

## Mass Calculations and Quantitative Analysis (Separate)

### 5.8—Concentration in mol dm<sup>-3</sup> and g dm<sup>-3</sup> (HT only)

Concentration is a measure of the quantity of **solute** which is dissolved in a **solvent**. It can be measured either in g dm<sup>-3</sup> or mol dm<sup>-3</sup>.

$$\text{Mass concentration} = \frac{\text{mass (g)}}{\text{volume (dm}^3\text{)}}$$

$$\text{Molar concentration} = \frac{\text{number of moles (mol)}}{\text{volume (dm}^3\text{)}}$$

You may be expected to convert between mass and moles. To do this, use the equation:

$$\text{number of moles} = \frac{\text{mass (g)}}{\text{relative mass (g mol}^{-1}\text{)}}$$

You are also likely to need to convert between cm<sup>3</sup> and dm<sup>3</sup>. To convert from cm<sup>3</sup> to dm<sup>3</sup>, you simply **divide** by 1000.

### 5.9—CP5—Titration

Method:

- 1) Measure out a set volume of alkali using a **pipette**.
- 2) Add this to a **conical flask**.
- 3) Add a couple of drops of **indicator** (for example **phenolphthalein** or **methyl orange**).
- 4) Fill a **burette** with acid. Record the start volume.
- 5) Place the **conical flask** on a white tile.
- 6) Add acid to the alkali. Towards the end, add it **dropwise**.
- 7) When the **indicator** has changed **colour** permanently, stop adding acid. Record the final volume.
- 8) Repeat until you have **concordant** titres (results).
- 9) Repeat steps 1-8, using the **same** volume of acid, and no **indicator**.

Suggest a safety precaution that should be taken when carrying out a titration:

- Ensure you wear safety glasses to protect the eyes.
- Ensure any spillages on the skin are rinsed with plenty of water.

### 5.11—Calculating percentage yield

Percentage yield is a measure of how much **product** is made compared to the amount that should **theoretically** have been made.

The calculation is:

$$\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

The value for a percentage yield can **never** be more than **100** %.

### 5.10—Calculating unknown concentration/volume from a titration (HT only)\*

The key formula here is:

$$\text{number of moles} = \text{concentration (mol dm}^{-3}\text{)} \times \text{volume (dm}^3\text{)}$$

e.g. calculate the concentration of hydrochloric acid, when 25.20 cm<sup>3</sup> reacts with 20 cm<sup>3</sup> of 0.800 mol dm<sup>-3</sup> sodium hydroxide solution

1) Set out a table (shown right)

	Acid	Alkali
n	4) 0.016	3) 0.016
C	5) 0.635	2) 0.800
V	2) 0.0252	2) 0.020

2) Populate the table with the data you are given (there will be three data given,

**concentrations** or **volumes**). Remember to convert volumes to **dm<sup>3</sup>**.

3) Calculate the number of **moles** of the substance you have a C and V for.

4) Use the balanced equation to identify the number of moles of substance you are finding the value for.

5) Calculate the missing value by rearranging  $n = CV$ :

$$C = n / V = 0.635 \text{ mol dm}^{-3}$$

### 5.12—Reasons why percentage yield will not be 100%

- a) There may be **incomplete** reactions, so not all of the **reactants** are converted to **products** (especially in a **reversible** reaction).
- b) There may be **loss** of substance during a reaction, for example when **transferring** a solid between containers.
- c) There may be **unwanted** side reactions, meaning some of the expected product actually becomes a **different** chemical.

### 5.13—Atom economy

The atom economy is a measure of how much of the **relative** mass of the reactants is converted into a **useful** product.

By definition, the atom economy of a reaction with only one product is always **100%**, as all of the reactants become the **useful** product.

### 5.14—Calculating atom economy

$$\text{Atom economy} = \frac{\text{Relative mass of useful products}}{\text{Relative mass of all products}} \times 100$$

The value for atom economy can **never** be more than **100%**.

### 5.11 & 5.14—Practice calculations\*

Calculate the atom economy & percentage yield for the following reaction to make hydrogen gas:  $\text{CH}_4 + \text{H}_2\text{O} \rightarrow 3 \text{H}_2 + \text{CO}$ .  $M_r$ :  $\text{CH}_4=16$ ,  $\text{H}_2\text{O}=18$ ,  $\text{H}_2=2$ ,  $\text{CO}=28$ . The actual yield was 254 g and the theoretical yield was 320 g.

$$\text{Percentage yield} = \frac{254}{320} \times 100 = 79.4 \%$$

$$\text{Atom economy} = \frac{3 \times 2}{(3 \times 2) + 28} \times 100 = 17.6 \%$$

### 5.15—Explaining choice of reaction pathway (HT only)\*

Methods of making ethanol

Method	% yield	Atom economy	Rate
Hydration of ethene	Very high	100	Quick
Fermentation of glucose	Low	51	Very slow

When selecting a reaction pathway, many factors need to be considered. As well as the above, the usefulness of **side** products should be considered, as well as position of **equilibrium** (for a reversible reaction).

• Briefly explain which method is best for making ethanol.

*Either hydration of ethene, as it has a higher atom economy, yield and rate. (Although ethene is a product of crude oil, and is non-renewable).*

*Or fermentation of glucose as it has lower energy costs and the raw materials are from plants, which are renewable. (Although low rate, yield & atom economy)*

### 5.16—Molar volume of a gas, a.k.a. Avogadro's law (HT only)

One mole of **any** gas, at room **temperature** and **pressure**, will have a volume of **24 dm<sup>3</sup>** (which is **24 000 cm<sup>3</sup>**).

### 5.17—Using molar volume of a gas (HT only)\*

These calculations involve using molar volume, reacting masses and balanced equations to find a volume of gas produced in a reaction. e.g. 1.95 g of potassium reacts completely with water according to the equation:  $2 \text{K} + \text{H}_2\text{O} \rightarrow 2 \text{KOH} + \text{H}_2$ . Calculate the volume of  $\text{H}_2$  formed in dm<sup>3</sup>.

$A_r$ : K = 39, H = 1, O = 16.

1) Calculate number of moles of potassium:

$$\text{number of moles} = \frac{\text{mass (g)}}{\text{relative mass (g mol}^{-1}\text{)}} = \frac{1.95}{39} = 0.05 \text{ moles}$$

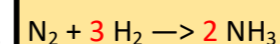
2) From the balanced equation, **2** moles of potassium react to form **1** mole of hydrogen, therefore the number of moles of  $\text{H}_2$  = answer from step 1 divided by **2** = **0.025** moles.

3) Multiply the number of moles calculated in step 2 by the molar volume of a gas (24 dm<sup>3</sup>): **0.025** x 24 dm<sup>3</sup> = **0.6** dm<sup>3</sup>.

### 5.18—Calculating volumes of gases involved in reactions (HT only)\*

In these questions, you will need to use balanced equations, and the molar gas volume, to identify the volume of gases involved in reactions.

E.g. calculate the volume of ammonia that could (theoretically) be formed from 1250 cm<sup>3</sup> of nitrogen and an **excess** of hydrogen.



1) Balance the equation (in an exam, this may be done for you).

2) Identify the ratio of the gases in the question. In this example, the ratio of nitrogen:ammonia is **1:2**.

3) Convert the known volume to the unknown volume by multiplying or dividing by the appropriate value. In this case, **multiply** by **2**.

4) Write your final answer. In this case, it is **2 500** cm<sup>3</sup>.