Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME										
CENTRE NUMBER						CANDIDATE NUMBER				

3265018670

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **October/November 2022**

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.

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[Turn over

1 A student attempts to determine the percentage by mass of magnesium chloride in the solid mixture containing magnesium chloride, $MgCl_2$, and anhydrous magnesium nitrate, $Mg(NO_3)_2$, using the following method.

step 1 Accurately weigh about 1.5 g of the solid mixture and record the mass.

step 2 Dissolve the solid mixture in distilled water.

step 3 Add an excess of silver nitrate solution.

step 4 Filter the solid mixture and wash the precipitate collected with distilled water.

step 5 Dry the precipitate in an oven.

step 6 Weigh the precipitate and record the mass.

In this process only the chloride ions from the magnesium chloride form a precipitate with the silver nitrate solution.

$$MgCl_2(aq) + 2AgNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + 2AgCl(s)$$

One student in the class obtains the following results.

mass of solid mixture = 1.52 g

mass of AgCl solid after drying = 3.63 g

(a) **(i)** Calculate the amount, in mol, of magnesium chloride present in the sample.

amount of magnesium chloride = ... mol [1]

(ii) Use your answer to **(i)** to calculate the percentage by mass of magnesium chloride in the sample. (If you were unable to answer **(i)** use 0.0102 mol. This is not the correct answer.)

percentage by mass = ... [2]

(b) **(i)** Suggest what the student could do in **step 2** to ensure the solid dissolves as quickly as possible.

....

....

.... [1]

(ii) Explain why the precipitate was washed with distilled water before it was dried.

....

....

.... [1]

(iii) Suggest why the precipitate is dried in an oven and not by direct heating with a Bunsen burner.

....

....

.... [1]

(c) (i) In **step 1**, a small beaker was weighed, using a balance accurate to two decimal places, and its mass recorded. The sample was placed in the beaker and the mass of the beaker increased by 1.52 g.

Calculate the percentage error in measuring the mass of this sample.

Show your working.

percentage error = ... [1]

(ii) Other than by changing the balance, state how this percentage error could be reduced.

.... [1]

(iii) State what could be done in **step 5** to ensure that the precipitate was completely dried.

....

.... [1]

(d) Another student in the class did not dry their silver chloride.

State how this would affect the value of the percentage by mass of magnesium chloride in the sample. Explain your answer.

....

.... [1]

[Total: 10]

2 Charles' law states that for a fixed mass of gas at constant pressure, its volume is proportional to its absolute temperature. Most gases are non-ideal and do not obey this law, but at lower pressures and high temperatures some gases are close to ideal behaviour. One gas that behaves like this is oxygen.

Oxygen can be prepared by decomposing hydrogen peroxide with the catalyst manganese(IV) oxide, MnO_2.

The equation for the decomposition of hydrogen peroxide is shown.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Safety hazard: hydrogen peroxide is corrosive to skin and can cause serious eye damage.

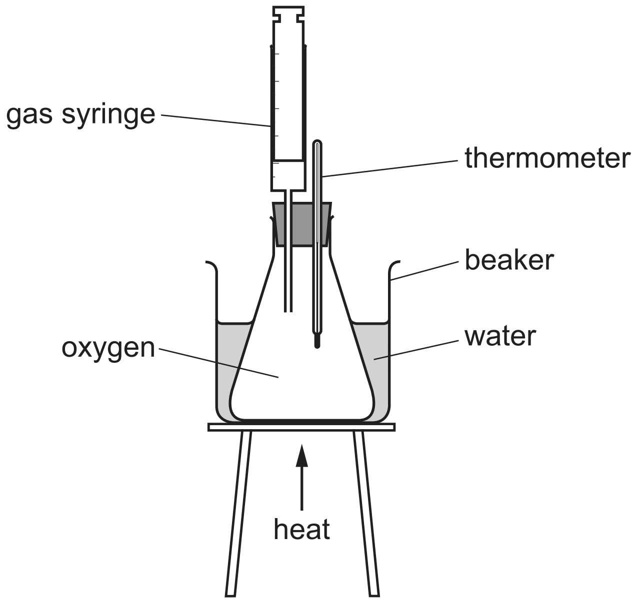


Fig. 2.1

Once the apparatus is assembled the volume of oxygen in the gas syringe is 2 cm^3. There are 80 cm^3 of oxygen remaining in the flask. The total volume of oxygen is 82 cm^3.

Charles' law is investigated by the following method.

step 1 Once assembled allow the apparatus to reach room temperature.

step 2 Record this temperature and the total volume of oxygen reading on the syringe.

step 3 Gently heat the apparatus until the temperature reaches 30 °C and record the total volume of oxygen.

step 4 Repeat at intervals of 5 °C until the temperature reaches 70 °C.

Question 2 continues on the next page.

The student carried out the experiment and obtained the following results:

Table 2.1

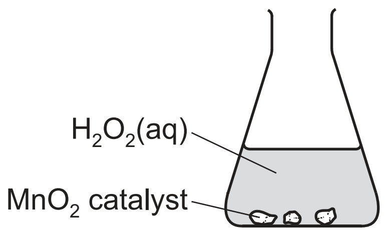
temperature / °C	absolute temperature / K	total volume of oxygen gas / cm^3
24	297	82
30	303	84
35	308	88
40	313	88
45	318	89
50	323	91
55	328	93
60	333	95
65	338	97
70	343	98

(a) Other than the wearing of safety goggles, give a safety precaution that the student must take during the preparation of oxygen.

....

.... [1]

(b) **(i)** Complete the following diagram to show how the student can obtain oxygen by gas collection over water for use in the experiment shown in Fig. 2.1.



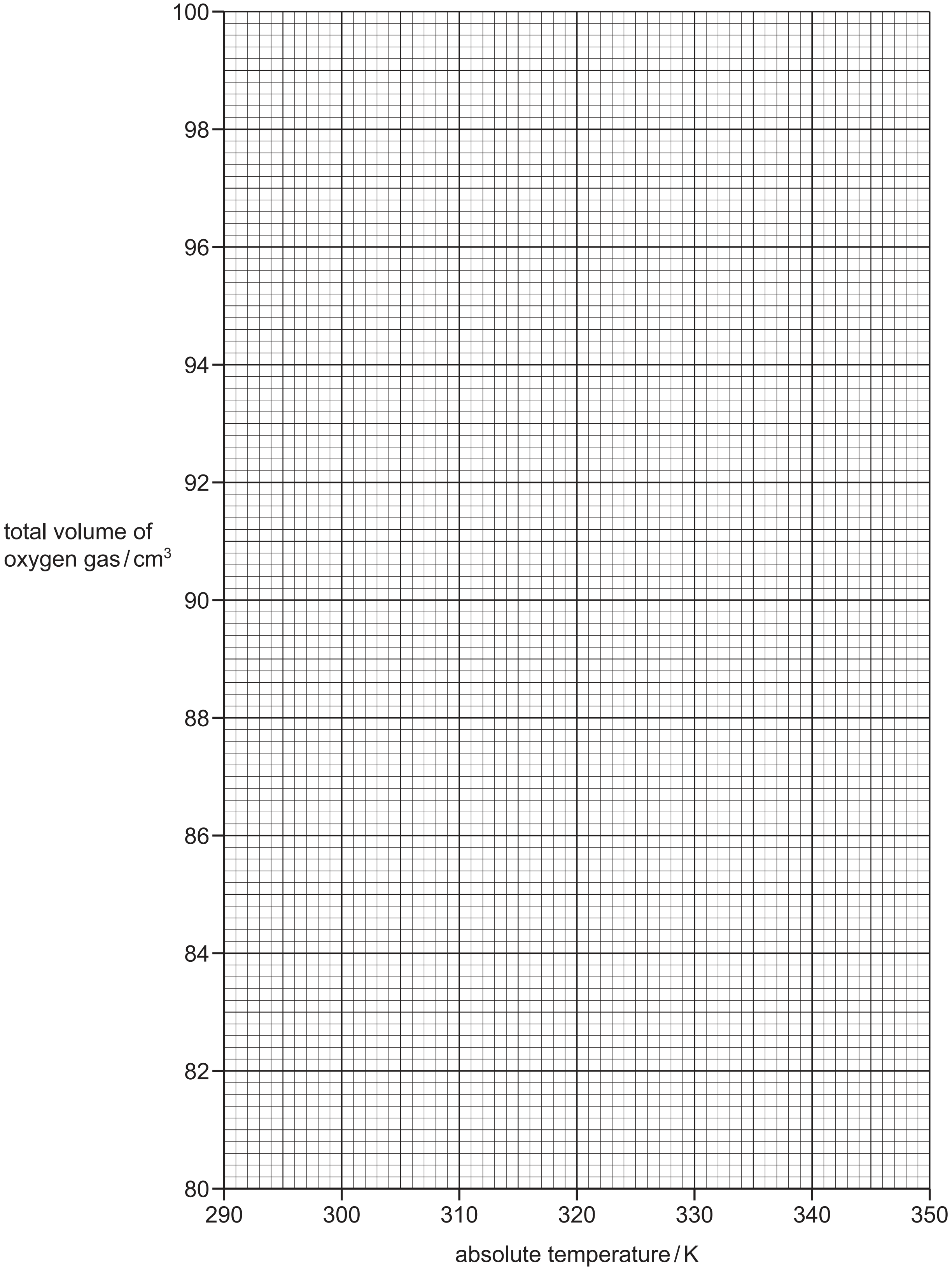
[2]

(ii) Suggest how the student could ensure they collect pure oxygen gas in the conical flask.

....

.... [1]

(c) (i) Plot a graph on the grid to show the relationship between volume of oxygen and absolute temperature. Use a cross (×) to plot each data point. Draw a line of best fit.



[2]

(ii) Determine the gradient of your line of best fit. State the coordinates of both points you used in your calculation. These must be selected from your line of best fit. Give the gradient to three significant figures.

coordinates 1 .... coordinates 2 ....

gradient = ... $cm^3 K^{-1}$

[2]

(d) (i) On the graph, circle the point which you believe to be the most anomalous. [1]

(ii) Suggest a possible explanation for this anomaly.

....

.... [1]

(e) (i) Identify the independent variable.

.... [1]

(ii) Suggest how the experiment could be made to be more reliable.

.... [1]

(f) The ideal gas equation is shown.

$$pV = nRT$$

p = the pressure of the gas in Pa; V = the volume of gas in m^3; n = the number of moles of gas; R = the universal gas constant 8.31 $J mol^{-1} K^{-1}$ and T = absolute temperature in K

Using this equation, describe how the gradient of the graph you have plotted would be affected by using a smaller volume of oxygen at the start of the experiment. Explain your answer.

....

....

....

....

.... [1]

[Total: 13]

3 Potassium bromate(V) reacts with potassium bromide and sulfuric acid to form potassium sulfate, bromine and water according to the following equation.

$$KBrO_3(aq) + 5KBr(aq) + 3H_2SO_4(aq) \rightarrow 3K_2SO_4(aq) + 3Br_2(aq) + 3H_2O(l)$$

A student is investigating how the rate of this reaction is affected by changing the concentration of the reactants in turn. This is done by keeping the total volume of mixture constant and adding different, small volumes of each reagent.

The reaction produces bromine which is orange in colour. The student times the reaction and then determines the rate as $\frac{1}{\text{time}}$.

The rate equation for the reaction is of the form:

$$\text{rate} = k[KBrO_3]^x[KBr]^y[H_2SO_4]^z$$

k is the rate constant for the reaction and *x*, *y* and *z* are the respective orders of the reaction for each reagent.

The student carried out the experiment and obtained the following data.

Table 3.1

mixture	$[KBrO_3]$ / mol dm^{-3}	[KBr] / mol dm^{-3}	$[H_2SO_4]$ / mol dm^{-3}	rate of reaction / s^{-1}
A	0.025	0.125	0.075	0.059
B	0.050	0.125	0.075	0.117
C	0.025	0.250	0.075	0.118
D	0.025	0.125	0.150	0.235
E	0.050	0.250	0.150	0.941

(a) **(i)** Suggest how the student might time the reaction and judge the end point of the reaction for each mixture.

....

....

.... [1]

(ii) By comparing the data for the mixtures deduce the values of *x*, *y* and *z*.

[2]

(b) The student carried out each reaction using a boiling tube (capacity 50 cm^3) and varied the concentration by adding different volumes of each reagent. For example, in mixture A, 5.0 cm^3 of $KBrO_3(aq)$ is required.

Name a suitable piece of apparatus which could be used to measure this volume.

.... [1]

(c) Suggest why the reagents are heated to the same temperature before mixing.

.... [1]

(d) The solution of sulfuric acid used in each mixture was of concentration 0.150 $mol\,dm^{-3}$. This acid was prepared from a solution of concentration 1 $mol\,dm^{-3}$.

Briefly describe how to make the more dilute solution, stating the capacity of any apparatus used.

....

....

....

.... [2]

[Total: 7]

Important values, constants and standards

molar gas constant	R = 8.31 J K^{-1} mol^{-1}
Faraday constant	F = 9.65 × 10^{4} C mol^{-1}
Avogadro constant	L = 6.022 × 10^{23} mol^{-1}
electronic charge	e = –1.60 × 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 × 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 144.4	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 –