

# C3 Quantitative Chemistry. RP2 = Titrations

## Triple Chemistry Page 1 of 2

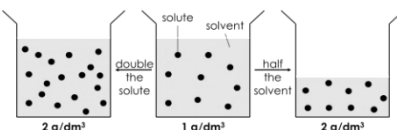
### Keywords

<b>chemical formula</b>	Represents chemicals with symbols and numbers
<b>mole</b>	Used to represent the number of particles. One mole is $6.02 \times 10^{23}$ particles.
<b>limiting reactant</b>	The reactant that is completely used up during a reaction – this limits the amount of product.
<b>excess</b>	More of a chemical than you need for a reaction.
<b>titration</b>	Method used to accurately determine an unknown concentration
<b>concordant</b>	Results within $0.1 \text{ cm}^3$ of each other
<b>yield</b>	The amount (mass, volume etc) of product produced in a reaction
<b>mean</b>	The average of a set of numbers
<b>range</b>	The highest minus the lowest number
<b>uncertainty</b>	How close the highest and lowest numbers are to the mean

### Concentrations of solutions (in $\text{g/dm}^3$ )

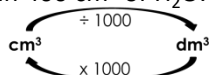
This is the mass of solute in  $1 \text{ dm}^3$  ( $\approx 1$  litre) of solution.

The concentration will increase if solute is added, or solvent is removed.



**Example:** Find the concentration of the solution formed when 2 g of HCl is dissolved in  $400 \text{ cm}^3$  of  $\text{H}_2\text{O}$ .

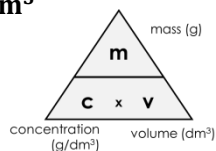
**Step 1:** Convert  $\text{cm}^3$  to  $\text{dm}^3$



$$\text{volume in dm}^3 = \frac{400}{1000} = 0.4 \text{ dm}^3$$

**Step 2:** Use equation

$$c = \frac{m}{v} = \frac{2}{0.4} = 0.05 \text{ g/dm}^3$$



### The mole (mol)

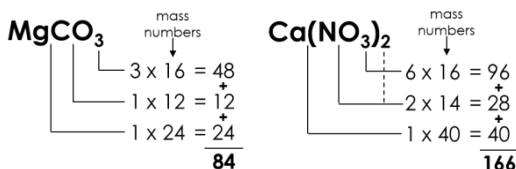
A mole represents the number of particles in a reaction. These particles can be ions, electrons, atoms, molecules etc. The number of particles in one mole is the same as Avogadro's constant –  $6.02 \times 10^{23}$ .

**Example:**

1 mole of NaBr contains  $6.02 \times 10^{23}$   $\text{Na}^+$  ions

### Relative formula mass ( $M_r$ )

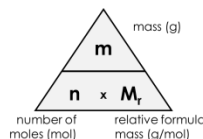
The  $M_r$  is the mass of one mole of a chemical in grams. It is found by adding the mass numbers of each atom in a chemical:



### Mole equations

**Masses**

$$n = \frac{m}{M_r}$$

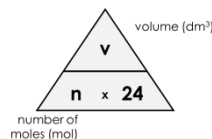


**Gases**

At room temperature and pressure ( $20^\circ\text{C}$ , 1 atm) one mole of any gas occupies a volume of  $24 \text{ dm}^3$ .

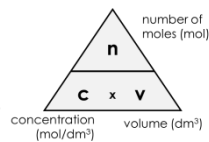
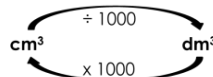
Therefore this equation is used:

$$n = \frac{v}{24}$$



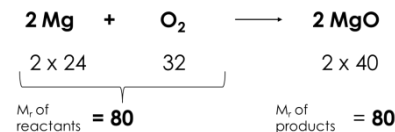
**Solutions**

$$n = c \times v$$



### Conservation of mass

The law of conservation of mass states that no atoms are lost or made during a chemical reaction.



Therefore:

**mass of the products = mass of the reactants**

Also

**$M_r$  products =  $M_r$  reactants**

In an open system, the mass can change during an experiment involving gases as the gas can be 'added' or 'escape'.

- If a reactant is a gas, the mass increases (eg.  $2 \text{ Ca} + \text{O}_2 \rightarrow 2 \text{ CaO}$ ).
- If a product is a gas, the mass decreases (eg.  $\text{ZnCO}_3 \rightarrow \text{ZnO} + \text{CO}_2$ )

### Uncertainty in measurements

**Example:** A beaker containing  $100 \text{ cm}^3$  water was heated by  $20^\circ\text{C}$  using a Bunsen burner. The experiment was repeated, and the times taken in seconds were **90, 100, 93, 95**.

- Calculate the mean:  $90 + 100 + 93 + 95 = \frac{378}{4} = 94.5 \text{ s}$   
(add numbers then divide by number of numbers)
- Calculate the range:  $100 - 90 = 10 \text{ s}$   
(highest – lowest)
- Calculate the uncertainty:  $\frac{10}{2} = 5 \text{ s}$   
(range  $\div$  2)
- Result is mean  $\pm$  uncertainty:  **$94.5 \pm 5 \text{ s}$**

### Using the mole equations

Calculations can be performed by inputting numbers into the appropriate equation.

**Example:** Find the mass of 0.75 moles of  $\text{Na}_2\text{O}$ .

$$M_r \text{ Na}_2\text{O} = 23 \times 2 + 16 = 62$$

$$m = n \times M_r = 0.75 \times 62 = 46.5 \text{ g}$$

Sometimes two equations need to be used. As the equations are all linked by the number of moles:

**Example:** What mass of  $\text{O}_2$  gas has a volume of  $36 \text{ dm}^3$ ?

$$1. n = \frac{v}{24} = \frac{36}{24} = 1.5 \text{ mol}$$

$$2. m \text{ O}_2 = n \times M_r \quad (M_r \text{ O}_2 = 2 \times 16 = 32)$$

$$= 1.5 \times 32 = 48 \text{ g}$$

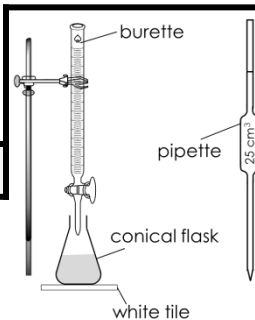
# C3 Quantitative Chemistry

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### RP2 = Titrations

#### Titrations

Titrations are used to accurately find an unknown concentration of a chemical.



**Method:** (can swap the acid and alkali)

- Use the pipette and pipette filler to add 25 cm<sup>3</sup> of alkali to a clean conical flask.
- Add a few drops of indicator and put the conical flask on a white tile.
- Fill the burette with acid and record the volume.
- Slowly add the acid from the burette to the alkali in the conical flask, swirling to mix.
- Stop adding the acid when the end-point is reached (the appropriate colour change happens) and record the final volume of acid.
- Repeat until you have concordant results (within 0.1 cm<sup>3</sup>).

**Results:**  
Use two decimal places.

Volume acid / cm <sup>3</sup>	Rough	1 <sup>st</sup> titration	2 <sup>nd</sup> titration	3 <sup>rd</sup> titration
Initial volume (cm <sup>3</sup> )	0.30	5.80	10.90	15.80
Final volume (cm <sup>3</sup> )	5.80	10.90	15.80	21.00
<b>Titre (cm<sup>3</sup>)</b> (final vol. - initial vol.)	5.50	5.10	4.90	5.20

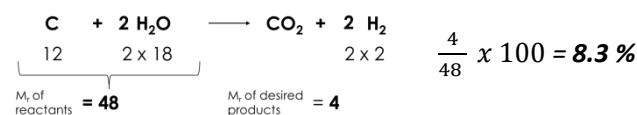
Concordant results: only use these to calculate the mean

#### Atom economy

This measures the proportion of starting material that is converted into useful product.

$$\text{atom economy} = \frac{M_r \text{ of desired product}}{M_r \text{ s of all reactants}} \times 100$$

**Example:** What is the atom economy for making hydrogen by reacting coal with steam?

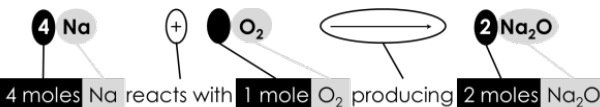


**Note - If only useful products are produced then the atom economy is 100%.**

#### Balanced chemical equations

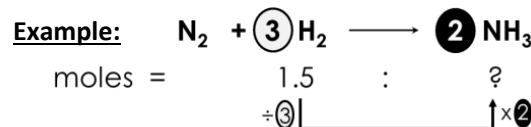
Balancing numbers

The 'balancing number' before each chemical shows the ratio of the number of moles of each chemical that reacts. No number before the chemical means there is only one mole reacting.



Mole ratios

The **mole ratios** from a balanced chemical equation can be used to find the moles of one chemical from the moles of another.



If 1.5 moles H<sub>2</sub> react with excess N<sub>2</sub> how many moles of NH<sub>3</sub> are formed?

$$\text{moles NH}_3 = \frac{1.5}{3} \times 2 = 1 \text{ mol}$$

Masses to balanced equations

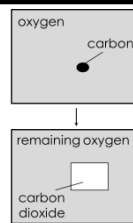
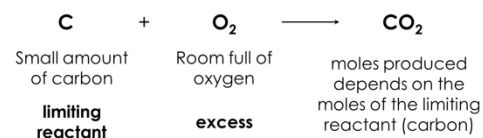
The mass can be used to find the mole ratio and write a balanced chemical equation

**Example:** 36 g Mg reacts with 24 g of O<sub>2</sub> producing 60 g of MgO. Find the balanced chemical equation for this reaction.

	Mg	+	O <sub>2</sub>	→	MgO
1. Write mass	36		24		60
2. Find moles	$n = \frac{m}{M_r} = \frac{36}{24} = 1.5$		$n = \frac{m}{M_r} = \frac{24}{32} = 0.75$		$n = \frac{m}{M_r} = \frac{60}{40} = 1.5$
3. ÷ smallest number	$\frac{1.5}{0.75} = 2$		$\frac{0.75}{0.75} = 1$		$\frac{1.5}{0.75} = 2$
4. Balanced equation	2 Mg	+	O <sub>2</sub>	→	2 MgO

**Always check the equation is balanced!**

#### Excess and limiting reactants



#### Mole calculations

These calculations have three steps:

- Find the moles.
- Use mole ratios.
- Answer the question.

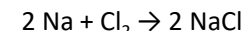
$$n = \frac{m}{M_r} \quad n = v \times c \quad n = \frac{v}{24}$$

masses      solutions      gas volumes

**mole ratios**  
(from balanced equation)

**Note** – it is useful to keep track of the moles by writing them under the balanced equation

**Example:** 69 g of sodium was reacted with chlorine gas to make sodium chloride. What volume of chlorine gas was needed for the reaction?



$$n = \frac{m}{M_r} \quad M_r \text{ of Na} = 23$$

$$n \text{ Na} = \frac{69}{23} = 3 \text{ mol}$$



$$n \text{ Cl}_2 = 1.5 \text{ mol} \quad n = 3 : 1.5$$

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$$v = n \times 24 = 1.5 \times 24 = \underline{136 \text{ dm}^3}$$

#### Percentage yield (should always be less than 100!)

In a reaction, not all of the reactants necessarily turn into the expected products. This could be because:

- a reaction is reversible
  - product is lost when separated from reaction mixture
  - the reactants reacted in a different way than expected
- The % yield compares the amount of product obtained with the amount you'd expect in a 'perfect' reaction.

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

**Example:** Rob expected to get 186g of copper sulfate crystals, but got 158g. Calculate the percentage yield.

$$\% \text{ yield} = \frac{158}{186} \times 100 = \underline{84.9\%}$$

**Note - The theoretical mass can be calculated by using mole calculations**