GCSE Combined Science
Chemistry

Topic 3 – Quantitative Chemistry

Name: ______________________________

C3 Quantitative Chemistry

Can you...?	☺	😐	☹
3.1.1 Conservation of mass and balanced chemical equations			
Recall that 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.			
Interpret symbol equations representing chemical reactions.			
3.1.2 Relative formula mass			
Calculate the relative formula mass of a compound.			
Recall that 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.			
3.1.3 Mass changes when a reactant or product is a gas			
Give examples of reactions that appear to involve a change in mass.			
Explain why some reactions appear to involve a change in mass.			
3.1.4 Chemical measurements			
Explain what is meant by measurement uncertainty.			
Represent the distribution of results and estimate uncertainty.			
Use the range of a set of measures about the mean as a measure of uncertainty.			
3.2.1 Moles (HT only)			
Recall that chemical amounts are measured in moles. The symbol for the unit mole is mol.			
Recall that 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.			
Recall that the mass of one mole of a substance in grams is equal to its relative formula mass.			
Use the relative formula mass of a substance to calculate the number of moles in a given mass of that substance and vice versa.			
3.2.2 Amounts of substances in equations (HT only)			
Interpret chemical equations in terms of moles.			
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.			
3.2.3 Using moles to balance equations (HT only)			
Recall that 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.			

C3 Quantitative Chemistry

Can you...?	☺	😐	☹
Balance an equation given the masses of reactants and products.			
3.2.4 Limiting reactants (HT only)			
State what it means if a reactant is the limiting reactant.			
State what it means if a reactant is in excess.			
Explain the effect of a limiting quantity of a reactant on the amount of products it is possible to obtain in terms of amounts in moles or masses in grams.			
3.2.5 Concentration of solutions			
Recall that the concentration of a solution can be measured in mass per given volume of solution, eg grams per dm^3 (g/dm^3).			
Calculate the mass of solute in a given volume of solution of known concentration in terms of mass per given volume of solution.			
Explain how the mass of a solute and the volume of a solution is related to the concentration of the solution. (HT only)			

Topic 3 - Quantitative chemistry

Atoms are rearranged during chemical reactions, and are not lost or gained. Chemical reactions can be represented using equations.

The changes in chemical reactions can be modelled using equations. In general, you write:

Reactants → Products

The reactants are shown on the left of the arrow, and the products are shown on the right of the arrow. Do not write an equals sign instead of an arrow. If there is more than one reactant or product, they are separated by a plus sign.

Word equations

A word equation shows the names of each substance involved in a reaction, and must not include any chemical symbols or formulae. For example:

copper + oxygen → copper oxide

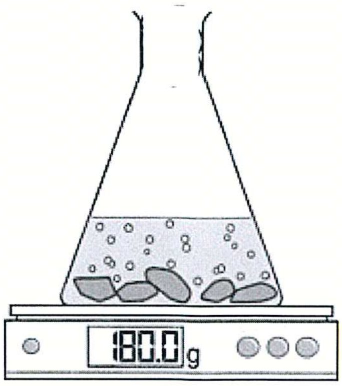
In this reaction, copper and oxygen are the reactants, and copper oxide is the product.

Chemical reactions are often written as symbol equations, where instead of the word the substance is given is chemical formula (e.g. water = H_2O). Symbol equations give chemists more detail about the reactions which they can use in other calculations (which you will see later…)

Conservation of mass

The law of conservation of mass states the mass of the reactants must equal the mass of the products in a chemical reaction as no atoms are lost or gained.

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.



For example: when marble chips react with acid the mass of the reaction appears to decrease as carbon dioxide gas is given off during the reaction and escapes into the atmosphere.
If the gas was collected and measured with the mass of the rest of the product it would be equal to the mass of the starting reactants.

Another example of where mass seems to change is when the mass appears to increase. This is due to one of the reactants being a gas (usually oxygen in the air) which reacts with something else. The products appears to get heavier as atoms of the gas (which would not have been measured) combine with the other reactant.

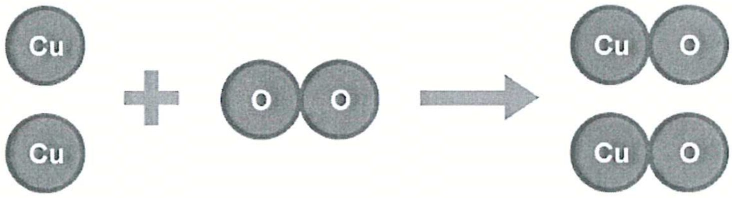
Balancing equations

Due to the conservation of mass in a chemical reaction, this also means that the number of atoms on the reactants side of the arrow (left hand side) must equal the number of atoms on the products side of the arrow (right hand side).

To represent chemical reactions accurately, it may be necessary to balance the equations to make sure the number of atoms on each side of the arrow are the same.

To balance chemical equations you need to:

- Check if the number of each atom on either side is the same, you're all good, and the equation is balanced.
- BUT, if the number of each atom on either side is NOT the same, you need to use big numbers in front of each element or compound to even them out.
- Every time you add a big number, you multiply the whole compound by that number, and so you adjust the numbers of atoms accordingly.
- Repeat until you have the same number of every atom on the left hand side as on the right hand side.



Relative formula mass

The relative formula mass (Mr) of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula. e.g. NaCl = 23 + 35.5 = 58.5

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.

Percentage Composition

Percentage composition is just a way to describe what proportions of the different elements there are in a compound.

If you have the formula of a compound, you should be able to work out the percentage by mass of an element in it.

$$\% \text{ by mass} = \frac{\text{number of atoms x relative atomic mass}}{\text{relative formula mass of compound}}$$

Writing formulae

1. A molecule of boron fluoride contains 3 fluorine (F) atoms and 1 boron (B) atom.

What is the formula of boron fluoride?

Tick **one** box.

☐ B_3F ☐ BF_3 ☐ F3B ☐ F_3B [1 mark]

2. Lead(IV) oxide is made up of Pb^{4+} and O^{2-} ions.

Write the formula for lead(IV) oxide.

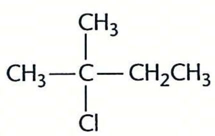
____________________________ [1 mark]

3. Determine the number of hydrogen atoms in each of the following.

a NH_3 ____________________________

b $2H_2O$ ____________________________

c [3 marks]



4. A student reacts calcium carbonate with hydrochloric acid.

Practical

Synoptic

The products of the reaction are calcium chloride, water and carbon dioxide.

a Suggest how they could collect and measure the volume of carbon dioxide made.

____

____ [1 mark]

b Draw **one** line from the name of each substance to its formula. [3 marks]

Substance	Formula
Calcium carbonate	CO_2
Calcium chloride	$CaCl_2$
Carbon dioxide	$CaCO_3$

Conservation of mass and balanced chemical equations

1. Draw a ring around the correct answer to complete each sentence.

The law of conservation of mass states that no atoms are [gained / rearranged / lost] or made during a [physical change. / chemical reaction. / reversible change.]

This means that the mass of the products is [less than / equal to / more than] the mass of the reactants.

[3 marks]

2. A student carries out a reaction: A + B → C.

Maths

They use 2.3 g of A and 1.2 g of B.

Calculate the expected mass of C.

____

____ [2 marks]

3. A student is asked to balance the symbol equation for the reaction of hydrogen and oxygen to make water.

$H_2 + O_2 \rightarrow H_2O$

This is their answer.

$H_2 + O_2 \rightarrow H_2O_2$

Explain why this is incorrect.

Write the correct answer.

> **Remember**
> When you balance an equation you cannot change the small (subscript) numbers. This changes the substance. For example, O_2 is oxygen, O_3 is the toxic gas ozone.
>
> However, you can change the number of atoms of each substance by adding a number in front of the formula. E.g. $2O_2$ contains 4 oxygen atoms.

____

____ [2 marks]

Mass changes when a reactant or product is a gas

1. When magnesium is burnt a white powder called magnesium oxide is formed.

The balanced symbol equation for the reaction is:

$2Mg + O_2 \rightarrow 2MgO$

Maths

A student burns 3 g of magnesium. The mass of the magnesium oxide produced is 4.2 g.

Calculate the increase in mass

____

____

____________ g [1 mark]

2. A class carries out an experiment.

Practical

They heat copper carbonate to form copper oxide and carbon dioxide.

Figure 1 shows the equipment they used.

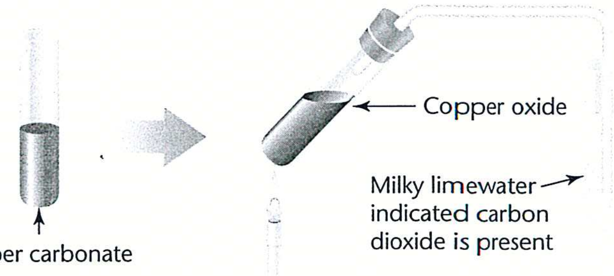


Figure 1

a What kind of reaction is this?

Tick **one** box.

☐ Combustion ☐ Oxidation

☐ Neutralisation ☐ Thermal decomposition [1 mark]

Maths

Worked Example

b They use 4.6 g of copper carbonate.

The mass of the **limewater** increases by 0.8 g.

Calculate the mass of **copper oxide** produced. [2 marks]

Because of the law of conservation of mass we know that the total mass of products must be the same as the reactant which is 4.6 g.

One product is carbon dioxide. This went into the limewater so the mass of carbon dioxide produced was 0.8 g.

Therefore, the mass of the copper oxide can be calculated by:

4.6 g – 0.8 g

= 3.8 g

Marks gained: [2 marks]

Maths **c** They repeat the experiment a further 4 times.

Their measurements for the decrease in mass of the copper carbonate in grams were:

0.8, 0.5, 0.9, 0.4, 0.6

> **Maths**
> Range = the highest measurement – the lowest measurement

Worked Example

i Calculate the range in measurements [1 mark]

0.9 - 0.4

= *0.5 (g)* *Marks gained:* [1 mark]

ii Calculate the percentage uncertainty.

Use the formula: percentage uncertainty = (range/mean) × 100

Give your answer to 1 decimal place.

____

______________________ % [3 marks]

Relative formula mass

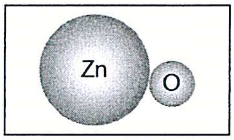
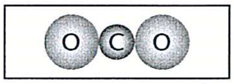
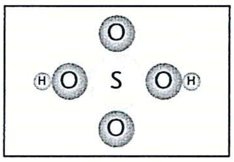
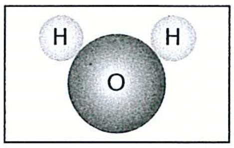
1. What is the relative formula mass, M_r, of an oxygen molecule, O_2?

Tick **one** box.

☐ 2 ☐ 16 ☐ 24 ☐ 32 [1 mark]

> **Remember**
> To calculate the relative formula mass, or M_r, you add up the relative atomic masses (A_r) of the atoms in the formula.
>
> If these are not given in the exam question, use your copy of the periodic table.

2. Draw **one** line from each molecule diagram to its relative formula mass.

Molecule diagram	Formula mass
	44
	81
	18
	98

[4 marks]

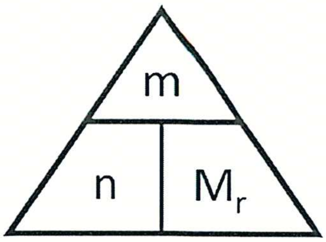
Moles (HT only)

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 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.
E.g. the mass of 1 mole of carbon = 12g as the atomic mass of carbon is 12.

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. For example that 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).

Moles of a substance can be calculated using the formula:

$$\text{moles (mol)} = \frac{\text{mass (g)}}{\text{relative formula mass (g/mol)}}$$



Amounts of substances in equations (HT only)

The masses of reactants and products can be calculated from balanced symbol equations. Chemical equations can be interpreted in terms of moles.
For example:

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

This 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.

If we have too much of a reactant it will be wasted, if we have too little of a reactant not all of the other reactant will react. We can use reacting mass calculations to work out the amount of reactant needed or product produced.

Worked Example

If we have a solution containing 100g of sodium hydroxide, how much chlorine gas should we pass through the solution to make bleach?

$$2NaOH + Cl_2 \rightarrow NaOCl + NaCl + H_2O$$

Step 1:	Work out the mass of one mole of each substance in the question.	NaOH: n = m / Mr n = 100 / (23+16+1) n = 100 / 40 = 2.5 mol
Step 2:	Find the molar ratio from the balanced symbol equation.	NaOH : Cl_2 2 mol : 1 mol
Step 3	Use the molar ratio to calculate the actual number of moles needed.	2.5 mol : 1.25 mol
Step 4:	Use the moles to calculate the mass of the reactant needed.	m = n x Mr m = 1.25 x (35.5 x 2) m = 1.25 x 71 = 88.75g

Helpful hint Decimal places and significant figures:
If the question asks for a specific number of decimal places or significant figures, make sure your answer matches what they ask for (you will lose a mark if you don't do this!)

If the question does not give you a specific number of decimal places or significant figures and your answer has lots of numbers before/after the decimal place; a good rule to follow is:

- If there are numbers in the question, give you answer to the same number of significant figures/decimal places they are in.
- If there are no numbers given in the question and no instruction on how many decimal places/significant figures to give your answer to 2 decimal places.

3. Maths

A student carries out a precipitation reaction.

potassium iodide + lead(II) nitrate → lead(II) iodide + potassium nitrate

$$2KI + Pb(NO_3)_2 \rightarrow PbI_2 + 2KNO_3$$

Use the symbol equation to prove that the relative formula mass of reactants is equal to the relative formula mass of the products.

(A_r K = 39; I = 127; Pb = 207; N = 14; O = 16)

____

____

____

____ [6 marks]

Moles

1. Higher Tier only Maths

What is the mass of 2 moles of sodium?

Tick **one** box.

☐ 2 g ☐ 22 g ☐ 23 g ☐ 46 g [1 mark]

2. Higher Tier only

How many moles are in 60 g of calcium?

Tick **one** box.

☐ 1 ☐ 1.5 ☐ 3 ☐ 4.5 [1 mark]

Remember

You can calculate mass of a substance by using the formula:

Mass = moles × relative atomic (A_r) or formula mass (M_r)

This can be rearranged to work out the number of moles:

Moles = mass / relative atomic (A_r) or formula mass (M_r)

3. Higher Tier only

Calculate the mass in grams of:

a 4 moles of carbon:

_______________________________ [1 mark]

Worked Example

b 5 moles of oxygen (O_2): [4 marks]

The A_r for one oxygen atom is 16.

There are 2 oxygen atoms in each oxygen molecule.

So the M_r of oxygen is 16 × 2 = 32

Mass = moles × M_r [2 marks]

Mass of O_2 = 5 × 32 [1 mark]

Mass of O_2 = 160 g [1 mark]

Marks gained: [4 marks]

c Calculate the number of moles in 283.5 g of hydrogen bromide (HBr) [2 marks]

____

____

4. Higher Tier only

There are 6.02×10^{23} atoms, molecules or ions in a mole of a given substance.

How many molecules are in 1 mole of water? ________________ [1 mark]

Amounts of substances in equations

1. Higher Tier only, Maths

200 g of calcium carbonate is heated to produce calcium oxide and carbon dioxide.

The balanced symbol equation for this reaction is:

$CaCO_3 \rightarrow CaO + CO_2$

a Calculate the number of moles of calcium carbonate.

____

____

________________ moles [2 marks]

Maths

b Calculate the maximum mass of calcium oxide made.

____

________________ kg [2 marks]