project calibrate

Summative Assessment Resources for Practical Science

Chemistry

Chromatography

DEPARTMENT OF EDUCATION

UNIVERSITY OF OXFORD

About Project Calibrate

Project Calibrate is a research and development collaboration between University of Oxford and AQA, and aims to foster effective teaching, learning and assessment of practical science. The resource pack contains five summative assessments developed as part of the project to assess learners' understanding of and skills in GCSE practical science. The underlying framework of practical science is Brandon's matrix which highlights a variety of methods used in science. According to Brandon, there are four main categories of scientific methods (described on the next page). Four assessment tasks were designed using each category. The fifth assessment task includes all four categories and engages the learners in an evaluation of the different scientific methods.

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Project team

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Project Calibrate (2020). *Summative Assessment Resources for Practical Science: Chromatography.* Oxford: University of Oxford.

Brandon's Matrix

Brandon provides an account of diversity in scientific methods. His framework has been adapted by Project Calibrate (see Table 1) and illustrates that not all experiments rely on hypothesis testing, and that not all descriptive work is non-manipulative. Brandon represents the connections between experiments and observations in terms of a matrix (i.e. two-by-two table) in which an investigation (experiment/observation) is related to whether or not it involves manipulation, and whether or not it involves hypothesis testing or parameter measurement.

Table 1. Adaptation of Brandon's matrix

Experiment or observation		
	Change variable	**Don't change variable**
Test hypothesis	Manipulative hypothesis testing	Non-manipulative hypothesis testing
Describe or measure	Manipulative description or parameter measurement	Non-manipulative description or parameter measurement

The importance of the matrix is that it challenges the traditional linear model of the scientific method in the science curriculum. A fairly typical depiction in school of how science is done involves the so-called 'scientific method', which is described as a process through which scientists produce robust evidence by applying procedures such as experimentation and observation. According to this model, scientists begin with a question they want to answer. They then design an experiment and, by carefully tracing independent and dependent variables, they produce findings that help them answer the question. However, such a step-wise and linear description of the scientific method is simplistic and hardly a realistic representation of how scientists actually do science. Rather, scientists engage in a wide array of methods some of which include hypothesis testing, and some other approaches including those where there is no manipulation of variables (Erduran & Dagher, 2014).

A contemporary example about Brandon's matrix involves the Covid-19 pandemic (Erduran, Childs & Baird, 2020). Scientists collect data on how the virus might be influencing a patient's breathing over a period of time. Such observation is simply based on the recording of parameters where there is no manipulation of variables in the sense of an experimental design. Sometimes the data might be subjected to hypothesis testing about correlation between incubation period and extent of lung disease, but without an experiment resulting in non-manipulative hypothesis testing. Scientists may conduct randomised control trials in which a drug could be treated as a variable in interventions that also include control groups to test the placebo effect. All of these different approaches are used in science, and there is no one single method but rather a diversity of scientific methods.

References

Brandon, R. (1994). Theory and experiment in evolutionary biology. *Synthese*, 99, 59-73.

Erduran, S., Childs, A., & Baird, J. (2020). Practical science and pandemics. https://www.bera.ac.uk/blog/practical-science-and-pandemics

Erduran, S., & Dagher, Z. (2014). *Reconceptualising the nature of science for science education: Scientific knowledge, practices and other family categories*. Dordrecht: Springer.

Chemistry: Chromatography

Question 1 [manipulative hypothesis testing]

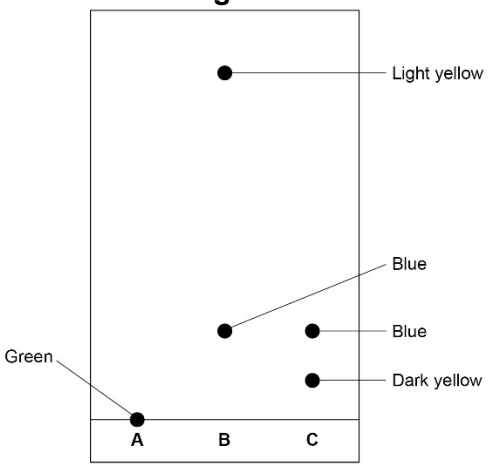
Ali tested the hypothesis that all green inks are made up of blue and yellow pigments.

He set up a chromatography experiment using three different types of green ink, **A**, **B** and **C**.

He left the chromatogram to run in water for 20 minutes.

Figure 1 shows the results after the chromatogram had dried.

Figure 1



1.1 What conclusion can you make about ink **A**?

[1 mark]

1.2 Give **three** conclusions you can make about the composition of inks **B** and **C**.

[3 marks]

1. _____

_____

2. _____

_____

3. _____

_____

1.3 The **dependent** variable in the experiment was the pattern produced.

Name the **independent** variable.

[1 mark]

_____

_____

1.4 Ali could have placed the three inks on different pieces of chromatography paper, in different beakers.

Name **two** control variables in that Ali should use.

[2 marks]

1. _____

_____

2. _____

_____

1.5 To see whether his hypothesis is correct, Ali needs to do a further test on one of the inks.

Which ink should he test?

Suggest how he should test this ink.

[3 marks]

_____

_____

_____

_____

_____

Question 2 [manipulative parameter measurement]

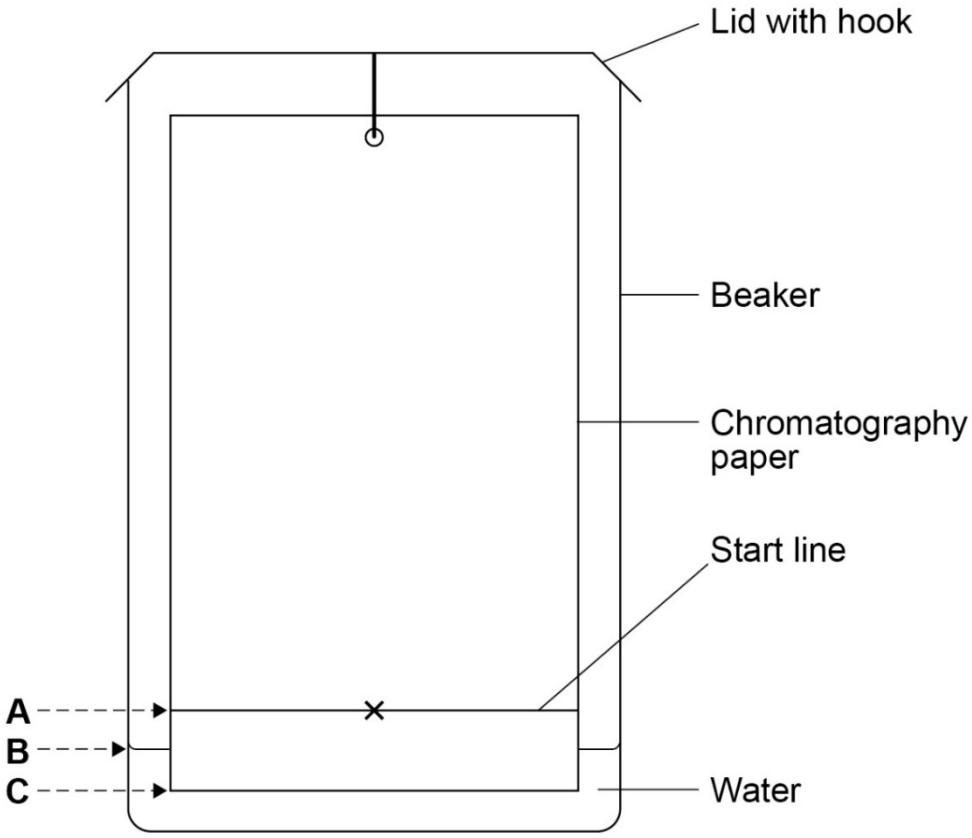
Bella investigated the chromatography of a blue dye.

This is the method used:

1. She drew a pencil line 2 cm from the edge of a piece of chromatography paper.
2. She put a spot of the blue dye on the line.
3. She placed the chromatography paper in a beaker in 1 cm depth of water.
4. She taped a ruler to the side of the beaker.
5. Every two minutes, she measured the distance travelled by the spot and the distance travelled by the water.

Figure 2 shows the apparatus.

Figure 2



2.1 Why did Bella make the original water level below the start line?

[1 mark]

_____

_____

2.2 Bella measured the distance travelled by the water.

Which level, **A**, **B** or **C**, should Bella start her measurement from?

Use **Figure 2**.

Tick (✓) **one** box.

[1 mark]

A ☐ **B** ☐ **C** ☐

Table 1 shows the results.

Table 1

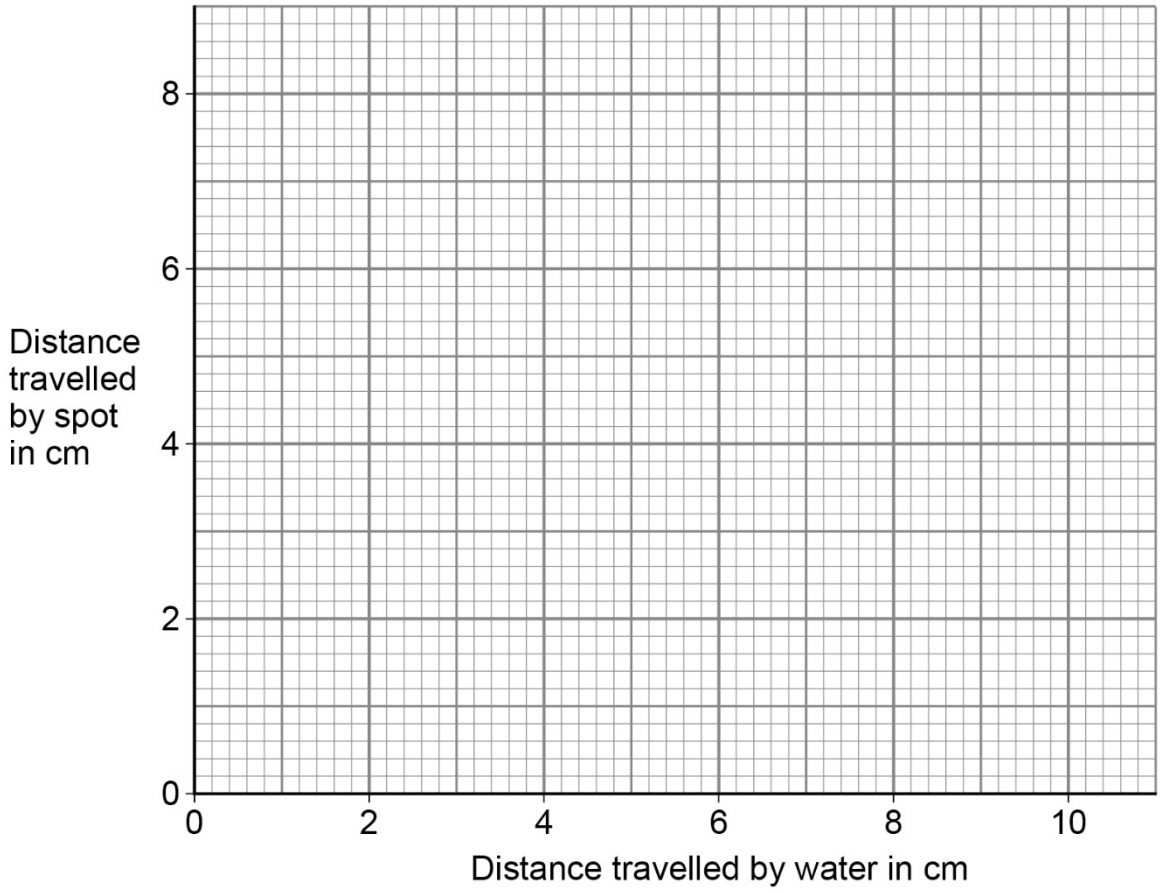
Time in min	2	4	6	8	10
Distance travelled by spot in cm	1.5	3.3	4.5	5.4	6.7
Distance travelled by water in cm	2.1	4.6	6.2	7.5	9.3

2.3 Plot the data from **Table 1** on **Figure 3**.

Draw a line of best fit.

[3 marks]

Figure 3



2.4 Calculate the gradient of the line.

Give your answer to 2 significant figures.

[3 marks]

gradient = _____

2.5 What is the link between the gradient of the line and the R_f value of the spot?

[1 mark]

Question 3 [non-manipulative hypothesis testing]

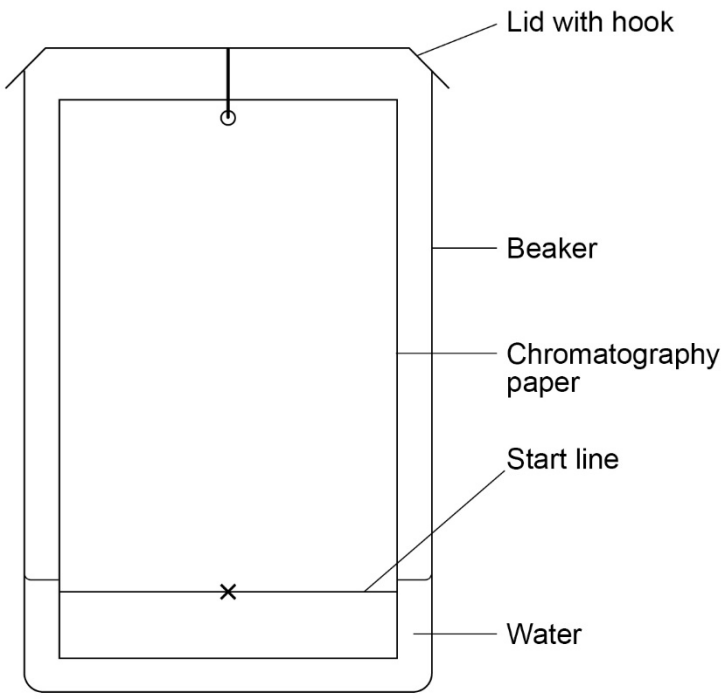
Two students predicted that the green food colour in a sweet was made up of blue and yellow colours.

This is the method Dan used:

1. He drew a start line on a piece of chromatography paper.
2. He drew a cross on the start line.
3. He dipped the sweet in water.
4. He rubbed the sweet onto the cross he had drawn, to make a spot of green colour.
5. He placed the paper in a beaker.

Figure 4 shows the apparatus set up.

Figure 4



3.1 Dan drew the start line using a ruler.

What else should Dan use to draw the start line?

Give a reason for your answer.

[2 marks]

3.2 What mistake has Dan made in setting up the apparatus?

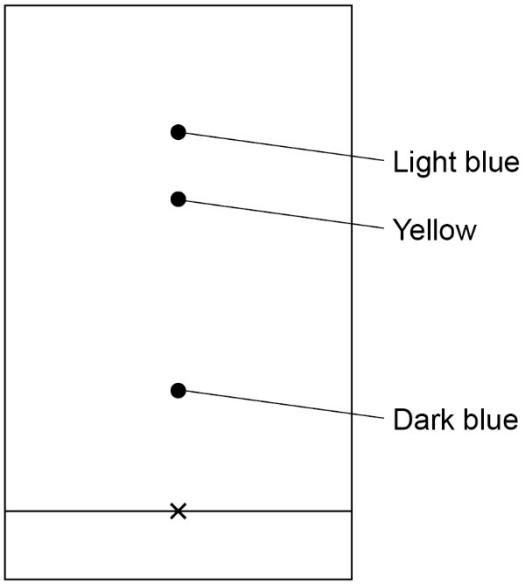
Give a reason for your answer.

[2 marks]

Emma set up the apparatus correctly.

Figure 5 shows Emma's results.

Figure 5



3.3 Give **two** conclusions you could make from Emma's results.

[2 marks]

1 _____

_____

2 _____

_____

3.4 Emma measured the R_f value of the yellow spot.

What must she do before letting the paper dry?

[1 mark]

_____

_____

3.5 Two statements about the experiment are given.

Tick **true** or **false** for each statement.

[1 mark]

Statement	**True**	**False**
At least one variable was changed.		
A hypothesis was tested.		

Question 4 [non-manipulative parameter measurement]

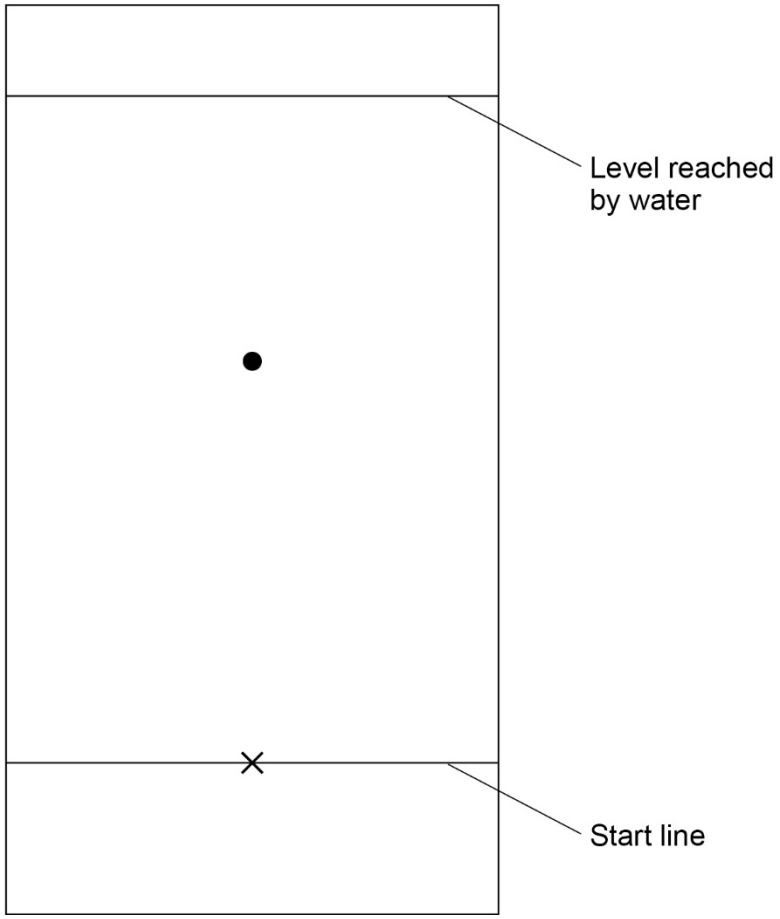
Eva measured the R_f value of a blue food colouring.

This is the method she used:

1. She drew a line 2 cm from the edge of a piece of chromatography paper.
2. She drew a cross on the line.
3. She put a spot of the blue food colouring on the cross.
4. She placed the chromatography paper in a beaker in 1 cm depth of water.
5. She let the chromatogram run until the water had nearly reached the top of the paper.
6. She removed the paper and marked the final position of the water.
7. She allowed the paper to dry.

Figure 6 shows the chromatogram Eva obtained.

Figure 6



4.1 Determine the R_f value of the blue colouring.

Use **Figure 6**.

Give your answer to 2 significant figures.

[4 marks]

R_f value = _____

4.2 Explain what **Figure 6** shows about the attraction of the blue food colouring for the mobile phase and the stationary phase.

[2 marks]

4.3 Ben said that Eva's experiment was not scientific because she was not changing a variable or testing a hypothesis.

Give **one** reason why Ben is wrong.

[1 mark]

Question 5 [combined task]

Ali, Bella, Dan and Eva are studying chromatography.

Table 2 shows four different investigations.

Table 2

Ali	Bella
Ali tested three inks using chromatography. He examined the chromatograms to see if the inks contained blue and yellow pigments.	Bella observed how the distance travelled by a blue dye changed as the distance travelled by the water changed.

Dan	Eva
Dan thought the food colouring in a sweet was a banned additive. He measured the R_f value of the colouring from the sweet. He compared the R_f value with a table of data including the banned additive to see if he was correct.	Eva calculated the R_f value of a food colouring from a chromatogram.

5.1 Name **one** student who tested a hypothesis.

Justify your answer.

[2 marks]

Name _____

Justification _____

_____

5.2 Name **one** student who changed a variable but did not test a hypothesis.

Justify your answer.

[3 marks]

Name _____

Justification _____

_____

_____

_____

5.3 Ali thinks he is changing a variable. Do you agree with him? Give a reason for your answer.

[1 mark]

_____

_____

5.4 Do you think Eva's study is a proper scientific experiment? Give reasons for your answer, referring to variables and hypothesis testing.

[3 marks]

_____

_____

_____

Mark Scheme

Question 1

Question	Answers	Extra information	Mark	AO/Spec ref
1.1	(the pigments in) A is not soluble in water		1	4.8.1.3 AO3 WS 3.5
1.2		allow dyes / inks / colours for pigments ignore statements about solubility or R_f value		4.8.1.3 AO3 WS 3.5
	they both contain two pigments		1	
	they contain the same blue pigment		1	
	they contain a different yellow pigment		1	
1.3	(type of) ink		1	4.8.1.3 AO1 WS 2.7
1.4	the same solvent	allow use water as solvent	1	4.8.1.3 AO1
	leave for 20 minutes		1	WS 2.7

		allow same volume /size of dots		
1.5	test **A** in a different solvent e.g. ethanol / propanone	 allow any suitable non-aqueous solvent	1 1 1	4.8.1.3 AO3 WS2.7
Total			**10**	

Question 2

Question	Answers	Extra information	Mark	AO/Spec ref
2.1	so the dye did not wash off the paper.		1	4.8.1.3 AO1 WS 2.7
2.2	**A**		1	4.8.1.3 AO1 WS 2.2
2.3	all points plotted correctly best fit line	± half a small square allow **1** mark for 3 or 4 points correct	2 1	4.8.1.3 AO2 WS 3.2
2.4	correct co-ordinates from two points on the line **or** correct triangle on graph calculates $\frac{\text{y step}}{\text{x step}}$ correct evaluation to 2 sig figs	 should be about 0.72	1 1 1	4.8.1.3 AO2 WS 3.3
2.5	they are the same		1	4.8.1.3 AO3 WS 3.5
Total			**9**	

Question 3

Question	Answers	Extra information	Mark	AO/Spec ref
3.1	a pencil pencil is not soluble in water	 allow ink would dissolve in the water	1 1	4.8.1.3 AO1 WS 2.2 WS 2.3
3.2	water level should be below the spot the spot would wash off the paper (instead of or as well as moving up the paper)	allow water level is too high	1 1	4.8.1.3 AO3 WS 2.7
3.3	any **two** of: • the green (food) colour is a mixture of blue and yellow • there are two blue colours and one yellow • the light blue colour is the most soluble (in water) **or** the dark blue colour is the least soluble	allow dyes / pigments / colours for colours do **not** accept inks allow there are three colourings	2	4.8.1.3 AO3 WS 3.5
3.4	mark the position of the solvent front	allow mark where the water got to on the paper	1	4.8.1.3 AO1

				WS 2.2 WS 2.3
3.5	false true	both must be correct for the mark	1	4.8.1.3 AO1 WS 2.7
Total			**8**	

Question 4

Question	Answers	Extra information	Mark	AO/Spec ref
4.1	(distance travelled by solvent / water =) 8.8 cm	allow distances in cm or mm	1	4.8.1.3 AO2 WS 2.6
	(distance travelled by spot =) 5.3 cm	allow 5.2 to 5.4 cm	1	WS 3.3
	(R_f value =) $\frac{5.3}{8.8}$	allow correct use of incorrect measurements from step 1 and / or step 2	1	
	= 0.60	allow a correct evaluation to 2 sig figs of an incorrect expression in step 3 as long as this is the ratio of 2 distances.	1	
4.2	more attraction for the water **or** mobile phase than the paper **or** stationary phase		1	4.8.1.3 AO1
	as travels more than half the distance that the water travels	allow as travels a long way up the paper	1	
4.3	obtaining (accurate) data is also science	allow making (accurate) measurements is also science	1	4.8.1.3 AO1 WS2.7
Total			**7**	

Question 5

Question	Answers	Extra information	Mark	AO/Spec ref
5.1	Ali **or** Dan Ali tested whether all green inks are made of blue and yellow pigments **or** Dan tested whether a food colouring was a banned additive.		1 1	4.8.1.3 AO3 WS2.7
5.2	Bella Bella varied the distance travelled by the solvent. Bella did not suggest what would happen to the distance travelled by the spot		1 1 1	4.8.1.3 AO3 WS2.7
5.3	yes because he is using three different inks		1	4.8.1.3 AO3 WS2.7
5.4	yes because she is obtaining (accurate) data so it is a valid scientific experiment although she is not changing a variable and she is not testing a hypothesis		1 1 1	4.8.1.3 AO3 WS2.7
Total			**9**	**Total**

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