Please check the examination details below before entering your candidate information

Candidate surname	Other names
StemUp Model Solution	

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Tuesday 16 May 2023

Morning (Time: 1 hour 30 minutes)

Paper reference **8CH0/01**

Chemistry

Advanced Subsidiary
PAPER 1: Core Inorganic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Atoms of silicon contain protons, neutrons and electrons.

(a) Which are the correct data for a proton and a neutron?

(1)

		Proton		Neutron	
		Relative charge	Relative mass	Relative charge	Relative mass
☒	**A**	+1	1	−1	0.0005
☒	**B**	+1	1	0	1
☒	**C**	−1	0.0005	0	1
☒	**D**	0	1	+1	1

(b) (i) State the shape of the 2s orbital of a silicon atom.

(1)

Spherical (a sphere).

(ii) State the difference between the two subatomic particles in the 2s orbital.

(1)

The two electrons have opposite spins.

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(c) Silicon has three stable isotopes.
A sample of silicon was found to have a relative atomic mass, A_r, of 28.11 due to the presence of only the three stable isotopes.
The abundance for two of the isotopes is given in the table.

Isotope	Abundance / %
^{28}Si	92.2
^{30}Si	3.1

Determine the relative isotopic mass of the third stable isotope.
You **must** show your working.

(2)

abundance of third isotope = 100 − 92.2 − 3.1 = 4.7 %

28.11 = (28 × 92.2 + 30 × 3.1 + m × 4.7) ÷ 100

4.7m = 2811 − 2581.6 − 93 = 136.4

m = 136.4 ÷ 4.7 = 29.02

relative isotopic mass of third isotope = 29.0

(d) Give the symbol, including the mass number and atomic number, for an atom of element **X** that has four fewer protons and three fewer neutrons than an atom of $^{28}_{14}$Si.

(1)

$^{21}_{10}Ne$

(Total for Question 1 = 6 marks)

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2 This question is about the double salt $K_2Mg(SO_4)_2 \cdot 6H_2O$.
A double salt is a salt containing more than one cation or more than one anion.

(a) (i) Give the reason why the term relative formula mass is used, rather than relative molecular mass, when discussing $K_2Mg(SO_4)_2 \cdot 6H_2O$.

(1)

Because $K_2Mg(SO_4)_2.6H_2O$ is ionic: it has a giant ionic lattice structure and is not made up of molecules.

(ii) Give the reason why relative formula mass has no mathematical units.

(1)

Because it is a relative mass: it is the mass compared with 1/12 of the mass of an atom of carbon-12, so the units cancel (g ÷ g).

(iii) What is the relative formula mass of $K_2Mg(SO_4)_2 \cdot 6H_2O$?
Use the Periodic Table as a source of data.

(1)

- ☒ **A** 206.0
- ☒ **B** 322.7
- ☒ **C** 402.7
- ☒ **D** 595.3

(iv) Calculate the amount of substance, in mol, in 25.0 g of $K_2Mg(SO_4)_2 \cdot 6H_2O$.

(1)

amount = mass ÷ M_r = 25.0 ÷ 402.7

amount = 0.0621 mol

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(b) Cations may be identified using a flame test on a solid or by the addition of aqueous sodium hydroxide to an aqueous solution containing the cation.

Describe the expected results of performing these tests on $K_2Mg(SO_4)_2 \cdot 6H_2O$. Include the observation for each cation in each test.

(4)

Flame test: potassium ions (K^+) give a lilac flame, but magnesium ions (Mg^{2+}) give no flame colour.

Adding aqueous sodium hydroxide: magnesium ions (Mg^{2+}) form a white precipitate of magnesium hydroxide, $Mg(OH)_2$:

$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$

Potassium ions (K^+) do not form a precipitate with sodium hydroxide, because KOH is soluble.

(c) The test used to show the presence of the **anion** in $K_2Mg(SO_4)_2 \cdot 6H_2O$ gives a white precipitate as the positive result.

(i) What are the reagents used for this test?

(1)

- ☐ **A** dilute hydrochloric acid and aqueous silver nitrate
- ☐ **B** dilute sulfuric acid and aqueous silver nitrate
- ☒ **C** dilute hydrochloric acid and aqueous barium chloride
- ☐ **D** dilute sulfuric acid and aqueous barium chloride

(ii) Write an ionic equation, including state symbols, for the formation of the white precipitate in the test for the anion in the double salt.

(1)

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

(Total for Question 2 = 10 marks)

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3 This question is about elements in Group 7.

(a) Group 7 elements react with many metals.

(i) What happens to the atoms of a metal and the Group 7 element when they react together?

(1)

		Metal	Group 7 element
☒	**A**	gains electrons to form a positive ion	loses electrons to form a negative ion
☒	**B**	increases in oxidation number	gains electrons to form a negative ion
☒	**C**	loses electrons to form a negative ion	decreases in oxidation number
☒	**D**	loses electrons to form a positive ion	increases in oxidation number

(ii) Which is **not** true when calcium reacts with bromine?

(1)

☒ **A** bromine reacts less vigorously than chlorine

☒ **B** during the reaction bromine oxidises the calcium

☒ **C** the percentage by mass of calcium in the product is 33 %

☒ **D** the product gives a brick-red flame test

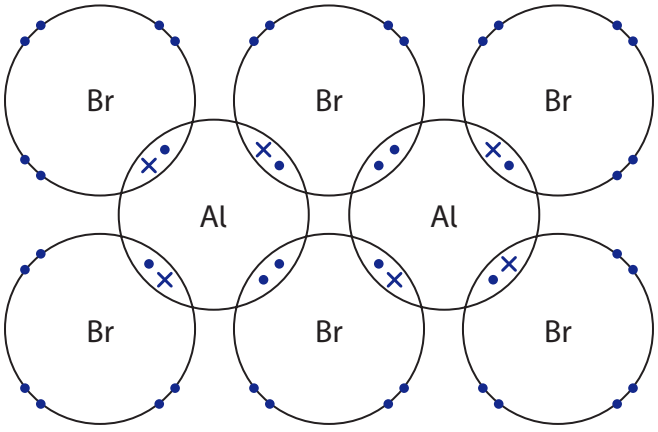
(iii) The equation for the reaction between aluminium and bromine is shown.

$$2Al + 3Br_2 \rightarrow Al_2Br_6$$

The compound is a dimer made up of two covalently bonded monomers joined by dative covalent bonds.

Complete the dot-and-cross diagram, showing outer shell electrons only, of this dimer.
Use • for bromine electrons and × for aluminium electrons.

(2)



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(iv) Platinum metal reacts with fluorine to give a compound of platinum with an oxidation number of +6.

Give the formula of this compound of platinum.

(1)

PtF_6

(v) Chromium reacts with iodine.
The only product contains 12.0 % chromium by mass.

Calculate the empirical formula of the chromium iodide formed.
You **must** show your working.

(2)

% iodine = 100 − 12.0 = 88.0 %

Cr : I = 12.0 ÷ 52.0 : 88.0 ÷ 126.9

Cr : I = 0.2308 : 0.6935 = 1 : 3.005 = 1 : 3

empirical formula = CrI_3

(b) Chlorine, bromine and iodine are three of the Group 7 elements. The bond length and bond enthalpies in molecules of these elements are shown in the table.

Bond	Bond length / nm	Bond enthalpy / kJ mol^{-1}
Cl—Cl	0.199	243.4
Br—Br	0.228	192.9
I—I	0.267	151.2

(i) Explain how the trend in bond length relates to the trend in bond strength on **descending** the group.

(2)

Going down the group the bond length increases and the bond strength decreases, so less energy is needed to break the bond.

This is because the bonding pair of electrons is further from the nuclei and more shielded, so it is less strongly attracted to the nuclei (poorer overlap of orbitals).

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(ii) The relative reactivity of chlorine and iodine can be demonstrated using the reaction between one of these elements and the potassium salt of the other halogen.

Describe an experiment to show how this is deduced and give the expected observation for the reaction that occurs.
Include an ionic equation for this reaction.
State symbols are not required.

(3)

Add chlorine water (a solution of chlorine) to aqueous potassium iodide in a test tube and shake.

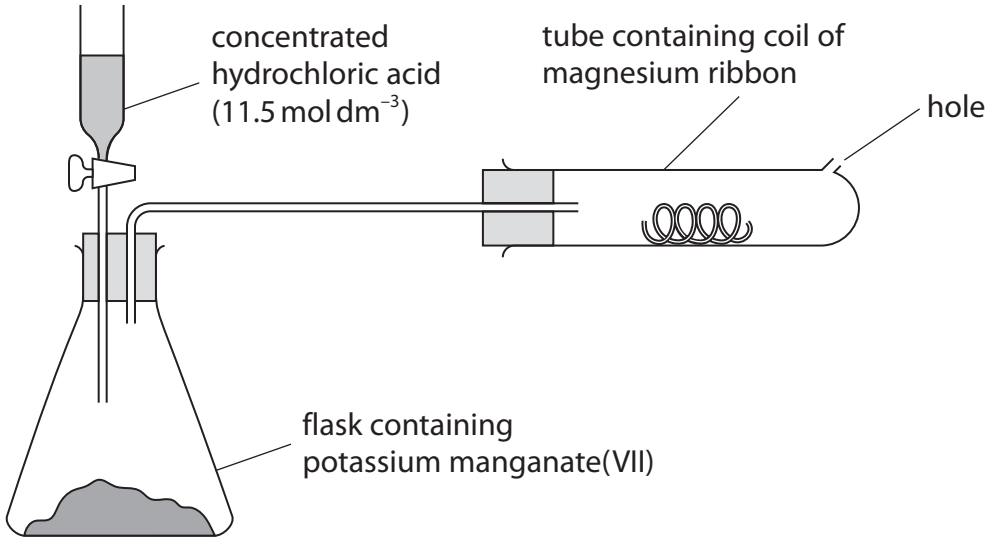
The colourless solution turns brown because iodine is formed. Chlorine has displaced iodine from the iodide, so chlorine is more reactive than iodine.

Ionic equation: $Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$

(Total for Question 3 = 12 marks)

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4 The reaction between magnesium and chlorine can be carried out using the apparatus shown.



The coil of magnesium ribbon is first heated strongly until it just melts.
Chlorine gas is then produced by a chemical reaction in the conical flask.

The chlorine gas is passed over the heated magnesium, resulting in the formation of magnesium chloride.

(a) In order to melt the magnesium, it must be heated strongly.

Explain why the structure of magnesium gives it a high melting temperature.

(2)

Magnesium has a giant metallic lattice structure: a lattice of positive magnesium ions (Mg^{2+}) surrounded by a sea of delocalised electrons.

There is strong electrostatic attraction between the positive metal ions and the delocalised electrons, so a lot of energy is needed to overcome it.

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(b) The equation for the reaction to produce chlorine is shown.

$$2KMnO_4 + 8HCl \rightarrow 3Cl_2 + 2KCl + 2MnO_2 + 4H_2O$$

The concentration of the hydrochloric acid is 11.5 mol dm^{-3}.

The equation for the reaction between the chlorine and the magnesium is shown.

$$Mg + Cl_2 \rightarrow MgCl_2$$

Calculate the minimum volume of concentrated hydrochloric acid, in **cm^3**, required to produce 4.00 g of magnesium chloride, $MgCl_2$.
Give your answer to an appropriate number of significant figures.

(4)

M_r of $MgCl_2$ = 24.3 + (2 × 35.5) = 95.3

moles of $MgCl_2$ = 4.00 ÷ 95.3 = 0.041973 mol

Cl_2 : $MgCl_2$ = 1 : 1, so moles of Cl_2 = 0.041973 mol

HCl : Cl_2 = 8 : 3

moles of HCl = 0.041973 × 8 ÷ 3 = 0.11193 mol

volume = moles ÷ concentration = 0.11193 ÷ 11.5

volume = 0.0097328 dm^3 = 9.7328 cm^3

minimum volume of HCl = 9.7 cm^3 (2 s.f.)

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(c) Bottles of potassium manganate(VII), $KMnO_4$, have three hazard warning labels. One of these is shown.



This hazard symbol means that potassium manganate(VII) is liable to

(1)

- ☒ **A** burn easily in the presence of oxygen
- ☒ **B** explode
- ☒ **C** react dangerously with oxygen
- ☒ **D** react vigorously with reducing agents

(Total for Question 4 = 7 marks)

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5 The question is about electronegativity and its influence on bonding.

(a) State what is meant by the term electronegativity.

(1)

The ability of an atom to attract the bonding (shared) pair of electrons in a covalent bond.

(b) Explain the trend in electronegativity for the Group 7 elements.

(3)

Electronegativity decreases down Group 7 (fluorine is the most electronegative element). Down the group the atomic radius increases, so the bonding pair of electrons is further from the nucleus.

There are also more shells of inner electrons, so there is more shielding of the bonding pair.

So, although the number of protons increases, the bonding pair is less strongly attracted to the nucleus.

(c) Describe what you understand by the term 'continuum of bonding type' in relation to electronegativities.

(2)

Ionic and covalent bonding are the two extremes of a continuum, with polar covalent (intermediate) bonding in between.

The greater the difference in electronegativity between two atoms, the more ionic the bonding; the smaller the difference, the more covalent. Intermediate differences give intermediate bonding.

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(d) The table gives data for chlorine and chlorine compounds of some Period 3 elements. The data show evidence that the type of bonding in compounds is a continuum across Period 3.

	Empirical formula	Melting temperature / °C	Electrical conductivity
Sodium chloride	NaCl	801	Yes, when molten
Magnesium chloride	$MgCl_2$	714	Yes, when molten
Aluminium chloride	$AlCl_3$	180 (sublimes)	No
Silicon tetrachloride	$SiCl_4$	–70	No
Phosphorus(III) chloride	PCl_3	–112	No
Chlorine	Cl_2	–102	No

Discuss the extent to which the data in the table demonstrate a continuum of bonding type.
Include reference to the data of **three** of the substances in the table with different types of bonding.

(3)

Sodium chloride is ionic, so it conducts electricity when molten (mobile ions) and has a high melting temperature (801 °C).

Silicon tetrachloride is simple molecular (covalent), so it has a low melting temperature (–70 °C), as only weak intermolecular forces are overcome, and it does not conduct.

Aluminium chloride has intermediate bonding (ionic with covalent character): it sublimes at 180 °C, lower than the ionic chlorides but higher than the covalent ones, and does not conduct.

So the data show a gradual change from ionic to covalent bonding, which supports a continuum of bonding type.

(Total for Question 5 = 9 marks)

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6 Redox reactions can be understood in terms of electron transfer **or** in terms of changes of oxidation number.

(a) The equation for a redox reaction is shown.

$$8KI + 5H_2SO_4 \rightarrow 4I_2 + 4K_2SO_4 + H_2S + 4H_2O$$

(i) State, in terms of electron transfer, what you understand by the terms oxidation and reduction.

(1)

Oxidation is the loss of electrons and reduction is the gain of electrons.

(ii) Explain, in terms of electron transfer, which of the species is the oxidising agent and which is the reducing agent.

(2)

Iodide ions (I^- in KI) are the reducing agent, because each iodide ion loses one electron to form iodine (oxidation number −1 to 0).

Sulfur in the sulfate ion (in H_2SO_4) is the oxidising agent, because each sulfur atom gains eight electrons when it forms H_2S (+6 to −2).

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(b) Bromine reacts with sodium hydroxide solution in a disproportionation reaction to form BrO_3^-.

Complete the equation for this disproportionation.
Justify the balancing of the equation in terms of the changes in oxidation number.

(4)

3 Br_2 + 6 OH^- → BrO_3^- + 5Br^- + 3H_2O

$3Br_2 + 6OH^- \rightarrow BrO_3^- + 5Br^- + 3H_2O$

Br is oxidised to BrO_3^-: oxidation number increases from 0 to +5 (an increase of 5).

Br is reduced to Br^-: oxidation number decreases from 0 to −1 (a decrease of 1).

The total increase in oxidation number must equal the total decrease, so five Br^- ions must form for each BrO_3^- ion.

This needs 6 Br atoms ($3Br_2$); $6OH^-$ then balances the charge and oxygen, giving $3H_2O$.

(Total for Question 6 = 7 marks)

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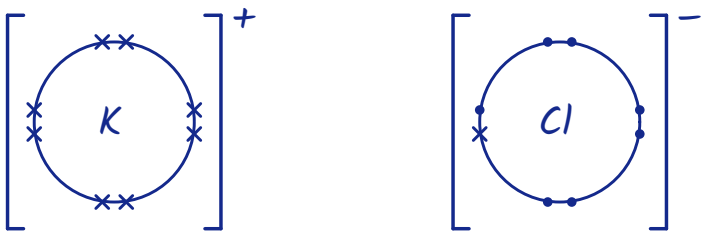
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7 This question is about ions.

(a) Draw a dot-and-cross diagram of the ionic compound potassium chloride.
Show outer shell electrons only.

(1)



(b) Deduce the order of increasing size of the ions:

Br^-, Ca^{2+}, Cl^-, K^+

Justify your answer.

(4)

Ca^{2+}, K^+ and Cl^- are isoelectronic: they all have the same number of electrons (18, arrangement 2,8,8).

From Cl^- (17 protons) to K^+ (19 protons) to Ca^{2+} (20 protons) the number of protons in the nucleus increases, so the electrons are attracted more strongly and pulled closer to the nucleus, so the ion gets smaller.

Br^- has one more shell of electrons than the other ions, so it is the largest.

Order of increasing size: $Ca^{2+} < K^+ < Cl^- < Br^-$

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(c) A saturated aqueous calcium hydroxide solution contains 17.3 g in 10.0 dm^3 of solution.
Under these conditions the calcium hydroxide is fully dissociated into ions.

What is the concentration of the calcium ions in this solution, in mol dm^{-3} ?

(1)

- ☒ **A** 0.0233
- ☐ **B** 0.0303
- ☐ **C** 0.0431
- ☐ **D** 0.0597

(Total for Question 7 = 6 marks)

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8 Reactions between calcium carbonate and acids produce carbon dioxide gas.

$$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$$

This reaction can be used in an experiment to determine the molar volume of carbon dioxide.

Procedure

Step **1** Place 50 cm^3 of 1 mol dm^{-3} nitric acid in a conical flask.

Step **2** Set up the apparatus as shown in the diagram.

Step **3** Place approximately 0.4 g of calcium carbonate in a test tube and weigh the test tube and its contents accurately.

Step **4** Remove the bung from the conical flask.

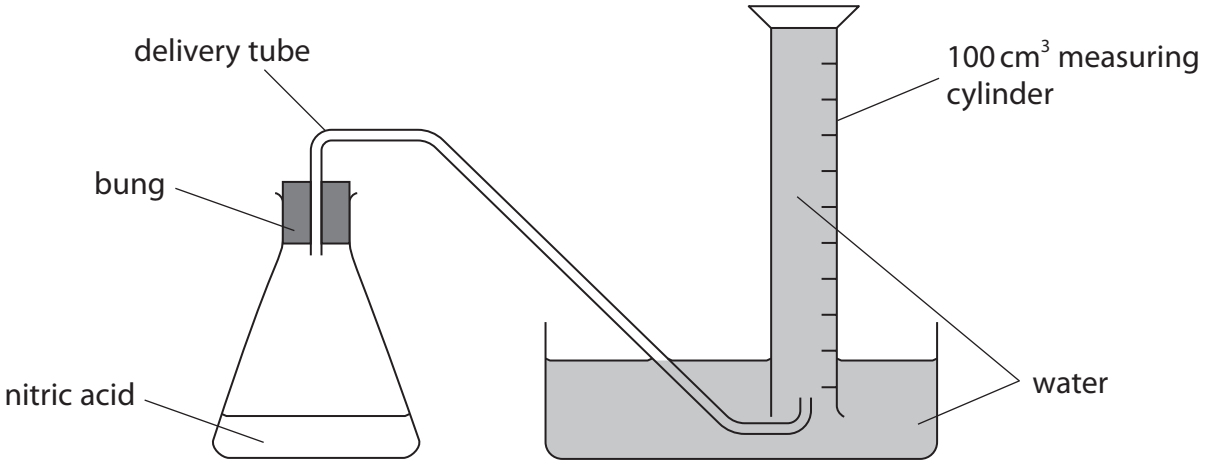
Step **5** Tip the calcium carbonate into the conical flask.

Step **6** Replace the bung in the conical flask.

Step **7** Once all the calcium carbonate has reacted, measure the volume of gas collected in the measuring cylinder.

Step **8** Reweigh the test tube that had contained the calcium carbonate.

Step **9** Repeat the experiment decreasing the mass of calcium carbonate added each time.



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(a) A major source of inaccuracy in this experiment occurs between Steps **5** and **6** when carbon dioxide gas is lost before the bung is replaced.

(i) Identify a change to the acid in Step **1** that would reduce the volume of gas lost between Steps **5** and **6**. Justify your answer.

(2)

Use a lower concentration of nitric acid (or use a weak acid such as ethanoic acid), still in excess.

This decreases the rate of reaction, so carbon dioxide is formed more slowly and less gas is lost before the bung is replaced.

(ii) Identify a change to the procedure in Steps **5** and **6** that would prevent loss of gas.

(2)

Put the calcium carbonate in a small container (e.g. an ignition tube) standing inside the conical flask, so it is kept separate from the acid.

Replace the bung first, then shake (swirl) the flask so the calcium carbonate mixes with the acid and no gas escapes.

(b) A second source of inaccuracy results from the significant solubility in water of carbon dioxide.

Give **two** improvements which together prevent this problem.

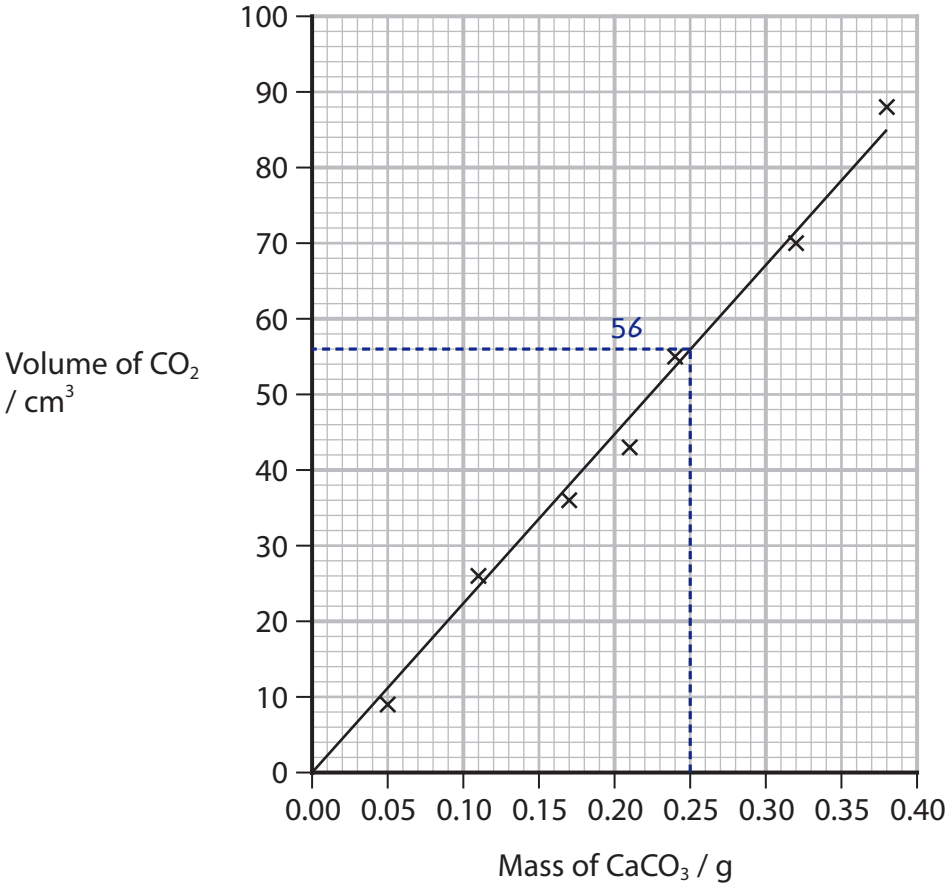
(2)

Collect the gas in a gas syringe instead of over water (or first bubble CO_2 through the water to saturate it).

Saturate the nitric acid with CO_2 before the experiment, by bubbling CO_2 through it (or adding a pinch of $CaCO_3$ first).

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(c) After appropriate improvements, the procedure was carried out and the results were plotted on a graph. A line of best fit was drawn.



(i) Use the graph to find the molar volume of carbon dioxide, in dm^3. You must show your working on the graph.

[Assume molar mass of $CaCO_3$ = 100 g mol^{-1}]

(3)

From the graph, 0.25 g of $CaCO_3$ gives 56 cm^3 of CO_2

moles of $CaCO_3$ = 0.25 ÷ 100 = 0.0025 mol = moles of CO_2

molar volume = 56 ÷ 0.0025 = 22 400 cm^3 mol^{-1}

molar volume = 22.4 dm^3 mol^{-1}

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(ii) The procedure was carried out at a temperature of 22 °C and a pressure of 1.01×10^5 Pa.

Calculate the theoretical molar volume, giving units with your answer.

[The ideal gas equation is $pV = nRT$. Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(3)

pV = nRT, so for n = 1 mol, V = RT ÷ p

T = 22 + 273 = 295 K

V = (1 × 8.31 × 295) ÷ (1.01 × 10^5)

V = 0.0243 m^3 mol^{-1}

theoretical molar volume = 24.3 dm^3 mol^{-1}

(Total for Question 8 = 12 marks)

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9 This question is about ionisation energy.

(a) The first four ionisation energies, in kJ mol^{-1}, of four elements are shown.

Which element is in Group 3?

(1)

- ☒ **A** 738 1451 7753 10 541
- ☒ **B** 578 1817 2745 11 578
- ☒ **C** 789 1577 3232 4356
- ☒ **D** 1012 1903 2912 4957

(b) The second ionisation energy of beryllium is more endothermic than the first ionisation energy.

(i) Write an equation for the second ionisation of beryllium.
Include state symbols.

(2)

$Be^{+}(g) \rightarrow Be^{2+}(g) + e^{-}$

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*(ii) Explain how the nuclear structure and the electronic structure of the Group 2 elements affect ionisation energies.

Include:

- an explanation of the trend of the first ionisation energies down the group
- a comparison of the first two ionisation energies for an element.

(6)

Down Group 2, the first ionisation energy decreases (becomes less endothermic).

This is because the outer electron is removed from a shell that is further from the nucleus, as the atomic radius increases.

There are also more inner shells of electrons, so the outer electron is more shielded (it experiences greater repulsion from the inner electrons).

Although the nuclear charge (number of protons) increases down the group, the greater distance and shielding outweigh this, so the attraction between the nucleus and the outer electron is weaker and less energy is needed to remove it.

For each Group 2 element, the second ionisation energy is greater (more endothermic) than the first.

The second electron is removed from the same shell (the same s subshell) as the first, so the distance from the nucleus and the shielding are about the same.

However, the second electron is removed from a positive ion: the same number of protons now attracts one fewer electron, so there is less repulsion between the electrons. The electron is held more strongly, so more energy is needed to remove it.

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(iii) The value of the sum of the first and second ionisation energies changes on descending Group 2.

Explain how this changing value might contribute to the relative reactivity of the elements with chlorine.

(2)

The sum of the first and second ionisation energies decreases down Group 2, so less energy is needed to remove the two outer electrons.

Group 2 elements react with chlorine by losing their two outer electrons to form M^{2+} ions (ionic bonding), so the reactivity with chlorine increases down the group.

(Total for Question 9 = 11 marks)

TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)						(8)					(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)		(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Key: relative atomic mass / **atomic symbol** / name / atomic (proton) number

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series

* Actinide series

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

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