OCR
Oxford Cambridge and RSA

Wednesday 17 January 2024 – Morning

Level 3 Cambridge Technical in Applied Science

05848/05849/05874 Unit 3: Scientific analysis and reporting

Time allowed: 2 hours
C342/2401

You must have:
- a ruler (cm/mm)

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) ______________________

Last name ______________________

Date of birth | D | D | M | M | Y | Y | Y | Y |

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- Answer **all** the questions.

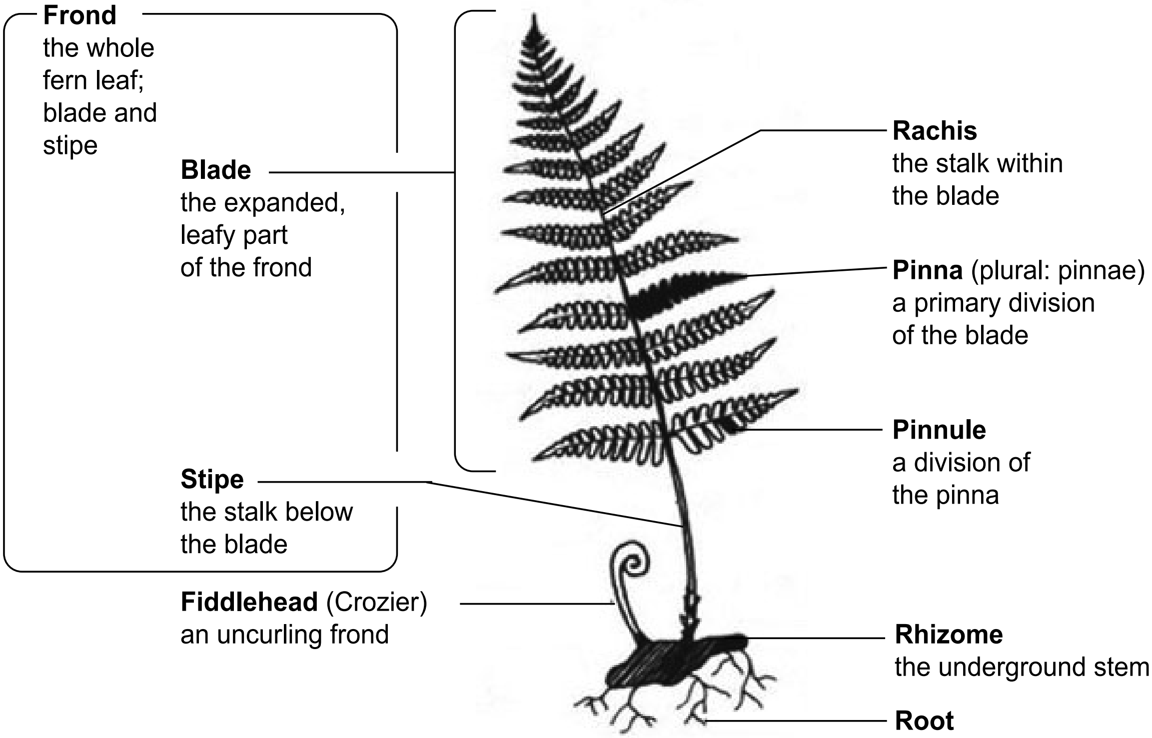
INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- The Periodic Table is on the back page.
- This document has **28** pages.

ADVICE
- Read each question carefully before you start your answer.

1 Ferns come in various shapes and sizes, but they all have two major parts – the **fronds** and the **rhizome**.

The fronds are divided into leaf-like structures called pinnae. The pinnae are attached to a central stem called a rachis.

The diagram below shows the key features of a fern.



(a) Most ferns have divided fronds which resemble feathers. The fronds can be classified as pinnate, bi-pinnate or tri-pinnate.

(i) The frond shown in the diagram below is pinnate.

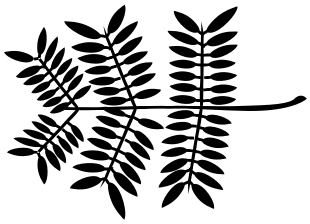
This type of frond may be even-pinnate or odd-pinnate.

Describe the difference between an even-pinnate frond and an odd-pinnate frond.

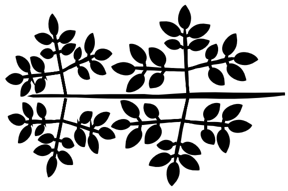
....

.... **[1]**

(ii) Some ferns have divided fronds which can be bi-pinnate or tri-pinnate.



bi-pinnate



tri-pinnate

Describe the differences between pinnate, bi-pinnate and tri-pinnate fronds.

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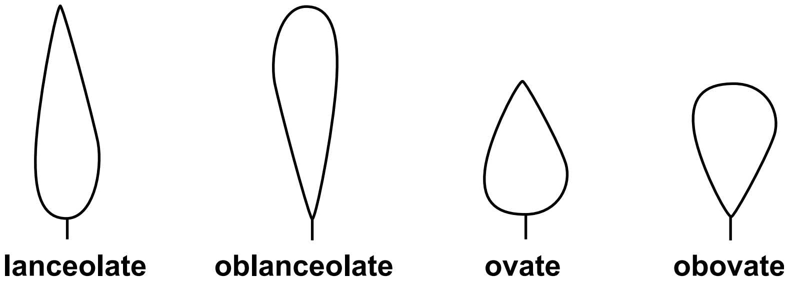
.... **[5]**

Turn over for the next question

(b) The part of the frond containing the pinnae is called the blade.

The overall shape of the blade may be described as lanceolate, oblanceolate, ovate or obovate:



Lanceolate is described as long, wider nearer the base and tapering at the tip.

(i) Describe the overall shape of oblanceolate.

.... **[1]**

(ii) Explain why oblanceolate and obovate may be difficult to tell apart.

.... **[1]**

(iii) Suggest how the length and width of the leaf may be used to distinguish between lanceolate and ovate.

.... **[1]**

(c) *Dryopteris filix-mas* is widespread throughout the British Isles. It is commonly known as the male fern.

(i) Explain the naming convention used for *Dryopteris filix-mas*.

....

....

.... **[2]**

(ii) Henry and Sasha are studying *D. filix-mas* for a school project.

In their journal they write a description to help with the identification of *D. filix-mas*.

Firstly, they look at the type of frond to determine whether it is pinnate, bi-pinnate or tri-pinnate.

Suggest **four other** features of the plant that they could consider for identification purposes.

1 ....

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2 ....

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3 ....

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4 ....

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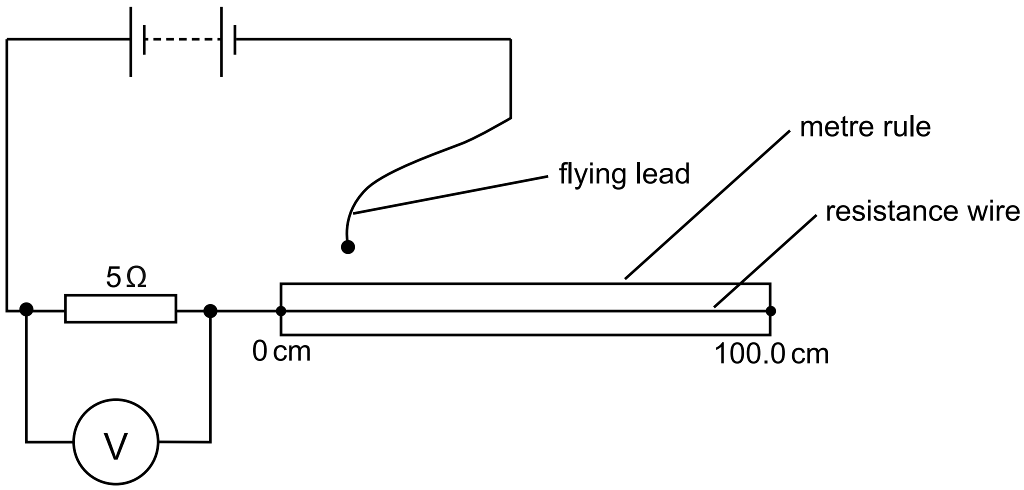
[4]

Turn over for the next question

2 Tom is a physics student. He is investigating an electrical circuit.

A diagram of the circuit he uses is shown below.



The resistance wire is attached to a metre rule.

A 5 Ω fixed resistor is connected in series with the resistance wire and a battery of cells.

A voltmeter measures the voltage across the fixed resistor.

Tom varies the length *L*, of the resistance wire in the circuit by attaching a flying lead to the wire at different positions along its length.

Table 2.1 shows Tom's measurements and calculations.

Table 2.1

Length *L* (cm)	**Voltage *V* (V)**	**Current *I* (A)**	**1/*I* (A^{-1})**
100	1.8	0.35	2.8
80	2.0	0.40	2.5
60	2.3	0.46	2.2
40	2.7	0.54	1.9
20	3.2		

(a) Complete **Table 2.1** by calculating:

- the value of I using the equation: $V = I R$ where R is the resistance of the fixed resistor
- the value of $1/I$.

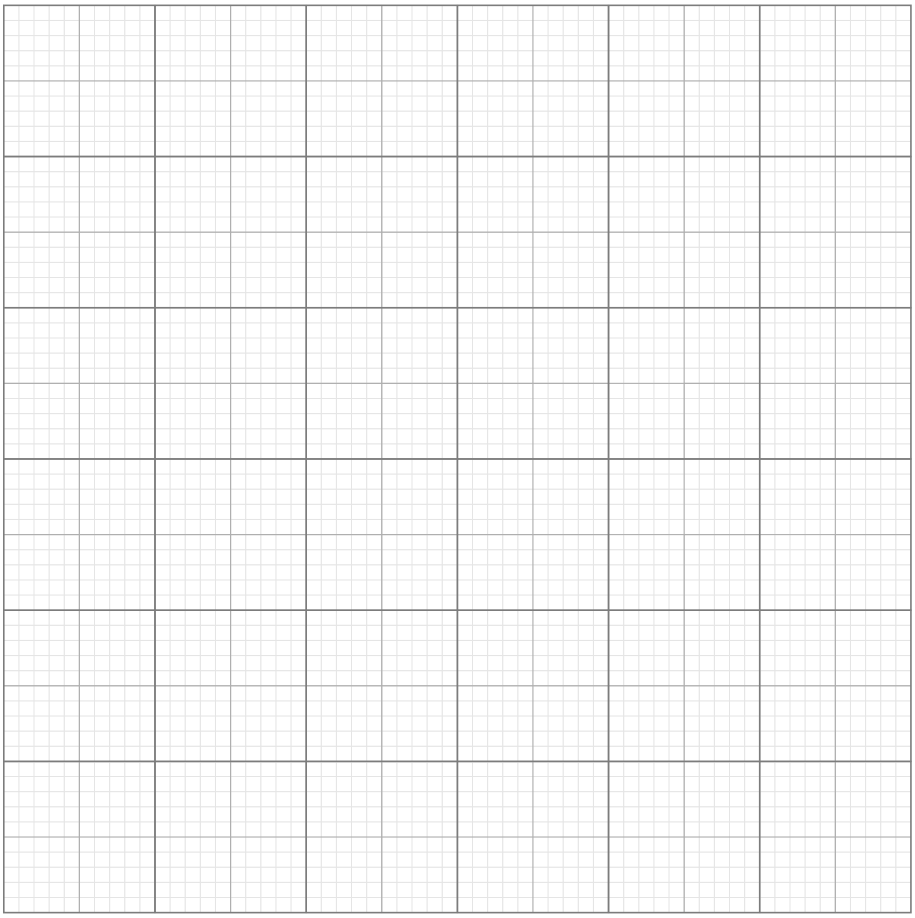
Record both of your calculations in **Table 2.1** to a suitable number of significant figures.

[3]

(b) Plot a graph of $1/I$ (A^{-1}) on the vertical axis against L (cm) on the horizontal axis.

Start both axes at the origin (0, 0).

Draw the straight line of best fit. Extend this line to intercept the y-axis.



[5]

(c)
(i) On your graph show how to determine the gradient of the line of best fit.

Calculate the gradient *G* and its units.

Show your working.

G = ……………………………........... units ……................... **[4]**

(ii) Determine the value of the y-intercept, *c*, of your line of best fit.

c = ……………………………........... units ……................... **[1]**

(d) Tom's teacher says:

> You can calculate the resistance R_w of the wire using the equation:
>
> $$R_w = \frac{500\,G}{c}$$
>
> The accepted value for a 100 cm length of this type of wire is 8 Ω.

(i) Calculate the resistance R_w of the wire.

Use your values of *G* in **(c)(i)** and *c* in **(c)(ii)**.

R_w = ……………………………........... Ω **[2]**

(ii) The percentage error in the value for R_w can be calculated using the equation:

$$\%\ \text{error} = \frac{(\text{experimental value} - \text{accepted value}) \times 100}{\text{accepted value}}$$

Calculate the percentage error in the value of R_w and comment on the accuracy of Tom's results.

Percentage error = ……………………………........... %

Comment on accuracy ....

....
[2]

(e) Use the data in **Table 2.1** to describe the relationship between *L* and *V*.

....

.... **[2]**

(f) Tom says that the total supply voltage stayed the same during the investigation.

(i) What further evidence would make Tom's conclusion more secure?

.... **[1]**

(ii) Assuming that the total supply voltage remains constant, suggest an explanation for the trend in *V* in **Table 2.1**.

....

....

.... **[2]**

Turn over for the next question

3

(a) Zac is a chemistry student investigating the thermal decomposition of iron(II) sulfate, $FeSO_4$.

When iron(II) sulfate is heated strongly it decomposes as shown in the following equation:

$$2FeSO_4(s) \rightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

Zac does an experiment to determine the percentage yield of iron(III) oxide, Fe_2O_3 in this reaction.

He uses a data book to find the relevant molar masses.

Compound	**Molar mass (g mol^{-1})**
$FeSO_4$	152
Fe_2O_3	160

Zac uses the following steps in his experiment:

1 Measure and record the mass of an empty crucible.

2 Put three spatula-fulls of iron(II) sulfate into the crucible.

3 Measure and record the mass of the crucible and its contents.

4 In a fume cupboard, heat the crucible using a Bunsen burner.

5 After ten minutes turn off the Bunsen burner and allow the crucible to cool down.

6 Measure and record the mass of the crucible and its contents.

He obtains the following results:

- Mass of empty crucible (step 1) = 50.32 g.
- Mass of crucible and iron(II) sulfate before heating (step 3) = 56.40 g.
- Mass of crucible and iron(III) oxide after heating (step 6) = 52.54 g.

(i) Calculate the mass of iron(II) sulfate used by Zac.

.... **[1]**

(ii) Zac calculates that 304 g of iron(II) sulfate should produce 160 g of iron(III) oxide.

Use the chemical equation and the molar masses to show that he is correct.

....

.... **[1]**

(iii) Use your answer to **(a)(i)** and the information in **(a)(ii)** to calculate the mass of Fe_2O_3 that Zac should expect to produce in his experiment.

Expected mass = ………….…………................ g **[1]**

(iv) Use his experimental results to calculate the actual mass of Fe_2O_3 produced.

.... **[1]**

(v) Use the following equation to calculate the percentage yield of Fe_2O_3.

$$\% \text{ yield} = \frac{\text{mass of product obtained} \times 100}{\text{expected mass of product}}$$

Percentage yield = ……………..…………................. % **[1]**

(vi) Suggest how Zac could improve his experiment to make sure that the reaction had finished.

.... **[1]**

(vii) Zac uses these definitions of experimental analysis to evaluate the investigation.

Letter	Definition
A	Error due to measurements differing from the true value by a consistent amount.
B	Error due to measurements varying in an unpredictable way.
C	The closeness of agreement between measured values obtained by repeated measurements.
D	The closeness of a measurement to the true value.
E	The difference between a measured value and the true value.

Write down which letter, **A**, **B**, **C**, **D** or **E** describes:

- Accuracy ....
- Measurement error ....
- Precision ....
- Random error ....
- Systematic error ....

[5]

(b) Jamila is a chemistry student investigating the rate of reaction between magnesium carbonate powder and hydrochloric acid.

She measures the volume of carbon dioxide produced at regular time intervals.

The table shows Jamila's measurements.

Time (s)	0	20	40	60	80	100	120	140	160	180	200
Volume of CO_2 produced (cm^3)	0	24	44	56	68	74	82	87	91	93	95

(i) Describe the interval and range of Jamila's independent variable.

interval ....

range ....

[2]

(ii) Suggest why Jamila's range was **not** suitable.

.... **[1]**

(iii) Jamila's experimental method is used by another student.

Suggest **three** pieces of information the student will need to know in order to obtain repeatable results.

1 ....

2 ....

3 ....

[3]

(iv) Explain how Jamila will know whether the method is repeatable.

.... **[1]**

(v) Jamila uses the results to determine how the rate of reaction changes over time.

Using the data in the table:

- describe the trend in the rate of the reaction.

....

- justify your answer by determining the mean rate of reaction:
  - between 0 and 20 s.

Rate = …………..…………................ $cm^3\ s^{-1}$

  - between 180 and 200 s.

Rate = …………..…………................ $cm^3\ s^{-1}$

[3]

Turn over for the next question

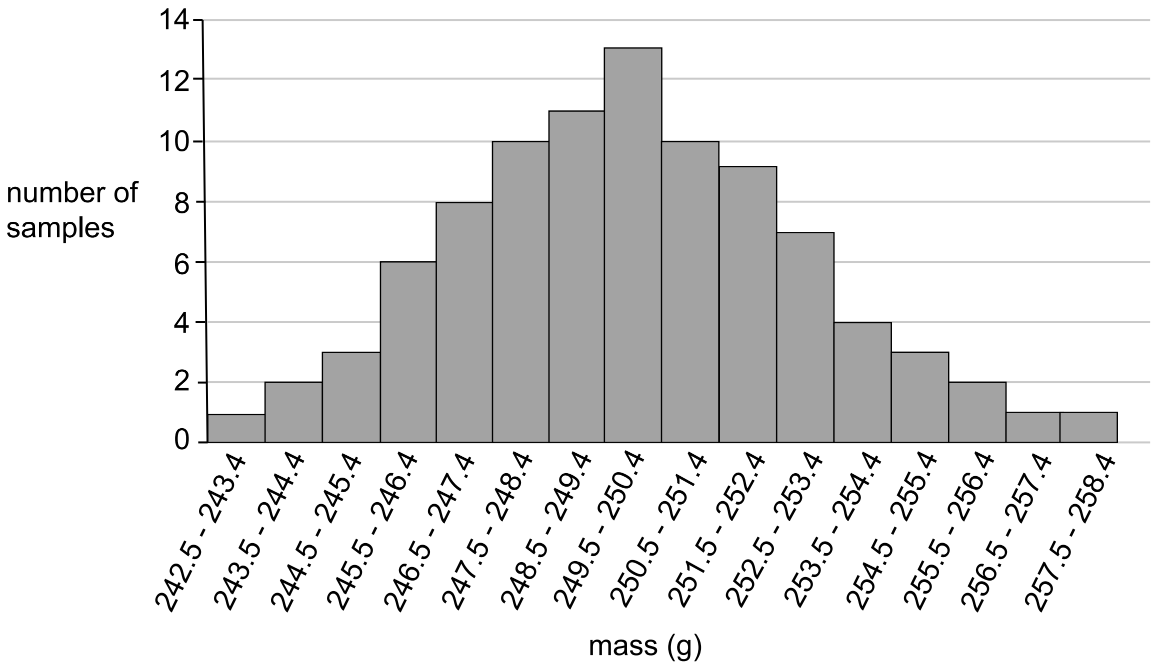
4 Sara is an engineer working for a company in the food industry. She works on a production line which dispenses cocoa powder into tins.

She needs to ensure that the filling machine is delivering the correct amount of cocoa powder into each tin. She does this using a sampling technique.

She randomly removes a tin of cocoa from the production line and weighs it. She subtracts the mass of the empty tin and records the mass of cocoa powder to one decimal place. She repeats this process at regular intervals.

(a) Sara groups the masses into ranges and counts how many samples fall into each mass range. She then displays her results as shown in **Fig. 4.1**.

Fig. 4.1



(i) From the list below choose the type of graph shown in **Fig. 4.1** and explain why it is appropriate for this data.

Tick (✓) **one** box.

Bar chart ☐

Histogram ☐

Kite diagram ☐

Pie graph ☐

Scatter graph ☐

Explanation ....

.... **[2]**

(ii) Suggest why there is a variation in the mass of the samples.

....

.... **[1]**

(iii) Sara planned to determine the mass of 90 samples, but on this occasion she weighed 91 samples.

Use the data displayed in **Fig. 4.1** to show how she knew that she had weighed 91 samples.

....

.... **[2]**

(b) Sara must test the reliability of the production process. She assumes that the data in **Fig. 4.1** is normally distributed and uses her data to calculate the 95% confidence interval for the mean mass.

The 95% confidence interval is the range of values that she would expect the mean mass to fall between 95% of the time.

The 95% confidence interval can be calculated using the following equation:

$$95\% \text{ confidence interval} = \bar{x} \pm \frac{1.96\,s}{\sqrt{n}}$$

where n is the number of samples = 91

s is the standard deviation = 3.07

$\bar{x}$ is the mean mass of cocoa = 250 g

(i) Use these values to determine the 95% confidence interval.

95% confidence interval = ……………..….. g ± ……………..….. g **[1]**

(ii) Calculate the lower and upper limits of the mean masses within the 95% confidence limit.

Give your answers to **one** decimal place.

Lower limit = ………….…………................ g

Upper limit = ………….…………................ g

[2]

(iii) To comply with the company's regulations, the mean mass of cocoa in the tins must lie between 249.5 and 250.5 g.

Suggest **two** reasons why the company specifies an upper and lower limit.

1 ....

2 ....

[2]

(iv) Sara looks at her calculations and concludes that she cannot be sufficiently confident that the mean mass of cocoa is between 249.5 g and 250.5 g.

Explain why you think Sara's conclusion is correct.

....

.... **[1]**

(v) Calculate the smallest value of s (the standard deviation) which would be needed to give a mean mass range of 250 ± 0.5 g with a sample size of 91 and a confidence level of 95%.

Use the formula:

$$\frac{1.96\,s}{\sqrt{n}} = 0.5$$

[1]

(vi) Suggest how the production process could be modified to reduce the value of s from 3.07 to the value you have calculated in **(b)(v)**.

....

.... **[1]**

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5 Ali and Ryan keep pet chickens. Sometimes the chickens lay eggs with soft shells.

Ali and Ryan use a titration technique to determine whether chicken eggs with soft shells contain less calcium carbonate than chicken eggs with normal shells.

They decide to extract the calcium ions, Ca^{2+}, from eggshells by dissolving the shell in acid and then titrating the solution with EDTA.

They use the following steps:

Step 1 Determine the mass of a soft eggshell.

Step 2 Break up the eggshell into small pieces and add excess dilute nitric acid.

Step 3 When all the eggshell has dissolved, neutralise the solution from **Step 2** with dilute sodium hydroxide.

Step 4 Transfer the solution from **Step 3** to a 250 cm^3 volumetric flask and make up to the mark with distilled water. This is **solution 1**.

Step 5 Transfer 10.0 cm^3 of **solution 1** into a conical flask, add 5 cm^3 of ammonia buffer solution and then add a few drops of Eriochrome Black T indicator.

Step 6 Titrate against 0.050 mol dm^{-3} of EDTA solution.

Step 7 Repeat **Steps 5** and **6** until concordant titres are obtained.

(a) Put a (ring) around the word that describes this type of titration.

complexometric **neutralisation** **precipitation** **redox**

[1]

(b) Tick (✓) the box that shows the colour change of the indicator at the end point of this reaction.

Blue to red ☐

Colourless to red ☐

Red to blue ☐

Red to colourless ☐

[1]

(c) State what **concordant titres** means.

.... cm^3 **[1]**

(d) Describe how the EDTA solution should be added to ensure accurate titre values are achieved.

....

....

.... **[2]**

(e) Ali and Ryan obtained the following results:

- Mass of one eggshell = 5.18 g.
- 27.05 cm^3 of 0.050 mol dm^{-3} EDTA was required to react with 10.0 cm^3 of **solution 1**.

You will need to use the following equations in your calculations:

- Number of moles of a solution = $\frac{\text{concentration (mol dm}^{-3}\text{) × volume (cm}^3\text{).}}{1000}$
- Number of moles of a solid = $\frac{\text{mass (g)}}{\text{molar mass (g mol}^{-1}\text{).}}$

(i) Calculate the number of moles of EDTA needed to reach the end point.

Number of moles EDTA = ………….………….............. mol **[1]**

(ii) One mole of Ca^{2+} ions reacts with one mole of EDTA.

Deduce the number of moles of Ca^{2+} ions in 10.0 cm^3 of **solution 1**.

Number of moles Ca^{2+} = ………….………….............. mol **[1]**

(iii) The number of moles of Ca^{2+} ions in 250.0 cm^3 of **solution 1** is equal to the number of moles of $CaCO_3$ in the eggshell.

Calculate the number of moles $CaCO_3$ in the eggshell.

Number of moles $CaCO_3$ = ………….………….............. mol **[1]**

(iv) The molar mass of $CaCO_3$ is 100.1 g mol^{-1}.

Calculate the mass of $CaCO_3$ in the eggshell.

Mass of $CaCO_3$ = ………….………….............. g **[1]**

(v) Calculate the percentage by mass of $CaCO_3$ in the eggshell.

Give your answer to **three** significant figures.

Percentage by mass = ………….………….............. % **[2]**

(f) Ali and Ryan read that the percentage by mass of $CaCO_3$ in a normal eggshell should be between 95 and 97%.

Evaluate whether Ali and Ryan's titration proves that soft-shelled eggs contain less $CaCO_3$ than normal eggshells.

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....

....

.... **[3]**

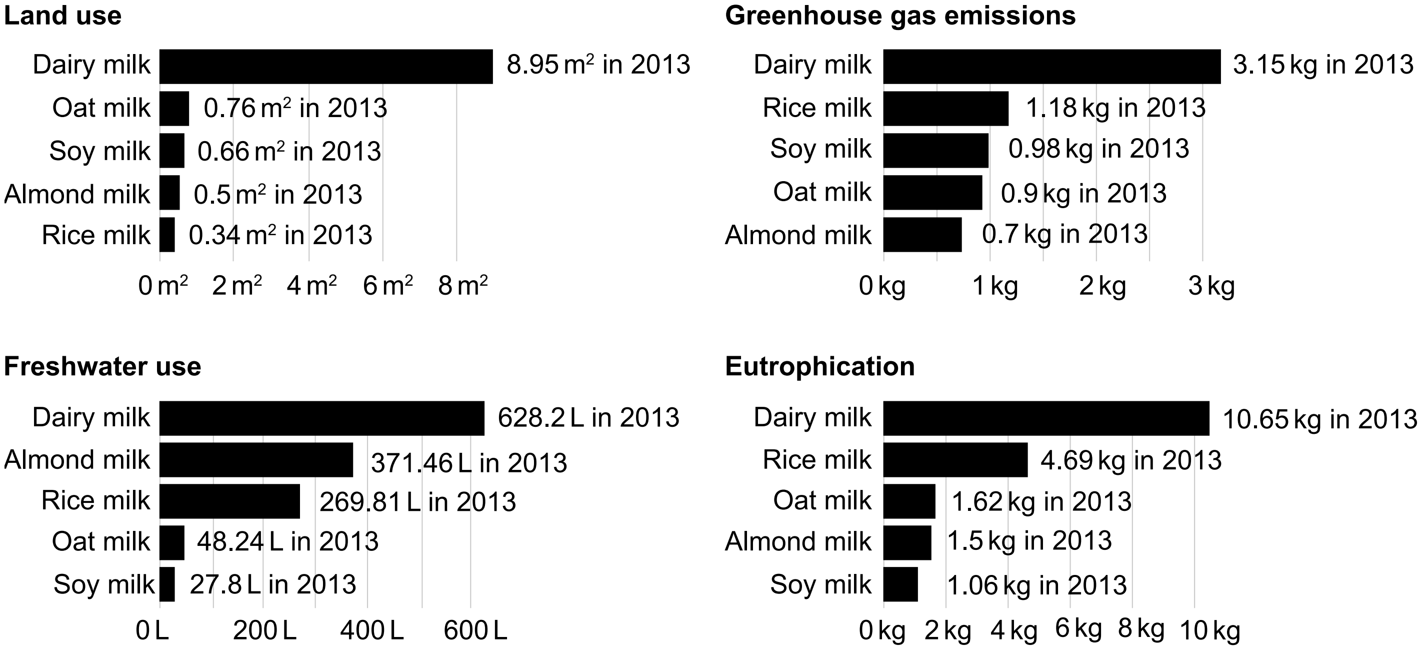
6 Some students are studying climate change.

As part of their investigation, they decide to compare the environmental impact of dairy and plant-based milks.

They found the graph shown in **Fig. 6.1**. It is part of a web page from a University of Oxford research group who collate global data from many sources. This page shows the environmental footprints of dairy and a range of plant-based milks.

Fig. 6.1

Environmental footprints of dairy and plant-based milks
Impacts are measured per litre of milk. These are based on a meta-analysis of food system impact studies across the supply-chain which includes land use change, on-farm production, processing, transport, and packaging.



Source:
Poore, J & Nemecek, T (2018). Reducing food's environmental impacts through producers and consumers. Science, <https://OurWorldInData.org/environmental-impacts-of-food>

(a) The students say that the graph is secondary data.

(i) Describe what **secondary data** means.

.... **[1]**

(ii) Explain how the web page confirms that the data is secondary.

....

.... **[1]**

(iii) Explain why the students might think that the data has a high validity.

....

.... **[1]**

(b) One of the intended audiences for the website is the public.

(i) Suggest **two other** audiences that would be interested in the data in the graph.

1 ....

2 ....
[2]

(ii) Explain how and why the public might use the information in the graph.

....

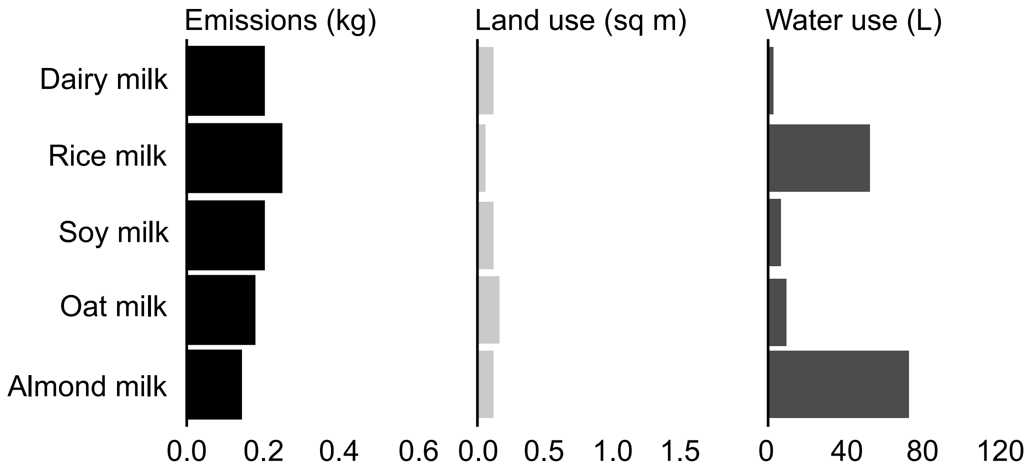
.... **[2]**

(c) The graph in **Fig. 6.2** is on a website published by the New Zealand dairy industry.

It uses the data shown in **Fig. 6.1** but has been amended using their own calculations.

Fig. 6.2

Environmental impact of one glass (200 ml) of different milks



Source:

Poore & Nemecek (2018), Science. Additional calculations, Poore, J <http://www.stuff.co.nz/national/2457029/1L-milk-creates-1kg-of-CO2> <https://www.dairynznewslink.co.nz/wp-content/uploads/2018/12/Dairy-sector-quick-facts-2017-18_Farms-and-herds_newslink-002_LATEST-VERSION-061218-1.pdf> <https://www.dairynz.co.nz/news/latest-news/how-now-new-zealand-cow/> <https://www.dairynz.co.nz/environment/water-use/water-use-calculator>

Suggest **two** reasons why the students might challenge the validity of the data in **Fig. 6.2**.

1 ....

2 ....
[2]

(d)* Discuss the scientific data in **Fig. 6.1** and **Fig. 6.2** considering the quality of the reporting in terms of clarity, conciseness and appropriateness for the intended audience.

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.... **[6]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

The Periodic Table of the Elements

Key
atomic number
Symbol
name
relative atomic mass

(1) 1	(2) 2	3	4	5	6	7	8	9	10	11	12	(3) 13	(4) 14	(5) 15	(6) 16	(7) 17	(0) 18
1 **H** hydrogen 1.0																	2 **He** helium 4.0
3 **Li** lithium 6.9	4 **Be** beryllium 9.0											5 **B** boron 10.8	6 **C** carbon 12.0	7 **N** nitrogen 14.0	8 **O** oxygen 16.0	9 **F** fluorine 19.0	10 **Ne** neon 20.2
11 **Na** sodium 23.0	12 **Mg** magnesium 24.3											13 **Al** aluminium 27.0	14 **Si** silicon 28.1	15 **P** phosphorus 31.0	16 **S** sulfur 32.1	17 **Cl** chlorine 35.5	18 **Ar** argon 39.9
19 **K** potassium 39.1	20 **Ca** calcium 40.1	21 **Sc** scandium 45.0	22 **Ti** titanium 47.9	23 **V** vanadium 50.9	24 **Cr** chromium 52.0	25 **Mn** manganese 54.9	26 **Fe** iron 55.8	27 **Co** cobalt 58.9	28 **Ni** nickel 58.7	29 **Cu** copper 63.5	30 **Zn** zinc 65.4	31 **Ga** gallium 69.7	32 **Ge** germanium 72.6	33 **As** arsenic 74.9	34 **Se** selenium 79.0	35 **Br** bromine 79.9	36 **Kr** krypton 83.8
37 **Rb** rubidium 85.5	38 **Sr** strontium 87.6	39 **Y** yttrium 88.9	40 **Zr** zirconium 91.2	41 **Nb** niobium 92.9	42 **Mo** molybdenum 95.9	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57–71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89–103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium		114 **Fl** flerovium		116 **Lv** livermorium		

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium 144.9	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.2	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.0	71 **Lu** lutetium 175.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium	92 **U** uranium 238.1	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium