STOICHIOMETRY SL & HL (Core)

||DEFAULT : Sig figs given to same number as the question||

1. The drug AHA is a potent enzyme inhibitor, which consists of 20.2% carbon, 11.4% nitrogen, 65.9% oxygen and 2.50% hydrogen by mass. Determine the empirical formula of AHA, showing your working.

Error carried forward is allowed in all calculations.

[3]

	C	N	O	H
Assume 100g and	20.2	11.4	65.9	2.50
find moles of atoms	12.01	14.01	16.00	1.01
=	1.6819...	0.8137...	4.1175	2.4752... (don't round yet)
÷ by smallest =	2.06...	1	5.06...	3.04...
≈	2	: 1 :	5	: 3

empirical formula is $C_2NO_5H_3$

2. A sample of a compound gas, T, is investigated. At 0°C and 1.00×10^5 Pa, 0.817g of compound T occupies a volume of 0.686dm^3. Calculate the molar mass of compound T.

[2]

Using $PV = nRT$ and $n = \frac{m}{M_r}$ UNITS: { carpe diem kPa dm^3

100kPa, 0.686 dm^3, 273K (0°C), 8.31 $JK^{-1}mol^{-1}$ (databook)

$n = \frac{100 \times 0.686}{8.31 \times 273} = \frac{68.6}{2268.63} = 0.030238513$

$M_r = \frac{m}{n} = \frac{0.817}{0.03023...} = 27.0$ (3 sig figs)

correct answer scores 2

3. Magnesium hydroxide can be used to neutralise hydrochloric acid. 0.400mol of $Mg(OH)_2$ is mixed with 0.600mol of HCl(aq) and the following reaction occurs:

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$$

(a) State the limiting reactant, explain your reasoning.

[1]

$Mg(OH)_2 + 2HCl$

must show some explanation to get the mark.

0.4mol of $Mg(OH)_2$ would react with 0.8mol of HCl

1 : 2

0.400 ... 0.800

0.300 ... 0.600

And 0.6mol of HCl would react with 0.3 mol of $Mg(OH)_2$

So HCl is the limiting reactant (and there will be some $Mg(OH)_2$ left over)

(b) Determine the amount (in moles) of excess reactant that remains.

[1]

$Mg(OH)_2$ is in excess. Initial − used = excess

0.400 − 0.300 = **0.100 mol**

(c) Calculate the mass of $MgCl_2$ produced.

[2]

Mole ratio $Mg(OH)_2$: $MgCl_2$ is 1:1 (see equation)

So 0.300 : 0.300 moles

Mass = n × Mr = 0.300 × 95.21 = 28.563

= **28.6 g**

4. Iron undergoes a replacement reaction with copper sulfate solution:

$$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$$

2.46g of iron powder are added to 800cm^3 of 0.800 mol dm^{-3} copper sulfate solution. The resulting copper is filtered off and dried.

(a) Show that the copper sulfate is in excess.

[2]

moles of iron = $\frac{m}{Mr} = \frac{2.46}{55.85} =$ **0.04404...** ✓

moles of $CuSO_4$ = conc × vol = 0.800 × 0.800 (dm^3) = **0.640** ✓

(ratio is 1:1)

(b) 2.32g of copper is obtained. Determine the percentage yield.

[2]

moles of iron = moles of copper (equation ratio Fe : Cu 1 : 1)

So maximum mass of copper = 0.04404... × 63.55 ✓

= 2.799...

% yield = $\frac{\text{mass obtained}}{\text{maximum mass}} = \frac{2.32}{2.799...} \times 100 =$ **82.9 %** ✓

(×100)

Correct answer scores 2

5. Alkanes, like butane, are used as fuels.

(a) Formulate an equation to show butane, C_4H_{10}, reacting completely with oxygen to produce carbon dioxide and water.

[1]

$C_4H_{10} + 6\frac{1}{2}O_2 \longrightarrow 4CO_2 + 5H_2O$ ✓

(b) 4.845g of butane is completely combusted with excess oxygen. The resulting carbon dioxide is captured and stored at STP. Calculate the volume of the stored carbon dioxide.

(Molar volume of an ideal gas at STP = 22.7dm^3 mol^{-1})

[3]

moles of butane $= \frac{4.845}{58.14} = 0.08\dot{3}$ ✓

mole ratio of C_4H_{10} : CO_2 is 1 : 4

moles of $CO_2 = 0.08\dot{3} \times 4 = 0.\dot{3}$ ✓

volum of $CO_2 = 0.\dot{3} \times 22.7 = 7.5\dot{6} =$ **7.57 dm^3** ✓

correct answer scores 3

6. Ammonium nitrate, NH_4NO_3, is widely used in fertilisers and explosives. Calculate the percentage by mass of nitrogen in ammonium nitrate. Give your answer to 3 significant figures.

[2]

NH_4NO_3 has 2 nitrogen atoms.

% by mass of N $= \frac{28.02}{80.06} \times 100$ ✓ (3 sig figs)

$= 34.99 =$ **35.0** % ✓ to 3 sig figs.

PTO

Questions 7, 8 and 9 are more challenging questions.

7. The percentage by mass of calcium carbonate in a sample of eggshell was determined by adding excess hydrochloric acid to ensure that all the calcium carbonate had reacted. The excess acid left was then titrated with aqueous sodium hydroxide. Initially, 13.60 cm^3 of 0.400 mol dm^{-3} HCl was added to 0.180 g of eggshell.

(a) Calculate the amount, in mol, of HCl initially added.

[1]

moles = conc × vol = 0.400 × 0.01360 = 5.44×10^{-3}
(dm³) (0.00544) ✓

(b) The excess acid required 23.40 cm^3 of 0.100 mol dm^{-3} NaOH for neutralization. Calculate the amount, in mol, of acid that is in excess.

[1]

moles of NaOH = 0.100 × 0.02340 = 2.34×10^{-3} ✓
(conc × vol) (0.00234)
= moles of HCl (NaOH : HCl react 1 : 1)

(c) Determine the amount, in mol, of HCl that reacted with the calcium carbonate in the eggshell.

[1]

Initial − reacted = excess
0.00544 − 0.00234 = 0.00310 mol (3.10×10^{-3}) ✓

(d) Formulate an equation for the reaction between the calcium carbonate and the hydrochloric acid, and hence determine the amount, in mol, of calcium carbonate in the sample of the eggshell.

[3]

$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$
1 : 2
✓ formulae
✓ balanced

moles of $CaCO_3$ = moles of HCl ÷ 2
= 0.00310 ÷ 2 = 0.00155 mol ✓

correct answer without equation scores 2.

(e) Calculate the mass **and** the percentage by mass of calcium carbonate in the eggshell sample.

[3]

Mr of $CaCO_3$ is 100.09 ✓

mass of $CaCO_3$ = moles × Mr = 0.00155 × 100.09

= 0.1551395g ✓

% by mass = $\frac{0.1551395}{0.180} \times 100$ = **86.2** % ✓

8. A fluorescent dye, X, contains **only** carbon, hydrogen, and oxygen. It is an aromatic compound containing benzene rings.

(a) 6.640g of X was completely oxidised to produce 20.85g of carbon dioxide and 3.282g of water. Calculate the percentage by mass of carbon and the percentage by mass of hydrogen in X.

[4]

mass of carbon = $\frac{12.01}{44.01} \times 20.85 = 5.689...$g ✓ ← (fraction of C in CO_2)

mass of hydrogen = $\frac{2.02}{18.02} \times 3.282 = 0.367...$g ✓ ← (fraction of H in H_2O)

% carbon = 5.689.../6.640 × 100 = **85.7** % ✓

% hydrogen = 0.367.../6.640 × 100 = **5.54** % ✓

correct answers score 2 each.

(b) Using your answers in (a) above, determine the empirical formula of X.

[3]

mass of oxygen = 6.640 − 5.689... − 0.367... = 0.582...g

(or % of oxygen = 100 − 85.7 − 5.54 = 8.76%) ✓

	C	H	O
moles =	$\frac{5.689...}{12.01}$	$\frac{0.367}{1.01}$	$\frac{0.582...}{16.00}$ ✓
=	0.473...	0.364...	0.0363
(÷ by 0.0363)	13	10	1

$C_{13}H_{10}O$ ✓

correct answer scores 3

9. 13.91g of hydrated sodium carbonate crystals, $Na_2CO_3.xH_2O$, were dissolved in water and made up to 1000cm^3. A titration was carried out: 25.00 cm^3 of the sodium carbonate solution required an average of 24.40 cm^3 of 0.2000 mol dm^{-3} hydrochloric acid for neutralisation:

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

(a) Calculate the concentration, in mol dm^{-3}, of the sodium carbonate solution neutralised by the hydrochloric acid.

[3]

Moles of HCl = $0.02440 \times 0.2000 = 4.880 \times 10^{-3}$ (0.004880) ✓

(Na_2CO_3 : HCl
1 : 2)

Moles of Na_2CO_3 = $0.004880 \div 2 = 0.002440$ ✓

Conc = $\frac{0.002440}{0.02500} = 0.09760$ ✓ mol dm^{-3}

(9.760×10^{-2}) correct answer scores 3

(b) Calculate the total mass of sodium carbonate present in the 1000cm^3 of solution.

[2]

Conc of solution = 0.09760 mol dm^{-3}

moles in 1 dm^3 = 0.09760 mol

mass = $0.09760 \times 105.99 = 10.344624$ ✓ ✓

= 10.34g (4 sig fig)

correct answer scores 2

(c) Calculate the mass of water in the original hydrated sodium carbonate crystals, and hence find the value of x.

[4]

mass of water = $13.91 - 10.34 = 3.57$ g ✓

(or 10.344624)

moles of water = $\frac{3.57}{18.02} = 0.198$ ✓ (approx).

mole ratio Na_2CO_3 : H_2O

0.09976 : 0.198 $x = 2$ ✓

✓ 1 : 2