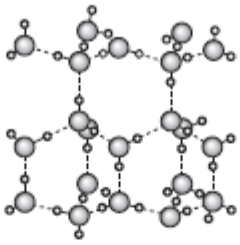
1 (a) The following diagram shows the arrangement of some of the water molecules in a crystal of ice.



With reference to the structure shown above give **one** reason why ice is less dense than water.

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(1 mark)

1 (b) Water and methane have similar relative molecular masses and both contain the element hydrogen.
The table below gives some information about water and methane.

	H_2O	CH_4
M_r	18.0	16.0
Melting point / K	273	91

1 (b) (i) State the strongest type of intermolecular force holding the water molecules together in the ice crystal.

.....

(1 mark)

1 (b) (ii) State the strongest type of intermolecular force in methane.

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(1 mark)

1 (b) (iii) Give **one** reason why the melting point of ice is higher than the melting point of methane.

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(1 mark)

1 (c) A molecule of H_2O can react with an H^+ ion to form an H_3O^+ ion.

1 (c) (i) Draw and name the shape of the H_3O^+ ion. Include any lone pairs of electrons.

Shape of the H_3O^+ ion

Name of shape.....

(2 marks)

1 (c) (ii) Suggest a value for the bond angle in the H_3O^+ ion.

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(1 mark)

1 (c) (iii) Identify **one** molecule with the same number of atoms, the same number of electrons and the same shape as the H_3O^+ ion.

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(1 mark)

1 (d) Water can also form the hydroxide ion.
State the number of lone pairs of electrons in the hydroxide ion.

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(1 mark)

2 Indium is in Group 3 in the Periodic Table and exists as a mixture of the isotopes ^{113}In and ^{115}In.

2 (a) Use your understanding of the Periodic Table to complete the electron configuration of indium.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$ .....

(1 mark)

2 (b) A sample of indium must be ionised before it can be analysed in a mass spectrometer.

2 (b) (i) State what is used to ionise a sample of indium in a mass spectrometer.

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(1 mark)

2 (b) (ii) Write an equation, including state symbols, for the ionisation of indium that requires the minimum energy.

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(1 mark)

2 (b) (iii) State why more than the minimum energy is **not** used to ionise the sample of indium.

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(1 mark)

2 (b) (iv) Give two reasons why the sample of indium must be ionised.

Reason 1 .....

Reason 2 .....

(2 marks)

2 (c) A mass spectrum of a sample of indium showed two peaks at *m*/z = 113 and *m*/z = 115. The relative atomic mass of this sample of indium is 114.5

2 (c) (i) Give the meaning of the term *relative atomic mass*.

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(2 marks)

2 (c) (ii) Use these data to calculate the ratio of the relative abundances of the two isotopes.

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(2 marks)

(Extra space) .....

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2 (d) State and explain the difference, if any, between the chemical properties of the isotopes ^{113}In and ^{115}In

Difference in chemical properties .....

Explanation .....

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(2 marks)

2 (e) Indium forms a compound **X** with hydrogen and oxygen. Compound **X** contains 69.2% indium and 1.8% hydrogen by mass.
Calculate the empirical formula of compound **X**.

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(3 marks)

3 (a) An unknown metal carbonate reacts with hydrochloric acid according to the following equation.

$$M_2CO_3(aq) + 2HCl(aq) \longrightarrow 2MCl(aq) + CO_2(g) + H_2O(l)$$

A 3.44 g sample of M_2CO_3 was dissolved in distilled water to make 250 cm^3 of solution. A 25.0 cm^3 portion of this solution required 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid for complete reaction.

3 (a) (i) Calculate the amount, in moles, of HCl in 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid. Give your answer to 3 significant figures.

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(1 mark)

3 (a) (ii) Calculate the amount, in moles, of M_2CO_3 that reacted with this amount of HCl. Give your answer to 3 significant figures.

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(1 mark)

3 (a) (iii) Calculate the amount, in moles, of M_2CO_3 in the 3.44 g sample. Give your answer to 3 significant figures.

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(1 mark)

3 (a) (iv) Calculate the relative formula mass, M_r, of M_2CO_3
Give your answer to 1 decimal place.

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(1 mark)

3 (a) (v) Hence determine the relative atomic mass, A_r, of the metal M and deduce its identity.

A_r of M .....

Identity of M .....

(2 marks)

3 (b) In another experiment, 0.658 mol of CO_2 was produced. This gas occupied a volume of 0.0220 m^3 at a pressure of 100 kPa.
Calculate the temperature of this CO_2 and state the units.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(3 marks)

3 (c) Suggest **one** possible danger when a metal carbonate is reacted with an acid in a sealed flask.

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(1 mark)

3 (d) In a different experiment, 6.27 g of magnesium carbonate were added to an excess of sulfuric acid. The following reaction occurred.

$$MgCO_3 + H_2SO_4 \longrightarrow MgSO_4 + CO_2 + H_2O$$

3 (d) (i) Calculate the amount, in moles, of $MgCO_3$ in 6.27 g of magnesium carbonate.

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(2 marks)

3 (d) (ii) Calculate the mass of $MgSO_4$ produced in this reaction assuming a 95% yield.

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(3 marks)

4 The following table gives the melting points of some elements in Period 3.

Element	Na	Al	Si	P	S
Melting point / K	371	933	1680	317	392

(a) State the type of structure shown by a crystal of silicon.
Explain why the melting point of silicon is very high.

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(3 marks)

(Extra space) .....

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(b) State the type of structure shown by crystals of sulfur and phosphorus.
Explain why the melting point of sulfur is higher than the melting point of phosphorus.

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(3 marks)

(Extra space) .....

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(c) Draw a diagram to show how the particles are arranged in aluminium and explain why aluminium is malleable.
(You should show a minimum of six aluminium particles arranged in two dimensions.)

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(3 marks)

(Extra space) .....

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(d) Explain why the melting point of aluminium is higher than the melting point of sodium.

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(3 marks)

(Extra space) .....

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5 A sample of nitrogen dioxide gas (NO_2) was prepared by the reaction of copper with concentrated nitric acid.

5 (a) (i) Balance the equation for the reaction of copper with concentrated nitric acid.

$$Cu + \ldots\ldots HNO_3 \longrightarrow Cu(NO_3)_2 + \ldots\ldots NO_2 + \ldots\ldots H_2O$$

(1 mark)

5 (a) (ii) Give the oxidation state of nitrogen in each of the following compounds.

HNO_3 .....

NO_2 .....

(2 marks)

5 (a) (iii) Deduce the half-equation for the conversion of HNO_3 into NO_2 in this reaction.

.....

(1 mark)

5 (b) The following equilibrium is established between colourless dinitrogen tetraoxide gas (N_2O_4) and dark brown nitrogen dioxide gas.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +58\,kJ\,mol^{-1}$$

5 (b) (i) Give two features of a reaction at equilibrium.

Feature 1 .....

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Feature 2 .....

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(2 marks)

5 (b) (ii) Use Le Chatelier's principle to explain why the mixture of gases becomes darker in colour when the mixture is heated at constant pressure.

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(2 marks)

5 (b) (iii) Use Le Chatelier's principle to explain why the amount of NO_2 decreases when the pressure is increased at constant temperature.

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(2 marks)

6 Metals can be extracted by different methods.

(a) Give **one** reason why titanium cannot be extracted directly from titanium(IV) oxide using carbon.

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(1 mark)

(b) Titanium steel is an alloy of titanium and iron. Titanium steel is extracted from the mineral ilmenite ($FeTiO_3$) in a two-stage process.
Purified $FeTiO_3$ is first converted into a mixture of two metal chlorides. These two metal chlorides are then reduced simultaneously using sodium.

(b) (i) Write an equation for the reaction of $FeTiO_3$ with chlorine and carbon to produce iron(III) chloride ($FeCl_3$), titanium(IV) chloride and carbon monoxide.

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(1 mark)

(b) (ii) Write an equation for the simultaneous reduction of the mixture of iron(III) chloride and titanium(IV) chloride to iron and titanium using sodium.

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(1 mark)

(c) Scrap iron is used to extract copper from dilute aqueous solutions containing copper(II) ions.
Explain, in terms of redox, what happens to the copper(II) ions in this extraction.

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(2 marks)

(d) Aluminium is an expensive metal because it is extracted from molten aluminium oxide using electrolysis.
Write the half-equation for the reaction that occurs at the positive electrode during this extraction.

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(1 mark)