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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

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* 3 0 1 9 7 9 6 5 7 4 *

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **October/November 2025**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **12** pages. Any blank pages are indicated.

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1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $AgNO_3(aq)$.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

The indicator used is aqueous potassium chromate(VI), $K_2CrO_4(aq)$.

As $AgNO_3(aq)$ is added to aqueous chloride ions, a white precipitate of $AgCl(s)$ is formed.

When all the chloride ions have reacted, further addition of $AgNO_3(aq)$ leads to the formation of a red precipitate of silver chromate(VI), $Ag_2CrO_4(s)$. The first appearance of the red precipitate shows the end-point of the titration.

A student carries out an experiment to determine the number of molecules of water of crystallisation, *x*, in hydrated barium chloride, $BaCl_2{\bullet}xH_2O(s)$.

(a) The student makes $250.0\,cm^3$ of $0.0500\,mol\,dm^{-3}$ $AgNO_3(aq)$ to use for the titration.

(i) Calculate the mass of solid silver nitrate, $AgNO_3(s)$, needed to make $250.0\,cm^3$ of $0.0500\,mol\,dm^{-3}$ $AgNO_3(aq)$.

Give your answer to **two** decimal places.

mass of $AgNO_3(s)$ = ... g [1]

(ii) Describe how the student should make $250.0\,cm^3$ of $0.0500\,mol\,dm^{-3}$ $AgNO_3(aq)$ starting from the mass of $AgNO_3(s)$ calculated in **(a)(i)** in a $50\,cm^3$ beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

....

....

....

....

....

....

.... [3]

(b) The student uses the following method.

step 1 Dissolve 1.58 g of $BaCl_2•xH_2O(s)$ to form 250 cm^3 of aqueous solution. Label this solution **A**.

step 2 Transfer 20.0 cm^3 of solution **A** into a conical flask.

step 3 Add aqueous sodium sulfate, $Na_2SO_4(aq)$, to the flask and swirl the mixture to remove barium ions from the solution.

step 4 Add 2–3 drops of $K_2CrO_4(aq)$ indicator to the flask.

step 5 Titrate the contents of the flask against 0.0500 mol dm^{-3} $AgNO_3(aq)$.

step 6 Repeat steps 2 to 5 to collect sufficient data for analysis.

(i) Suggest a suitable piece of apparatus for transferring 20.0 cm^3 of solution **A** in step 2.

.... [1]

(ii) Suggest why barium ions are removed in step 3 before performing the titration.

....

.... [1]

(iii) Suggest why chemically resistant gloves should be worn to carry out step 4.

.... [1]

(c) The student's results are shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
burette reading (final) / cm^3	20.10	40.55	20.75	20.90
burette reading (initial) / cm^3	0.00	20.25	0.05	0.30
titre / cm^3	20.10	20.30	20.70	20.60

The student uses the titres from titrations 2 and 3 shown in Table 1.1 to calculate a mean titre value of 20.65 cm^3.

(i) Explain why only these two values are used.

.... [1]

(ii) Calculate the percentage error in the titre volume for titration 3.
Show your working.

percentage error = ... [1]

(d) The equation for the reaction of silver nitrate with barium chloride is shown.

$$2AgNO_3(aq) + BaCl_2(aq) \rightarrow Ba(NO_3)_2(aq) + 2AgCl(s)$$

(i) Calculate the amount, in mol, of $AgNO_3$(aq) in the mean titre of 20.65 cm^3.

amount of $AgNO_3$ = ... mol [1]

(ii) Calculate the amount, in mol, of $BaCl_2$(aq) in 250 cm^3 of solution **A**.

amount of $BaCl_2$ = ... mol [1]

(iii) Calculate the value of *x* in the formula $BaCl_2 \bullet xH_2O$.

x = ... [2]

(e) Another student uses a different experimental method to check the value of *x* obtained by the method described in **(b)**.

Give a **brief** description of another method, not involving titration, that could be used to determine the value of *x* in the formula $BaCl_2 \cdot xH_2O(s)$. Write your answer using a series of numbered steps.

Your plan should include details of the following:

- the apparatus and method you would use
- the measurements you would make.

You are provided with standard laboratory apparatus.

....

....

....

....

....

....

....

....

.... [3]

[Total: 16]

2 Effusion is the process in which a gas escapes through a small hole.

A student investigates the relationship between rate of effusion and relative molar mass of a gas using the apparatus shown in Fig. 2.1.

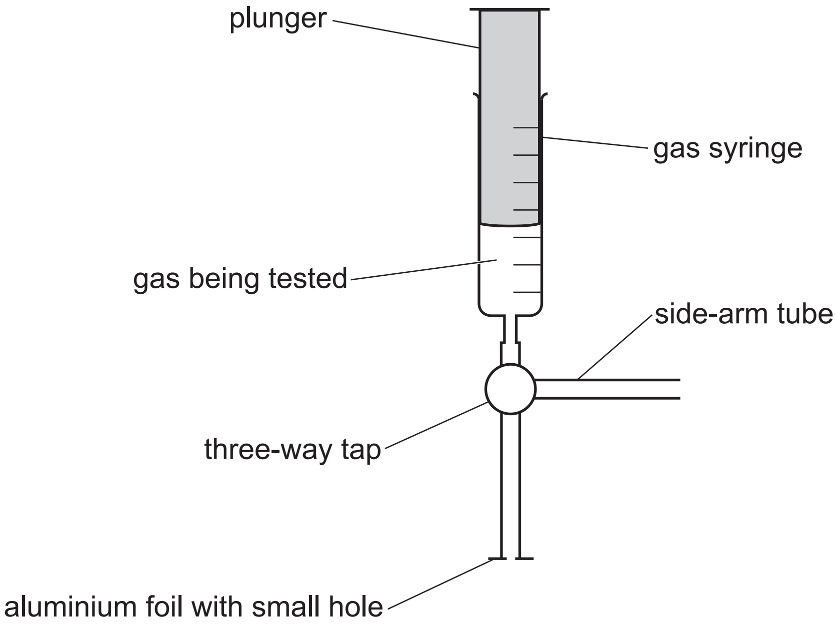

Fig. 2.1

The following method is used:

step 1 Turn the tap and remove any gas from the syringe through the side-arm tube, by pushing in the plunger.

step 2 Add 50 cm^3 of the gas being tested to the syringe through the side-arm tube.

step 3 Remove the gas from the syringe, through the side-arm tube, by pushing in the plunger.

step 4 Add 70 cm^3 of the gas being tested to the syringe through the side-arm tube.

step 5 Turn the tap to connect the syringe to the tube with the aluminium foil and small hole.

step 6 Allow the syringe plunger to fall and start a timer when the volume of gas in the syringe reaches 60 cm^3.

step 7 Stop the timer when the volume of gas in the syringe reaches 10 cm^3. Record the time taken.

step 8 Repeat steps 1 to 7 with different gases.

(a) Suggest why the student adds 50 cm^3 of the gas being tested to the syringe in step 2 and then removes this gas in step 3.

....

.... [1]

(b) The student's results are shown in Table 2.1.

Table 2.1

gas	hydrogen, H_2	helium, He	neon, Ne	argon, Ar	krypton, Kr
relative molar mass, *M*	2.0	4.0	20.2	39.9	83.8
$\sqrt{\frac{1}{M}}$					
time taken / s	10.8	15.3	34.5	39.7	70.4
rate of effusion / $cm^3 s^{-1}$					

$$\text{rate of effusion} = \frac{\text{volume of gas}}{\text{time taken}}$$

(i) Complete Table 2.1.

Give the values for $\sqrt{\frac{1}{M}}$ to **three** significant figures.

Give the values for rate of effusion to **two** decimal places. [2]

(ii) Identify the dependent variable in this experiment.

.... [1]

(iii) Identify a variable, other than temperature, that is controlled when carrying out this experiment.

.... [1]

(c) Plot a graph on the grid in Fig. 2.2 to show the relationship between rate of effusion and $\sqrt{\frac{1}{M}}$.
Use a cross (×) to plot each data point. Draw a suitable line of best fit.

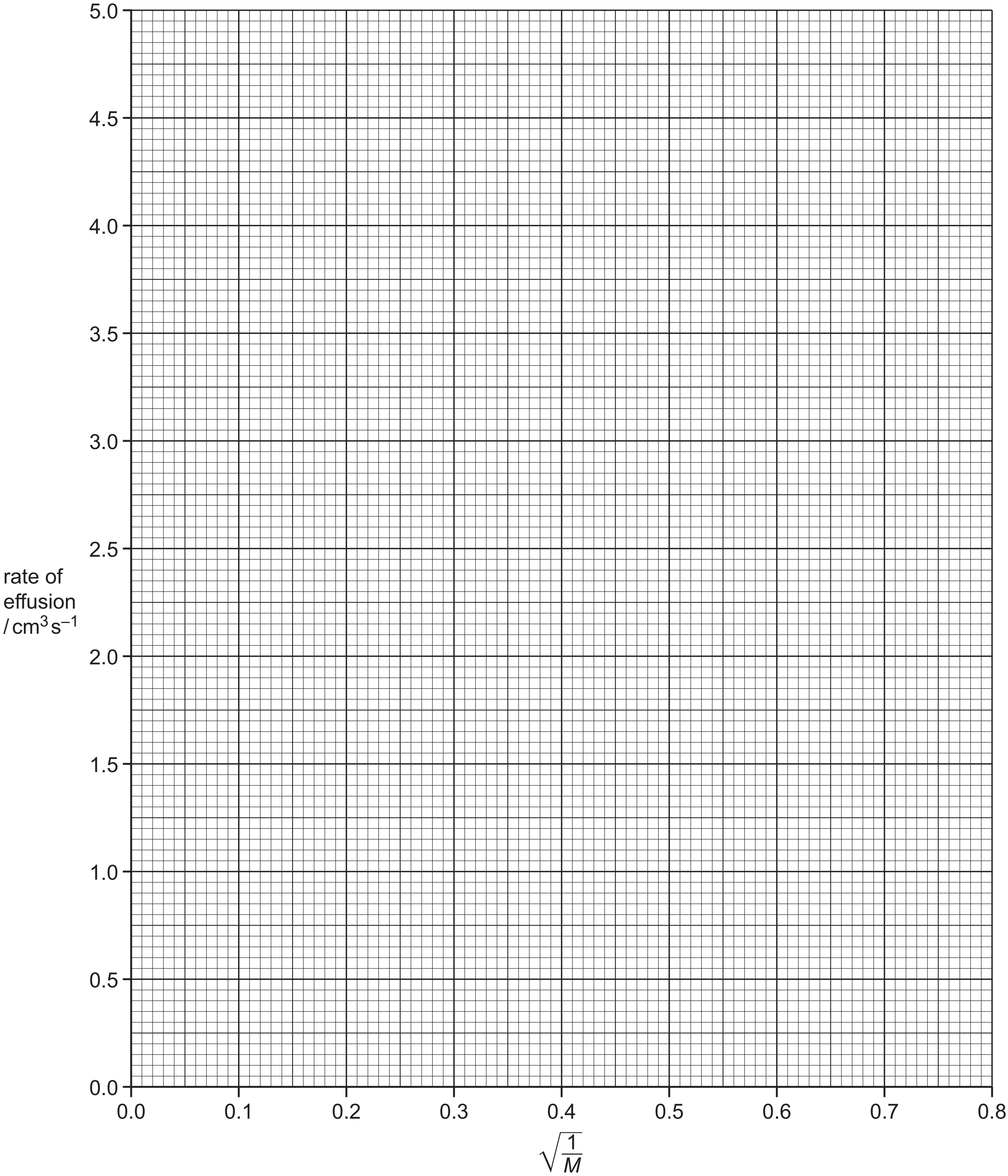

Fig. 2.2

[2]

(d) Circle **one** point on the graph in Fig. 2.2 which you consider to be most anomalous.

Suggest **one** reason for this anomaly. Assume there is no error in $\sqrt{\frac{1}{M}}$.

....

.... [1]

(e) Graham's law of effusion can be expressed as:

the rate of effusion of a gas is proportional to $\sqrt{\frac{1}{M}}$.

State whether or not the student's results support Graham's law of effusion.

Explain your answer, using the graph in Fig. 2.2.

....

.... [1]

(f) Suggest how the position of the plotted points relative to the line of best fit in Fig. 2.2 is related to the reliability of the results.

....

.... [1]

(g) The student then repeats this method to determine the value of *M* of a sample of natural gas.

The time recorded in step 7 is 31.6 s.

(i) Use the graph in Fig. 2.2 and the student's result to calculate the value of *M* for this sample.

M = ... [2]

(ii) Natural gas is a mixture of mainly methane, CH_4, with small amounts of other gases.

Suggest what your calculated value of the *M* of natural gas in **(g)(i)** tells you about the other gases in the mixture.

....

.... [1]

(h) The experiment described in **(g)** is repeated at a higher temperature.

Suggest how the rate of effusion for this sample of natural gas would change, if at all.

Explain your answer.

effect on the rate of effusion ....

explanation ....

....

[1]

[Total: 14]

Important values, constants and standards

molar gas constant	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,C\,mol^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,dm^3\,mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	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 –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	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 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	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 –