Liebig's *Kaliapparat* and the Origins of Scientific Glassblowing

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Abstract

In the fall of 1830, a young chemist named Justus Liebig developed a new piece of apparatus for organic analysis called the Kaliapparat. Using the Kaliapparat enabled Liebig to establish a reputation as one of Europe's leading analytical chemists and ultimately assured his status as one of the nineteenth century's greatest chemists. But the Kaliapparat changed much more than the course of Liebig's career. As this essay explains, Liebig's decision to produce the Kaliapparat by bending and blowing glass tubing radically changed the way that chemists do experimental work – so much so that an image of this device was incorporated into the logo of the American Chemical Society. This transformation of chemical practice had profoundly important consequences. As chemists came to rely on hollow glassware, they sought skilled assistance in its manufacture. This is the origin of the scientific glassblower.

In the fall of 1830, an ambitious young chemist named Justus Liebig posed a tricky chemical question [Figure 1]. Liebig, then professor of chemistry in Giessen, Germany, wanted to know what morphine was made of – exactly. That meant finding out how much of the elements carbon, hydrogen, oxygen, and nitrogen made up each molecule of morphine. Today, we think of morphine as a dangerous drug. But in 1830 it was the world's best painkiller, one of only a handful of pure chemical remedies then available. Made into laudanum, morphine was used to relieve the symptoms of just about every ailment. Liebig had chosen an important question, one that none of his contemporaries could answer, and one whose solution he hoped would make him famous.

Liebig tried to answer this question using state-of-the-art methods of chemical analysis he had learned from the world's most eminent chemists in the French capital Paris – the city where Liebig had trained. He failed. But he worked out why his analyses weren't working. The problem was nitrogen. Morphine contains a very small amount of nitrogen, and Liebig showed that this was impossible to measure reliably using existing methods of analysis.

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Organic analysis worked by burning the sample, converting carbon to carbon dioxide gas and hydrogen to water vapor. In theory, combustion released nitrogen gas unchanged, while oxygen was always determined as the residue once all the other elements had been fixed. Parisian science around 1800 focused heavily on the precision measurement of gas volumes and this expertise was central to how Liebig's teachers approached organic analysis. By the 1820s, Parisian analysts had begun to trap water vapor in a calcium chloride tube whose increase in mass equaled the mass of water produced on combustion. But they still determined nitrogen and carbon by measuring the total volume of carbon dioxide and nitrogen gases produced in a single experiment, a procedure that tended to give extremely inaccurate results for nitrogen.

This was the problem that Liebig tackled by bending and blowing glass tubing in the flame of a glassblower's torch. He produced a new piece of analytical apparatus that provided a separate measure of the mass of carbon dioxide produced on combustion. Liebig used his new experiment to show whether the combined gas volume experiment had worked properly, and whether nitrogen was being determined accurately. Liebig called his new apparatus the *Kaliapparat* – potash apparatus in English – and he used it to produce the best analysis of morphine the world had yet seen. This work established Liebig as a world-class analyst, and he eventually became leading chemist of his generation. Here's his Kaliapparat – part of the reason why he was made a Baron, Justus *von* Liebig [Figure 2].

One of us has published essays elsewhere concerning the technicalities of how Liebig's *Kaliapparat* worked, what made this approach so much better than previous methods of analysis, why Liebig produced this apparatus in glass, and how the *Kaliapparat* transformed chemical training and practice.[1] Several aspects of this work may be of particular interest to readers of *Fusion*, and we devote the remainder of this essay to a brief illustrated account of these highlights.

1. *Liebig made the original Kaliapparat himself but he soon learned that a more skillful glassblower could make useful refinements to his device.*

Historians believe that one of Liebig's assistants, Karl Ettling, produced the *Kaliapparat* in its final form. Among other changes, Ettling reduced the *Kaliapparat*'s size so that it could fit inside an analytical balance [Figure 3]. This decreased the *Kaliapparat*'s weight, thereby increasing the likely accuracy of the analytical results it produced. But it also made the *Kaliapparat* significantly harder to make.

2. ***Liebig knew that if other chemists were to use the Kaliapparat, they would have to make it for themselves.***

We know of only one chemist, the master analyst Jöns Jacob Berzelius, who made Liebig's *Kaliapparat* for himself without any form of instruction. Berzelius, who was already a highly skilled glassblower, made a *Kaliapparat* with the finished article as his only guide. That's why in 1833 Liebig published a short introduction to glassblowing in his journal, the *Annals of Chemistry and Pharmacy* [Figure 4].

3. ***The* Kaliapparat *was so successful that by 1837 Liebig published a textbook of organic analysis that included pictorial instructions for its construction and a life-size image of the final product.***

During the 1830s, Liebig developed a new approach to organic chemistry that was based on organic analysis. Liebig supplied the manpower for this project by involving students in his research. His Giessen laboratory became the first site of large scale training for research, an important milestone in the development of academic research groups as we know them today. Liebig was so successful that chemists elsewhere wanted to copy his approach, and Liebig published a textbook to help them [Figure 5].

4. ***The success of Liebig's Kaliapparat prompted chemists everywhere to begin working in flame worked glass apparatus, a change so important it warrants begin called the "glassware revolution."***

Other chemists were quick to adopt Liebig's *Kaliapparat* and they soon began to teach its use. They also began using the *Kaliapparat* anywhere they wished to absorb gas in liquid. The *Kaliapparat* was widely used in nineteenth-century experiments in physics and physiology as well as chemistry. Many studies of respiration, photosynthesis, and carbon dioxide assimilation, for example, relied on the *Kaliapparat*. In learning how to use the *Kaliapparat*, chemists learned that working in hollow glassware could solve problems that much larger, more expensive apparatus could not. This was how chemists began to work almost exclusively in flame worked glass apparatus, a change so important that it warrants being called the "glassware revolution." Many chemists learned to blow glass for themselves, but they also began to rely on specialist suppliers of chemical glassware for standard items such as the *Kaliapparat*. These developments began in Europe but by about 1850 they had also reached North America [Figure 6].

5. ***Working in glass gave chemists unprecedented experimental flexibility and control, features they began to exploit by collaborating with the first professional scientific glassblowers.***

Chemists benefitted enormously from the control glass gave them over their experiments. Basic glassblowing skills allowed them to modify existing apparatus relatively easily. Even without glassblowing skills, the increasing commercial availability of chemical glassware meant that chemists could combine these components in almost limitless variations. Access to this kind of innovation and flexibility transformed mid nineteenth-century chemistry.

Chemists also learned – as Liebig had done before them – that collaborating with expert glassblowers was very helpful in refining their ideas. Especially in cases where standardization was important, working with a professional scientific glassblower soon became essential. One of the first scientific glassblowers to work this way was Heinrich Geissler. Best known for the vacuum pump and discharge tubes that bear his name, Geissler's work has usually been considered in the context of physics. In fact, Geissler spent much of his career realizing and improving upon chemists' experimental visions. His 1851 variation on Liebig's *Kaliapparat* was one of the most successful ever made.

Conclusions

The *Kaliapparat* made it possible for Liebig to do cutting edge research in Giessen, a small German market town. By the 1840's, Giessen had become the world center for chemical training and research. Using the *Kaliapparat* showed Liebig where the limits of organic analysis lay. In response, he introduced the synthetic method to organic chemistry. This was the origin of organic synthesis, which by about 1900 was one of the world's most powerful and productive sciences, and it was how chemistry became a German science. This extraordinary transformation made Liebig the nineteenth century's greatest chemist and it all started with a small piece of hollow glassware.

Mid nineteenth-century chemists everywhere began making and using Liebig's *Kaliapparat*. Using the *Kaliapparat* taught them that apparatus made by glassblowing offered important practical advantages. Working in glass increased chemists' control over chemical processes because innovation was easier and they could combine commercially available components in a variety of ways. At the same time, working with professional glassblowers allowed chemists to achieve better results and it meant that important apparatus could be reliably standardized. To this day, scientific glassblowers work with chemists to

develop innovative chemical glassware and to make this widely available in standard form. This essay has provided a glimpse of how this situation arose, and it begins a series in which we examine its further development. Glassblowing emerges as essential to present-day understanding of and control over the natural world, a core expertise at the heart of technical modernity.

Acknowledgments

We gratefully acknowledge the University of Wisconsin-Madison Chemistry Department's continuing support of the glass shop, and of this collaborative project.

Figure 1. Justus Liebig (1803-1873) was an ambitious young man who rose to become one of the greatest chemists of his generation. This image in the collections of the Liebig Museum in Giessen, Germany, is an 1843 lithograph of an 1821 painting.
Public domain image downloaded from https://en.wikipedia.org/wiki/Justus_von_Liebig November 9 2016.

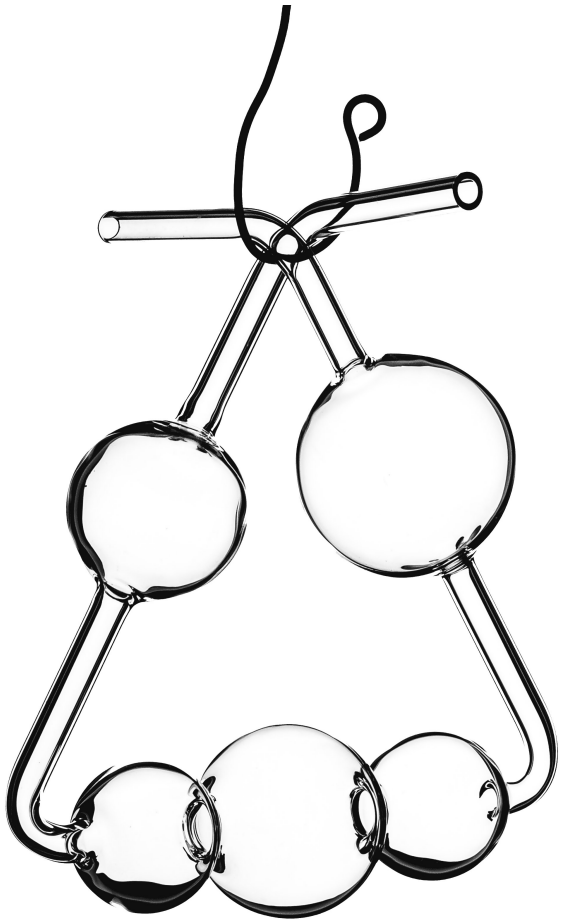

Figure 2. Liebig's Kaliapparat provided an independent measure of the carbon content of an organic substance. It worked by dissolving the carbon dioxide gas produced when an organic substance burned in potassium hydroxide or potash solution. This was how the Kaliapparat got its English name: potash apparatus or potash bulbs. Weighing the Kaliapparat before and after combustion gave the mass of carbon dioxide, and hence the mass of carbon in the sample.
2016 reconstruction of Liebig's Kaliapparat in borosilicate glass by Tracy Drier.
Photograph courtesy of Ilia Guzei.

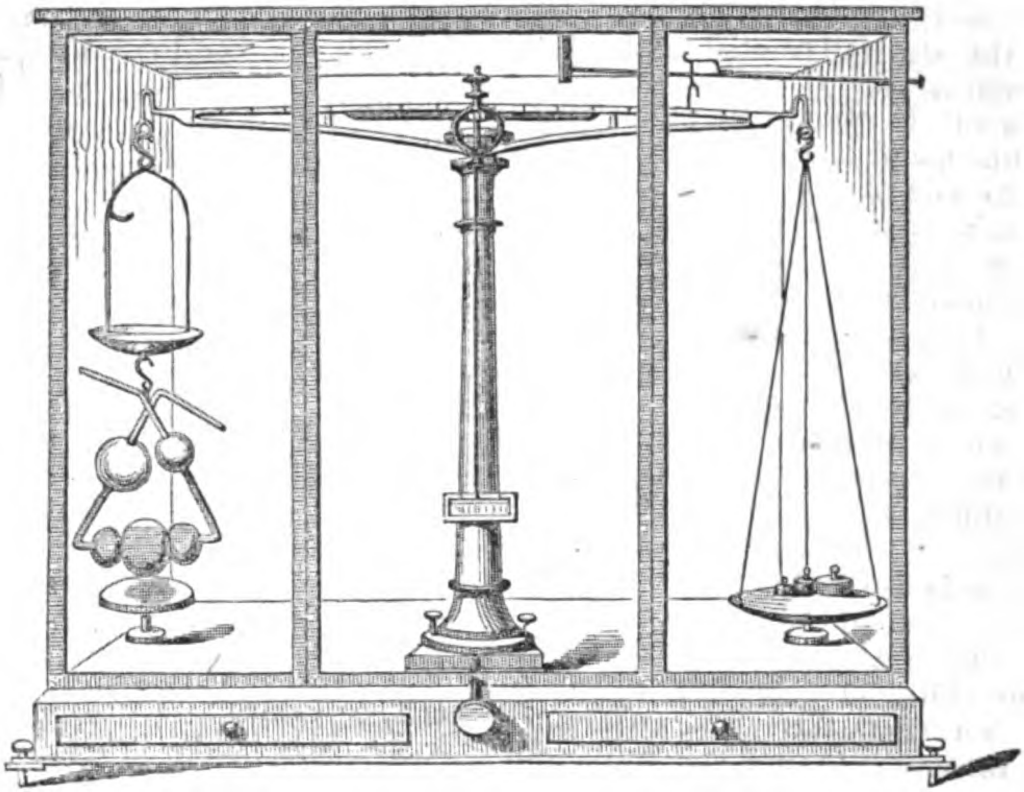

Figure 3: This analytical balance was made around 1850 by the London instrument maker Ludiwg Oertling for Henry Noad, who taught chemistry at St George's Hospital Medical School, London. Noad's illustration showed how the balance was used to weight Liebig's Kaliapparat*, one of the principal measurements of organic analysis. Henry M. Noad, Chemical Manipulation and Analysis, Qualitative and Quantitative, 2nd ed. (London: Baldwin, 1852), 120, Figure 2. Original in the public domain. Image courtesy of Google books.*

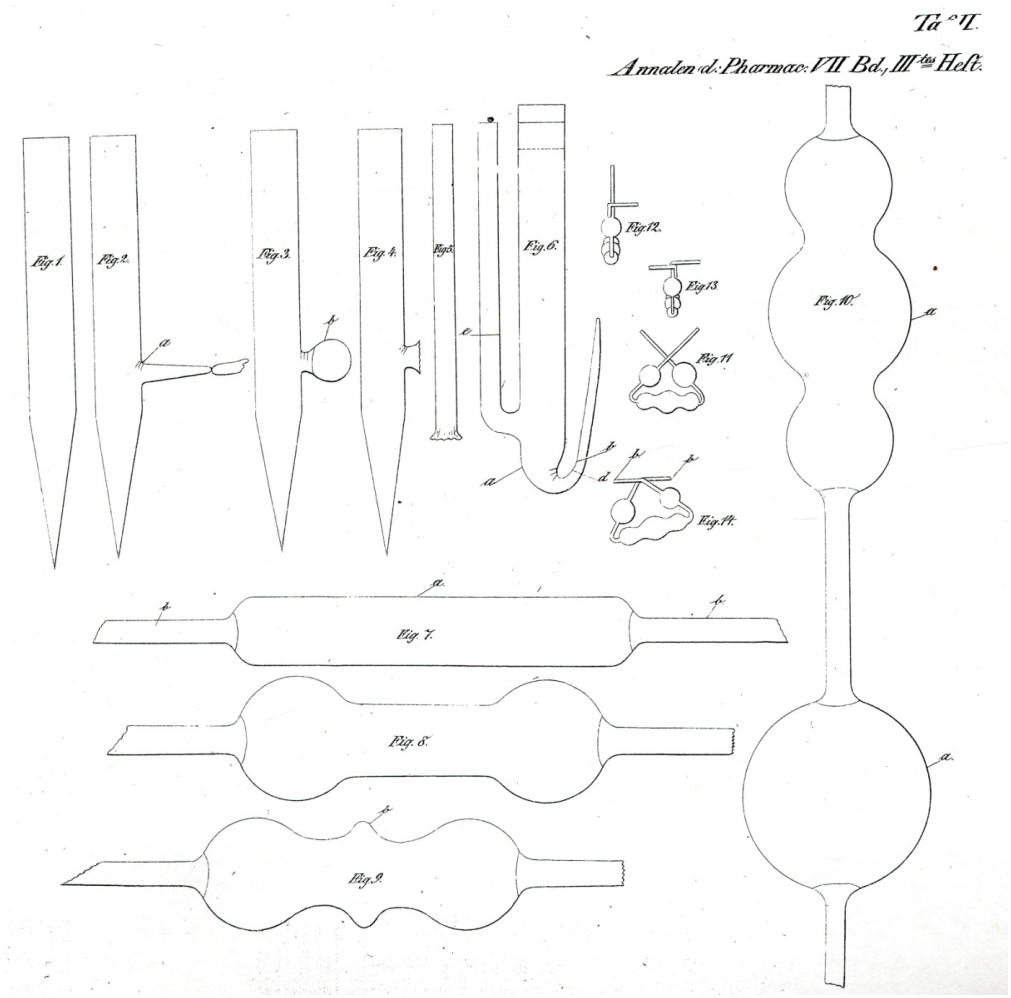

Figure 4. Liebig's first published instructions for making a Kaliapparat appeared alongside basic instructions in glassblowing. In 1833, you could not buy a Kaliapparat. Liebig knew that if other chemists were to adopt his approach to analysis, they would need to make the apparatus for themselves.
(Figs. 1-6 above show how to make Berzelius's washing apparatus.)
Lafond, "Ueber die Kunst Glas zu blasen, mit Verbesserungen von Danger," Annalen der Chemie, 1833, 7: 298-313, Tafel II. Original in the public domain. Image courtesy of Google books.

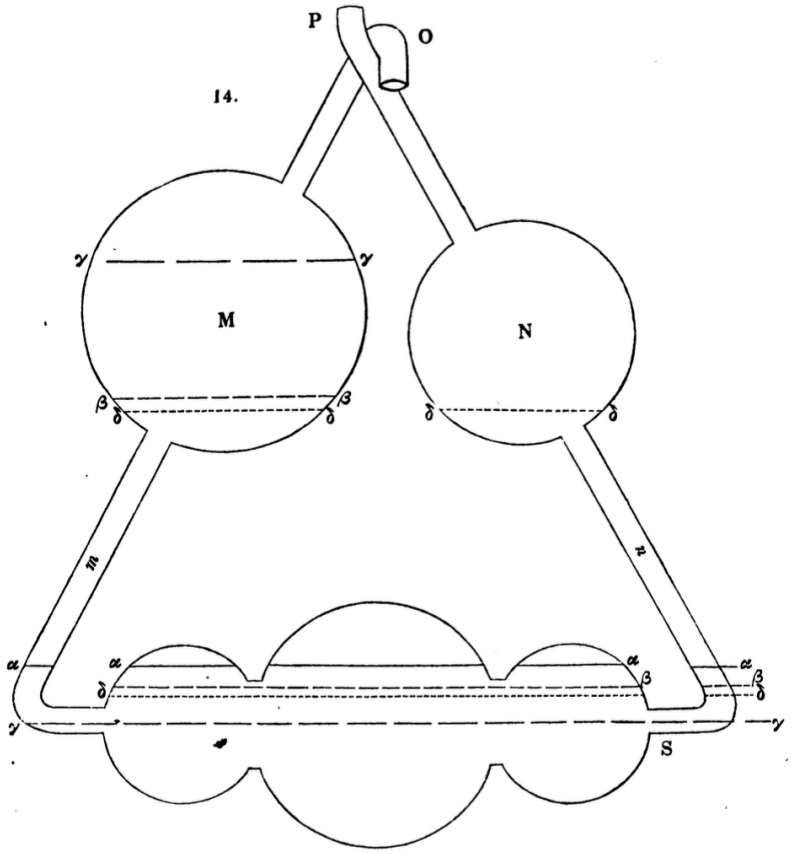

Figure 5. Liebig's 1837 instructions followed the sequence developed by 1833.

Justus Liebig, Instructions for the Chemical Analysis of Organic Bodies, Transl. William Gregory (Glasgow: Griffin, London: Tegg, 1839), 11. Original in the public domain. Image courtesy of Google books

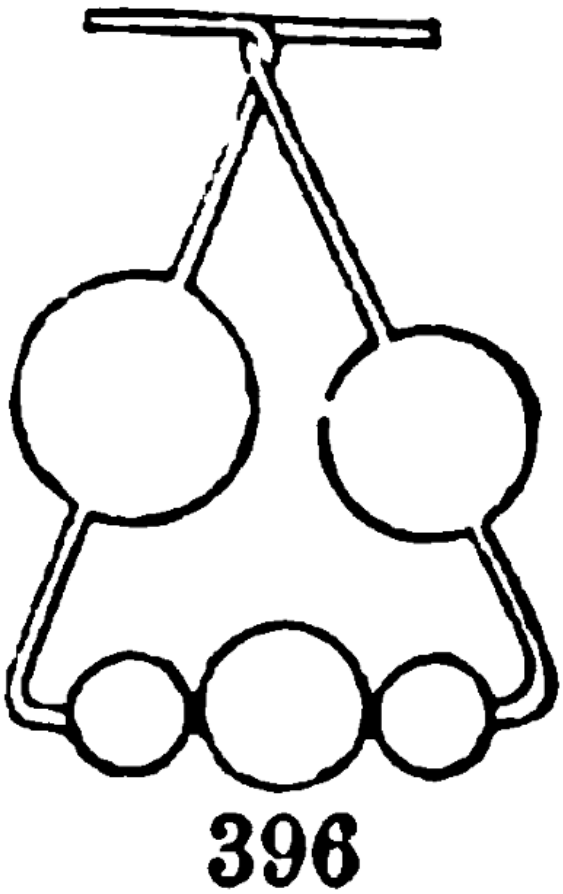

Figure 6. The New York chemist and apparatus supplier Edward N. Kent was among those who supplied Liebig's Kaliapparat.
Edward N. Kent, Descriptive Catalogue of Chemical Apparatus, Chemicals and Pure Reagents (New York: van Norden, 1854), 33. Original in the public domain. Image courtesy of Google books

Figure 7. Heinrich Geissler (1814-1879) was one of the first professional scientific glassblowers. Public domain image downloaded from https://commons.wikimedia.org/wiki/File:Heinrich_Geissler.jpg, November 9 2016.

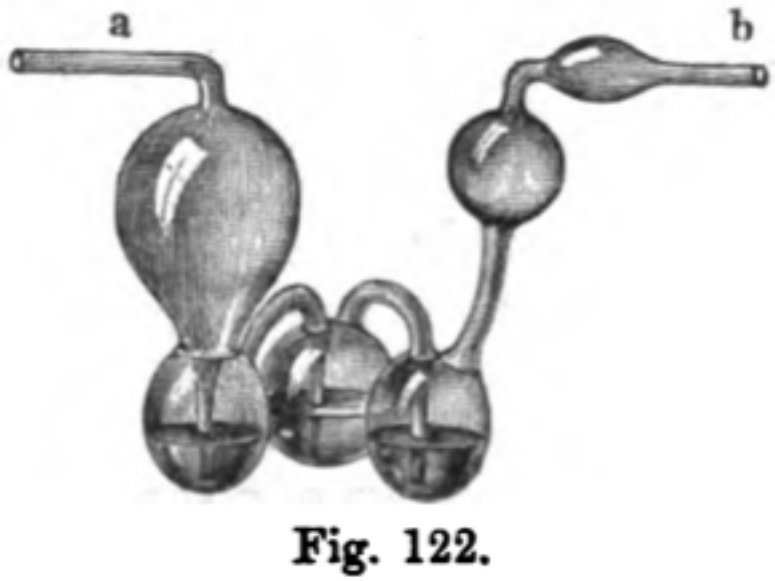

Fig. 122.

Figure 8. Geissler's modification of Liebig's Kaliapparat greatly improved its precision by incorporating a bubbler in each of the three absorption bulbs and reducing the overall size and mass of the device. It also made it much too difficult for an amateur glassblower to make. Drier is presently working to reconstruct the Geissler Kaliapparat. Carl Remigius Fresenius, A System of Instruction in Quantitative Chemical Analysis, 5th ed. transl. John Lloyd Bullock and Arthur Vacher (London: Churchill, 1865), 477. Original in the public domain. Image courtesy of Google books

[1] Catherine M. Jackson, "Visible Work: the Role of Students in the Creation of Liebig's Giessen Research School," *Notes and Records of the Royal Society* 62 (2008): 31-49; Catherine M. Jackson, "The 'Wonderful Properties of Glass': Liebig's Kaliapparat and the Practice of Chemistry in Glass," *Isis* 106 (2015): 43-69.