Q1.

Which sample, measured at room temperature and pressure, contains the greatest number of the stated particles?

A 1 g of hydrogen molecules ⬭

B 1 g of helium atoms ⬭

C 1 dm^3 of hydrogen molecules ⬭

D 1 dm^3 of helium atoms ⬭

(Total 1 mark)

Q2.

Which of the following contains the most chloride ions?

A 10 cm^3 of 3.30×10^{-2} mol dm^{-3} aluminium chloride solution ⬭

B 20 cm^3 of 5.00×10^{-2} mol dm^{-3} calcium chloride solution ⬭

C 30 cm^3 of 3.30×10^{-2} mol dm^{-3} hydrochloric acid ⬭

D 40 cm^3 of 2.50×10^{-2} mol dm^{-3} sodium chloride solution ⬭

(Total 1 mark)

Q3.

Analysis of a sample of a chemical with formula $C_{22}H_{30}N_6O_4S$, showed that it contained 0.0195 mol of carbon.

What mass of nitrogen was present in the sample?

A 0.041 g ⬭

B 0.057 g ⬭

C 0.074 g ⬭

D 0.420 g ⬭

(Total 1 mark)

Q4.

Which sample contains the most molecules?

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

A 2.10×10^{22} molecules of methane, CH_4 ⬭

B 1.00 g of oxygen, O_2 ⬭

C 65.0 mg of hydrogen, H_2 ⬭

D 0.0300 mol of ethane, C_2H_6 ⬭

(Total 1 mark)

Q5.

Which of the following contains the most chloride ions?

A 15 cm^3 of 3.40×10^{-2} mol dm^{-3} aluminium chloride solution ⬭

B 30 cm^3 of 5.50×10^{-2} mol dm^{-3} calcium chloride solution ⬭

C 40 cm^3 of 2.30×10^{-2} mol dm^{-3} hydrochloric acid ⬭

D 45 cm^3 of 2.20×10^{-2} mol dm^{-3} sodium chloride solution ⬭

(Total 1 mark)

Q6.

A gas cylinder contains 5.0 kg of propane.

How many propane molecules are in the cylinder?

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

A 6.8×10^{22} ⬭

B 7.2×10^{22} ⬭

C 6.8×10^{25} ⬭

D 7.2×10^{25} ⬭

(Total 1 mark)

Q7.

The M_r of hydrated copper sulfate ($CuSO_4.5H_2O$) is 249.6.

Which of the following is the mass of hydrated copper sulfate required to make 50.0 cm^3 of a 0.400 mol dm^{-3} solution?

A 3.19 g ○

B 3.55 g ○

C 3.71 g ○

D 4.99 g ○

(Total 1 mark)

Q8.

The heat released when 1.00 g of ethanol (M_r = 46.0) undergoes complete combustion is 29.8 kJ

What is the heat released by each molecule, in joules, when ethanol undergoes complete combustion?

(the Avogadro constant $L = 6.022 \times 10^{23}$ mol^{-1})

A 2.28×10^{-18} J ○

B 4.95×10^{-20} J ○

C 2.28×10^{-21} J ○

D 4.95×10^{-23} J ○

(Total 1 mark)

Q9.

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 (M_r = 46.0) per 100 cm^3 of blood?

A 0.00017 ○

B 0.0017 ○

C 0.017 ○

D 1.7 ⬭

(Total 1 mark)

Q10.

CCl_4 is an effective fire extinguisher but it is no longer used because of its toxicity and its role in the depletion of the ozone layer. In the upper atmosphere, a bond in CCl_4 breaks and reactive species are formed.

(c) A small amount of the freon CF_3Cl with a mass of 1.78×10^{-4} kg escaped from a refrigerator, into a room of volume 100 m^3. Assuming that the freon is evenly distributed throughout the air in the room, calculate the number of freon molecules in a volume of 500 cm^3.
Give your answer to the appropriate number of significant figures.

The Avogadro constant = 6.02×10^{23} mol^{-1}.

Number of molecules = _____

(3)

Q11.

The oxidising agent in solution **A** is sodium bromate(V), $NaBrO_3$. A laboratory technician wanted to make up enough of this solution for use in a class practical.

Calculate the mass of sodium bromate(V) needed to prepare 5.00 dm^3 of a 5.00×10^{-3} mol dm^{-3} solution.

Show your working. Give your answer to the appropriate precision.

_____

_____

_____

(Total 2 marks)

Q12.

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

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

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

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

(3)

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

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

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

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

(4)

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

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

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

mass of 10.7 g.

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

(4)

Q13.

(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)

(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.

(4)

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, $Na_2CO_3.xH_2O$

(3)

Q15.

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)

Q16.

This question is about a white solid, $MHCO_3$, that dissolves in water and reacts with hydrochloric acid to give a salt.

$$MHCO_3 + HCl \longrightarrow MCl + H_2O + CO_2$$

A student was asked to design an experiment to determine a value for the M_r of $MHCO_3$.

The student dissolved 1464 mg of $MHCO_3$ in water and made the solution up to 250 cm^3. 25.0 cm^3 samples of the solution were titrated with 0.102 mol dm^{-3} hydrochloric acid. The results are shown in the table.

	Rough	**1**	**2**	**3**
Initial burette reading / cm^3	0.00	10.00	19.50	29.25
Final burette reading / cm^3	10.00	19.50	29.25	38.90
Titre / cm^3	10.00	9.50	9.75	9.65

(a) Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with 25.0 cm^3 of the $MHCO_3$ solution.

(3)

(b) Calculate the amount, in moles, of $MHCO_3$ in 250 cm^3 of the solution.
Then calculate the experimental value for the M_r of $MHCO_3$.
Give your answer to the appropriate number of significant figures.

(3)

(c) The student identified use of the burette as the largest source of uncertainty in the experiment.

Using the same apparatus, suggest how the procedure could be improved to reduce the percentage uncertainty in using the burette.

Justify your suggested improvement.

Suggestion _____

Justification _____

(2)

(d) Another student is required to make up 250 cm^3 of an aqueous solution that contains a known mass of $MHCO_3$. The student is provided with a sample bottle containing the $MHCO_3$.

Describe the method, including apparatus and practical details, that the student should use to prepare the solution.

(6)

(Total 14 marks)

Q17.

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. (part a omitted)

(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})

_____

_____

(4)

(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.

_____

_____

_____

_____

_____

(4)

(Total 13 marks)

Q18.

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

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

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

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

_____

_____

(1)

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

_____

_____

(1)

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

_____

_____

(1)

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

_____

_____

(1)

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

A_r of M _____

Identity of M _____

(2)

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

_____

_____

(1)

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

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

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

_____

_____

(2)

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

_____

(3)

Q19.

In this question give all your answers to three significant figures.

Magnesium nitrate decomposes on heating to form magnesium oxide, nitrogen dioxide and oxygen as shown in the following equation.

$$2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(a) Thermal decomposition of a sample of magnesium nitrate produced 0.741 g of magnesium oxide.

(i) Calculate the amount, in moles, of MgO in 0.741 g of magnesium oxide.

(2)

(ii) Calculate the total amount, in moles, of gas produced from this sample of magnesium nitrate.

(1)

(c) A 0.0152 mol sample of magnesium oxide, produced from the decomposition of magnesium nitrate, was reacted with hydrochloric acid.

$$MgO + 2HCl \rightarrow MgCl_2 + H_2O$$

(i) Calculate the amount, in moles, of HCl needed to react completely with the 0.0152 mol sample of magnesium oxide.

(1)

(ii) This 0.0152 mol sample of magnesium oxide required 32.4 cm^3 of hydrochloric acid for complete reaction. Use this information and your answer

to part (c) (i) to calculate the concentration, in mol dm^{-3}, of the hydrochloric acid.

_____

_____

_____

(1)

(Total 8 marks)

Q20.

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

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

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

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

_____

_____

_____

(2)

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

_____

(1)

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

_____

_____

(1)

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

_____

_____

(2)

(c) Ammonia is manufactured by the Haber Process.

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

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

(1)

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

(3)

Q21.

(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.

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

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

(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 $MgCO_3$ _____

Mass of $MgCO_3$ _____

Percentage of $MgCO_3$ _____

(8)

(b) (interleave) 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

(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.

(4)

(Total 12 marks)

Q22.

This question is about sodium fluoride (NaF).

Some toothpastes contain sodium fluoride.
The concentration of sodium fluoride can be expressed in parts per million (ppm).
1 ppm represents a concentration of 1 mg in every 1 kg of toothpaste.

(a) A 1.00 g sample of toothpaste was found to contain 2.88×10^{-5} mol of sodium

fluoride.

Calculate the concentration of sodium fluoride, in ppm, for the sample of toothpaste. Give your answer to 3 significant figures.

Concentration of sodium fluoride _____ ppm

(4)

(b) Sodium fluoride is toxic in high concentrations.
Major health problems can occur if concentrations of sodium fluoride are greater than 3.19×10^{-2} g per kilogram of body mass.

Deduce the maximum mass of sodium fluoride, in mg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of sodium fluoride _____ mg

(1)

(c) The concentration of sodium fluoride in a prescription toothpaste is 2800 ppm.

Use your answer to Question (b) to deduce the mass of toothpaste, in kg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of toothpaste _____ kg

(1)

Q23.

Norgessaltpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula $Ca(NO_3)_2$

(a) Norgessaltpeter can be made by the reaction of calcium carbonate with dilute nitric acid as shown by the following equation.

$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$

In an experiment, an excess of powdered calcium carbonate was added to 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid.

(i) Calculate the amount, in moles, of HNO_3 in 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(ii) Calculate the amount, in moles, of $CaCO_3$ that reacted with the nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(iii) Calculate the minimum mass of powdered $CaCO_3$ that should be added to react with all of the nitric acid.

Give your answer to 3 significant figures.

_____

_____

_____

(2)

(iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

_____

(1)

(c) Hydrated calcium nitrate can be represented by the formula $Ca(NO_3)_2.xH_2O$ where x is an integer.

A 6.04 g sample of $Ca(NO_3)_2.xH_2O$ contains 1.84 g of water of crystallisation.

Use this information to calculate a value for x.
Show your working.

_____

_____

_____

_____

_____

_____

(3)

Q24.

A student does an experiment to determine the percentage of copper in an alloy.

The student

- reacts 985 mg of the alloy with concentrated nitric acid to form a solution (all of the copper in the alloy reacts to form aqueous copper(II) ions)
- pours the solution into a volumetric flask and makes the volume up to 250 cm^3 with distilled water
- shakes the flask thoroughly
- transfers 25.0 cm^3 of the solution into a conical flask and adds an excess of potassium iodide
- uses exactly 9.00 cm^3 of 0.0800 mol dm^{-3} sodium thiosulfate ($Na_2S_2O_3$) solution to react with all the iodine produced.

The equations for the reactions are

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

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

(a) Calculate the percentage of copper by mass in the alloy.

Give your answer to the appropriate number of significant figures.

% copper _____

(6)

(b) Suggest **two** ways that the student could reduce the percentage uncertainty in the measurement of the volume of sodium thiosulfate solution, using the same apparatus as this experiment.

1 _____

_____

2 _____

_____

3 _____

_____

(2)

Q25.

A student does an experiment to determine the percentage by mass of sodium chlorate(I), NaClO, in a sample of bleach solution.

Method:

- Dilute a 10.0 cm^3 sample of bleach solution to 100 cm^3 with distilled water.
- Transfer 25.0 cm^3 of the diluted bleach solution to a conical flask and acidify using sulfuric acid.
- Add excess potassium iodide to the conical flask to form a brown solution containing $I_2(aq)$.
- Add 0.100 mol dm^{-3} sodium thiosulfate solution ($Na_2S_2O_3$) to the conical flask from a burette until the brown solution containing $I_2(aq)$ becomes a colourless solution containing $I^-(aq)$.

The student uses 33.50 cm^3 of sodium thiosulfate solution.

The density of the original bleach solution is 1.20 g cm^{-3}

The equations for the reactions in this experiment are

$$ClO^-(aq) + 2\ H^+(aq) + 2\ I^-(aq) \rightarrow Cl^-(aq) + H_2O(l) + I_2(aq)$$

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

(a) Use all the information given to calculate the percentage by mass of NaClO in the original bleach solution.

Give your answer to 3 significant figures.

Percentage by mass _____

(7)

(b) The total uncertainty from two readings and an end point error in using a burette is ± 0.15 cm^3

What is the total percentage uncertainty in using the burette in this experiment?

Tick (✓) **one** box.

0.45% ☐

0.90% ☐

1.34% ☐

(1)

(Total 8 marks)

Q26.

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

(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.

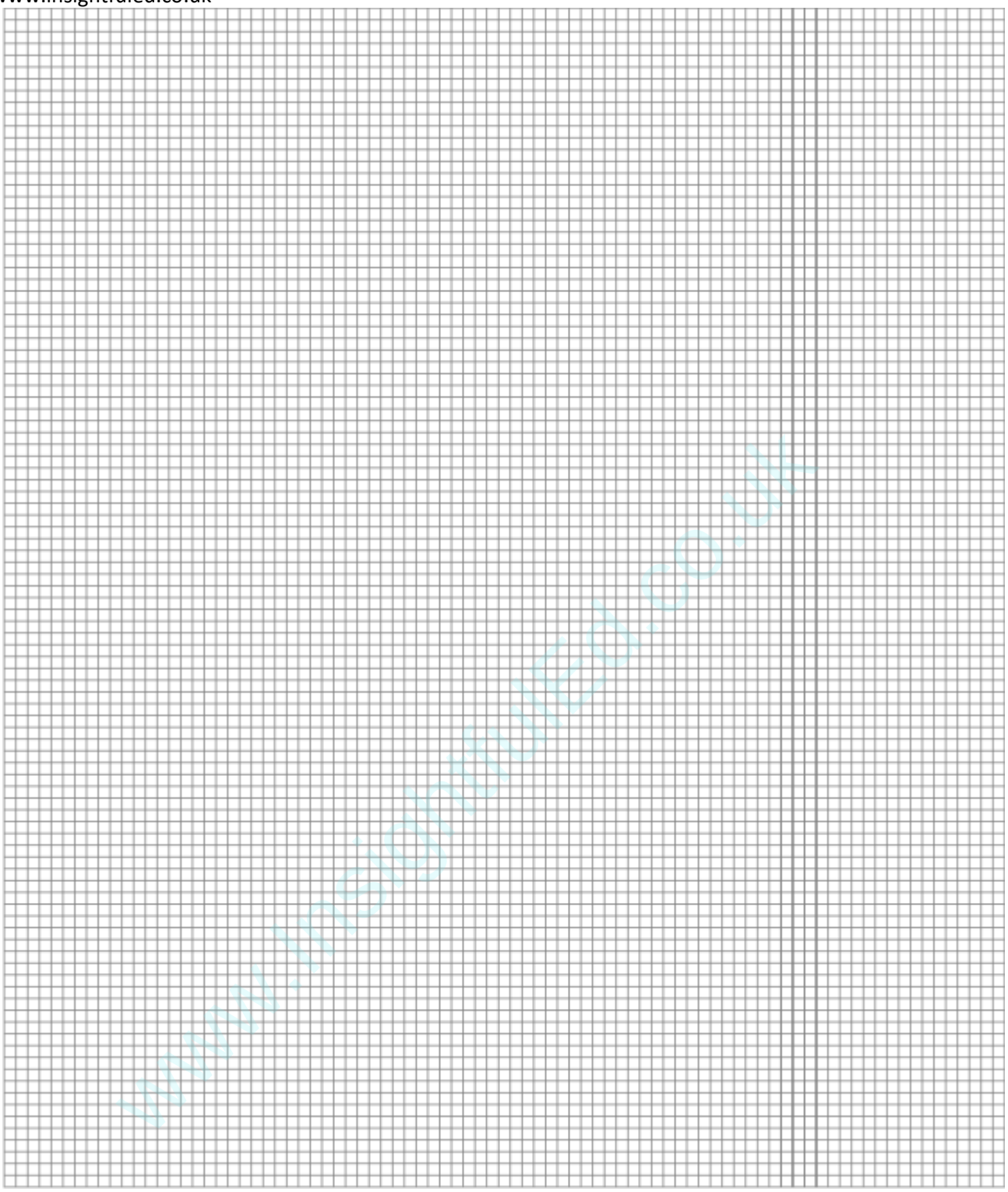
(ii) (GRAPH ANALYSIS) The experiment was repeated with further weighed

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.

_____

(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.

_____

_____

(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 _____

_____

Reason 2 _____

_____

(2)

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

_____

_____

(1)

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

_____

_____

(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.

_____

(1)

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

_____

_____

(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.

_____

(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.

_____

(1)

(Total 20 marks)

Q1.

A

[1]

Q2.

B

[1]

Q3.

C

[1]

Q4.

A

[1]

Q5.

B

[1]

Q6.

C

[1]

Q7.

D

[1]

Q8.

A

2.28×10^{-18} J

[1]

Q9.

C

0.017

[1]

Q10.

(c) M_r of CF_3Cl = 104.5

Moles freon = $1.78 \times 10^{-4} \times 10^3 / 104.5 = 1.70 \times 10^{-3}$

1

Number of molecules = $1.70 \times 10^{-3} \times 6.02 \times 10^{23} = 1.02 \times 10^{21}$

1

Molecules in 500 cm^3 = $(1.02 \times 10^{21} \times 500 \times 10^{-6}) / 100$
= 5.10×10^{15}

Allow answer in the range 5.10–5.13 × 10^{15}
Answer must be given to this precision

1

[7]

Q11.

M_r of sodium bromate(V) = 150.9
and
Mol sodium bromate(V) = 5.00 x (5.00 x 10^{-3}) = 0.0250 **M1**

*Lose **M1** if 151 used (final answer may appear as 3.78).*

1

Mass sodium bromate(V) = 0.025 x 150.9 = 3.77 g **M2**

*Lose **M2** if answer not to 3 sig figs.*
*Correct answer without working scores **M2** only.*

1

[2]

Q12.

(a)

Method 1		Method 2	
Mass of H_2O = 4.38−2.46		Percentage of H_2O = 44%	
(= 1.92 g)			

If there is an AE in M1 then can score M2 and M3
If M_r incorrect can only score M1

1

$ZnSO_4$	H_2O	ZnSO4	H2O
2.46	1.92	56	44
161.5	18	161.5	18

1

(0.0152	0.107)	(0.347	2.444)
(1	: 7)	(1	: 7)

x = 7 x = 7

If x = 7 with working then award 3 marks.
Allow alternative methods.
If M1 incorrect due to AE, M3 must be an integer.

1

(b) Moles HCl = 0.12(0)

1

mol $ZnCl_2$ = 0.06(0) ***OR*** 0.12 / 2

1

If M2 incorrect then CE and cannot score M2, M3 and M4.

mass $ZnCl_2$ = 0.06 × 136.4

Allow 65.4 + (2 × 35.5) for 136.4

1

= 8.18(4) (g) ***OR*** 8.2 (g)

Must be to 2 significant figures or more.
Ignore units.

1

(c) Moles $ZnCl_2$ = $\frac{10.7}{136.4}$ (= 0.0784)

1

OR moles Zn = 0.0784

Mass Zn reacting = 0.0784 × 65.4 = (5.13 g)

M2 is for their M1 × 65.4

1

$$\%\text{ purity of Zn} = \frac{5.13}{5.68} \times 100$$

M3 is M2 × 100 / 5.68 provided M2 is < 5.68

1

= 90.2% ***OR*** 90.3%

Allow alternative methods.

M1 = Moles $ZnCl_2$ = 10.7 (= 0.0784)
136.4

M2 = Theoretical moles Zn =
5.68 (= 0.0869)
65.4

M3 = M1 × 100 / M2 = (0.0784 × 100 / 0.0869)

*M4 = 90.2% **OR** 90.3%*

1

Q13.

(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) $^{17}O/O^{17}$ 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

(d) M_r ($Mg(NO_3)_2$ = 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 = $\frac{0.0343 \times 1000}{1}$ = 34.3 – 34.5 (cm^3) *(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]

Q14.

(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) $3.01/2.43 \times 10^{-2}$

(mark conseq on (a)(iii))

1

124

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

1

(b) $M_r(Na_2CO_3) = 106$
M_r (xH_2O) = 250 –106 = 144 *(mark conseq on M1)*
x = 8 *(mark conseq on M2)*

(Penalise sf errors once only)

3

Q15.

(a) (i) Avogadro's number/constant of molecules/particles/species / 6×10^{23}

[Not 'atoms']

1

Or same number of particles as (there are atoms)

[Not molecules]

in 12.(00)g of ^{12}C

1

(ii) *Moles* $O_2 = \frac{0.350}{32}$ *(= 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 = $4 \times 1.09 \times 10^{-2}$ (= 0.0438 mol)

[Mark conseq on their moles of O_2]

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 M_r] [Penalise wrong units]

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

Q16.

(a) Selects correct titres

If 3 or more titres used them MAX 1 for conseq M3

1

$$\text{mean titre} = \frac{9.75 + 9.65}{2}$$

= 9.7(0) cm^3

Calculates mean

1

mol HCL = $0.102 \times 9.70/1000 = 9.89 \times 10^{-4}$

(allow $9.9 \times 10\text{-}4$ for M3 but check not via 4 titres in which case only 1 mark)

Calculates mol (working or result gains credit)

9.92×10^{-4} scores 1 if all 4 titres used

9.83×10^{-4} scores 1 if titres 1,2, and 3 used

1

(b) mol $MHCO_3$ = ANS 3.1×10 (= 9.89×10^{-3})

Use ecf if wrong mean calculated above

1

$$\text{Mr} = \frac{1464/1000}{M1}$$

1

Mr = 148 (3sf)

Allow ecf following wrong mass conversion

1

(c) Suggestion: Use a larger mass of solid OR use a more concentrated solution of $MHCO_3$ OR less concentrated / more dilute solution of HCl OR more $MHCO_3$

1

Cannot score justification mark unless suggestion correct, but suggestion could be after justification

Justification: So a larger titre/reading will be needed OR larger volume of HCl

Assume reference to the solution means the $MHCO_3$

1

(d) This question is marked using levels of response.

Level 3

Must use volumetric flask to access level 3

Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.

All stages are covered and the description of each stage is complete

6 marks

All stages are covered but up to 2 omissions/errors from different stages. If 2 omissions/errors from same stage only level 2 possible

5 marks

Level 2

Answer is mainly coherent and shows progression from stage 1 to stage 3

All stages are covered but 3 omissions/errors

4 marks

All stages are attempted

3 marks

Level 1
Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

2 stages attempted

2 marks

1 stage attempted

1 mark

Level 0
Insufficient correct chemistry to gain a mark.

0 marks

Indicative Chemistry content

***Stage 1**: transfers known mass of solid*

a) Weigh the sample bottle containing the solid on a (2 dp) balance

b) Transfer to beaker and reweigh sample bottle*

c) Record the difference in mass

Or

d) Place beaker on balance and tare*

e) Transfer solid into beaker

f) Record mass

Or

g) Known mass provided

*h) Transfers (known) mass into beaker**

i) Wash all remaining solid from sample bottle into beaker

Allow use of weighing boat

**Allow other suitable glassware including volumetric flask*

***Stage 2**: Dissolves in water*

a) Add distilled / deionised water

b) Stir (with a glass rod) or swirl

c) Until all solid has dissolved

***Stage 3**: Transfer, washing and agitation*

a) Transfer to <u>volumetric / graduated</u> flask. Allow if a clear description/diagram given eg long necked flask with 250 cm^3 mark

b) With washings

c) Make up to 250 cm^3 / mark with water

d) Shakes/inverts/mixes

6

[14]

Q17.

(b) (i) $Mg_3N_2 + \mathbf{6}H_2O \rightarrow \mathbf{3}Mg(OH)_2 + \mathbf{2}NH_3$ **(1)**

(ii) Moles $NH_3 = \frac{0.263}{17}$ (=0.0155 mol) **(1)**

Number of molecules of $NH_3 = 0.0155 \times 6.02 \times 10^{23}$ **(1)**

[mark conseq] = 9.31×10^{21} **(1)**
[range 9.2×10^{21} to 9.4×10^{21}]

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

4

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

Moles of $NaHCO_3$ = 13.68 **(1)**

Moles of $Na2CO_3$ = 13.68/2 = 6.84 **(1)**

Mass of $Na_2CO_3 = 6.84 \times 106 = 725$ 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:Na_2CO_3

4

[13]

Q18.

(a) (i) $\underline{4.98 \times 10^{-3}}$

1

Only

(ii) 2.49×10^{-3}

Allow answer to (a)(i) ÷ 2
Allow answers to 2 or more significant figures

1

(iii) 2.49×10^{-2}

Allow (a)(ii) × 10
Allow answers to 2 or more significant figures

1

(iv) 138.2

3.44 divided by the candidate.s answer to (a)(iii)
138.2 or 138.1 (i.e. to 1 d.p.)

1

(v) (138 – 60) ÷ 2 = 39.1

Allow 39 – 39.1
Allow ((a)(iv) – 60) ÷ 2

1

K/potassium

Allow consequential on candidate's answer to (a)(iv) and (a)(v) if a group 1 metal

Ignore + sign

1

(c) Pressure build up from gas/may explode/stopper fly out/glass shatters/breaks

Penalise incorrect gas

1

(d) (i) M_r = 84.3

If 84 used, max 1

1

$\frac{6.27}{84.3}$ = 0.074(4)

CE if not 84 or 84.3

Allow answers to 2 or more significant figures

M2 = 0.074-0.075

1

(ii) M1 M_r $MgSO_4$ = 120(.4)

allow 120.3 and 120.1

CE if wrong Mr

1

M2 Expected mass $MgSO_4$ = 0.074(4) × 120(.4) = 8.96 g

Allow 8.8 – 9.0 or candidate's answer to (d)(i) × 120(.4)

1

M3 95% yield = $\frac{8.96 \times 95}{100}$ = 8.51 g

Allow 8.3 – 8.6

M3 dependent on M2

Alternative method

M2 0.074(4) × 95/100 = 0.0707

M3 0.0707 × 120(.4) = 8.51 g

Allow (d)(i) × 95/100

Allow 8.3 – 8.6

M3 dependent on M2

1

[15]

Q19.

(a) (i) M_r MgO = 40.3

If used 40 then penalise this mark but allow consequential M2 (0.0185)

1

0.741/40.3 = 0.0184

0.018 with no M_r shown = 0
Penalise if not 3 sig figs in this clip only

1

(ii) 0.0184 × 5/2 = 0.0460

Allow 0.0459 to 0.0463
Allow their (a)(i) × 5/2 ie allow process mark of × 5/2 but insist on a correct answer being written down
Ignore sig figs

1

(c) (i) 0.0152 × 2 = 0.0304

Allow 0.03

1

(ii) 0.938 mol dm^{-3}

Allow range 0.92 – 0.94
Minimum 2 sig figs
Allow consequential marking from (c)(i)
Ignore units even if wrong

1

[8]

Q20.

(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) $\frac{34 \times 100}{212.1}$

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

(e) (Na_2SO_4) H_2O
(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]

Q21.

(a) (i) $75.0 \times 10^{-3} \times 0.500 = 0.0375$ (mol) **(1)**

accept 0.037 or 0.038

(ii) $21.6 \times 10^{-3} \times 0.500 = 0.0108$ (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 $MgCO_3$* = 0.0267/2 = 0.01335 (mol) **(1)**

allow 0.0134 - 0.0133

Mass of $MgCO_3$ = 0.01335 × 84.3 **(1)**

allow 84

mark conseq on moles $MgCO_3$

= 1.125g **(1)**

accept 1.13g

mark conseq

Percentage $MgCO_3$ = 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) $Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2$ **(1)**

allow multiples

allow $SO_3^{2-} + 2H^+ \rightarrow H_2O + SO_2$

4

[12]

Q22.

(a) M_r NaF = 42(.0)

Incorrect M_r loses M1 & M4

1

Mass NaF in 1 g = $2.88 \times 10^{-5} \times 42.0$ (= 1.210 (1.2096) $\times 10^{-3}$ g)

1

Mass NaF in 1 kg = 1.210 (1.2096) g

M3 = M2 × 1000 (g)

Units, if given, must match answer

1

(Mass in mg = 1210 (1209.6) mg)

Concentration of NaF = 1210 (ppm)

Allow 1.21 × 10^3 ppm

1

(b) Toxic mass = $3.19 \times 10^{-2} \times 75 \times 1000$

= 2390 mg

Allow 2393

1

(c) Mass of toothpaste needed = $\frac{2390}{2800}$

= 0.854 kg

Mark consequential to (b)

(b) ÷ 2800 (to at least 2 sig fig)

Allow 0.85 - 0.86 kg

1

Q23.

(a) (i) 0.0212

Need 3 sig figs

Allow correct answer to 3 sig figs eg 2.12 x 10^{-2}

1

(ii) 0.0106

Mark is for (a)(i) divided by 2 leading to correct answer 2 sig figs

1

(iii) M_r = 100.1

1.06 g

Allow 100.1 as 'string'

Need 3 sig figs or more

Consequential on (a)(ii) x 100(.1)

2

(iv) Neutralisation or acid / base reaction

Allow acid / alkali reaction

Apply list principle

1

(c) 4.20 g $Ca(NO_3)_2$

1

$Ca(NO_3)_2$ H_2O

$\frac{4.20}{164(.1)}$ $\frac{1.84}{18}$

Mark is for dividing by the correct Mr values

M2 and M3 dependent on correct M1

0.0256 0.102

M2 can be awarded here instead

1 : 3.98

$x = 4$

If $Ca(NO_3)_2.4H_2O$ seen with working then award 3 marks

Credit alternative method which gives $x = 4$

1

[12]

Q24.

(a) **M1** Amount of $S_2O_3^{2-}$ = $\frac{9.00 \times 0.0800}{1000}$ = 7.20×10^{-4} mol

1

(From equations mol $S_2O_3^{2-}$ = mol Cu^{2+})

M2 Amount of Cu^{2+} in 25 cm^3 = 7.20×10^{-4} mol

M2 = *answer to* ***M1*** *(1:1 ratio)*

1

M3 Amount of Cu^{2+} in 250 cm^3 = 7.20 v 10^{-4} **× 10** = 7.20 × 10^{-3} mol

M3 = ***M2*** × *10*

1

M4 Mass of copper = 7.20 × 10^{-3} mol **× 63.5** = 0.457 g

M4 = ***M3*** × *63.5*

1

M5 mass = 0.985 g

M5 *converting 985 mg to g*

1

M6 $\% \text{ Cu} = 0.457 \times \frac{100}{0.985} = 46.4\ \%$

M6 *is for the answer to* ***3 sf***

Allow % Cu = 457 × $\frac{100}{985}$ *= 46.4 % for* ***M5*** *and* ***M6***

*Allow (****M4*** *×1000)/985 v 100 for* ***M5*** *and* ***M6***

1

(b) Use more of the alloy

1

Use a lower concentration of the thiosulfate solution/lower mass of $Na_2S_2O_3$ to make solution

1

Q25.

(a) **M1** $n(S_2O_3^{2-})$ = 33.50 x 0.100 ÷1000 = 0.00335

1

M2 $n(I_2)$ = 0.00335 **÷ 2** = 0.001675 (from eqn 2)

M2 = ***M1****÷2*

1

M3 $n(ClO^-)$ in 25 cm^3 pipette = 0.001675 (from eqn 1)

M3 = ***M2***

1

M4 $n(ClO^-)$ in 100 cm^3 flask = 0.001675 **x 4** = 0.00670 = n(NaClO) in original 10 cm^3 sample

M4 = ***M3*** *x 4*

1

M5 mass (NaClO) = 0.00670 x 74.5 = 0.499 g

M5 = ***M4*** *x 74.5*

1

M6 mass (bleach) = 10.0 x 1.20 = 12 g

M6 = *mass of bleach*

1

M7 % by mass of NaClO = $\frac{0.499}{12}$ = 4.16 %

***M7** = (**M5**÷**M6**) x 100 to 3 significant figures*
Allow 4.15% to 4.17%

1

(b) 0.45%

1

[8]

Q26.

(c) (i) suitable reaction vessel
eg sealed flask or test-tube with side arm or
eg tube in bung

1

suitable collection method
eg gas syringe / over water in measuring
eg cylinder

1

Notes
** collection vessel must allow measurement of gas*
** if apparatus would leak lose second mark*
** ignore heating*
** can draw tubing as single line*
** accept 2D or 3D diagrams*
** do not need labels, and ignore mis-labelling*

(ii) (1) mass on *x*-axis

1

Notes
** If axes unlabelled use data to decide that mass is on the x-axis*

sensible scales

1

Notes
** lose this mark if the **plotted points** do not cover at least half of the paper*
** lose this mark if the graph plot goes off the squared paper*

plots points correctly ± one square

1

(2) draws appropriate straight line of best fit, omitting point at 1.17g / 86 cm^3

Notes
** lose this mark if the line deviates towards the point at 1.17g / 86 cm^3*
** candidates does not have to extrapolate the line to the*

origin to score this mark
** when checking for best fit, candidate's line **must** go through the origin ± one square. Extend candidate's line if necessary*

1

(3) 129 ± 1 cm^3

Notes
** accept this answer **only***

1

(d) CO_2 / gas formed distends stomach / produces wind / increases pressure in stomach

1

(e) molecular formula has to be a simple multiple of the empirical formula

1

so approximate M_r value will distinguish between the options or equivalent wording

1

(f) gas escapes before bung inserted any 2 × 1 for

syringe sticks

carbon dioxide soluble in water

Notes
** do **not** accept 'operator error' / 'inaccurate equipment' / 'equipment leaks'*

2

(g) volume depends on pressure and temperature

Notes
** do **not** accept 'to get a more accurate result' or equivalent wording without qualification*

1

(h) Tablets could vary between samples or equivalent wording

Notes
** do **not** accept 'to get a more accurate / reliable result' or 'to make a fair test' without qualification*

1

(i) (i) $NaHCO_3$ **least** soluble

1

(ii) exhaust gases passed into mixture of NaCl and NH_3

1

(j) $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Notes
** accept multiples*

1

(k) 106.0 divided by 217.1 × 100 = 48.8%

Notes * *ignore precision of answer* **1**

[22]