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 14 May 2024

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

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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P 7 6 8 9 3 A 0 1 2 4

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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 What is the electronic configuration of the phosphide ion, $^{31}_{15}P^{3-}$?

☐ **A** $1s^2 2s^2 2p^6 3s^2 3p^3$

☒ **B** $1s^2 2s^2 2p^6 3s^2 3p^6$

☐ **C** $1s^2 2s^2 2p^6 3s^2$

☐ **D** $1s^2 2s^2 2p^6 3p^6$

(Total for Question 1 = 1 mark)

2 Which could be the first four successive ionisation energies, in kJ mol^{-1}, of a Group 4 element?

☐ **A** 496 4563 6913 9544

☐ **B** 900 1757 14 849 21 007

☐ **C** 801 2427 3610 25 026

☒ **D** 1086 2353 4621 6223

(Total for Question 2 = 1 mark)

3 Which pair of responses show the trend in atomic radii of atoms, excluding the noble gases (Group 0)?

	Trend across Period 2	Trend down Group 2
☐ **A**	increasing	increasing
☐ **B**	increasing	decreasing
☐ **C**	decreasing	decreasing
☒ **D**	decreasing	increasing

(Total for Question 3 = 1 mark)

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4 A student was provided with three aqueous solutions of potassium chloride, potassium bromide and potassium iodide.

To identify the halide present, dilute nitric acid and silver nitrate solution were added to each of the three solutions.

(a) (i) Give the observations that the student would make in each case.

(3)

KCl *white precipitate*

KBr *cream (off-white) precipitate*

KI *yellow precipitate*

(ii) Describe how the student could confirm the halide ions present in the products of (a)(i) by adding ammonia **solutions**.

(3)

Add dilute aqueous ammonia to each precipitate, then concentrated ammonia to any precipitate that remains.

The white precipitate (AgCl) dissolves in dilute ammonia (and in concentrated ammonia), confirming chloride ions.

The cream precipitate (AgBr) does not dissolve in dilute ammonia, but it does dissolve in concentrated ammonia, confirming bromide ions.

The yellow precipitate (AgI) does not dissolve in dilute or in concentrated ammonia, confirming iodide ions.

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(b) Nitric acid removes other ions that would interfere with the halide test, for example carbonate ions.

(i) State the observation when silver nitrate is added to a solution of carbonate ions in the **absence** of nitric acid.

(1)

A white precipitate forms (silver carbonate).

(ii) State the observation when nitric acid is added to a solution of carbonate ions.

(1)

Bubbles (effervescence) of carbon dioxide gas.

(iii) Write the ionic equation for the reaction of nitric acid with carbonate ions. Include state symbols.

(2)

$2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$

(Total for Question 4 = 10 marks)

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5 This question is about chlorine dioxide, ClO_2, and the chlorate(III) ion, ClO_2^-.

Chlorine dioxide can be used to sterilise drinking water.
Chlorine dioxide is a gas at room temperature and pressure (r.t.p.).

Chlorine dioxide can be prepared by reacting sodium chlorate(III) with hydrochloric acid.

The equation for this reaction is shown.

$$5NaClO_2 + 4HCl \rightarrow 5NaCl + 4ClO_2 + 2H_2O$$

(a) Chlorine dioxide is very toxic by inhalation and skin absorption.

State **two** precautions that must be taken when preparing chlorine dioxide in a laboratory.

You may assume that a lab coat and eye protection are worn.

(2)

Prepare it in a fume cupboard (toxic gas).

Wear gloves (absorbed through the skin).

(b) Calculate the mass of sodium chlorate(III) needed to make 5.40 g of chlorine dioxide.

[A_r values: H = 1.00 O = 16.0 Na = 23.0 Cl = 35.5]

(4)

$M_r(ClO_2) = 35.5 + (2 \times 16.0) = 67.5 \text{ g mol}^{-1}$

$n(ClO_2) = 5.40 \div 67.5 = 0.0800 \text{ mol}$

$n(NaClO_2) = 0.0800 \times 5 \div 4 = 0.100 \text{ mol}$

$M_r(NaClO_2) = 23.0 + 35.5 + (2 \times 16.0) = 90.5 \text{ g mol}^{-1}$

$\text{mass of } NaClO_2 = 0.100 \times 90.5 = 9.05 \text{ g}$

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(c) (i) Chlorine dioxide decomposes to form chlorine and oxygen.

The equation for this decomposition is shown.

$$2ClO_2(g) \rightarrow Cl_2(g) + 2O_2(g)$$

Calculate the **increase** in volume, in **cm^3**, when 0.125 mol of chlorine dioxide gas completely decomposes.

[Molar gas volume = 24.0 $dm^3\,mol^{-1}$]

(2)

2 mol of gas form 3 mol of gas, so the moles of gas

increase by 0.5 mol for every 1 mol of ClO_2

increase in moles = 0.125 × 0.5 = 0.0625 mol

increase in volume = 0.0625 × 24 000 = 1500 cm^3

(ii) A swimming pool contains 400 m^3 water. Chlorine dioxide has been suggested as a disinfectant for use in swimming pools.

Calculate the mass of **chlorine dioxide** needed to produce a concentration of chlorine of 7.82×10^{-8} mol dm^{-3} in this pool.
Give your answer to an appropriate number of significant figures.

(3)

volume of water = 400 m^3 = 400 000 dm^3

$n(Cl_2) = 7.82 \times 10^{-8} \times 400\,000 = 0.03128$ mol

$n(ClO_2) = 2 \times 0.03128 = 0.06256$ mol

mass of $ClO_2 = 0.06256 \times 67.5 = 4.2228$ g

mass of ClO_2 = 4.22 g (3 s.f.)

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(d) The **strongest** of the attractions between molecules in liquid chlorine dioxide is

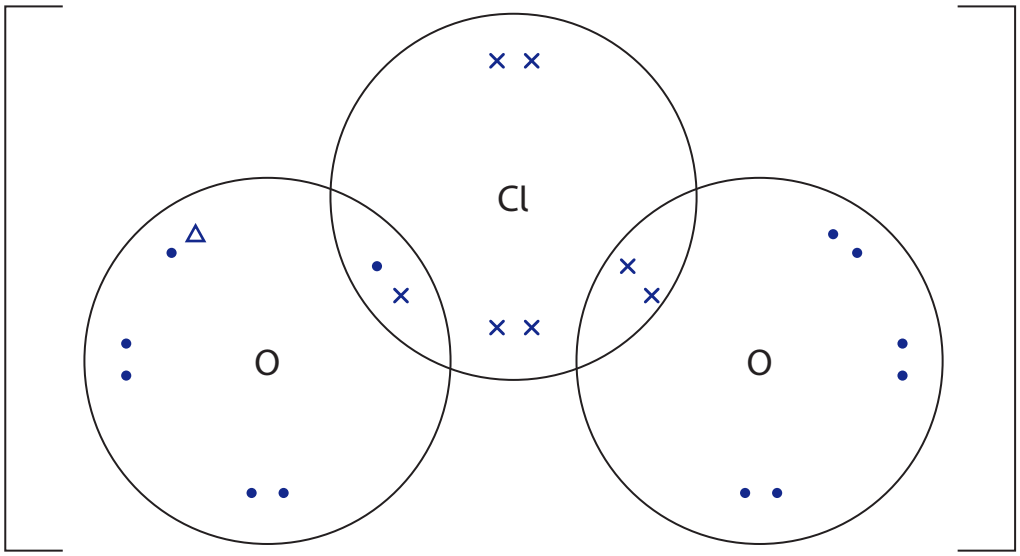
(1)

- ☒ **A** covalent bonding
- ☒ **B** hydrogen bonding
- ☒ **C** ionic bonding
- ☒ **D** permanent dipoles

(e) (i) Complete a dot-and-cross diagram for the chlorate(III) ion, ClO_2^-.

Use crosses (×) for chlorine electrons, dots (•) for oxygen electrons and a triangle (Δ) for the extra electron.

(2)



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(ii) Predict the bond angle in this ion. Justify your answer.

(3)

Bond angle = 104.5°

There are four pairs of electrons around the chlorine atom (two bonding pairs and two lone pairs), which repel each other as far apart as possible to minimise repulsion, giving a tetrahedral arrangement (109.5°).

However, lone pairs repel more strongly than bonding pairs, so the bond angle is reduced from 109.5° to 104.5°.

(f) What is the oxidation number of **oxygen** in the chlorate(III) ion, ClO_2^-?

(1)

- ☐ **A** −1
- ☐ **B** +1
- ☒ **C** −2
- ☐ **D** +2

(Total for Question 5 = 18 marks)

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6 This question is about mass spectrometry and relative atomic mass.

(a) Compound **A** contains carbon, hydrogen and oxygen only. Analysis shows that the percentage composition, by mass, of **A** is 26.7 % carbon, 2.2 % hydrogen and the remainder is oxygen.

Molar mass of **A** = 90 g mol^{-1}

(i) Calculate the empirical formula of compound **A**.

(3)

% O = 100 − 26.7 − 2.2 = 71.1%

C : H : O

26.7 ÷ 12.0 : 2.2 ÷ 1.0 : 71.1 ÷ 16.0

= 2.225 : 2.2 : 4.444

÷ 2.2: 1.01 : 1 : 2.02

= 1 : 1 : 2

Empirical formula = CHO_2 (CO_2H)

(ii) Calculate the **molecular** formula of compound **A**.

(1)

empirical formula mass of CHO_2 = 12 + 1 + 32 = 45

90 ÷ 45 = 2

Molecular formula = $C_2H_2O_4$

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(b) A mass spectrometer was used to obtain the mass number and relative abundance of each isotope of an unknown element, **B**.

Mass number of isotope	Relative isotopic abundance / %
50	4.31
52	83.76
53	9.55
54	2.38

Calculate the relative atomic mass of **B**, using data from the table.
Give your answer to **two** decimal places.

(2)

$A_r = [(50 \times 4.31) + (52 \times 83.76) + (53 \times 9.55) + (54 \times 2.38)] \div 100$

$A_r = (215.5 + 4355.52 + 506.15 + 128.52) \div 100$

$A_r = 5205.69 \div 100 = 52.0569$

$A_r = 52.06$

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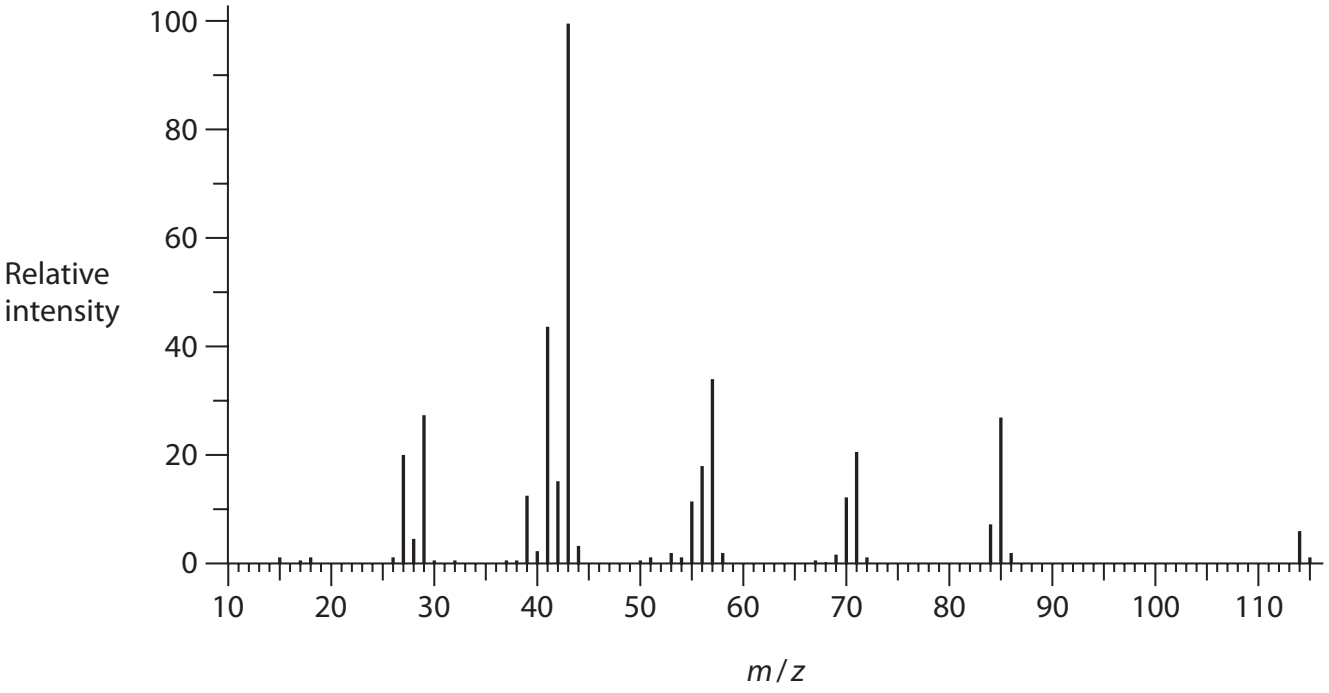
(c) Cations are formed in a mass spectrometer.

Which species is a cation?

(1)

		Number of protons	Number of neutrons	Number of electrons
☒	**A**	3	4	3
☒	**B**	6	6	6
☒	**C**	12	12	10
☒	**D**	35	44	36

(d) The mass spectrum of another compound, **D**, is shown.



Use the spectrum to determine the relative molecular mass of compound **D**.

(1)

114

(Total for Question 6 = 8 marks)

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7 This question is about comparing the chemical and physical properties of Group 1 and Group 2 compounds.

*(a) Potassium chloride and potassium bromide are white crystalline solids which react with concentrated sulfuric acid.

Give the observations in these reactions and an explanation, using oxidation numbers, of which is the stronger reducing agent.
Include equations for any reactions that occur.

(6)

With potassium chloride, misty (steamy) fumes of hydrogen chloride are seen:

$KCl + H_2SO_4 \rightarrow KHSO_4 + HCl$

With potassium bromide, misty fumes of hydrogen bromide are seen at first, and also brown (orange-brown) fumes of bromine, because the HBr formed is oxidised by the concentrated sulfuric acid:

$KBr + H_2SO_4 \rightarrow KHSO_4 + HBr$

$2HBr + H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_2O$

In the reaction with potassium chloride there is no change in the oxidation numbers: chlorine stays at -1 and sulfur stays at +6 in H_2SO_4 and in $KHSO_4$. This is an acid-base reaction, not a redox reaction, so chloride ions do not reduce the sulfuric acid.

With potassium bromide the oxidation number of bromine increases from -1 in HBr to 0 in Br_2, so bromide is oxidised. The oxidation number of sulfur decreases from +6 in H_2SO_4 to +4 in SO_2, so the sulfur is reduced.

Therefore bromide ions are able to reduce sulfuric acid but chloride ions are not, so potassium bromide (Br^-) is the stronger reducing agent.

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(b) A student was asked to confirm the cation present in a sample of white powder that was known to be a Group 1 compound. The student carried out a flame test using the procedure shown.

Procedure

Step **1** A platinum wire was first cleaned by dipping it into concentrated hydrochloric acid and then heating in a colourless Bunsen flame.

Step **2** After cleaning, the cleaned wire was dipped into a fresh, clean sample of concentrated hydrochloric acid and then into the white powder to pick up a sample for testing.

Step **3** The sample was tested by placing the wire in the colourless Bunsen flame.

Result

The flame was coloured lilac.

(i) State a reason why, in Step **2**, the acid used was hydrochloric acid.

(1)

Metal chlorides are more volatile (more easily vaporised) than other compounds, so the cation gives a clear flame colour.

(ii) Identify the cation present in this sample of white powder.

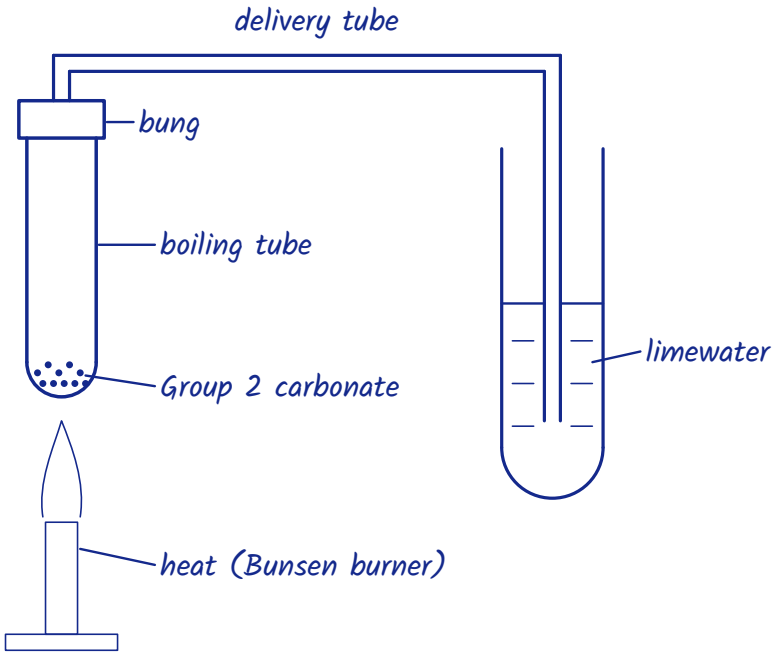
(1)

potassium ion, K^+

(c) The thermal stability of compounds in Group 2 is investigated.

(i) Draw a labelled diagram of apparatus that would enable you to compare the thermal stability of Group 2 carbonates.

(2)



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(ii) State the conditions that must be used with the apparatus shown in your diagram to ensure that the test is fair.

(2)

Use the same Bunsen flame setting (same Bunsen temperature) for each carbonate.

Keep the same distance between the flame and the tube, and use the same number of moles (amount) of each carbonate.

(iii) State what data could be obtained in this experiment to compare thermal stability.

(1)

Measure the time taken for the limewater to turn milky (cloudy).

(iv) Which pair of responses show the trend in thermal stability of compounds **down** Group 2?

(1)

		Carbonates	Nitrates
☒	**A**	increasing	decreasing
☒	**B**	decreasing	decreasing
☒	**C**	increasing	increasing
☒	**D**	decreasing	increasing

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(d) The table shows the electrical conductivity of some pure substances in the solid and liquid states.

	Electrical conductivity	
Substance	Solid state	Liquid state
potassium chloride	poor	good
iron	good	good
water	poor	poor

Explain the electrical conductivity of potassium chloride, iron and water in the solid and liquid states.

(4)

Solid potassium chloride is a poor conductor because it is an ionic lattice and the ions are in fixed positions, so they cannot move to carry charge.

Liquid (molten) potassium chloride conducts well because the ions are free to move and carry the charge.

Iron is a good conductor when solid and when liquid because it has metallic bonding with delocalised electrons, which are free to move and carry the charge.

Water is a poor conductor in both states because it is simple molecular: there are no delocalised electrons and (almost) no ions that are free to move, so there are no charge carriers.

(Total for Question 7 = 18 marks)

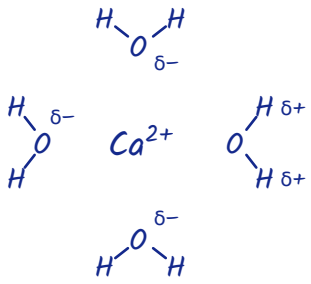
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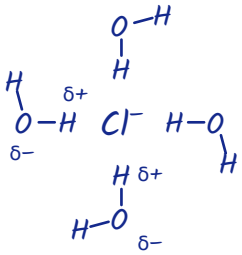
8 This question is about the physical properties of some substances.

(a) Water is able to dissolve many compounds.

(i) Explain, using suitable labelled diagrams, why water is a good solvent for calcium chloride.

(4)





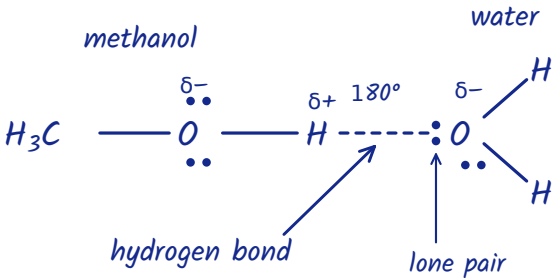
water molecules (polar: Oδ−, Hδ+) surround each ion

Water is polar. The δ− oxygen atoms of water molecules are attracted to the Ca^{2+} ions and the δ+ hydrogen atoms are attracted to the Cl^- ions, so the ions are surrounded (hydrated) by water molecules.

The energy released when these new ion to water interactions form is about the same as (compensates for) the energy needed to break the ionic lattice and the hydrogen bonds between water molecules.

(ii) Explain why methanol dissolves in water.
Include a suitable labelled diagram.

(3)



Methanol has a polar O–H group (δ− O and δ+ H), so it can form hydrogen bonds with water molecules: the δ+ H of one molecule is attracted to a lone pair on the δ− O of the other.

The energy released forming these hydrogen bonds compensates for breaking the hydrogen bonds in water and in methanol.

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(b) The boiling temperature of a compound is dependent on the intermolecular forces present and the shape of the molecule.

(i) Data about two isomeric alkanes are shown.

Compound	Formula	Boiling temperature / K
2,2-dimethylpropane	$C(CH_3)_4$	283
pentane	$CH_3(CH_2)_3CH_3$	309

Explain why pentane has a higher boiling temperature than 2,2-dimethylpropane.

(3)

2,2-dimethylpropane is branched (it has two methyl branches), so its molecules are more spherical, while pentane is an unbranched chain.

So the surface area of contact between 2,2-dimethylpropane molecules is much smaller than between pentane molecules.

Therefore the London forces (instantaneous dipole to induced dipole forces) between 2,2-dimethylpropane molecules are weaker, so less energy is needed to overcome them and its boiling temperature is lower.

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(ii) Data about two silicon compounds are shown.

Name of compound	Formula	Boiling temperature / K
silicon(IV) oxide	SiO_2	2503
silicon tetrachloride	$SiCl_4$	331

Explain why these two covalently bonded substances have very different boiling temperatures.

(4)

Silicon(IV) oxide has a giant covalent (macromolecular) lattice of atoms.

Silicon tetrachloride is a simple molecular substance.

To boil SiO_2, many strong covalent bonds must be broken, which requires a large amount of energy, so its boiling temperature is very high.

To boil $SiCl_4$, only the weak London forces between the molecules have to be overcome, which requires much less energy, so its boiling temperature is low.

(Total for Question 8 = 14 marks)

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9 This question is about some redox reactions.

(a) Iodine is reduced by thiosulfate ions. The relevant half-equations are shown.

$$\tfrac{1}{2}I_2 + e^- \rightarrow I^-$$

$$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^-$$

Deduce an overall equation for this reaction.
State symbols are not required.

(1)

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

(b) In a different redox reaction, the chlorate(I) ion, ClO^-, can react with the chloride ion as shown in this equation.

$$ClO^- + Cl^- + 2H^+ \rightarrow Cl_2 + H_2O$$

(i) State a reason why this is **not** a disproportionation reaction.

(1)

A single species is not both oxidised and reduced: chlorine in two different species (ClO^- and Cl^-) forms the same product, Cl_2.

(ii) Identify the reducing agent in this reaction.

(1)

chloride ion, Cl^-

(iii) Which is the half-equation for the chlorate(I) ion, ClO^-, in this reaction?

(1)

☒ **A** $ClO^- + Cl^- \rightarrow Cl_2 + \tfrac{1}{2}O_2 + 2e^-$

☒ **B** $ClO^- + H^+ + e^- \rightarrow \tfrac{1}{2}Cl_2 + OH^-$

☒ **C** $ClO^- + 2H^+ + e^- \rightarrow \tfrac{1}{2}Cl_2 + H_2O$

☒ **D** $ClO^- \rightarrow \tfrac{1}{2}Cl_2 + \tfrac{1}{2}O_2 + e^-$

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(c) A 5.00 g sample of solid potassium chlorate(V) was heated until fully decomposed.

The equation for this reaction is shown.

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

Calculate the volume, **in cm^3**, of oxygen produced at a temperature of 30 °C and pressure of 110 000 Pa.

[The ideal gas equation is $pV = nRT$
Molar mass of $KClO_3$ = 122.6 g mol^{-1}
Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(5)

$n(KClO_3) = 5.00 \div 122.6 = 0.040783$ mol

$n(O_2) = 0.040783 \times 3 \div 2 = 0.061175$ mol

$T = 30 + 273 = 303$ K

$V = nRT \div p$

$V = (0.061175 \times 8.31 \times 303) \div 110\,000$

$V = 1.4003 \times 10^{-3}$ m^3

$V = 1.4003 \times 10^{-3} \times 10^6 = 1400$ cm^3

(Total for Question 9 = 9 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)											(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)	(8)	(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

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

* Lanthanide series

* Actinide series

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