A level Chemistry KS4 to KS5

Transition Pack

Blackfen School for Girls

1 - FORMULAS

Elements

Monatomic	Simple molecular	Ionic	Metallic	Giant covalent
helium neon argon krypton xenon radon	hydrogen nitrogen oxygen fluorine chlorine bromine iodine phosphorus sulfur	There are no ionic elements!!	The formula is just the symbol, e.g. magnesium iron sodium nickel	The formula is just the symbol diamond graphite silicon

Compounds

Monatomic	Simple molecular	Ionic	Metallic	Giant covalent
There are no monatomic compounds!!	Some common molecular compounds: carbon dioxide carbon monoxide nitrogen monoxide nitrogen dioxide sulfur dioxide sulfur trioxide ammonia methane hydrogen sulfide	These have to be worked out using ion charges – you have to know these at A level! LEARN them ASAP. Note these acids: hydrochloric acid sulfuric acid nitric acid phosphoric acid	There are no metallic compounds!!	silicon dioxide

Positive ions		Negative ions	
Group 1 ions: lithium sodium potassium Group 2 ions: magnesium calcium barium	Group 3 ions: aluminium Other common ions silver zinc ammonium hydrogen	Group 7 ions: fluoride chloride bromide iodide Group 6 ions: oxide sulfide	Other common ions nitrate sulfate carbonate hydrogencarbonate hydroxide hydride phosphate

TASK 1 – WRITING FORMULAS OF IONIC COMPOUNDS

1) silver bromide ……..
2) sodium carbonate ……..
3) potassium oxide ……..
4) iron (III) oxide ……..
5) chromium (III) chloride ……..
6) calcium hydroxide ……..
7) aluminium nitrate ……..
8) sodium sulfate ……..
9) lead (II) oxide ……..
10) sodium phosphate ……..
11) zinc hydrogencarbonate ……..
12) ammonium sulphate ……..
13) gallium hydroxide ……..
14) strontium selenide ……..
15) radium sulfate ……..
16) sodium nitride ……..

TASK 2 – WRITING FORMULAS 1

1) lead (IV) oxide ……..
2) copper ……..
3) sodium ……..
4) ammonium chloride ……..
5) ammonia ……..
6) sulfur ……..
7) sulfuric acid ……..
8) neon ……..
9) silica ……..
10) silicon ……..
11) barium hydroxide ……..
12) tin (IV) chloride ……..
13) silver nitrate ……..
14) iodine ……..
15) nickel ……..
16) hydrogen sulfide ……..
17) titanium (IV) oxide ……..
18) lead ……..
19) strontium sulfate ……..
20) lithium ……..

TASK 3 – WRITING FORMULAS 2

1) silver carbonate ……..
2) gold ……..
3) platinum (II) fluoride ……..
4) nitric acid ……..
5) ammonia ……..
6) silicon (IV) hydride ……..
7) phosphorus ……..
8) diamond ……..
9) vanadium (V) oxide ……..
10) cobalt (II) hydroxide ……..
11) barium hydroxide ……..
12) ammonia ……..
13) hydrochloric acid ……..
14) fluorine ……..
15) silicon ……..
16) calcium phosphate ……..
17) rubidium ……..
18) germanium (IV) oxide ……..
19) magnesium astatide ……..
20) nitrogen oxide ……..

2 - EQUATIONS

From an early age you should have been able to balance chemical equations. However, at A level, you will often need to:

- work out the formulas yourselves
- work out what is made (so you need to know some basic general equations)
- for reactions involving ions in solution, write ionic equations

Some general reactions you should know:

General Reaction	**Examples**
substance + oxygen → oxides	$2\ Mg + O_2 \rightarrow 2\ MgO$ $2\ H_2S + 3\ O_2 \rightarrow 2\ H_2O + 2\ SO_2$ $C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$
metal + water → metal hydroxide + hydrogen	$2\ Na + 2\ H_2O \rightarrow 2\ NaOH + H_2$
metal + acid → salt + hydrogen	$Mg + 2\ HCl \rightarrow MgCl_2 + H_2$
oxide + acid → salt + water	$MgO + 2\ HNO_3 \rightarrow Mg(NO_3)_2 + H_2O$
hydroxide + acid → salt + water	$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$
carbonate + acid → salt + water + carbon dioxide	$CuCO_3 + 2\ HCl \rightarrow CuCl_2 + H_2O + CO_2$
hydrogencarbonate + acid → salt + water + carbon dioxide	$KHCO_3 + HCl \rightarrow KCl + H_2O + CO_2$
ammonia + acid → ammonium salt	$NH_3 + HCl \rightarrow NH_4Cl$
metal carbonate → metal oxide + carbon dioxide (on heating)	$CaCO_3 \rightarrow CaO + CO_2$

TASK 4 – WRITING BALANCED EQUATIONS

1) Balance the following equations.

   a) $Mg + HNO_3 \rightarrow Mg(NO_3)_2 + H_2$

   b) $CuCl_2 + NaOH \rightarrow Cu(OH)_2 + NaCl$

   c) $SO_2 + O_2 \rightarrow SO_3$

   d) $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$

2) Give balanced equations for the following reactions.

   a) sodium + oxygen → sodium oxide

   b) aluminium + chlorine → aluminium chloride

   c) calcium + hydrochloric acid → calcium chloride + hydrogen

   d) ammonia + sulphuric acid → ammonium sulphate

TASK 5 – WRITING BALANCED EQUATIONS 2

Write balance equations for the following reactions:

1) burning aluminium
2) burning hexane (C_6H_{14})
3) burning ethanethiol (CH_3CH_2SH)
4) reaction of lithium with water
5) reaction of calcium carbonate with nitric acid
6) thermal decomposition of lithium carbonate
7) reaction of ammonia with nitric acid
8) reaction of potassium oxide with water
9) reaction of calcium hydroxide with hydrochloric acid
10) reaction of zinc with phosphoric acid
11) reaction of sodium hydrogencarbonate with sulfuric acid
12) reaction of potassium hydroxide with sulfuric acid

TASK 6 – IONIC EQUATIONS

1) Use your knowledge of ionic equations to give the molar ratio in which the following acids react with bases. Complete the table to show your answers.

Acid	Formula of acid	Base	Formula of base	Molar ratio of acid:base
hydrochloric acid		lithium hydroxide		
sulphuric acid		sodium hydrogencarbonate		
nitric acid		ammonia		
sulphuric acid		potassium carbonate		
nitric acid		strontium hydroxide		

2) Write ionic equations for each of the following reactions.

a) reaction of hydrochloric acid (aq) with potassium hydroxide (aq)

b) precipitation of silver iodide from reaction between silver nitrate (aq) and potassium iodide (aq)

c) reaction of potassium carbonate (aq) with nitric acid (aq)

d) precipitation of calcium hydroxide from reaction between sodium hydroxide (aq) and calcium chloride (aq)

e) reaction of ammonia (aq) with hydrochloric acid (aq)

f) reaction of sodium hydrogencarbonate (aq) with sulfuric acid (aq)

g) precipitation of calcium sulfate from reaction between calcium chloride (aq) and sulfuric acid (aq)

h) precipitation of lead (II) chloride from reaction between lead nitrate (aq) and sodium chloride (aq)

i) reaction of barium hydroxide (aq) with nitric acid (aq)

3 – SIGNIFICANT FIGURES & STANDARD FORM

Some general rules in chemistry:

- usually give final answers to 3 significant figures (but it is best to keep the whole number on your a during the calculation)
- give M_r's to 1 decimal place

Note: 0.00346678 = 0.00347 (3 sig fig) = 3.47×10^{-3} (3 sig fig) 346678 = 347000 (3 sig fig) = 3.47×10^{5} (3 sig fig)

TASK 7 – SIGNIFICANT FIGURES & STANDARD FORM

1) Write the following numbers to the quoted number of significant figures.

a) 345789 4 sig figs …… d) 6 3 sig figs ……

b) 297300 3 sig figs …… e) 0.001563 3 sig figs ……

c) 0.07896 3 sig figs …… f) 0.01 4 sig figs ……

2) Complete the following sums and give the answers to 3 significant figures.

a) 6125 x 384 …… d) 750 ÷ 25 ……

b) 25.00 x 0.01 …… e) 0.000152 x 13 ……

c) 13.5 + 0.18 …… f) 0.0125 x 0.025 ……

3) Write the following numbers in non standard form.

a) 1.5×10^{-3} …….. d) 0.0534×10^{4} ……

b) 0.046×10^{-2} ……..... e) 10.3×10^{5} ……

c) 3.575×10^{5} ……..... f) 8.35×10^{-3} ……

4) Write the following numbers in standard form.

a) 0.000167 …….. d) 34500 ……

b) 0.0524 ……..... e) 0.62 ……

c) 0.000000015 ……..... f) 87000000 ……

5) Complete the following calculations and give the answers to 3 significant figures.

a) $6.125 \times 10^{-3} \times 3.5$ ……..

b) $4.3 \times 10^{-4} \div 7.0$ ……..

c) $4.0 \times 10^{8} + 35000$ …….....

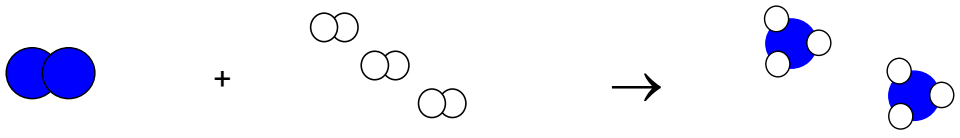
d) $0.00156 + 2.4 \times 10^{3}$ …….

e) $6.10 \times 10^{-2} - 3.4 \times 10^{-5}$ …….

f) $8.00 \times 10^{-3} \times 0.100 \times 10^{-3}$ …….

5 – REACTING MASS CALCULATIONS

What a chemical equation means



N_2 + 3 H_2 → 2 NH_3

1 molecule N_2	3 molecules H_2	2 molecules NH_3
12 molecules N_2 1 dozen molecules N_2	36 molecules H_2 3 dozen molecules H_2	24 molecules NH_3 2 dozen molecules NH_3
6 x 10^{23} molecule N_2 1 mole N_2	18 x 10^{23} molecules H_2 3 moles H_2	12 x 10^{23} molecules NH_3 2 moles NH_3
10 moles N_2	30 moles H_2	20 moles NH_3
0.5 moles N_2	1.5 moles H_2	1 mole NH_3

TASK 9 – WHAT EQUATIONS MEAN

4 Na	**+**	**O_2**	**→**	**2 Na_2O**		
12 mol						
0.1 mol						
2 Al	**+**	**3 Cl_2**	**→**	**2 $AlCl_3$**		
5 mol						
0.1 mol						
C_4H_{10}	**+**	**6½ O_2**	**→**	**4 CO_2**	**+**	**5 H_2O**
0.5 mol						
20 mol						
4 NH_3	**+**	**3 O_2**	**→**	**2 N_2**	**+**	**6 H_2O**
0.5 mol						
10 mol						

Reacting mass calculations

- You can use balanced chemical equations to find out what mass of chemicals (or volume of gases) react or are produced in a chemical reaction. To do this, calculate:

  (a) moles of ✓ (b) moles of ? (c) mass of ?

e.g. What mass of iron is produced when 32 kg of iron (III) oxide is heated with CO?

$$\underset{\checkmark}{Fe_2O_3(s)} + 3\,CO(g) \rightarrow \underset{?}{2\,Fe(s)} + 3\,CO_2(g)$$

$$\text{moles of } Fe_2O_3 = \frac{\text{mass (g)}}{M_r} = \frac{32{,}000}{159.6} = 200.5 \text{ mol}$$

1 mole of Fe_2O_3 forms 2 moles of Fe

$\therefore$ moles of Fe = 2 x 200.5 = 401.0 mol

$\therefore$ mass of Fe = moles x M_r = 401.0 x 55.8 = **22,400 g (3 sig fig)**

e.g. What mass of oxygen is needed to convert 102 g of ammonia into nitrogen?

$$\underset{\checkmark}{4\,NH_3(g)} + \underset{?}{3\,O_2(g)} \rightarrow 2\,N_2(g) + 6\,H_2O(g)$$

$$\text{moles of } NH_3 = \frac{\text{mass (g)}}{M_r} = \frac{102}{17.0} = 6.00 \text{ mol}$$

4 moles of NH_3 reacts with 3 moles of O_2 $\therefore$ 1 mole of NH_3 reacts with ¾ mole of O_2

$\therefore$ moles of O_2 = 6.00 x ¾ = 4.50 mol

$\therefore$ mass of O_2 = moles x M_r = 4.50 x 32.0 = **144 g (3 sig fig)**

e.g. When 5.00 g of crystals of hydrated tin (II) chloride, $SnCl_2.xH_2O$, are heated, 4.20 g of anhydrous tin (II) chloride are formed. Calculate the number of molecules of water of crystallisation are in $SnCl_2.xH_2O$ (i.e. the value of x).

$$SnCl_2.xH_2O \rightarrow SnCl_2 + x\,H_2O$$

$$\text{moles of } SnCl_2 = \frac{\text{mass (g)}}{M_r} = \frac{4.20}{189.7} = 0.02214 \text{ moles}$$

$\therefore$ moles of $SnCl_2.xH_2O$ = 0.02214 mol

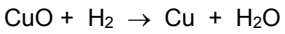
$\therefore$ M_r of $SnCl_2.xH_2O$ = $\frac{\text{mass}}{\text{moles}} = \frac{5.00}{0.02214} = 225.8$

$\therefore$ M_r of xH_2O = 225.8 – 189.7 = 36.1

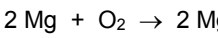
$\therefore$ x = $\frac{36.1}{18.0}$ = 2 (x is a whole number)

TASK 10 – REACTING MASS CALCULATIONS 1

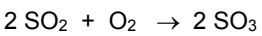
1) What mass of hydrogen is needed to react with 40 g of copper oxide?



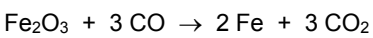
2) What mass of oxygen reacts with 192 g of magnesium?



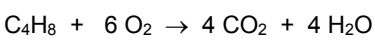
3) What mass of sulfur trioxide is formed from 96 g of sulfur dioxide?



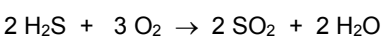
4) What mass of carbon monoxide is needed to react with 480 kg of iron oxide?



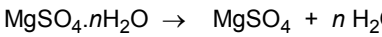
5) What mass of carbon dioxide is produced when 5.6 g of butene is burnt.



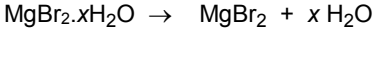
6) What mass of oxygen is needed to react with 8.5 g of hydrogen sulphide (H_2S)?



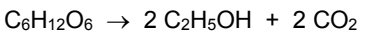
7) 4.92 g of hydrated magnesium sulphate crystals ($MgSO_4.nH_2O$) gave 2.40 g of anhydrous magnesium sulphate on heating to constant mass. Work out the formula mass of the hydrated magnesium sulphate and so the value of *n*.



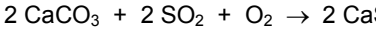
8) In an experiment to find the value of *x* in the compound $MgBr_2.xH_2O$, 7.30 g of the compound on heating to constant mass gave 4.60 g of the anhydrous salt $MgBr_2$. Find the value of *x*.



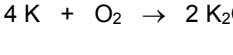
9) What mass of glucose must be fermented to give 5.00 kg of ethanol?



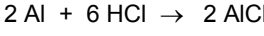
10) The pollutant sulfur dioxide can removed from the air by reaction with calcium carbonate in the presence of oxygen. What mass of calcium carbonate is needed to remove 1 ton of sulfur dioxide?



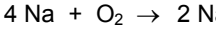
11) What mass of potassium oxide is formed when 7.8 mg of potassium is burned in oxygen?



12) What mass of hydrogen is produced when 10.0 g of aluminium reacts with excess hydrochloric acid?

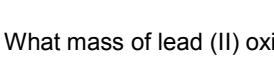


13) What mass of sodium just reacts with 40.0 g of oxygen?



14) What mass of nitrogen is produced when 2.00 tonnes of ammonia gas decomposes?

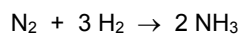
15) What mass of oxygen is produced when 136 g of hydrogen peroxide molecules decompose?



16) What mass of lead (II) oxide is produced when 0.400 moles of lead (II) nitrate decomposes?

TASK 11 – REACTING MASS CALCULATIONS 2

1) In each case work out the limiting reagent and moles of ammonia formed (assuming complete reaction).



$$N_2 + 3\,H_2 \rightarrow 2\,NH_3$$

a) 3 moles of N_2 + 3 moles of H_2

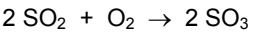
b) 3 moles of N_2 + 10 moles of H_2

c) 0.1 moles of N_2 + 0.2 moles of H_2

d) 0.5 moles of N_2 + 2.0 moles of H_2

e) 2 moles of N_2 + 10 moles of H_2

2) In each case work out the limiting reagent and moles of sulphur dioxide formed (assuming complete reaction).



$$2\,SO_2 + O_2 \rightarrow 2\,SO_3$$

a) 3 moles of SO_2 + 3 moles of O_2

b) 3 moles of SO_2 + 2 moles of O_2

c) 0.1 moles of SO_2 + 0.02 moles of O_2

d) 2.0 moles of SO_2 + 0.4 moles of O_2

e) 2 moles of SO_2 + 10 moles of O_2

3) 5.00 g of iron and 5.00 g of sulphur are heated together to form iron (II) sulphide. Which reactant is in excess and what is the maximum mass of iron (II) sulphide that can be formed?

$$Fe + S \rightarrow FeS$$

4) In the manufacture of the fertiliser ammonium sulphate, what is the maximum mass of ammonium sulphate that can be obtained from 2.00 kg of sulphuric acid and 1.00 kg of ammonia?

$$H_2SO_4 + 2\,NH_3 \rightarrow (NH_4)_2SO_4$$

5) In the Solvay process, ammonia is recovered by the reaction shown. What is the maximum mass of ammonia that can be recovered from 2 tonnes of ammonium chloride and 0.5 tonnes of calcium oxide?

$$2\,NH_4Cl + CaO \rightarrow CaCl_2 + H_2O + 2\,NH_3$$

6) In the manufacture of titanium, what mass of titanium can theoretically be formed when 0.5 kg of titanium chloride reacts with 0.1 kg of magnesium?

$$TiCl_4 + 2\,Mg \rightarrow Ti + 2\,MgCl_2$$

7) In the manufacture of ammonia, what mass of ammonia can theoretically be formed when 1 kg of nitrogen reacts with 0.5 kg of hydrogen?

$$N_2 + 3\,H_2 \rightarrow 2\,NH_3$$

8) In the manufacture of sulphur troxide, what mass of sulphur trioxide can theoretically be formed when 1 kg of sulphur dioxide reacts with 0.5 kg of oxygen?

$$2\,SO_2 + O_2 \rightarrow 2\,SO_3$$

9) Hydrazine (N_2H_4) was used as the rocket fuel for the Apollo missions to the moon. It is by reaction of ammonia with sodium chlorate. What mass of hydrazine is made by reaction of 100 g of ammonia with 100 g of sodium chloriate?

$$2\,NH_3 + NaOCl \rightarrow N_2H_4 + NaCl + H_2O$$

TASK 12 – PERCENTAGE YIELD

1) Sulfur dioxide reacts with oxygen to make sulfur trioxide. $2\ SO_2 + O_2 \rightarrow 2\ SO_3$

   a) Calculate the maximum theoretical mass of sulfur trioxide that can be made by reacting 96 g of sulfur dioxide with an excess of oxygen.

   b) In the reaction, only 90 g of sulfur trioxide was made. Calculate the percentage yield.

   c) Give three reasons why the amount of sulfur trioxide made is less than the maximum theoretical maximum.

2) Iron is extracted from iron oxide in the Blast Furnace as shown. $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$

   a) Calculate the maximum theoretical mass of iron that can be made from 1 tonne of iron oxide.

   b) In the reaction, only 650000 g of iron was made. Calculate the percentage yield.

3) Nitrogen reacts with hydrogen to make ammonia. $N_2 + 3\ H_2 \rightarrow 2\ NH_3$

   a) Calculate the maximum theoretical mass of ammonia that can be made by reacting 90 g of hydrogen with an excess of nitrogen.

   b) In the reaction, only 153 g of ammonia was produced. Calculate the percentage yield.

4) Titanium can be extracted from titanium chloride by the following reaction. $TiCl_4 + 2\ Mg \rightarrow Ti + 2\ MgCl_2$

   a) Calculate the maximum theoretical mass of titanium that can be extracted from 100 g of titanium chloride .

   b) In the reaction, only 20 g of titanium was made. Calculate the percentage yield.

   c) Give three reasons why the amount of titanium made is less than the maximum theoretical maximum.

5) Aluminium is extracted from aluminium oxide in the following reaction. $2\ Al_2O_3 \rightarrow 4\ Al + 3\ O_2$

   a) Calculate the maximum theoretical mass of aluminium that can be made from 1 kg of aluminium oxide.

   b) In the reaction, only 500 g of aluminium was made. Calculate the percentage yield.

6) The fertiliser ammonium sulpfate is made as follows. $2\ NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

   a) Calculate the maximum theoretical mass of ammonium sulfate that can be made by reacting 85 g of ammonia with an excess of sulfuric acid.

   b) In the reaction, only 300 g of ammonium sulfate was produced. Calculate the percentage yield.

7) 0.8500 g of hexanone, $C_6H_{12}O$, is converted into its 2,4-dinitrophenylhyrazone during its analysis. After isolation and purification, 2.1180 g of product $C_{12}H_{18}N_4O_4$ are obtained. Calculate the percentage yield.

TASK 16 – SOLUTION CALCULATIONS

1) Calculate the number of moles in the following.
   a) 2 dm^3 of 0.05 mol dm^{-3} HCl
   b) 50 litres of 5 mol dm^{-3} H_2SO_4
   c) 10 cm^3 of 0.25 mol dm^{-3} KOH

2) Calculate the concentration of the following in **both** mol dm^{-3} and g dm^{-3}
   a) 0.400 moles of HCl in 2.00 litres of solution
   b) 12.5 moles of H_2SO_4 in 5.00 dm^3 of solution
   c) 1.05 g of NaOH in 500 cm^3 of solution

3) Calculate the volume of each solution that contains the following number of moles.
   a) 0.00500 moles of NaOH from 0.100 mol dm^{-3} solution
   b) 1.00 x 10^{-5} moles of HCl from 0.0100 mol dm^{-3} solution

4) 25.0 cm^3 of 0.020 mol dm^{-3} sulphuric acid neutralises 18.6 cm^3 of barium hydroxide solution.

$$H_2SO_4 + Ba(OH)_2 \rightarrow BaSO_4 + 2\,H_2O$$

   a) Find the concentration of the barium hydroxide solution in mol dm^{-3}.
   b) Find the concentration of the barium hydroxide solution in g dm^{-3}.

5) 25.0 cm^3 of a solution of sodium hydroxide required 18.8 cm^3 of 0.0500 mol dm^{-3} H_2SO_4.

$$H_2SO_4 + 2\,NaOH \rightarrow Na_2SO_4 + 2\,H_2O$$

   a) Find the concentration of the sodium hydroxide solution in mol dm^{-3}.
   b) Find the concentration of the sodium hydroxide solution in g dm^{-3}.

6) Calculate the volume of 0.05 mol dm^{-3} KOH is required to neutralise 25.0 cm^3 of 0.0150 mol dm^{-3} HNO_3.

$$HNO_3 + KOH \rightarrow KNO_3 + H_2O$$

7) 25.0 cm^3 of arsenic acid, H_3AsO_4, required 37.5 cm^3 of 0.100 mol dm^{-3} sodium hydroxide for neutralisation.

$$3\,NaOH(aq) + H_3AsO_4(aq) \rightarrow Na_3AsO_4(aq) + 3\,H_2O(l)$$

   a) Find the concentration of the acid in mol dm^{-3}.
   b) Find the concentration of the acid in g dm^{-3}.

8) A 250 cm^3 solution of NaOH was prepared. 25.0 cm^3 of this solution required 28.2 cm^3 of 0.100 mol dm^{-3} HCl for neutralisation. Calculate what mass of NaOH was dissolved to make up the original 250 cm^3 solution.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

9) What volume of 5.00 mol dm^{-3} HCl is required to neutralise 20.0 kg of $CaCO_3$?

$$2\,HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$$

10) 3.88 g of a monoprotic acid was dissolved in water and the solution made up to 250 cm^3. 25.0 cm^3 of this solution was titrated with 0.095 mol dm^{-3} NaOH solution, requiring 46.5 cm^3. Calculate the relative molecular mass of the acid.

11) A 1.575 g sample of ethanedioic acid crystals, $H_2C_2O_4.nH_2O$, was dissolved in water and made up to 250 cm^3. One mole of the acid reacts with two moles of NaOH. In a titration, 25.0 cm^3 of this solution of acid reacted with exactly 15.6 cm^3 of 0.160 mol dm^{-3} NaOH. Calculate the value of n.

12) A solution of a metal carbonate, M_2CO_3, was prepared by dissolving 7.46 g of the anhydrous solid in water to give 1000 cm^3 of solution. 25.0 cm^3 of this solution reacted with 27.0 cm^3 of 0.100 mol dm^{-3} hydrochloric acid. Calculate the relative formula mass of M_2CO_3 and hence the relative atomic mass of the metal M.

13) An impure sample of barium hydroxide of mass 1.6524 g was allowed to react with 100 cm^3 of 0.200 mol dm^{-3} hydrochloric acid. When the excess acid was titrated against sodium hydroxide, 10.9 cm^3 of sodium hydroxide solution was required. 25.0 cm^3 of the sodium hydroxide required 28.5 cm^3 of the hydrochloric acid in a separate titration. Calculate the percentage purity of the sample of barium hydroxide.

8 – EMPIRICAL & MOLECULAR FORMULAS

- Every substance has an empirical formula. It shows the simplest ratio of atoms of each element in a substance.

  e.g. SiO_2 (giant covalent) – the ratio of Si:O atoms in the lattice is 1:2
  Al_2O_3 (ionic) – the ratio of Al^{3+}:O^{2-} ions in the lattice is 2:3
  H_2O (molecular) – the ratio of H:O atoms in the substance is 1:2

- Substances made of molecules also have a molecular formula. This indicates the number of atoms of each element in **one molecule**.

a) Finding the molecular formula from the formula mass and empirical formula

e.g. Empirical formula = CH_2, M_r = 42.0

Formula mass of empirical formula = 14.0 ∴ M_r / formula mass of empirical formula = 42.0/14.0 = 3

Molecular formula = 3 x empirical formula = C_3H_6

b) Finding the empirical formula of a compound from its composition by percentage or mass

i) Write out the mass or percentage of each element,

ii) Divide each mass or percentage by the A_r of the element **(not the M_r)**

iii) Find the simplest whole number ratio of these numbers by dividing by the smallest number. If the values come out as near $^1/_2$'s then times them by 2, if they are near $^1/_3$'s then times by 3.

e.g. i) A compound is found to contain, by mass, iron 72.4% and oxygen 27.6%.

Fe $\frac{72.4}{56} = 1.29$ O $\frac{27.6}{16} = 1.73$

Simplest ratio Fe:O = 1.29 : 1.73 (divide by smallest, i.e. 1.29)
1 : 1.34 (involves $^1/_3$'s so x3)
3 : 4

∴ empirical formula = **Fe_3O_4**

e.g. ii) 0.25 g of hydrogen reacts with oxygen to produce 4.25 g of hydrogen peroxide (M_r = 34.0).

Mass of oxygen reacting with hydrogen = 4.25 – 0.25 = 4.00 g

H $\frac{0.25}{1} = 0.25$ O $\frac{4.00}{16} = 0.25$

Simplest ratio H:O = 0.25 : 0.25 (divide by smallest, i.e. 0.25)
1 : 1

∴ empirical formula = **HO**

Formula mass of empirical formula = 17.0

∴ M_r / formula mass of empirical formula = 34.0/17.0 = 2

Molecular formula = 2 x empirical formula = **H_2O_2**

TASK 18 – EMPRICIAL & MOLECULAR FORMULAS

1) Write the empirical formula of each of the following substances.

a) C_2H_6 b) P_2O_3 c) SO_2 d) C_6H_{12}

e) $C_2H_4O_2$ f) C_2H_7N g) B_6H_{10} h) $C_{12}H_{22}O_{11}$

2) The empirical formula and relative molecular mass of some simple molecular compounds are shown below. Work out the molecular formula of each one.

a) NH_2 $M_r = 32$ d) PH_3 $M_r = 34$

b) C_2H_5 $M_r = 58$ e) CH $M_r = 78$

c) CH_2 $M_r = 70$ f) CH_2 $M_r = 42$

3) Find the simplest whole number ratio for each of the following. The numbers come from experiments so there will be some small random errors which mean that you can round the numbers a little bit.

a) 1.5 : 1 b) 1 : 1.98 c) 4.97 : 1 d) 1 : 2.52

e) 1 : 1.33 f) 1.66 : 1 g) 1 : 1.26 h) 1 : 1.74

4) Find the empirical formulae of the following compounds using the data given.

a) Ca 20 % Br 80 %

b) Na 29.1 % S 40.5 % O 30.4 %

c) C 53.3 % H 15.5 % N 31.1 %

d) C 2.73 g O 7.27 g

e) N 15.2 g O 34.8 g

5) 3.53 g of iron reacts with chlorine to form 10.24 g of iron chloride. Find the empirical formula of the iron chloride.

6) 50.0 g of a compound contains 22.4 g of potassium, 9.2 g of sulphur, and the rest oxygen. Calculate the empirical formula of the compound.

7) An oxide of phosphorus contains 56.4 % phosphorus and 43.6 % oxygen. Its relative molecular mass is 220. Find both the empirical and the molecular formula of the oxide.

8) A compound contains 40.0 g of carbon, 6.7 g of hydrogen and 53.5 g of oxygen. It has a relative molecular formula of 60. Find both the empirical and the molecular formula of the compound.

9) An organic compound X, which contains carbon, hydrogen and oxygen only, has an M_r of 85. When 0.43 g of X are burned in excess oxygen, 1.10 g of carbon dioxide and 0.45 g of water are formed. Find the empirical and molecular formulae of compound X.

10) When ammonium dichromate (VI) is added gradually to molten ammonium thiocyanate, Reinecke's salt is formed. It has the formula $NH_4[Cr(SCN)_x(NH_3)_y]$ and the following composition by mass: Cr = 15.5%, S = 38.15%, N = 29.2%. Calculate the values of *x* and *y* in the above formula.