Balancing Equations

All symbol equations must be balanced. An equation can only be balanced by adding large numbers (coefficients) in front of the chemical formulae – subscripts in the formulae must NOT be changed as that would change the formula of a compound.

The question will ask specifically for a word equation if one is required – otherwise write a symbol equation.

State Symbols: (s) solid (l) liquid
(g) gas (aq) aqueous anything dissolved in water

Note – Water is $H_2O(l)$, not (aq)

Moles Calculations

Relative atomic mass (A_r): of an element is the average mass of the isotopes of an element relative to the mass of $^1/_{12}$ of an atom of carbon-12.

Relative formula (molecular) mass (M_r): of a compound is the sum of the relative atomic masses of the atoms making up a molecule. **M_r has no unit**

e.g. M_r of CH_4 = 12 + 4 x 1 = 16 M_r of $Ca(OH)_2$ = 40 + (16 + 1) x 2 = 74

1 mole (mol) is the unit of the amount of substance

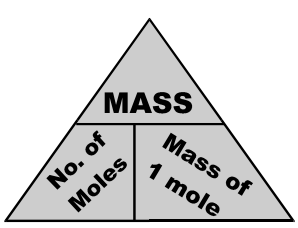
The mass of one mole (molar mass) of a substance is the relative molecular mass in grams

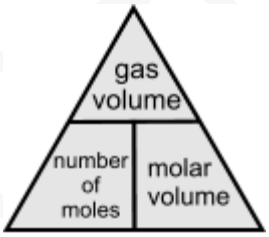
e.g. the mass of one mole of CH_4 is 16 g
the mass of 1 mole of $Ca(OH)_2$ is 74 g

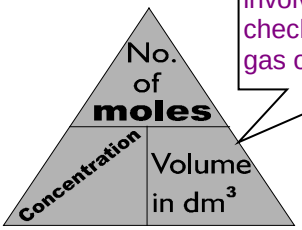
The molar volume (volume of 1 mole) of any gas at *room temperature and pressure* is 24 dm^3 or 24 000 cm^3.

The three steps in a mole calculation:

1 Calculate number of moles present using one of the three triangles







2 of the triangles involve volumes… check… do you have a gas or a solution?

2 Use the chemical equation to work out the number of moles of substance required
3 Use the triangles again to convert number of moles to the required quantity.

$2Fe_{(s)} + 3Cl_{2(g)} \rightarrow 2FeCl_{3(s)}$

Calculate the mass of chlorine which will react exactly with 5.6g of iron

No. of moles of Fe atoms in 5.6 g of Fe is $\frac{5.6}{56}$ = 0.10 mol

From the equation: 2 mol Fe react with 3 mol Cl_2

Therefore: 0.10 mol Fe react with 3/2 x 0.10 i.e. 0.15 mol Cl_2

Mass of Cl_2 0.15 x 71 = **10.65 g**

71 since Cl_2

Calculate the volume of chlorine (in dm^3) that reacts with 5.6 g of iron

No. of moles of Cl_2 that reacts is 0.15 mol

Volume of Cl_2 = 0.15 x 24 = **3.6 dm^3**

Titration

Sulfuric acid is titrated against 25 cm^3 of 0.25 mol/dm^3 sodium hydroxide solution. 21.50 cm^3 is required for neutralisation. Calculate the concentration of the sulphuric acid.

$2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$

No. of moles in 25 cm^3 of 0.25 mol dm^{-3} NaOH: vol in dm^3 x conc

25/1000 x 0.25 = 0.00625 mol

Convert cm^3 to dm^3

From the equation: 2 mol NaOH react with 1 mol H_2SO_4

Therefore 0.00625 mol NaOH react with $\frac{0.00625}{2}$ mol H_2SO_4 i.e. 0.003125 mol H_2SO_4

Therefore 21.50 cm^3 of H_2SO_4 contains 0.003125 mol

Concentration = $\frac{\text{moles}}{\text{volume in dm}^3}$

= $\frac{0.003125}{(21.50/1000)}$ = 0.145 mol/dm^3

Therefore concentration of H_2SO_4 is **0.145 mol/dm^3**

Percentage yield

percentage yield = **$\frac{\text{actual yield}}{\text{theoretical yield}}$ x 100**

Work out the theoretical yield by doing a moles calculation.
The actual yield will be given in the question.

A student reacted excess copper(II) oxide with 50.0 cm^3 of 1.00 mol/dm^3 sulfuric acid. They made 8.50 g of $CuSO_4.5H_2O$ crystals. The equations for the reactions are:

$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$

$CuSO_4 + 5H_2O \rightarrow CuSO_4.5H_2O$

Calculate the percentage yield.

Moles of H_2SO_4 = 50.0/1000 x 1.00 = 0.0500 mol
Moles of $CuSO_4$= 0.0500 mol
Moles of $CuSO_4.5H_2O$ = 0.0500 mol
Mass of $CuSO_4.5H_2O$ = 0.0500 x 249.5 = 12.475 g (theoretical yield)

M_r of $CuSO_4.5H_2O$

Percentage yield = 8.50/12.475 x 100 = 68.1 %

Excess reactants

2.3 g Na reacts with 1.6 g O_2. Which reactant is in excess? $4Na + O_2 \rightarrow 2Na_2O$

Moles of Na = 2.3/23 = 0.10 mol Moles of O_2 = 1.6/32 = 0.050 mol
From the equation 0.10 mol Na reacts with 0.10/4 = 0.025 mol O_2
0.050 mol (the amount of O_2 present) > 0.025 mol (the amount of O_2 required for exact reaction)
Oxygen is in excess

Empirical and Molecular formulae

Empirical Formula: the simplest whole number ratio of the elements present Molecular Formula: the total number of atoms of each element present in a molecule of the compound. (The molecular formula is a multiple of the empirical formula.)

10.237g of an iron chloride contains 34.46 % of Fe. Calculate the empirical formula.

Elements	Fe	Cl
Percentage	34.46	65.54
Divide by A_r	$\frac{34.46}{56}$	$\frac{65.54}{35.5}$
Number of moles	0.615	1.846
Divide by smallest to get ratio	$\frac{0.615}{0.615}$	$\frac{1.846}{0.615}$
Ratio	1	3
Empirical formula	$FeCl_3$	

To work out the molecular formula from the empirical formula the relative molecular mass (mass of 1 mole) is also required. The molecular formula is a whole number *multiple* of the empirical formula.

The empirical formula of a hydrocarbon is CH_2. The relative formula mass is 56. Work out the molecular formula.

Empirical formula mass is 12 + 2x1 = 14 for CH_2
56/14 = 4 therefore the molecular formula is $(CH_2)_4$, i.e. **C_4H_8**

Water of crystallisation

When some substances crystallise molecules of water must be present in the lattice for proper crystals to form. e.g. $CuSO_4.5H_2O$ or $MgSO_4.7H_2O$ **hydrated** compounds

The molecules of water can be driven off by heating to form the **anhydrous** compound.

Heat to constant mass to ensure all water given off – heat, weigh, heat, weigh…until mass stays constant

To determine the number of moles of water of crystallisation:

2.50 g of hydrated copper sulphate is heated so that all the water is driven off. The mass of anhydrous copper sulphate left at the end was 1.60 g. Calculate the formula of the hydrated salt.

Mass of water 2.50-1.60 = 0.90 g Moles of water = 0.90 /18 = 0.050 mol

Moles of copper sulfate = 1.60/159.5 = 0.010 mol

Ratio of water:copper sulphate = 0.050/0.010 = 5 therefore 5:1 Formula: $CuSO_4.5H_2O$

Formulae of metal oxides

Reacting the metal with oxygen

In an experiment a sample of magnesium (Mg) was weighed in crucible then heated strongly in oxygen. When no further reaction occurred the crucible and contents were weighed again. Calculate the empirical formula.

Mass of crucible	48.53g
Crucible + magnesium	48.77 g
Crucible + contents at end of experiment	48.93 g

mass of Mg = 48.77 – 48.53 = 0.24 g

mass of magnesium oxide = 48.93 – 48.53 = 0.40 g

mass of O that combines with Mg = 0.40 – 0.24 = 0.16 g

The rest of the question is now an empirical formula question:

Elements	Mg	O
mass / g	0.24	0.16
Divide by A_r	$\frac{0.24}{24}$	$\frac{0.16}{16}$
Number of moles / mol	0.01	0.01
Divide by smallest to get ratio	$\frac{0.01}{0.01}$	$\frac{0.01}{0.01}$
Ratio	1	1
empirical formula	MgO	

Reduction of a metal oxide

Many metal oxides can be reduced by, for instance, heating with hydrogen. The mass goes gown as the oxygen is lost (combines with hydrogen to make water).

An oxide of copper was reduced to copper in a stream of hydrogen. The following results were obtained.

Mass of empty dish = 13.80 g
Mass of dish and contents before heating (copper oxide) = 21.75 g
Mass of dish and contents after heating and leaving to cool (copper) = 20.15 g

Calculate the empirical formula of the oxide of copper using assuming complete reduction of the oxide to copper.

Mass of copper oxide = 21.75 – 13.80 = 7.95 g
Mass of copper at end = 20.15 – 13.80 = 6.35 g
Mass of oxygen = 7.95 – 6.35 = 1.60 g

The rest of the question is an empirical formula question – answer – CuO.

Formula of water

A student heated copper(II) oxide in hydrogen and then condensed the water in an ice bath. Determine the empirical formula of water.

Mass of empty dish /g	14.20
Mass of dish + CuO before heating /g	19.40
Mass of dish after heating and leaving to cool /g	18.35
Mass of water /g	1.18

The mass of the dish + contents decreases because the hydrogen reduces the CuO to Cu, so the change in mass is the amount of O lost – this all goes into the water
mass of O = 19.40 -18.35 = 1.05 g
1.18 g of water contains 1.05 g of O – the rest is H
Mass of H = 1.18-1.05 = 0.13 g

Elements	O	H
mass / g	1.05	0.13
Divide by A_r	$\frac{1.05}{16}$	$\frac{0.13}{1}$
Number of moles / mol	0.066	0.13
Divide by smallest to get ratio	$\frac{0.066}{0.066}$	$\frac{0.13}{0.066}$
Ratio	1	2
empirical formula	OH_2	