OCR
Oxford Cambridge and RSA

Wednesday 22 May 2024 – Morning

Level 3 Cambridge Technical in Applied Science

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

Time allowed: 2 hours
C342/2406

C342/2406

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

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

05848-03

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.
- 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 Jupiter has more than 90 moons.

Eleven of these moons were discovered in the 20th century. Their diameters are shown in the table below.

Moon	Year of discovery	Diameter (km)
S/1999 J1	1999	13
Metis	1979	40
Adrastea	1979	25
Thebe	1979	100
Leda	1974	15
Ananke	1951	30
Carme	1938	49
Lysithea	1938	35
Sinope	1914	35
Pasiphae	1908	50
Elara	1905	75

(a)

(i) Use the data in the table to determine the mode, median and range of these diameters.

- mode = ...
- median = ...
- range = ...

[3]

(ii) Use the data in the table to calculate the mean of the moon diameters.

Give your answer to the nearest whole number.

Mean = ……..……..... km **[1]**

(b) The data in the table can be compared across two time periods.

Six of the moons in the table were discovered between 1905 and 1951 and five after 1951.

Compare the diameters of the moons discovered between 1905 and 1951 with the diameters of the moons discovered after 1951.

(i) Identify the name of the outlier in the data for moons discovered after 1951.

..... **[1]**

(ii) Describe the trend in the data between the two time periods if the outlier is ignored.

.....

..... **[1]**

(iii) Suggest an explanation for the trend.

.....

..... **[1]**

(c) Elara was discovered in 1905.

Elara has a radius, R of 3.75×10^{4} m and a mass, M of 8.7×10^{17} kg.

The gravitational field strength, g at the surface of Elara can be calculated using the equation:

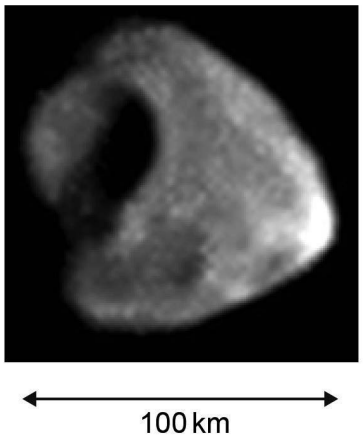
$g = \frac{GM}{R^2}$, where G = 6.67×10^{-11} N m^2 kg^{-2}

Calculate g.

Give your answer to **2** significant figures and state the units.

g = ... units ..... **[4]**

(d) An image of Thebe taken by a spacecraft is shown below.



According to internet sources, the diameter of Thebe is 100 ± 4 km.

(i) Suggest how this value would be determined from the image.

.....

..... **[2]**

(ii) Explain why there is uncertainty in the quoted value.

..... **[1]**

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Turn over for the next question

2 Moths belong to a large order of insects called *Lepidoptera*. This order is divided into two groups: butterflies (*Rhopalocera*) and moths (*Heterocera*).

(a) *Lepidoptera*, *Rhopalocera* and *Heterocera* are terms used to classify living things.

Give **two** reasons why scientists use a classification system for living things.

1 .....

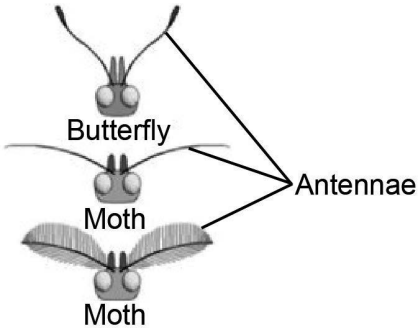
2 .....

[2]

(b) A biology student is investigating insects classified as *Lepidoptera*.

The student finds a diagram on the internet which shows how to tell moths and butterflies apart by the shape of their antennae.

The diagram is shown below.



(i) Describe **two** features of the butterfly antennae that are different from the moth antennae.

1 .....

2 .....

[2]

(ii) Suggest **two** additions to the diagram that would improve the quality of the information.

1 .....

.....

2 .....

.....

[2]

(c) The student investigates the possibility of designing a key to assist with identifying moths.

The table below shows descriptions of the larvae (caterpillars) of three different moths.

Arctia caja (garden tiger moth)	The larvae are extremely furry, the hairs being long. They are mostly black with reddish or ginger hairs at the sides. The tips of the long black hairs are white. As they grow larger, they moult several times until reaching full size at around 4 cm long.
Arctia villica (cream-spot tiger moth)	The young larvae are very furry and are black in the early stages. The larvae will eat dandelion, nettle and many other wild and garden plants.
Callimorpha jacobaeae (cinnabar moth)	The larvae are black-and-orange banded and are found feeding on the flowers of ragwort during July and August.

(i) The garden tiger moth is also known as *Arctia caja*.

Explain the nomenclature used for *Arctia caja*.

.....

..... **[2]**

(ii) The student needs more information to construct a key.

What **two** pieces of further information are needed for *Arctia caja* to compare with the other moths?

1 .....

2 .....

[2]

(iii) What **three** pieces of further information are needed for *Arctia villica* to compare with the other moths?

1 .....

2 .....

3 .....

[3]

(d) A recent study concluded that the total number of moths in Britain decreased by 33% over the 50-year period up to 2017.

Explain why moths can be used as indicator species.

.....

..... **[2]**

3 Amylase is an enzyme responsible for breaking down starch.

The rate at which starch is broken down can be monitored in a laboratory by testing with iodine solution. If starch is present, iodine changes from orange-brown to blue-black.

A group of students is investigating how the activity of the enzyme amylase changes with temperature. They use the method outlined below.

1 Set up a water bath at 25 °C.
2 Add 10 cm^3 of starch solution to a test tube, and 10 cm^3 of amylase solution to another test tube.
3 Place both test tubes in the water bath for 5 minutes.
4 During this period, put one drop of iodine into each dimple on a spotting tile.
5 Pour the amylase into the test tube containing the starch and start a timer.
6 Immediately remove a sample of the starch-amylase mixture and add to a drop of iodine on the spotting tile.
7 Remove a sample of the starch-amylase mixture every 2 minutes and add to another drop of iodine on the tile.
8 Continue for 14 minutes.
9 Repeat the experiment at different temperatures in the water bath, set at 30 °C, 35 °C, 40 °C and 45 °C.

Fig. 3.1 shows the results of the investigation.

Fig. 3.1

	Temperature (°C)				
Time (mins)	25	30	35	40	45
0	●	●	●	●	●
2	●	●	●	●	●
4	●	●	●	●	●
6	●	●	◐	●	●
8	●	●	◐	◐	●
10	●	◐	◐	◐	●
12	●	◐	◐	◐	◐
14	◐	◐	◐	◐	◐

Key:

Colour of iodine solution

● = blue-black

◐ = orange-brown

(a)

(i) Describe the trends in the results shown in **Fig. 3.1**.

.....

.....

.....

..... **[3]**

(ii) Explain **three** trends in the results shown in **Fig. 3.1**.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(b) The students use their results to determine the optimum temperature for the activity of amylase.

(i) Explain why the results only give an approximate estimate of the optimum temperature.

.....

.....

.....

..... **[2]**

(ii) Suggest **three** modifications the students could make to the method to obtain a more accurate value for the optimum temperature.

1 .....

.....

2 .....

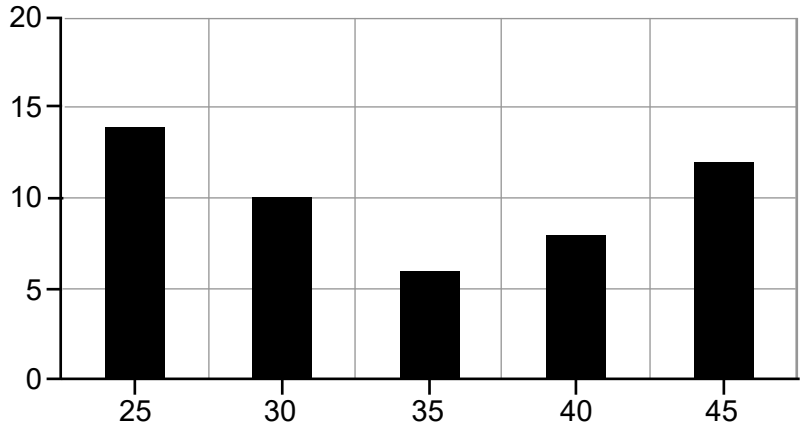
.....

3 .....

.....

[3]

(c) The students plot a graph of their results as shown below.



(i) What information should the students include to complete their graph?

..... **[1]**

(ii) The students' teacher says that a scatter graph would be more appropriate than a bar graph.

Explain why a scatter graph is more appropriate.

.....

..... **[1]**

(iii) The students decide to repeat the investigation three times at each temperature before constructing a scatter graph.

What **three** pieces of extra information should the students include to complete their scatter graph?

1 .....

2 .....

3 .....

[3]

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Turn over for the next question

4 Scientists are investigating the chemical reaction between sodium thiosulfate and a dilute acid.

A precipitate is produced which makes the reaction mixture turn cloudy.

(a) The scientists first investigate how the rate of reaction changes as the initial concentration of sodium thiosulfate is changed.

They use the following method.

Step 1: place a card with a cross on it under a conical flask.

Step 2: put 10 cm^3 sodium thiosulfate solution and 40 cm^3 water into the conical flask.

Step 3: add 5 cm^3 of dilute acid.

Step 4: swirl the flask and measure the time taken for the cross to become invisible when viewed from above.

Step 5: repeat the procedure using different volumes of sodium thiosulfate and water in **Step 2**.

The scientists' results are shown in the table.

Volume of sodium thiosulfate (cm^3)	**Volume of water (cm^3)**	**% concentration of sodium thiosulfate**	**Time taken for the cross to disappear (s)**	**$\frac{1}{\text{time}}$ (s^{-1})**
10	40		164	
20	30		85	
30	20		56	
40	10		42	

Complete the table by doing the following calculations:

- Calculate the % concentration of the sodium thiosulfate solution in the flask at the start of each experiment and record the values in the results table.

  Use the equation: $\%\ \text{concentration} = \frac{\text{volume of thiosulfate}}{\text{volume of thiosulfate plus volume of water}} \times 100$

- Calculate the value of $\frac{1}{\text{time}}$ for each experiment and record each value in the table.

  Record your answers to **2** significant figures.

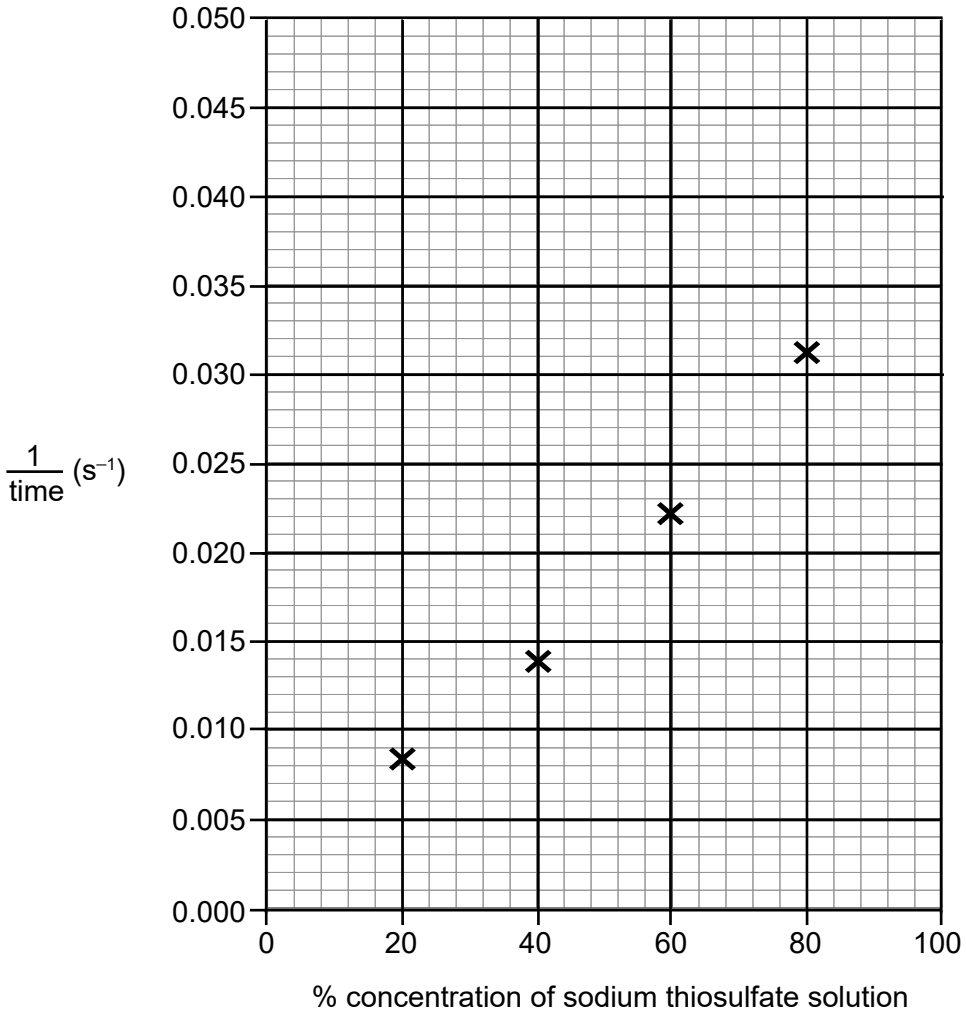
  The value of $\frac{1}{\text{time}}$ can be taken as a measure of the rate of reaction.

[3]

(b) The scientists then investigate whether changing the initial concentration of acid affects the rate of reaction.

They follow the same method as in part **(a)** but use a different concentration of acid in **Step 3**.

The graph shows their results.



(i) Draw the line of best fit.

[2]

(ii) Use the graph to estimate the time taken for the cross to disappear when the concentration of sodium thiosulfate is 70%.

Show your working on the graph.

Time = ……..……..... s **[3]**

(c) The scientists make **two** conclusions from their investigations in **(a)** and **(b)**:

Conclusion 1: the rate of reaction is directly proportional to the concentration of sodium thiosulfate.

Conclusion 2: the acid used in **(b)** is more concentrated than the acid used in **(a)**.

Use the data from the table and the graph to justify **both** conclusions.

(i) Justification for **Conclusion 1**.

.....

.....

..... **[2]**

(ii) Justification for **Conclusion 2**.

.....

.....

.....

..... **[3]**

(d) What **four** pieces of extra information must be included in the procedure in **(a)** to ensure that it is repeatable by other scientists?

1 .....

.....

2 .....

.....

3 .....

.....

4 .....

.....

[4]

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Turn over for the next question

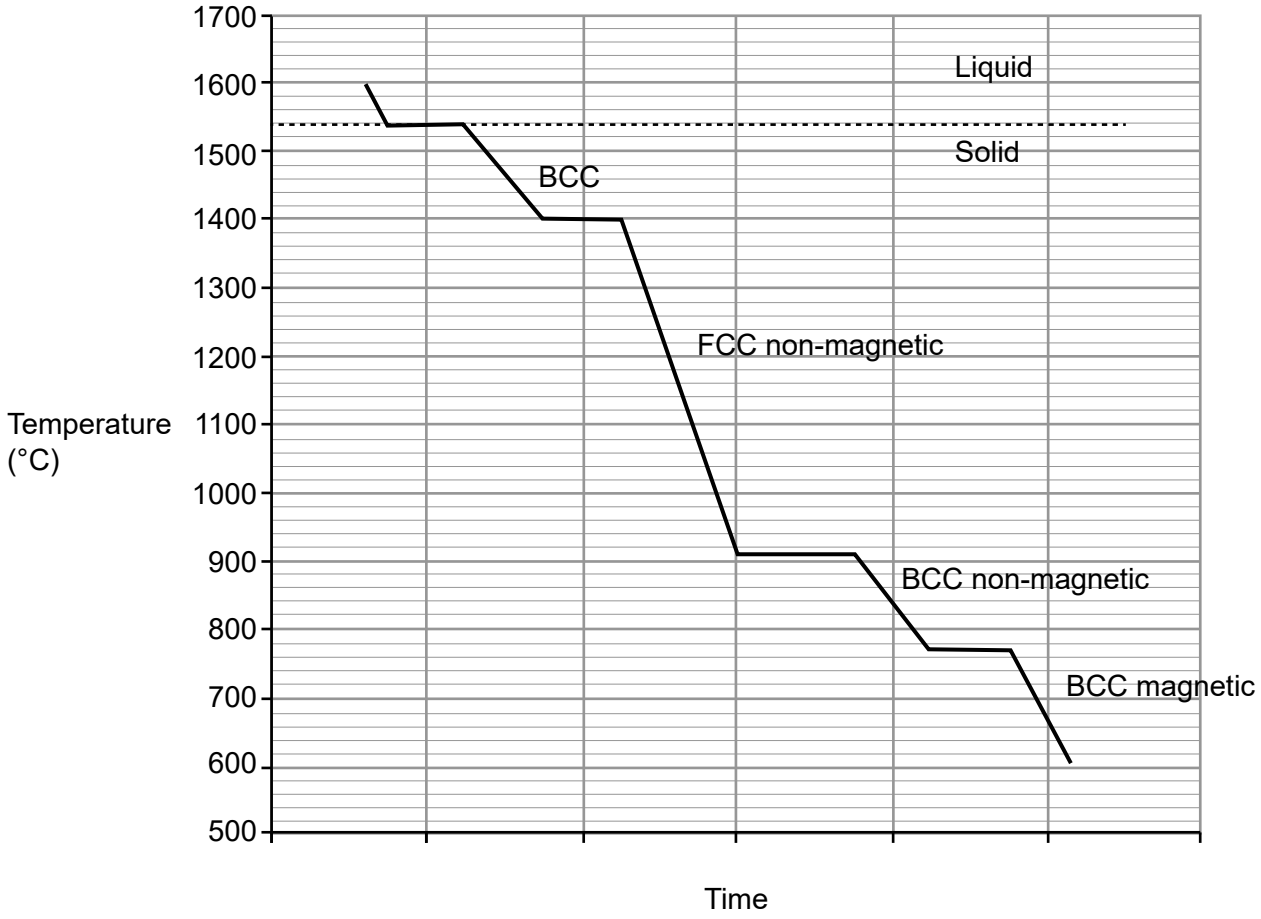
5 Iron is an important metal in the construction industry.

(a) Liquid iron is poured into a mould.

As the iron cools the arrangements of its atoms change. One arrangement is known as body-centred cubic (BCC) and the other is known as face-centred cubic (FCC).

The magnetic property of the iron also changes as it cools.

The graph shows how the structure of pure iron changes as it cools.



Use the graph to describe how the structure of iron changes as molten iron cools down.

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..... **[6]**

(b) Mild steel is an alloy of iron.

This alloy contains five elements in addition to iron.

The table shows the relative amounts of the five elements in proportion to each other.

Element	Symbol	Proportion (%)
Carbon	C	37%
Silicon	Si	25%
Manganese	Mn	21%
Phosphorus	P	16%
Sulfur	S	1%

Complete the pie chart below using the following steps:

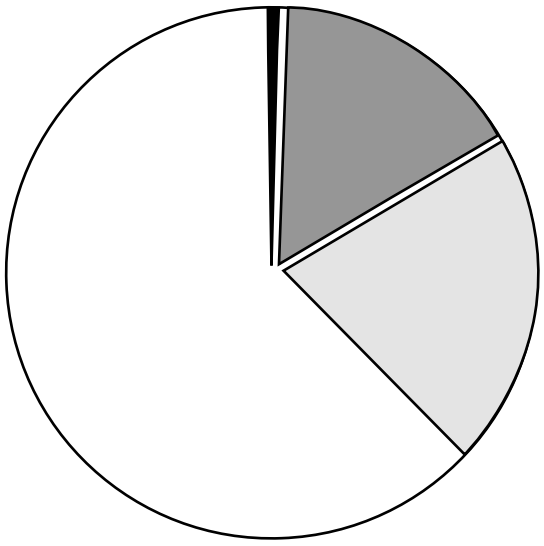
(i) Convert the percentages of carbon and silicon in the table to degrees.

Carbon = ... °

Silicon = ... °

[1]

(ii) Draw the segments for carbon and silicon in the correct positions on the pie chart and label each segment of the pie chart with the correct symbol.



[2]

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Turn over for the next question

6 Hydrogen peroxide (H_2O_2) is an active ingredient in some mouthwashes and in contact lens solutions.

A chemist determines the concentration of hydrogen peroxide in mouthwash by titration with acidified potassium manganate (VII), $KMnO_4$.

$$5H_2O_2(aq) + 2MnO_4^- + 6H^+ \longrightarrow 5O_2(g) + 2Mn^{2+} + 8H_2O$$

Purple Colourless

A 5.00 cm^3 portion of mouthwash was transferred to a 100 cm^3 volumetric flask and made up to the mark with water.

10.00 cm^3 portions of the diluted mouthwash were acidified and titrated against 0.020 mol dm^{-3} $KMnO_4$.

(a) The titration is a **redox** reaction.

(i) Balance the half equation for the conversion of MnO_4^- ions to Mn^{2+} ions.

$MnO_4^-(aq)$ + …….$H^+(aq)$ + …….e^- ⟶ $Mn^{2+}(aq)$ + …….$H_2O(l)$

[1]

(ii) Is $MnO_4^-(aq)$ oxidised or reduced?

Explain your answer in terms of electrons.

.....

..... **[2]**

(iii) State the colour change at the end point of the titration.

From ..... to .....

[1]

(b) The mean titre was found to be 12.20 cm^3.

(i) Calculate the number of moles of $KMnO_4$ in 12.20 cm^3 of 0.020 mol dm^{-3} $KMnO_4$.

Use the following equation in your calculation.

$$\text{Number of moles} = \frac{\text{concentration in mol dm}^{-3} \times \text{volume in cm}^3}{1000}$$

Number of moles $KMnO_4$ = ……..……..... **[1]**

(ii) In this reaction 5 moles of H_2O_2 react with 2 moles of $KMnO_4$.

Use this information to calculate the number of moles of H_2O_2 in 10.00 cm^3 of the diluted mouthwash.

Number of moles H_2O_2 = …….……..... **[1]**

(iii) Calculate the concentration in mol dm^{-3} of H_2O_2 in the diluted mouthwash.

Concentration of H_2O_2 in the diluted mouthwash = …….……..... mol dm^{-3} **[1]**

(iv) Calculate the dilution factor and use this value to calculate the concentration of H_2O_2 in the original mouthwash.

Dilution factor =…….…….....

Concentration of H_2O_2 in original mouthwash = …….……..... mol dm^{-3} **[2]**

(c) Contact lens solutions contain ingredients such as hydrogen peroxide which sterilise contact lenses.

The label on a bottle of contact lens solution says it is a 3% solution of hydrogen peroxide. A 3% solution means there are 3 g of H_2O_2 in 100 cm^3 of solution.

Calculate the concentration of H_2O_2 in mol dm^{-3}.

Concentration of H_2O_2 in contact lens solution = ……..……..... mol dm^{-3} **[3]**

(d) Some contact lens solutions contain sodium chloride solution to sterilise contact lenses.

The chemist decides to do a titration to determine the concentration of NaC*l* in a brand of saline contact lens solution.

The chemist titrates 10.0 cm^3 portions of the contact lens solution against 0.100 mol dm^{-3} silver nitrate ($AgNO_3$).

(i) What type of titration is this?

Put a (ring) around the correct answer.

Acid-base **Complexometric** **Precipitation** **Redox**

[1]

(ii) The indicator for this titration is potassium chromate.

Describe what you would observe at the end point.

.....

.....

..... **[1]**

(iii) The chemist obtained the following results.

	Trial	**Accurate 1**	**Accurate 2**	**Accurate 3**
Final burette reading (cm^3)	17.95	35.75	17.70	35.50
Initial burette reading (cm^3)	0.00	17.95	0.10	17.70
Titre (cm^3)	.....	.....	.....	.....

Complete the results table to show the titre obtained for each titration and use the concordant values to calculate the mean titre.

Mean titre = ……..……..... cm^3 **[2]**

(iv) The burette has an uncertainty of ± 0.05 cm^3 in each reading. Calculate the percentage error in the first **accurate** titre.

% error = ……..……..... % **[2]**

7 **Fig. 7.1** and **Fig. 7.2** both relate to discoveries made by the James Webb Space Telescope, the largest optical telescope in space.

Fig. 7.1 is an article published in the online newspaper *The Independent* in January 2023.

Fig. 7.1

Astonishing new Nasa image shows stars and planets as they form.

NGC 346, shown here in this image from NASA's James Webb Space Telescope Near-Infrared Camera (NIRCam), is a dynamic star cluster that lies within a nebula 200,000 light years away.

A new image taken by the James Webb Space Telescope could show the very beginnings of planets. The vast, swirling new image shows a young cluster of stars known as NGC 346, located in the Small Magellanic Cloud or SMC. They are found more than 200,000 lightyears from Earth.

Scientists believe that conditions in that star cluster are similar to those in the early universe, when it was giving birth to new stars at a rapid rate.

The image allows scientists to look at that process as it happens, watching stars as they are formed. But it might also include planets – which would suggest that new worlds were forming earlier in the universe than scientists realised.

Fig. 7.2 shows part of a publication in *The Astronomical Journal* about discoveries made using the James Webb Space Telescope.

Fig. 7.2

THE ASTRONOMICAL JOURNAL, 165:14 (12pp), 2023 January https://doi.org/10.3847/1538-3881/ac9f45

Importance of Sample Selection in Exoplanet-atmosphere Population Studies

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Abstract

Understanding planet formation requires robust population studies, which are designed to reveal trends in planet properties. In this work we aim to determine if and how different methods for selecting populations of exoplanets for atmospheric characterization with JWST could influence population-level inferences. We generate three hypothetical surveys of super-Earths/sub-Neptunes, with each survey designed to span a similar radius-insolation

(a) The two reports are designed for different audiences.

(i) Choose the intended audience (peers, public or scientific community) for the two reports and justify your answer.

Fig. 7.1

Intended audience .....

Justification .....

.....

.....

Fig. 7.2

Intended audience .....

Justification .....

.....

.....

[4]

(ii) Suggest **one** reason why it is important to publish scientific findings which are easily accessible to members of the public.

.....

..... **[1]**

(b) **Fig. 7.2** was published in a peer reviewed journal.

(i) State **one** advantage of peer reviewed publications.

.....

..... **[1]**

(ii) Describe the process of peer review.

.....

.....

.....

..... **[3]**

(c) Use **Fig. 7.2** to deduce:

(i) how many months it took to complete the peer review.

..... **[1]**

(ii) the number of institutions that collaborated on this work.

..... **[1]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use this lined page. 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	13 (3)	14 (4)	15 (5)	16 (6)	17 (7)	18 (0)
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