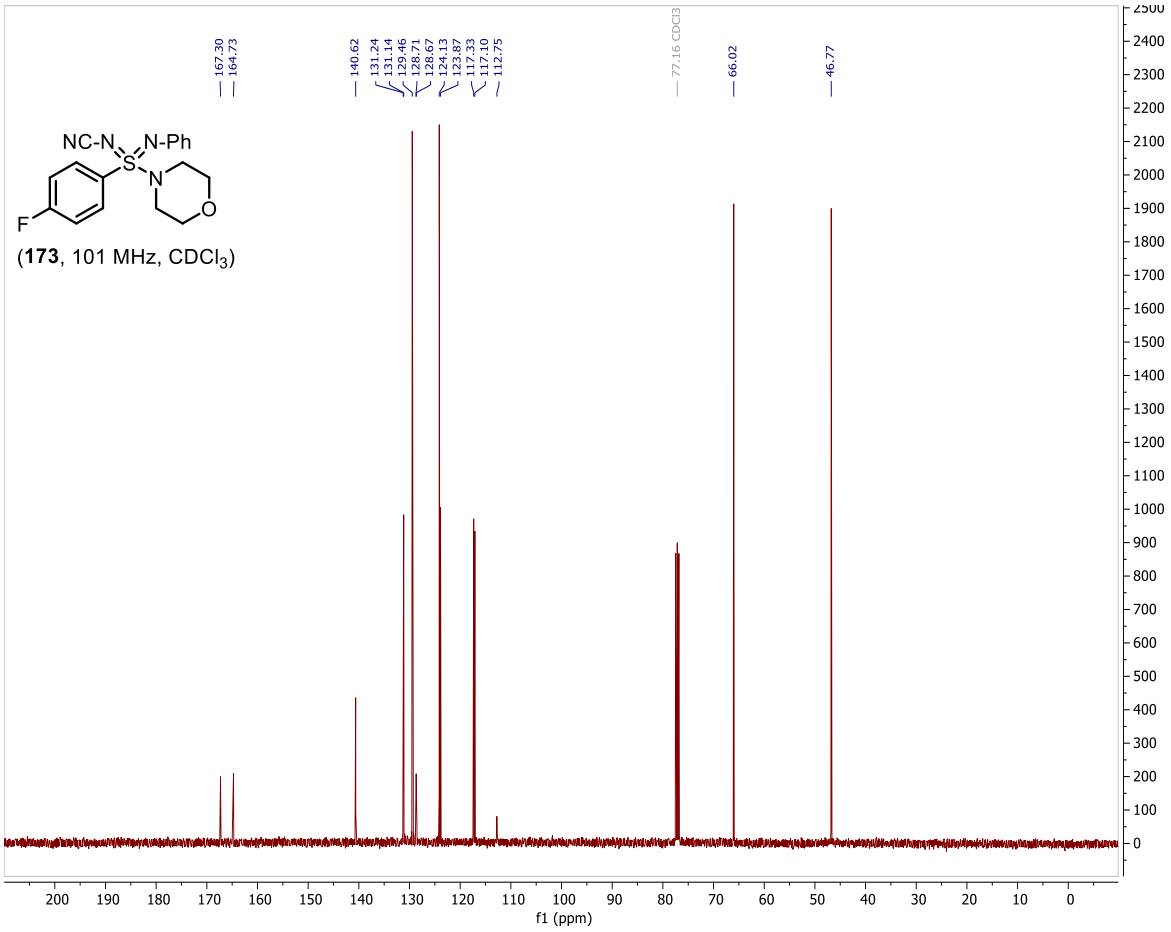
(**172**, 101 MHz, $CDCl_3$)

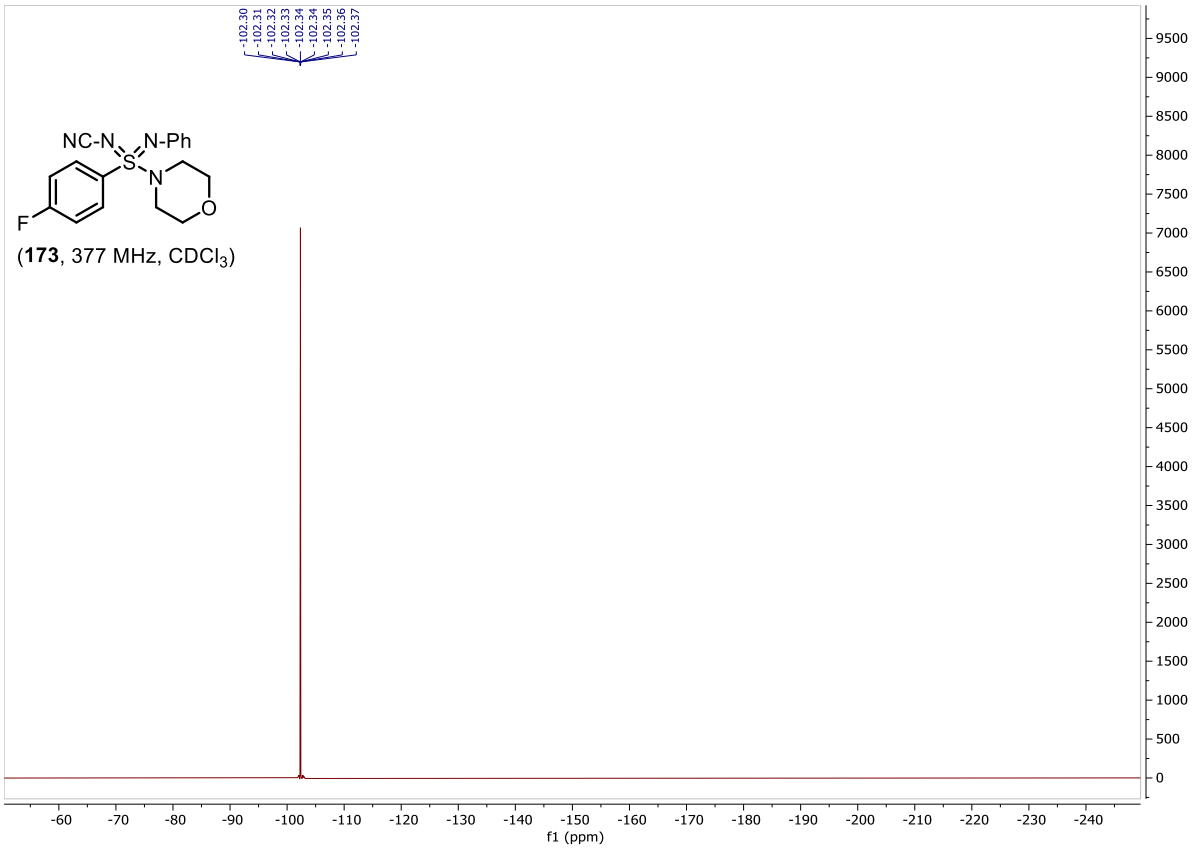


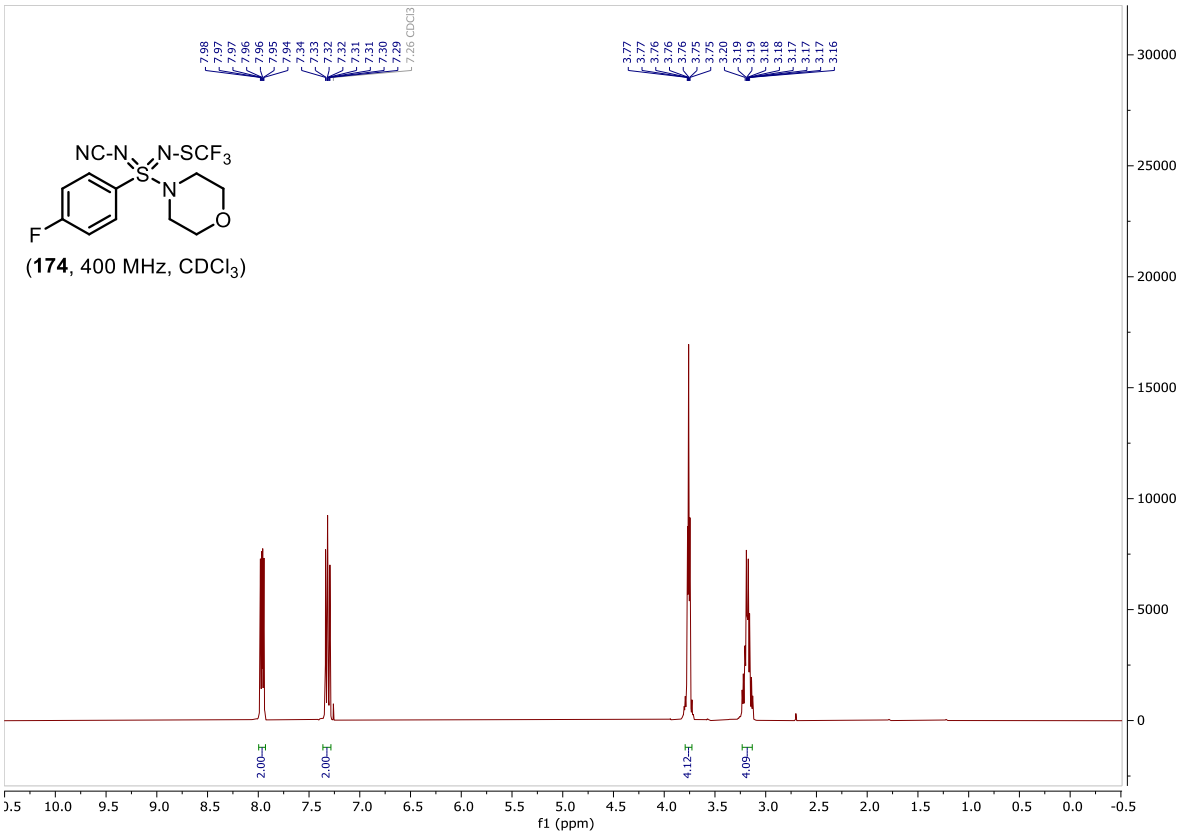
(**172**, 377 MHz, $CDCl_3$)

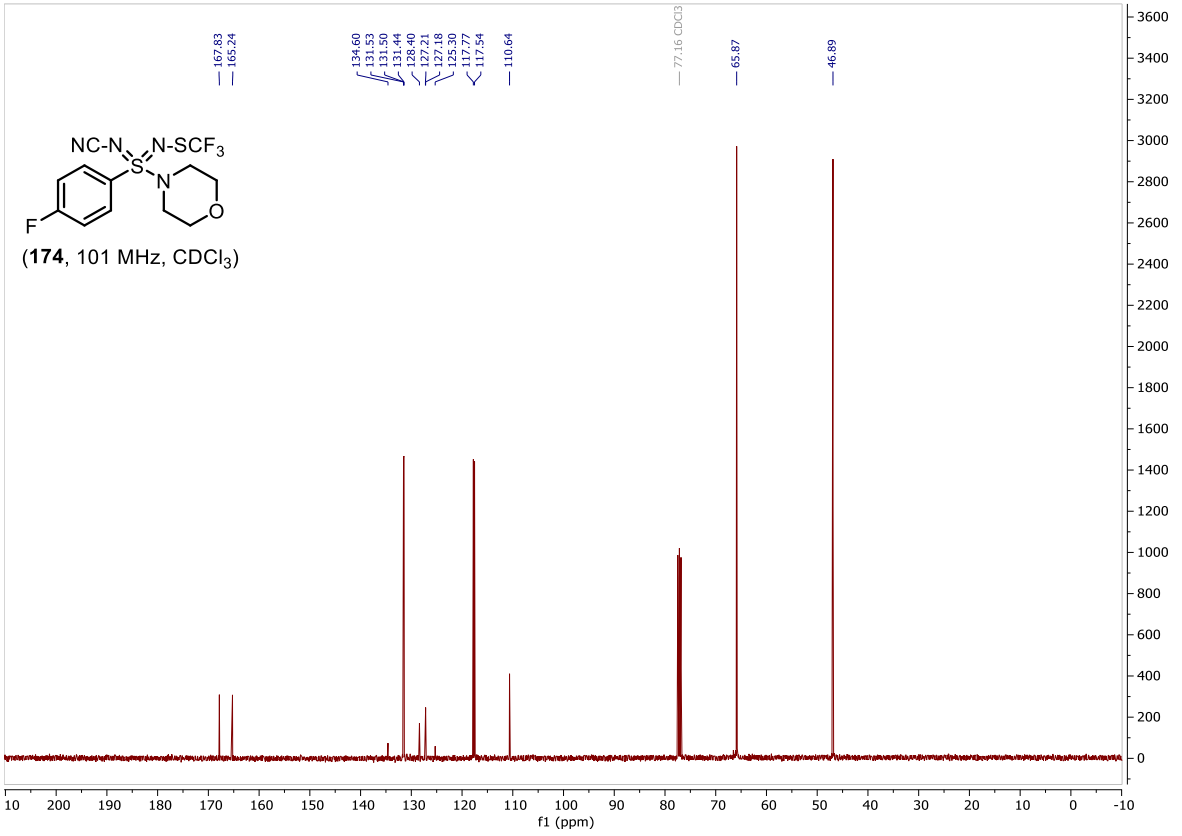


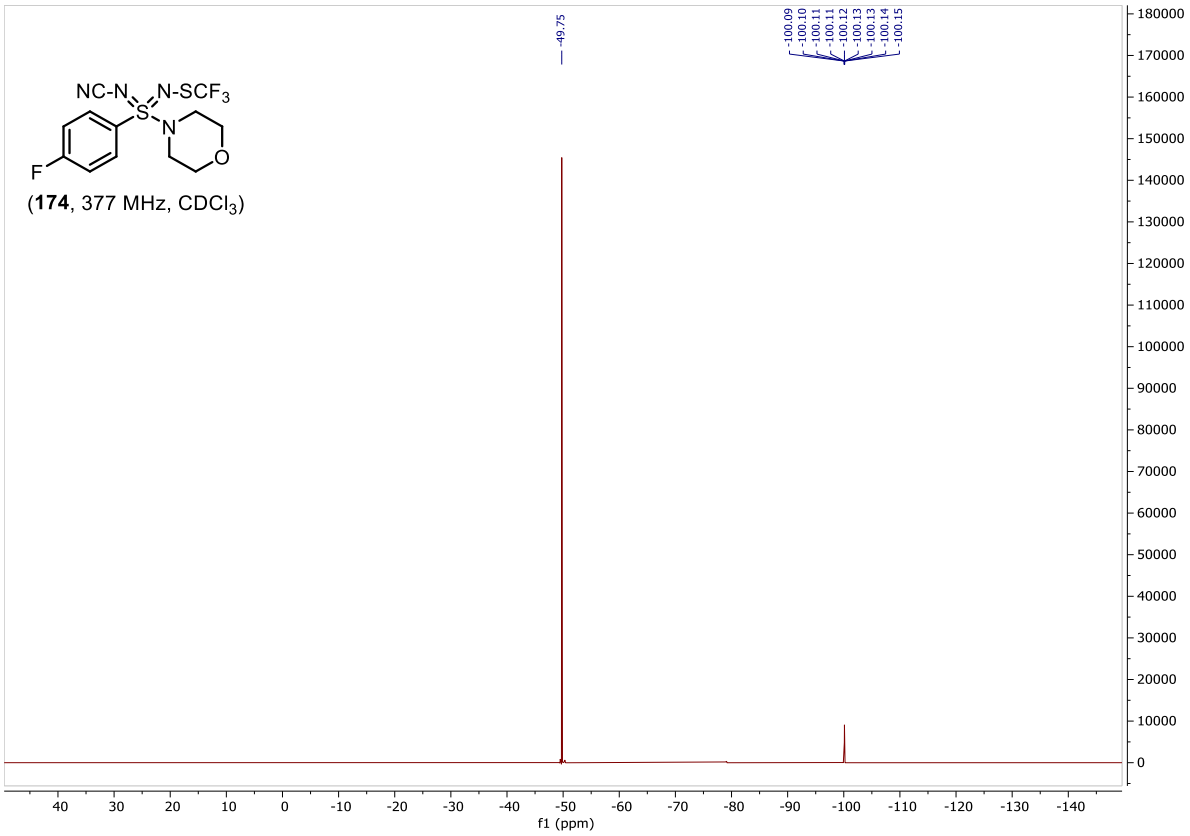
(**173**, 400 MHz, $CDCl_3$)

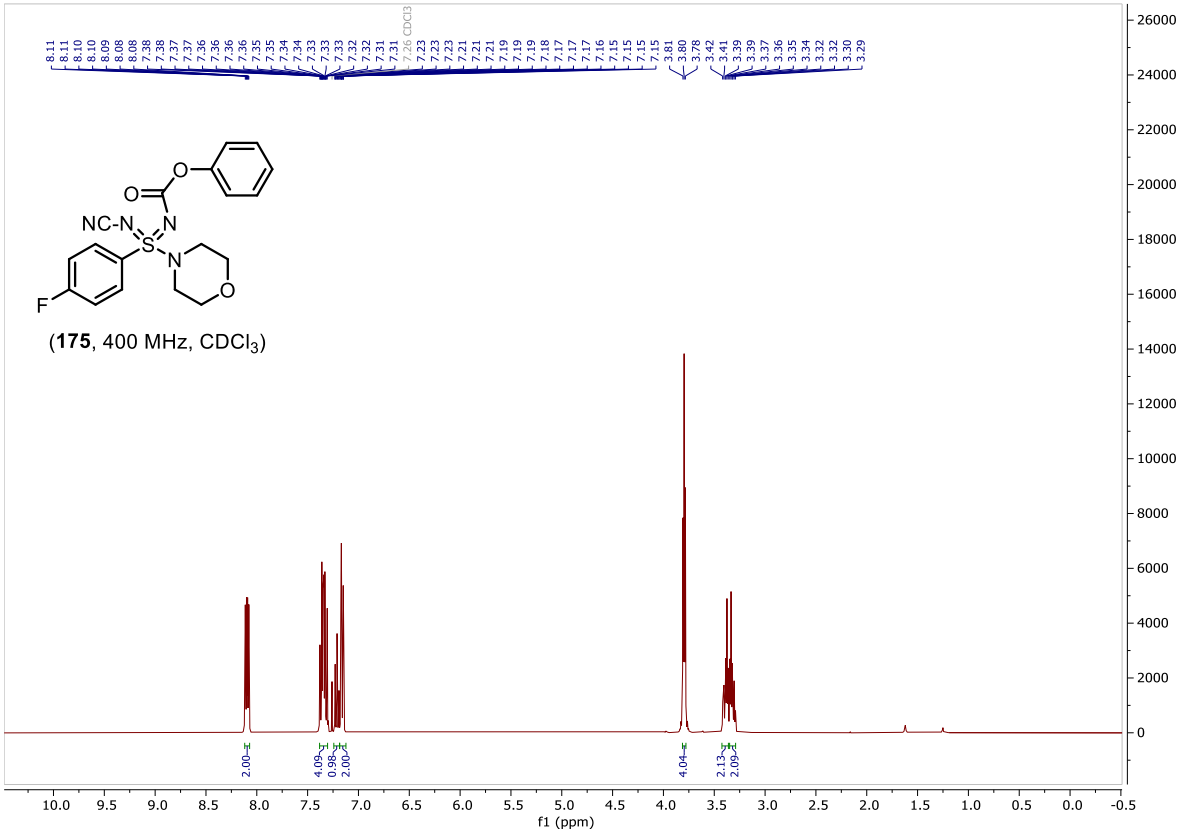

167.30
164.73
140.62
131.24
131.14
129.46
128.71
128.67
124.13
123.87
117.33
117.10
112.75
77.16 CDCl3
66.02
46.77
NC-N
N-Ph
S
N
O
F
(173, 101 MHz, CDCl3)
f1 (ppm)

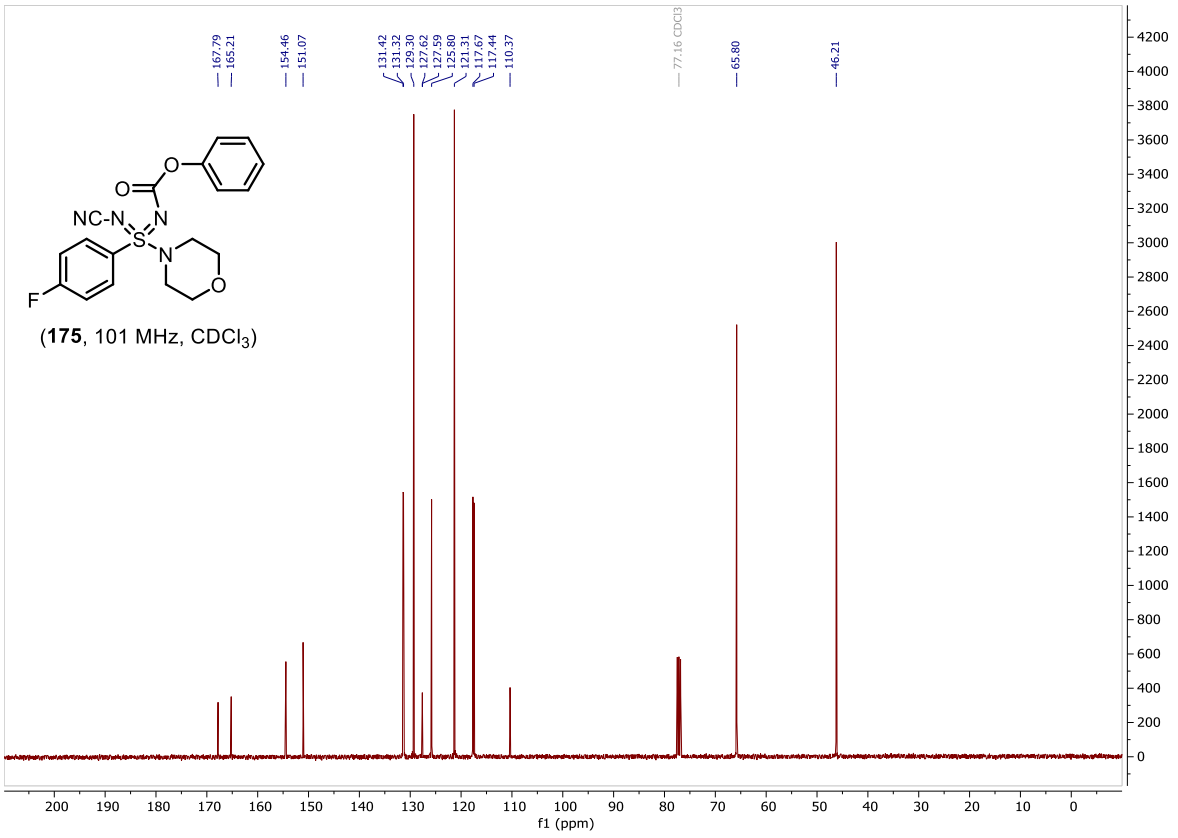

-102.30
-102.31
-102.32
-102.33
-102.34
-102.34
-102.35
-102.36
-102.37
NC-N
N-Ph
S
N
O
F
(173, 377 MHz, CDCl3)
f1 (ppm)


NC-N
N-SCF3
S
N
O
F
(174, 400 MHz, CDCl3)
7.98
7.97
7.97
7.96
7.96
7.95
7.94
7.34
7.33
7.32
7.32
7.31
7.31
7.30
7.29
7.26 CDCl3
3.77
3.77
3.76
3.76
3.76
3.75
3.75
3.20
3.19
3.19
3.18
3.18
3.17
3.17
3.17
3.16
2.00
2.00
4.12
4.09
f1 (ppm)

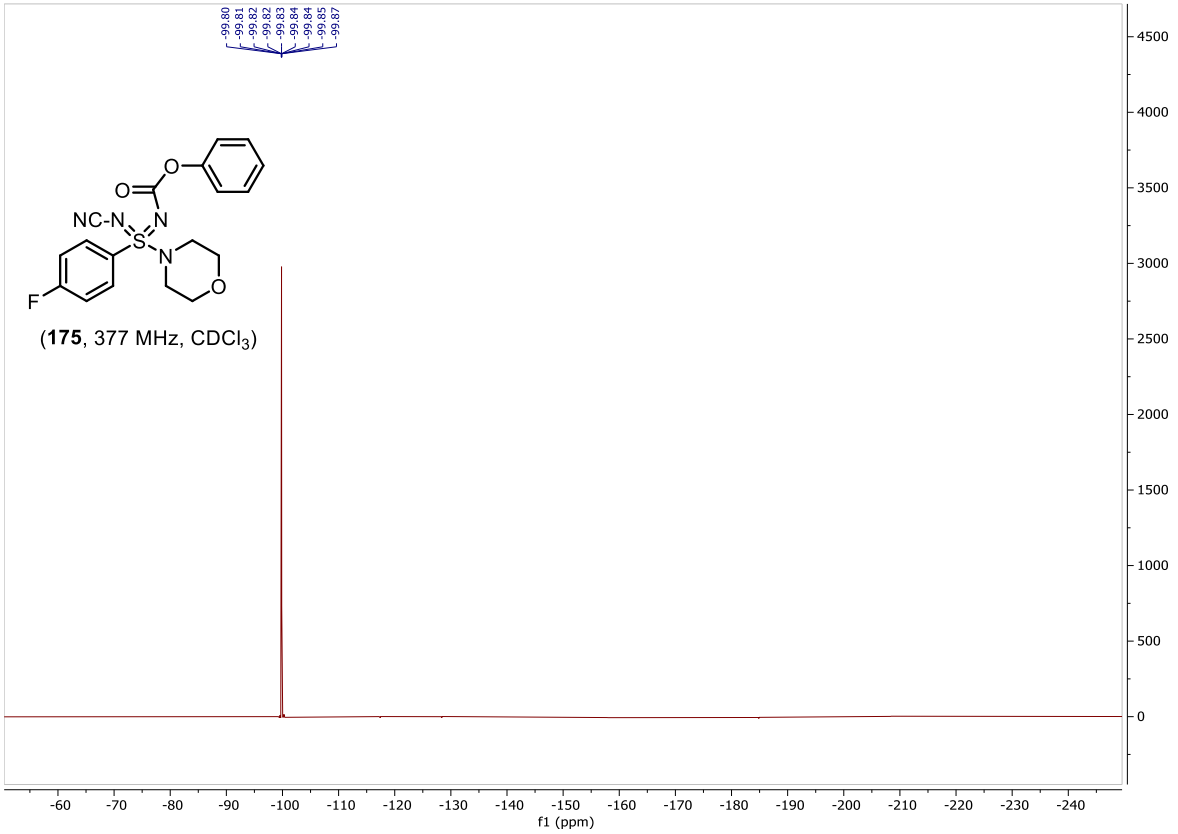

NC-N
N-SCF3
S
N
O
F
(174, 101 MHz, CDCl3)
167.83
165.24
134.60
131.53
131.50
131.44
128.40
127.21
127.18
125.30
117.77
117.54
110.64
77.16 CDCl3
65.87
46.89
f1 (ppm)


NC-N
N-SCF3
S
N
O
F
(174, 377 MHz, CDCl3)
-49.75
-100.09
-100.10
-100.11
-100.11
-100.12
-100.13
-100.13
-100.14
-100.15
f1 (ppm)

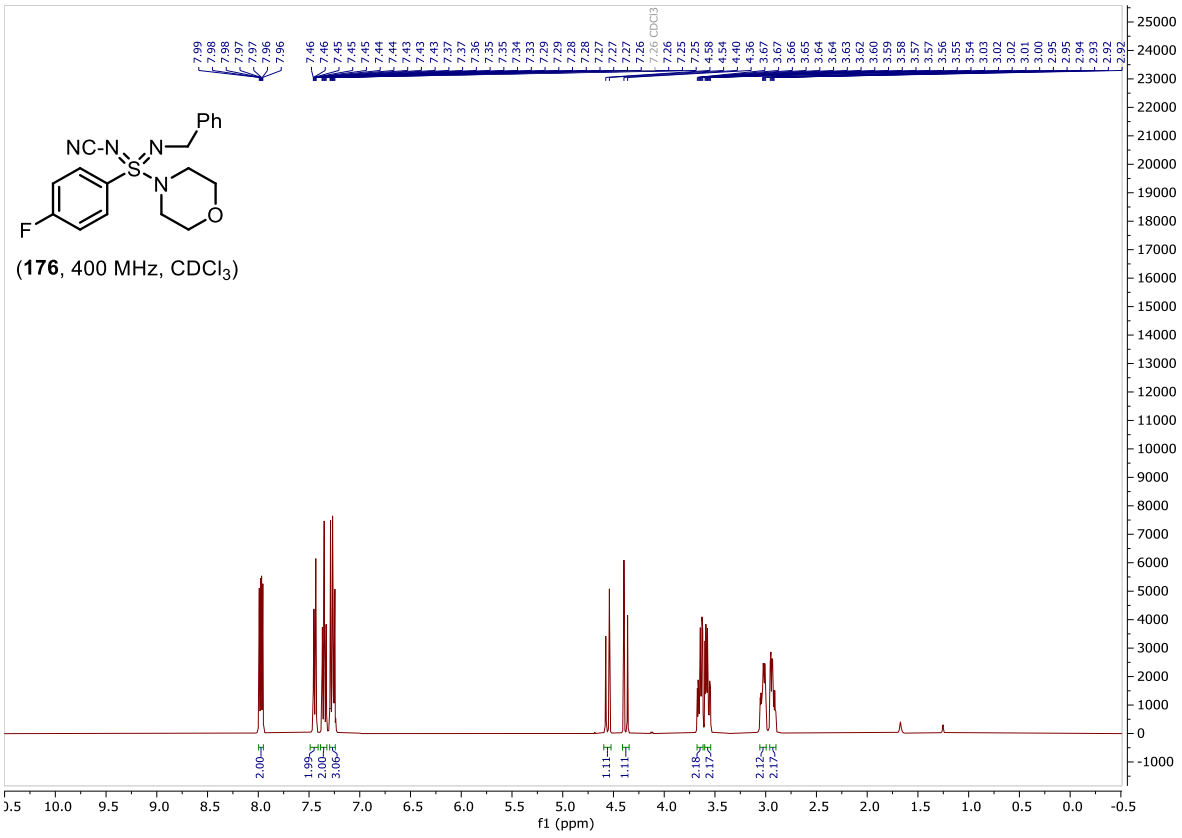

O
O
NC-N
N
S
N
O
F
(175, 400 MHz, CDCl3)
CDCl3
2.00
4.09
0.98
2.00
4.04
2.13
2.09
f1 (ppm)

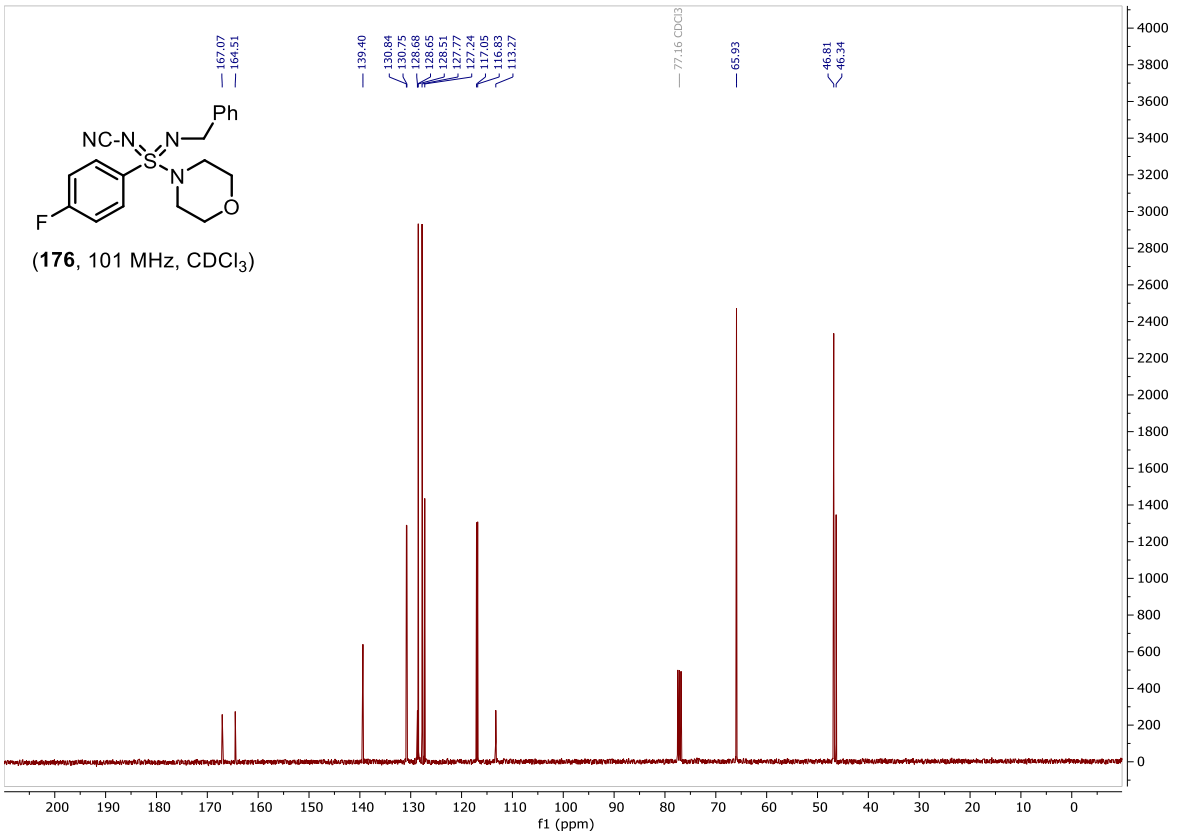


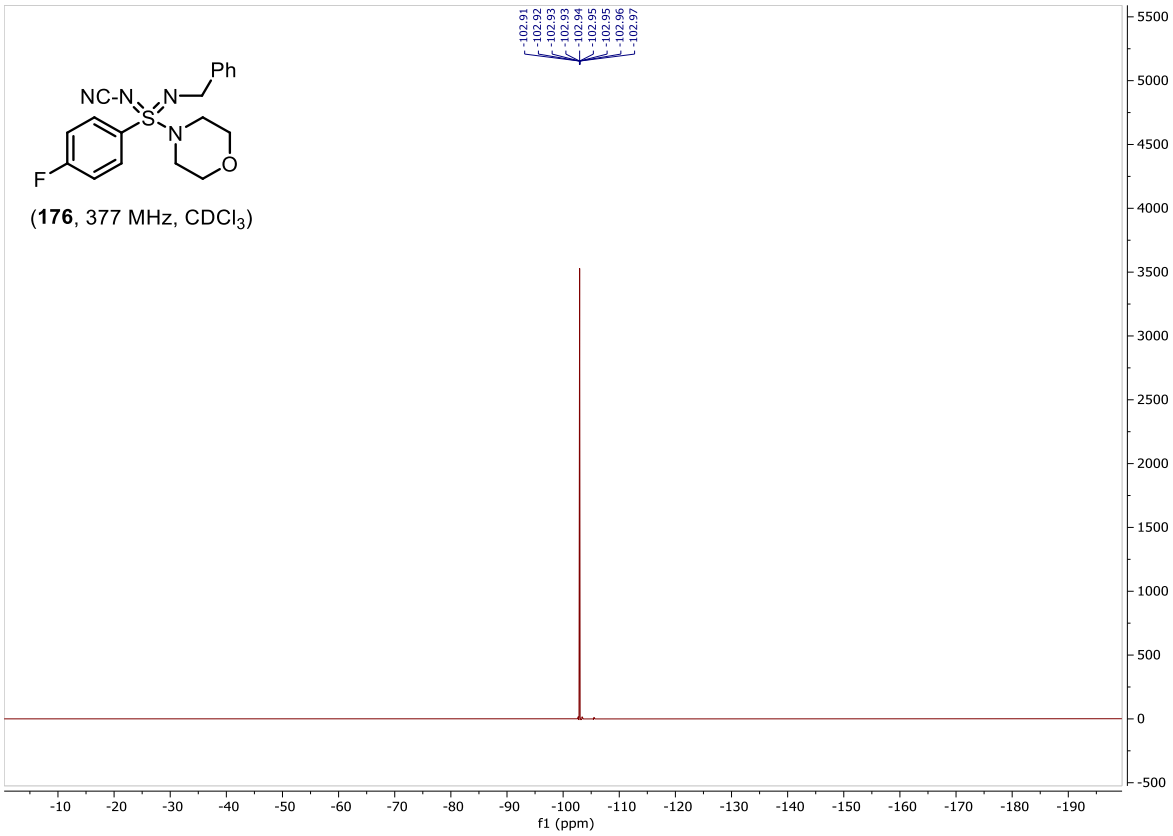
(**175**, 101 MHz, $CDCl_3$)

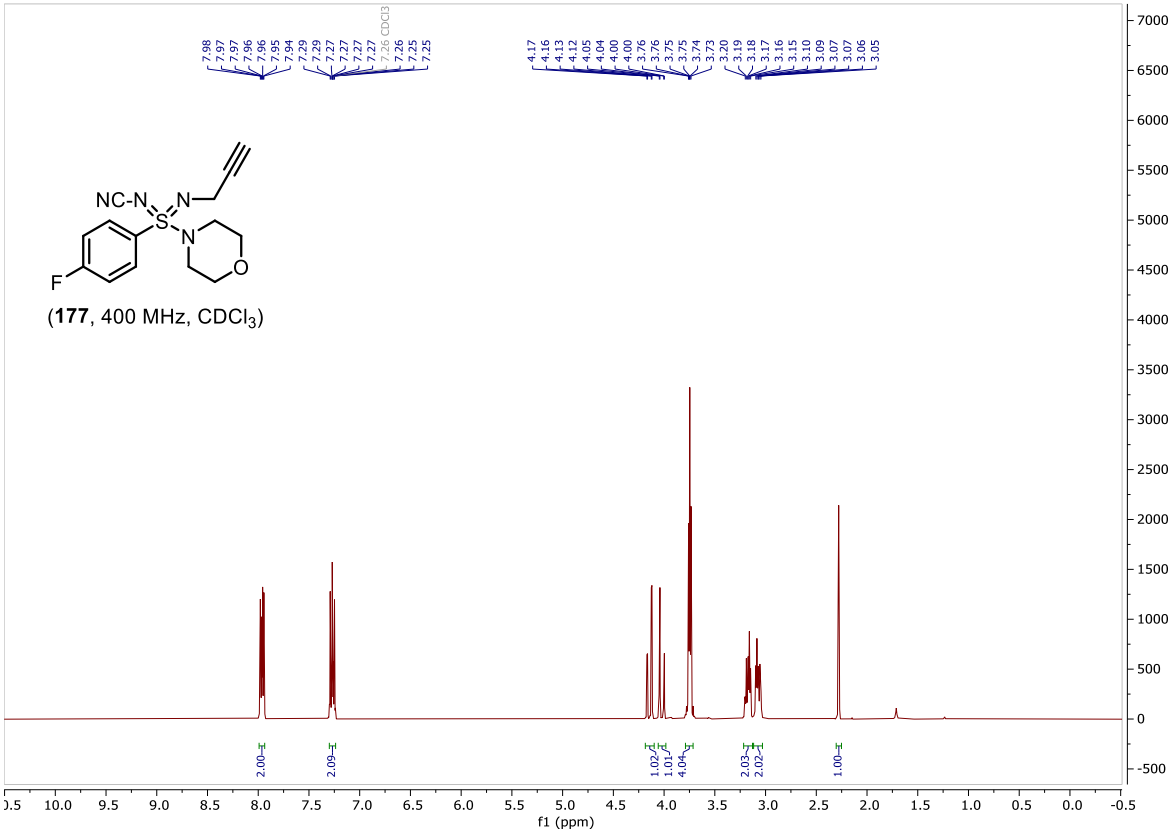


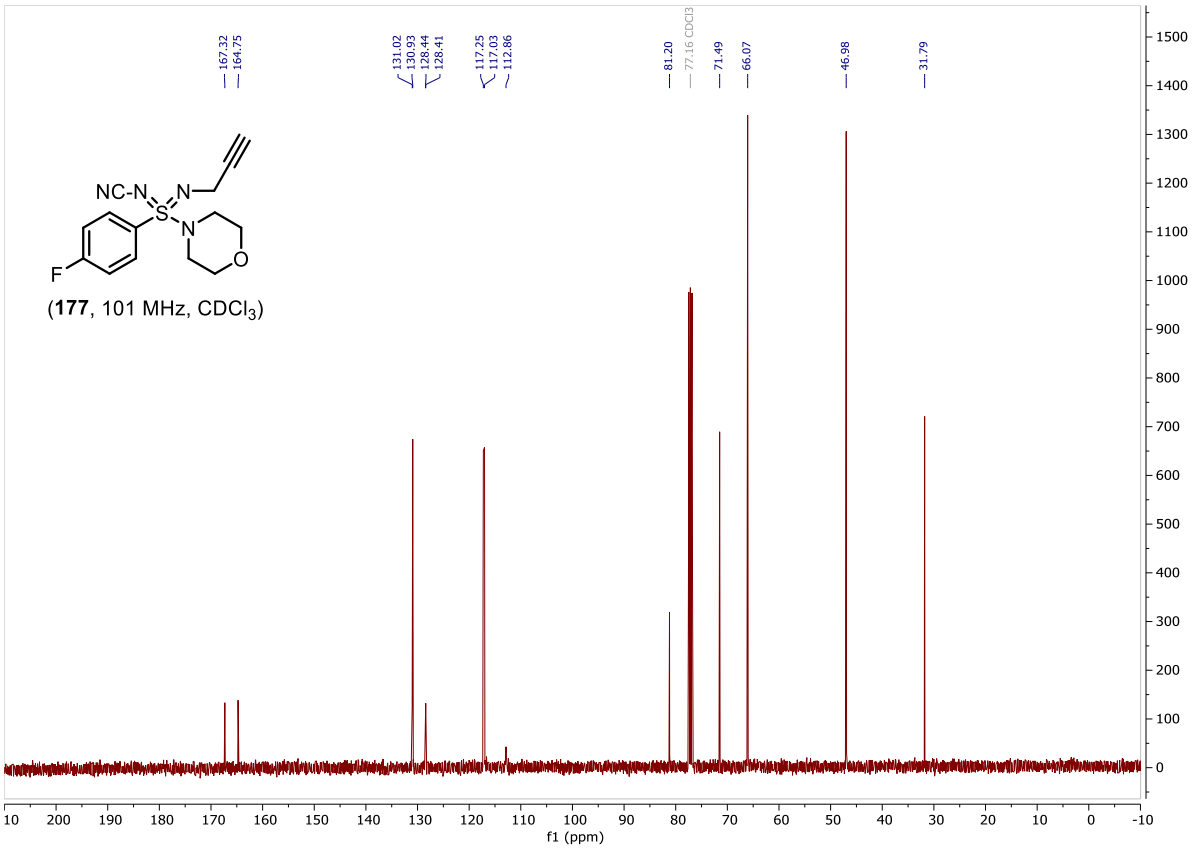
(**175**, 377 MHz, $CDCl_3$)

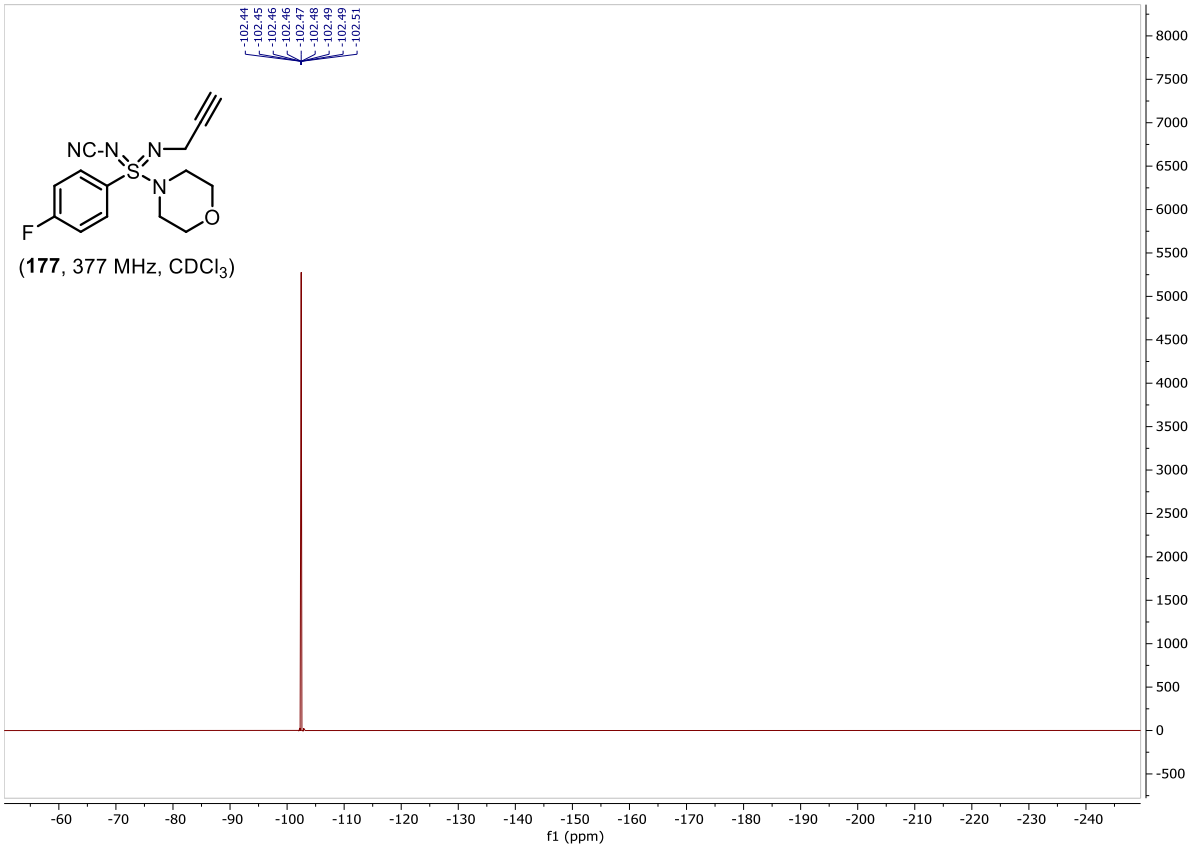

NC-N
S
N
Ph
N
O
F
(176, 400 MHz, CDCl3)
f1 (ppm)

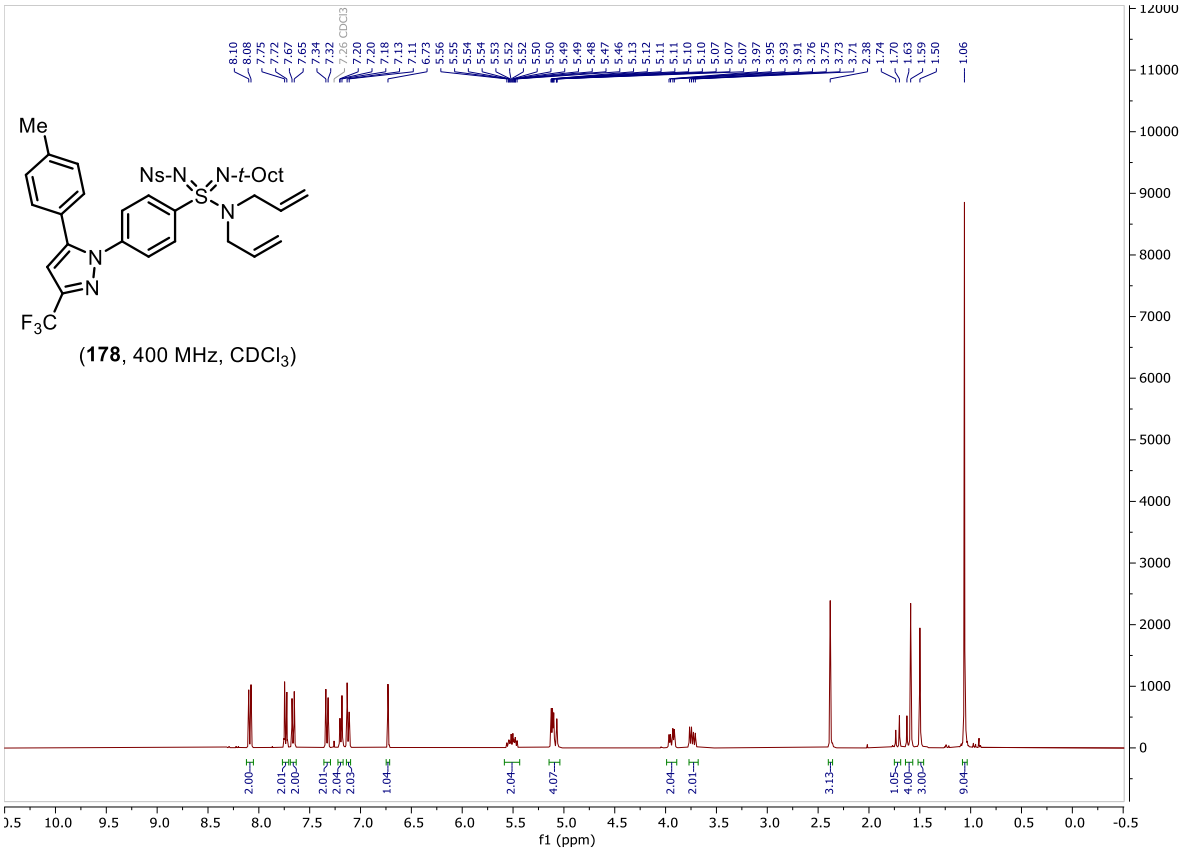

NC-N
S
N
Ph
N
O
F
(176, 101 MHz, CDCl3)
f1 (ppm)

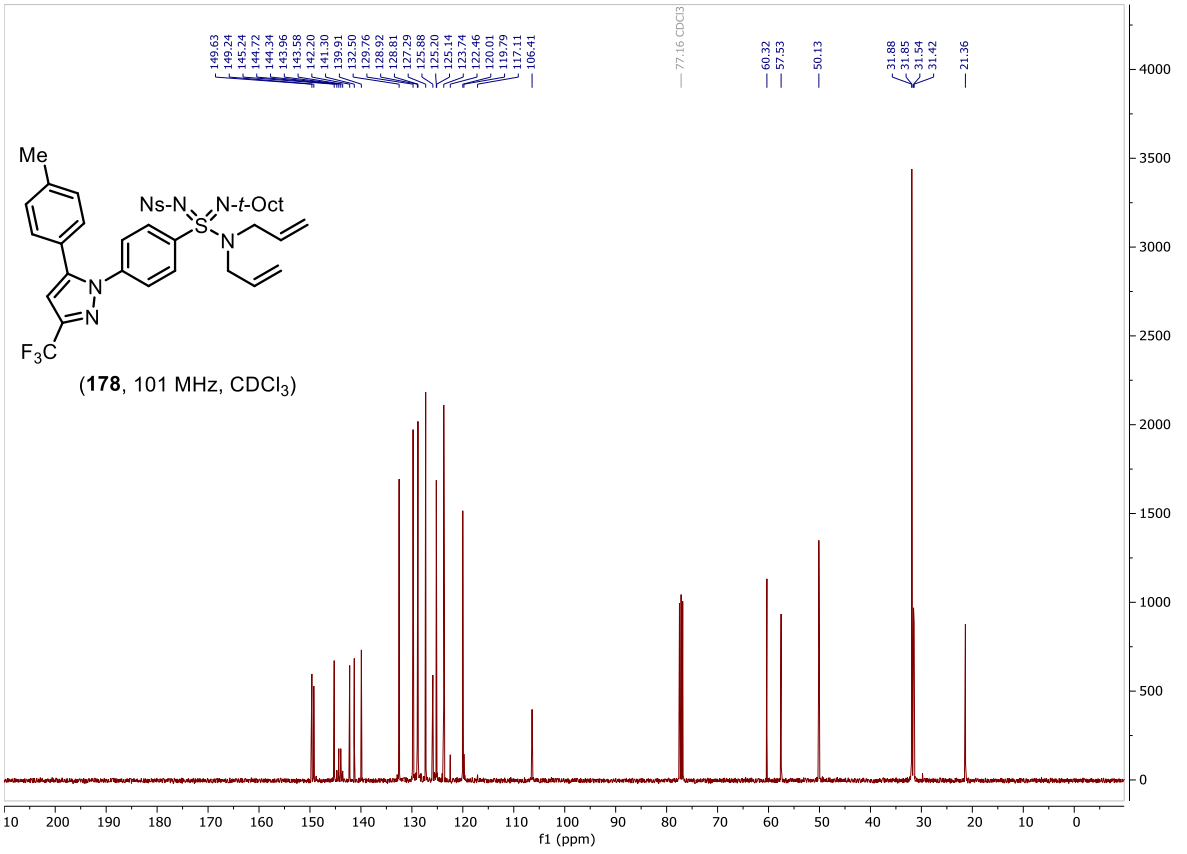

Ph
NC-N
N
S
N
O
F
(176, 377 MHz, CDCl3)
-102.91
-102.92
-102.93
-102.93
-102.94
-102.95
-102.95
-102.96
-102.97
f1 (ppm)

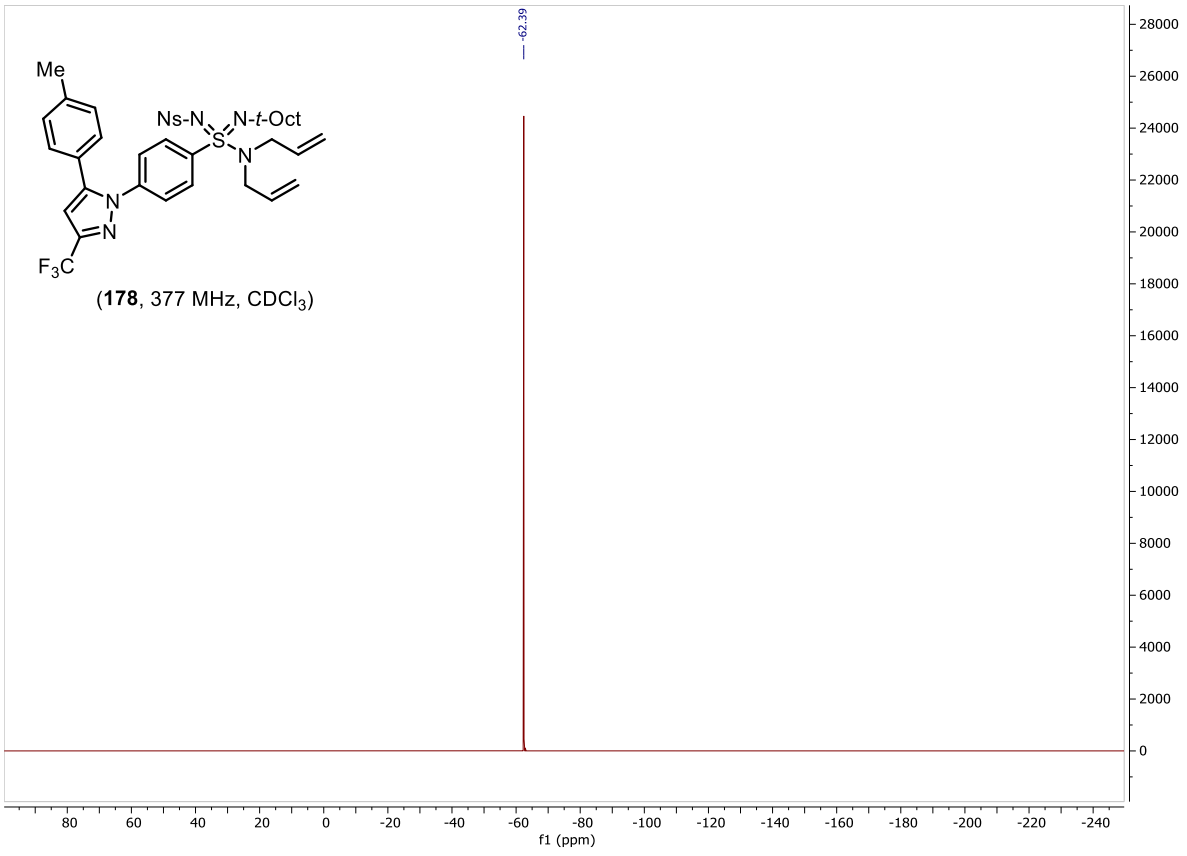

NC-N
N
S
N
O
F
(177, 400 MHz, CDCl3)
7.98
7.97
7.97
7.96
7.96
7.95
7.94
7.29
7.29
7.27
7.27
7.27
7.27
7.27
7.26 CDCl3
7.26
7.25
7.25
4.17
4.16
4.13
4.12
4.05
4.04
4.00
4.00
3.76
3.76
3.75
3.75
3.74
3.73
3.20
3.19
3.18
3.17
3.16
3.15
3.10
3.09
3.07
3.07
3.06
3.05
2.00
2.09
1.02
1.01
4.04
2.03
2.02
1.00
f1 (ppm)


167.32
164.75
131.02
130.93
128.44
128.41
117.25
117.03
112.86
81.20
77.16 CDCl3
71.49
66.07
46.98
31.79
NC-N
S
N
N
O
F
(177, 101 MHz, CDCl3)
f1 (ppm)

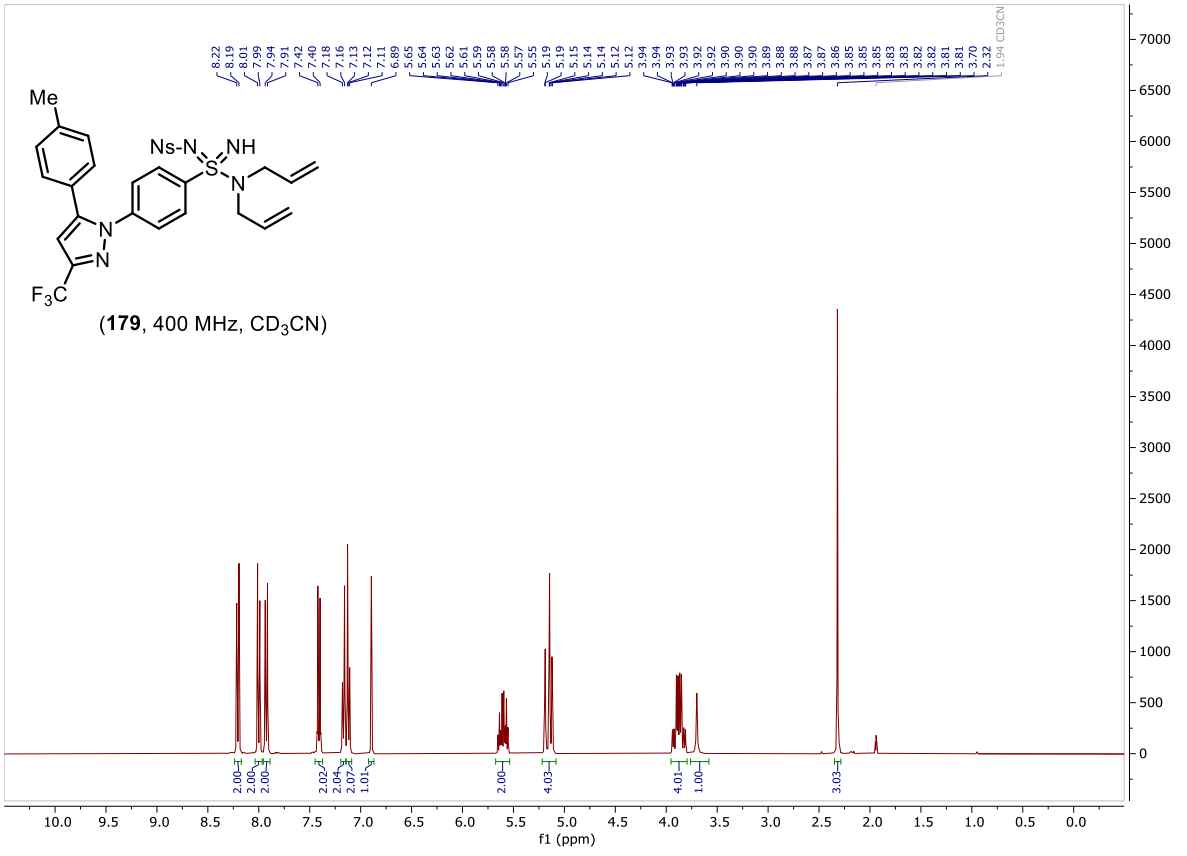

-102.44
-102.45
-102.46
-102.46
-102.47
-102.48
-102.49
-102.49
-102.51
NC-N
S
N
N
O
F
(177, 377 MHz, CDCl3)
f1 (ppm)


Me
Ns-N
N-t-Oct
F3C
(178, 400 MHz, CDCl3)
f1 (ppm)

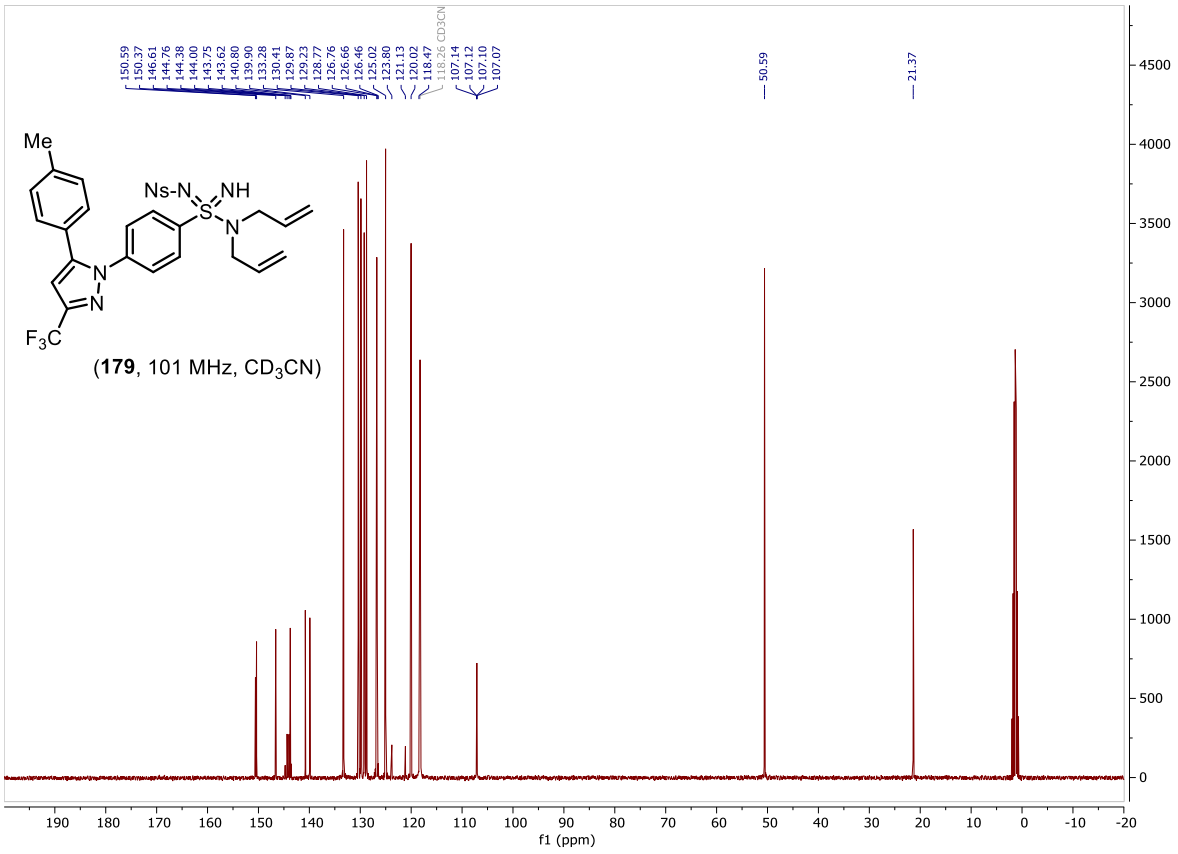

Me
Ns-N
N-t-Oct
F3C
(178, 101 MHz, CDCl3)
f1 (ppm)

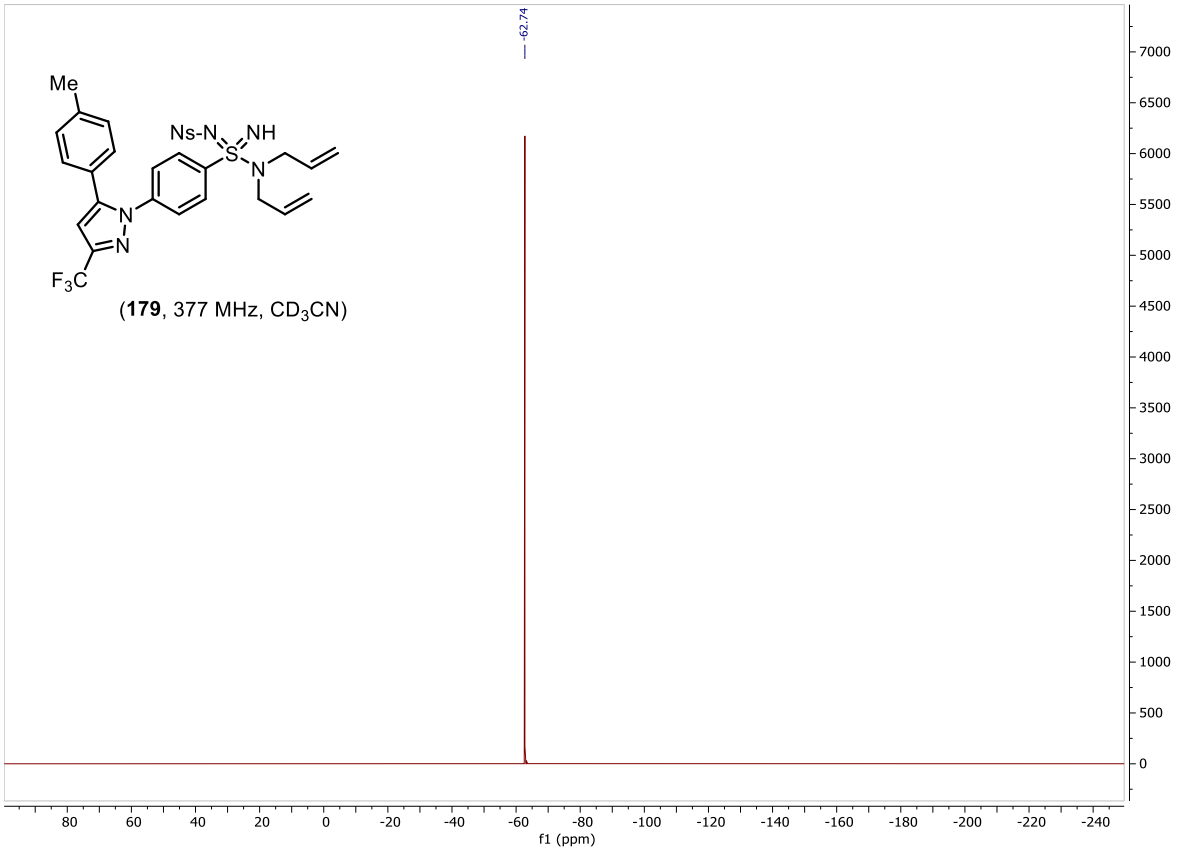


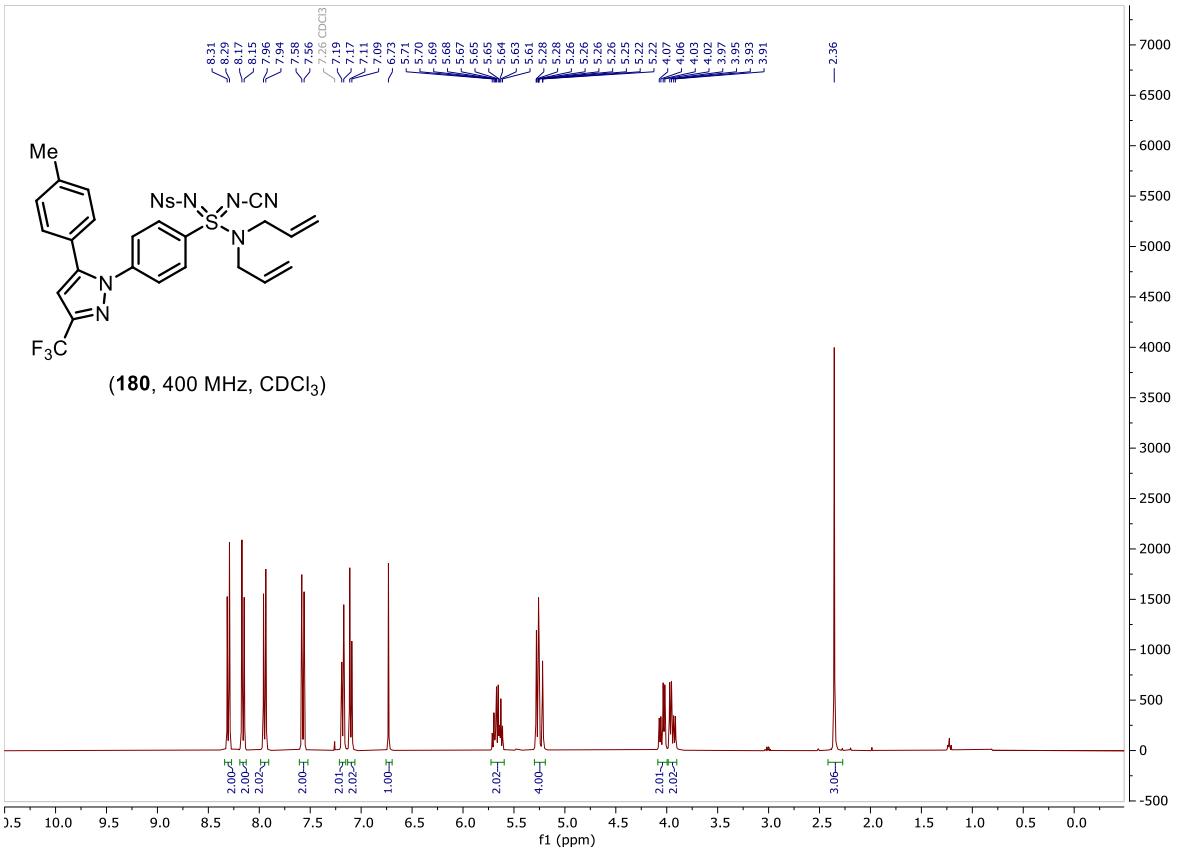
(**178**, 377 MHz, $CDCl_3$)

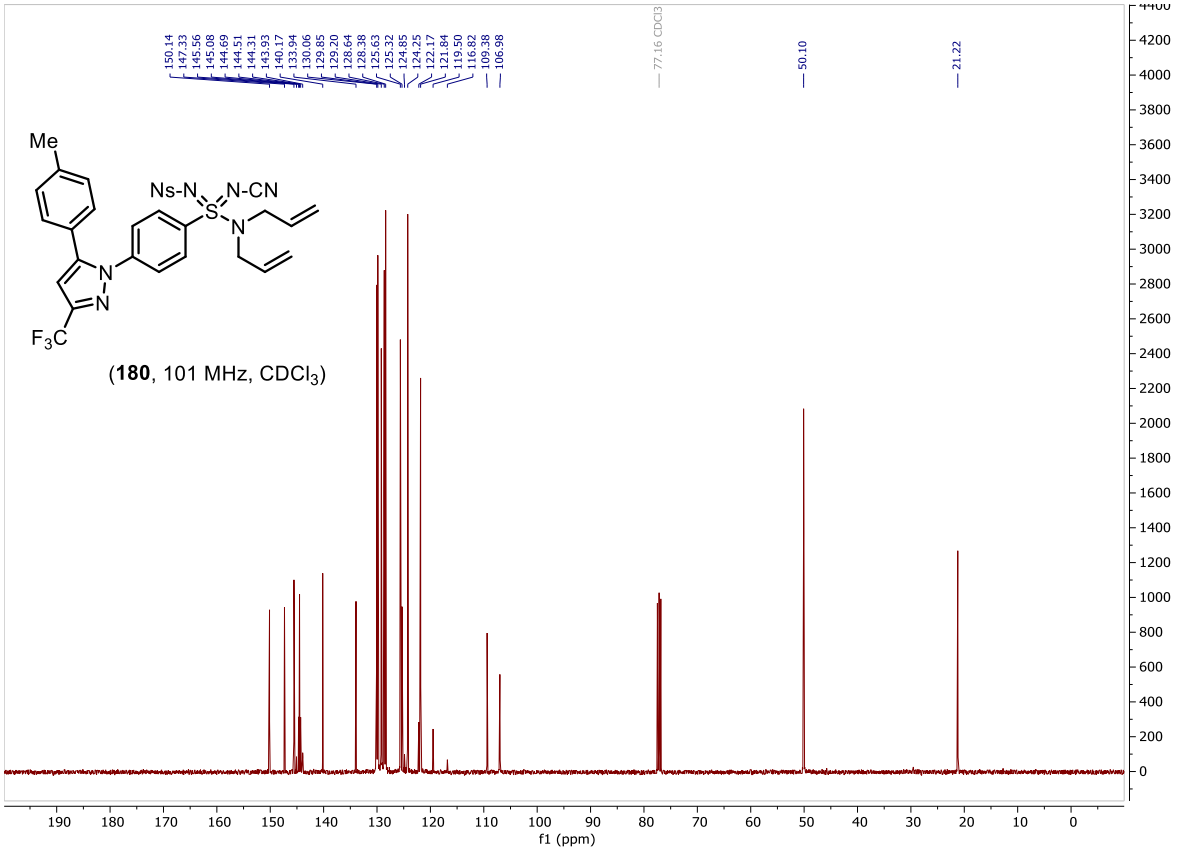


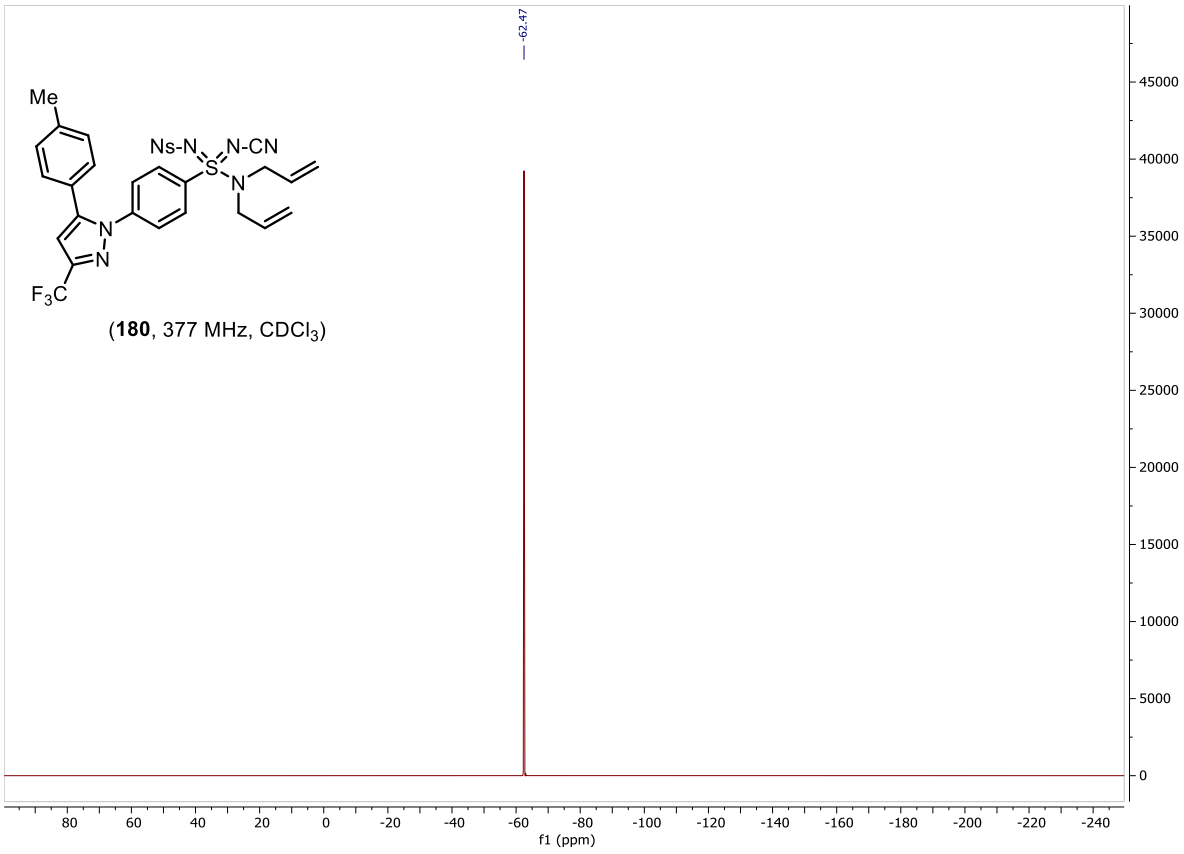
(**179**, 400 MHz, CD_3CN)


150.59
150.37
146.61
144.76
144.38
144.00
143.75
143.62
140.80
139.90
133.28
130.41
129.87
129.23
128.77
126.76
126.66
126.46
125.02
123.80
121.13
120.02
118.47
118.26 CD3CN
107.14
107.12
107.10
107.07
50.59
21.37
Me
Ns-N
NH
S
N
N
N
F3C
(179, 101 MHz, CD3CN)
f1 (ppm)

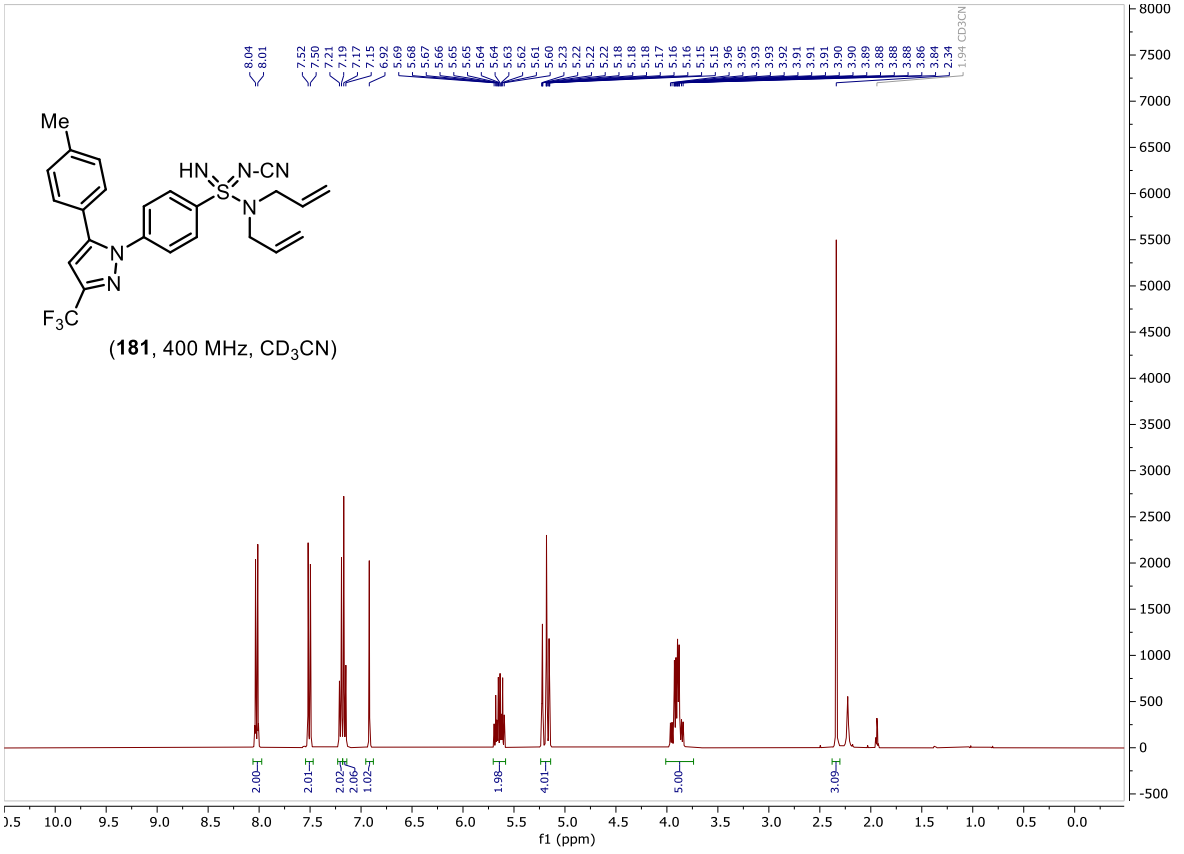

-62.74
Me
Ns-N
NH
S
N
N
N
F3C
(179, 377 MHz, CD3CN)
f1 (ppm)


Me
Ns-N
N-CN
S
N
N
N
F3C
(180, 400 MHz, CDCl3)
f1 (ppm)

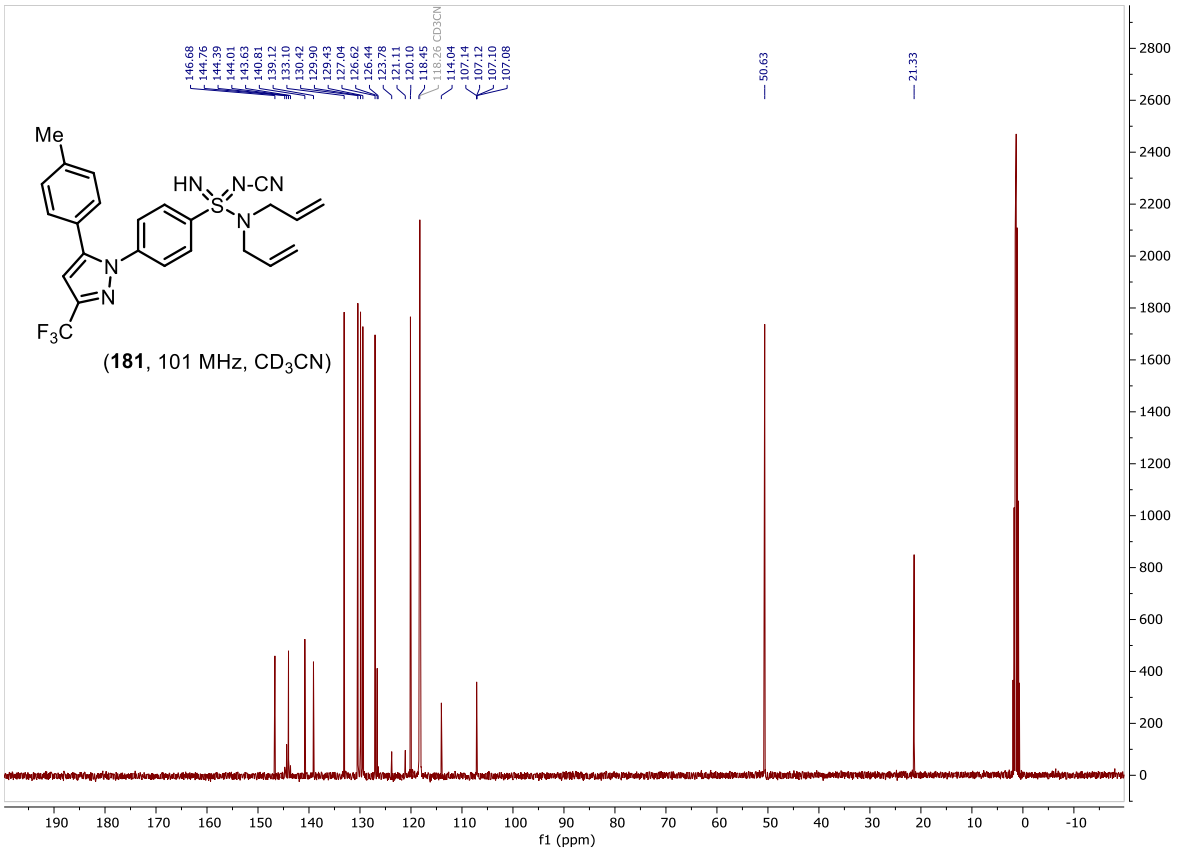

Me
Ns-N
N-CN
S
N
N
N
F3C
(180, 101 MHz, CDCl3)
77.16 CDCl3
50.10
21.22
f1 (ppm)

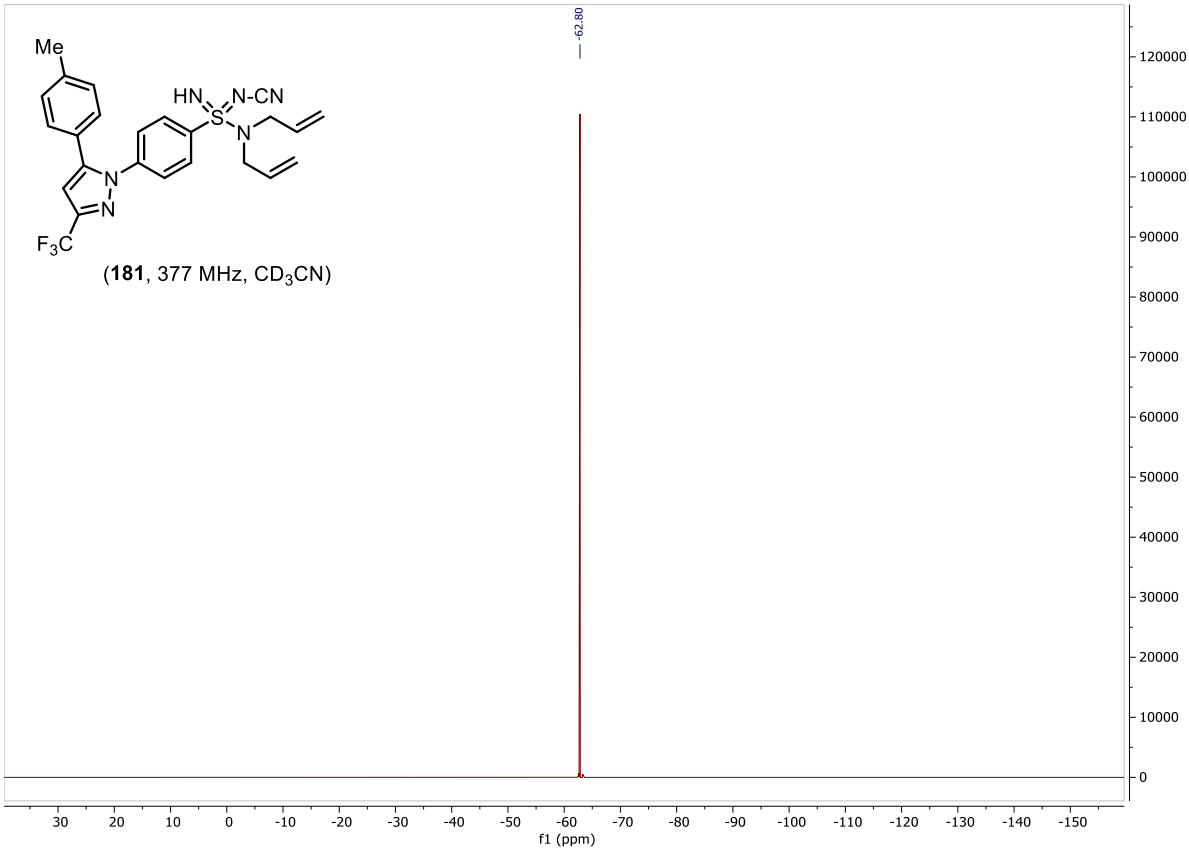


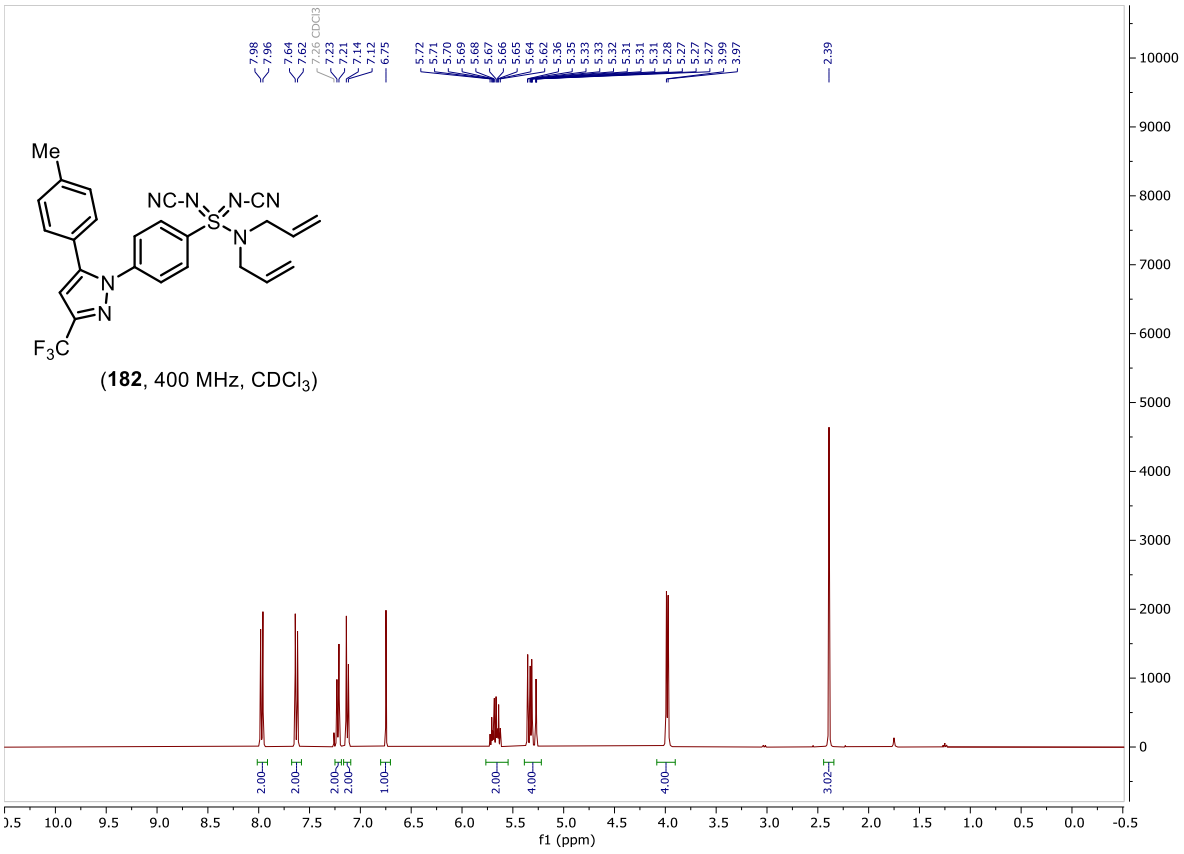
(**180**, 377 MHz, $CDCl_3$)

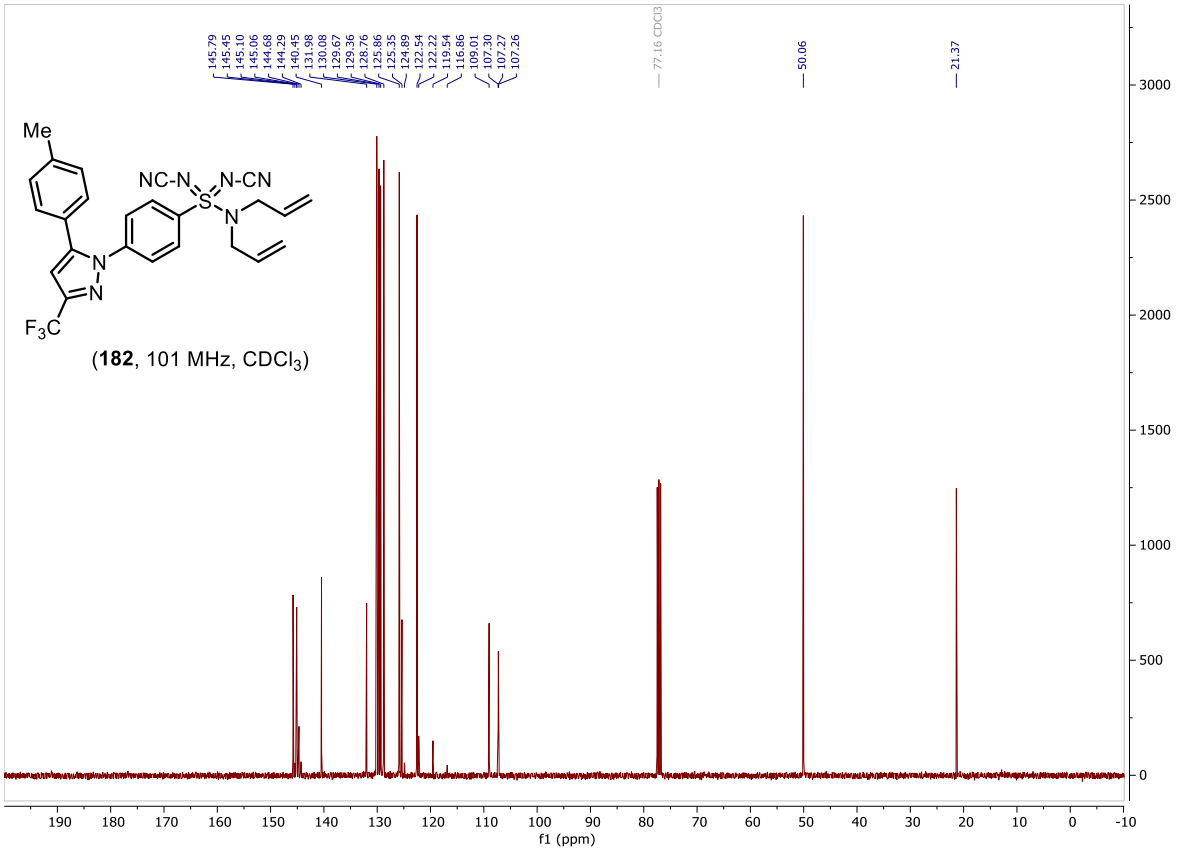


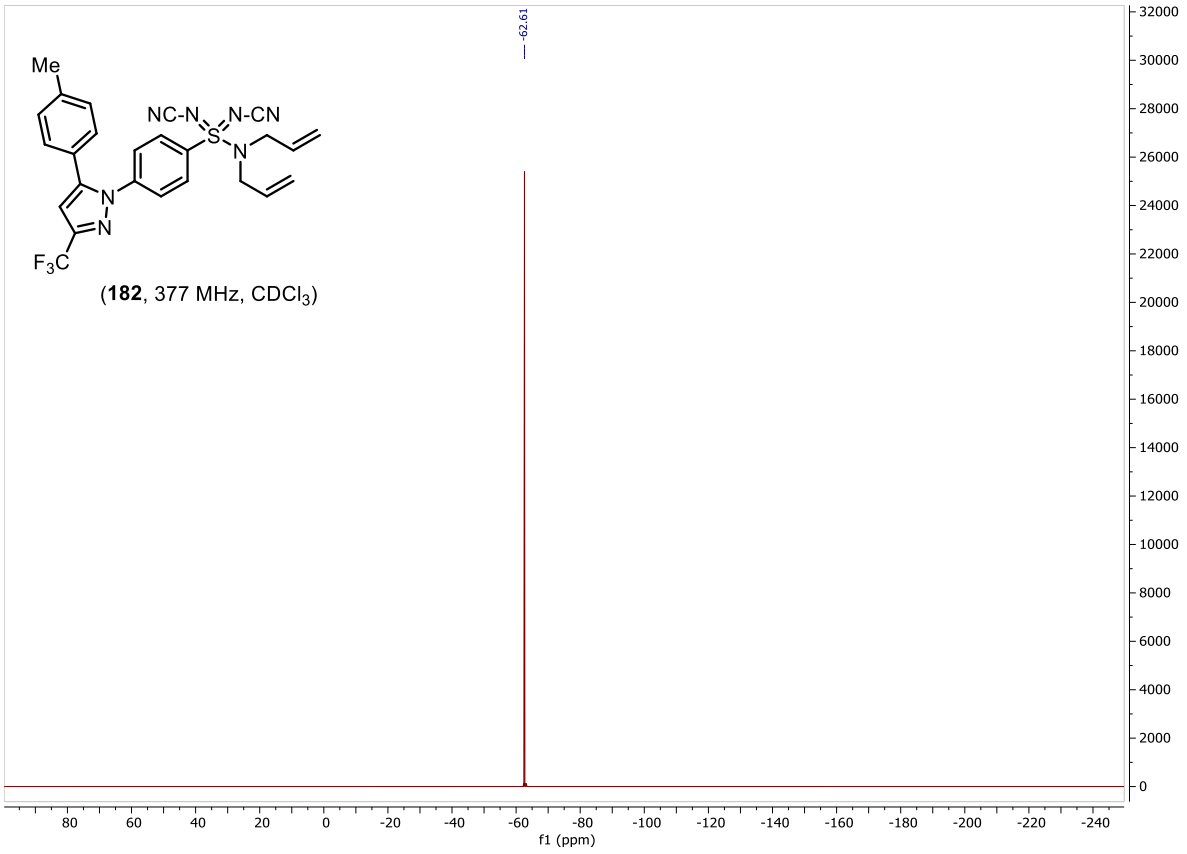
(**181**, 400 MHz, CD_3CN)


146.68
144.76
144.39
144.01
143.63
140.81
139.12
133.10
130.42
129.90
129.43
127.04
126.62
126.44
123.78
121.11
120.10
118.45
118.26 CD3CN
114.04
107.14
107.12
107.10
107.08
50.63
21.33
Me
HN
N-CN
S
N
N
N
F3C
(181, 101 MHz, CD3CN)
f1 (ppm)

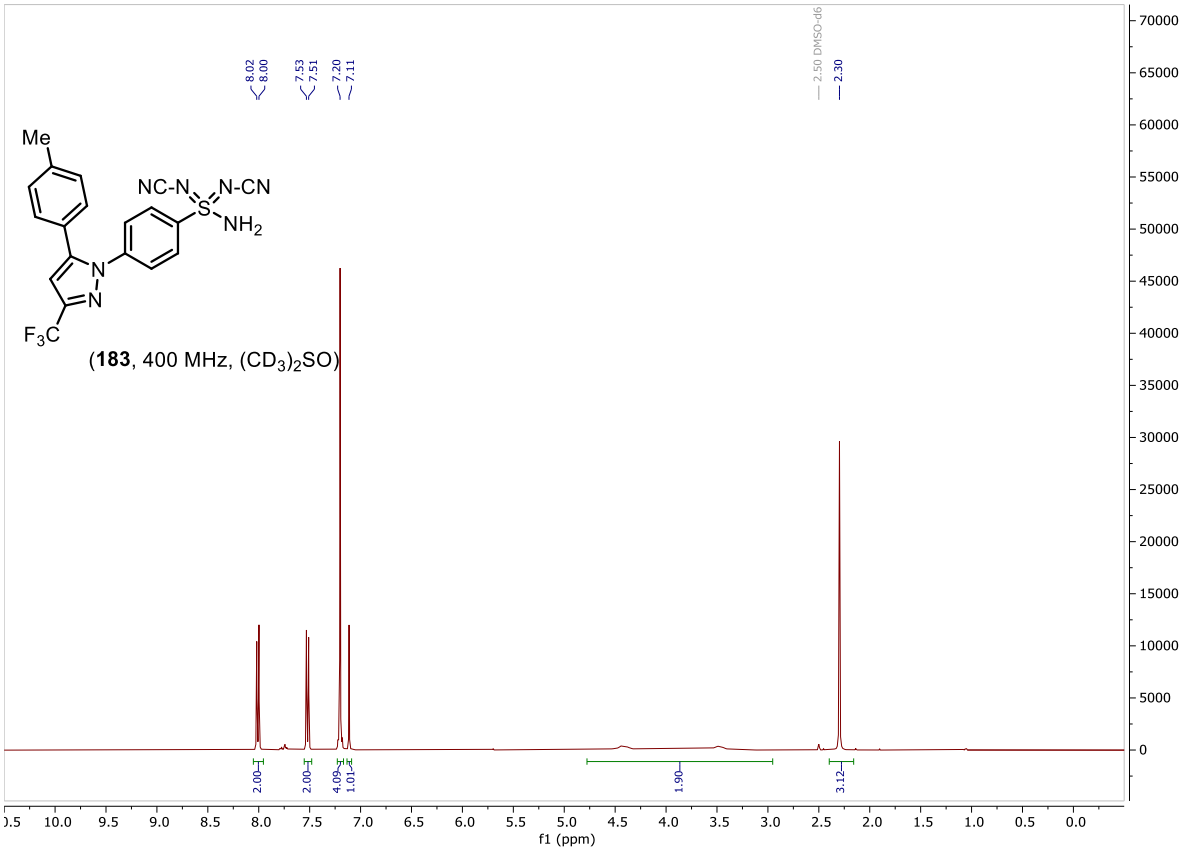

-62.80
Me
HN
N-CN
S
N
N
N
F3C
(181, 377 MHz, CD3CN)
f1 (ppm)


Me
NC-N
N-CN
S
N
N
N
F3C
(182, 400 MHz, CDCl3)
f1 (ppm)

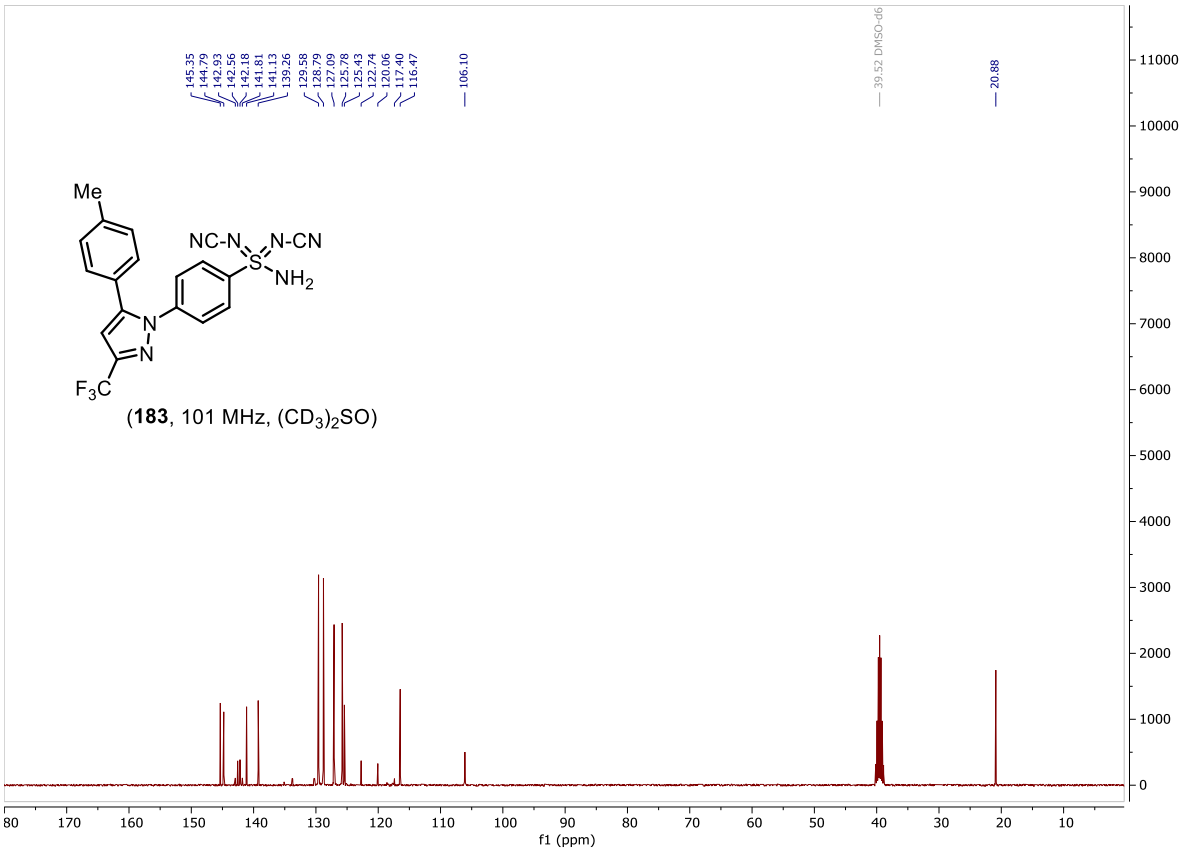

Me
NC-N
N-CN
S
N
N
N
F3C
(182, 101 MHz, CDCl3)
f1 (ppm)

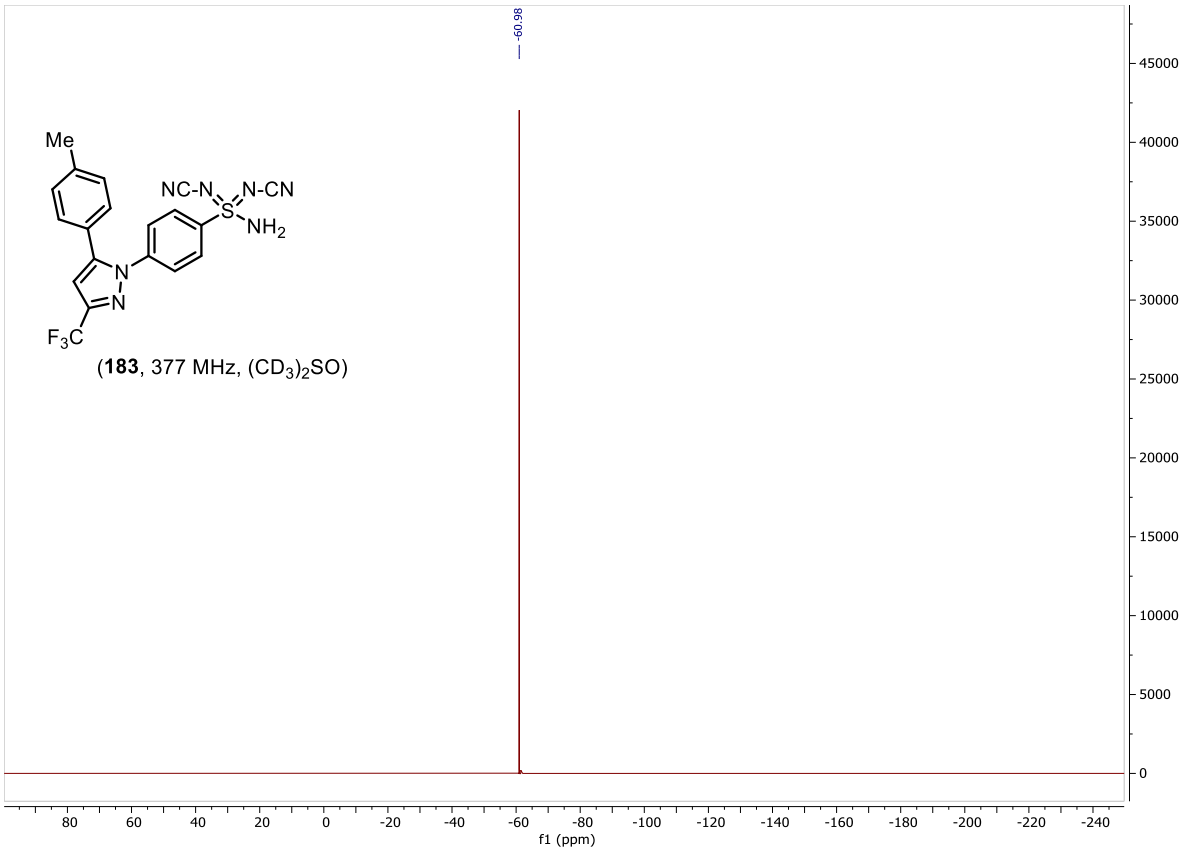


(**182**, 377 MHz, $CDCl_3$)

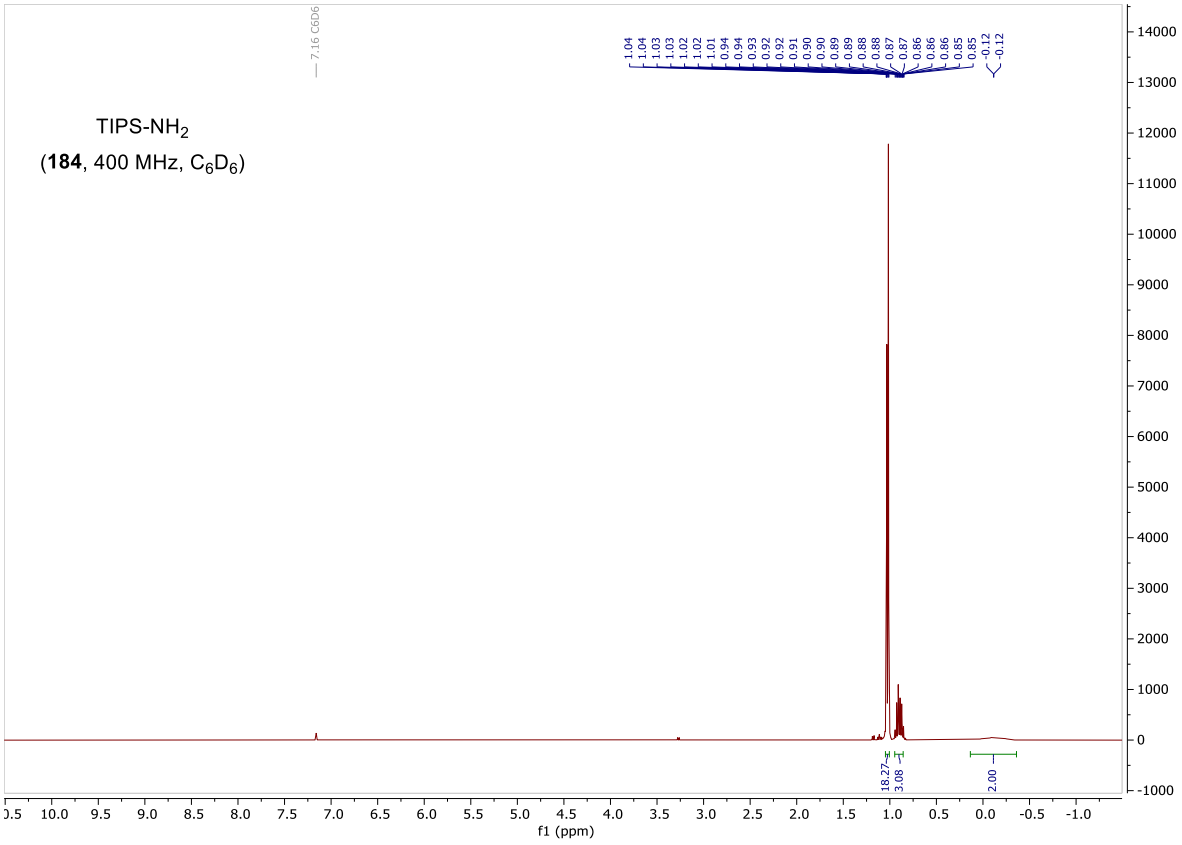


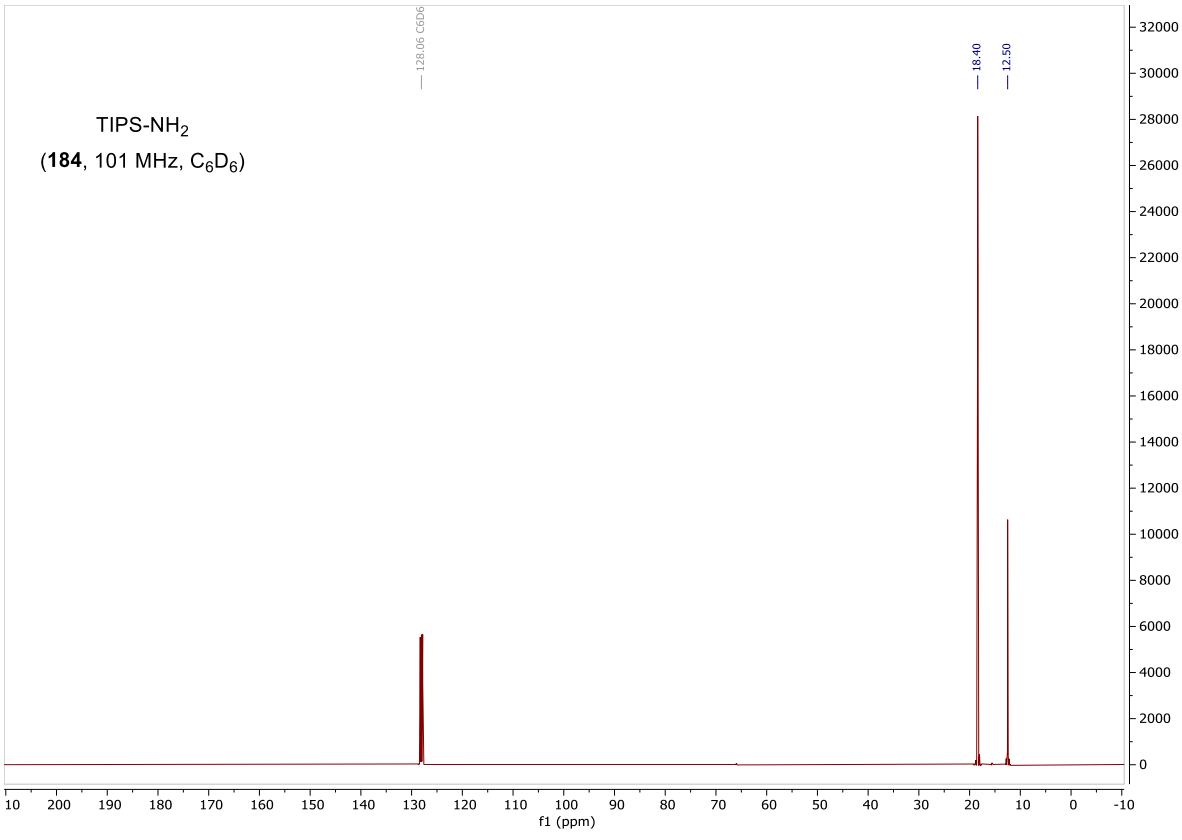
(**183**, 400 MHz, $(CD_3)_2SO$)

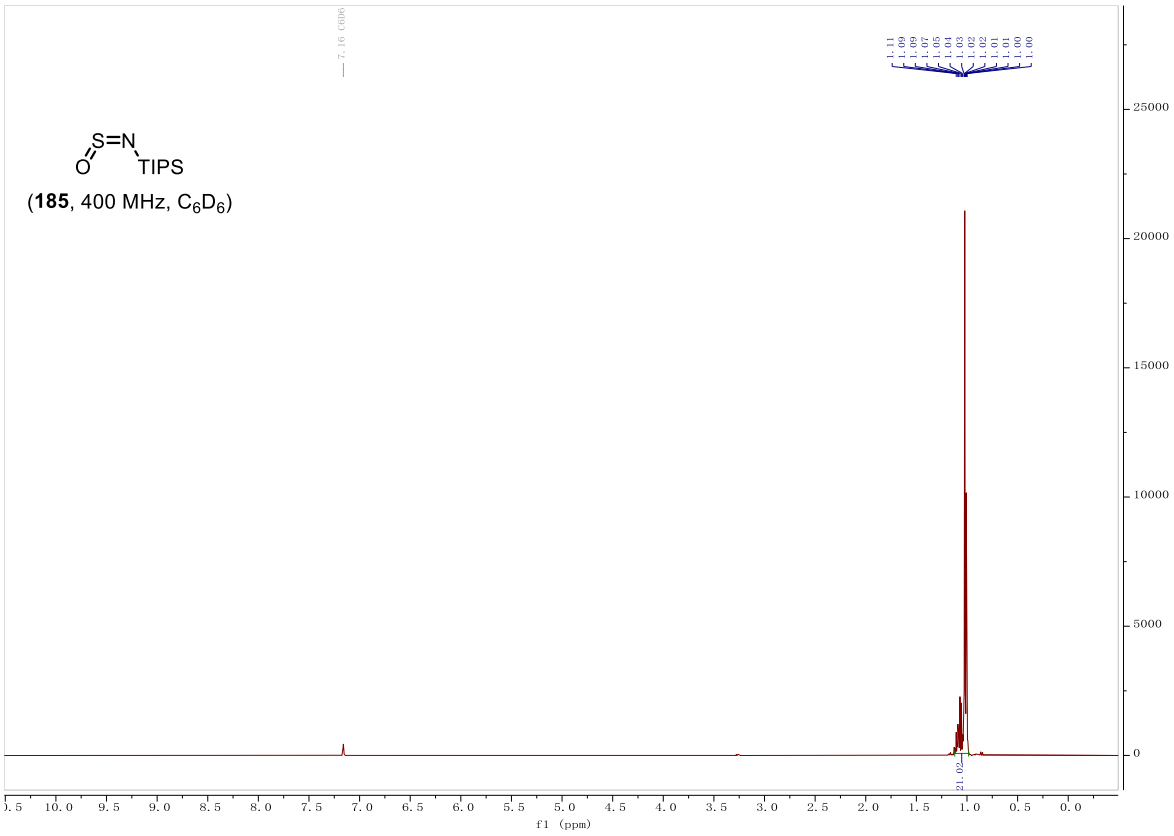

145.35
144.79
142.93
142.56
142.18
141.81
141.13
139.26
129.58
128.79
127.09
125.78
125.43
122.74
120.06
117.40
116.47
106.10
39.52 DMSO-d6
20.88
Me
NC-N
N-CN
S
NH2
N
N
F3C
(183, 101 MHz, (CD3)2SO)
f1 (ppm)

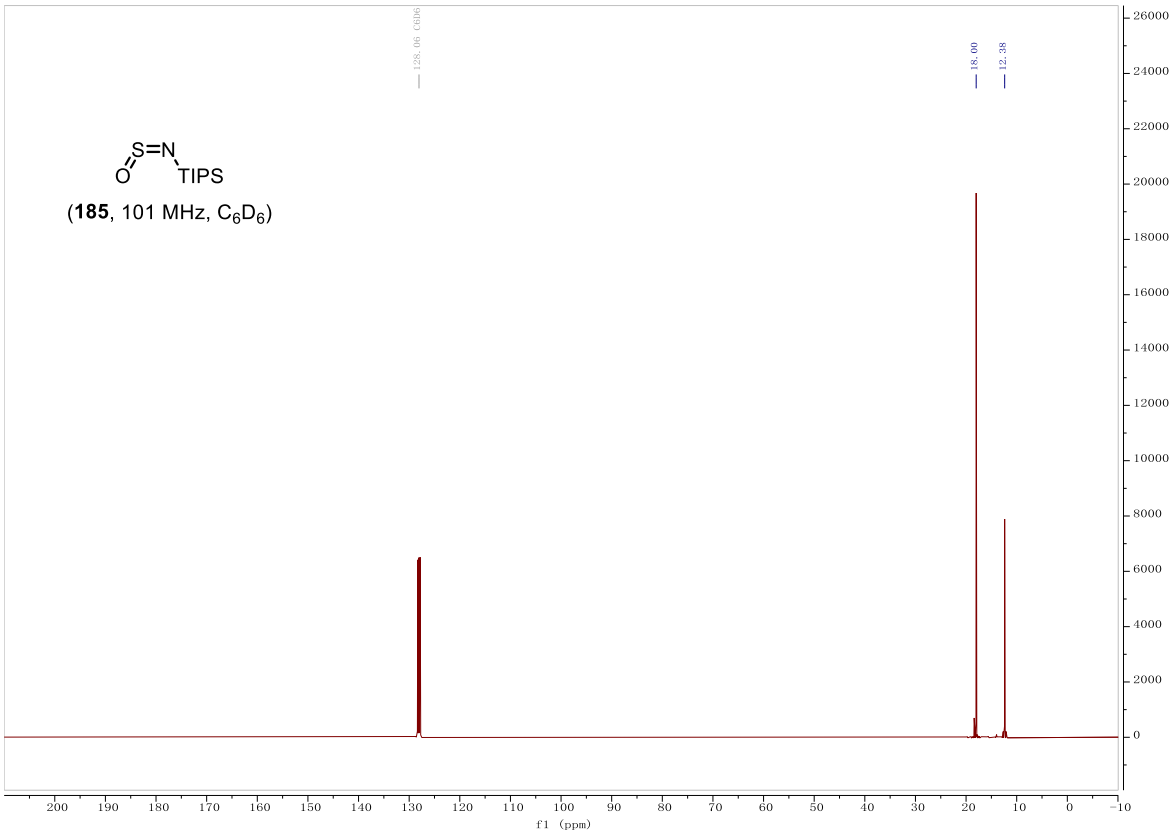

-60.98
Me
NC-N
N-CN
S
NH2
N
N
F3C
(183, 377 MHz, (CD3)2SO)
f1 (ppm)

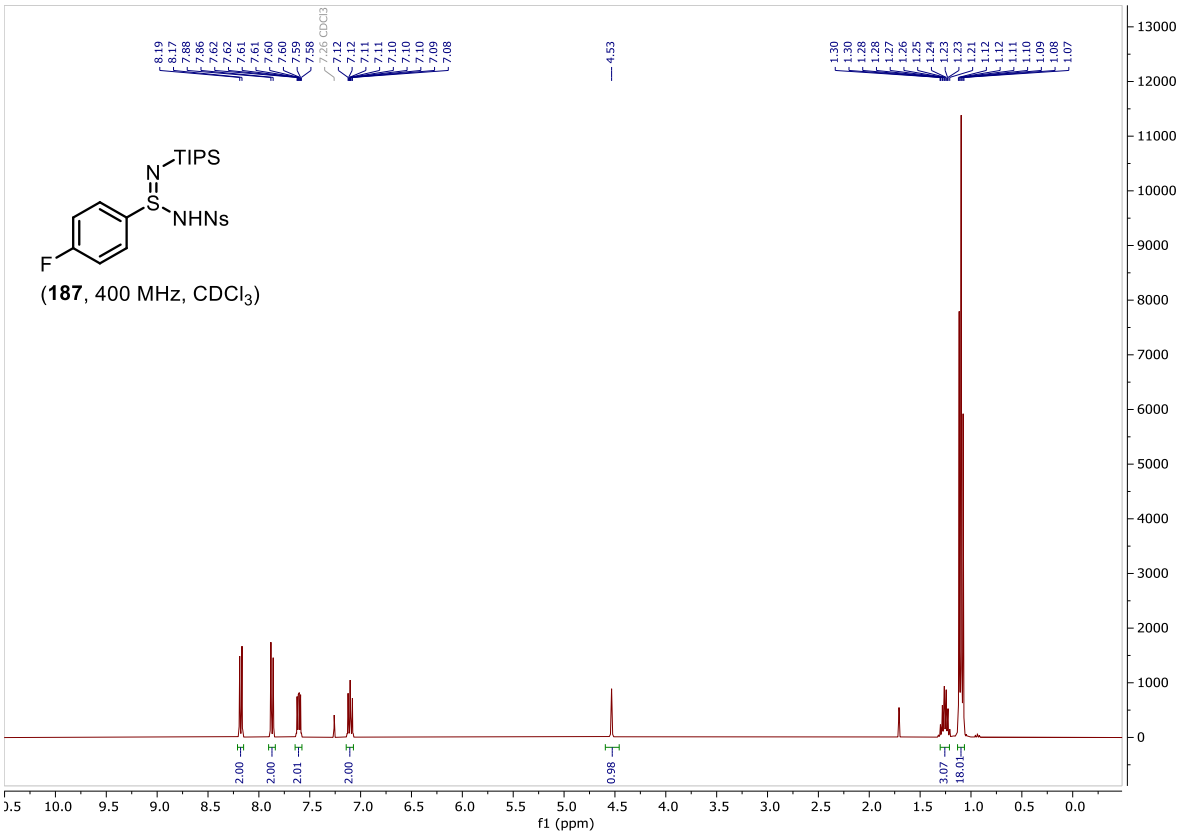
Chapter 4 NMR Spectra

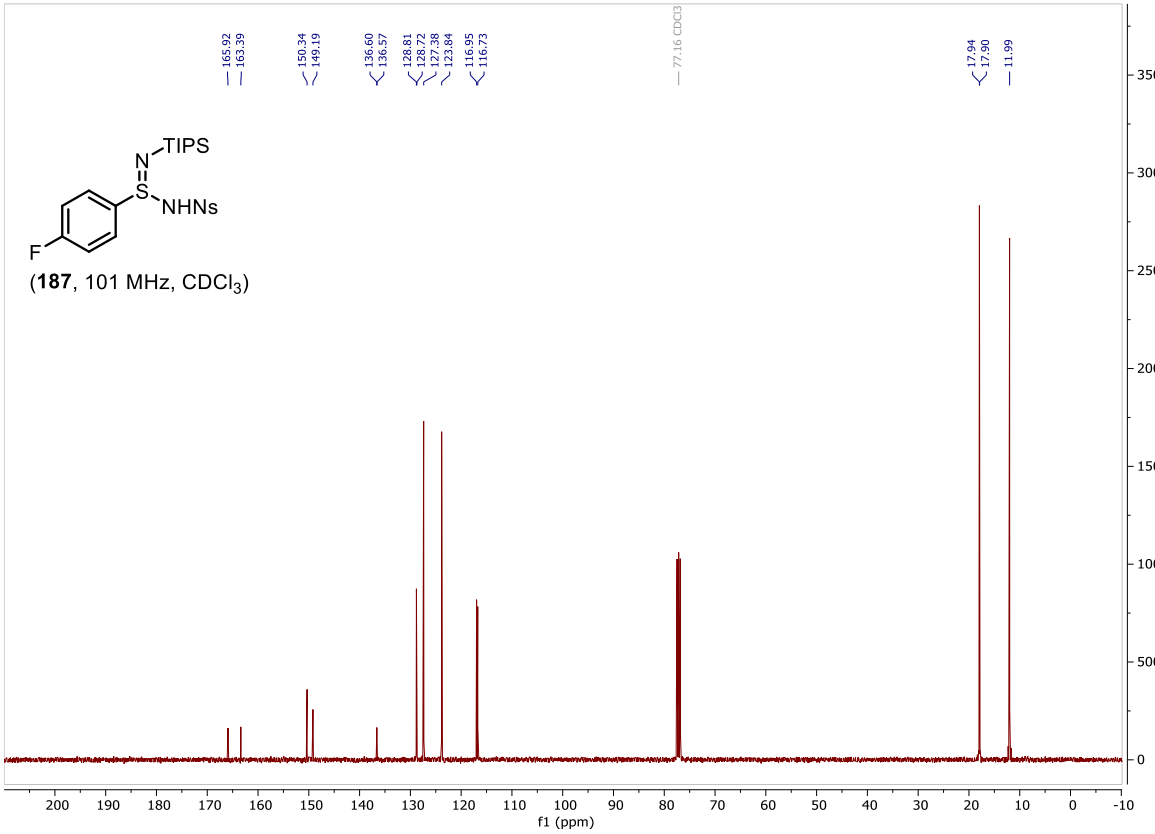


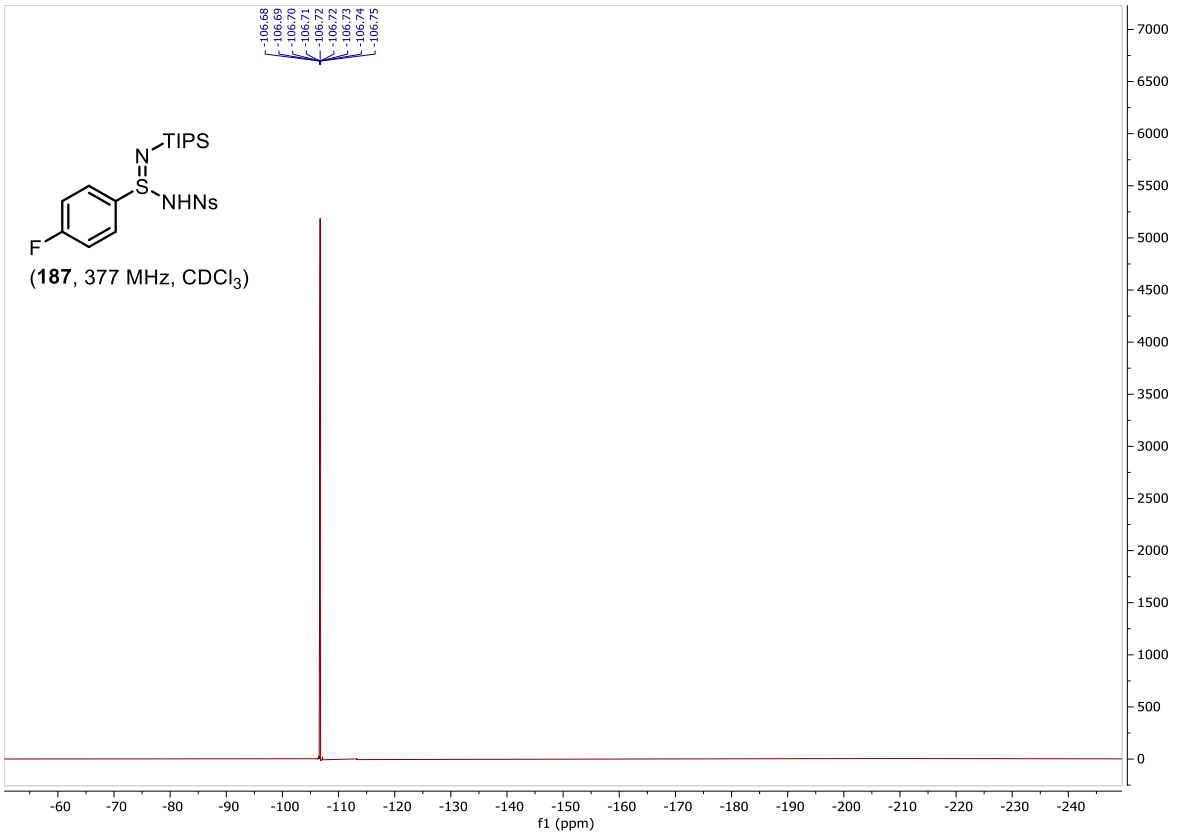



S=N
O
TIPS
(185, 400 MHz, C6D6)
f1 (ppm)

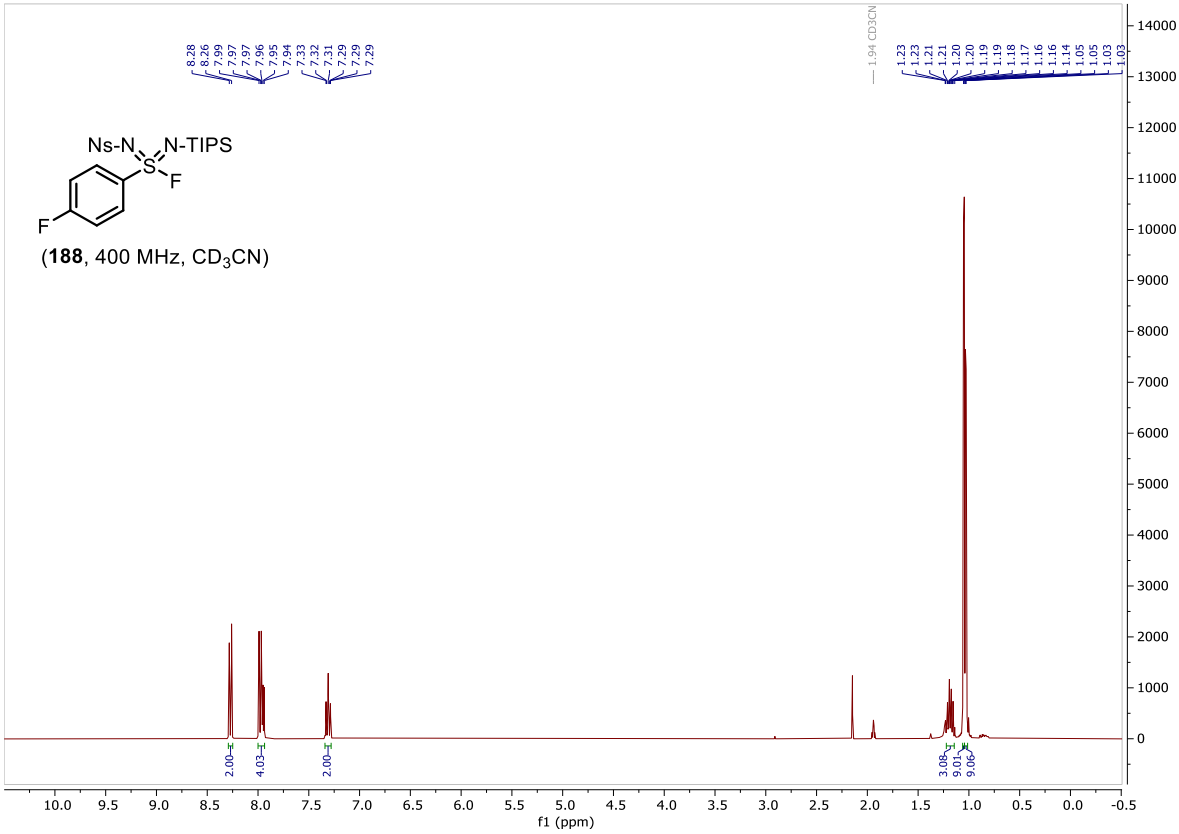

S=N
O
TIPS
(185, 101 MHz, C6D6)
f1 (ppm)


TIPS
N
S
NHNs
F
(187, 400 MHz, CDCl3)
f1 (ppm)

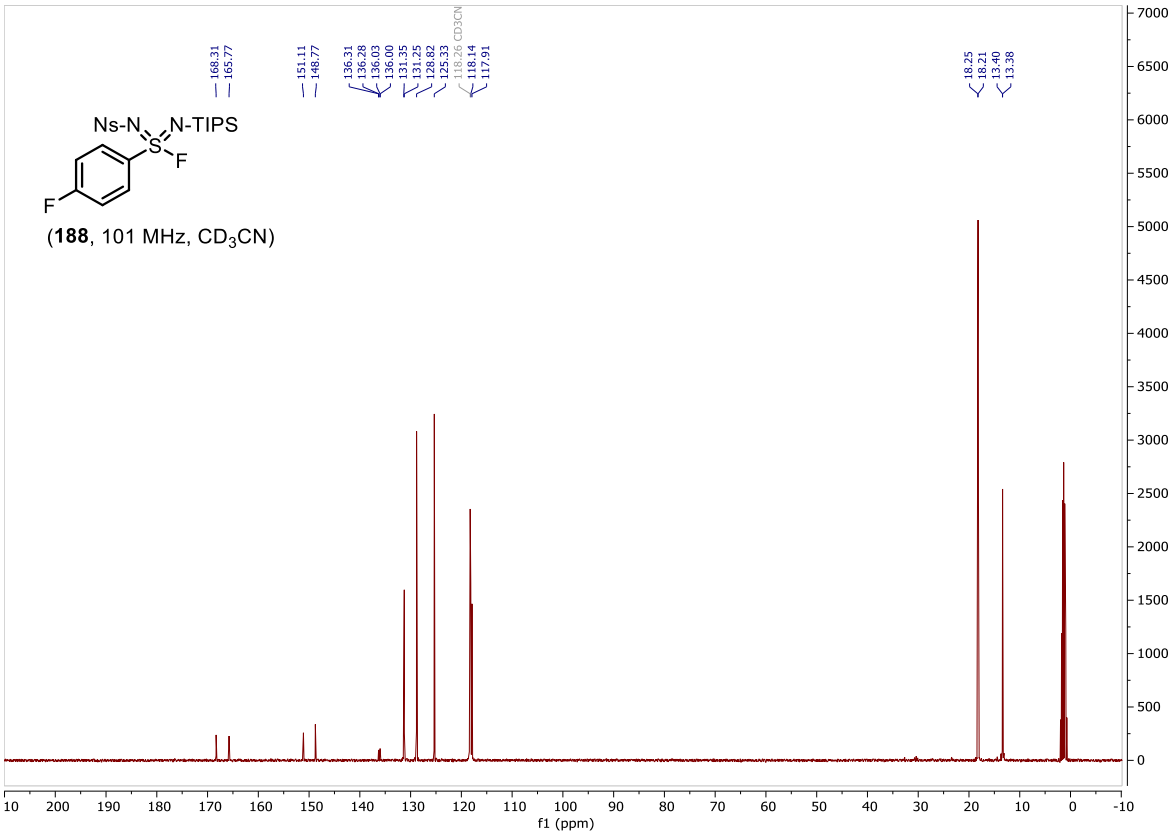

TIPS
N
S
NHNs
F
(187, 101 MHz, CDCl3)
f1 (ppm)

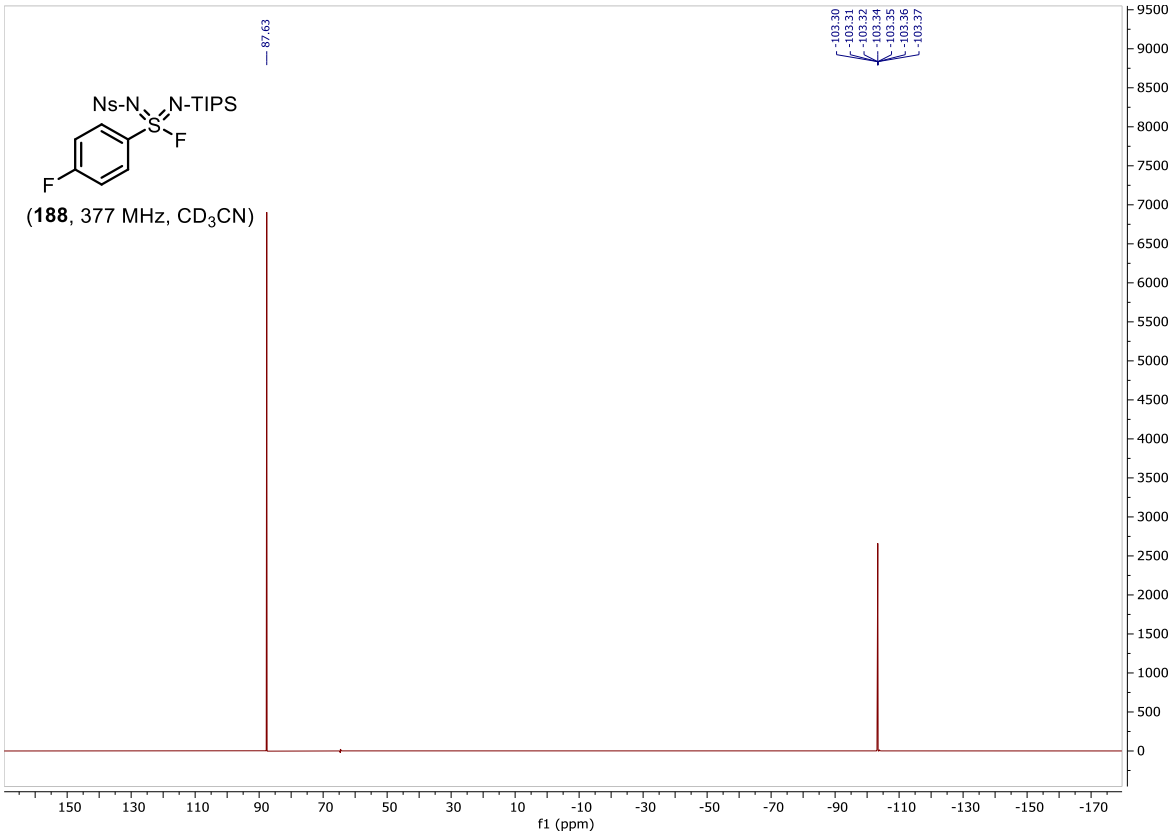


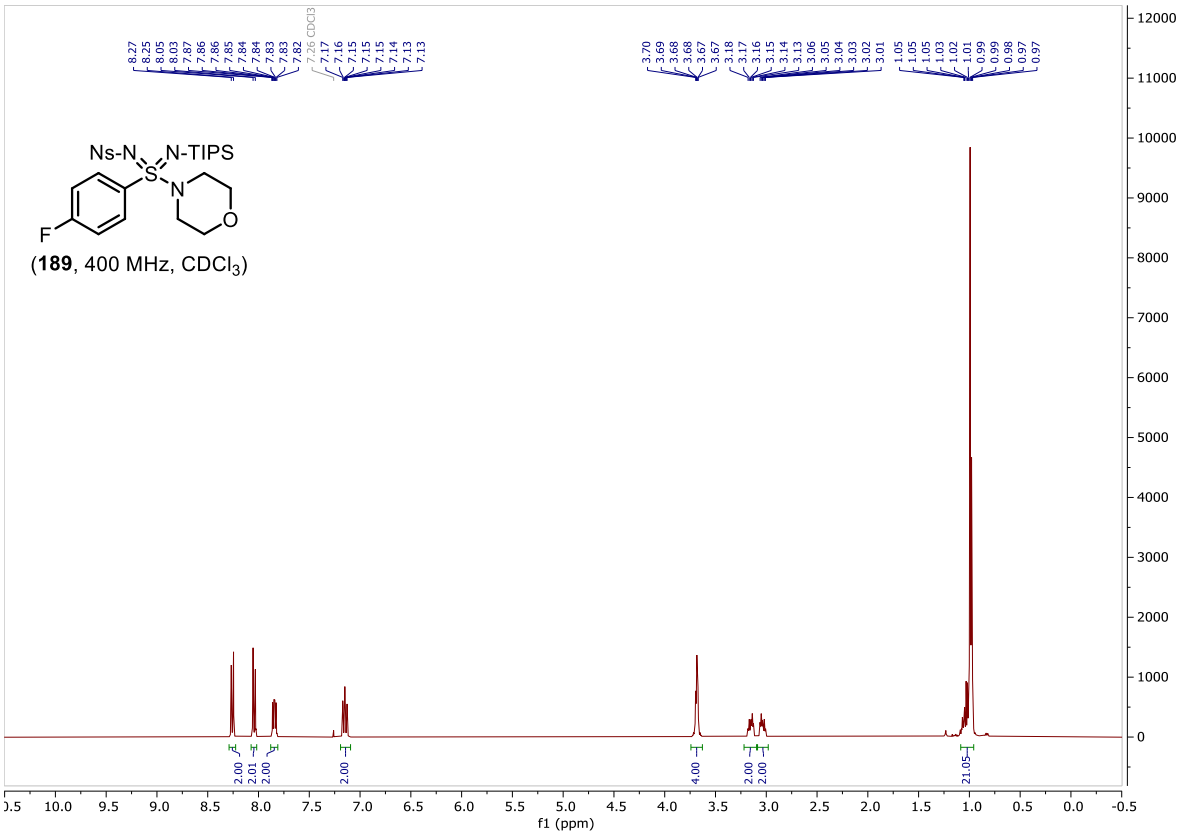
(**187**, 377 MHz, $CDCl_3$)

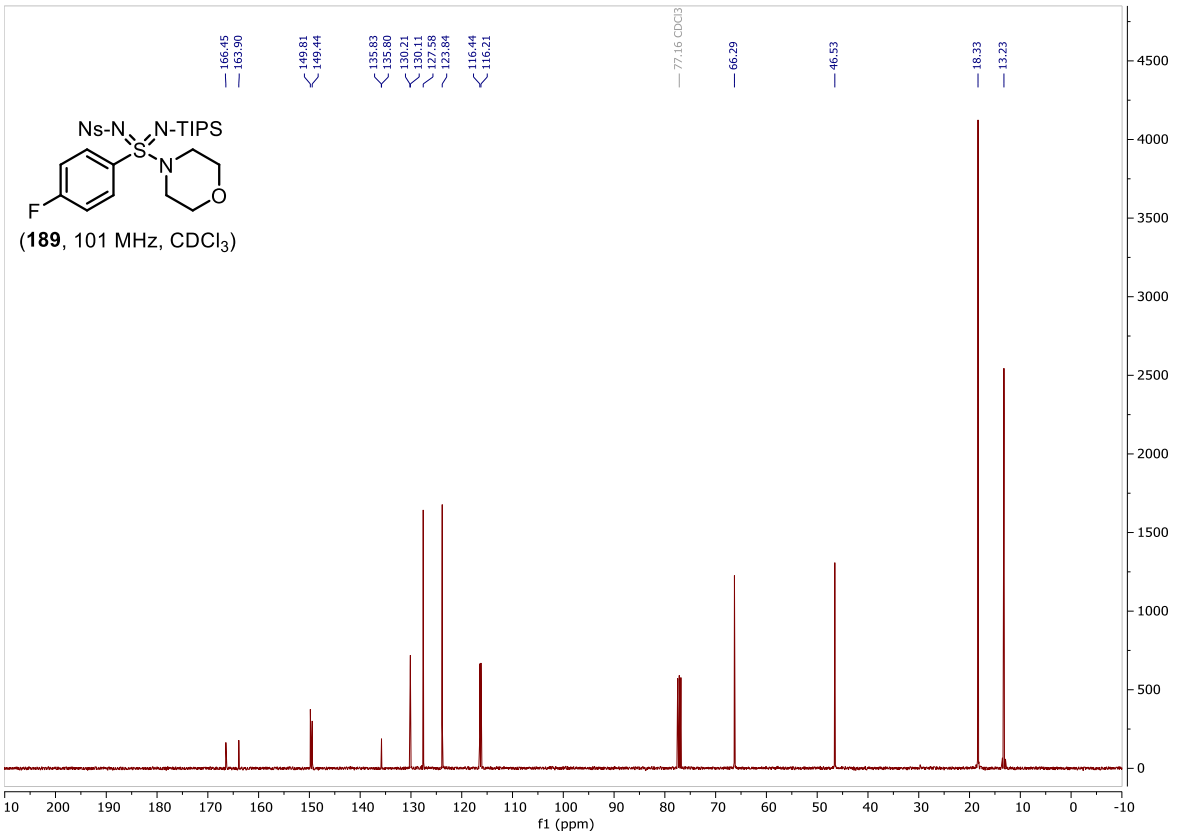


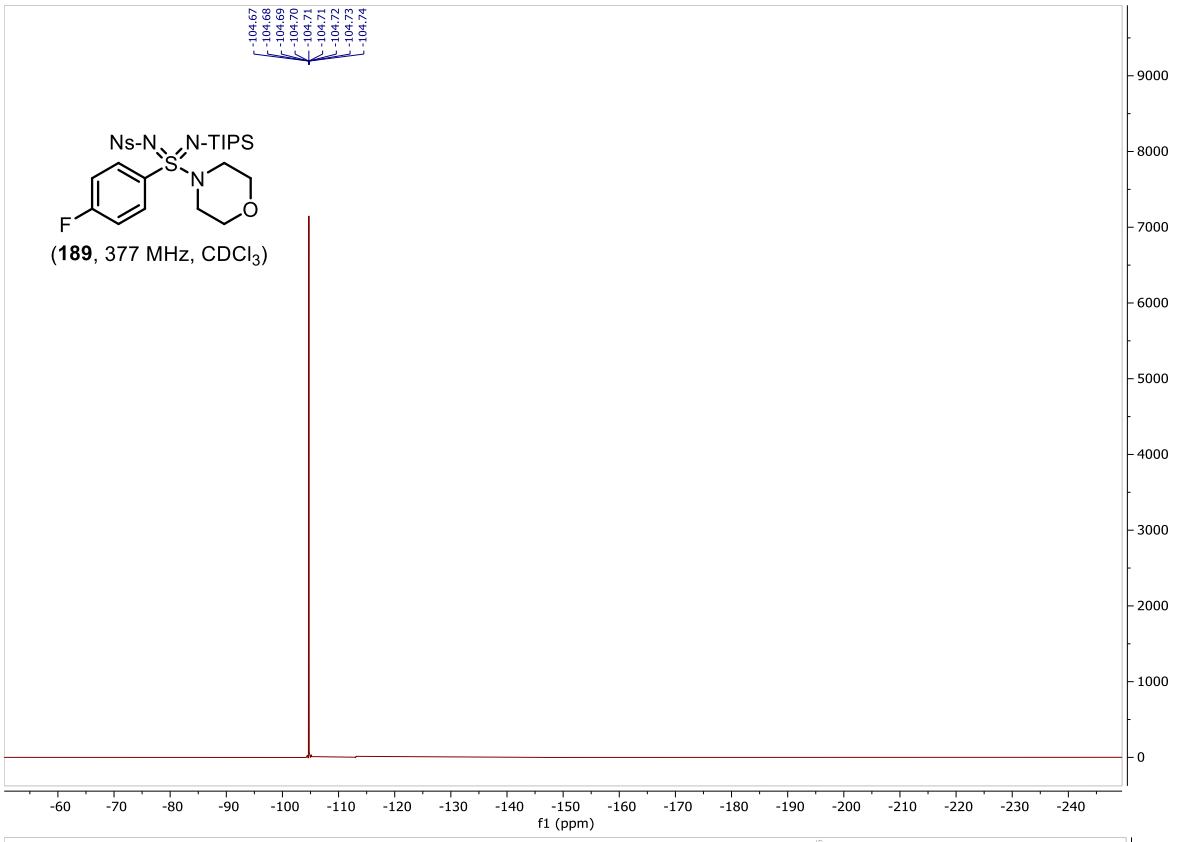
(**188**, 400 MHz, CD_3CN)


168.31
165.77
151.11
148.77
136.31
136.28
136.03
136.00
131.35
131.25
128.82
125.33
118.26 CD3CN
118.14
117.91
18.25
18.21
13.40
13.38
Ns-N
N-TIPS
S
F
F
(188, 101 MHz, CD3CN)
f1 (ppm)

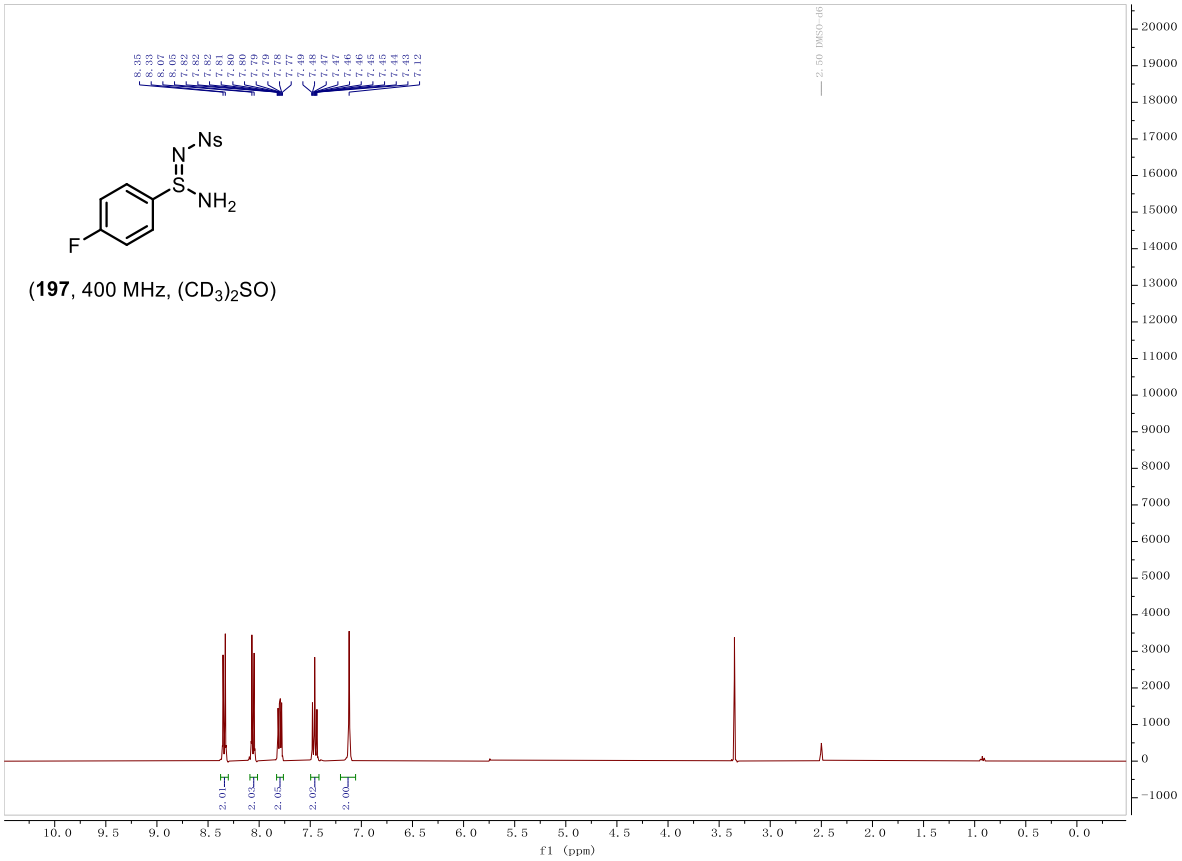

87.63
-103.30
-103.31
-103.32
-103.34
-103.35
-103.36
-103.37
Ns-N
N-TIPS
S
F
F
(188, 377 MHz, CD3CN)
f1 (ppm)


Ns-N
N-TIPS
S
N
O
F
(189, 400 MHz, CDCl3)
f1 (ppm)

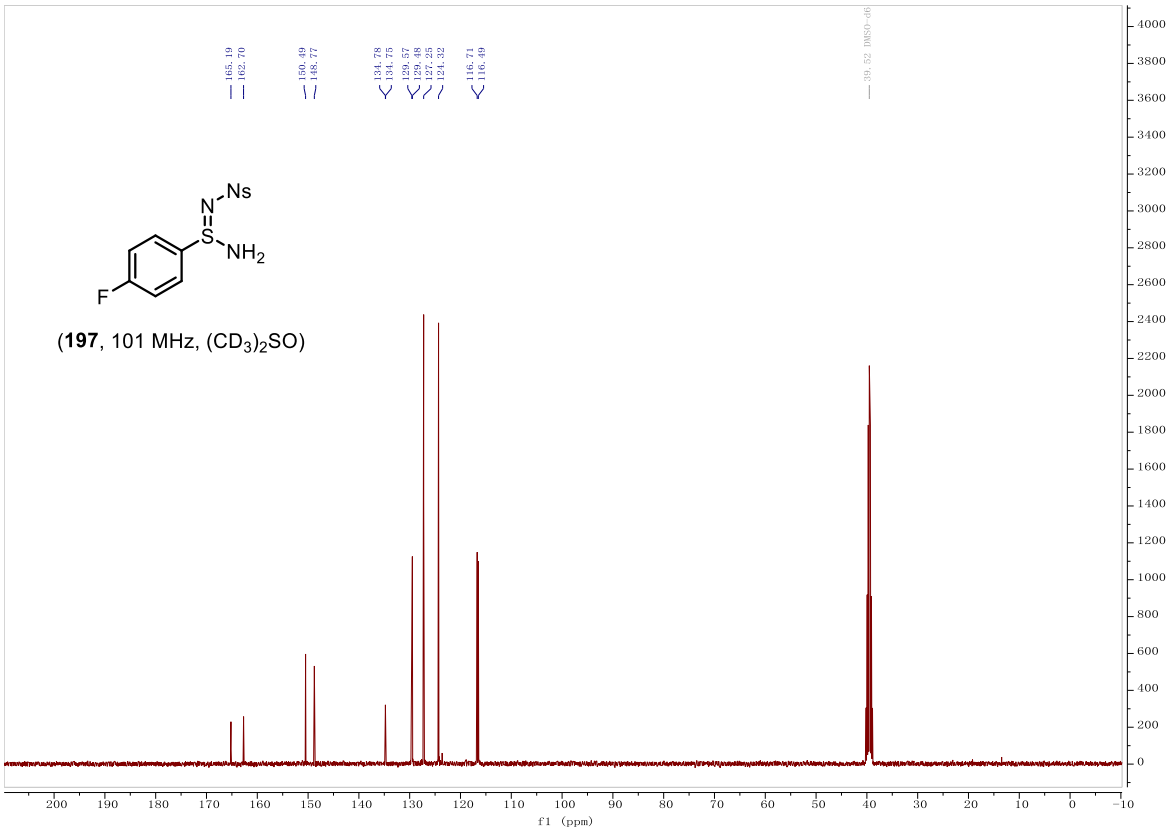

Ns-N
N-TIPS
S
N
O
F
(189, 101 MHz, CDCl3)
f1 (ppm)



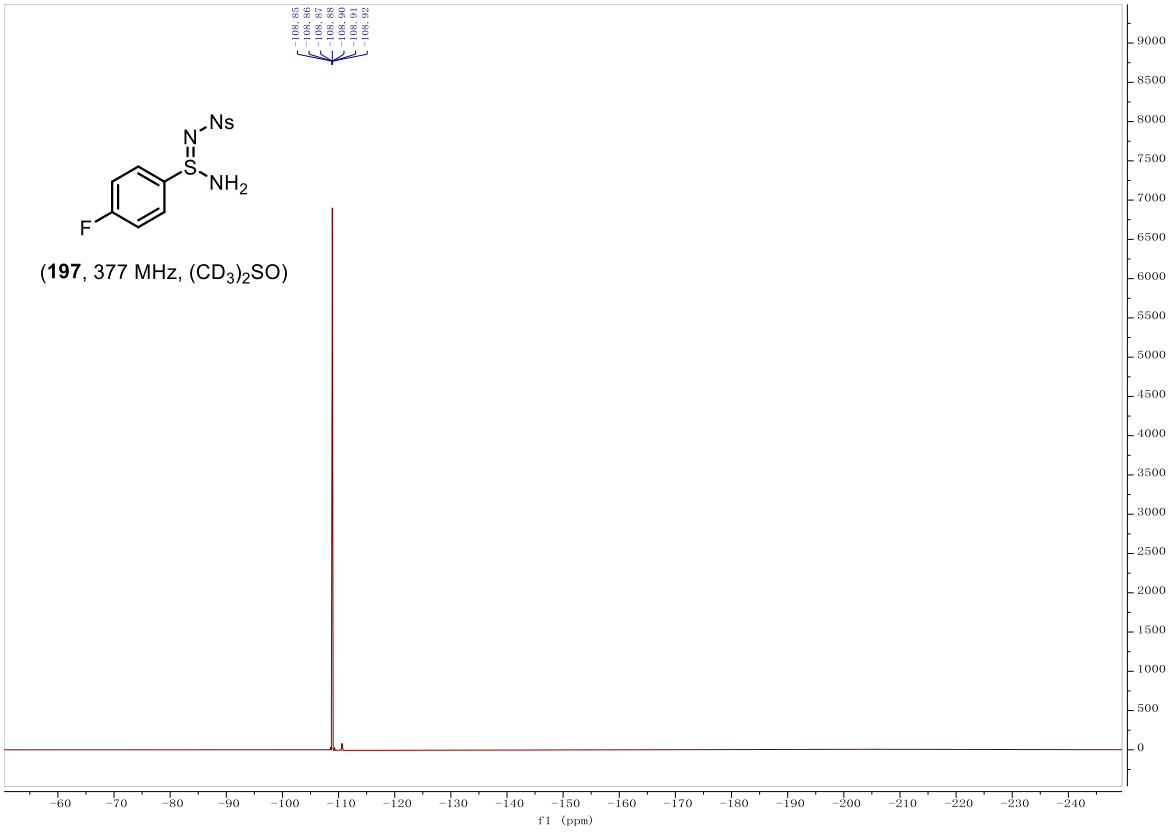
(**189**, 377 MHz, $CDCl_3$)



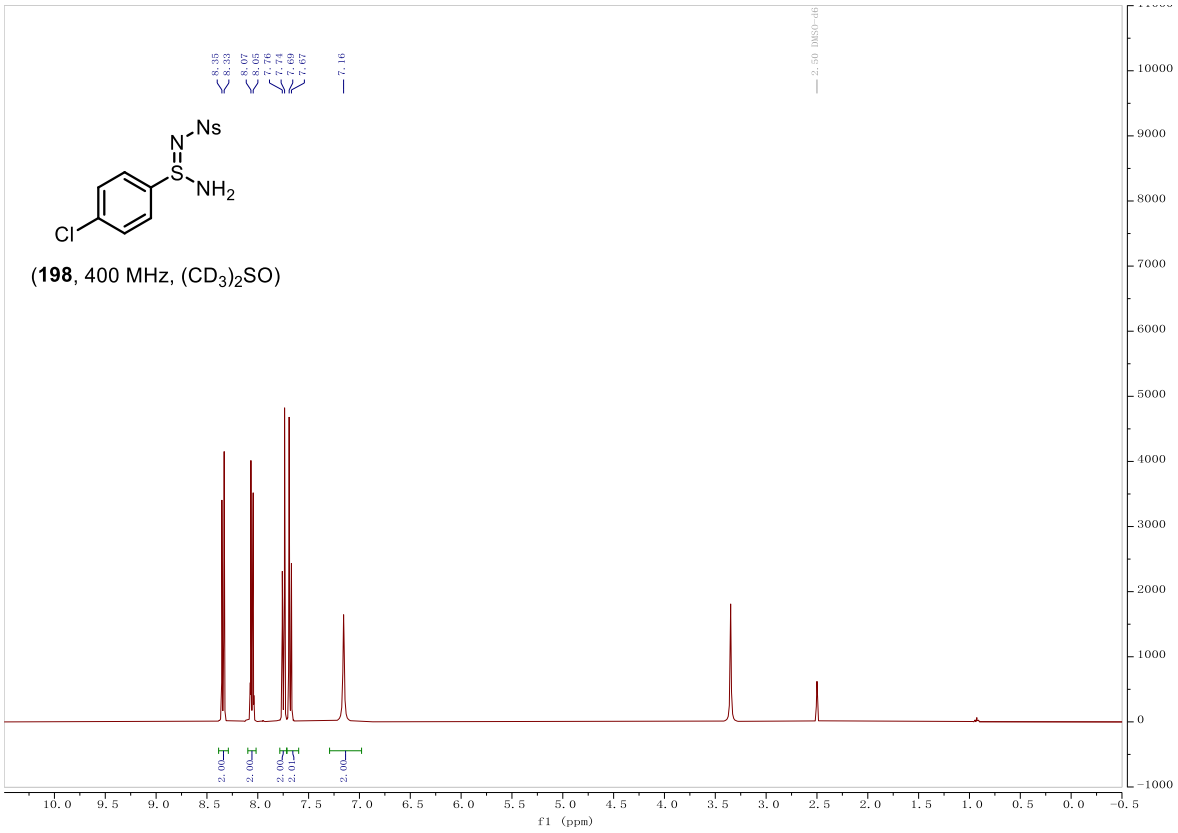
(**197**, 400 MHz, $(CD_3)_2SO$)



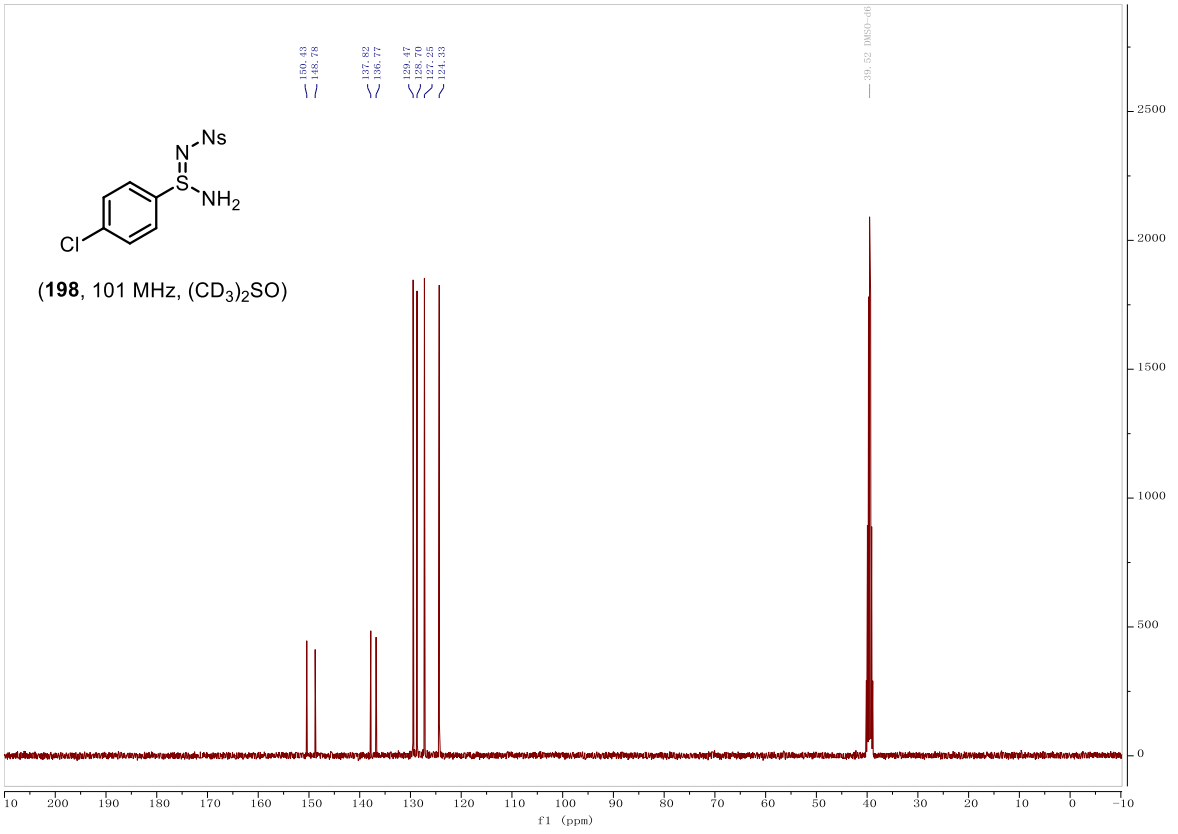
(**197**, 101 MHz, $(CD_3)_2SO$)



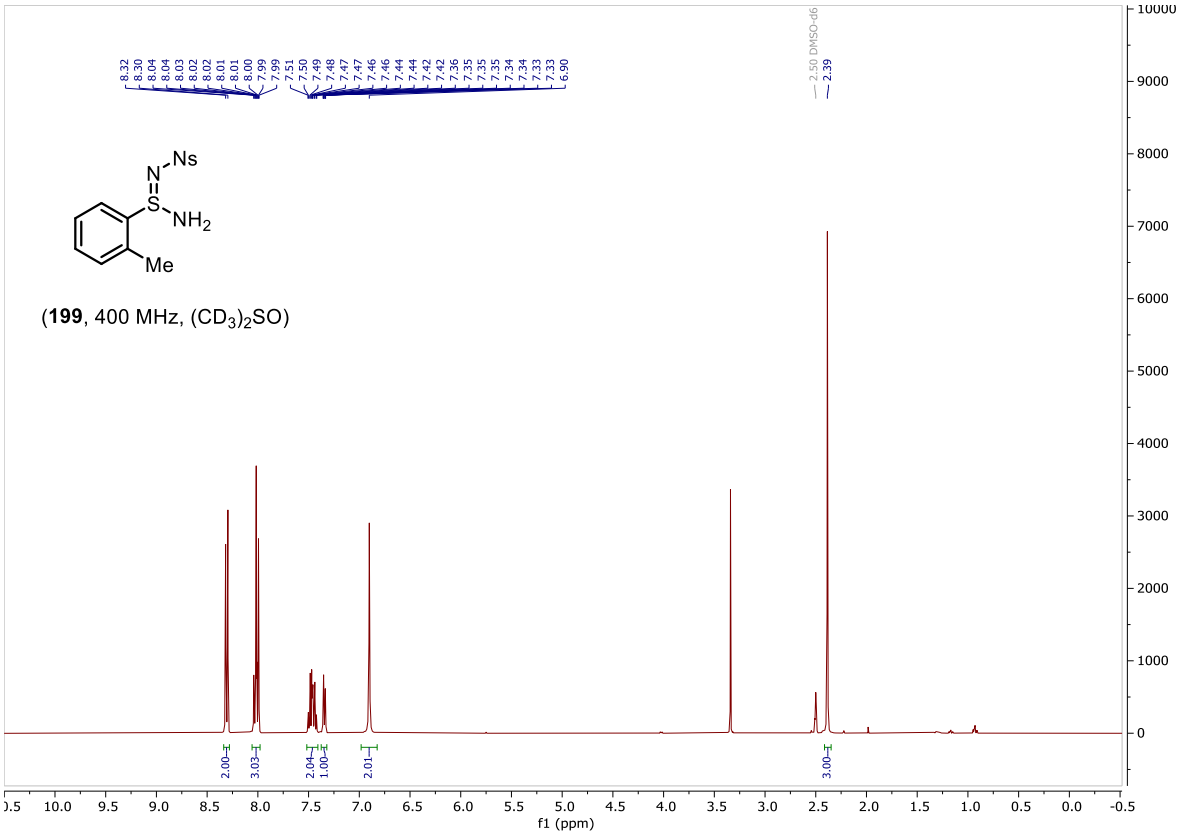
(**197**, 377 MHz, $(CD_3)_2SO$)



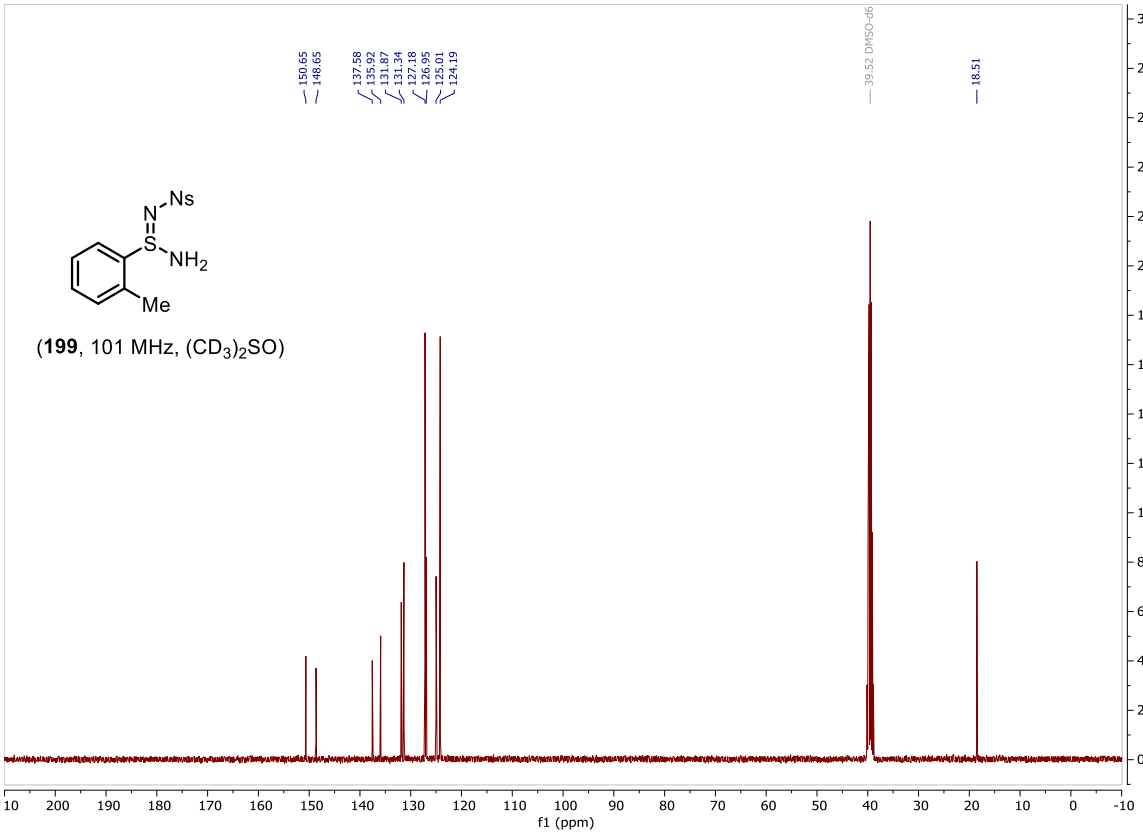
(**198**, 400 MHz, $(CD_3)_2SO$)



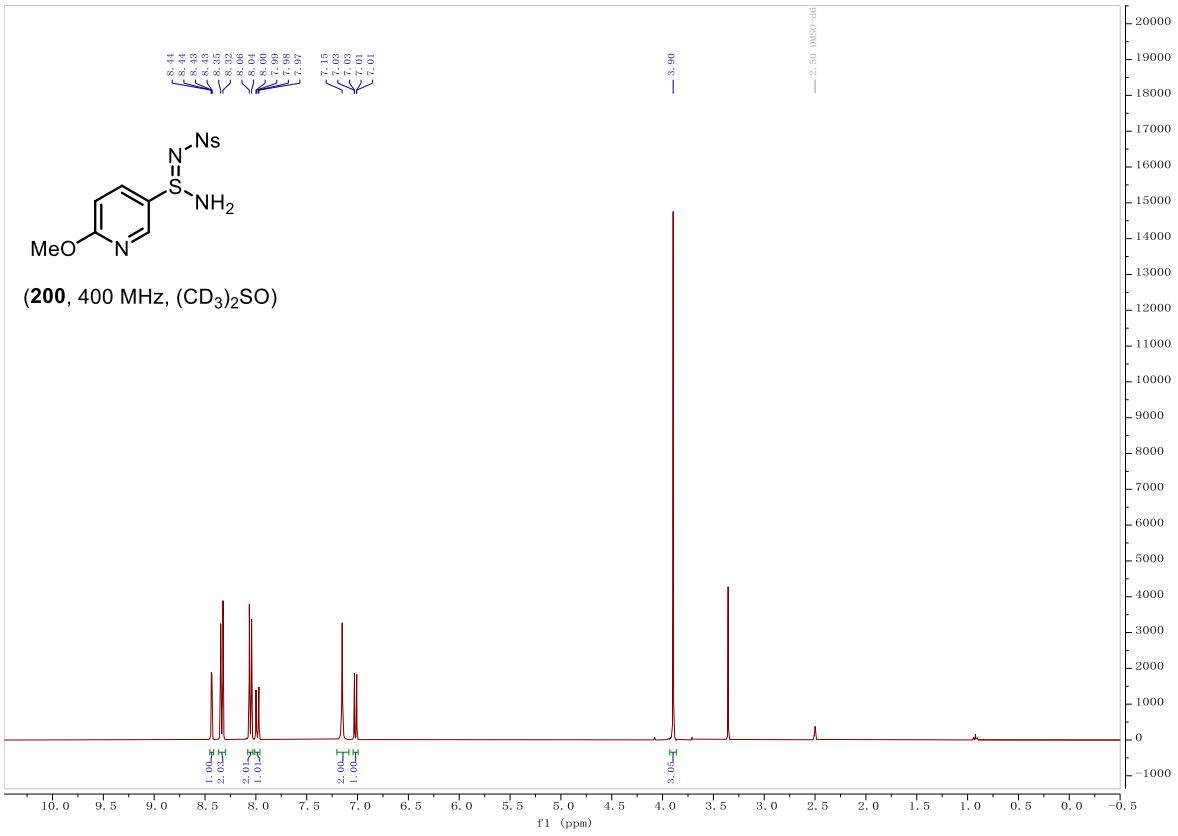
(**198**, 101 MHz, $(CD_3)_2SO$)



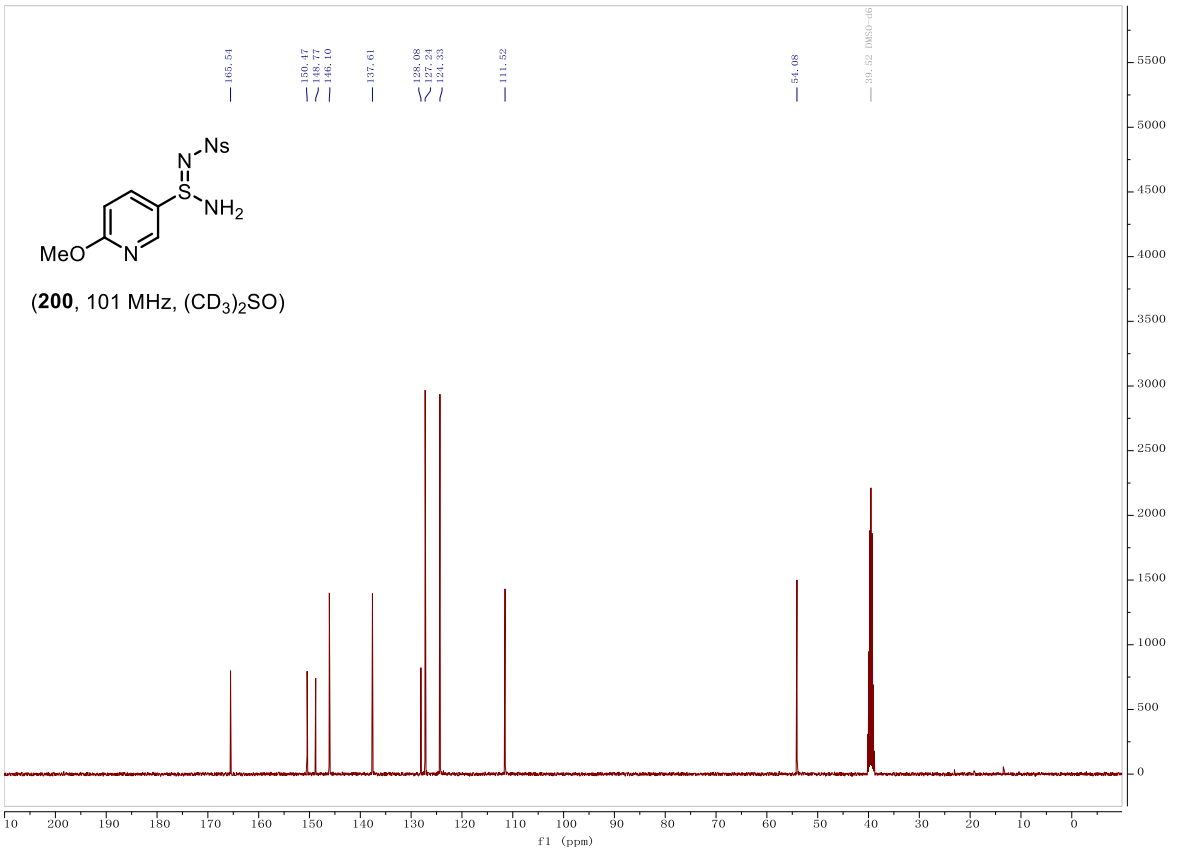
(**199**, 400 MHz, $(CD_3)_2SO$)



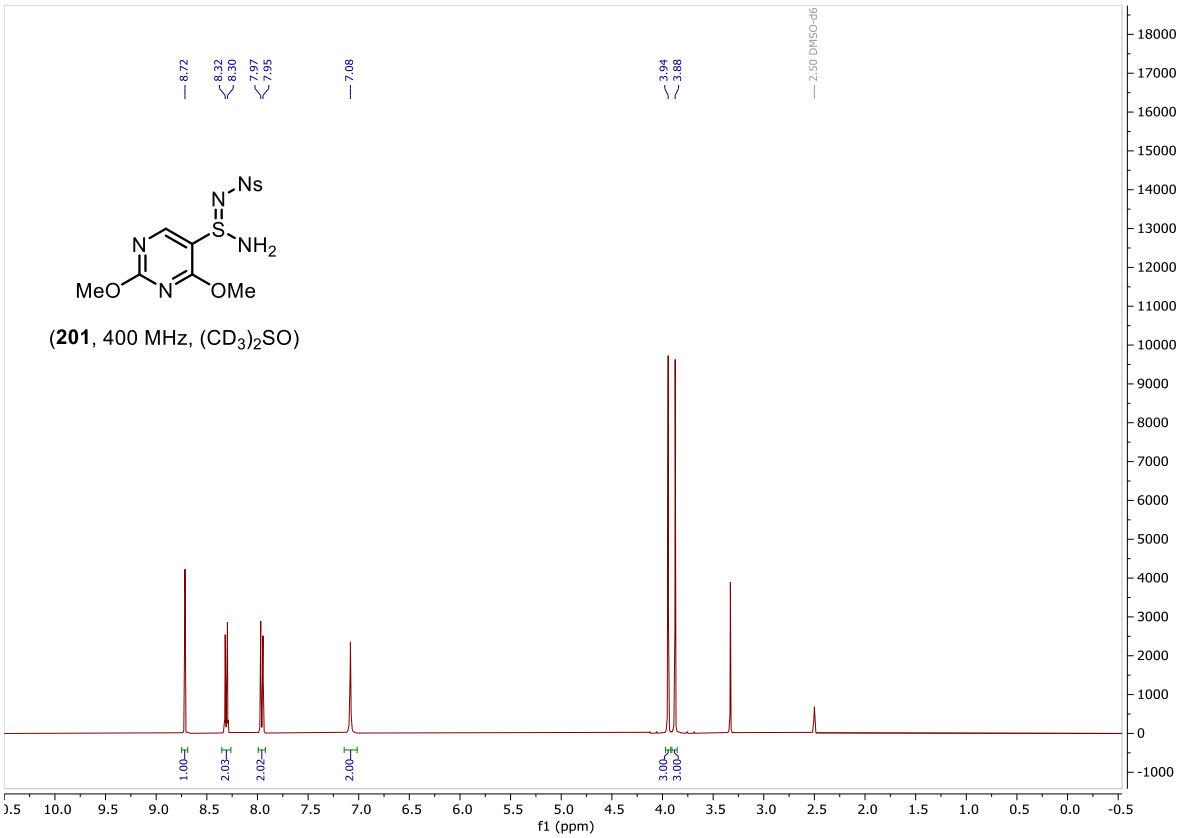
(**199**, 101 MHz, $(CD_3)_2SO$)



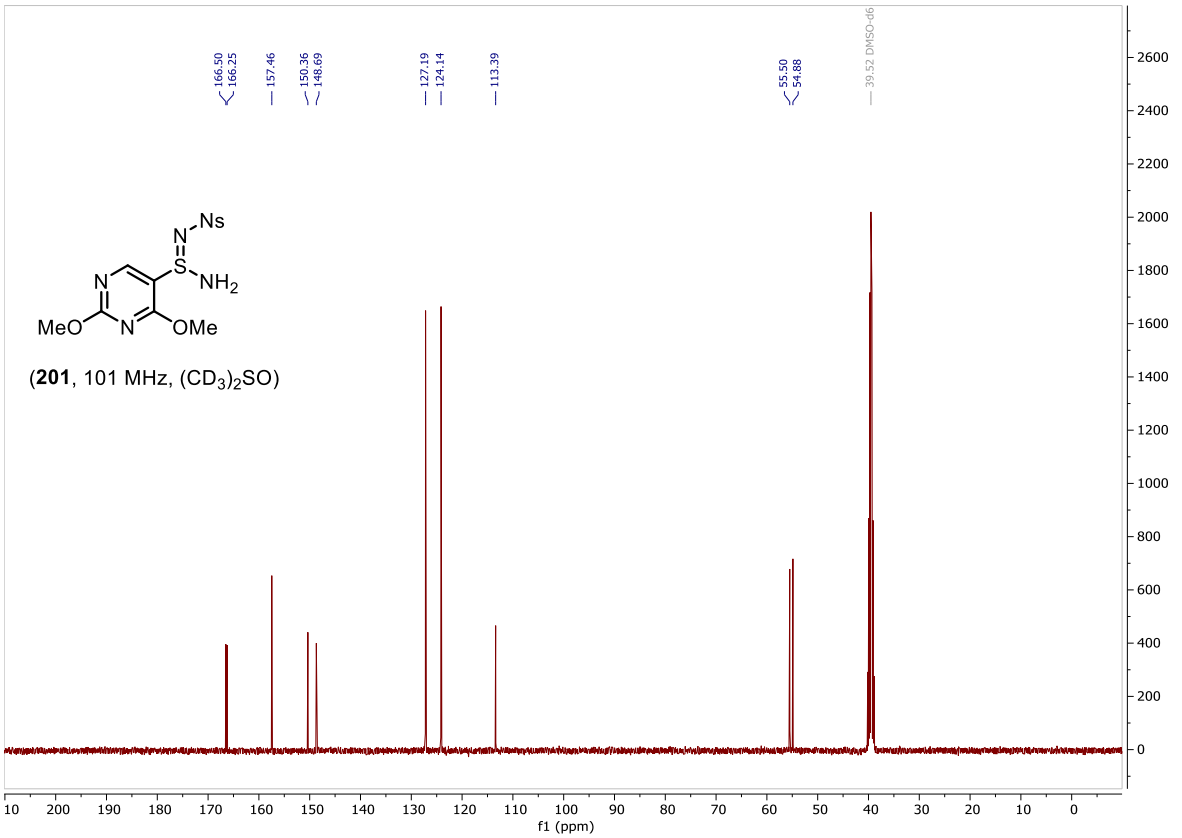
(**200**, 400 MHz, $(CD_3)_2SO$)



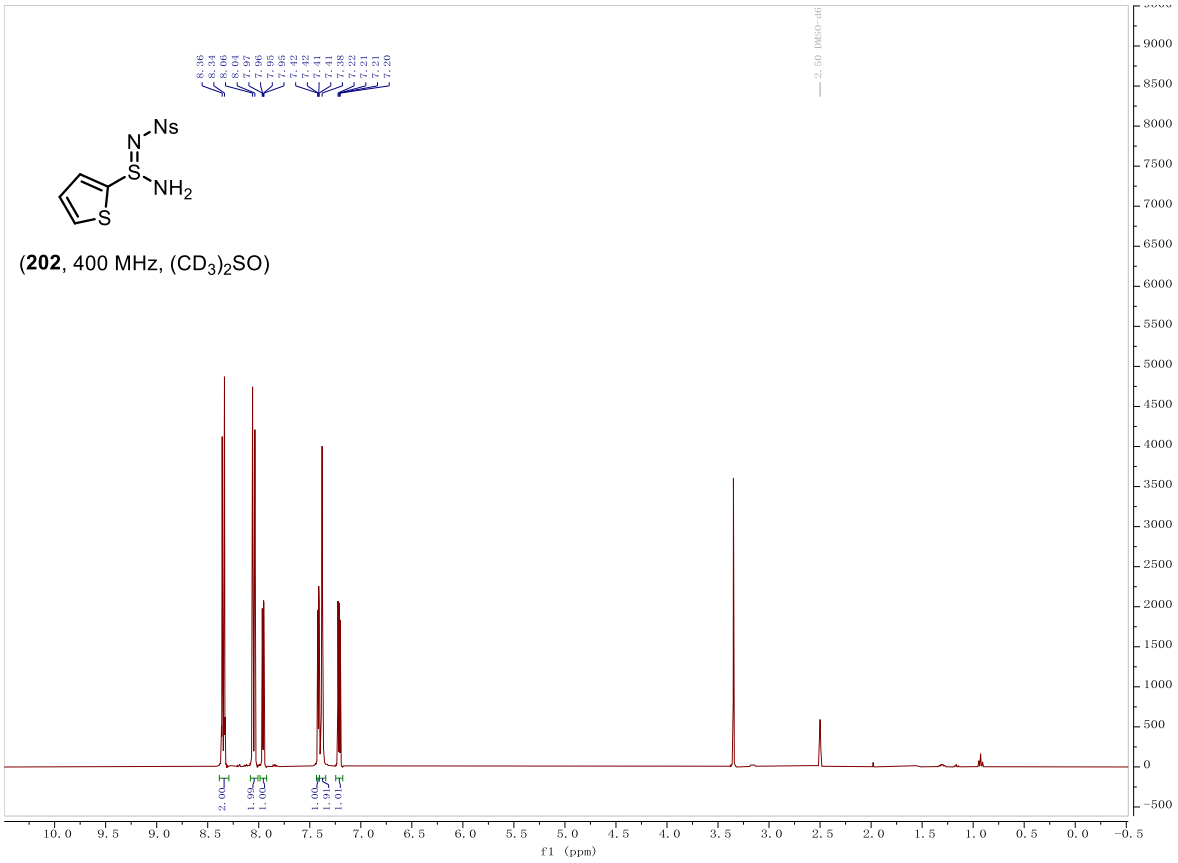
(**200**, 101 MHz, $(CD_3)_2SO$)



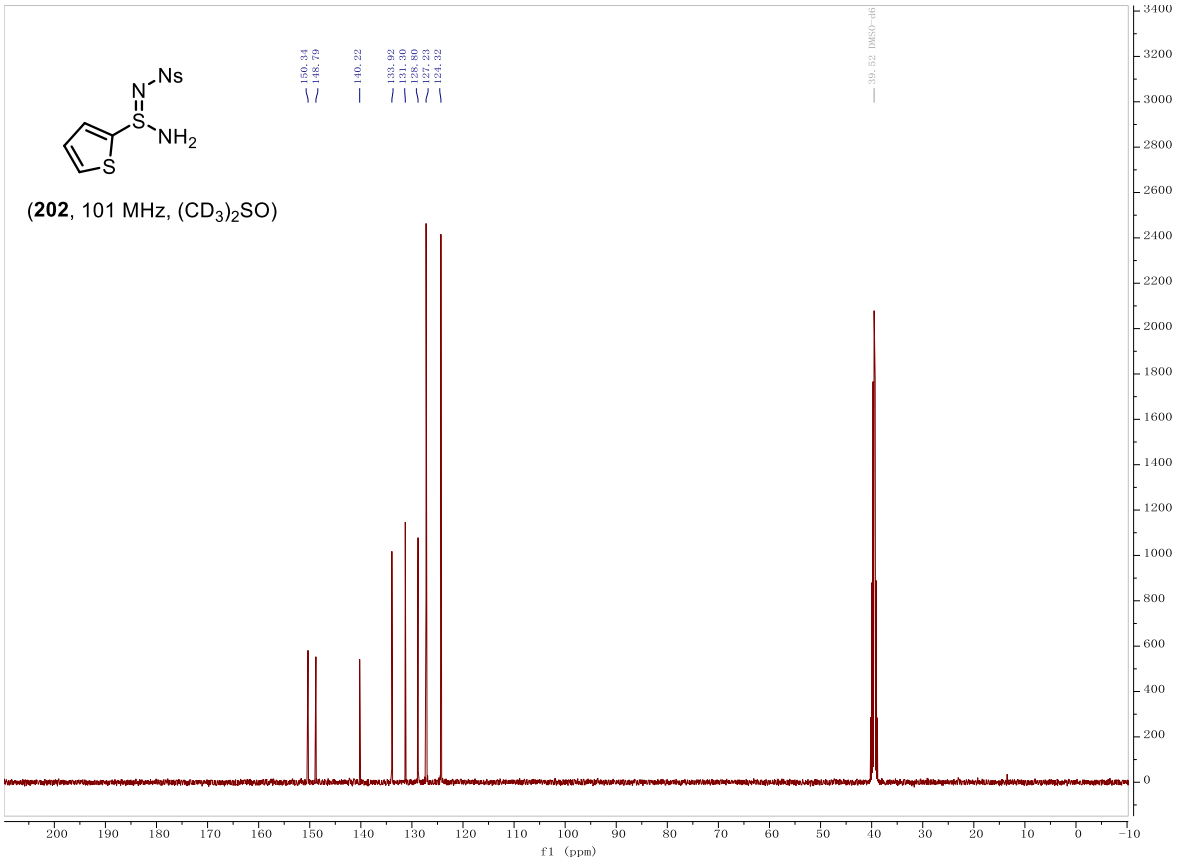
(**201**, 400 MHz, $(CD_3)_2SO$)



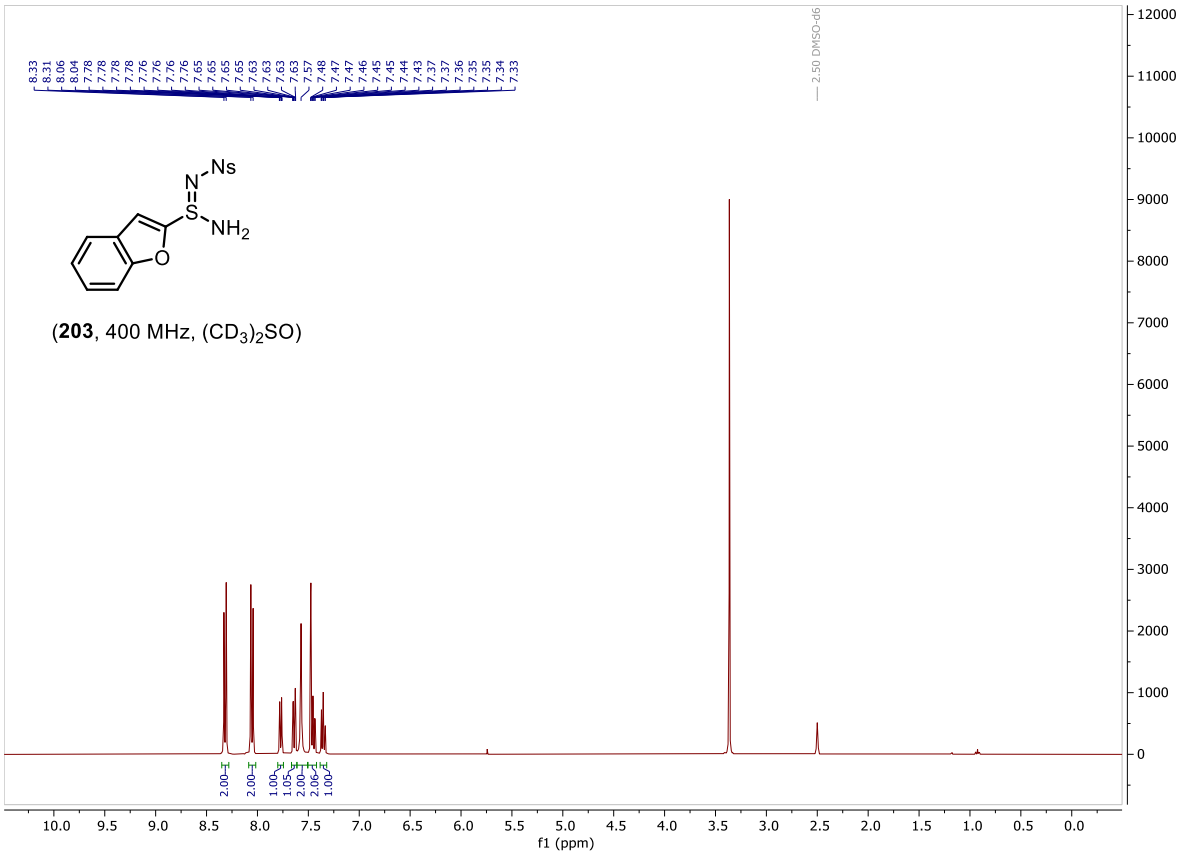
(**201**, 101 MHz, $(CD_3)_2SO$)

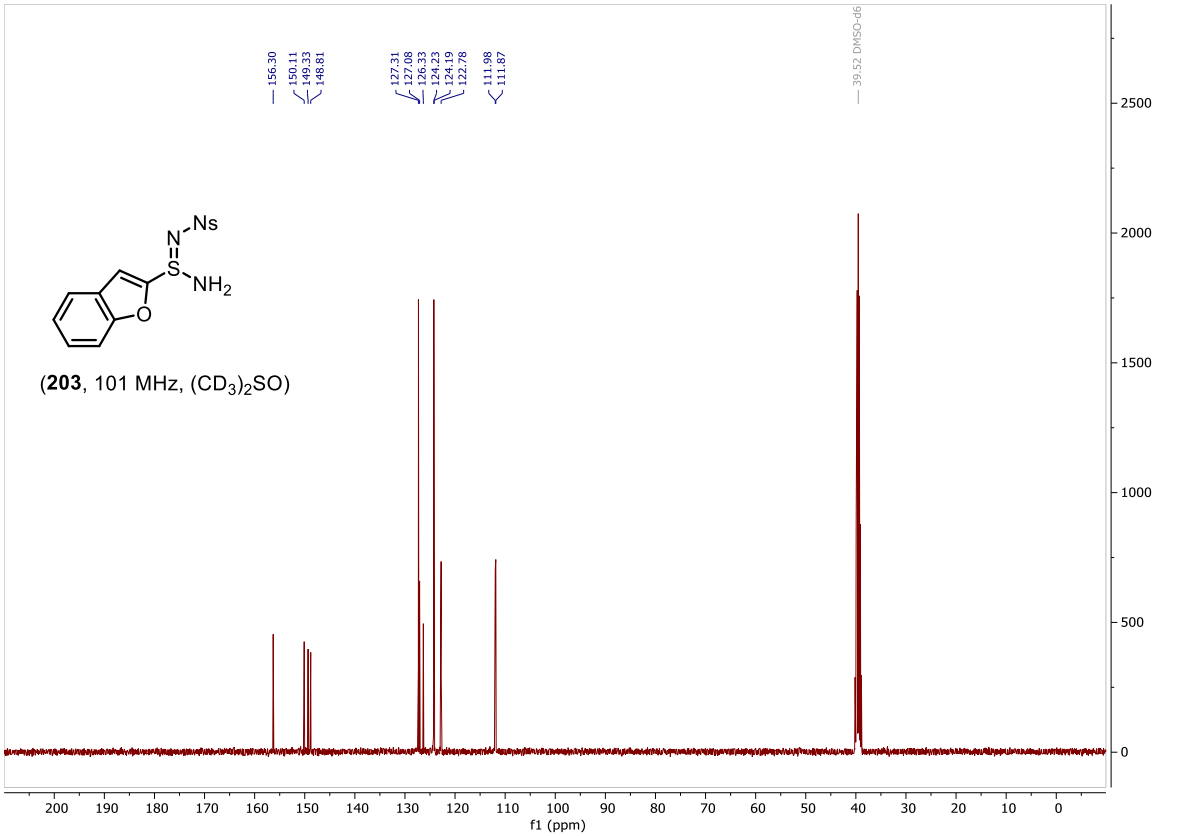


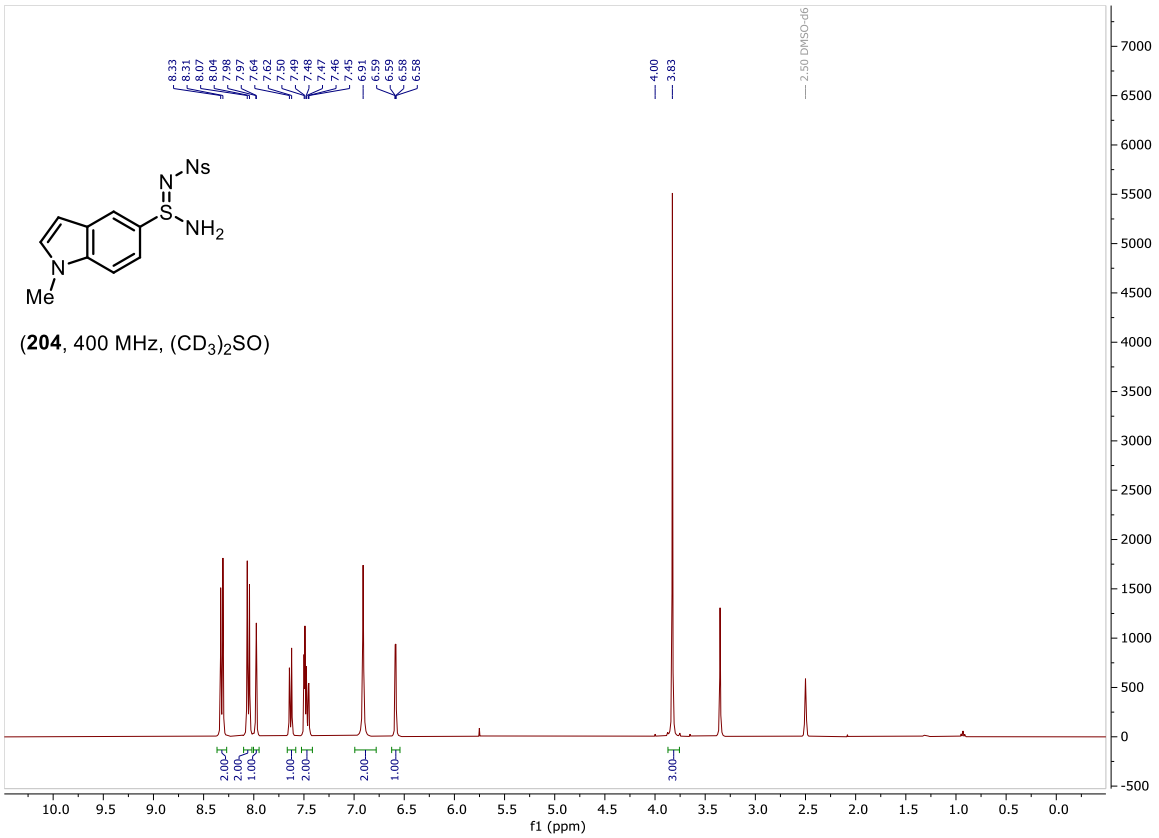
(**202**, 400 MHz, $(CD_3)_2SO$)



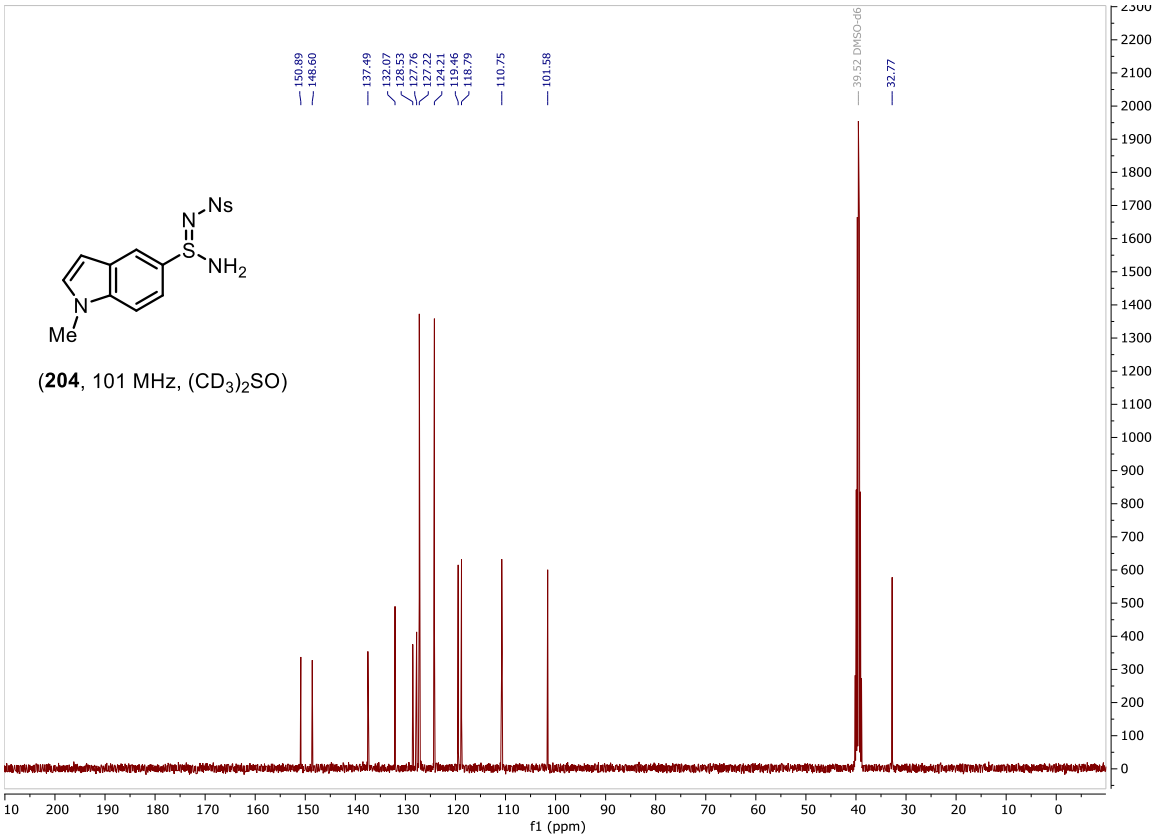
(**202**, 101 MHz, $(CD_3)_2SO$)


8.33
8.31
8.06
8.04
7.78
7.78
7.78
7.78
7.76
7.76
7.76
7.76
7.76
7.65
7.65
7.65
7.63
7.63
7.63
7.63
7.57
7.48
7.47
7.47
7.46
7.45
7.45
7.44
7.43
7.37
7.37
7.36
7.35
7.35
7.34
7.33
2.50 DMSO-d6
Ns
N
S
NH2
O
(203, 400 MHz, (CD3)2SO)
2.00
2.00
1.00
1.05
2.00
2.06
1.00
f1 (ppm)

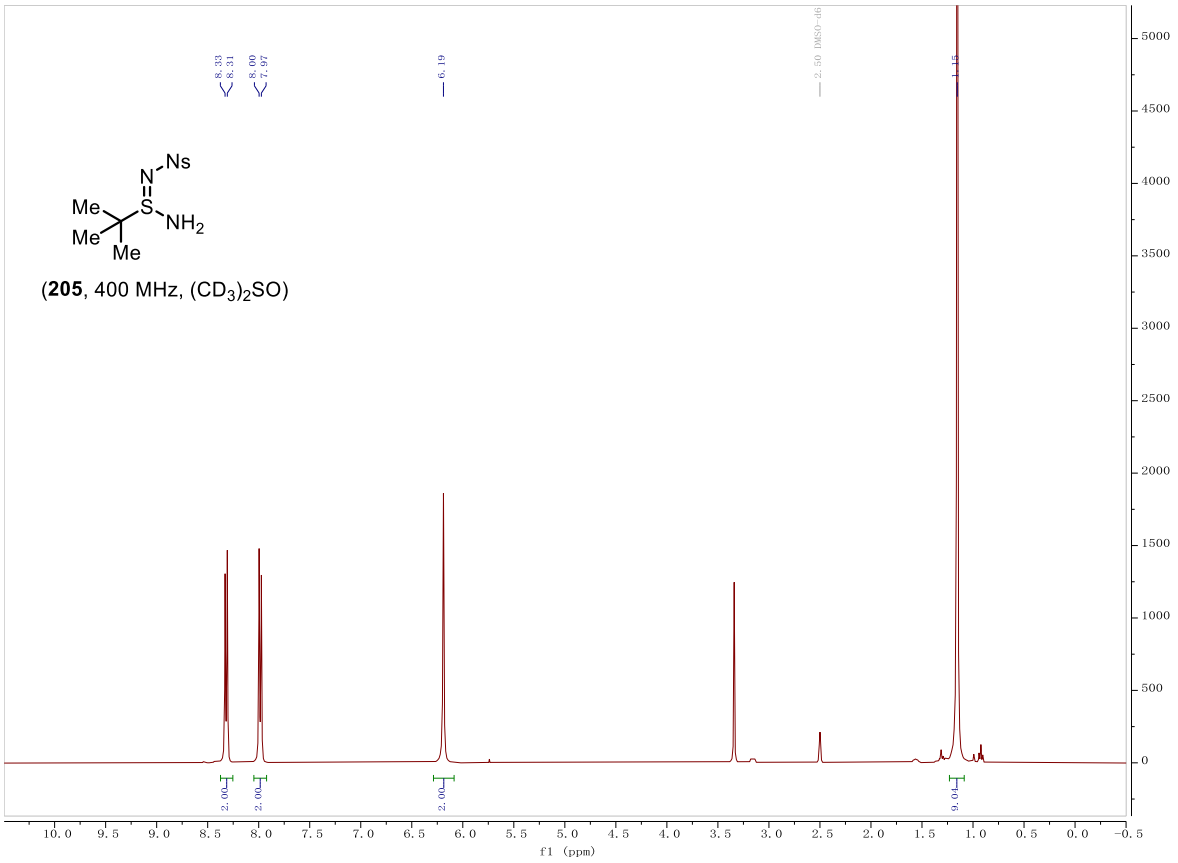

156.30
150.11
149.33
148.81
127.31
127.08
126.33
124.23
124.19
122.78
111.98
111.87
39.52 DMSO-d6
Ns
N
S
NH2
O
(203, 101 MHz, (CD3)2SO)
f1 (ppm)



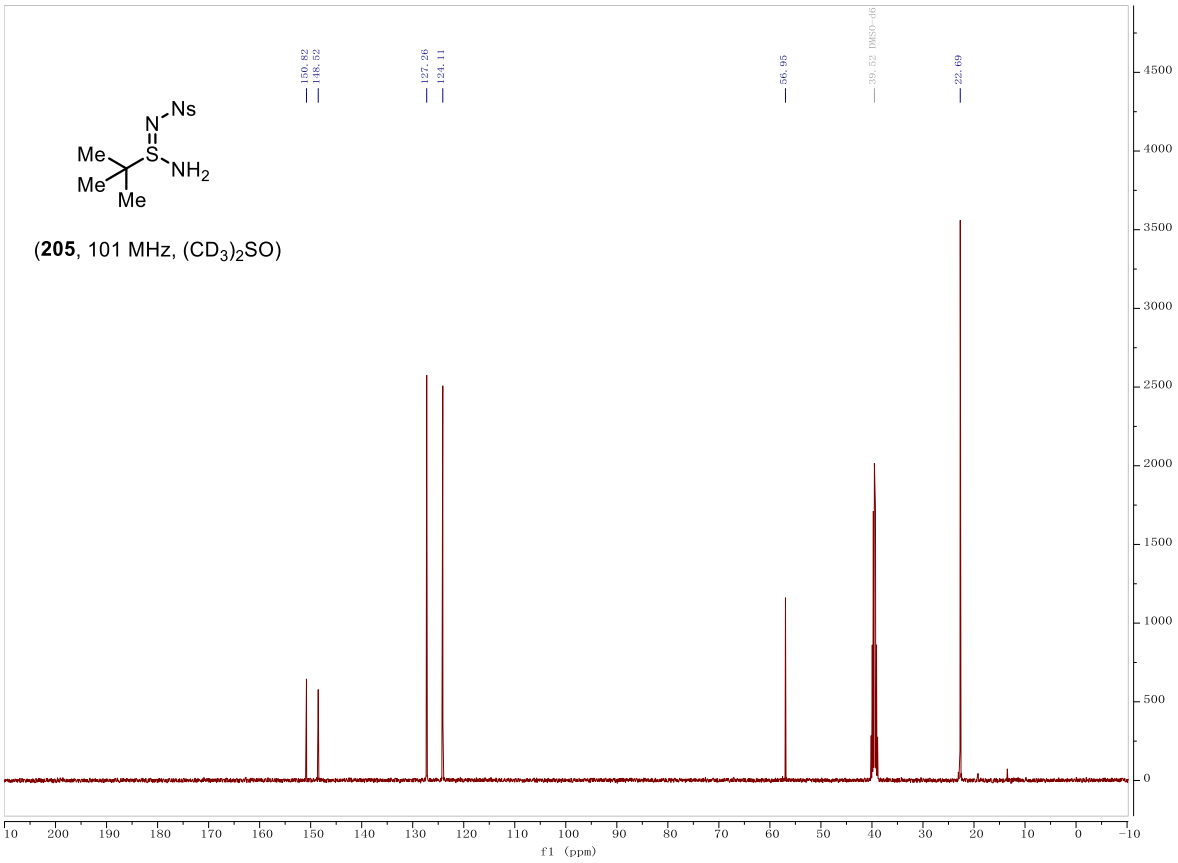
(**204**, 400 MHz, $(CD_3)_2SO$)



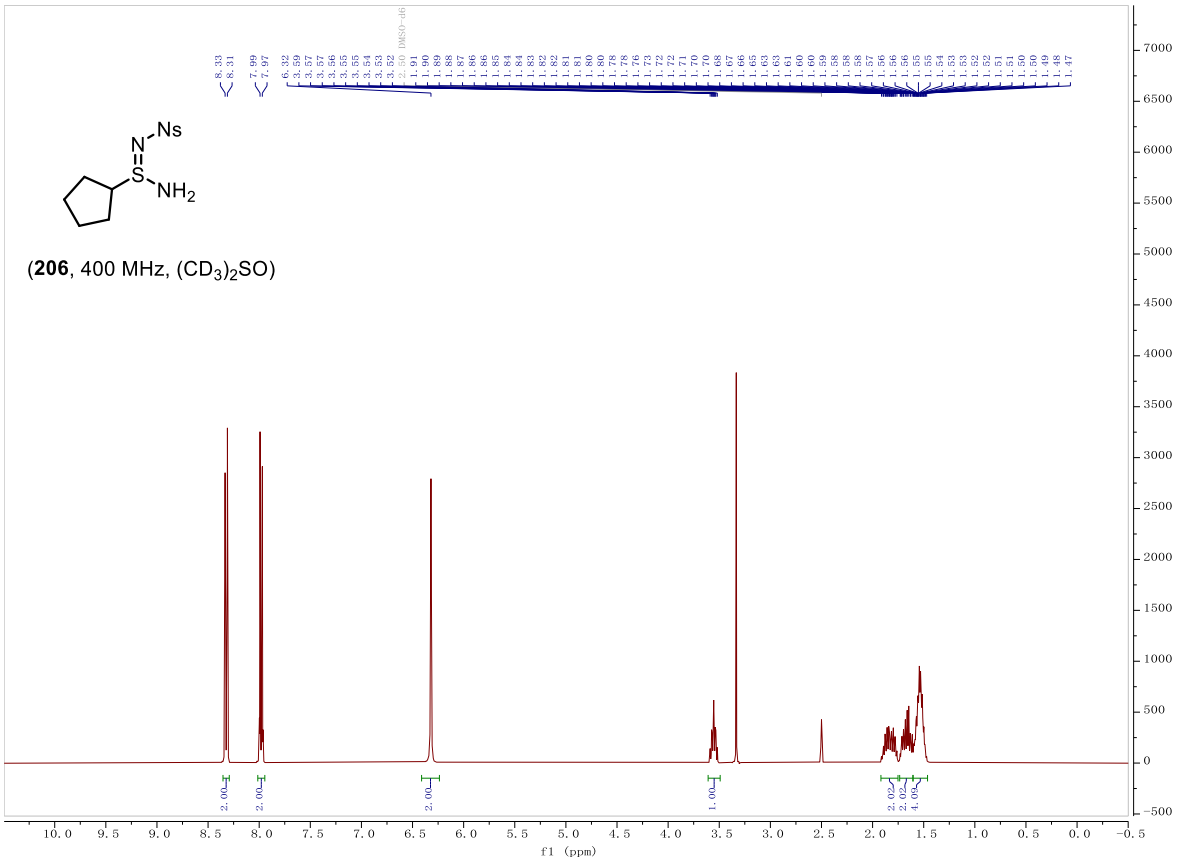
(**204**, 101 MHz, $(CD_3)_2SO$)

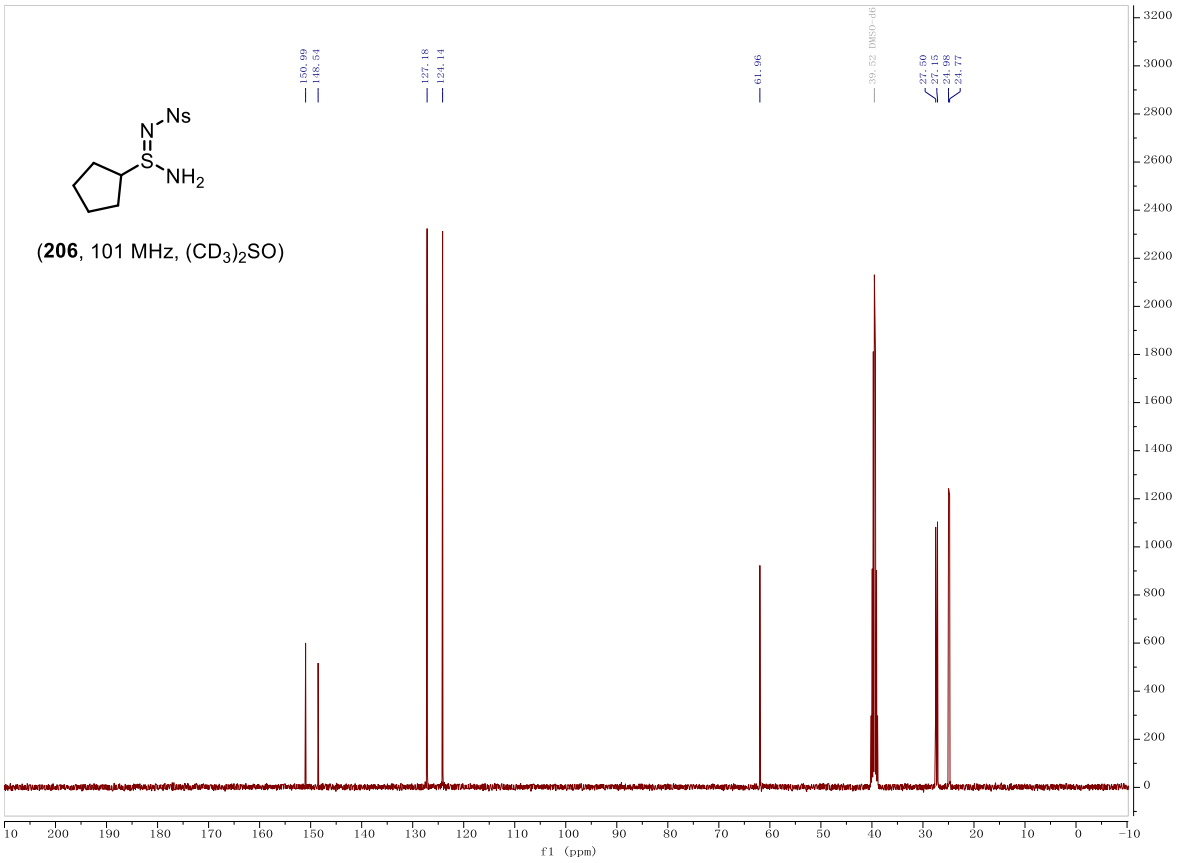


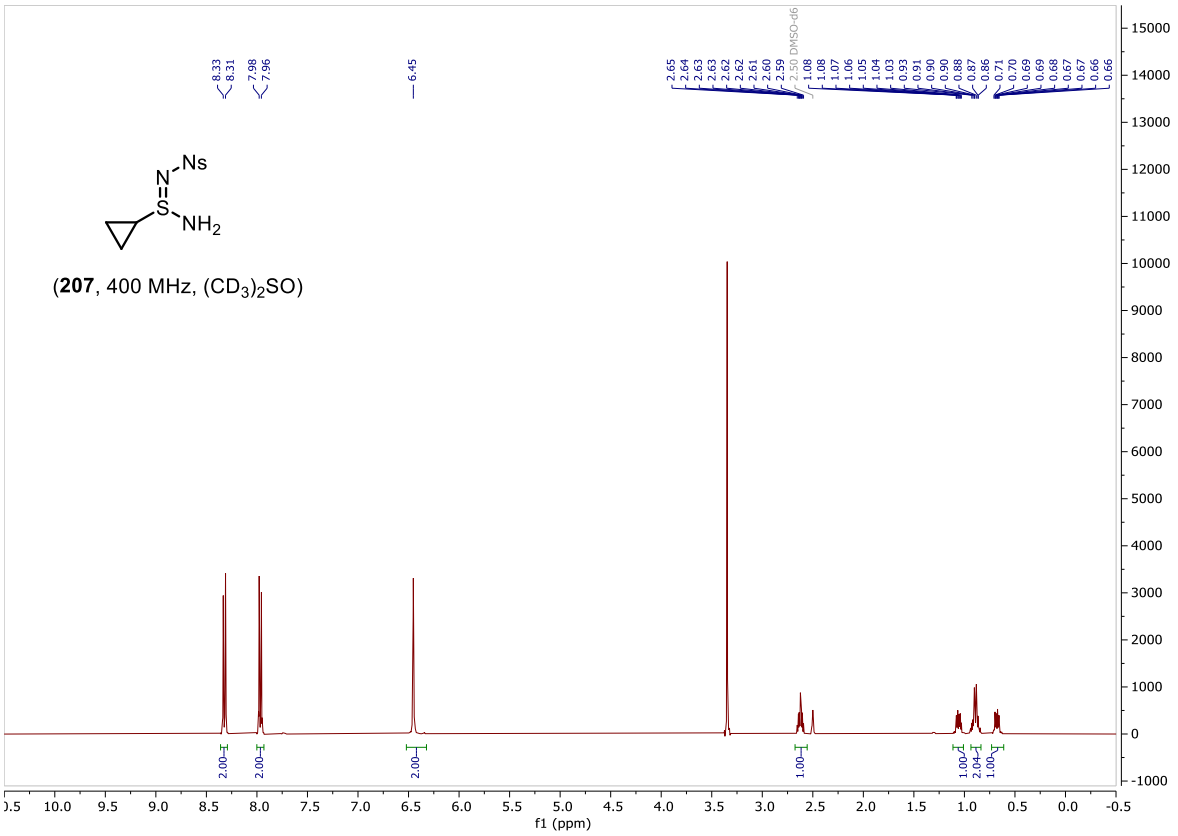
(**205**, 400 MHz, $(CD_3)_2SO$)

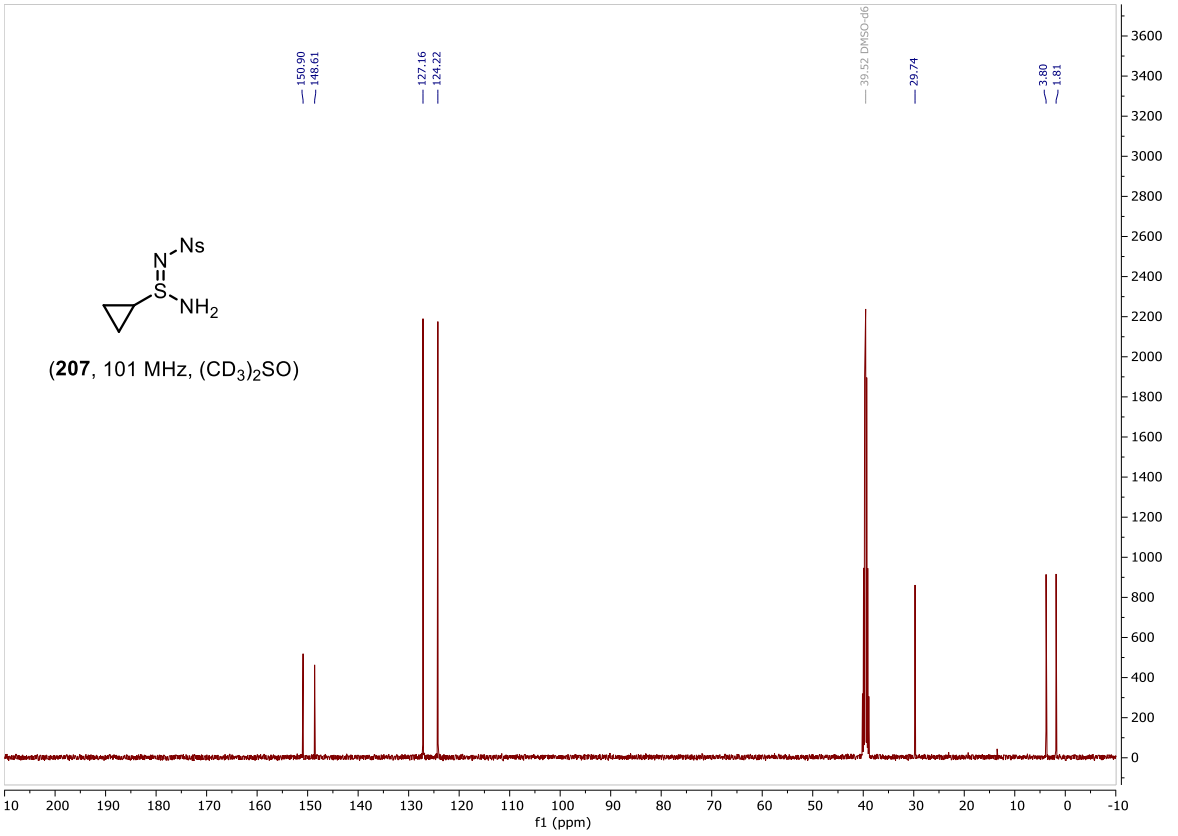


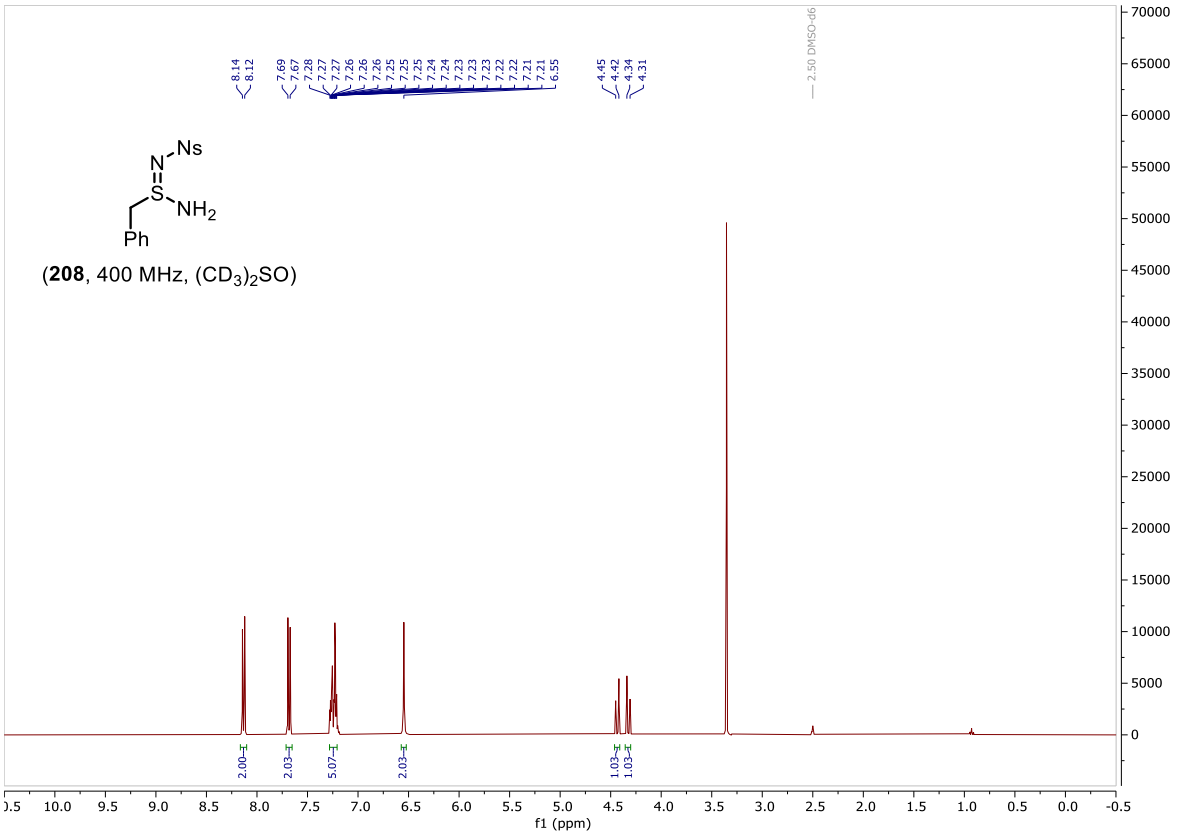
(**205**, 101 MHz, $(CD_3)_2SO$)

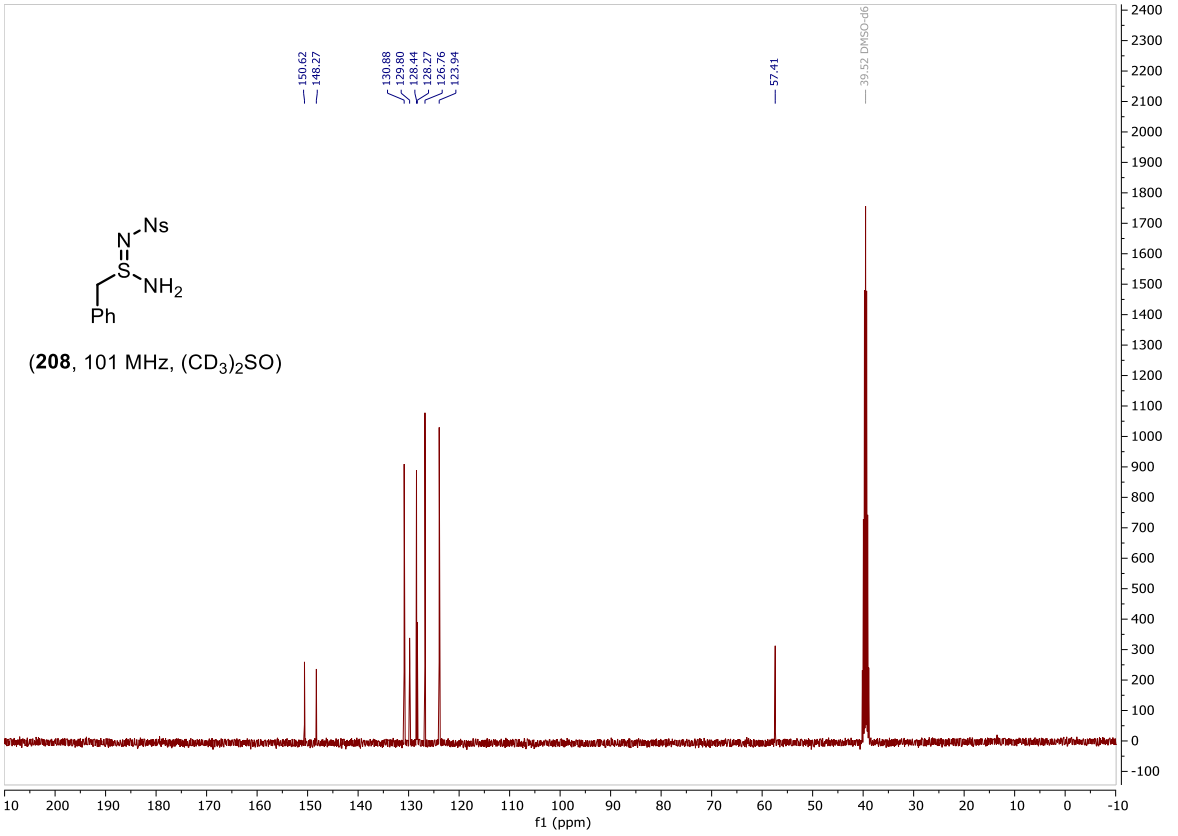

Ns
N
S
NH2
(206, 400 MHz, (CD3)2SO)
f1 (ppm)

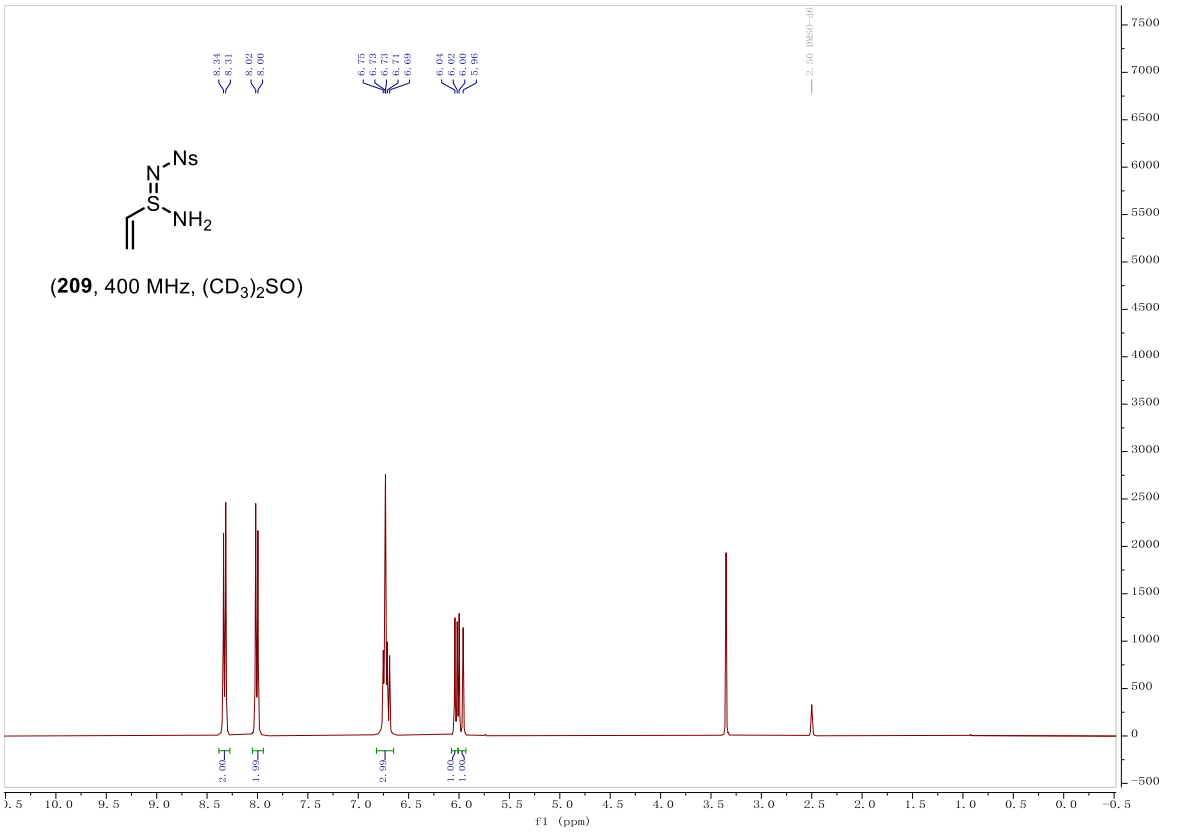

Ns
N
S
NH2
(206, 101 MHz, (CD3)2SO)
f1 (ppm)

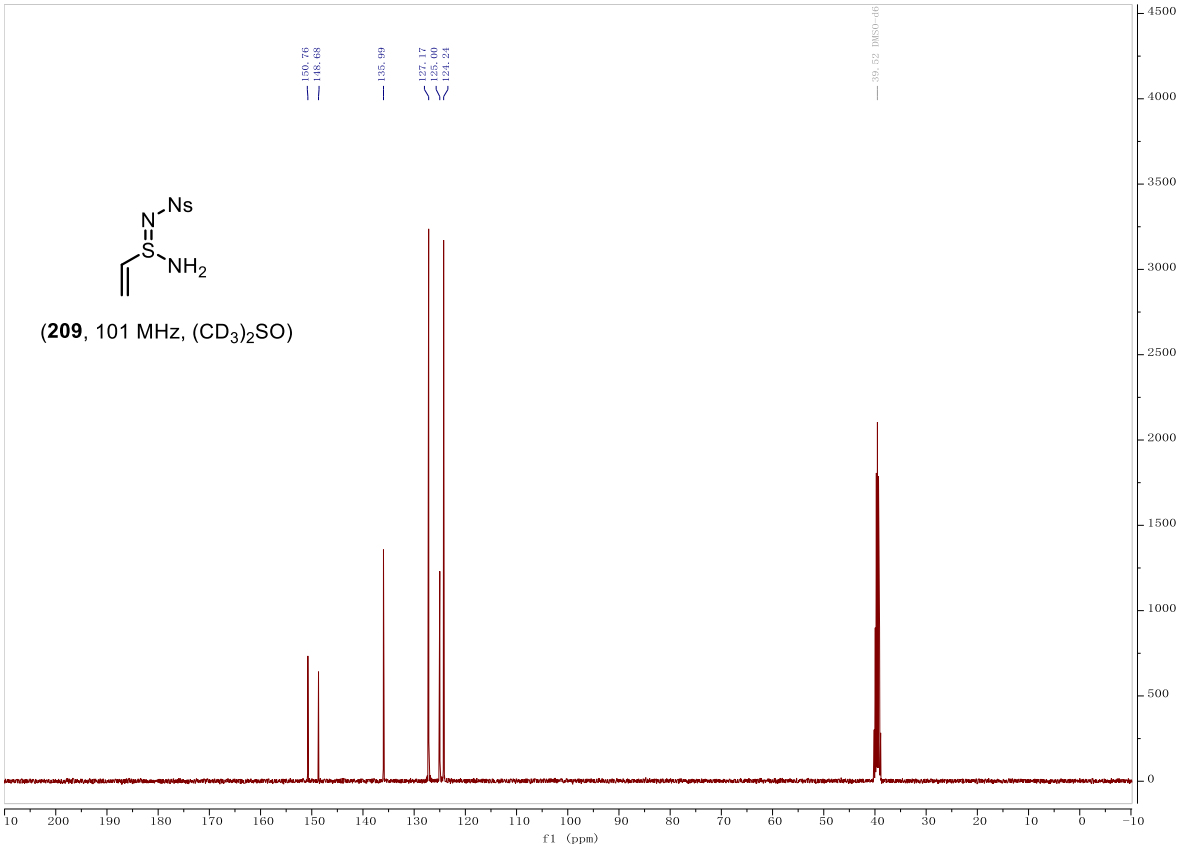

8.33
8.31
7.98
7.96
6.45
2.65
2.64
2.63
2.63
2.62
2.62
2.61
2.60
2.59
2.50 DMSO-d6
1.08
1.08
1.07
1.06
1.05
1.04
1.03
0.93
0.91
0.90
0.90
0.88
0.87
0.86
0.71
0.70
0.69
0.69
0.68
0.67
0.67
0.66
0.66
Ns
N
S
NH2
(207, 400 MHz, (CD3)2SO)
2.00
2.00
2.00
1.00
1.00
2.04
1.00
f1 (ppm)

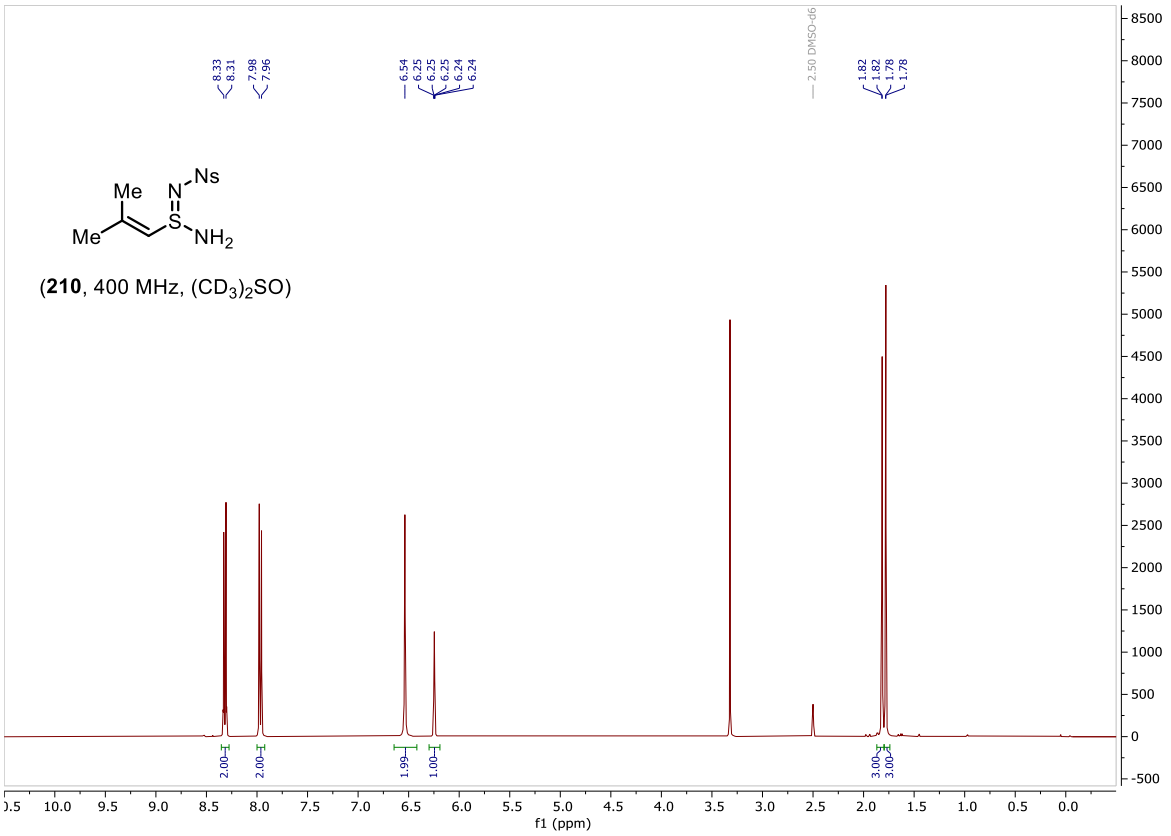

150.90
148.61
127.16
124.22
39.52 DMSO-d6
29.74
3.80
1.81
Ns
N
S
NH2
(207, 101 MHz, (CD3)2SO)
f1 (ppm)


8.14
8.12
7.69
7.67
7.28
7.27
7.27
7.26
7.26
7.26
7.25
7.25
7.25
7.24
7.24
7.23
7.23
7.23
7.22
7.22
7.21
7.21
6.55
4.45
4.42
4.34
4.31
2.50 DMSO-d6
Ns
N
S
NH2
Ph
(208, 400 MHz, (CD3)2SO)
2.00
2.03
5.07
2.03
1.03
1.03
f1 (ppm)

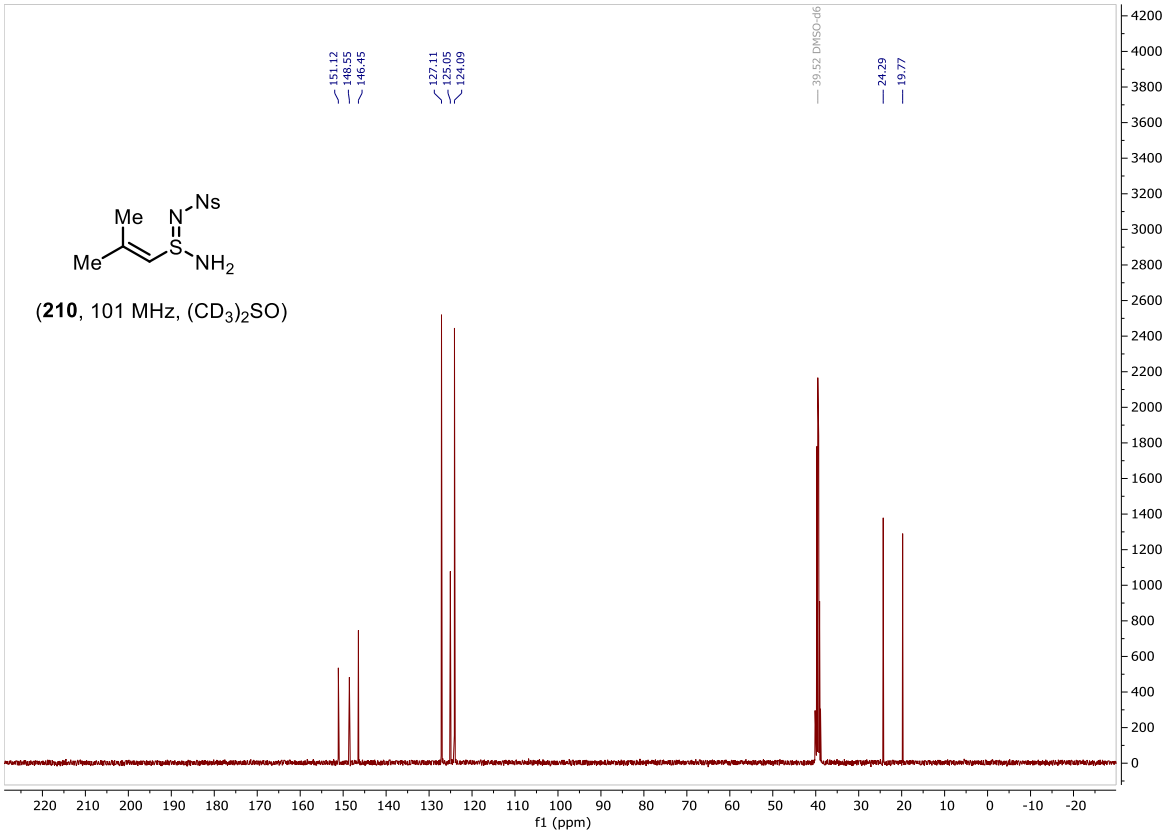

150.62
148.27
130.88
129.80
128.44
128.27
126.76
123.94
57.41
39.52 DMSO-d6
Ns
N
S
NH2
Ph
(208, 101 MHz, (CD3)2SO)
f1 (ppm)


8.34
8.31
8.02
8.00
6.75
6.73
6.73
6.71
6.69
6.04
6.02
6.00
5.98
2.50 DMSO-d6
Ns
N
S
NH2
(209, 400 MHz, (CD3)2SO)
2.00
1.99
2.99
1.00
1.00
f1 (ppm)

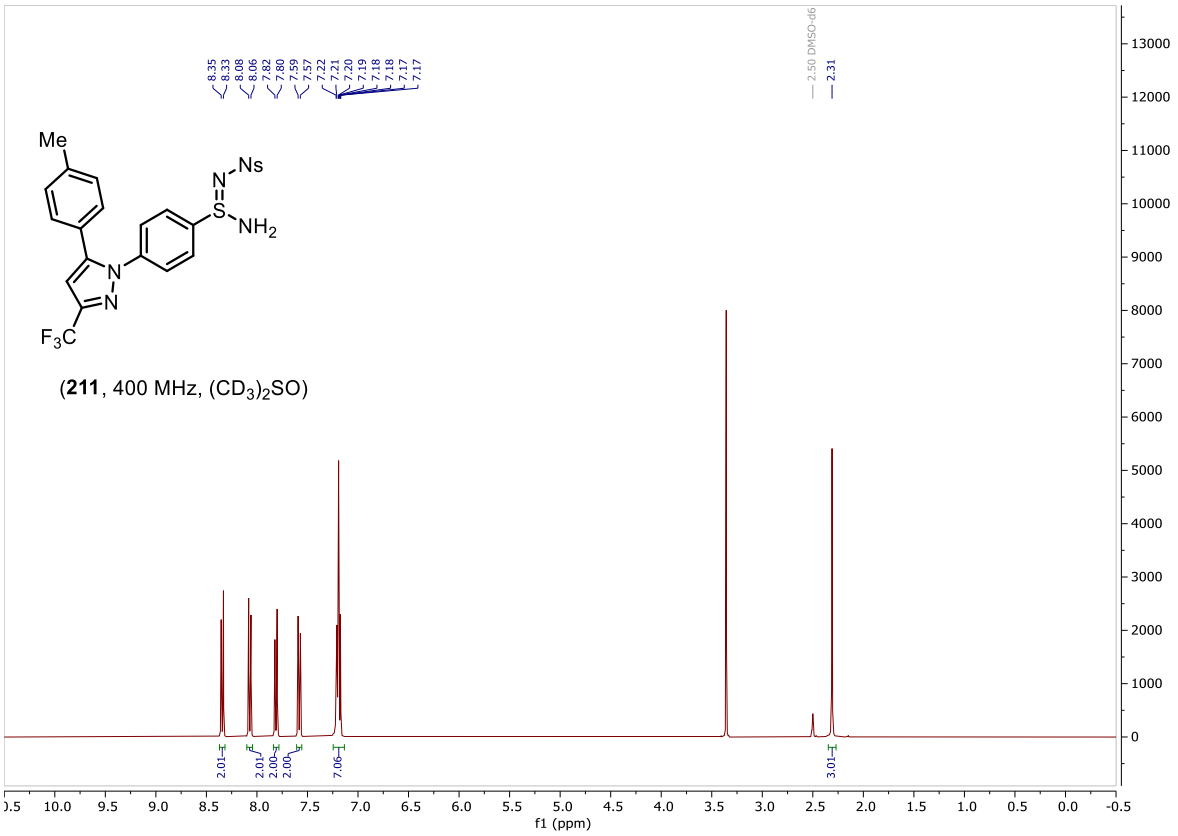

150.76
148.68
135.99
127.17
125.00
124.24
39.52 DMSO-d6
Ns
N
S
NH2
(209, 101 MHz, (CD3)2SO)
f1 (ppm)

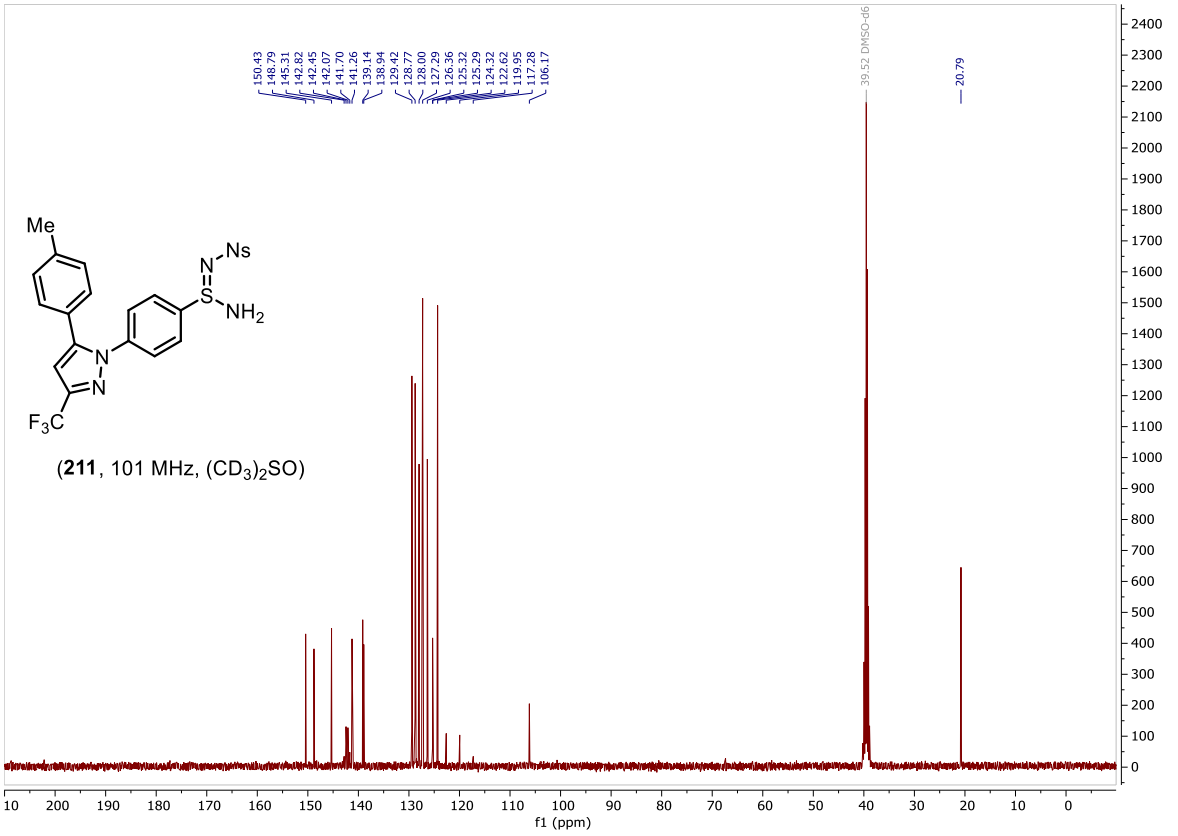


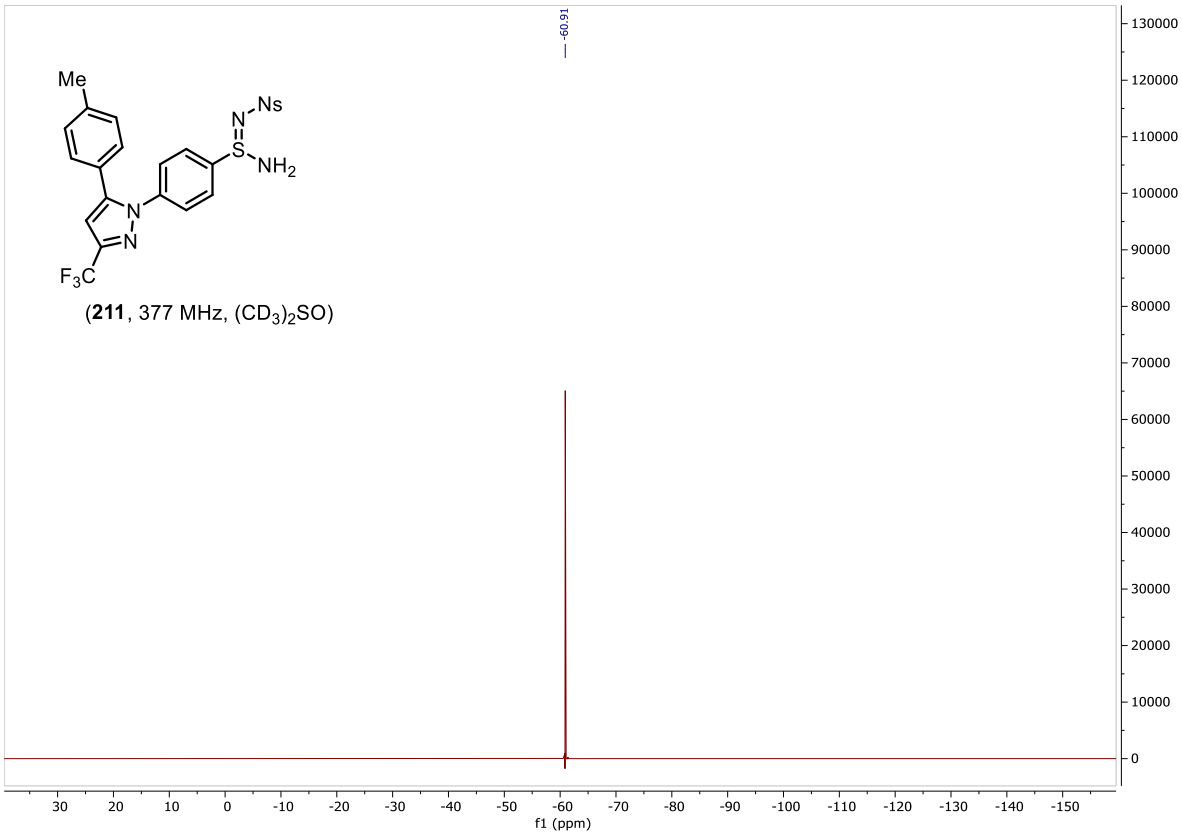
(**210**, 400 MHz, $(CD_3)_2SO$)



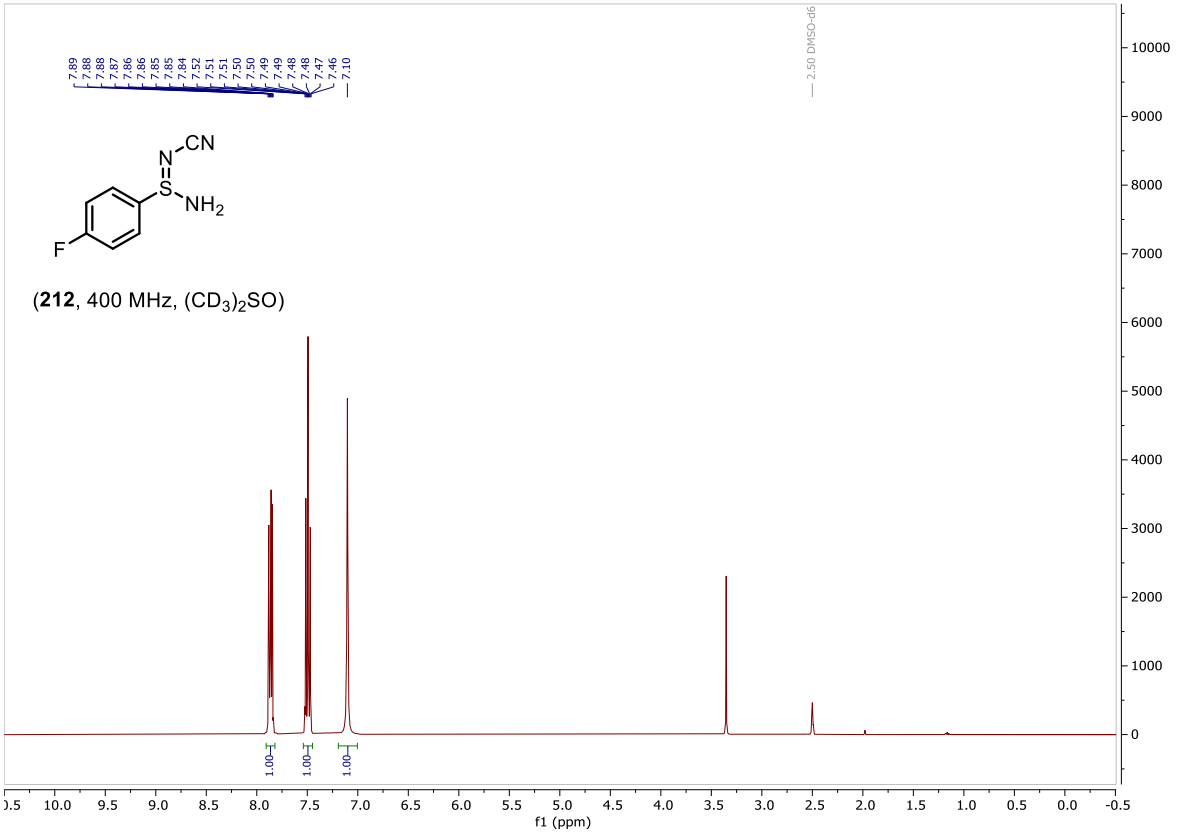
(**210**, 101 MHz, $(CD_3)_2SO$)


8.35
8.33
8.08
8.06
7.82
7.80
7.59
7.57
7.22
7.21
7.20
7.19
7.18
7.18
7.17
7.17
2.50 DMSO-d6
2.31
Me
Ns
N
S
NH2
N
N
F3C
(211, 400 MHz, (CD3)2SO)
2.01
2.01
2.00
2.00
7.06
3.01
f1 (ppm)

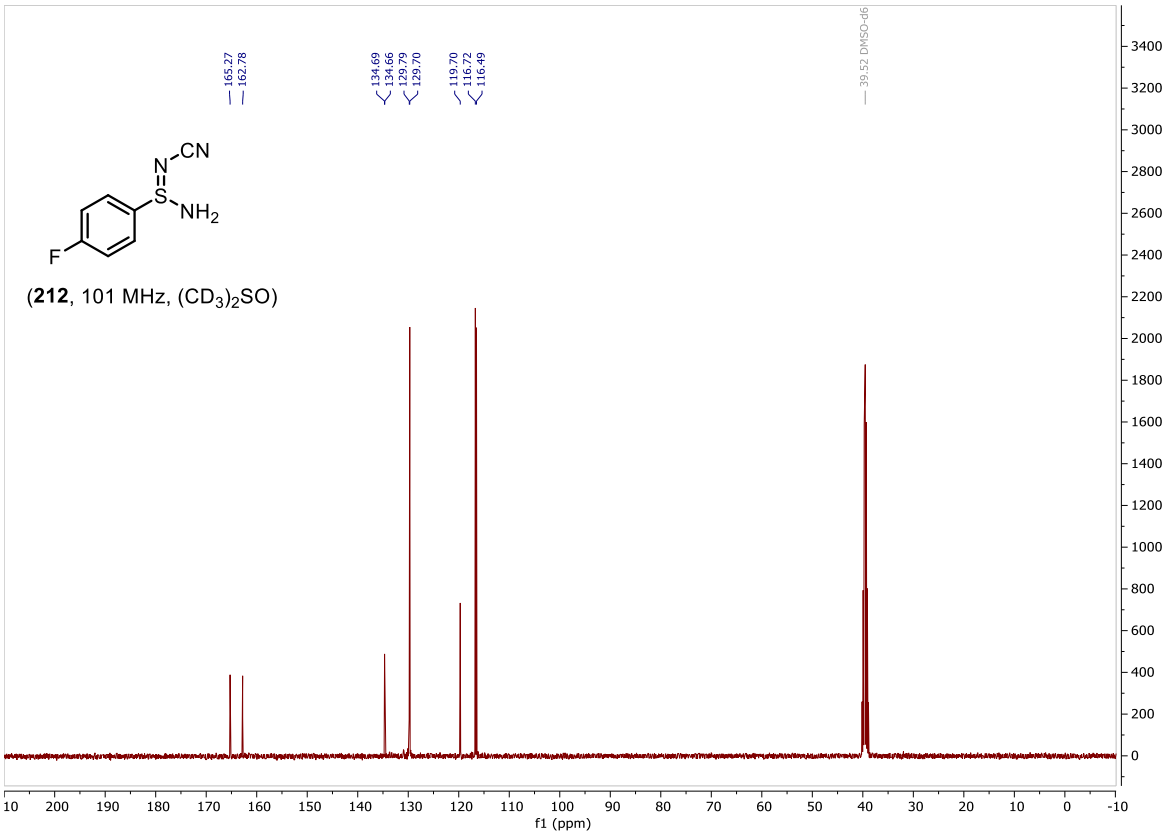

150.43
148.79
145.31
142.82
142.45
142.07
141.70
141.26
139.14
138.94
129.42
128.77
128.00
127.29
126.36
125.23
125.19
124.32
122.62
119.95
117.28
106.17
39.52 DMSO-d6
20.79
Me
Ns
N
S
NH2
N
N
F3C
(211, 101 MHz, (CD3)2SO)
f1 (ppm)

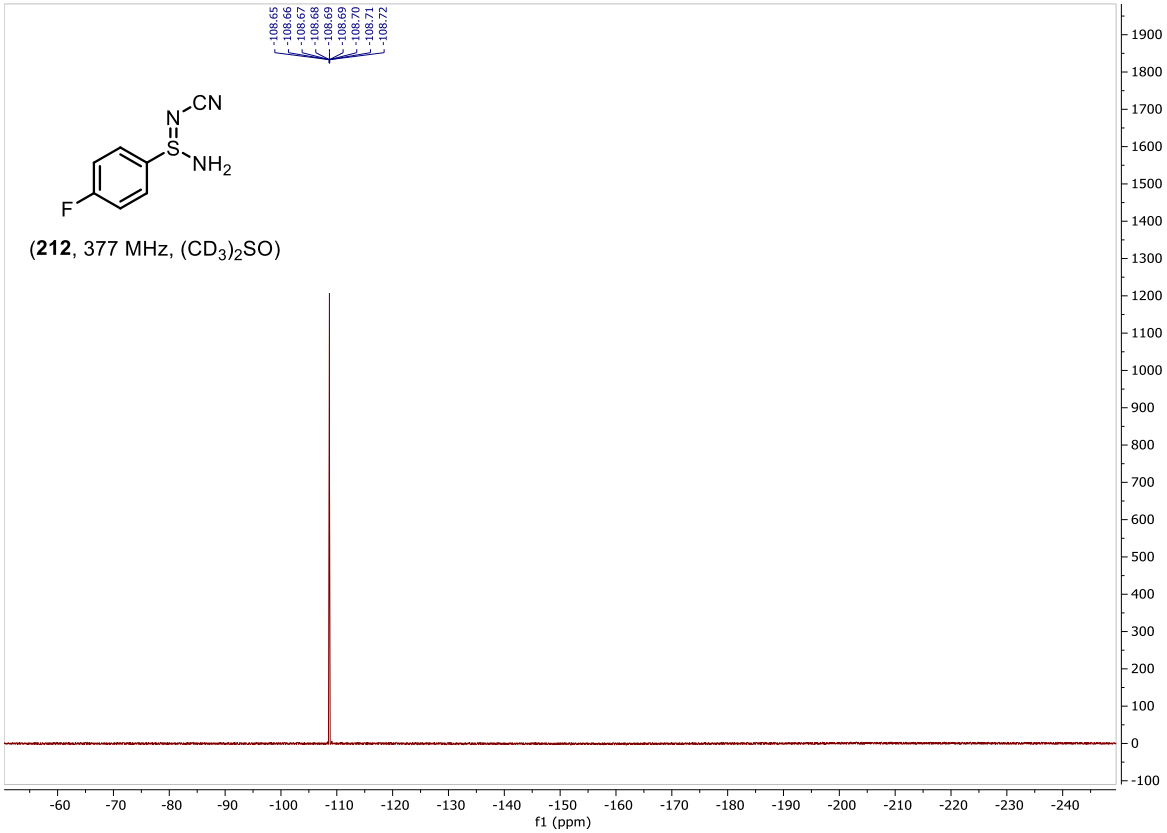


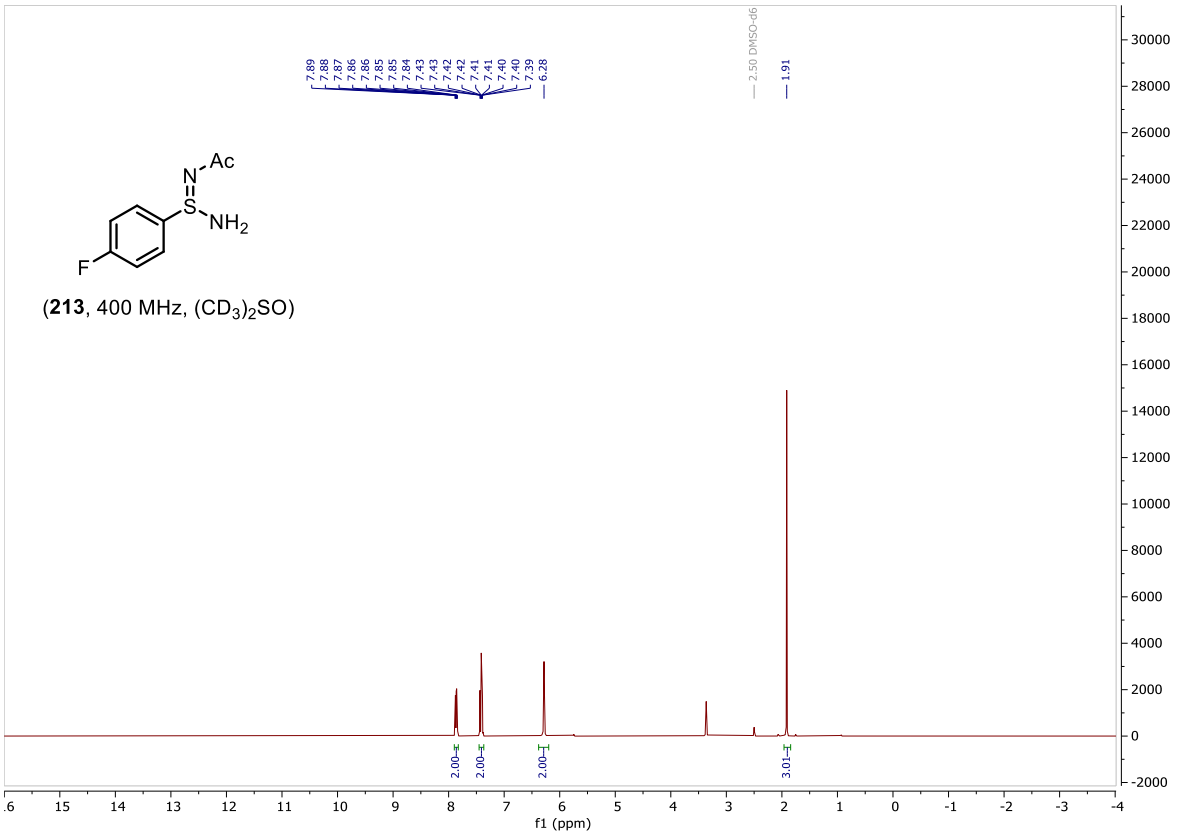
(**211**, 377 MHz, $(CD_3)_2SO$)



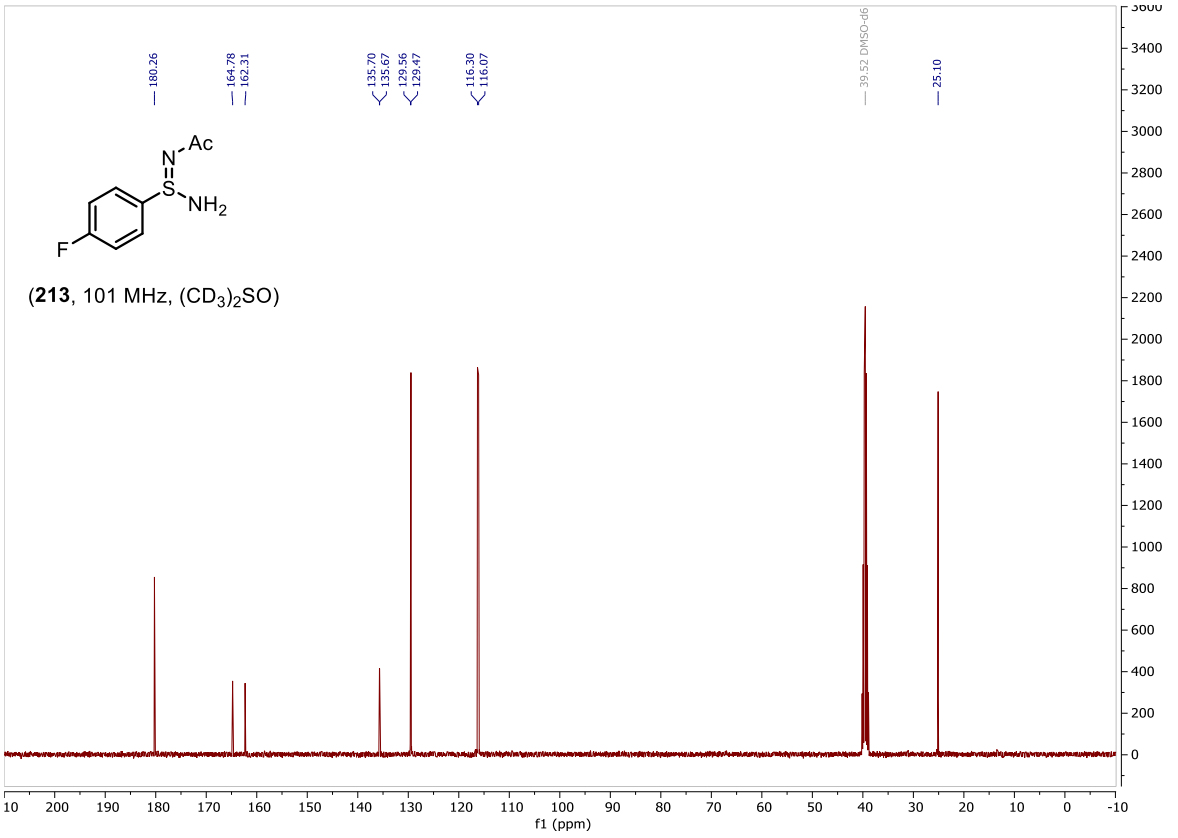
(**212**, 400 MHz, $(CD_3)_2SO$)


165.27
162.78
134.69
134.66
129.79
129.70
119.70
116.72
116.49
39.52 DMSO-d6
CN
N
S
NH2
F
(212, 101 MHz, (CD3)2SO)
f1 (ppm)

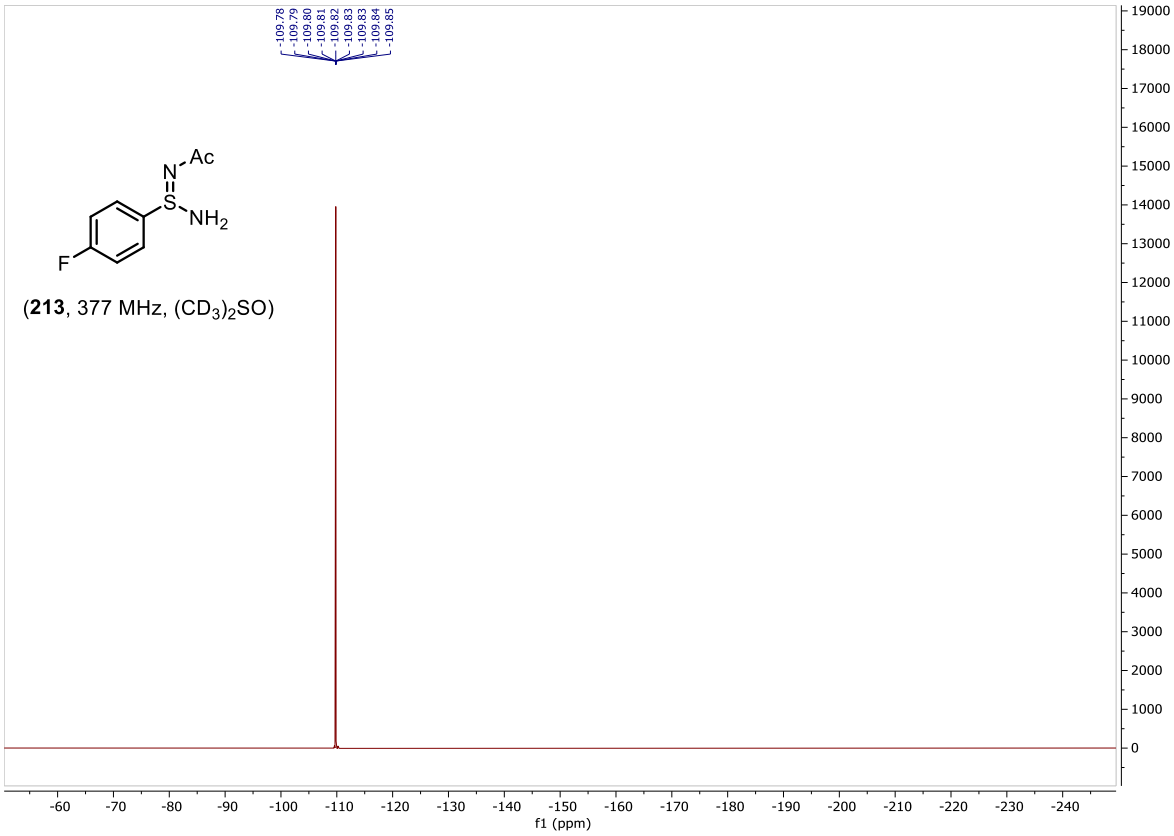

-108.65
-108.66
-108.67
-108.68
-108.69
-108.69
-108.70
-108.71
-108.72
CN
N
S
NH2
F
(212, 377 MHz, (CD3)2SO)
f1 (ppm)



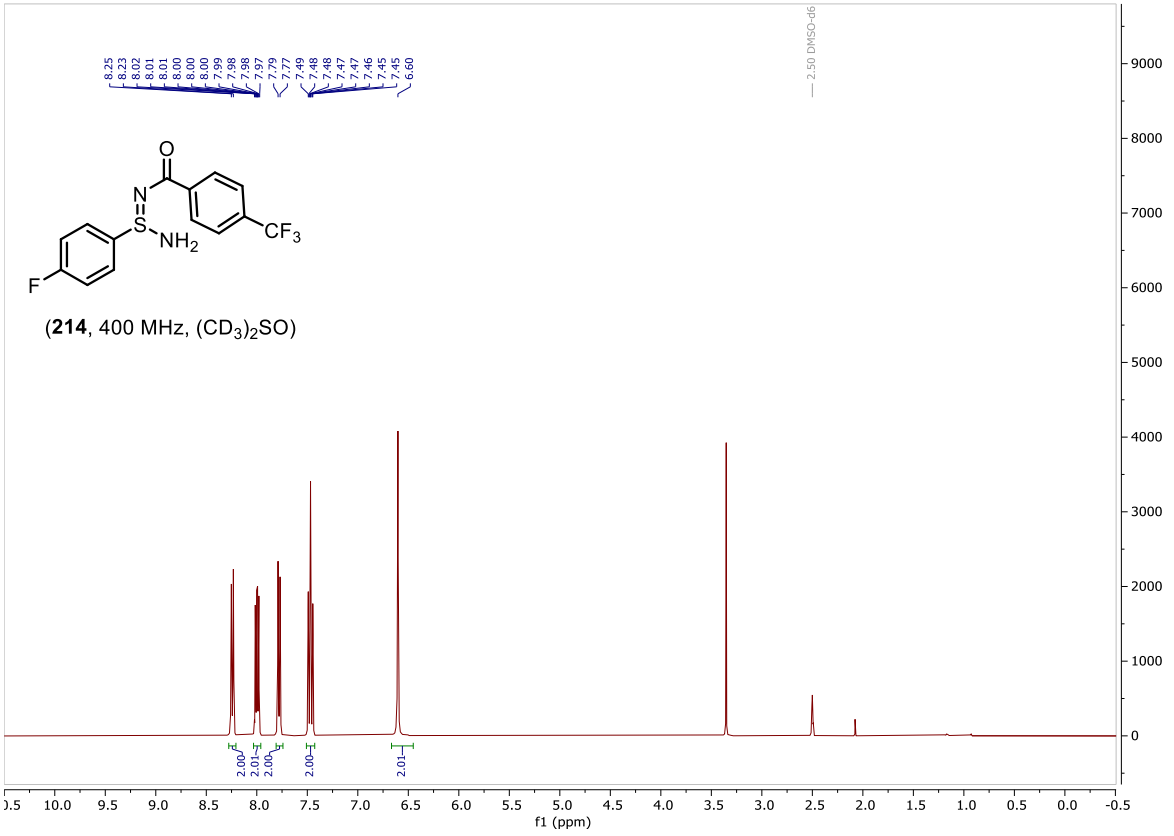
(**213**, 400 MHz, $(CD_3)_2SO$)



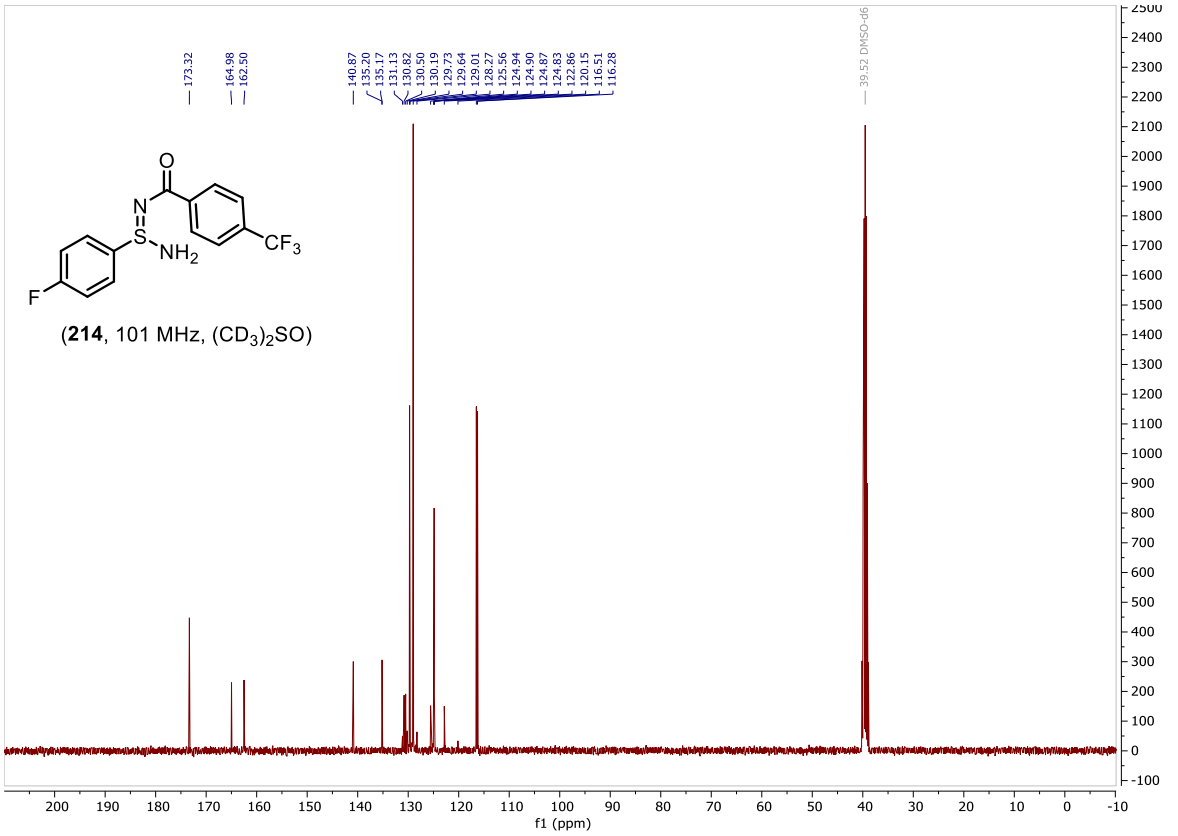
(**213**, 101 MHz, $(CD_3)_2SO$)



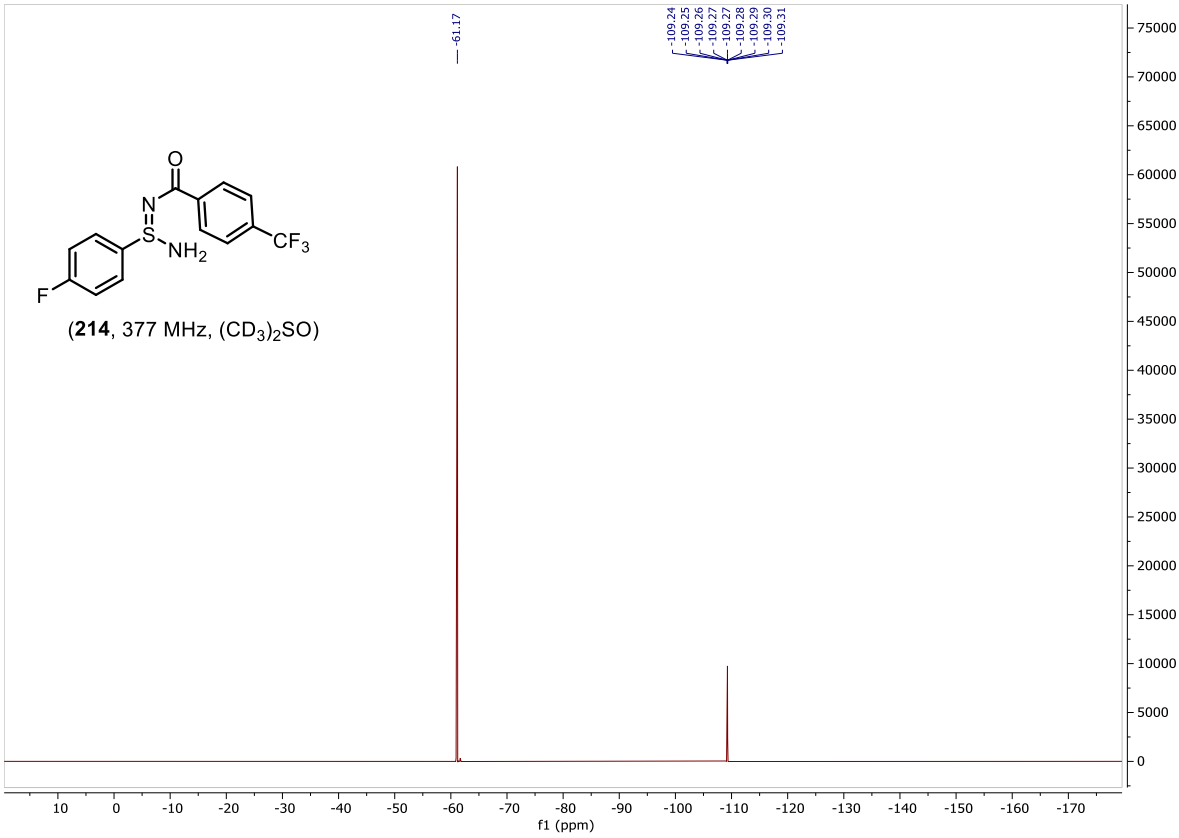
(**213**, 377 MHz, $(CD_3)_2SO$)



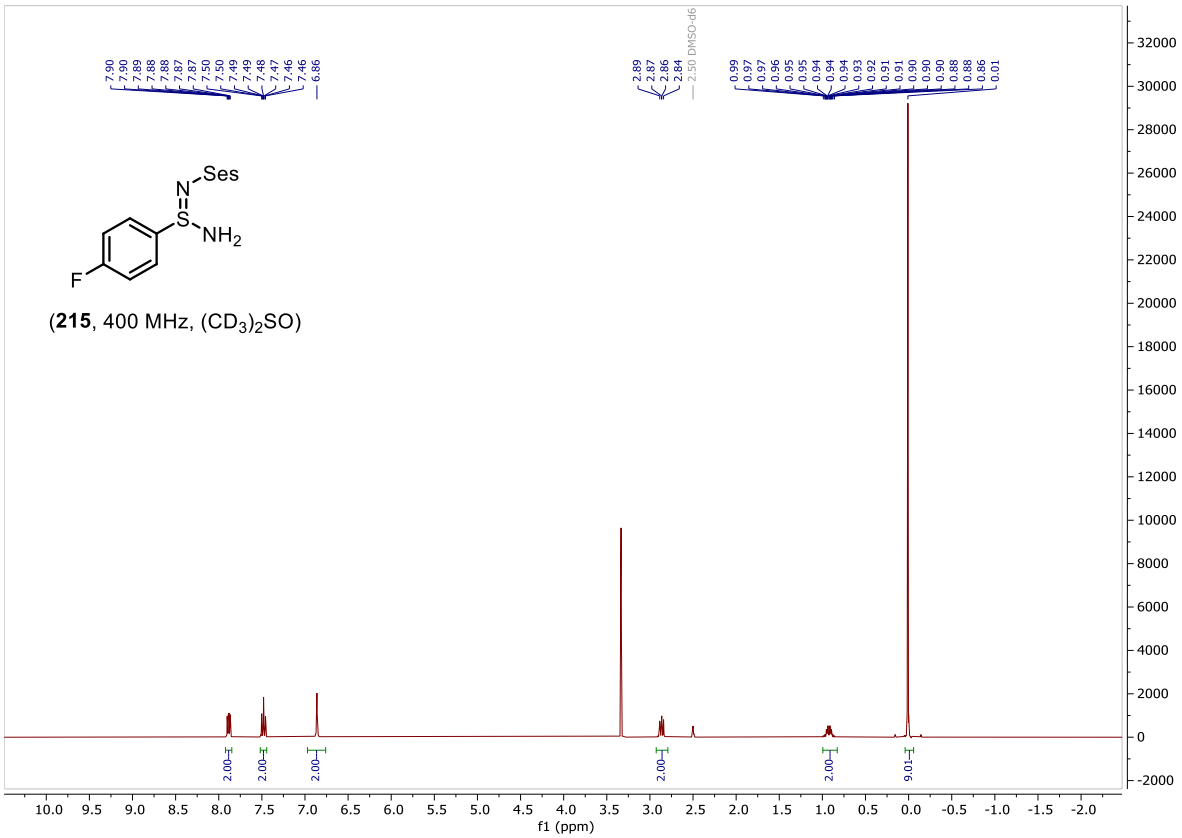
(**214**, 400 MHz, $(CD_3)_2SO$)

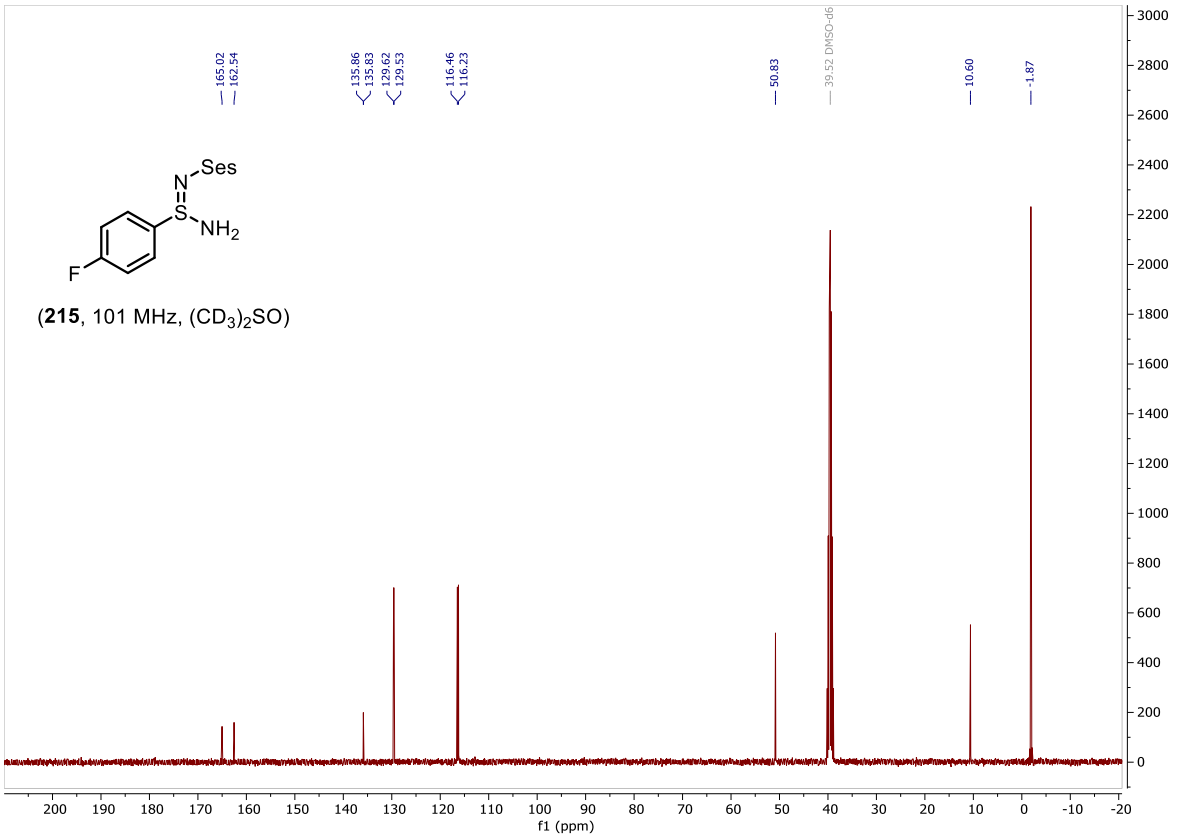


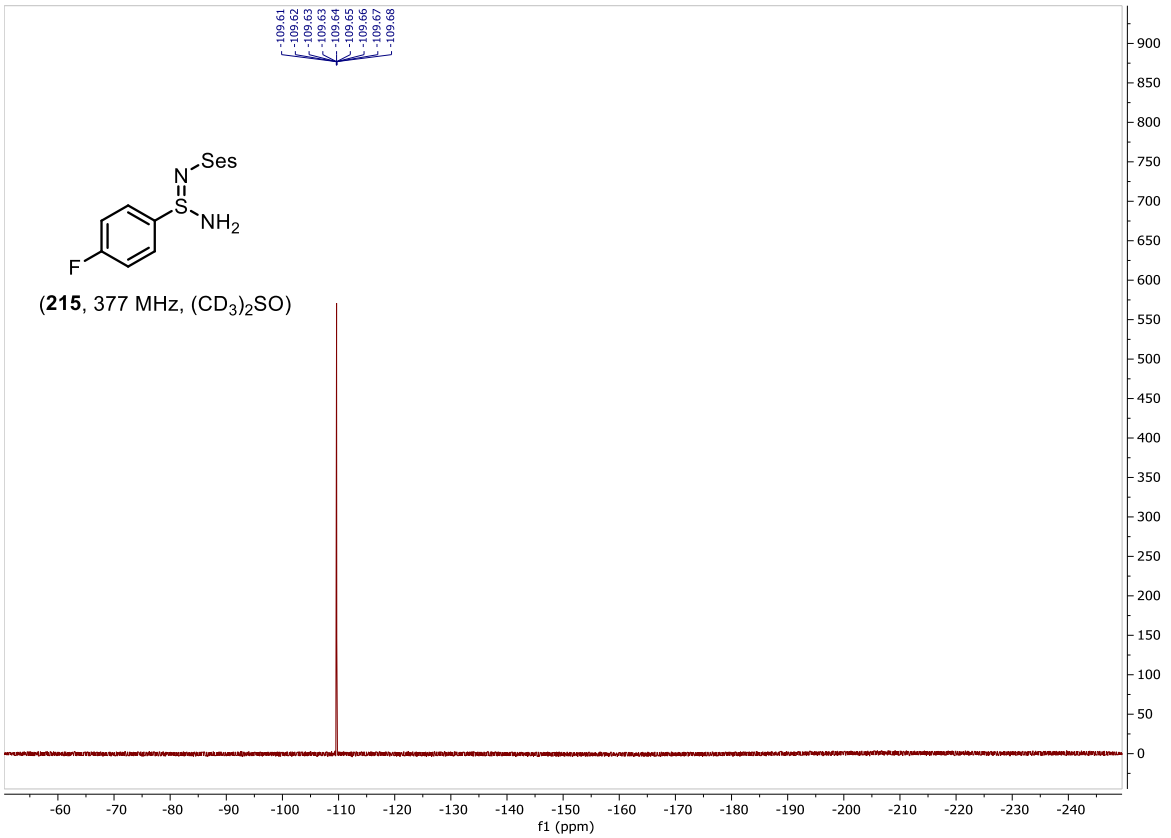
(**214**, 101 MHz, $(CD_3)_2SO$)

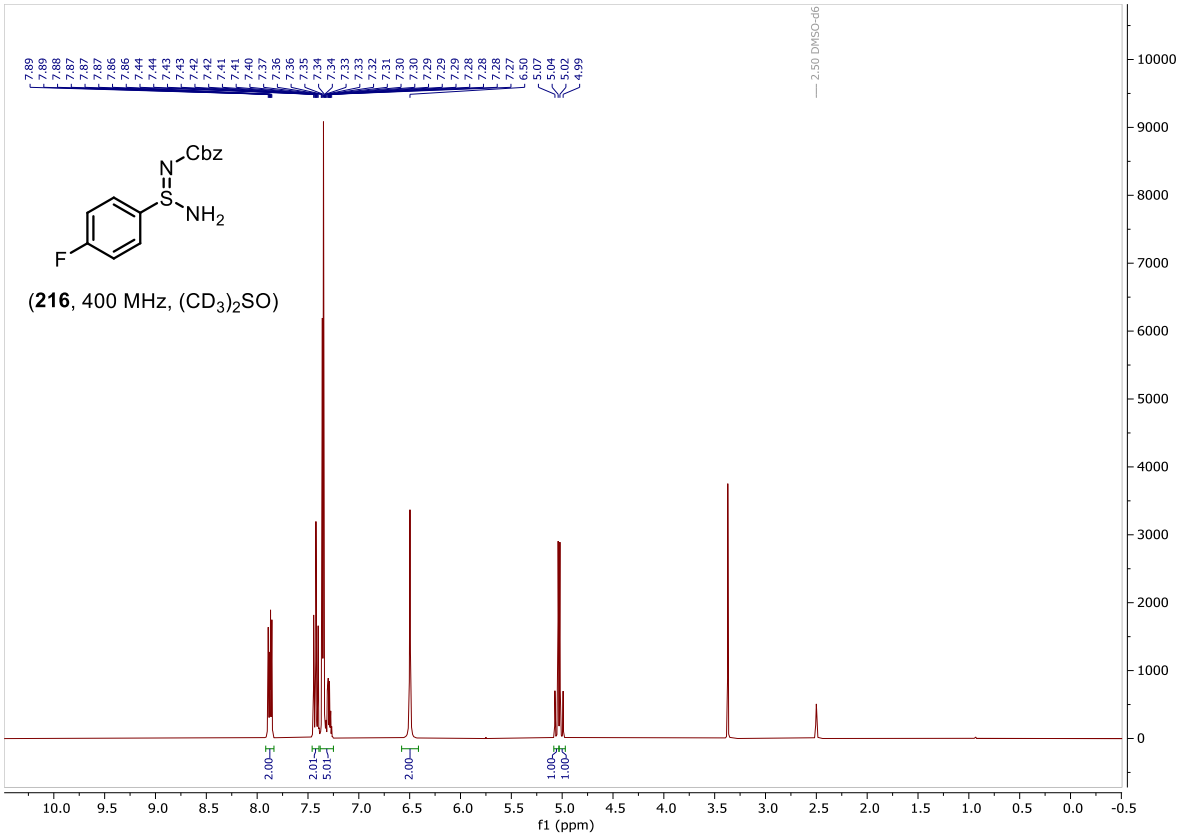


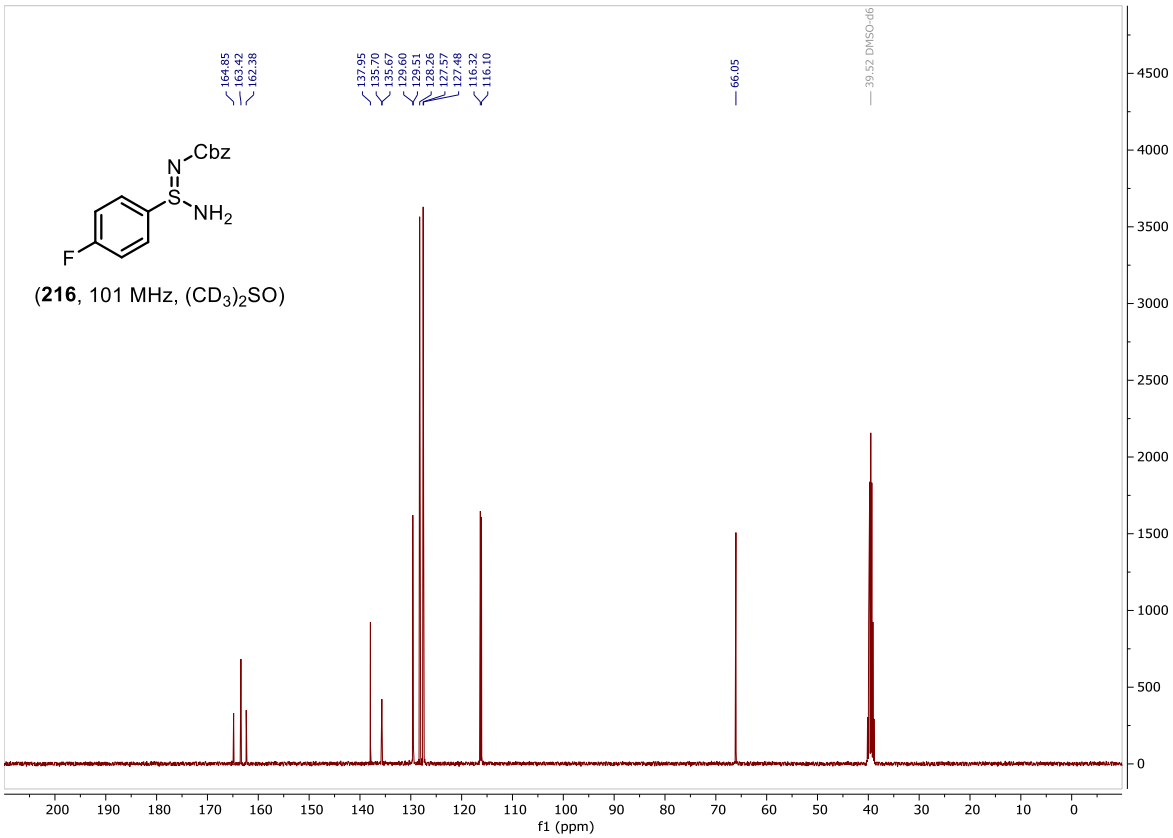
(**214**, 377 MHz, $(CD_3)_2SO$)


Ses
N
S
NH2
F
(215, 400 MHz, (CD3)2SO)
f1 (ppm)

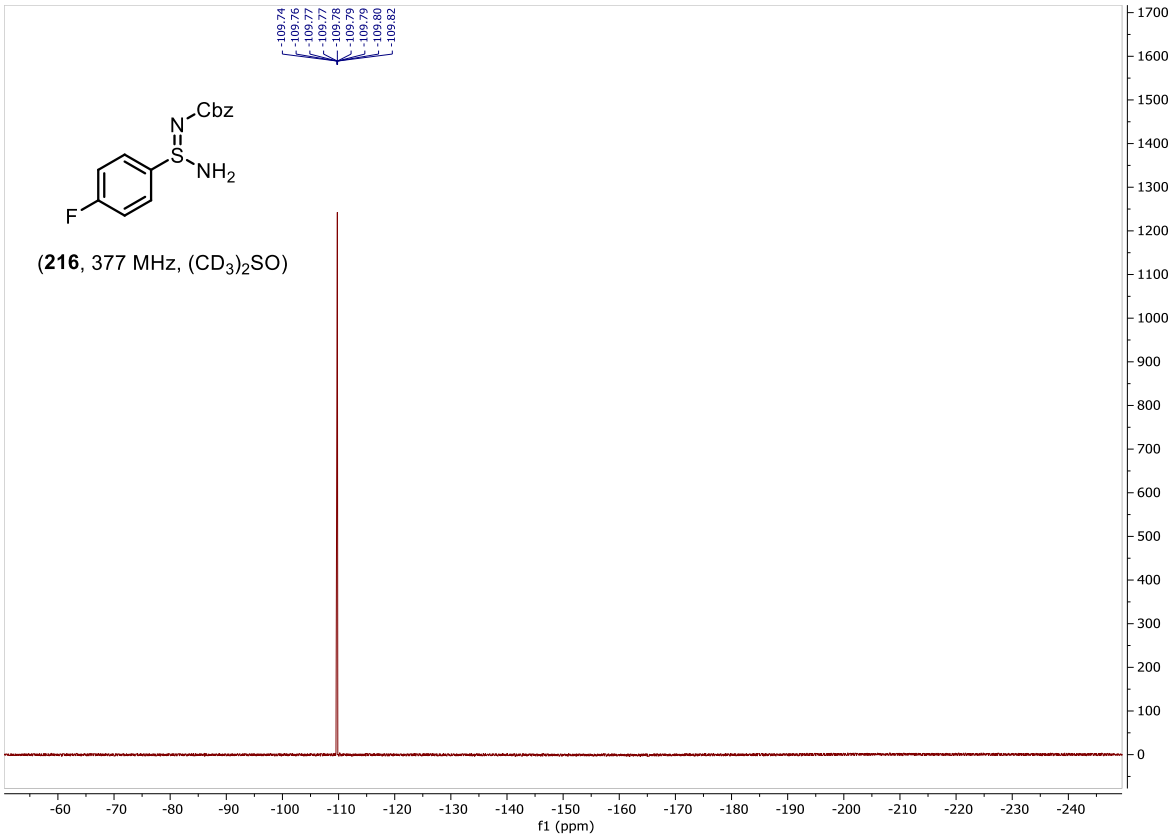

Ses
N
S
NH2
F
(215, 101 MHz, (CD3)2SO)
f1 (ppm)


-109.61
-109.62
-109.63
-109.63
-109.64
-109.65
-109.66
-109.67
-109.68
N
Ses
S
NH2
F
(215, 377 MHz, (CD3)2SO)
f1 (ppm)

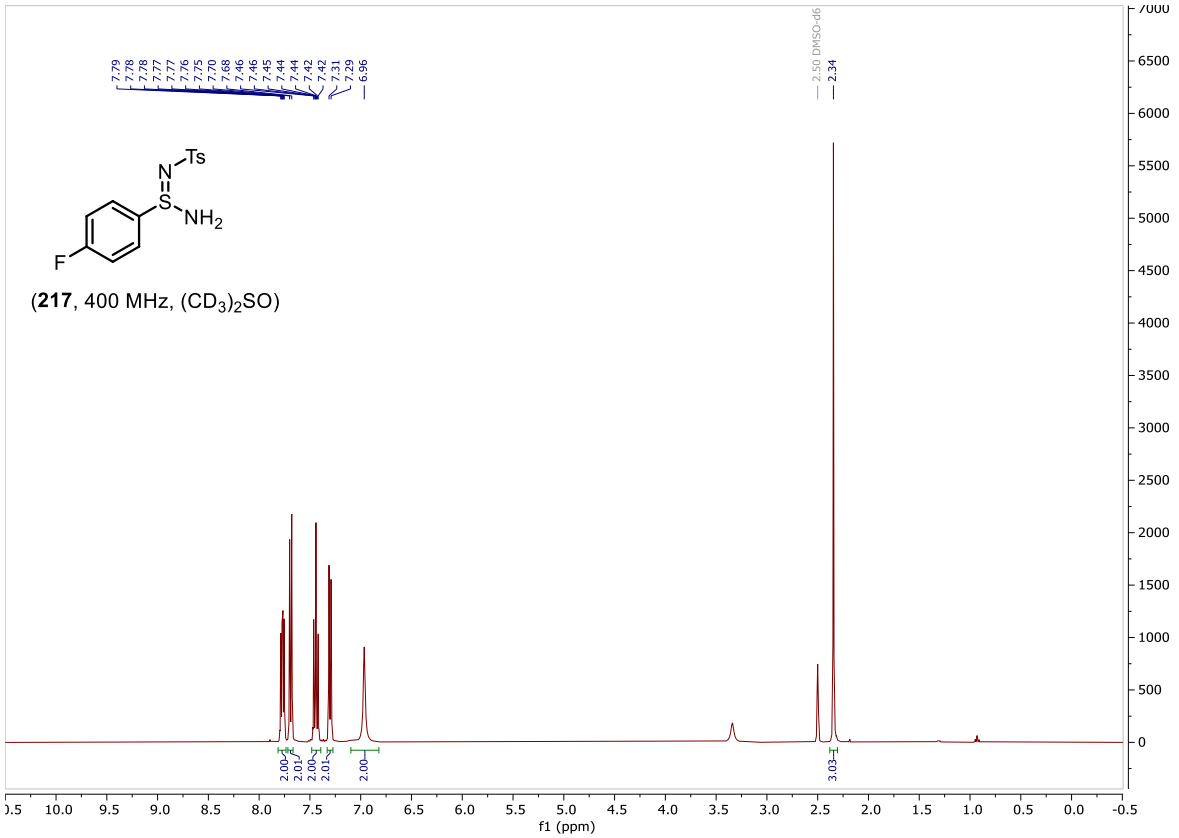

7.89
7.89
7.88
7.87
7.87
7.86
7.86
7.44
7.43
7.43
7.42
7.42
7.41
7.41
7.40
7.37
7.36
7.36
7.35
7.34
7.34
7.33
7.33
7.32
7.31
7.30
7.30
7.29
7.29
7.29
7.28
7.28
7.28
7.27
6.50
5.07
5.04
5.02
4.99
2.50 DMSO-d6
N
Cbz
S
NH2
F
(216, 400 MHz, (CD3)2SO)
2.00
2.01
5.01
2.00
1.00
1.00
f1 (ppm)



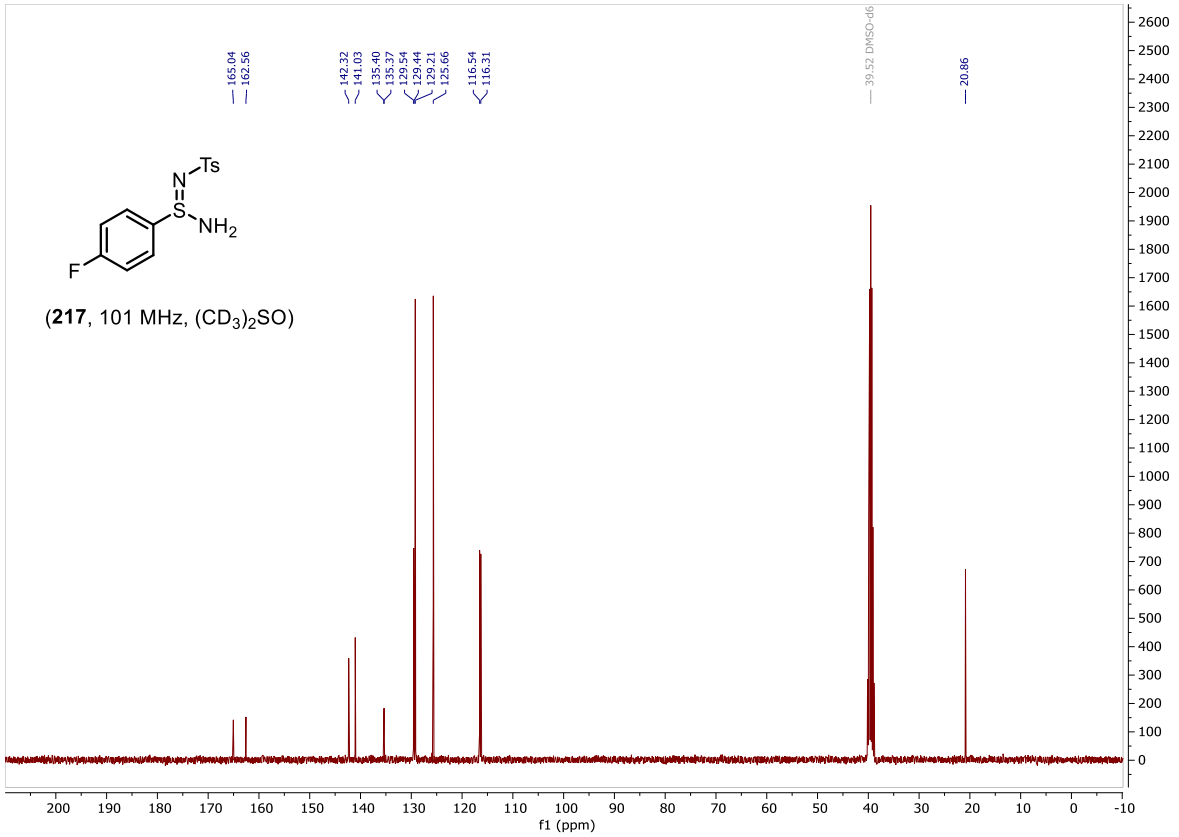
(**216**, 101 MHz, $(CD_3)_2SO$)



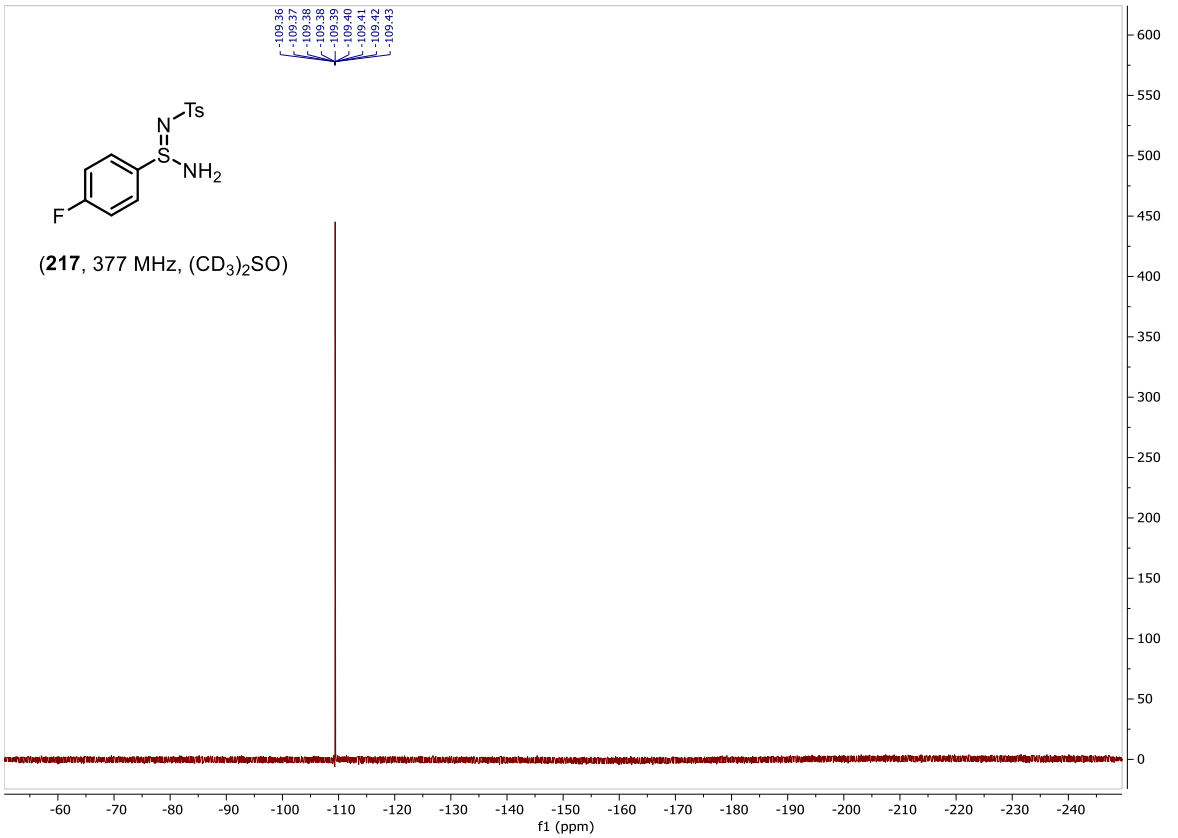
(**216**, 377 MHz, $(CD_3)_2SO$)

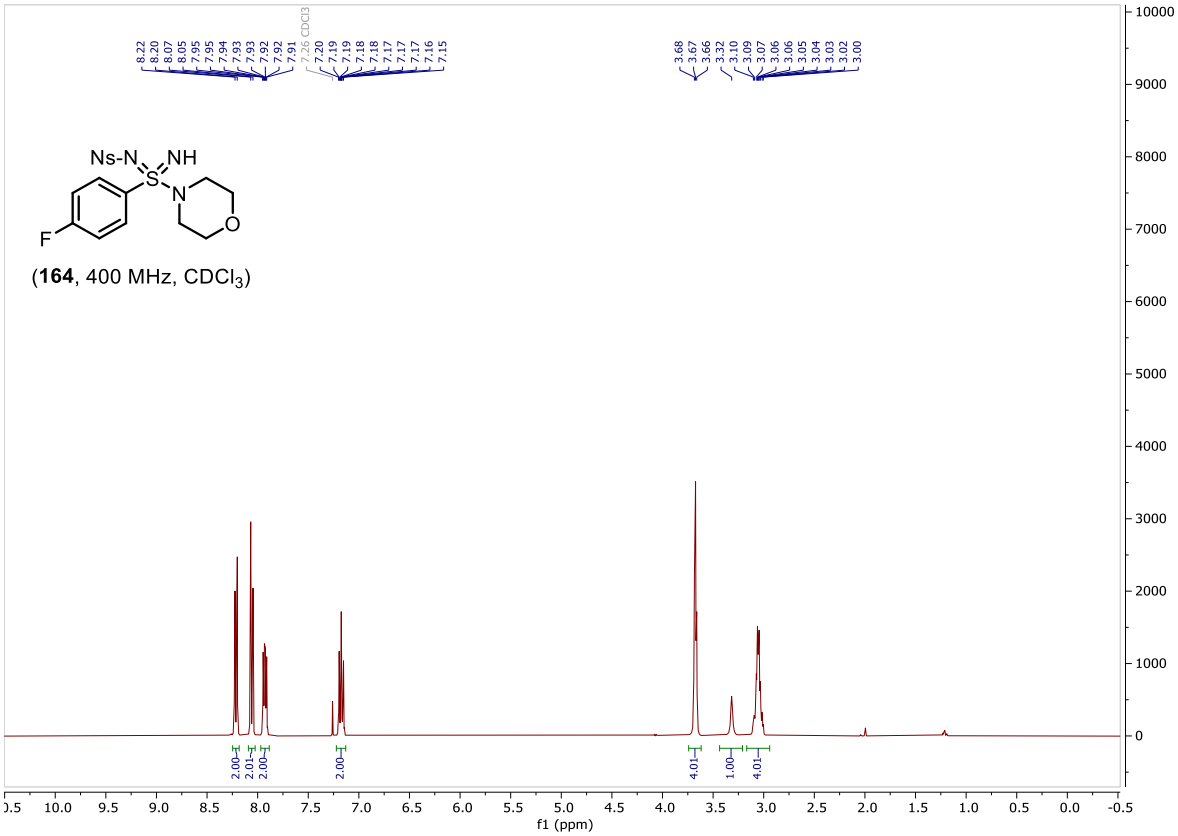


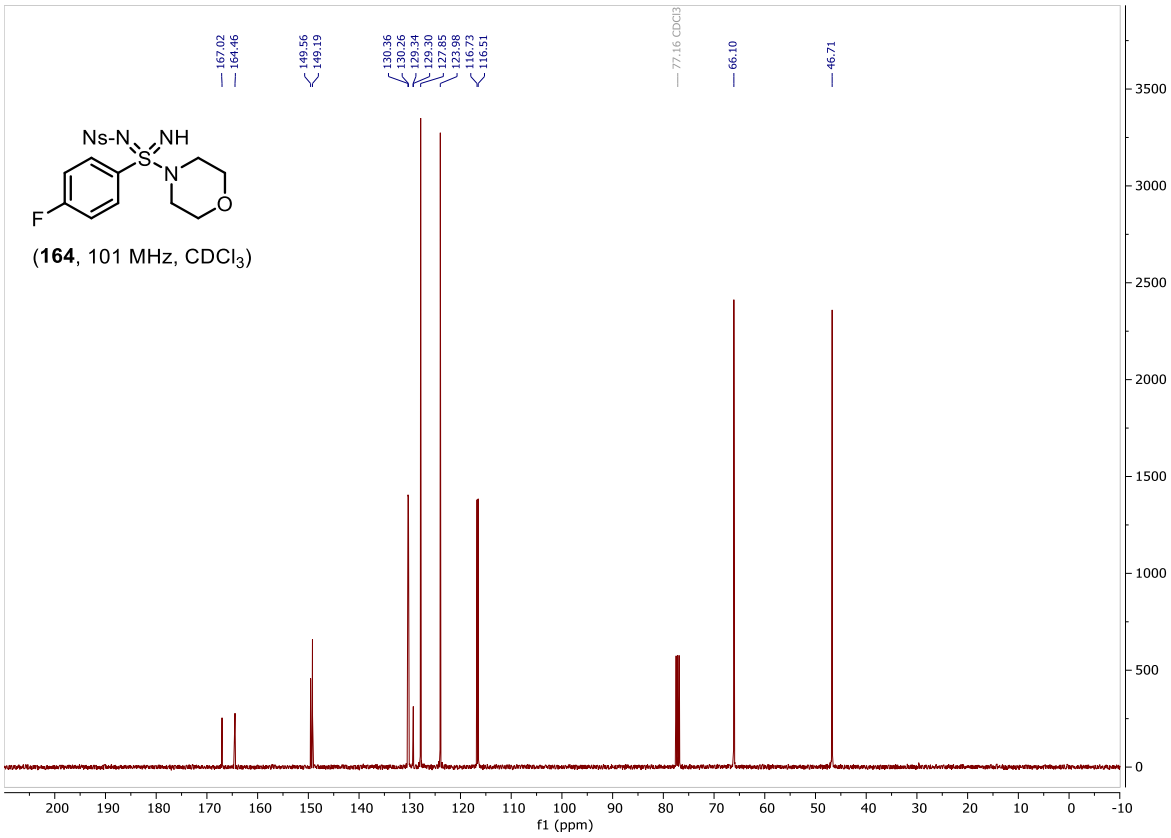
(**217**, 400 MHz, $(CD_3)_2SO$)



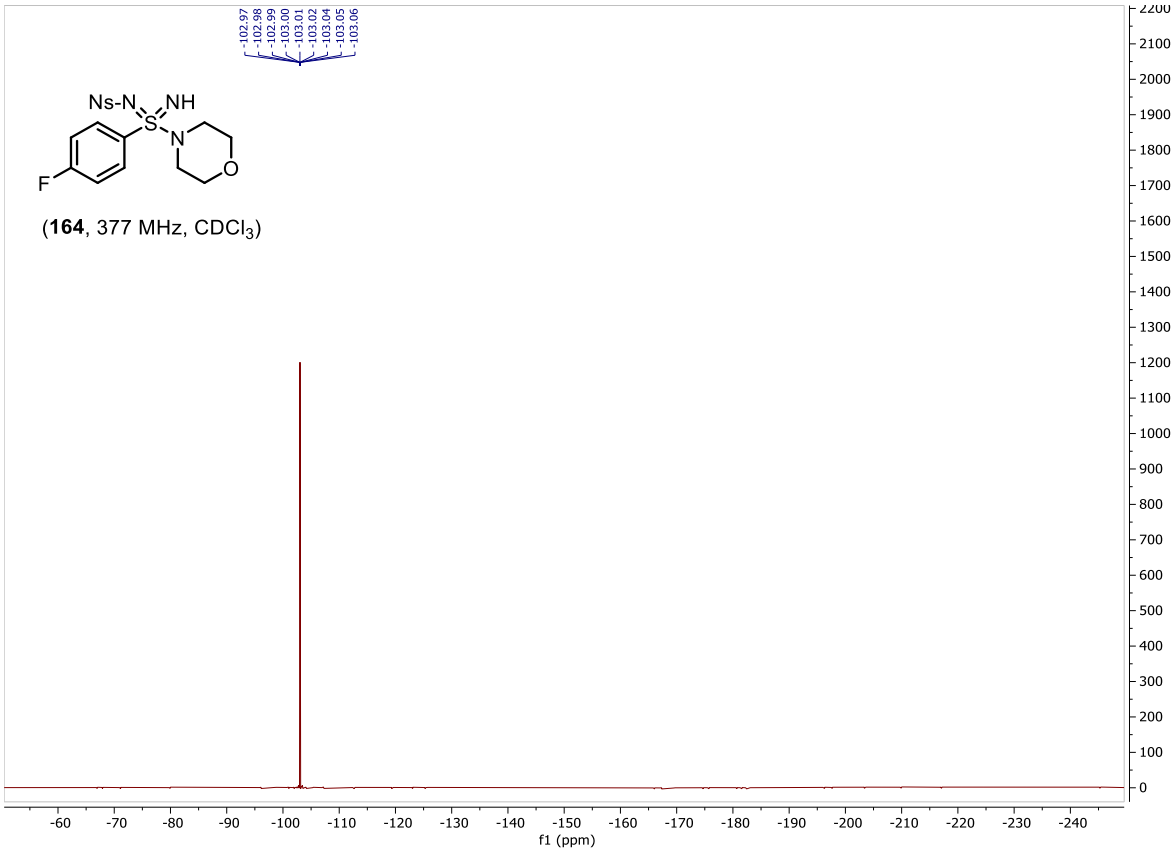
(**217**, 101 MHz, $(CD_3)_2SO$)


-109.36
-109.37
-109.38
-109.38
-109.39
-109.40
-109.41
-109.42
-109.43
Ts
N
S
NH2
F
(217, 377 MHz, (CD3)2SO)
f1 (ppm)

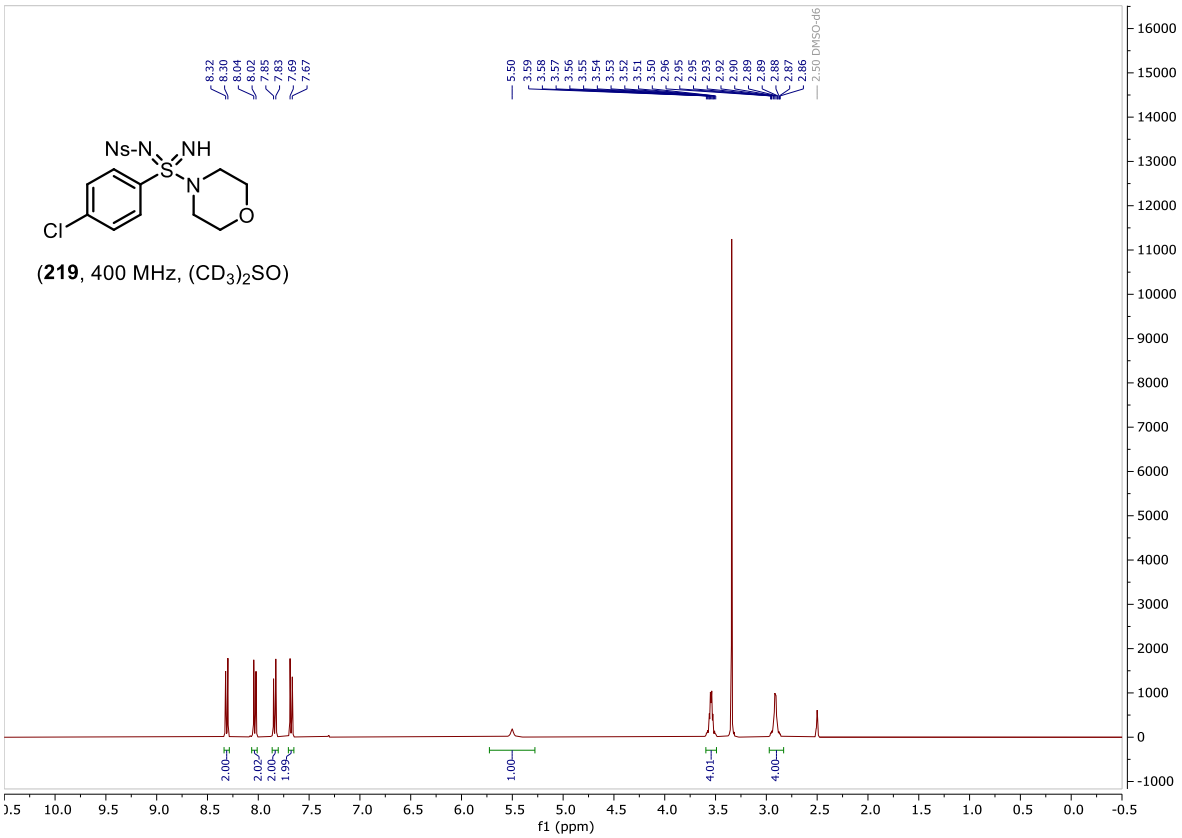

8.22
8.20
8.07
8.05
7.95
7.95
7.94
7.93
7.93
7.92
7.92
7.91
7.26 CDCl3
7.20
7.19
7.19
7.18
7.18
7.17
7.17
7.17
7.17
7.16
7.15
3.68
3.67
3.66
3.32
3.10
3.09
3.07
3.06
3.06
3.05
3.04
3.03
3.02
3.00
Ns-N
NH
S
N
O
F
(164, 400 MHz, CDCl3)
2.00
2.01
2.00
2.00
4.01
1.00
4.01
f1 (ppm)



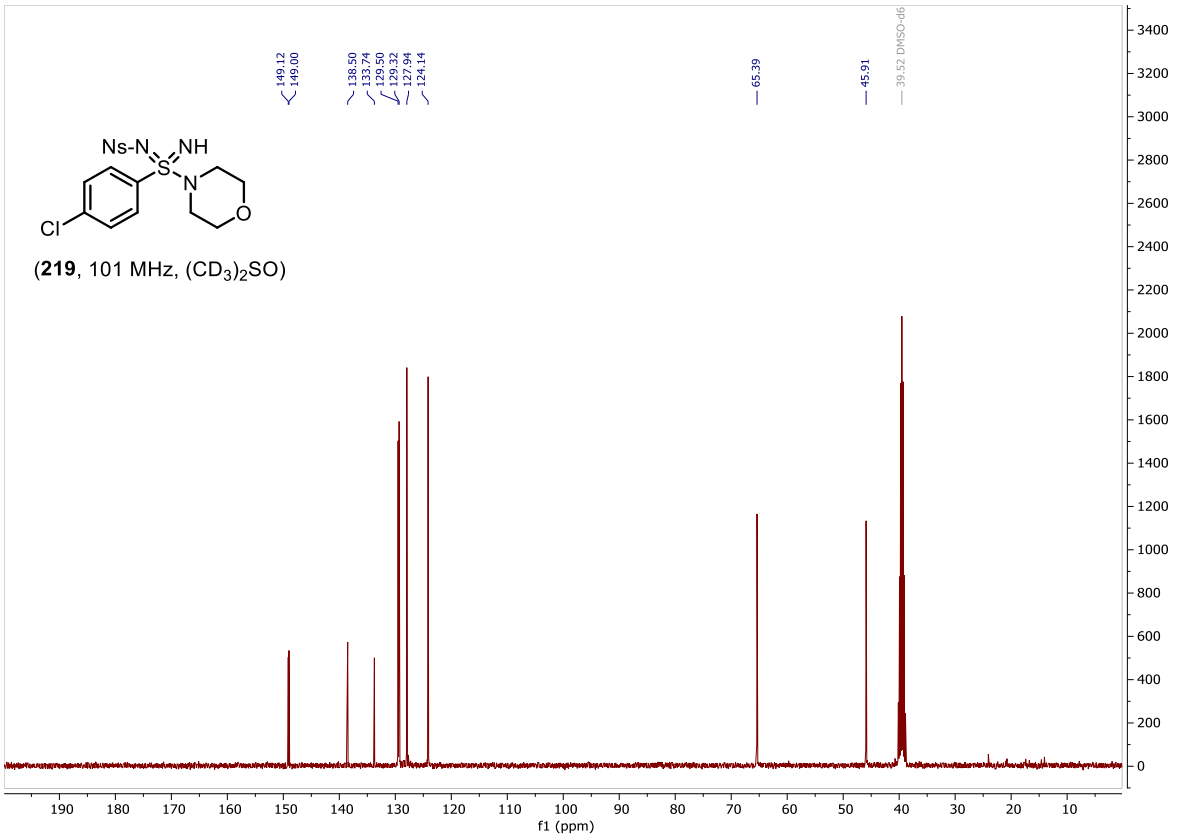
(**164**, 101 MHz, $CDCl_3$)



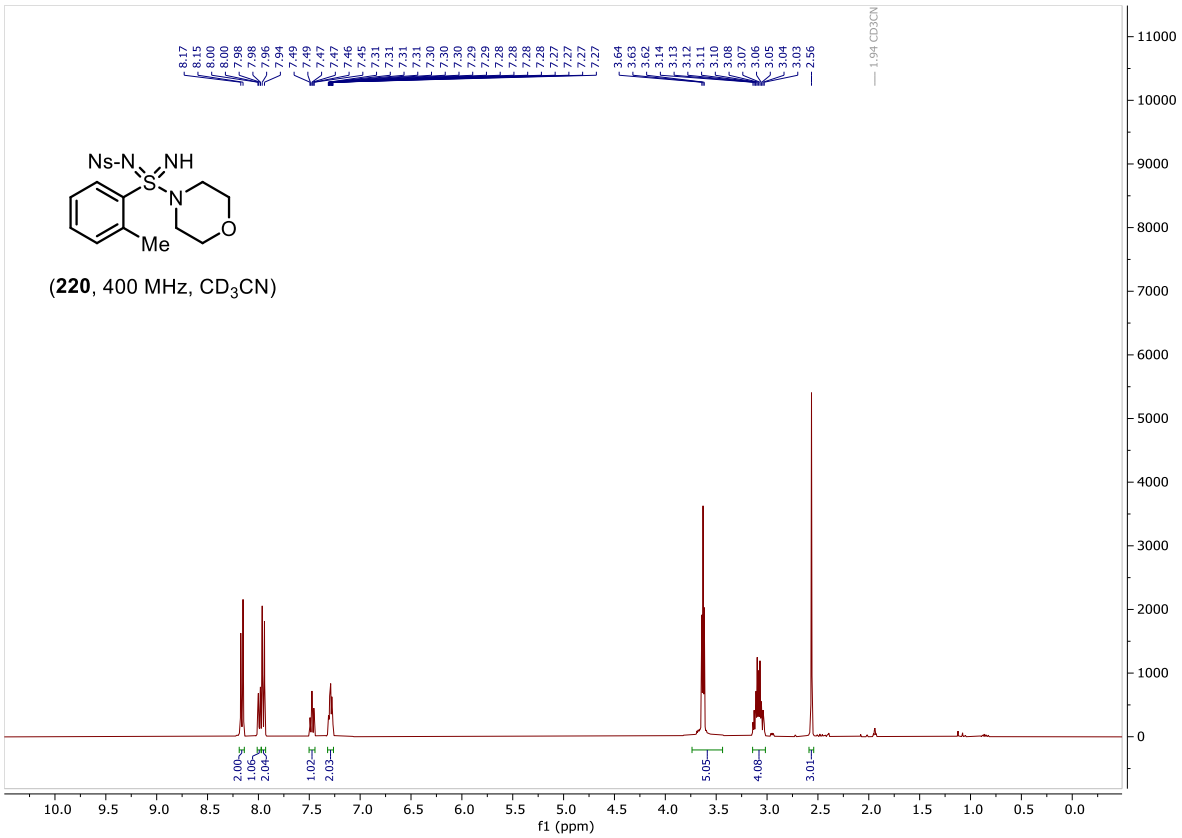
(**164**, 377 MHz, $CDCl_3$)



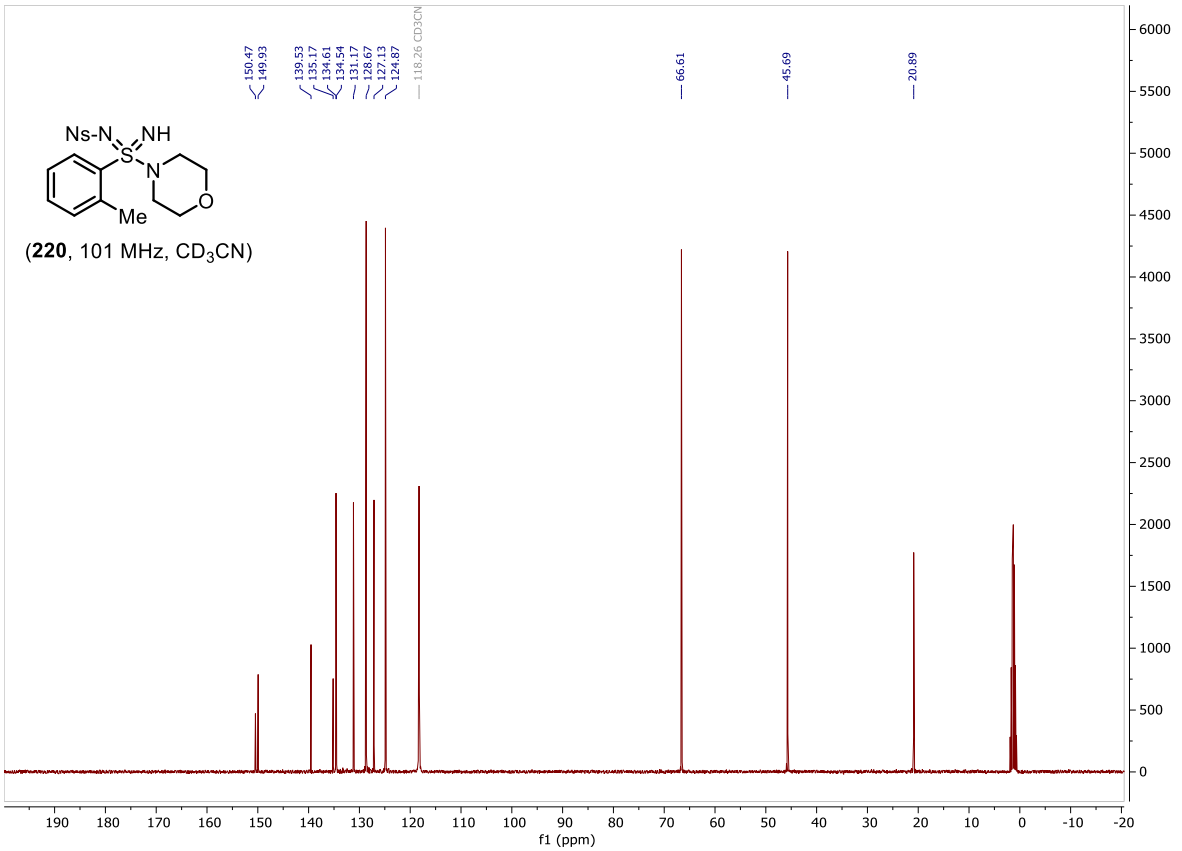
(**219**, 400 MHz, $(CD_3)_2SO$)



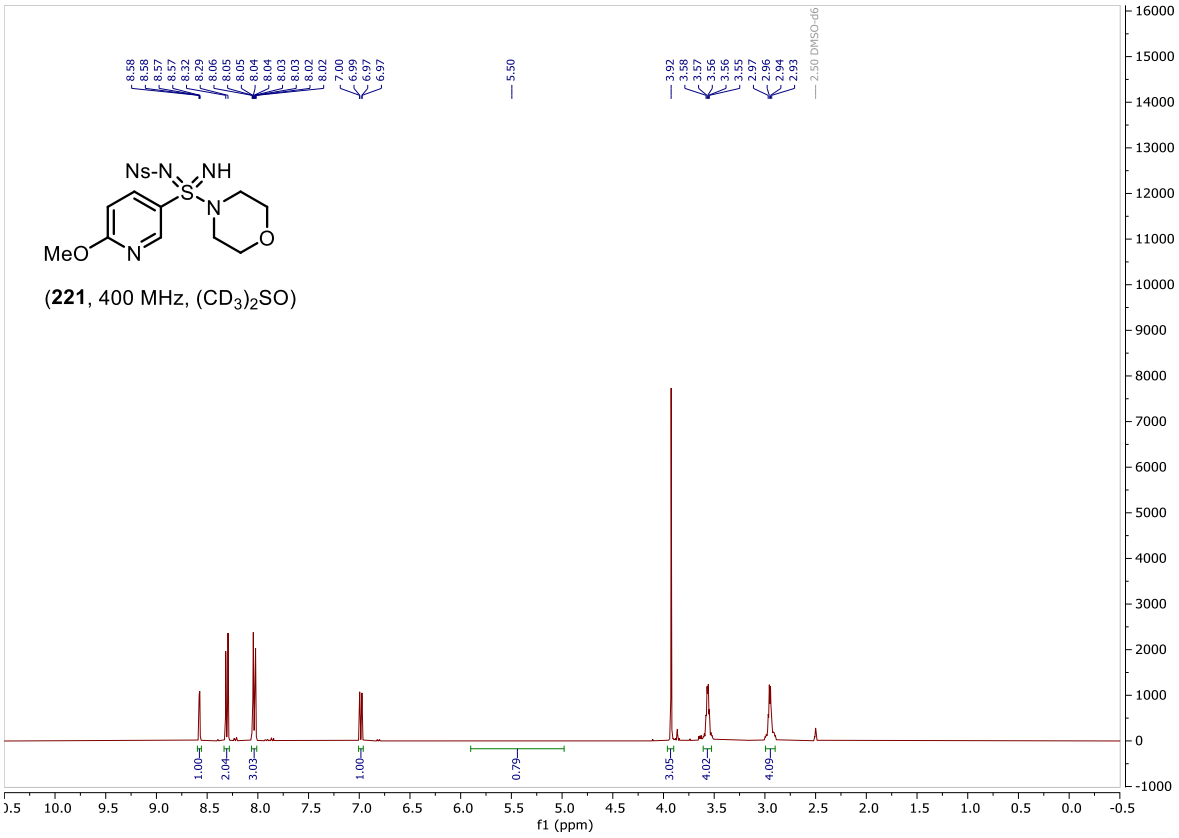
(**219**, 101 MHz, $(CD_3)_2SO$)



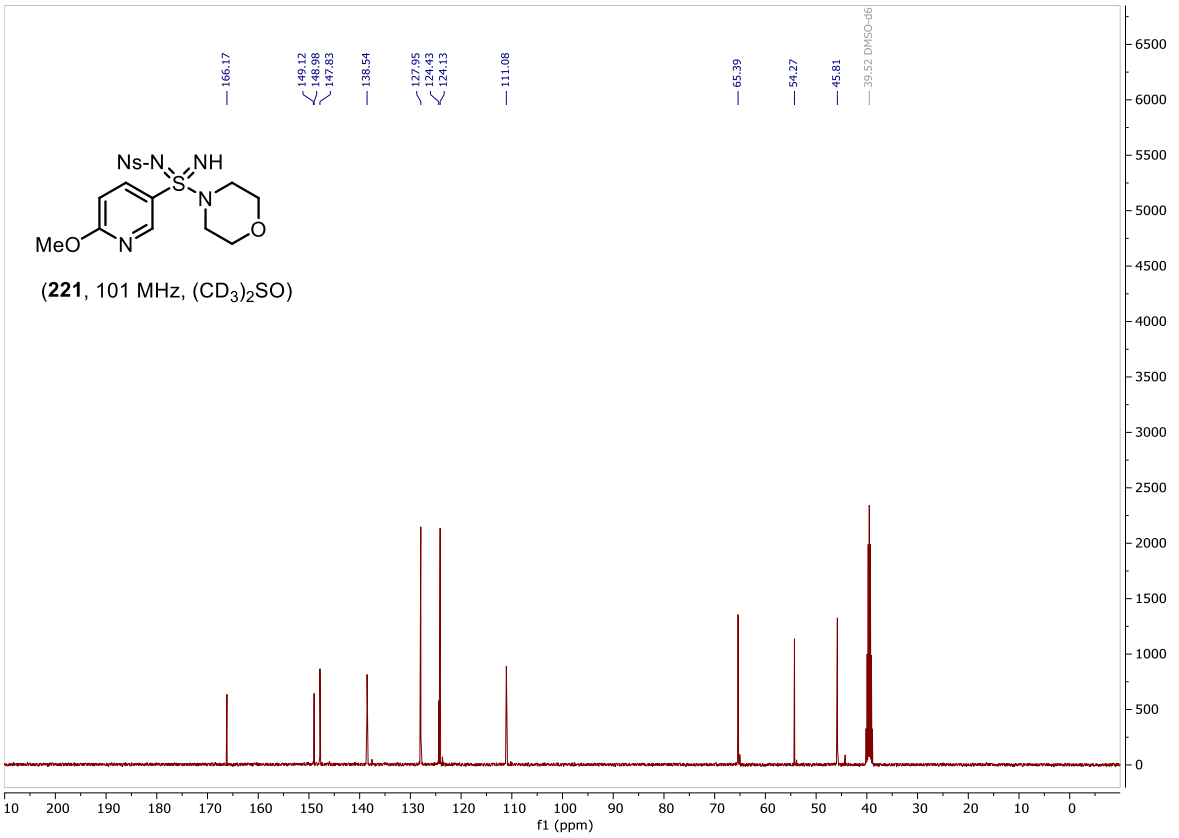
(**220**, 400 MHz, CD_3CN)



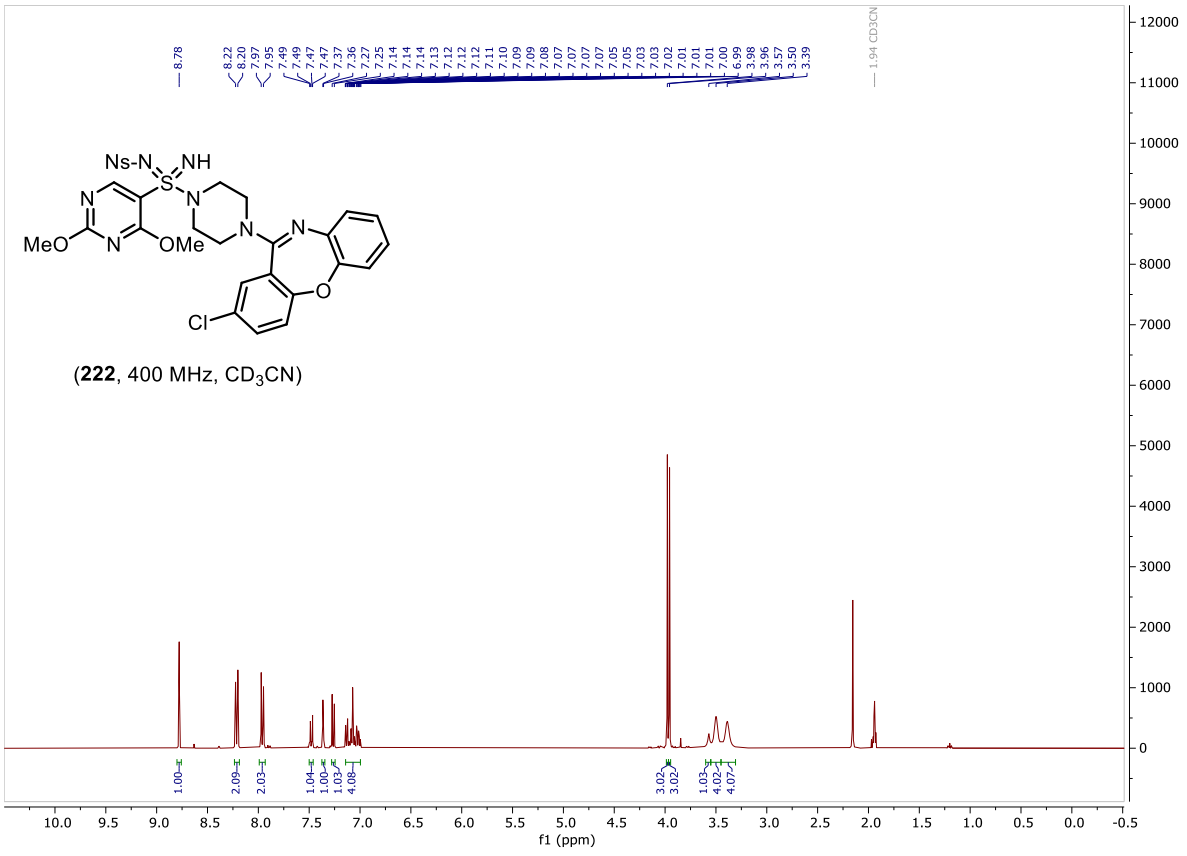
(**220**, 101 MHz, CD_3CN)

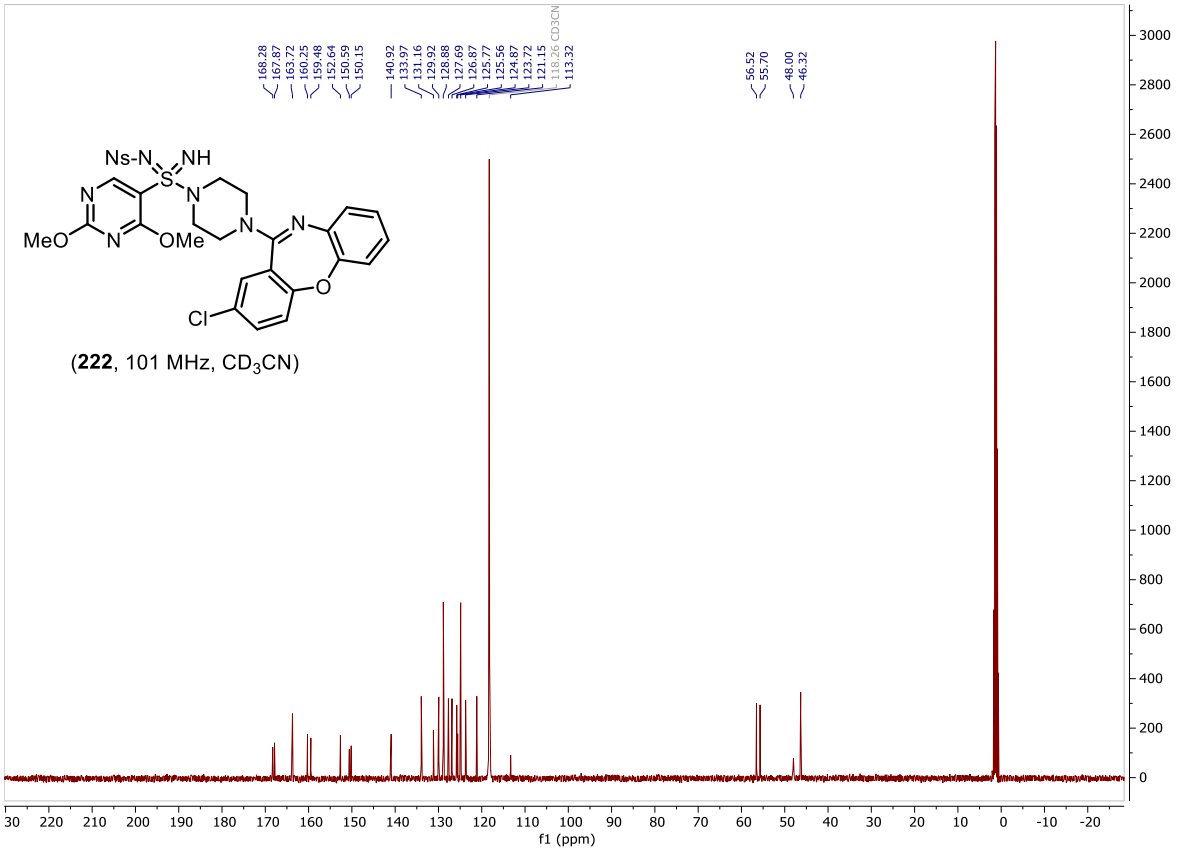


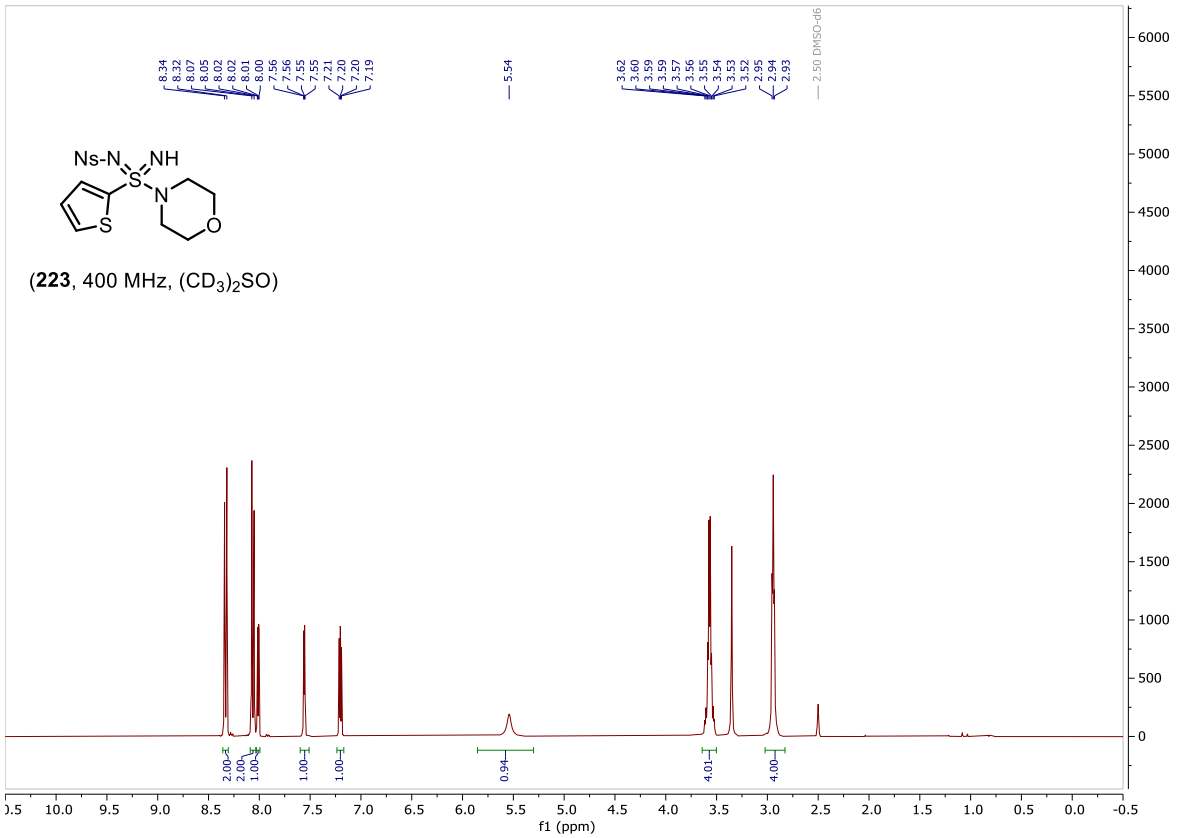
(**221**, 400 MHz, $(CD_3)_2SO$)

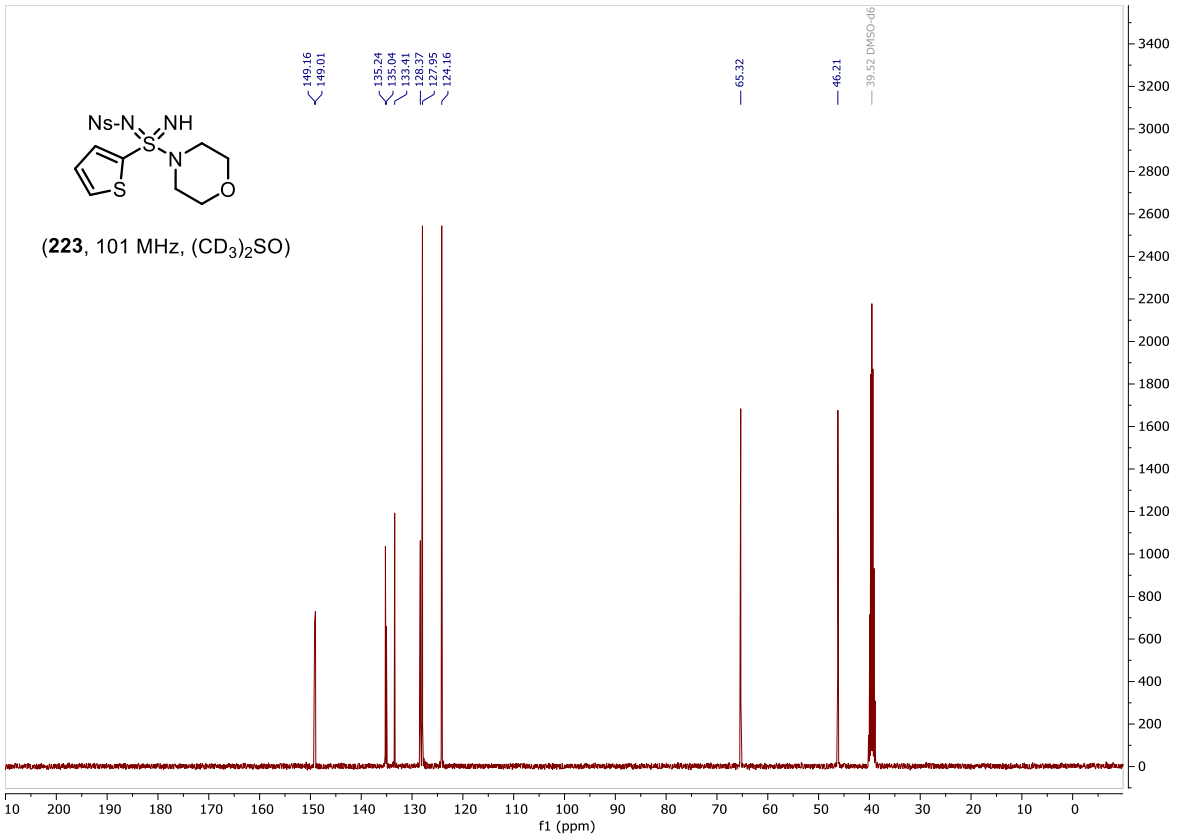


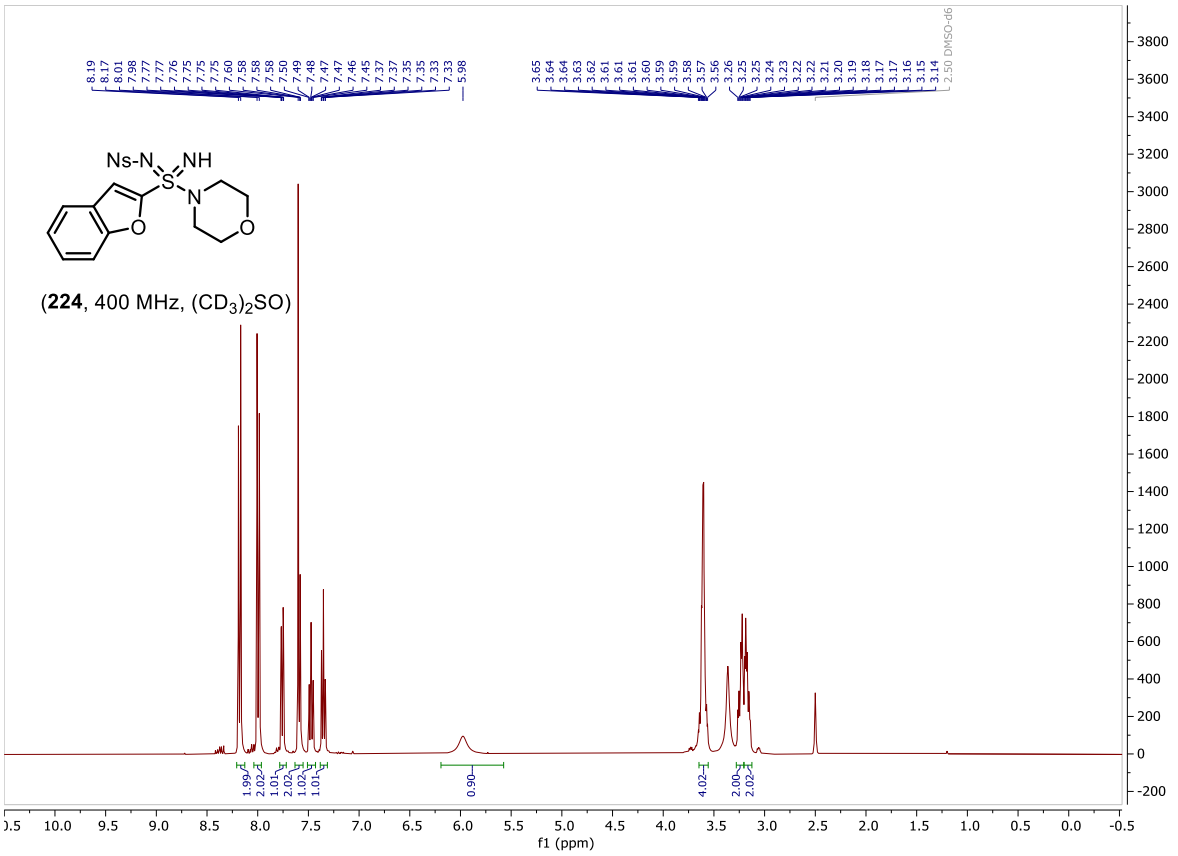
(**221**, 101 MHz, $(CD_3)_2SO$)

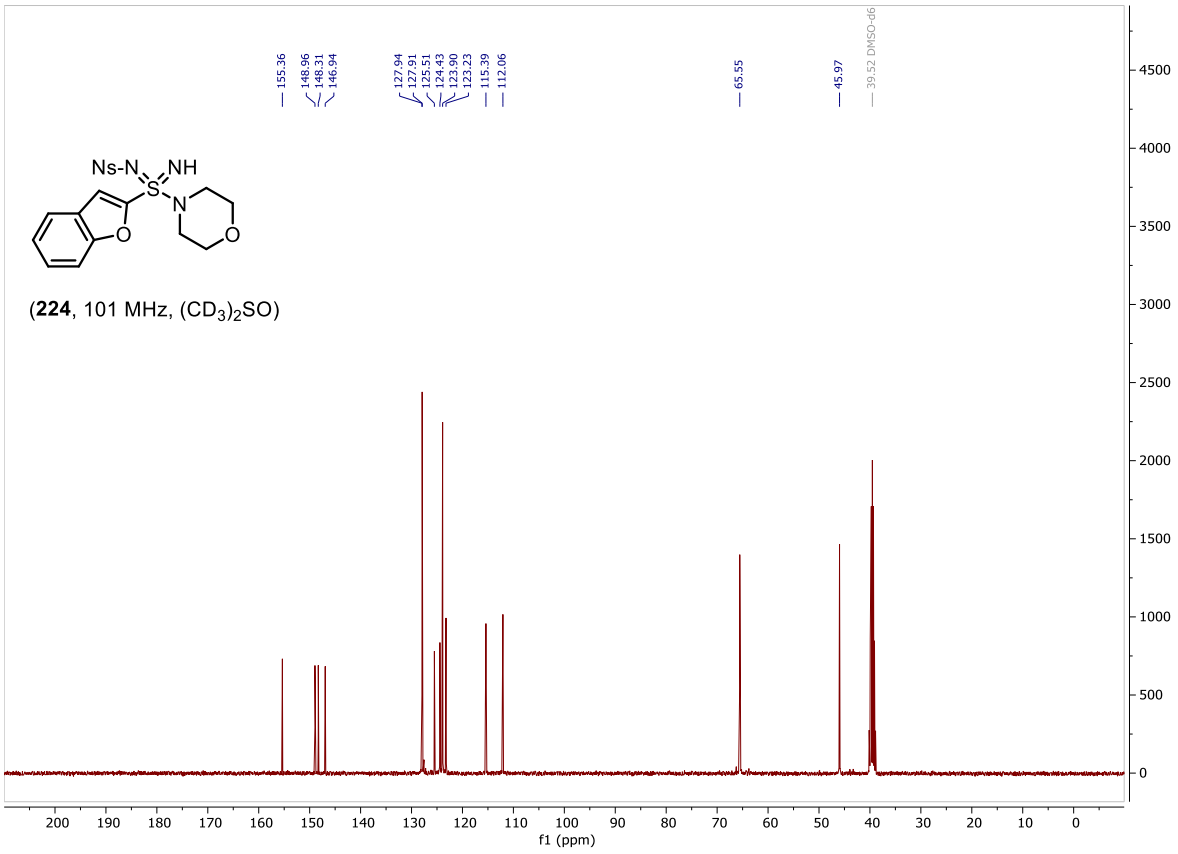

8.78
8.22
8.20
7.97
7.95
7.49
7.49
7.47
7.47
7.37
7.36
7.27
7.25
7.14
7.14
7.13
7.13
7.12
7.12
7.11
7.10
7.09
7.09
7.08
7.07
7.07
7.07
7.07
7.05
7.05
7.03
7.03
7.02
7.01
7.01
7.01
7.00
6.99
3.98
3.96
3.57
3.50
3.39
1.94 CD3CN
Ns-N
NH
S
N
N
N
N
N
MeO
OMe
Cl
O
(222, 400 MHz, CD3CN)
1.00
2.09
2.03
1.04
1.00
1.03
4.08
3.02
3.02
1.03
4.02
4.07
f1 (ppm)

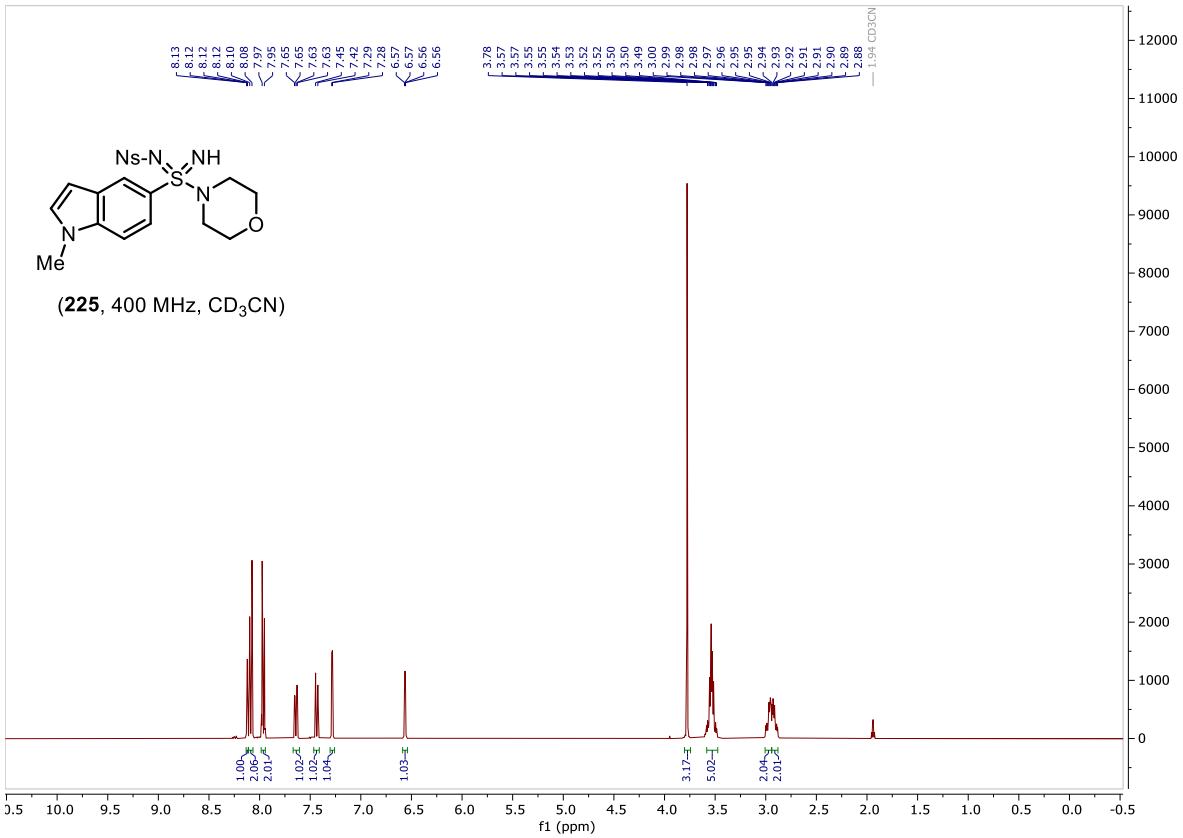

168.28
167.87
163.72
160.25
159.48
152.64
150.59
150.15
140.92
133.97
131.16
129.92
128.88
127.69
126.87
125.77
125.56
124.87
123.72
121.15
118.26 CD3CN
113.32
56.52
55.70
48.00
46.32
Ns-N
NH
S
N
N
N
N
N
MeO
OMe
Cl
O
(222, 101 MHz, CD3CN)
f1 (ppm)

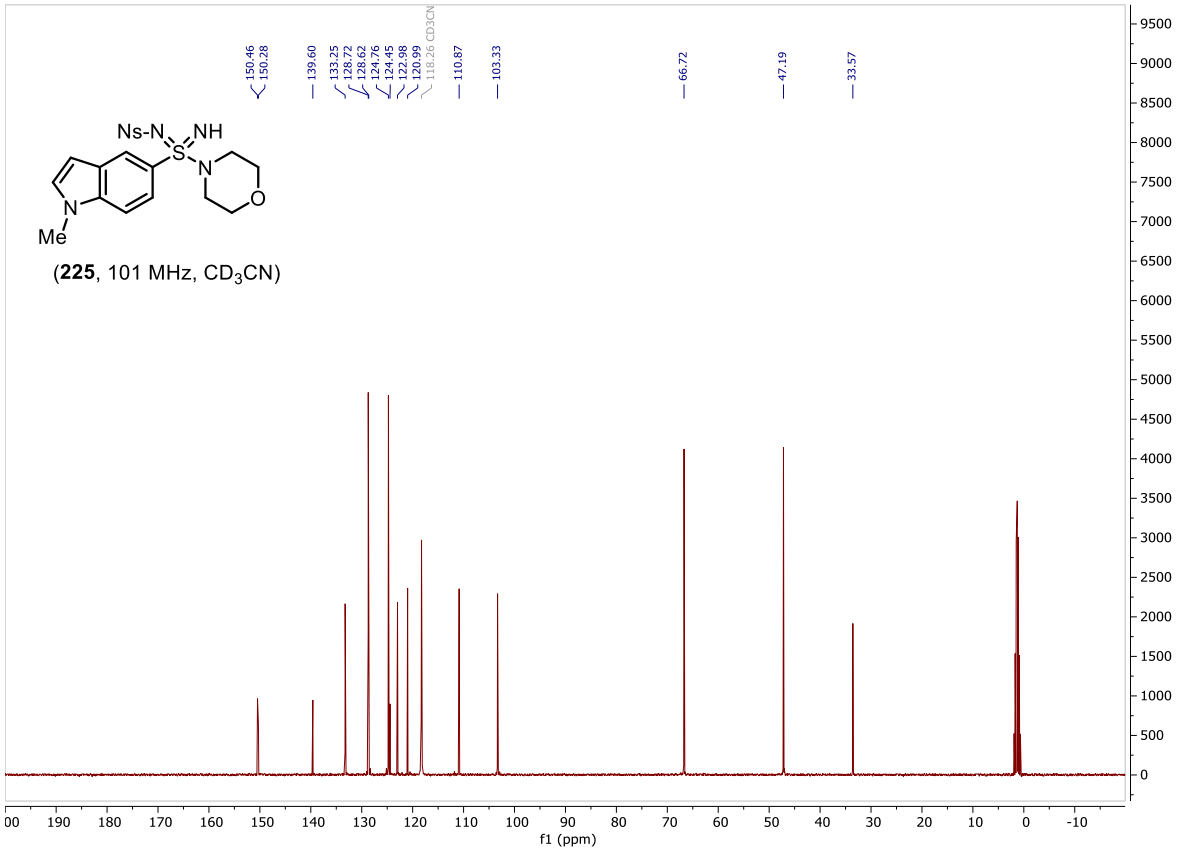

8.34
8.32
8.07
8.05
8.02
8.02
8.01
8.00
7.56
7.56
7.55
7.55
7.21
7.20
7.20
7.19
5.54
3.62
3.60
3.59
3.59
3.57
3.56
3.55
3.54
3.53
3.52
2.95
2.94
2.93
2.50 DMSO-d6
Ns-N
NH
S
N
O
S
(223, 400 MHz, (CD3)2SO)
2.00
2.00
1.00
1.00
1.00
0.94
4.01
4.00
f1 (ppm)

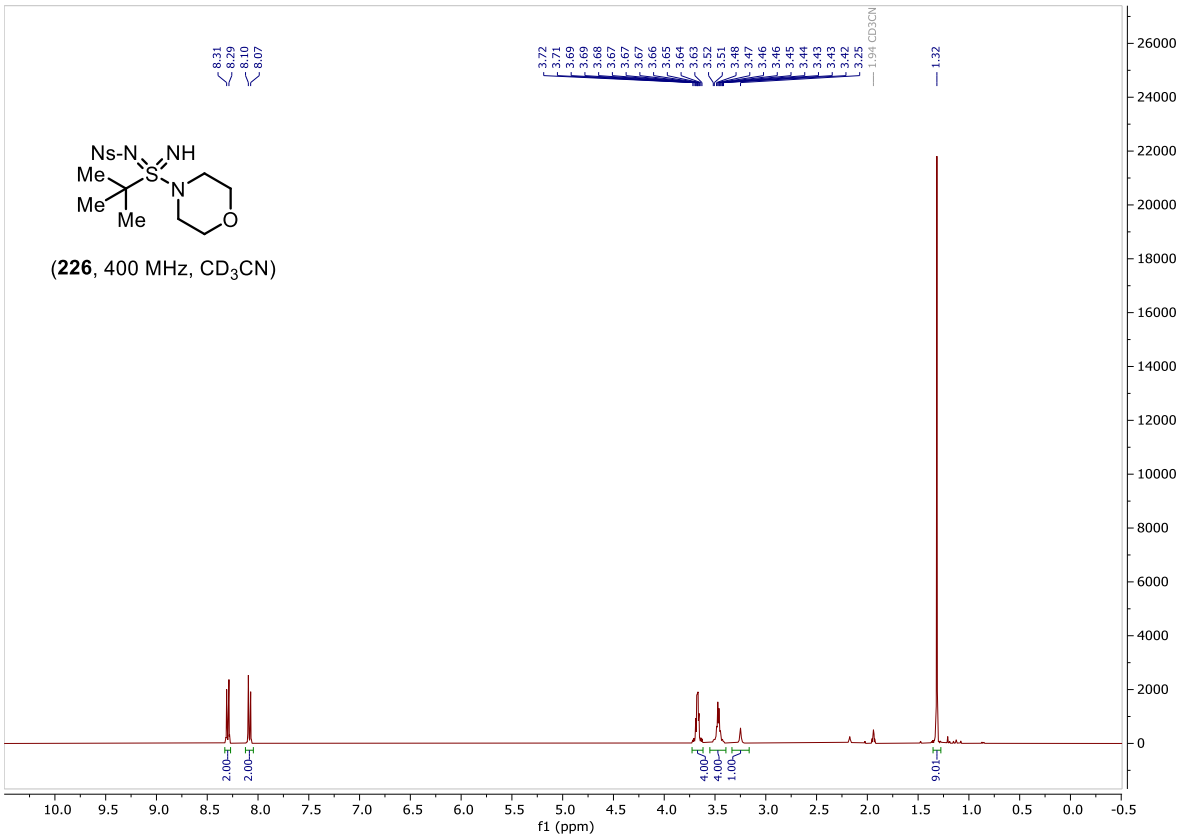

149.16
149.01
135.24
135.04
133.41
128.37
127.95
124.16
65.32
46.21
39.52 DMSO-d6
Ns-N
NH
S
N
O
S
(223, 101 MHz, (CD3)2SO)
f1 (ppm)

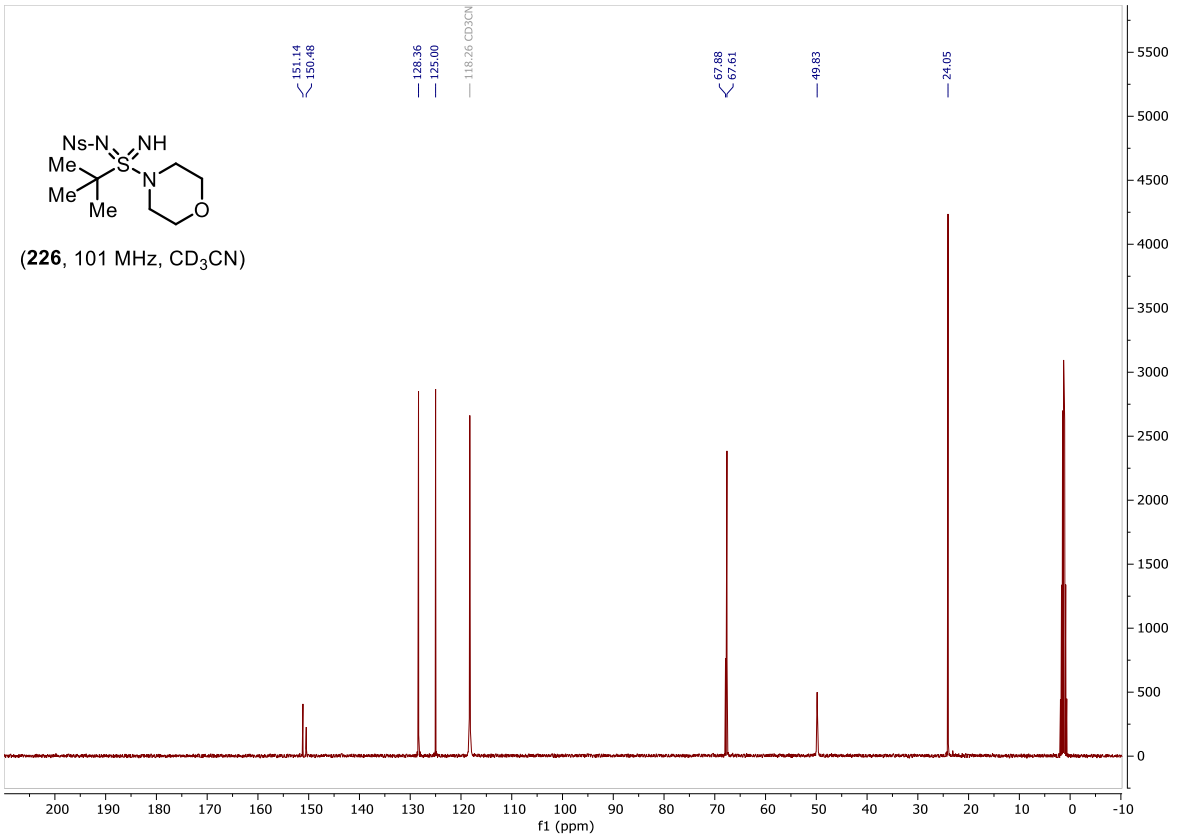

Ns-N
NH
S
N
O
O
(224, 400 MHz, (CD3)2SO)
f1 (ppm)

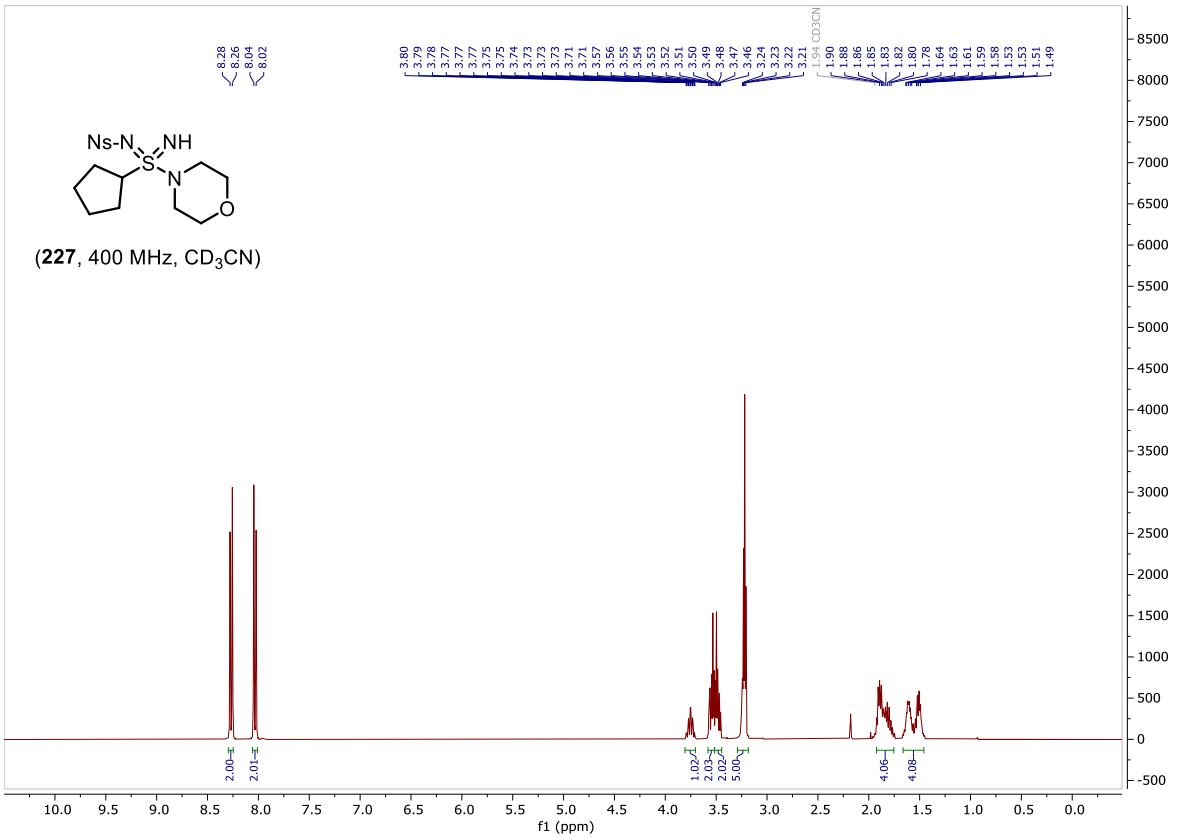

Ns-N
NH
S
N
O
O
(224, 101 MHz, (CD3)2SO)
f1 (ppm)


Ns-N
NH
S
N
N
Me
O
(225, 400 MHz, CD3CN)
f1 (ppm)

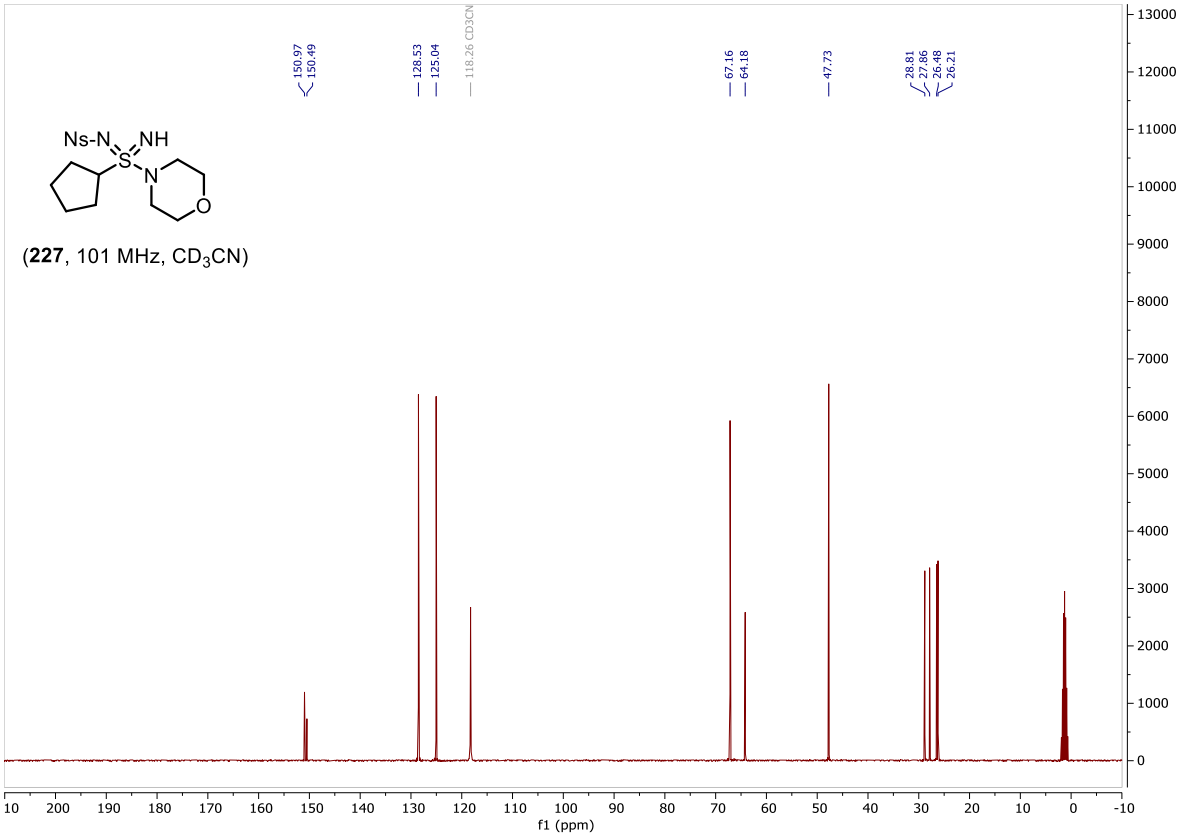

Ns-N
NH
S
N
N
Me
O
(225, 101 MHz, CD3CN)
f1 (ppm)


8.31
8.29
8.10
8.07
3.72
3.71
3.69
3.69
3.68
3.67
3.67
3.67
3.66
3.65
3.64
3.63
3.52
3.51
3.48
3.47
3.46
3.46
3.45
3.44
3.43
3.43
3.42
3.25
1.94 CD3CN
1.32
Ns-N
NH
Me
Me
Me
S
N
O
(226, 400 MHz, CD3CN)
2.00
2.00
4.00
4.00
1.00
9.01
f1 (ppm)

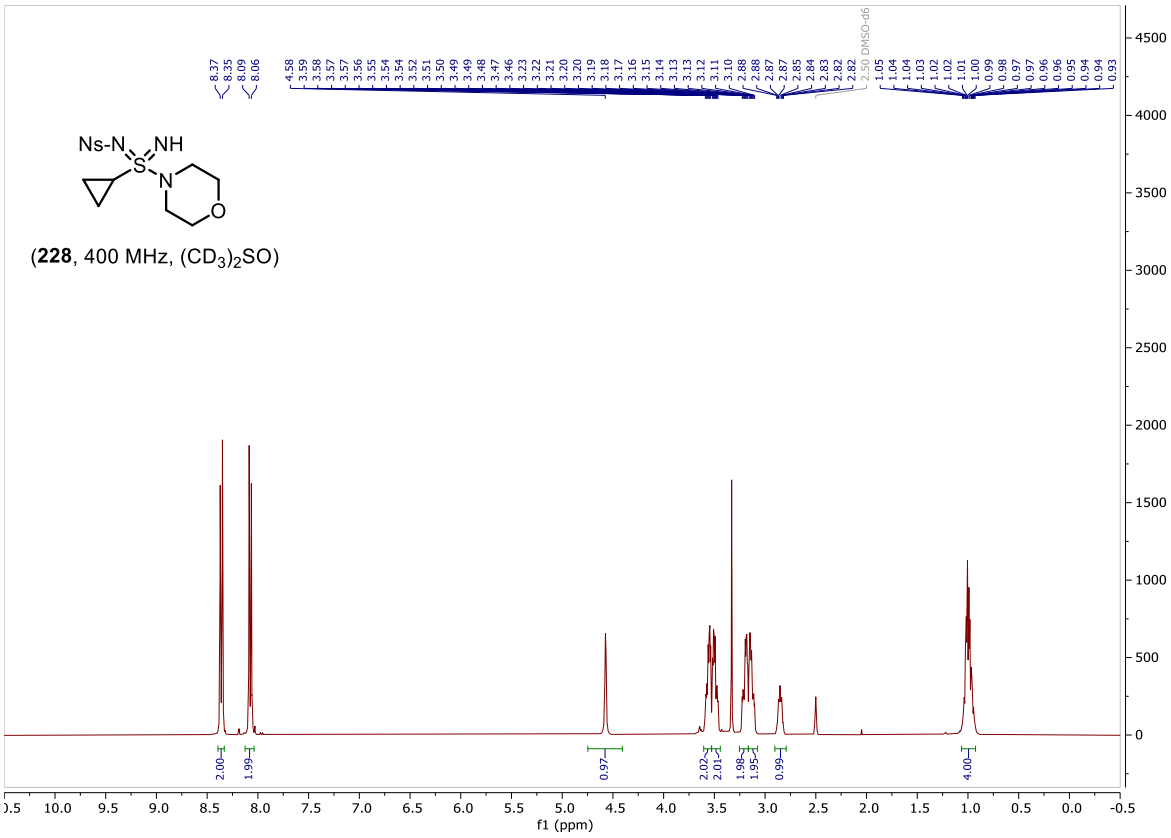

151.14
150.48
128.36
125.00
118.26 CD3CN
67.88
67.61
49.83
24.05
Ns-N
NH
Me
Me
Me
S
N
O
(226, 101 MHz, CD3CN)
f1 (ppm)

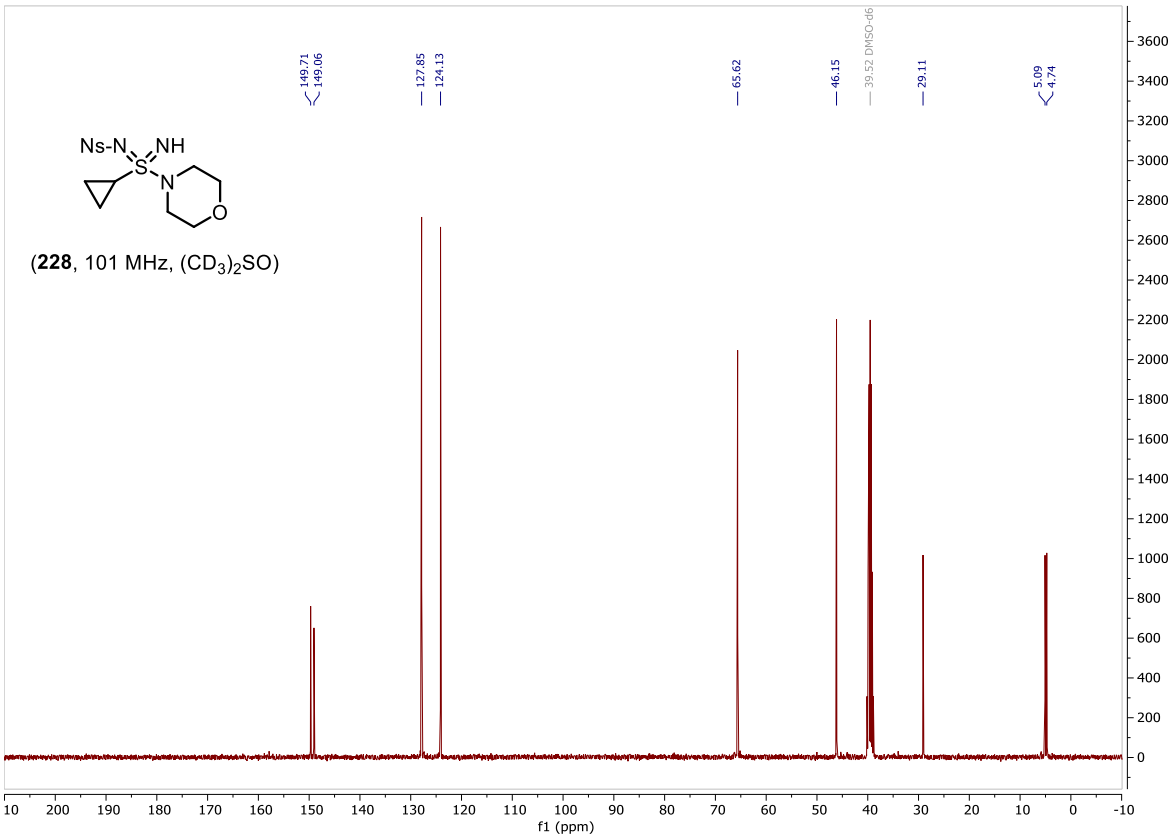


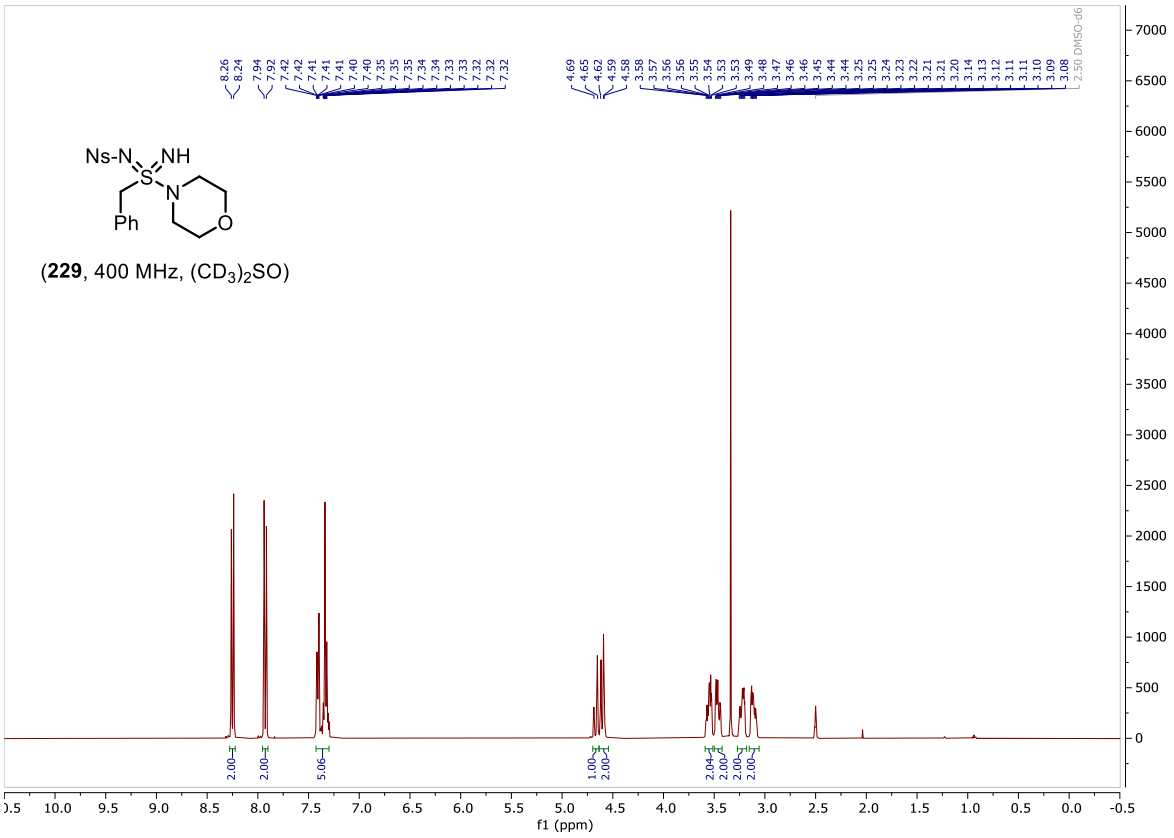
(**227**, 400 MHz, CD_3CN)

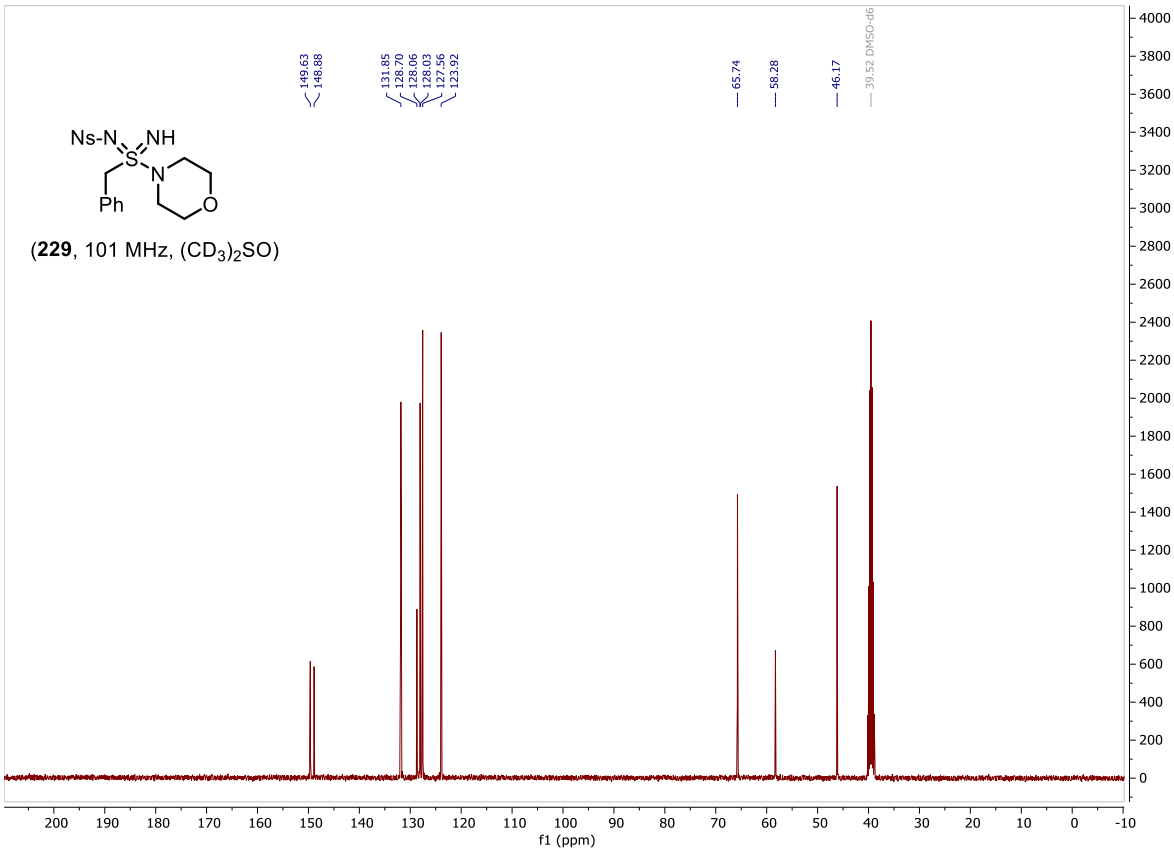


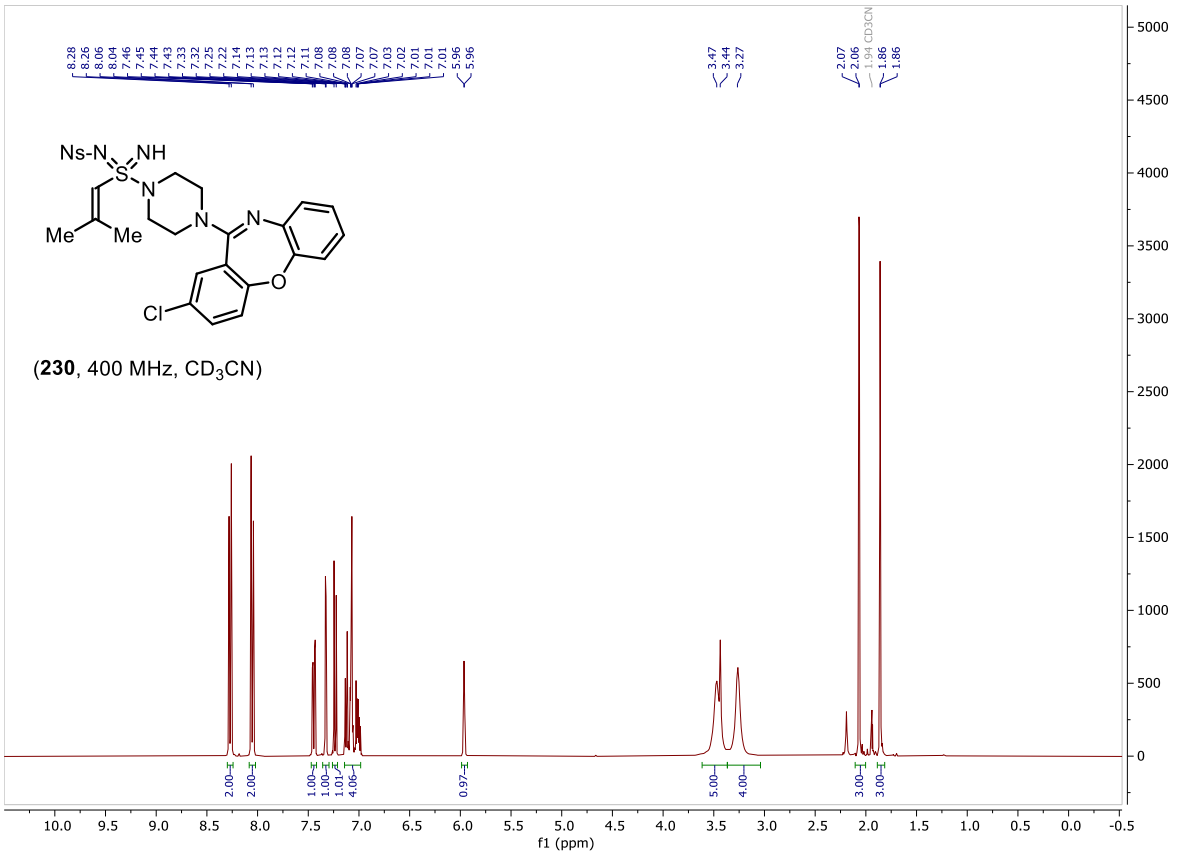
(**227**, 101 MHz, CD_3CN)


Ns-N
NH
S
N
O
(228, 400 MHz, (CD3)2SO)
f1 (ppm)

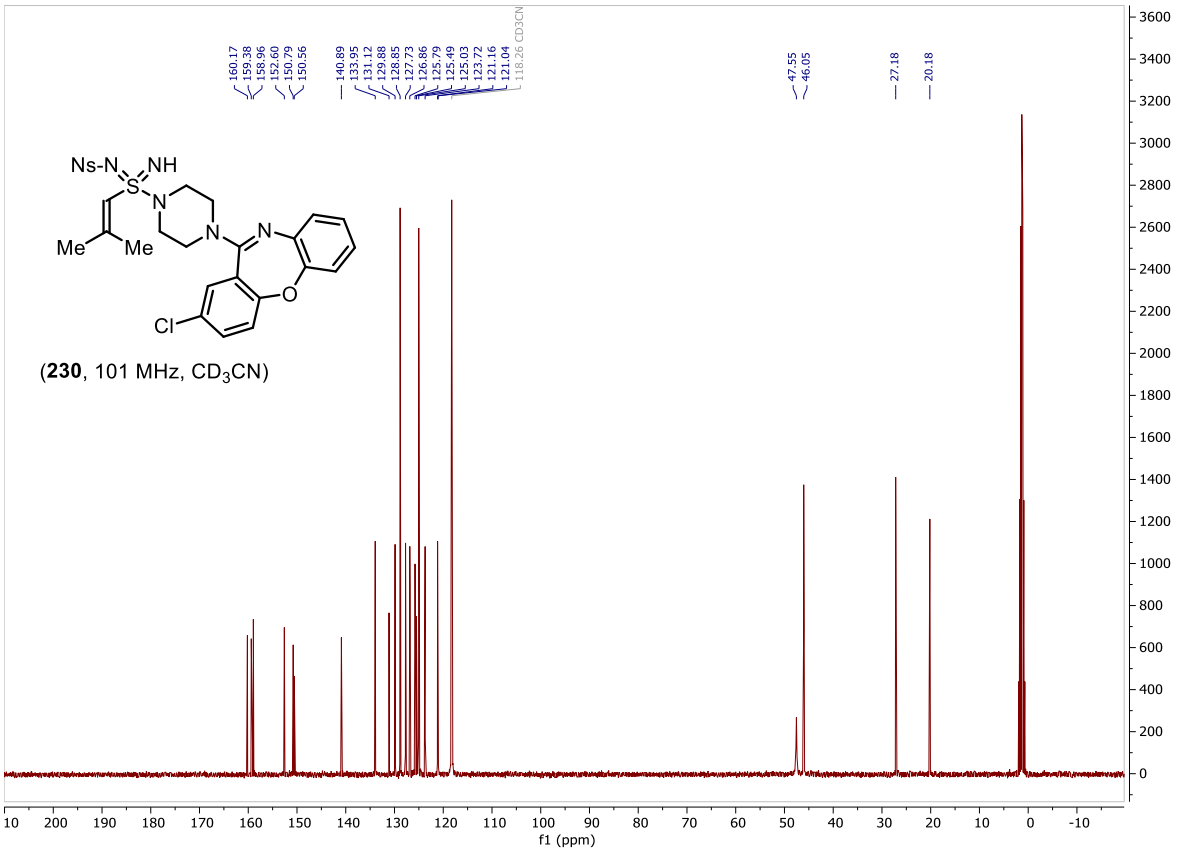

Ns-N
NH
S
N
O
(228, 101 MHz, (CD3)2SO)
f1 (ppm)


Ns-N
NH
S
N
Ph
O
(229, 400 MHz, (CD3)2SO)
f1 (ppm)

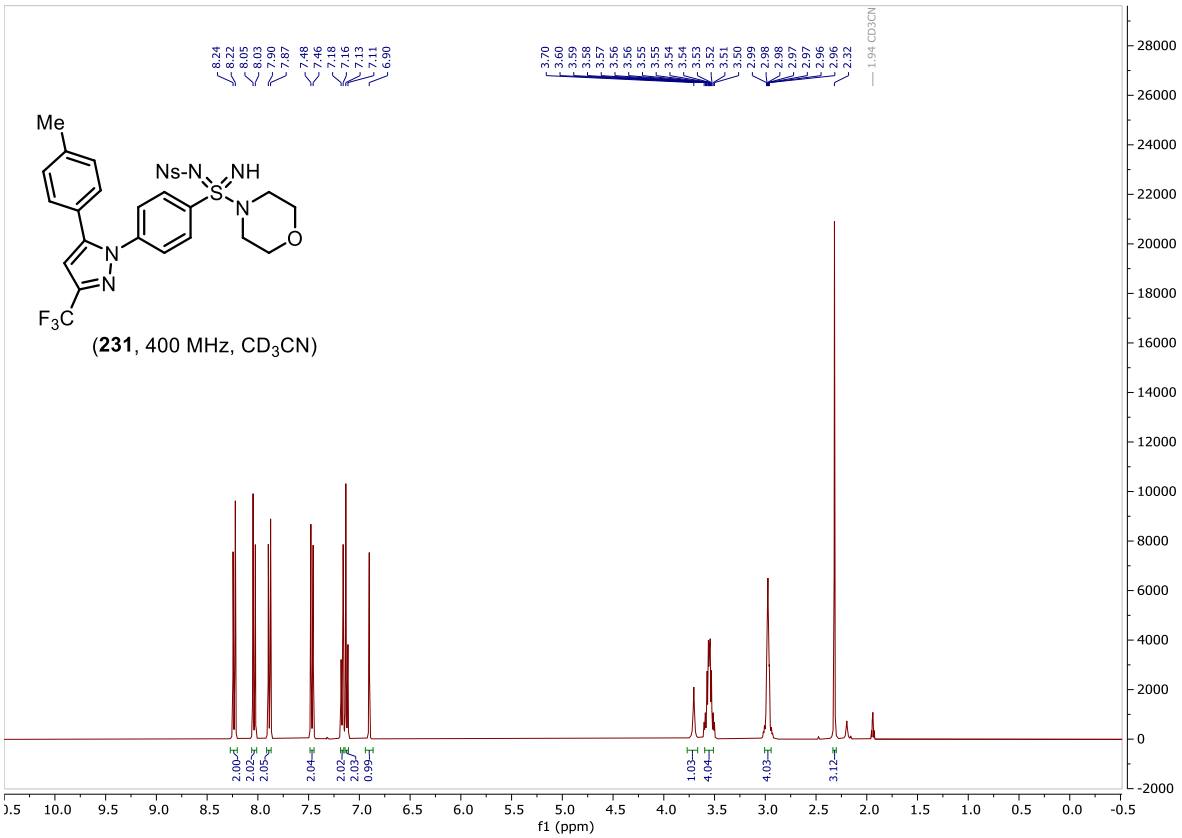

Ns-N
NH
S
N
Ph
O
(229, 101 MHz, (CD3)2SO)
f1 (ppm)

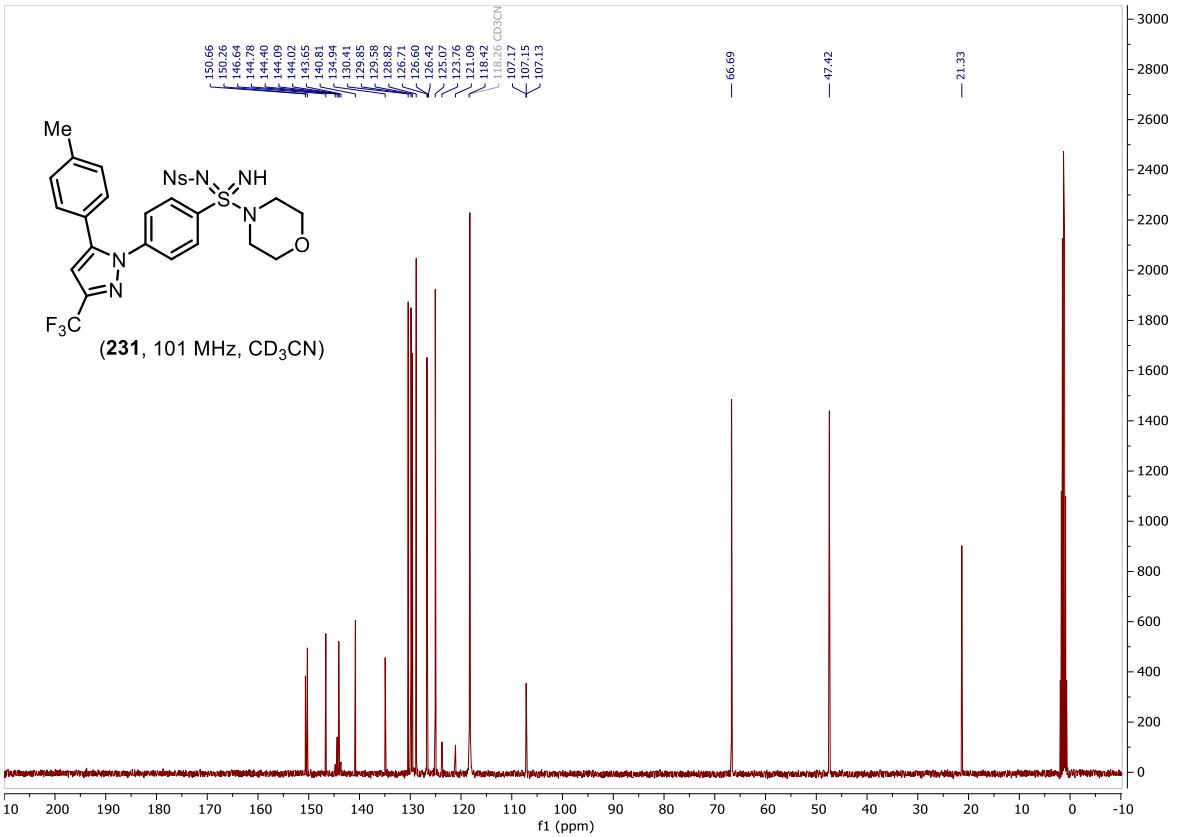


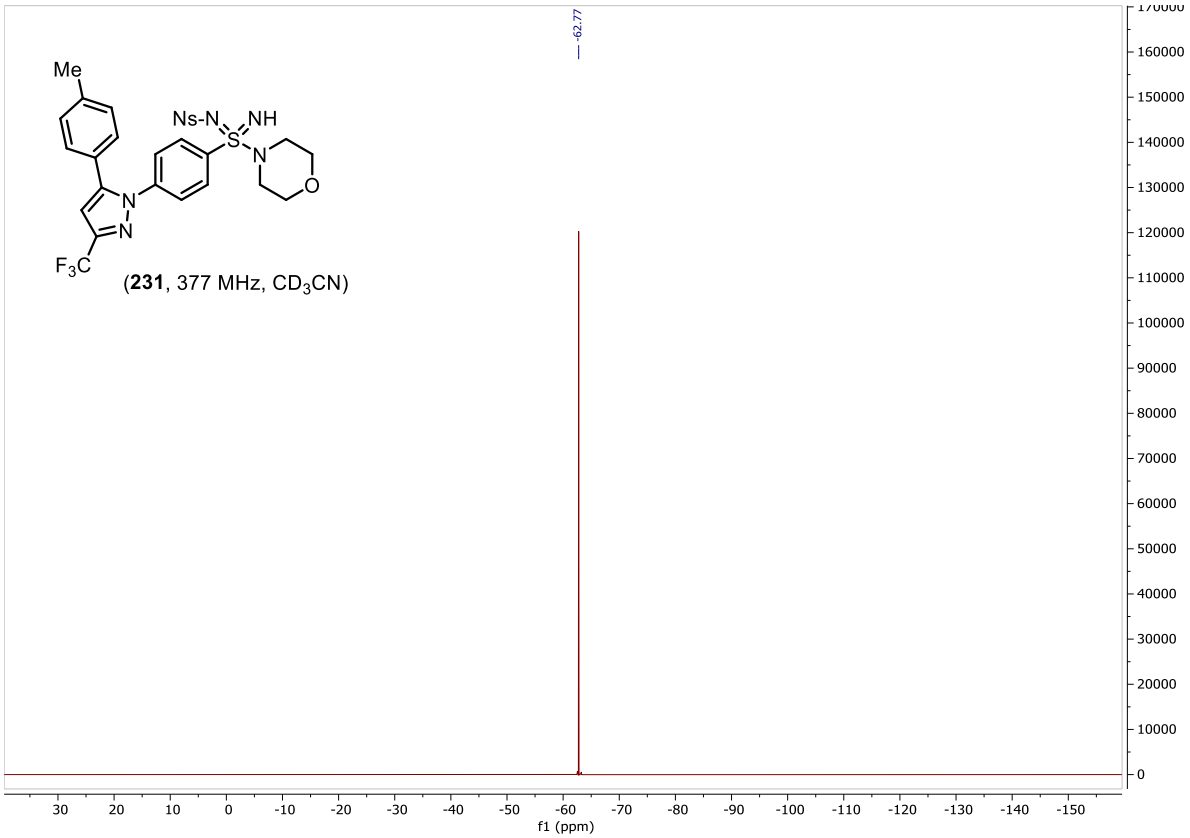
(**230**, 400 MHz, CD_3CN)

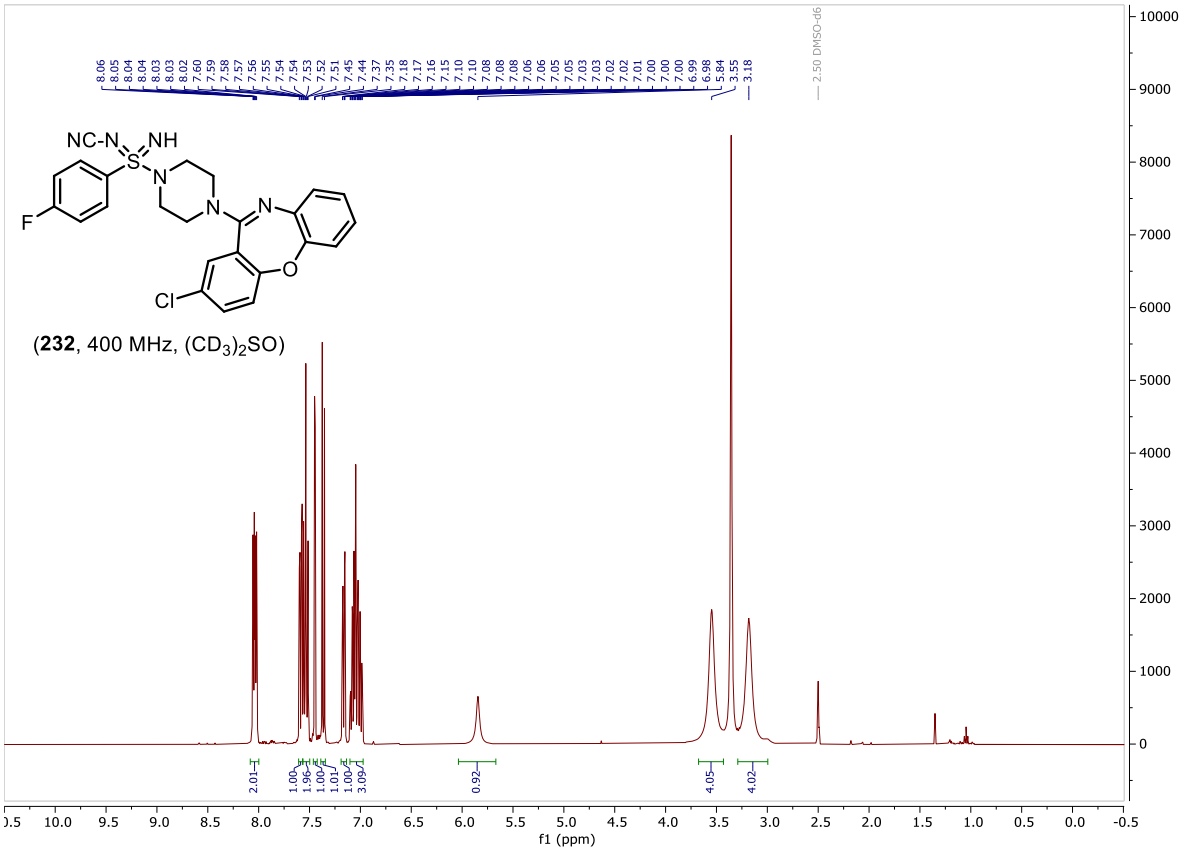


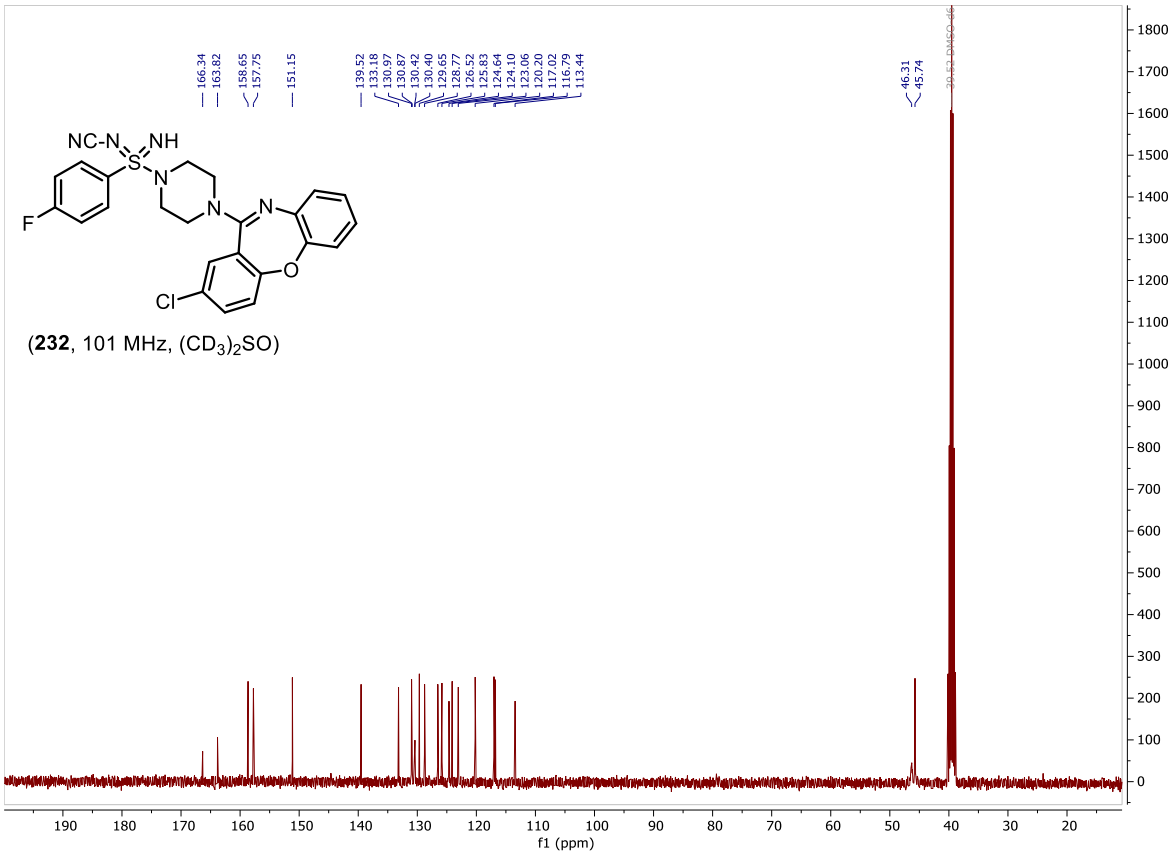
(**230**, 101 MHz, CD_3CN)


Me
Ns-N
NH
S
N
O
N
N
F3C
(231, 400 MHz, CD3CN)
f1 (ppm)

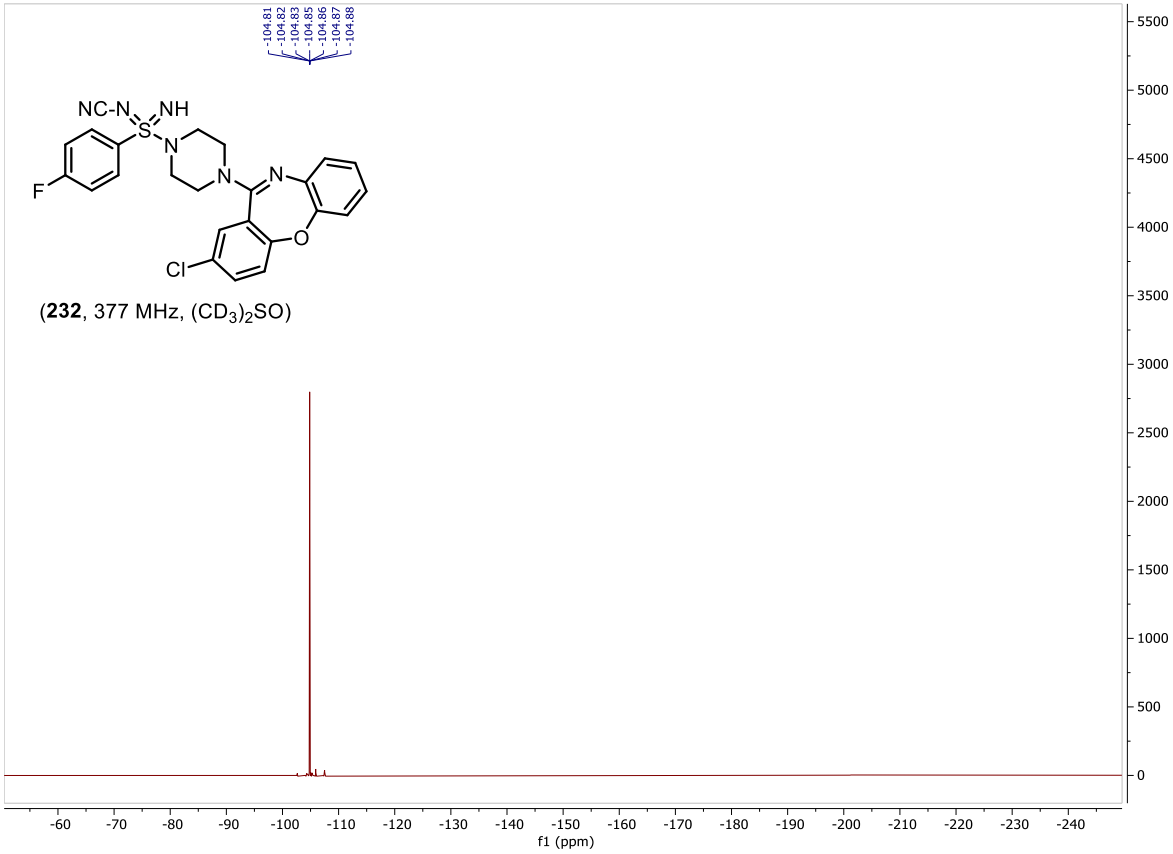

Me
Ns-N
NH
S
N
O
N
N
F3C
(231, 101 MHz, CD3CN)
f1 (ppm)


Me
Ns-N
NH
S
N
O
N
N
F3C
-62.77
(231, 377 MHz, CD3CN)
f1 (ppm)

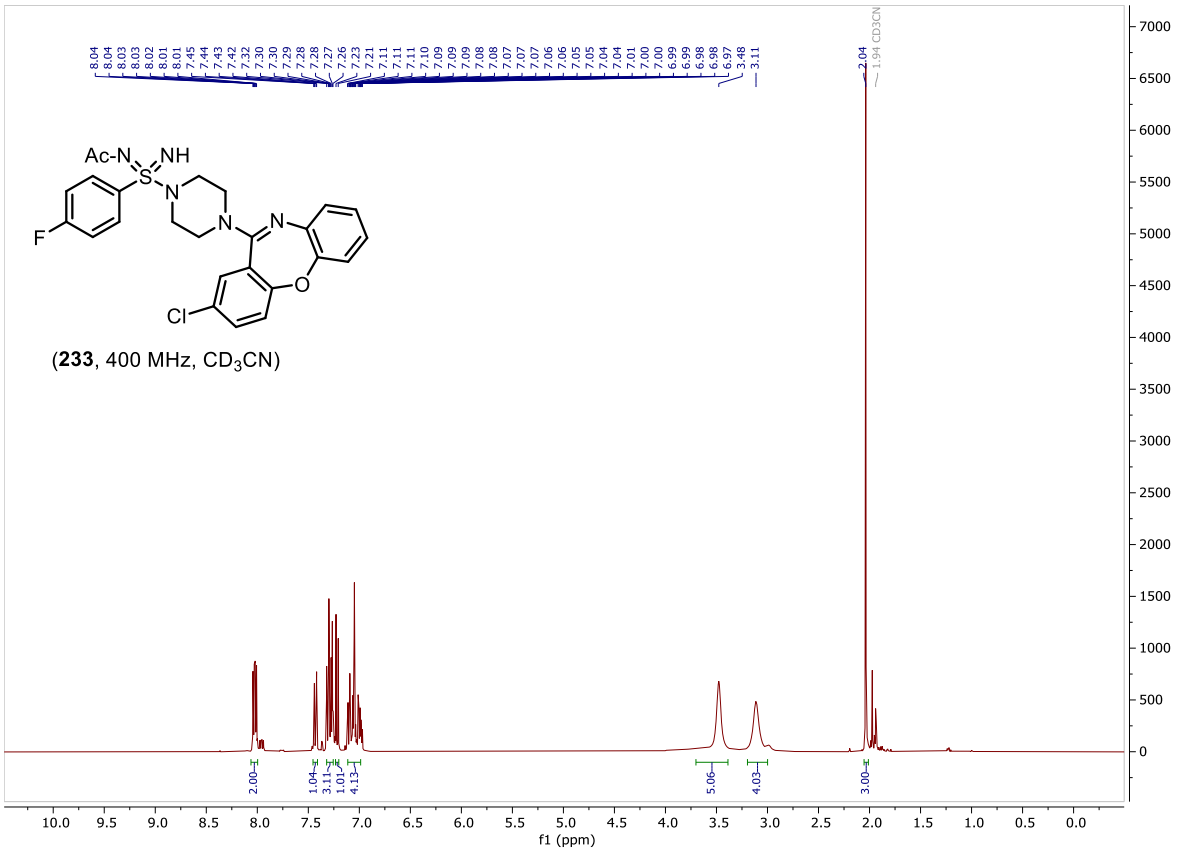

NC-N
NH
S
N
N
N
F
O
Cl
2.50 DMSO-d6
3.18
(232, 400 MHz, (CD3)2SO)
f1 (ppm)



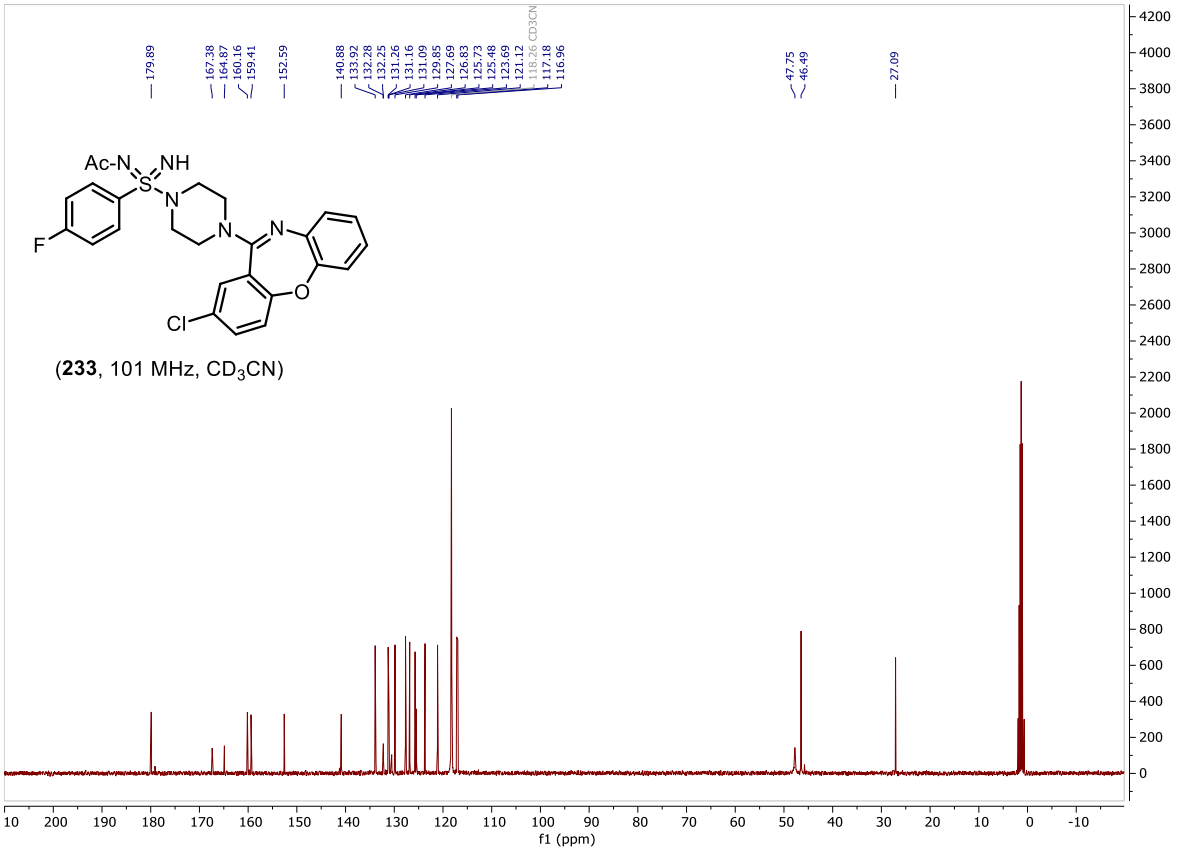
(**232**, 101 MHz, $(CD_3)_2SO$)



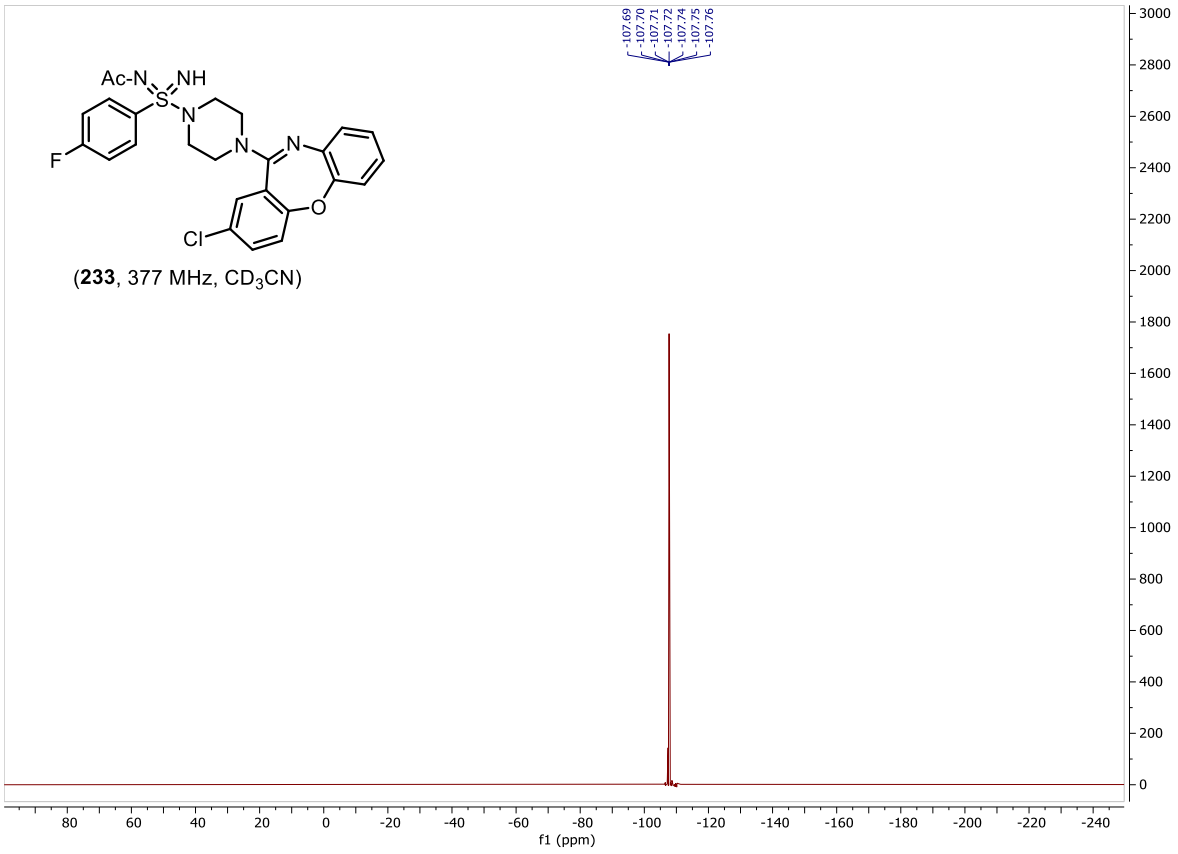
(**232**, 377 MHz, $(CD_3)_2SO$)



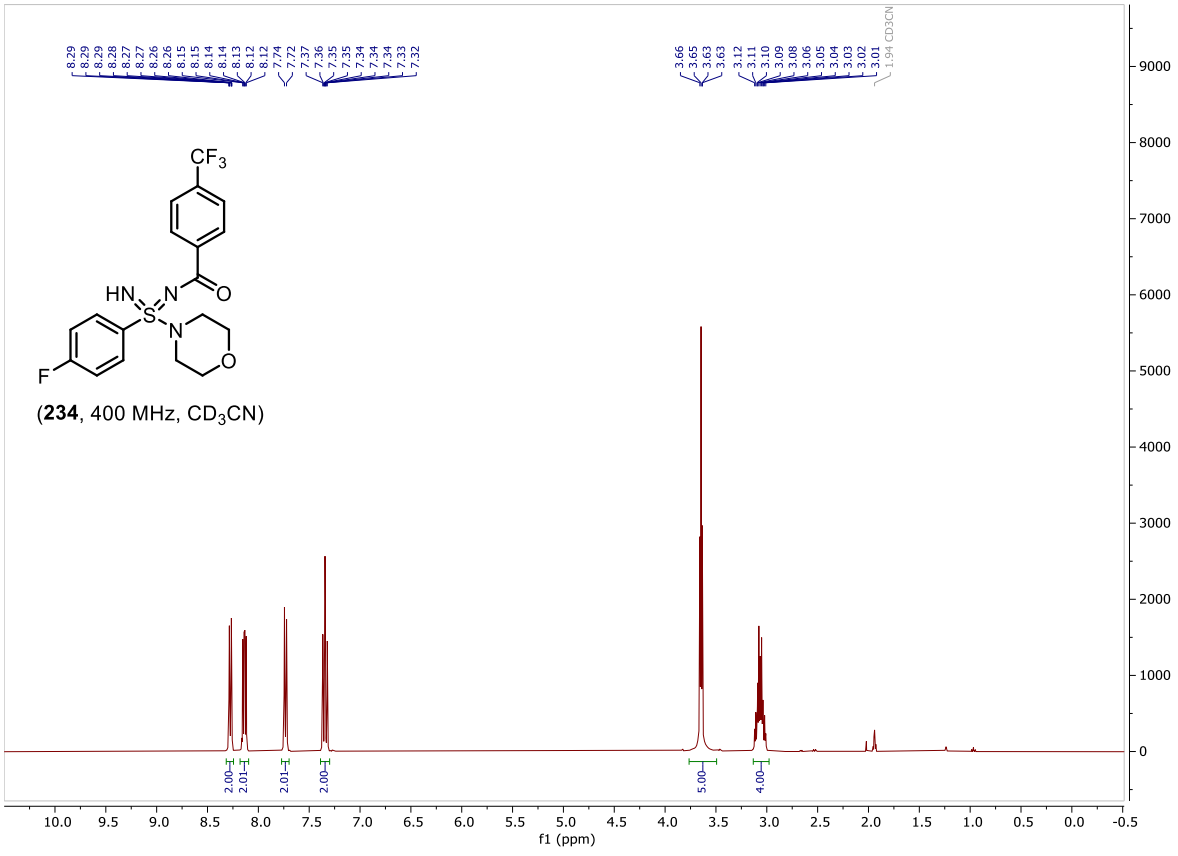
(**233**, 400 MHz, CD_3CN)



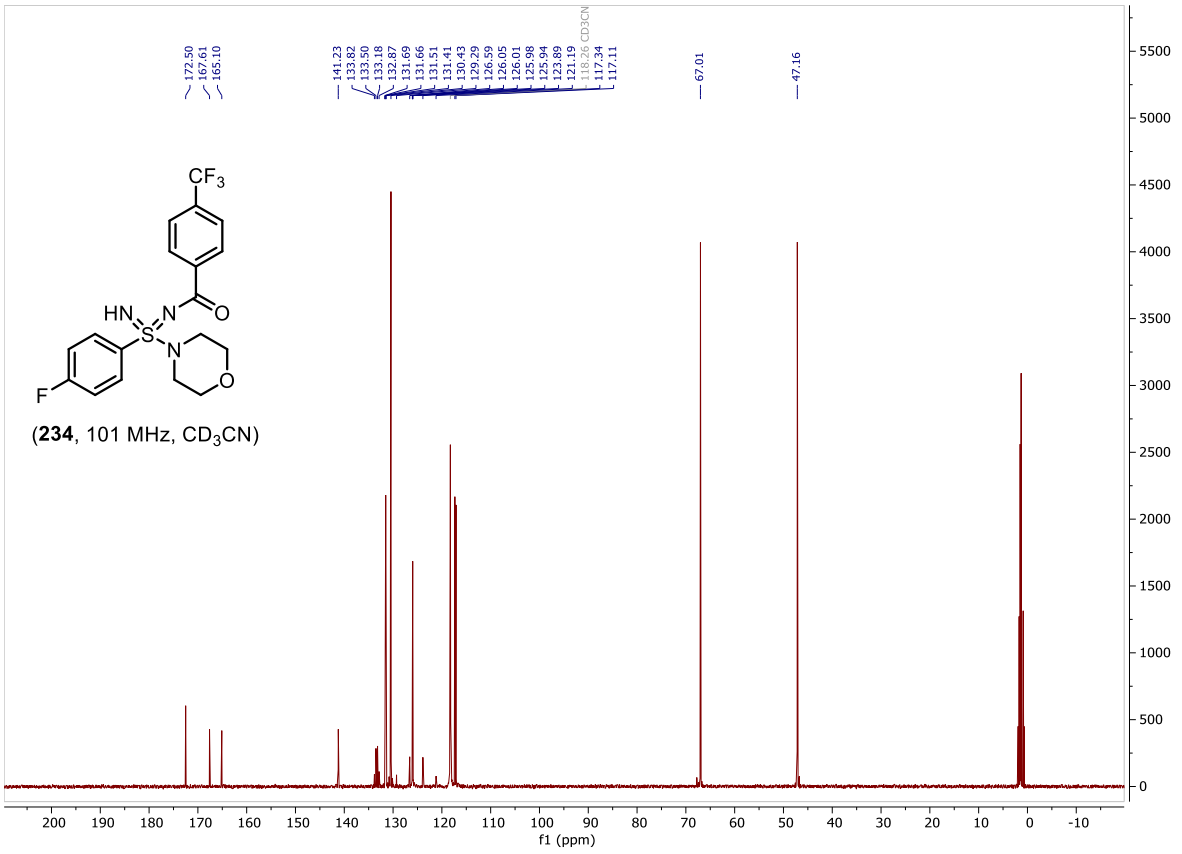
(**233**, 101 MHz, CD_3CN)



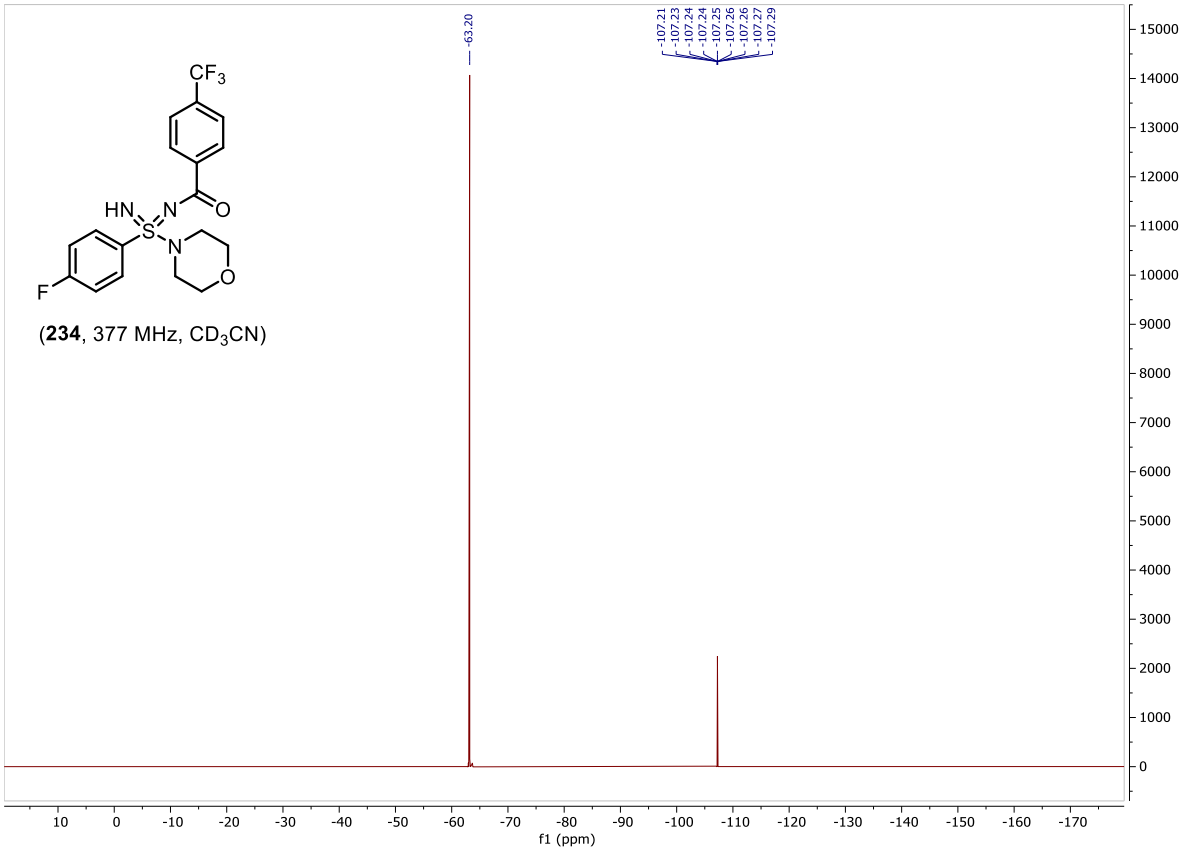
(**233**, 377 MHz, CD_3CN)



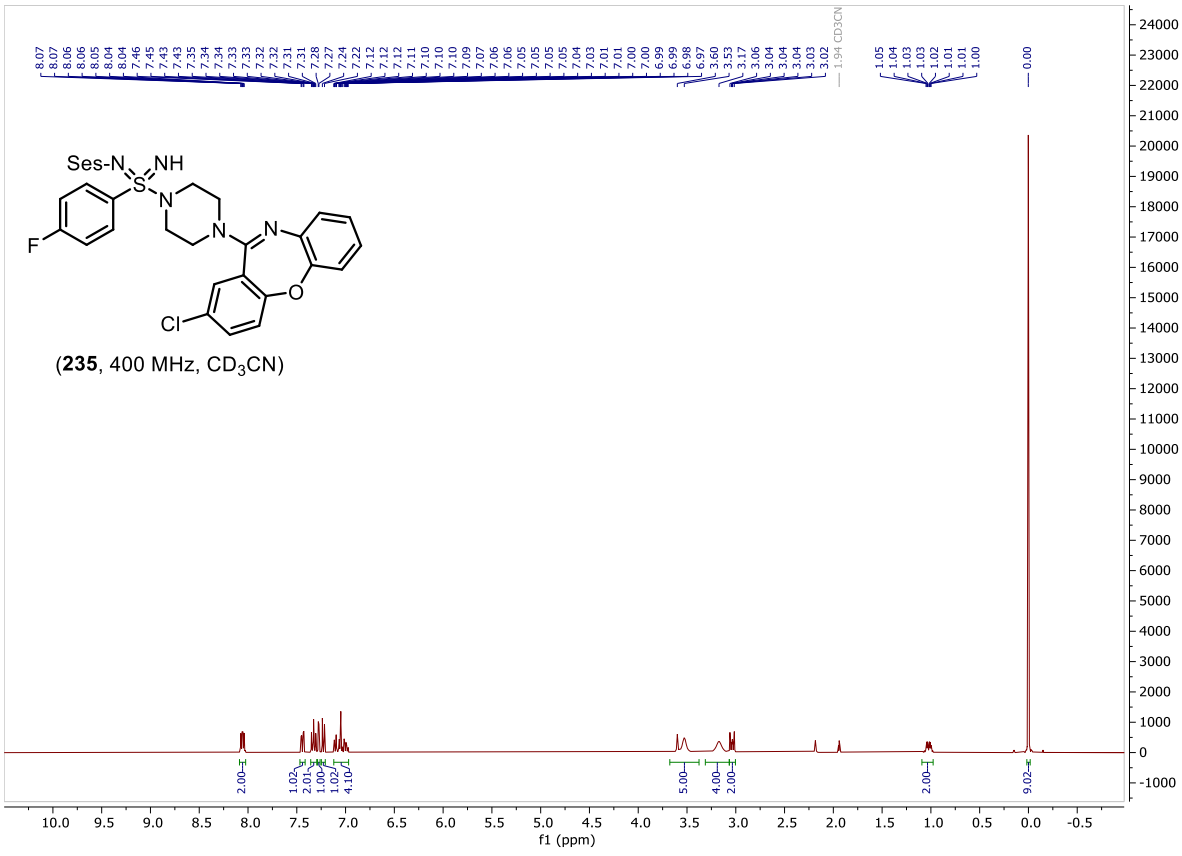
(**234**, 400 MHz, CD_3CN)



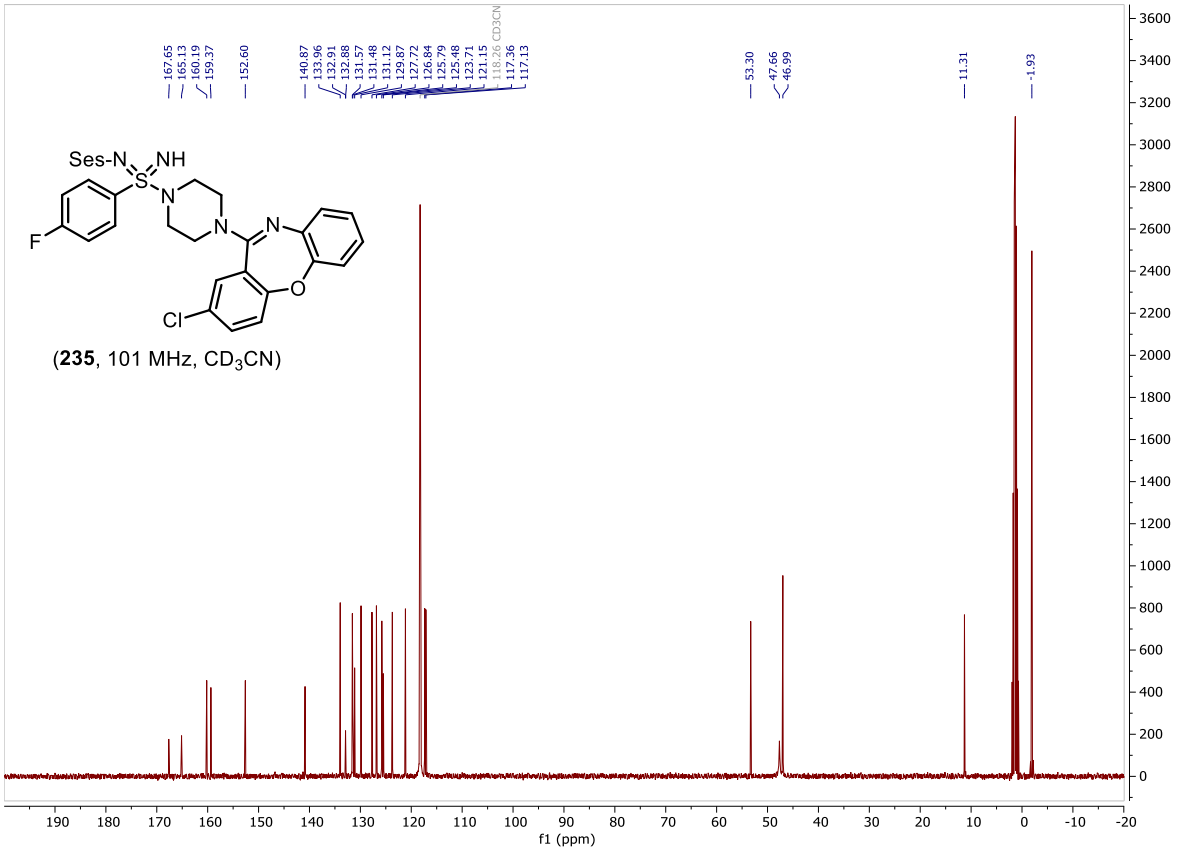
(**234**, 101 MHz, CD_3CN)



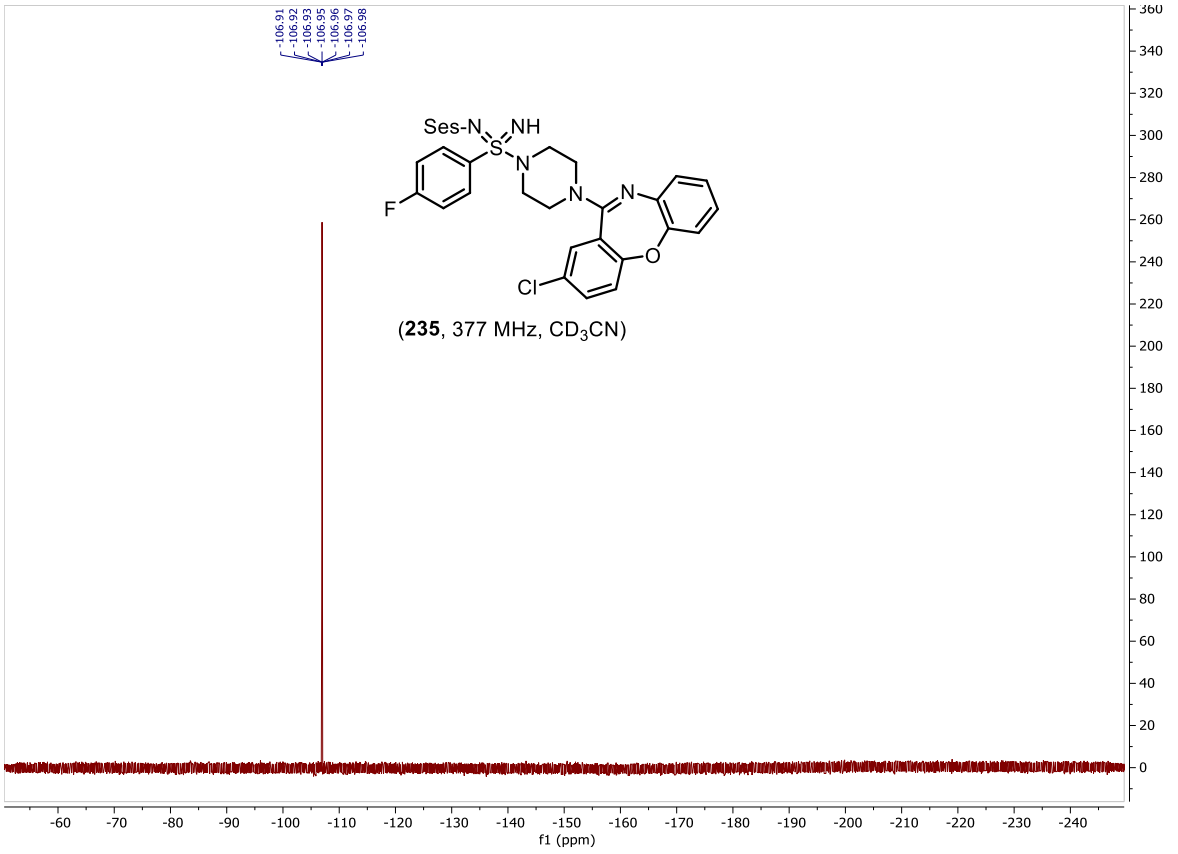
(**234**, 377 MHz, CD_3CN)



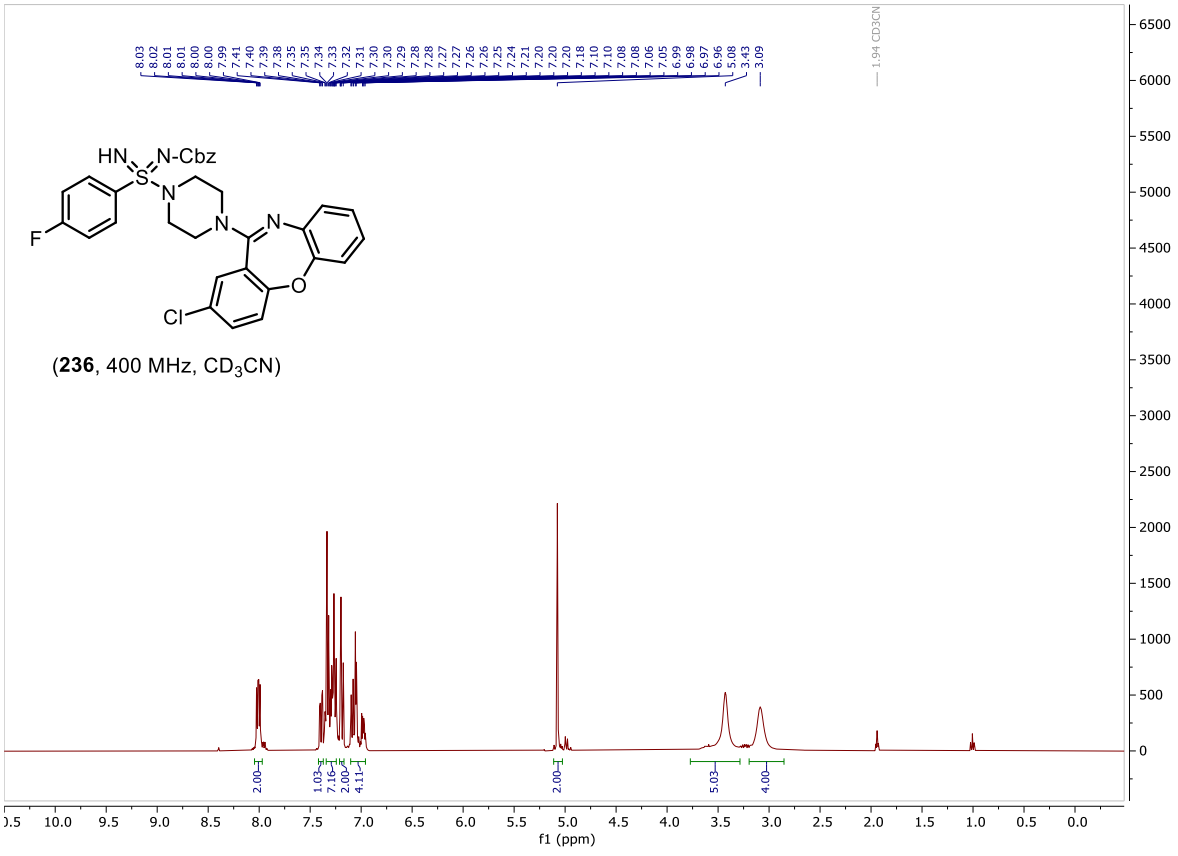
(**235**, 400 MHz, CD_3CN)



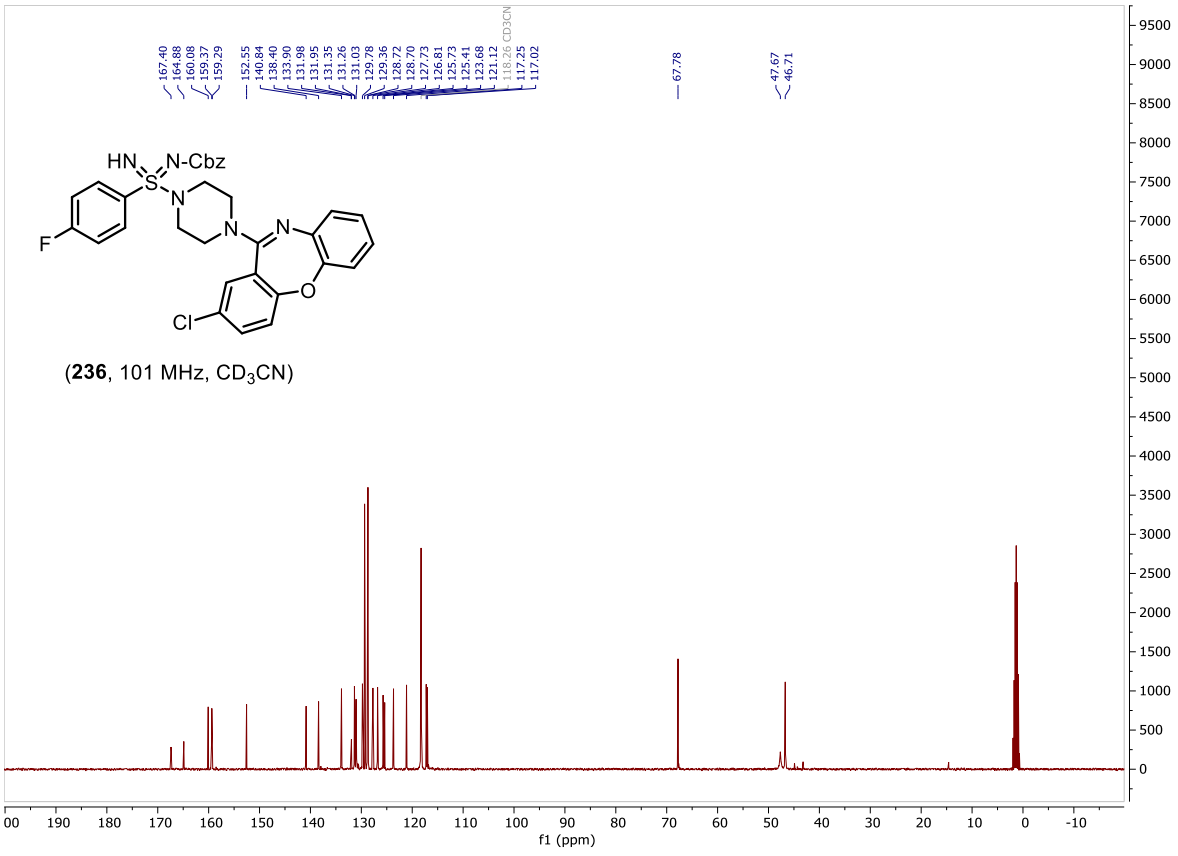
(**235**, 101 MHz, CD_3CN)

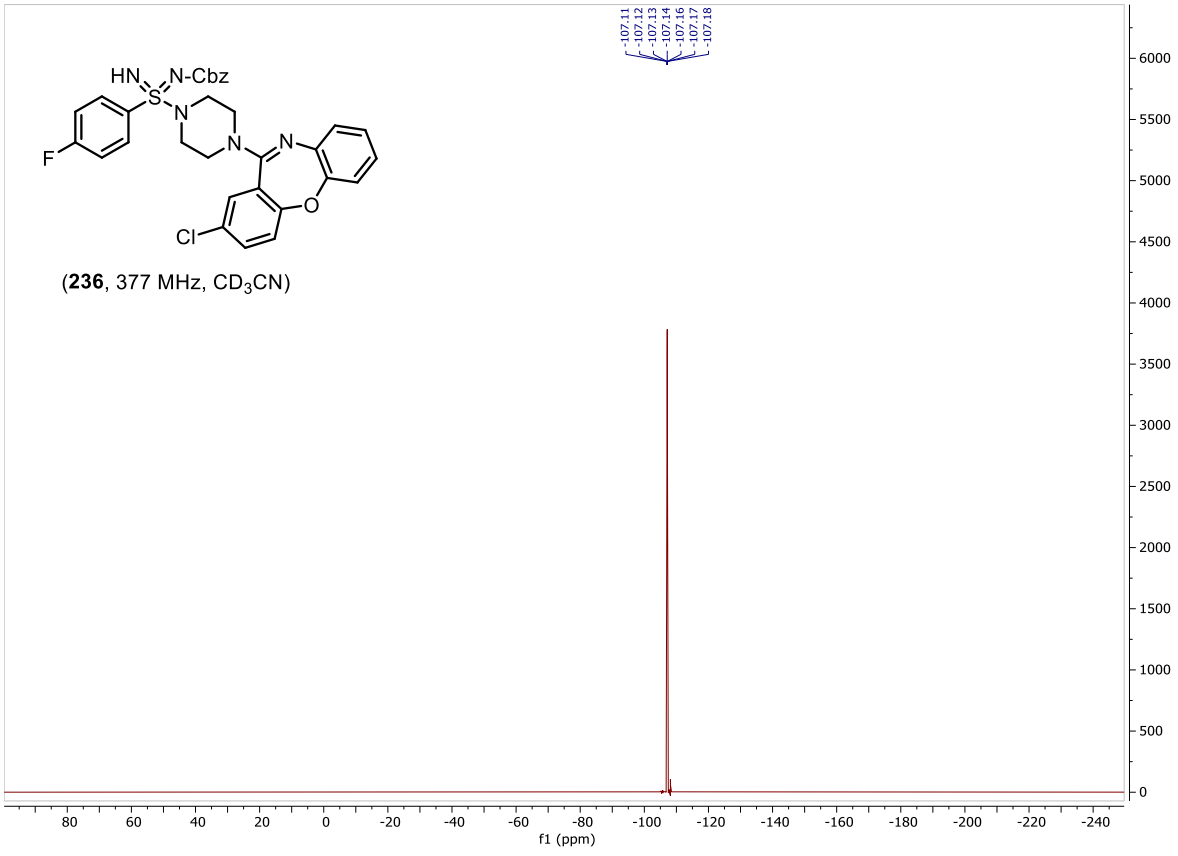


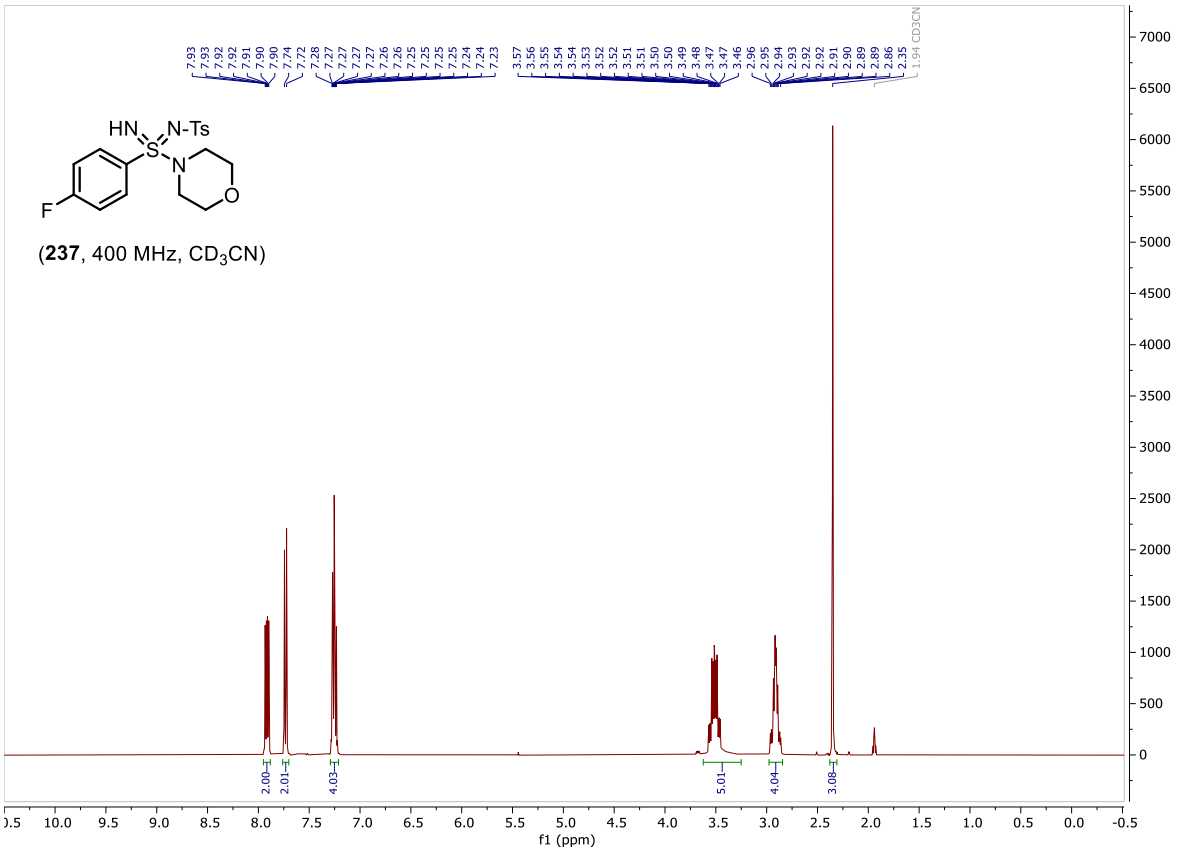
(**235**, 377 MHz, CD_3CN)

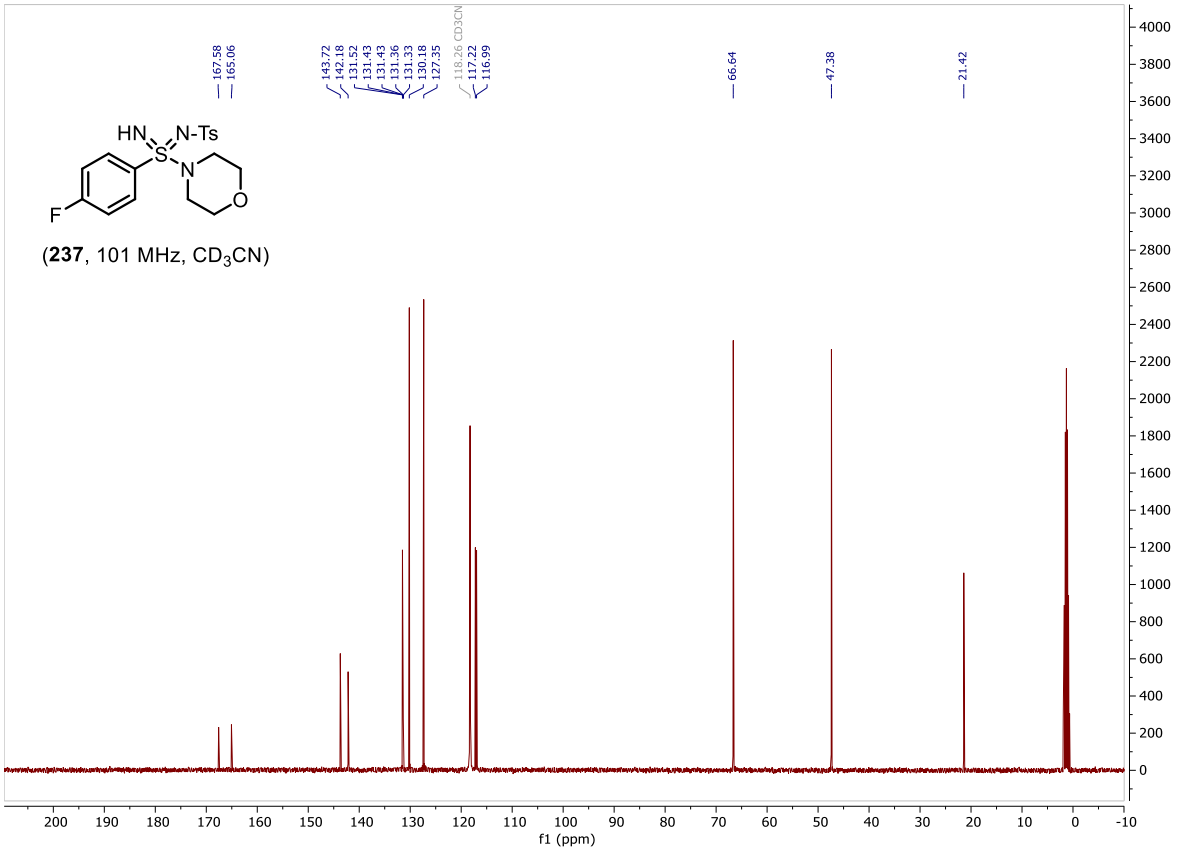


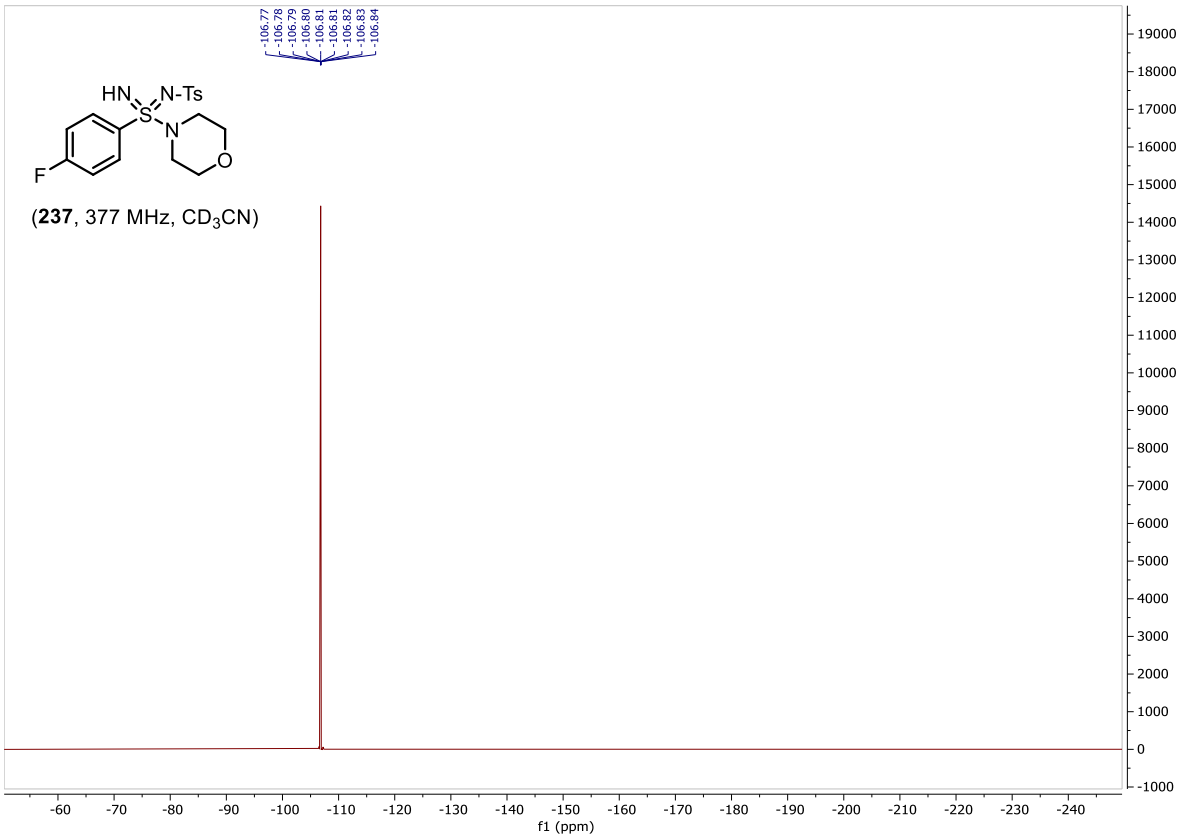
(**236**, 400 MHz, CD_3CN)

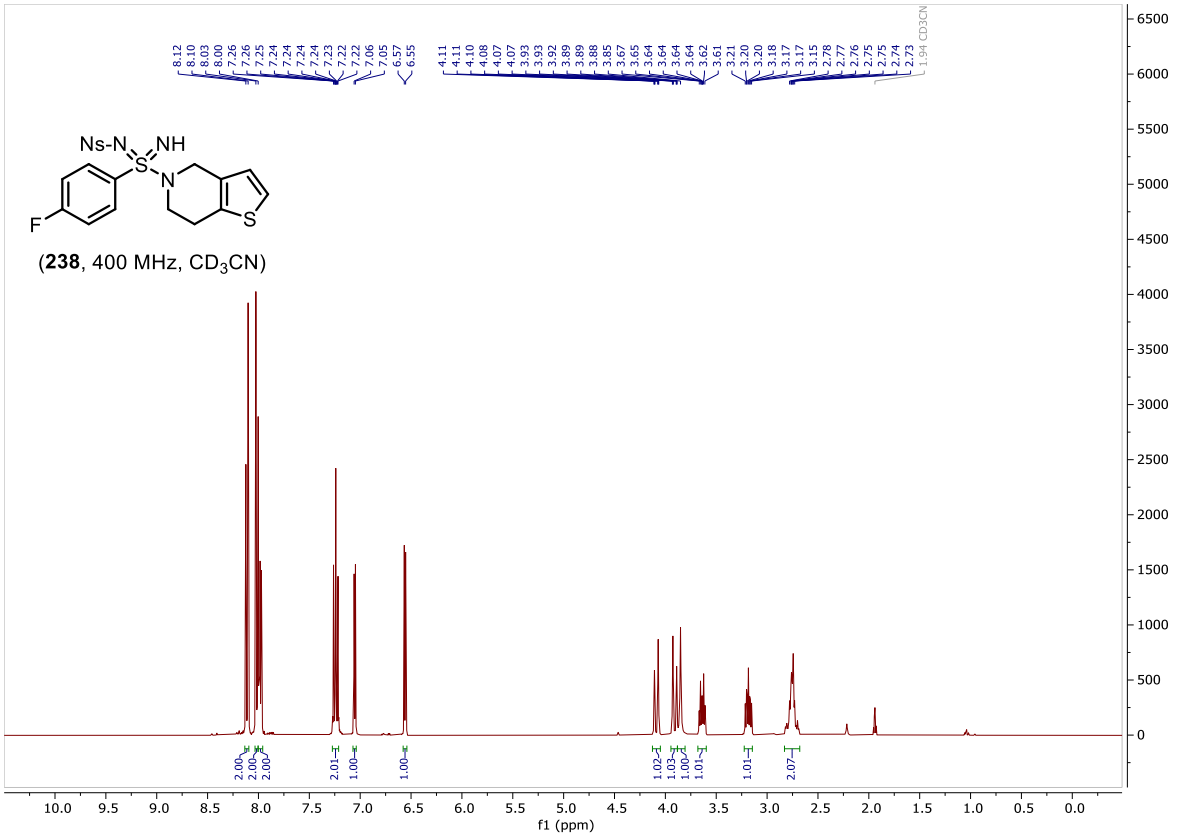

HN
N-Cbz
S
N
N
N
F
Cl
O
(236, 101 MHz, CD3CN)
f1 (ppm)

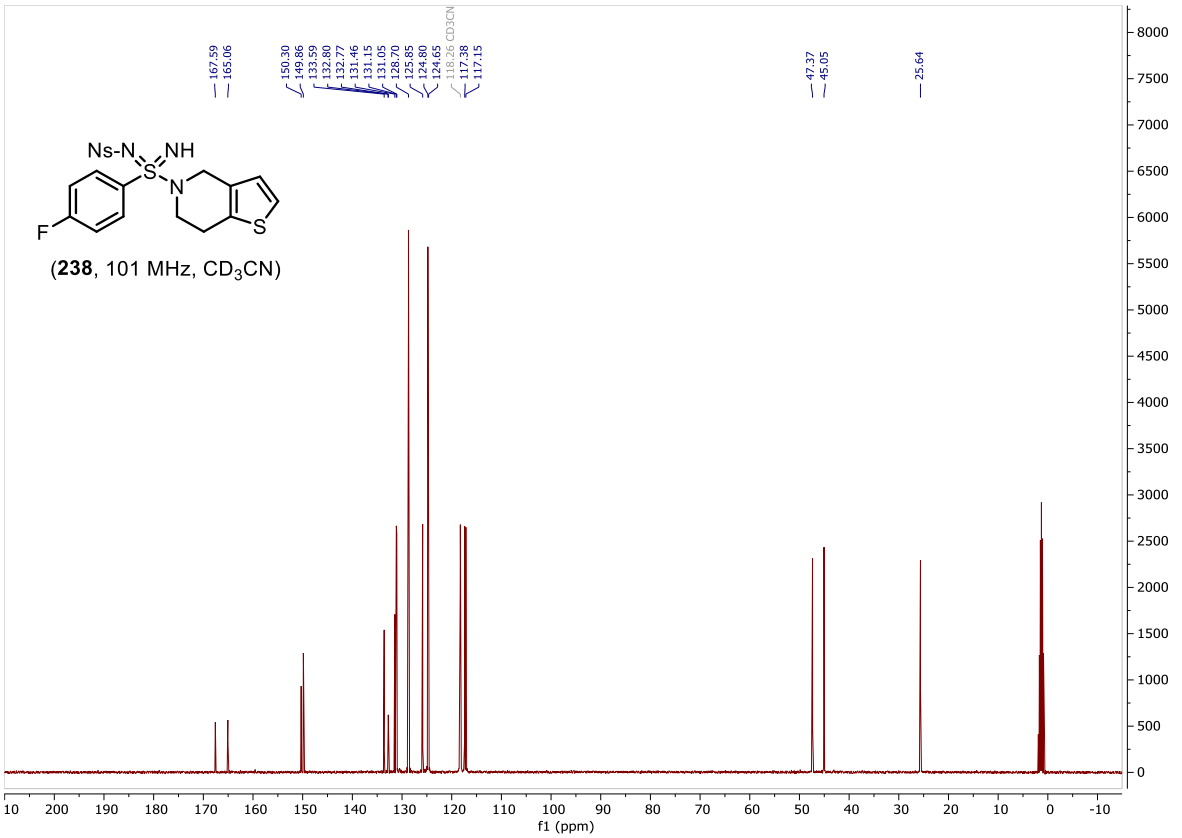

HN
N-Cbz
S
N
N
N
F
Cl
O
(236, 377 MHz, CD3CN)
f1 (ppm)

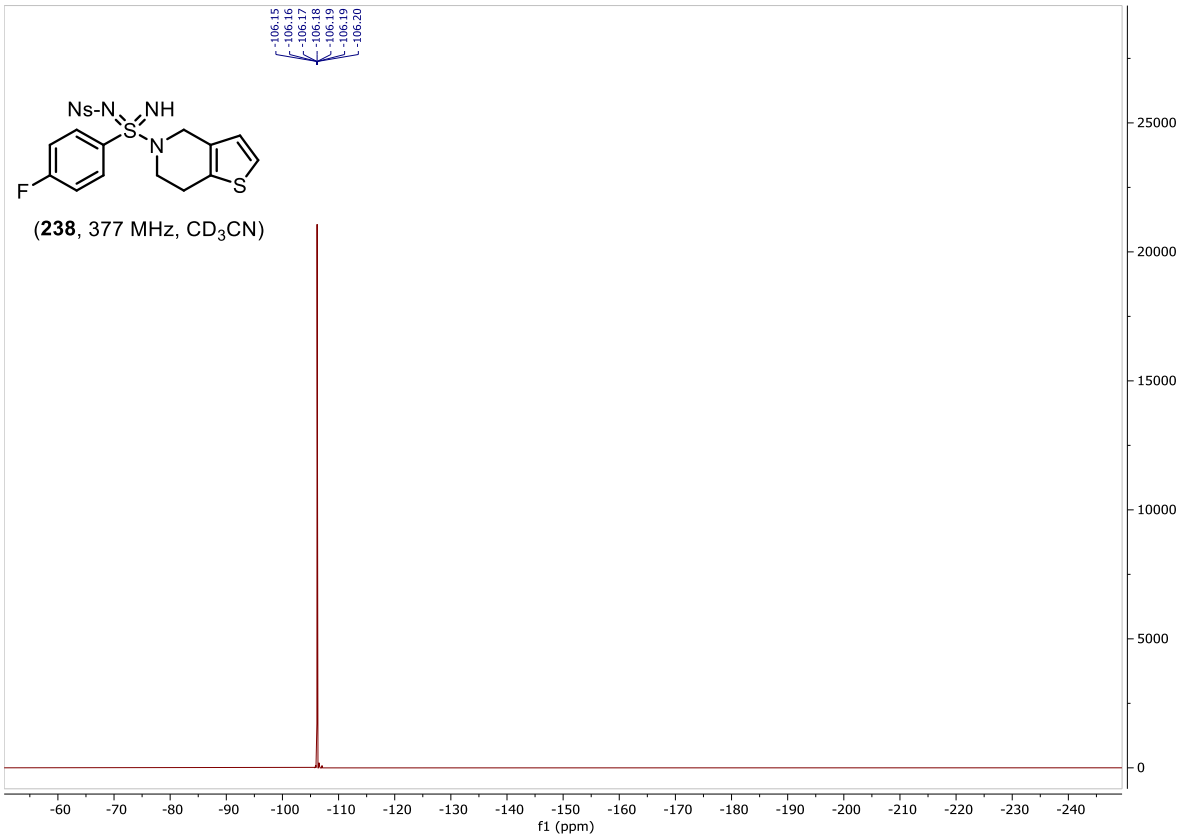

HN
N-Ts
S
N
O
F
(237, 400 MHz, CD3CN)
f1 (ppm)

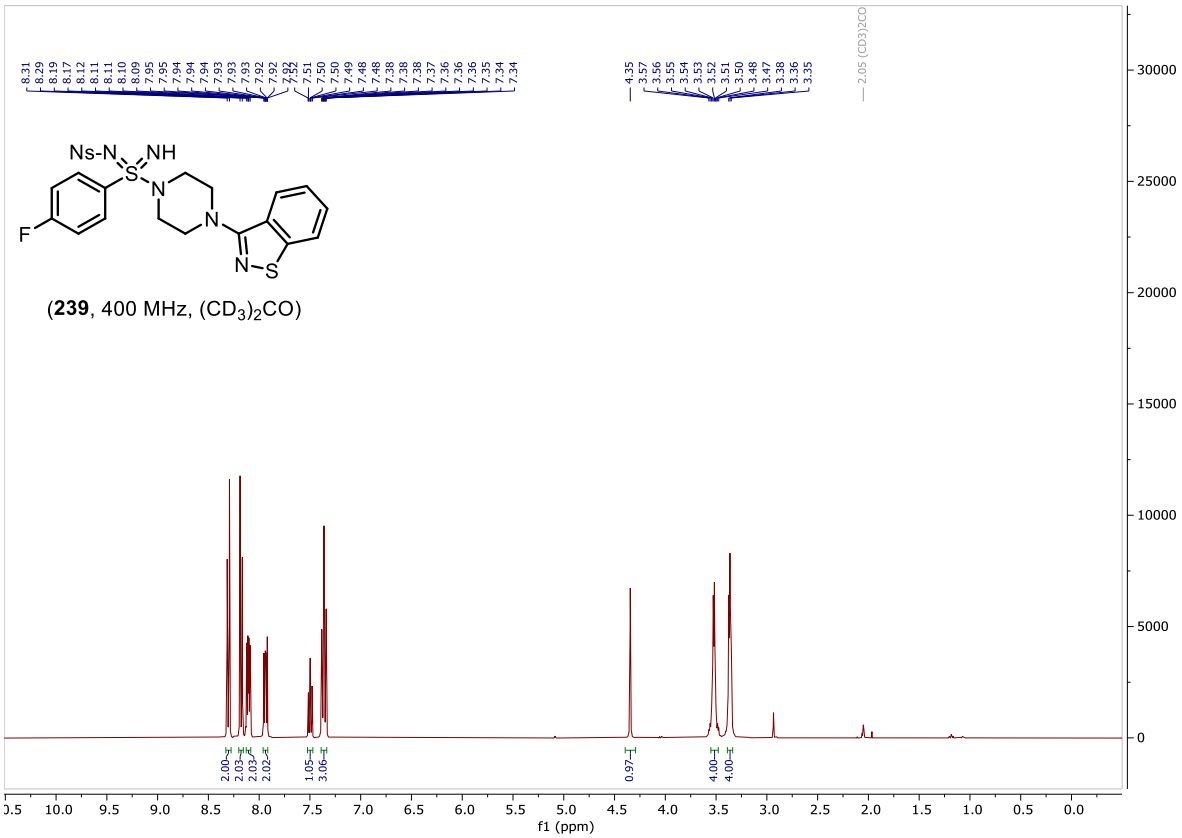

HN
N-Ts
S
N
O
F
(237, 101 MHz, CD3CN)
f1 (ppm)

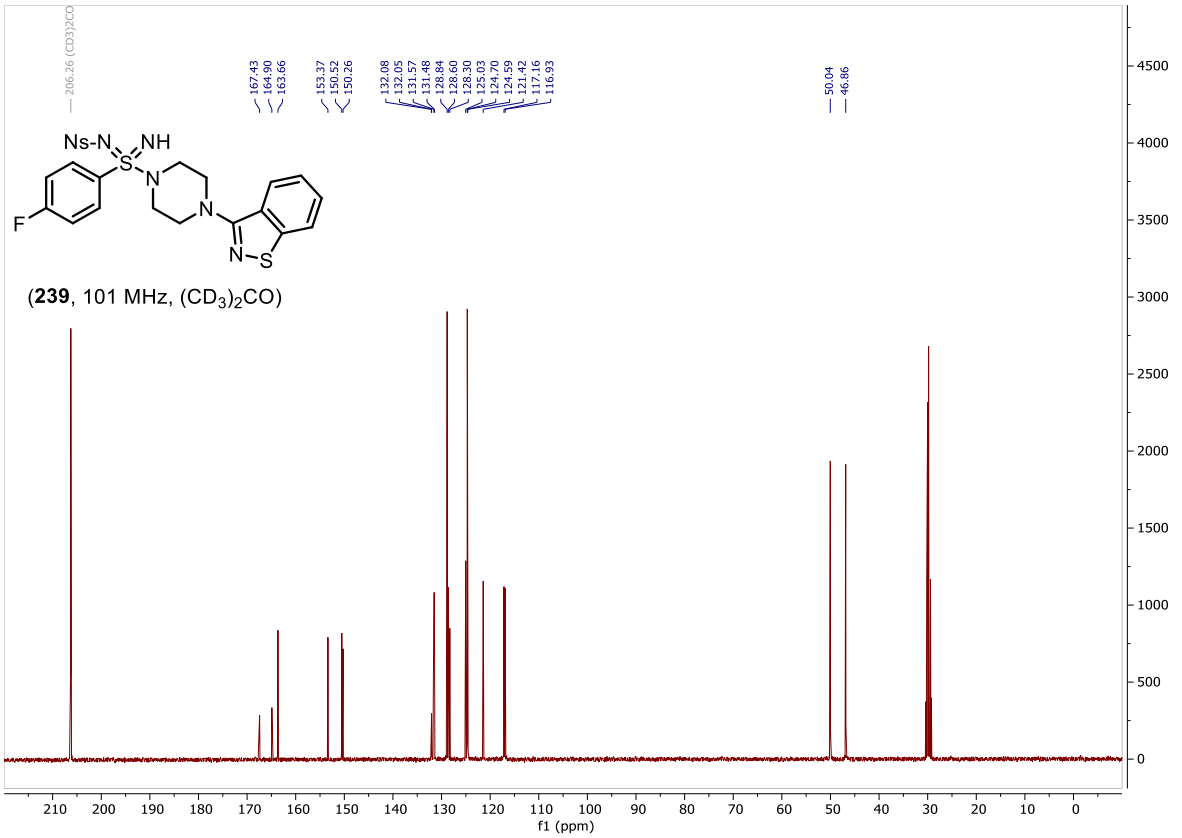

-106.77
-106.78
-106.79
-106.80
-106.81
-106.81
-106.82
-106.83
-106.84
HN
N-Ts
S
N
O
F
(237, 377 MHz, CD3CN)
f1 (ppm)

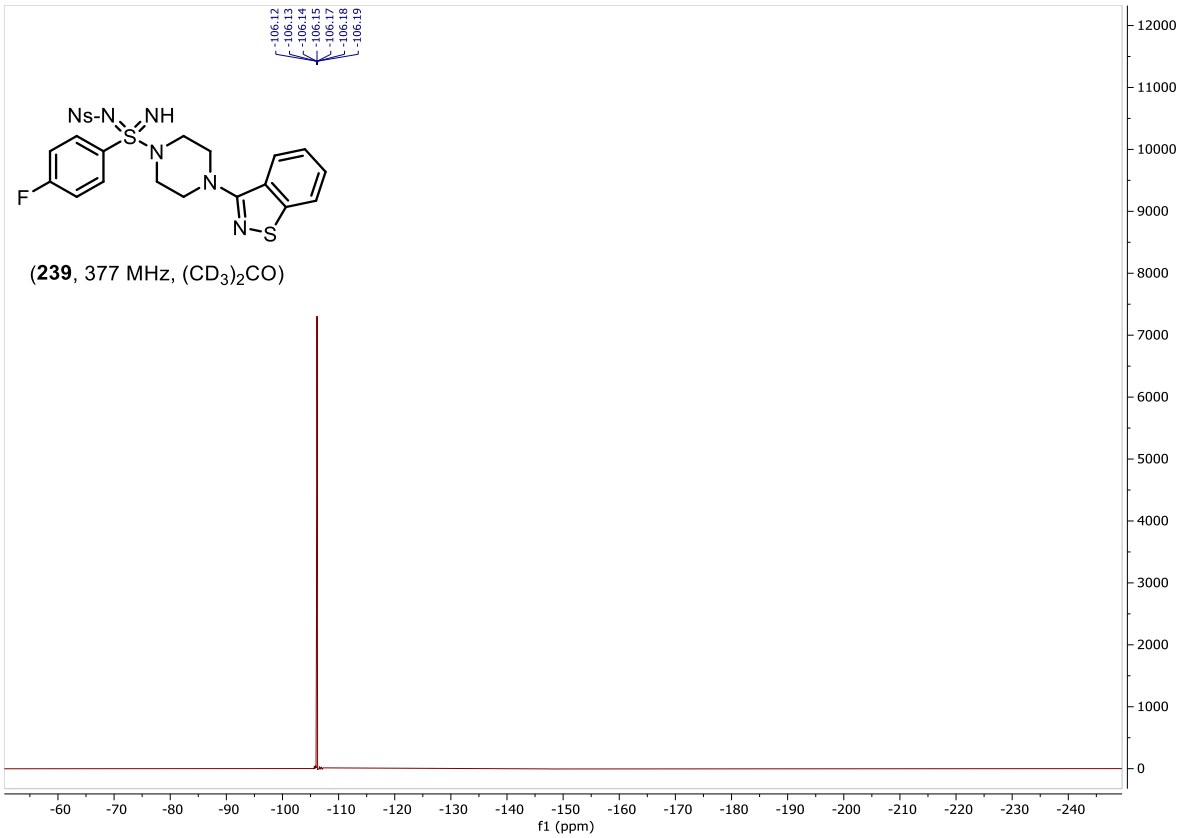

8.12
8.10
8.03
8.00
7.26
7.26
7.25
7.24
7.24
7.24
7.24
7.23
7.22
7.22
7.06
7.05
6.57
6.55
4.11
4.11
4.10
4.08
4.07
4.07
3.93
3.93
3.92
3.89
3.89
3.88
3.85
3.67
3.65
3.64
3.64
3.64
3.64
3.62
3.61
3.21
3.20
3.20
3.18
3.17
3.17
3.15
2.78
2.77
2.76
2.75
2.75
2.74
2.73
1.94
CD3CN
Ns-N
NH
S
N
F
S
(238, 400 MHz, CD3CN)
2.00
2.00
2.00
2.01
1.00
1.00
1.02
1.03
1.00
1.01
1.01
2.07
f1 (ppm)


167.59
165.06
150.30
149.86
133.59
132.80
132.77
131.46
131.15
131.05
128.70
125.85
124.80
124.65
118.26 CD3CN
117.38
117.15
47.37
45.05
25.64
Ns-N
NH
S
N
F
S
(238, 101 MHz, CD3CN)
f1 (ppm)

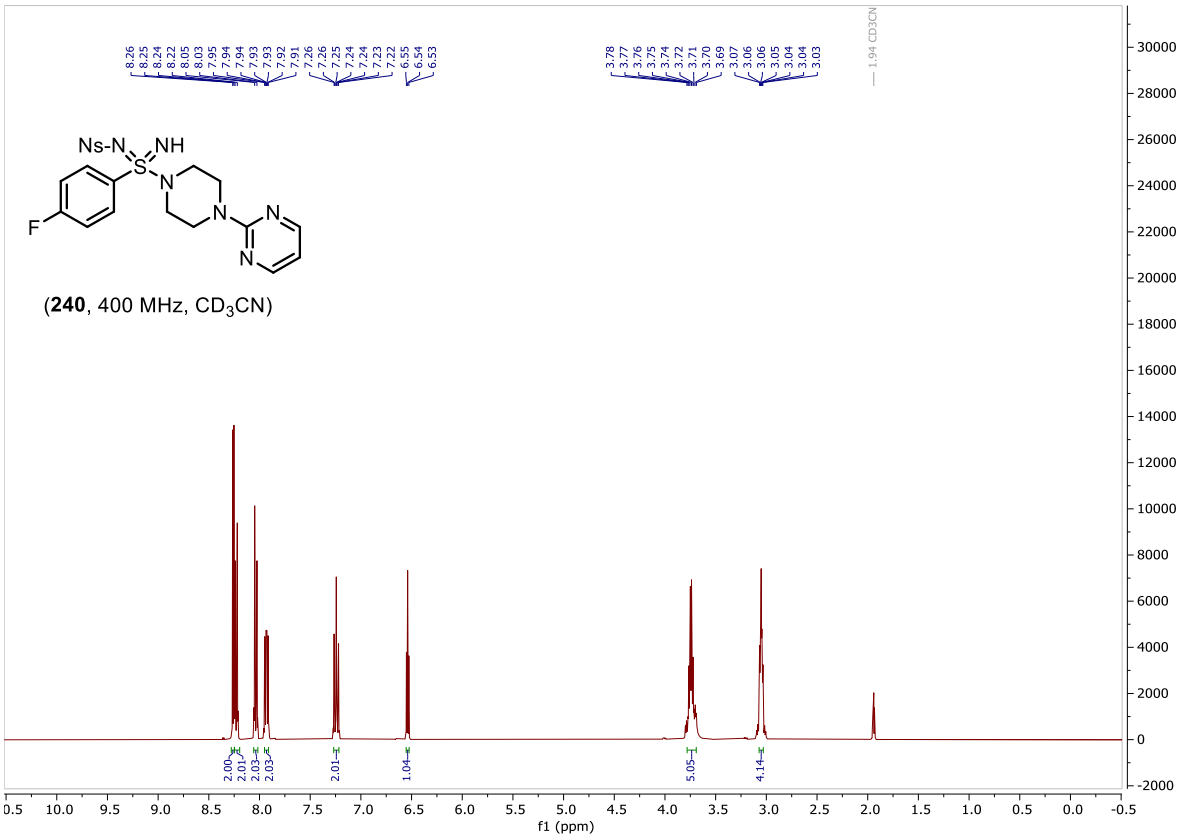

106.15
106.16
106.17
106.18
106.19
106.19
106.20
Ns-N
NH
S
N
F
S
(238, 377 MHz, CD3CN)
f1 (ppm)


Ns-N
NH
S
N
N
F
N
S
(239, 400 MHz, (CD3)2CO)
f1 (ppm)

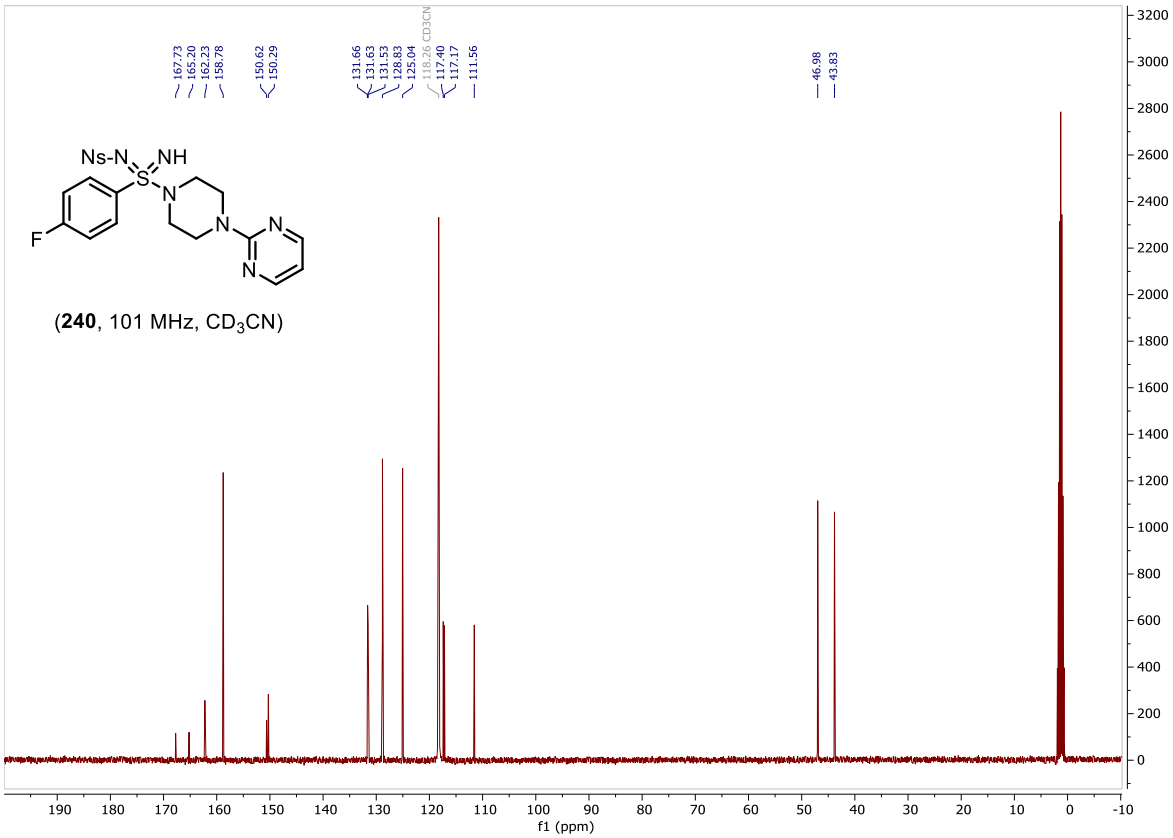

Ns-N
NH
S
N
N
F
N
S
(239, 101 MHz, (CD3)2CO)
f1 (ppm)

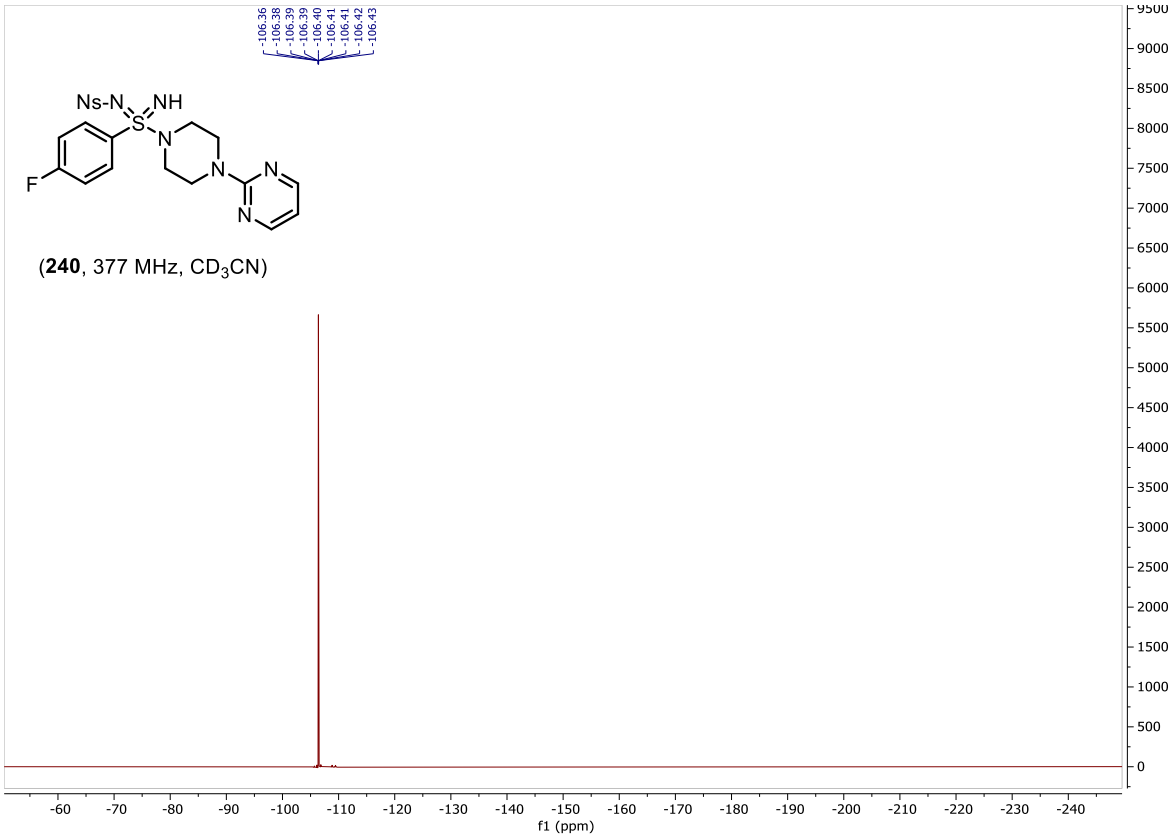


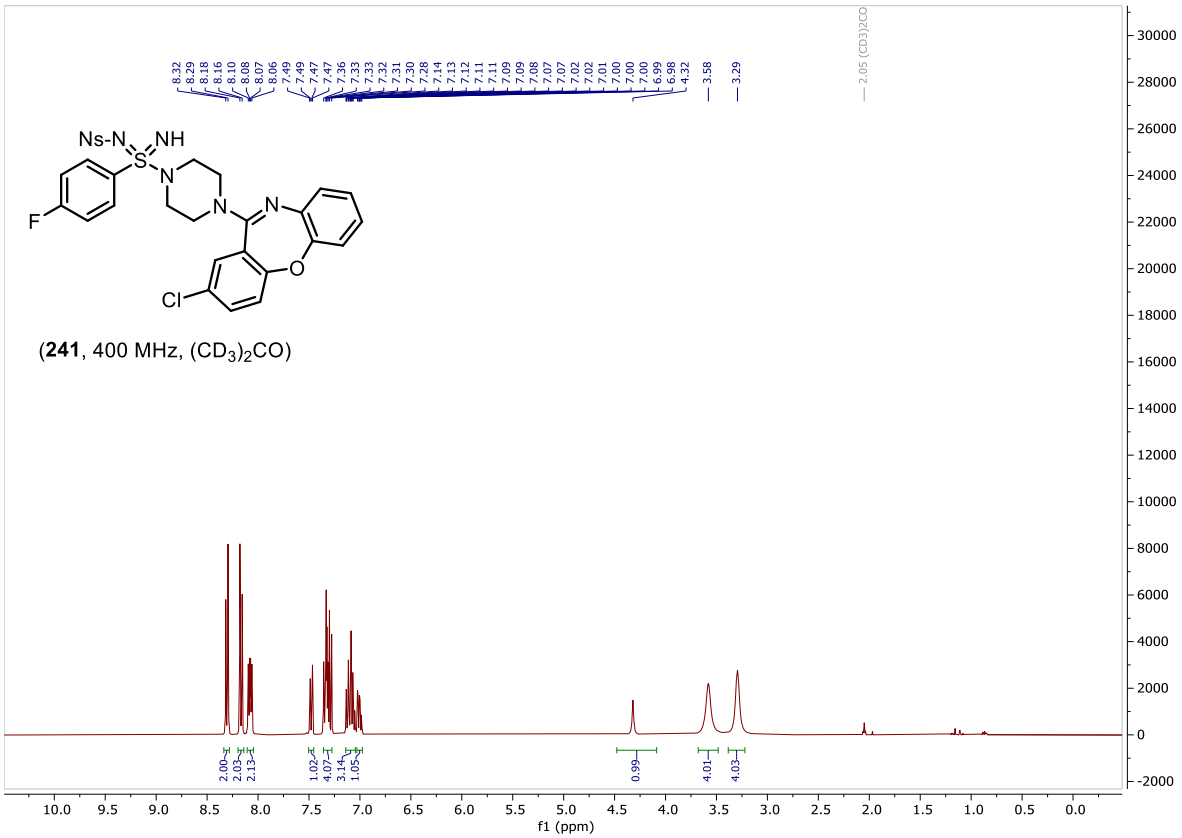
(**239**, 377 MHz, $(CD_3)_2CO$)

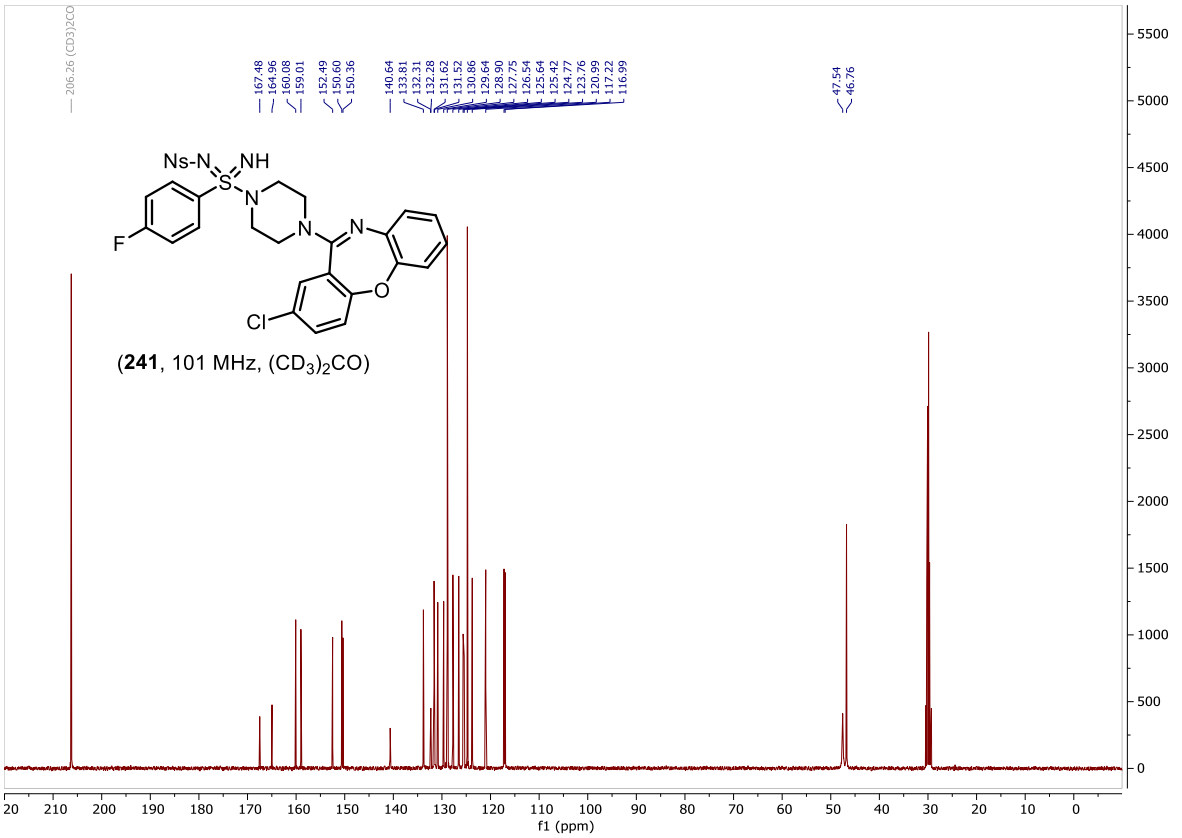


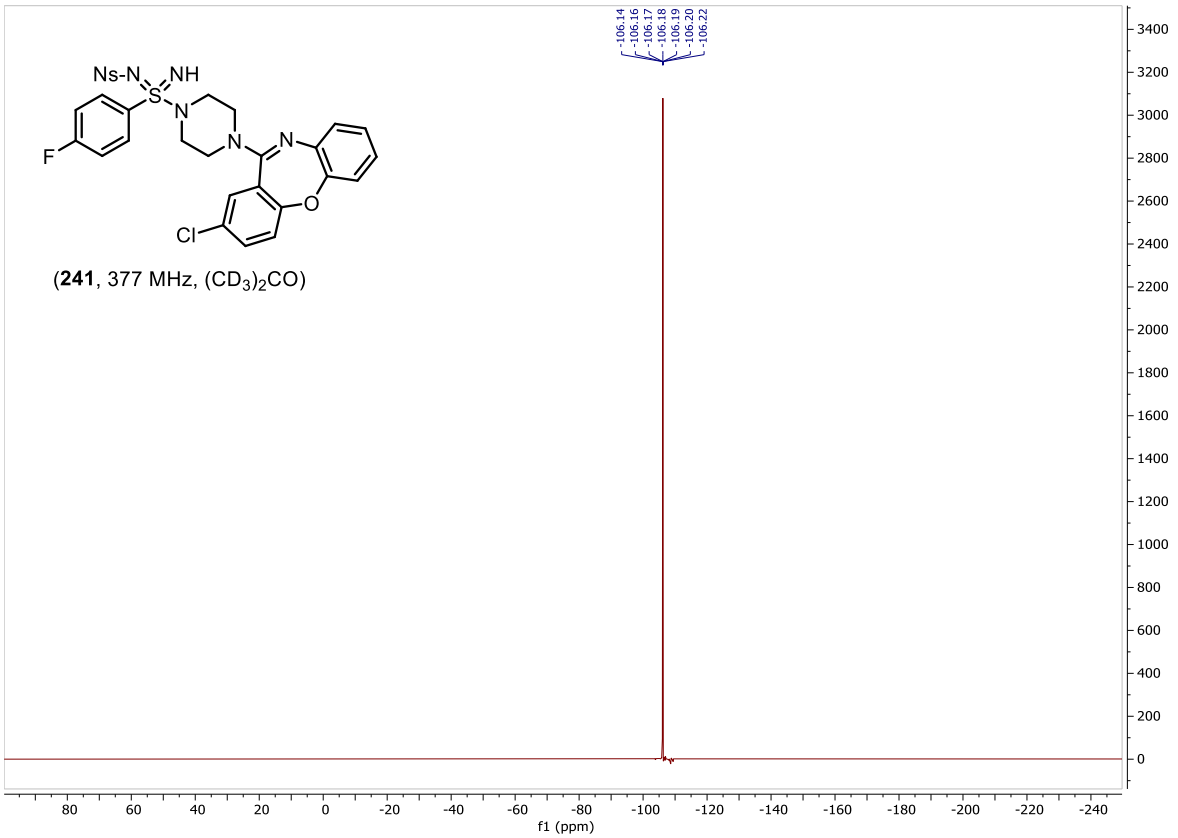
(**240**, 400 MHz, CD_3CN)


167.73
165.20
162.23
158.78
150.62
150.29
131.66
131.63
131.53
128.83
125.04
118.26 CD3CN
117.40
117.17
111.56
46.98
43.83
Ns-N
NH
S
N
F
(240, 101 MHz, CD3CN)
f1 (ppm)

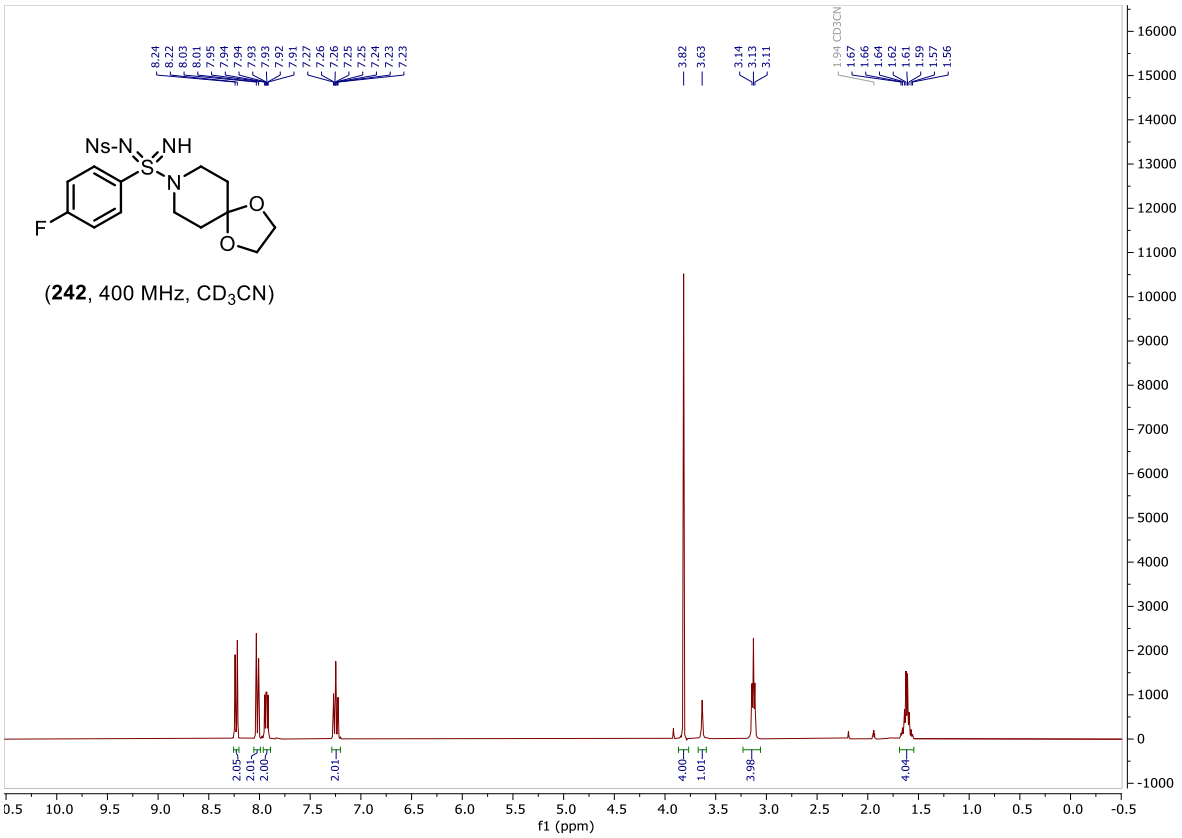

-106.36
-106.38
-106.39
-106.39
-106.40
-106.41
-106.41
-106.42
-106.43
Ns-N
NH
S
N
F
(240, 377 MHz, CD3CN)
f1 (ppm)


Ns-N
NH
S
N
N
N
F
Cl
O
(241, 400 MHz, (CD3)2CO)
f1 (ppm)

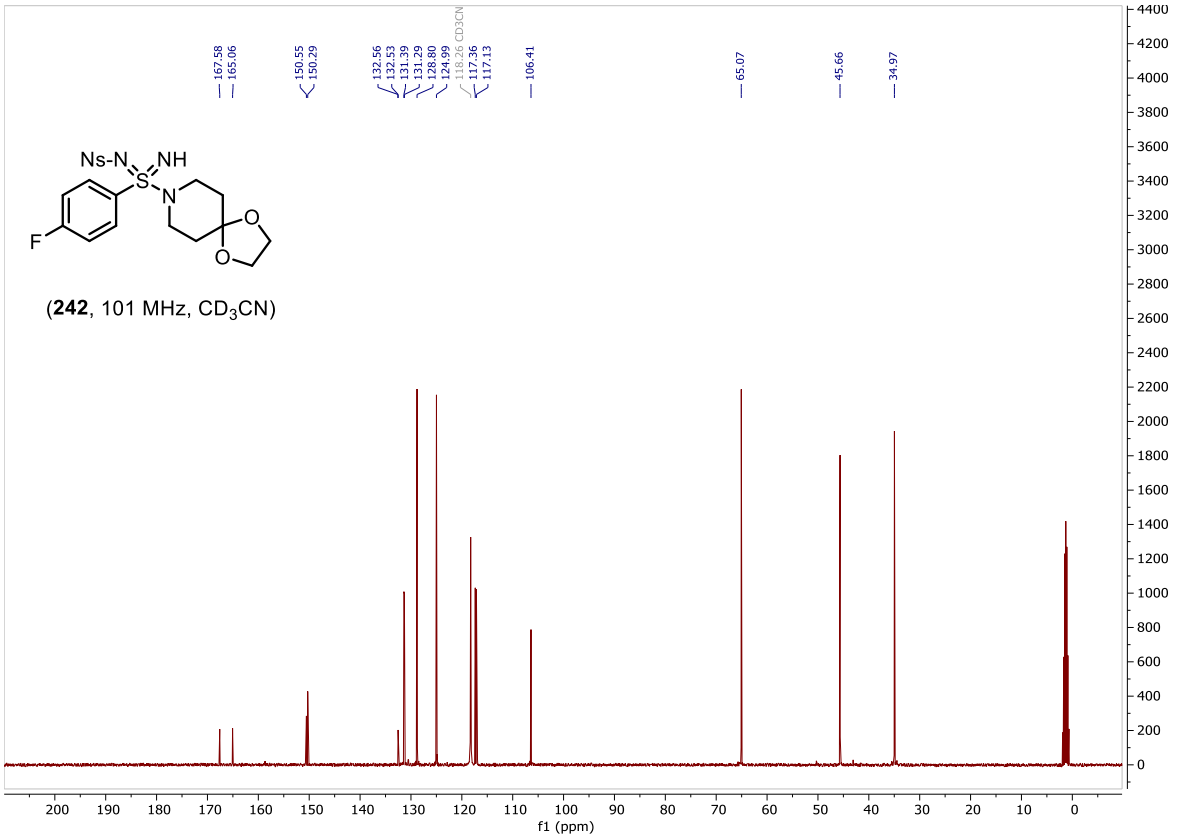

Ns-N
NH
S
N
N
N
F
Cl
O
(241, 101 MHz, (CD3)2CO)
f1 (ppm)



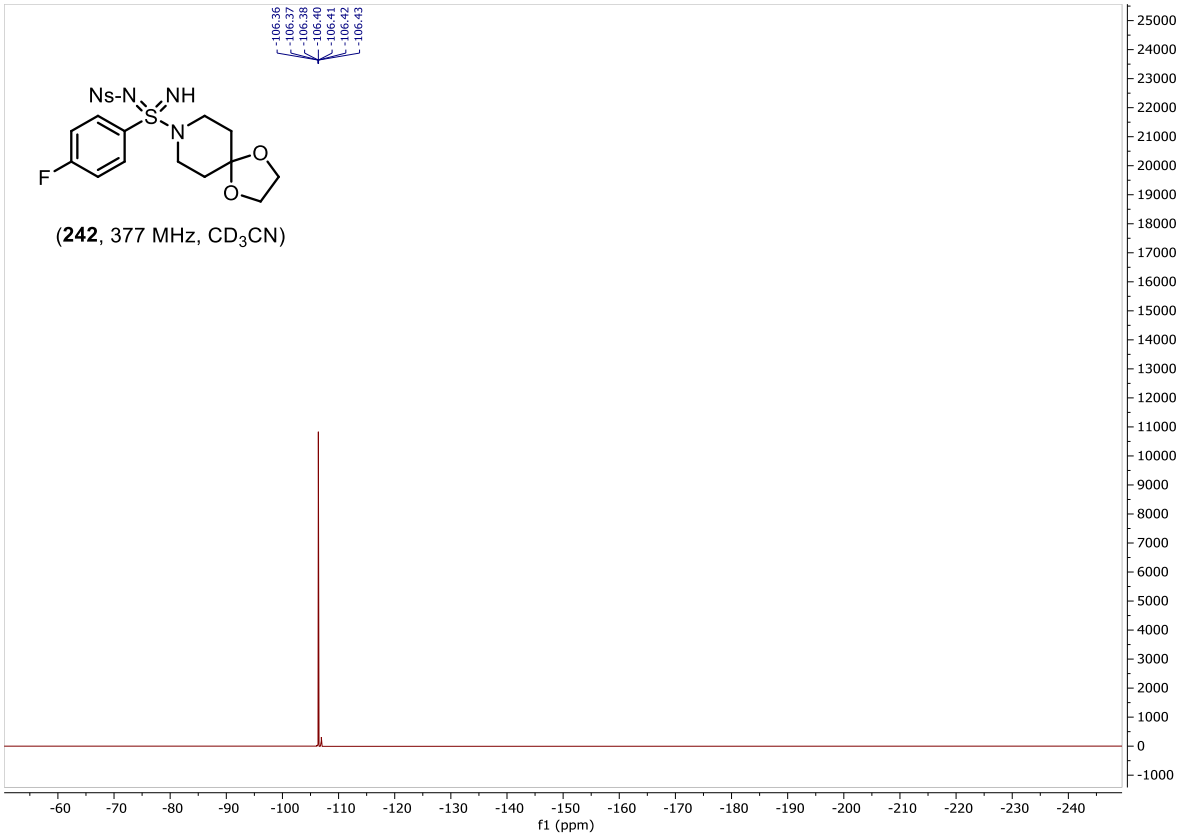
(**241**, 377 MHz, $(CD_3)_2CO$)



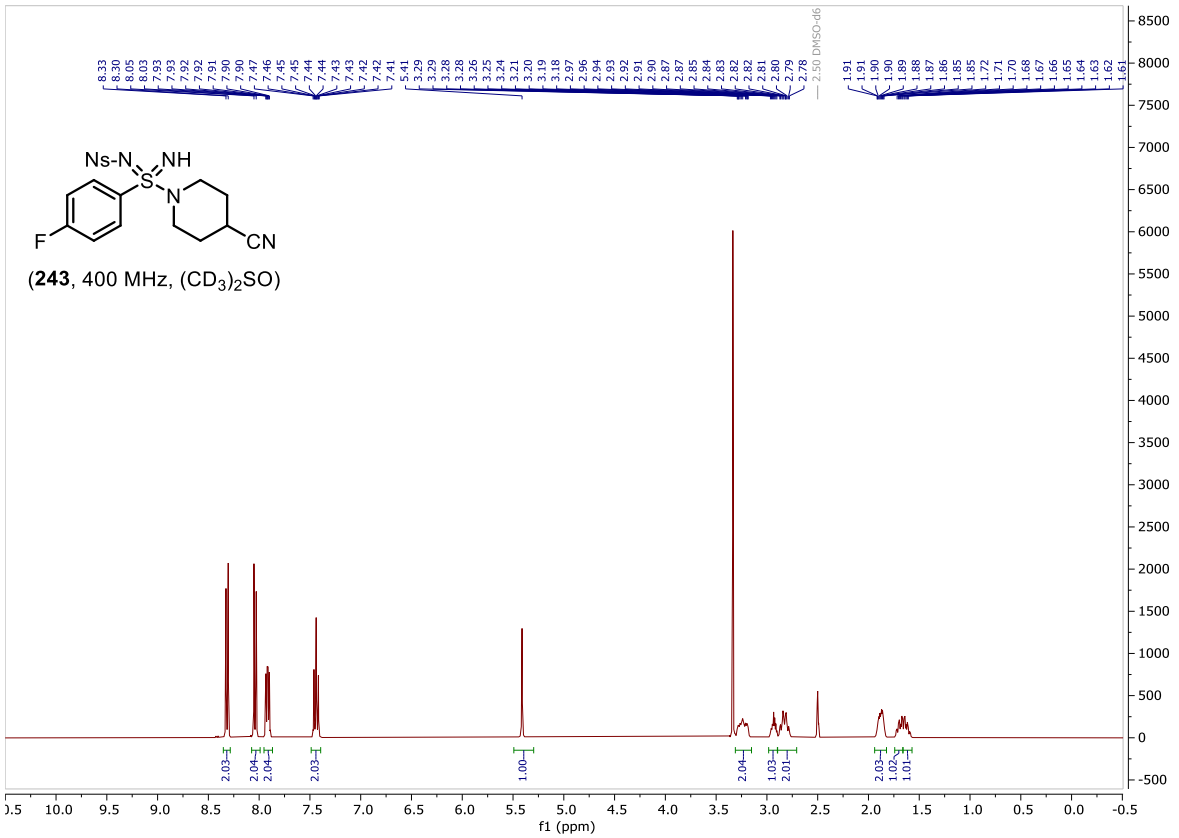
(**242**, 400 MHz, CD_3CN)

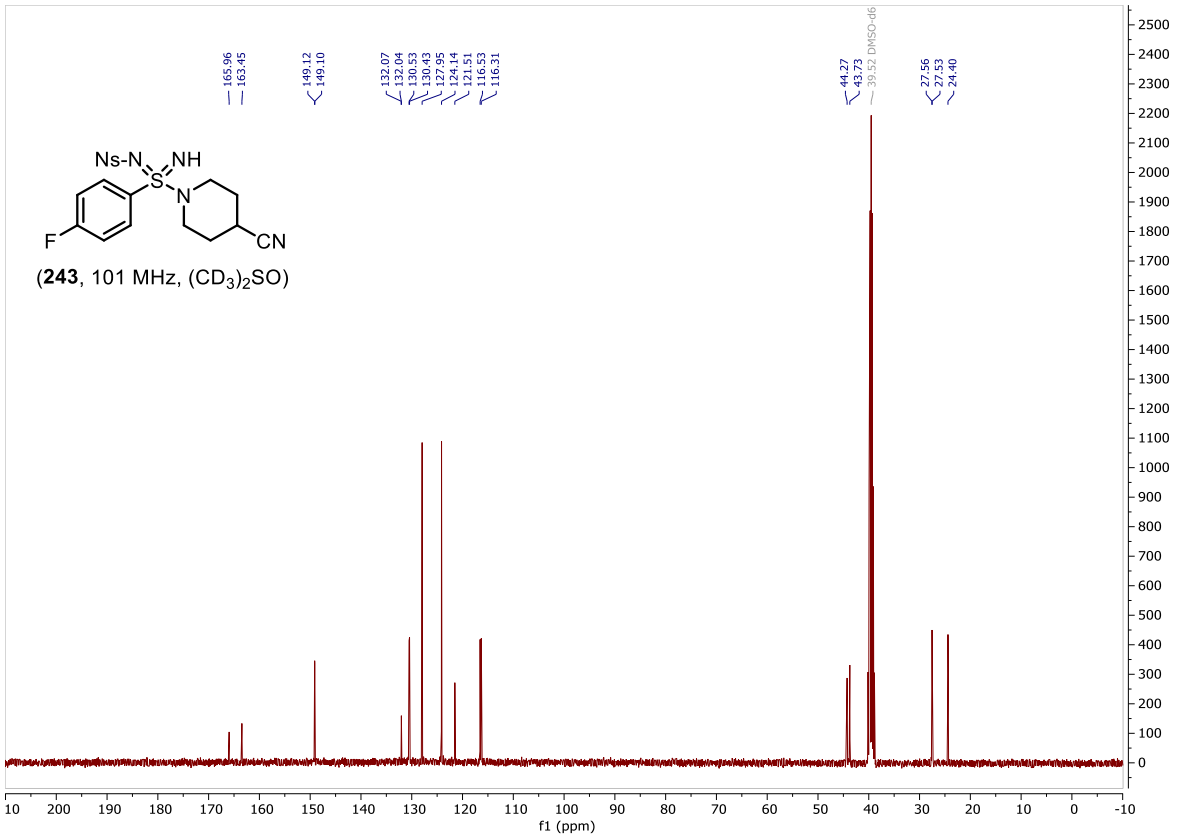


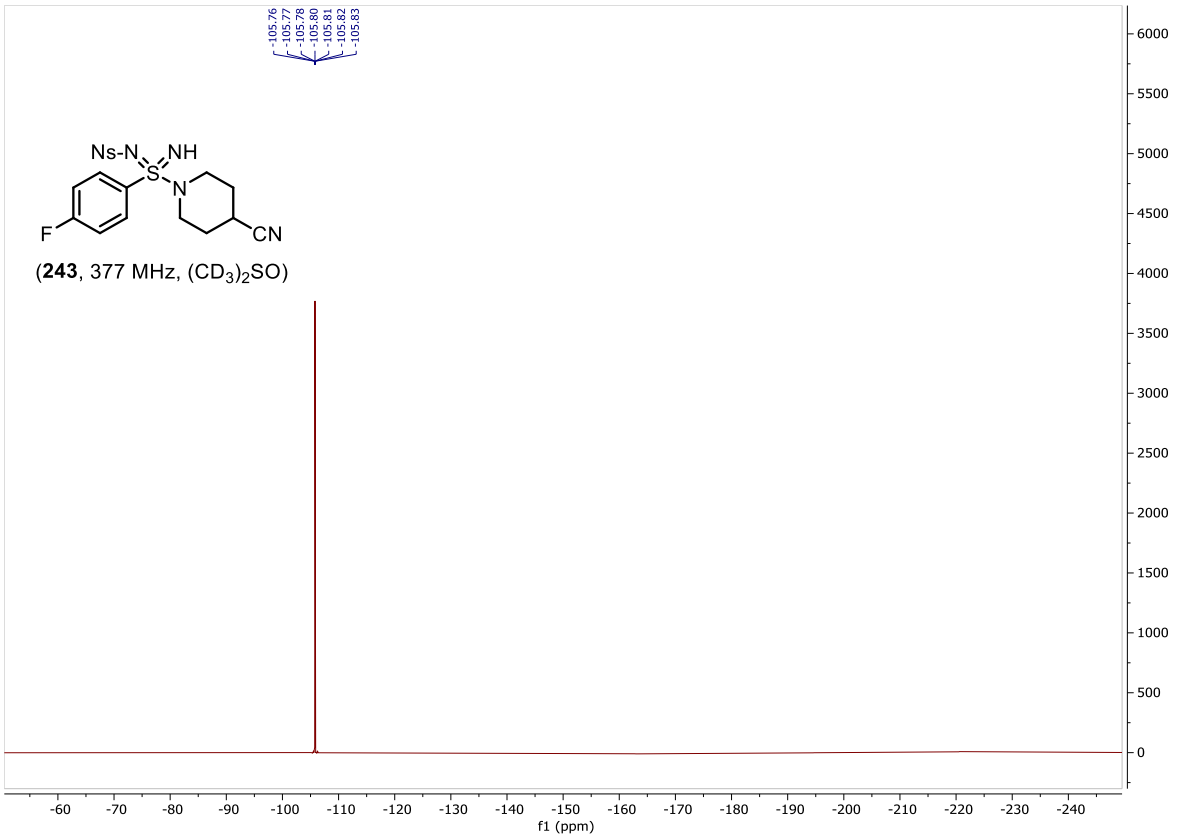
(**242**, 101 MHz, CD_3CN)



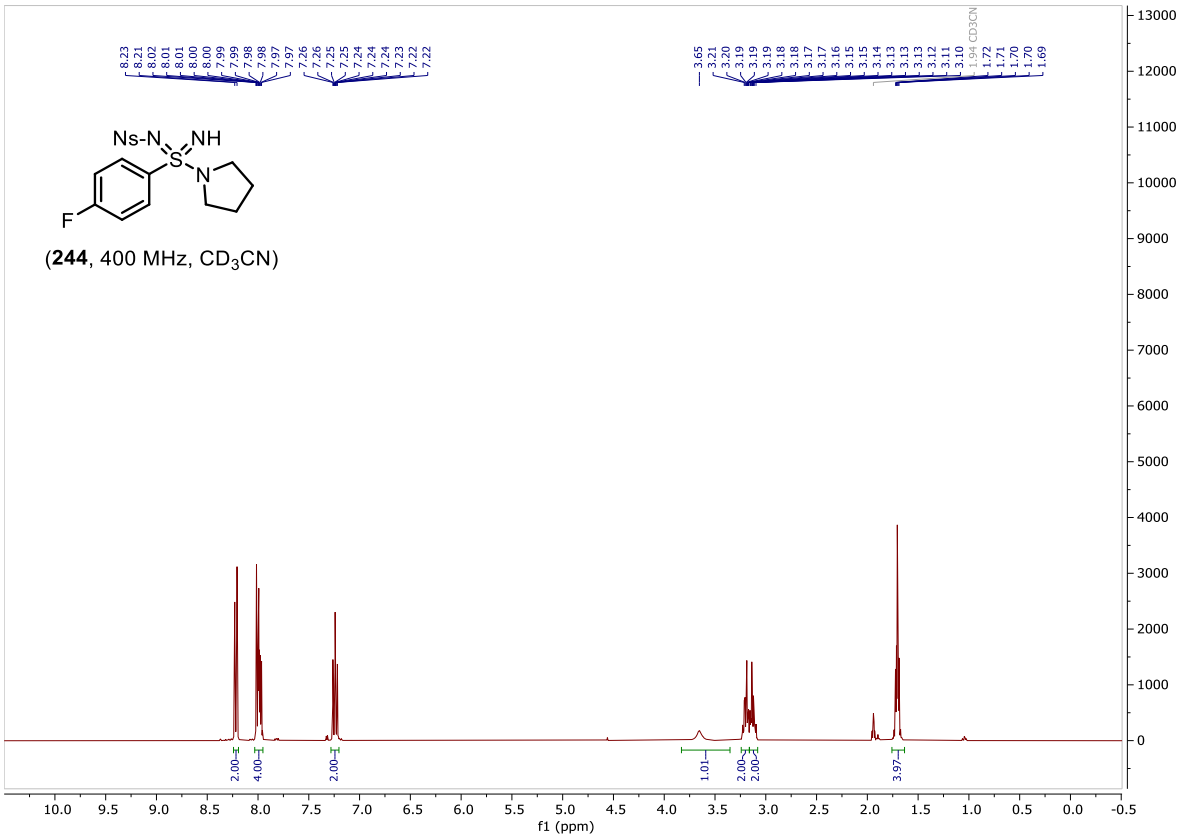
(**242**, 377 MHz, CD_3CN)


Ns-N
NH
S
N
F
CN
(243, 400 MHz, (CD3)2SO)
f1 (ppm)

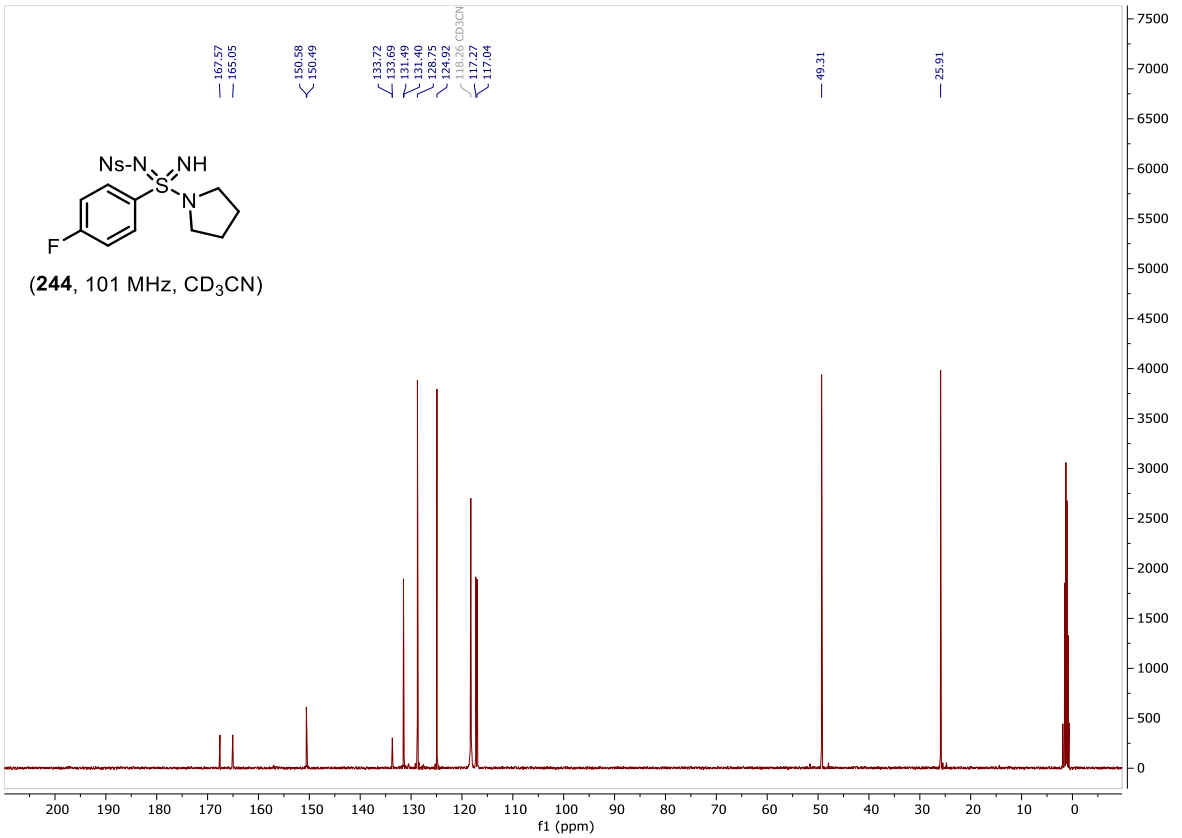

Ns-N
NH
S
N
F
CN
(243, 101 MHz, (CD3)2SO)
f1 (ppm)



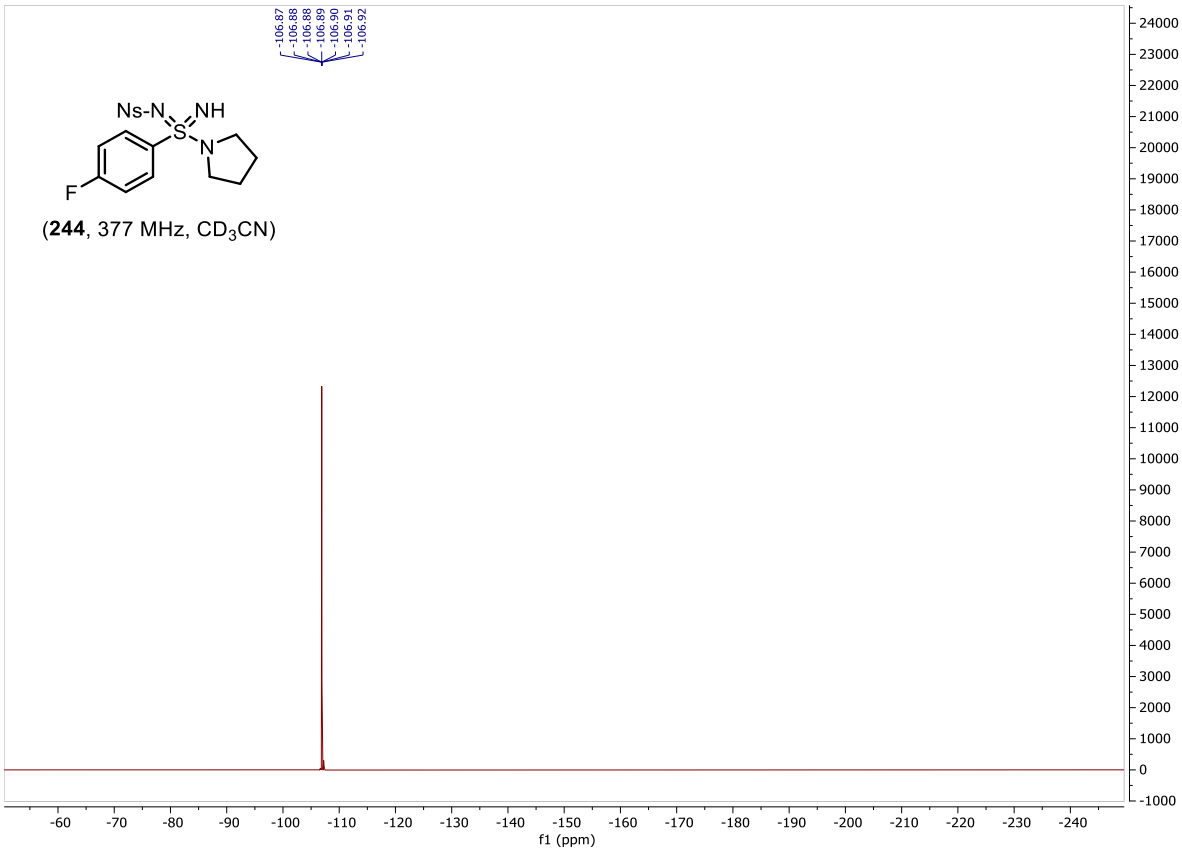
(**243**, 377 MHz, $(CD_3)_2SO$)



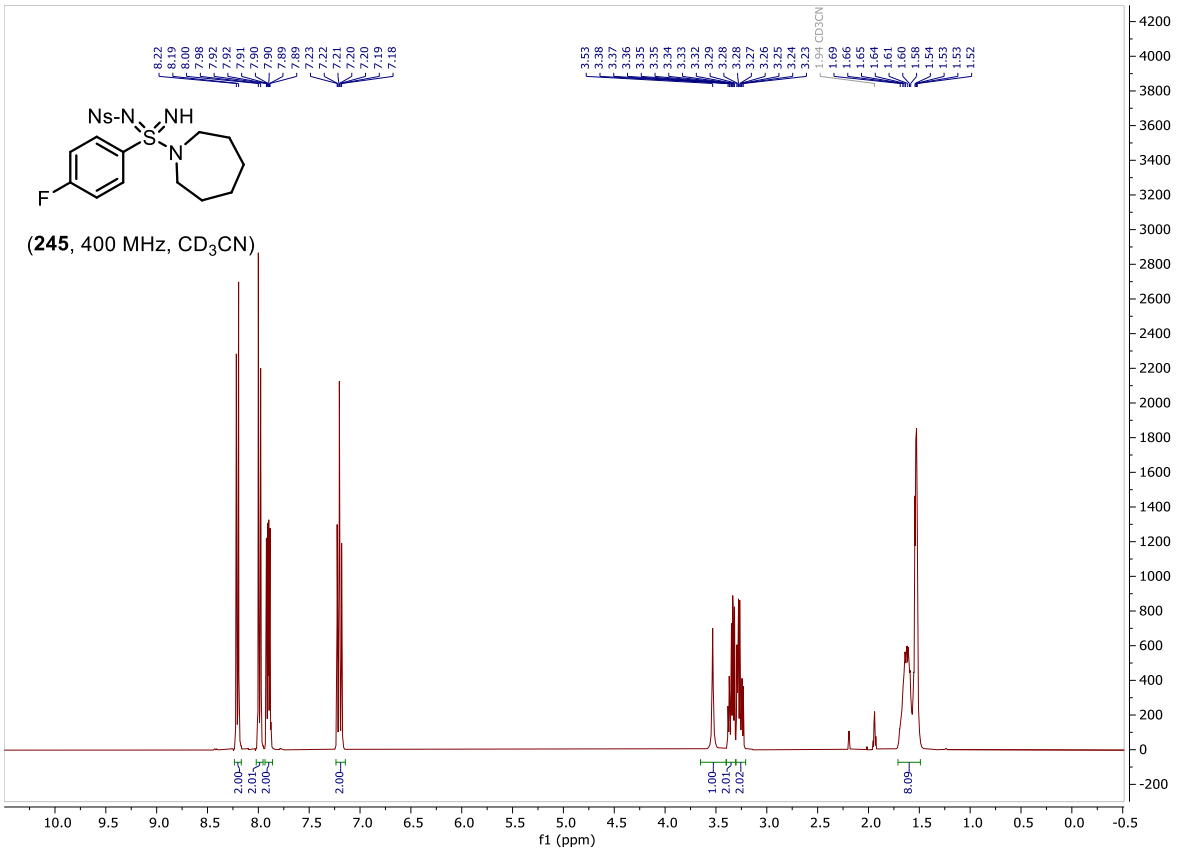
(**244**, 400 MHz, CD_3CN)

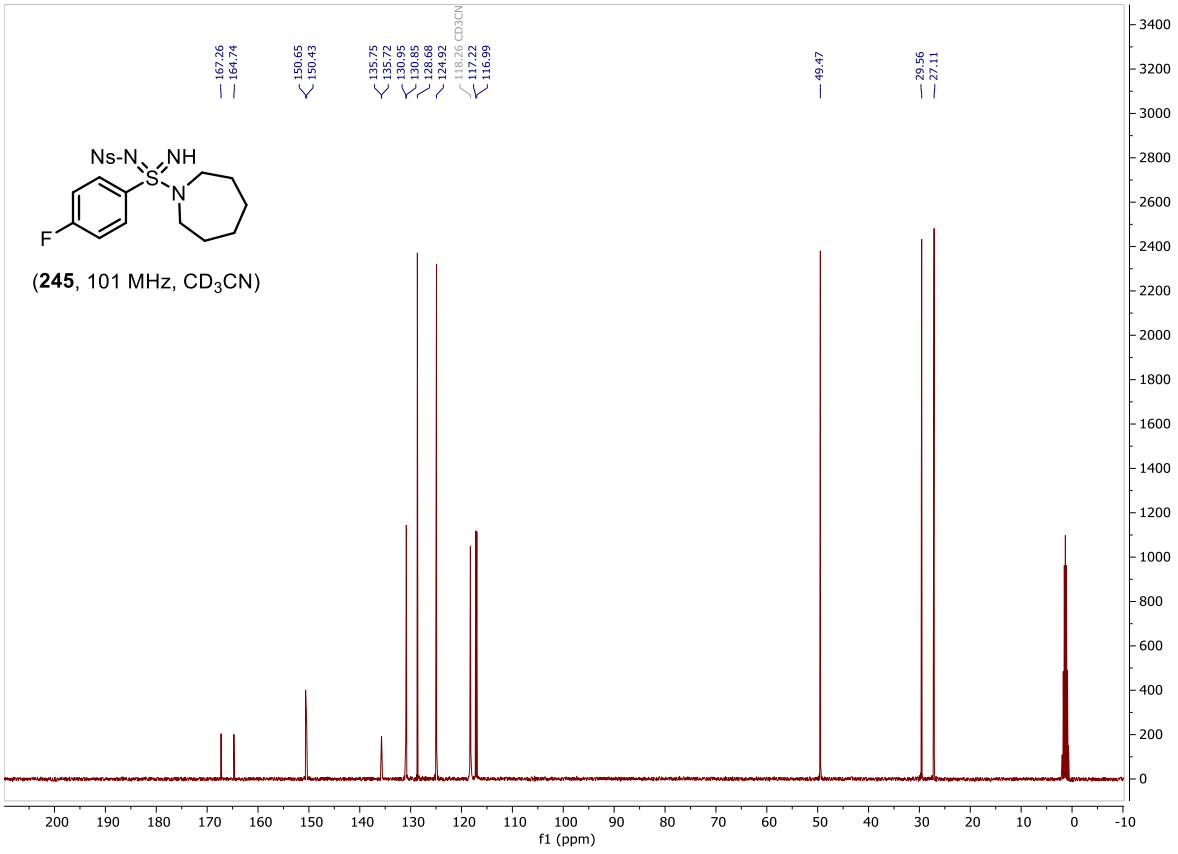


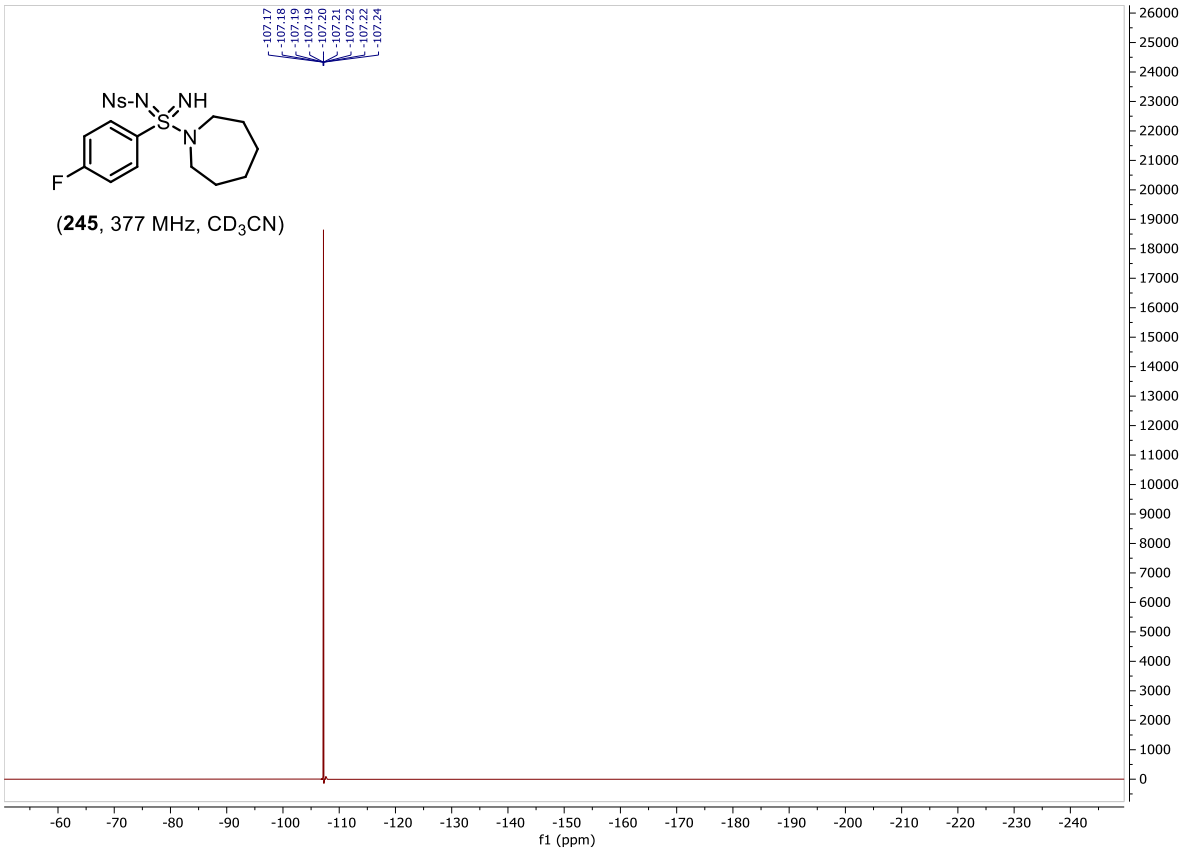
(**244**, 101 MHz, CD_3CN)



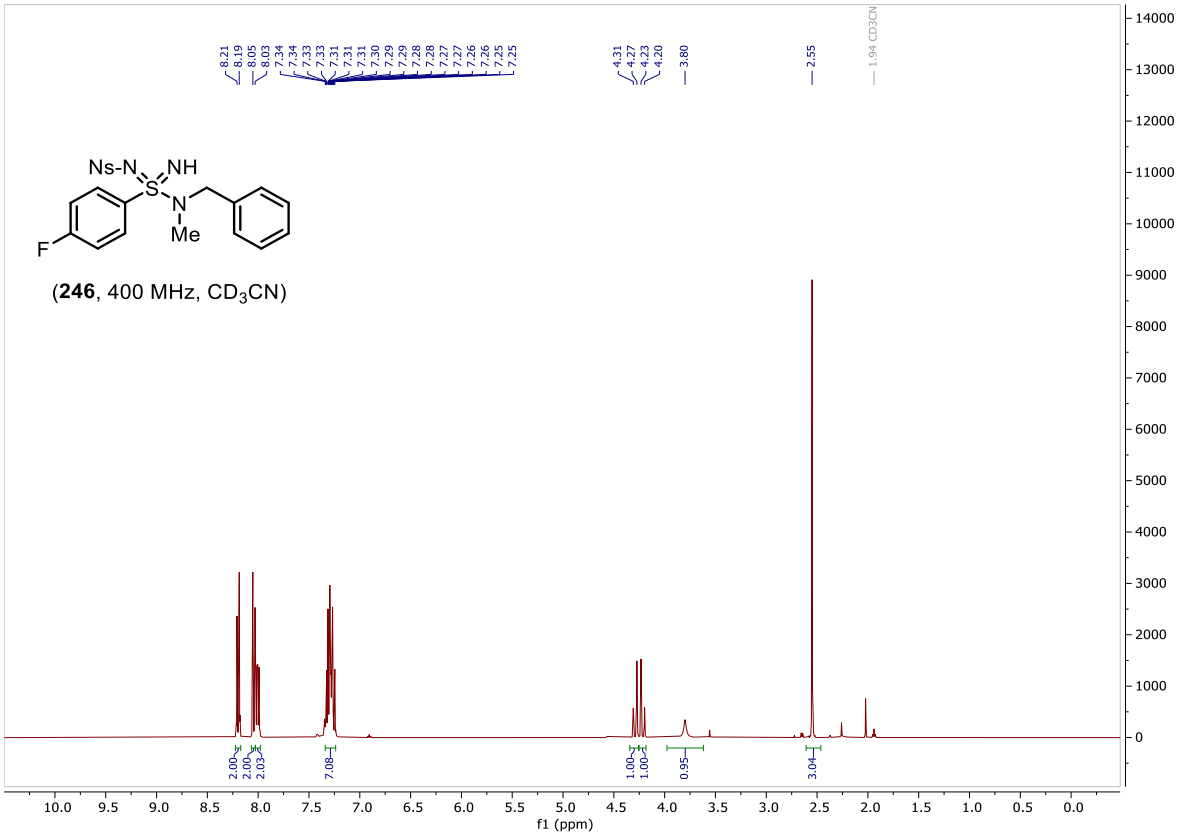
(**244**, 377 MHz, CD_3CN)


Ns-N
NH
S
N
F
(245, 400 MHz, CD3CN)
f1 (ppm)

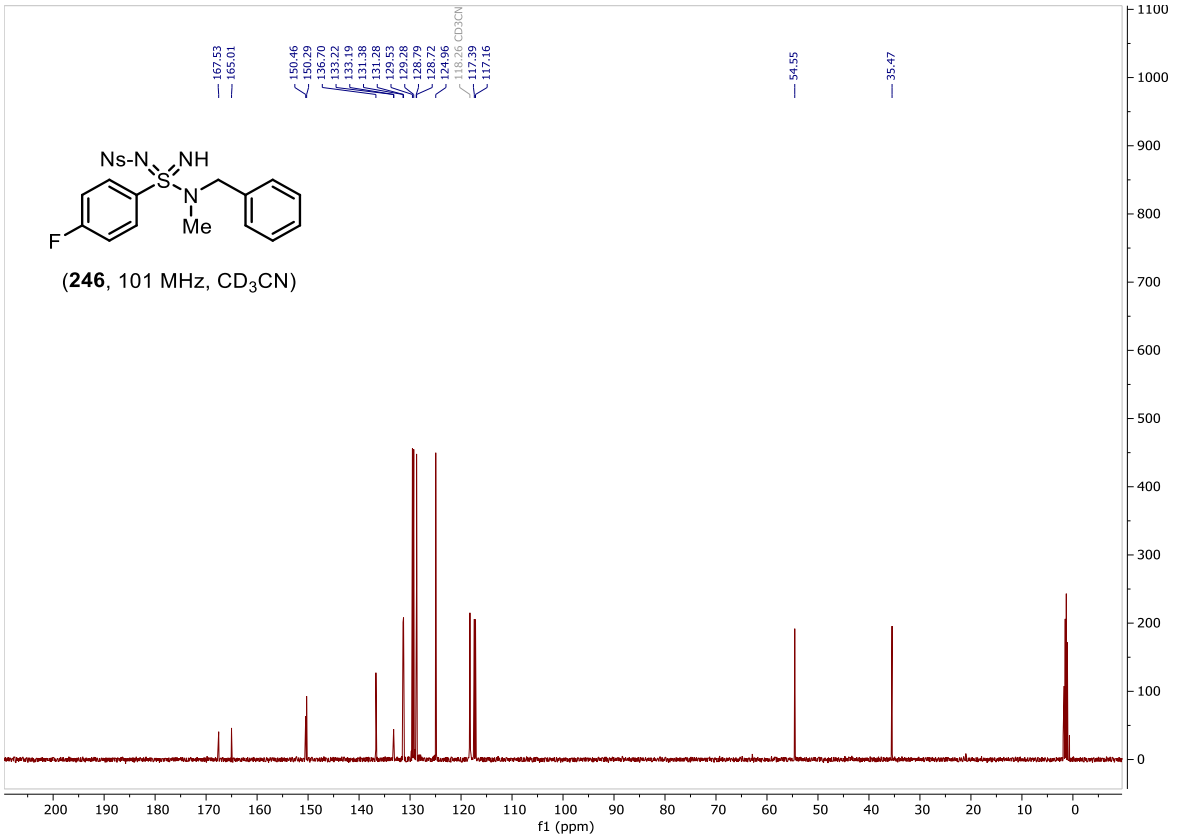

Ns-N
NH
S
N
F
(245, 101 MHz, CD3CN)
f1 (ppm)



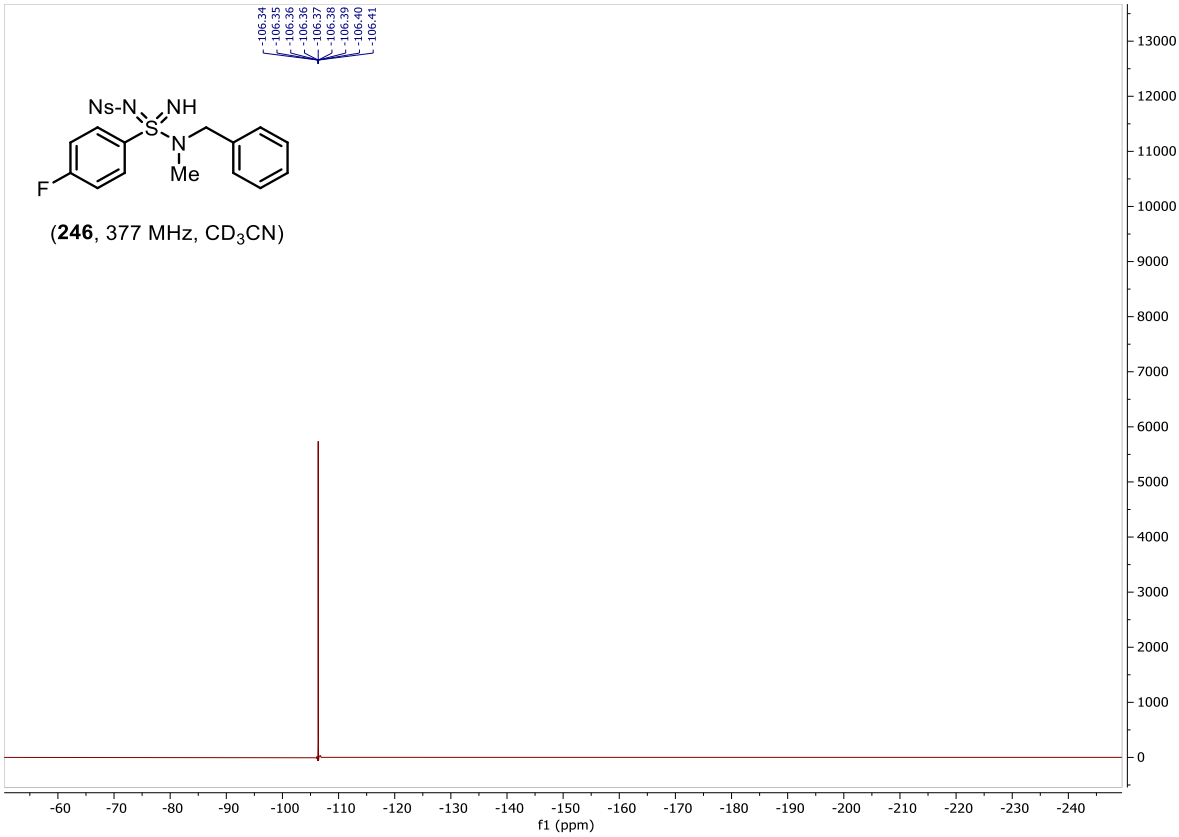
(**245**, 377 MHz, CD_3CN)



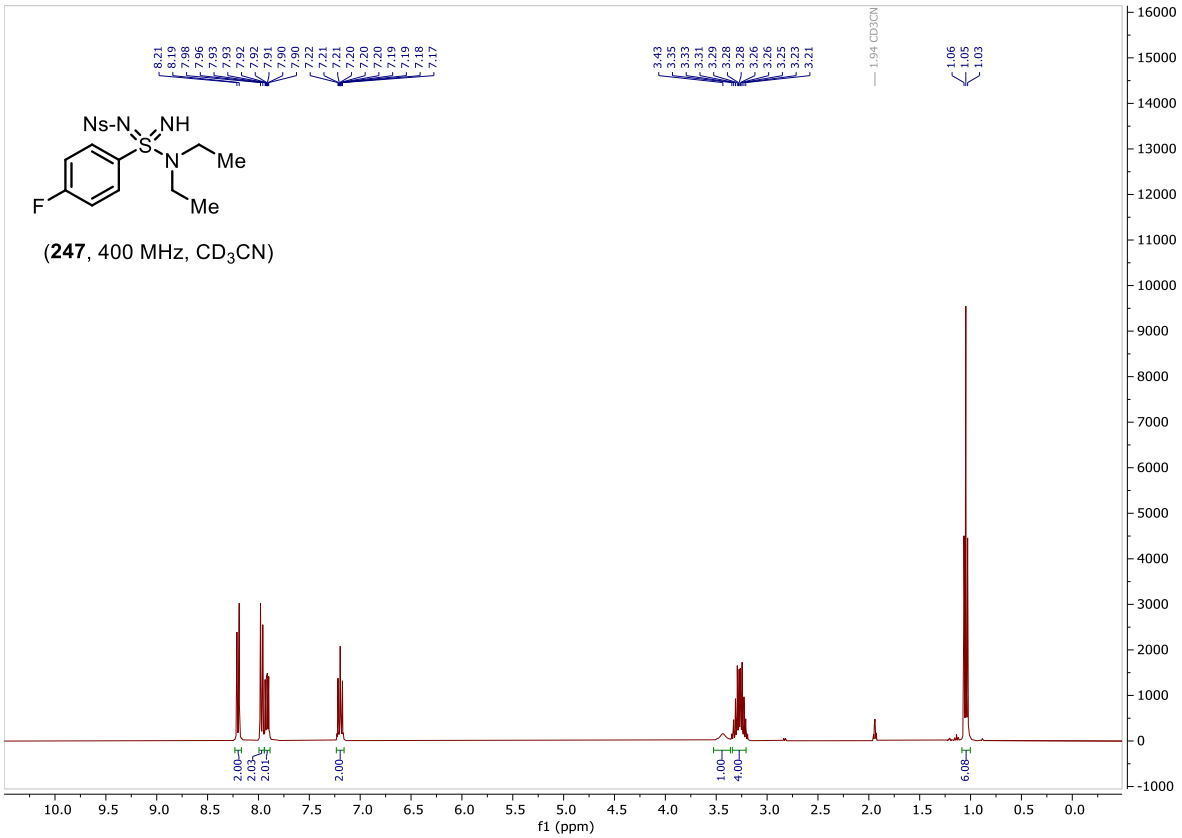
(**246**, 400 MHz, CD_3CN)

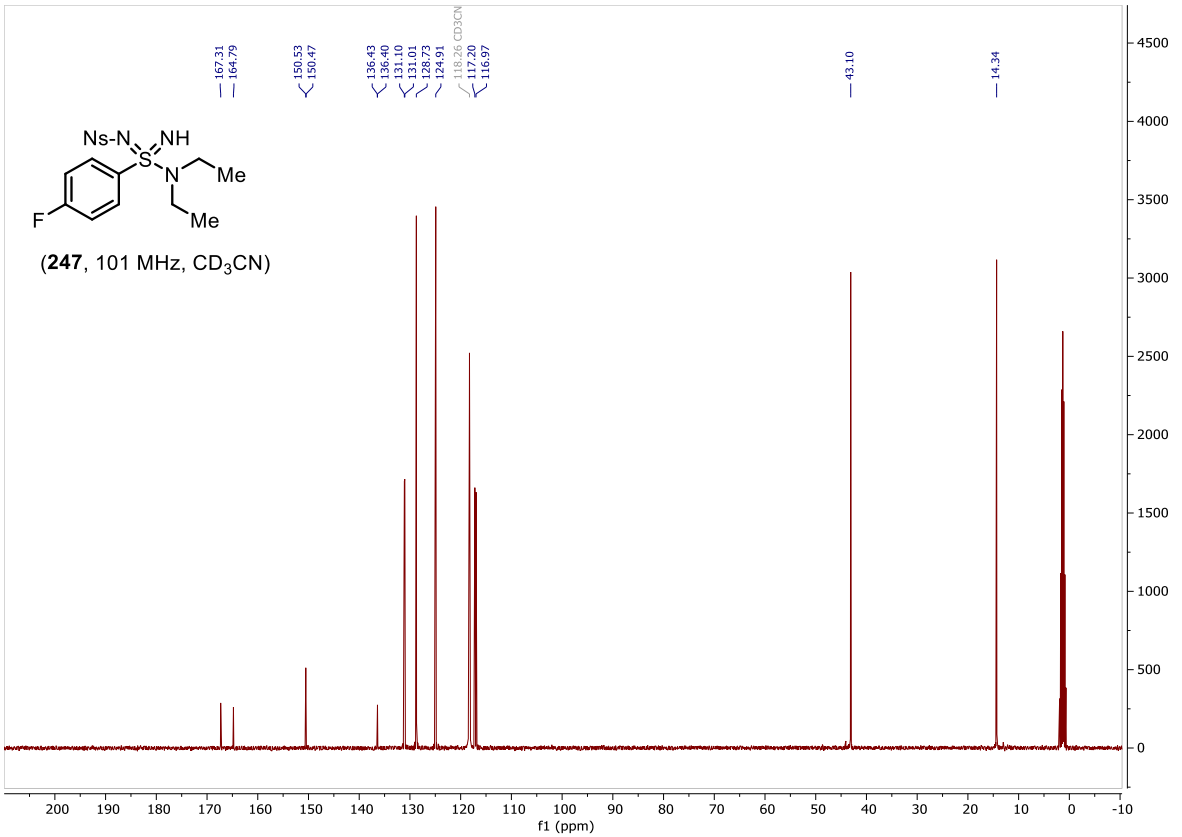


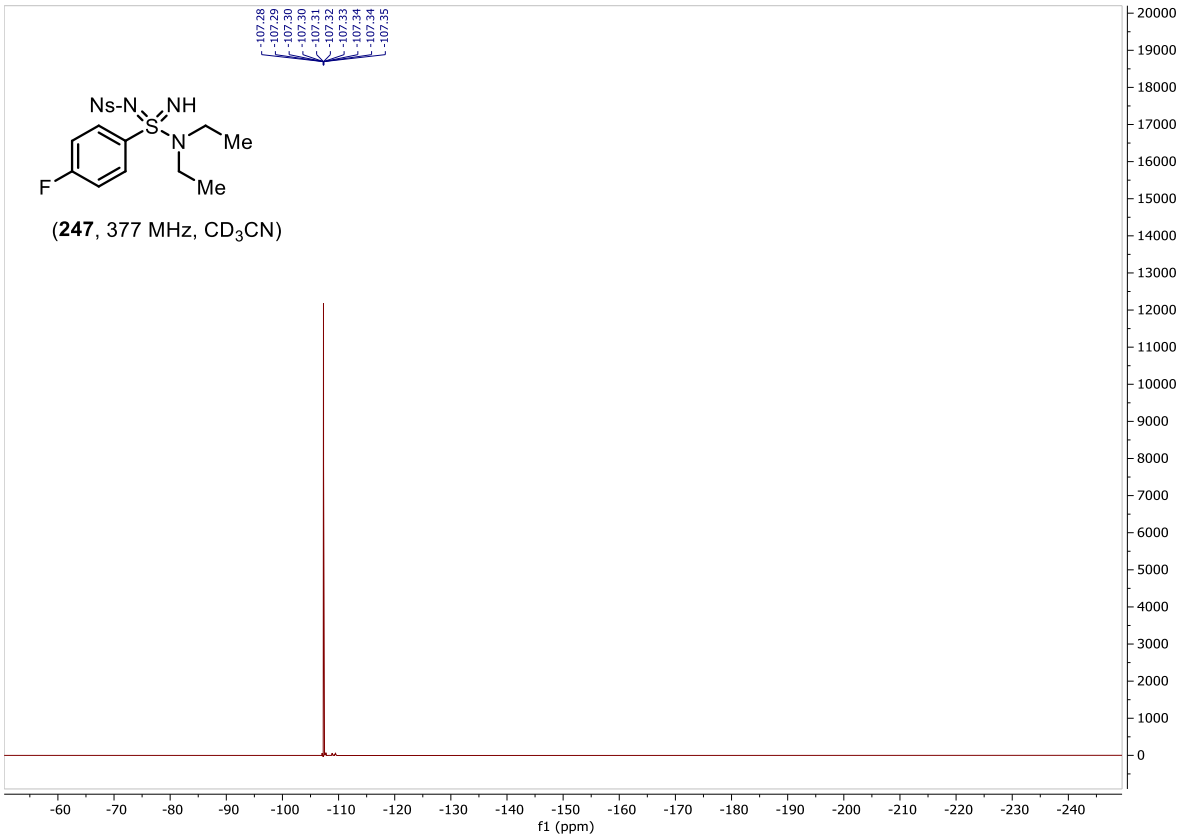
(**246**, 101 MHz, CD_3CN)



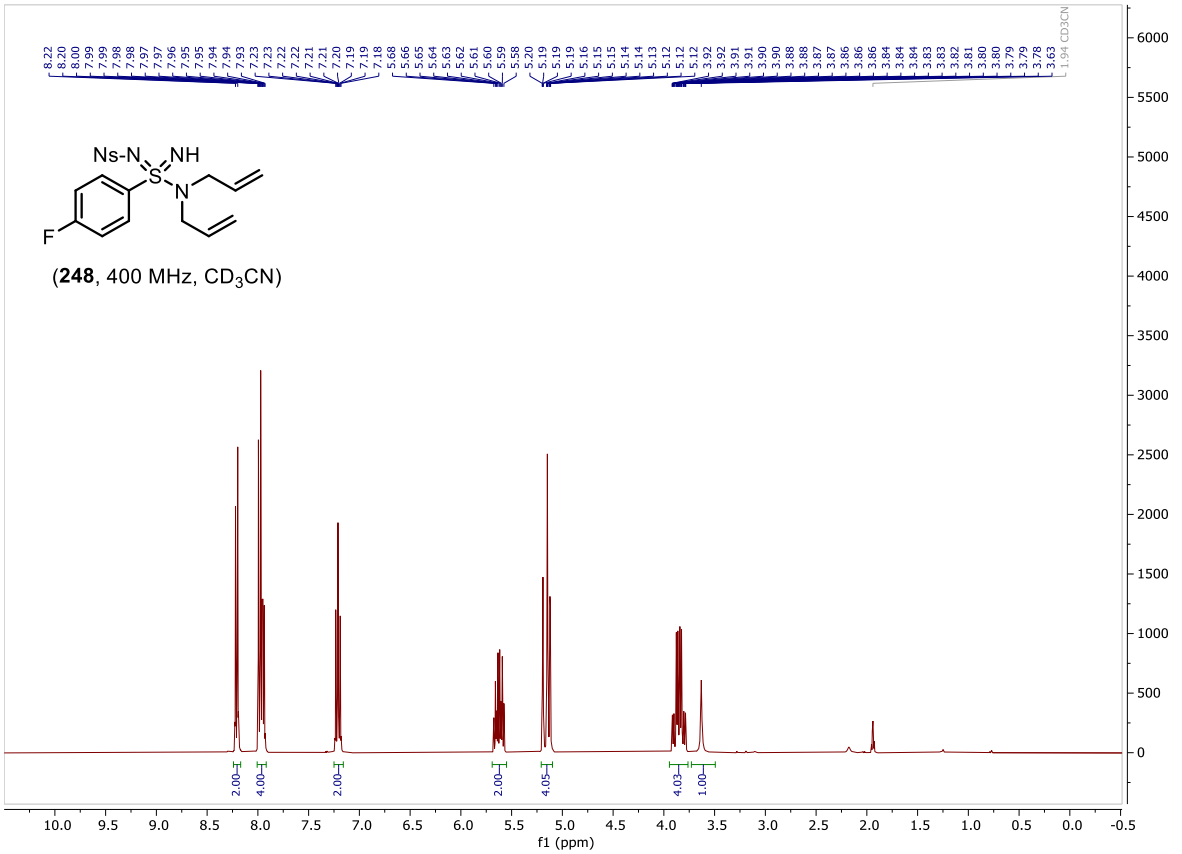
(**246**, 377 MHz, CD_3CN)


Ns-N
NH
S
N
Me
Me
F
(247, 400 MHz, CD3CN)
f1 (ppm)

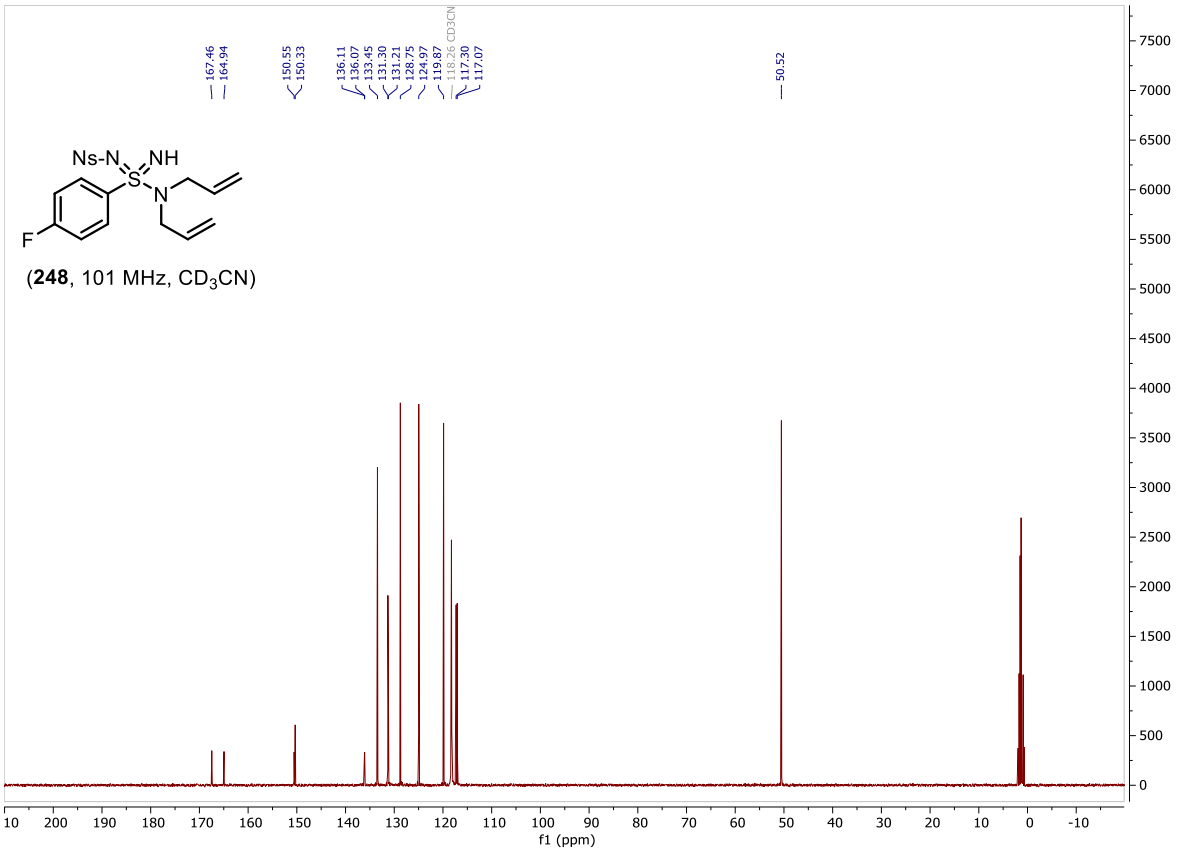

Ns-N
NH
S
N
Me
Me
F
(247, 101 MHz, CD3CN)
f1 (ppm)



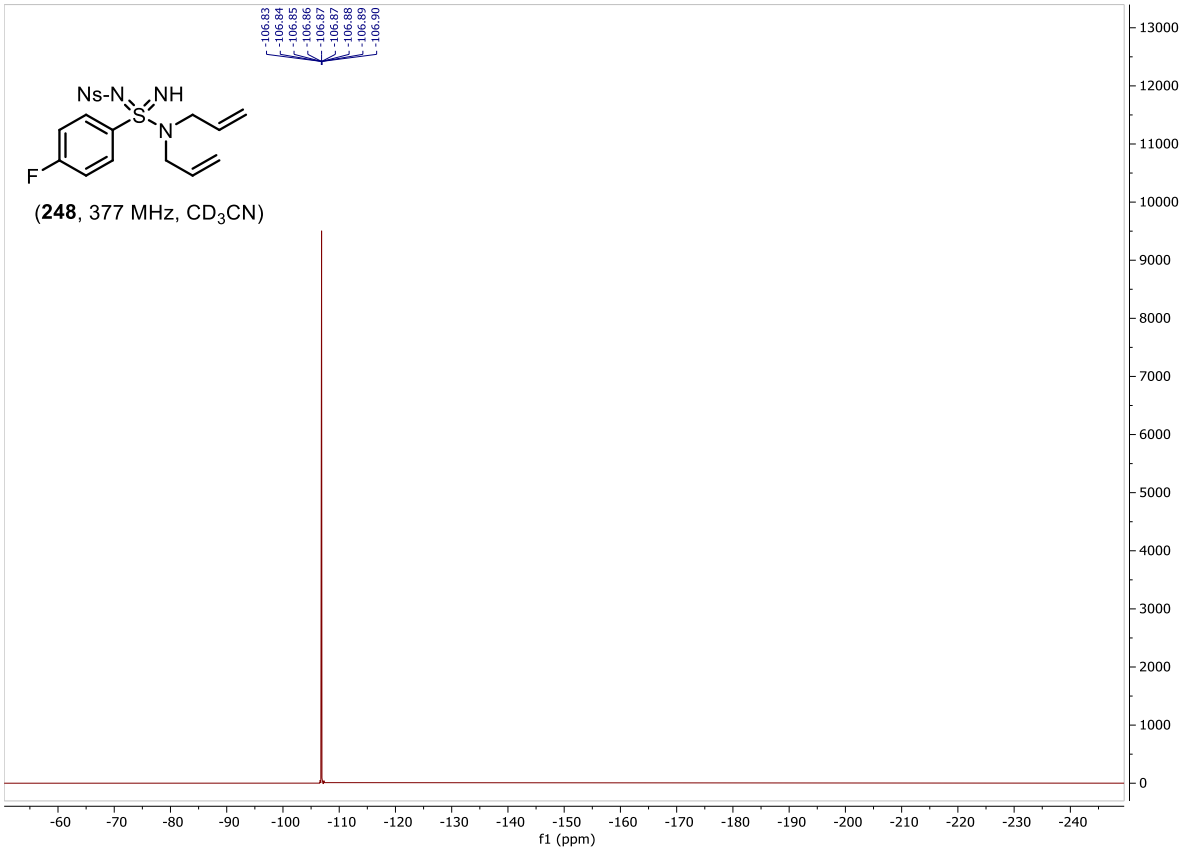
(**247**, 377 MHz, CD_3CN)



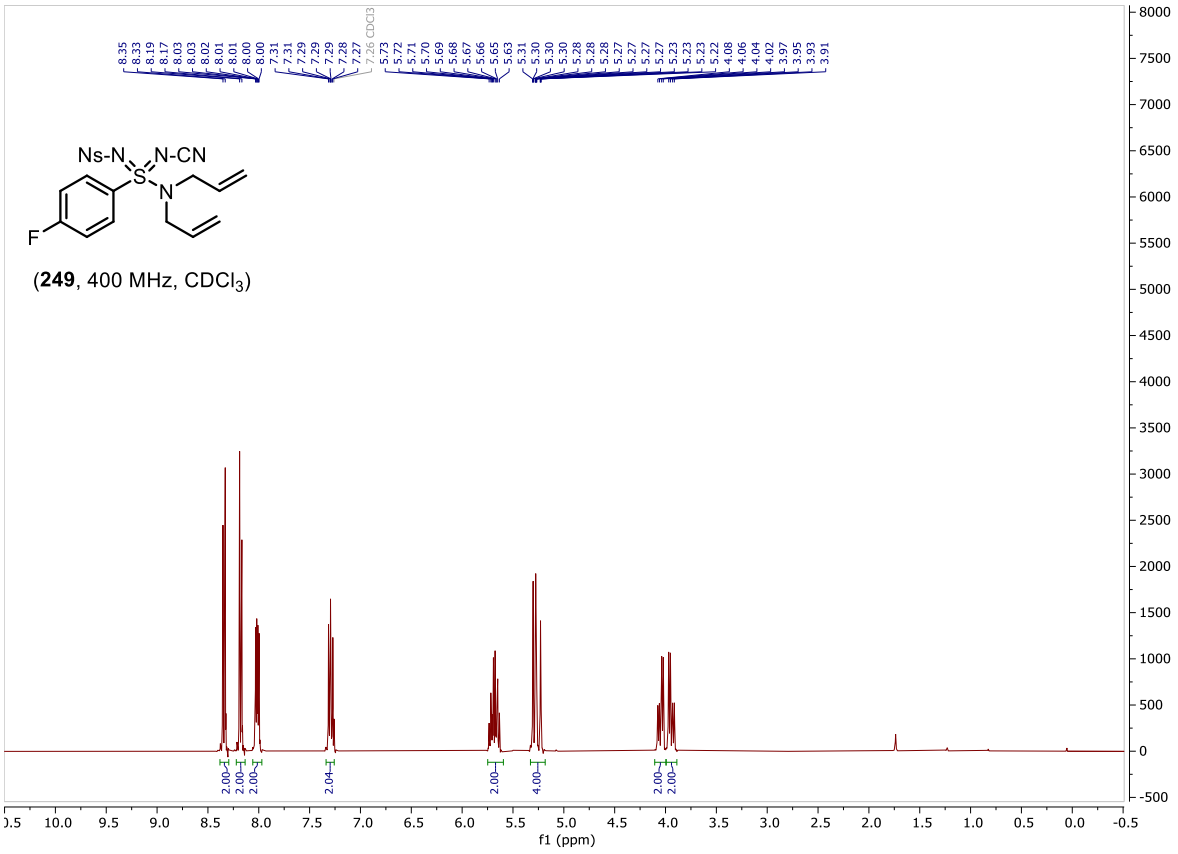
(**248**, 400 MHz, CD_3CN)

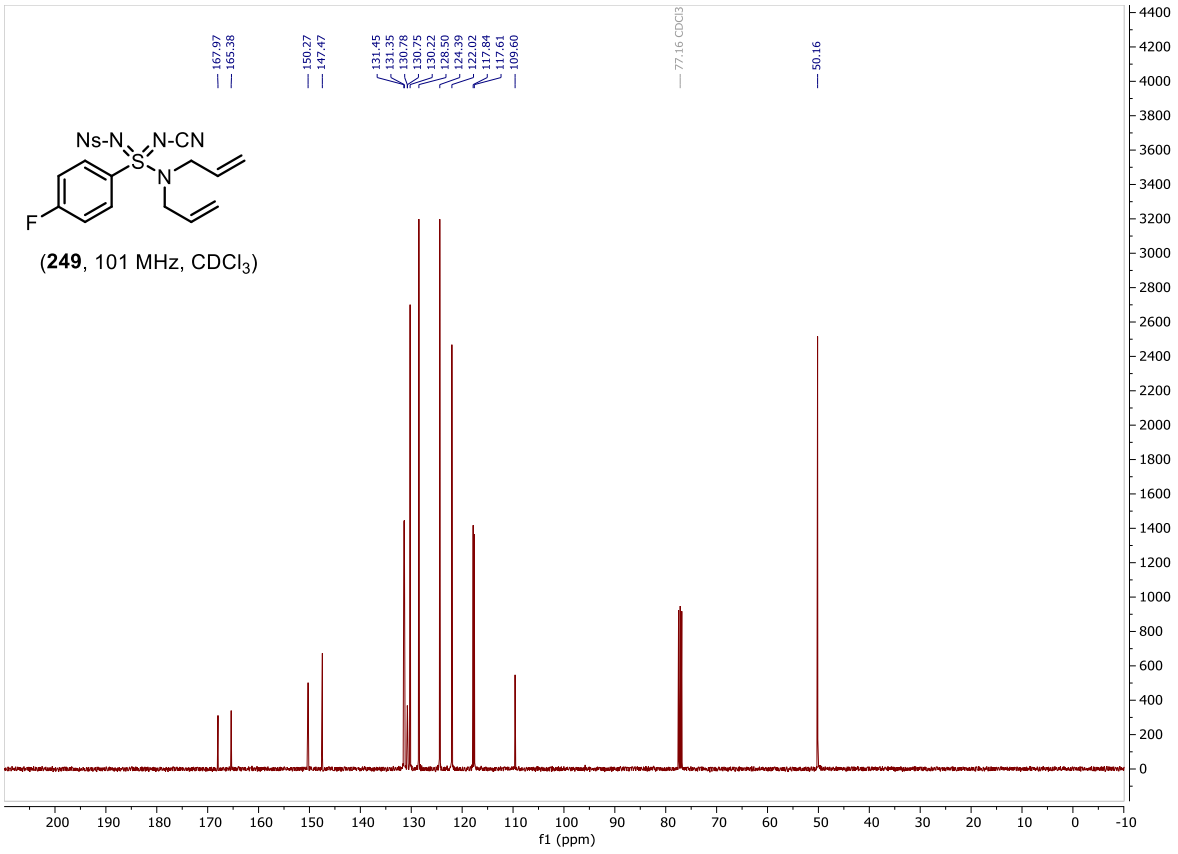


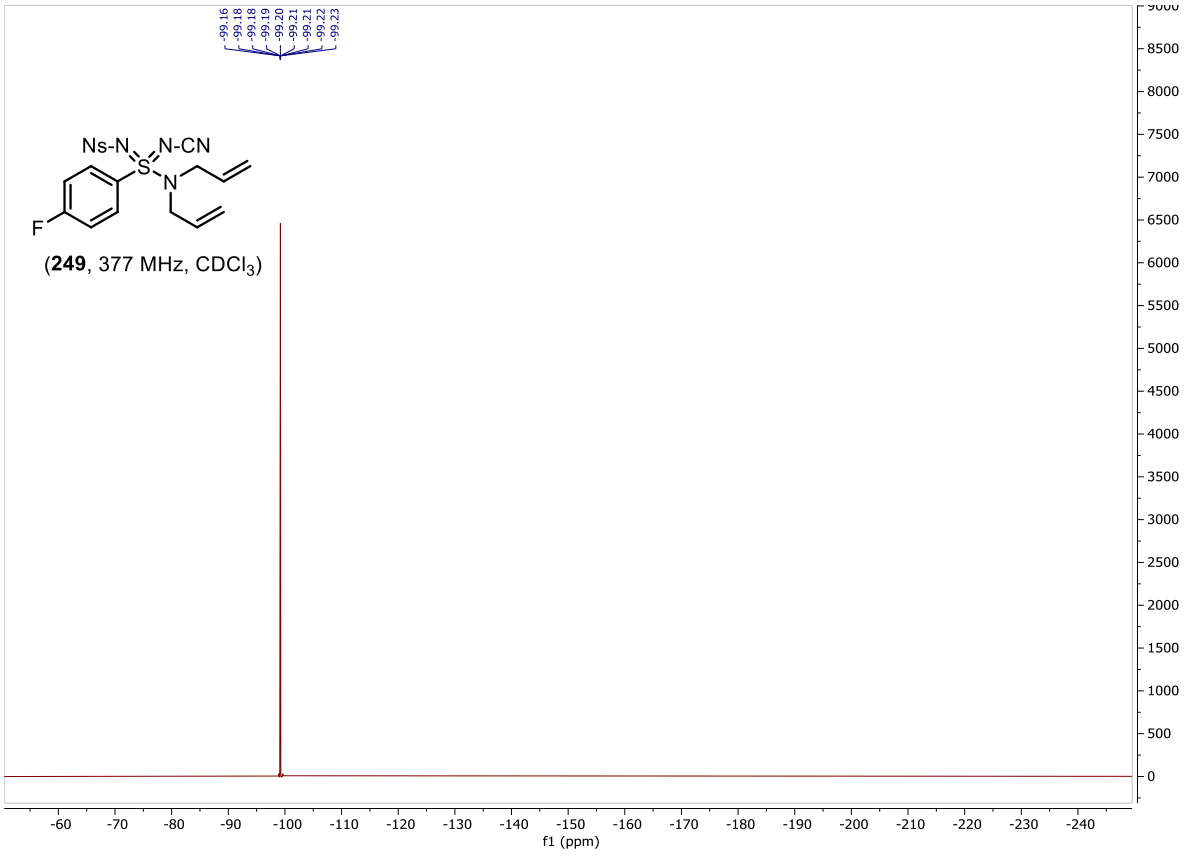
(**248**, 101 MHz, CD_3CN)



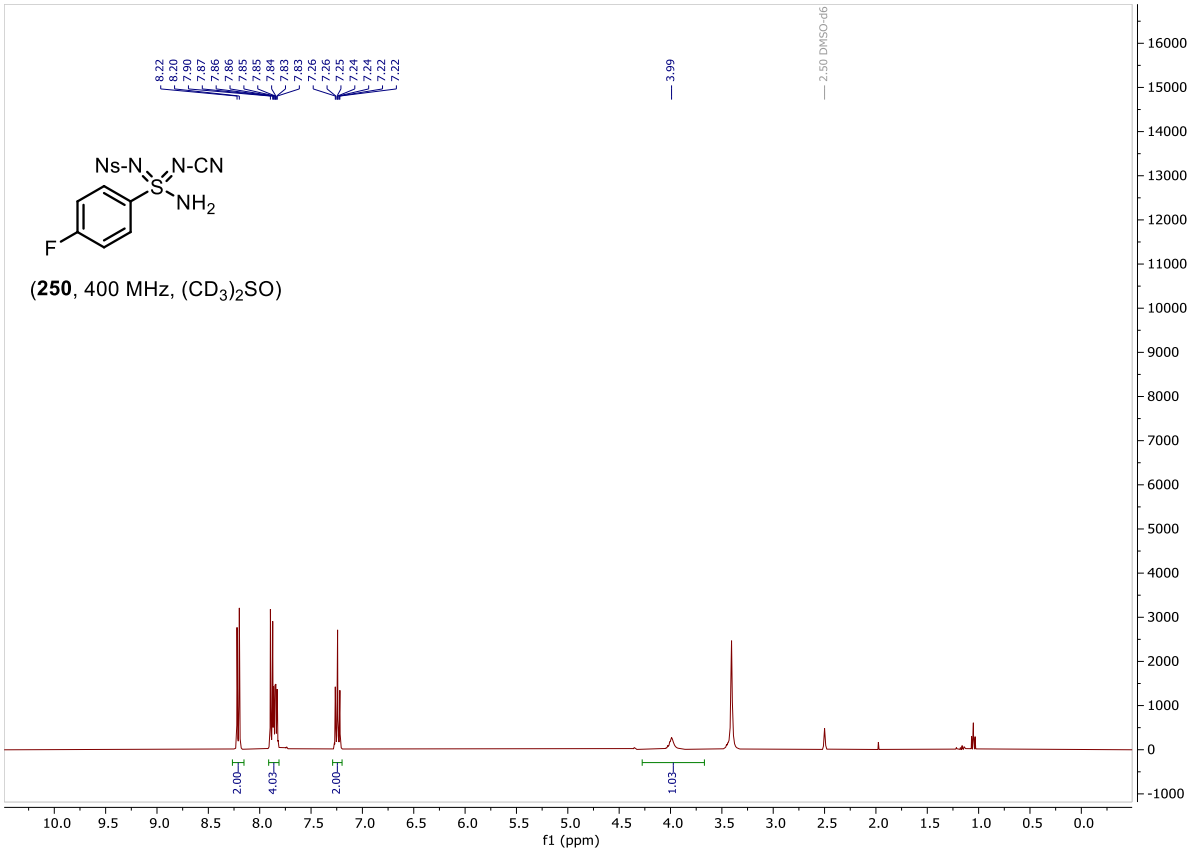
(**248**, 377 MHz, CD_3CN)


Ns-N
N-CN
S
N
F
(249, 400 MHz, CDCl3)
f1 (ppm)

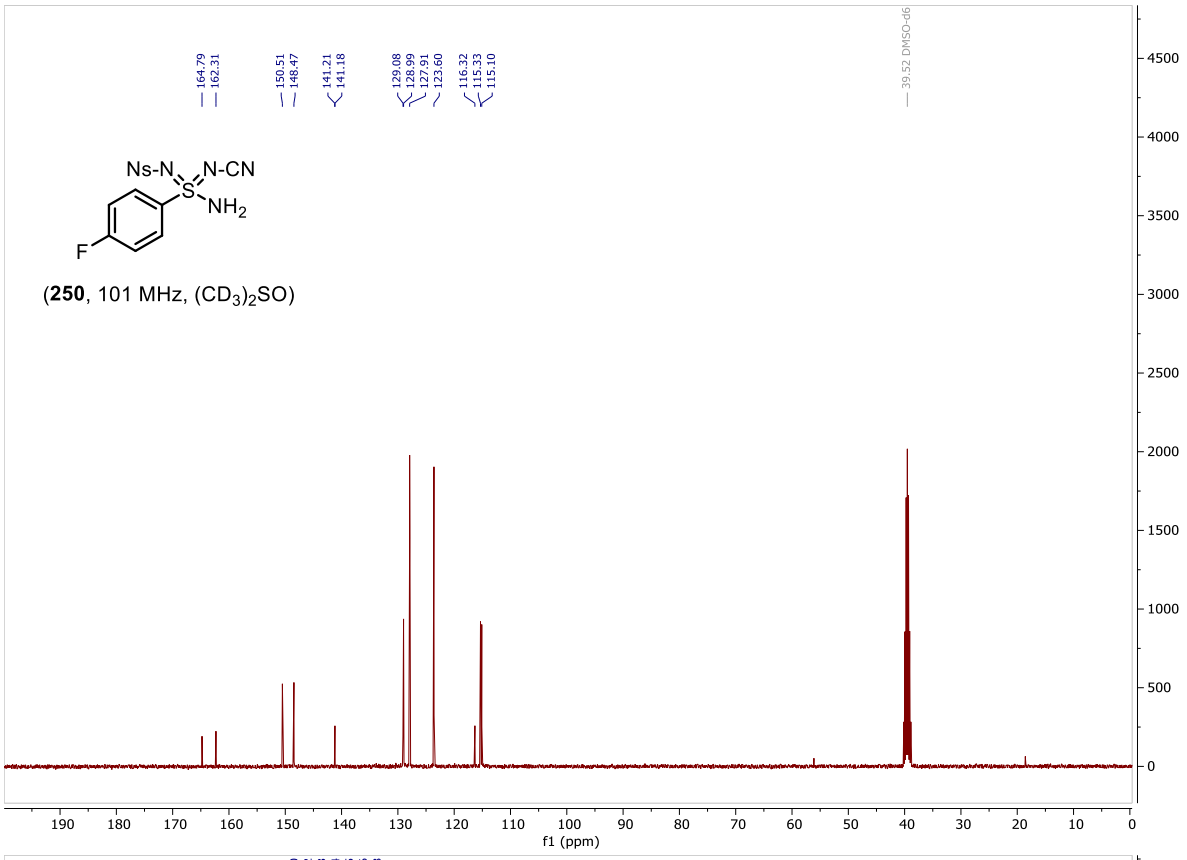

Ns-N
N-CN
S
N
F
(249, 101 MHz, CDCl3)
f1 (ppm)



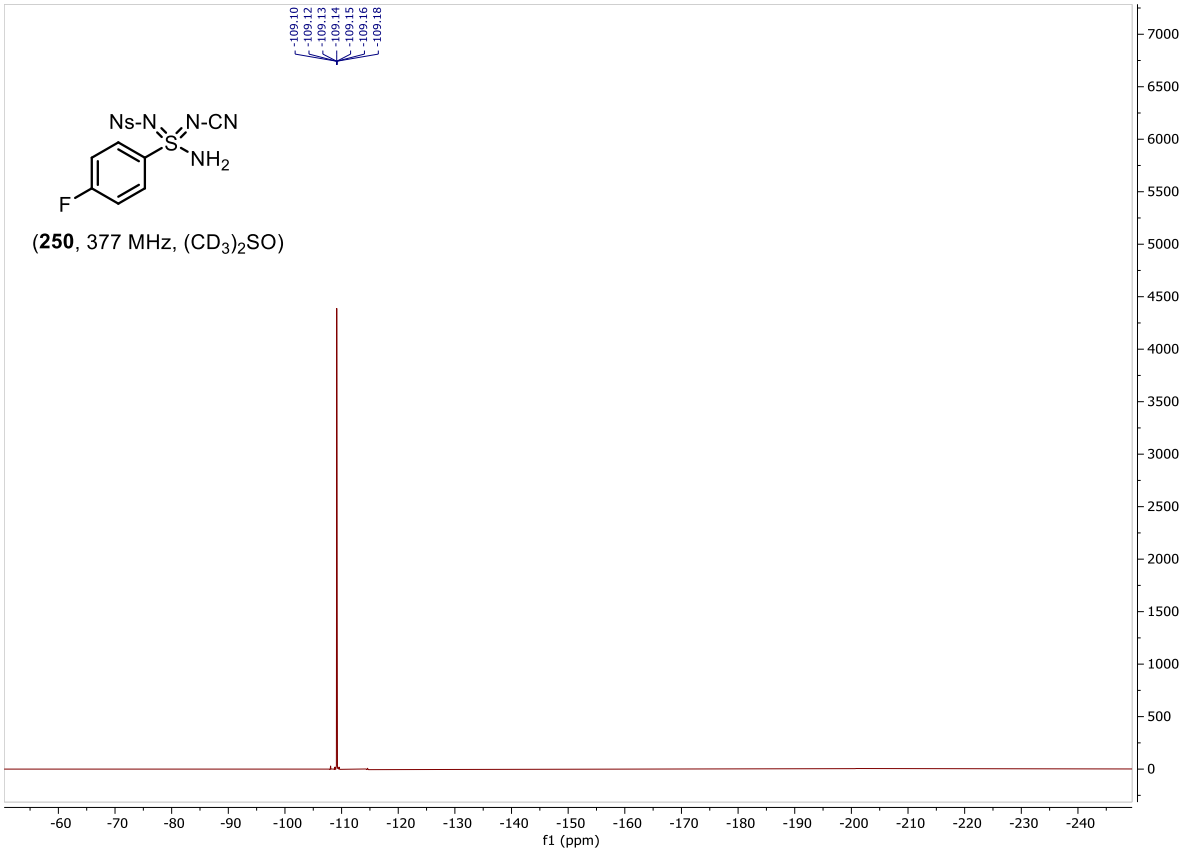
(**249**, 377 MHz, $CDCl_3$)



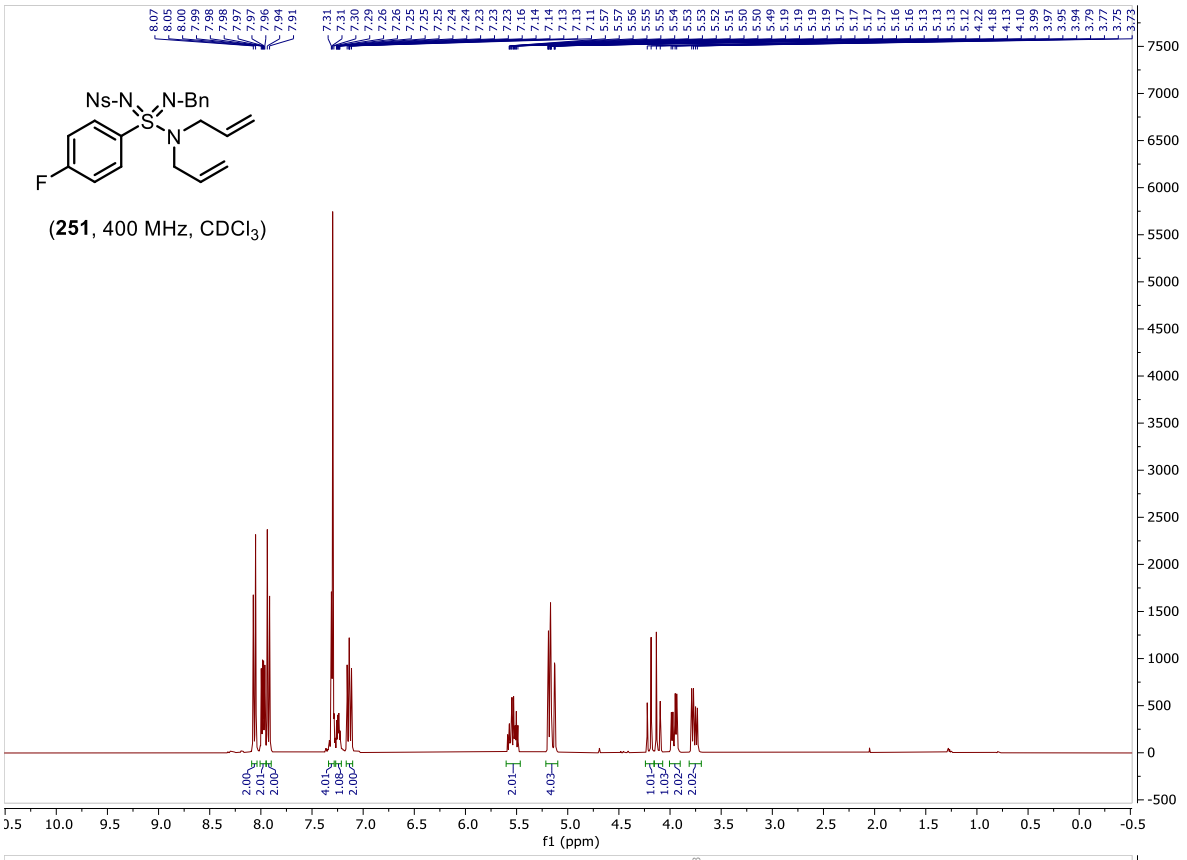
(**250**, 400 MHz, $(CD_3)_2SO$)

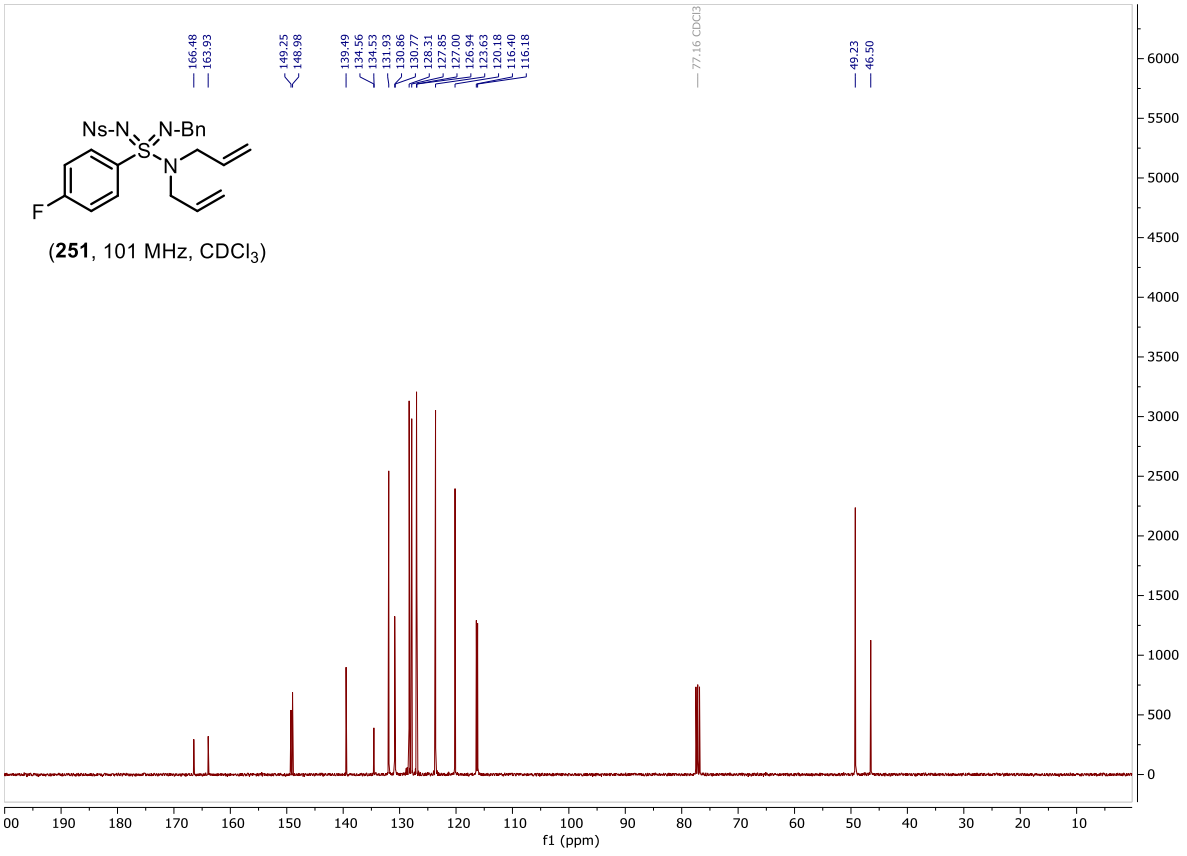


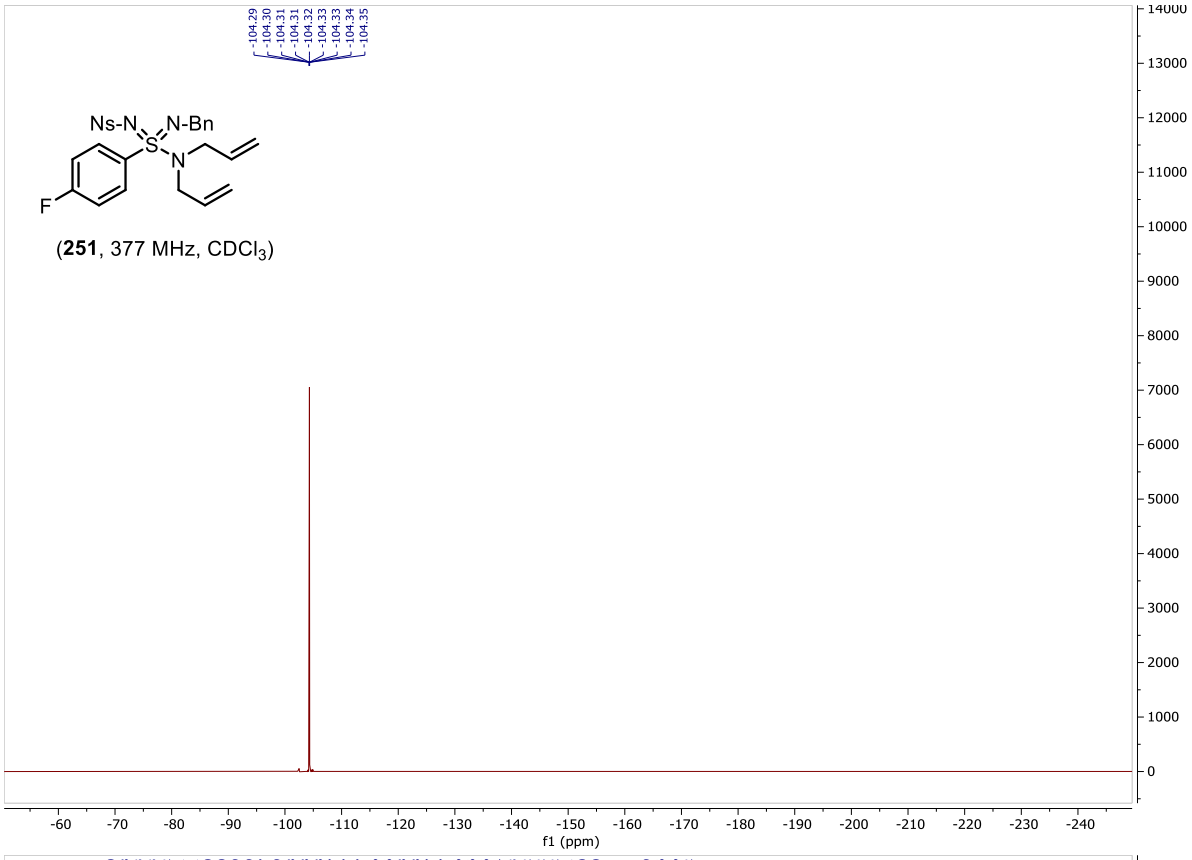
(**250**, 101 MHz, $(CD_3)_2SO$)



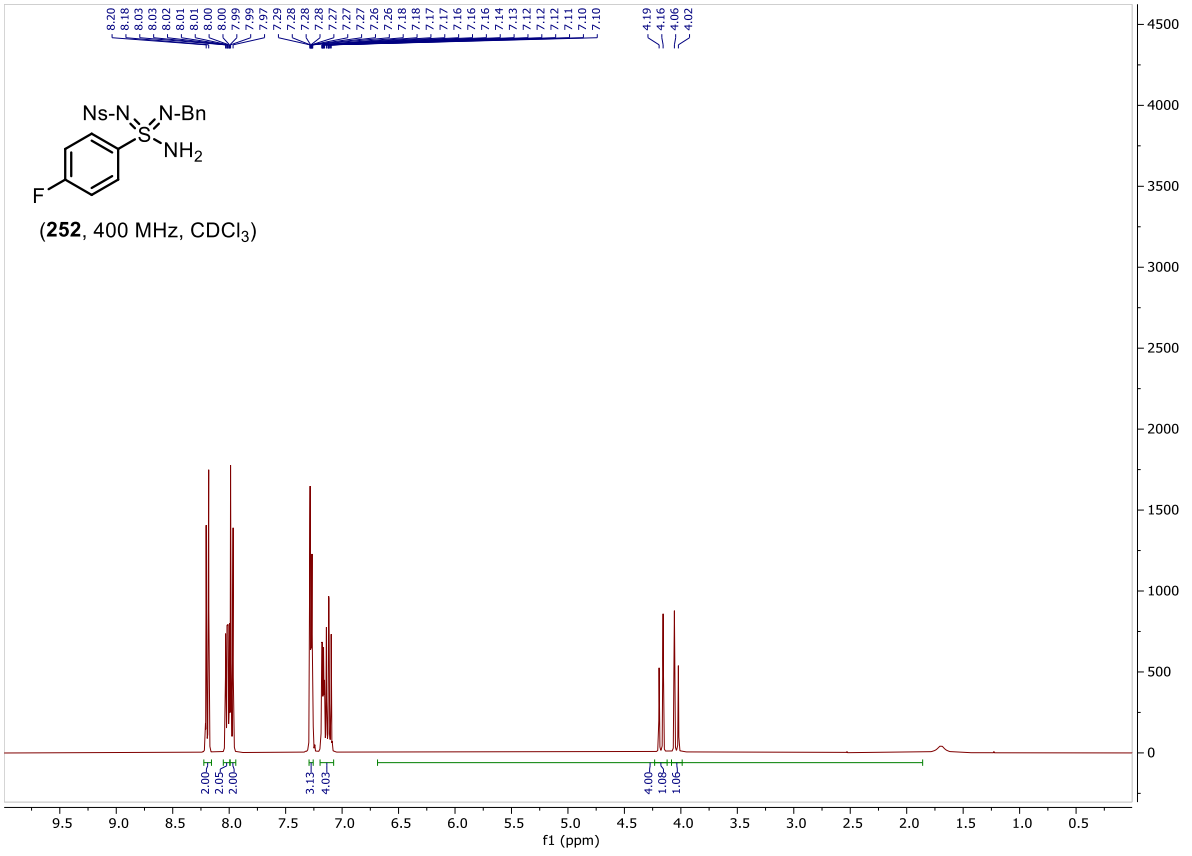
(**250**, 377 MHz, $(CD_3)_2SO$)


Ns-N
N-Bn
S
N
F
(251, 400 MHz, CDCl3)
f1 (ppm)

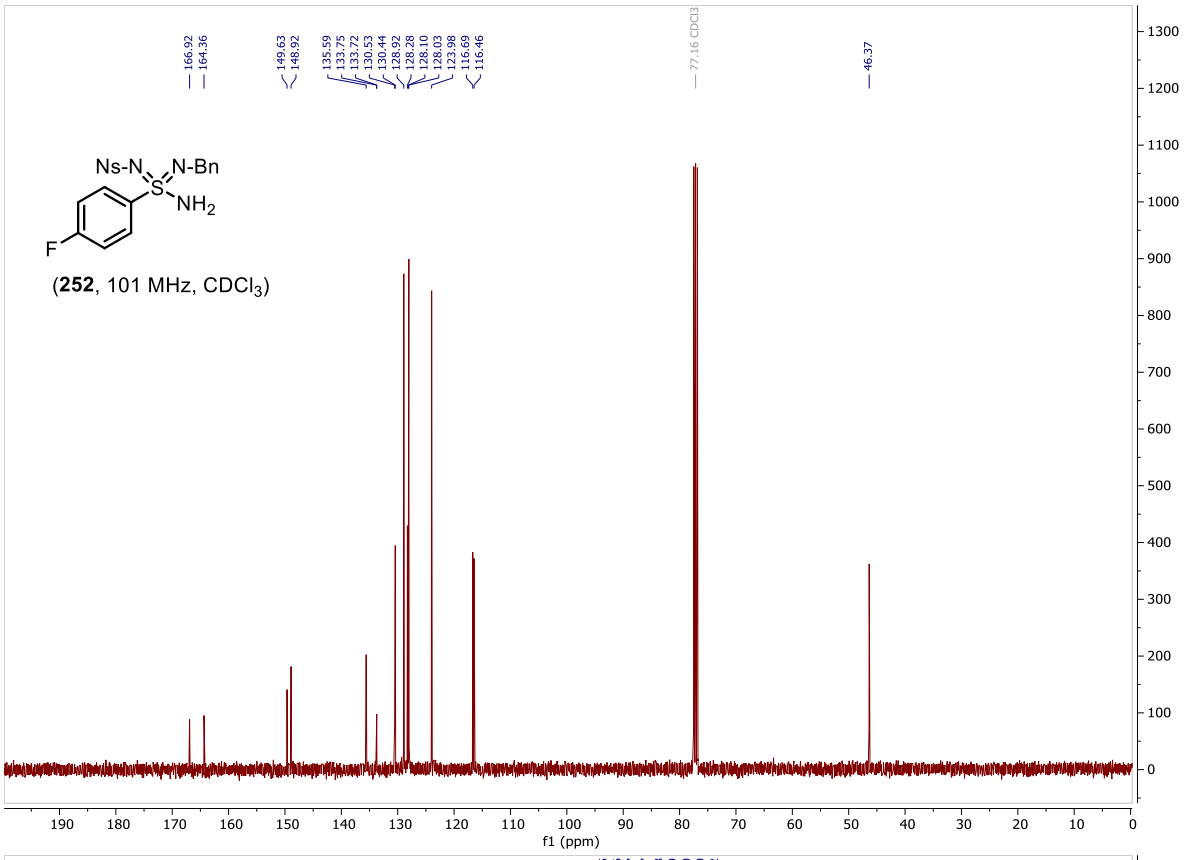

Ns-N
N-Bn
S
N
F
(251, 101 MHz, CDCl3)
f1 (ppm)

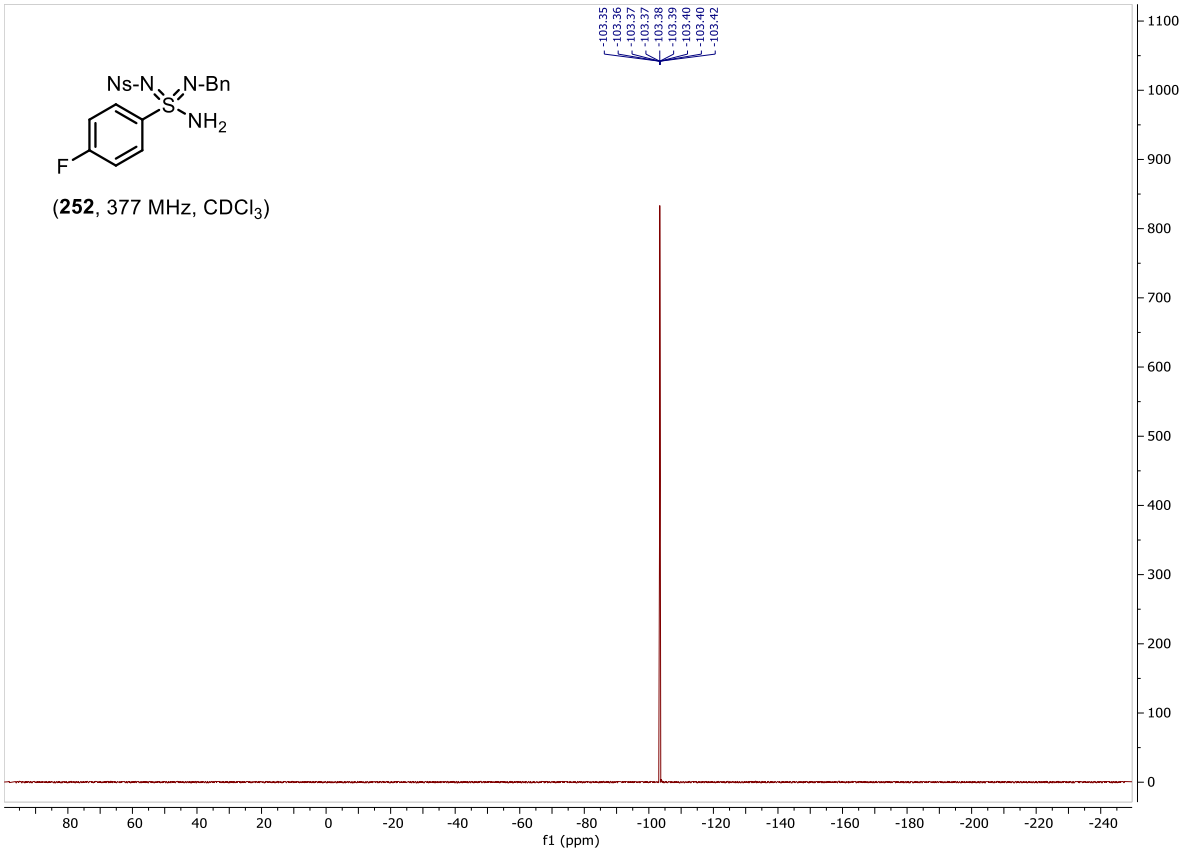


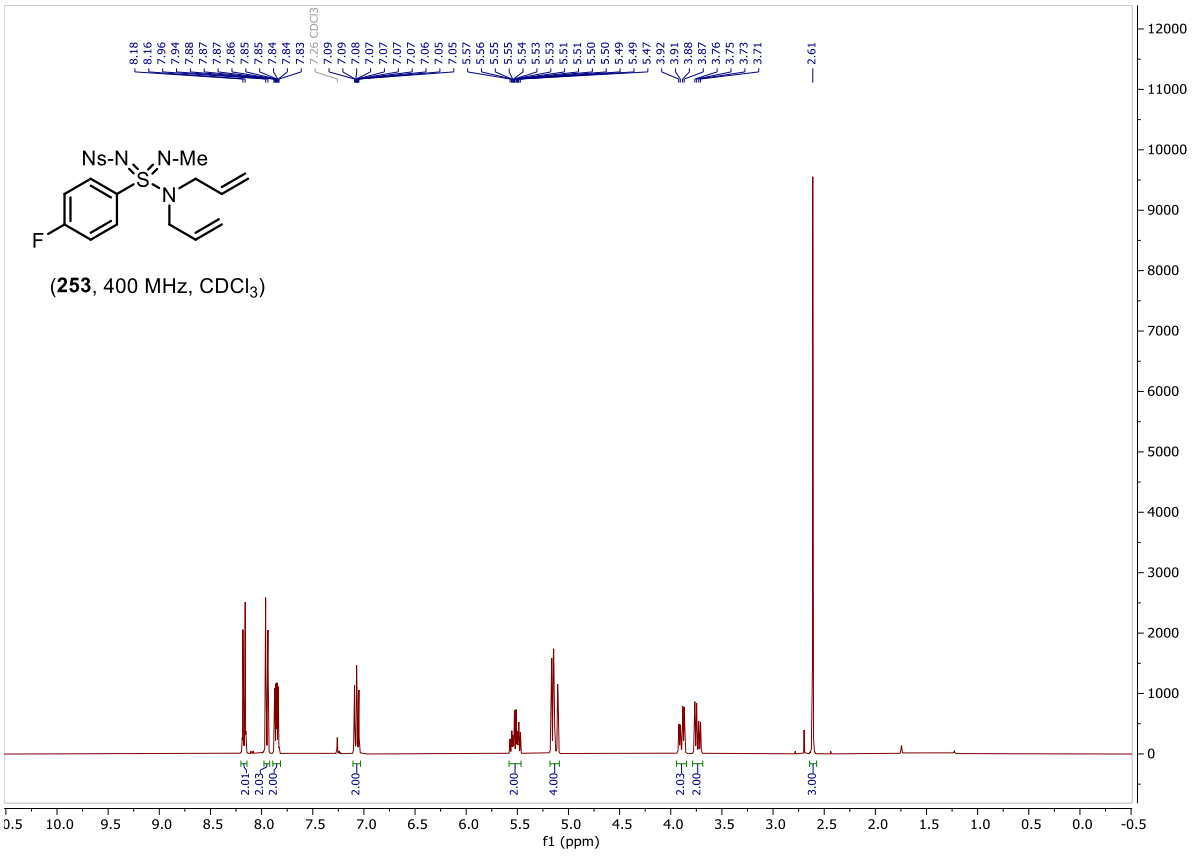
(**251**, 377 MHz, $CDCl_3$)

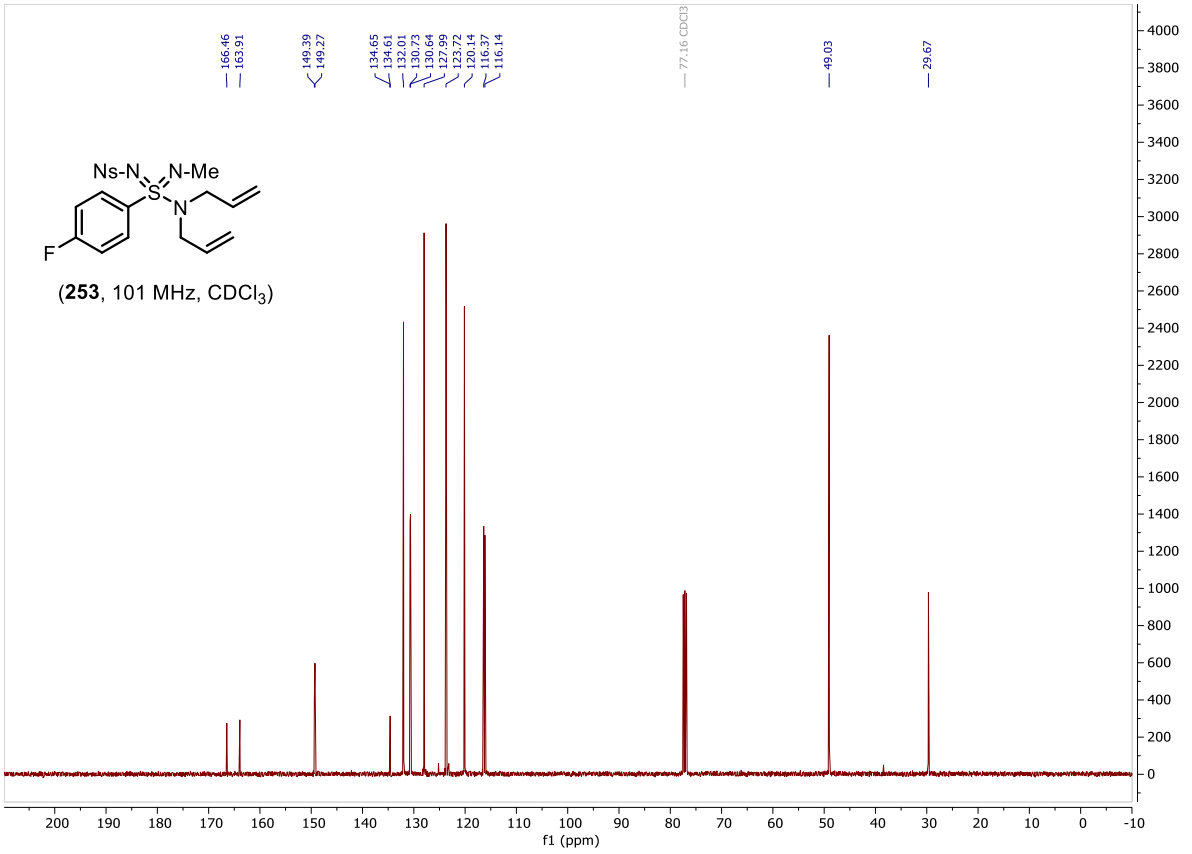


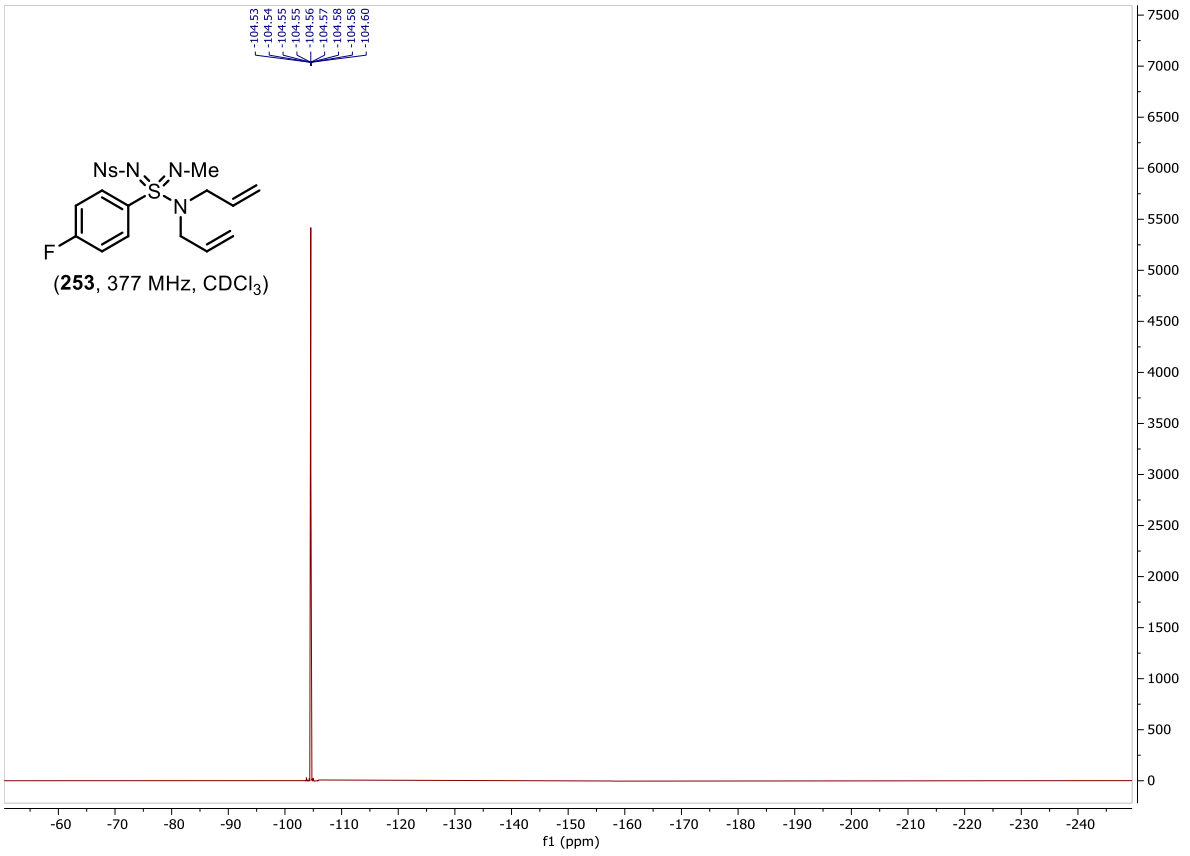
(**252**, 400 MHz, $CDCl_3$)


166.92
164.36
149.63
148.92
135.59
133.75
133.72
130.53
130.44
128.92
128.28
128.10
128.03
123.98
116.69
116.46
77.16 CDCl3
46.37
Ns-N
N-Bn
S
NH2
F
(252, 101 MHz, CDCl3)
f1 (ppm)

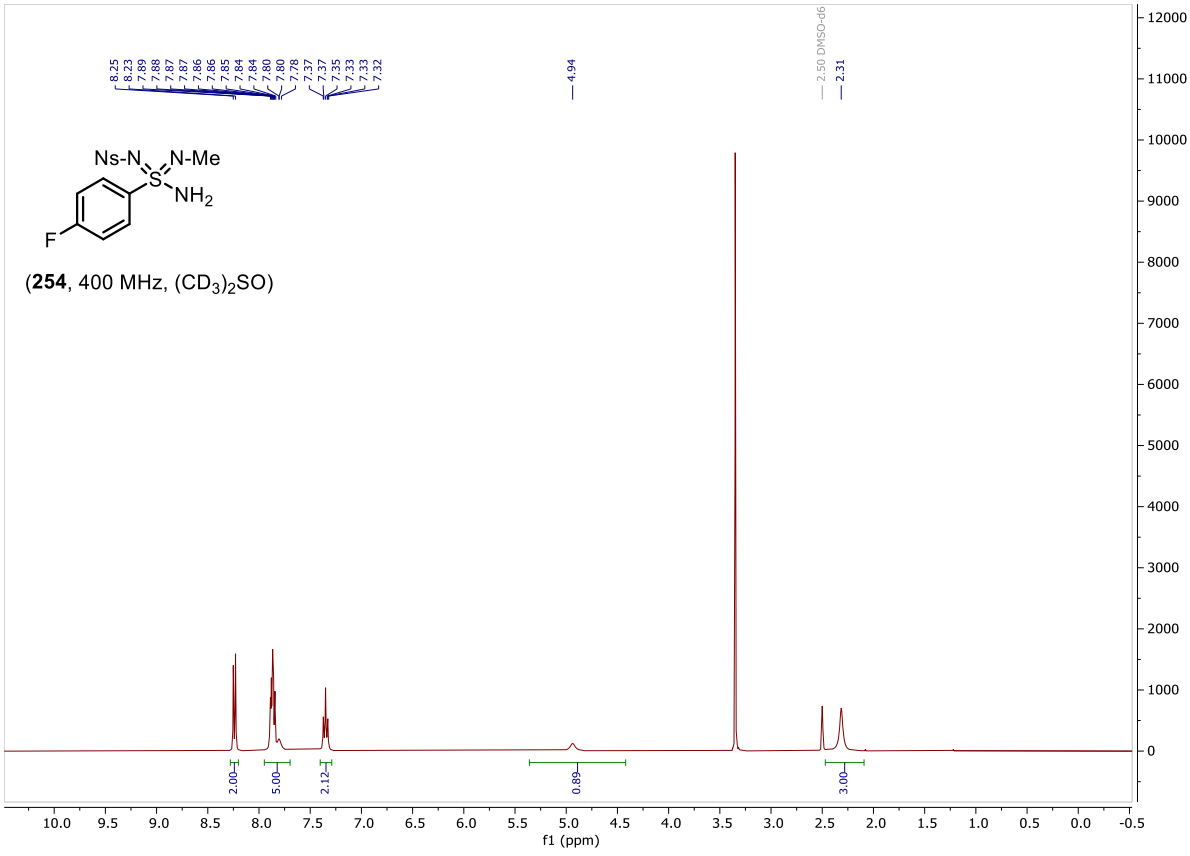

-103.35
-103.36
-103.37
-103.37
-103.38
-103.39
-103.40
-103.40
-103.42
Ns-N
N-Bn
S
NH2
F
(252, 377 MHz, CDCl3)
f1 (ppm)


Ns-N
N-Me
S
N
F
(253, 400 MHz, CDCl3)
f1 (ppm)

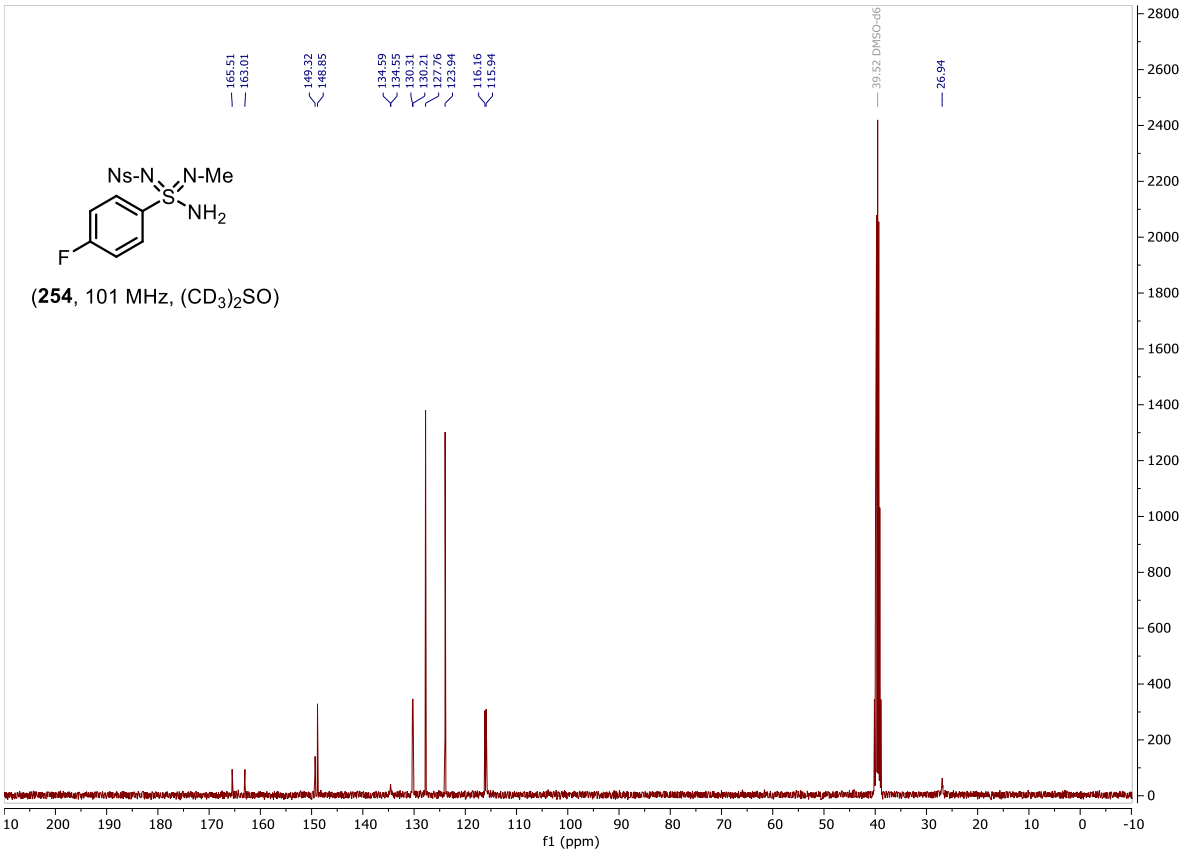

Ns-N
N-Me
S
N
F
(253, 101 MHz, CDCl3)
f1 (ppm)



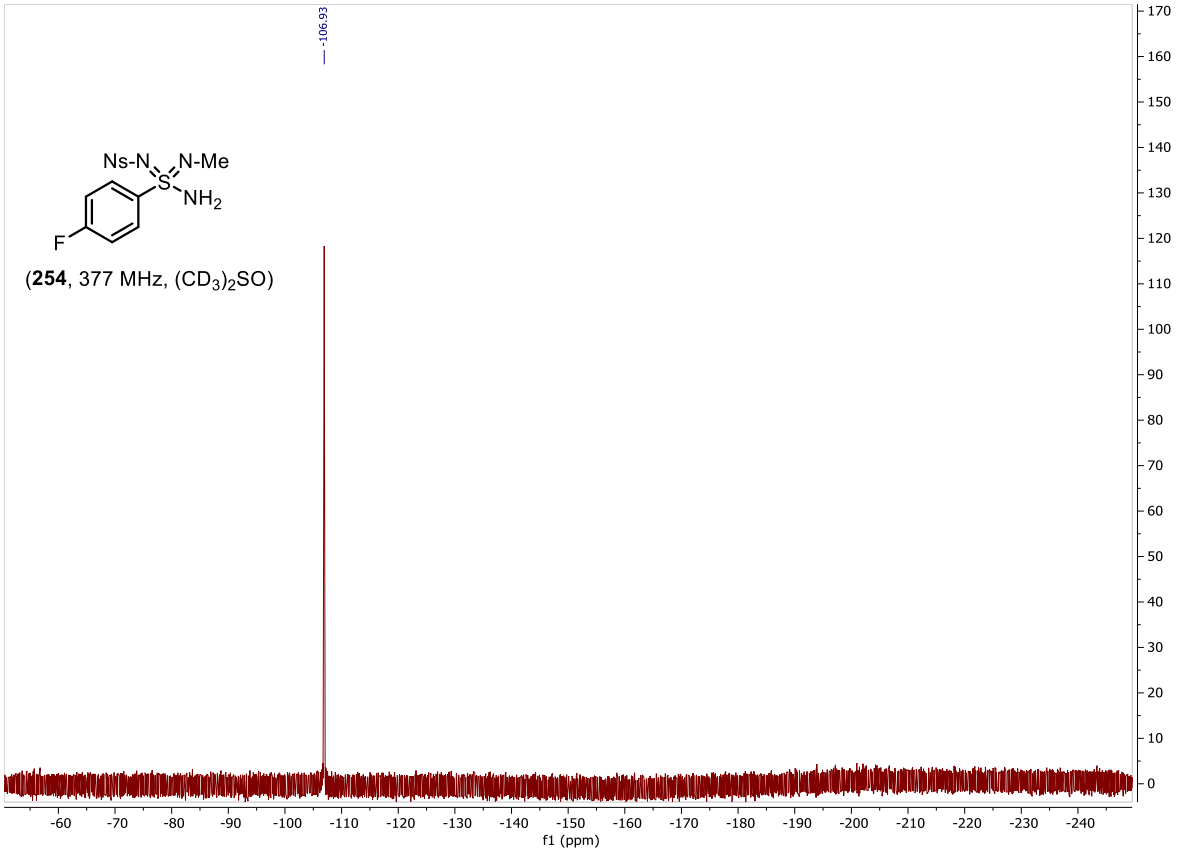
(**253**, 377 MHz, $CDCl_3$)



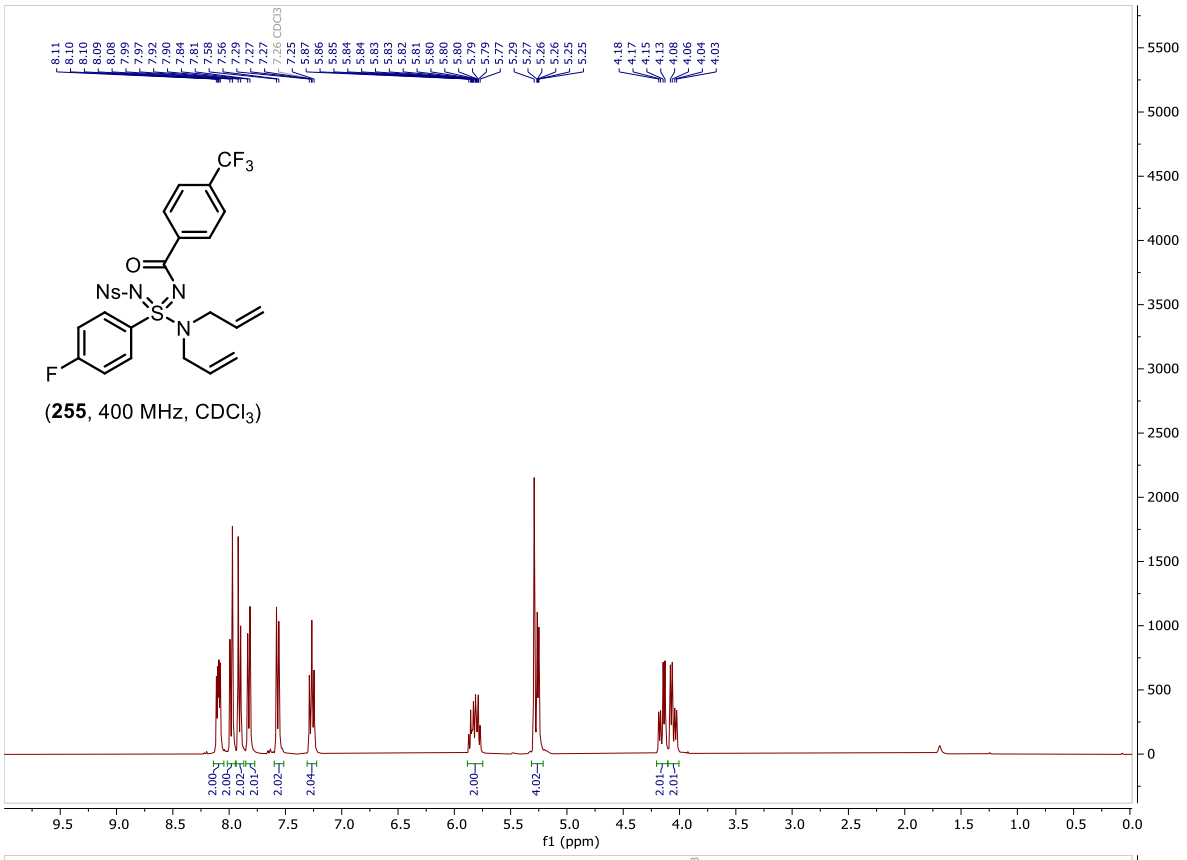
(**254**, 400 MHz, $(CD_3)_2SO$)

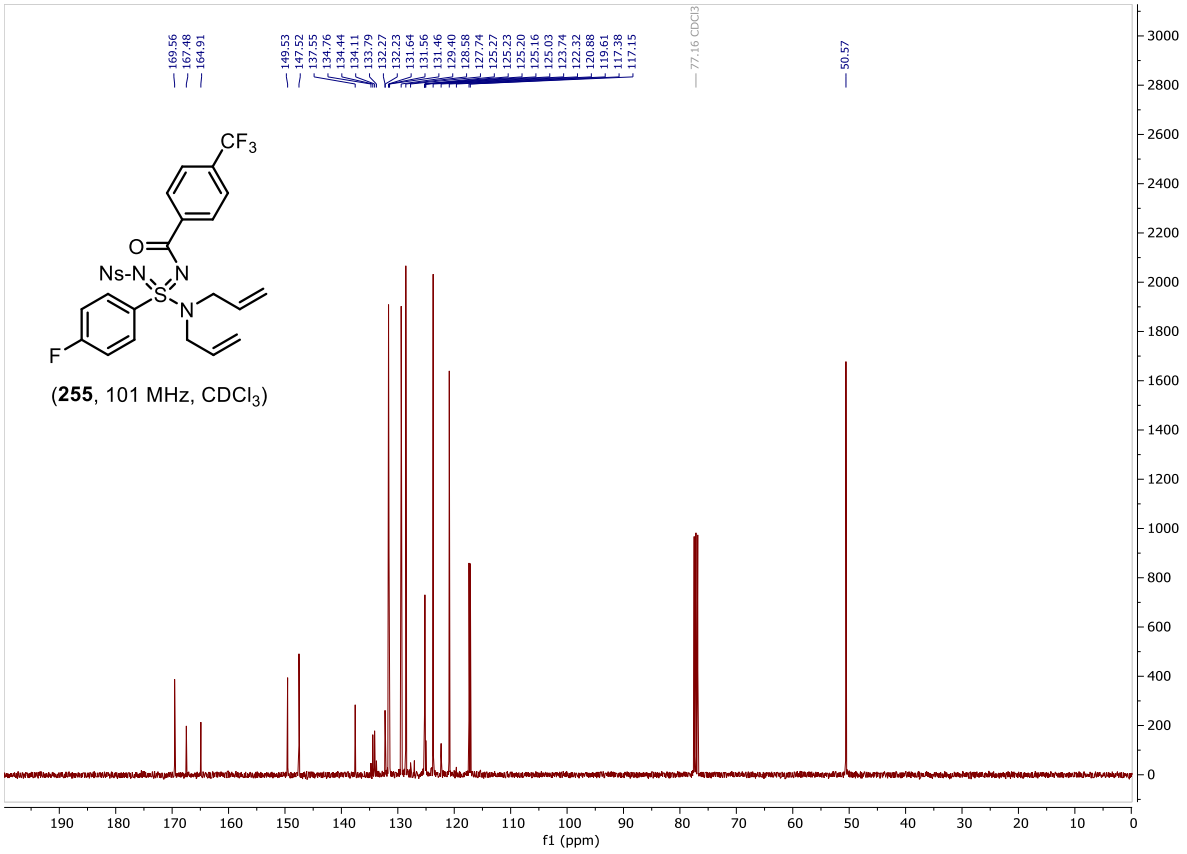


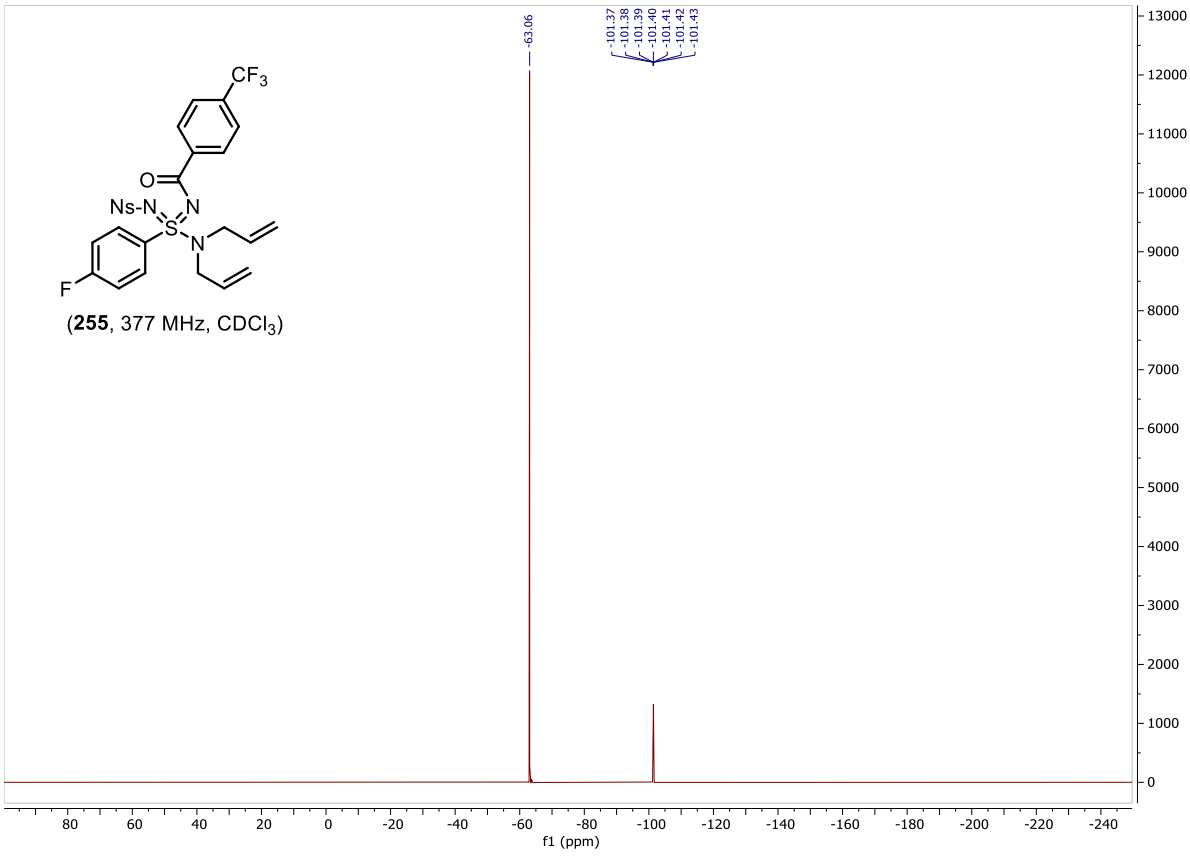
(**254**, 101 MHz, $(CD_3)_2SO$)



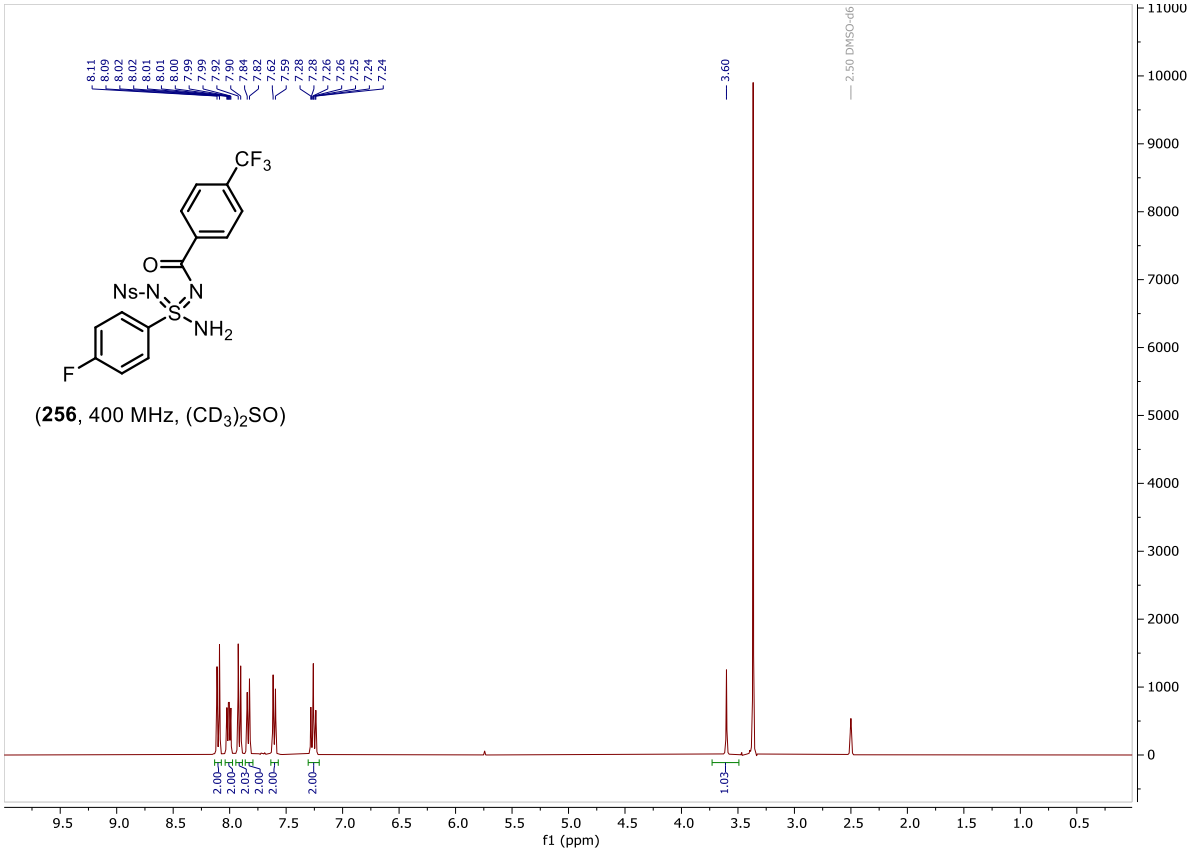
(**254**, 377 MHz, $(CD_3)_2SO$)


CF3
O
Ns-N
N
S
N
F
(255, 400 MHz, CDCl3)
f1 (ppm)

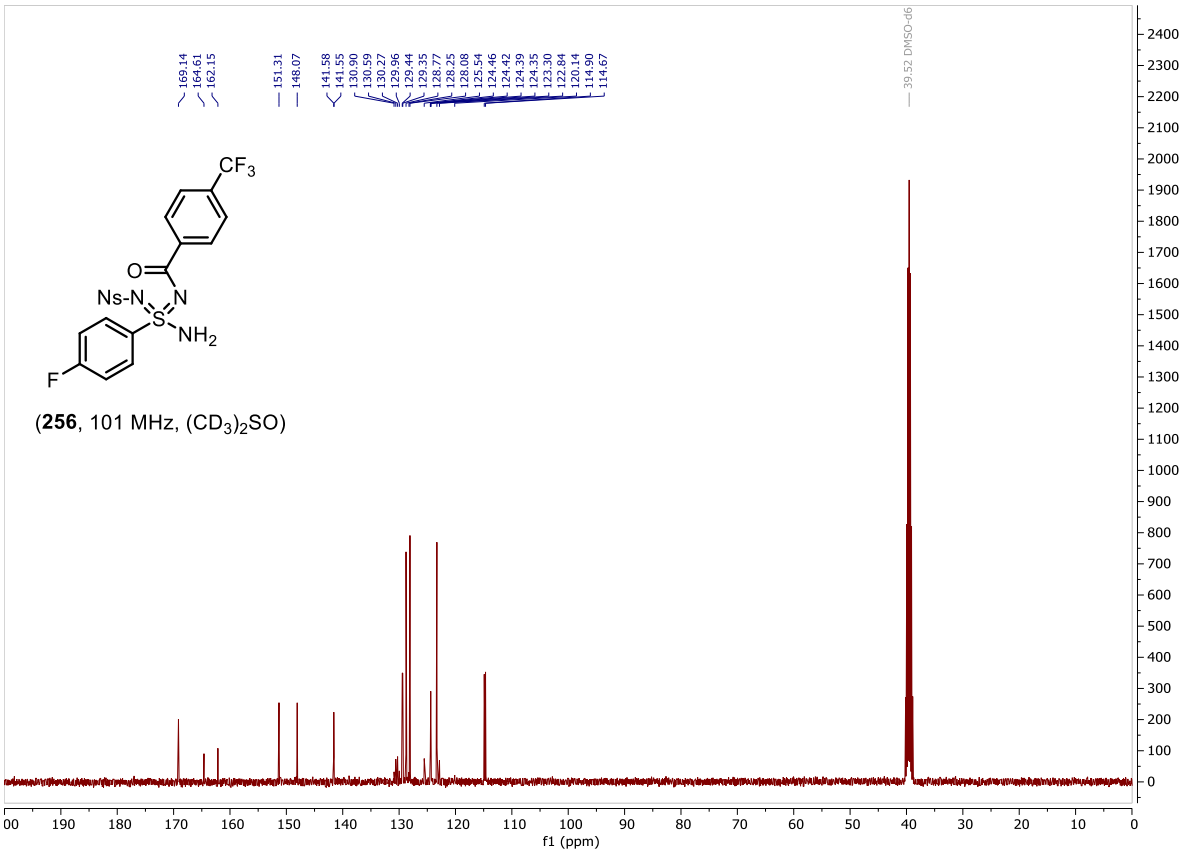

CF3
O
Ns-N
N
S
N
F
(255, 101 MHz, CDCl3)
f1 (ppm)



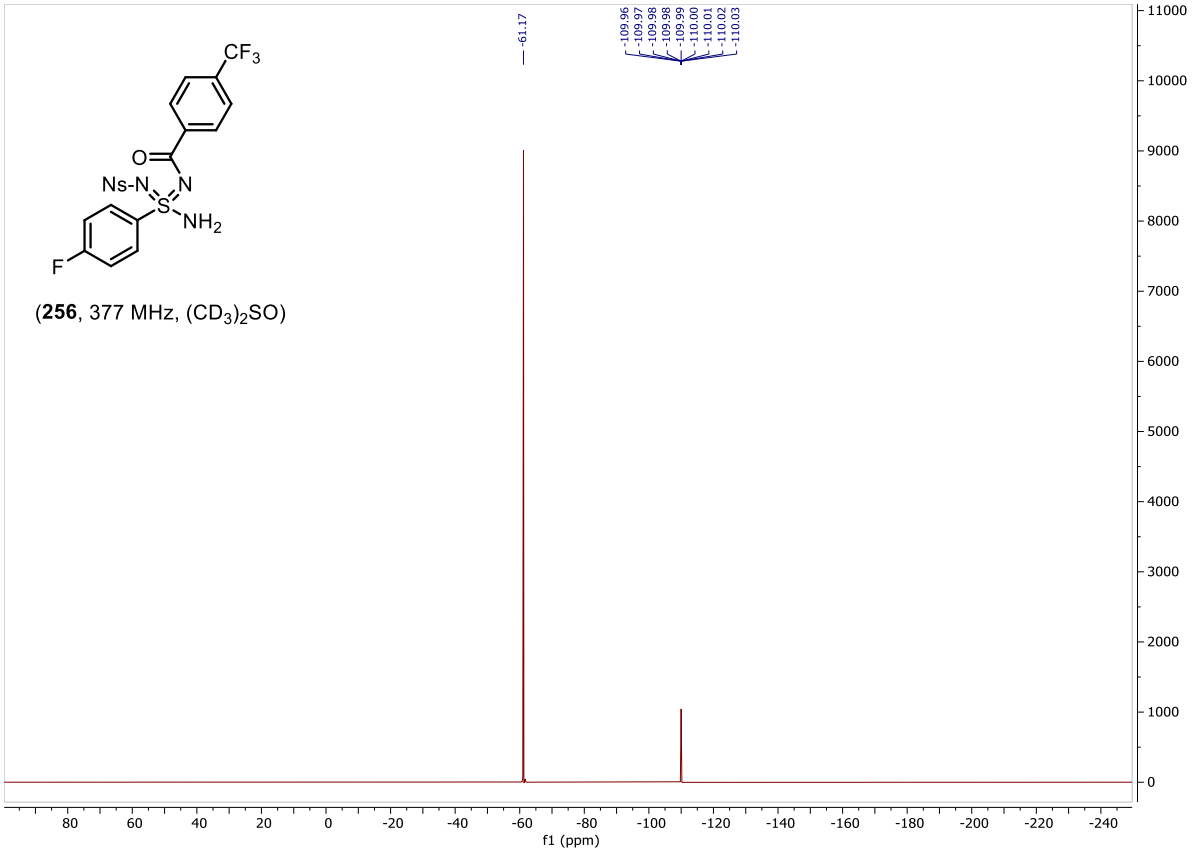
(**255**, 377 MHz, $CDCl_3$)



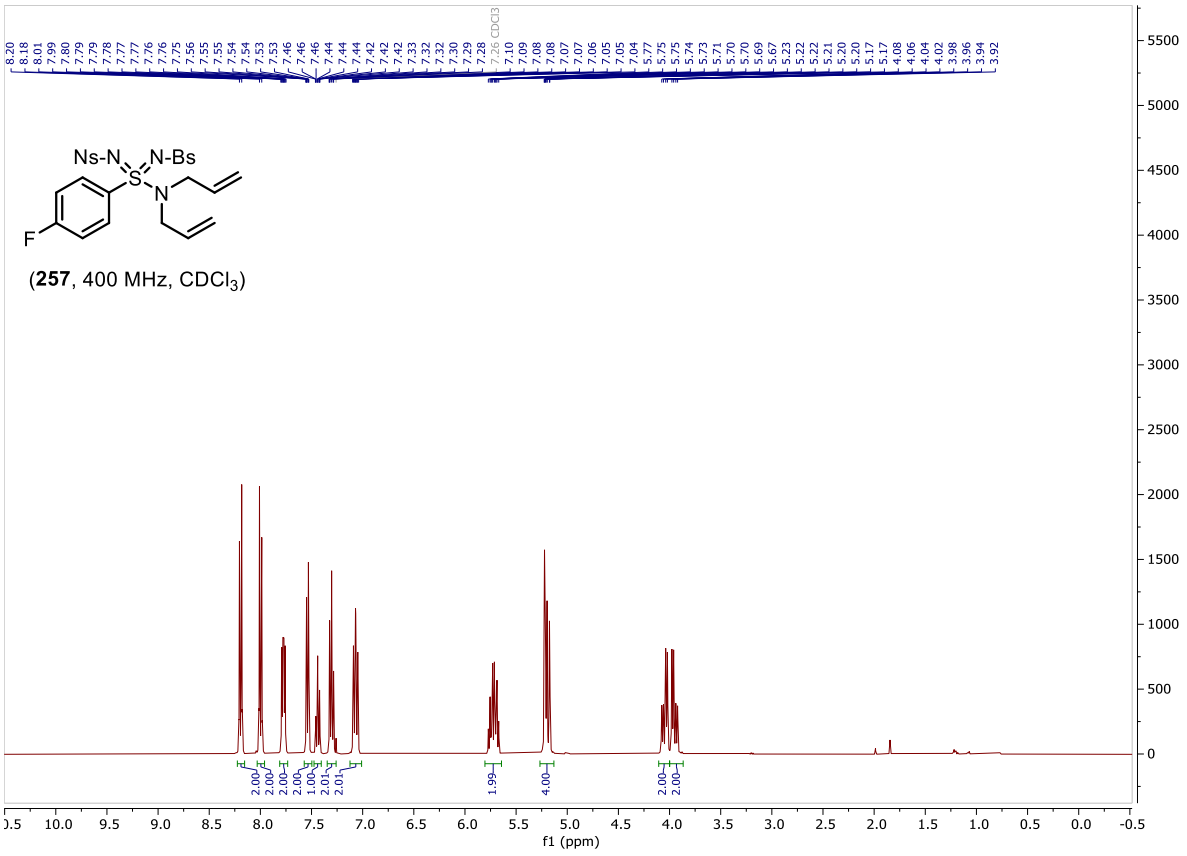
(**256**, 400 MHz, $(CD_3)_2SO$)

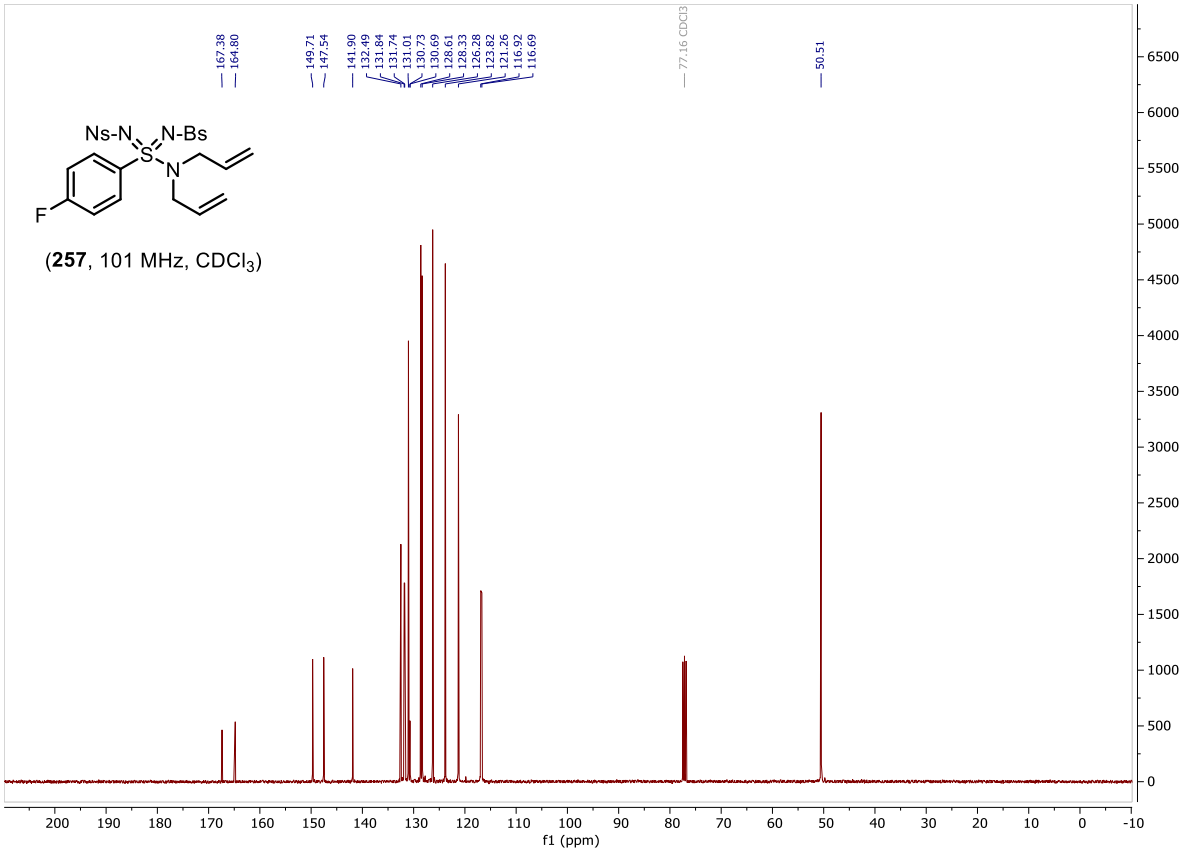


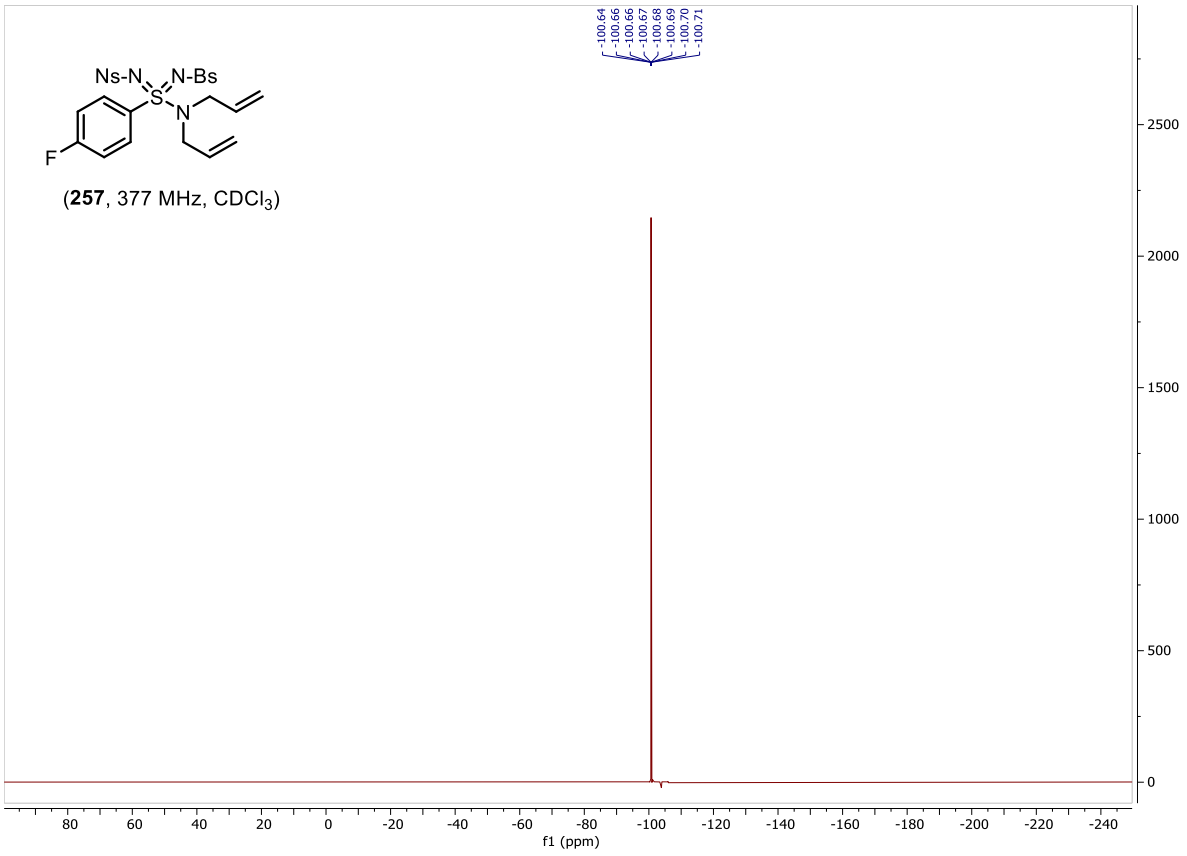
(**256**, 101 MHz, $(CD_3)_2SO$)

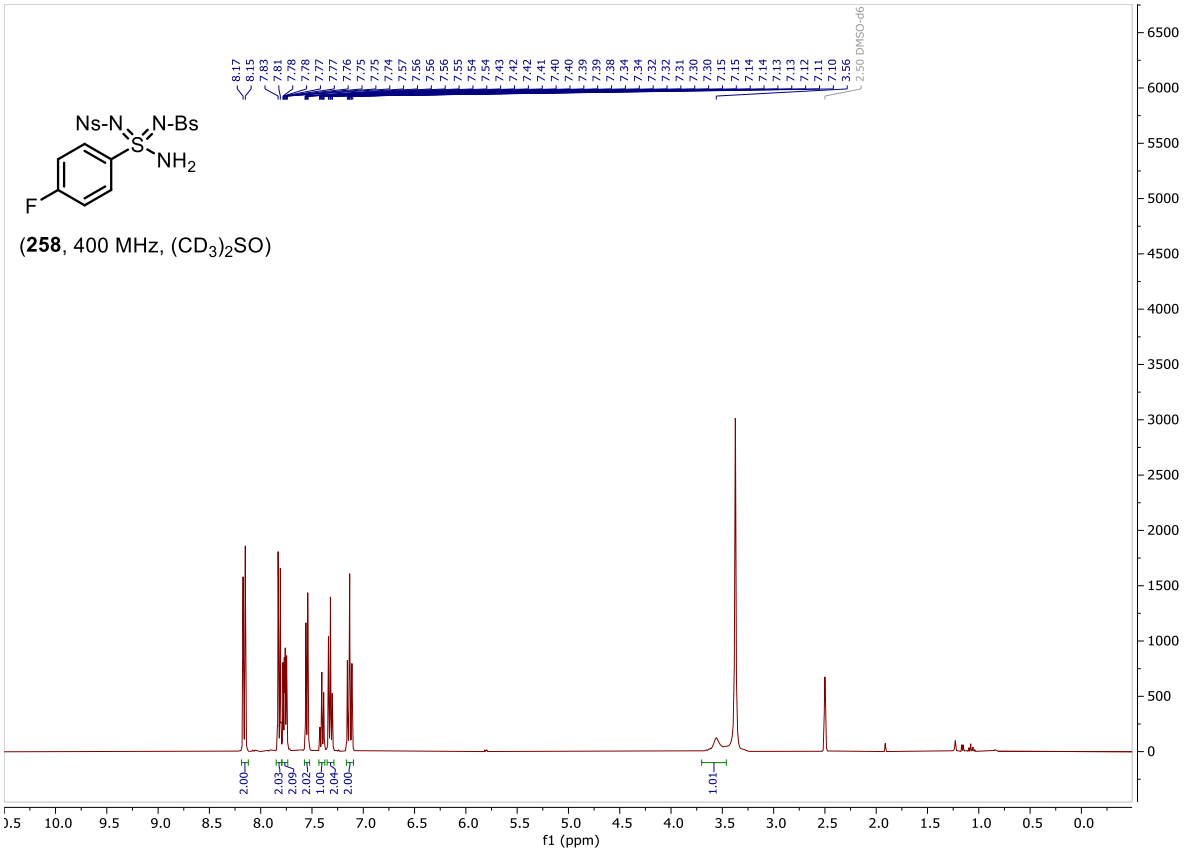


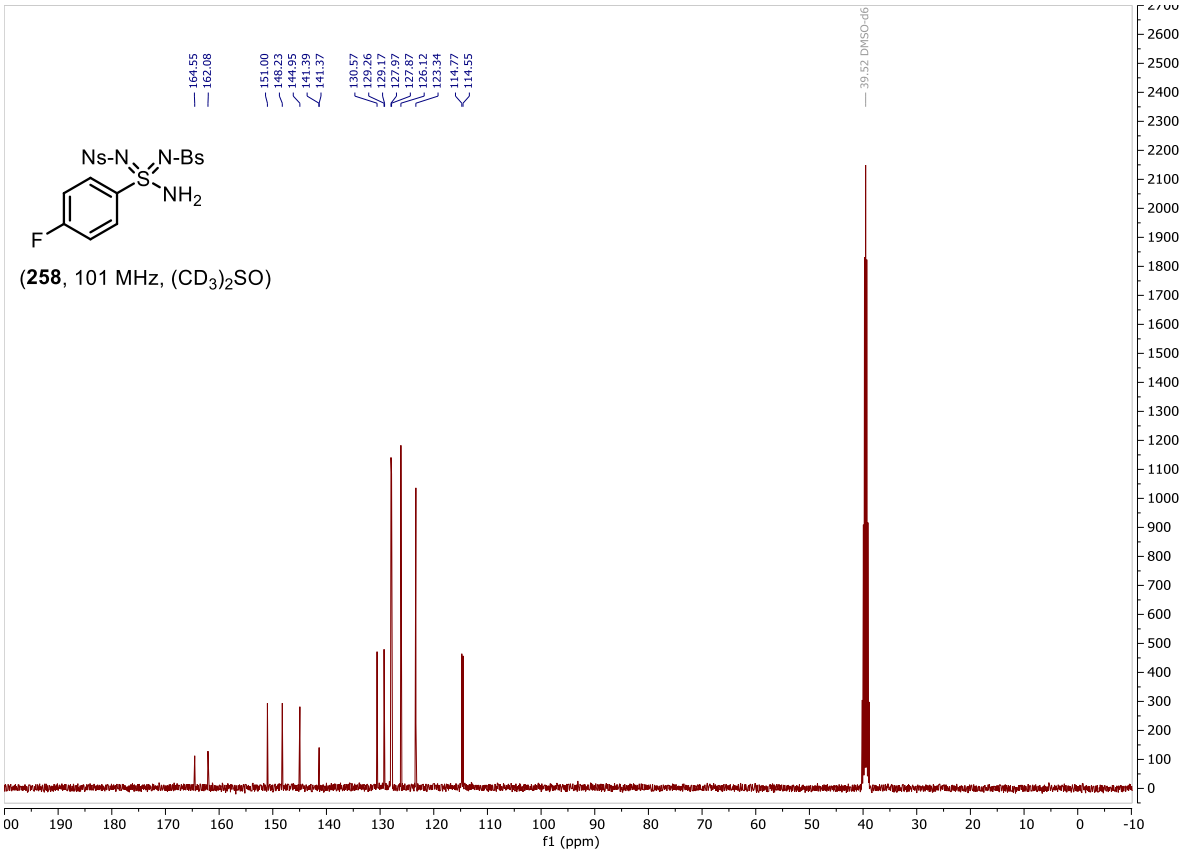
(**256**, 377 MHz, $(CD_3)_2SO$)


Ns-N
N-Bs
S
N
F
(257, 400 MHz, CDCl3)
f1 (ppm)

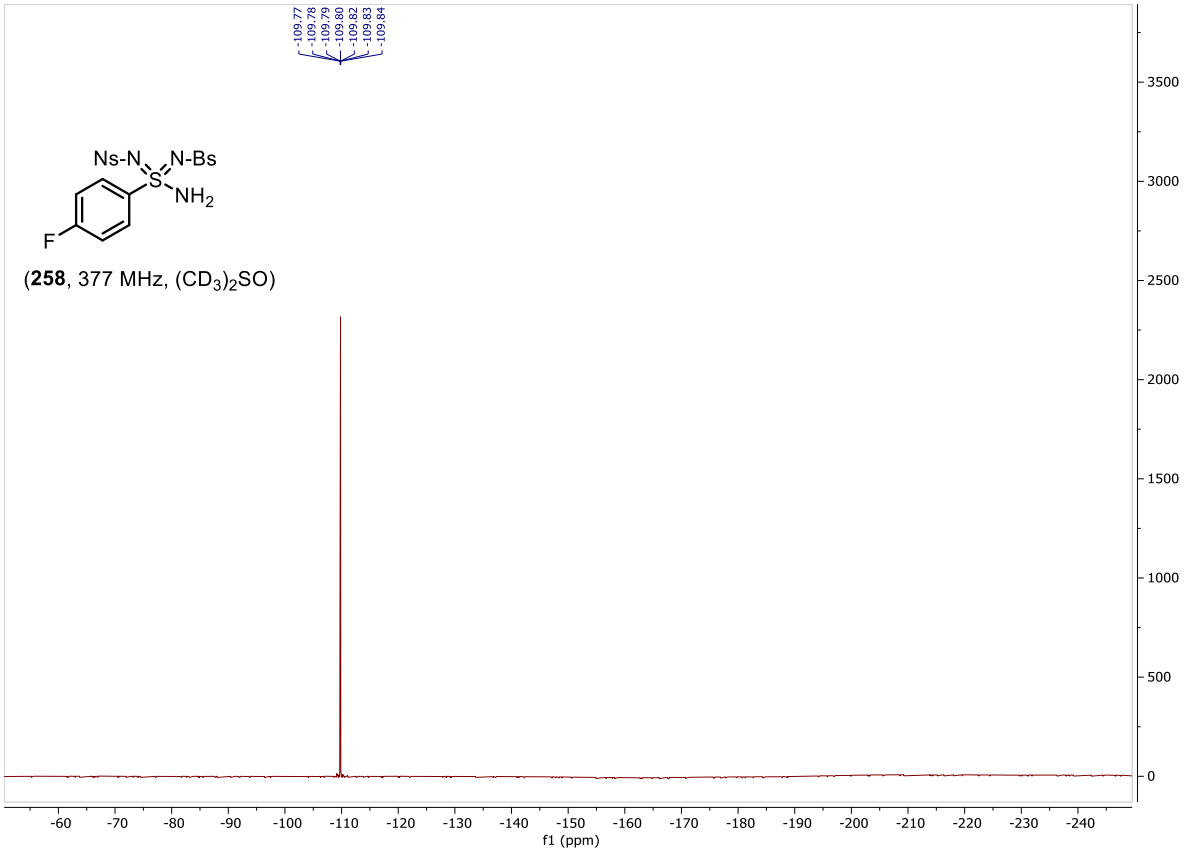

Ns-N
N-Bs
S
N
F
(257, 101 MHz, CDCl3)
f1 (ppm)


-100.64
-100.66
-100.66
-100.67
-100.68
-100.69
-100.70
-100.71
Ns-N
N-Bs
S
N
F
(257, 377 MHz, CDCl3)
2500
2000
1500
1000
500
0
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
f1 (ppm)

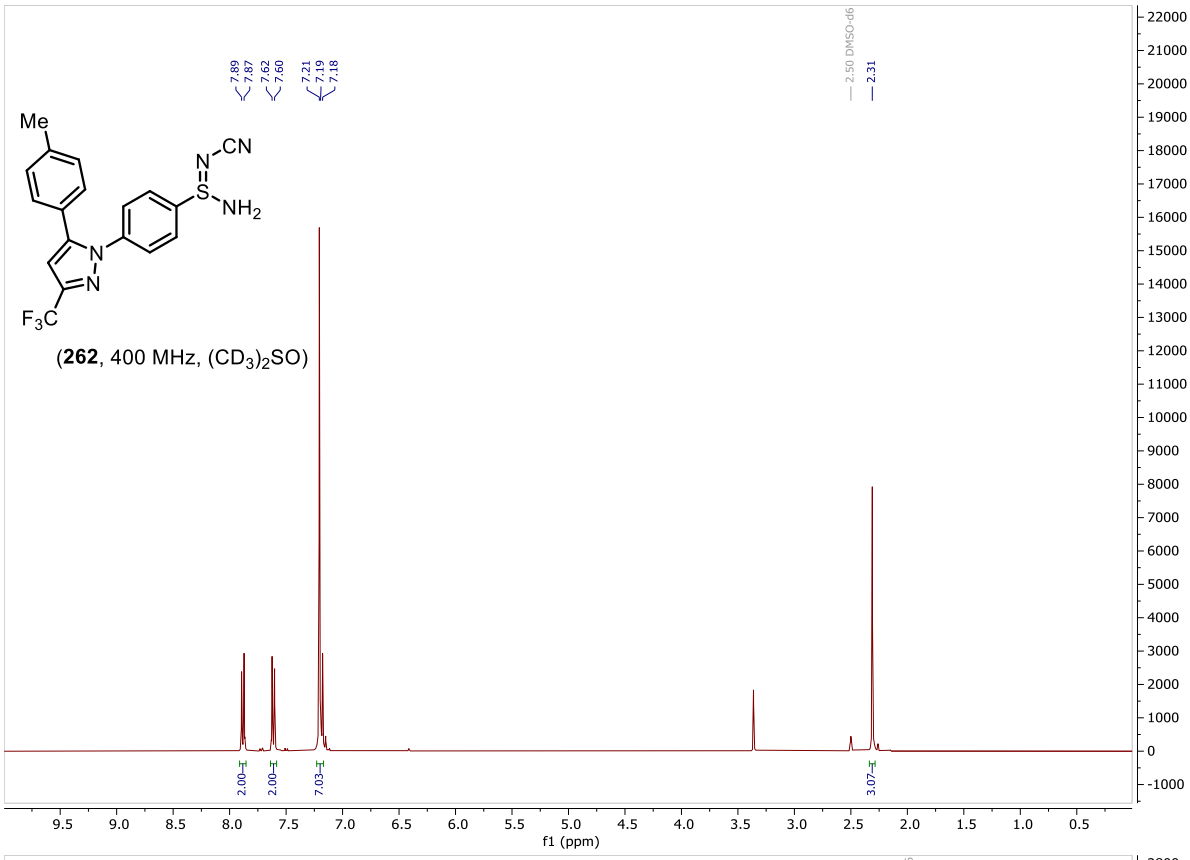

8.17
8.15
7.83
7.81
7.78
7.78
7.77
7.77
7.76
7.75
7.75
7.74
7.57
7.56
7.56
7.56
7.55
7.54
7.54
7.43
7.42
7.42
7.41
7.40
7.40
7.39
7.39
7.38
7.34
7.34
7.32
7.32
7.31
7.30
7.30
7.15
7.15
7.14
7.13
7.13
7.12
7.11
7.10
3.56
2.50 DMSO-d6
Ns-N
N-Bs
S
NH2
F
(258, 400 MHz, (CD3)2SO)
2.00
2.03
2.09
2.02
1.00
2.04
2.00
1.01
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

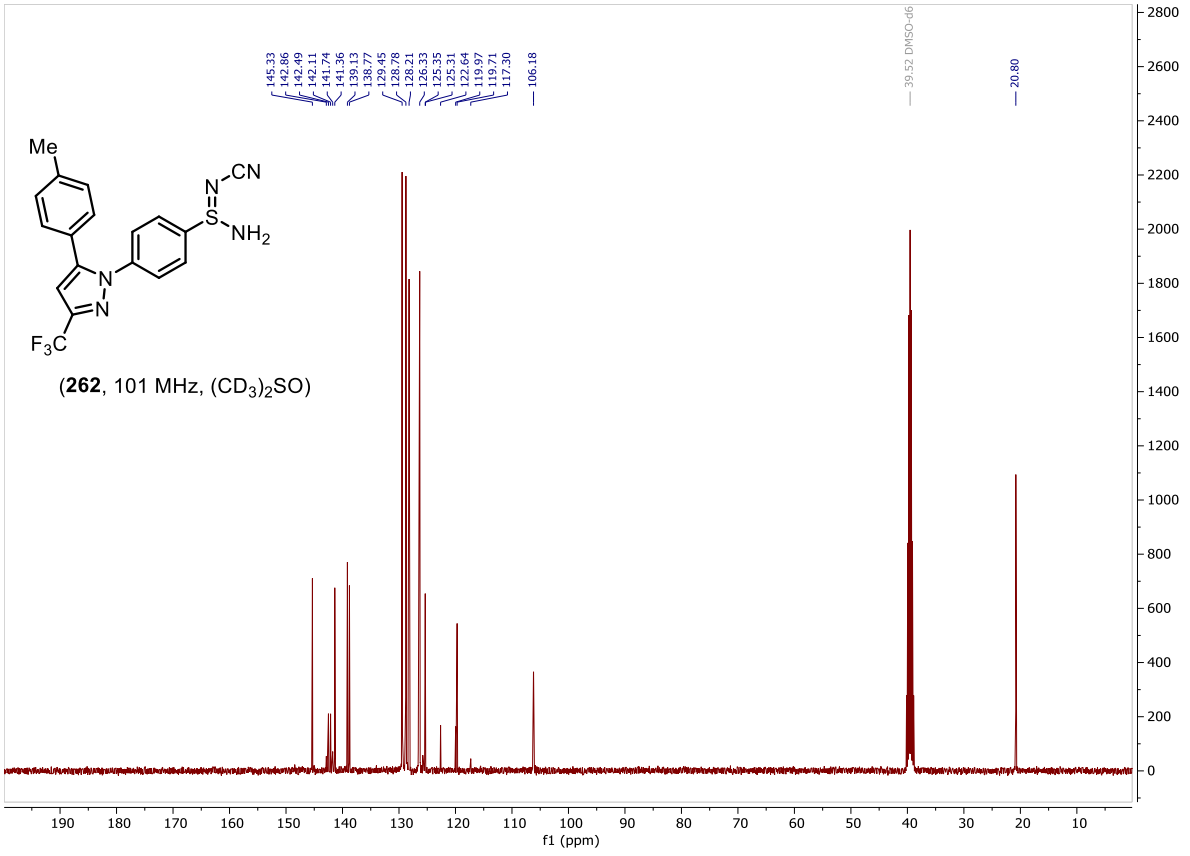


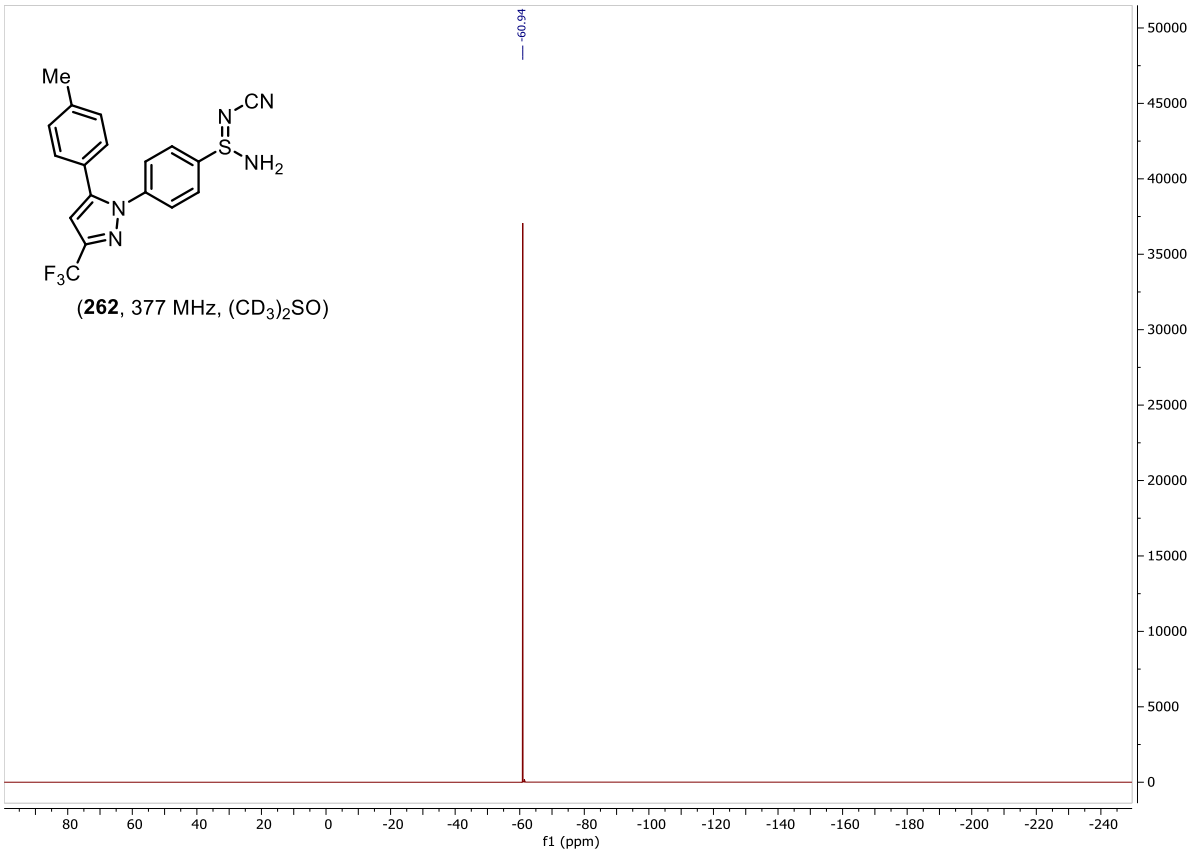
(**258**, 101 MHz, $(CD_3)_2SO$)



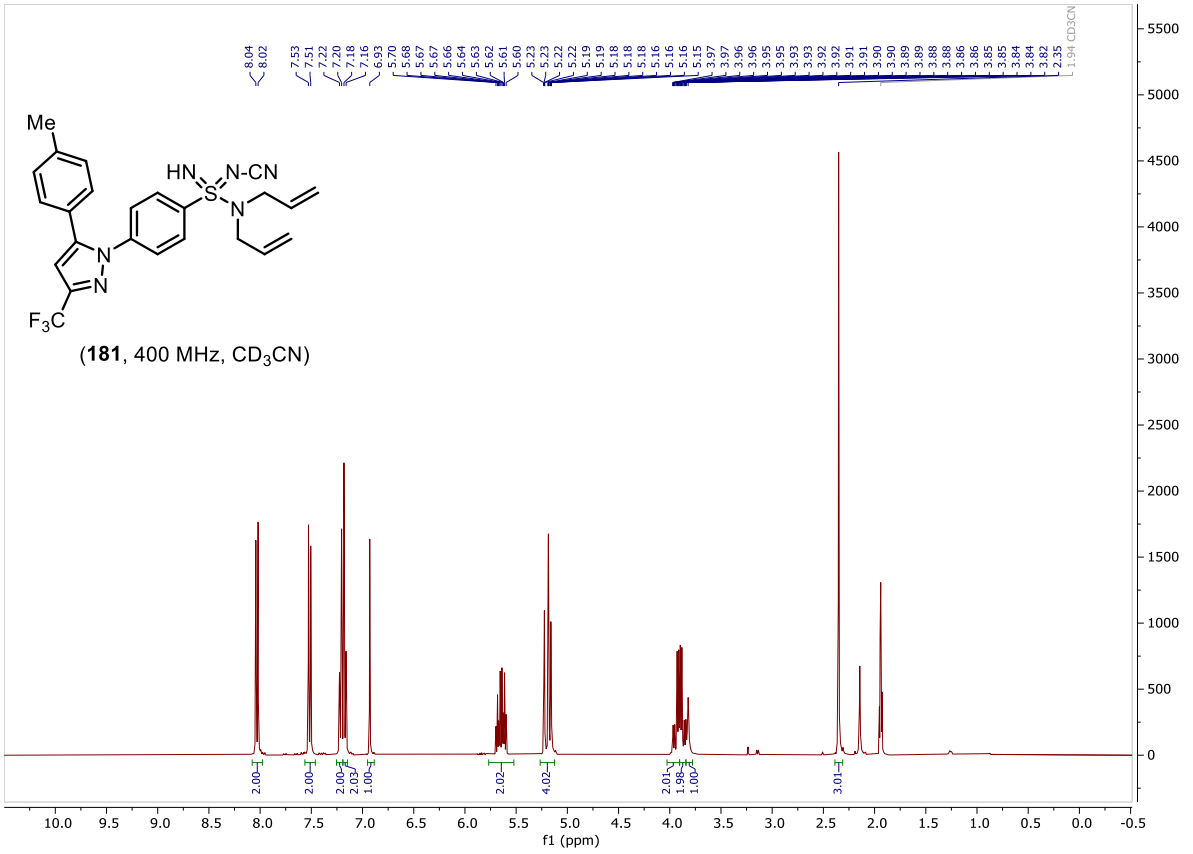
(**258**, 377 MHz, $(CD_3)_2SO$)


Me
N
CN
S
NH2
N
N
F3C
(262, 400 MHz, (CD3)2SO)
7.89
7.87
7.62
7.60
7.21
7.19
7.18
2.50 DMSO-d6
2.31
2.00
2.00
7.03
3.07
f1 (ppm)

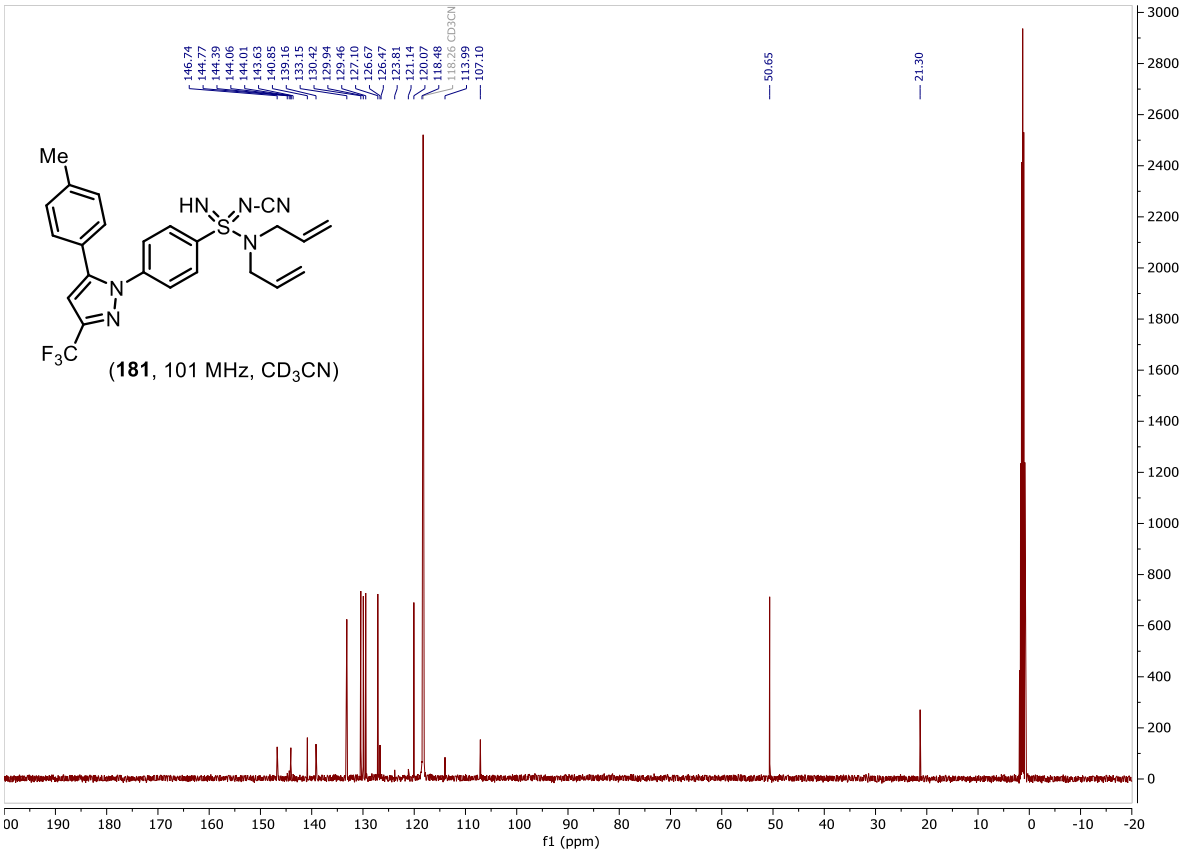

Me
N
CN
S
NH2
N
N
F3C
(262, 101 MHz, (CD3)2SO)
145.33
142.86
142.49
142.11
141.74
141.36
139.13
138.77
129.45
128.78
128.21
126.33
125.35
125.31
122.64
119.97
119.71
117.30
106.18
39.52 DMSO-d6
20.80
f1 (ppm)

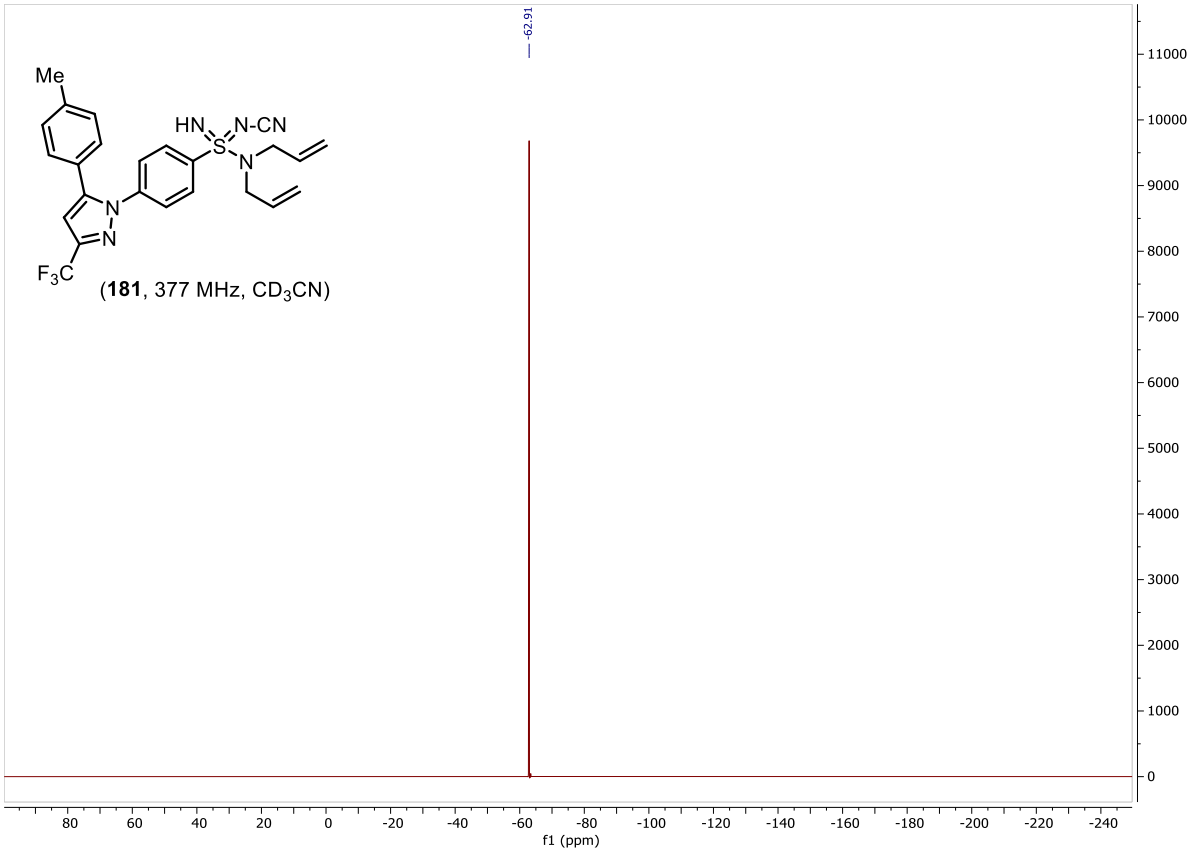


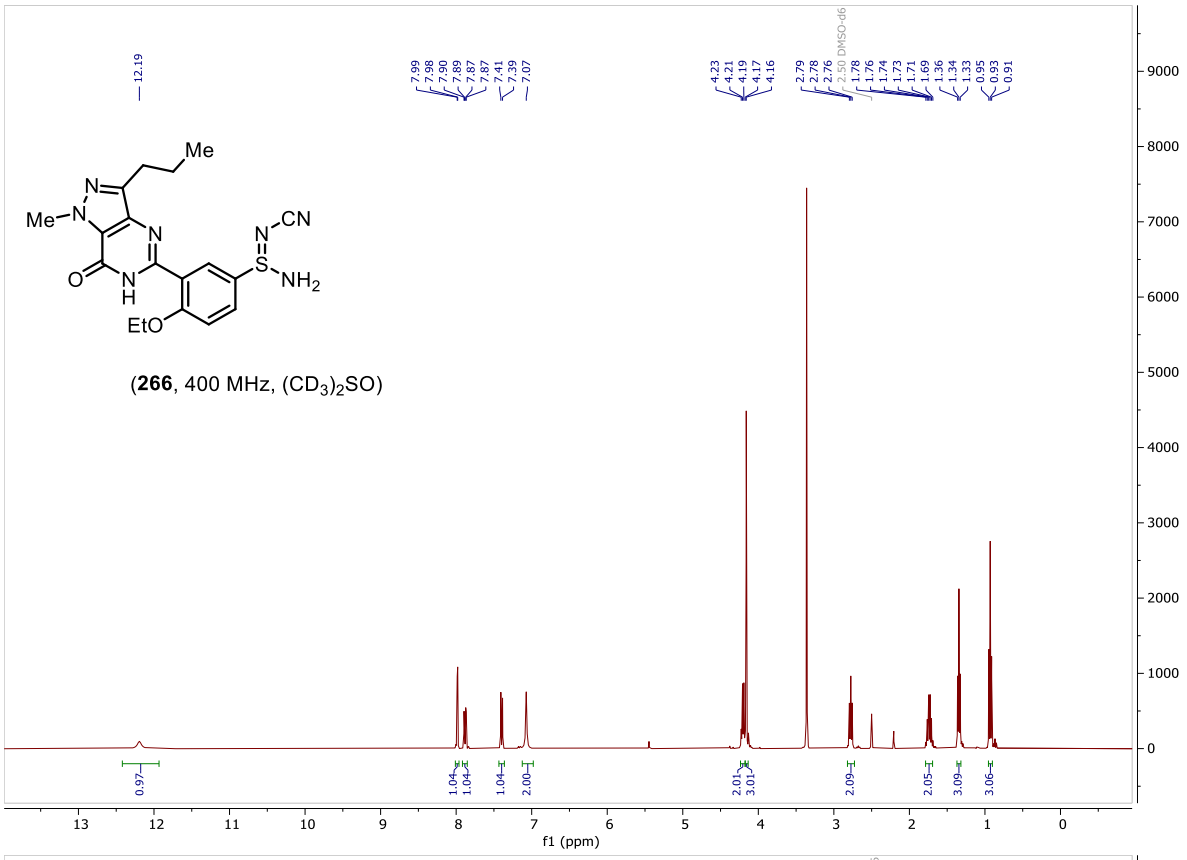
(**262**, 377 MHz, $(CD_3)_2SO$)



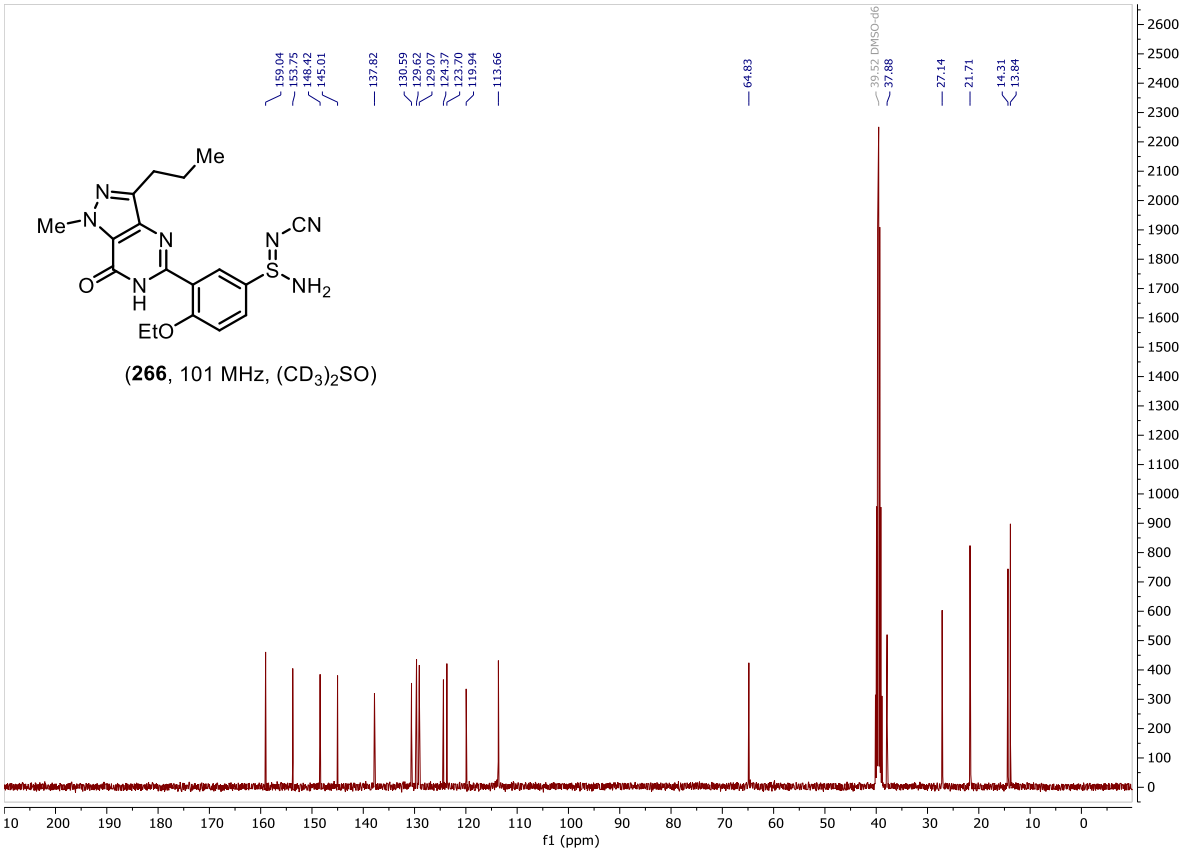
(**181**, 400 MHz, CD_3CN)


146.74
144.77
144.39
144.06
144.01
143.63
140.85
139.16
133.15
130.42
129.94
129.46
127.10
126.67
126.47
123.81
121.14
120.07
118.48
118.26 CD3CN
113.99
107.10
50.65
21.30
Me
HN
N-CN
S
N
N
N
F3C
(181, 101 MHz, CD3CN)
f1 (ppm)

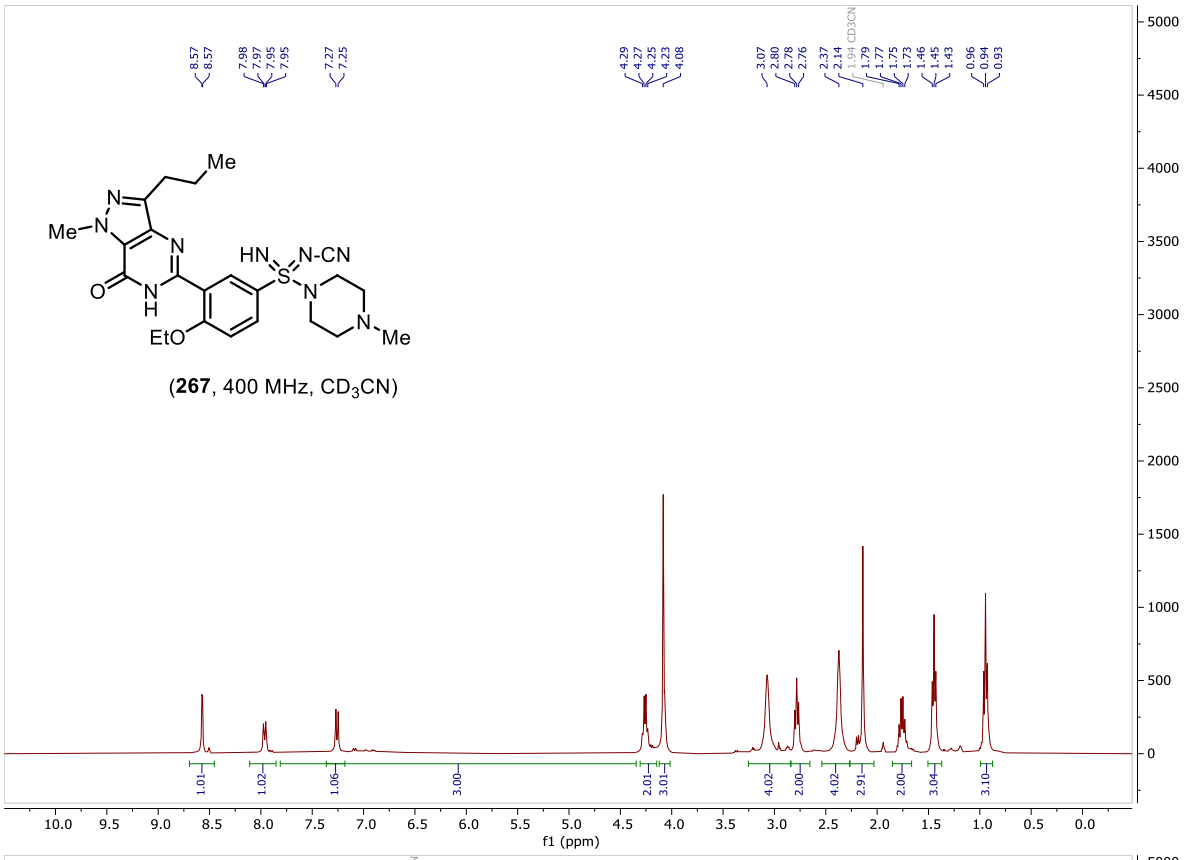

-62.91
Me
HN
N-CN
S
N
N
N
F3C
(181, 377 MHz, CD3CN)
f1 (ppm)



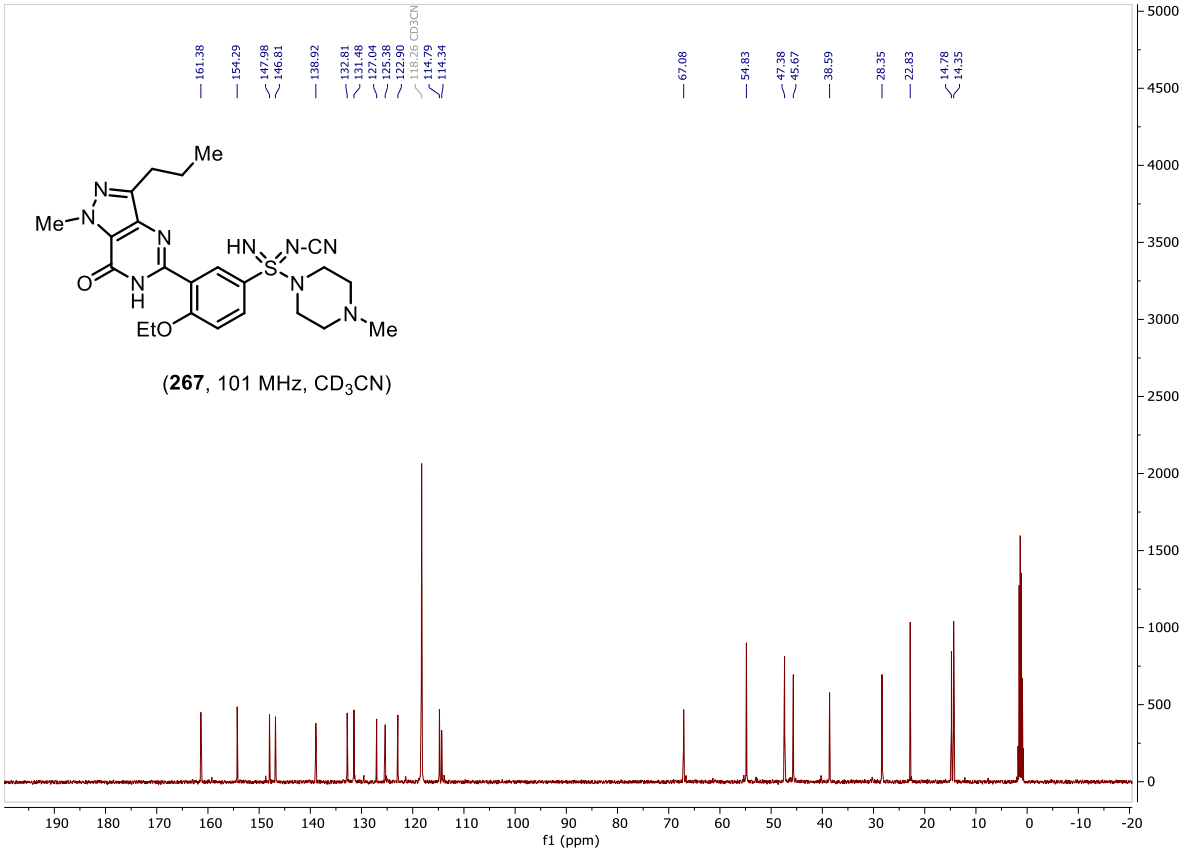
(**266**, 400 MHz, $(CD_3)_2SO$)



(**266**, 101 MHz, $(CD_3)_2SO$)



(**267**, 400 MHz, CD_3CN)



(**267**, 101 MHz, CD_3CN)