project calibrate

Summative Assessment Resources for Practical Science

Chemistry

Mixtures & Distillation

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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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: Mixtures & Distillation

Question 1 [non-manipulative hypothesis testing]

Student **A** predicted sea water contains salt and water.

The student tested the prediction.

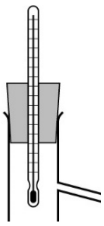
This is the equipment the student used:

- A rubber stopper with a thermometer attached
- A round bottomed flask
- A delivery tube
- A beaker
- 100 cm^3 of seawater
- A Bunsen burner

1.1 Complete **Figure 1** to show how the apparatus should be set up to test the prediction.

[4 marks]

Figure 1



1.2 Predict the temperature reading shown on the thermometer when the experiment is nearly complete.

[1 mark]

Temperature = __________ °C

1.3 Student **A** evaporated all the water from the seawater sample.

The student's prediction was correct.

Describe what would be seen in the beaker and the round bottomed flask at the end of the experiment.

[2 marks]

Beaker

____

____

Round bottomed flask

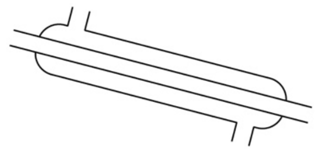
____

____

1.4 Student **B** said that more water would be collected if another piece of equipment was used.

Figure 2 shows the piece of equipment.

Figure 2



Student **B** was correct.

Explain why:

[3 marks]

____

____

____

____

____

Question 2 [non-manipulative parameter measurement]

Two students measured the pH of a sample of seawater.

2.1 Student **A** used universal indicator.

Describe how the student **A** could use universal indicator to test the pH of the seawater sample.

[2 marks]

____

____

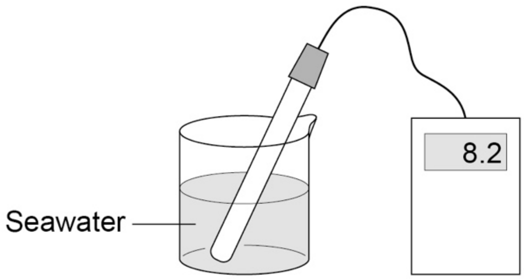
____

____

2.2 Student **B** used a pH meter.

Figure 3 shows the apparatus.

Figure 3



What is the pH of the seawater sample?

[1 mark]

pH = ______________

2.3 What type of substance is the seawater sample?

Use your answer to **question 2.2**

[2 marks]

____

____

2.4 What is the resolution of the pH meter?

Tick (✓) **one** box.

0.1 ☐

0.2 ☐

1.0 ☐

8.0 ☐

2.5 Student **B**'s method was more accurate.

Explain why.

[2 marks]

____

____

____

____

Question 3 [manipulative hypothesis testing]

A student predicted that bottled water contained more dissolved salts than tap water.

This is the method used to test bottled water.

1. Measure out 50 cm^3 of bottled water.
2. Weigh an evaporating basin.
3. Add 50 cm^3 of bottled water to the evaporating basin.
4. Weigh the bottled water and evaporating basin.
5. Heat the evaporating basin and contents to dryness.
6. Reweigh the evaporating basin and contents.

Table 1 shows the student's results.

Table 1

Mass of evaporating basin in g	109.62
Mass of evaporating basin + contents before heating in g	159.88
Mass of evaporating basin + contents after heating in g	109.85

3.1 Name two measuring instruments the student used.

[2 marks]

1. ______________________________

2. ______________________________

3.2 What was the mass of water in the sample of bottled water?

[1 mark]

____

Mass of water = ____________ g

3.3 What was the mass of dissolved salts in the sample of bottled water?

[1 mark]

____

Mass of dissolved salts = ____________ g

The student then tested tap water using the same method **except** that the student used 100 cm^3 of tap water.

The student repeated the tests three times more.

Table 2 shows the results.

Table 2

	Test 1	**Test 2**	**Test 3**	**Test 4**
Mass of dissolved solids in g	0.38	0.41	0.73	0.37

3.4 Which result is anomalous?

Suggest **one** reason for this anomalous result.

[2 marks]

Anomalous result = Test ______________

Reason:

____

____

3.5 Suggest how the student could improve the method:

[2 marks]

____

____

____

____

3.6 Calculate the mean value for the mass of dissolved solids in 100 cm^3 of tap water.

Give your answer to 2 significant figures.

[3 marks]

____

____

____

____

Mean value = ___________ g

3.7 Was the student's prediction correct?

Justify your answer.

[2 marks]

____

____

____

____

Question 4 [manipulative parameter measurement]

A student measured the solubility of potassium nitrate in water at different temperatures.

This is the method the student used.

1. Measure 20 cm^3 of water using a measuring cylinder.
2. Place the water in a boiling tube.
3. Put the boiling tube in a water bath.
4. Record the temperature of the water bath.
5. Add 1g potassium nitrate to the water in the boiling tube and stir the mixture.
6. Repeat step 5 until the potassium nitrate no longer dissolves.
7. Record the mass of potassium nitrate added.
8. Repeat steps 1-7 at different temperatures.

4.1 Another student improved the method by leaving the water and boiling tube in the water bath for 10 minutes before adding potassium nitrate.

Suggest why this improves the method.

[1 mark]

____

____

4.2 What would you see when the potassium nitrate no longer dissolves?

[1 mark]

____

____

4.3 Adding 1 g of potassium nitrate at a time does not give a very accurate result.

Explain why.

[2 marks]

____

____

____

____

4.4 Suggest extra steps you could add to the method above to give a more accurate result.

[4 marks]

____

____

____

____

____

____

____

____

4.5 In the student's investigation the mass of potassium nitrate that dissolved at 20 °C was 7 g

The student then measured the mass of potassium nitrate dissolved at 10 °C intervals.

The masses of potassium nitrate that dissolved at the different temperatures were 10 g, 13 g, 18 g, 23g

Design a results table to display these results.

Include the results at 20°C in the table.

[3 marks]

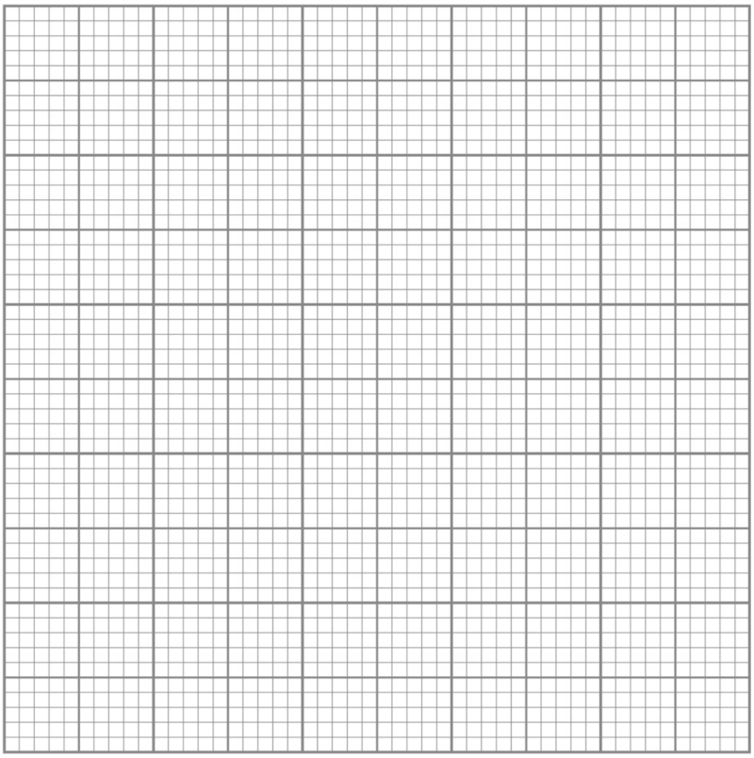
4.6 Plot the data from your table on the graph on **Figure 4**

You should:

- label the axes
- use suitable scales
- plot the data
- draw a line of best fit

[4 marks]

Figure 4



4.7 Give a conclusion you could make from the results.

Use data from **Figure 1**

[2 marks]

Question 5 [combined task]

Students are investigating water samples.

Student **A** thought that a water sample with a pH of 7 was pure. To find the pH the student added universal indicator solution to a sample of tap water.	Student **B** investigated the boiling point of the water samples. The student measured the temperature the samples boiled at.
Student **C** compared sea water and bottled water. The student predicted that sea water contained more impurities than bottled water.	Student **D** tested a sample of bottled water to see which ions were dissolved in the water.

5.1 Which two students are testing a hypothesis?

[1 mark]

Student ________ and student ________

5.2 Write down the hypothesis that one of these students is investigating.

[1 mark]

Student ________

Hypothesis:

____

____

5.3 Name one student who did not make a hypothesis.

Is this a scientific investigation?

Circle either 'Yes' or 'No below, and then justify your answer.

[3 marks]

Student _________ Scientific investigation? Yes / No

Justification:

____

____

____

____

5.4 Make a prediction about the results of student **B**'s experiment with a pure water sample and with an impure water sample.

Draw a line from the type of water sample to the predicted boiling point.

[2 marks]

Water sample	**Boiling Point**
	-2 °C
	0 °C
Impure water	2 °C
	98 °C
Pure water	100 °C
	102 °C

5.5 Compare the methods of student **A** and of student **B**.

Which method is likely to be the most accurate in showing if a water sample is pure?

Explain why the method is more accurate.

[3 marks]

Mark Scheme

Question 1

Question	Answers	Extra information	Mark	AO/Spec ref
1.1	bunsen burner heating container with seawater in round bottomed flask in correct place delivery tube connecting round bottomed flask to just above beaker beaker to collect water	ignore any water collected in beaker do **not** accept seawater in beaker used for collection	1 1 1 1	AO1 WS 2.2, 2.3 Low
1.2	100 ^{0}C		1	AO3 WS 2.1 Low
1.3	(beaker) colourless liquid	allow correct responses using the equipment shown in the student's diagram allow water do **not** accept seawater	1	AO3 WS 3.5 Standard

	(round bottomed flask) white powder / solid	allow salt	 1	
1.4	(equipment is a) condenser (which condenses) water vapour to (liquid) water (so) less water vapour escapes as a gas **or** (so) less water vapour escapes into the atmosphere	allow (equipment) condenses allow (which condenses) gas to liquid	1 1 1	AO1 AO2 WS 2.3, 2.7 High
Total			**10**	**Total**

Question 2

Question	**Answers**	**Extra information**	**Mark**	**AO/Spec ref**
2.1	add a few drops (of universal indicator) to seawater **or** dip (universal indicator) paper into seawater		1 1	AO1 WS 2.3, 2.6 Low mp1 Standard mp2

	compare colour with colour chart			
2.2	8.2		1	AO2 WS 2.6 Low
2.3	(seawater is a) weak alkali	allow (seawater is) alkali(ne) for 1 mark	2	AO2 WS 3.5 High (weak) Low (alkali)
2.4	0.1		1	AO2 WS 3.5 Standard
2.5	closer to true value because scale is smaller divisions		1 1	AO3 WS 2.7, 3.7 High
Total			**8**	

Question 3

Question	Answers	Extra information	Mark	AO/Spec ref
3.1	measuring cylinder balance	allow burette / pipette	1 1	AO1 WS 2.3 Low
3.2	50.03 (g)		1	AO1 WS 2.2, 2.3 Low
3.3	0.23 (g)	allow ecf from **3.2** (159.88 – 109.62) – answer to **3.2**	1	AO3 WS 2.1 Low
3.4	Test 3 student did not heat to dryness **or** sample still contained water	 allow student did not heat for long enough	1 1	AO3 WS 3.7 Low
3.5	reheat until constant mass obtained		1 1	AO1 WS 2.7 Standard High
3.6	$= \frac{0.38+0.41+0.37}{3}$ = 0.386(66666….)		1 1	AO2 WS 3.3, 4.6 Standard High

	= 0.39	allow for **2** marks an answer of 0.3866….(answer correctly calculated but not given to 2 sig figs) **or** 0.47 allow for **1** mark an answer of 0.4725	1	

3.7	(bottled water contains 0.23 g in 50 cm^3) so has 0.46 g dissolved salts in 100 cm^3 of water yes because bottled water contained 0.46 g dissolved salts in 100 cm^3 of water and tap water only contained 0.39 g in 100 cm^3 of water	allow answers based on student's calculated values. Alternative approach (tap water contains 0.39 g in 100 cm^3) so has 0.195 g dissolved salts in 50 cm^3 of water yes because bottled water contained 0.23 g dissolved salts in 50 cm^3 of water and tap water only contained 0.195 g in 50 cm^3 of water allow for 1 mark yes because bottled water	2	AO3 WS 3.5 Standard

		contained more dissolved salts in 50 / 100 cm^3 of water		
Total			**13**	

Question 4

Question	Answers	Extra information	Mark	AO/Spec ref
4.1	allows water to reach required temperature.		1	AO3 WS 2.2, 2.4, 2.7 standard
4.2	(white) solid / precipitate	allow cloudy	1	AO3 WS 3.5 standard
4.3	(in last 1 g) not all potassium nitrate dissolves don't know how much hasn't dissolved.		1 1	AO3 WS 2.4, 2.7 high
4.4	filter the solution and undissolved potassium nitrate leave the residue to dry weigh the residue		1 1 1 1	AO3 WS 2.4, 2.7 High

	subtract weight of residue from total mass added to find mass dissolved	allow as an alternative approach. repeat experiment (1) using smaller increments **or** use of specified increments (1) between last measurement where all dissolved **and** value where didn't dissolve (1)		

<table>
<tr>
<td>4.5</td>
<td>heading temperature in °C

heading mass of potassium nitrate dissolved in grams

values correctly recorded</td>
<td>if no mark scored for MP1 and MP2, allow 1 mark for both variables correct or both units correct

This table scores 3 marks:

<table>
<tr><th>Temperature in ^{o}C</th><th>Mass of potassium nitrate dissolved in grams</th></tr>
<tr><td>20</td><td>7</td></tr>
<tr><td>30</td><td>10</td></tr>
<tr><td>40</td><td>13</td></tr>
<tr><td>50</td><td>18</td></tr>
<tr><td>60</td><td>23</td></tr>
</table>
</td>
<td>1

1

1</td>
<td>AO2
WS 2.6
Standard</td>
</tr>
<tr>
<td>4.6</td>
<td>X and y axis labelled with heading and units</td>
<td></td>
<td>1</td>
<td>AO2
WS 3.1, 3.2
High</td>
</tr>
</table>

	suitable scale using at least half of grid all points correctly plotted line of best fit	 allow ecf from 4.5	1 1 1	
4.7	as the water temperature increases, the solubility of potassium nitrate increases solubility increases at an increasing rate	 allow the increase is not linear	1 1	AO2 AO3 WS 3.2, 3.5 Standard
Total			**17**	

Question 5

Question	Answers	Extra information	Mark	AO/Spec ref
5.1	student **A and** student **C**		1	AO3 WS 2.1 Low
5.2	(student **A**) a water sample with a pH of 7 is pure **or** (student **C**) sea water contains more impurities than bottled water		1	AO3 WS 2.1 Low

5.3	student **B** **or** student **D** yes because conclusions are based on data collected from observations		1 1 1	AO3 WS 2.1, 2.2, 3.5 Low High
5.4	impure water ------- 102 °C pure water --------- 100 °C		1 1	AO1 AO3 WS 3.5 Low Standard
5.5	student **B** can be pH 7 but still have impurities in but pure water boils at a fixed temperature	allow but pure water boils at 100 °C	1 1 1	AO3 WS 2.7, 3.7 Standard
Total			10	

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