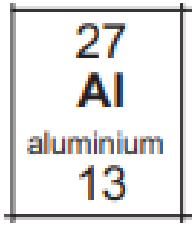
C3 – Quantitative Chemistry

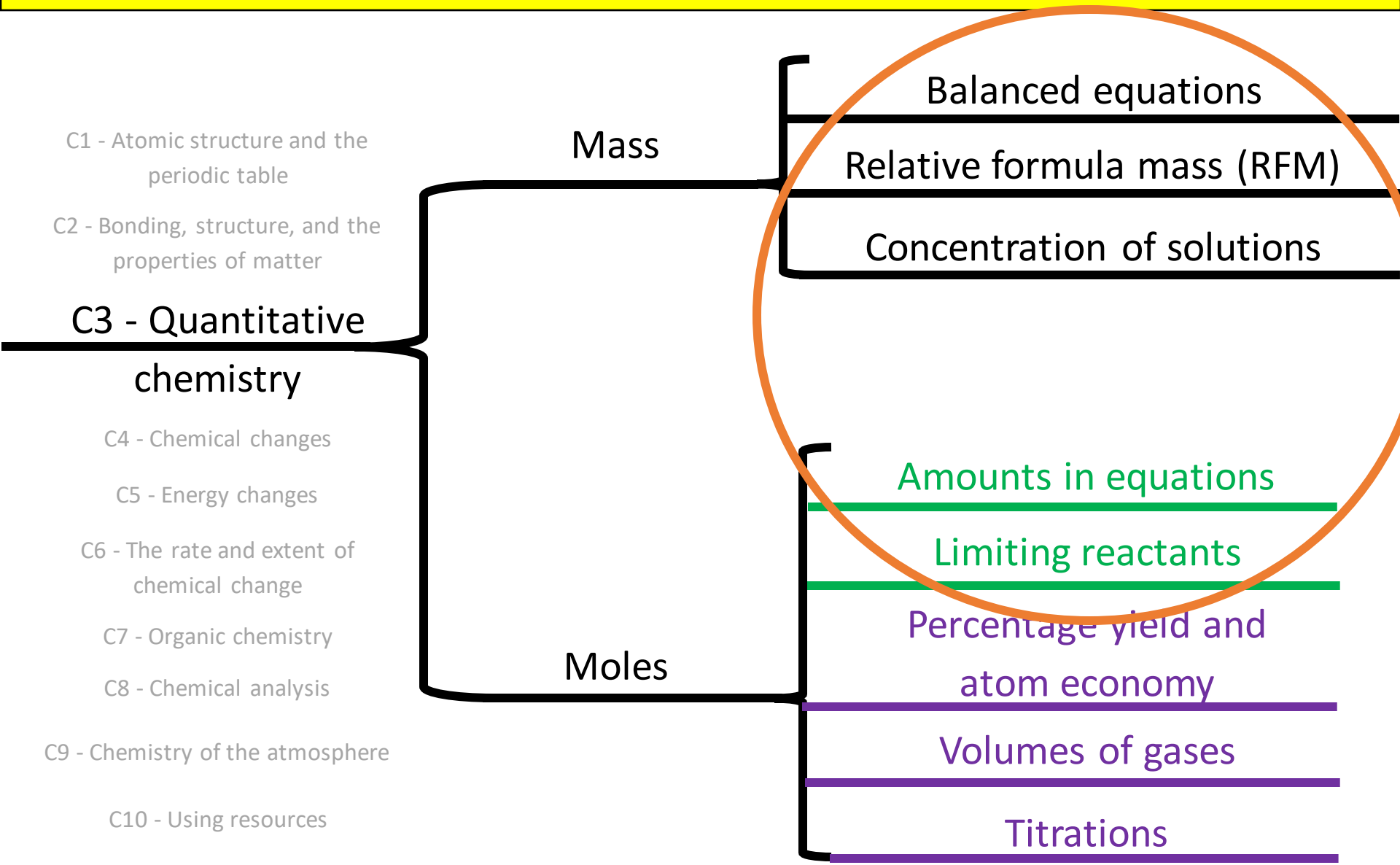
Describe what could be done to solid sodium chloride to make it conduct electricity. It could be melted or it could be dissolved.	Explain why oxygen (O_2) is a gas at room temperature. Oxygen (covalent) has a low boiling point due to weak intermolecular forces	Why are alloys stronger than pure metals? Different sized atoms means the layers are disrupted, so atoms can't slide over each other.
Why do polymers have high melting points? The atoms are bonded with strong covalent bonds that need a lot of energy to break.	What is the mass number of aluminium? 27 	How many of each atom are in the following compounds? H_2SO_4 = 2 H, 1 S, 4 O $CaCO_3$= 1 Ca, 1 A, 3 O 2 CaOH = 2Ca, 2O, 2H 3 $MgCl_2$= 3 Mg, 6 Cl

Independent *= concentration of acid*

Dependent *= temperature change*

Control variables *= VOLUME of acid, VOLUME of alkali, concentration of alkali, starting temperature*

C3 - Quantitative chemistry



TRIPLE **HIGHER**

DECODE IT NOW

Word:

Relative (tier 2)

Define it:
Considered in relation or in proportion to something else

Write a sentence of your own that uses the word relative.

Write your own definition of the word **relative.**

Which subjects or topics will this word be relevant to?

Link it (similar words):
comparative, comparable, correlative

Digging Deeper:

Relative can also be used to describe a person connected by blood or marriage (family) e.g. brother, sister

Use it:

The masses of protons, electrons and neutrons are all relative to each other.

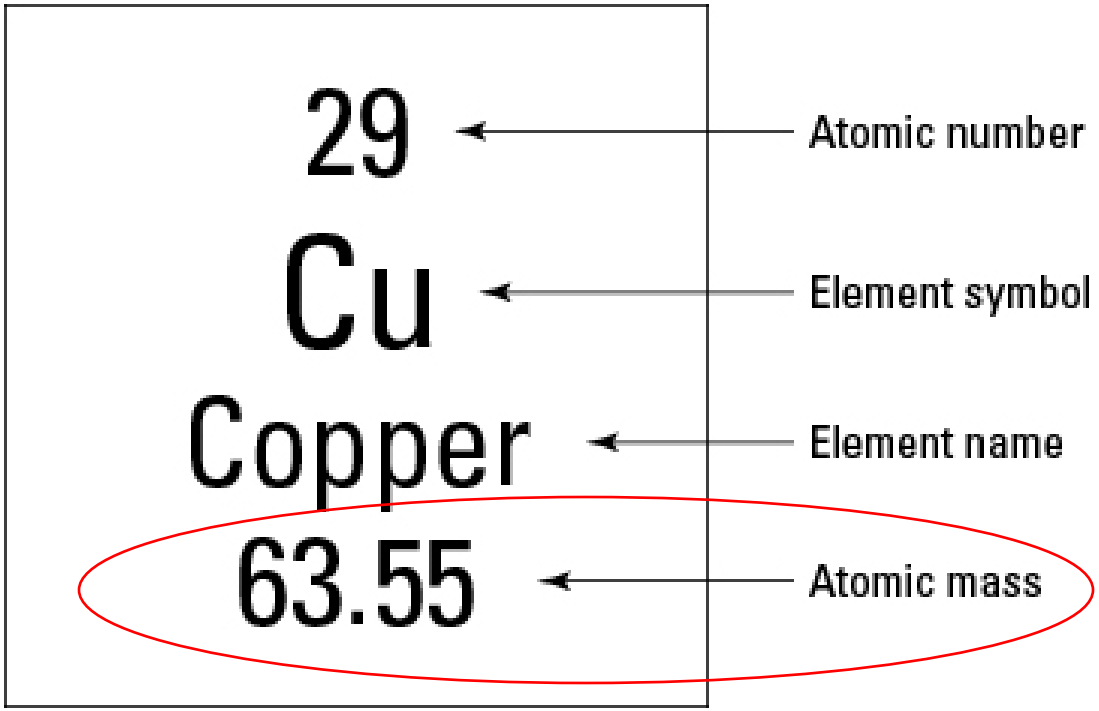
Deconstruct it (Root word):

The word **relative** is derived from the Latin **word** relativum, which means having relation to or dependence on something else.

The ***Relative Atomic Mass (RAM)*** is the average mass of an **atom.**

The atomic mass is **always the biggest number** associated with that element in the periodic table.

I Do



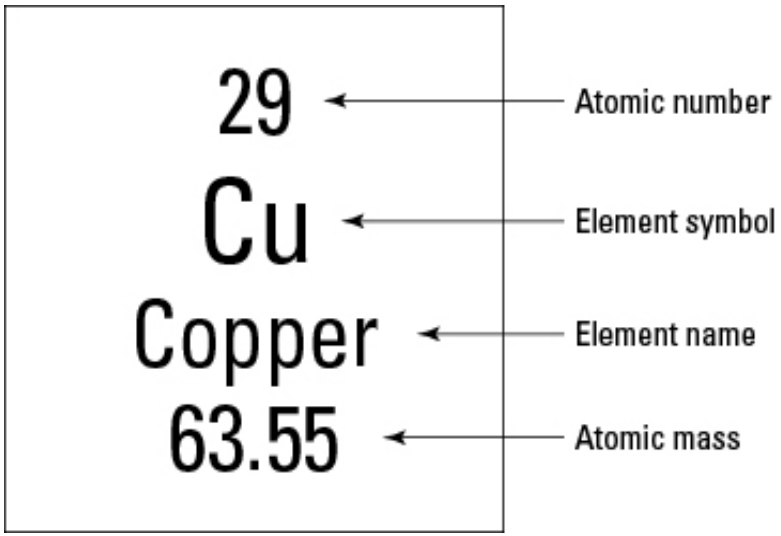
Hint:

*Think of the **mass number** as the **most massive number!***

The RAM of copper is 63.55, not 29.

*Due to **isotopes!** (next slide…)*

LO: **Define** RFM and RAM



Challenge *– Why is the mass number of copper a decimal?*

Due to ***isotopes!*** *Isotopes are atoms with the same number of protons but a* ***different number of neutrons****:*

Some Cu atoms have a mass of 63. Some Cu atoms have a mass of 65:

$^{63}_{29}Cu$

p = 29
e = 29
n = 34

$^{65}_{29}Cu$

p = 29
e = 29
n = 36

The atomic mass number on the periodic table in an ***average mass of all Cu atoms,*** *so it is a decimal number.*

The ***Relative Formula Mass (RFM)*** is the average mass of an **compound.**

It is the **total sum** of the masses of each atom in a compound.

e.g. water, H_2O

1	1	16
H	**H**	**O**
hydrogen	hydrogen	oxygen
1	1	8

Relative Formula Mass of water is 1+1+16 = 18!

The ***Relative Formula Mass (RFM)*** is the average mass of an **compound.**

It is the **total sum** of the masses of each atom in a compound.

e.g. salt, NaCl

23	35.5
Na	**Cl**
sodium	chlorine
11	17

Relative Formula Mass of NaCl is 23+35.5 = 58.5!

The RAM and RFM is easy for you to work out in your exams, as long as you have your trusty periodic table (AKA your best friend in any chemistry test!)

1	2											3	4	5	6	7	0
							1 H hydrogen 1										4 He helium 2
7 Li lithium 3	9 Be beryllium 4											11 B boron 5	12 C carbon 6	14 N nitrogen 7	16 O oxygen 8	19 F fluorine 9	20 Ne neon 10
23 Na sodium 11	24 Mg magnesium 12											27 Al aluminium 13	28 Si silicon 14	31 P phosphorus 15	32 S sulfur 16	35.5 Cl chlorine 17	40 Ar argon 18
39 K potassium 19	40 Ca calcium 20	45 Sc scandium 21	48 Ti titanium 22	51 V vanadium 23	52 Cr chromium 24	55 Mn manganese 25	56 Fe iron 26	59 Co cobalt 27	59 Ni nickel 28	63.5 Cu copper 29	65 Zn zinc 30	70 Ga gallium 31	73 Ge germanium 32	75 As arsenic 33	79 Se selenium 34	80 Br bromine 35	84 Kr krypton 36
85 Rb rubidium 37	88 Sr strontium 38	89 Y yttrium 39	91 Zr zirconium 40	93 Nb niobium 41	96 Mo molybdenum 42	[98] Tc technetium 43	101 Ru ruthenium 44	103 Rh rhodium 45	106 Pd palladium 46	108 Ag silver 47	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	128 Te tellurium 52	127 I iodine 53	131 Xe xenon 54
133 Cs caesium 55	137 Ba barium 56	139 La* lanthanum 57	178 Hf hafnium 72	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 Os osmium 76	192 Ir iridium 77	195 Pt platinum 78	197 Au gold 79	201 Hg mercury 80	204 Tl thallium 81	207 Pb lead 82	209 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111	Elements with atomic numbers 112 – 116 have been reported but not fully authenticated						

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.

We Do

Exam example 1:

Calculate the relative formula mass (M_r) of lithium oxide (Li_2O).

Relative atomic masses (A_r): Li = 7 O = 16

$Li_2O = (7 \times 2) + 16$

$= 30$

Relative formula mass = _____

(2)

Exam example 2:

The formula for the chemical compound magnesium sulphate is $MgSO_4$.

Calculate the relative formula mass (M_r) of this compound. (Show your working.)

$MgSO_4 = 24 + 32 + (16 \times 4)$

$= 120$

(Total 2 marks)

LO: Calculate percentage by mass of an element in a compound

Exam example 3:

You Do It Alone

Group 2 metal carbonates thermally decompose to produce a metal oxide and a gas.

(a) Give the formula of each product when calcium carbonate ($CaCO_3$) is heated.

CaO and CO_2

(2)

(b) The relative formula mass (M_r) of a Group 2 metal carbonate is 197

Relative atomic masses (A_r): C = 12 O = 16

Calculate the relative atomic mass (A_r) of the Group 2 metal in the metal carbonate.

Name the Group 2 metal.

Mr of CO3 = 12 + (16x3)

= 60

Mr of metal = 197 – 60

= 137

Relative atomic mass (A_r) = 137

Metal Barium

(3)

LO: Calculate percentage by mass of an element in a compound

As well as calculating RFM, you need to be able to calculate the percentage by mass of an element in a compound…

This sounds confusing, but it is simply working out one number as a percentage of another!

*'Value' is the **mass of the element** you are trying to work out.*

$$\frac{Value}{Total} \times 100$$

*'Total' is the **total mass of the whole compound**.*

LO: Calculate percentage by mass of an element in a compound

Exam example 1:

I Do

Follow the steps to find the percentage of iron in iron oxide.

Relative atomic masses: O 16; Fe 56.

(i) Step 1

Calculate the relative formula mass of iron oxide, Fe_2O_3.

Mr of iron oxide = (56 x 2) + (16 x 3)

= **160**

(1)

(ii) Step 2

Calculate the total relative mass of just the iron atoms in the formula, Fe_2O_3.

Mr of iron = 56 x 2 = **112**

(1)

(iii) Step 3

Calculate the percentage (%) of iron in the iron oxide, Fe_2O_3.

% of iron in iron oxide = (112 ÷ 160) x 100

= 70%

Percentage of iron _____ %

(1)

(Total 3 marks)

Exam example 2:

We Do

The percentage by mass of oxygen in carbon dioxide (CO_2) is calculated by the equation:

$$\text{percentage by mass} = \frac{\text{number of atoms of O} \times \text{Relative atomic mass of oxygen (O)}}{\text{relative molecular mass of carbon dioxide } (CO_2)} \times 100$$

Relative atomic masses (A_r): C = 12 O = 16

Calculate the percentage by mass of oxygen in carbon dioxide (CO_2).

Total mass of oxygen = 2 x 16 = **32**

Total mass of CO_2 = (2 x 16) + 12 = **44**

$$\frac{32}{44} \text{ x } 100 = 72.7\%$$

Percentage by mass of oxygen = **72.7** %

(3)

LO: Calculate percentage by mass of an element in a compound

We Do

Exam example 3:

Calculate the percentage by mass of titanium in titanium(IV) chloride ($TiCl_4$).

Give your answer to 3 significant figures.

Relative atomic masses (A_r): Cl = 35.5; Ti = 48

Total mass of titanium = 48

Total mass of $TiCl_4$ = 48 + (35.5 x 4) = 190

(48 / 190) x 100 = **25.26%**

Percentage of titanium by mass = **25.3** %

(3)

LO: Calculate percentage by mass of an element in a compound

You Do It Alone

Exam example 4:

Beryllium is found in beryllium aluminium silicate.

The formula of beryllium aluminium silicate is $Be_3Al_2(SiO_3)_6$

(b) What is the ratio of atoms of each element in beryllium aluminium silicate?

Ratio of Be : Al : Si : O = **3 : 2 : 6 : 18**

(1)

(c) What percentage by mass of beryllium is in beryllium aluminium silicate?

Give your answer to 2 significant figures.

Relative atomic mass (A_r) of Be = 9

Relative formula mass (M_r) of $Be_3Al_2(SiO_3)_6$ = 537

Total mass of Be = 3 x 9 = **36**

(36 / 537) x 100 = 5.02%

Percentage of beryllium = **5.0%** %

(2)

Describe the measurement of amounts of substances in moles

What is a mole?

Challenge *– How much would one mole of magnesium weigh?*
How much would one mole of water (H_2O) weigh?

Describe the measurement of amounts of substances in moles

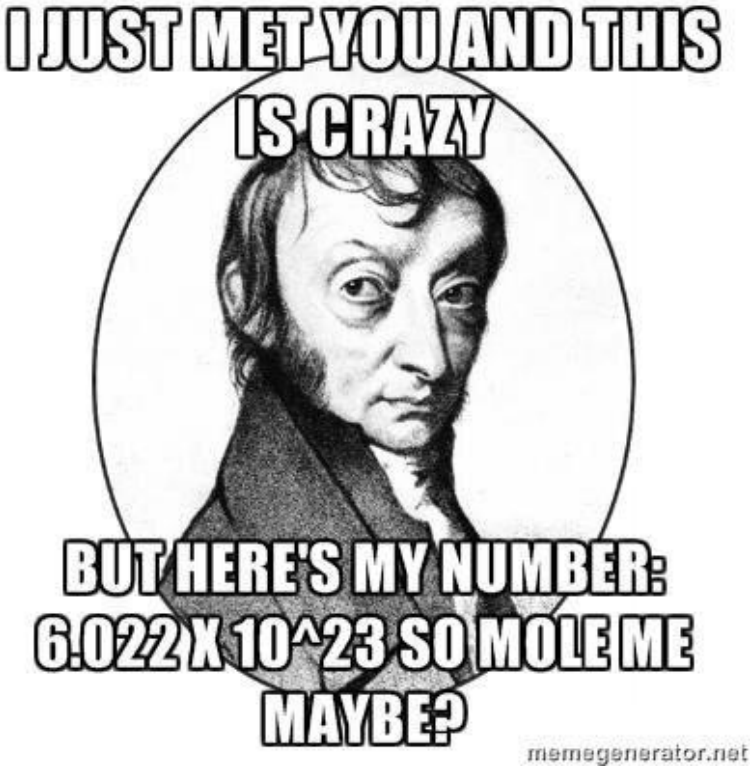
How big is a mole?

One mole of any substance contains 6.02 x 10^{23} atoms.

One mole of any substance contains **exactly the same amount of particles** as one mole of any other substance.

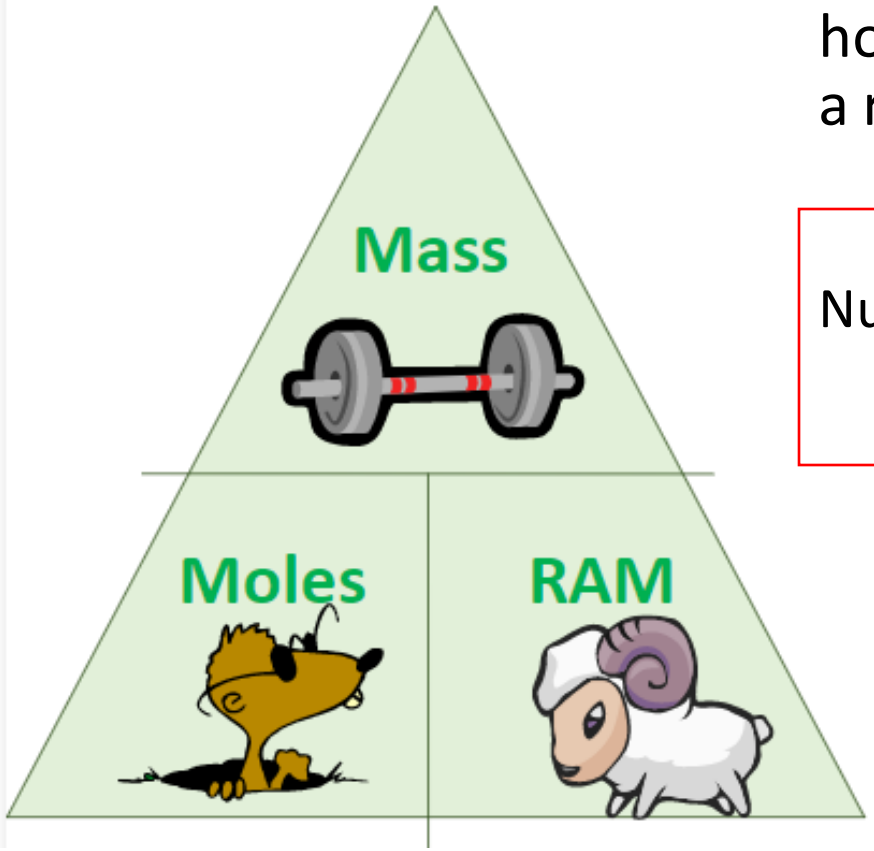
The mass of one mole of an substance (in grams) is equal to its RFM.

Avogadro's constant
= ***6.02 x 10^{23}***



https://www.youtube.com/watch?v=3Cq1Std7Mb8
Play up to 1:47

Why do we need to know about moles?



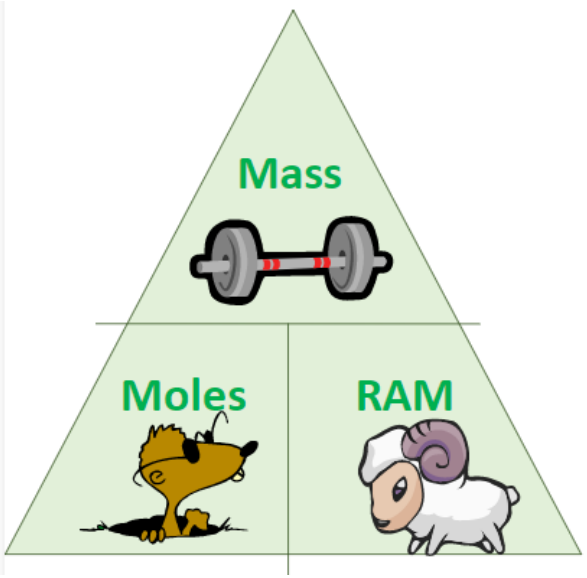
We can use this formula to work out how much of a substance we need in a reaction:

$$\text{Number of moles} = \frac{\text{Mass (g)}}{\text{Formula Mass}}$$

Questions involving moles

Calculate the number of moles

Calculate the mass



$$\text{Number of moles} = \frac{\text{Mass (g)}}{\text{Formula Mass}}$$

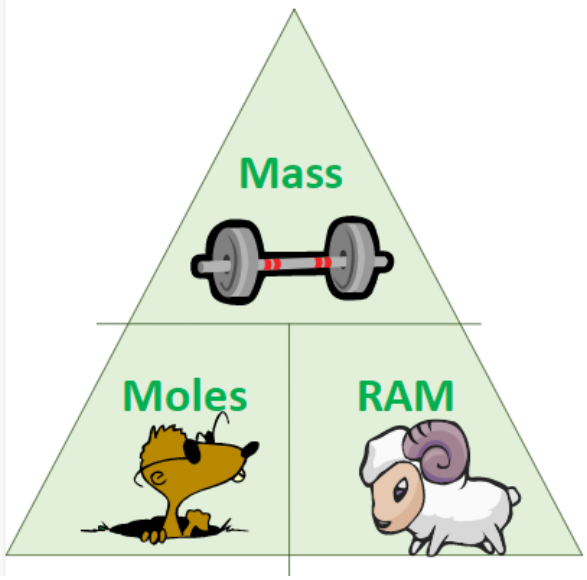
I Do

Calculate the number of moles in 40 grams of sodium:

Moles = mass / RFM

Moles = 40 / 23

Moles = 1.74 (3sf)



$$\text{Number of moles} = \frac{\text{Mass (g)}}{\text{Formula Mass}}$$

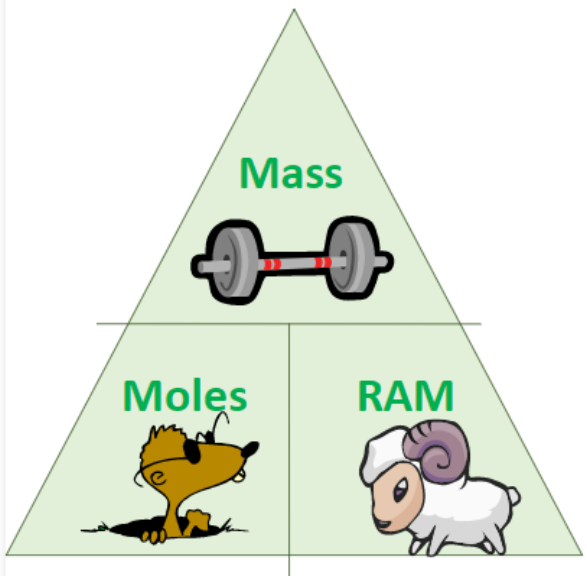
We Do

Calculate the number of moles in 24 grams of magnesium:

Moles = mass / RFM

Moles = 24 / 12

Moles = 2.00 (3sf)



$$\text{Number of moles} = \frac{\text{Mass (g)}}{\text{Formula Mass}}$$

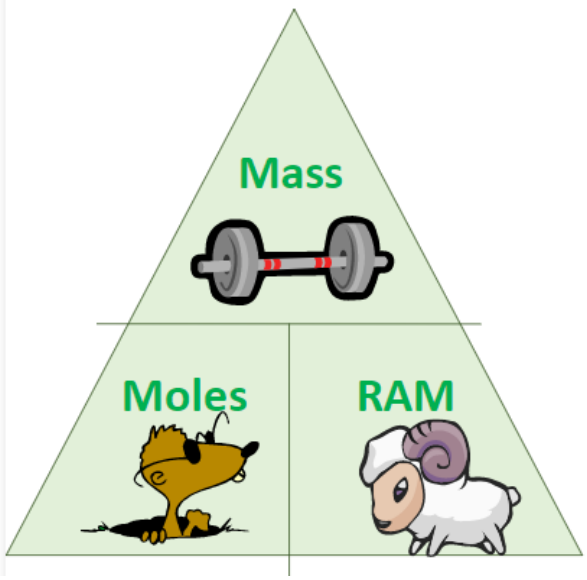
We Do

Calculate the mass of 10 moles of magnesium:

Mass = moles x RFM

Mass = 10 x 24

Mass = 240 grams



$$\text{Number of moles} = \frac{\text{Mass (g)}}{\text{Formula Mass}}$$

Exam example 1:

I Do

A 0.050 mol sample of a hydrocarbon was burned in excess oxygen.

The products were 3.60 g of water and 6.60 g of carbon dioxide.

(i) Calculate the number of moles of carbon dioxide produced.

Relative atomic masses: C = 12; O = 16.

Moles = mass / RFM

Moles = 6.60 / 44

Moles of carbon dioxide = **0.15 moles**

(2)

You Do It Alone

Exam example 2:

A bag of fertiliser contains 14.52 kg of ammonium nitrate (NH_4NO_3).

Relative formula mass (M_r): NH_4NO_3 = 80

Calculate the number of moles of ammonium nitrate in the bag of fertiliser.

Give your answer in standard form to 2 significant figures.

mass = 14 520 g (1)

moles = 14 520 g / 80 (1)

= 181.5 (mol) (1)

= 1.8 × 102 (mol) (1)

Moles of ammonium nitrate = _____ mol

(4)

Exam example 3:

We Do

Calculate the **number of molecules** in 14 g of carbon dioxide.

Give your answer in standard form.

Relative atomic masses (A_r): C = 14; O = 16

Moles = mass / RFM

= 14 / 44

= 0.3181818…

1 mole has 6.022×10^{23} molecules

$0.31818… \times 6.022 \times 10^{23} = 1.91 \times 10^{23}$ molecules

Answer = ***1.91×10^{23}*** molecules

(4)

LO: **Calculate** the moles of substances in a balanced symbol equation.

LET'S RECAP...

Because of the **conservation of mass**! Mass reactants = mass products.

Challenge: What do the large numbers in balancing equations show?

LO: Calculate the moles of substances in a balanced symbol equation.

Balanced equations can show us how many moles of reactants can be used to produce a certain amount of products:

e.g. $Mg + 2HCl \rightarrow MgCl_2 + H_2$

*1 **mole** of magnesium reacts with 2 **moles** of hydrochloric acid…*

*…to form 1 **mole** of magnesium chloride and 1 **mole** of hydrogen.*

Remember, everything is directly proportional! If you double the moles on the reactants side, you have to double the moles on the products side:

e.g. $2Mg + 4HCl \rightarrow 2MgCl_2 + 2H_2$

LO: Calculate the moles of substances in a balanced symbol equation.

Example:

How many moles of H_2O will be made when **six moles** of propane fuel react with oxygen?

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

If you put a 6 in front of C_3H_8 (6 moles of propane), then you have to multiply all other mole numbers by 6.

$$6C_3H_8 + 30O_2 \rightarrow 18CO_2 + 24H_2O$$

*So **24 moles** of water would be made!*

LO: Calculate the moles of substances in a balanced symbol equation.

Exam example:

Calcium oxide (quicklime) is made by heating calcium carbonate (limestone).

calcium carbonate	→	calcium oxide	+	carbon dioxide
100 g		?		44 g

The conservation of mass says that mass reactants = mass of products.

(a) 44 grams of carbon dioxide is produced when 100 grams of calcium carbonate is heated.

Calculate the mass of calcium oxide produced when 100 grams of calcium carbonate is heated.

100g – 44g = **66g**

mass _____ g

(1)

(b) What mass of carbon dioxide could be made from 100 tonnes of calcium carbonate?

mass **44** tonnes

(1)

(Total 2 marks)

*If **100g** of calcium carbonate makes **44g** of carbon dioxide, how much would **100 tonnes** make?*

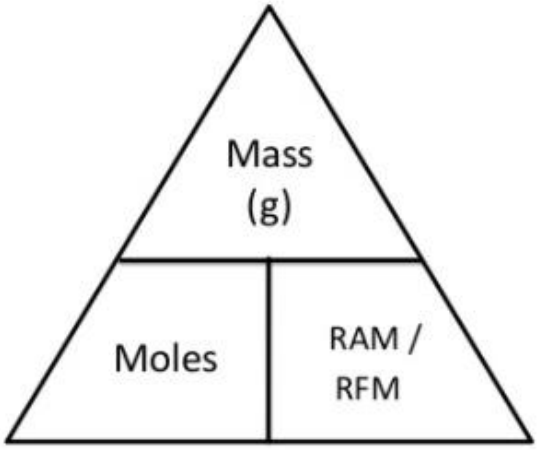
LO: Calculate the masses of reactants and products from a balanced symbol equation.

We can use the numbers from balanced equations…

… along with our moles equation…

… to **predict the mass** of products and reactants in chemical equations.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$



5.3.2.2 Amounts of substances in equations (HT only)

Students should be able to:

- calculate the masses of substances shown in a balanced symbol equation
- calculate the masses of reactants and products from the balanced symbol equation and the mass of a given reactant or product.

LO: Calculate the masses of reactants and products from a balanced symbol equation.

Task: Write down the flow map to show how to predict masses formed from balanced equations.

We are going to have a go at some practice questions together.

Step 1: Write down the **mass** of substance 1
(that you are given in the question)

↓

Step 2: Calculate the **RFM** for all substances involved.

↓

Step 3: Calculate the **moles** of substance 1
(using moles = mass ÷ RFM)

↓

Step 4: Use the **molar ratio** to calculate the moles of the substance 2

↓

Step 5: Calculate the **mass** of substance 2
(using mass = moles x RFM)

LO: Calculate the masses of reactants and products from a balanced symbol equation.

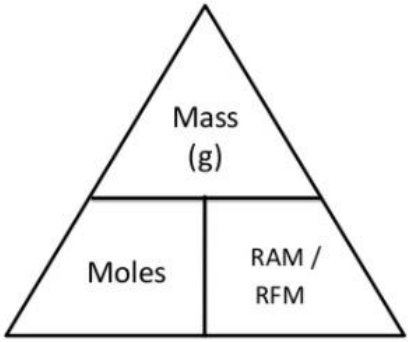
Question: *Calculate the mass of calcium oxide formed from 11 grams of calcium in the reaction below.*

$$2Ca + O_2 \rightarrow 2CaO$$

Mass:	**11** grams		0.275 mol x 56 = **15.4 grams**
RFM:	**40**		40 + 16 = **56**
Moles:	11 ÷ 40 = **0.275 mol**		**0.275 mol**
Ratio	2 Ca	:	2 CaO

Therefore, the molar ratio is 1:1.
If there are 0.275 moles of Ca, there are also 0.275 moles for CaO.

So **15.4 grams** of calcium oxide will be formed from 11 grams of calcium!



LO: Calculate the masses of reactants and products from a balanced symbol equation.

I Do

Q1. At the start of a reaction there was 174.5 g of uranium hexafluoride, UF_6.
Relative atomic masses: F 19; U 235

$$UF_6 + 3Ca \rightarrow 3CaF_2 + U$$

(i) Calculate the relative formula mass of uranium hexafluoride, UF_6.

_____

_____

Relative formula mass UF_6 = _____ g

(1)

(ii) Calculate the mass of uranium that would be produced from 134.5 g of uranium hexafluoride.

_____

_____

_____

_____

Mass of uranium = _____ g

(2)

LO: Calculate the masses of reactants and products from a balanced symbol equation.

We Do

Q2. (i) The formula for the chemical compound magnesium sulphate is $MgSO_4$.
Calculate the relative formula mass (M_r)of this compound. (Show your working.)

_____

_____

(2)

(ii) Magnesium sulphate can be made from magnesium and dilute sulphuric acid:

$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

Calculate the mass of magnesium sulphate that would be obtained from 4g of magnesium. (Show your working.)

_____

_____

_____

_____

_____

Answer_____ g | **(2)**

LO: Calculate the masses of reactants and products from a balanced symbol equation.

We Do

Q3. (i) Calculate the formula mass (M_r) of the compound iron (III) oxide, Fe_2O_3. (Show your working.)

_____

_____

_____

_____

_____

(3)

(ii) Calculate the mass of iron produced when 32g of iron (III) oxide is completely reduced by aluminium. (Show your working.)

The reaction is shown in the symbol equation:

$$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$$

_____

_____

_____

_____

Answer = _____ grams

(3)

LO: Calculate the masses of reactants and products from a balanced symbol equation.

You Do It Together

Q4. The balanced symbol equation for the reaction is

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

Starting with 2 g of hydrogen, what mass of hydrogen chloride would be produced?
(Relative atomic masses: H = 1; Cl = 35.5)

_____

_____

_____

_____

Mass of hydrogen chloride = _____ g

(Total 3 marks)

LO: Calculate the masses of reactants and products from a balanced symbol equation.

You Do It Together

Q5. $GeO_2 + 2H_2 \rightarrow Ge + 2H_2O$

Calculate the mass of germanium which could be made from 525 g of germanium oxide.
(Relative atomic masses: Ge = 73; O = 16).

_____

_____

_____

_____

Mass _____ g

(3)

LO: Calculate the masses of reactants and products from a balanced symbol equation.

You Do It Alone

Q6. A student wanted to make 11.0 g of copper chloride.

The equation for the reaction is:

$$CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$$

Relative atomic masses, A_r: H = 1; C = 12; O = 16; Cl = 35.5; Cu = 63.5

Calculate the mass of copper carbonate the student should react with dilute hydrochloric acid to make 11.0 g of copper chloride.

_____

_____

_____

_____

Mass of copper carbonate = _____ g

(4)

LO: Calculate the masses of reactants and products from a balanced symbol equation.

You Do It Alone

Needs to be in grams!

Q7. $4Na(s) + TiCl_4(l) \rightarrow Ti(s) + 4NaCl(s)$

Calculate the mass of titanium that can be extracted from 570 kg of titanium chloride.

Relative atomic masses: Cl 35.5; Ti 48.

Mass of titanium = _____ kg

(Total 3 marks)

LO: Calculate the masses of reactants and products from a balanced symbol equation.

You Do It Alone

Q8.

Limestone is a useful mineral. Every day, large amounts of limestone are heated in limekilns to produce lime. Lime is used in the manufacture of iron, cement and glass and for neutralising acidic soils.

$$CaCO_3 \rightleftharpoons CaO + CO_2$$

Needs to be in grams!

Calculate the mass of lime, CaO, that would be produced from 250 tonnes of limestone, $CaCO_3$.

Relative atomic masses: C 12; O 16; Ca 40.

Mass of lime = _____ tonnes

(3)

LO: Calculate the masses of reactants and products from a balanced symbol equation.

You Do It Alone

Q9. Ammonia is manufactured from nitrogen and hydrogen.
The equation for the reaction between them is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Calculate the mass, in tonnes, of ammonia which could be produced from 560 tonnes of nitrogen.

The relative atomic masses are: H 1; N 14.

_____

_____

_____

Mass of ammonia = _____ tonnes

(3)

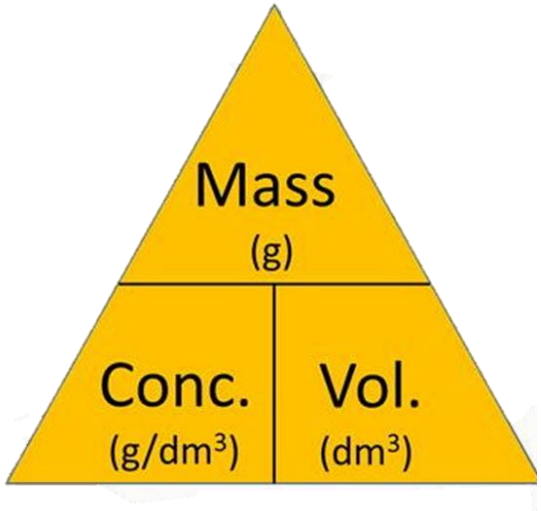
Needs to be in grams!

LO: **Describe** the relationship between mass, volume and concentration

In chemistry we can calculate concentration by working out the ***number of grams in a dm³ of solution.***

Concentration (g/dm³) = Mass (g) ÷ Volume (dm³)

1 dm^3 = 1000cm^3 (or a litre)



Task: Use the triangle to write the equations for calculating mass and volume.

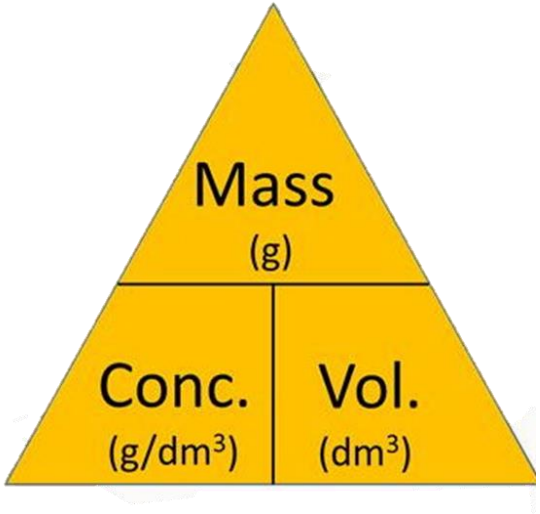
Mass (g) = concentration (g/dm^3) x volume (dm^3)

Volume (dm^3) = mass (g) ÷ concentration (g/dm^3)

LO: **Describe** the relationship between mass, volume and concentration

Concentration (g/dm^3) = Mass (g) ÷ Volume (dm^3)

1 dm^3 = 1000cm^3 (or a litre)



Example:

A solution has **40 grams** of solute dissolved in **20dm^3** of solvent. What is the concentration?

Concentration = mass (g) ÷ volume (dm^3)

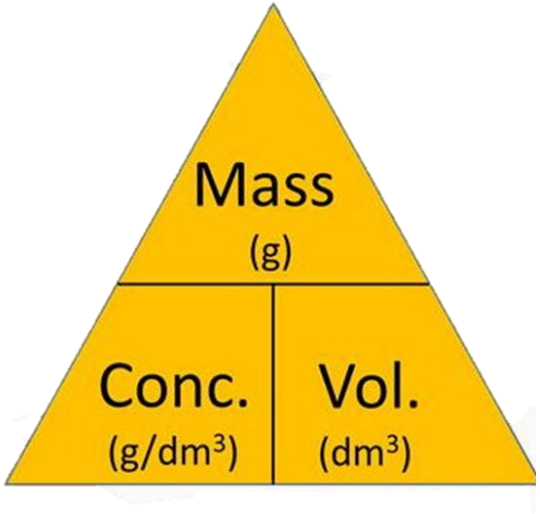
= 40g ÷ 20dm^3

= 2 g/dm^3

LO: **Describe** the relationship between mass, volume and concentration

$$\text{Concentration (g/dm}^3\text{)} = \text{Mass (g)} \div \text{Volume (dm}^3\text{)}$$

$1\ dm^3 = 1000cm^3$ (or a litre)



Example:

A solution has a concentration **6g/dm³.** What is the mass of solute in **100dm³** of this solution?

Mass (g) = concentration (g/dm^3) x volume (dm^3)

= $6g/dm^3$ x $100dm^3$

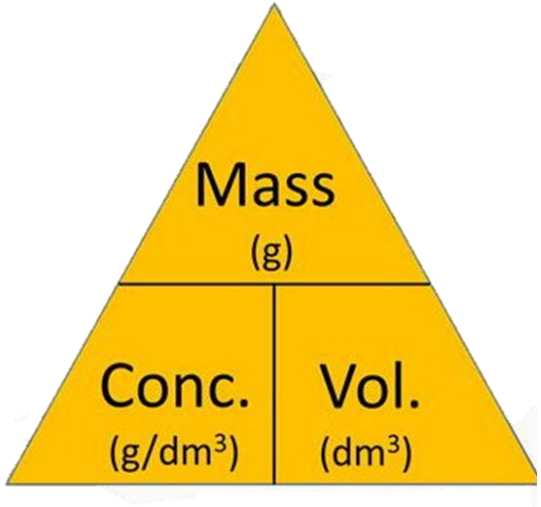
= 600 g

We Do

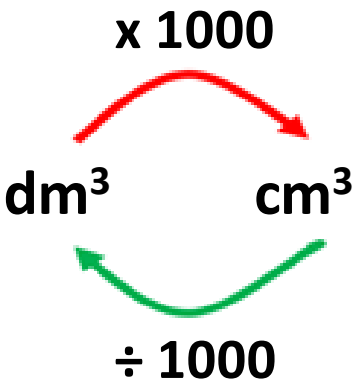
LO: **Describe** the relationship between mass, volume and concentration

Concentration (g/dm^3) = Mass (g) ÷ Volume (dm^3)

1 dm^3 = 1000cm^3 (or a litre)



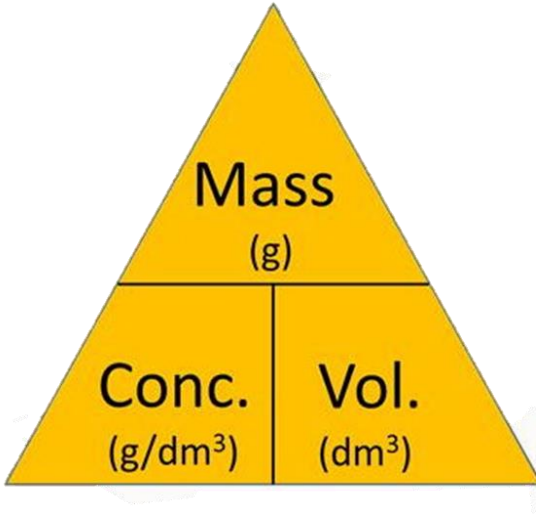
You must ensure you are working in dm^3, which may mean you need to do a conversion first (mean examiners!!)



LO: **Describe** the relationship between mass, volume and concentration

Concentration (g/dm^3) = Mass (g) ÷ Volume (dm^3)

1 dm^3 = 1000cm^3 (or a litre)



Example:

A solution has **50 grams** of solute dissolved in **2000cm^3** of solvent. What is the concentration?

Concentration = mass (g) ÷ volume (dm^3)

2000 cm^3 = 2 dm^3

= 50g x 2dm^3

= 100 g/dm^3

LO: **Describe** the relationship between mass, volume and concentration

The sodium hydroxide solution in this investigation contains 80 grams per dm^3

You Do It Alone

The students use 40 cm^3 of sodium hydroxide solution.

Calculate the mass of sodium hydroxide in 40 cm^3

$40cm^3 = 0.04dm^3$

$Mass = 0.04dm^3 \times 80\ g/dm^3$

= 3.2 grams

Mass = **= 3.2 grams** g

(3)

The copper chloride solution used in the investigation contained 300 grams per dm^3 of solid $CuCl_2$ dissolved in 1 dm^3 of water.

The students used 50 cm^3 of copper chloride solution in each experiment.

Calculate the mass of solid copper chloride used in each experiment.

$50cm^3 = 0.05dm^3$

$Mass = 0.05dm^3 \times 300\ g/dm^3$

Mass = **= 15 grams** g

(3)

Titrations (C3) TRIPLE ONLY

Monday, 25 September 2023

Do it now:

1. How is the periodic table arranged?
2. Why did Mendeleev leave gaps in his periodic table?
3. What does the mass number of an atom tell you?
4. What is an isotope?
5. What did the gold foil experiment show?
6. Complete the word equations:
   Magnesium oxide + hydrochloric acid →
   Aluminium hydroxide + nitric acid →
   Barium carbonate + sulphuric acid →
7. What ion is present in all acids? What ion is present in all alkalis?

Challenge: Write a half equation showing a reaction between an acid and an alkali.
Extra challenge: Write the symbol equations for reactions in question 6.

Titrations (C3) TRIPLE ONLY
Monday, 25 September 2023

1. How is the periodic table arranged?

   Elements are arranged by increasing atomic (proton) number *(NOT MASS NUMBER!)*

2. Why did Mendeleev leave gaps in his periodic table?

   For undiscovered elements (that were later discovered.)

3. What does the mass number of an atom tell you?

   The number of protons + the number of neutrons

4. What is an isotope?

   Isotopes contain the same number of protons but a different number of neutrons, so isotopes have different mass numbers.

5. What did the gold foil experiment show?

   Most of the alpha particles passed straight through the foil. This showed that the majority of the atom is just empty space.
   A small number of alpha particles were deflected. This showed that there is a ball of positive charge in the centre of the atom (the nucleus).

Titrations (C3) TRIPLE ONLY

Monday, 25 September 2023

6. Complete the word equations:

   Magnesium oxide + hydrochloric acid → Magnesium chloride + water

   Aluminium hydroxide + nitric acid → Aluminium nitrate + water

   Barium carbonate + sulphuric acid → Barium sulphate + water + carbon dioxide

7. What ion is present in all acids? What ion is present in all alkalis?

   H+ ions are present in all acids. OH- ions are present in all alkalis.

Extra challenge: Write a half equation showing a reaction between an acid and an alkali.

$$H^+ + OH^- \rightarrow H_2O$$

Challenge: Write the symbol equations for reactions in question 6.

$$MgO + HCl \rightarrow MgCl_2 + H_2O$$

$$Al(OH)_3 + HNO_3 \rightarrow Al(NO_3)_3 + H_2O$$

$$BaCO_3 + H_2SO_4 \rightarrow BaSO_4 + H_2O + CO_2$$

C3 - Quantitative chemistry

C1 - Atomic structure and the periodic table

C2 - Bonding, structure, and the properties of matter

C3 - Quantitative chemistry

C4 - Chemical changes

C5 - Energy changes

C6 - The rate and extent of chemical change

C7 - Organic chemistry

C8 - Chemical analysis

C9 - Chemistry of the atmosphere

C10 - Using resources

Conservation of mass

- Balanced equations
- Relative formula mass (RFM)
- Concentration of solutions

Moles

- Amounts in equations
- Limiting reactants
- Percentage yield and atom economy
- Volumes of gases
- Titrations

TRIPLE **HIGHER**

Key definition:

Neutralisation *is when an* ***acid*** *reacts with a* ***base****, to form a* ***neutral*** *solution. A base that can dissolve in water is called an alkali.*

Bases can be **metal oxides** e.g. MgO or **metal hydroxides** e.g. LiOH.
If an acid and a metal oxide/hydroxide react together, salt and water are formed.

General word equation:

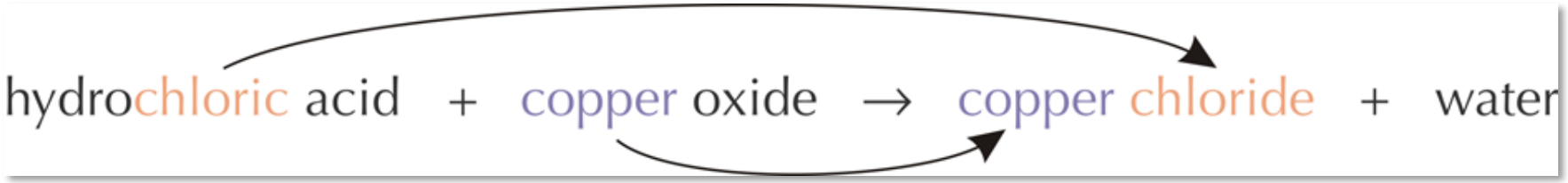
acid **+** ***metal oxide/metal hydroxide*** **→** ***salt*** **+** ***water***

Bases can also be **metal carbonates** e.g. calcium carbonate, $CaCO_3$.
If an acid and a metal carbonate react together, carbon dioxide is also formed:

General word equation:

acid **+** ***metal carbonate*** **→** ***salt*** **+** ***water*** **+** ***carbon dioxide***

How do we name the salts formed in neutralisation reactions?



ACID **BASE** **SALT** **WATER**

The first part of the salt comes from the metal in the base.

The second part of the salt comes from the acid used:
Nitric acid = nitrate
Sulphuric acid = sulphate
Hydrochloric acid = chloride

The first part of the salt comes from the metal in the base.

The second part of the salt comes from the acid used:
Nitric acid = nitrate
Sulphuric acid = sulphate
Hydrochloric acid = chloride

magnesium oxide	+	hydrochloric acid	→	magnesium chloride	+	water
BASE		**ACID**		**SALT**		**WATER**

The first part of the salt comes from the metal in the base.

The second part of the salt comes from the acid used:
Nitric acid = nitrate
Sulphuric acid = sulphate
Hydrochloric acid = chloride

sodium hydroxide + nitric acid → sodium nitrate + water

BASE **ACID** **SALT** **WATER**

The first part of the salt comes from the metal in the base.

The second part of the salt comes from the acid used:
Nitric acid = nitrate
Sulphuric acid = sulphate
Hydrochloric acid = chloride

aluminium oxide + hydrochloric acid → aluminium chloride + water

The first part of the salt comes from the metal in the base.

The second part of the salt comes from the acid used:
Nitric acid = nitrate
Sulphuric acid = sulphate
Hydrochloric acid = chloride

magnesium hydroxide + sulphuric acid → magnesium sulphate + water

The first part of the salt comes from the metal in the base.

The second part of the salt comes from the acid used:
Nitric acid (HNO_3) = nitrate
Sulphuric acid (H_2SO_4) = sulphate
Hydrochloric acid (HCl) = chloride

calcium carbonate + sulphuric acid → calcium sulphate + water + carbon dioxide

BASE **ACID**

Titrations

Strong acid + strong alkali → salt + water

= *NEUTRALISATION*

The products are ***only neutral if they are in exactly the right quantities.*** If not, either the acid or the alkali will be in excess.

If there is more acid than alkali to start with in a neutralisation reaction, what will happen?

- *The final solution will be acidic.*

Titrations

Strong acid + strong alkali → salt + water

= *NEUTRALISATION*

Titration is a method of measuring precise volumes in a neutralisation reaction.

The point at which an acid have reacted completely is called the ***end point***.

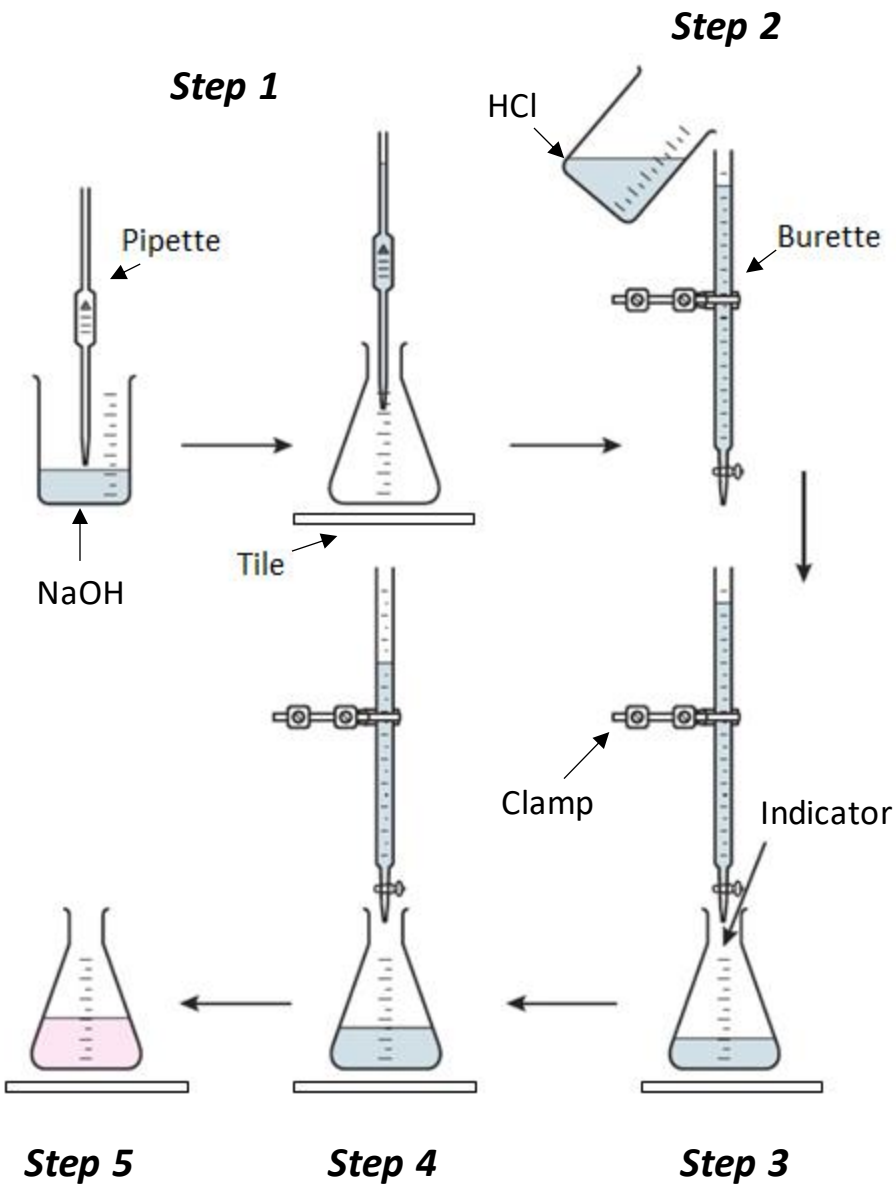
This is shown using an ***indicator***
e.g. p*henolphthalein – colour change* ***from pink to colourless***

https://www.youtube.com/watch?v=saRBT5oZfh8

https://www.youtube.com/watch?v=PVv76MUA6dc&feature=youtu.be

https://www.youtube.com/watch?v=vn3Rx3g1VPk

Titration method



Step 1:

Step 2:

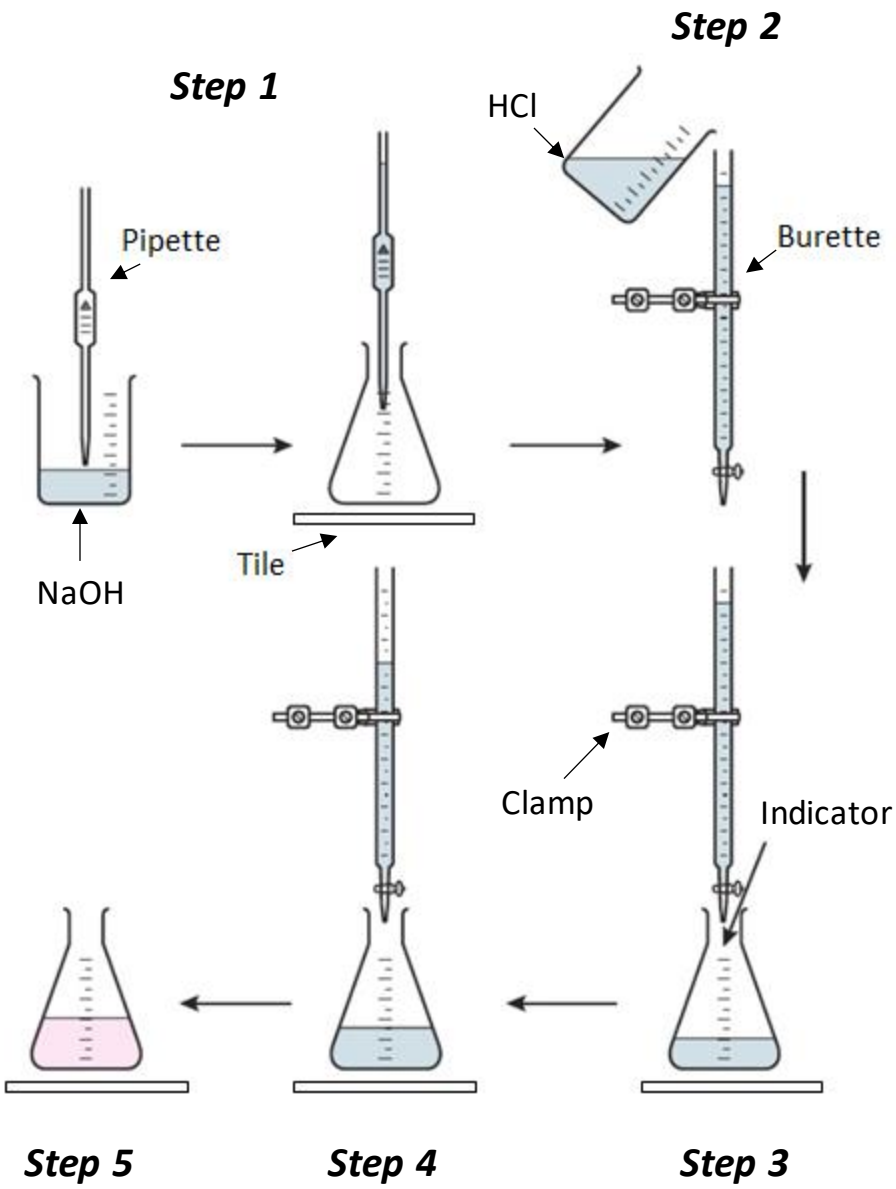
Step 3:

Step 4:

Step 5:

Step 6:

Titration method



Step 1: Use a pipette to measure **25cm^3 of sodium hydroxide** into a conical flask. Place the conical flask on a white tile.

Step 2: Carefully fill a burette with **hydrochloric acid** and place it in a clamp, ensuring the tap is closed.

Step 3: Place a few drops of **indicator** into the sodium hydroxide and swirl the conical flask. Phenolphthalein will turn the NaOH **pink**.

Step 4: Open the tap on the burette and **slowly add the hydrochloric acid** to the sodium hydroxide, whilst swirling the flask.

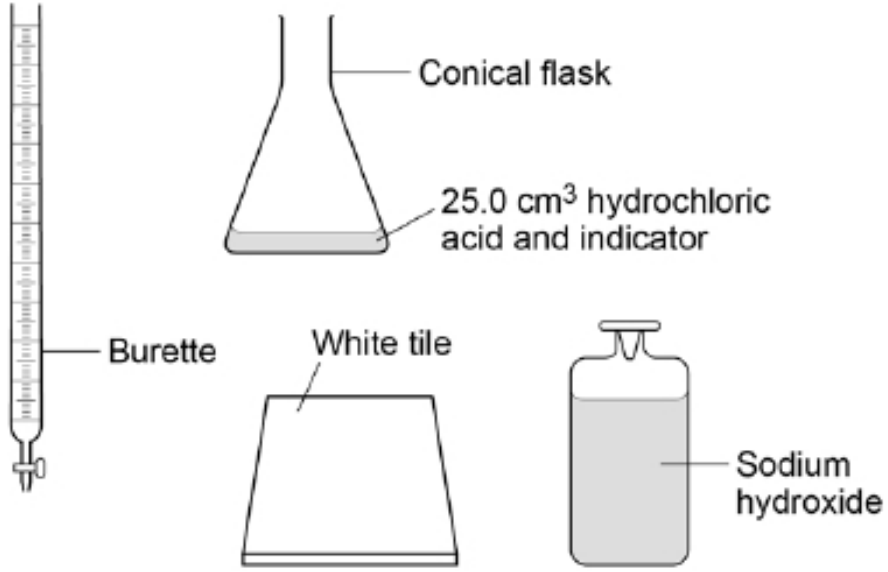
Step 5: When the solution turns from **pink to colourless**, the solution is neutral. **Record the volume of acid** added in total from the burette.

Step 6: Repeat the experiment 3 times and **calculate the mean** volume of acid used.

Exam practice

Sodium hydroxide reacts with hydrochloric acid.

The diagram shows apparatus that can be used to find the volume of sodium hydroxide reacting with 25.0 cm^3 hydrochloric acid.



(a) Describe a method to find the exact volume of sodium hydroxide that reacts with 25.0 cm^3 of hydrochloric acid.

(6)

Exam practice

fill burette with sodium hydroxide

1

add sodium hydroxide from the burette to the hydrochloric acid and indicator

1

stop when colour changes

1

measure volume used from burette

1

plus any **two** from:

- stand flask on white tile
- swirl
- add dropwise near the endpoint
- repeat

2

LO: **Describe** the relationship between mass, volume and concentration

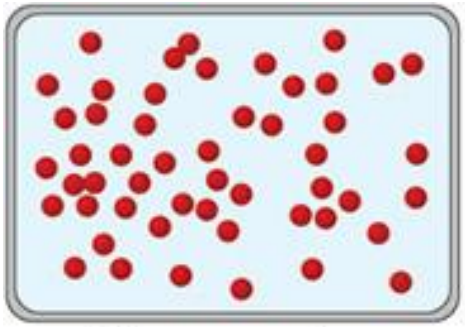
As well as knowing how to calculate moles from mass, you need to be able to calculate moles from concentration:

Key definition:

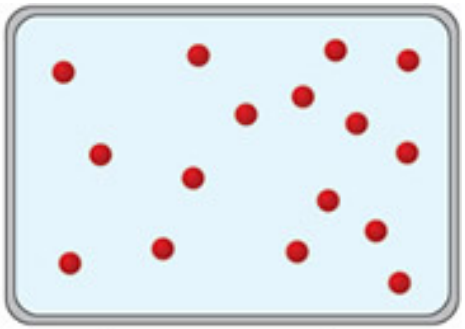
Concentration is a measure of how many solute particles are dissolved in a specific volume of solvent.

*If a solution is **more** concentrated then there are **more** solute particles present in the solvent.*

*If a solution is **less** concentrated (dilute) then there are **fewer** solute particles present in the solvent.*



High concentration



Low concentration

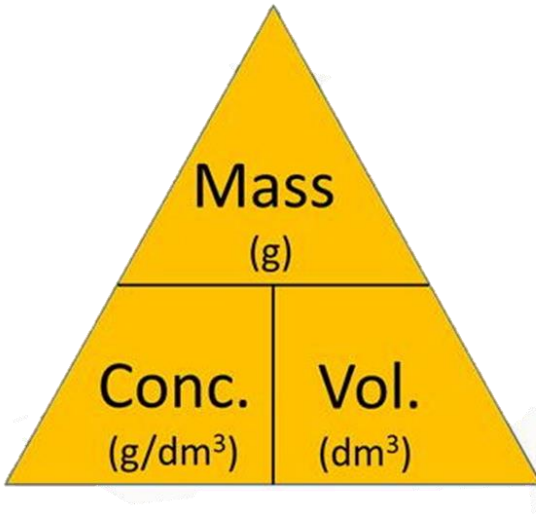
TRIPLE ONLY

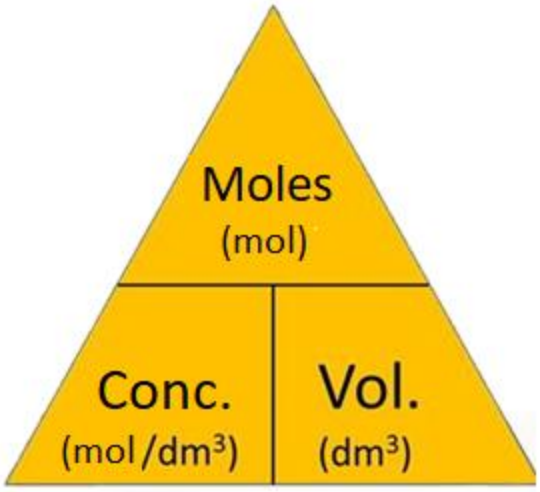
LO: Calculate concentration in mol/dm^3

Concentration (**g/dm^3**) = **Mass (g)** / Volume (dm^3)

1 dm^3 = 1000cm^3 (or a litre)

Concentration (**mol/dm^3**) = **Moles (mol)** / Volume (dm^3)

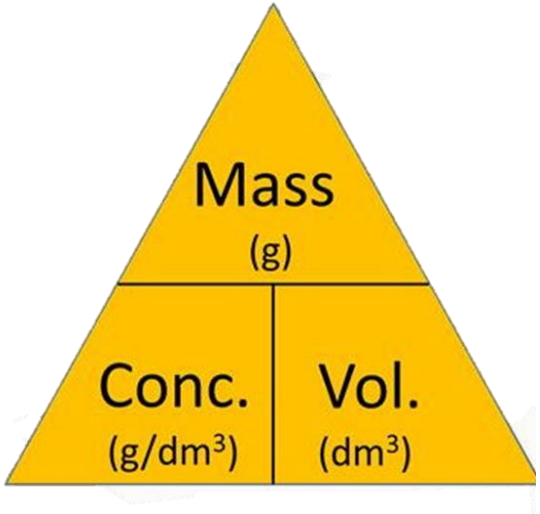




LO: **Describe** the relationship between mass, volume and concentration

Concentration (g/dm^3) = Mass (g) ÷ Volume (dm^3)

1 dm^3 = 1000cm^3 (or a litre)



Example:

A solution has **40 grams** of solute dissolved in **20dm^3** of solvent. What is the concentration?

Concentration = mass (g) ÷ volume (dm^3)

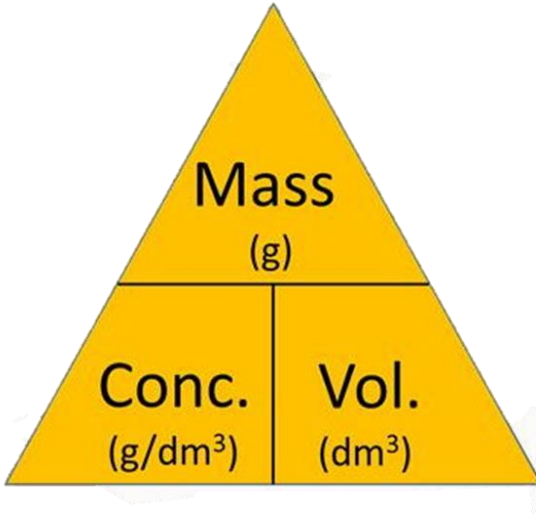
= 40g ÷ 20dm^3

= 2 g/dm^3

LO: **Describe** the relationship between mass, volume and concentration

$$\text{Concentration (g/dm}^3\text{)} = \text{Mass (g)} \div \text{Volume (dm}^3\text{)}$$

$1\ dm^3 = 1000cm^3$ (or a litre)



Example:

A solution has a concentration **6g/dm³.** What is the mass of solute in **100dm³** of this solution?

Mass (g) = concentration (g/dm^3) x volume (dm^3)

= $6g/dm^3$ x $100dm^3$

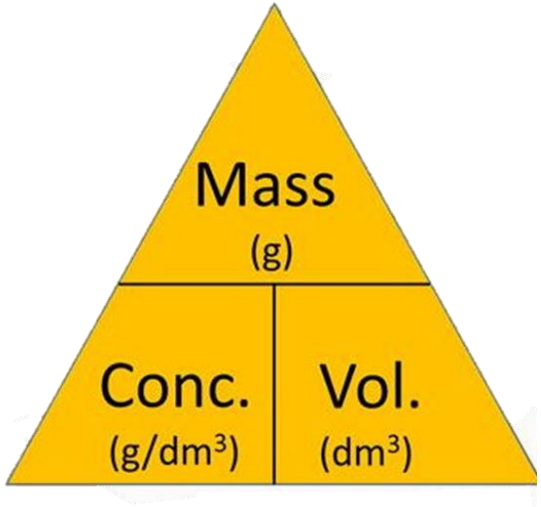
= 600 g

We Do

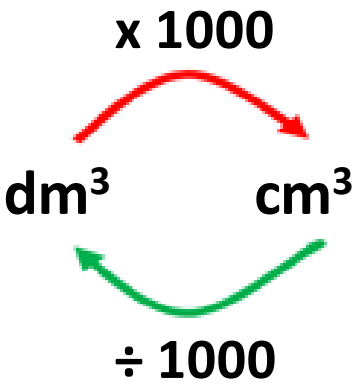
LO: **Describe** the relationship between mass, volume and concentration

Concentration (g/dm^3) = Mass (g) ÷ Volume (dm^3)

1 dm^3 = 1000cm^3 (or a litre)



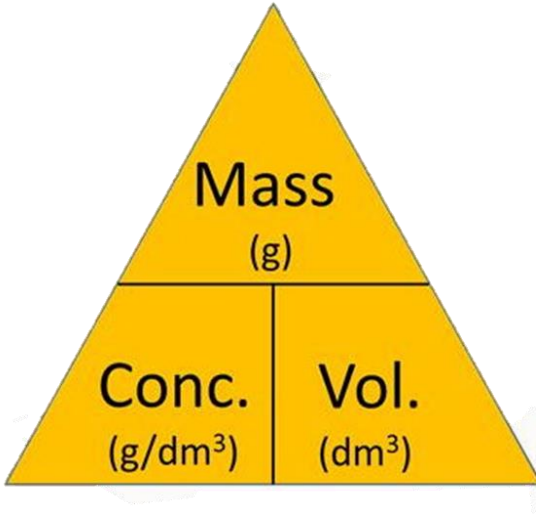
You must ensure you are working in dm^3, which may mean you need to do a conversion first (mean examiners!!)



LO: **Describe** the relationship between mass, volume and concentration

Concentration (g/dm^3) = Mass (g) ÷ Volume (dm^3)

1 dm^3 = 1000cm^3 (or a litre)



Example:

A solution has **50 grams** of solute dissolved in **2000cm^3** of solvent. What is the concentration?

Concentration = mass (g) ÷ volume (dm^3)

2000 cm^3 = 2 dm^3

= 50g x 2dm^3

= 100 g/dm^3

LO: **Describe** the relationship between mass, volume and concentration

You Do It Alone

The sodium hydroxide solution in this investigation contains 80 grams per dm^3

The students use 40 cm^3 of sodium hydroxide solution.

Calculate the mass of sodium hydroxide in 40 cm^3

$40cm^3 = 0.04dm^3$

$Mass = 0.04dm^3 \times 80\ g/dm^3$

= 3.2 grams

Mass = **= 3.2 grams** g

(3)

The copper chloride solution used in the investigation contained 300 grams per dm^3 of solid $CuCl_2$ dissolved in 1 dm^3 of water.

The students used 50 cm^3 of copper chloride solution in each experiment.

Calculate the mass of solid copper chloride used in each experiment.

$50cm^3 = 0.05dm^3$

$Mass = 0.05dm^3 \times 300\ g/dm^3$

Mass = **= 15 grams** g

(3)

LO: **Describe** the relationship between mass, volume and concentration

You Do It Alone

Calculate the mass of sodium hydroxide in 30.0 cm^3 of a 0.105 mol/dm^3 solution.

Relative formula mass (M_r): NaOH = 40

$$(\text{moles} =) \frac{30}{1000} \times 0.105$$

or 0.00315 (mol)

or

(mass per dm^3 =) 0.105 × 40

or 4.2 (g)

1

$$(\text{mass} = \frac{30}{1000} \times 0.105 \times 40)$$

= 0.126 (g)

1

LO: **Describe** the relationship between mass, volume and concentration

You Do It Alone

The student did another experiment using 20 cm^3 of sodium hydroxide solution with a concentration of 0.18 mol / dm^3.

Relative formula mass (M_r) of NaOH = 40

Calculate the mass of sodium hydroxide in 20 cm^3 of this solution.

(f) $\frac{20}{1000}$ × 0.18 = no of moles

or

0.15 × 40 g

1

0.144 (g)

1

Mark schemes for the following questions are in the notes section

Exam practice 1

A student titrated 25.0 cm^3 portions of dilute sulfuric acid with a 0.105 mol/dm^3 sodium hydroxide solution.

(c) The table below shows the student's results.

	Titration 1	**Titration 2**	**Titration 3**	**Titration 4**	**Titration 5**
Volume of sodium hydroxide solution in cm^3	23.50	21.10	22.10	22.15	22.15

The equation for the reaction is:

$$2\ NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2\ H_2O$$

Calculate the concentration of the sulfuric acid in mol/dm^3

Use only the student's concordant results.

Concordant results are those within 0.10 cm^3 of each other.

Concentration of sulfuric acid = _____ mol/dm^3

(5)

Exam practice 2

(c) A student used a pipette to add 25.0 cm^3 of sodium hydroxide of unknown concentration to a conical flask.

The student carried out a titration to find out the volume of 0.100 mol / dm^3 sulfuric acid needed to neutralise the sodium hydroxide.

Describe how the student would complete the titration.

You should name a suitable indicator and give the colour change that would be seen.

adds indicator, eg phenolpthalein / methyl orange / litmus added to the sodium hydroxide (in the conical flask)

*do **not** accept universal indicator*

1

(adds the acid from a) burette

1

with swirling **or** dropwise towards the end point **or** until the indicator just changes colour

1

until the indicator changes from pink to colourless (for phenolphthalein) or yellow to red
(for methyl orange) or blue to red (for litmus)

1

Exam practice 2

(d) The student carried out five titrations. Her results are shown in the table below.

	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Volume of 0.100 mol / dm^3 sulfuric acid in cm^3	27.40	28.15	27.05	27.15	27.15

Concordant results are within 0.10 cm^3 of each other.

Use the student's concordant results to work out the mean volume of 0.100 mol / dm^3 sulfuric acid added.

Mean volume = _____ cm^3

(2)

(e) The equation for the reaction is:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

Calculate the concentration of the sodium hydroxide.

Give your answer to three significant figures.

Concentration = _____ mol / dm^3

(4)

Exam practice 3

A student titrated citric acid with sodium hydroxide solution.

This is the method used.

1. Pipette 25.0 cm^3 of sodium hydroxide solution into a conical flask.
2. Add a few drops of thymol blue indicator to the sodium hydroxide solution.
   Thymol blue is blue in alkali and yellow in acid.
3. Add citric acid solution from a burette until the end-point was reached.

(b) Explain what would happen at the end-point of this titration.

Refer to the acid, the alkali and the indicator in your answer.

indicator changes colour

1

from blue to yellow

allow from blue to green

1

(when) the acid and alkali are (exactly) neutralised

or

(when) no excess of either acid or alkali

1

(3)

Exam practice 3

(d) The table shows the student's results.

	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Volume of citric acid solution in cm^3	13.50	12.10	11.10	12.15	12.15

The equation for the reaction is:

$$C_6H_8O_7 + 3\,NaOH \rightarrow C_6H_5O_7Na_3 + 3\,H_2O$$

The concentration of the sodium hydroxide was 0.102 mol / dm^3

Concordant results are those within 0.10 cm^3 of each other.

Calculate the concentration of the citric acid in mol / dm^3

Use only the concordant results from the table in your calculation.

You must show your working.

Concentration = _____ mol / dm^3

(5)