



Cambridge International AS & A Level

CANDIDATE
NAME
CENTRE
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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.

2

- 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, $\text{Mg}(\text{NO}_3)_2$, using the following method.

- step 1** Accurately weigh about 1.5g 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.



One student in the class obtains the following results.

mass of solid mixture = 1.52g

mass of AgCl solid after drying = 3.63g

- (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]

3

- (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.



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

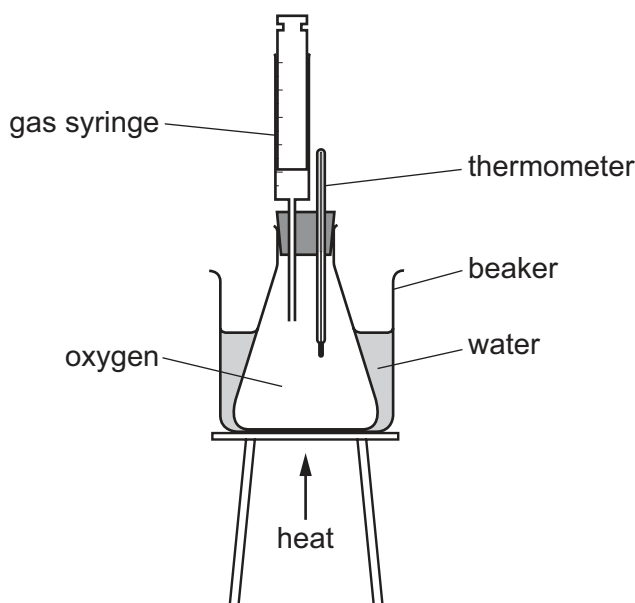


Fig. 2.1

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:

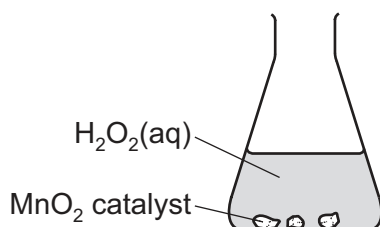
Table 2.1

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.



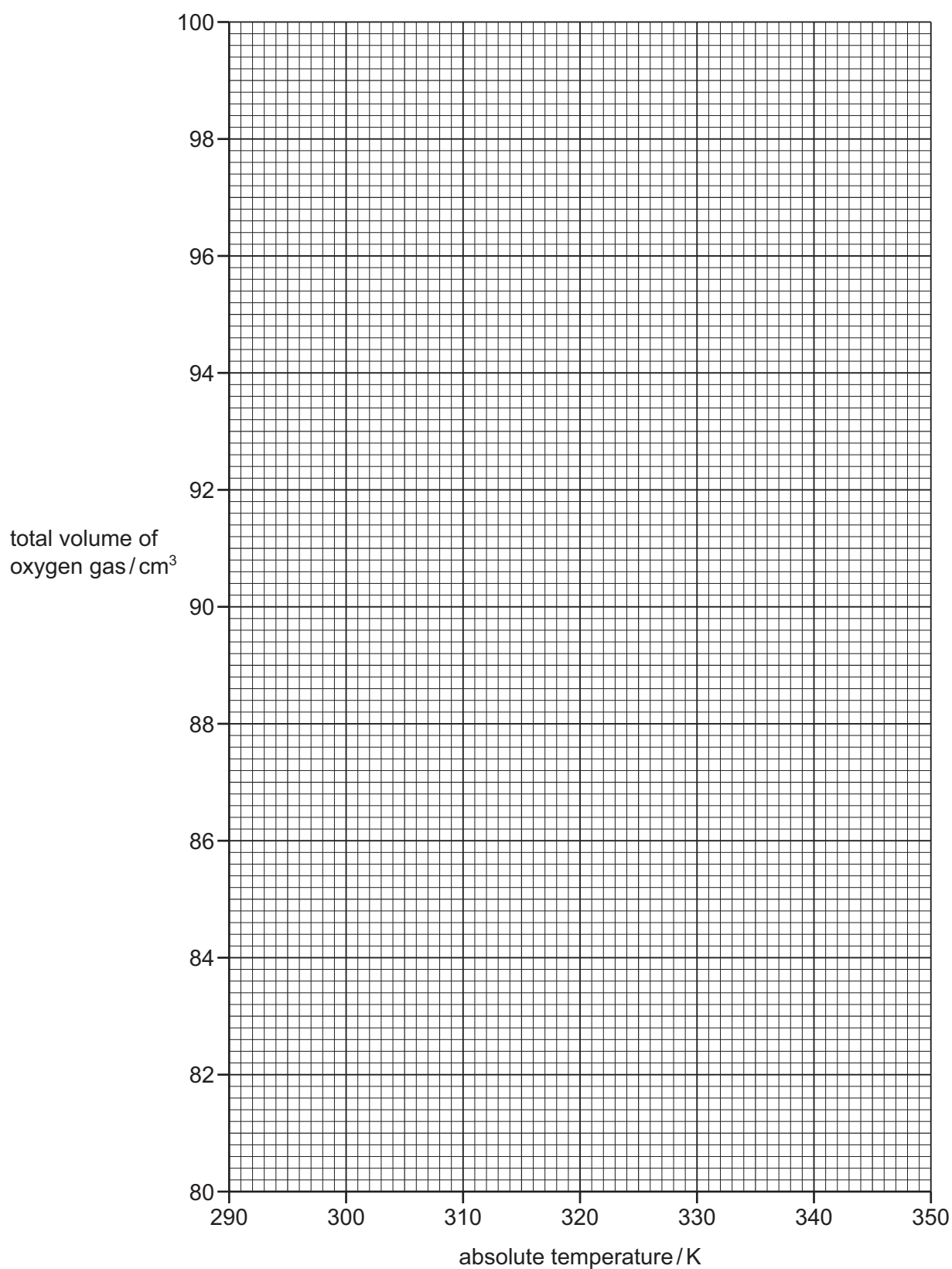
[2]

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

.....
 [1]

7

- (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]

8

- (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 = $\text{cm}^3 \text{K}^{-1}$ [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.

$$pV = nRT$$

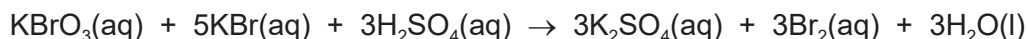
p = the pressure of the gas in Pa; V = the volume of gas in m^3 ; n = the number of moles of gas;
 R = the universal gas constant $8.31 \text{ J mol}^{-1} \text{ K}^{-1}$ and T = absolute temperature in K

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.



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:

$$\text{rate} = k[\text{KBrO}_3]^x[\text{KBr}]^y[\text{H}_2\text{SO}_4]^z$$

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	$[\text{KBrO}_3]$ / mol dm^{-3}	$[\text{KBr}]$ / mol dm^{-3}	$[\text{H}_2\text{SO}_4]$ / 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]

10

- (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 $\text{KBrO}_3(\text{aq})$ 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	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

Group																										
1	2	Key						1Hhydrogen1.0									13	14	15	16	17	18				
3Li lithium 6.9	4Be beryllium 9.0	atomic number atomic symbol name relative atomic mass															5B boron 10.8	6C carbon 12.0	7N nitrogen 14.0	8O oxygen 16.0	9F fluorine 19.0	10Ne neon 20.2				
11Na sodium 23.0	12Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12										13Al aluminium 27.0	14Si silicon 28.1	15P phosphorus 31.0	16S sulfur 32.1	17Cl chlorine 35.5	18Ar argon 39.9
19K potassium 39.1	20Ca calcium 40.1	21Sc scandium 45.0	22Ti titanium 47.9	23V vanadium 50.9	24Cr chromium 52.0	25Mn manganese 54.9	26Fe iron 55.8	27Co cobalt 58.9	28Ni nickel 58.7	29Cu copper 63.5	30Zn zinc 65.4										31Ga gallium 69.7	32Ge germanium 72.6	33As arsenic 74.9	34Se selenium 79.0	35Br bromine 79.9	36Kr krypton 83.8
37Rb rubidium 85.5	38Sr strontium 87.6	39Y yttrium 88.9	40Zr zirconium 91.2	41Nb niobium 92.9	42Mo molybdenum 95.9	43Tc technetium —	44Ru ruthenium 101.1	45Rh rhodium 102.9	46Pd palladium 106.4	47Ag silver 107.9	48Cd cadmium 112.4										49In indium 114.8	50Sn tin 118.7	51Sb antimony 121.8	52Te tellurium 127.6	53I iodine 126.9	54Xe xenon 131.3
55Cs caesium 132.9	56Ba barium 137.3	57–71lanthanoids		73Ta tantalum 180.9	74W tungsten 183.8	75Re rhenium 186.2	76Os osmium 190.2	77Ir iridium 192.2	78Pt platinum 195.1	79Au gold 197.0	80Hg mercury 200.6										81Tl thallium 204.4	82Pb lead 207.2	83Bi bismuth 209.0	84Po polonium —	85At astatine —	86Rn radon —
87Fr francium —	88Ra radium —	89–103actinoids		104Rf rutherfordium —	106Sg seaborgium —	107Bh bohrium —	108Hs hassium —	109Mt meitnerium —	110Ds darmstadtium —	111Rg roentgenium —	112Cn copernicium —										113Nh nihonium —	114Fl flerovium —	115Mc moscovium —	116Lv livermorium —	117Ts tennessine —	118Og oganesson —

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	europtium	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	yterbium	173.1
71	Lu	lutetium	175.0
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	208.9
84	Po	polonium	—
85	At	astatine	—
86	Rn	radon	—
87	Fr	francium	—
88	Ra	radium	—
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	—

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	europtium	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	yterbium	173.1
71	Lu	lutetium	175.0
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	208.9
84	Po	polonium	—
85	At	astatine	—
86	Rn	radon	—
87	Fr	francium	—
88	Ra	radium	—
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	—