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 1/12th the mass of an atom of $^{12}_{6}C$.
By definition, $A_r(C) = 12$ 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 1/12th the mass of an atom of $^{12}_{6}C$.
To find the M_r of a substance, do these things:

Write down the formula of the compound	Na_2SO_4
Write down the A_r values for each element in the compound	$A_r(Na) = 23$ $A_r(S) = 32$ $A_r(O) = 16$
Multiply the number of each atom in the compound by its A_r	2 x Na = 2 x 23 = 46 1 x S = 1 x 32 = 32 4 x O = 4 x 16 = 64
Add all the products together … all done!	46 + 32 + 64 = **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 $^{12}_{6}C$. 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 (Na_2SO_4) = 142
Divide the mass given by the A_r or M_r … all done!	Mass given is 14.2g ∴moles = 14.2 ÷ 142 = **0.10 mol**

To convert from moles to mass, do these things:

Work out the A_r or M_r of the substance	M_r (Na_2SO_4) = 142
Multiply the moles given by the A_r or M_r … all done!	Moles given is 0.5 mol ∴mass = 0.5 x 142 = **71g**

The Avogadro constant, *L*, is the number of particles in a mole of a substance.
It is 6.022 x 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 x 6.022 x 10^{23} = **1.204 x 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% $\therefore$% S = 100 – 32.4 – 45.0 = **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 ÷ 23 Na : 22.6 ÷ 32 S : 45.0 ÷ 16 O = 1.4 Na : 0.7 S : 2.8 O
Divide all the numbers by the smallest number	1.4 ÷ 0.7 Na : 0.7 ÷ 0.7 S : 2.8 ÷ 0.7 O = 2 Na : 1 S : 4 O
If necessary, divide again to get the simplest ratio, then write out the empirical formula … all done!	$\mathbf{Na_2SO_4}$

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_2H_6 and its empirical formula is CH_3 (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_3 (e.g. given in question) $\therefore M_r(CH_3)$ = (1 x 12) + (3 x 1) = **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 ÷ 15 = 2
Multiply the empirical formula by the number worked out above to get the molecular formula … all done!	CH_3 x 2 = $\mathbf{C_2H_6}$

Concentration

Concentration is measured in moles per cubic decimetre: mol dm^{-3}.

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

Ideal gas equation

You must learn this: $pV = nRT$ where
$p \equiv$ pressure in pascal (Pa)
$V \equiv$ volume in **cubic metres, $\mathbf{m^3}$** (not in dm^3 – take care)
$n \equiv$ number of moles
$R \equiv$ the gas constant, 8.31 $JK^{-1}mol^{-1}$ (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 $100cm^3$ 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	$100cm^3 = 100 \div 1,000,000\ m^3 = 0.0001\ m^3$ 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	$n = 100,000 \times 0.0001 / 8.31 \times 300$ mol
Calculate the answer … all done!	**n = 0.004 mol**

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
$dm^3 \rightarrow m^3$	divide by 1000
$cm^3 \rightarrow m^3$	divide by 1000,000 and
°C → K	add 273

Titrations 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^{2+} solution and potassium manganate(VII) solution, $20cm^3$ of 0.10M $KMnO_4$ reacted completely with $25cm^3$ of acidified Fe^{2+} solution. What was the concentration of Fe^{2+}?" Do these things:

1a) Half-equations: $Fe^{2+}(aq) \rightleftharpoons Fe^{3+}(aq) + e^-$

$MnO_4^-(aq) + 8H^+ + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$

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

$5Fe^{2+}(aq) \rightleftharpoons 5Fe^{3+}(aq) + 5e^-$

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

$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$

2. Underline the substances mentioned in the question:

$\underline{5Fe}^{2+}(aq) + \underline{MnO}_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$

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 mol dm^{-3}
volume = $20cm^3$ = 20 ÷ 1000 = $0.020dm^3$

moles = 0.10 x 0.020 = **0.002**

4. Look at the stoichiometry: 5 mol of Fe^{2+} react with 1 mol of MnO_4^-, so multiply by 5:

   moles of Fe^{2+} = 0.002 x 5 = **0.010**

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

   concentration = moles ÷ volume

   moles = 0.010
   volume = $25cm^3$ = 25 ÷ 1000 = $0.025dm^3$

   concentration = 0.010 ÷ 0.025 mol dm^{-3}
   = **0.40 mol dm^{-3}**

Energetics

Remember these definitions:

- Standard enthalpy of formation, $\Delta H^\ominus_f$ 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, $\Delta H^\ominus_c$ 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, $\Delta H^\ominus_r = \Sigma(\Delta H^\ominus_f$ products) – $\Sigma(\Delta H^\ominus_f$ reactants)
  i.e. add up the $\Delta H^\ominus_f$ values of all the products, then subtract the $\Delta H^\ominus_f$ values of all the reactants.

- The enthalpy change for a reaction, $\Delta H^\ominus_r = \Sigma(\Delta H^\ominus_c$ reactants) – $\Sigma(\Delta H^\ominus_c$ products)
  i.e. add up the $\Delta H^\ominus_c$ values of all the reactants, then subtract the $\Delta H^\ominus_c$ values of all the products.

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

Finally, remember:

- combustion reactions are always exothermic, so if your answer for $\Delta H^\ominus_c$ is a positive number, you have gone wrong!
- the $\Delta H^\ominus_f$ 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?!

