C4H Chemical Changes: Higher Tier Practice

AQA 8462 · Calculator allowed · about 105 minutes

Total Marks

Name: _______________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 A student adds a small piece of magnesium ribbon to dilute hydrochloric acid in a test tube and observes bubbles and heat.

(a) Write the symbol equation for the reaction between magnesium and hydrochloric acid. **(1)**

....

(b) State two observable changes that would support the student's report of bubbles and heat. **(2)**

(Total for Question 1 is 3 marks)

2 Aqueous copper(II) sulfate is electrolysed using inert electrodes. The ions present are Cu2+, SO4 2-, H+ and OH- from water.

(a) State which species is reduced at the cathode and give the half equation for its reduction. **(2)**

(b) State what is observed at the cathode during the electrolysis. **(1)**

(Total for Question 2 is 3 marks)

3 A student reacts 2.00 g of magnesium with excess oxygen to form magnesium oxide. Relative atomic masses: Mg = 24.3, O = 16.0.

(a) Calculate the moles of magnesium used. Give your answer to 3 significant figures. **(2)**

....

(b) Using the balanced equation $2Mg + O_2 \rightarrow 2MgO$, calculate the mass of magnesium oxide produced, to 3 significant figures. **(2)**

....

(Total for Question 3 is 4 marks)

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4 Chromium can form ions with different charges. A sample contains Cr^{2+} and Cr^{3+} ions.

(a) Explain, in terms of electron transfer, what happens when a Cr^{2+} ion is converted into a Cr^{3+} ion, and state what type of reaction this is. **(3)**

(b) Give one chemical test that distinguishes an aqueous solution of Cr^{3+} from one of Cr^{2+}. **(1)**

(Total for Question 4 is 4 marks)

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5 A student titrates 25.0 cm^3 of 0.100 mol/dm^3 hydrochloric acid with 0.100 mol/dm^3 sodium hydroxide. The equation is $HCl + NaOH \rightarrow NaCl + H_2O$.

(a) Calculate the number of moles of HCl in the 25.0 cm^3 sample. **(1)**

....

(b) Calculate the volume of 0.100 mol/dm^3 NaOH needed to neutralise this acid. **(2)**

....

(Total for Question 5 is 3 marks)

6 Iron reacts with dilute sulfuric acid in a displacement reaction. A sample of iron filings is added to 50.0 cm3 of 0.150 mol/dm3 H_2SO_4. The equation is $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$. Relative atomic mass Fe = 55.8.

(a) Calculate the initial number of moles of H_2SO_4 present in the 50.0 cm3. **(2)**

....

(b) Calculate the mass of iron that would be needed to react with all the acid (assume 100% reaction). Give your answer in grams to 3 significant figures. **(3)**

....

(c) State one practical reason why a student might obtain a lower mass of iron reacted than the calculated value. **(1)**

(Total for Question 6 is 6 marks)

7 A student prepares 250 cm3 of a 0.200 mol/dm3 sodium carbonate solution by dissolving sodium carbonate decahydrate, Na2CO3.10H2O (Mr = 286.14). The student weighs out 15.0 g of the decahydrate. The student then dilutes to 250 cm3.

(a) Calculate the number of moles of Na2CO3.10H2O in 15.0 g. Give your answer to 3 significant figures. **(2)**

....

(b) Calculate the concentration in mol/dm3 of sodium carbonate (Na2CO3) in the final 250 cm3 solution, assuming all decahydrate provides one mole of Na2CO3 per mole of decahydrate. Give your answer to 3 significant figures. **(3)**

....

(c) The target concentration was 0.200 mol/dm3. Calculate the percentage error in concentration achieved by the student, using percentage error = (measured - target)/target x 100%. Give your answer to 2 significant figures and comment whether the preparation is acceptable if an allowed error is ±5%. **(3)**

....

(Total for Question 7 is 8 marks)

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8 Explain why a student observing the electrolysis of molten aluminium oxide (with cryolite present) uses a carbon-lined cell and why oxygen is evolved at the anode rather than oxide ions reacting with the carbon to give CO2 directly. Your answer should consider the reactions occurring, the role of cryolite, and the limitations of the anode material.

(Total for Question 8 is 6 marks)

9 A student investigates the reaction of chlorine with aqueous potassium iodide. They mix 50.0 cm3 of 0.0200 mol/dm3 potassium iodide (KI) solution with an excess of chlorine solution. The iodine produced is filtered, dried and weighed; its mass is 0.1143 g. The equation is $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$. Relative atomic masses: I = 127.0, Cl = 35.5.

(a) Calculate the initial moles of iodide ions present in the 50.0 cm3 of 0.0200 mol/dm3 KI solution. **(2)**

....

(b) From the balanced equation, calculate the maximum moles of I_2 that could be formed from the iodide present. **(2)**

....

(c) Calculate the moles of iodine the student actually collected, using the measured mass of 0.1143 g and Mr of I_2. **(3)**

....

(d) Calculate the percentage yield of iodine in this experiment, and suggest one reason why the actual yield is less than the theoretical maximum. **(3)**

....

(Total for Question 9 is 10 marks)

10 An unknown metal M reacts with dilute nitric acid to produce a nitrate solution containing M2+ ions. A 0.250 g sample of the metal produced 9.24 cm3 of H2 gas measured at room temperature and pressure in a reaction producing hydrogen according to M + 2H+ -> M2+ + H2. A student uses the ideal gas approximation and assumes that 1 mol gas occupies 24.0 dm3 at these conditions. Relative atomic mass of M is to be determined.

(a) Calculate the number of moles of H2 produced, using the gas volume data and 1 mol = 24.0 dm3. **(3)**

....

(b) Use the balanced equation M + 2H+ -> M2+ + H2 to calculate the moles of metal M that reacted. **(3)**

....

(c) Calculate the relative atomic mass Ar of metal M from the mass 0.250 g sample and the moles found. Give your answer to 3 significant figures. **(4)**

....

(d) Comment on the plausibility of this result and give two possible experimental sources of error that could lead to an incorrect Ar value. **(3)**

(Total for Question 10 is 13 marks)

Mark scheme · C4H Chemical Changes: Higher Tier Practice

Question 1

- (a) **B1** $Mg + 2HCl \rightarrow MgCl_2 + H_2$ cao
- **(a) Answer: $Mg + 2HCl \rightarrow MgCl_2 + H_2$**
- (b) **B1** bubbling or effervescence (hydrogen gas produced)
- (b) **B1** temperature of the mixture increases or test tube gets warm (exothermic), oe
- **(b) Answer: Bubbling (effervescence) and the test tube gets warm (exothermic).**

Question 2

- (a) **M1** identifies that Cu^{2+} is reduced at the cathode
- (a) **A1** $Cu^{2+} + 2e^- \rightarrow Cu$ cao
- **(a) Answer: Cu^{2+} is reduced; $Cu^{2+} + 2e^- \rightarrow Cu$**
- (b) **B1** brown/red solid copper deposits on the cathode
- **(b) Answer: Brown/red copper metal deposits on the cathode.**

Question 3

- (a) **M1** uses n = mass / Mr with 2.00 / 24.3
- (a) **A1** 0.0823 mol cao
- **(a) Answer: 0.0823 mol**
- (b) **M1** uses mole ratio: $2Mg \rightarrow 2MgO$ so moles MgO = moles Mg = 0.0823
- (b) **A1** mass MgO = 0.0823 x (24.3 + 16.0) = 0.0823 x 40.3 = 3.32 g cao
- **(b) Answer: 3.32 g**

Question 4

- (a) **B1** recalls that oxidation is the loss of electrons (and reduction is the gain of electrons)
- (a) **M1** states that a Cr^{2+} ion loses one electron to become a Cr^{3+} ion: $Cr^{2+} \rightarrow Cr^{3+} + e^-$
- (a) **A1** concludes this is an oxidation reaction, and that something else must gain the electron lost (a reduction must happen at the same time), oe
- **(a) Answer: A Cr^{2+} ion loses one electron to form Cr^{3+} ($Cr^{2+} \rightarrow Cr^{3+} + e^-$); since oxidation is the loss of electrons, this is an oxidation reaction, and another species must gain that electron at the same time (a reduction).**
- (b) **B1** oxidation of Cr^{2+} to Cr^{3+} with acidified potassium manganate(VII) or other oxidising agent, producing a colour change; or observation that Cr^{2+} is typically pale blue while Cr^{3+} is green, oe
- **(b) Answer: Oxidise with acidified $KMnO_4$: Cr^{2+} (pale blue) is oxidised to Cr^{3+} (green), producing a colour change.**

Question 5

- (a) **B1** uses n = concentration x volume (in dm^3) and calculates 0.100 x 0.0250 = 0.00250 mol
- **(a) Answer: 0.00250 mol**
- (b) **M1** uses stoichiometry: n NaOH = n HCl = 0.00250 mol
- (b) **A1** volume = n / concentration = 0.00250 / 0.100 = 0.0250 dm^3 = 25.0 cm^3 cao
- **(b) Answer: 25.0 cm^3**

Question 6

- (a) **M1** calculates n = concentration x volume (in dm3): 0.150 x 0.0500
- (a) **A1** 0.00750 mol cao
- **(a) Answer: 0.00750 mol**
- (b) **M1** uses mole ratio: Fe : H_2SO_4 is 1 : 1 so moles Fe = 0.00750
- (b) **M1** calculates mass = moles x Mr = 0.00750 x 55.8
- (b) **A1** mass = 0.4185 g -> 0.419 g cao
- **(b) Answer: 0.419 g**
- (c) **B1** loss of iron during transfer, incomplete reaction, formation of oxide layer preventing full reaction, or acid not in excess in practice, contamination, oe
- **(c) Answer: Practical losses such as some iron remaining in the weighing boat or not all iron reacting due to an oxide layer; so less mass reacts.**

Question 7

- (a) **M1** uses n = mass / Mr = 15.0 / 286.14
- (a) **A1** 0.0524 mol cao
- **(a) Answer: 0.0524 mol**
- (b) **M1** uses n of Na_2CO_3 = 0.0524 mol and volume 0.250 dm3 to calculate concentration
- (b) **M1** calculates c = 0.0524 / 0.250
- (b) **A1** 0.210 mol/dm3 cao
- **(b) Answer: 0.210 mol/dm3**
- (c) **M1** calculates percentage error: (0.210 - 0.200) / 0.200 x 100
- (c) **A1** 5.0% cao
- (c) **A1** states that this equals the allowed error so preparation is at the limit of acceptability (acceptable if ≤ 5%), oe
- **(c) Answer: 5.0% ; at the limit of acceptability (equals allowed error of ±5%).**

Question 8

- **Level 3** (5-6): Detailed explanation that links the function of cryolite, the half equations at the electrodes, and the consequences for the carbon anode. The response shows clear chemical reasoning and uses correct equations.
- **Level 2** (3-4): Partial explanation with correct statements about either the role of cryolite or the electrode reactions but lacking full linkage or detail.
- **Level 1** (1-2): Basic statements about electrolysis with limited or superficial chemistry and missing key equations or links.
- **Indicative content:**
  - Cryolite lowers the melting point of aluminium oxide and increases its conductivity so electrolysis is feasible at lower temperature.
  - At the cathode Al^{3+} ions are reduced: $Al^{3+} + 3e^- \rightarrow Al$; at the anode oxide ions give O_2: $2O^{2-} \rightarrow O_2 + 4e^-$ (or $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$ in other contexts).
  - Oxygen produced at the carbon anode reacts with the carbon to form CO_2 over time: $C + O_2 \rightarrow CO_2$, causing anode consumption; but the primary process is release of O_2 which then oxidises the anode, not oxide ions directly forming CO_2 at the electrode surface without intermediate O_2.
  - Carbon anodes are used because they conduct and are relatively cheap, even though they are consumed; inert anodes are being developed but are expensive and less common.
  - Linking the above points: cryolite makes the process energy efficient; electrode reactions determine products; anode consumption is a limitation and requires replacement.

Question 9

- (a) **M1** calculates moles KI = 0.0200 x 0.0500 = 0.00100 mol then moles I- = 0.00100 mol
- (a) **A1** 0.00100 mol I- cao
- **(a) Answer: 0.00100 mol I-**
- (b) **M1** uses mole ratio: 2I- -> I2 so moles I2 = 0.00100 / 2
- (b) **A1** 0.000500 mol I2 cao
- **(b) Answer: 0.000500 mol**
- (c) **M1** calculates Mr I2 = 127.0 x 2 = 254.0 and uses n = mass / Mr
- (c) **M1** calculates n = 0.1143 / 254.0
- (c) **A1** 0.000450 mol I2 cao
- **(c) Answer: 0.000450 mol**
- (d) **M1** substitutes into percentage yield = (actual / theoretical) x 100: (0.000450 / 0.000500) x 100
- (d) **A1** 90% cao
- (d) **B1** suggests a valid reason such as some iodine being lost during filtering or transferring the solid, some iodine remaining dissolved in the solution rather than being collected, or the reaction not going completely to completion, oe
- **(d) Answer: 90%. Some iodine may have been lost during filtering and transferring the solid, or some iodine may have remained dissolved in the solution rather than being collected.**

Question 10

- (a) **M1** converts 9.24 cm3 to dm3 and uses n = volume / 24.0
- (a) **M1** substitutes n = 0.00924 / 24.0
- (a) **A1** 3.85×10^{-4} mol H2 cao
- **(a) Answer: 3.85×10^{-4} mol H2**
- (b) **M1** uses mole ratio: 1 mol M produces 1 mol H2 so moles M = moles H2
- (b) **M1** substitutes moles M = 3.85×10^{-4}
- (b) **A1** 3.85×10^{-4} mol M cao
- **(b) Answer: 3.85×10^{-4} mol M**
- (c) **M1** uses Ar = mass / moles = 0.250 / 3.85×10^{-4}
- (c) **M1** performs division
- (c) **A1** Ar = 649 cao
- (c) **A1** gives Ar to 3 s.f. as 649 cao
- **(c) Answer: 649**
- (d) **M1** states that Ar = 649 is not plausible for a simple metal (too large compared with known metal atomic masses)
- (d) **A1** gives experimental error such as gas loss during collection, inaccurate volume measurement, or presence of impurities in the metal sample, oe (first reason)
- (d) **A1** gives a second error such as incorrect temperature/pressure assumption for 1 mol = 24.0 dm3, or balance calibration error, oe
- **(d) Answer: Result is implausible because Ar = 649 is far too large for a metallic element; likely errors include gas loss during collection or inaccurate volume measurement, impurities in the metal sample, or incorrect gas volume assumption (1 mol = 24.0 dm3 not exact for actual lab conditions).**