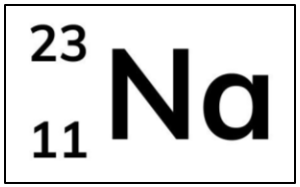
Quantitative chemistry (C3)

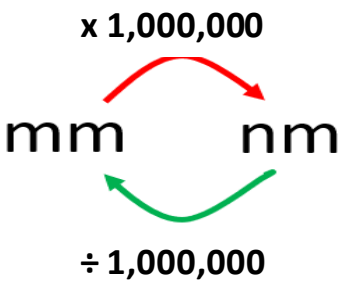
Monday, 25 September 2023

Do it now:

1. How is the periodic table arranged?
2. Why did Mendeleev leave gaps in his periodic table?
3. State the number of protons, neutrons and electrons in a sodium atom.



4. Draw the electronic configuration of sodium.
5. What does the mass number of an atom tell you?
6. What is an isotope?
7. State how many atoms of each element are in $Ca(OH)_2$?



Maths challenge!

The diameter of an atom ranges from about 0.1 to 0.5 nanometres**. Convert 0.1 nanometres into millimetres.**

Quantitative chemistry (C3)

Monday, 25 September 2023

1. How is the periodic table arranged?

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

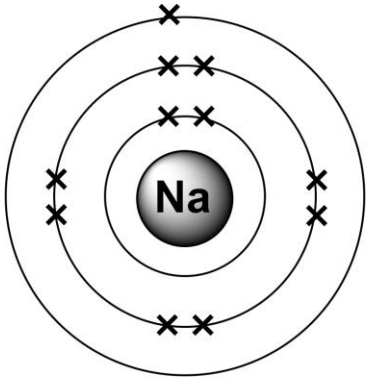
2. Why did Mendeleev leave gaps in his periodic table?

For undiscovered elements (that were later discovered)

3. State the number of protons, neutrons and electrons in a sodium atom.

Protons = 11, electrons = 11, neutrons = 23-11 = 12

4. Draw the electronic configuration of sodium.



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

The number of protons + the number of neutrons

6. What is an isotope?

Isotopes contain the same number of protons but a different number of neutrons.

7. State how many atoms of each element are in $Ca(OH)_2$?

1 calcium atom, 2 oxygen atoms and 2 hydrogen atoms.

Quantitative chemistry (C3)

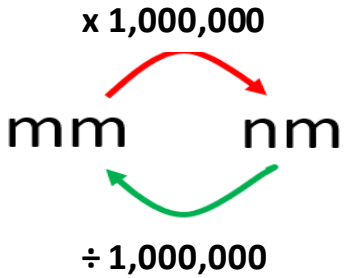
Monday, 25 September 2023

Maths challenge!

Convert 0.1 nanometres into millimetres.

0.1 nm = 0.1 / 1,000,000 mm

= 0.0000001 or $1x10^{-7}$ mm



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**

LO: **Identify** the law of conservation of mass

What is the conservation of mass?

Challenge: *Complete the equation and state the mass of the product.*

Copper + sulphur →

5.1 g ***2.4 g***

DECODE IT NOW

Word:

Conservation (tier 3)

Define it:

The act of preventing decay, waste or loss so the total value remains constant.

Write a sentence of your own that uses the word **conservation.**

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

Which subjects or topics will this word be relevant to?

Link it (similar words):

Maintain, preserve, sustain

Digging Deeper:

'Conservation' can also mean protecting natural resources such as wildlife, rivers and forests in order to protect them

Use it:

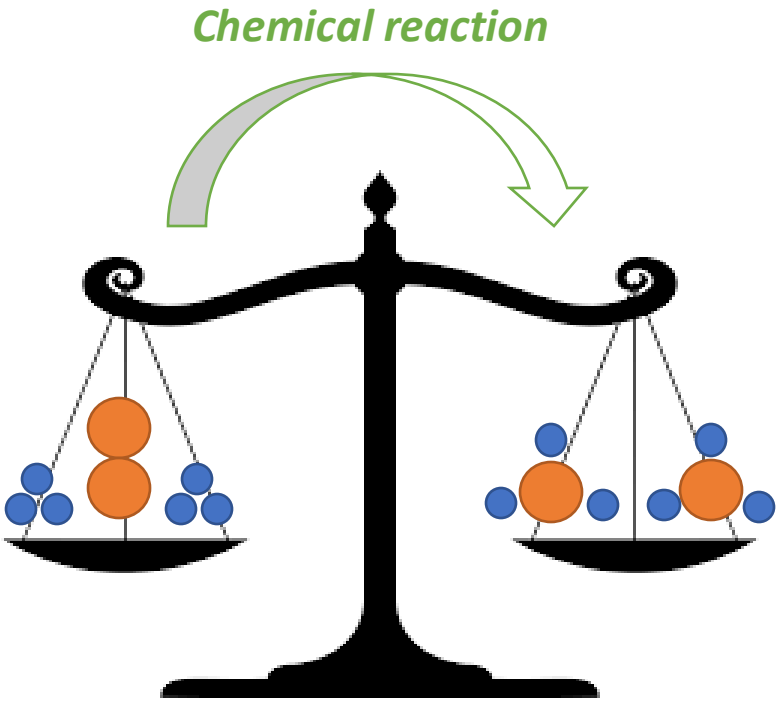
The conservation of energy states that energy cannot be created or destroyed.

Deconstruct it (root word):

From latin words ***con*** (which means **together**) and ***servare*** (which means to **preserve**)

The *Law of Conservation of Mass* states that '**matter cannot be created or destroyed in a chemical reaction**'.

This means that the number of atoms in the reactants…



…must be equal to the number of atoms in the products.

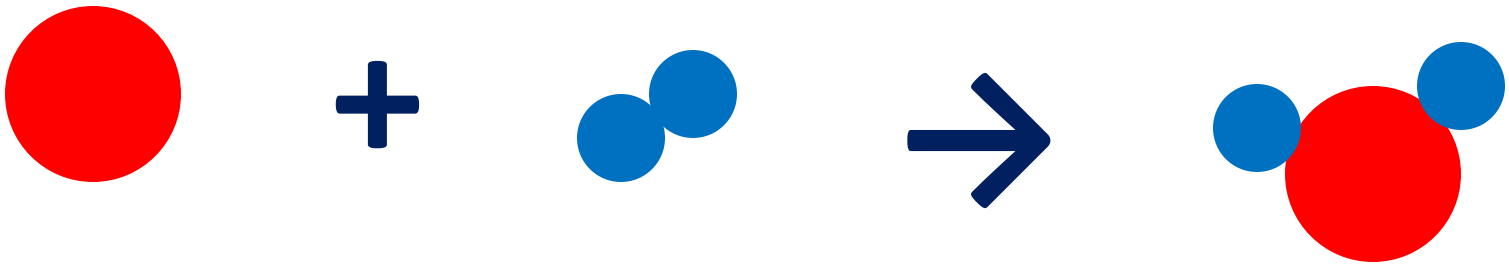
The *total mass of products* at the end of the reaction is **equal** to the *total mass of the reactants* at the beginning

LO: **Identify** the law of conservation of mass

The *total mass of products* at the end of the reaction is **equal** to the *total mass of the reactants* at the beginning

Reactants **Products**

$$C + O_2 \rightarrow CO_2$$



LO: **Explain** these changes in terms of the particle model.

Exam practice

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

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

(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.

100 – 44 = 56

mass **56** g

(1)

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

mass **44** tonnes

(1)

LO: **Explain** these changes in terms of the particle model.

Exam practice

An ore of zinc contains zinc carbonate.

The equation for the reaction when zinc carbonate is heated is:

$$\underset{\text{zinc carbonate}}{ZnCO_3} \longrightarrow \underset{\text{zinc oxide}}{ZnO} + \underset{\text{carbon dioxide}}{CO_2}$$

Complete the table below to show the number of atoms of carbon and oxygen in the formula of zinc carbonate.

Element	Number of atoms in the formula $ZnCO_3$
zinc, Zn	1
carbon, C	**1**
oxygen, O	**3**

(2)

When 125 g zinc carbonate is heated, 81 g zinc oxide is produced.

Calculate the mass of carbon dioxide produced.

125 – 81 = 44

Mass of carbon dioxide = **44** g

(1)

LO: **Describe** any observed changes in mass in a chemical reaction.

The mass of the raw ingredients in a cake is always **more** than the mass of the final product… why?

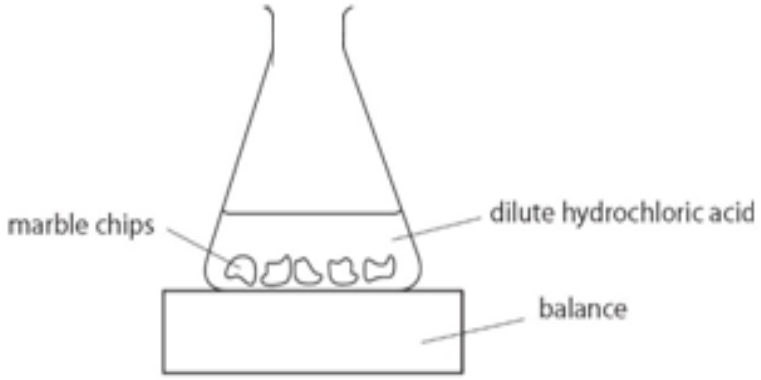
***Hint**: You need to add baking powder when you bake a cake to make it rise. Baking powder is sodium hydrogen **carbonate** ($NaHCO_3$) and it **decomposes** when it is heated…*

***Challenge**: How can you measure how much mass is being lost?*

LO: **Describe** any observed changes in mass in a chemical reaction.

Some reactions appear to show a change in mass. According to the conservation of mass, this isn't possible!

Some reactions release a gas and the mass appears to decrease. The particles are just 'rearranged' and are lost into the air – mass is never lost!

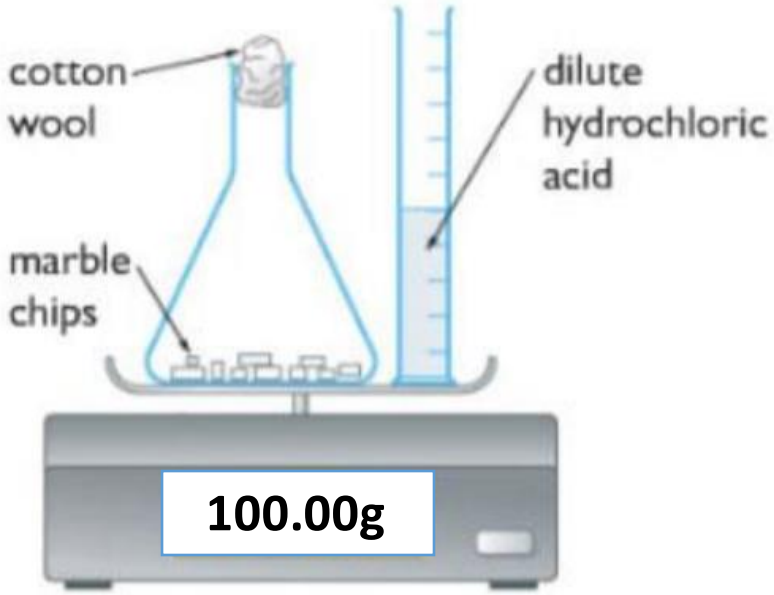


Challenge: *How can we measure the mass of gas released without using the conservation of mass?*

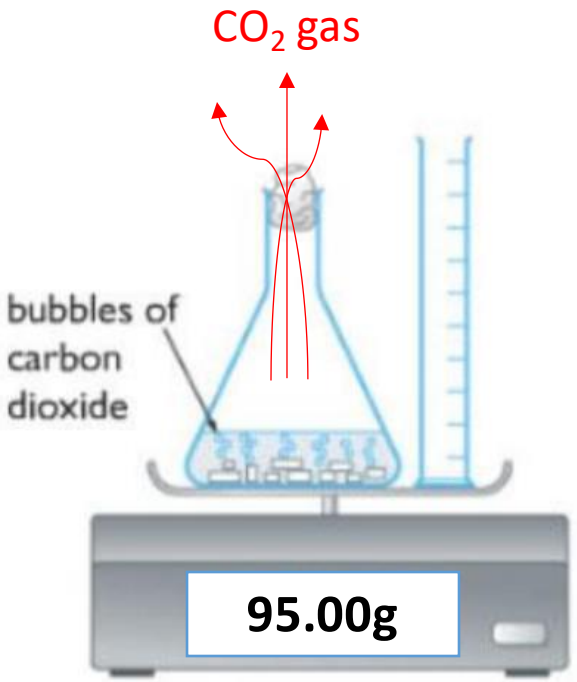
Using a gas syringe!

LO: **Explain** these changes in terms of the particle model.

Before the reaction, the mass of the **solid** marble chips and **aqueous** dilute HCl is 100 grams.



After the reaction, **some of the particles are lost as CO_2 gas**, so the mass **decreases** to 95 grams.



Cotton wool is used to stop any of the acid from coming out of the beaker, whilst also allowing to CO_2 gas to escape.

LO: **Explain** these changes in terms of the particle model.

Losing mass

We can find out how much has been lost in a chemical reaction.

For example…

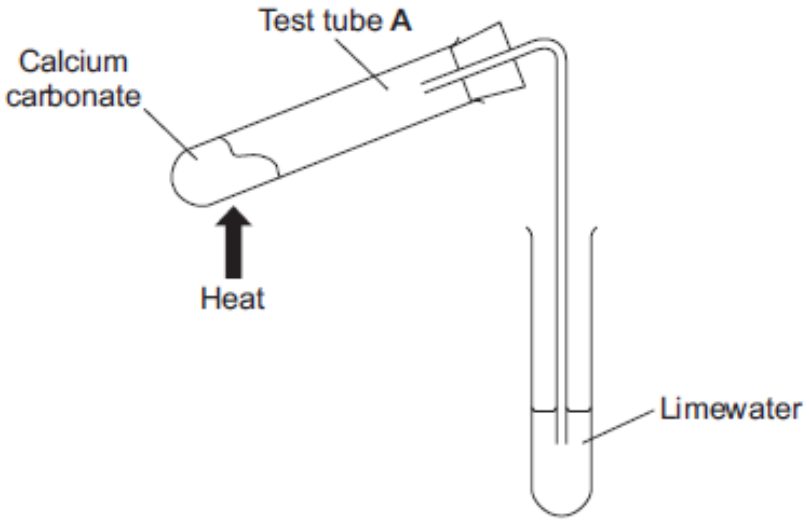
Sammy heats 5g of copper carbonate.
After heating, Sammy measured the mass of the product, copper oxide. The balance read 3.2g.

How much carbon dioxide was made?

LO: **Explain** these changes in terms of the particle model.

Exam practice

A student investigated the effect of heating calcium carbonate.



A student heated 10.0 g of calcium carbonate. At the end of the investigation, there was 5.6 g of a white powder in test tube **A**.

Explain how this information about masses shows that a gas was produced.

The mass of the products should equal the mass of the reactants (due to the conservation of mass). The mass has decreased by 4.4 grams because a gas has escaped.

(2)

Imagine the reaction below…

Why are they different sizes???

They have different *relative formula masses*

How coul me number of A particles a e wasted?

Could I cou e particles? N e particles are too small!

Could th react 1g of substance A with 1g of substance B?

No – the particles are **different sizes**, so 1 gram of A would be a different number of particles to 1 gram of B!

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.

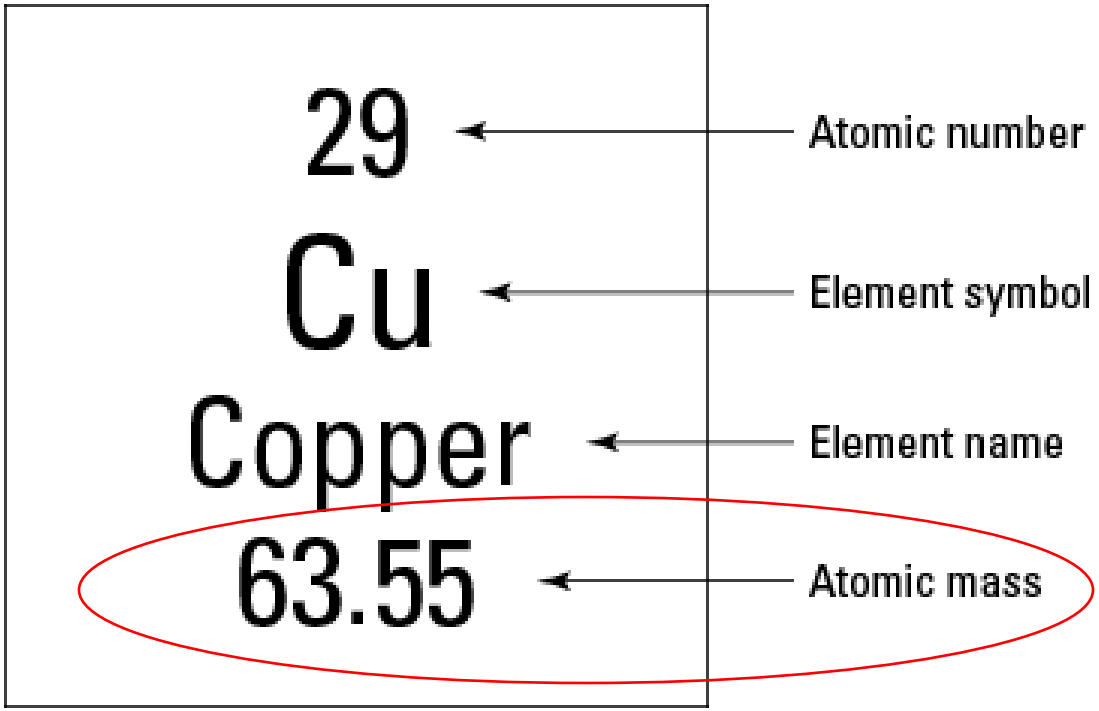
Deconstruct it (Root word):

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



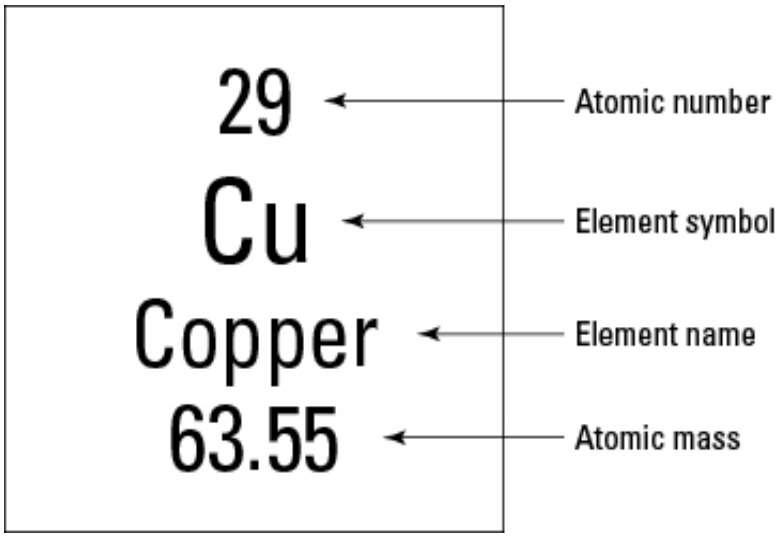
Hint:

*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.*

Quick quiz!

*What is the RAM of **aluminium**?*

27
Al
aluminium
13

27

Quick quiz!

*What is the RAM of **magnesium**?*

24
Mg
magnesium
12

24

Quick quiz!

*What is the RAM of **xenon**?*

131
Xe
xenon
54

131!

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.

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

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)

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

You Do It Alone

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.)

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

$= \mathbf{120}$

(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%

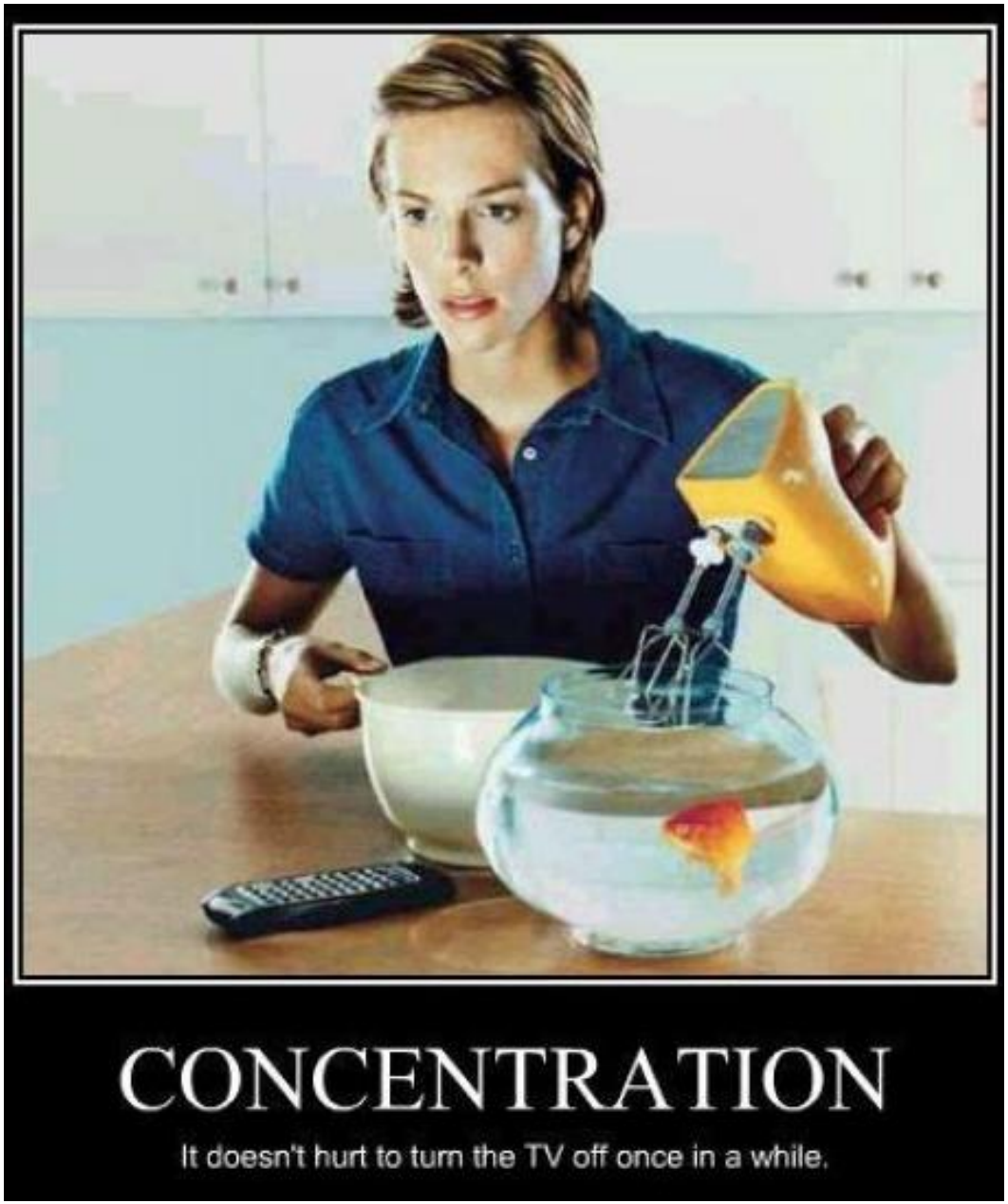
Percentage of beryllium = **5.0%** %

(2)

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

What could this have to do with chemistry?

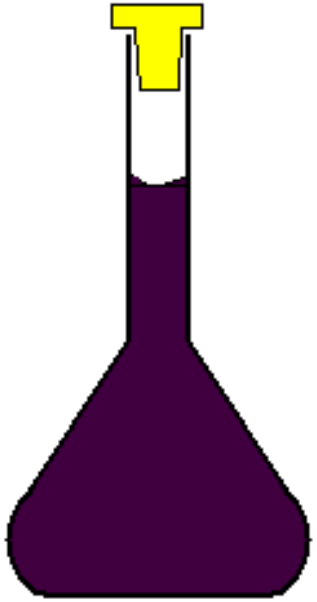
Challenge *– How can concentration be measured?*



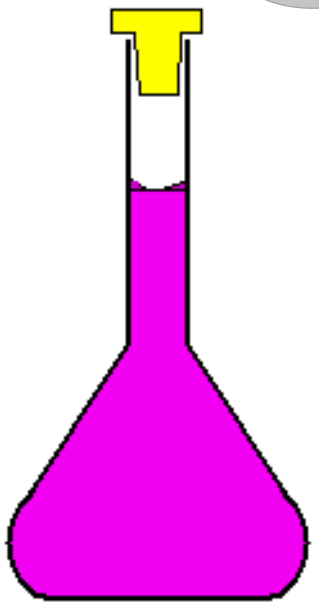
LO: **Describe** the relationship between mass, volume and concentration

Put simply, concentration is a measure of how much 'stuff' you have in a volume of liquid, making a solution.

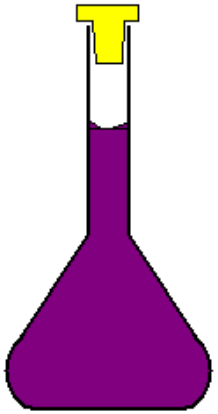
Which solution is the most concentrated? How do you know?



316g of $KMnO_4$ in 1 litre of water



79g of $KMnO_4$ in 1 litre of water



79g of $KMnO_4$ in 500mL of water

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

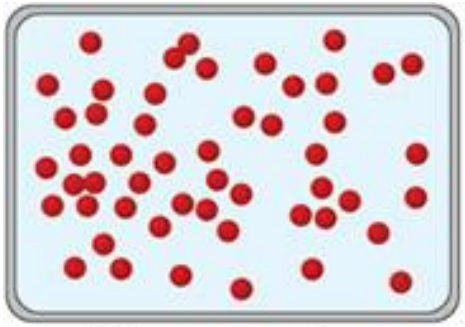
Put simply, concentration is a measure of how much 'stuff' you have in a volume of liquid, making a solution.

Key definition:

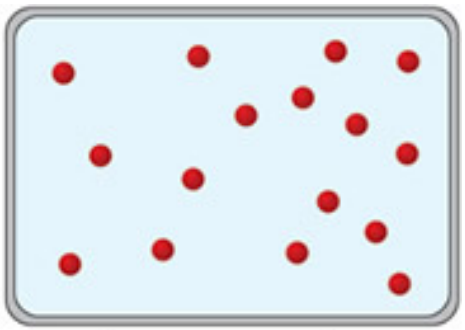
Concentration is a measure of how many solute particles are dissolved in a specific volume of solvent.

*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



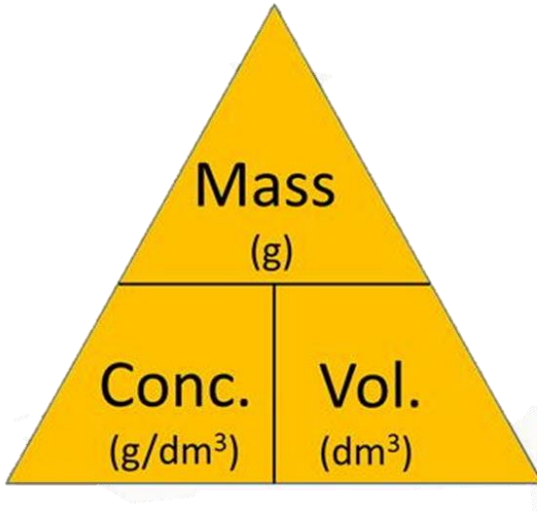
Low concentration

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.

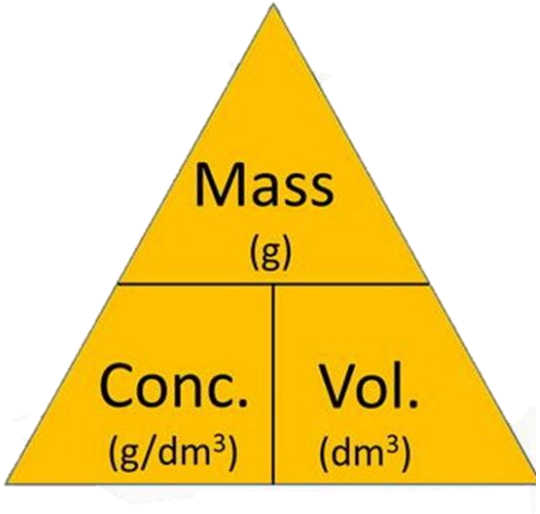
Mass (g) = concentration (g/dm^3) x volume (dm^3)

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)

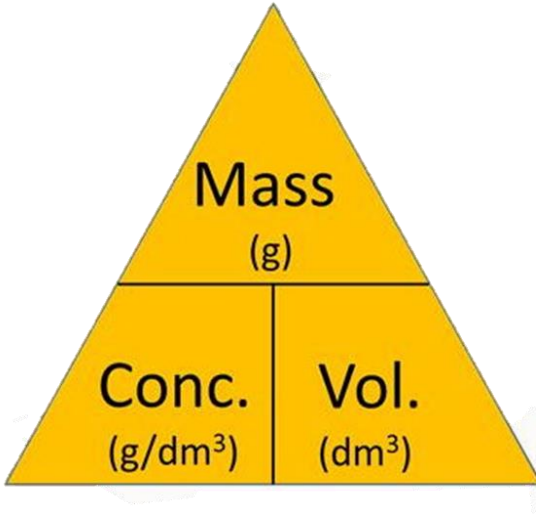
= 40g ÷ 20dm^3

= 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 $100dm^3$

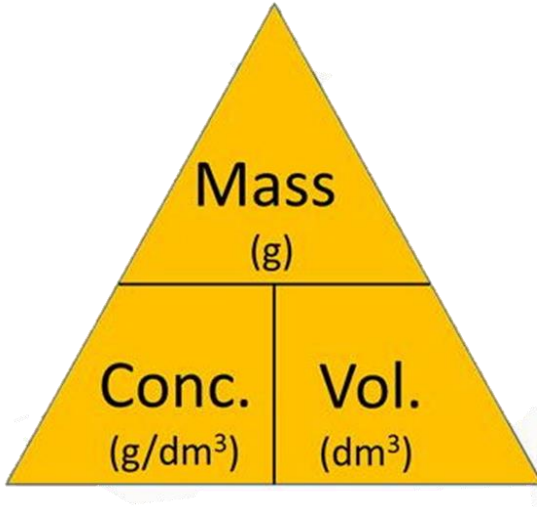
= 600 g

We Do

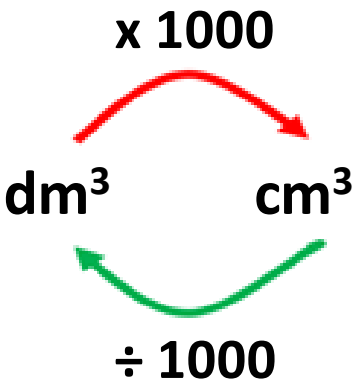
LO: **Describe** the relationship between mass, volume and concentration

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!!)



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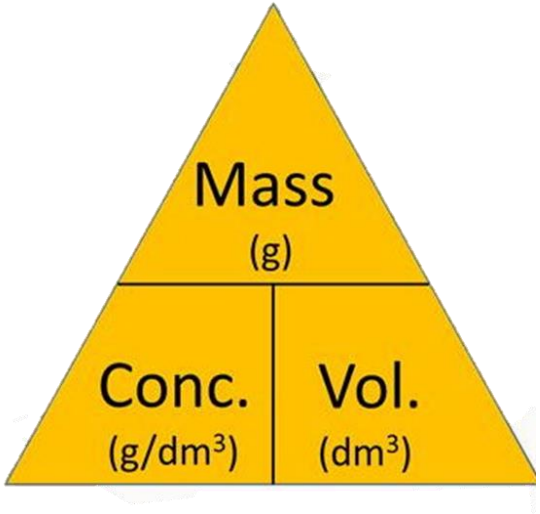


Example:

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

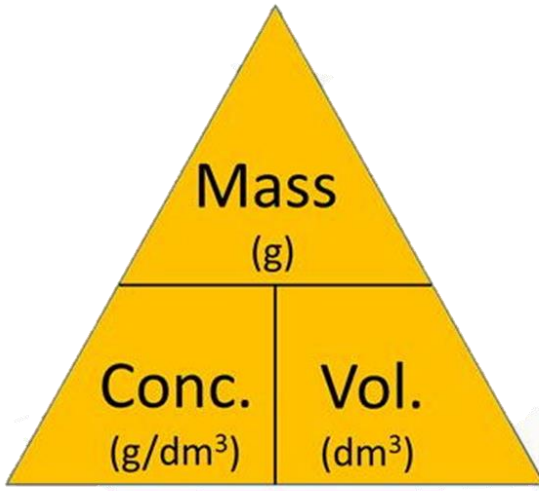
= 100 g/dm^3

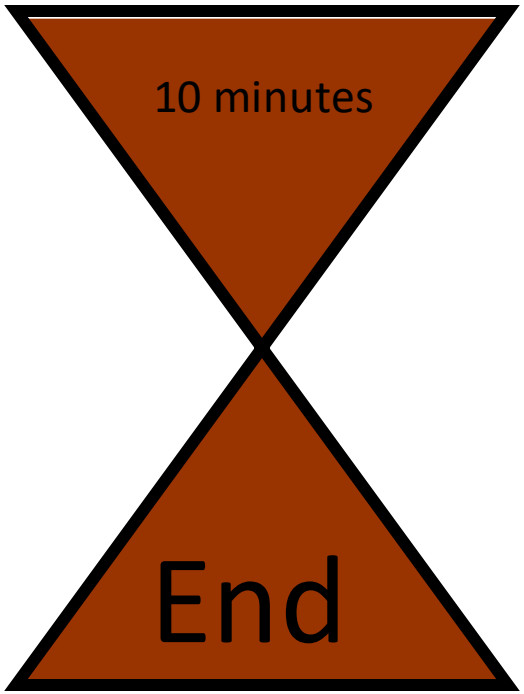
LO: Calculate the concentrations, volumes and masses in solutions

give it a Go!

Task: Complete the concentration calculations worksheet

You Do It Alone





Self assessment

1 a. **0.25dm^3**
b. **0.125dm^3**
c. **1500m^3**
d. **0.05dm^3**
e. **1dm^3**

2a. 10g / 1dm^3 = **10 g/dm^3**

b. 150cm^3 = 0.150dm^3
1.5g / 0.150dm^3 = **10 g/dm^3**

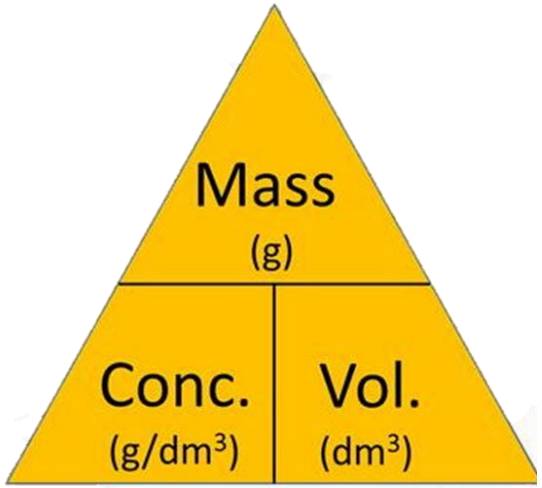
c. 500cm^3 = 0.500dm^3
2.3g / 0.500dm^3 = **4.6 g/dm^3**

3a. 2g/dm^3 x 0.5dm^3 = **10g**

b. 250cm^3 = 0.250dm^3
1.5g/dm^3 x 0.250dm^3 = **0.375g**

c. 10cm^3 = 0.01dm^3
0.4g/dm^3 x 0.01dm^3 = **0.004g**

d. 500cm^3 = 0.5dm^3
5g/dm^3 x 0.5dm^3 = **2.5g**



REVIEW IT NOW

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 = $0.04dm^3$ x 80 g/dm^3

= 3.2 grams

= 3.2 grams

Mass = _____ 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 = $0.05dm^3$ x 300 g/dm^3

= 15 grams

= 15 grams

Mass = _____ g

(3)

Review your exam skills