**Q1.**          The chloride of an element **Z** reacts with water according to the following equation.

ZCl4(l) + 2H2O(l) → ZO2(s) + 4HCl(aq)

A 1.304 g sample of ZCl4 was added to water. The solid ZO2 was removed by filtration and the resulting solution was made up to 250 cm3 in a volumetric flask. A 25.0 cm3 portion of this solution was titrated against a 0.112 mol dm–3 solution of sodium hydroxide, of which 21.7 cm3 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 ZCl4 present in the sample. Calculate the relative molecular mass, *M*r, of ZCl4.
From your answer deduce the relative atomic mass, *A*r, of element **Z** and hence its identity.

**(Total 9 marks)**

**Q2.**          (a)     A small sample of barium metal was added to water in a flask. When the reaction had ceased, the contents of the flask were treated with a small amount of dilute aqueous sodium sulphate.

Describe all that you would observe and write equations, with state symbols, for the reactions that occur.

**(8)**

(b)     Dilute sodium hydroxide solution was added dropwise until in excess to separate dilute aqueous solutions of beryllium chloride, magnesium chloride and barium chloride.

Describe what you would observe in each case and account for your observations.

**(8)**

(c)     (i)      A naturally occurring compound of calcium contains by mass 23.29% of calcium,18.64% of sulphur and 2.32% of hydrogen, the remainder being oxygen.

Determine the empirical formula of this compound.

(ii)     For any compound, what is the relationship between empirical and molecular formula? What additional information is required to determine a molecular formula from an empirical formula?

**(5)**

**(Total 21 marks)**

**Q3.**          (a)     Define the term *atomic number* of an element.

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**(1)**

(b)     Give the symbol, including mass number and atomic number, for an atom of an element which contains 12 neutrons and 11 electrons.

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**(2)**

(c)     In terms of s and p sub-levels, give the electronic configuration of an aluminium atom.

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**(1)**

(d)     How many neutrons are there in one 27Al atom?

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**(1)**

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

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**(2)**

(f)      Parts (i) to (iv) below refer to the operation of a mass spectrometer.

(i)      Name the device used to ionise atoms in a mass spectrometer.

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(ii)     Why is it necessary to ionise atoms before acceleration?

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(iii)     What deflects the ions?

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(iv)    What is adjusted in order to direct ions of different mass to charge ratio onto the detector?

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**(4)**

(g)     A meteorite was found to contain three isotopes of element **X**.
A mass spectrometer gave the following information about these isotopes.

|  |  |  |  |
| --- | --- | --- | --- |
| *m*/*z* | 24.0 | 25.0 | 26.0 |
| Relative abundance | 64.2 | 20.3 | 15.5 |

(i)      Calculate the relative atomic mass of **X**.

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(ii)     Using the Periodic Table, suggest the most likely identity of element **X**.

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(iii)     Suggest one reason why the relative atomic mass of **X**, given in the Periodic Table, differs from your answer to part (g)(i).

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**(5)**

**(Total 16 marks)**

**Q4.**          (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)**

**Q5.**          (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 m3 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 cm3 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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**(2)**

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

2NH3(aq)   +   H2SO4(aq)   →   (NH4)2SO4(aq)

In a titration, 25.0 cm3 of a 1.24 mol dm–3 solution of sulphuric acid required 30.8 cm3 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, Mg3N2, with water produces ammonia and magnesium hydroxide. Write an equation for this reaction.

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**(2)**

**(Total 16 marks)**

**Q6.**          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 m3 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)**

**Q7.**          (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 cm3.

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**(3)**

(b)     The carbonate of metal **M** has the formula M2CO3. The equation for the reaction of this carbonate with hydrochloric acid is given below.

M2CO3  +  2HCl  →  2MCl  +  CO2  +  H2O

A sample of M2CO3, of mass 0.394 g, required the addition of 21.7 cm3 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 M2CO3 in 0.394 g.

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(iii)     Calculate the relative molecular mass of M2CO3

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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)**

**Q8.**          (a)     A sample of ethanol vapour, C2H5OH (*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 cm3, 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.

Mg3N2   +               H2O   →             Mg(OH)2   +              NH3

(ii)     Calculate the number of moles, and hence the number of molecules, of NH3 in 0.263 g of ammonia gas.
(The Avogadro constant *L* = 6.02 × 1023 mol–1)

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**(4)**

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

NaCl    +   NH3    +     CO2   +  H2O   →    NaHCO3   +   NH4Cl

2NaHCO3 →    Na2CO3  +   H2O   +   CO2

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)**

**Q9.**          (a)     Give the relative charge and relative mass of an electron.

*Relative charge ..*.........................................................................................

*Relative mass* ..............................................................................................

**(2)**

(b)     Isotopes of chromium include 54Cr and 52Cr

(i)      Give the number of protons present in an atom of 54Cr

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(ii)     Deduce the number of neutrons present in an atom of 52Cr

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(iii)     Apart from the relative mass of each isotope, what else would need to be known for the relative atomic mass of chromium to be calculated?

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**(3)**

(c)     In order to obtain a mass spectrum of a gaseous sample of chromium, the sample must first be ionised.

(i)      Give **two** reasons why it is necessary to ionise the chromium atoms in the sample.

*Reason 1 .*..........................................................................................

*Reason 2* ............................................................................................

(ii)     State what is adjusted so that each of the isotopes of chromium can be detected in turn.

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(iii)     Explain how the adjustment given in part (c)(ii) enables the isotopes of chromium to be separated.

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**(4)**

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

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(ii)     A chromium compound contains 28.4% of sodium and 32.1% of chromium by mass, the remainder being oxygen.
Calculate the empirical formula of this compound.

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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 cm3 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.

MgCO3  +  2HCl  →  MgCl2  +  H2O  +  CO2

When 75.0 cm3 of 0.500 mol dm–3 hydrochloric acid were added to 1.25 g of impure MgCO3 some acid was left unreacted. This unreacted acid required 21.6 cm3 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 cm3 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 MgCO3 in the sample was 0.0267

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(iv)    Calculate the number of moles and the mass of MgCO3 in the sample, and hence deduce the percentage by mass of MgCO3 in the sample.

*Moles of MgCO3* ..................................................................................

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*Mass of MgCO3* ...................................................................................

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*Percentage of MgCO3 .*.........................................................................

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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 Na2SO3

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(ii)     When Na2SO3 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 × 1023 mol–1)

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**(5)**

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

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**(1)**

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

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**(1)**

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

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**(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 Na2CO3.*x*H2O

A 3.01 g sample of one of these hydrates was dissolved in water and the solution made up to 250 cm3.
In a titration, a 25.0 cm3 portion of this solution required 24.3 cm3 of 0.200 mol–1 dm–3 hydrochloric acid for complete reaction.

The equation for this reaction is shown below.

Na2CO3 + 2HCl → 2NaCl + H2O + CO2

(i)      Calculate the number of moles of HCl in 24.3 cm3 of 0.200 mol dm–3 hydrochloric acid.

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(ii)     Deduce the number of moles of Na2CO3 in 25.0 cm3 of the Na2CO3 solution.

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(iii)     Hence deduce the number of moles of Na2CO3 in the original 250 cm3 of solution.

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(iv)    Calculate the *M*r of the hydrated sodium carbonate.

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**(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, Na2CO3.*x*H2O

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**(3)**

(c)     A gas cylinder, of volume 5.00 × 10–3 m3, contains 325 g of argon gas.

(i)      Give the ideal gas equation.

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(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)

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**(4)**

**(Total 12 marks)**

**Q15.**          (a)     Complete the following table.

|  |  |  |
| --- | --- | --- |
|   | Relative mass | Relative charge |
| Proton |   |   |
| Electron |   |   |

**(2)**

(b)     An atom of element **Q** contains the same number of neutrons as are found in an atom of 27A1. An atom of **Q** also contains 14 protons.

(i)      Give the number of protons in an atom of 27A1.

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(ii)     Deduce the symbol, including mass number and atomic number, for this atom of element **Q**.

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**(3)**

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

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**(2)**

(d)     The table below gives the relative abundance of each isotope in a mass spectrum of a sample of magnesium.

|  |  |  |  |
| --- | --- | --- | --- |
| *m*/*z* | 24 | 25 | 26 |
| Relative abundance (%) | 73.5 | 10.1 | 16.4 |

Use the data above to calculate the relative atomic mass of this sample of magnesium.
Give your answer to one decimal place.

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**(2)**

(e)     State how the relative molecular mass of a covalent compound is obtained from its mass spectrum.

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**(1)**

**(Total 10 marks)**

**Q16.**          (a)     Ammonia, NH3, reacts with sodium to form sodium amide, NaNH2, and hydrogen.

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

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(ii)     Draw the shape of an ammonia molecule and that of an amide ion, NH

In each case show any lone pairs of electrons.

NH3                                                  NH

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

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

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**(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*.

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

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**(3)**

**(Total 9 marks)**

**Q17.**          (a)     Ammonium sulphate reacts with aqueous sodium hydroxide as shown by the equation below.

(NH4)2SO4 + 2NaOH  →  2NH3 + Na2SO4 + 2H2O

A sample of ammonium sulphate was heated with 100 cm3 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 cm3 of
0.600 mol dm–3 hydrochloric acid for neutralisation.

(i)      Calculate the original number of moles of NaOH in 100 cm3 of 0.500 mol dm–3 aqueous sodium hydroxide.

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(ii)     Calculate the number of moles of HCl in 27.3 cm3 of 0.600 mol dm–3 hydrochloric acid.

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

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(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.

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(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* .............................................................

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*Mass of ammonium sulphate* ..............................….............................

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**(7)**

(b)     A 0.143g gaseous sample of ammonia occupied a volume of 2.86 × 10–4 m3 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* ........................................................................................

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

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**(4)**

**(Total 11 marks)**

**Q18.**          (a)     Define the terms

(i)      *mass number* of an atom,

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(ii)     *relative molecular mass*.

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**(3)**

(b)     (i)      Complete the electron arrangement for a copper atom.

*1s*2 .......................................................................................................

(ii)     Identify the block in the Periodic Table to which copper belongs.

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(iii)     Deduce the number of neutrons in one atom of 65Cu

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**(3)**

(c)     A sample of copper contains the two isotopes 63Cu and 65Cu only. It has a relative atomic mass, *A*r, less than 64. The mass spectrum of this sample shows major peaks with *m/z* values of 63 and 65, respectively.

(i)      Explain why the *A*r of this sample is less than 64.

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(ii)     Explain how Cu atoms are converted into Cu+ ions in a mass spectrometer.

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(iii)     In addition to the major peaks at *m/z* = 63 and 65, much smaller peaks at *m/z* = 31.5 and 32.5 are also present in the mass spectrum. Identify the ion responsible for the peak at *m/z* = 31.5 in the mass spectrum. Explain why your chosen ion has this *m/z* value and suggest **one** reason why this peak is very small.

*Identity of the ion*

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*Explanation for m/z value* ....................................................................

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*Reason why this peak is very small* ....................................................

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**(6)**

**(Total 12 marks)**

**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 + 2HNO3 → Pb(NO3)2 + H2O

An excess of lead(II) oxide was allowed to react with 175 cm3 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(NO3)2(s) → 2PbO(s) + 4NO2(g) + O2(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 m3.

(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* ..............................................................

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(ii)     Deduce the number of moles, and the mass, of NO2 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 ......................................................................

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*Mass of NO*2........................................................................................

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**(7)**

**(Total 11 marks)**

**Q20.**          (a)     Dichloromethane, CH2Cl2, is one of the products formed when chloromethane, CH3Cl, 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*

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*First propagation step*

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*Second propagation step*

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

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**(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, CH2Br2, reacts with bromine.

*Compound 1* ................................................................................................

*Compound 2 .*...............................................................................................

**(2)**

**(Total 10 marks)**

**Q21.**          Potassium nitrate, KNO3, decomposes on strong heating, forming oxygen and solid **Y** as the only products.

(a)     A 1.00 g sample of KNO3 (*M*r = 101.1) was heated strongly until fully decomposed into **Y**.

(i)      Calculate the number of moles of KNO3 in the 1.00 g sample.

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(ii)     At 298 K and 100 kPa, the oxygen gas produced in this decomposition occupied a volume of 1.22 × 10–4 m3.

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 ..*................................................................................

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**(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*.

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

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**(4)**

(c)     Deduce an equation for the decomposition of KNO3 into **Y** and oxygen.

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**(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 9Be. Deduce the symbol, including the mass number, of this atom.

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**(2)**

(c)     Draw the shape of a molecule of BeCl2 and the shape of a molecule of Cl2O. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

*BeCl*2 Cl2O

*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) → MgCl2(aq) + 2H2O(l)

Calculate the volume, in cm3, of 1.00 mol dm–3 hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

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**(4)**

**(Total 12 marks)**

**Q23.**          A 0.263 g sample of impure iron, containing an unreactive impurity, was reacted with an excess of hydrochloric acid. All of the iron in the sample reacted, evolving hydrogen gas and forming a solution of iron(II) chloride. The volume of hydrogen evolved was 102 cm3, measured at 298 K and 110 kPa.

The percentage, by mass, of iron in the sample can be determined using either the volume of hydrogen produced or by titrating the solution of iron(II) chloride formed against a standard solution of potassium dichromate(VI).

(a)     (i)      Write an equation for the reaction between iron and hydrochloric acid.

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(ii)     Calculate the number of moles of hydrogen produced in the reaction.

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(iii)     Use your answers to parts (a)(i) and (ii) to determine the number of moles of iron and the mass of iron in the original sample. (If you have been unable to complete part (a)(ii) you should assume the answer to be 4.25 × 10–3 mol. This is not the correct answer.)

*Moles of iron .*......................................................................................

*Mass of iron* ........................................................................................

(iv)    Calculate the percentage of iron in the original sample.

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**(7)**

(b)     (i)      Write half-equations for the oxidation of Fe2+ and for the reduction of Cr2Oin acidic solution, and use these to construct an overall equation for the reaction between these two ions.

*Half*-*equation for the oxidation of Fe2+*

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*Half*-*equation for the reduction of Cr2O*

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*Overall equation*

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(ii)     The number of moles of iron in the sample was determined in part (a)(iii). Use this answer to calculate the volume of a 0.0200 mol dm–3 solution of potassium dichromate(VI) which would react exactly with the solution of iron(II) chloride formed in the reaction.

(If you have been unable to complete part (a)(iii) you should assume the answer to be 3.63 × 10–3 mol. This is not the correct answer.)

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(iii)     Explain why an incorrect value for the number of moles of iron(II) chloride formed would have been obtained if the original solution had been titrated with potassium manganate(VII).

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**(7)**

**(Total 14 marks)**

**Q24.**          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**                          Br2  2Br•

Step **2**         Br• + CH3CH3  CH3CH2• + HBr

Step **3**         CH3CH2• + Br2CH3CH2Br + Br•

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

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(ii)     Suggest an essential condition for this reaction.

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

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(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.

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(ii)     Write an equation for the reaction between bromine and ethane which produces hexabromoethane, C2Br6, by this substitution reaction.

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**(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*.

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(ii)     Calculate the *M*r of halothane.

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

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**(3)**

**(Total 11 marks)**

**Q25.**          Nitroglycerine, C3H5N3O9, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

4C3H5N3O9(l) → 12CO2(g) + 10H2O(g) + 6N2(g) + O2(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.

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(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* ..............................................................................

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

*Moles of nitroglycerine* ........................................................................

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*Mass of nitroglycerine* .........................................................................

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**(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 m3. 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–1mol–1)

*Ideal gas equation* ......................................................................................

*Pressure* ......................................................................................................

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**(4)**

**(Total 11 marks)**

**Q26.**          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.



**(2)**

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

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

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

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**(3)**

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

*Comparison* .................................................................................................

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*Explanation* ..................................................................................................

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**(3)**

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

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**(1)**

(e)     Sodium chlorate(V), NaClO3, 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 NaClO3

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

....... Cl2 + ....... NaOH → ....... NaCl + NaClO3 + 3H2O

**(3)**

**(Total 12 marks)**

**Q27.**          (a)     Nitromethane, CH3NO2, is used as an ‘energy rich’ fuel for motor-racing. It burns in oxygen forming three gases.

2CH3NO2(l) + 1½O2(g) → 2CO2(g) + 3H2O(g) + N2(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).

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(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 m3 but this is not the correct answer).

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**(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) + CO2(g) → Na2CO3(aq) + H2O(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* .......................................................................

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*Environmental disadvantage* ..............................................................

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**(4)**

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

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**(3)**

(d)     Another oxide of nitrogen, N2O, decomposes on warming to produce nitrogen and oxygen. Write an equation for the decomposition reaction.

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**(1)**

(e)     Internal combustion engines burn fuels in air. Suggest one advantage of using air mixed with N2O for this purpose.

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**(1)**

**(Total 14 marks)**

**Q28.**          A metal carbonate MCO3 reacts with hydrochloric acid as shown in the following equation.

MCO3  +  2HCl  →  MCl2  +  H2O  +  CO2

A 0.548 g sample of MCO3 reacted completely with 30.7 cm3 of 0.424 mol dm–3 hydrochloric acid.

(a)     (i)      Calculate the amount, in moles, of HCl which reacted with 0.548 g MCO3

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**(1)**

(ii)     Calculate the amount, in moles, of MCO3 in 0.548 g.

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**(1)**

(iii)     Calculate the relative formula mass of MCO3

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**(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 MCO3 you should assume it to be 147.6 but this is not the correct answer.)

Relative atomic mass ..................................................................................

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

**(2)**

**(Total 5 marks)**

**Q29.**          Titanium(IV) oxide (TiO2, *M*r = 79.9) is used as a white pigment in some paints. The pigment can be made as shown in the following equation.

TiCl4(l)   +   2H2O(l)   →  TiO2(s)   +   4HCl(aq)

(a)     (i)      Calculate the percentage atom economy for the formation of TiO2

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**(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.

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**(1)**

(b)     In an experiment 165 g of TiCl4 were added to an excess of water.

(i)      Calculate the amount, in moles, of TiCl4 in 165 g.

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**(2)**

(ii)     Calculate the maximum amount, in moles, of TiO2 which can be formed in this experiment.

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**(1)**

(iii)     Calculate the maximum mass of TiO2 formed in this experiment.

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**(1)**

(iv)    In this experiment only 63.0 g of TiO2 were produced. Calculate the percentage yield of TiO2

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**(1)**

**(Total 8 marks)**

**Q30.**          Under suitable conditions magnesium will react with dilute nitric acid according to the following equation.

Mg(s) + 2HNO3(aq) → Mg(NO3)2(aq) + H2(g)

A 0.0732 g sample of magnesium was added to 36.4 cm3 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)**

**Q31.**          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 **Z**+ ions in a mass spectrometer.

State and explain which of the **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)**

**Q32.**          Ammonium sulfate reacts with sodium hydroxide to form ammonia, sodium sulfate and water as shown in the equation below.

(NH4)2SO4(s) + 2NaOH(aq) → 2NH3(g) + Na2SO4(aq) + 2H2O(l)

(a)     A 3.14 g sample of ammonium sulfate reacted completely with 39.30 cm3 of a sodium hydroxide solution.

(i)      Calculate the amount, in moles, of (NH4)2SO4 in 3.14 g of ammonium sulfate.

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**(2)**

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

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**(1)**

(iii)     Calculate the concentration, in mol dm–3, of the sodium hydroxide solution used.

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**(1)**

(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)**

(c)     Ammonia is manufactured by the Haber Process.

N2 + 3H2  2NH3

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

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**(1)**

(d)     A sample of ammonia gas occupied a volume of 1.53 × 10–2 m3 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)**

(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 Na2SO4.*x*H2O where *x* is an integer. Calculate the value of *x*.

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**(3)**

**(Total 13 marks)**

**Q33.**          (a)     Define the term *relative atomic mass*.

An organic fertiliser was analysed using a mass spectrometer. The spectrum showed that the nitrogen in the fertiliser was made up of 95.12% 14N and 4.88% 15N

Calculate the relative atomic mass of the nitrogen found in this organic fertiliser.
Give your answer to two decimal places.

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**(4)**

(b)     In a mass spectrometer, under the same conditions, 14N+ and 15N+ ions follow different paths. State the property of these ions that causes them to follow different paths.

State **one** change in the operation of the mass spectrometer that will change the path of an ion.

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**(2)**

(c)     Organic fertilisers contain a higher proportion of 15N atoms than are found in synthetic fertilisers.

State and explain whether or not you would expect the chemical reactions of the nitrogen compounds in the synthetic fertiliser to be different from those in the organic fertiliser. Assume that the nitrogen compounds in each fertiliser are the same.

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**(2)**

**(Total 8 marks)**

**Q34.**          Define the term *mass number* of an atom.

The mass number of an isotope of nitrogen is 15. Deduce the number of each of the fundamental particles in an atom of 15N

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**(Total 3 marks)**

**Q35.**          Define the term *mass number* of an atom.

The mass number of an isotope of nitrogen is 15. Deduce the number of each of the fundamental particles in an atom of 15N

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**(Total 3 marks)**

**M1.**          moles NaOH used          = vol / 1000 × conc **(1)** = 21.7 *(if uses 25 here only scores
                                        first of first 4 marks)*/ 1000 × 0.112
                                        = 0.00243 **(1)** (consider 0.0024 as an arithmetic
                                        error loses 1 mark)
                                        *(range 0.00242 to 0.00244)*moles HCl in 25 cm3       = 0.00243 **(1)** (or 1 mol HCl reacts with 1 mol NaOH)
moles of HCl in 250 cm3 = 0.0243 **(1)**moles ZCl4                       = 0.0243 / 4 = 0.006075 **(1)** (or 0.006076 or 0.006 mark
                                        is for / 4)
*M*r                                    = mass / no. Moles **(1)** (method mark also 1.304 / 0.006075)
                                        = 214.7 **(1)** (or 0.006 gives 217) *(allow 214 to 215)
A*r                                     = 214.7 ‑ 142 = 72.7 **(1)** (217 gives 75, 142 is 35.5 × 4)
Therefore element is       Germanium **(1)** (allow conseq correct from *A*r)
                                        *(75 gives As)*

*If not / 4 C.E. from there on but can score 2 independent marks for (mass / moles / method and identity of element)
(for candidates who use m1v1 = m2v2 and calculate [HCl] = 0.0972 allow 1st 3 marks
if 25 and 21.7 wrong way round only award 1/3)*

**[9]**

**M2.**          (a)     Barium dissolves **(1)**                (or forms solution)
Gas evolved **(1)**                        (or hydrogen evolved) or
bubbles     gets hot **(1)**

*do not allow evolution of wrong gas*

Ba(s) + 2H2O(l) → Ba2+(aq) + 2OH–(aq)    (or Ba(OH)2(aq) + H2(g)
Species all correct **(1)**State symbols correct **(1)** (provided species are correct)
Balanced equation **(1)**

White precipitate with sodium sulphate **(1)**(or white solid or suspension or white cloudy or milky)
Ba2+(aq) + SO42–(aq) → BaSO4(s)
(or Ba(OH)2(aq) + Na2SO4(aq) → BaSO4(s) + 2NaOH(aq)
State symbols **(1)**Balanced equation **(1)**

*(mark obs. of ppts independently (and in (b))*

**8**

(b)     with BeCl2 and NaOH get a white precipitate **(1)** (or solid etc)
because Be(OH)2 is insoluble **(1)**      (or white ppt is Be(OH)2)
ppt is soluble in excess of the reagent **(1)**Because Be(OH)2 is amphoteric (or beryllium forms complex ion
(Be(OH)42–)) **(1)***(This is the quality of language mark so the terms must be used in
a sentence)*

With MgCl2 get white ppt **(1)**Because Mg(OH)2 is sparingly soluble (or insoluble) **(1)** (or white ppt is
Mg(OH)2)

With BaCl2 no ppt formed **(1)** (or no reaction) (or remains in solution)
Because Ba(OH)2 is soluble **(1)** (or all species are soluble)
Solubility of hydroxides increases down Group **(1)**

*Note can take marks for Be(OH)2(s), Mg(OH)2 (s), Ba(OH)2(aq)
from equations
Wrong formula for M(OH)2 loses mark*

**max 8**

(c)     (i)      %O = 55.75% **(1)**Ca : S : O : H =  **(1)**

*Allow 40, 32*

*= 1:    1:         6:      4:*

*therefore formula: CaSO6H4* ***(1)***

*if Oxygen omitted can score 2nd mark only*

**2**

(ii)      = an integer **(1) (or a number)**

*Allow correct definitions as an alternative for the mark
emp. form. The simplest ratio of atoms of each element in a compound molec. form. The actual number of atoms of
each element in a molecule*

         Mr **(1)** (or molar mass or RFM NOT molecular mass)

**5**

**[21]**

**M3.**          (a)     number of protons in one atom or nucleus **(1)**

*Allow protons & electrons*

*do not allow protons + electrons or electrons*

**1**

(b)     **(1)** Na **(1)**

*OR Na or Na (1) + unambiguous statement of mass no. and atomic no.*

**2**

(c)     1s2 2s2 2p6 3s2 3p1 **(1)**

*Allow Ne 3s2 3p1*

**1**

(d)     14 **(1)**

**1**

(e)     **(1)** × 12 **(1)**

*Reference to mass number not mass C.E. = 0
OR stated in moles*

*OR compared with 1/12 of a 12C atom or relative
to 12C when taken as 12*

**2**

(f)      (i)      electron gun **(1)**

(ii)     (particles must be charged) (ions) before attraction to
a charged plate (or electric field) **(1)**

(or only ions can be attracted or accelerated by an
electric field)

*or converse; if not charged not attracted to electric field*

(iii)     magnetic field (or magnet) **(1)**

(iv)    magnetic field **(1)** or (accelerating potential or strength of magnet)

*allow magnet*

**4**

(g)     (i)       **(1)**

(1) mark for any m/z × relative abundance

*If numerator is correct but 100 has A.E. conseq A.E. -1*

*If A.E. on 100 allow conseq correct answer provided numerator is correct*

= 24.5 **(1)**

*Allow 24.5 to 24.52*

*ignore units*

(ii)     magnesium **(1)** (or Mg) (allow conseq on wrong Ar)

(iii)     abundance of isotopes is different **(1) (or different isotopes)**

**5**

**[16]**

**M4.**         (a)     Proton: mass 1, charge + 1 **(1)**Neutron: mass 1, charge 0 **(1)**Electron mass 1/1840, charge -1 **(1)**

*Allow mass = 0, or negligible, or 1/1800 to 1/2000*

          Isotopes have the same number of protons **(1)**

*OR atomic number*

          different number of neutrons **(1)**

          Isotopes have the same electronic configuration **(1)**

*OR same number of electrons*

          Chemical properties depend on electrons **(1)**

**7**

(b)      ×12 **(1)**

*OR  × 12 or in words*

          Spectrum gives (relative) abundance **(1)**

*OR % or amount*

And *m/z* **(1)**Multiply *m/z* by relative abundance for each isotope **(1)**

*Allow instead of m/z mass no, Ar or actual value from example*

Sum these values **(1)**Divide by the sum of the relative abundances **(1)**

*only award this mark if previous 2 given*

*Max 2 if e.g. has only 2 isotopes*

**7**

**[14]**

**M5.**          (a)     L =  **(1)** or 

*must show working*

          = 6.0225 × 1023 **(1)**

*Ignore wrong units*

*NB answer only scores 1*

**2**

(b)     equal **(1)**

*Or same or 1:1*

**1**

(c)     PV = nRT (or n = ) **(1)**

          = **(1)**

          = 1.39 **(1)**

*Allow 1.390 to 1.395*

*ignore units even if incorrect*

*answer = 1.4 loses last mark*

**3**

(d)     0.732 ×  = 2.93 **(1)** mol.dm–3 **(1)**

*OR M, mol/dm3, mol.l–1*

*allow 2.928 to 2.93*

*Note unit mark tied to current answer but allow unit
mark if answer = 2.9 or 3*

**2**

(e)     (i)      moles H2SO4 =  × 1.24 = 0.0310 **(1)**

*If use m1v1 = m2v2 scores 3 if answer is correct otherwise zero*

         moles NH3 in 30.8 cm3 = 0.0310 × 2 = 0.0620  **(1)**

*Mark is for ×2*

*CE if × 2 not used*

         moles of NH3 in 1 dm3 = 0.620 ×  = 2.01 **(1)** (mol dm–3)

*Allow 2.010 to 2.015*

*No units OK, wrong units lose last mark*

(ii)     moles (NH4)2SO4 = moles H2SO4 = 0.310 **(1)**

*Allow consequential wrong moles in part (i) if clear H2SO4=(NH4)SO4*

*Wrong formula for (NH4)2SO4 CE=0*

         Mr (NH4)2SO4 = 132.1 **(1)**

*Allow (132)*

         mass = moles × Mr = 0.0310 × 132.1 = 4.10 **(1)**

*if moles of (NH4)2SO4 not clear CE*

*(g) wrong unit loses mark*

*Allow 4.09 – 4.1 – 4.11*

**6**

(f)      Mg3N2 + 6H2O → 3Mg(OH)2 + 2NH3

*Formulae (1)*

*Balanced equation (1)*

**2**

**[16]**

**M6.**          (a)     Ideal gas equation law **(1)**

**1**

(b)     *Moles of* ***X***: *n* =  **(1) = **

  = 6.55 × 10–3 **(1)**

*6.5 to 6.6 × 10–3 , min 2 sig figs*

*If write n =  zero here, but can score Mr*

          *Relative molecular mass of* ***X***: Mr =  **(1)**

 = 62 **(1)**

*61.5 to 62.5*

**4**

(c)     % oxygen = 51.6 **(2)**

|  |  |  |  |
| --- | --- | --- | --- |
| C =38.7 / 12 | H = 9.68 / 1 | O = 57.6**(2)** / 16 | **(1)** |
| = 3.23 | = 9.68 | = 3.23 |   |

1 : 3: 1                             CH3O **(1)**

*If no % O or if wrong Ar used then max 1
Correct empirical  formula earns all three marks*

**3**

(d)     ( × CH3O) = C2H6O2 **(1)**

**1**

**[9]**

**M7.**          (a)     Moles HCl =  =  **(1)** (= 0.537)

Concentration =  **(1)**

= 2.15 (mol dm–3) **(1)**

*Conseq on  correct*

*min 2 d.p. 2.14 to 2.15*

*Ignore wrong units*

*A.E. lose one mark*

**3**

(b)     (i)       = 5.7**(1)** × 10–3 (mol) **(1)**

*5.7 to 5.71 × 10–3*

(ii)      = 2.85 × 10–3 (mol) **(1)**

*Conseq*

(iii)      = 138 **(1)**

*Conseq*

(iv)    *Relative atomic mass of* ***M***: 138 ‑ 60 = 78 **(1)**

** = 39 (1)
*Identify of M*: Potassium or K or K+ (1)**

*Conseq*

*If 78 = Mr then M = selenium*

**6**

**[9]**

**M8.**          (a)     (i)      pV = nRT **(1)**

(ii)     Moles ethanol = n = 1.36/46 (=0.0296 mol) **(1)**

V = nRT/p =  **(1)**

*if V = p/nRT lose M3 and M4*

         = 8.996 × 10–4 (m3) **(1)**= 899 (900) cm3 **(1)** *range = 895 – 905*

*If final answer = 0.899 award (2 + M1); if = 0.899 dm3* ***or*** *if = 912 award (3 + M1)*

***Note:*** *If 1.36* ***or*** *46 or 46/1.36 used as number of moles (****n****) then M2 and M4 not available****Note:*** *If pressure = 100 then, unless answer = 0.899* ***dm****3, deduct M3 and mark consequentially*

**5**

(b)     (i)      Mg3N2 + **6**H2O → **3**Mg(OH)2 + **2**NH3 **(1)**

(ii)     Moles NH3 =  (=0.0155 mol) **(1)**

Number of molecules of NH3 = 0.0155 × 6.02 × 1023 **(1)**

[mark conseq] = 9.31 × 1021 **(1)**[range 9.2 × 1021 to 9.4 × 1021]

*Conseq (****min*** *2 sig fig)*

**4**

(c)     Moles NaCl = 800/58.5             (= 13.68) **(1)**

Moles of NaHCO3 = 13.68 **(1)**

Moles of Na2CO3 = 13.68/2     = 6.84 **(1)**

Mass of Na2CO3 = 6.84 × 106 = 725 g **(1)   [**range = 724 – 727]

[1450 g (range 1448 – 1454) is worth 3 marks]

*Accept valid calculation method, e.g. reacting masses or calculations via the mass of sodium present. Also, candidates may deduce a direct 2:1 ratio for NaCl:Na2CO3*

**4**

**[13]**

**M9.**          (a)     Relative charge –1 **(1)**

          Relative mass  1/1800 or  5.55 × 10–4 **(1)**

*Accept zero / negligible*

**2**

(b)     (i)      Protons = 24 **(1)**

(ii)     Neutrons = 28 **(1)**

(iii)     Need (relative) abundance or peak height or intensity
/ amount / number / % / fraction of each element **(1)**

*Not: ‘ratio of each isotope’*

**3**

(c)     (i)      *Reason 1:* To allow particles to be accelerated / deflected /
detected **or** to count

         *Reason 2:* Charged particles **or** to generate a current in the detector
*Any 2* **(2)**

*Not: ‘to allow m/z to be measured’*

(ii)     Magnetic field or electric field or electromagnet **(1)**

(iii)     Deflection depends on mass or m/z **(1)**

**4**

(d)     (i)      (simplest) ratio of atoms of each element in compound **(1)**

(ii)     % oxygen = 39.5% **(1)**

         Na 28.4/23             Cr 32.1/52                O 39.5/16 **(1)**= 1.23                     = 0.617                     = 2.47
(2:1:4) so empirical formula = Na2CrO4 **(1)**

*If % oxygen not calculated, only M2 available; if Ar values wrong, only M1 available*

**4**

**[13]**

**M10.**          *Ideal gas equation*: pV = nRT **(1)**

*Calculation*: n = pV/RT =  **(1)**

*mark for volume conversion fully correct*

                                             = 3.79 × 10–3 (mol) **(1)**

*range 3.79 × 10–3 to 3.8 × 10–3*

          Mr = m/n = .304/3.79 × 10–3 = 80.1 **(1)**

*range 80 – 80.3
min 2 s.f. conseq*

*If ‘V’ wrong lose M2; ‘p’ wrong lose M3; ‘inverted’ lose M3 and M4*

**[5]**

**M11.**          (a)     (i)      75.0 × 10–3 × 0.500 = 0.0375 (mol) **(1)**

*accept 0.037 or 0.038*

(ii)     21.6 × 10–3 × 0.500 = 0.0108 (mol) **(1)**

*accept 0.011*

*If both (i) and (ii) answers wrong, allow ONE process mark for both correct processes*

(iii)     0.0375 - 0.0108 = 0.0267 (mol) **(1)**

*Not conseq – must use figures shown*

(iv)    *Moles of MgCO3* = 0.0267/2          = 0.01335 (mol) **(1)**

*allow 0.0134 - 0.0133*

*Mass of MgCO3* = 0.01335 × 84.3 **(1)**

*allow 84*

*mark conseq on moles MgCO3*

= 1.125g **(1)**

*accept 1.13g*

*mark conseq*

*Percentage MgCO3* = 1.125/1.25 × 100 **(1)**

*mark conseq (check for inversion)*

= 90% **(1)**

*mark conseq*

                               range = 89.5 - 90.5%

*If % expression inverted, lose M4 and M5*

**8**

(b)     (i)      % oxygen = 38.0 **(1)**

Na = 36.5/23          S = 25.5/32(.1)              O = 38.0/16 **(1)**

     = 1.587              = 0.794                         = 2.375

     = 2:1:3 **(1)**

*If no % of oxygen Max 1 (allow M2 only)
If % for Na and S transposed, or atomic numbers used, M1 only available*

(ii)     Na2SO3 + 2HCl → 2NaCl + H2O + SO2 **(1)**

*allow multiples*

*allow SO32– + 2H+ → H2O + SO2*

**4**

**[12]**

**M12.**          (a)     (i)      Atoms with the same number of protons / proton number **(1)**

*NOT same atomic number*

with different numbers of neutrons **(1)**

***NOT*** *different mass number / fewer neutrons*

(ii)     Chemical properties depend on the number or amount of
(outer) electrons **(1)** OR, isotopes have the same electron
configuration / same number of e–

(iii)     23/6.023 × 1023 **(1)**

*CE = 0 if inverted or multiplied*

         tied to M1 3.8(2) × 10–23      [2-5 sig figs] **(1)**

**5**

(b)     1s2 2s2 2p6 3s1 **(1)**

*accept subscripted figures*

**1**

(c)     Highest energy e– / outer e–s / last e– in (3)d sub-shell **(1)**

*OR d sub-shell being filled / is incomplete
OR highest energy sub-shell is (3)d
NOT transition element / e– configuration ends at 3d*

*Q of L*

**1**

(d)                      N correct symbol **(1)**

*allow *

Mass number = 15 AND atomic number = 7 **(1)**

**2**

**[9]**

**M13.**          (a)     Mg + 2HCl → MgCl2 + H2

**1**

MgO + 2HCl → MgCl2 + H2O

*Allow ionic equations*

**1**

(b)     Hydrogen collection
Using a gas syringe or measuring cylinder/ graduated vessel over water

*Allow if shown in a diagram*

**1**

          Measurements                              (i) P 1
                                                      (ii) T 1
                                                      (iii) V 1

Use ideal gas equation to calculate mol hydrogen or mass/*M*r
Mol H2 = mol Mg (Mark consequentially to equation)

**2**

(c)     MgCl2 + 2NaOH → Mg(OH)2 + 2NaCl Species

**1**

          Balanced

**1**

*Allow an ionic equation*

          Mg(OH)2 → MgO + H2O

**1**

(d)     ***Allow 2 significant figures in these calculations and
ignore additional figures***

          EITHER

          Mol MgO obtained stage 2 = mass MgO/*M*rMgO

**1**

          = 6.41/ 40.(3)                     = 0.159 *Allow 0.16*

*Allow method mark if formula of magnesium oxide or Mr incorrect*

**1**

          Moles of Mg = moles of H2 hence

Mol original MgO = mol MgO from stage 2 - mol H2

**1**

= 0.159 – 0.0528 = 0.106 *Allow 0.11*

*Mark consequentially to moles of magnesium oxide determined above*

          OR

          Mass MgO formed from Mg = 0.0528 × *M*r MgO {or 40.(3)}             **(1)**

= 2.13 g

*Allow 2.1* ***(1)***

*Allow method mark if formula of magnesium oxide or Mr incorrect*

          Mass original MgO = total mass MgO - mass formed from Mg       **(1)**

                             = 6.41 – 2.13 = 4.28 g           *Allow 4.3*                 **(1)**

*Mark consequentially mass of magnesium oxide determined above*

**NB**

**As there is an error in part (d), the mass of sample should
have been 6.25 NOT 2.65, award full marks to any candidate
who has crossed out their correct first** **answer.**

**1**

**[15]**

**M14.**          (a)     (i)      4.86 × 10–3

**1**

(ii)     2.43 × 10–3

*(mark conseq on (a)(i))*

**1**

(iii)     2.43 × 10–2

*(mark conseq on (a)(ii))*

**1**

(iv)    3.01/2.43 × 10–2

*(mark conseq on (a)(iii))*

**1**

         124

*(Do not allow 124 without evidence of appropriate calculation in (a)(iii))*

**1**

(b)     Mr(Na2CO3) = 106
Mr (*x*H2O) = 250 –106 = 144*(mark conseq on M1)
x* = 8                                            *(mark conseq on M2)*

*(Penalise sf errors once only)*

**3**

(c)     (i)      PV = nRT

**1**

(ii)     Moles A r = 325/39.9 = 8.15

*(accept Mr = 40)*

**1**

         P = nRT/V = (8.15 × 8.31 × 298)/5.00 × 10–3    = 4.03 × 106 Pa   or   = 4.03 × 103 kPa

*Range = 4.02 × 106 Pa to 4.04 × 106 Pa*

*(If equation incorrectly rearranged, M3 & M4 = 0 If n =325,
lose M2)*

*(Allow M1 if gas law in (ii) if not given in (i))*

**2**

**[12]**

**M15.**         (a)     Proton        mass = 1                                             charge = +1
Electron     mass  1/1800 Or  5.6 × 10–4            charge = –1

*(Do not accept +1 for proton mass or ‘g’ units)*

**2**

(b)     (i)      13

**1**

(ii)     Si

**1**

Mass number = 28 **and** atomic number = 14

*(Do not accept 28.1 or 28.0 or ‘Silicon’)*

**5**

(c)     Mean (average) mass of an atom / all the isotopes
1/12th mass of atom of 12C
OrMass of 1 mole of atoms of an element**(1)**       1/12th mass of 1 mole of 12C**(1)**OrAverage mass of an atom / all the isotopes**(1)**       relative to the mass of a 12C atom taken as exactly 12 / 12.000**(1)**

*(Penalise ‘weight’ once only) (Ignore ‘average’ mass of 12C)*

*(Do not allow ‘mass of average atom’)*

**2**

(d)     Ar = (24 × 0.735) + (25 × 0.101) + (26 × 0.164) 1 = 24.4 1

*(mark M2 conseq on transcription error or incorrect addition of %)*

(e)     Mr = highest m/z value 1

*(NOT ‘highest/largest/right-hand’ peak)*

**3**

**[10]**

**M16.**          (a)     (i)      2Na   +   2NH3   →   2NaNH2   +   H2

*(or multiples)*

**1**

(ii)     (Missing ‘H’ penalise once only) [NOT dot-and-cross diagrams]



**1**

[NOT 90° / 180° angles]      (need 2 lp & ‘bent’ shape)

**1**

(iii)     107°

**1**

(iv)    More lone pairs on NH2–, than on NH3

**1**

         Lone pairs repel more than bonding pairs

*Must be comparison*

*(Mark separately)
[NOT repulsion between atoms or between bonds]*

**1**

(b)     (i)      Simplest ratio of atoms of each element in a
compound / substance / species / entity / molecule

**1**

(ii)                             Mg              N                   O

                                             

**1**

         *(0.675)*            0.667          1.37              4.06

                                      1               2                 6              MgN2O6

*(Mark M1 first. If any wrong Ar used = CE = 0)
(Accept Mg(NO3)2 for M3 if above working shown)*

**1**

**[9]**

**M17.**          (a)     (i)      100 ×10–3 × 0.500    =     5.00 × 10–2 (mol)

*accept 5 ×10–2 / 0.05*

**1**

(ii)     27.3 ×10–3× 0.600    =     1.64 × 10–2 / 1.638 × 10–2 (mol) only

**1**

(iii)     1.64 ×10–2 (mol)

*Mark conseq on (ii)*

**1**

(iv)    5.00 × 10–2   -   1.64 × 10–2   =   3.36 × 10–2 (mol)

*Mark conseq on (i) & (iii)*

**1**

(v)     3.36 × 10–2 × *½ =* 1.68 × 10–2 (mol)

*If 2.78 × 10–2 used 1.39 × 10–2*

*Mark conseq on (iv)*

**1**

1.68 × 10–2 × 132(.1) **or** 1.39 × 10–2 × 132(.1)

*Mark for Mr*

**1**

= 2.22 g **or** 1.83 g

**1**

(b)     pV = nRT

**1**

**** = 8.4(1) × 10–3 (mol)

**1**

**** =  (1)

**1**

= 408.5 – 410.5 (K)

*Mark conseq on moles*

***Note*** *Sig. fig. penalty - apply once if single sf given, unless calc works exactly*

**1**

**[11]**

**M18.**          (a)     (i)      p + n / number of nucleons

*(accept protons and neutrons)*

*(Incorrect reference to electrons = contradiction)*

**1**

(ii)     Mean /average mass of a molecule/entity/formula

**1**

1/12th mass of atom of 12C

*[Not 1/12th mass of molecule of 12C]*

*(mark independently)*

**1**

**OR**    Mass of 1 mole of molecules/entities (1)
1/12thmass of 1 mole of 12C (1)

**OR**    Average mass of a molecule/entity (1)
Relative to the mass of a 12C atom taken as 12 / 12.000 (1)

*(Mean/average = stated or explained)*

*(mass = stated or explained)*

*(Penalise ‘weight’ once only)*

*(Ignore ‘average ‘ mass of 12C)*

*(Do not allow ‘mass of average molecule)*

(b)     (i)      2s22p63s23p64s13d10

*(accept 3d 94s2)*

*(accept subscripts or caps)*

*[Penalise missing shell numbers]*

**1**

(ii)     d / D [NOT 3d/ ‘transition element]

**1**

(iii)     36 [NOT 36.0]

**1**

(c)     (i)      More 63Cu atoms than 65Cu atoms

*(idea of more abundant 63Cu isotope - NOT just reference to peak heights)*

**1**

(ii)     Electron from electron gun / high speed electron / high
energy electron

*(accept electron gun fired at)
[NOT ‘bombarded with electrons]*

**1**

knock electron off (Cu atom) / idea of loss of e- / appropriate
equation

*(Mark independently)*

**1**

(iii)     63Cu2+or equivalent [NOT 63.0 - penalise this error once only]

**1**

*m/z* = 63/2 (=31.5) or equivalent

**1**

More energy needed to remove second electron **OR**63Cu2+ statistically less likely to remove second electron
(Idea that not many 63Cu2+ ions formed **OR** explains why few are
formed e.g. more energy needed)

*If ‘63Cu’ not given, can only award M2 & M3*

**1**

Notes on [If 65 used, lose M1 **and** M2]

(c)     (iii)     [If mass number missing from identity but appears in explanation,
penalise Ml but allow M2 if earned]

**[12]**

**M19.**          (a)     moles HNO3 = 175 × 10–3 × 1.5 = (0.2625 mol);

**1**

moles Pb(NO3 )2 = ½ × 0.2625 = (0.131 mol);

**1**

Mr Pb(NO3 )2 = 331(.2);

**1**

mass Pb(NO3 )2 = 331.2 x 0.131=43.5 g;

*(accept 43.2 - 43.8)*

*(M1 & M2 are process marks. If error in M1, or in M2, do not mark M4 consequentially, i.e. do not award M4)
(if atomic numbers used in M3, do not award M4)*

**1**

(b)     (i)      pV = nRT;

**1**

****;

**1**

=       3.61 X 10–3;

*(If pressure not converted to Pa, max 2)*

*(If n =  used = CE; M2 = M3 = 0)*

**1**

(ii)     moles NO2 = 4/5 × 3.61 × 10–3;

*[mark is for use of 4/5]*

**1**

          *=* 2.89 × 10–3 *OR* 1.78×10–3;

**1**

Mr NO2         =       46;

**1**

massNO2    =       46 × 2.89 × l0–3 = 0.1.33(g)

*OR* 0.0821 (g);

*(if atomic numbers used, M3 = M4 = 0)*

**1**

**[11]**

**M20.**          (a)     (i)      (free–) radical substitution

*(both words required for the mark)*

**1**

initiation Cl2 → 2Cl·

*(credit correct half arrows, but penalise double headed arrows)*

**1**

first propagation CH3Cl + Cl· → ·CH2Cl + HCl

**1**

second propagation ·CH2Cl + Cl2 → CH2Cl2 + Cl

*(penalise the absence of dots on radicals once only)*

*(penalise radical dot on Cl of CH2Cl once only)*

**1**

(ii)     CH3Cl + Cl2 → CH2Cl2 + HCl

*(penalise if any radicals appear in this equation)*

**1**

(b)     **M1**:   mol C = 10.1/12.0    and    mol Cl = 89.9/35.5

**1**

**M2**:   Ratio 0.842 : 2.53     OR    1: 3      OR    CCl3

**1**

**M3**:   237.0/Mr of CCl3 = 237.0/118.5 = 2           Therefore C2Cl6

*(correct answer gains full credit)*

**1**

OR

**M1**:   237.0 × 10.1/100 and 237 × 89.9/100

**1**

**M2**:   Ratio 23.9/12.0 : 213/35.5 OR 2 : 6

**1**

**M3**:   C2Cl6

*(correct answer gains full credit)*

**1**

(c)     any two from CHBr3 or CBr4 or C2H2Br4 (or CHBr2CHBr2) or
C2Br6 (or CBr3CBr3)

*(ignore HBr or H2)*

*(ignore equations and ignore names when given in addition to formulae)*

*(penalise names alone)*

**2**

**[10]**

**M21.**          (penalty for sig fig error =1mark per question)

          (a)     (i)      moles KNO3 = 1.00/101.1 = 9.89 × 10-3 (mol)

**1**

(ii)     pV = nRT or n = pV/RT

**1**

moles O2 = n =  = **(1)** **(1)**

**2**

                                  = 4.93 × 10-3 (mol)

**1**

*(mark answer first – check back if wrong)*

*(transcription error lose M3, mark M4 conseq on error)*

*(if ‘untraceable’ figures used M3=M4=0)*

*(if wrong temp conversion – lose M3 – conseq M4)*

*(if n = RT/pV CE, lose M3 and M4)*

(b)     (i)      simplest/lowest ratio of atoms of each / element/s in a compound /
substance / species / entity / molecule

**1**

(ii)     *K*                 *N*              *O*

**                 (1)
                                               (1)

1.17          1.18          2.35

1               1               2               KNO2      (1)

*(M3 tied to M2), (M3 can be transferred from equation if ratio correct but EF not given) (if calc inverted, lose M2 and M3), (if used At N 1 / wrong No for Ar then CE, lose M2 and M3) (if % of O missing, award M2 only)*

**3**

(c)     2KNO3 → 2KNO2 + O2 or fractions/multiples

*(accept 2KNO3 → K2N2O4 + O2)*

*(do NOT accept ‘Y’ in equation)*

**1**

**[10]**

**M22.**          *(penalty for sig fig error =1 mark per question)*

(a)     neutron:          relative mass = 1          relative charge = 0

*(not ‘neutral’)*

**1**

electron:          relative mass = 1/1800 → 0/negligible *or*

5.56 × 10–4 → 0 relative charge = –1

**1**

(b)     17O/O17 mass number               (*Do not accept 17.0*)

**1**

          oxygen symbol ‘O’

*(if ‘oxygen’ + — ‘mass number = 17’(1))*

*(if ‘oxygen’+ — ‘mass number = 17’(0))*

*(if at N 0 given but ≠ 8, treat as ‘con’ for M2)*

*(if lp on Be, diagram = 0)*

*(ignore bond angles)*

*(not dot and cross diagrams)*

**1**

(c)



**2**

          QoL Linear **(1)**                        bent / V-shaped / angular **(1)**

*(mark name and shape independently)*

*(accept (distorted) tetrahedral)*

*(if balls instead of symbols, lose M1 – can award M2)*

*(penalise missing ‘Cl’ once only)*

*(not ‘non-linear’)*

**2**

(d)     *M*r (Mg(NO3)2 = 58(.3) *(if At N 0 used, lose M1 and M2)*

**1**

          moles Mg(OH)2 = 0.0172 (conseq on wrong M2) (answer to 3+ s.f.)

**1**

          moles HCl = 2 × 0.0172 = 0.0344 *or* 0.0343 (mol) *(process mark)*

**1**

          vol HCl = = 34.3 – 34.5 (cm3) *(unless wrong unit)*

*(if candidate* ***used*** *0.017 or 0.0171 lose M2)*

*(just answer with no working, if in range = (4).
if, say, 34 then =(2))*

*(if not 2:1 ratio, lose M3 and M4)*

*(if work on HCl, CE = 0/4)*

**1**

**[12]**

**M23.**          (a)     (i)      Fe + 2HCl → FeCl2 + H2

*(allow ionic formulae)*

or Fe + 2H+ → Fe2+ + H2

**1**

(ii)     PV = nRT n = PV/RT

*(allow either formula but penalise
contradiction)*

**1**

*n* = 

**1**

= 4.53 × 10–3 (mol)

*(answer must have at least 3 sig. figs. Ignore units)*

**1**

(iii)     Moles of iron = 4.5(3) × 10–3 mol

*(allow conseq on (a)(ii))*

(or = 4.2(5) × 10–3 if candidate uses given moles of hydrogen)

**1**

Mass of iron = 4.53 × 10–3 × 55.8 = 0.253 g
(mark is for method mass = moles × *A*r)
(Mass of iron can be 56)

**1**

(iv)    0.253 × 100/0.263 = 96.1 % (mark is for answer to 2 sig. figs.)

*(allow conseq on mass of iron. E.g. = 90% from
4.2(5) × 10–3 moles of H2 and Fe)*

*(Do not allow answers greater than or equal to 100%)*

**1**

(b)     (i)      Fe2+ → Fe3+ + e–

*(ignore state symbols)*

**1**

Cr2O72– + 14H+ + 6e– → 2Cr3+ + 7H2O

**1**

Cr2O72– + 14H+ + 6Fe2+ → 2Cr3+ + 7H2O + 6Fe3+

**1**

(ii)     Moles of dichromate = moles Fe2+/6
= 4.53 × 10–3/6 = 7.55 × 10–4

*(Allow conseq, mark is for method (a)(iii)/6)*

**1**

Volume of dichromate = moles/concentration
(= (7.55 × 10–4 × 1000)/0.0200)

*(mark is for this method)*

**1**

V = 37.75 (cm3)

*(allow 37.7 to 37.8, allow no units but penalise wrong units)*

*(allow conseq on moles of dichromate)*

*(if value of 3.63 × 10–3 used answer is 30.2 to 30.3,
otherwise ans = moles Fe2+/0.00012)*

*(if mole ratio wrong and candidate does not divide by 6,
max score is ONE for volume method)*

**1**

(iii)     (KMnO4) will also oxidise (or react with) Cl– (or chloride or HCl)

**1**

**[14]**

**M24.**          (a)     (i)      (free–)radical substitution

*(both words required for the mark)*

**1**

(ii)     uv light OR sunlight OR high temperature OR 150 °C to 500 °C

**1**

(iii)     Propagation

*(ignore “chain”, “first”, “second” in front of the word propagation)*

**1**

(iv)    Termination

**1**

•CH2CH3 + Br•  CH3CH2Br
OR 2•CH2CH3  C4H10

*(penalise if radical dot is obviously on CH3, but not otherwise)*

*(penalise C2H5•)*

*(credit 2Br• Br2)*

*(ignore “chain” in front of the word termination)*

**1**

(b)     (i)      Fractional distillation OR fractionation

*(credit gas–liquid chromatography, GLC)*

**1**

(ii)     CH3CH3 + 6Br2  C2Br6 + 6HBr

*(credit C2H6 for ethane)*

**1**

(c)     Correct structure for CF2BrCF2Br drawn out

*(penalise “Fl” for fluorine)*

**1**

(d)     (i)             2–bromo–2–chloro–1,1,1–trifluoroethane
OR 1–bromo–1–chloro–2,2,2–trifluoroethane

*(insist on all numbers, but do not penalise failure to use alphabet)*

*(accept “flourine” and “cloro” in this instance)*

**1**

(ii)     197.4 only

*(ignore units)*

**1**

(iii)     (57/197.4 × 100) = 28.9% OR 28.88%

*(credit the correct answer independently in part (d)(iii), even if (d)(ii) is blank or incorrectly calculated, but mark consequential on part (d)(ii), if part (d)(ii) is incorrectly calculated, accepting answers to 3sf or 4sf only)*

*(penalise 29% if it appears alone, but not if it follows a correct answer)*

*(do not insist on the % sign being given)*

*(the percentage sign is not essential here, but penalise the use of units e.g. grams)*

**1**

**[11]**

**M25.**          (a)     (i)      Avogadro’s number/constant of molecules/particles/species / 6 × 1023

*[Not ‘atoms’]*

**1**

**Or** same number of particles as (there are atoms)

*[Not molecules]*

in 12.(00)g of 12C

**1**

(ii)     *Moles O2 =  (= 1.09 × 10–2 mol)*

**1**

= 29 (× 1.09 × 10–2)

*[Accept answers via 4 separate mole calculations]*

**1**

= 0.316 – 0.317 mol [answer to 3 + sf]

*[Mark conseq on errors in M1/M2]   (1)*

**1**

(iii)     Moles of nitroglycerine = 4 × 1.09 × 10–2     (= 0.0438 mol)

*[Mark conseq on their moles of O2]*

**1**

*M*r of nitroglycerine = 227 or number string

**1**

Moles of nitroglycerine = 227 × 0.0438 = 9.90 – 9.93(g)

*[answer to 3+ sf]*

*[If string OK but final answer wrong then allow M6 but AE for M7]*

*[Mark conseq on error in Mr]     [Penalise wrong units]*

*[Penalise sig. fig. errors once only in whole question]*

(b)     pV = nRT **or** pV =     **or**     p = 

**1**

p =  = 

**1**

          = 7980093 **or** 7980 **or** 7.98

*[ignore s.f.]*

**1**

          units = Pa **or** kPa **or** MPa               (as appropriate)

*[If error in conversion from Pa, treat as a contradiction of the units mark]*

*[If transfer error, mark conseq but penalise M2]*

*[If data from outside of above used, penalise M2 and M3]*

*[If pV expression incorrectly rearranged, penalise M2 and M3]*

*[if T = 1373 K used, penalise M2]*

**1**

**[11]**

**M26.**          (a)



*[Diagrams must be complete and accurate]*

**2**

(b)     (i)      Attraction /electrostatic forces/bonds/attractions between (positive)
ions/lattice and delocalised/free electrons/sea of electrons.

*[Not metallic bonding]*

*[Not just ‘forces’]*

**1**

(ii)     Electrostatic attractions/forces between ions or attractions
between (oppositely charged) ions/ Na+ & Cl–

*[Not ionic bonding]*

**1**

(iii)     (Here) the ionic bonding in NaCl is stronger/requires more energy to
break than the metallic bonding in Na

**QoL**Accept ‘bonding/forces of attraction in NaCl is stronger than in Na’

*[If IMF/molecules/van der Waals’/dipole–dipole mentioned
in parts(i) or (ii), then CE = 0 for parts (i) and/or(ii) and
CE = 0 for part(iii)]*

**1**

(c)     Comparison:
Sodium conducts **and** sodium chloride does NOT conduct

*Allow ‘only Na conducts’*

*Accept ‘Na conducts, NaCl only conducts when molten’*

*[Do not accept sodium conducts better than sodium chloride etc.]*

**1**

Explanation:
(Delocalised) electrons flow though the metal

**1**

Allow e– move/carry current/are charge carriers/transfer charge.

*[Not ‘electrons carry electricity’]*

*[Not ‘NaCl has no free charged particles’]*

Ions can’t move in solid salt

**1**

(d)     Layers can slide over each other – idea that ions/atoms/particles move

*[Not molecules]*

*[Not layers separate]*

**1**

(e)     (i)                    Na                     Cl                      O

                                  

**1**

0.9(39)               0.9(38)               2.8(2)

Hence:     1                        1                      3
Accept backwards calculation, i.e. from formula to % composition,
and also accept route via *M*r to 23; 35.5; 48, and then to 1:1:3

*[If % values incorrectly copied, allow M1 only]*

*[If any wrong Arvalues/atomic numbers used = CE = 0]*

**1**

(ii)     3Cl2 + 6NaOH → 5NaCl + NaClO3 + 3H2O

**1**

**[12]**

**M27.**          (a)     (i)      Moles of gas produced = 3

**1**

         *PV* = *nRT*

**1**

*V = nRT/P =* 3 × 8.31 × 298/100000

**1**

= 7.43 × 10–2 m3

**1**

(ii)     7.43 × 10–2 × 1000/298 = 0.249 m3

**1**

(b)     (i)      any two from:

exhaust gases hot so would boil the solution away
solution would splash
reaction might be too slow
would need continuous supply of solution and/or replacement
of products

**2**

(ii)     *Commercial advantage*         could sell chlorine and/or hydrogen

**1**

*environmental disadvantage*         generation of electricity
                                                       likely to lead
                                                       to release of CO2                                                       (or chlorine toxic)

**1**

(c)     % O = 74%

**1**

N:O = 26/14:74/16

**1**

= 1.86: 4.63 = 1:2.5 therefore formula is N2O5

**1**

(d)     2N2O → 2N2 + O2

**1**

(e)     Proportion of O2 increased leading to higher T (or more
complete combustion)

**1**

**[14]**

**M28.**          (a)     (i)      0.013;

**1**

(ii)     0.0065;

*Answer to (i) ÷ 2*

**1**

(iii)      = 84.3;

*Allow 0.548 ÷ answer to (ii)
Allow 84.1 – 84.4*

**1**

(b)     84.3 – 60 = 24.3;

*1 mark for -60*

**1**

          Mg;

          If 147.6 used the answer is 87.6 (1)
And this is Sr (1)

*Allow consequential metal from their calculated A
Answer has got to be a metal to score M2*

**1**

**[5]**

**M29.**          (a)     (i)       × 100;

*Whole expression
Ignore >3 sig figs*

**1**

         = 35.37(%) allow 35.0 – 35.4%;

*Allow 35%
Allow 2 marks if correct %*

**1**

(ii)     Sell the HCl or sell the other product or sell the acid (formed
in the reaction);

*Need a financial gain*

**1**

(b)     (i)       = 0.869;

*One mark for Mr = 189.9*

         allow 0.86 – 0.87;;

*Ignore units*

**2**

(ii)     0.869

*Accept same value as in (i)*

**1**

(iii)     0.869 × 79.9 = 69.4;

         Allow 68.7 – 70;

*Accept answer to (ii) × 79.9*

**1**

(iv)     × 100;

*Accept 63 × 100 /answer to (iii)*

         = 90.75%;

*If > 100% lose this mark*

         Accept 90.6 to 92%

**1**

**[8]**

**M30.**          (a)     (i)      0.00301/ 3.01 × 10–3;

         Penalise < 3sf in (a)(i);

*Allow 3.01 × 10–3 – 3.05 × 10–3.
(for candidates who have used Mg as 24)*

**1**

(ii)     0.00602

*Allow correct answer a(i) × 2.*

**1**

(iii)     0.00965/ 9.65 × 10–3;

*Allow 0.009646/ 0.0096-0.0097.*

**1**

(iv)    0.00363 moles;

*Allow range 0.0035 to 0.0037.
Allow (a)(iii) – 2 (a)(ii) (must be positive).*

**1**

(b)     PV = nRT;

*Allow all capitals/ lower case.*

**1**

          V = ;

*M2 Mark is for all numbers correct.
If units in answer are in dm3 allow this expression with 96 in denominator.*

**1**

          0.0132 m3/ 13.2 dm3;

*M3 Must have correct units/
allow 13200 cm3.*

*Allow min 2 sig figs in answer.*

**1**

(c)     O = 69.6 (%);

**1**

                  2.17 : 4.35

*Use of 7/8 CE then M1 only.*

**1**

          (1 : 2) NO2

*Mark for formula not ratio.
If NO2 and no working shown then allow 1 mark.
If 69.6% + NO2 only = 2.
Need to see evidence of M2 working.
Allow M2 conseq on the wrong M1 (ie max 1).*

**1**

**[10]**

##

          (a)     Average/mean mass of (1) atom(s) (of an element)
1/12 mass of one atom of 12C

**1**

*If moles and atoms mixes Max = 1*

**1**

***OR***

(Average) mass of one mole of atoms
1/12 mass of one mole of 12C

***OR***

(Weighted) average mass of all the isotopes
1/12 mass of one atom of 12C

***OR***

Average mass of an atom/isotope compared to C-12 on a scale in
which an atom of C-12 has a mass of 12

*This expression = 2 marks*

(b)     d block

*Allow 3d/D
Other numbers lose M1
Ignore transition metals*

**1**

[Ar] 3d24s2

**1**

*Can be written in full
Allow subscripts
3d2 and 4s2 can be in either order*

27

**1**

(c)     

(= 1550)

**1**

(or ∑ their abundances)

*If one graph reading error lose M1 and allow consequential M2 and M3.
If 2 GR errors penalise M1 and M2 but allow consequential M3
If not 17 or ∑ their abundances lose M2 and M3*

**1**

= 91.2

*91.2 = 3 marks provided working shown.*

**1**

Zr/Zirconium

*M4 -allow nearest consequential element from M3
accept Zr in any circumstance*

**1**

(d)     High energy electrons/bombarded or hit with electrons

*accept electron gun*

**1**

knocks out electron(s) (to form ions)

**1**

Z+ = 90 deflected most

*If not 90 lose M3 and M4
If charge is wrong on 90 isotope lose M3 only
Accept any symbol in place of Z*

**1**

since lowest mass/lowest m/z

*Allow lightest*

**1**

(e)     (ions hit detector and) cause current/(ions) accept electrons/cause
electron flow

*QWC*

**1**

bigger current = more of that isotope/current proportional to abundance

*Implication that current depends on the number of ions*

**1**

**[15]**

**M32.**          (a)     (i)      *M*r *=* 132.1

**1**

*132*

0.0238

*Allow 0.024
Allow 0.0237
Penalise less than 2 sig fig once in (a)*

**1**

(ii)     0.0476

**1**

*0.0474-0.0476
Allow (a) (i) × 2*

(iii)     1.21

*Allow consequential from (a) (ii)
ie allow (a) (ii) × 1000/39.30
Ignore units even if wrong*

**1**

(b)     

*Allow mass or Mr of desired product times one hundred divided by total mass or Mr of reactants/products
If 34/212.1 seen correctly award M1*

**1**

= 16.0(3)%

*Allow 16%
16 scores 2 marks*

**1**

(c)     100(%)

*Ignore all working*

**1**

(d)     PV = nRT or n = 

*If rearranged incorrectly lose M1 and M3*

**1**

n = 

*M2 for mark for converting P and T into correct units in any expression*

**1**

= 0.59(4)

*Allow 0.593
M3 consequential on transcription error only not on incorrect P and T*

**1**

(e)     (Na2SO4)          H2O
(44.1%)           55.9%

*M1 is for 55.9*

**1**

44.1/142.1           55.9/18
0.310                   3.11
= 1                       = 10

*Alternative method gives180 for water part = 2 marks*

**1**

*x* = 10

*X = 10 = 3 marks
10.02 = 2 marks*

**1**

**[13]**

**M33.**          (a)     Average/mean mass of (1) atom(s) (of an element)

**1**

1/12 mass of one atom of 12C

*Accept answer in words
Can have top line × 12 instead of bottom line ÷ 12*

**1**

***OR***

(Average) mass of one mole of atoms
1/12 mass of one mole of 12C

***OR***

(Weighted) average mass of all the isotopes
1/12 mass of one atom of 12C

***OR***

Average mass of an atom/isotope compared to C-12
on a scale in which an atom of C-12 has a mass of 12



*Allow 95.12 + 4.88 instead of 100*

**1**

= 14.05

*If not to 2 d.p. then lose last mark
Not 14.04*

**1**

(b)     15N is heavier/15N has a bigger m/z/different m/z values

*Not different no’s of neutrons
Not ionisation potential*

**1**

Electromagnet/electric field/magnet/accelerating
potential or voltage/electric current

**1**

(c)     No difference

**1**

Same no of electrons (in outer orbital/shell/sub shell)/same
electron configuration

*M2 dependent on M1
Not just electrons determine chemical properties
Ignore protons*

**1**

**[8]**

**M34.**          Mass number = number of protons + neutrons (in the nucleus/atom)

*Not in a substance or compound or element*

**1**

7 protons and 7 electrons

**1**

8 neutrons

**1**

**[3]**

**M35.**          Mass number = number of protons + neutrons (in the nucleus/atom)

*Not in a substance or compound or element*

**1**

7 protons and 7 electrons

**1**

8 neutrons

**1**

**[3]**