1)

Ammonium sulfate reacts with sodium hydroxide to form ammonia, sodium sulfate and water as shown in the equation below.

$$(NH_4)_2SO_4(s) + 2NaOH(aq) \longrightarrow 2NH_3(g) + Na_2SO_4(aq) + 2H_2O(l)$$

(a) A 3.14 g sample of ammonium sulfate reacted completely with 39.30 cm^3 of a sodium hydroxide solution.

(a) (i) Calculate the amount, in moles, of $(NH_4)_2SO_4$ in 3.14 g of ammonium sulfate.

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(2 marks)

(a) (ii) Hence calculate the amount, in moles, of sodium hydroxide which reacted.

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(1 mark)

(a) (iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution used.

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(1 mark)

(b) Calculate the percentage atom economy for the production of ammonia in the reaction between ammonium sulfate and sodium hydroxide.

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(2 marks)

(c) Ammonia is manufactured by the Haber Process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Calculate the percentage atom economy for the production of ammonia in this process.

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(1 mark)

(d) A sample of ammonia gas occupied a volume of 1.53×10^{-2} m^3 at 37 °C and a pressure of 100 kPa.
(The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$)

Calculate the amount, in moles, of ammonia in this sample.

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(3 marks)

(Extra space) .....

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(e) Glauber's salt is a form of hydrated sodium sulfate that contains 44.1% by mass of sodium sulfate. Hydrated sodium sulfate can be represented by the formula $Na_2SO_4.xH_2O$ where x is an integer. Calculate the value of x.

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(3 marks)

(Extra space) .....

2)

The table below shows the boiling points of some hydrogen compounds formed by Group 6 elements.

	H_2O	H_2S	H_2Se	H_2Te
Boiling point/K	373	212	232	271

(a) State the strongest type of intermolecular force in water and in hydrogen sulfide (H_2S).

Water .....

Hydrogen sulfide .....

(2 marks)

(b) Draw a diagram to show how two molecules of water are attracted to each other by the type of intermolecular force you stated in part (a). Include partial charges and all lone pairs of electrons in your diagram.

(3 marks)

(c) Explain why the boiling point of water is much higher than the boiling point of hydrogen sulfide.

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(1 mark)

(d) Explain why the boiling points increase from H_2S to H_2Te

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(2 marks)

(e) When H^+ ions react with H_2O molecules, H_3O^+ ions are formed.

Name the type of bond formed when H^+ ions react with H_2O molecules.
Explain how this type of bond is formed in the H_3O^+ ion.

Type of bond .....

Explanation .....

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(2 marks)

(f) Sodium sulfide (Na_2S) has a melting point of 1223 K.
Predict the type of bonding in sodium sulfide and explain why its melting point is high.

Type of bonding .....

Explanation .....

3)

A mass spectrometer can be used to investigate the isotopes in an element.

(a) Define the term *relative atomic mass* of an element.

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(2 marks)

(Extra space) .....

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(b) Element **X** has a relative atomic mass of 47.9

Identify the block in the Periodic Table to which element **X** belongs and give the electron configuration of an atom of element **X**.

Calculate the number of neutrons in the isotope of **X** which has a mass number 49

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(3 marks)

(Extra space) .....

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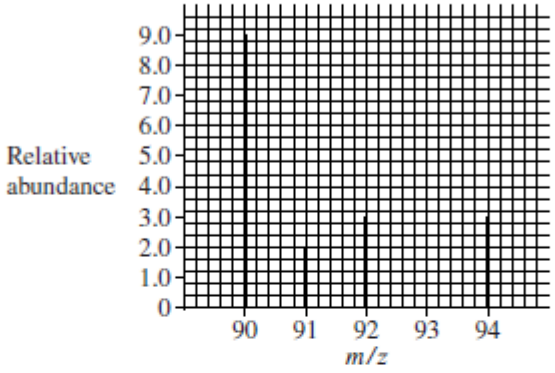
(c) The mass spectrum of element **Z** is shown below.

Use this spectrum to calculate the relative atomic mass of **Z**, giving your answer to one decimal place.

Identify element **Z**.



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(4 marks)

(Extra space) .....

(d) State how vaporised atoms of **Z** are converted into $\mathbf{Z}^+$ ions in a mass spectrometer.

State and explain which of the $\mathbf{Z}^+$ ions formed from the isotopes of **Z** in part (c) will be deflected the most in a mass spectrometer.

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(4 marks)

(Extra space) .....

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(e) Explain briefly how the relative abundance of an ion is measured in a mass spectrometer.

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(2 marks)

(Extra space) .....

4)
A molecule of ClF_3 reacts with a molecule of AsF_5 as shown in the following equation.

$$ClF_3 + AsF_5 \longrightarrow ClF_2^+ + AsF_6^-$$

Use your understanding of electron pair repulsion to draw the shape of the AsF_5 molecule and the shape of the ClF_2^+ ion. Include any lone pairs of electrons.

Name the shape made by the atoms in the AsF_5 molecule and in the ClF_2^+ ion.

Predict the bond angle in the ClF_2^+ ion.

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(5 marks)

(Extra space) .....

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5)

Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer x in $ZnSO_4.xH_2O$
Show your working.

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(3 marks)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3} hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

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(4 marks)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

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(4 marks)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

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(3 marks)

6)

The rate of a chemical reaction is influenced by the size of the activation energy. Catalysts are used to increase the rates of chemical reactions but are not used up in the reactions.

(a) Give the meaning of the term *activation energy*.

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(2 marks)

(b) Explain how a catalyst increases the rate of a reaction.

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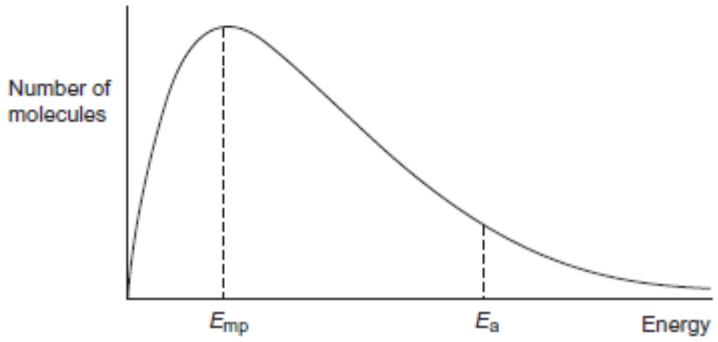
(2 marks)

(c) The diagram below shows the Maxwell–Boltzmann distribution of molecular energies, at a constant temperature, in a gas at the start of a reaction.
On this diagram the most probable molecular energy at this temperature is shown by the symbol E_{mp}
The activation energy is shown by the symbol E_a



To answer the questions **1 (c) (i)** to **1 (c) (iv)**, you should use the words **increases**, **decreases** or **stays the same**. You may use each of these answers once, more than once or not at all.

(c) (i) State how, if at all, the value of the most probable energy (E_{mp}) changes as the total number of molecules is increased at constant temperature.

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(1 mark)

(c) (ii) State how, if at all, the number of molecules with the most probable energy (E_{mp}) changes as the temperature is decreased without changing the total number of molecules.

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(1 mark)

(c) (iii) State how, if at all, the number of molecules with energy greater than the activation energy (E_a) changes as the temperature is increased without changing the total number of molecules.

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(1 mark)

(c) (iv) State how, if at all, the area under the molecular energy distribution curve changes as a catalyst is introduced without changing the temperature or the total number of molecules.

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(1 mark)

(d) For each of the following reactions, identify a catalyst and name the organic product of the reaction.

(d) (i) The fermentation of an aqueous solution of glucose.

Catalyst .....

Name of organic product .....

(2 marks)

(d) (ii) The hydration of but-2-ene.

Catalyst .....

Name of organic product .....

(2 marks)