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HIGHER

C3H Quantitative Chemistry: Higher Tier Practice

AQA 8462 · Calculator allowed · about 95 minutes

Total Marks

Name: ________________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 State the law of conservation of mass, and explain why the measured mass of a reaction mixture appears to decrease when a metal carbonate is heated in an open test tube.

(Total for Question 1 is 2 marks)

2 Calculate the relative formula mass, Mr, of ammonium sulfate, (NH4)2SO4. Relative atomic masses: N = 14, H = 1, S = 32, O = 16.

(Total for Question 2 is 3 marks)

3 A student reacts 4.8 g of magnesium with excess dilute hydrochloric acid. Relative atomic mass of Mg = 24.

Calculate the number of moles of magnesium used, using moles = mass / Ar.

(Total for Question 3 is 2 marks)

4 The equation for the reaction in question 3 is: $Mg + 2HCl \rightarrow MgCl_2 + H_2$.

Using your answer to question 3, calculate the number of moles of hydrogen gas, H_2, produced, and then the volume this occupies at room temperature and pressure (rtp). The molar volume of any gas at rtp is 24 dm^3/mol.

(Total for Question 4 is 3 marks)

5 A compound contains only carbon, hydrogen and oxygen. A sample of the compound with mass 4.60 g is found by analysis to contain 2.40 g of carbon, 0.60 g of hydrogen and 1.60 g of oxygen. Relative atomic masses: C = 12, H = 1, O = 16.

Calculate the empirical formula of the compound. Show your working clearly.

(Total for Question 5 is 3 marks)

6 Iron oxide reacts with carbon monoxide in a blast furnace: $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$.

A sample of iron oxide with mass 32.0 g is reacted with excess carbon monoxide. Relative formula mass of Fe_2O_3 = 160; relative atomic mass of Fe = 56.

Calculate the maximum theoretical mass of iron that could be produced.

(Total for Question 6 is 3 marks)

7 In the reaction in question 6, a student actually obtains 18.7 g of iron.

Calculate the percentage yield of iron, giving your answer to 3 significant figures.

(Total for Question 7 is 2 marks)

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8 Explain, giving two reasons, why the actual yield of a reaction carried out in a school laboratory is often less than the theoretical yield calculated from the balanced equation.

(Total for Question 8 is 2 marks)

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9 Atom economy measures the proportion of the mass of reactants that ends up as the desired product.

Calcium carbonate is heated to produce calcium oxide, releasing carbon dioxide as a by-product: $CaCO3 \rightarrow CaO + CO2$.
Relative formula masses: $CaCO3 = 100$, $CaO = 56$, $CO2 = 44$.

Calculate the atom economy for the production of calcium oxide in this reaction, giving your answer to 3 significant figures.

(Total for Question 9 is 2 marks)

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10 Explain why a chemical process with a high atom economy is generally considered more sustainable than a process with a low atom economy, even if both processes have the same percentage yield.

(Total for Question 10 is 2 marks)

11 A student carries out a titration. She pipettes 25.0 cm3 of sodium hydroxide solution of unknown concentration into a conical flask and titrates it with 0.150 mol/dm3 hydrochloric acid, using a burette. The mean titre of acid needed to exactly neutralise the alkali is 21.4 cm3.

The equation for the reaction is: NaOH + HCl -> NaCl + H2O.

(a) Calculate the number of moles of HCl used in the titration.
(b) Calculate the concentration of the sodium hydroxide solution, in mol/dm3.

(Total for Question 11 is 5 marks)

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12 Calculate the concentration, in g/dm3, of the sodium hydroxide solution in question 11. Relative formula mass of NaOH = 40.

(Total for Question 12 is 2 marks)

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13 Extended response (6 marks).

A student is asked to find the concentration of a hydrochloric acid solution using a titration with a standard solution of sodium carbonate, Na2CO3, of known concentration 0.100 mol/dm3.

Describe how the student should carry out this titration accurately, and explain how the results should be used to calculate the concentration of the hydrochloric acid.

(Total for Question 13 is 6 marks)

14 A gas cylinder contains 6.0 mol of oxygen gas, O_2, at room temperature and pressure.

Calculate the volume of gas in the cylinder, using the molar volume of a gas at rtp = 24 dm^3/mol.

(Total for Question 14 is 2 marks)

Mark scheme · C3H Quantitative Chemistry: Higher Tier Practice

Question 1

- **B1** no atoms are gained or lost in a chemical reaction, so the total mass of reactants equals the total mass of products, oe
- **B1** the mass appears to decrease because a gas (carbon dioxide) is produced and escapes into the atmosphere, so it is not included in the measured mass, oe
- **Answer: Mass is conserved because no atoms are gained or lost. The apparent decrease happens because carbon dioxide gas escapes and is not weighed.**

Question 2

- **M1** identifies atoms present: N x 2, H x 8, S x 1, O x 4
- **M1** substitutes: Mr = (2 x 14) + (8 x 1) + 32 + (4 x 16)
- **A1** 132 cao
- **Answer: 132**

Question 3

- **M1** substitutes: moles = 4.8 / 24
- **A1** 0.20 mol cao
- **Answer: 0.20 mol**

Question 4

- **M1** uses the 1 : 1 mole ratio Mg : H_2 to find moles H_2 = 0.20 mol
- **M1** substitutes into volume = moles x 24: volume = 0.20 x 24
- **A1** 4.8 dm^3 cao
- **Answer: 4.8 dm^3**

Question 5

- **M1** calculates moles of each element: C = 2.40/12 = 0.20, H = 0.60/1 = 0.60, O = 1.60/16 = 0.10
- **M1** divides each by the smallest value (0.10): C = 2, H = 6, O = 1
- **A1** empirical formula C_2H_6O cao
- **Answer: C_2H_6O**

Question 6

- **M1** calculates moles Fe_2O_3: 32.0 / 160 = 0.20 mol
- **M1** uses mole ratio Fe_2O_3 : Fe = 1 : 2, so moles Fe = 0.20 x 2 = 0.40 mol
- **A1** mass Fe = moles x Ar = 0.40 x 56 = 22.4 g cao
- **Answer: 22.4 g**

Question 7

- **M1** substitutes into percentage yield = (actual / theoretical) x 100: (18.7 / 22.4) x 100
- **A1** 83.5 % cao
- **Answer: 83.5 %**

Question 8

- **B1** some product may be lost during the practical steps (e.g. filtering, transferring between containers, or product left behind on apparatus), oe
- **B1** the reaction may not go to completion, or there may be unwanted side/reverse reactions producing other products, so not all reactant is converted to the desired product, oe
- **Answer: Some product is lost during transfer/filtration steps, and the reaction may not go to completion or may form unwanted side products, so less product than the theoretical maximum is obtained.**

Question 9

- **M1** substitutes into atom economy = (Mr of desired product / sum of Mr of all products) x 100: (56 / 100) x 100
- **A1** 56.0 % cao
- **Answer: 56.0 %**

Question 10

- **B1** a high atom economy means most of the mass of the reactants ends up as the useful (desired) product, with little mass wasted as by-products, oe
- **B1** a low atom economy means a large proportion of reactant mass becomes waste by-products, which uses up raw materials unnecessarily and often has to be disposed of, costing money and causing environmental impact, oe
- **Answer: High atom economy means less reactant mass is wasted as by-products, so raw materials are used more efficiently and there is less waste to dispose of, making the process cheaper and better for the environment.**

Question 11

- **M1** converts volume to dm3: 21.4 cm3 = 0.0214 dm3
- **M1** (a) substitutes into moles = concentration x volume: 0.150 x 0.0214
- **A1** (a) 0.00321 mol cao
- **M1** (b) uses 1:1 mole ratio so moles NaOH = 0.00321 mol, then concentration = moles / volume = 0.00321 / 0.0250
- **A1** (b) 0.128 mol/dm3 cao
- **Answer: (a) 0.00321 mol HCl. (b) 0.128 mol/dm3 NaOH.**

Question 12

- **M1** substitutes into concentration (g/dm3) = concentration (mol/dm3) x Mr: 0.128 x 40
- **A1** 5.12 g/dm3 cao (accept answers consistent with a rounded 11(b) answer, e.g. 5.1-5.2 g/dm3)
- **Answer: 5.12 g/dm3**

Question 13

- **Level 3** (5-6): A detailed, correctly sequenced method using appropriate apparatus (pipette, burette, indicator), a clear description of achieving concordant results, and a correct, logically explained calculation route from titre to concentration of HCl, including the mole ratio.
- **Level 2** (3-4): A mostly correct method with some detail missing (e.g. repeats or indicator not mentioned), and a broadly correct but incomplete explanation of the calculation route.
- **Level 1** (1-2): A brief or partial description of a titration with little or no explanation of how the concentration is calculated from the results.
- **Indicative content:**
  - Use a pipette (with a pipette filler) to measure a known, fixed volume of the sodium carbonate solution (e.g. 25.0 cm3) accurately into a conical flask, and add a few drops of a suitable indicator such as methyl orange.
  - Fill a burette with the hydrochloric acid, record the initial reading, then add the acid to the flask while swirling, stopping when the indicator just changes colour at the end point; record the final reading.
  - Repeat the titration until at least two concordant results (within 0.10 cm3 of each other) are obtained, and calculate a mean titre using only the concordant results, ignoring any anomalous readings.
  - Calculate the number of moles of sodium carbonate used, from moles = concentration x volume, using the known concentration and volume pipetted.
  - Use the balanced equation's mole ratio between Na2CO3 and HCl (2HCl + Na2CO3 -> 2NaCl + H2O + CO2, ratio 1:2) to find the moles of HCl that reacted.
  - Calculate the concentration of the HCl using concentration = moles / volume, using the mean titre volume (converted to dm3).

Question 14

- **M1** substitutes: volume = 6.0 x 24
- **A1** 144 dm3 cao
- **Answer: 144 dm3**