

Modified Enlarged 24 pt

**OXFORD CAMBRIDGE AND RSA
EXAMINATIONS**

Monday 17 January 2022 – Morning

**Level 3 Cambridge Technical in
Applied Science**

05848/05849/05874

Unit 3: Scientific analysis and reporting

**Time allowed: 2 hours plus your additional
time allowance**

You must have:

the Loose Sheet for Question 6 (Fig. 6.2)

a ruler (cm/mm)

the Periodic Table

You can use:

a scientific or graphical calculator

an HB pencil

Please write clearly in black ink.

Centre

number

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Candidate

number

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First name(s) _____

Last name _____

**Date of
birth**

D	D	M	M	Y	Y	Y	Y
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READ INSTRUCTIONS OVERLEAF

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 [].

ADVICE

Read each question carefully before you start your answer.

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Answer ALL the questions.

1 The title page of a publication in a science journal is shown in FIG. 1.1.

The contents are fictional.

FIG. 1.1

Laboratory Technology Reports

Volume 11, September 2016,

Pages 11 – 32

An evaluation of different chromatography techniques: manual and automated.

**Friedrich B. Bauer ^a, Burkhard A. Fischer ^a,
Lucia C. Garcia ^b, Pablo González ^b,
Jurgen D. Koch ^a, Paula R. López ^b,
Ella A. Neumann ^a, Hans R. Schmidt ^a,
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Germany**

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Tecnologicas, Spain**

**Received 11 January 2016, Revised
20 February 2016, Accepted 10 April 2016,
Available online 12 April 2016.**

- (a) State the name of the journal that this work was published in.**

_____ **[1]**

- (b) (i) State the year that this scientific investigation was published.**

_____ **[1]**

- (ii) Determine the approximate number of months between the paper submission date and when it was finally accepted for publication.**

_____ **[1]**

- (c) Explain how you can tell that this work was a collaboration between two research groups.**

_____ **[1]**

- (d) State the name of the country where most of the authors worked.**

[1]

- (e) One advantage of an online publication is that the findings can be made available to the wider scientific community very quickly.**

Explain how FIG. 1.1 shows that this is true.

[1]

(f) This article was published in a peer-reviewed journal.

(i) Describe what 'peer review' means.

[2]

(ii) State why peer review is important.

[1]

2 Amari is a student who is interested in astronomy.

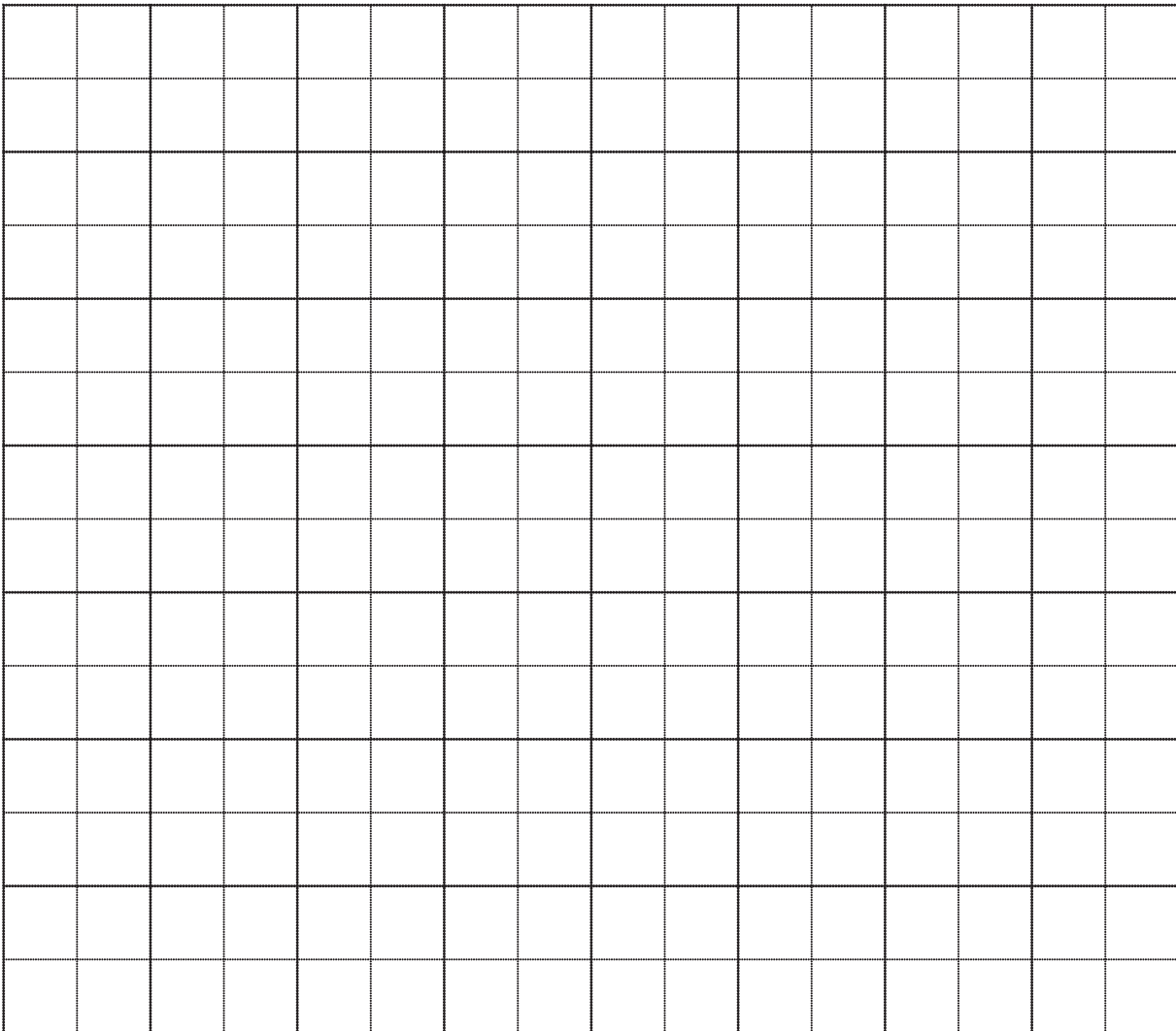
He finds the infographic in FIG. 2.1 displayed in a science museum.

FIG. 2.1

Colours of the 100 brightest stars as seen from Earth
2% dark blue
30% blue
19% light blue
9% white
12% yellow
22% orange
6% red

- (a) On FIG. 2.2, draw and label a bar chart of the percentage data shown in FIG. 2.1, in the order of colour shown. [3]

FIG. 2.2



- (b) Amari finds some more information about stars and their colours.**

FIG. 2.3 opposite shows the range of wavelengths produced by three different stars:

a G-type star with a temperature of 5000°C

a K-type star with a temperature of 4000°C

a M-type star with a temperature of 3000°C.

The peak of each curve is the wavelength at which each type of star emits most of its light.

FIG. 2.3

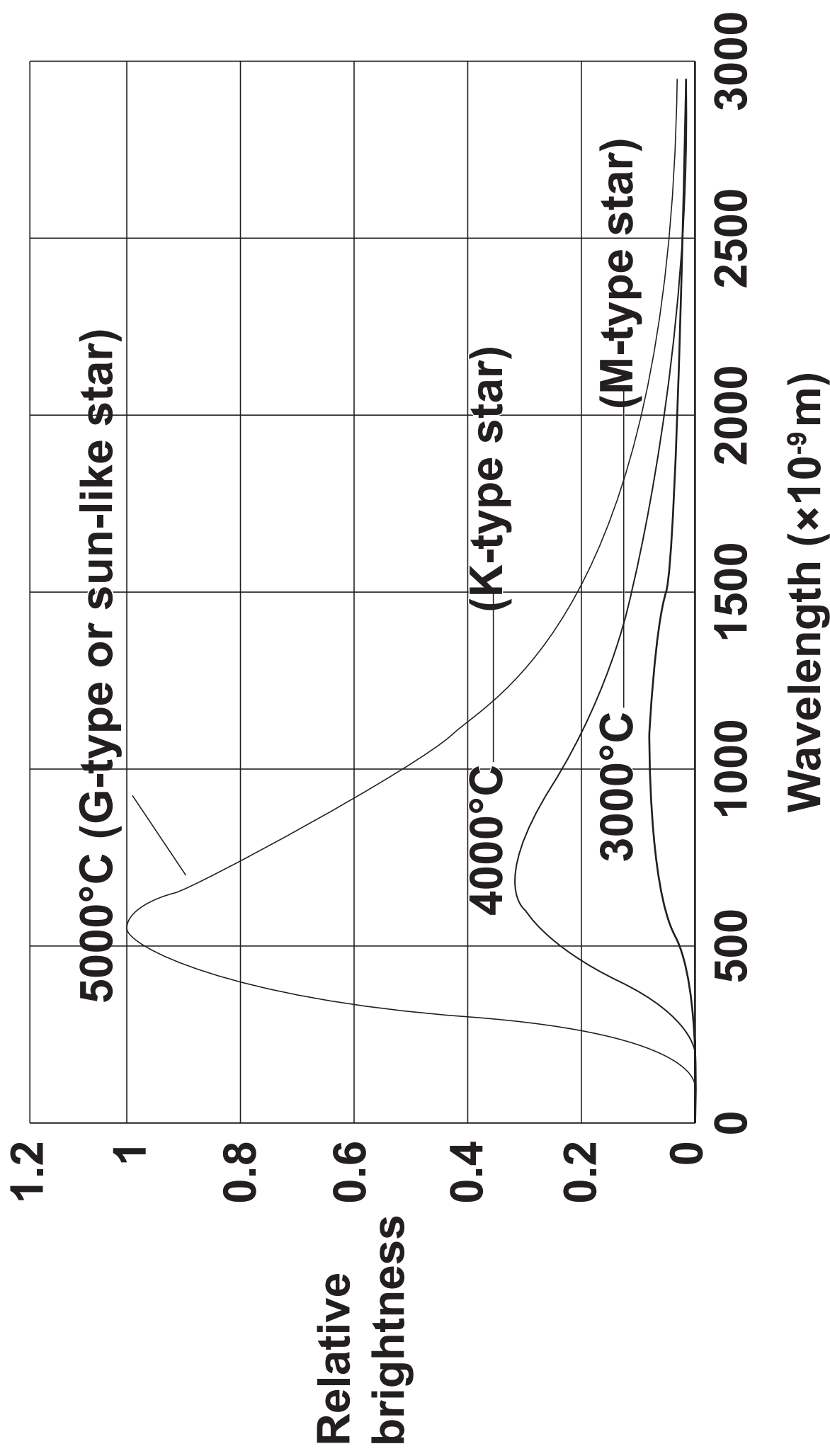


TABLE 2.1 shows the range of wavelengths for the colours of the visible part of the electromagnetic spectrum.

TABLE 2.1

Colour	Wavelength range (m)
red	$(635 \text{ to } 700) \times 10^{-9}$
orange	$(590 \text{ to } 635) \times 10^{-9}$
yellow	$(560 \text{ to } 590) \times 10^{-9}$
green	$(520 \text{ to } 560) \times 10^{-9}$
cyan	$(490 \text{ to } 520) \times 10^{-9}$
blue	$(450 \text{ to } 490) \times 10^{-9}$

- (i) Draw two vertical lines on FIG. 2.3 to indicate the range of wavelengths of the visible part of the electromagnetic spectrum. [1]

- (ii) Amari thinks it is possible to deduce the average colour of the stars in FIG. 2.3.

Which TWO statements are reasons why Amari CANNOT deduce the average colour of these stars?

Tick (✓) TWO boxes. [2]

A single colour is a range of wavelengths.

☐

Colour is discontinuous but wavelength is continuous.

☐

Colour is continuous but wavelength is discontinuous.

☐

Stars emit a range of wavelengths.

☐

The wavelength ranges are irregular.

☐

- (iii) Determine the wavelength and colour of the maximum relative brightness of the G-type star in FIG. 2.3.

Wavelength = _____ $\times 10^{-9} \text{ m}$

Colour = _____
[2]

- (iv) Suggest why the G-type star appears to be white.

_____ [1]

- (c) (i) Amari thinks that red stars are cooler than blue stars.**

Explain why Amari is correct.

**Use information from
FIG. 2.3 and TABLE 2.1 to
support your answer.**

[2]

- (ii) Amari then concludes that most of the stars near Earth are hotter than the sun.

Suggest why Amari could be correct, and suggest why he could also be incorrect.

Use information from FIG. 2.1 and FIG. 2.3 to support your answers.

Reason Amari could be correct

Reason Amari could be incorrect

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- 3 Layla measures the e.m.f. of seven AAA batteries.**

She connects each battery across the terminals of a digital multi-meter and records the e.m.f.

Her results are shown in TABLE 3.1.

TABLE 3.1

Battery	e.m.f. (V)
1	1.60
2	1.48
3	1.57
4	1.60
5	1.60
6	1.44
7	1.58

(a) Using the data in TABLE 3.1:

(i) Find out the mode and median of the e.m.f. values.

Mode = _____ V

Median = _____ V

[2]

(ii) Calculate the mean e.m.f.

Give your answer to 3 significant figures.

Mean = _____ V [3]

- (b) Calculate the variance, s^2 , and standard deviation, s , of the e.m.f values.

Use the equation:

$$(n - 1) \times s^2 = \sum (X_i - \bar{X})^2$$

n = number of samples

X_i = e.m.f. of each individual cell

\bar{X} = mean e.m.f. calculated in (a)(ii).

$s^2 =$ _____

$s =$ _____

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- (c) Layla measures the e.m.f. of the batteries again, in millivolts, mV.

Her new results are shown in TABLE 3.2.

TABLE 3.2

Battery	e.m.f. (mV)
1	1614
2	1618
3	1516
4	1618
5	1591
6	1619
7	1619

Layla concludes that:

‘there are two batteries in TABLE 3.1 whose e.m.f values are due to measurement error’.

(i) Identify the two batteries.

**Battery number _____ and
battery number _____ .**
[1]

**(ii) Explain your answer to (c)(i).
Use ideas about precision in
your answer.**

_____ **[2]**

- (d) On the diagram opposite, draw lines to connect each experimental analysis term with its correct definition. [5]**

Experimental analysis term

Accuracy

Definition

The closeness of agreement between measured values obtained by repeated measurements.

**Measurement
error**

Error due to measurements varying in an unpredictable way.

Precision

Error due to measurements differing from the true value by a consistent amount.

Random error

The closeness of the instrument reading to the true value.

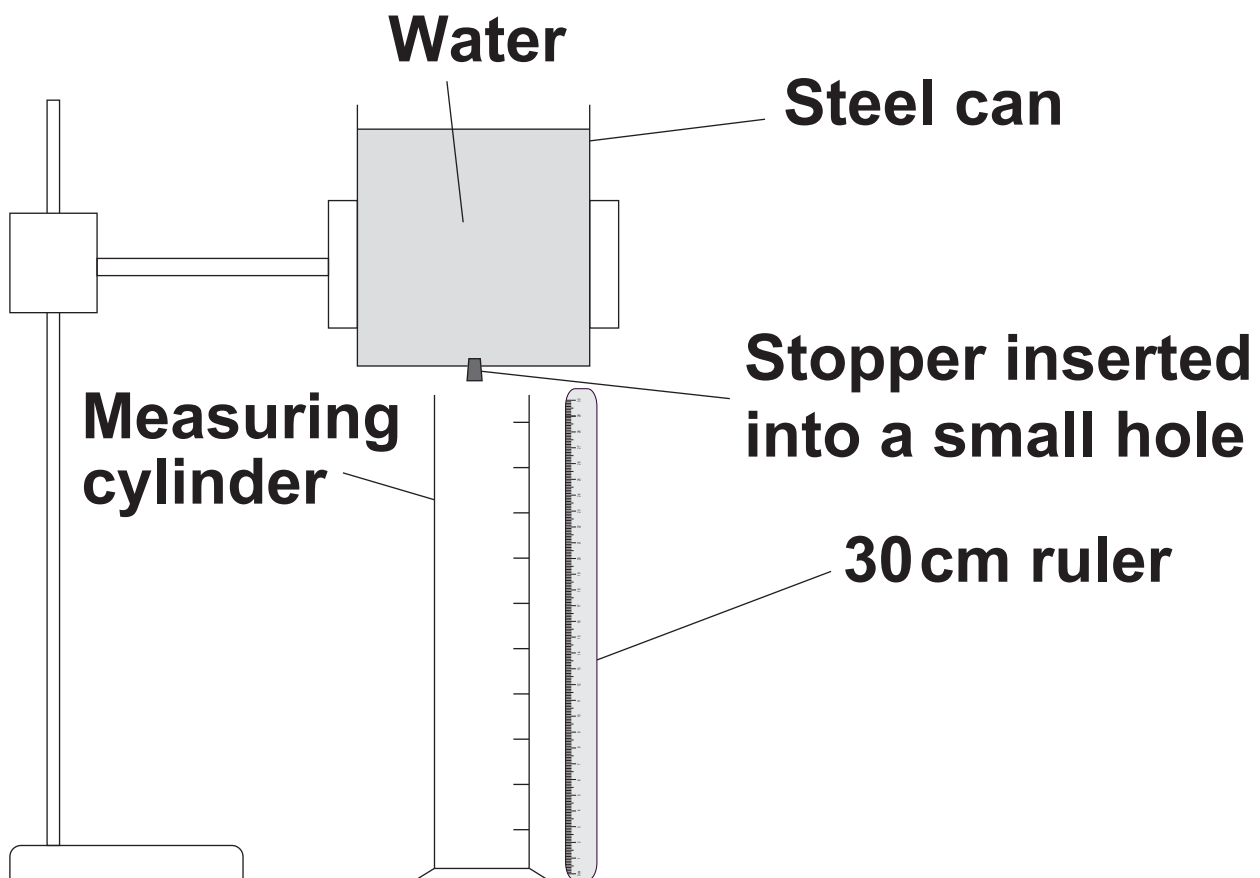
**Systematic
error**

The difference between a measured value and the true value.

- 4 Felix is investigating changes in the rate of flow of water.**

FIG. 4.1 is a diagram of the apparatus he uses.

FIG. 4.1



Felix removes the stopper from the steel can and starts a stopwatch.

Felix records the time taken for the water level inside the measuring cylinder to reach a height of 2.0cm, 4.0cm and so on up to 14.0cm.

- (a) The time, t_1 , when the water level reaches a height, h_1 , of 12.0 cm is 251 s.

The time, t_2 , when the water level reaches a height, h_2 , of 14.0 cm is 330 s.

The diameter, d , of the measuring cylinder is 7.1 cm.

- (i) Calculate the change in height, Δh , and the time taken, Δt , for the change in height.

$$\Delta h = (h_2 - h_1) = \underline{\hspace{10cm}} \text{ cm}$$

$$\Delta t = (t_2 - t_1) = \underline{\hspace{10cm}} \text{ s}$$

[1]

- (ii) Calculate the average rate of flow, R , of the water as the water level increases from h_1 to h_2 .

Give the units of R .

Use your values of Δh and Δt from (a)(i) in the equation:

$$R = \frac{\pi d^2 \Delta h}{4 \Delta t}$$

$R =$ _____ units _____ [3]

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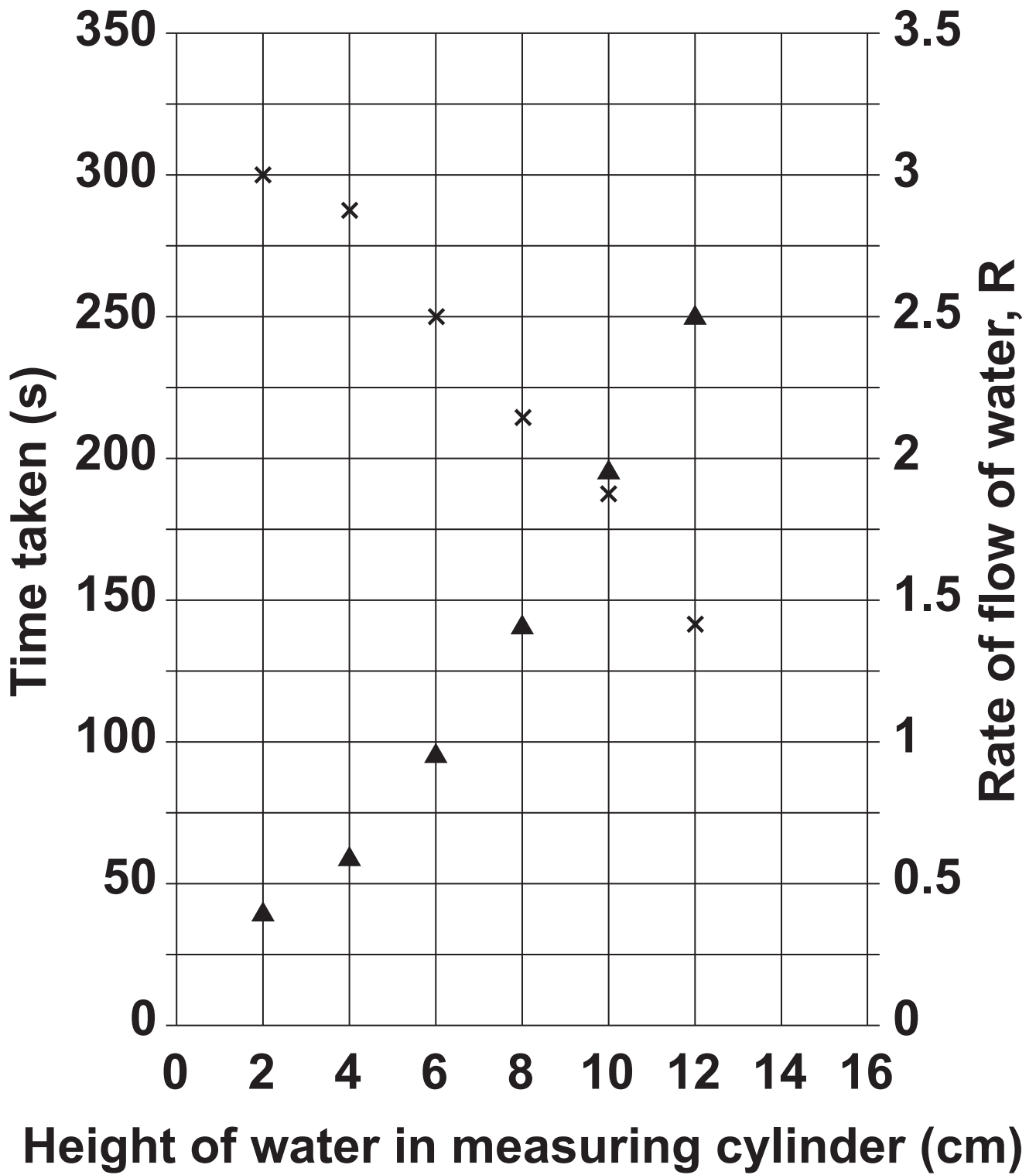
(iii) Felix plots two graphs as shown in FIG. 4.2 opposite.

The graphs show:

the time taken against height of water in the measuring cylinder (marked with triangles ▲)

the rate of flow of water, R , against height of water in the measuring cylinder (marked with crosses ×)

FIG. 4.2



On the grid in FIG. 4.2:

draw the symbol \blacktriangle to plot the value of t_2 used for the calculation in (a)(i).

draw the symbol \times to plot your value of R calculated in (a)(ii). [2]

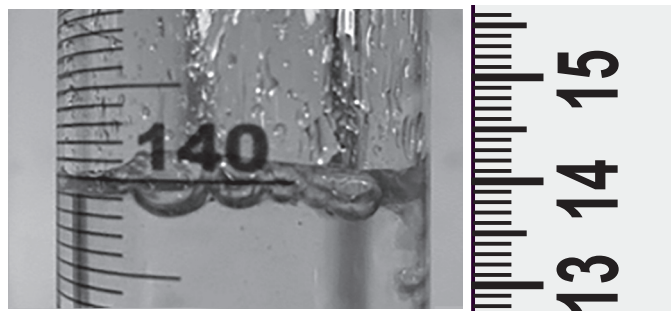
- (iv) Use FIG. 4.2 to estimate R when the height of the water in the measuring cylinder is 1.0 cm.**

$R =$ _____ [1]

- (b) Felix takes a photograph of the water in the measuring cylinder as it reaches the 14cm mark on the ruler.

The photograph is shown in FIG. 4.3.

FIG. 4.3



Describe and explain the trend in R , and suggest why there are errors in Felix's time measurement at 14cm.

Use information from FIG. 4.2 and FIG. 4.3 to support your answer. [6]

- (c) Felix concludes that the rate of flow of water, R , depends on the depth of water in the steel can.

Which equation can be used to increase confidence in Felix's conclusion?

Tick (✓) ONE box. [1]

Acceleration = change in speed \div time

☐

Density = mass \div volume

☐

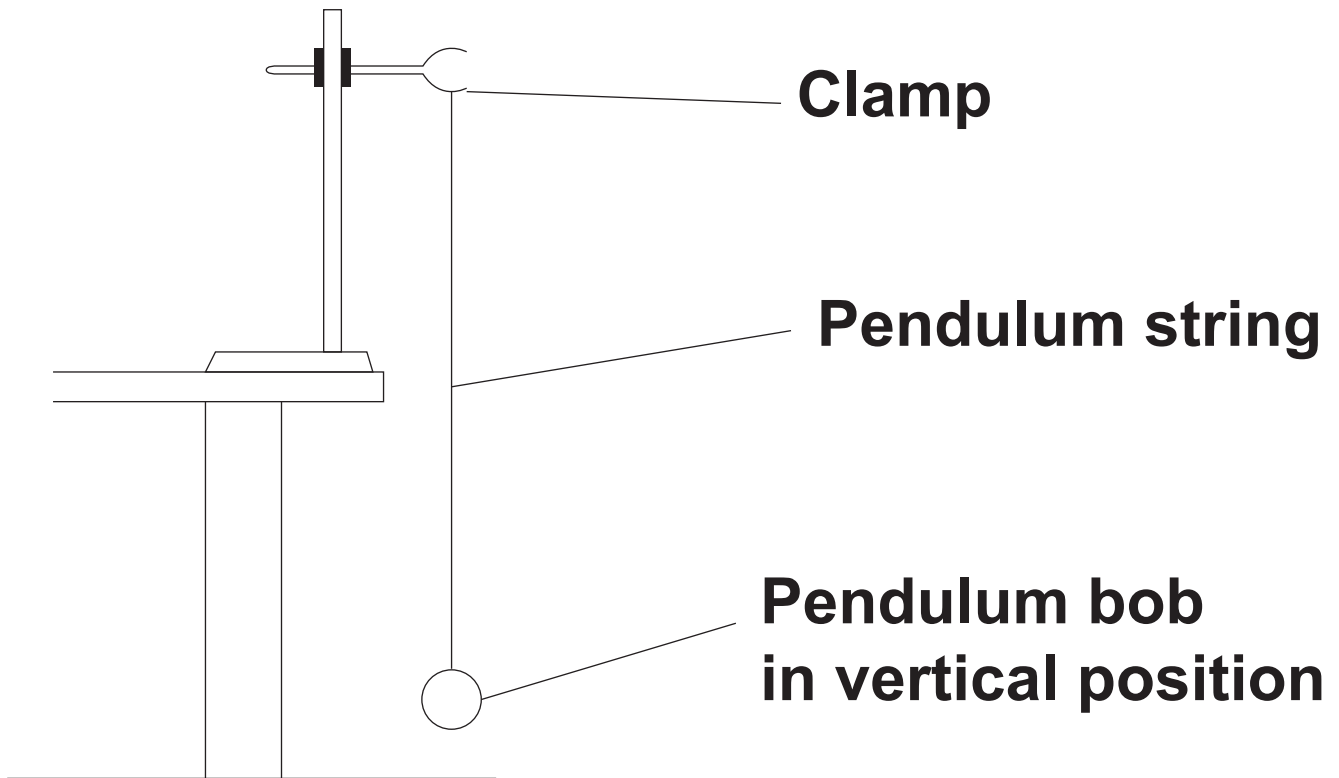
Force = mass \times acceleration

☐

Pressure = density \times gravitational
field strength \times depth

☐

- 5 Amos is investigating a simple pendulum. He sets up the apparatus shown in the diagram.**



A pendulum string is tied to a clamp at one end and has a heavy weight known as a pendulum bob at the other.

Amos moves the pendulum bob from the vertical position to 12cm to the right.

When he releases the pendulum bob, it swings to the left and then swings back. The size of the swing (amplitude) decreases slightly with each swing.

Amos starts a stopwatch when the pendulum is 12cm to the right of the vertical position.

When the distance of the pendulum bob from the vertical position decreases to 10cm, he records the time taken.

He continues to record the time taken each time this distance decreases by 2cm.

He carries out two experiments using two different lengths of pendulum string.

The results of his investigation are shown in the table.

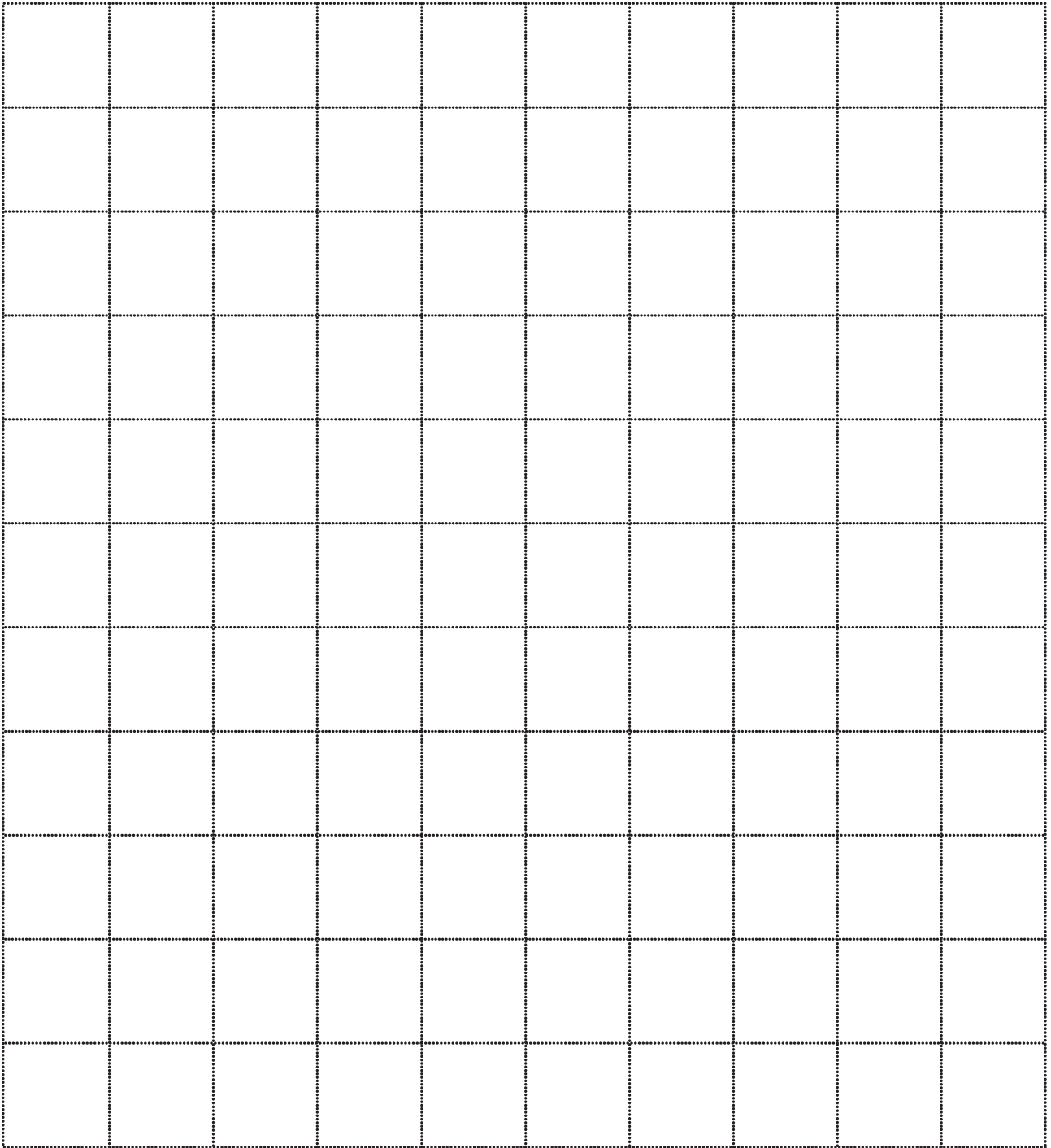
Decrease in distance of pendulum bob from vertical position (cm)	0	2.0	4.0	6.0	8.0	10.0
FIRST experiment: length of pendulum string = 130cm:						
Time (s)	0	60	200	230	330	480
SECOND experiment: length of pendulum string = 54cm:						
Time (s)	0	30	70	120	170	220

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- (a) Plot a graph of time (s) on the vertical axis against decrease in distance of pendulum bob from vertical position (cm), for both sets of results from the table.**

Draw curves of best fit for both sets of results AND label the lines '130cm pendulum' and '54cm pendulum'.

Put a ring around the outlier on your graph. [7]



(b) Amos estimates that the percentage uncertainty in his time measurements is $\pm 10\%$.

(i) Calculate the minimum and maximum possible times when the decrease in distance is 6.0 cm, using the 130 cm pendulum string.

Minimum time = _____ s

Maximum time = _____ s

[2]

(ii) Draw a range bar on the graph to indicate the values calculated in (b)(i). [1]

- (iii) Which TWO changes will cause the percentage UNCERTAINTY in the time measurements to INCREASE?
Tick (✓) TWO boxes. [2]**

A larger decrease in the distance from the vertical position with each swing.

☐

A smaller decrease in the distance from the vertical position with each swing.

☐

The pendulum bob changing direction more quickly.

☐

The pendulum bob changing direction more slowly.

☐

An increase in the time for one swing of the pendulum bob.

☐

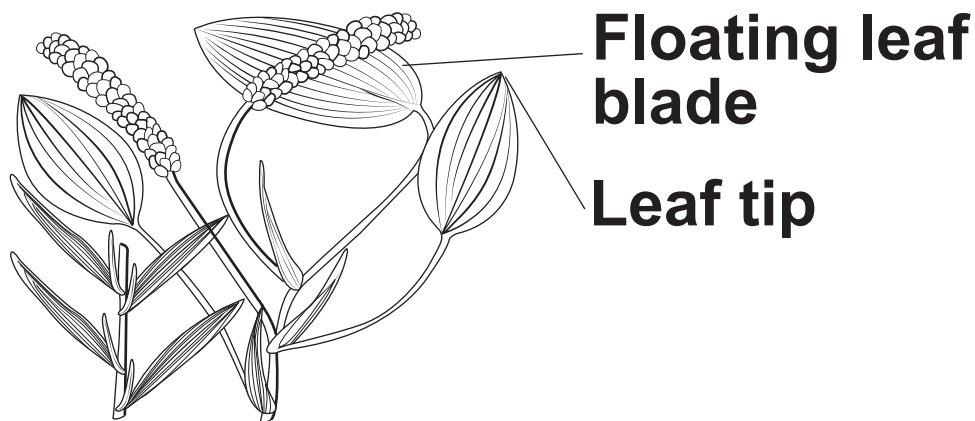
- 6 Potamogeton is a type of aquatic plant, commonly known as pondweed.**

Many species have leaves that float on the surface of the water and leaves that are underwater.

Some species are entirely submerged, and all of their leaves and stems are underwater.

The features of one species of Potamogeton are shown in FIG. 6.1.

FIG. 6.1



The table opposite shows some features of Potamogeton.

The table is used to identify individual species.

Species	Underwater leaf width (mm)	Underwater leaf tip shape	Underwater leaf blade shape	Floating leaf tip shape
P. biculpatus	0.1 – 0.4	acute	linear	lanceolate
P. spirillus	0.5 – 2	obtuse	linear	obtuse
P. robbinsii	3 – 8	acute	linear	n/a
P. crispus	3 – 8	rounded	linear	n/a
P. gramineus	3 – 27	acuminate	elliptic	acuminate
P. perfoliatus	7 – 40	acute	lanceolate	n/a
P. nodosus	10 – 35	acute	lanceolate	obtuse
P. amplifolius	15 – 58	acuminate	lanceolate	obtuse
P. pulcher	60 – 165	acute	lanceolate	acute

n/a = the species does not have any floating leaves, all leaves are submerged.

- (a) A partly completed classification key of the information in the table is shown in FIG. 6.2 on the Loose Sheet.

Complete the classification key in FIG. 6.2 on the Loose Sheet by writing the correct word next to each number in the list.

Use the table.

- 1 _____
- 2 _____
- 3 _____
- 4 _____
- 5 _____
- 6 _____
- 7 _____

[7]

- (b) (i) Explain why it is difficult to distinguish between *P. nodosus* and *P. amplifolius*.**

[2]

- (ii) Suggest ONE feature, other than those described in TABLE 6.1, which can be used to identify different plants.**

[1]

(c) Complete the sentences about Potamogeton.

Use the words.

You can use each word once, more than once, or not at all.

binomial	family
genus	monomial
numerical	phylum
polynomial	

Potamogeton is the name of a plant

The naming system used to identify all plants, including for example *P. crispus* is

[2]

- (d) Environmental scientists often study the presence of pondweeds in freshwater.**

Pondweeds are indicator species.

Explain why the ability to distinguish between different species of pondweed is important for assessing the quality of the environment.

[3]

7 An acid-base titration is one technique that chemical laboratories can use to determine the concentration of a substance.

Other titration techniques can be used to determine the concentration of substances that are not acids or bases.

(a) Complete the table by identifying TWO alternative titration techniques.

Tick (✓) TWO boxes. [2]

Complex formation	
Density	
Optometry	
Redox	
Spectroscopy	

- (b) Ivan is a technician working in a scientific analysis laboratory.**

He determines the concentration of chloride ions (Cl^-) in seawater by titration against silver nitrate, using potassium chromate as the indicator.

When silver nitrate is added from the burette to the sample of seawater, Ivan observes a white precipitate.

When sufficient silver nitrate has been added to react with all the chloride ions in the seawater, additional silver nitrate reacts with the potassium chromate indicator forming a coloured precipitate. This is the end point of the titration.

- (i) State the name of the precipitate formed at the end point.**

- (ii) State the colour of the precipitate at the end point.**

[1]

- (c) Potassium chromate is a carcinogen.**

State ONE precaution that Ivan should take when working with potassium chromate.

[1]

- (d) Silver nitrate solutions can cause chemical burns.**

State what action Ivan should immediately take if silver nitrate gets onto his skin.

[1]

- (e) Ivan dissolves 2.125g of silver nitrate solid, AgNO_3 , in distilled water. He then transfers the solution to a 250cm^3 volumetric flask and makes up to the 250cm^3 mark with more distilled water.
- (i) Calculate the molar mass of silver nitrate and use it to calculate the number of moles of silver nitrate present in the 250cm^3 volumetric flask.

Use the equation:

$$\text{number of moles} = \frac{\text{mass (g)}}{\text{molar mass (g mol}^{-1}\text{)}}$$

Molar mass of $\text{AgNO}_3 =$ _____ g mol^{-1}

Number of moles of $\text{AgNO}_3 =$

_____ moles

- (ii) Calculate the concentration, in mol dm^{-3} , of the silver nitrate solution.

Use the equation:

$$\text{concentration (mol dm}^{-3}\text{)} = \frac{\text{number of moles}}{\text{volume (dm}^3\text{)}}$$

Concentration = _____ mol dm^{-3} [1]

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- (f) The normal concentration of chloride ions (Cl^-) in tap water in a coastal village is 0.01mol dm^{-3} .**

After a severe storm there is concern that the village tap water might be contaminated with sea water.

Ivan has been asked to investigate whether the tap water is contaminated.

He uses a pipette to measure out 20.0cm^3 of the tap water and adds distilled water to make a final volume of 100.0cm^3 .

He titrates 25.0cm^3 of the diluted tap water against a 0.100mol dm^{-3} standard solution of silver nitrate, using potassium chromate as the indicator.

He finds that the average volume of 0.100mol dm^{-3} silver nitrate needed to reach the end point is 15.5cm^3 .

- (i) Calculate the number of moles of Ag^+ ions in 15.5cm^3 of silver nitrate.

Use the equation: number of moles =

$$\frac{\text{volume (cm}^3\text{)} \times \text{concentration (mol dm}^{-3}\text{)}}{1000}$$

1000

Number of moles of Ag^+ ions =

_____ mol [1]

- (ii) The equation for the reaction between silver ions (Ag^+) and chloride ions (Cl^-) is



Deduce the number of moles of chloride (Cl^-) ions in the 25.0 cm^3 of diluted tap water.

Number of moles of Cl^- ions =

_____ mol [1]

(iii) Calculate the concentration of chloride (Cl^-) ions in the DILUTED tap water.

Use the equation:

$$\text{concentration (mol dm}^{-3}\text{)} = \frac{\text{number of moles}}{\text{volume (dm}^3\text{)}}$$

Concentration = _____ mol dm⁻³ [1]

(iv) Calculate the concentration of chloride (Cl^-) ions in the UNDILUTED tap water.

Concentration = _____ mol dm⁻³ [1]

- (v) State if the tap water tested by Ivan was contaminated with sea water.

Explain your answer.

[1]

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- (g) Ivan's job also involves finding the concentration of calcium ions in water samples taken from the local area.

Complete the sentences about the determination of calcium ions by titration.

Use the terms.

You can use each term once, more than once, or not at all. [2]

potassium dichromate

starch

EDTA

eriochrome black T

iodine

methyl orange

sodium thiosulfate

Ivan measures out 25.0 cm^3 of a sample of water and places it in a conical flask with a few drops of _____ as the indicator.

He fills up the burette with a standard solution of _____ and adds it to the solution in the flask until the indicator changes colour.

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question numbers must be clearly shown in the margins – for example, 1(f)(i) or 4(b).

[illegible]



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