Revision Checklist :4.3 Quantitative Chemistry

Conservation of Mass
The law of conservation of mass states that **no atoms** are **lost or made** during a chemical reaction so the mass of the products equals the mass of the reactants

This means that chemical reactions can be represented by symbol equations which are balanced in terms of the numbers of atoms of each element involved on both sides of the equation.

Balancing Equations
- know how to balance chemical equations
  $CaCO_3$ + **2**HCl → $CaCl_2$ + H_2O + CO_2 (The 2 is put in front of the HCl to balance the numbers of H's and Cl's on both sides)
  2Mg + O_2 → **2**MgO (The 2 is put in front of the MgO to balance with the 2O's on the left and then a 2 needs to be put in front of the Mg to balance with the 2Mg's on the right.)
- Remember when balancing equations you cannot change the formulae

Relative Formula Mass
The relative formula mass (*M*r) of a compound is the sum of the relative atomic masses (*A*r) of the atoms in the numbers shown in the formula.

Be able to work out the relative formula mass (*M*r) of a substance using data from the periodic table.
e.g. the *M*r of $CaCO_3$ = 40 + 12 + (16 x 3) = 100

Balanced chemical equations

In a balanced chemical equation, the sum of the relative formula masses of the reactants in the quantities shown equals the sum of the relative formula masses of the products in the quantities shown

Mass changes when a reactant or product is a gas

Some reactions may appear to involve a change in mass but this can usually be explained because a reactant or product is a gas and its mass has not been taken into account

When a metal reacts with oxygen the mass of the oxide produced is greater than the mass of the metal.
2Mg (s) + O_2 (g) → 2MgO (s)

In **thermal decompositions** of metal carbonates, carbon dioxide is produced which escapes into the atmosphere leaving the metal oxide as the only solid product.
$CaCO_3$ (s) → CaO (s)+ CO_2 (g)

Chemical measurements

Whenever a measurement is made there is always some uncertainty about the result obtained.

The **range** of a set of measurements about the **mean** can be used as a measure of uncertainty.

Example: Calculate the mean and uncertainty of the following volumes in cm^3: 20.10, 20.20, 20.00, 20.05, 20.25
Mean = (20.10+ 20.20+ 20.00+ 20.05+ 20.15)/5 =20.10 cm^3
Uncertainty = ± 0.10 cm^3 (all readings are within ± 0.10 of mean

Moles

Chemical amounts are measured in moles.
The symbol for the unit mole is **mol.**

The mass of one mole of a substance in grams is numerically equal to its relative formula mass.

One mole of a substance contains the same number of the stated particles, atoms, molecules or ions as one mole of any other substance.
For example in one mole of carbon (C) the number of atoms is the same as the number of molecules in one mole of carbon dioxide (CO_2).

The number of atoms, molecules or ions in a mole of a given substance is the **Avogadro constant**.
The value of the Avogadro constant is 6.02 x 10^{23} per mole.

be able to work out the number of moles of a given substance from its mass using the equation
moles = mass/*M*r or rearranged to **mass = *M*r x moles**

Example 1: Calculate the number of moles in 35.0g of $CuSO_4$

moles = mass/*M*r

= 35.0/ (63.5 + 32 +16 x4)

= 0.219 mol

Many questions will involve changes of units
1000 mg =1g
1000 g =1 kg
1000 kg = 1 tonne

Example 2: Calculate the number of moles in 75.0mg of $CaSO_4.2H_2O$

moles = mass/*M*r

= 0.075/ (40 + 32 +16 x4 + 18x2)

= $4.36x10^{-4}$ mol

Calculate the percentage by mass of an element in a compound

$$\text{percentage by mass} = \frac{\text{number of atoms of element x } Ar \text{ of element}}{Mr \text{ of compound}} \times 100$$

Example 3. Calculate the percentage by mass of oxygen in calcium sulfate ($CaSO_4$)

$$\text{percentage by mass} = \frac{\text{number of atoms of element x } Ar \text{ of element}}{Mr \text{ of compound}} \times 100$$

$$= \frac{4 \times 16}{(40 + 32 + 16 \times 4)} \times 100$$

= 47 %

Avogadro's Constant

The number of atoms, molecules or ions in a mole of a given substance is the Avogadro constant. The value of the Avogadro constant is 6.02×10^{23} per mole.

Avogadro's Constant can be used for atoms, molecules and ions

1 mole of copper atoms will contain 6.02×10^{23} atoms
1 mole of carbon dioxide molecules will contain 6.02×10^{23} molecules
1 mole of sodium ions will contain 6.02×10^{23} ions

No of particles = number of moles x Avogadro's constant

Example 4 : Calculate the number of tin atoms in a 6.00 g sample of Tin metal.

Step 1 calculate the number of moles

moles = mass/*A*r

= 6/ 119

= 0.0504 mol

Step 2 use Avogadro's number to calculate no of atoms

Number of atoms = moles x 6.02×10^{23}

= 0.0504 x 6.02×10^{23}

= 3.04×10^{22}

Example 5 Calculate the mass of 1 atom of sodium

Mass of 1 atom = mass of 1 mole of sodium(*A*r)/Avogadro's number

= $23/6.02 \times 10^{23}$

= 3.82×10^{-23} g

Reacting mass questions

The masses of reactants and products can be calculated from balanced symbol equations.

Chemical equations can be interpreted in terms of moles.
For example:
$Mg + 2HCl \rightarrow MgCl_2 + H_2$
shows that one mole of magnesium reacts with two moles of hydrochloric acid to produce one mole of magnesium chloride and one mole of hydrogen gas.

General method for reacting mass questions
step 1: work out the number of moles of the substance for which the mass has been given.

Using $\text{number of moles} = \frac{\text{mass}}{M\text{r}}$

step2 : use the ratios of moles in the balanced equation to work out the moles of the other substance

Step 3: work out the mass of the second substance

Using mass = moles x *M*r

Example 6: Calculate the mass of carbon dioxide produced from heating 5.5 g of sodium hydrogencarbonate.
$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Step 1: work out moles of sodium hydrogencarbonate
moles = mass / *M*r
= 5.5 /84
= 0.0655 mol

Step 2: use balanced equation to give moles of CO_2
2 moles $NaHCO_3$: 1 moles CO_2
So 0.0655 HNO_3 : 0.0328moles CO_2

Step 3: work out mass of CO_2
Mass = moles x *M*r
= 0.0328 x 44
=1.44 g

Working out the balancing numbers from masses

The balancing numbers in a symbol equation can be calculated from the masses of reactants and products by converting the masses in grams to amounts in moles and converting the numbers of moles to simple whole number ratios.

Example 7. A sample of lead was heated strongly in oxygen. It was found that 8.28g of lead reacts with 0.64g of oxygen to form a lead oxide.
There are two possible lead oxides that could be formed: lead (II) oxide (PbO) and lead (IV) oxide (PbO_2)
Determine which is the correct equation.

Equation 1 $2Pb + O_2 \rightarrow 2PbO$
Equation 2 $Pb + O_2 \rightarrow PbO_2$

Step 1: calculate moles of each chemical whose mass if given
Moles of Pb = mass / *A*r
= 8.28 /207
= 0.04 mol

Moles of O_2 = mass / *M*r
= 0.64 /32
= 0.02 mol

Step 3: divide each moles in step 2 by the smallest number of moles to get a whole number ratio

Pb = 0.04/0.02
= 2

O_2 = 0.02/0.02
= 1

Step 4 choose correct balanced equation:
$2Pb + O_2 \rightarrow 2PbO$

Limiting Reactant

In a chemical reaction involving two reactants, it is common to use an **excess** of one of the reactants to ensure that all of the other reactant is used.

The reactant that is completely used up is called the **limiting reactant** because it limits the amount of products.
The number of moles of the limiting reactant will determine the number of moles of product formed.
Not all of the excess reactant will react.

General method for Limiting Reactant Questions

step 1: work out the number of moles of the substance for each reactant.

Using number of moles = $\frac{\text{mass}}{Mr}$

step2 : use the ratios of moles in the balanced equation to work out which reactant is the limiting reactant

Step 3 : use the ratios of moles in the balanced equation to convert the moles of the limiting reactant to the moles of a product

Step 4: work out the mass of the product
Using mass = moles x *M*r

Some questions may only ask you to calculate which reactant is in excess. In those questions only do the first two steps in the above method

Example 8: 5.0g of magnesium are reacted with 6.0g of oxygen to make magnesium oxide. What is the limiting reactant and calculate the mass of magnesium oxide that will be formed?

$2Mg + O_2 \rightarrow 2\ MgO$

step 1: calculate the number of moles of the substance for each reactant.

Work out moles of Mg
Moles = mass /*A*r
= 5/24
= 0.208mol

Work out moles of O_2
Moles = mass /*M*r
= 6/32
= 0.188 mol

step2 : use the ratios of moles in the balanced equation to work out which reactant is the limiting reactant

Using ratio of 2Mg: 1 O_2 from balanced equation

0.208 moles of Mg should react with 0.104 of O_2

but we have 0.188 mol of O_2 so O_2 is in excess and **Mg is limiting reactant**

step 3 : use the ratios of moles in the balanced equation to convert the moles of the limiting reactant to the moles of a product

Ignore excess moles of O_2 and use moles of Mg to work out moles of MgO
There are 0.208 mol of Mg, so using ratio of 2Mg:2MgO from balanced equation there must be 0.208 mol of MgO

step 4: calculate the mass of the product

Mass = moles x *M*r of MgO
= 0.208 x 40
= 8.32 g

Concentration calculations

The concentration of a solution can be measured in g/dm^3 or mol/dm^3.

Concentration(in mol/dm^3) = moles/volume (in dm^3)

Concentration(in g/dm^3) = mass (in g) /volume (in dm^3)

The volume in the above equation must be in **dm^3** . Volumes are often given in cm^3.
To **convert cm^3 into dm^3 divide by 1000**

Example 9: Calculate the concentration of a solution in g/dm^3 made by dissolving 500mg of $NaNO_3$ in 250 cm^3 water.

Convert units 500 mg= 0.50g
250cm^3 = 0.25dm^3

Conc in g/dm^3= mass/volume
= 0.50 / **0.25**
= 2.0 g /dm^3

Example 10: Calculate the concentration in mol/dm^3 of a solution made by dissolving 5.00g of Na_2CO_3 in 250 cm^3 water.

moles = mass/*M*r
= 5.00 / (23 x2 + 12 +16 x3)
= 0.0472 mol

conc= moles/volume
= 0.0472 / **0.25**
= 0.189 mol/dm^3

Example 11 Calculate the mass of sodium chloride needed to make 100cm^3 of 0.100 mol/dm^3 NaCl solution.

moles= conc x volume
= 0.1 x **0.1**
= 0.01 mol

mass = mol x *M*r
= 0.01 x (23+35.5)
= 0.585 g

To convert a concentration in **g/dm^3** to **mol/dm^3** divide by ***M*r**

Example 12: A solution of HCl has a concentration of 1.825g/dm^3 . Calculate the concentration of the solution in mol/dm^3

Conc in mol/dm^3 = conc in g/dm^3 /*M*r
= 1.825 / 36.5
= 0.05 mol/dm^3