

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]

Assume 100g and	C	N	O	H	
	20.2	11.4	65.9	2.50	
find moles of atoms	12.01	14.01	16.00	1.01	✓
=	1.6819...	0.8137...	4.11875	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 0.686 dm³. Calculate the molar mass of compound T.

[2]

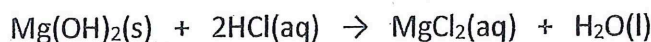
Using $PV = nRT$ and $n = \frac{m}{M_r}$ UNITS: { carpe diem
kPa dm³

100kPa 273K (0°C)

0.686 dm³ 8.31 J K⁻¹ mol⁻¹ $n = \frac{100 \times 0.686}{8.31 \times 273} = 68.6$
(databook)

$M_r = \frac{m}{n} = \frac{0.817}{0.03023...} = \boxed{27.0}$ = 0.030238513
(3 sig figs) correct answer scores 2

3. Magnesium hydroxide can be used to neutralise hydrochloric acid. 0.400 mol of Mg(OH)₂ is mixed with 0.600 mol of HCl(aq) and the following reaction occurs:



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

[1]

$Mg(OH)_2 + 2HCl$ must show some explanation to get the mark.

0.4 mol of Mg(OH)₂ 1 : 2

would react with 0.400 ... 0.800 And 0.6 mol of HCl would

0.8 mol of HCl 0.300 ... 0.600 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]

$$\text{Mg(OH)}_2 \text{ is in excess. Initial - used = excess}$$
$$0.400 - 0.300 = \boxed{0.100} \text{ mol}$$

(c) Calculate the mass of MgCl_2 produced.

[2]

mole ratio $\text{Mg(OH)}_2 : \text{MgCl}_2$ is 1:1 (see equation)

So $0.300 : 0.300$ moles

$$\text{Mass} = n \times \text{Mr} = 0.300 \times 95.21 = 28.563$$
$$= \boxed{28.6} \text{ g}$$

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



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

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

[2]

$$\text{moles of iron} = \frac{m}{\text{Mr}} = \frac{2.46}{55.85} = \boxed{0.04404} \dots \checkmark$$
$$\text{moles of CuSO}_4 = \text{conc} \times \text{vol} = 0.800 \times 0.800 = \boxed{0.640} \checkmark$$

(ratio is 1:1) (dm³)

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

[2]

$$\text{moles of iron} = \text{moles of copper (equation ratio Fe:Cu)} \\ 1:1$$
$$\text{So maximum mass of copper} = 0.04404 \dots \times 63.55 \\ = 2.799 \dots \checkmark$$
$$\% \text{ yield} = \frac{\text{mass obtained}}{\text{maximum mass}} \times 100 = \frac{2.32}{2.799 \dots} \times 100 = \boxed{82.9} \% \checkmark$$

(x100) 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]



(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]

$$\text{moles of butane} = \frac{4.845}{58.14} = 0.083$$

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

$$\text{moles of } CO_2 = 0.083 \times 4 = 0.3$$

$$\text{volume of } CO_2 = 0.3 \times 22.7 = 7.56 = 7.57 dm^3$$

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.

$$\% \text{ by mass of N} = \frac{28.02}{80.06} \times 100$$

$$= 34.99 = 35.0\%$$

(3 sig figs)
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 $0.400 \text{ mol dm}^{-3}$ HCl was added to 0.180 g of eggshell.

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

[1]

$$\text{moles} = \text{conc} \times \text{vol} = 0.400 \times 0.01360 = \boxed{5.44 \times 10^{-3}}$$

(dm^3) (0.00544)

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

[1]

$$\text{moles of NaOH} = 0.100 \times 0.02340 = \boxed{2.34 \times 10^{-3}}$$

$(\text{conc} \times \text{vol})$ (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.

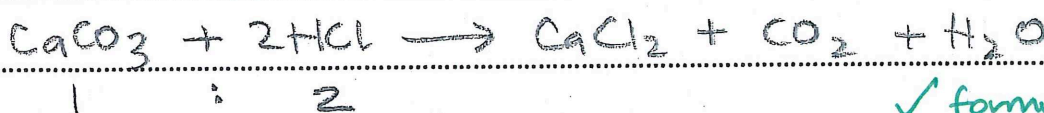
[1]

Initial - reacted = excess

$$0.00544 - 0.00234 = \boxed{0.00310 \text{ mol}} \quad \left(3.10 \times 10^{-3} \right)$$

(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]



✓ formulae
✓ balanced

$$\text{moles of CaCO}_3 = \text{moles of HCl} \div 2$$

$$= 0.00310 \div 2 = \boxed{0.00155 \text{ mol}}$$

correct answer without equation scores 2.

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

[3]

$$\text{Mr of CaCO}_3 \text{ is } 100.09 \checkmark$$

$$\begin{aligned} \text{mass of CaCO}_3 &= \text{moles} \times \text{Mr} = 0.00155 \times 100.09 \\ &= 0.1551395 \text{g} \checkmark \end{aligned}$$

$$\% \text{ by mass} = \frac{0.1551395}{0.180} \times 100 = \boxed{86.2} \% \checkmark$$

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]

$$\text{mass of carbon} = \frac{12.01}{44.01} \times 20.85 = 5.689... \text{g} \checkmark$$

$$\text{mass of hydrogen} = \frac{2.02}{18.02} \times 3.282 = 0.367... \text{g} \checkmark$$

$$\% \text{ carbon} = \frac{5.689...}{6.640} \times 100 = \boxed{85.7} \% \checkmark$$

$$\% \text{ hydrogen} = \frac{0.367...}{6.640} \times 100 = \boxed{5.54} \% \checkmark$$

correct answers score 2 each.

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

[3]

$$\text{mass of oxygen} = 6.640 - 5.689... - 0.367... = 0.582... \text{g} \checkmark$$

$$(\text{or } \% \text{ of oxygen} = 100 - 85.7 - 5.54 = 8.76\%) \checkmark$$

$$\begin{array}{ccc} \textcircled{\text{C}} & \textcircled{\text{H}} & \textcircled{\text{O}} \\ \text{moles} = \frac{5.689...}{12.01} & = \frac{0.367}{1.01} & = \frac{0.582...}{16.00} \checkmark \end{array}$$

$$= 0.473... \quad = 0.364... \quad = 0.0363$$

$$(\div \text{ by } 0.0363) \quad 13 \quad : \quad 10 \quad : \quad 1 \quad \boxed{\text{C}_{13}\text{H}_{10}\text{O}} \checkmark$$

correct answer scores 3

9. 13.91g of hydrated sodium carbonate crystals, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, were dissolved in water and made up to 1000cm^3 . A titration was carried out: 25.00cm^3 of the sodium carbonate solution required an average of 24.40cm^3 of 0.2000mol dm^{-3} hydrochloric acid for neutralisation:



(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) ✓
 ($\text{Na}_2\text{CO}_3 : \text{HCl}$)
 $1 : 2$

Moles of $\text{Na}_2\text{CO}_3 = 0.004880 \div 2 = 0.002440$ ✓

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

moles in $1\text{ dm}^3 = 0.09760\text{ mol}$

mass = $0.09760 \times 105.99 = 10.344624$ ✓
 $= 10.34\text{g}$ (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 = $13.91 - 10.34 = 3.57\text{ g}$ ✓
 (or 10.344624)

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

mole ratio $\text{Na}_2\text{CO}_3 : \text{H}_2\text{O}$
 $0.0976 : 0.198$

✓ $1 : 2$ $x = 2$ ✓