AS Paper 1 and 2 – Amount of Substance

MCQs

Q1. A brand of fluoride tablets, recommended by a dentist to strengthen the enamel on teeth, contains 2.2×10^{-3} sodium fluoride per tablet. The total mass of fluoride ion present in 100 tablets is

A $2.2 \times 10^{-3} \times \frac{19}{42} \times 100$

B $2.2 \times 10^{-3} \times \frac{19}{23} \times 100$

C $2.2 \times 10^{-3} \times \frac{9}{20} \times 100$

D $\frac{100 \times 19}{2.2 \times 10^{-3}}$

(Total 1 mark)

Q2. When $TiCl_4$ is reduced with hydrogen under certain conditions, a new compound is produced which contains 68.9% chlorine by mass. Which one of the following could be the formula of the new compound?

A TiH_2Cl_2

B TiCl

C $TiCl_2$

D $TiCl_3$

(Total 1 mark)

Q3. CH_2O is the empirical formula of

A methanol

B methyl methanoate

C ethane-1,2-diol

D butanal

(Total 1 mark)

Q4. The oxidation of ethanedioate (*oxalate*) ions by manganate(VII) ions can be represented by the half equations:

$$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

What volume (in cm^3) of 0.02 M $KMnO_4$ is required to oxidise completely a solution containing 0.02 mol of ethanedioate ions?

A 25

B 40

C 250

D 400

(Total 1 mark)

Q5. When vanadium reacts with chlorine at 400°C, a brown compound is obtained. When an aqueous solution containing 0.193 g of this compound was treated with aqueous silver nitrate all the chlorine in the compound was precipitated as silver chloride. The mass of silver chloride (AgCl) produced was 0.574 g. Which one of the following could be the formula of the brown compound?

A VCl

B VCl_2

C VCl_3

D VCl_4

(Total 1 mark)

Q6. A "drink-driving" offence is committed if the blood alcohol level of a driver is over 80 mg of ethanol per 100 cm^3 of blood.

What is the concentration (in mol dm^3) of ethanol if there are 80 mg of ethanol per100 cm^3 of blood?

A 0.0017

B 0.017

C 0.080

D 0.80

(Total 1 mark)

Q7. Copper(II) ions can be estimated volumetrically by the addition of an excess of potassium iodide followed by titration of the liberated iodine with sodium thiosulphate solution. The following equations apply:

$$2Cu^{2} + 4I^{-} \rightarrow 2CuI + I_2$$

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

What volume (in cm^3) of 0.1 M $Na_2S_2O_3$ would be required to react with the iodine produced from 1.249 g of $CuSO_45H_2O$ (M_r 249.7)?

A 10

B 25

C 50

D 100

(Total 1 mark)

Q8. Which one of the following samples of gas occupies the largest volume?

A 1.0 g of ozone (O_3) at l00 kPa and 300 K

B 1.0 g of oxygen at 100 kPa and 300 K

C 1.0 g of water vapour at 250 kPa and 450 K

D 1.0 g of methane at 333 kPa and 500 K

(Total 1 mark)

Q9. Hydrolysis of the ester, $CH_3COOCH_2CH_2CH_3$, produces ethanoic acid. In an experiment, 2.04 g of the ester was used and 0.90 g of ethanoic acid was produced. The percentage yield of ethanoic acid was:

A 44

B 59

C 75

D 90

(Total 1 mark)

Q10. An alkane contains 30 hydrogen atoms per molecule. Its empirical formula is

A C_6H_{15}

B C_7H_{15}

C $C_{14}H_{30}$

D $C_{15}H_{30}$

(Total 1 mark)

Q11. Which one of the following contains the greatest number of moles of methanol? (The Avogadro number (L) is 6.02×10^{23}, the relative molecular mass (M_r) of methanol is 32.)

A 6.6×10^{22} molecules

B 3.3 g of methanol

C 2.5×10^{-3} m^3 of methanol vapour at 300 K and 100 kPa

D 70 cm^3 of 1.5 M aqueous methanol

(Total 1 mark)

Q12. What is the volume occupied by 10.8 g of the freon CCl_2F_2 at 100 kPa and 273 K?

A 2.02 dm^3

B 2.05 dm^3

C 2.02 cm^3

D 2.05 cm^3

(Total 1 mark)

Q13. In a titration, 0.52 g of a diprotic acid, H_2X, reacts exactly with 100 cm^3 of 0.10 M sodium hydroxide.

$$H_2X + 2NaOH \rightarrow Na_2X + 2H_2O$$

The acid could be

A ethanedioic

B propanedioic

C butanedioic

D pentanedioic

(Total 1 mark)

Q14. Which one of the following samples of gas, when sealed into a vessel of volume 0.10 m^3, is at the highest pressure?

A 1.6 g of helium (He) at 100 K

B 1.6 g of methane (CH_4) at 100 K

C 1.6 g of oxygen (O_2) at 600 K

D 1.6 g of sulphur dioxide (SO_2) at 1200 K

(Total 1 mark)

Q15. An excess of methanol was mixed with 12 g of ethanoic acid and an acid catalyst. At equilibrium the mixture contained 8 g of methyl ethanoate. The percentage yield of ester present was

A 11

B 20

C 54

D 67

(Total 1 mark)

Q16. On complete combustion, 0.0150 mol of an organic acid produced 735 cm^3 of carbon dioxide (measured at 101 kPa and 298 K). The same amount of acid required 15.0 cm^3 of 2.00 M sodium hydroxide solution for neutralisation. Which one of the following could be the formula of the acid?

A HCOOH

B CH_3COOH

C HOOCCOH

D $HOOCCH_2CH_2COOH$

(Total 1 mark)

Q17. When one mole of ammonia is heated to a high temperature, 50% dissociates according to the following equilibrium.

$$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$$

What is the total number of moles of gas present in the equilibrium mixture?

A 1.5

B 2.0

C 2.5

D 3.0

(Total 1 mark)

Q18. Which one of the following compounds contains the smallest percentage, by mass, of oxygen?

A $CH_3OCH_2CH_3$

B $CH_3OCH_2NH_2$

C COS

D $C_4H_9Al(OH)_2$

(Total 1 mark)

Q19. Which one of the following contains the smallest number of moles of carbon dioxide gas?

A 2.65 g

B 0.0150 m^3 at 1000 K and 33.0 kPa

C 1.50 dm^3 at 327 °C and 200 kPa

D 1500 cm^3 at 300 K and 100 kPa

(Total 1 mark)

Q20. On heating, magnesium reacts vigorously with element **X** to produce compound **Y**. An aqueous solution of **Y**, when treated with aqueous silver nitrate, gives a white precipitate that is readily soluble in dilute aqueous ammonia. What is the minimum mass of **X** that is needed to react completely with 4.05 g of magnesium?

A 11.83 g

B 5.92 g

C 5.33 g

D 2.67 g

(Total 1 mark)

Q21. The percentage of copper in a copper(II) salt can be determined by using a thiosulphate titration. 0.305 g of a copper(II) salt was dissolved in water and added to an excess of potassium iodide solution, liberating iodine according to the following equation:

$$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$$

The iodine liberated required 24.5 cm^3 of a 0.100 mol dm^{-3} solution of sodium thiosulphate:

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

The percentage of copper, by mass, in the copper(II) salt is

A 64.2

B 51.0

C 48.4

D 25.5

(Total 1 mark)

Q22. This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
$SO_3(g)$	−396	+257
$SO_2(g)$	–297	+248
$O_2(g)$	0	+204

This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm^3. At equilibrium, the vessel contains 0.0500 mol of $SO_2(g)$, 0.0800 mol of $O_2(g)$ and 0.0700 mol of $SO_3(g)$.

At equilibrium in the same vessel of volume 1.80 dm^3 under altered conditions, the reaction mixture contains 0.0700 mol of $SO_3(g)$, 0.0500 mol of $SO_2(g)$ and 0.0900 mol of $O_2(g)$ at a total

pressure of 623 kPa. The temperature in the equilibrium vessel is

A 307 °C

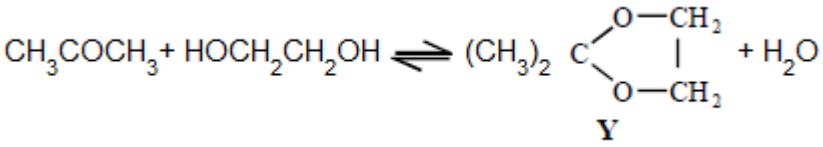
B 596 K

C 337 °C

D 642 K

(Total 1 mark)

Q23. This question is about the reaction between propanone and an excess of ethane-1,2-diol, the equation for which is given below.



Y

In a typical procedure, a mixture of 1.00 g of propanone, 5.00 g of ethane-1,2-diol and 0.100 g of benzenesulphonic acid, $C_6H_5SO_3H$, is heated under reflux in an inert solvent. Benzenesulphonic acid is a strong acid.

If 1.00 g of propanone was vapourised at 100 °C and 100 kPa pressure, the volume in m^3 of gas formed would be

A 31.0

B 8.31

C 0.534

D 5.34×10^{-4}

(Total 1 mark)

Q24. Butan-1-ol was converted into butyl propanoate by reaction with an excess of propanoic acid. In the reaction, 6.0 g of the alcohol gave 7.4 g of the ester. The percentage yield of ester was

A 57

B 70

C 75

D 81

(Total 1 mark)

Q25. Use the information below to answer this question.

A saturated solution of magnesium hydroxide, $Mg(OH)_2$, contains 0.1166 g of $Mg(OH)_2$ in 10.00 dm^3 of solution. In this solution the magnesium hydroxide is fully dissociated into ions.

Which one of the following is the concentration of $Mg^{2+}(aq)$ ions in the saturated solution?

A 2.82×10^{-2} mol dm^{-3}

B 2.00×10^{-3} mol dm^{-3}

C 2.82×10^{-3} mol dm^{-3}

D 2.00×10^{-4} mol dm^{-3}

(Total 1 mark)

Q26. Sodium hydrogencarbonate decomposes on heating as shown by the equation below.

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

The volume of carbon dioxide, measured at 298 K and 101 kPa, obtained by heating 0.0500 mol of sodium hydrogencarbonate is

A 613 cm^3

B 1226 cm^3

C 613 dm^3

D 1226 dm^3

(Total 1 mark)

Q27. An equation for the incomplete combustion of butane in oxygen is

$$C_4H_{10} + 4\ \tfrac{1}{2}O_2 \rightarrow 4CO + 5H_2O$$

The volume in dm^3 of oxygen at 295 K and 100 kPa required to burn 0.1 mol of butane to form steam and carbon monoxide only is

A 8.6

B 11

C 12

C 16

(Total 1 mark)

Q28. A particular sample of iron ore contains 85% by mass of Fe_2O_3 (M_r = 159.6) and no other iron compound. The maximum mass of iron that could be extracted from 1.0 tonne of this ore is

A 0.59 tonne

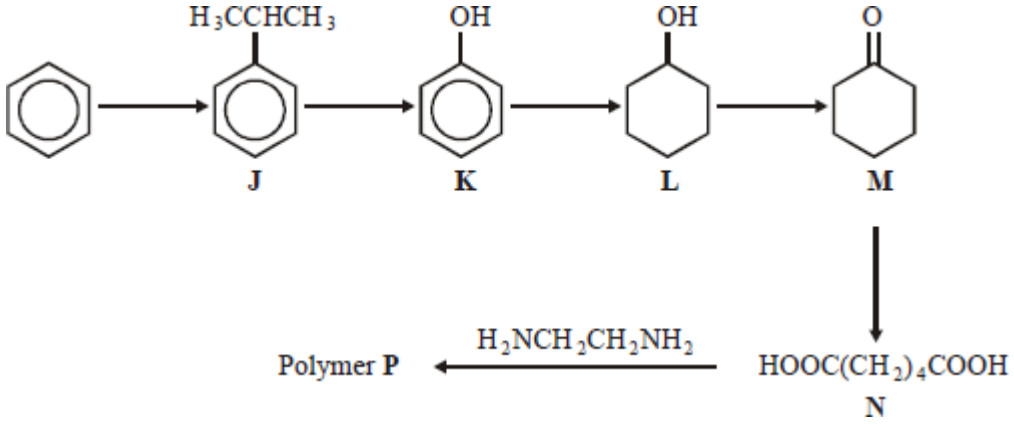
B 0.66 tonne

C 0.75 tonne

C 0.85 tonne

(Total 1 mark)

Q29. This question is about the following reaction scheme which shows the preparation of polymer **P**.



If 1.0 kg of benzene gave 0.98 kg of **J**, the percentage yield of **J** was

A 64

B 66

C 68

D 70

(Total 1 mark)

Q30. Propanoic acid reacts with methanol in the presence of a small amount of concentrated sulphuric acid. The empirical formula of the ester formed is

A CH_2O

B $C_2H_6O_2$

C $C_2H_4O_2$

D C_2H_4O

(Total 1 mark)

Q31. The percentage by mass of carbon is 83.3% in

A propane.

B butane.

C pentane.

D hexane.

(Total 1 mark)

Q32. Silver oxide, Ag_2O, can be reduced by passing hydrogen gas over the heated oxide. The maximum mass of silver that could be obtained from 2.32 g of silver oxide is

A 2.02 g

B 2.06 g

C 2.12 g

D 2.16 g

(Total 1 mark)

Q33. 25.0 cm^3 of ethanedioic acid required 22.5 cm^3 of 0.100 mol dm^{-3} potassium hydroxide solution for complete neutralisation.

The concentration of ethanedioic acid is

A 0.0225 mol dm^{-3}

B 0.0450 mol dm^{-3}

C 0.0560 mol dm^{-3}

D 0.0900 mol dm^{-3}

(Total 1 mark)

Q34. When 0.10 g of propane was burned the quantity of heat evolved was 5.0 kJ. The enthalpy of combustion of propane in kJ mol^{-1} is

A −800

B −1500

C −2200

D −2900

(Total 1 mark)

Q35. When 0.10 g of propane was burned the quantity of heat evolved was 5.0 kJ. The enthalpy of combustion of propane in kJ mol^{-1} is

A −800

B −1500

C −2200

D −2900

(Total 1 mark)

Short and Long Answer Questions

Q1. (a) State and explain the trend in electronegativities across Period 3 from sodium to sulfur.

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(4)

(b) Explain why the oxides of the Period 3 elements sodium and phosphorus have different melting points. In your answer you should discuss the structure of and bonding in these oxides, and the link between electronegativity and the type of bonding.

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(c) A chemical company has a waste tank of volume 25 000 dm^3. The tank is full of phosphoric acid (H_3PO_4) solution formed by adding some unwanted phosphorus(V) oxide to water in the tank.

A 25.0 cm^3 sample of this solution required 21.2 cm^3 of 0.500 mol dm^{-3} sodium hydroxide solution for complete reaction.

Calculate the mass, in kg, of phosphorus(V) oxide that must have been added to the water in the waste tank.

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(5)
(Total 15 marks)

Q2. The chloride of an element **Z** reacts with water according to the following equation.

$$ZCl_4(l) + 2H_2O(l) \rightarrow ZO_2(s) + 4HCl(aq)$$

A 1.304 g sample of ZCl_4 was added to water. The solid ZO_2 was removed by filtration and the resulting solution was made up to 250 cm^3 in a volumetric flask. A 25.0 cm^3 portion of this solution was titrated against a 0.112 mol dm^{-3} solution of sodium hydroxide, of which 21.7 cm^3 were required to reach the end point.

Use this information to calculate the number of moles of HCl produced and hence the number of moles of ZCl_4 present in the sample. Calculate the relative molecular mass, M_r, of ZCl_4. From your answer deduce the relative atomic mass, A_r, of element **Z** and hence its identity.

(Total 9 marks)

Q3. (a) State the relative charge and relative mass of a proton, of a neutron and of an electron.

In terms of particles, explain the relationship between two isotopes of the same element. Explain why these isotopes have identical chemical properties.

(7)

(b) Define the term *relative atomic mass*. An element exists as a mixture of three isotopes. Explain, in detail, how the relative atomic mass of this element can be calculated from data obtained from the mass spectrum of the element.

(7)

(Total 14 marks)

Q4. (a) The mass of one mole of $_1H$ atoms is 1.0078 g and that of one $_1H$ atom is 1.6734×10^{-24} g.

Use these data to calculate a value for the Avogadro constant accurate to five significant figures. Show your working.

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(2)

(b) How does the number of atoms in one mole of argon compare with the number of molecules in one mole of ammonia?

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(1)

(c) A sample of ammonia gas occupied a volume of 0.0352 m^3 at 298 K and 98.0 kPa. Calculate the number of moles of ammonia in the sample.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(3)

(d) A solution containing 0.732 mol of ammonia was made up to 250 cm^3 in a volumetric flask by adding water. Calculate the concentration of ammonia in this final solution and state the appropriate units.

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(e) A different solution of ammonia was reacted with sulphuric acid as shown in the equation below.

$$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

In a titration, 25.0 cm^3 of a 1.24 mol dm^{-3} solution of sulphuric acid required 30.8 cm^3 of this ammonia solution for complete reaction.

(i) Calculate the concentration of ammonia in this solution.

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(ii) Calculate the mass of ammonium sulphate in the solution at the end of this titration.

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(6)

(f) The reaction of magnesium nitride, Mg_3N_2, with water produces ammonia and magnesium hydroxide. Write an equation for this reaction.

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(2)
(Total 16 marks)

Q5. Nitrogen dioxide dissociates according to the following equation.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

When 21.3 g of nitrogen dioxide were heated to a constant temperature, *T*, in a flask of volume 11.5 dm^3, an equilibrium mixture was formed which contained 7.04 g of oxygen.

(a) (i) Calculate the number of moles of oxygen present in this equilibrium mixture and deduce the number of moles of nitrogen monoxide also present in this equilibrium mixture.

Number of moles Of O_2 at equilibrium .....

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Number of moles of NO at equilibrium .....

(ii) Calculate the number of moles in the original 21.3 g of nitrogen dioxide and hence calculate the number of moles of nitrogen dioxide present in this equilibrium mixture.

Original number of moles of NO_2 .....

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Number of moles of NO_2 at equilibrium .....

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(4)

(b) Write an expression for the equilibrium constant, K_c, for this reaction. Calculate the value of this constant at temperature T and give its units.

Expression for K_c .....

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Calculation .....

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(4)

(c) The total number of moles of gas in the flask is 0.683. Use the ideal gas equation to determine the temperature *T* at which the total pressure in the flask is 3.30×10^5 Pa. (The gas constant $R = 8.31$ J $K^{-1}mol^{-1}$)

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(3)

(d) State the effect on the equilibrium yield of oxygen and on the value of K_c when the same mass of nitrogen dioxide is heated to the same temperature *T*, but in a different flask of greater volume.

Yield of oxygen .....

Value of K_c .....

(2)

(Total 13 marks)

Q6. The alkanes form an homologous series of hydrocarbons. The first four straight-chain alkanes are shown below.

methane	CH_4
ethane	CH_3CH_3
propane	$CH_3CH_2CH_3$
butane	$CH_3CH_2CH_2CH_3$

(a) (i) State what is meant by the term *hydrocarbon.*

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(ii) Give the general formula for the alkanes.

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(iii) Give the molecular formula for hexane, the sixth member of the series.

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(3)

(b) Each homologous series has its own general formula. State **two** other characteristics of an homologous series.

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(2)

(c) Branched-chain structural isomers are possible for alkanes which have more than three carbon atoms.

(i) State what is meant by the term *structural isomers.*

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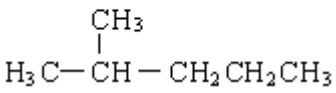
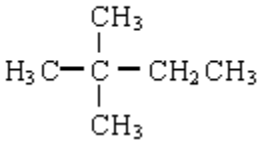
(ii) Name the **two** isomers of hexane shown below.

Isomer 1



Name ….....

Isomer 2



Name .....

(iii) Give the structures of **two** other branched-chain isomers of hexane.

Isomer 3 *Isomer 4*

(6)

(d) A hydrocarbon, **W,** contains 92.3% carbon by mass. The relative molecular mass of **W** is 78.0

(i) Calculate the empirical formula of **W**.

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(ii) Calculate the molecular formula of **W**.

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(4)
(Total 15 marks)

Q7. When a sample of liquid, **X,** of mass 0.406 g was vaporised, the vapour was found to occupy a volume of 2.34×10^{-4} m^3 at a pressure of 110 kPa and a temperature of 473 K.

(a) Give the name of the equation $pV = nRT$.

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(1)

(b) Use the equation $pV = nRT$ to calculate the number of moles of **X** in the sample and hence deduce the relative molecular mass of **X.**
(The gas constant R = 8.31 J K^{-1} mol^{-1})

*Moles of **X*** .....

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*Relative molecular mass of **X*** .....

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(4)

(c) Compound **X,** which contains carbon, hydrogen and oxygen only, has 38.7% carbon and 9.68% hydrogen by mass. Calculate the empirical formula of **X**.

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(3)

(d) Using your answers to parts (b) and (c) above, deduce the molecular formula of **X**.

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(1)
(Total 9 makrs)

Q8. (a) Calculate the concentration, in mol dm^{-3}, of the solution formed when 19.6 g of hydrogen chloride, HCl, are dissolved in water and the volume made up to 250 cm^3.

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(3)

(b) The carbonate of metal **M** has the formula M_2CO_3. The equation for the reaction of this carbonate with hydrochloric acid is given below.

$M_2CO_3 + 2HCl \rightarrow 2MCl + CO_2 + H_2O$

A sample of M_2CO_3, of mass 0.394 g, required the addition of 21.7 cm^3 of a 0.263 mol dm^{-3} solution of hydrochloric acid for complete reaction.

(i) Calculate the number of moles of hydrochloric acid used.

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(ii) Calculate the number of moles of M_2CO_3 in 0.394 g.

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(iii) Calculate the relative molecular mass of M_2CO_3

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(iv) Deduce the relative atomic mass of **M** and hence suggest its identity.

*Relative atomic mass of **M*** .....

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*Identity of **M*** .....

(6)
(Total 9 marks)

Q9. (a) A sample of ethanol vapour, C_2H_5OH (M_r = 46.0), was maintained at a pressure of 100 kPa and at a temperature of 366K.

(i) State the ideal gas equation.

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(ii) Use the ideal gas equation to calculate the volume, in cm^3, that 1.36 g of ethanol vapour would occupy under these conditions.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(5)

(b) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.

(i) Balance the equation, given below, for the reaction between magnesium nitride and water.

$$Mg_3N_2 + H_2O \rightarrow Mg(OH)_2 + NH_3$$

(ii) Calculate the number of moles, and hence the number of molecules, of NH_3 in 0.263 g of ammonia gas.
(The Avogadro constant $L = 6.02 \times 10^{23}$ mol^{-1})

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(c) Sodium carbonate is manufactured in a two-stage process as shown by the equations below.

$$NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Calculate the maximum mass of sodium carbonate which could be obtained from 800 g of sodium chloride.

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(4)
(Total 13 marks)

Q10. Compound **A** is an oxide of sulphur. At 415 K, a gaseous sample of **A**, of mass 0.304 g, occupied a volume of 127 cm^3 at a pressure of 103 kPa.

State the ideal gas equation and use it to calculate the number of moles of **A** in the sample, and hence calculate the relative molecular mass of **A**.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation .....

Calculation .....

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(Total 5 marks)

Q11. (a) The equation for the reaction between magnesium carbonate and hydrochloric acid is given below.

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$$

When 75.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid were added to 1.25 g of impure $MgCO_3$ some acid was left unreacted. This unreacted acid required 21.6 cm^3 of a 0.500 mol dm^{-3} solution of sodium hydroxide for complete reaction.

(i) Calculate the number of moles of HCl in 75.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid.

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(ii) Calculate the number of moles of NaOH used to neutralise the unreacted HCl.

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(iii) Show that the number of moles of HCl which reacted with the $MgCO_3$ in the sample was 0.0267

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(iv) Calculate the number of moles and the mass of $MgCO_3$ in the sample, and hence deduce the percentage by mass of $MgCO_3$ in the sample.

Moles of $MgCO_3$ .....

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Mass of $MgCO_3$ .....

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Percentage of $MgCO_3$ .....

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(8)

(b) A compound contains 36.5% of sodium and 25.5% of sulphur by mass, the rest being oxygen.

(i) Use this information to show that the empirical formula of the compound is Na_2SO_3

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(ii) When Na_2SO_3 is treated with an excess of hydrochloric acid, aqueous sodium chloride is formed and sulphur dioxide gas is evolved. Write an equation to represent this reaction.

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(4)
(Total 12 marks)

Q12. (a) One isotope of sodium has a relative mass of 23.

(i) Define, in terms of the fundamental particles present, the meaning of the term *isotopes*.

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(ii) Explain why isotopes of the same element have the same chemical properties.

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(iii) Calculate the mass, in grams, of a single atom of this isotope of sodium.
(The Avogadro constant, L, is 6.023×10^{23} mol^{-1})

.....

.....

.....

(5)

(b) Give the electronic configuration, showing all sub-levels, for a sodium atom.

.....

(1)

(c) Explain why chromium is placed in the d block in the Periodic Table.

.....

.....

(1)

(d) An atom has half as many protons as an atom of ^{28}Si and also has six fewer neutrons than an atom of ^{28}Si. Give the symbol, including the mass number and the atomic number, of this atom.

.....

(2)

(Total 9 marks)

Q13. The following two-stage method was used to analyse a mixture containing the solids magnesium, magnesium oxide and sodium chloride.

Stage 1

A weighed sample of the mixture was treated with an excess of dilute hydrochloric acid. The sodium chloride dissolved in the acid. The magnesium oxide reacted to form a solution of magnesium chloride. The magnesium also reacted to form hydrogen gas and a solution of magnesium chloride. The hydrogen produced was collected.

(a) Write equations for the two reactions involving hydrochloric acid.

(b) State how you would collect the hydrogen. State the measurements that you would make in order to calculate the number of moles of hydrogen produced. Explain how your results could be used to determine the number of moles of magnesium metal in the sample.

(8)

Stage 2

Sodium hydroxide solution was added to the solution formed in **Stage 1** until no further precipitation of magnesium hydroxide occurred. This precipitate was filtered off, collected, dried and heated strongly until it had decomposed completely into magnesium oxide. The oxide was weighed.

(c) Write equations for the formation of magnesium hydroxide and for its decomposition into magnesium oxide.

(d) When a 2.65 g sample of the mixture of the three solids was analysed as described above, the following results were obtained.

Hydrogen obtained in **Stage 1** 0.0528 mol

Mass of magnesium oxide obtained in **Stage 2** 6.41 g

Use these results to calculate the number of moles of original magnesium oxide in 100 g of the mixture.

(7)
(Total 15 marks)

Q14. (a) Sodium carbonate forms a number of hydrates of general formula $Na_2CO_3.xH_2O$

A 3.01 g sample of one of these hydrates was dissolved in water and the solution made up to 250 cm^3.
In a titration, a 25.0 cm^3 portion of this solution required 24.3 cm^3 of 0.200 mol^{-1} dm^{-3} hydrochloric acid for complete reaction.

The equation for this reaction is shown below.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

(i) Calculate the number of moles of HCl in 24.3 cm^3 of 0.200 mol dm^{-3} hydrochloric acid.

.....

(ii) Deduce the number of moles of Na_2CO_3 in 25.0 cm^3 of the Na_2CO_3 solution.

.....

(iii) Hence deduce the number of moles of Na_2CO_3 in the original 250 cm^3 of solution.

.....

(iv) Calculate the M_r of the hydrated sodium carbonate.

.....

.....

(5)

(b) In an experiment, the M_r of a different hydrated sodium carbonate was found to be 250. Use this value to calculate the number of molecules of water of crystallisation, *x*, in this hydrated sodium carbonate, $Na_2CO_3.xH_2O$

.....

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.....

(3)

(c) A gas cylinder, of volume 5.00×10^{-3} m^3, contains 325 g of argon gas.

(i) Give the ideal gas equation.

.....

(ii) Use the ideal gas equation to calculate the pressure of the argon gas in the cylinder at a temperature of 298 K.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

.....

.....

.....

.....

(4)
(Total 12 marks)

Q15. (a) Ammonia, NH_3, reacts with sodium to form sodium amide, $NaNH_2$, and hydrogen.

(i) Write an equation for the reaction between ammonia and sodium.

.....

(ii) Draw the shape of an ammonia molecule and that of an amide ion, NH_2^-

In each case show any lone pairs of electrons.

NH_3 NH_2^-

(iii) State the bond angle found in an ammonia molecule.

.....

(iv) Explain why the bond angle in an amide ion is smaller than that in an ammonia molecule.

.....

.....

.....

.....

(6)

(b) A salt, **X**, contains 16.2% by mass of magnesium, 18.9% by mass of nitrogen and 64.9% by mass of oxygen.

(i) State what is meant by the term *empirical formula*.

.....

.....

(ii) Determine the empirical formula of **X**.

.....

.....

.....

.....

(3)
(Total 9 marks)

Q16. (a) Ammonium sulphate reacts with aqueous sodium hydroxide as shown by the equation below.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

A sample of ammonium sulphate was heated with 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide. To ensure that all the ammonium sulphate reacted, an excess of sodium hydroxide was used.
Heating was continued until all of the ammonia had been driven off as a gas.
The unreacted sodium hydroxide remaining in the solution required 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid for neutralisation.

(i) Calculate the original number of moles of NaOH in 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

.....

.....

(ii) Calculate the number of moles of HCl in 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid.

.....

.....

(iii) Deduce the number of moles of the unreacted NaOH neutralised by the hydrochloric acid.

.....

(iv) Use your answers from parts (a) (i) and (a) (iii) to calculate the number of moles of NaOH which reacted with the ammonium sulphate.

.....

.....

(v) Use your answer in part (a) (iv) to calculate the number of moles and the mass of ammonium sulphate in the sample.
(If you have been unable to obtain an answer to part (a) (iv), you may assume that the number of moles of NaOH which reacted with ammonium sulphate equals 2.78×10^{-2} mol. This is not the correct answer.)

Moles of ammonium sulphate .....

.....

Mass of ammonium sulphate .....

.....

(7)

(b) A 0.143g gaseous sample of ammonia occupied a volume of 2.86×10^{-4} m^3 at a temperature ***T*** and a pressure of 100 kPa.

State the ideal gas equation, calculate the number of moles of ammonia present and deduce the value of the temperature ***T***.

(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

Ideal gas equation .....

Moles of ammonia .....

.....

Value of ***T*** .....

.....

.....

.....

.....

(4)
(Total 11 marks)

Q17. 25.0 cm^3 of ethanedioic acid required 22.5 cm^3 of 0.100 mol dm^{-3} potassium hydroxide solution for complete neutralisation.

The concentration of ethanedioic acid is

A 0.0225 mol dm^{-3}

B 0.0450 mol dm^{-3}

C 0.0560 mol dm^{-3}

D 0.0900 mol dm^{-3}

(Total 1 mark)

Q18. When 0.10 g of propane was burned the quantity of heat evolved was 5.0 kJ. The enthalpy of combustion of propane in kJ mol^{-1} is

A −800

B −1500

C −2200

D −2900

(Total 1 mark)

Q19. (a) Lead(II) nitrate may be produced by the reaction between nitric acid and lead(II) oxide as shown by the equation below.

$PbO + 2HNO_3 \rightarrow Pb(NO_3)_2 + H_2O$

An excess of lead(II) oxide was allowed to react with 175 cm^3 of 1.50 mol dm^{-3} nitric acid. Calculate the maximum mass of lead(II) nitrate which could be obtained from this reaction.

.....

.....

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.....

.....

(4)

(b) An equation representing the thermal decomposition of lead(II) nitrate is shown below.

$2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$

A sample of lead(II) nitrate was heated until the decomposition was complete. At a temperature of 500 K and a pressure of 100 kPa, the total volume of the gaseous mixture produced was found to be 1.50×10^{-4} m^3.

(i) State the ideal gas equation and use it to calculate the total number of moles of gas produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation .....

Total number of moles of gas .....

.....

.....

.....

(ii) Deduce the number of moles, and the mass, of NO_2 present in this gaseous mixture. (If you have been unable to calculate the total number of moles of gas in part (b)(i), you should assume this to be 2.23×10^{-3} mol. This is not the correct answer.)

Number of moles of NO_2 .....

.....

Mass of NO_2 .....

.....

(7)
(Total 11 marks)

Q20. (a) Dichloromethane, CH_2Cl_2, is one of the products formed when chloromethane, CH_3Cl, reacts with chlorine.

(i) Name the type of mechanism involved in this reaction and write an equation for each of the steps named below.

Name of type of mechanism .....

Initiation step

.....

First propagation step

.....

Second propagation step

.....

(ii) Write an overall equation for the formation of dichloromethane from chloromethane.

.....

(5)

(b) A compound contains 10.1% carbon and 89.9% chlorine by mass. Calculate the molecular formula of this compound, given that its relative molecular mass (M_r) is 237.0

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(3)

(c) Suggest the formulae of two bromine-containing organic compounds formed when dibromomethane, CH_2Br_2, reacts with bromine.

Compound 1 .....

Compound 2 .....

(2)
(Total 10 marks)

Q21. Potassium nitrate, KNO_3, decomposes on strong heating, forming oxygen and solid **Y** as the only products.

(a) A 1.00 g sample of KNO_3 (M_r = 101.1) was heated strongly until fully

decomposed into **Y**.

(i) Calculate the number of moles of KNO_3 in the 1.00 g sample.

.....

.....

(ii) At 298 K and 100 kPa, the oxygen gas produced in this decomposition occupied a volume of 1.22×10^{-4} m^3.

State the ideal gas equation and use it to calculate the number of moles of oxygen produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation .....

Moles of oxygen .....

.....

.....

.....

.....

(5)

(b) Compound **Y** contains 45.9% of potassium and 16.5% of nitrogen by mass, the remainder being oxygen.

(i) State what is meant by the term *empirical formula*.

.....

.....

(ii) Use the data above to calculate the empirical formula of **Y**.

.....

.....

.....

(4)

(c) Deduce an equation for the

decomposition of KNO_3 into **Y** and

oxygen.

.....

(1)
(Total 10 marks)

Q22. (a) Complete the following table.

	Relative mass	Relative charge
Neutron		
Electron		

(2)

(b) An atom has twice as many protons as, and four more neutrons than, an atom of ^{9}Be. Deduce the symbol, including the mass number, of this atom.

.....

(2)

(c) Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of Cl_2O. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

$BeCl_2$ Cl_2O

Name of shape ..... *Name of shape* .....

(4)

(d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the volume, in cm^3, of 1.00 mol dm^{-3} hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

.....

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.....

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.....

.....

(4)
(Total 12 marks)

Q23. The reaction of bromine with ethane is similar to that of chlorine with ethane. Three steps in the bromination of ethane are shown below.

Step **1** $Br_2 \longrightarrow 2Br^{\bullet}$

Step **2** $Br^{\bullet} + CH_3CH_3 \longrightarrow CH_3CH_2^{\bullet} + HBr$

Step **3** $CH_3CH_2^{\bullet} + Br_2 \longrightarrow CH_3CH_2Br + Br^{\bullet}$

(a) (i) Name this type of mechanism.

.....

(ii) Suggest an essential condition for this reaction.

.....

(iii) Steps **2** and **3** are of the same type. Name this type of step.

.....

(iv) In this mechanism, another type of step occurs in which free-radicals combine. Name this type of step. Write an equation to illustrate this step.

Type of step .....

Equation.....

(5)

(b) Further substitution in the reaction of bromine with ethane produces a mixture of liquid organic compounds.

(i) Name a technique which could be used to separate the different compounds in this mixture.

.....

(ii) Write an equation for the reaction between bromine and ethane which produces hexabromoethane, C_2Br_6, by this substitution reaction.

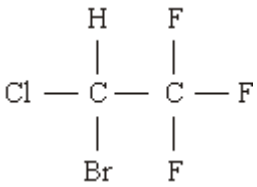
.....

(2)

(c) The compound 1,2-dibromo-1,1,2,2-tetrafluoroethane is used in some fire extinguishers. Draw the structure of this compound.

(1)

(d) Halothane is used as an anaesthetic and has the following structure.



(i) Give the systematic name of *halothane*.

.....

(ii) Calculate the M_r of halothane.

.....

(iii) Calculate the percentage by mass of fluorine in halothane.

.....

(3)
(Total 11 marks)

Q24. Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

.....

(ii) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

Moles of oxygen gas .....

Total moles of gas .....

.....

.....

(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

Moles of nitroglycerine .....

.....

Mass of nitroglycerine .....

.....

.....

(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container

and detonated. The volume of this container was 1.00×10^{-3} m^3. The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.

(The gas constant R = 8.31 J $K^{-1}mol^{-1}$)

Ideal gas equation .....

Pressure .....

.....

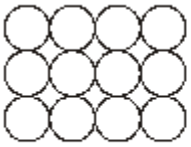
.....

.....

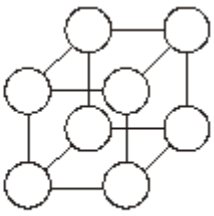
(4)
(Total 11 marks)

Q25. At room temperature, both sodium metal and sodium chloride are crystalline solids which contain ions.

(a) On the diagrams for sodium metal and sodium chloride below, mark the charge for each ion.



Sodium metal



Sodium chloride

(2)

(b) (i) Explain how the ions are held together in solid sodium metal.

.....

.....

(ii) Explain how the ions are held together in solid sodium chloride.

.....

.....

(iii) The melting point of sodium chloride is much higher than that of sodium metal. What can be deduced from this information?

.....

.....

(3)

(c) Compare the electrical conductivity of solid sodium metal with that of solid sodium chloride. Explain your answer.

Comparison .....

.....

Explanation .....

.....

.....

(3)

(d) Explain why sodium metal is malleable (can be hammered into shape).

.....

.....

(1)

(e) Sodium chlorate(V), $NaClO_3$, contains 21.6% by mass of sodium, 33.3% by mass of chlorine and 45.1% by mass of oxygen.

(i) Use the above data to show that the empirical formula of sodium chlorate(V) is $NaClO_3$

.....

.....

.....

.....

.....

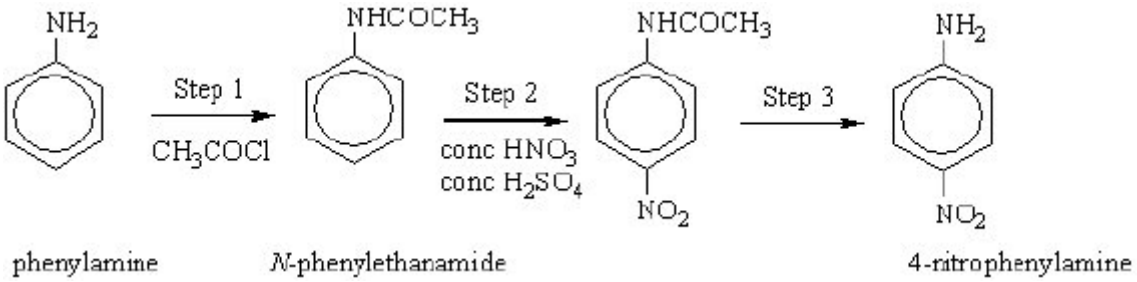
(ii) Sodium chlorate(V) may be prepared by passing chlorine into hot aqueous sodium hydroxide. Balance the equation for this reaction below.

..... Cl_2 + ... NaOH → ..... NaCl + $NaClO_3$ + $3H_2O$

(3)
(Total 12 marks)

Q26. Synthetic dyes can be manufactured starting from compounds such as 4-nitrophenylamine.

A synthesis of 4-nitrophenylamine starting from phenylamine is shown below.



(a) An equation for formation of *N*-phenylethanamide in Step 1 of the synthesis is shown below.

$2C_6H_5NH_2 + CH_3COCl \rightarrow \underset{\text{N-phenylethanamide}}{C_6H_5NHCOCH_3} + C_6H_5NH_3Cl$

(i) Calculate the % atom economy for the production of *N*-phenylethanamide (M_r = 135.0).

(ii) In a process where 10.0 kg of phenylamine are used, the yield of *N*-phenylethanamide obtained is 5.38 kg.

Calculate the percentage yield of *N*-phenylethanamide.

(iii) Comment on your answers to parts (i) and (ii) with reference to the commercial viability of the process.

(7)

(b) Name and outline a mechanism for the reaction in Step 1.

(5)

(c) The mechanism of Step 2 involves attack by an electrophile. Write an equation showing the formation of the electrophile. Outline a mechanism for the reaction of this electrophile with benzene.

(4)
(Total 16 marks)

Q27. (a) Nitromethane, CH_3NO_2, is used as an 'energy rich' fuel for motor-racing. It burns in oxygen forming three gases.

$$2CH_3NO_2(l) + 1½O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) + N_2(g)$$

(i) A 1.00 mol sample of nitromethane was burned in oxygen forming the products shown in the equation above. Calculate the total volume of gases produced at 298 K and 100 kPa (assume that the water is gaseous).

.....

.....

.....

.....

.....

(ii) This combustion reaction is very exothermic and reaches a temperature of 1000 K. Determine the total volume of gases when the temperature is raised to 1000 K at a constant pressure.

(If you have been unable to determine a volume in your answer to part (a)(i), you may assume it to be 8.61×10^{-4} m^3 but this is not the correct answer).

.....

.....

(5)

(b) It has been suggested that, instead of releasing it into the atmosphere, the carbon dioxide gas evolved during a combustion reaction can be absorbed by sodium hydroxide solution, as shown by the following equation.

$2NaOH(aq) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O(l)$

(i) Give two reasons why this reaction might not be suitable for the removal of carbon dioxide from the exhaust gases of an engine.

Reason 1 .....

Reason 2 .....

(ii) The sodium hydroxide solution for this reaction can be made on an industrial scale, together with chlorine gas and hydrogen gas, by electrolysis of a dilute solution of sodium chloride. Suggest one commercial advantage and one environmental disadvantage of this industrial process.

Commercial advantage .....

.....

Environmental disadvantage .....

.....

(4)

(c) Nitrogen forms several different oxides. Calculate the empirical formula of an oxide of nitrogen which contains 26% of nitrogen by mass.

.....

.....

.....

.....

(3)

(d) Another oxide of nitrogen, N_2O, decomposes on warming to produce nitrogen and oxygen. Write an equation for the decomposition reaction.

.....

(1)

(e) Internal combustion engines burn fuels in air. Suggest one advantage of using air mixed with N_2O for this purpose.

.....

(1)

(Total 14 marks)

Q28. A metal carbonate MCO_3 reacts with hydrochloric acid as shown in the following equation.

$$MCO_3 + 2HCl \rightarrow MCl_2 + H_2O + CO_2$$

A 0.548 g sample of MCO_3 reacted completely with 30.7 cm^3 of 0.424 mol dm^{-3} hydrochloric acid.

(a) (i) Calculate the amount, in moles, of HCl which reacted with 0.548 g MCO_3

.....

.....

(1)

(ii) Calculate the amount, in moles, of MCO_3 in 0.548 g.

.....

.....

(1)

(iii) Calculate the relative formula mass of MCO_3

.....

.....

(1)

(b) Use your answer from part (a)(iii) to deduce the relative atomic mass of metal M and suggest its identity.
(If you have been unable to calculate a value for the relative formula mass of MCO_3 you should assume it to be 147.6 but this is not the correct answer.)

Relative atomic mass .....

.....

.....

Identity of M .....

(2)
(Total 5 marks)

Q29. Titanium(IV) oxide (TiO_2, M_r = 79.9) is used as a white pigment in some paints. The pigment can be made as shown in the following equation.

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(aq)$$

(a) (i) Calculate the percentage atom economy for the formation of TiO_2

.....

.....

.....

(2)

(ii) In view of the low atom economy of this reaction, suggest how a company can maximise its profits without changing the reaction conditions or the production costs.

.....

.....

(1)

(b) In an experiment 165 g of $TiCl_4$ were added to an excess of water.

(i) Calculate the amount, in moles, of $TiCl_4$ in 165 g.

.....

.....

.....

(2)

(ii) Calculate the maximum amount, in moles, of TiO_2 which can be formed in this experiment.

.....

.....

(1)

(iii) Calculate the maximum mass of TiO_2 formed in this experiment.

.....

.....

(1)

(iv) In this experiment only 63.0 g of TiO_2 were produced. Calculate the percentage yield of TiO_2

.....

.....

.....

(1)
(Total 8 marks)

Q30. Magnesium carbonate, $MgCO_3$, can occur as the anhydrous compound, or as hydrates with 2, 3 or 5 molecules of water of crystallisation. All types of magnesium carbonate can be decomposed to form magnesium oxide, an important starting material for many processes. This decomposition reaction can be used to identify the type of magnesium carbonate present in a mineral.

A chemist was asked to identify the type of magnesium carbonate present in a mineral imported from France. The chemist weighed a clean dry crucible, and transferred 0.25 g of the magnesium carbonate mineral to the crucible. The crucible was then heated for a few minutes. The crucible was then allowed to cool, and the crucible and its contents were reweighed. This process was repeated until the crucible and its contents had reached constant mass. The mass of the crucible and its contents was then recorded.

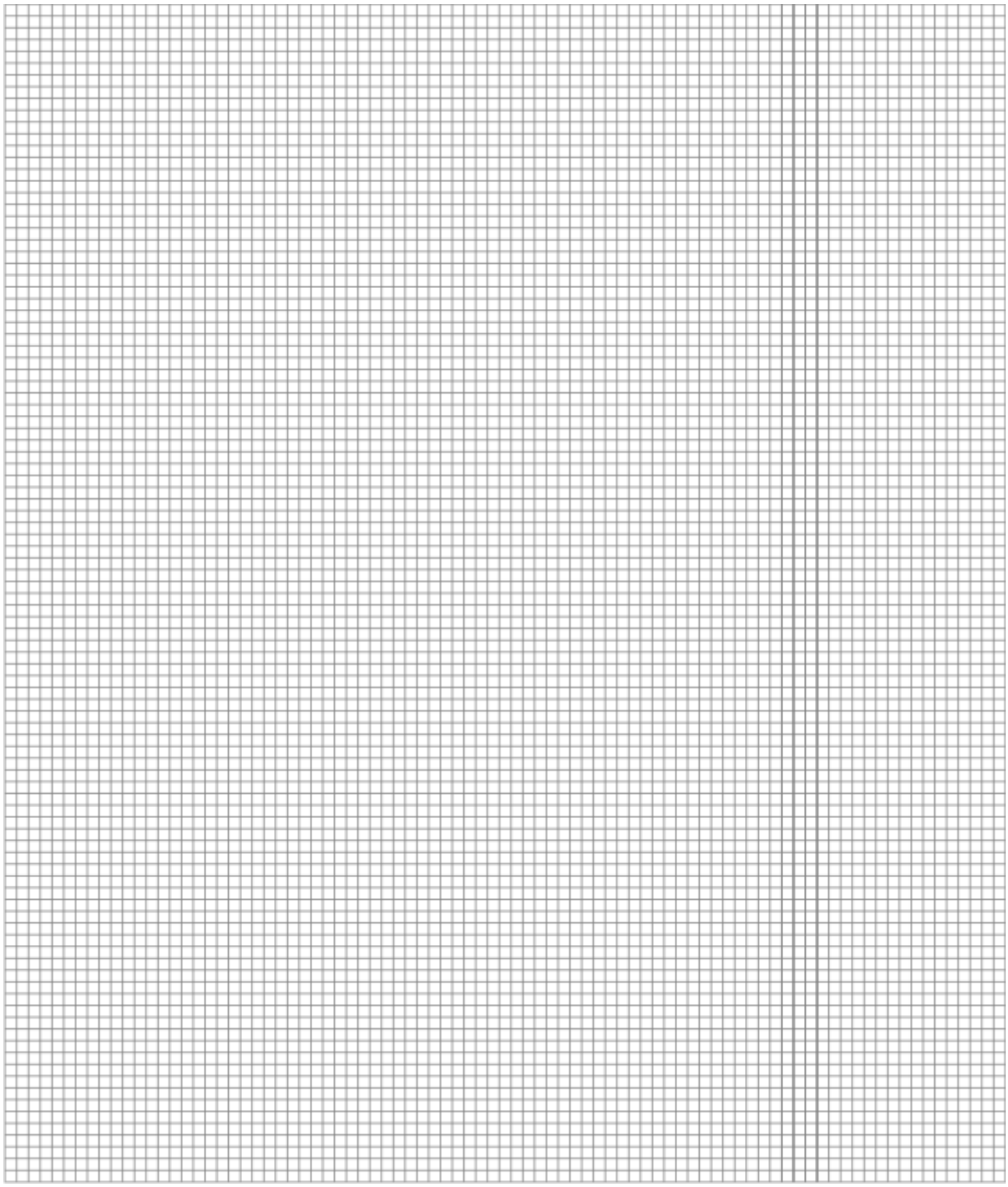
The experiment was repeated using different masses of the magnesium carbonate mineral.

For each experiment the chemist recorded the original mass of the mineral and the mass of magnesium oxide left after heating to constant mass. The chemist's results are shown in the table below.

Experiment	1	2	3	4	5	6
Mass of mineral / g	1.60	1.17	0.74	1.31	1.80	1.34
Mass of magnesium oxide / g	0.54	0.39	0.24	0.44	0.61	0.49

(a) Plot a graph of the mass of the mineral (x-axis) against the mass of magnesium oxide on the grid below.

Draw a straight line of best fit on your graph.



(4)

(b) Use the graph to determine the mass of the mineral which would have formed 0.50 g of magnesium oxide.

Mass of the mineral .....

(1)

(c) Calculate the amount, in moles, of MgO present in 0.50 g of magnesium oxide.

.....

.....

(1)

(d) Use your answers from part (b) and from part (c) to calculate the M_r of the magnesium carbonate present in the mineral.

.....

.....

.....

(1)

(e) Use your answer from part (d) to confirm that this mineral is $MgCO_3.2H_2O$

(If you could not complete the calculation in part (d), you should assume that the experimental M_r value is 122.0 This is not the correct answer.)

.....

.....

.....

(1)

(f) Explain why it was **not** necessary to use a more precise balance in this experiment.

.....

.....

(1)

(g) Consider your graph and comment on the results obtained by the chemist. Identify any anomalous results.

Comment .....

.....

Anomalous results .....

.....

(2)

(h) Explain why it was necessary for the chemist to heat the crucible and its contents to constant mass.

.....

(1)

(i) Suggest **one** reason in each case why

(i) small amounts of the mineral, such as 0.10 g, should **not** be used in this experiment.

.....

.....

(1)

(ii) large amounts of the mineral, such as 50 g, should **not** be used in this experiment.

.....

.....

(1)

(j) Analysis of a different hydrated magnesium carbonate showed that it contained 39.05% by mass of water. Determine the formula of this hydrated magnesium carbonate.

.....

.....

.....

.....

(2)

(k) Magnesium oxide is produced by the thermal decomposition of magnesium carbonate and by the thermal decomposition of magnesium hydroxide. The equations for the reactions taking place are shown below.

Reaction 1 $MgCO_3 \rightarrow MgO + CO_2$
Reaction 2 $Mg(OH)_2 \rightarrow MgO + H_2O$

Show that Reaction 2 has the greater atom economy for the production of magnesium oxide.

.....

.....

(2)

(l) Apart from cost, suggest **one** advantage of using magnesium hydroxide rather than magnesium carbonate to reduce acidity in the stomach.

.....

.....

(1)
(Total 19 marks)

Q31. Some antacid tablets contain sodium hydrogencarbonate, sucrose and citric acid.

(a) Analysis of a pure sample of citric acid showed that it contained 37.50% of carbon and 4.17% of hydrogen by mass, the remainder being oxygen. Use these data to show that the empirical formula of the acid is $C_6H_8O_7$.

.....

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.....

.....

(3)

(b) When the antacid tablet is added to water, sodium hydrogencarbonate and citric acid react together to form a gas. Identify this gas.

.....

(1)

(c) A weighed portion of this antacid was added to water. The gas formed was collected and its volume measured.

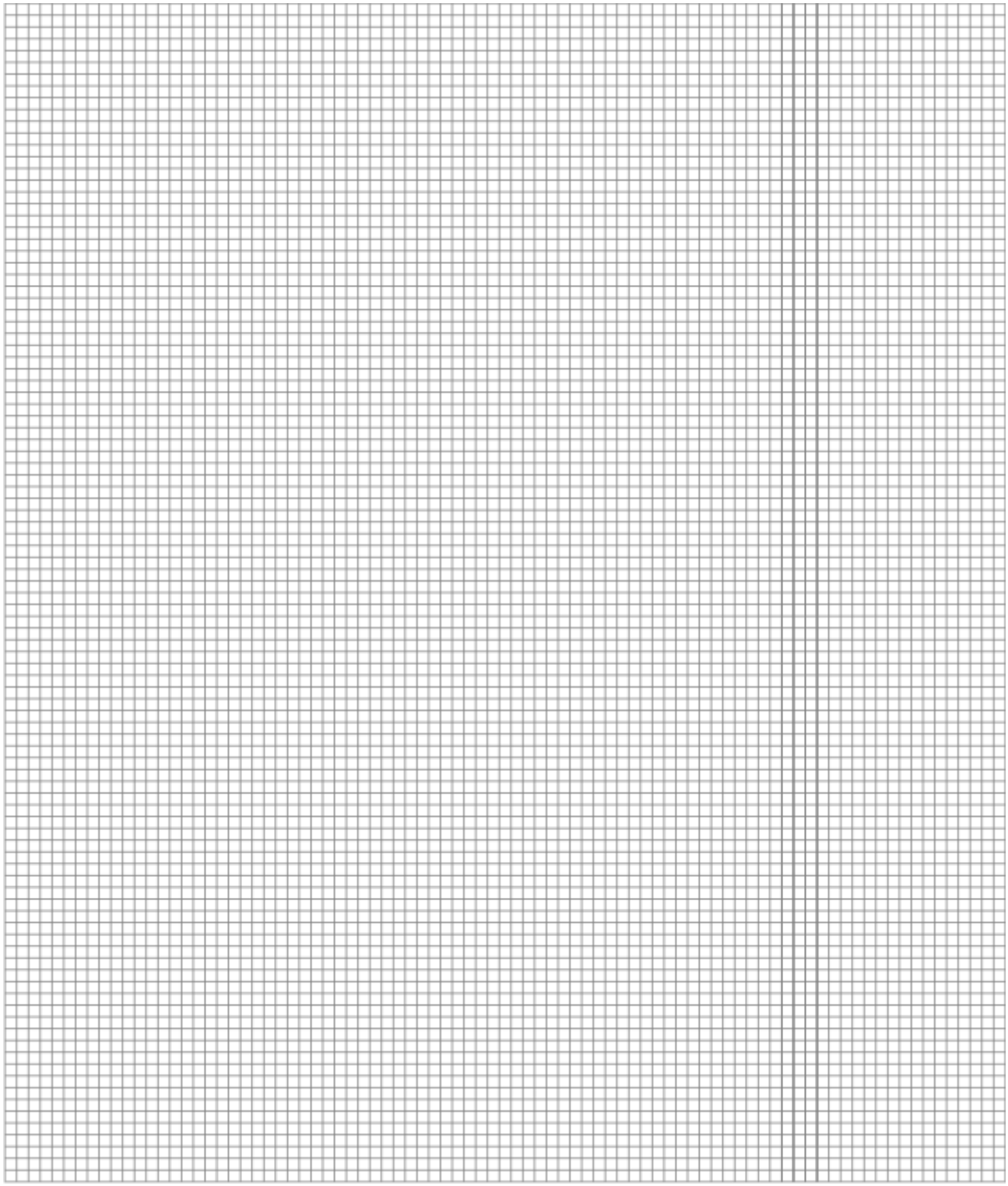
(i) Draw a diagram to show how this experiment could have been carried out to collect and measure the volume of the gas.

(ii) The experiment was repeated with further weighed portions of the same antacid.

The results are shown below.

Experiment	1	2	3	4	5
Mass of antacid / g	2.60	1.17	0.88	2.31	1.80
Volume of gas collected / cm^3	168	86	57	149	116

1 On the graph paper below, plot a graph of mass of antacid (x-axis) against volume of gas collected.



(3)

2 Draw a line of best fit on the graph, ignoring any anomalous points.

(1)

3 Use the graph to determine the volume of gas which would have been collected using 2.00 g of antacid.

Volume of gas collected .....

(1)

(d) Suggest **one** reason why the presence of sodium hydrogencarbonate in the stomach may cause a person to suffer some extra discomfort for a short time.

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(1)

(e) Explain why the value for the M_r of citric acid does not need to be an exact value to deduce the molecular formula of citric acid from its empirical formula.

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(2)

(f) Apart from misreading the gas volume, suggest **two** reasons why the volumes of gas collected may be lower than the volumes of gas produced.

Reason 1 .....

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Reason 2 .....

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(2)

(g) Explain why it is important to record the temperature and pressure when measuring the volume of a gas.

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(1)

(h) Suggest why, in an analysis of an antacid, it is important to test samples from more than one bottle of the antacid.

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(1)

(i) In the industrial production of sodium hydrogencarbonate, ammonia and carbon dioxide are bubbled through a saturated solution of sodium chloride. The equation for this reaction, and some solubility data, are shown below.

$$NaCl(aq) + NH_3(aq) + CO_2(g) + H_2O(l) \rightarrow NaHCO_3(s) + NH_4Cl(aq)$$

Compound	Solubility in water at 20 °C / g dm^{-3}
sodium chloride	360
sodium hydrogencarbonate	96
ammonium chloride	370

(i) Suggest **one** reason why sodium hydrogencarbonate precipitates from the reaction mixture at this temperature.

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(1)

(ii) Explain how this reaction could be used to remove carbon dioxide from the gases formed when fossil fuels are burned.

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(1)

(j) The thermal decomposition of sodium hydrogencarbonate produces sodium carbonate. The other products are water and carbon dioxide. Write an equation for this thermal decomposition.

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(1)

(k) Sodium carbonate is produced on an industrial scale by a multi-step process. The equation which summarises the reactions taking place is shown below.

$$CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$$

Calculate the percentage atom economy for the production of sodium carbonate by this reaction.

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(1)

(Total 20 marks)

Q32. (a) (i) Define the term *relative atomic mass* (A_r) of an element.

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(2)

(ii) A sample of the metal silver has the relative atomic mass of 107.9 and exists as two isotopes. In this sample, 54.0% of the silver atoms are one isotope with a relative mass of 107.1

Calculate the relative mass of the other silver isotope.

State why the isotopes of silver have identical chemical properties.

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(4)

(b) The isotopes of silver, when vaporised, can be separated in a mass spectrometer.

Name the **three** processes that occur in a mass spectrometer before the vaporised isotopes can be detected.

State how each process is achieved.

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(6)

(c) State the type of bonding involved in silver.

Draw a diagram to show how the particles are arranged in a silver lattice and show the charges on the particles.

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(3)

(d) Silver reacts with fluorine to form silver fluoride (AgF).

Silver fluoride has a high melting point and has a structure similar to that of sodium chloride.

State the type of bonding involved in silver fluoride.

Draw a diagram to show how the particles are arranged in a silver fluoride lattice and show the charges on the particles.

Explain why the melting point of silver fluoride is high.

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(5)
(Total 20 marks)

Q33. Under suitable conditions magnesium will react with dilute nitric acid according to the following equation.

$$Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$$

A 0.0732 g sample of magnesium was added to 36.4 cm^3 of 0.265 mol dm^{-3} nitric acid. The acid was in excess.

(a) (i) Calculate the amount, in moles, of magnesium in the 0.0732 g sample.

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(1)

(ii) Hence calculate the amount, in moles, of nitric acid needed to react completely with this sample of magnesium.

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(1)

(iii) Calculate the amount, in moles, of nitric acid originally added to this

sample of magnesium.

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(1)

(iv) Hence calculate the amount, in moles, of nitric acid that remains unreacted.

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(1)

(b) In a second experiment, 0.512 mol of hydrogen gas was produced when another sample of magnesium reacted with dilute nitric acid. Calculate the volume that this gas would occupy at 298 K and 96 kPa. Include units in your final answer.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(3)

(c) Concentrated nitric acid reacts with magnesium to form an oxide of nitrogen which contains 30.4% by mass of nitrogen.

Calculate the empirical formula of this oxide of nitrogen. Show your working.

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(3)
(Total 10 marks)

Q34. 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)

(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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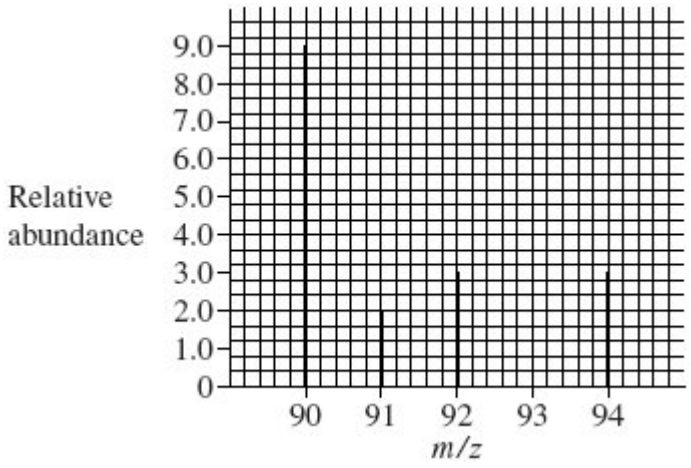
(3)

(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)

(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)

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

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(2)
(Total 15 marks)

Q35. 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)

(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)

(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.

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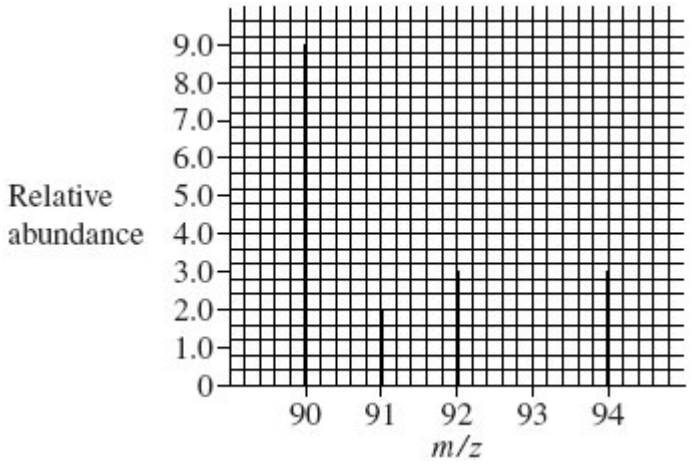

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(4)

(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)

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

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(2)
(Total 15 marks)