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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Atomic Structure and the Periodic Table (1)

A Level Chemistry Topic 1

29 questions · 247 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

29 questions · 247 marks · grouped by sub-topic



SUB-TOPIC 1(a)

ATOMIC STRUCTURE AND ISOTOPES

9 questions in this sub-topic · 51 marks · lowest tariff first



1 Relative isotopic mass is an important concept in chemistry.

(a) Define relative isotopic mass.

(2)

(b) A sample of hydrogen gas is formed from atoms of three isotopes, ^1H , ^2H and ^3H .

Deduce the number of peaks due to molecular ions, H_2^+ , in the mass spectrum of this sample.

(1)

(Total for Question 1 = 3 marks)



1 This question is about atoms, molecules and ions.

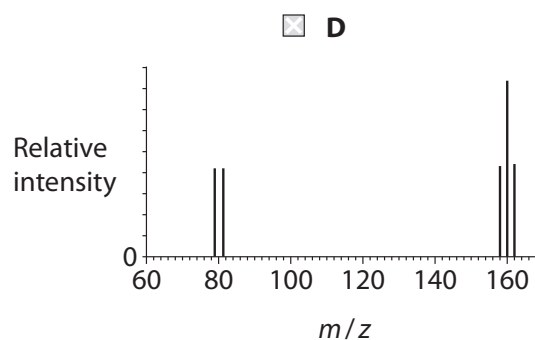
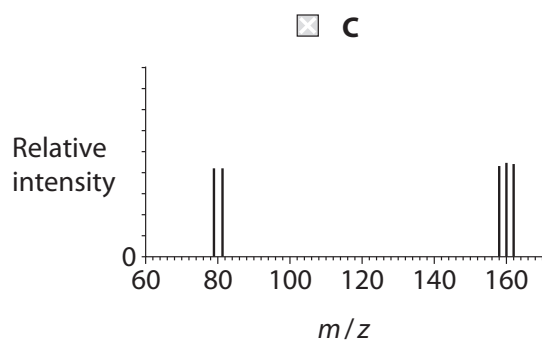
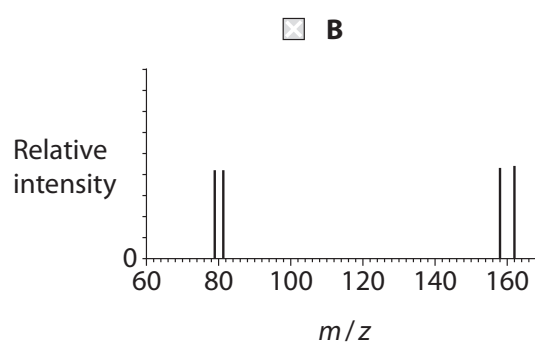
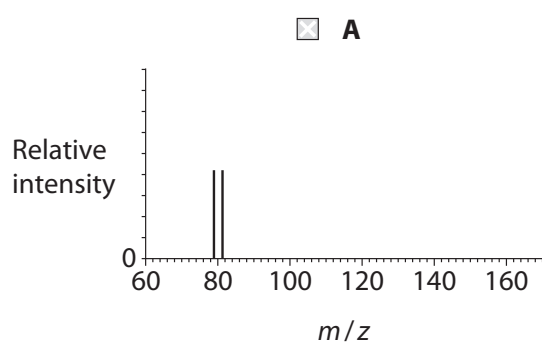
(a) The numbers of subatomic particles in an ^{18}O atom are

(1)

- ☐ A 8 protons, 10 neutrons and 8 electrons
- ☐ B 9 protons, 9 neutrons and 9 electrons
- ☐ C 10 protons, 8 neutrons and 10 electrons
- ☐ D 18 protons, 18 neutrons and 18 electrons

(b) The mass spectrum of a sample of bromine **molecules** with approximately equal proportions of the ^{79}Br and ^{81}Br isotopes is

(1)



(c) The total number of electrons in **all** the occupied **p** orbitals in a chloride ion, Cl^- , is (1)

- ☐ A 5
- ☐ B 6
- ☐ C 12
- ☐ D 18

(d) Which of these isoelectronic ions has the largest ionic radius? (1)

- ☐ A N^{3-}
- ☐ B O^{2-}
- ☐ C Na^+
- ☐ D Al^{3+}

(Total for Question 1 = 4 marks)



1 This is a question about atoms, isotopes and ions.

(a) Which of the following pairs of ions is isoelectronic?

(1)

- ☐ A N^{3-} and Cl^-
- ☐ B O^{2-} and S^{2-}
- ☐ C Na^+ and K^+
- ☐ D Na^+ and Mg^{2+}

(b) Which is a correct definition of relative isotopic mass?

(1)

- ☐ A the weighted mean mass of an atom of an element relative to one twelfth of the mass of an atom of the isotope carbon-12
- ☐ B the mass of one atom of an isotope relative to one twelfth of the mass of an atom of the isotope carbon-12
- ☐ C the weighted mean mass of an atom of an element relative to 12 g of the isotope carbon-12
- ☐ D the mass of one atom of an isotope relative to the mass of 12 g of the isotope carbon-12



- (c) The percentage composition of the two bromine isotopes in a sample is given in the table.

Isotope	Relative isotopic mass	Percentage abundance
bromine-79	78.918	50.52
bromine-81	80.916	49.48

Calculate the relative atomic mass of bromine in this sample.
Give your answer to two decimal places.

(2)

(Total for Question 1 = 4 marks)



1 Relative atomic mass is an important concept in chemistry.

(a) Define the term relative atomic mass.

(2)

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(b) A sample of neon consisted of three isotopes.

Isotope	Percentage abundance
^{20}Ne	84.80
^{21}Ne	2.26
^{22}Ne	12.94

Calculate the relative atomic mass of neon in this sample.
Give your answer to three significant figures.

(2)

(Total for Question 1 = 4 marks)



1 This question is about atomic structure.

(a) Complete the table.

(3)

Species	Number of protons	Number of neutrons	Number of electrons
^{32}S			
^{33}S			
$^{34}\text{S}^{2-}$			

(b) A sample of sulfur was found to contain only four isotopes.

(i) Complete the table to show the percentage abundance of ^{34}S .

(1)

Isotope	^{32}S	^{33}S	^{34}S	^{36}S
Percentage abundance	95.02	0.75		0.02

(ii) Calculate the relative atomic mass (A_r) of the sulfur in this sample using the data in the table. Give your answer to **two** decimal places.

(2)

(Total for Question 1 = 6 marks)



1 The table shows data for the three stable isotopes of argon.

Isotope	Relative isotopic mass	Percentage abundance
^{36}Ar	35.97	0.337
^{38}Ar	37.96	0.063
^{40}Ar	39.96	99.600

(a) State what is meant by the term 'relative isotopic mass'.

(2)

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(b) State what is meant by the term 'isotope'.

Illustrate your answer by referring to the numbers of sub-atomic particles in these isotopes of argon.

(2)

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- (c) Calculate the relative atomic mass of argon.
Give your answer to **two** decimal places.

(2)

(Total for Question 1 = 6 marks)



1 This question is about atomic structure and the Periodic Table.

(a) Complete the table to show the relative charges and masses for a neutron and an electron.

(2)

Particle	Relative charge	Relative mass
proton	+1	1
neutron		
electron		

(b) Atomic emission spectroscopy provides evidence for the existence of

(1)

- ☒ **A** atoms
- ☒ **B** electrons
- ☒ **C** isotopes
- ☒ **D** quantum shells

(c) Draw the shape of a p orbital.

(1)



(d) The melting temperatures of two elements in Period 3 are given in the table.

Element	silicon	chlorine
Melting temperature / K	1683	172

Explain, in terms of the structure and bonding of each element, the difference between these values.

(3)

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(Total for Question 1 = 7 marks)



2 This question is about atoms, molecules and ions.

(a) Lithium exists as two isotopes.

Complete the table to show the numbers of subatomic particles in a ${}^6\text{Li}$ **atom** and a ${}^7\text{Li}^+$ **ion**.

(2)

Particle	Protons	Neutrons	Electrons
${}^6\text{Li}$			
${}^7\text{Li}^+$			

(b) The mass spectrum of a diatomic molecule, X_2 , has peaks at the following m/z values for the X_2^+ ion:

32, 33, 34, 35, 36

Deduce the formulae of all the species responsible for **each** of the peaks in the mass spectrum of X_2 , identifying element X and showing clearly the isotopes present.

(3)

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(c) Complete the table to show the maximum number of electrons which can fill each region of an atom.

(3)

Region	Maximum number of electrons
the 1s orbital	
the 2p subshell	
the third quantum shell	

(Total for Question 2 = 8 marks)



1 This question is about chlorine.

(a) Chlorine has two isotopes with mass numbers 35 and 37.

(i) Complete the table to show the numbers of subatomic particles in a ^{35}Cl atom and a $^{37}\text{Cl}^-$ ion.

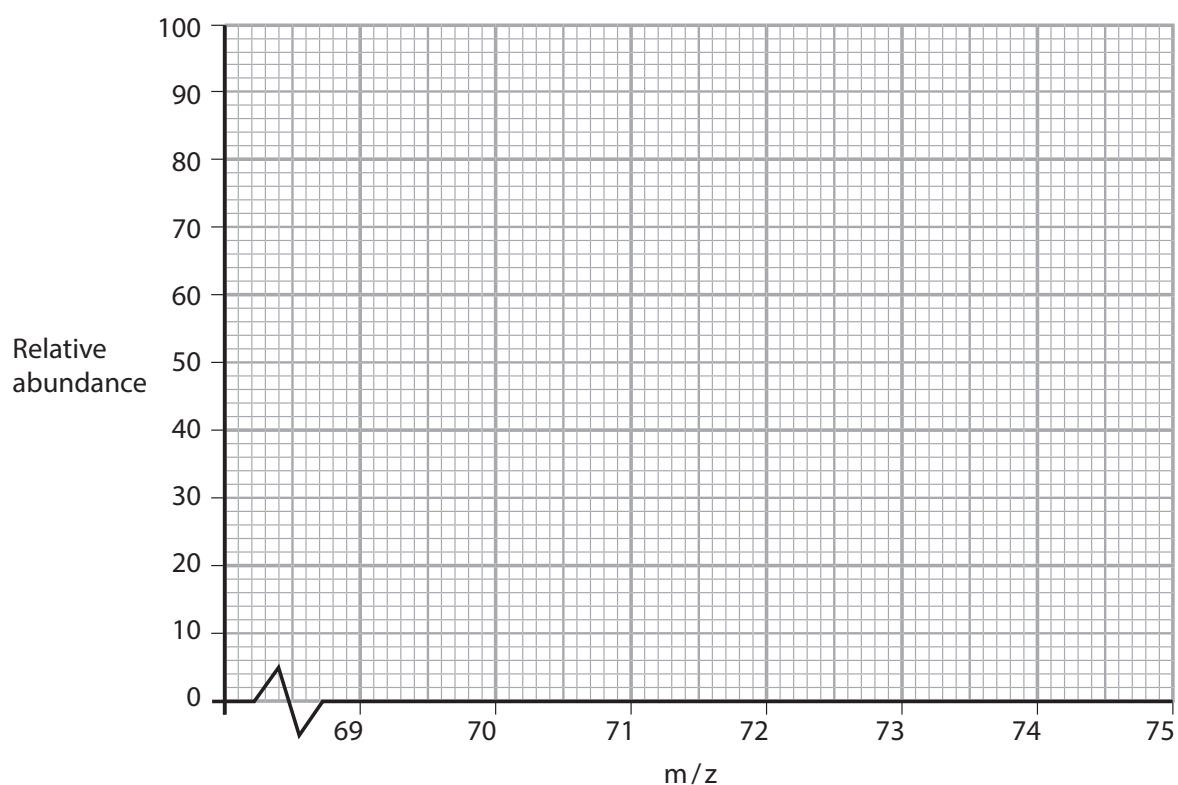
(2)

Particle	Protons	Neutrons	Electrons
^{35}Cl atom			
$^{37}\text{Cl}^-$ ion			

(ii) A sample of chlorine contained 75 % of ^{35}Cl and 25 % of ^{37}Cl .

Complete the mass spectrum to show the peaks you would expect for the molecular ion Cl_2^+ from this sample of chlorine gas.

(2)



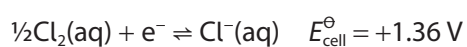
(b) Write the formula of potassium chlorate(V).

(1)

(c) Write the equation for the first electron affinity of chlorine. Include state symbols.

(2)

(d) The standard electrode potential for the chlorine / chloride ion half-cell is



(i) Identify an oxidising agent from the Data Booklet that will convert chloride ions into chlorine under standard conditions.

(1)

(ii) Calculate the value of $E_{\text{cell}}^{\ominus}$ for the reaction in (d)(i).

(1)

(Total for Question 1 = 9 marks)



SUB-TOPIC 1(b)

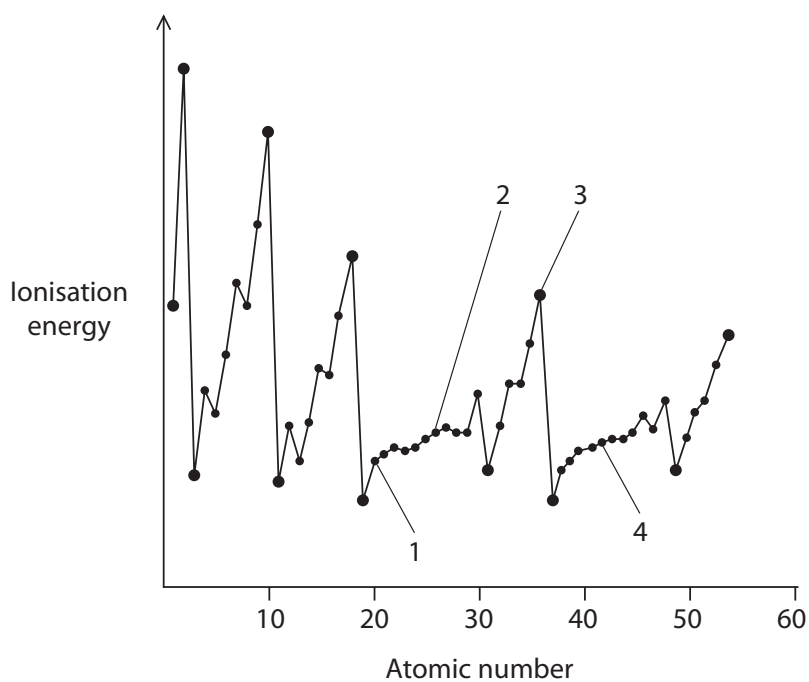
ELECTRONIC CONFIGURATION

5 questions in this sub-topic · 38 marks · lowest tariff first



1 This question is about d-block elements.

(a) Which of the labels 1–4 identifies a d-block element in Period 4?



☐ **A** 1

☐ **B** 2

☐ **C** 3

☐ **D** 4

(1)

(b) State what is meant by the term d-block element.

(1)

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(Total for Question 1 = 2 marks)

2 Chemists often use the term 'orbital' when considering atomic structure.

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

(2)

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(b) Draw diagrams to show the shape of an s and a p orbital.

(2)

s orbital	p orbital

(c) What is the electronic configuration of a copper atom?

(1)

- ☐ A $[\text{Ar}]4s^13d^{10}$
- ☐ B $[\text{Ar}]4s^23d^9$
- ☐ C $[\text{Ar}]4s^24p^13d^8$
- ☐ D $[\text{Ar}]4s^24p^23d^7$

(Total for Question 2 = 5 marks)



***6** Explain why aqueous solutions of Cu^{2+} ions and Fe^{2+} ions are coloured but have different colours, whereas aqueous solutions of Zn^{2+} ions are colourless. Include any relevant electronic configurations.

(6)



Handwriting practice area with 25 horizontal dotted lines.

(Total for Question 6 = 6 marks)

2 Ammonium cobalt(II) sulfate is made by mixing aqueous solutions of ammonium sulfate and excess cobalt(II) sulfate.

(a) Dry crystals of ammonium cobalt(II) sulfate, $(\text{NH}_4)_2\text{SO}_4 \cdot \text{CoSO}_4 \cdot 6\text{H}_2\text{O}$, are obtained by the procedure shown.

Step 1 The reaction mixture is transferred to an evaporating basin, heated gently and then left to crystallise.

Step 2 The crystals are separated by gravity filtration.

Step 3 The crystals are then **rinsed** with a small amount of **ice-cold** water.

Step 4 The rinsed crystals are placed in a **warm oven** for 30 minutes.

(i) The colour of the cobalt(II) sulfate solution used is pink due to the complex cobalt(II) ion, $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.

Explain why the solution is coloured.

(4)

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(ii) Explain the shape of the cobalt(II) ion, $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$, using electron-pair repulsion theory.

(3)

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(iii) Give the reasons for carrying out Steps **3** and **4** of the procedure, referring particularly to the words in bold.

(3)

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(b) The percentage yield of this reaction is 70.0%.

Give **two** possible reasons, other than an incomplete reaction, why the yield is less than 100%.

(2)

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(Total for Question 2 = 12 marks)



7 This question is about chromium and chromium compounds.

(a) Naturally occurring chromium has four isotopes, ^{50}Cr , ^{52}Cr , ^{53}Cr and ^{54}Cr .

State what is meant by the term isotopes.

(2)

(b) Both chromium and calcium can form ions with a +2 charge.

(i) Complete the electronic configuration of a Cr^{2+} ion.

(1)

$1s^2$

(ii) Explain which of chromium or calcium most easily forms a +2 ion using all of the data in the table.

Element	Atomic number	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}	Metallic radius / nm
Chromium	24	653	1592	0.129
Calcium	20	590	1145	0.197

(3)



(c) Chromium(III) sulfate, $\text{Cr}_2(\text{SO}_4)_3$, dissolves in water to form the complex ion $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$.

(i) State the colour of this complex ion.

(1)

(ii) Explain why the aqueous solution of this complex ion has an acidic pH by considering the interaction between the metal ion and the ligands.

(2)



- (d) A student researching the role of dichromate(VI) ions, $\text{Cr}_2\text{O}_7^{2-}$, as an oxidising agent made the statement shown.

'Standard electrode potential data shows that it is never feasible for a 1.00 mol dm^{-3} solution of potassium dichromate(VI) to oxidise the chloride ions in hydrochloric acid.'

Comment on this statement using the data and equilibria shown.

Equilibrium 1



Equilibrium 2



(4)

(Total for Question 7 = 13 marks)



SUB-TOPIC 1(c)

IONISATION ENERGIES

7 questions in this sub-topic · 81 marks · lowest tariff first



1 This question is about ionisation energies.

The table shows the first four ionisation energies of three elements in the same group of the Periodic Table.

The letters used are not the symbols of the elements.

Element	First ionisation energy / kJ mol^{-1}	Second ionisation energy / kJ mol^{-1}	Third ionisation energy / kJ mol^{-1}	Fourth ionisation energy / kJ mol^{-1}
X	403	2632	3900	5080
Y	419	3051	4412	5877
Z	496	4563	6913	9544

(a) State what is meant by the term '**first** ionisation energy'.

(2)

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(b) Explain to which group the elements **X**, **Y** and **Z** belong.

(2)

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(c) Explain which of the elements **X**, **Y** and **Z** has the highest atomic number.

(3)

(Total for Question 1 = 7 marks)



1 (a) Which equation shows the third ionisation energy of aluminium?

(1)

- ☐ **A** $\text{Al(g)} \rightarrow \text{Al}^{3+}(\text{g}) + 3\text{e}^-$
- ☐ **B** $\text{Al}^{2+}(\text{g}) \rightarrow \text{Al}^{3+}(\text{g}) + \text{e}^-$
- ☐ **C** $\text{Al}^{3+}(\text{g}) + 3\text{e}^- \rightarrow \text{Al(g)}$
- ☐ **D** $\text{Al}^{3+}(\text{g}) + \text{e}^- \rightarrow \text{Al}^{2+}(\text{g})$

(b) Which element in this table is in Group 2?

Element	Ionisation energy / kJ mol^{-1}			
	First	Second	Third	Fourth
W	1086	2353	4621	6223
X	653	1592	2987	4740
Y	590	1145	4912	6474
Z	496	4563	6913	9544

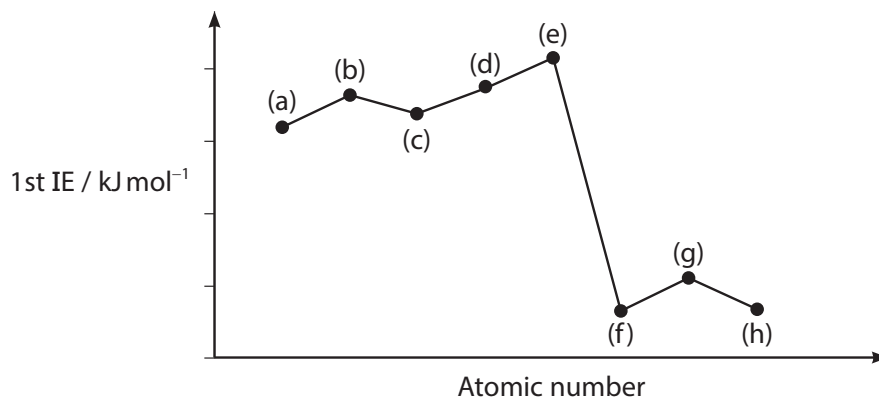
(1)

- ☐ **A** W
- ☐ **B** X
- ☐ **C** Y
- ☐ **D** Z



- (c) The graph shows the first ionisation energies (IE) of eight successive elements from the first 20 elements in the Periodic Table.

Which letter represents the first ionisation energy of oxygen?



(1)

- ☐ A (a)
- ☐ B (b)
- ☐ C (c)
- ☐ D (h)

- (d) Give the formula of a stable **ion** that is isoelectronic with the magnesium ion, Mg^{2+} .

(1)

- (e) A student stated that 'the elements scandium and zinc are d-block elements but are not transition metals'.

Discuss this statement, using appropriate electronic configurations to support your answer.

(4)

(Total for Question 1 = 8 marks)



6 Magnesium bromide, MgBr_2 , is an ionic compound.

- (a) (i) Draw a dot-and-cross diagram to show the bonding in magnesium bromide.
Only outer shell electrons are required.

(1)

- (ii) State all the conditions under which magnesium bromide conducts electricity.

(1)

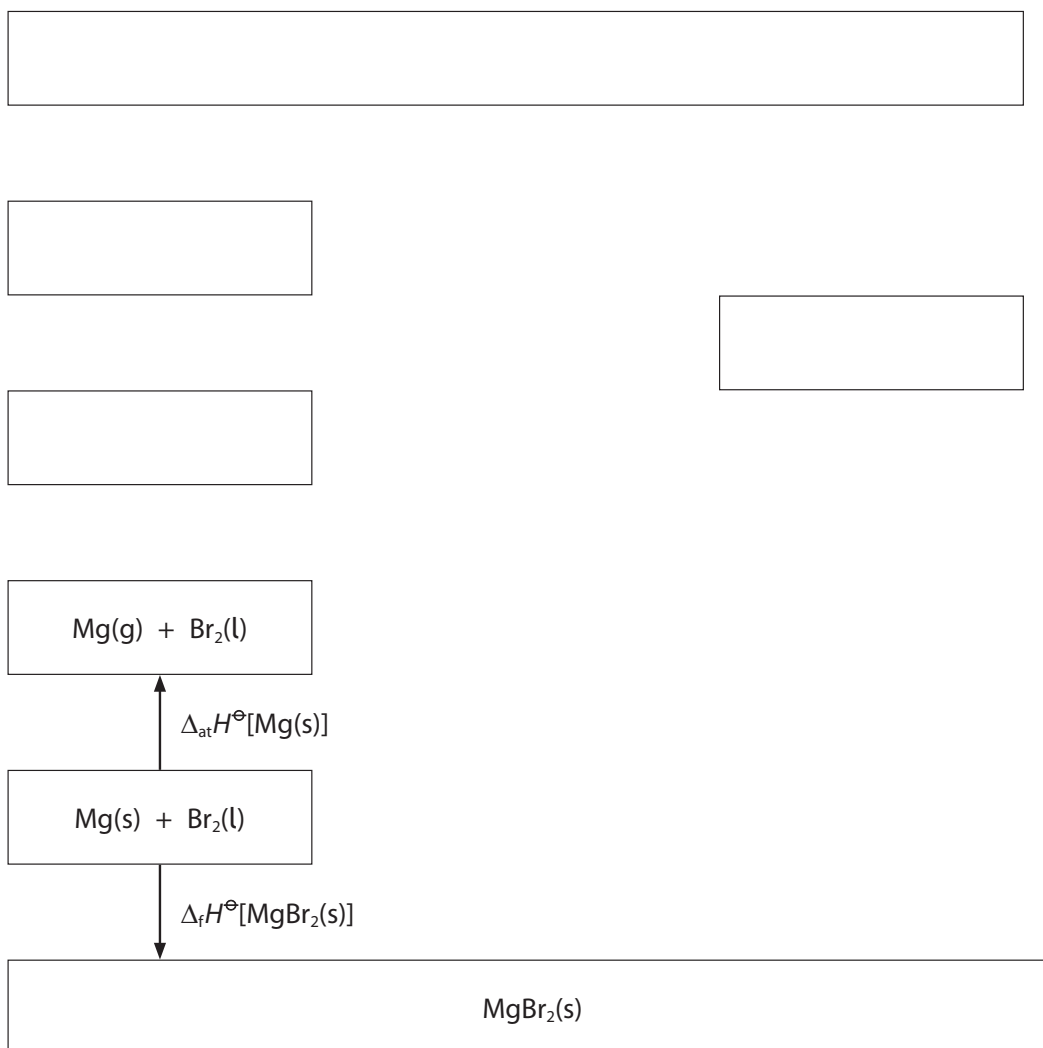


- (b) The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Enthalpy change	Value / kJ mol^{-1}
enthalpy change of atomisation of magnesium, $\Delta_{\text{at}}H^\ominus[\text{Mg(s)}]$	+148
1 st ionisation energy of magnesium, 1 st IE[Mg(g)]	+738
2 nd ionisation energy of magnesium, 2 nd IE[Mg ⁺ (g)]	+1 451
enthalpy change of atomisation of bromine, $\Delta_{\text{at}}H^\ominus[\frac{1}{2}\text{Br}_2(\text{l})]$	+112
lattice energy of magnesium bromide, LE[MgBr ₂ (s)]	-2 440
enthalpy change of formation of magnesium bromide, $\Delta_f H^\ominus[\text{MgBr}_2(\text{s})]$	-524

- (i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1} .

(2)

(c) (i) The first ionisation energy of sodium is 496 kJ mol^{-1} .

Explain why the first ionisation energy of magnesium is higher than that of sodium.

(3)

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(ii) Write the equation, including state symbols, to show the **third** ionisation energy of magnesium.

(1)

(Total for Question 6 = 11 marks)



8 This question is about ions and ionic compounds.

(a) The first three ionisation energies of calcium are shown in the table.

	First ionisation	Second ionisation	Third ionisation
Ionisation energy / kJ mol^{-1}	590	1145	4912
Orbital			

(i) Complete the table by identifying the specific orbital from which each electron is removed.

(2)

(ii) Write the equation for the **third** ionisation energy of calcium. Include state symbols.

(1)

(iii) Explain why the difference between the second and third ionisation energies of calcium is much larger than the difference between the first and second ionisation energies.

(2)

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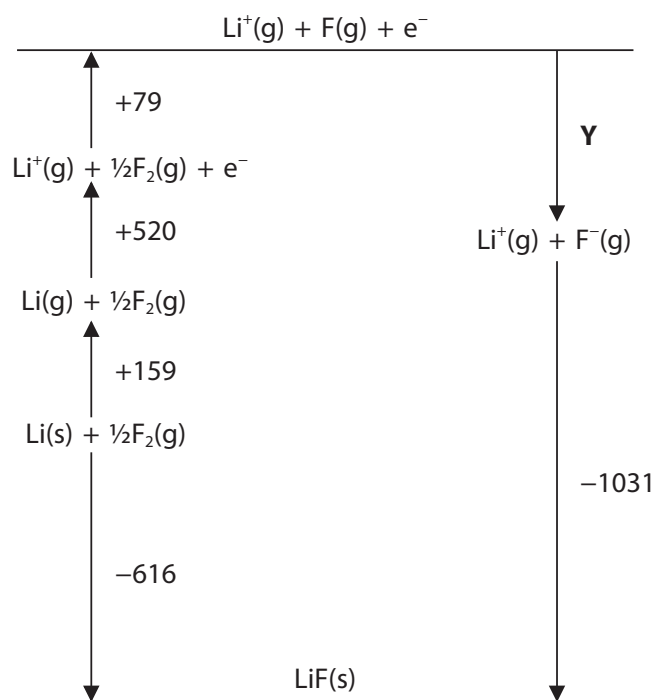
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(b) The diagram, which is not drawn to scale, shows the Born-Haber cycle for lithium fluoride. The energy changes are given in kJ mol^{-1} .



What is the value for Y , in kJ mol^{-1} ?

(1)

- ☒ A -273
- ☒ B -343
- ☒ C -432
- ☒ D -889

*(c) The table shows the theoretical and experimental lattice energy values of two compounds.

Compound	Theoretical lattice energy / kJ mol^{-1}	Experimental lattice energy / kJ mol^{-1}
lithium chloride, LiCl	−845	−848
magnesium iodide, MgI_2	−1944	−2327

Comment on the theoretical and experimental lattice energy values, giving the reasons for any differences and similarities.

(6)

[illegible]

Handwriting practice area with 25 horizontal dotted lines.

(Total for Question 8 = 12 marks)



8 This question is about ionic compounds.

- (a) Draw dot-and-cross diagrams of the ions in magnesium hydroxide, showing the outer shell electrons only.

Use $\times$ for magnesium electrons, $\bullet$ for oxygen electrons and Δ for each hydrogen electron.

(2)

- (b) Which definition correctly describes the enthalpy change of solution, $\Delta_{\text{sol}}H$?

(1)

Enthalpy change of solution, $\Delta_{\text{sol}}H$	
☐ A	The enthalpy change when 1 mol of gaseous ions dissolves in sufficient water to give an infinitely dilute solution.
☐ B	The enthalpy change when 1 mol of an ionic substance dissolves in water to give an infinitely dilute solution.
☐ C	The enthalpy change when 1 mol of gaseous ions dissolves in sufficient water to give a solution of concentration 1 mol dm^{-3} .
☐ D	The enthalpy change when 1 mol of an ionic substance dissolves in water to give a solution of concentration 1 mol dm^{-3} .

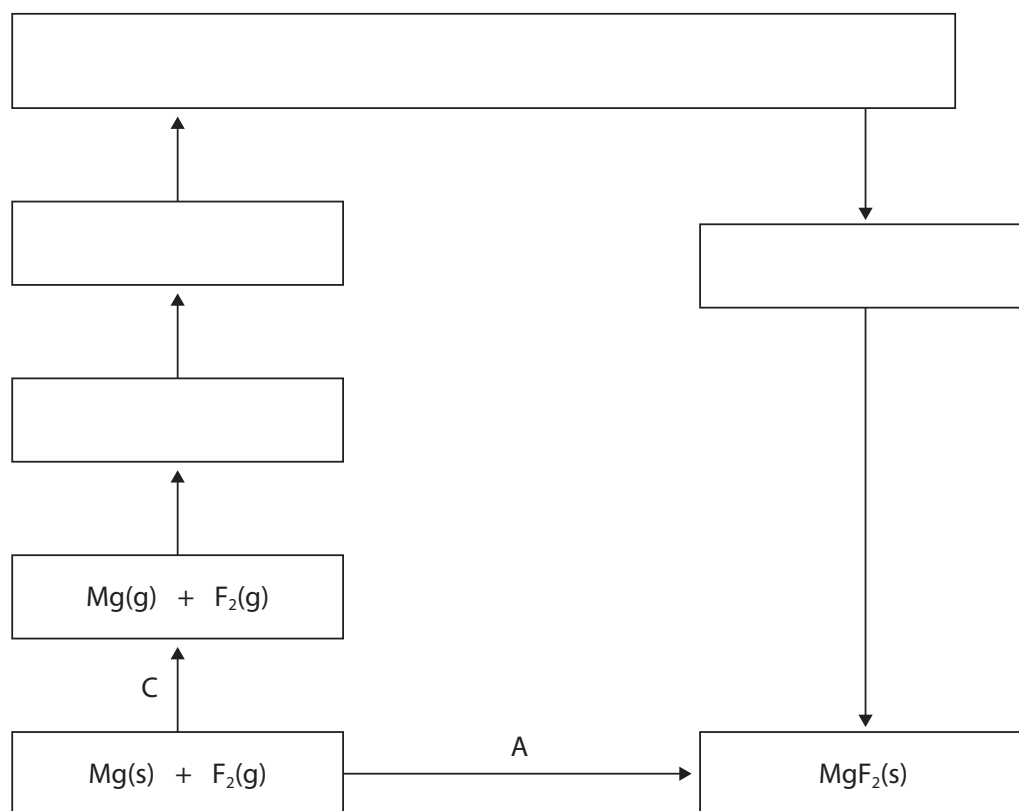


- (c) The table shows the information needed to calculate the standard enthalpy change of formation of magnesium fluoride.

Label	Description	Value / kJ mol^{-1}
A	enthalpy change of formation of magnesium fluoride	
B	lattice energy of magnesium fluoride	−2957
C	enthalpy change of atomisation of magnesium	+148
D	1st ionisation energy of magnesium	+738
E	2nd ionisation energy of magnesium	+1451
F	enthalpy change of atomisation of fluorine	+79
G	1st electron affinity of fluorine	−328

- (i) Complete the Born–Haber cycle for magnesium fluoride with formulae, state symbols, electrons and correctly labelled arrows. The cycle is not drawn to scale.

(4)



- (ii) Calculate the value of $\Delta_f H^\ominus [\text{MgF}_2(\text{s})]$.

(1)

- (iii) The experimental and theoretical values of the lattice energy for MgF_2 and MgI_2 are given in the table.

Explain the differences in these values.

(4)

Compound	Experimental lattice energy / kJ mol^{-1}	Theoretical lattice energy / kJ mol^{-1}
MgF_2	–2957	–2913
MgI_2	–2327	–1944

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(Total for Question 8 = 12 marks)



- 4 Ionisation energies provide information about the number of electrons and the arrangement of the electrons in an atom of an element.

(a) A student's definition of first ionisation energy is shown.

First ionisation energy is the energy released when one mole of gaseous atoms loses one mole of electrons to form one mole of gaseous 1+ ions.

There is one incorrect word in the student's definition.

Identify the word, giving the reason why this word is incorrect.

(2)

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- (b) Write an equation for the **second** ionisation energy of oxygen.
Include state symbols.

(2)



(c) A sodium atom has 11 protons whereas a potassium atom has 19 protons.

Explain why the first ionisation energy of sodium is greater than that of potassium.

(3)

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(d) The successive ionisation energies for magnesium are given in the table.

Electron number removed	1	2	3	4	5	6	7	8	9	10	11	12
Ionisation energy / kJ mol^{-1}	738	1451	7733	10541	13629	17995	21704	25657	31644	35463	169996	189371
Log (ionisation energy)	2.87	3.16	3.89	4.02	4.13		4.34	4.41	4.50	4.55	5.23	

(i) Complete the table.

(1)

(ii) Give a reason why the logarithm of the ionisation energy, rather than just the ionisation energy, is used to plot a graph.

(1)

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(iii) Give a reason why the successive ionisation energies increase.

(1)

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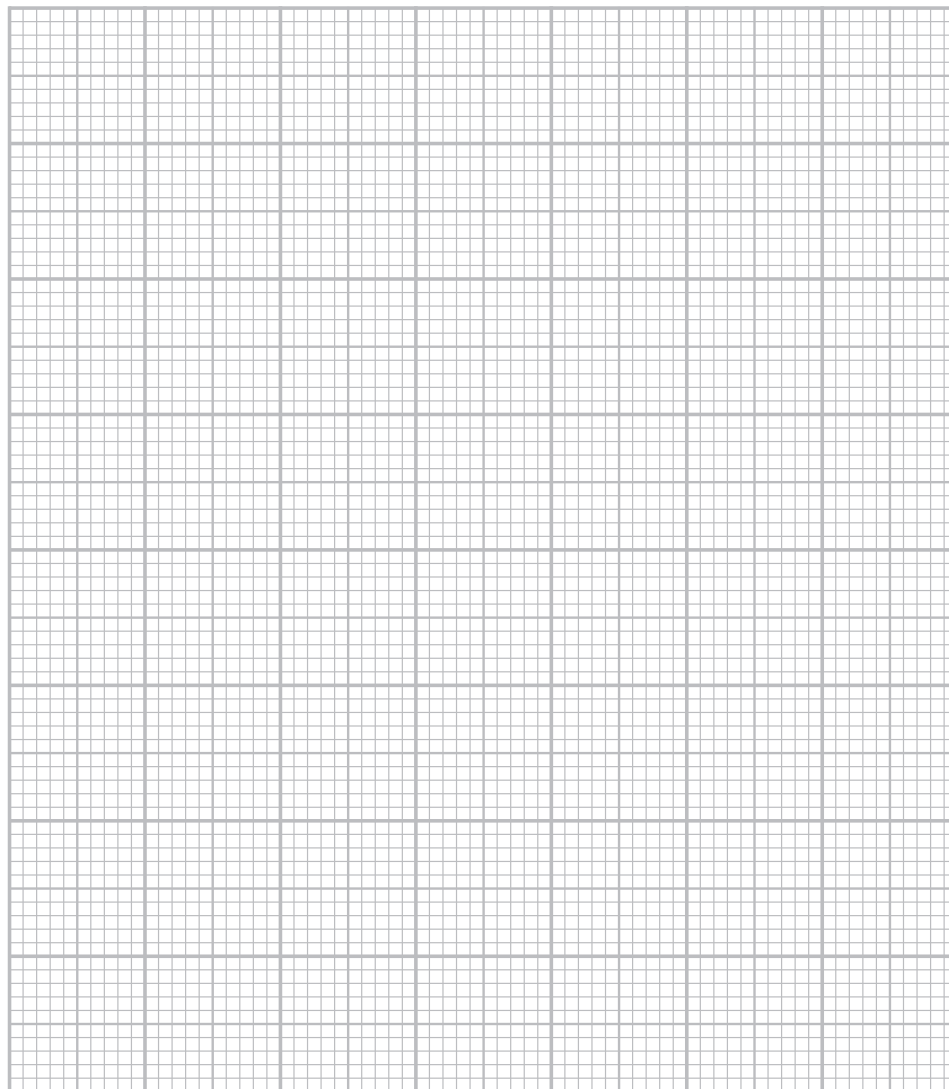
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(iv) Plot the graph of $\log(\text{ionisation energy})$ against electron number removed.

Join the individual points using straight lines.

(3)



(v) Identify on the graph, using a circle, the points that represent the removal of the electrons in the **outermost** energy level of magnesium.

(1)



(e) Estimate a value for the first ionisation energy of oxygen given the data in the table.

(1)

Element	First ionisation energy / kJ mol^{-1}
carbon	1086
nitrogen	1402
oxygen	

(Total for Question 4 = 15 marks)



- (c) Write the equation for the **second** ionisation energy of beryllium.
Include state symbols.

(1)

- (d) Which orbital is an electron removed from during the second ionisation of calcium?

(1)

☐ **A** 3s

☐ **B** 3p

☐ **C** 4s

☐ **D** 4p

- (e) Which of these isoelectronic ions has the **largest** ionic radius?

(1)

☐ **A** S^{2-}

☐ **B** Cl^{-}

☐ **C** K^{+}

☐ **D** Ca^{2+}



(Total for Question 2 = 16 marks)

SUB-TOPIC 1(d)

PERIODICITY

1 question in this sub-topic · 6 marks · lowest tariff first



(Total for Question 4 = 6 marks)

TOPIC 1

SYNOPTIC AND MIXED QUESTIONS

7 questions in this sub-topic · 71 marks · lowest tariff first



1 Aqueous sodium carbonate and aqueous sodium sulfate are both colourless solutions.

(a) Give the reagent and the observation to show the presence of carbonate ions.

(2)

(b) Give the reagent and the observation to show the presence of sulfate ions.

(2)

(Total for Question 1 = 4 marks)



3 This question is about catalytic converters.

(a) Catalytic converters contain metals such as platinum.

Describe the bonding in platinum.

You may include a diagram in your answer.

(2)

(b) A catalytic converter decreases the emissions of gases, such as carbon monoxide and nitrogen monoxide, from an internal combustion engine.

Describe the stages in a catalytic converter that result in this decrease.

No equations are required.

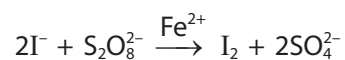
(3)

(Total for Question 3 = 5 marks)



5 This is a question about catalysis.

(a) The reaction between iodide ions and peroxodisulfate ions is catalysed by iron(II) ions.



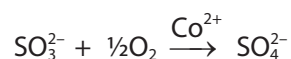
(i) Give a reason why the reaction between iodide ions and peroxodisulfate ions has a high activation energy and is therefore very slow without a catalyst.

(1)

(ii) Explain, with the aid of two equations, how the iron(II) ions catalyse this reaction. State symbols are not required.

(3)

(b) The oxidation of sulfate(IV) ions to sulfate(VI) ions is catalysed by cobalt(II) ions in **acidic** solution. The role of cobalt(II) ions is similar to that of iron(II) ions in (a).

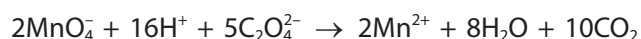


Deduce two ionic equations to show how cobalt(II) ions catalyse the reaction in **acidic** solution. State symbols are not required.

(2)



- (c) The rate of oxidation of ethanedioate ions by manganate(VII) ions starts slowly and then rapidly increases.



What is the catalyst in this reaction?

(1)

- ☐ A CO_2
- ☐ B H^+
- ☐ C Mn^{2+}
- ☐ D MnO_4^-

- (d) The trend in the strength of gaseous adsorption by three transition elements is

tungsten > platinum > silver

Silver is not suitable as a replacement for platinum in a catalytic converter because the adsorption of gases is too weak to allow significant chemical reaction.

Give a possible reason why tungsten would also **not** be a suitable replacement for platinum in a catalytic converter. Refer to the mechanism of heterogeneous catalysis in your answer.

(1)

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(Total for Question 5 = 8 marks)



5 Tests are carried out on aqueous solutions of two salts, **X** and **Y**.

(a) **X** contains one cation and one anion.

The observations for each test are recorded in the table.

(i) Complete the table by writing the names or formulae of the species.

(2)

Test	Observation	Inference
Test 1 Add aqueous sodium hydroxide to an aqueous solution of X	A green precipitate forms The precipitate turns brown on the top after a few minutes	The cation in X is
Test 2 To an aqueous solution of X , add dilute hydrochloric acid followed by aqueous barium chloride	A white precipitate forms	The anion in X is

(ii) Write the ionic equation for the reaction between the cation in **X** and aqueous sodium hydroxide in **Test 1**. Include state symbols.

(2)

(iii) Give a reason why the green precipitate turns brown on the top after a few minutes.

(1)

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(iv) Give a reason why dilute hydrochloric acid is needed in **Test 2**.

(1)

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(b) **Y** contains one cation and one anion.

The observations for each test are recorded in the table.

(i) Complete the table by writing the names or formulae of the species.

(2)

Test	Observation	Inference
Test 3 Add dilute aqueous ammonia to an aqueous solution of Y until it is present in excess	A pale blue precipitate forms The precipitate dissolves in excess ammonia to form a deep blue solution	The cation in Y is
Test 4 To an aqueous solution of Y , add dilute nitric acid followed by aqueous silver nitrate	A white precipitate forms	The anion in Y is

(ii) Give the formula of the complex ion present in the deep blue solution at the end of **Test 3**.

(1)

(iii) Give a reagent that could be added to the mixture at the end of **Test 4** to confirm the identity of the anion in **Y**.
Include the observation when this reagent is added.

(2)

(Total for Question 5 = 11 marks)



- 3** A student carried out an experiment to identify the Group 1 metal ion, M^+ , in a sulfate, M_2SO_4 .

Procedure

Step 1 A 0.48 g sample of M_2SO_4 was added to about 50 cm³ of deionised water in a beaker. The mixture was stirred with a glass rod until the sample dissolved completely.

Step 2 An excess of acidified barium chloride solution, $BaCl_2(aq)$, was added very slowly to the solution from Step 1 to ensure the crystals of barium sulfate that formed were as large as possible.

Step 3 The barium sulfate crystals were collected by gravity filtration onto a dry filter paper of known mass.

Step 4 The crystals were rinsed using deionised water.

Step 5 The filter paper containing the crystals was dried in a warm oven for an hour and then weighed.

Results

Mass of dry filter paper = 0.17 g

Mass of dry filter paper and barium sulfate crystals = 1.19 g

- (a) Give a reason, with reference to the filtration in Step 3, why the formation of **extremely** small crystals in Step 2 would lead to a lower mass of dry barium sulfate in Step 5.

(1)

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- (b) Explain why the crystals are rinsed in Step 4.

(2)

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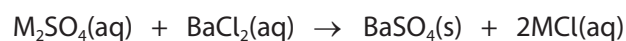
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- (c) Calculate the relative formula mass of M_2SO_4 and hence identify M.



$[M_r \text{ of } BaSO_4 = 233.4]$

(3)

- (d) Another student carrying out the experiment placed the glass rod on the laboratory bench when the stirring was complete in Step 1.

- (i) Explain what effect this would have on the calculated value of the relative formula mass of M_2SO_4 .

(2)

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- (ii) Describe how the student should amend the procedure.

(1)

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(e) Another way to identify a metal ion is a flame test.

(i) Explain what causes the flame colour in such a test.

(2)

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(ii) Give one advantage and one disadvantage of using a flame test to identify a metal cation, rather than the method followed by the students in Steps 1–5.

(2)

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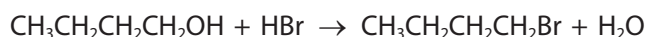
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(Total for Question 3 = 13 marks)



- 8 1-bromobutane can be prepared from butan-1-ol and hydrogen bromide.



Hydrogen bromide can be made from sodium bromide and 50% concentrated sulfuric acid.

- (a) The steps for the preparation of impure 1-bromobutane are summarised.

Step 1 Dissolve the sodium bromide in distilled water in a pear-shaped flask and then add 20.0 cm^3 of butan-1-ol.

Step 2 Surround the flask with an ice bath to **cool the mixture**, before adding concentrated sulfuric acid drop by drop.

Step 3 Remove the flask from the ice bath and add a few **anti-bumping granules** to the reaction mixture.

Step 4 Set up the apparatus for **heating under reflux**. Heat the mixture in the flask for 30 minutes and then allow the apparatus to cool.

Step 5 Rearrange the apparatus for distillation and heat the mixture until no more 1-bromobutane distils over.

- (i) Parts of the method are given in **bold** type in Steps 2, 3 and 4.
Give a reason why each of these parts is necessary.

(3)

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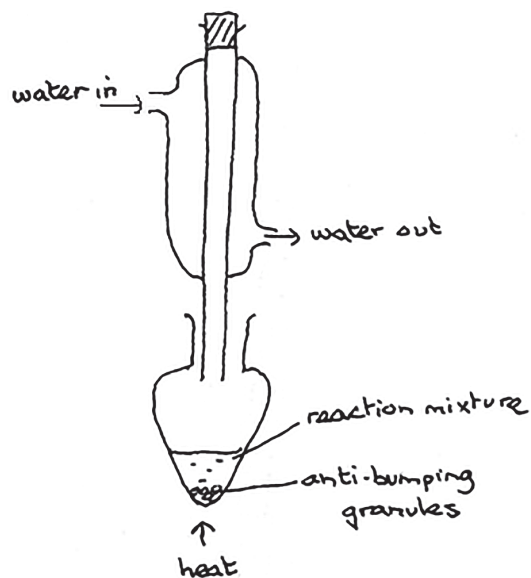
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- (ii) A student drew a diagram of the apparatus used for heating under reflux in Step 4. There are three errors in the apparatus shown in the diagram. Assume the apparatus is suitably clamped.



Identify the three errors, including the effect of each error.

(3)

(iii) The student corrected the errors.

While the mixture was heating under reflux, the student noticed a small amount of a brown vapour was formed.

Explain why the brown vapour forms.

(2)

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(b) The distillate collected in Step 5 is a mixture consisting of two layers.

There is an aqueous layer and a layer containing impure 1-bromobutane.

Data

Densities:

water 1.00 g cm^{-3}

butan-1-ol 0.81 g cm^{-3}

1-bromobutane 1.27 g cm^{-3}

Boiling temperature of 1-bromobutane = 102°C

The steps for the purification of the 1-bromobutane are summarised.

Step 6 Transfer the mixture from Step 5 to a separating funnel and remove the aqueous layer.

Step 7 Wash the impure 1-bromobutane with concentrated hydrochloric acid in the separating funnel. Remove the aqueous layer.

Step 8 Add aqueous sodium hydrogencarbonate to the impure 1-bromobutane in the separating funnel.

Step 9 Shake the mixture in the separating funnel and, from time to time, invert the funnel and open the tap.

Step 10 Collect the 1-bromobutane layer from Step 9 in a small conical flask. Add anhydrous sodium sulfate and swirl the flask until the liquid becomes clear.

Step 11 Decant the 1-bromobutane into a clean pear-shaped flask and redistil it. Measure the volume of 1-bromobutane produced.



- (i) State the position of the aqueous layer in the separating funnel at the start of Step 6. Justify your answer.

(1)

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- (ii) Concentrated hydrochloric acid is used to remove any unreacted butan-1-ol in the mixture in Step 7.

Give the reasons for carrying out Steps 8, 9 and 10.

(3)

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- (iii) Give a suitable temperature **range** over which to collect the pure 1-bromobutane in the redistillation in Step 11.

(1)

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- (iv) The volume of 1-bromobutane collected was 12.0 cm^3 .

Calculate the number of molecules of 1-bromobutane produced in this experiment.

Give your answer to an appropriate number of significant figures.

(2)

(Total for Question 8 = 15 marks)



9 This is a question about isomers of $C_8H_8O_2$.

(a) One of these isomers, methyl benzoate, is hydrolysed by alkali or by acid.

(i) Hydrolysis with aqueous sodium hydroxide is followed by acidification to form benzoic acid.

Give a reason why acidification is required after hydrolysis.

(1)

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(ii) Write an equation, using structural formulae, for the acid hydrolysis of methyl benzoate.

(1)



(b) Four other $C_8H_8O_2$ isomers were investigated.

- **W** and **X** are mono-substituted aromatic compounds with the same functional group as methyl benzoate but only **W** is made from methanoic acid
- **Y** is a mono-substituted aromatic compound which reacts with sodium carbonate to give carbon dioxide
- **Z** is a disubstituted aromatic compound with six peaks in its ^{13}C NMR spectrum and forms a sweet-smelling compound on reaction with ethanol

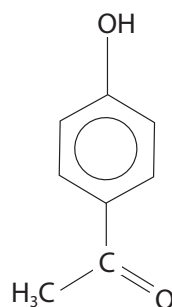
Deduce the structures of isomers **W**, **X**, **Y** and **Z**. Justify your answers.

(7)





(c) Piceol is found in the needles of Norway spruce trees. Its structure is shown.

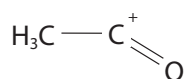
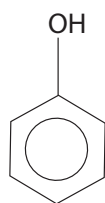


- (i) Piceol can be produced from the reaction of ethanoyl chloride and phenol. Assume the mechanism for the reaction with phenol is similar to that with benzene and involves the use of an aluminium chloride catalyst, which produces the electrophile $[\text{CH}_3\text{C}=\text{O}]^+$.

Complete the diagram, including curly arrows, to show the mechanism for this reaction to produce piceol.

Include the regeneration of the catalyst.

(4)



- (ii) Piceol can be distinguished from $\text{HOC}_6\text{H}_4\text{CH}_2\text{CHO}$ using simple chemical tests.

Give the reagents for a chemical test, and the observation that would only be positive for piceol.

(2)

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(Total for Question 9 = 15 marks)

MARK SCHEMES

official Pearson Edexcel mark schemes



Question Number	Answer	Additional Guidance	Mark
1(a)	An answer that makes reference to the following points: • (the relative isotopic mass is) the mass of an atom (of an isotope) (1) • relative to 1/12 of the mass of a carbon-12 atom or relative to a carbon-12 atom which has a mass of (exactly) 12 (1)	Allow weight for mass Do not award reference to average/mean mass Accept divided by 1/12 of the mass of a carbon-12 atom Allow reference to moles such as The mass of one mole of atoms of an isotope relative to 1/12 of the mass of one mole of carbon-12 atoms	(2)
Question Number	Answer	Additional Guidance	Mark
1(b)	An answer that makes reference to the following point: • five / 5		(1)

(Total for Question 1 = 3 marks)



Question Number	Answer	Mark
1(a)	The only correct answer is A <i>B is not correct because oxygen atoms do not have this number of protons</i> <i>C is not correct because oxygen atoms do not have this number of protons</i> <i>D is not correct because oxygen atoms do not have this number of protons</i>	(1)

Question Number	Answer	Mark
1(b)	The only correct answer is D <i>A is not correct because there are no peaks for bromine molecules</i> <i>B is not correct because the peak for the $^{79}\text{Br}-^{81}\text{Br}^+$ molecular ion is missing</i> <i>C is not correct because the peak for the $^{79}\text{Br}-^{81}\text{Br}^+$ molecular ion is not twice the height of the other molecular ion peaks</i>	(1)

Question Number	Answer	Mark
1(c)	The only correct answer is C <i>A is not correct because this is only the number of electrons in the 3p orbitals of the chlorine atom</i> <i>B is not correct because this is only the number of electrons in the 3p orbitals of the chloride ion</i> <i>D is not correct because this is the total number of electrons in the chloride ion, not just those in the p orbitals</i>	(1)



Question Number	Answer	Mark
1(d)	The only correct answer is A <i>B is not correct because oxygen has more protons to exert an attractive force to reduce the ionic radius</i> <i>C is not correct because sodium has more protons to exert an attractive force to reduce the ionic radius</i> <i>D is not correct because aluminium has more protons to exert an attractive force to reduce the ionic radius</i>	(1)

(Total Question 1 = 4 marks)



Question Number	Answer	Mark
1(a)	The only correct answer is D (Na^+ and Mg^{2+}) <i>A is not correct because the chloride ion has an extra shell of electrons compared to the nitride ion</i> <i>B is not correct because the sulfide ion has an extra shell of electrons compared to the oxide ion</i> <i>C is not correct because the potassium ion has an extra shell of electrons compared to the sodium ion</i>	(1)

Question Number	Answer	Mark
1(b)	The only correct answer is B (the mass of one atom of an isotope relative to one twelfth of the mass of an atom of the isotope carbon-12) <i>A is not correct because this is the relative atomic mass definition</i> <i>C is not correct because this is part of the relative atomic mass definition and because of the comparison of one atom to 12 g</i> <i>D is not correct because of the comparison of one atom to 12 g</i>	(1)

Question Number	Answer	Additional Guidance	Mark
1(c)	- correct expression (1) - evaluation of calculation and answer to 2 dp (1)	<u>Example of calculation</u> $\text{RAM} = \frac{(50.52 \times 78.918) + (49.48 \times 80.916)}{100}$ (= 79.9066104) = 79.91 ALLOW units of g mol^{-1} only Do not award units of % Correct answer without working scores (2)	(2)

(Total Question 1 = 4 marks)



Question Number	Answer	Additional guidance	Mark
1(a)	An answer that makes reference to the following points: (the relative atomic mass of an element is) the weighted mean of the masses of its atoms / isotopes (1) - relative to 1/12 of the mass of carbon-12 / relative to carbon-12 which has a mass of exactly 12 units (1)	mass and atom only need to be mentioned once each in M1 or M2 Accept the weighted mean mass of an atom Allow 'average' for 'mean' but not for 'weighted' Allow the mean mass of all atoms Do not award just 'element' for atom / isotope Do not award the weighted mean mass of an isotope Ignore mention of mole. Allow compared instead of relative Do not award M2 if mass number mentioned Note: the equation: $\frac{\text{weighted mean mass of an atom}}{\frac{1}{12} \text{ of the mass of a carbon 12 atom}}$ scores both marks	(2)

Question Number	Answer	Additional guidance	Mark
1(b)	- expression for weighted mean (1) - calculation of relative atomic mass and correct rounding to 3 SF (1)	<u>Example of calculation</u> $\frac{(84.80 \times 20) + (2.26 \times 21) + (12.94 \times 22)}{100}$ $= (20.2814) = 20.3$ Correct answer with no / some working scores (2) Allow TE only on a transcription error from data Ignore units	(2)

(Total for Question 1 = 4 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark																
1(a)	An answer that makes reference to the following points: - first row correct - second row correct - third row correct	<table> <tr> <th>Species</th><th>Number of protons</th><th>Number of neutrons</th><th>Number of electrons</th></tr> <tr> <td>^{32}S</td><td>16</td><td>16</td><td>16</td></tr> <tr> <td>^{33}S</td><td>16</td><td>17</td><td>16</td></tr> <tr> <td>$^{34}\text{S}^{2-}$</td><td>16</td><td>18</td><td>18</td></tr> </table> If no marks are scored, allow 1 mark for each correct column	Species	Number of protons	Number of neutrons	Number of electrons	^{32}S	16	16	16	^{33}S	16	17	16	$^{34}\text{S}^{2-}$	16	18	18	(3)
Species	Number of protons	Number of neutrons	Number of electrons																
^{32}S	16	16	16																
^{33}S	16	17	16																
$^{34}\text{S}^{2-}$	16	18	18																

Question Number	Acceptable Answer	Additional Guidance	Mark
1(b)(i)	calculation of missing value	<u>Example of calculation</u> $(100 - 95.02 - 0.75 - 0.02 =) 4.21 \text{ (\%)}$	(1)



Question Number	Acceptable Answer	Additional Guidance	Mark
1(b)(ii)	- correct expression for calculation of RAM (1) - value given to 2 decimal places (1)	<u>Example of calculation</u> $\text{RAM} = \frac{((95.02 \times 32) + (0.75 \times 33) + (4.21 \times 34) + (36 \times 0.02))}{100}$ (= 32.0925) Allow TE on 1(b)(i). = 32.09 Allow units of g mol⁻¹ / g mol⁻ Allow units of g/mol Do not award any other unit Correct answer with no working scores 2	(2)

(Total for Question 1 = 6 marks)



Question Number	Answer	Additional Guidance	Mark
1(a)	An answer that makes reference to the following points: (relative isotopic mass) is the mass of an atom (of the isotope / element) (1) - relative to $1/12^{\text{th}}$ (the mass of an atom) of carbon-12 (1)	Allow mass of an isotope of an atom Do not award any reference to average / mean / weighted or moles in M1 or M2, but penalise only once if in both Allow for two marks $\frac{\text{Mass of one atom of an isotope} \times 12}{\text{Mass of one atom of carbon-12}}$ COMMENT M1 can be awarded if atom mentioned somewhere in response	(2)

Question Number	Answer	Additional Guidance	Mark												
1(b)	An answer that makes reference to the following points: - all isotopes have 18 protons (and 18 electrons) (1) - the isotopes have different numbers of neutrons, 18, 20 and 22 (1)	Do not award incorrect number of electrons <table><tr><th>Isotope</th><th>Protons</th><th>Neutrons</th></tr><tr><td>^{36}Ar</td><td>18</td><td>18</td></tr><tr><td>^{38}Ar</td><td>18</td><td>20</td></tr><tr><td>^{40}Ar</td><td>18</td><td>22</td></tr></table> If no other mark awarded allow isotopes have the same number of protons but a different number of neutrons for 1 mark Ignore same atomic number and different mass number	Isotope	Protons	Neutrons	^{36}Ar	18	18	^{38}Ar	18	20	^{40}Ar	18	22	(2)
Isotope	Protons	Neutrons													
^{36}Ar	18	18													
^{38}Ar	18	20													
^{40}Ar	18	22													



Question Number	Answer	Additional Guidance	Mark
1(c)	- correct expression for calculation of A_r (1) - value given to 2 dp (1)	<u>Example of calculation</u> $A_r = \frac{((35.97 \times 0.337) + (37.96 \times 0.0630) + (39.96 \times 99.6))}{100}$ (= 39.945) = 39.95 TE on correct calculation from incorrect transposed numbers or use of whole numbers for relative isotopic mass Ignore g mol^{-1} but penalise other units Correct answer with no working scores 2	(2)

(Total for Question 1 = 6 marks)



Question Number	Answer	Additional Guidance	Mark												
1(a)	- any two or three values correct (1) - all four values correct (1)	<u>Example of table</u> <table><tr><th>Particle</th><th>Relative charge</th><th>Relative mass</th></tr><tr><td>proton</td><td>(+1)</td><td>(1)</td></tr><tr><td>neutron</td><td>0 / no charge</td><td>1</td></tr><tr><td>electron</td><td>−1</td><td>1/1840</td></tr></table> Allow negligible / very small or words to that effect / values in a range from 1/1800 to 1/2000 (0.0005) for the relative mass of electron Do not award 0 / none for mass of electron Ignore + sign for neutron	Particle	Relative charge	Relative mass	proton	(+1)	(1)	neutron	0 / no charge	1	electron	−1	1/1840	(2)
Particle	Relative charge	Relative mass													
proton	(+1)	(1)													
neutron	0 / no charge	1													
electron	−1	1/1840													



Question number	Answer	Mark
1(b)	The only correct answer is D (quantum shells) <i>A is incorrect because atomic emission spectroscopy does not provide evidence for the existence of atoms</i> <i>B is incorrect because atomic emission spectroscopy does not provide evidence for the existence of electrons</i> <i>C is incorrect because evidence for isotopes is provided by mass spectrometry</i>	(1)

Question Number	Answer	Additional Guidance	Mark
1(c)	• diagram of a p orbital	<u>Example of diagram</u>  Allow any orientation of p orbital Ignore axes	(1)

Question Number	Answer	Additional Guidance	Mark
1(d)	An explanation that makes reference to the following points: - silicon – giant atomic / giant covalent / giant molecular / macromolecular and contains covalent bonds (1) - chlorine - (simple) molecular / molecules / diatomic / Cl₂ and contains London forces (1) (covalent) bonds in silicon are stronger than London forces/ intermolecular forces in chlorine or covalent bonds take more energy to break than London forces / intermolecular forces (1)	Do not allow just 'silicon is a covalent molecule' Do not allow reference to ions or metallic bonding Allow dispersion forces / van der Waals' / attractions between temporary dipole and induced dipole/ attractions between instantaneous dipole (- induced dipole) for London forces Do not award covalent bonds being broken in chlorine Ignore silicone for silicon as correct spelling is given in the paper	(3)

(Total for Question 1 = 7 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark												
2(a)	${}^6\text{Li}$ – 3 protons and 3 neutrons and 3 electrons (1) ${}^7\text{Li}^+$ – 3 protons and 4 neutrons and 2 electrons (1)	Example of table <table border="1"> <thead> <tr> <th>Particle</th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr> </thead> <tbody> <tr> <td>${}^6\text{Li}$</td><td>3</td><td>3</td><td>3</td></tr> <tr> <td>${}^7\text{Li}^+$</td><td>3</td><td>4</td><td>2</td></tr> </tbody> </table> If no other mark is scored, allow (1) for any 4 correct numbers Ignore + or - signs	Particle	Protons	Neutrons	Electrons	${}^6\text{Li}$	3	3	3	${}^7\text{Li}^+$	3	4	2	(2)
Particle	Protons	Neutrons	Electrons												
${}^6\text{Li}$	3	3	3												
${}^7\text{Li}^+$	3	4	2												

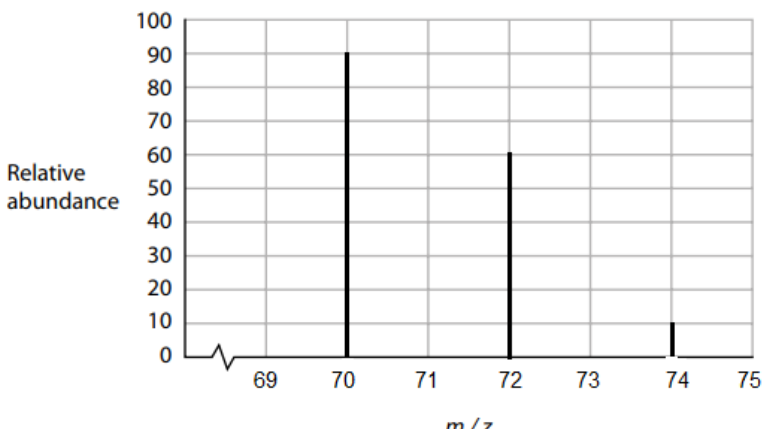
Question Number	Acceptable Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to the following points: - identification of oxygen / O (1) - identification of isotopes corresponding to any 3 m/z values (1) - Conditional on M2 awarded identification of isotopes corresponding to other 2 m/z values (1)	Isotopes in ions at each m/z value: (32 –) ${}^{16}\text{O} = {}^{16}\text{O}^+ / {}^{16}\text{O}_2^+$ (33 –) ${}^{16}\text{O} = {}^{17}\text{O}^+$ (34 –) ${}^{16}\text{O} = {}^{18}\text{O}^+$ and ${}^{17}\text{O} = {}^{17}\text{O}^+ / {}^{17}\text{O}_2^+$ (35 –) ${}^{17}\text{O} = {}^{18}\text{O}^+$ (36 –) ${}^{18}\text{O} = {}^{18}\text{O}^+ / {}^{18}\text{O}_2^+$ Allow single bonds Allow any other unambiguous ways of showing the masses of the isotopes for each m/z value e.g. $16+16$, O_2^{16} Allow use of X / another symbol e.g. Cl instead of O for M2 and M3 Ignore missing charges as given in question Penalise negative charge once only	(3)

Question Number	Acceptable Answer		Additional Guidance	Mark								
2(c)	1s orbital – 2 electrons 2p subshell – 6 electrons - third quantum shell – 18 electrons	(1) (1) (1)	<u>Example of table</u> <table><tr><th>Region</th><th>Maximum number of electrons</th></tr><tr><td>the 1s orbital</td><td>2</td></tr><tr><td>the 2p subshell</td><td>6</td></tr><tr><td>the third quantam shell</td><td>18</td></tr></table> Allow 1s² for 2 Allow 2p⁶ for 6 Ignore 3s²3p⁶3d¹⁰ for the third number Do not award more than one number written in the box e.g. 8 or 18 in the third box	Region	Maximum number of electrons	the 1s orbital	2	the 2p subshell	6	the third quantam shell	18	(3)
Region	Maximum number of electrons											
the 1s orbital	2											
the 2p subshell	6											
the third quantam shell	18											

(Total for Question 2 = 8 marks)



Question Number	Answer	Additional Guidance	Mark												
1(a)(i)	- all numbers for ^{35}Cl correct - all numbers for $^{37}\text{Cl}^-$ correct	(1) (1) Example of table <table border="1"> <thead> <tr> <th>Particle</th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr> </thead> <tbody> <tr> <td>^{35}Cl atom</td><td>17</td><td>18</td><td>17</td></tr> <tr> <td>$^{37}\text{Cl}^-$ ion</td><td>17</td><td>20</td><td>18</td></tr> </tbody> </table> If no other mark is awarded, allow (1) for any four numbers correct	Particle	Protons	Neutrons	Electrons	^{35}Cl atom	17	18	17	$^{37}\text{Cl}^-$ ion	17	20	18	(2)
Particle	Protons	Neutrons	Electrons												
^{35}Cl atom	17	18	17												
$^{37}\text{Cl}^-$ ion	17	20	18												

Question Number	Answer	Additional Guidance	Mark
1(a)(ii)	- lines at 70 and 72 and 74 - relative abundances 9:6:1	(1) (1) Example of spectrum  Allow any abundances in an approximate 9:6:1 ratio e.g. 56:37-38:6 as %, or 75 : 50 : 8	(2)



Question Number	Answer	Additional Guidance	Mark
1(b)	KClO_3	Allow K^+ClO_3^-	(1)

Question Number	Answer	Additional Guidance	Mark
1(c)	equation	Example of equation $\text{Cl(g)} + \text{e}^- \rightarrow \text{Cl}^-\text{(g)}$ Allow just e for electron	(2)
	state symbols	Stand alone mark for species on both sides of equation Ignore state symbol for electron	

Question Number	Answer	Additional Guidance	Mark
1(d)(i)	identification of oxidising agent	Either acidified (potassium) manganate(VII) / MnO_4^- and H^+ Or acidified hydrogen peroxide / H_2O_2 and H^+ Allow H^+ shown in equation in (i) or (ii) If the acid is specified it must be sulfuric acid	(1)

Question Number	Answer	Additional Guidance	Mark
1(d)(ii)	value of $E^\ominus_{\text{cell}}$	Either $E^\ominus_{\text{cell}} = (+)0.15 \text{ (V)}$ for acidified (potassium) manganate(VII) Or $E^\ominus_{\text{cell}} = (+)0.41 \text{ (V)}$ for acidified hydrogen peroxide No TE on any other reagent in (i)	(1)

(Total for Question 1 = 9 marks)



Question Number	Answer	Mark
1(a)	The only correct answer is B (2) <i>A is not correct because it is an s-block element</i> <i>C is not correct because it is a p-block element</i> <i>D is not correct because it is a d-block element in Period 5</i>	(1)

Question Number	Answer	Additional Guidance	Mark
1(b)	An answer that makes reference to the following point: an element which has its last electron added to a d-subshell (according to the Aufbau principle)	Allow 'd orbital(s)' for 'd-subshell' throughout Do not award 'd block orbital' Allow an element with its valence / outer / outermost / last / highest energy electron in the d-subshell Allow outer occupied orbital is d Allow electronic configuration ends with d-subshell Allow 3d specified Ignore just 'outer orbital is d' Ignore reference to forming stable ions with incomplete d orbitals Ignore general properties of transition metals e.g. has variable oxidation states Do not award just 'has electron(s) in d orbitals / d-subshell'	(1)

(Total for Question 1 = 2 marks)



Question Number	Answer	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: - a region / space (in an atom) in which there is a high probability of finding electron(s) / electron(s) are (most) likely to be found (1) - containing (a maximum of) 2 / a pair of electrons (with opposite spin) (1)	Mark independently Allow area / for region / space Allow a percentage between 90 and 98% for the probability Allow just 'a region / space (in an atom) that holds electrons' Allow an area of high electron density where an electron can be predicted to be found Allow region / space around the nucleus that holds electrons Ignore just 'where the electron(s) are' Ignore energy level / sub-level	(2)



Question Number	Answer	Additional Guidance		Mark				
2(b)	An answer that makes reference to the following points: - s orbital shown as a sphere / circle - p orbital shown as a figure of 8 / dumb-bell shaped	<table><tr><th>s orbital</th><th>p orbital</th></tr><tr><td></td><td></td></tr></table>	s orbital	p orbital			Allow p orbital in any orientation Lower p orbital does not need to be shaded Allow all 3 p orbitals shown separately or altogether Ignore x, y and/or z axes marked Do not award p-orbital lobes of very different sizes Note Do not award 2 p orbitals shown as a clover shape unless labelled as separate orbitals (p_x etc)	(2)
s orbital	p orbital							
								

Question Number	Answer	Mark
2(c)	The only correct answer is A ($[\text{Ar}]4s^13d^{10}$) B is not correct because a full d-subshell is more stable C is not correct because the atom does not have any 4p electrons D is not correct because the atom does not have any 4p electrons	(1)

(Total for Question 2 = 5 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark																				
*6	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning. <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2	Answer is partially structured with some linkages and lines of reasoning.	1	Answer has no linkages between points and is unstructured.	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points, which is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Incorrect chemistry Penalise the incorrect mention of a single d-orbital instead of d-orbitals or d-subshell once only in whole response	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5–4	3																						
3–2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained line of reasoning																						
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2																						
Answer is partially structured with some linkages and lines of reasoning.	1																						
Answer has no linkages between points and is unstructured.	0																						



	Indicative content: • IP1 (electron configurations of Cu²⁺ and Fe²⁺) correct electron configuration of both Cu²⁺ and Fe²⁺ ions • IP2 (ligands and d orbitals) ligand splits the (3) d-orbitals / (3) d-subshell splits (into higher and lower energy levels) • IP3 (energy gap) energy gap / ΔH / ΔE (between d-orbitals) is different in different (metal) ions / between Cu²⁺ and Fe²⁺ ions • IP4 (electron promoted) electron is promoted / excited / d–d transition and absorbing (visible) light energy / photons of different wavelength / colour • IP5 (colour) complementary colour seen / transmitted / reflected • IP6 (zinc) (zinc ions / Zn²⁺) colourless because the (3)-d subshell / d-orbitals in Zn²⁺ are full / and Zn²⁺ is [Ar] 3d¹⁰ / 1s², 2s², 2p⁶, 3s², 3p⁶, 3d¹⁰ (and so d-d transitions cannot occur)	Cu²⁺ is [Ar] 3d⁹ / 1s², 2s², 2p⁶, 3s², 3p⁶, 3d⁹ Fe²⁺ is [Ar] 3d⁶ / 1s², 2s², 2p⁶, 3s², 3p⁶, 3d⁶ Allow the energy gap / energy difference determines the frequency of absorbed light Ignore the energy gap is dependent on the ligand. Allow energy levels for energy gap as long as it is clear they mean in the d-subshell / between the split d-orbitals Allow transition / promotion between energy levels Do not award transition / promotion between d-subshells Allow colour / light not absorbed seen Do not award reference to electrons returning to the ground state or emission of colour / light Ignore zinc (3)d subshell does not split Ignore zinc cannot bind ligands Allow no space for an electron to be promoted Do not award shell for subshell Penalise the incorrect mention of a single d-orbital instead of d-orbitals or d-subshell once only in whole response	
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Question Number	Answer	Additional Guidance	Mark
2(a)(i)	An explanation that makes reference to the following points: Splitting (ligand / water molecule causes) d orbitals to split (into 2 energy levels) (1) Absorption - electrons absorb energy (in the visible region) / photons (of visible light) (1) Promotion - to promote electrons (to higher d orbitals) or electrons move from lower to higher energy (d) orbitals / levels (1) Colour - the remaining light / unabsorbed light / complementary colour / pink light is transmitted (1)	Penalise omission of 'd' once only Allow d subshell / shell for d orbitals Do not award 'a d orbital is split' Do not award 'electrons are split' Allow energy / photons / light absorbed Allow d-d transitions occur Allow electrons are excited / jump for promote Ignore reference to electron(s) relaxing / dropping to ground state Do not award d-s transitions Allow reflected / emerged / seen Do not award 'emitted'	(4)



Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An explanation that makes reference to the following points: Electron pairs 6 (dative) pairs of (bonding) electrons (around cobalt ion) (1) Minimise repulsion (electron / bond pairs) arranged in order to minimise repulsion (1) Shape - so shape is octahedral (1)	Pairs only needs to be mentioned once in M1 or M2 Allow areas of electron density for pairs of electrons Allow 6 bond(ing) pairs May be shown on diagram but dative bonds must be between O and Co^{2+} Do not award mention of having any lone pairs Allow to maximise separation between electron / bond pairs or the electron / bond pairs are as far apart as possible Ignore equal repulsion between bond pairs Ignore comments based on repulsion / separation between bonds / atoms Ignore comments on repulsion between bond pairs and lone pairs Allow 3-D diagram to show octahedral shape Allow square based bipyramidal Do not award octagonal No TE on incorrect number of electron pairs Ignore bond angles	(3)



Question Number	Answer	Additional Guidance	Mark
2(a)(iii)	An answer that makes reference to the following points: Rinsed - rinsed to remove cobalt(II) sulfate (solution) (1) Ice-cold water - ice-cold water minimises / prevents ammonium cobalt(II) sulfate / crystals (re)dissolving (1) Warm oven - warm oven (rather than hot) to ensure water of crystallisation is not removed (during drying) or to stop the crystals melting (1)	Allow to remove remaining solution Allow to remove impurities that didn't crystallise Allow just 'to remove impurities' Ignore to remove ammonium sulfate Ignore to remove solvent Do not award to remove insoluble impurities Allow the crystals are insoluble / less soluble in cold water Ignore to stop the reaction Do not award to stop the crystals melting Allow to dry crystals / remove water Do not award to remove water of crystallisation / heat to constant mass	(3)



Question Number	Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to two of the following points: - some ammonium cobalt(II) sulfate solution lost if it ‘spits’ out of basin when heated (in Step 1) (1) - some ammonium cobalt(II) sulfate remains in solution (in Step 1) (1) - some ammonium cobalt(II) sulfate is soaked into the filter paper/ some ammonium cobalt(II) sulfate crystals remain on filter paper (in Step 2) (1) - transfer losses from reaction flask / beaker to evaporating basin / from evaporating basin to filter funnel (in Steps 1 and 2) (1) - some water of crystallisation is lost during the drying process (in Step 4) (1)	Allow e.g. crystals / salt / solid / product for ammonium cobalt(II) sulfate Do not award crystals evaporated for M1 only Allow the crystals weren’t left to crystallise for long enough Allow just ‘solid is lost during filtration’ Allow any type of specific transfer loss e.g. some product left behind in the beaker / flask / evaporating basin Allow crystals decompose during drying Allow some ammonium cobalt(II) sulfate dissolves in ice-cold water (in Step 3) Ignore formation of alternative product Ignore reaction is reversible	(2)

(Total for Question 2 = 12 marks)



Question Number	Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to the following points (atoms with) the same atomic number / number of protons - but with a different mass number / number of neutrons	(1) Ignore atoms of the same element Ignore comments about same number of electrons Do not award compounds (1) Do not award different number of electrons Note Allow both M1 and M2 in terms of Cr i.e. M1 Cr has 24 protons M2 but may have 26, 28, 29 or 30 / different numbers of neutrons	(2)

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	An answer that makes reference to the following point $(1s^2)2s^22p^63s^23p^63d^4$	Allow numbers of electrons as subscripts but not as large numbers Allow the $2p^6$ written as $2p_x^22p_y^22p_z^2$ and similar for $3p^6$ Ignore $1s^2$ repeated Ignore $4s^0$	(1)



Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to the following points: - calcium forms a +2 ion more readily as (the sum of) its first and second ionisation energies is lower (1) - as (calcium's atomic number is lower so) its nuclear charge is less or (calcium's metallic / atomic radius is greater so) its outer / valence electrons are further from the nucleus (1) - so the outer / valence electrons experience weaker attraction from the nucleus (1)	Allow reverse arguments Ignore references to group / period trends Allow it takes 1735 (kJ mol⁻¹) to form Ca²⁺ but 2245 (kJ mol⁻¹) to form Cr²⁺ so calcium forms a +2 ion most easily Allow just 'the ionisation energies of calcium are lower so it forms a +2 ion more easily' Allow calcium atoms have fewer protons Ignore shielding	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	green	Allow violet Ignore shades of colours e.g. pale / light Do not award mixed colours e.g. blue-green	(1)



Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	An explanation that makes reference to the following points - the (highly charged, small) Cr^{3+} ion weakens / polarises / distorts the O-H bonds (in the water ligands) (1) - allowing some water ligands to release hydrogen ions / to form the oxonium ion or water molecule (from the solution) deprotonates (one of) the water ligands (1)	Mark independently Allow Cr^{3+} forms dative bonds with the O (of H_2O) so the H is less strongly attached Accept M2 for correct equation $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + \text{H}_2\text{O} \rightleftharpoons [\text{Cr}(\text{H}_2\text{O})_5\text{OH}]^{2+} + \text{H}_3\text{O}^+$ Allow $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} \rightleftharpoons [\text{Cr}(\text{H}_2\text{O})_5\text{OH}]^{2+} + \text{H}^+$ Allow equations forming $[\text{Cr}(\text{H}_2\text{O})_4(\text{OH})_2]^+$ Allow just 'deprotonation of water ligand occurs' Allow H^+ ions released / donated from water ligands Ignore formation of $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$ and any chromium anions Ignore an acid-base reaction occurs Ignore chromium(III) hydroxide is amphoteric Ignore reference to sulfate ions forming sulfuric acid Do not award reference to ligand exchange	(2)

Question Number	Answer	Additional Guidance	Mark
7(d)	An answer that makes reference to the following points: • $E^\ominus_{\text{cell}} = -0.03\text{V}$ and so reaction / oxidation of chloride ions is not feasible (under standard conditions) (1) • (this is small so) changing the conditions may make $E^\ominus_{\text{cell}}$ positive so the oxidation reaction becomes feasible (1) • (it is possible under non-standard conditions if you) increase the concentration of $\text{HCl} / \text{H}^+ / \text{Cl}^-$ (1) • so equilibrium 1 moves to RHS or equilibrium 2 moves to LHS (so oxidation of Cl^- ions is more likely / feasible) (1)	Allow $E^\ominus_{\text{cell}} = +0.03\text{V}$ for the reduction of chlorine (so oxidation of chloride not feasible) Allow Eqm 1 $E^\ominus$ is more negative / less positive Allow proof using anti-clockwise rule Allow $E^\ominus_{\text{cell}}$ is close to 0V / only just negative (so some Cl^- ions are oxidised) Allow increase the concentration of H^+ / Cl^- Ignore increasing the concentration of $\text{Cr}_2\text{O}_7^{2-}$ ions Allow changing / increasing / decreasing the temperature Allow so eqm 1 $E^\ominus$ becomes more positive / better at accepting electrons Allow eqm 2 $E^\ominus$ becomes more negative / better at donating electrons Allow Cl_2 that forms escapes driving eqm 2 to LHS Allow increasing the concentration of $\text{Cr}_2\text{O}_7^{2-}$ ions moves equilibrium 1 to RHS (so oxidation of Cl^- ions is more likely / feasible)	(4)

(Total for Question 7 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
1(a)	An answer that makes reference to the following points: - energy (required) to remove / lose 1 electron / first electron / last electron from an / each atom (of an element) (1) - in 1 mol (e) of gaseous atoms (to form 1 mol of positive ions) (1)	Allow $e^{(-)}$ for electron 1 mol(e) must be referenced in either M1 or M2 to score both marks e.g. 'energy to remove 1 mol of electrons from gaseous atoms' scores 2 marks Correct example symbol or generic equation, for first IE, including state symbols scores 1 mark e.g. $X(g) \rightarrow X^+(g) + e^{(-)}$ / $X(g) - e^{(-)} \rightarrow X^+(g)$ Ignore references to standard conditions / standard states	(2)

Question Number	Answer	Additional Guidance	Mark
1(b)	An explanation that makes reference to the following points: - as there is a large difference / large increase / (large) jump / in ionisation energy between first and second ionisation energy / after first ionisation energy / before second ionisation energy (1) - Group 1 (1)	Allow there is a very large increase in 2nd IE Allow alkali metal M2 dependent on M1 Ignore reference to the subshell / orbital of the (outer) electron even if incorrect	(2)



Question Number	Answer	Additional Guidance	Mark
1(c)	An explanation that makes reference to the following points: • element X as it has the lowest (first) ionisation energy • as electron removed is furthest from nucleus • so there is greater shielding (even though there is an increase in the number of protons)	Penalise ionic radius once only (1) Allow X as the (first) ionisation energy decreases down the group Do not award reference to other ionisation energies (unless all are mentioned as being lower) (1) Allow 'outer electron' for 'electron removed' Allow atomic radius is greater Ignore more shells Do not award ionic radius (1) Allow greater repulsion from inner electron shells Allow 1 mark for there is less attraction between the nucleus and the outer electron if neither M2 or M3 is awarded. Allow 1 mark for 'Z, because the nuclear charge / number of protons is the greatest' Ignore effective nuclear charge	(3)

(Total for Question 1 = 7 marks)



Question Number	Answer	Mark
1(a)	The only correct answer is B ($\text{Al}^{2+}(\text{g}) \rightarrow \text{Al}^{3+}(\text{g}) + \text{e}^{-}$) <i>A is not correct because it is the equation for the first three ionisation energies</i> <i>C is not correct because an ion is gaining electrons</i> <i>D is not correct because an ion is gaining an electron</i>	(1)

Question Number	Answer	Mark
1(b)	The only correct answer is C (Y) <i>A is not correct because there is a steady increase in ionisation energies</i> <i>B is not correct because there is a steady increase in ionisation energies</i> <i>D is not correct because there is a large increase after the first ionisation energy, so Z is a Group 1 element</i>	(1)

Question Number	Answer	Mark
1(c)	The only correct answer is C (c) <i>A is not correct because it is carbon</i> <i>B is not correct because it is nitrogen</i> <i>D is not correct because it is aluminium</i>	(1)



Question Number	Answer	Additional Guidance	Mark
1(d)	$\text{N}^{3-} / \text{O}^{2-} / \text{F}^{-} / \text{Na}^{+} / \text{Al}^{3+}$	Do not award Ne , C^{4-} , Si^{4+}	(1)

Question Number	Answer	Additional guidance	Mark
1(e)	A discussion that makes reference to the following points: - both elements / atoms have the last added electron in the d-subshell / d orbital (so are d-block elements) (1) - but neither forms a (stable) ion with an incomplete d-subshell / d orbital (so are not transition metals) (1) Zn^{2+} is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ (so d subshell is full) (1) Sc^{3+} is $1s^2 2s^2 2p^6 3s^2 3p^6$ (so d subshell is empty) (1)	Do not award just ‘contains d electrons’ Allow ‘transition elements form a (stable) ion with an incomplete d-subshell / d orbital’ Allow $[\text{Ar}]3d^{10}$ Allow $[\text{Ar}]$	(4)

(Total Question 1 = 8 marks)



Question Number	Answer	Additional Guidance	Mark
6(a)(i)	dot-and-cross diagram and charges	<u>Example of diagram</u>  Circles are not needed Allow no electrons or 8 electrons on outer shell of Mg Allow dots or crosses for all electrons Allow diagrams without square brackets, provided charges are shown Allow alternative ways of showing that there are 2 bromide ions Ignore inner shell electrons	(1)

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	(conducts electricity when) molten / liquid and dissolved in water / (in) aqueous (solution)	Both needed for the mark Ignore gaseous Allow 'in solution / dissolved'	(1)

Question Number	Answer and Additional Guidance	Mark
6(b)(i)	Box 3 $\text{Mg}^{2+}(\text{g}) + 2\text{Br}(\text{g}) + 2\text{e}^{(-)}$ $2\Delta_{\text{at}}H[\frac{1}{2}\text{Br}_2(\text{l})]/2 \times (+)112/(+)224$ Box 2 $\text{Mg}^{2+}(\text{g}) + \text{Br}_2(\text{l}) + 2\text{e}^{(-)}$ $2^{\text{nd}} \text{IE}[\text{Mg}^{+}(\text{g})]/(+)1451$ Box 1 $\text{Mg}^{+}(\text{g}) + \text{Br}_2(\text{l}) + \text{e}^{(-)}$ $1^{\text{st}} \text{IE}[\text{Mg}(\text{g})]/(+)738$ $\text{Mg}(\text{g}) + \text{Br}_2(\text{l})$ $\Delta_{\text{at}}H[\text{Mg}(\text{g})]/(+)148$ $\text{Mg}(\text{s}) + \text{Br}_2(\text{l})$ $\Delta_{\text{f}}H[\text{MgBr}_2(\text{s})]/-524$ $\text{MgBr}_2(\text{s})$ $\text{Mg}^{2+}(\text{g}) + 2\text{Br}^{-}(\text{g})$ $2 \times \text{EA}[\text{Br}(\text{g})]$ $\text{Mg}^{2+}(\text{g}) + 2\text{Br}^{-}(\text{g})$ $\text{LE}[\text{MgBr}_2(\text{s})]/-2440$ Box 4 - Correct arrows with 1st and 2nd IE of Mg labelled and correct Mg symbols with state symbols in boxes 1 and 2 or 2 and 3 (1) $2 \times \Delta_{\text{at}}H[\frac{1}{2}\text{Br}_2(\text{l})] / 2 \times (+)112 / (+)224$ and $2\text{Br}(\text{g})$ in box 3 or 1 and $2 \times \text{EA}[\text{Br}(\text{g})]$ labelled and $2\text{Br}^{-}(\text{g})$ in box 4 and correct arrows (1) $\text{LE}[\text{MgBr}_2(\text{s})] / -2440$ labelled and arrow in correct direction (1) Allow any unambiguous labels for the arrows with words and/or numbers – state symbols not required Accept enthalpy change of atomisation of bromine before IEs of magnesium Ignore missing electrons / $2\text{e}^{(-)}$ in boxes 1, 2 and 3 Allow 1 state symbol missing but penalise 2 missing, or an incorrect state symbol in boxes once only	(3)

Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	- correct expression for 2 x EA(Br) in numbers or symbols (1) - calculation of EA(Br) (1)	<u>Example of calculation</u> $2 \times \text{EA}(\text{Br}) = - (2 \times +112) - (+1451) - (+738) - (+148) + (-524) - (-2440)$ $\text{EA}(\text{Br}) = \frac{-645}{2} = -322.5 / -323 \text{ (kJ mol}^{-1}\text{)}$ Correct answer with no working scores (2) Allow for 1 mark: (+)322.5 / (+)323 (wrong sign) -266.5 / -267 (2 missing from $\Delta_{\text{at}}H$ (Br)) -645 (2 missing from EA) -533 (both 2s missing for Br) Ignore units No TE on incorrect arrows in (b)(i)	(2)

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	An explanation that makes reference to the following points: Nuclear charge magnesium (atom) / Mg has more protons than sodium (atom) / Na or magnesium / Mg has a greater (effective) nuclear charge (than sodium / Na) (1) Shielding (outer) electron in magnesium (atom) / Mg in the same (quantum) shell / energy level / sub-shell / orbital as in a sodium atom / Na or shielding in magnesium atom / Mg similar to / same as that in sodium atom / Na (1) Attraction so the force of attraction between the nucleus and the (outer) electron is greater in magnesium (atom) / Mg (than in sodium atom / Na) (1)	Penalise reference to ion once only Ignore reference to atomic radius Allow correct E.C of both atoms Allow same number of (quantum) shells / energy levels in Mg and Na Allow the (outer) electron in Mg is held more tightly to the nucleus (than in Na) Note An answer that describes the trend across a period, without one reference to either sodium or magnesium, scores maximum (2) marks	(3)

Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	correct equation with state symbols	<u>Examples of equations</u> $\text{Mg}^{2+}(\text{g}) \rightarrow \text{Mg}^{3+}(\text{g}) + \text{e}^{(-)}$ $\text{Mg}^{2+}(\text{g}) - \text{e}^{(-)} \rightarrow \text{Mg}^{3+}(\text{g})$ Ignore state symbol for the electron Do not allow $\rightleftharpoons$	(1)

(Total for Question 6 = 11 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark									
8(a)(i)	- any 2 correct - all 3 correct (1) (2)	Example of table <table><tr><td>1st IE</td><td>2nd IE</td><td>3rd IE</td></tr><tr><td>(590)</td><td>(1145)</td><td>(4912)</td></tr><tr><td>4s</td><td>4s</td><td>3p</td></tr></table> Accept 3p_x / 3p_y / 3p_z for 3rd IE Ignore any superscript numbers by 4s and 3p Allow (1) for just 's, s, p' or 's, s, p' with one or more incorrect numbers in front	1 st IE	2 nd IE	3 rd IE	(590)	(1145)	(4912)	4s	4s	3p	(2)
1 st IE	2 nd IE	3 rd IE										
(590)	(1145)	(4912)										
4s	4s	3p										

Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)(ii)	correct equation	Examples of equations $\text{Ca}^{2+}(\text{g}) \rightarrow \text{Ca}^{3+}(\text{g}) + \text{e}^{(-)}$ or $\text{Ca}^{2+}(\text{g}) - \text{e}^{(-)} \rightarrow \text{Ca}^{3+}(\text{g})$ Correct state symbols are required Ignore any state symbol for the electron	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)(iii)	An explanation that makes reference to the following points: (there is a much larger difference between the 2nd and 3rd ionisation energies because the) 3rd electron is lost from a shell / energy level / sub-shell / (3p) orbital closer to the nucleus or the 3rd electron is lost from a shell / energy level / sub-shell / (3p) orbital of lower energy (1) (there is a smaller difference between the 1st and 2nd ionisation energies because the) 1st and 2nd electrons removed from the same shell / energy level / sub-level / orbital or the first two electrons experience similar shielding (from the inner electrons) or there is only a small change in electron-electron repulsion as the first two electrons are removed (1)	Ignore electron is lost from a full (sub-)shell / a full (sub-)shell is more stable Ignore just '3rd electron lost is more strongly attracted to the nucleus' Allow the same amount of shielding Allow the 3rd electron (to be lost) experiences less shielding (from inner electrons)	(2)

Question Number	Answer	Mark
8(b)	The only correct answer is B A is incorrect because $(-1031) + (79 + 520 + 159)$ is incorrect C is incorrect because $(-1031) + (79 + 520)$ is incorrect D is incorrect because $(-1031) + 79 + 520 + 159 - 616$ is incorrect	(1)



Question Number	Acceptable Answers	Additional Guidance	Mark												
8(c)*	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning.	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5-4	3														
3-2	2														
1	1														
0	0														



Comment:

Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning

General points to note

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

e.g.

penalise any reference to 'molecule' once only

or

penalise 'ion' not mentioned in word or formula at least once in answer, once only

Allow reverse arguments for IP3 to IP6 Ignore mention of stoichiometry Ignore references to electronegativity



	Indicative content IP1 - Ionic lithium chloride / LiCl (has very similar theoretical and experimental lattice energy values so) is (almost 100%) ionic IP2 - Covalency magnesium iodide / MgI₂ (has different theoretical and experimental lattice energy values so) has (some) covalent character IP3 - Charge on cations magnesium is Mg²⁺ and lithium is Li⁺ IP4 - Polarising – what does the polarising magnesium ion/Mg²⁺ is (more) polarising / has a large(r) polarising power (than lithium ion) IP5 - Size of anion iodide ion / I⁻ is larger (than chloride ion / Cl⁻) IP6 – Polarisable – what is polarised iodide ion / I⁻ is (more easily) polarised / distorted	Allow very small amount of / no covalent character in LiCl Allow assumption that ions act as point charges / are spherical is true for LiCl Allow MgI₂ more covalent character than LiCl Allow magnesium has 2+ charge and lithium has 1+ charge / magnesium ion has a larger charge than a lithium ion Allow charge density for charge Allow iodine ion / I⁻ is a large atom / has a large atomic radius Ignore size of cation Do not award iodide has a larger charge density Allow this shown in a diagram Ignore just 'greater attraction to cation'	
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(Total for Question 8 = 12 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)	An explanation that makes reference to the following points: - magnesium ion with correct structure and charge (1) - structure of two hydroxide ions with correct charge (1)	Handwritten diagrams showing the structure of a magnesium ion and two hydroxide ions. The magnesium ion is shown as Mg^{2+} with two outer shell electrons (represented by 'x' marks) and a charge of $2+$. The hydroxide ions are shown as OH^- with one outer shell electron (represented by 'x' marks) and a charge of $-$. The diagram shows two such ions, with a $\times 2$ multiplier. Allow Mg^{2+} with no electrons in the outer shell Ignore inner shell electrons Allow circle(s) of electron shells to be shown Allow square brackets missing Penalise incorrect symbols once	(2)

Question Number	Answer	Mark
8(b)	The only correct answer is B (The enthalpy change when 1 mol of an ionic substance dissolves in water to give an infinitely dilute solution.) <i>A is not correct as the mention of gaseous ions is incorrect</i> <i>C is not correct as the mention of gaseous ions is incorrect and the concentration is incorrect</i> <i>D is not correct as the concentration is incorrect</i>	(1)



Question Number	Answer and Additional Guidance	Mark
8(c)(i)	Box 3 $\text{Mg}^{2+}(\text{g}) + 2\text{F}(\text{g}) + 2\text{e}^{-}$ E / (+) 1451 Box 4 $\text{Mg}^{2+}(\text{g}) + 2\text{F}^{-}(\text{g})$ 2 x G or 2 x -328 / or -656 Box 2 $\text{Mg}^{+}(\text{g}) + 2\text{F}(\text{g}) + \text{e}^{-}$ D or (+) 738 Box 1 $\text{Mg}(\text{g}) + 2\text{F}(\text{g})$ 2 x F / or (+) 2 x 79 or (+) 158 C or (+) 148 $\text{Mg}(\text{g}) + \text{F}_2(\text{g})$ A $\text{Mg}(\text{s}) + \text{F}_2(\text{g})$ B or - 2957 $\text{MgF}_2(\text{s})$ • correct letters B, D, E, F, G or correct values corresponding to their cycle, G and B must be on the correct boxes (1) • multiplying F and G by 2 (must be seen on the cycle for this mark) (1) • correct formulae in every box (1) • state symbols and electrons (charge does not need to be shown on electrons) (1) Accept order of alternative order of boxes 2 – 3 – 1 with accompanying letters etc	(4)

Question Number	Acceptable Answer	Additional Guidance	Mark
8(c)(ii)	correct answer	<u>Example of calculation</u> $(148 + (2 \times 79) + 738 + 1451 + (-328 \times 2) + (-2957))$ $= -1118 \text{ (kJ mol}^{-1}\text{)}$ Comment if -1118 seen then award the mark no matter what their cycle indicates No TE on incorrect values mis-transcribed on their cycle Allow TE if matches cycle -790 scores 1 (electron affinity not doubled) -869 scores 1 (both values not doubled) -1197 scores 1 (atomisation not doubled)	(1)



Question Number	Acceptable Answer	Additional Guidance	Mark
8(c)(iii)	An explanation that makes reference to the following points: (theoretical and experimental values of MgF_2 are close / similar as) MgF_2 is (nearly) 100% ionic (1) (theoretical and experimental values of MgI_2 are different as) MgI_2 has some covalent character / more covalent character than MgF_2 (1) I^- / iodide ions are more polarisable (than F^- (ions)) / highly polarisable / because the I^- ions are larger / have a larger radius (1) - values for MgF_2 are more negative / more exothermic than for MgI_2 as the (ionic) bonding is stronger in MgF_2 (because the F^- ion is smaller than the I^- ion) (1)	Allow reverse argument throughout Allow MgF_2 is more ionic than MgI_2 Allow iodine ions / fluorine ions Allow I^- can be distorted more Allow bond between Mg and I more polarised as long as ions mentioned in response. Do not award species other than ions (e.g. atom, molecule) Do not award atomic radius is larger Allow 'higher' for 'more negative'	(4)

(Total for Question 8 = 12 marks)



Question Number	Answer	Additional Guidance	Mark
4(a)	An answer that makes reference to the following points (energy) released (1) - energy is required to overcome the (electrostatic) attraction from the nucleus for the electron (1)	Allow energy is required to remove an electron Allow (the removal of an electron) is endothermic	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)	An answer that includes - species in suitable equation (1) - state symbols (1)	<u>Example of equation</u> $\text{O}^+(\text{g}) \rightarrow \text{O}^{2+}(\text{g}) + \text{e}^-$ ALLOW $\text{O}^+(\text{g}) - \text{e}^- \rightarrow \text{O}^{2+}(\text{g})$ Ignore state symbols on electron Do not allow multiples for M1 M2 dependent on M1 or near miss	(2)

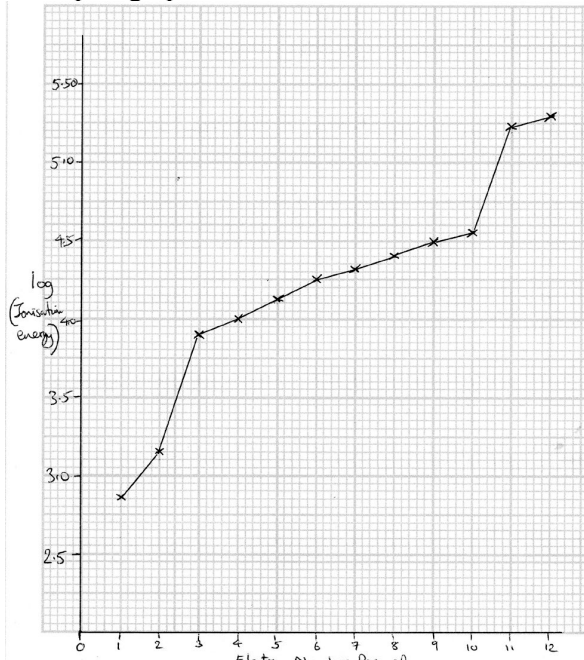


Question Number	Answer	Additional Guidance	Mark
4(c)	An explanation that makes reference to the following points - the outer electron in a sodium atom is closer to the nucleus (than that in potassium) (1) (and) less shielding from inner electron shells (1) - these outweigh the greater nuclear charge / number of protons in potassium (1)	Accept reverse arguments throughout Allow sodium atoms are smaller (than potassium) Allow sodium has electron in 3s whereas potassium has electron in 4s Allow diagram to illustrate Do not award reference to ionic radius Do not award if reference given to both have a +1 charge/ same nuclear charge	(3)
Question Number	Answer	Additional Guidance	Mark
4(d)(i)	completed table	4.26 and 5.28	(1)



Question Number	Answer	Additional Guidance	Mark
4(d)(ii)	An answer that includes the range of numbers / 738 to 189 371 is too large (to fit on a graph / axis) or logarithms make it easier to plot the numbers	Allow: a (very) long y axis would be needed (some of) the numbers are too large the difference between the ionisation energies is too large so the numbers will fit on the graph logs give smaller (range of) numbers Ignore simpler to read Do not award reference to averages	(1)

Question Number	Answer	Additional Guidance	Mark
4(d)(iii)	An answer that includes one of the following points the same number of protons is attracting a decreasing number of electrons or electron is removed from an increasingly positively charged ion or electron removed is closer to the nucleus or the electron removed is experiencing less electron-electron repulsion	Do not award each electron is removed from shells closer to the nucleus	(1)

Question Number	Answer	Additional Guidance	Mark
4(d)(iv)	An answer that includes a suitable graph - labelled axes - suitable scale - plotting of points and lines joining points	(1) Do not award if any units given on y axis (1) Plotted points must cover at least $\frac{1}{2}$ the graph paper on each axis (1) Allow $\pm\frac{1}{2}$ square Do not award line going from point 1 to the origin Ignore plotting of electron 6 and 12 Exemplar graph  The exemplar graph is plotted on a grid. The y-axis is labeled 'log (Ionisation Energy)' and has major ticks at 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, and 5.5. The x-axis is labeled 'Electron Number Removed' and has major ticks from 0 to 12. The data points are plotted at approximately (1, 2.9), (2, 3.2), (3, 4.0), (4, 4.1), (5, 4.2), (6, 4.3), (7, 4.4), (8, 4.5), (9, 4.6), (10, 4.7), (11, 5.3), and (12, 5.4). Lines connect the points from 1 to 2, 2 to 3, 3 to 4, 4 to 5, 5 to 6, 6 to 7, 7 to 8, 8 to 9, 9 to 10, 10 to 11, and 11 to 12. There is a significant jump in the log ionisation energy between electron 10 and electron 11.	(3)

Question Number	Answer	Additional Guidance	Mark
4(d)(v)	An answer that includes circle around the first two points/circles around individual points	Exemplar circle on graph 	(1)
4(e)	An answer that includes (estimated value) between 1100 – 1380 (kJ mol⁻¹)		(1)

(Total Question 4 = 15 marks)



Question Number	Answer	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: - nitrogen above both carbon and oxygen and below fluorine - oxygen below both nitrogen and fluorine and above carbon - sodium below lithium	<u>Example of graph</u> First ionisation energy / kJ mol^{-1} Element Accept just points Penalise plots on x-axis between elements once only	(3)

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following points: (the value for) beryllium is higher than lithium - as beryllium has one more proton / a higher nuclear charge - shielding is the same / similar in beryllium and lithium or - electron repulsion is the same / similar in beryllium and lithium or - the outer electron is a same / similar distance from the nucleus or - the outer electron is in the same / 2s orbital (the value for) beryllium is higher than boron - as the outer electron in boron is in the (2)p orbital / subshell (rather than the 2s orbital in beryllium) - the effect of the additional proton / increased nuclear charge in boron is outweighed by increased shielding / repulsion (from inner subshell)	Allow reverse argument throughout Penalise omission of 'outer' once only Ignore electron configurations unless incorrect Allow greater proton number Ignore reference to atomic or ionic radius Allow outer electron in B is in a higher energy level Allow by increased distance from the nucleus (of the outer electron in B)	(4)

Question Number	Answer	Additional Guidance	Mark
2(c)	An answer that makes reference to the following point: correct equation with state symbols	$\text{Be}^+(\text{g}) \rightarrow \text{Be}^{2+}(\text{g}) + \text{e}^{(-)}$ Allow $\text{Be}^+(\text{g}) - \text{e}^{(-)} \rightarrow \text{Be}^{2+}(\text{g})$ Ignore state symbol for the electron Do not allow $\rightleftharpoons$	(1)

Question Number	Answer	Mark
2(d)	The only correct answer is C (4s) <i>A is not correct because this would be Mg</i> <i>B is not correct because this could relate to a p-block element in period 3</i> <i>D is not correct because this could relate to a p-block element in period 4</i>	(1)

Question Number	Answer	Mark
2(e)	The only correct answer is A (S^{2-}) <i>B is not correct because the ionic radius of Cl^- is smaller than S^{2-} as it has one more proton</i> <i>C is not correct because the ionic radius of K^+ is smaller than both S^{2-} and Cl^- as it has more protons</i> <i>D is not correct because Ca^{2+} has the smallest ionic radius since it has the most protons</i>	(1)



Question Number	Answer	Additional Guidance	Mark
2(f)	An answer that makes reference to the following points: - hydrogen bonding is the strongest intermolecular force (1) - there is hydrogen bonding between H₂O (molecules) and between HF (molecules) (1) - H₂O has two hydrogen bonds (per molecule, as it has two lone pairs on the oxygen) and so its boiling temperature is higher than HF (1) - there are permanent dipoles between the HCl molecules (1) - there are stronger / more London forces between HI (molecules) than HCl (molecules) because there are more electrons (in a molecule of HI) (1) (the increased) London forces between HI (molecules) outweigh the permanent dipole forces (between HCl (molecules)) (1)	Penalise reference to covalent bonds breaking once only Allow H bonds take more energy to break than other types of intermolecular force Allow water can form twice as many hydrogen bonds (than HF) Ignore H₂O has more hydrogen bonds Allow HCl has dipole-dipole (forces) Ignore HI has a permanent dipole Accept van der Waals / temporary dipole – induced dipole Allow London forces require more energy to break / be overcome than permanent dipole (forces) Allow London forces outweigh the (greater) electronegativity difference between H and Cl	(6)

(Total for Question 2 = 16 marks)



Question Number	Answer	Additional guidance	Mark
4	An explanation that makes reference the following trends: Na, Mg and Al - Na, Mg and Al have metallic bonding (in a giant lattice) (1) - charge on ion increases / (cation) radius decreases / charge density increases (so strength of metallic bonding increases and melting temperature increases) (1) Si - Si is giant covalent (lattice) / giant molecular / macromolecular (1) - so a lot of energy required to break (many strong) covalent bonds (and it has the highest melting temperature) (1) P (large decrease from Si to) phosphorus as it consists of simple / discrete molecules / is simple molecular (1) - so only weak London forces (are broken on melting) (1)	Allow marks for any relevant annotations on the graph Ignore reference to boiling point Ignore general trends across the period Allow description of metallic bonding – attraction between cations and delocalised electrons Ignore aluminium missing from answer Do not award simple molecular / London forces / ionic for any of these metals Allow increasing number / more delocalised electrons Allow atomic radius decreases Ignore nuclear charge / number of protons increases Ignore any explanation about why Al has similar melting temperature to Mg Do not award silicon has metallic bonding / London forces Allow a lot of energy is needed to overcome the electrostatic forces (in the covalent bonds) Ignore covalent bonding is stronger than metallic bonding Allow P₄ molecules Ignore formula of phosphorus even if incorrect Do not award phosphorus has ionic / metallic bonding / permanent dipoles / hydrogen bonding Allow London forces are weaker than covalent bonds / covalent bonds are stronger than London forces Allow not a lot of energy is required to overcome the (London) forces Allow just ‘weak intermolecular forces’ Do not award covalent bonds broken in P Allow dispersion / temporary dipole-induced dipole / instantaneous dipole / van der Waals forces as alternatives to London forces throughout Ignore abbreviations e.g. LDF / VDW / ID-ID	(6)

(Total Question 4 = 6 marks)

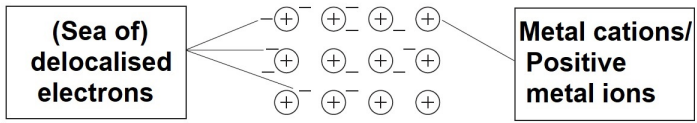


Question Number	Answer	Additional Guidance	Mark
1(a)	An answer that makes reference to: - addition of (dilute/strong) name/formula of acid (1) - effervescence/bubbling/fizzing (1)	Allow weak acids If formula given then must be correct Allow Gas given off which turns limewater cloudy Do not award just 'gas/ CO₂ given off' Do not award incorrect observations such as precipitate forming due to addition of acid M2 dependent on M1 or 'near miss'	(2)

Question Number	Answer	Additional Guidance	Mark
1(b)	An answer that makes reference to: - addition of barium chloride/nitrate (solution) (1) - white precipitate forms (1)	Accept formulae BaCl₂/Ba(NO₃)₂ Ignore addition of acids such as HCl or HNO₃ but do not award M1 if addition of sulfuric acid Allow white solid If ppt identified then must be correct M2 dependent on M1 or 'near miss'	(2)

(Total Question 1 = 4 marks)



Question Number	Answer	Additional Guidance	Mark
3(a)	An answer that makes reference to the following points - metal cations in a ‘sea’ of delocalised electrons (1) (metallic bonding is the strong) electrostatic attraction between (cations and electrons) (1)	ACCEPT suitable annotated diagram ALLOW reference to metal ions IGNORE ‘free’ electrons/positive nucleus Do not award reference to molecules Example diagram  Approximately equal numbers of positive ions and negative electrons	(2)



Question Number	Answer	Additional Guidance	Mark
3(b)	An answer that makes reference to the following points • adsorption of CO and/or NO molecules on the catalytic surface (1) • weakening of bonds (and chemical reaction between CO and NO) (1) • desorption of CO₂ and/or N₂ /product (molecules) from the catalytic surface (1)	Allow 'active site' for surface Do not award absorption Do not award weaken the bonds between molecules Allow bonds break (within CO and NO) Allow de-adsorption for desorption Do not award desorption of the reactants Do not award reference to incorrect products such as H₂/O₂/C/NO₂ Penalise omission of catalytic surface once only	(3)

(Total Question 3 = 5 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)(i)	An answer that makes reference to the following point: the two negative ions repel each other	Reference to both charge and repulsion needed	(1)

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	An explanation that makes reference to the following points: - equation with oxidation of iron(II) ions (1) - equation with reduction of iron(III) ions (1) (catalysis is possible because) variable oxidation state/iron has more than one oxidation state/number or both steps now involve oppositely charged ions (1)	<u>Example of equations</u> $2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$ $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$ Allow multiples Ignore state symbols even if incorrect Allow one mark if the two correct equation are given in the wrong order Allow reference to iron being oxidised and reduced Allow reference to the iron ions being positive and so not repelled	(3)



Question Number	Answer	Additional Guidance	Mark
5(b)	- equation with oxidation of cobalt(II) ions - equation with reduction of cobalt(III) ions	<u>Example of equations</u> $2\text{Co}^{2+} + \frac{1}{2}\text{O}_2 + 2\text{H}^+ \rightarrow 2\text{Co}^{3+} + \text{H}_2\text{O}$ $2\text{Co}^{3+} + \text{SO}_3^{2-} + \text{H}_2\text{O} \rightarrow 2\text{Co}^{2+} + \text{SO}_4^{2-} + 2\text{H}^+$ Allow multiples Ignore state symbols even if incorrect	(2)

Question Number	Answer	Mark
5(c)	The only correct answer is C <i>A is not correct because only Mn^{2+} is an autocatalyst for this reaction</i> <i>B is not correct because only Mn^{2+} is an autocatalyst for this reaction</i> <i>D is not correct because only Mn^{2+} is an autocatalyst for this reaction</i>	(1)

Question Number	Answer	Additional Guidance	Mark
5(d)	Tungsten (because) adsorption is too strong and so desorption would be too slow	Ignore references to oxidation or reactivity series or cost Do not award 'absorption'	(1)

(Total Question 5 = 8 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)(i)	(The cation in X is) Fe^{2+} / iron(II) / Fe(II) (1) (The anion in X is) SO_4^{2-} / sulfate(VI) (1)	Allow Fe^{+2} Allow sulfate / SO_4^{-2} Do not award sulfite / sulfate(IV)	(2)

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	- species and balancing (1) - state symbols (1)	<u>Examples of equation</u> $\text{Fe}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Fe}(\text{OH})_2(\text{s})$ or $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Fe}(\text{OH})_2(\text{s}) + 6\text{H}_2\text{O}(\text{l})$ or $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4(\text{s}) + 2\text{H}_2\text{O}(\text{l})$ Ignore missing square brackets TE on cation that forms an insoluble hydroxide in Test 1 State symbols conditional on correct species or ‘near miss’ / non-ionic equation	(2)



Question Number	Answer	Additional Guidance	Mark
5(a)(iii)	An answer that makes reference to the following point: • Fe^{2+} is oxidised (to Fe^{3+}) by oxygen / air	Allow iron(III) hydroxide / iron(III) (ions) are formed by reaction with oxygen / air TE on cation in Test 1 Allow just 'the precipitate / it is oxidised by oxygen / air'	(1)

Question Number	Answer	Additional Guidance	Mark
5(a)(iv)	An answer that makes reference to the following point: • to react with / remove any carbonate / sulfite / sulfate(IV) ions or to eliminate the possibility of carbonate / sulfite / sulfate(IV) ions	Allow to prevent any other ions forming a precipitate with barium ions / Ba^{2+}	(1)

Question Number	Answer	Additional Guidance	Mark
5(b)(i)	• (The cation in Y is) Cu^{2+} / copper(II) (1) • (The anion in Y is) Cl^- / chloride (1)	Allow Cu^{+2} Ignore water ligands Do not award just copper / Cu Do not award just 'chlorine' / Cl	(2)



Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$	Allow $[\text{Cu}(\text{NH}_3)_4]^{2+}$ Allow $[\text{Co}(\text{NH}_3)_6]^{2+}$ if Co^{2+} in (i) Ignore missing square brackets	(1)

Question Number	Answer	Additional Guidance	Mark
5(b)(iii)	A description that makes reference to the following points: - add dilute (aqueous) ammonia (and stir the mixture) - the precipitate dissolves	If Cl^- / chloride / chlorine ion: Allow add aqueous ammonia / $\text{NH}_3(\text{aq})$ Do not award concentrated ammonia Conditional on use of ammonia Ignore colourless solution If Br^- / bromide / bromine ion identified in Test 4: precipitate is insoluble in dilute ammonia (1) but soluble in concentrated ammonia (1) If I^- / iodide / iodine ion identified in test 4: precipitate is insoluble (1) in dilute and concentrated ammonia (1) Do not award addition of concentrated sulfuric acid	(2)

(Total for Question 5 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	(crystals will be small enough) to get through (pores in) the filter paper	Ignore references to just not being filtered Do not award references to crystals being 'stuck' on the filter paper or dissolving	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)	An explanation that makes reference to the following points: - to remove (excess) $\text{BaCl}_2(\text{aq})$ / $\text{MCl}(\text{aq})$ - which would otherwise crystallise / add to mass (of sulfate)	(1) Allow to remove remaining solution Allow reference to removing filtrate Ignore reference to residue (1) Allow reference to 'change the mass' Do not award a decrease in mass If no other mark awarded then allow (1) for to remove (soluble) impurities Do not award removal of solid impurities	(2)



Question Number	Answer	Additional Guidance	Mark
3(c)	- calculation of moles of BaSO_4 - calculation of RFM of M_2SO_4 - deduction of identity of M	(1) $1.02 \div 233.4 = 4.3702 \times 10^{-3} / 0.0043702 \text{ (mol)}$ (1) $0.48 \div 4.3702 \times 10^{-3} = 109.84 / 110 \text{ (g mol}^{-1}\text{)}$ Ignore SF except 1 SF for M1 and M2 (1) $(109.84 - (32.1 + 64) = 13.74 \text{ hence } A_r \text{ of M} = 6.87 / 6.9) \text{ so M} = \text{Li}$ Allow Li^+ Ignore SF for M3 Allow TE from M1 to M2 Allow TE from M2 to M3 provided value is positive and linked to an appropriate metal that can form a +1 ion Correct answer without working scores (1)	(3)



Question Number	Answer	Additional Guidance	Mark
3(d)(i)	An explanation that makes reference to the following points: (some of) M_2SO_4 (solution) would be lost (from the beaker) (1) - so (calculated) moles/amount (of M_2SO_4) would be less and (calculated) formula mass would be more/higher (1)	Allow just some of the solution would be lost Allow reference to moles of $BaSO_4$ for M_2SO_4 Ignore less mass of $BaSO_4$ Allow M2 for answers that show understanding of the negligible change (of RFM) M2 dependent upon M1 attempt Allow M2 for a TE such as the moles of M_2SO_4 would be more which results in a lower RFM provided the answer states that the mass has increased	(2)

Question Number	Answer	Additional Guidance	Mark
3(d)(ii)	rinse glass rod with deionised/distilled water into the beaker	Allow wash for rinse Allow 'to the solution' for "into the beaker" Do not award rinsings go down the sink References to the use of a magnetic stirrer can score if rinsing is mentioned of the 'flea'	(1)



Question Number	Answer	Additional Guidance	Mark
3(e)(i)	An explanation that makes reference to the following points: - heat causes electrons to be promoted / excited / move to a higher energy level (1) - light is emitted when electrons fall back (to lower level / ground state) (1)	Electrons need to be mentioned once in M1 or M2 Allow just 'energy (from flame) causes electrons to be promoted/excited' Accept reference to photons for light Allow released/ given out for emitted Ignore reference to just energy Do not award reference to complementary colours/absorption colour Do not award reference to reflected/transmitted	(2)

Question Number	Answer	Additional Guidance	Mark
3(e)(ii)	An answer that makes reference to the following points: - Advantage – simpler (process) / quicker (process) (1) - Disadvantage – flame colours are subjective (by eye) / some metal (ions) produce very similar flame colours (by eye) / often more than one colour may be seen (due to contamination) (1)	Allow just 'easier' Ignore just 'cheaper' Ignore references to more accurate Allow several metal (ions) produce red flames / not all metal (ions) produce a flame colour (in the visible range) If metals are named then their colours must be correct	(2)

(Total for Question 3 = 13 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(i)	An answer that makes reference to the following points: - cool the mixture because the reaction (with concentrated sulfuric acid / H_2SO_4) is (very) exothermic / releases (a lot of) heat (1) - anti-bumping granules are added to prevent violent / sudden / localised boiling or to prevent superheating / large bubbles forming or to promote smooth / even / controlled boiling or to promote the formation of small bubbles or to provide nucleation centres / (rough) surface for bubble formation (1) - heating under reflux is used to prevent the loss of any volatile substances / volatile reactants / volatile products / organic compound / named organic compound or to make sure the vapour / gas condenses or to prevent vapour escaping (1)	Ignore reaction is violent / to prevent splashing / to slow down the reaction / to stop reactants evaporating Do not award to quench the reaction / reference to explosion Ignore to stop bumping / spitting / explosion / liquid splashing out / vigorous reaction / loss of reactants / to distribute heat more evenly / any reference to rate / to promote smooth heating Allow so that the reaction goes to completion Ignore just 'to prevent gas escaping' / just 'to prevent loss of reactants / products' / just 'reactants / products are volatile' / 'because 1-bromobutane / butan-1-ol is flammable' / to increase yield / reference to safety Do not award for reference to oxidation or reduction	(3)



Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(ii)	An answer that makes reference to the following points: - there is a gap between the condenser and the flask / seal the joint between the flask and condenser and so vapour / gas / reactants / products will escape (1) - the water is flowing the wrong way through the condenser / the water should go in at the bottom (and out at the top) and so it doesn't fill with water / is only part filled /there is an airlock (1) - there is a stopper on the condenser / there should not be a stopper on the condenser and so there will be a build-up of pressure (if the gap between condenser and flask is closed) (1)	Allow answers shown on annotated diagram e.g. gap circled Ignore any additional errors Ignore additional suggested modifications even if incorrect Do not award just 'the apparatus is not sealed' unless it is clear it means between the condenser and flask Allow so this will lower the yield of product / 1-bromobutane Ignore condenser is fitted the wrong way up Allow so there will be inefficient condensation / cooling Allow so the stopper will blow off / there will be an explosion / it will be dangerous	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(iii)	An explanation that makes reference to the following points: (brown vapour / it) is bromine / Br₂ (1) - bromide ions / Br⁻ / HBr oxidised (by concentrated sulfuric acid) (1)	Stand alone mark Do not award just 'Br' Do not award any other brown gas in addition to bromine Allow bromide ions / Br⁻ / HBr reduce sulfuric acid / act as a reducing agent Ignore sodium bromide / NaBr is oxidised Ignore just 'redox reaction' Do not award bromine is oxidised Do not award oxidation by anything other than sulfuric acid	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(i)	An answer that makes reference to the following: aqueous layer is on the top and because water / it has a lower density than 1-bromobutane	Allow 'it' for aqueous layer Allow because 1-bromobutane has a higher density than water Ignore reference to butanol unless in a third layer Do not award water is 'lighter' Do not award reference to three layers	(1)



Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(ii)	An answer that makes reference to the following points: Step 8 (aqueous sodium hydrogencarbonate / NaHCO_3) reacts with / neutralises / removes the (hydrochloric) acid / H^+ (ions) in the mixture (1) Step 9 (the tap is opened) to release the carbon dioxide / gas (formed) or to allow the carbon dioxide / gas to escape or to prevent the build-up of pressure (1) Step 10 (anhydrous sodium sulfate is added) to remove / absorb water (1)	Do not award reacts with incorrect acid e.g. H_2SO_4 / HBr / ethanoic acid Ignore removes water Do not award an incorrect gas e.g. hydrogen Allow (anhydrous) sodium sulfate is a drying agent / added to dry the product Do not award dehydration / reacts with water	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(iii)	starting temperature 99 or 100 or 101 ($^{\circ}\text{C}$) and final temperature 103 or 104 or 105 ($^{\circ}\text{C}$)	Do not award just one value / 102 ($^{\circ}\text{C}$) Do not award 102 ($^{\circ}\text{C}$) with another temperature	(1)

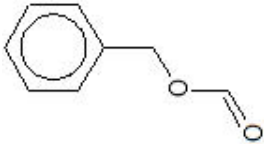
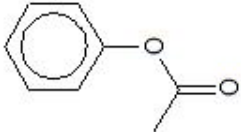
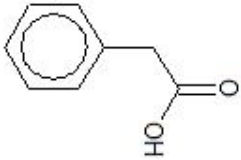
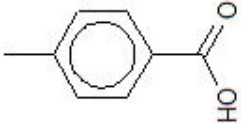


Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(iv)	- calculation of mol of 1-bromobutane (1) - calculation of number of molecules and answer to 2/3 SF (1)	<u>Example of calculation</u> mol of 1-bromobutane = $\frac{12.0 \times 1.27}{136.9}$ = 0.11132 (mol) Do not award 0.1 number of molecules = $0.11132 \times 6.02 \times 10^{23}$ = $6.7 \times 10^{22} / 6.70 \times 10^{22}$ TE on a calculated mol 1-bromobutane using M_r Correct answer to 2 or 3 SF with no working scores (2)	(2)

(Total for Question 8 = 15 marks)



Question Number	Answer	Additional Guidance	Mark
9(a)(i)	An answer that makes reference to one of the following points: - benzoate (ion) / sodium benzoate / (sodium) salt produced (not benzoic acid) - or - the hydrogen ion protonates the benzoate ion - or - equation	Allow (acid needed) to displace the sodium (ion) and form benzoic acid Allow the benzoic acid is deprotonated in the hydrolysis e.g.  Allow the answer given in general terms of a carboxylate ion being protonated to the carboxylic acid or to protonate the conjugate base to give the acid Ignore reference to neutralising the hydroxide ions	(1)
Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	equation	<u>Example of equation</u> $\text{C}_6\text{H}_5\text{COOCH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{C}_6\text{H}_5\text{COOH} + \text{CH}_3\text{OH}$ Allow use of $\text{C}_6\text{H}_5\text{CO}_2\text{CH}_3$ and $\text{C}_6\text{H}_5\text{CO}_2\text{H}$ Allow $\rightarrow$ for $\rightleftharpoons$ Allow displayed, semi-displayed, skeletal formulae Ignore state symbols even if incorrect Ignore H^+ or stated acid above the arrow Do not award molecular formulae	(1)

Question Number	Answer	Additional Guidance	Mark
9(b)	An answer that makes reference to the following points: (M1) structure of W (M2) structure of X (M3) (justification for W and X) both have ester group and W must have HCOO group (and are monosubstituted) (M4) structure of Y (M5) (justification for Y) has a carboxylic acid group / COOH group (since carbonate broken down to give carbon dioxide and is monosubstituted) (M6) structure of Z (M7) (justification for Z) 1,4 / para orientation/ 6 different carbon environments (to give only 6 NMR peaks) and has a carboxylic acid group/COOH group/ makes an ester (with ethanol)	Accept displayed / structural formulae (1)  (1)  (1) Accept X is made from ethanoic acid (1)  (1) Allow acid group (1)  Allow 6 environments shown on a diagram Allow acid group	(7)

Question Number	Answer	Additional Guidance	Mark
9(c)(i)	- electron pair movement from ring to electrophile (1) - formula of intermediate ion (1) - curly arrow from C-H to reform delocalised ring (and correct piceol product) (1) - regeneration of catalyst (1)	Example of mechanism $[AlCl_4]^- + H^+ \longrightarrow AlCl_3 + HCl$ Allow arrow starting anywhere within the hexagon Do not award curly arrow that ends at the CH_3 ‘Horseshoe’ to cover at least three carbon atom and face the tetrahedral carbon and with some part of the plus sign inside ‘horseshoe’ Do not award dotted bonds unless part of a 3D structure Regeneration of catalyst can be shown as part of reaction mechanism where the $AlCl_4^-$ attacks the H which is being lost from the ring Square brackets around $AlCl_4^-$ are not essential Allow any Friedel-Crafts catalyst that would work, e.g. iron(III) halides Allow Kekulé structures	(4)

Question Number	Answer	Additional Guidance	Mark
9(c)(ii)	An answer that makes reference to the following point: - alkaline iodine / NaOH and I₂ or NaOCl with KI (pale) yellow precipitate / solid	Ignore triiodomethane test/iodoform test Ignore concentrations Allow antiseptic smell M2 dependent on M1 or 'near miss' e.g. iodoform	(2)

(Total Question 9 = 15 marks)

