SeaHawk Tutors

AQA Chemistry GCSE Topic 4.3 - Quantitative Chemistry

Topic 4.3 only

1. An organic compound is found to have composition by mass as follows: Carbon 61.5%, Hydrogen 11.1%, Oxygen 27.4%.

   a. Determine the empirical formula of the compound. [3]

   b. The M_r of the substance is 234. What is the molecular formula of the compound? [2]

Total marks [5]

2. The thermite reaction is a displacement reaction between Iron (III) Oxide and Aluminium. It uses the fact that Aluminium is more reactive than Iron and is used in welding, especially in forming continuous rails for smooth railway operations. The balanced equation for the reaction is:

   $Fe_2O_3 + 2\ Al \rightarrow 2\ Fe + Al_2O_3$

   A welder requires 220g of Iron. Calculate the minimum mass of Iron Oxide that could produce this mass of Iron. [4]

Total marks [4]

3. Lithium reacts with Hydrochloric acid according to the 'MASH' equation: metal + acid goes to salt + water. The balanced equation is:

   2 Li (s) + 2 HCl (aq) → 2 LiCl (aq) + H_2 (g)

   A chemist uses a 6g sample of Lithium with excess acid. Calculate the volume of Hydrogen gas produced at room temperature and pressure. [3]

Total marks [3]

4.

   a. A compound is found to have composition by mass as follows:
   Sodium 27.4%, Hydrogen 1.2%, Carbon 14.3%, Oxygen 57.1%
   Determine the empirical formula of the compound. [3]

   b. Put these reactions in order of atom economy from lowest to highest. The intended product is in brackets.

      A. 2 Na + 2 H_2O → 2 NaOH + H_2 (NaOH)
      B. 2 LiOH + $CuSO_4$ → Li_2SO_4 + $Cu(OH)_2$ (Li_2SO_4)
      C. C + O_2 → CO_2 (CO_2) [2]

Total marks [5]

5. Magnesium reacts with Hydrochloric acid according to the 'MASH' equation: metal + acid goes to salt + water. The balanced equation is:

   $Mg\ (s) + 2\ HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$

   A chemist measures 25 cm^3 of 0.1 mol/dm^3 Hydrochloric acid and an excess of Magnesium powder to create the reaction. Calculate the theoretical volume of Hydrogen gas produced at room temperature and pressure. [4]

Total marks [4]

6. The balanced equation for the combustion reaction of ethanol is:

   $C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$

   0.5 g of ethanol undergoes complete combustion in 3,600 cm^3 of air. Air is 21% Oxygen.

   a. Explain what is meant by 'complete combustion.' [2]

   b. Calculate the number of moles of Oxygen in 3,600 cm^3 of air. [2]

c. Determine the limiting reactant in the reaction. [3]

Total marks [5]

7. Calculate the mass of Iron produced when 500kg of Iron (III) Oxide is reduced using excess Carbon if the reaction has a 82.6% yield. [6]
[*Note: this is not a normal exam style question. You would normally be given some intermediate questions to lead you through what you need to do. If you can figure out the steps for yourself and follow them to the answer you are in good shape on this topic.]*

Total marks [6]

8. A chemist needs to produce 60g of Copper (II) Nitrate using a neutralisation reaction between Copper (II) Oxide and Nitric acid according to the equation below. The chemist adds CuO until it no longer reacts, ensuring that it is in excess.

$$CuO\ (s) + 2HNO_3\ (aq) \rightarrow Cu(NO_3)_2\ (aq) + H_2O\ (l)$$

a. Calculate how many moles of Copper (II) Nitrate the chemist is looking to produce. Atomic masses - Cu: 63.5, N: 14, O: 16 [2]

b. Calculate the volume of 0.5 mol/dm^3 Nitric Acid that is required to produce this quantity of Copper (II) Nitrate. Assume that the reaction goes to completion with 100% yield. [4]

c. Suggest why the chemist decided to make the Copper (II) Oxide the excess reactant rather than the Nitric Acid. [1]

Total marks [7]

9. This question concerns Calcium Nitrate, $Ca(NO_3)_2$.

a. Calculate the M_r of Calcium Nitrate.
A_r : Ca = 40, N = 14, O = 16 [1]

b. What is the mass of 3 moles of this compound? [1]

c. Calculate the number of moles of Calcium Nitrate in 1kg. Give your answer to 1 decimal place. [1]

d. What is the percentage by mass of Oxygen in this compound? Give your answer to the nearest whole number. [2]

Total marks [5]

10. Bicarbonate of soda is the household name for Sodium Hydrogen Carbonate, $NaHCO_3$. Ethanoic acid, CH_3COOH, is the acidic component in vinegar, which also contains other substances such as esters which give the vinegar its flavour. These other substances do not react with $NaHCO_3$.

The ethanoic acid in the vinegar is known to be of concentration 0.5 mol/dm^3. A chemist wishes to test what percentage of the vinegar is the other substances.

The reaction between the two follows the word equation: Acid + Carbonate goes to Salt + Water + Carbon Dioxide.

0.21g of $NaHCO_3$ is the precise volume to react with 6.1 cm^3 of vinegar.

a. Calculate how many moles of $NaHCO_3$ are in 0.21g. [2]

The balanced equation for the reaction is:

$NaHCO_3 + CH_3COOH \rightarrow CH_3COONa + H_2O + CO_2$

b. State how many moles of ethanoic acid will neutralise 0.21g of $NaHCO_3$. [1]

c. Calculate the volume of 0.5 mol/dm^3 ethanoic acid that contains the number of moles found in (b). [3]

d. Deduce the percentage of the vinegar comprised of ethanoic acid. [2]

e. State the percentage of the vinegar that is the other substances. [1]

Total marks [9]

Synoptic Questions Involving Topic 4.3

11. A student takes 52.3g of Barium Hydroxide, $Ba(OH)_2$, and dissolves it in 150 cm^3 of distilled water to create Barium Hydroxide solution.

    a. Calculate the concentration of the solution she created in g/dm^3. [2]

    b. Calculate the Mr of Barium Hydroxide. [1]

    c. Calculate the concentration of the solution in mol/dm^3. [2]

    She uses a 25cm^3 sample of the solution to test a sample of Hydrochloric acid of unknown concentration. By titrating them she wishes to determine the concentration of the acid.

    She runs three titrations, and the start and end readings on the burette are shown below.

cm^3	Titration 1	Titration 2	Titration 3
Initial reading	48.6	44.5	45.1
End reading	28.9	24.5	25.2
Titre			

d. Complete the table by calculating the titres. [1]

Concordant titres are those that are within 0.1 cm^3 of each other.
Non-concordant titres are eliminated from the analysis.

e. State which titre should she exclude. [1]

f. Calculate the mean titre of the concordant results. [1]

g. Write the balanced equation for the reaction between Barium Hydroxide solution and Hydrochloric acid. Include state symbols. [2]

h. Calculate the concentration of the acid in mol/dm^3 to 3sf. [4]

Total Marks - 14

Synoptic topic 4.4

12. Potassium reacts with Nitrogen (and no other substances) to form a new compound.

a. Name the compound formed. [1]

b. State the bonding and structure of this compound. [2]

Bonding: _____ Structure: _____

c. By drawing outer shell electron structures for the atoms involved, or otherwise, deduce the chemical formula for this compound formed. [2]

d. Write a balanced chemical equation, with state symbols, for this reaction. [2]

e. Find the mass of Potassium required to produce 50g of the product. [4]
A_r : K = 39, N = 14

f. In reality, this mass of Potassium produces 48.2g of the product. Suggest a possible reason why this is the case. [1]

g. Calculate the percentage yield of the reaction in (f). [2]

h. Assuming that the mass you found in (e) does produce exactly 50g of the product, state the mass of Nitrogen that reacted. [1]

i. State the law that you used to answer (g). [1]

Total marks [16]

Synoptic topics: 4.2

13. Sodium Hydroxide undergoes a reaction with Sulfuric acid according to the ***unbalanced*** equation below.

$$NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$$

a. What type of reaction is this? [1]

b. Complete the word equation:

Alkali + Acid → _____ + _____ [2]

c. Write the balanced equation for the reaction. [2]

d. Calculate the theoretical mass of Sodium Sulfate that would be produced in this reaction from 4g of Sodium Hydroxide. [4]

e. The actual mass of Sodium Sulfate produced in a practical test of this reaction was 5.32g. Calculate the percentage yield achieved in this reaction. [2]

Total marks [11]

Synoptic Topic 4.4

14. Most Sulfates are soluble in water. All Chlorides of Group I and II metals are soluble in water.

A chemist takes measured masses of solid Calcium Chloride and Potassium Sulfate and dissolves in water to create an aqueous solution of each of the two chemicals. She then adds the two solutions to a single conical flask. The incomplete equation for the reaction that occurs is:

$CaCl_2$ (aq) + K_2SO_4 (aq) → _____ (s) + 2 _____ (aq)

a. Complete the equation by writing in the chemical formulae for the missing products. [2]

b. What type of reaction is this?

Neutralisation	☐	Combustion	☐	Substitution	☐

c. What would be observed in the flask as the reaction occurs? [1]

d. Calculate the mass of solid Potassium Sulfate that would be needed to precisely react with 3.3g of (solid) Calcium Chloride. [3]

e. An industrial chemist uses this reaction to produce Calcium Sulphate. Calculate the atom economy of this process. [3]

Total marks [9]

15. Magnesium Oxide undergoes a reaction with Hydrochloric acid according to the ***unbalanced*** equation below.

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

a. Complete the following statements:

Magnesium oxide is a base. A base will _____ an acid. An alkali is a _____ base. [2]

b. Write the balanced equation for the reaction. [2]

c. A chemist needs to produce 3.8g of Magnesium Chloride. Calculate the mass of Magnesium Oxide required if the acid is in excess. You may assume that all of the Magnesium Oxide reacts and none of the products is lost. [4]

d. In reality the reaction has a yield of 72%. Calculate the actual amount of Magnesium Chloride that was produced. [2]

Total marks [10]

Synoptic Topic 4.4

16. When heated with no other reactants present, Magnesium Carbonate undergoes the following reaction:

$$MgCO_3 \rightarrow MgO + X$$ *where X represents an unidentified substance.*

a. Identify the missing product X. [1]

b. State the name for this type of reaction. [1]

c. Calculate the maximum mass of Magnesium Oxide that could be produced from 2.1g of Magnesium Carbonate. [3]

d. Using your answer to part c, write down the mass of substance X that would be produced. [1]

e. State the law of chemistry that you used to answer part d. [1]

f. In reality, the amount of Magnesium Oxide that a chemist is able to produce from 2.1g of Magnesium Carbonate is less than the answer to part c. Suggest two reasons why this might be the case. [2]

Total marks [9]

Synoptic Topic 4.4

17. Iron is produced by the reduction of Iron (III) Oxide using carbon in the form of coke. The *unbalanced* equation for this reaction is:

$$Fe_2O_3 + C \rightarrow Fe + CO_2$$

a. Balance the equation. [2]

b. Calculate the maximum possible mass of Iron that can be produced when 500kg of Iron (III) Oxide is reduced using excess Carbon. [3]

c. The reaction requires the intense heat of a blast furnace. Suggest two possible reasons why the production of Iron by this reaction has negative environmental consequences. [2]

Total marks [7]

Synoptic Topics 4.4, 4.9

18. The combustion reaction of ethanol in pure oxygen follows the ***unbalanced*** equation:

$C_2H_5OH\ (l) + \quad O_2\ (g) \rightarrow \quad CO_2\ (g) + \quad H_2O\ (g)$

a. Balance the equation. [2]

b. Suggest why the state symbol for the product water is given as (g). [1]

c. At room temperature, ethanol has a density of 0.8 g/cm^3. An experiment uses 10 cm^3 of ethanol.

i. Calculate the mass of 10 cm^3 of ethanol Use the formula:
density = mass ÷ volume [2]

ii. Calculate the number of moles of ethanol in 10 cm^3. C - 12; H - 1; O - 16.

iii. Calculate the volume of CO_2 that will be produced if the reaction occurs perfectly. [2]

iv. In reality, the experiment had a yield of 76%. What volume of CO_2 was produced? [2]

v. The student running the experiment was adamant that none of the products of the reaction could have been lost. The teacher agreed. Give one reason why the yield might have been less than 100%. [1]

Total marks [10]

Synoptic Topics 4.4

Answers

1.

a. C: 61.5 ÷ 12 = 5.13
H: 11.1 ÷ 1 = 11.1
O: 27.4 ÷ 16 = 1.71 M1 for any one correct
Divide each by smallest number
C: 5.13 ÷ 1.71 = 3
H: 11.1 ÷ 1.71 = 6.5
O: 1.71 ÷ 1.71 = 1
Ratio 3 : 6.5 : 1 M1
Simplest whole number ratio = 6 : 13 : 2
Empirical formula $C_6H_{13}O_2$ A1

b. Mr of $C_6H_{13}O_2$ = 117
234 ÷ 117 = 2
Molecular formula = $C_{12}H_{26}O_4$

2.

Mols of Iron = 220 ÷ 56 = 3.93
Ratio = 1 : 2
Mols of Iron Oxide = 3.93 ÷ 2 = 1.96
Mr of Iron Oxide = 160
Mass of Iron Oxide = 1.96 × 160 = 314g

3.

Mols of Li = 6 ÷ 7 = 0.857
Ratio = 2 : 1
Mols of H_2 = 0.857 ÷ 2 = 0.429
Volume of gas = 0.428 × 24 = 10.3 dm^3

4.

a. Na: 27.4 ÷ 23 = 1.19
H: 1.2 ÷ 1 = 1.2
C: 14.3 ÷ 12 = 1.19
O: 57.1 ÷ 16 = 3.57
Divide by smallest
Na: 1.19 ÷ 1.19 = 1
H: 1.2 ÷ 1.19 = 1
C: 1.19 ÷ 1.19 =31
O: 3.57 ÷ 1.19 = 3
Empirical formula $NaHCO_3$

b. B, A, C (C must have 100% atom economy as only one product)

5.

Mols of HCl = 0.025 × 0.1 = 0.025
Ratio = 2 : 1
Mols of H_2 = 0.025 × 0.5 = 0.0125
Vol of gas = 0.0125 × 24 = 0.3 dm^3

6.

a. 3600 cm^3 = 3.6 dm^3
   Mols of gas = 3.6 ÷ 24 = 0.15
   Mols of Oxygen = 0.21 × 0.15 = 0.0315
b. Mr of ethanol = 46
   Mols of ethanol = 0.5 ÷ 46 = 0.0109
   Ratio = 1 : 3
   Mols of O_2 for 0.0109 mols ethanol = 0.0109 × 3 = 0.0326
   Oxygen is limiting reactant (must state Oxygen or O_2)

7.

Equation 2 Fe_2O_3 + 3 C → 4 Fe + 3 CO_2	M1
Mr of Fe_2O_3 = 160	
Mols of Fe_2O_3 = 500,000 ÷ 160 = 3,125	M1 (allow 3.125)
Ratio = 2 : 4	
Mols of Fe = 2 × 3125 = 6,250	M1 (allow 6.25)
Mass of Iron = 6,250 × 56 = 350,000g = 350 kg	M1
Actual mass = Theoretical mass × Yield = 350 × 0.826	M1
= 289kg	A1

8.

a. Mr of $Cu(NO_3)_2$ = 187.5
   Mols = 60 ÷ 187.5 = 0.32
b. Ratio = 2 : 1
   Mols of acid = 0.64
   Volume = mols ÷ concentration = 0.64 ÷ 0.5 = 1.28 dm^3
c. To ensure that the contents of the vessel at the end of the reaction were **neutral / not acidic**. Ignore 'safe' or 'not dangerous.'

9.

a. 164
b. 492g
c. 6.1
d. 59%

10.

a. Mr = 23 + 1 + 12 + (3 × 16) = 84
   0.21 ÷ 84 = 0.0025 mols
b. 0.0025 mols
c. [0.0025] ÷ 0.5 = 0.005 dm^3 (= 5 cm^3)
d. 0.005 ÷ 0.0061 or 5 ÷ 6.1
   = 82%.
e. 100 - 82 = 18%.

11.

a. 52.3 ÷ 150 = 0.349 g/dm^3
b. Mr = 171
c. 0.349 ÷ 171 = 0.00204 mol/dm^3
d. 19.7; 20.0; 19.9
e. Titration 1

f. 19.95 cm^3
g. $Ba(OH)_2$ (aq) + 2 HCl (aq) → $BaCl_2$ (aq) + 2 H_2O (l)
h. Mols of $Ba(OH)_2$ = 0.025 × [0.00204] = 5.1×10^{-5}
Mols of HCl = $2 \times 5.1 \times 10^{-5} = 1.02 \times 10^{-4}$
Conc of HCl = mols / volume = $1.20 \times 10^{-4} \div 0.1995 = 0.0051$ mol/dm^3

12.

a. Potassium Nitride
b. Ionic, giant lattice
c. K_3N
d. 6K (s) + N_2 (g) -> $2K_3N$ (s)
e. Mr of K_3N = 131
Mols of K_3N = 50/131 = 0.382
Ratio = 6 : 2 / 3 : 1
Mols of K = 1.15
Mass of K = 1.15 × 39 = 44.7g
f. Not all reactants reacted; reactants were not 100% pure; some reactants underwent a side reaction; some product lost.
g. 48.2 ÷ 50 = 96.4%
h. 50 - 44.2 = 5.8g
i. Law of Conservation of Mass

13.

a. Neutralisation
b. Salt + Water
c. 2 NaOH + H_2SO_4 → Na_2SO_4 + 2 H_2O
d. Mr of NaOH = 40
Mols of NaOH = 4 ÷ 40 = 0.1
Ratio = 2:1
Mols of Na_2SO_4 = 0.1 ÷ 2 = 0.05
Mr of Na_2SO_4 = 142
Mass of Na_2SO_4 = 0.05 × 142 = 7.1g

14.

a. $CaSO_4$ and KCl. Must be in that order to match state symbols.
b. Substitution
c. Milky / cloudy / (white) precipitate
d. Mr of $CaCl_2$ = 111
Mols of $CaCl_2$ = 3.3 ÷ 111 = 0.0297
Ratio = 1 : 1
Mols of K_2SO_4 = 0.0297
e. Mr: $CaCl_2$ = 111; of K_2SO_4 = 174; $CaSO_4$ = 136
Mr of reactants = 285
Atom economy = 136 ÷ 285 = 48%

15.

a. Neutralise; (water) soluble
b. $MgO + 2\ HCl \rightarrow MgCl_2 + H_2O$
c. Mr of $MgCl_2$ = 95
Mols of $MgCl_2$ = 3.8 ÷ 95 = 0.04

Ratio = 1 : 1
Mols of MgO = 0.04
Mr of MgO = 40
Mass of MgO = 0.04 × 40 = 1.6g

d. Actual = Yield × Theoretical = 0.72 × 3.8 = 2.74g

16.

a. Carbon Dioxide / CO_2
b. (Thermal) decomposition
c. Mr of $MgCO_3$ = 84
Mols of $MgCO_3$ =2.1 ÷ 84 = 0.025
Ratio = 1 : 1
Mols of MgO = 0.025
Mr of MgO = 36
Mass of MgO = 0.9g
d. 2.1 - 0.9 = 1.2g
e. (Law of) conservation of mass
f. Any two of: not all reactant reacted; some of reactant underwent different reaction; reactant was not 100% pure; some of product escaped

17.

a. $2\ Fe_2O_3 + 3\ C \rightarrow 4\ Fe + 3\ CO_2$
b. Mols of Fe_2O_3 = 500,000 ÷ 160 = 3,125 (allow 3.125)
Ratio 2 : 4
Mols of Fe = 6,250 × 56 = 350,000 = 350kg
c. Produces Carbon dioxide; uses large amounts of energy; mining of coal (Carbon) and/or Iron Oxide does damage to the landscape / uses a lot of energy

18.

a. $C_2H_5OH\ (l) + 3\ O_2\ (g) \rightarrow 2\ CO_2\ (g) + 3\ H_2O\ (g)$ Deduct one mark for each incorrect molar figure
b. The temperature is high enough to vaporise the water; temperature over 100°C
c.
i. Mass = 10 × 0.8 = 8g
ii. Mr = 46
Moles = 8 ÷ 46 = 0.174
iii. Ratio = 1 : 2 (allow ECF for their ratio from (a))
Moles CO_2 = 2 × 0.174 = 0.348
Volume = 0.348 × 24 = 8.3 dm^3
iv. 0.76 × [8.3] = 6.3 dm^3
v. Not all the ethanol reacted; some of the ethanol evaporated; not all of the ethanol underwent complete combustion; ethanol was not 100% pure.