

## Maths for AS Chemistry

### Relative atomic mass

Relative atomic mass is abbreviated to  $A_r$ .

It is the mean mass of an atom relative to  $1/12^{\text{th}}$  the mass of an atom of  $^{12}_6\text{C}$ .

By definition,  $A_r(\text{C}) = 12$  exactly. Use the Periodic Table to find the  $A_r$  values of other elements.

### Relative formula mass

Relative formula mass is abbreviated to  $M_r$ . It is often also called relative molecular mass.

It is the mean mass of a molecule relative to  $1/12^{\text{th}}$  the mass of an atom of  $^{12}_6\text{C}$ .

To find the  $M_r$  of a substance, do these things:

Write down the formula of the compound	$\text{Na}_2\text{SO}_4$
Write down the $A_r$ values for each element in the compound	$A_r(\text{Na}) = 23$ $A_r(\text{S}) = 32$ $A_r(\text{O}) = 16$
Multiply the number of each atom in the compound by its $A_r$	$2 \times \text{Na} = 2 \times 23 = 46$ $1 \times \text{S} = 1 \times 32 = 32$ $4 \times \text{O} = 4 \times 16 = 64$
Add all the products together ... all done!	$46 + 32 + 64 = \mathbf{142}$

### The mole and the Avogadro constant

One mole of a substance is the number of particles (atoms, ions, molecules) of that substance as there are atoms in 12g of  $^{12}_6\text{C}$ . Put simply, it is the  $A_r$  or  $M_r$  of a substance in grams.

To find the number of moles in a mass of a substance, do these things:

Work out the $A_r$ or $M_r$ of the substance	$M_r(\text{Na}_2\text{SO}_4) = 142$
Divide the mass given by the $A_r$ or $M_r$ ... all done!	Mass given is 14.2g $\therefore \text{moles} = 14.2 \div 142 = \mathbf{0.10 \text{ mol}}$

To convert from moles to mass, do these things:

Work out the $A_r$ or $M_r$ of the substance	$M_r(\text{Na}_2\text{SO}_4) = 142$
Multiply the moles given by the $A_r$ or $M_r$ ... all done!	Moles given is 0.5 mol $\therefore \text{mass} = 0.5 \times 142 = \mathbf{71\text{g}}$

The Avogadro constant,  $L$ , is the number of particles in a mole of a substance.

It is  $6.022 \times 10^{23}$  (this number is given on the front of the examination paper).

To work out the number of particles of something, do these things:

Work out the number of moles	e.g. there are 0.20 mol of carbon
Multiply the moles given by Avogadro number ... all done!	Number of particles = $0.20 \times 6.022 \times 10^{23} = \mathbf{1.204 \times 10^{23}}$ (ignore any extra decimals)

## Empirical formula

The empirical formula is the simplest ratio of the elements in a compound.

You can work out the empirical formula from % composition data (given to you in questions).

To find the empirical formula of a compound, do these things:

Work out any missing %	In a substance containing sodium, sulphur and oxygen only, Na is 32.4%, O is 45.0% $\therefore \% \text{ S} = 100 - 32.4 - 45.0 = \mathbf{22.6\%}$
Assume 100g of the substance (turn % into g)	32.4g Na : 22.6g S : 45.0g O
Divide the mass of each elements by its $A_r$	$32.4 \div 23 \text{ Na} : 22.6 \div 32 \text{ S} : 45.0 \div 16 \text{ O}$ $= 1.4 \text{ Na} : 0.7 \text{ S} : 2.8 \text{ O}$
Divide all the numbers by the smallest number	$1.4 \div 0.7 \text{ Na} : 0.7 \div 0.7 \text{ S} : 2.8 \div 0.7 \text{ O}$ $= 2 \text{ Na} : 1 \text{ S} : 4 \text{ O}$
If necessary, divide again to get the simplest ratio, then write out the empirical formula ... all done!	<b>Na<sub>2</sub>SO<sub>4</sub></b>

## Molecular formula

The molecular formula is the actual number of atoms of each element in a compound. It can be the same as the empirical formula, but it need not be. For example:

The molecular formula of ethane is C<sub>2</sub>H<sub>6</sub> and its empirical formula is CH<sub>3</sub> (half of everything).

If you know the  $M_r$  of a compound and its empirical formula, you can work out its molecular formula.

To work out the molecular formula, do these things:

Work out the $M_r$ of the empirical formula	Empirical formula is CH <sub>3</sub> (e.g. given in question) $\therefore M_r (\text{CH}_3) = (1 \times 12) + (3 \times 1) = \mathbf{15}$
Divide the $M_r$ of the compound by the $M_r$ of the empirical formula	$M_r$ of the compound is 30 (e.g. given in question) $\therefore 30 \div 15 = 2$
Multiply the empirical formula by the number worked out above to get the molecular formula ... all done!	$\text{CH}_3 \times 2 = \mathbf{C_2H_6}$

## Concentration

Concentration is measured in moles per cubic decimetre: mol dm<sup>-3</sup>.

- To find the concentration of a solution, divide the number of moles by the volume in dm<sup>3</sup>.  
If the volume is in cm<sup>3</sup>, divide the volume by 1000 first to convert it into dm<sup>3</sup>.
- To find the number of moles in a solution, multiply the concentration by the volume in dm<sup>3</sup>.  
Again, if the volume is in cm<sup>3</sup>, divide the volume by 1000 first to convert it into dm<sup>3</sup>.
- To find the volume of a solution, divide the moles by the concentration in mol dm<sup>-3</sup>.  
This will give the volume in dm<sup>3</sup>; multiply by 1000 to convert it into cm<sup>3</sup> if necessary.

## Ideal gas equation

You must learn this:  $pV = nRT$

where  $p \equiv$  pressure in pascal (Pa)

$V \equiv$  volume in **cubic metres, m<sup>3</sup>** (not in dm<sup>3</sup> – take care)

$n \equiv$  number of moles

$R \equiv$  the gas constant, 8.31 JK<sup>-1</sup>mol<sup>-1</sup> (given in exam)

$T \equiv$  temperature in **kelvin, K** (not in °C – take care)

In the exam, you are always asked to find one of the factors in the equation given all the rest. For example, how many moles of gas will there be in a 100cm<sup>3</sup> sample of gas at 100kPa and 27°C? To answer a question like this, do the following things:

Convert any numbers given into the correct amounts	100cm <sup>3</sup> = 100 ÷ 1,000,000 m <sup>3</sup> = 0.0001 m <sup>3</sup> 100kPa = 100 x 1000 Pa = 100,000 Pa 27°C = 273 + 27 = 300K
Write down the ideal gas equation, then rearrange it as needed	pV = nRT ∴ n = pV / RT
Put all the numbers into the equation	n = 100,000 x 0.0001 / (8.31 x 300) mol
Calculate the answer ... all done!	<b>n = 0.004 mol</b>

These are traps that students fall into:

- Forgetting to write out pV = nRT (you often get a mark just for that)
- Rearranging the equation incorrectly
- Forgetting to convert into the correct amounts:

kPa → Pa      multiply by 1000  
dm<sup>3</sup> → m<sup>3</sup>    divide by 1000  
cm<sup>3</sup> → m<sup>3</sup>    divide by 1000,000    and  
°C → K        add 273

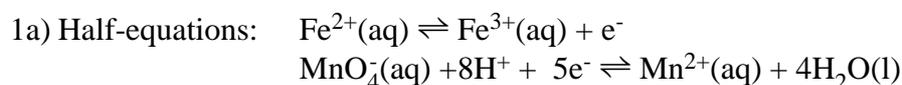
### Titration and reacting masses

These are just a combination of all the techniques mentioned earlier. Follow these steps:

1. Write out the balanced symbol equation (sometimes given, but usually you have to work it out)
2. Underline the substances mentioned in the question
3. One of the substances will have enough information to work out the number of moles – do it
4. Look at the stoichiometry between the two substances – multiply or divide as necessary
5. Work out the answer in the units asked for in the question

There are two sorts of question, acid-alkali titration and redox titration (harder). A typical difficult question goes like this:

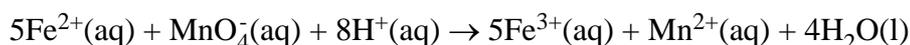
“In a titration between acidified Fe<sup>2+</sup> solution and potassium manganate(VII) solution, 20cm<sup>3</sup> of 0.10M KMnO<sub>4</sub> reacted completely with 25cm<sup>3</sup> of acidified Fe<sup>2+</sup> solution. What was the concentration of Fe<sup>2+</sup>?” Do these things:



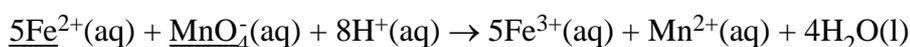
1b) Equalise the number of electrons by multiplying the first equation by 5:



1c) Add the two half-equations together and cancel common substances:



2. Underline the substances mentioned in the question:



3. You know a lot about the manganate ion (its concentration and volume), so work out the number of moles:

moles = concentration x volume

concentration =  $0.10 \text{ mol dm}^{-3}$

moles =  $0.10 \times 0.020 = \mathbf{0.002}$

volume =  $20 \text{ cm}^3 = 20 \div 1000 = 0.020 \text{ dm}^3$

4. Look at the stoichiometry: 5 mol of  $\text{Fe}^{2+}$  react with 1 mol of  $\text{MnO}_4^-$ , so multiply by 5:

moles of  $\text{Fe}^{2+} = 0.002 \times 5 = \mathbf{0.010}$

5. The answer must be in terms of concentration, so

concentration = moles  $\div$  volume

moles = 0.010

concentration =  $0.010 \div 0.025 \text{ mol dm}^{-3}$   
 $= \mathbf{0.40 \text{ mol dm}^{-3}}$

volume =  $25 \text{ cm}^3 = 25 \div 1000 = 0.025 \text{ dm}^3$

## Energetics

Remember these definitions:

- Standard enthalpy of formation,  $\Delta H_f^\ominus$  is the enthalpy change when one mole of a substance is formed from its elements in their standard states under standard conditions.
- Standard enthalpy of combustion,  $\Delta H_c^\ominus$  is the enthalpy change when one mole of a substance is completely burned in oxygen under standard conditions.

Remember that:

- The enthalpy change for a reaction,  $\Delta H_r^\ominus = \Sigma(\Delta H_f^\ominus \text{ products}) - \Sigma(\Delta H_f^\ominus \text{ reactants})$   
i.e. add up the  $\Delta H_f^\ominus$  values of all the products, then subtract the  $\Delta H_f^\ominus$  values of all the reactants.
- The enthalpy change for a reaction,  $\Delta H_r^\ominus = \Sigma(\Delta H_c^\ominus \text{ reactants}) - \Sigma(\Delta H_c^\ominus \text{ products})$   
i.e. add up the  $\Delta H_c^\ominus$  values of all the reactants, then subtract the  $\Delta H_c^\ominus$  values of all the products.

Always write down the + or – sign in front of your answer, and give the units (usually  $\text{kJ mol}^{-1}$ ).

Finally, remember:

- combustion reactions are always exothermic, so if your answer for  $\Delta H_c^\ominus$  is a positive number, you have gone wrong!
- the  $\Delta H_f^\ominus$  of an element in its standard state is 0, so don't mess about looking for the value in questions.

Remember, this guide is not a substitute for thorough learning and practice. Use questions from past papers and the text books – how do you think I learnt it when I was at school?!