

Chemical Formula

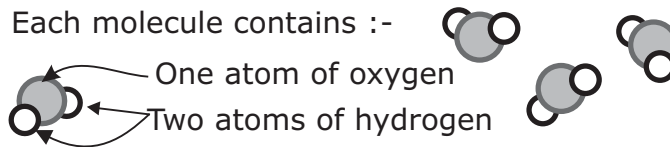
Many substances are made by joining together a small group of atoms to form a **molecule** for example water.



To write formulae for simple molecules

To distinguish between prefixes and suffixes in

The **formula** for water **H₂O** shows which atoms and how many of each are used to make one molecule.



Why should we actually write **H₂O₁** ?

It is quite common to leave the number '1' out of a chemical formula.



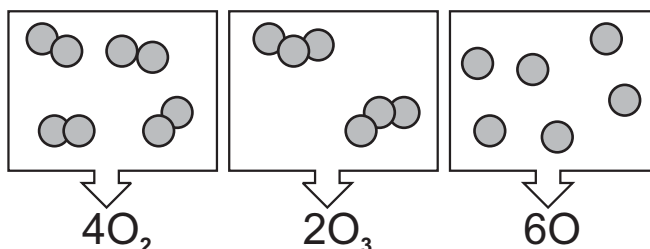
For the next task you should include it. Use the key to work out the formula for each substances shown below.

Key

	O Oxygen
	C Carbon
	H Hydrogen
	Cl Chlorine
	N Nitrogen

	Water		Methane
	H₂O		C₁H₄
	Hydrochloric acid		Ammonia
	Trichloroethane		Alcohol (ethanol)
	Nitric acid		Hydrogen peroxide

There is an important difference when numbers are used either in-front-of or after a chemical symbol. Look at the following pictures using oxygen atoms:



In your own words describe the difference between the numbers in front (prefix) and numbers which go after (suffix) the symbol for oxygen.

Try to use the terms **molecule** and **atom** carefully.

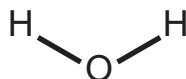
Chemical Formula

To show that different substances are joined together we can use either pictures of atoms or symbols.

Water can be drawn using circles as atoms



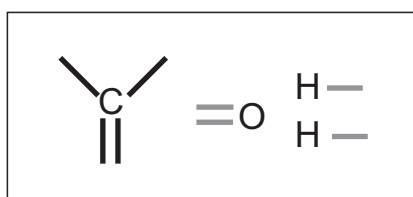
It can also be drawn as **stick structures** showing how the atoms are joined.



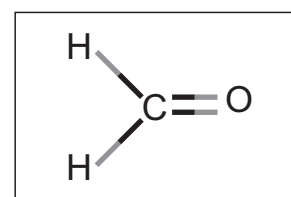
When drawing stick structures there are rules to control the number of links (bonds) an atom can have. These are shown below.

Hydrogen only 1 link	Oxygen always 2 links	Nitrogen always 3 links	Carbon always 4 links
H —			

To draw out **C₁H₂O₁**, take the pictures below

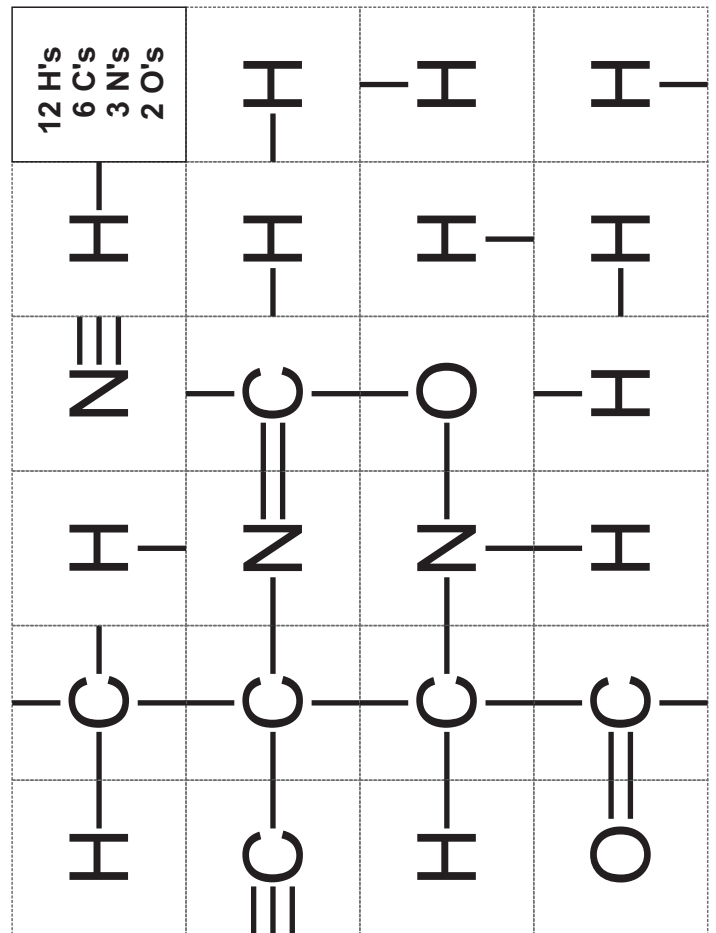
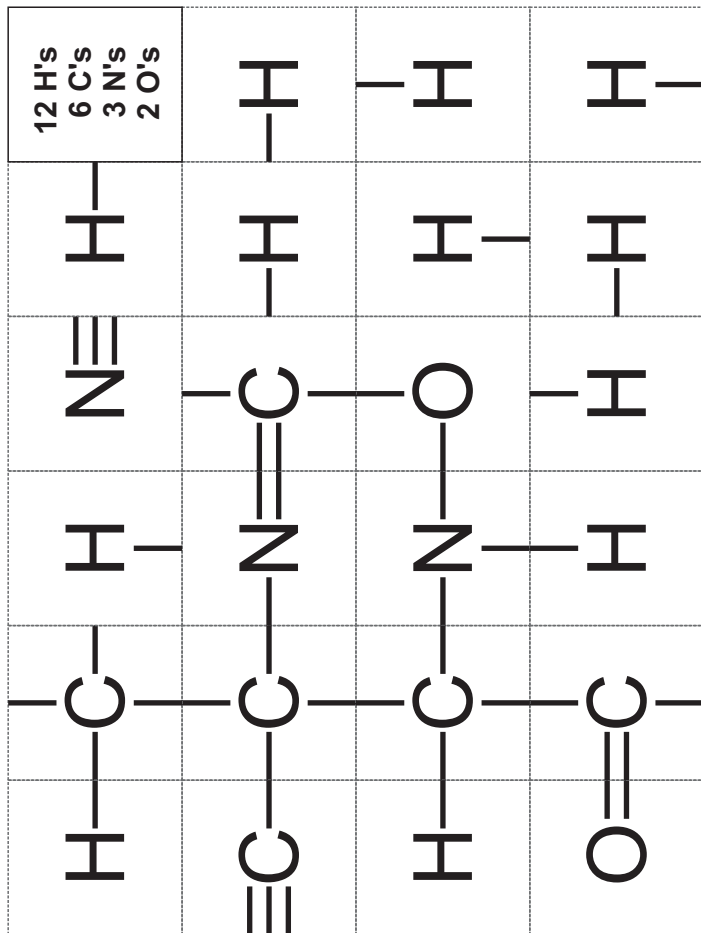
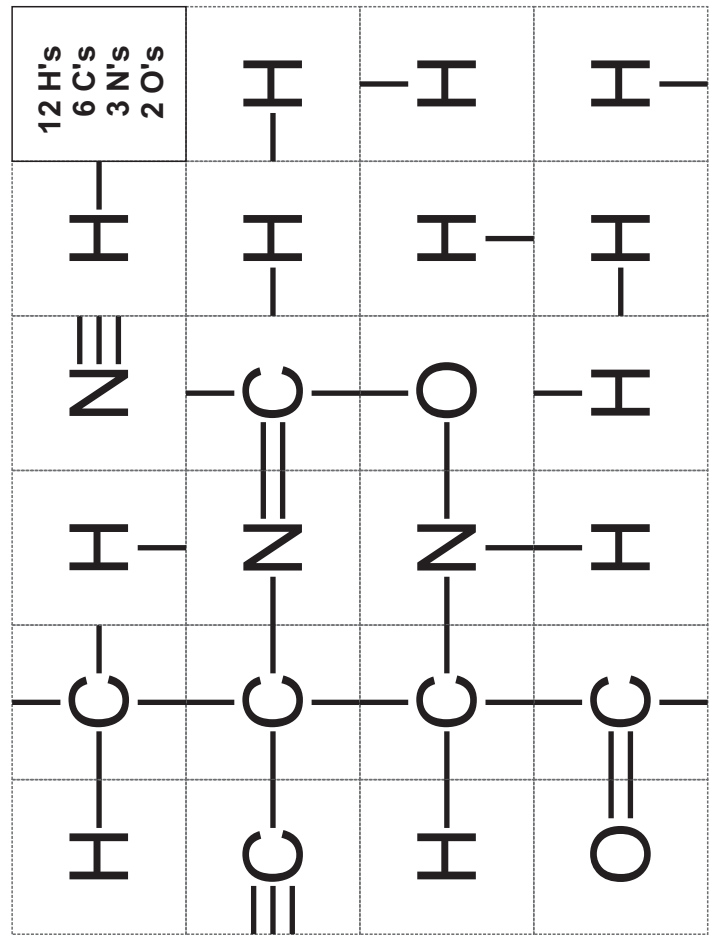
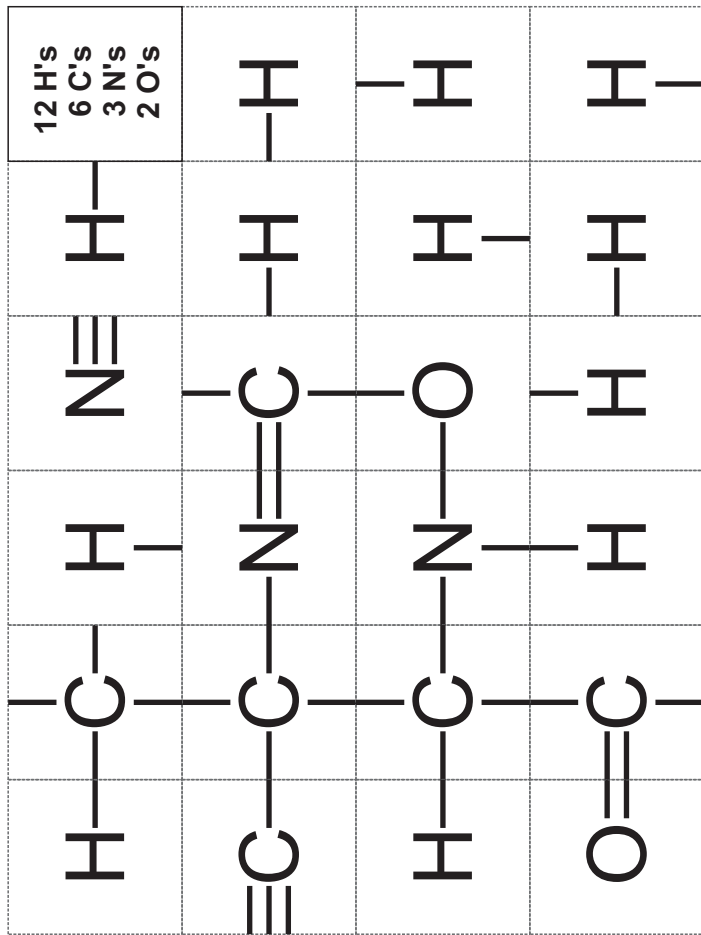


to make
this picture



Use the 'rules' above and draw out the following molecules





Chemical Formula



To write formulae for ionic compounds

To apply rules for formula writing to complex examples

Some substances are made up from charged particles called **ions**. These are found inside **ionic compounds**. When ions are joined together to make ionic compounds the total combination of +ve and -ve ions is **neutral**

Aluminium chloride is made up of positive aluminium ions (Al^{+++}) and negative chloride ions (Cl^-) These ions can also be written as Al^{3+} and Cl^{1-} .

If one aluminium Al^{3+} joins with three chlorides Cl^{1-} Cl^{1-} Cl^{1-} because this gives **+++** and **- - -** the combination would be **neutral**. This is written as **Al_1Cl_3** to show how many of each ion is needed.

For the following questions, write down the symbol for each part of the name and then balance the ions so that the total number of + and - charges are balanced. Finally work out the formula for each compound.

- a) Zinc bromide = $\text{Zn}^{2+} \text{Br}^{1-} \text{Br}^{1-}$ = Zn_1Br_2 or simplified ZnBr_2
- b) Magnesium chloride = =
- c) Sodium chloride = =
- d) Copper(II) oxide = =
- e) Iron(III) oxide = =
- f) Iron(II) sulphide = =
- g) Aluminium bromide = =
- h) Sodium oxide = =
- i) Aluminium sulphide = =

Complex examples - ions like carbonate ions already contain a number of joined atoms. To avoid confusion we often use brackets - see the two examples below.

- a) Aluminium hydroxide = $\text{Al}^{3+} \text{OH}^{1-} \text{OH}^{1-} \text{OH}^{1-}$ = **not** AlOH_3 **but** $\text{Al}(\text{OH})_3$
- a) Ammonium carbonate = $\text{NH}_4^{1+} \text{NH}_4^{1+} \text{CO}_3^{2-}$ = **not** $\text{NH}_{42}\text{CO}_3$ **but** $(\text{NH}_4)_2\text{CO}_3$
- b) Magnesium hydroxide = =
- c) Ammonium sulphide = =
- d) Calcium nitrate = =

Positive ions			
Aluminium	Al^{3+}	Lead	Pb^{2+}
Ammonium	NH_4^{1+}	Lithium	Li^{1+}
Barium	Ba^{2+}	Magnesium	Mg^{2+}
Calcium	Ca^{2+}	Potassium	K^{1+}
Copper	Cu^{2+}	Silver	Ag^{1+}
Hydrogen	H^{1+}	Sodium	Na^{1+}
Iron(II)	Fe^{2+}	Zinc	Zn^{2+}
Iron(III)	Fe^{3+}		

Negative ions			
Bromide	Br^{1-}	Nitrate	NO_3^{1-}
Carbonate	CO_3^{2-}	Oxide	O^{2-}
Chloride	Cl^{1-}	Sulphate	SO_4^{2-}
Fluoride	F^{1-}	Sulphide	S^{2-}
Hydroxide	OH^{1-}		
Iodide	I^{1-}		

Word Equations

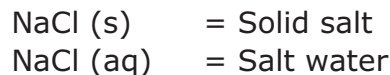
Chemical reactions can be represented with either words or with symbols and formulae.



To construct word equations from supplied symbols

To construct word equations from descriptions of reactions

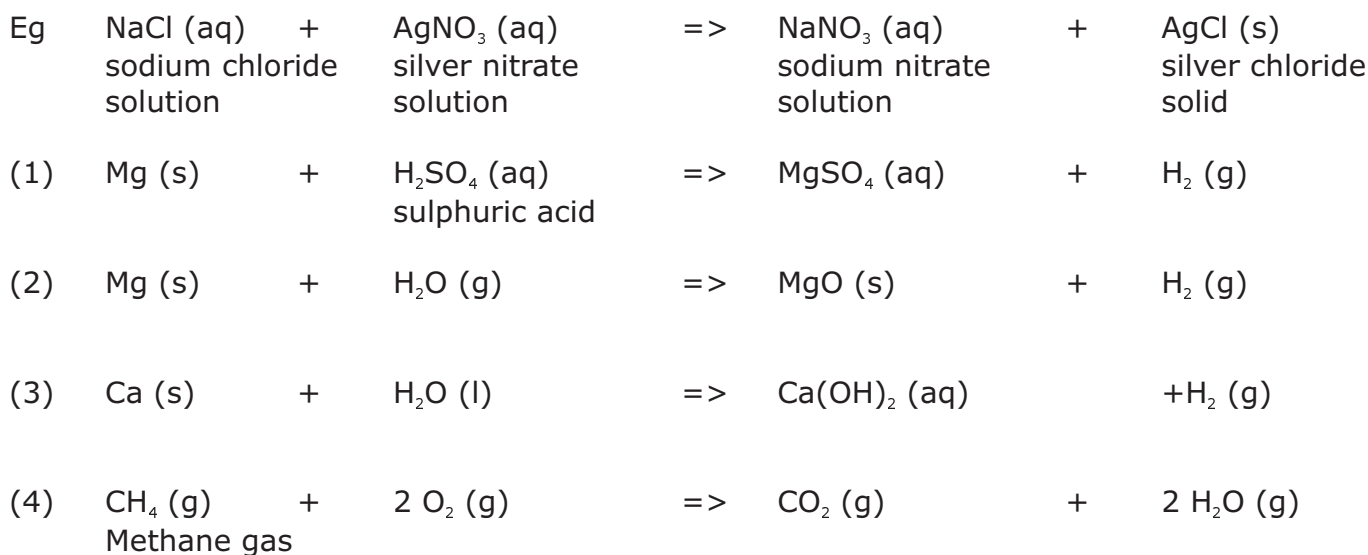
Often when chemical symbols are used, an important addition is the use of **(s)**, **(l)**, **(g)** and **(aq)** just after each of the formulae. Using these **state symbols** can make subtle differences :



The **state symbols**, therefore, mean : (s) = (l) = (g) =
The state symbol (aq) is often misinterpreted. It is used when a chemical is dissolved in water or used to represent a dilute acid - diluted with water - (aq) means **aqueous**.



On lined paper convert each of the following symbols into complete **word equations**.



Carefully read through the following descriptions and construct **word equations**.

A block of **carbon** burns in pure **oxygen** to give only one product, **carbon dioxide** gas.



Word equation = **Carbon + Oxygen => Carbon dioxide**

- (5) Water is the only product from the reaction between hydrogen and oxygen.
- (6) Dilute hydrochloric acid reacts with magnesium solid. One of the products is a solution of magnesium chloride. The second product is a colourless gas which 'pops' when tested with a lighted splint.
- (7) Calcium oxide is made by heating up calcium carbonate. A second product is a gas which turns limewater cloudy.
- (8) If magnesium is added to copper sulphate solution, one of the products is a brown metal.
- (9) Calcium carbonate gives carbon dioxide, a sulphate and water when added to a beaker containing dilute sulphuric acid.
- (10) Liquid magnesium oxide can be decomposed by electricity into magnesium and oxygen.

Word Equations



To construct word equations from descriptions of reactions

Chemical reactions can be represented with either words or with symbols and formulae.

Carefully read through the following descriptions and construct **word equations**.

eg A block of carbon burns in pure oxygen to give only one product, carbon dioxide gas.

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- (4) If magnesium is added to copper sulphate solution, one of the products is a brown metal.

- (5) Calcium carbonate gives carbon dioxide, calcium sulphate and water when added to a beaker containing dilute sulphuric acid.

- (6) Liquid magnesium oxide can be broken up by electricity into magnesium and oxygen.

- (7) When sodium is added to water it floats on the surface and fizzes. The gas made is explosive. The sodium also turns the water into an alkali called sodium hydroxide.

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Balanced Symbol Equations



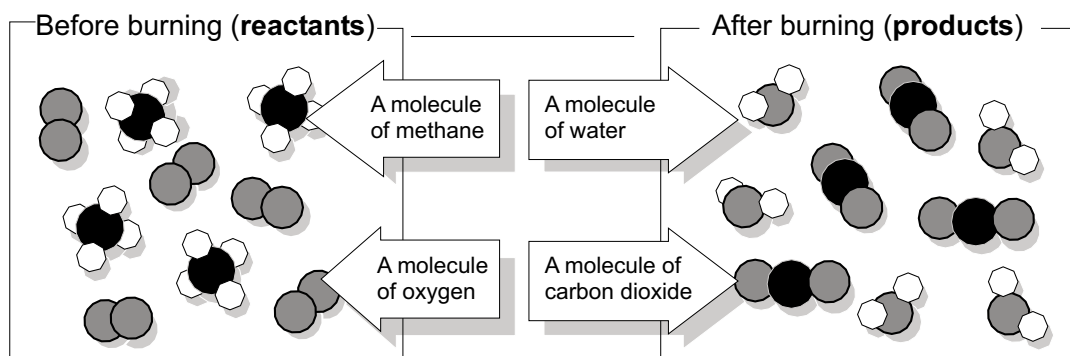
CQ1d HF

To recognise number of atoms in reactants must be balanced by those in products

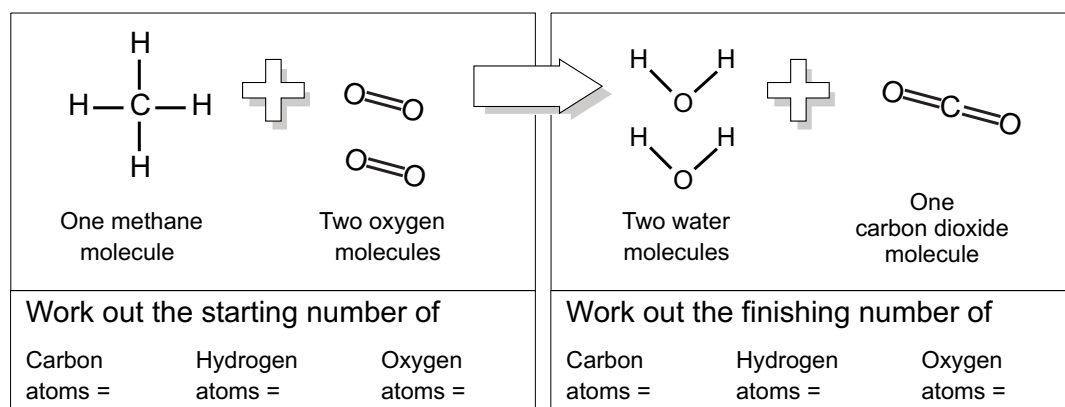
To create a balanced equation from supplied information

When methane (natural gas) burns in air, oxygen turns the fuel into carbon dioxide and water.

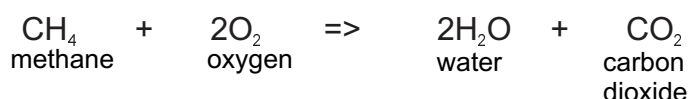
The following pictures show this happening



These pictures can be simplified using stick diagrams and by using as few molecules as possible.



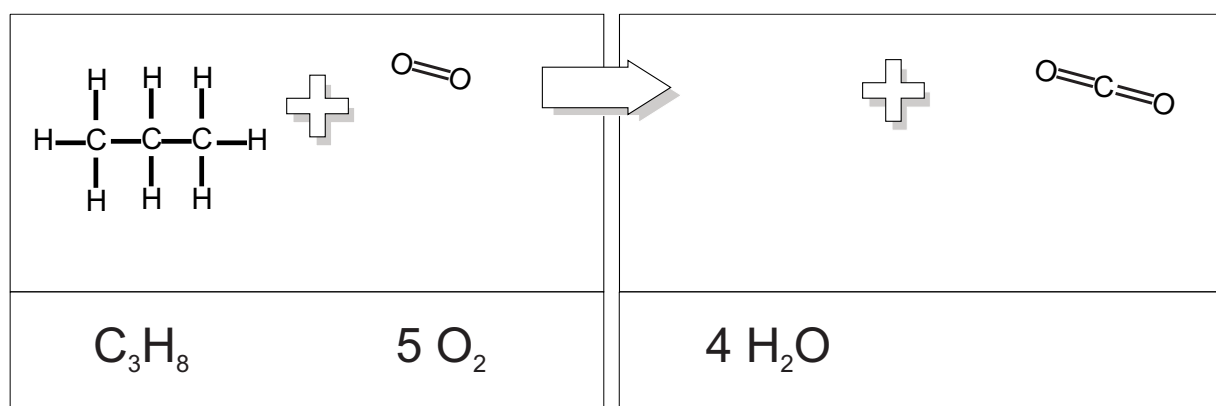
Another way to represent the burning of methane is to use the following **symbol equation**



Using your answers to the task above, say why this is called a **balanced** chemical equation:



Another fuel which can be burned in a similar way is propane (camping gas). **Complete** the following boxes and symbols to create a balanced equation.



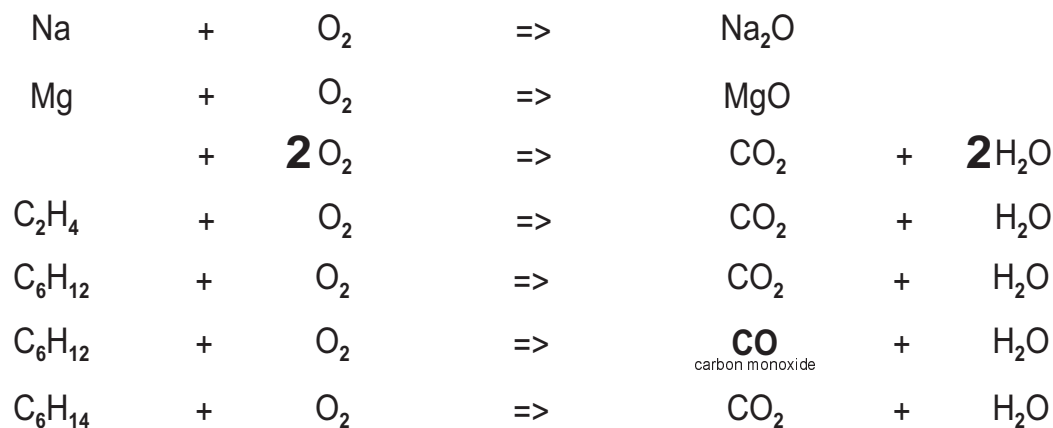
Balanced Symbol Equations



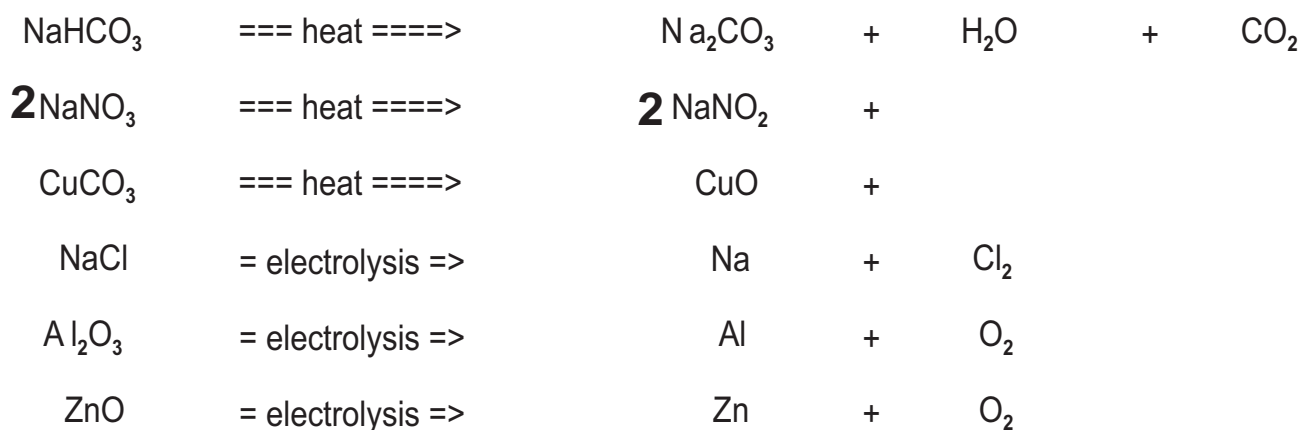
To complete and balance supplied chemical equations

Balance the following equations by inserting numbers **in front** or by filling in the missing chemical formula.

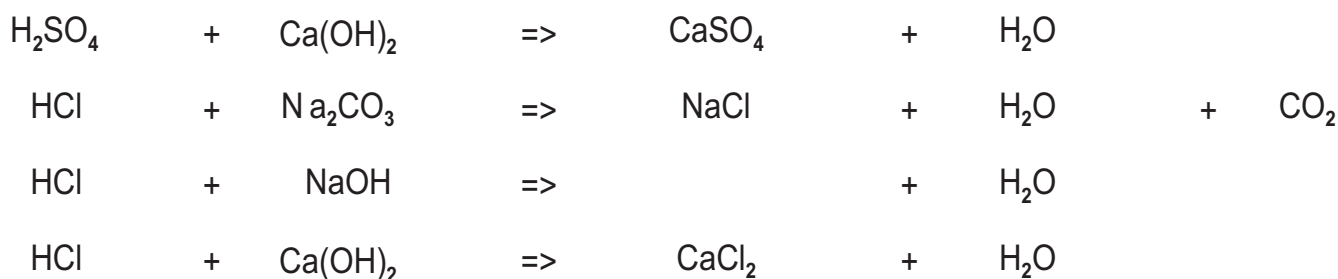
Oxidation Reactions



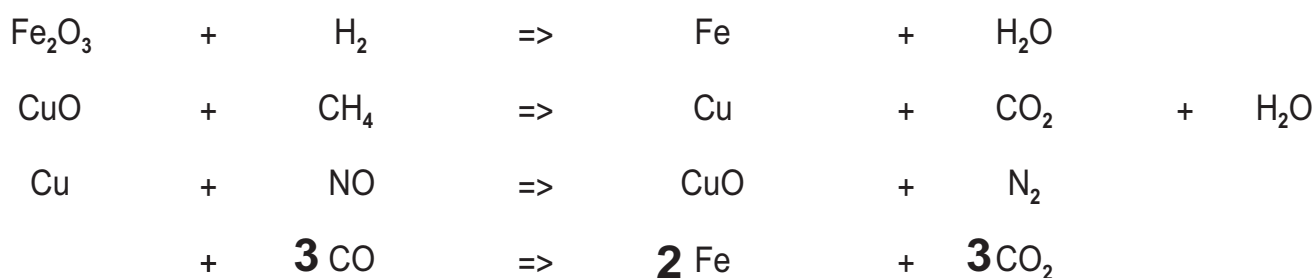
Decomposition Reactions

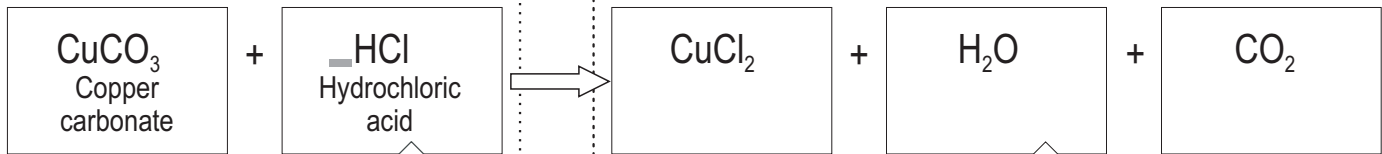
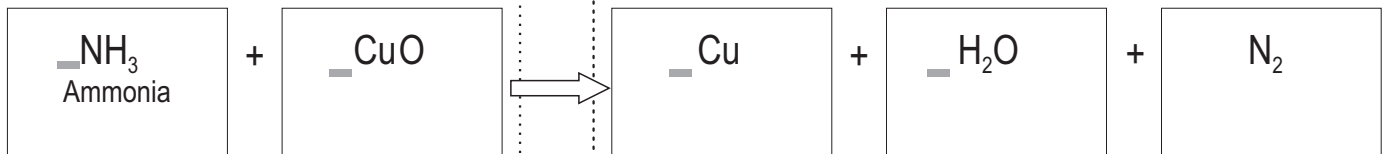
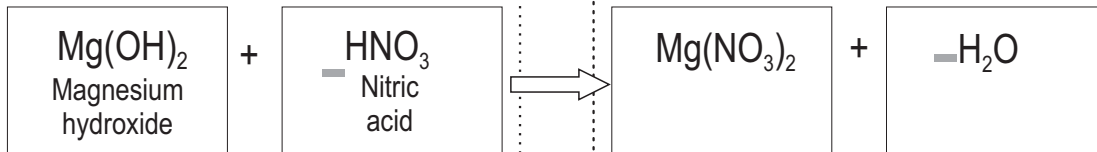
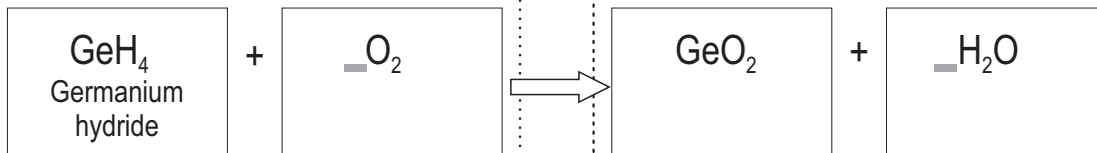
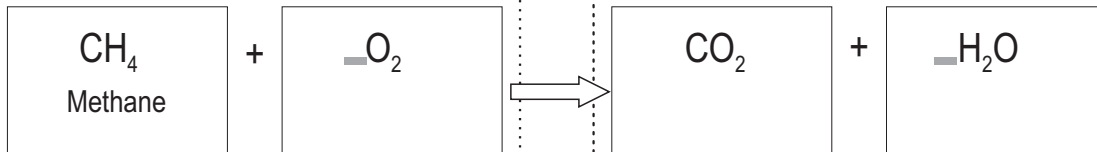
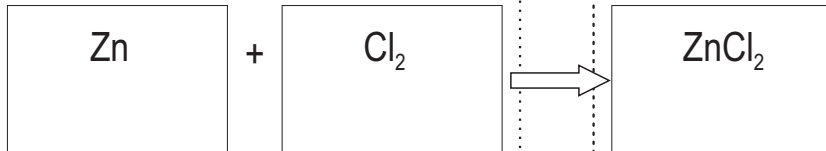
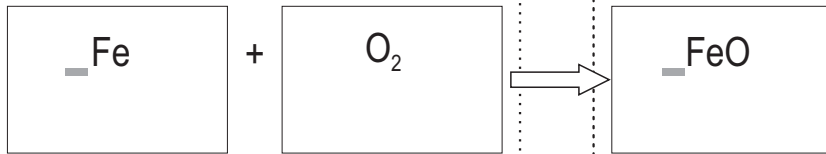
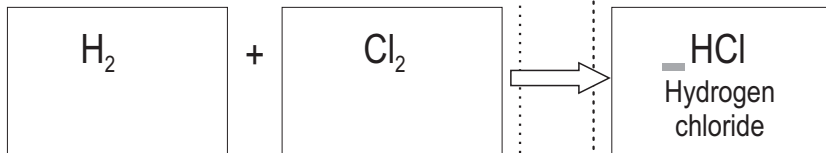


Neutralisation Reactions



Redox Reactions





To convert symbol equations into word equations

Higher : To balance equations

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Word and Symbol Equations



Complete each box by adding the name of each substance.

The chemicals on this side of the equation are called the **reactants** because

The chemicals on this side of the equation are called the **products** because



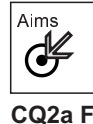
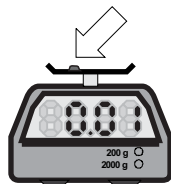
Six of the equations can either be described as neutralisation, combustion or redox. Shade in the arrows in the middle of each equation according to the following key
Green = Neutralisation **Red** = Combustion (oxidation) **Blue** = Redox



Higher only Make sure each equation is fully balanced.

Chemical Masses

Atoms are incredibly small particles. It takes **30,500,000,000,000,000,000** gold atoms just to show up as **0.01** grams on a top pan balance

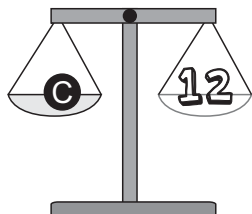


To know that atoms are measured on a relative scale (RAMs)

To use RAMs to calculate formula masses (RMMs)

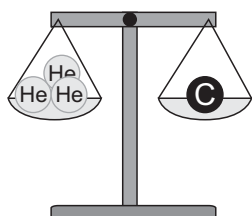
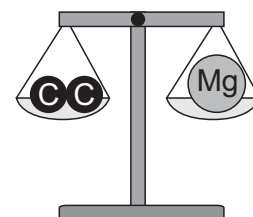
Atoms are very light indeed!

To help scientists an alternative weighing scales called the **Relative Atomic Mass** scale are used.



On this scale one atom of **carbon** is said to have a mass of 12 no units. Scientists then compare other atoms against carbon.

Magnesium atoms are **twice** as heavy as carbon atoms, so scientists say that magnesium weighs no units.



Three helium atoms would have the same mass as one carbon atom. On the relative atomic mass scale one helium atom would weigh no units.

Here is a small table of the masses of other atoms (**RAMs**)

H 1 Hydrogen	Li 7 Lithium	C 12 Carbon	N 14 Nitrogen	O 16 Oxygen	F 19 Fluorine	Na 23 Sodium	Mg 24 Magnesium
Al 27 Aluminium	Si 28 Silicon	S 32 Sulphur	Cl 35.5 Chlorine	K 39 Potassium	Ca 40 Calcium	Fe 56 Iron	Cu 64 Copper

Formula Masses

Carbon dioxide, CO₂, is made by joining = carbon + oxygen + oxygen
 Using the numbers in the table above = 12 + 16 + 16
 = 44

This is known as its relative molecular mass or **RMM**. It tells us how heavy one molecule is.

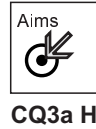


Calculate the mass for each of the substances which follow:.

Magnesium oxide	MgO =	Copper oxide	CuO =
Sodium oxide	Na ₂ O =	Sodium hydroxide	NaOH =
Sand	SiO ₂ =	Sulphur dioxide	SO ₂ =
Ammonia	NH ₃ =	Methane	CH ₄ =
Rust	Fe ₂ O ₃ =	Aluminium oxide	Al ₂ O ₃ =
Ethanol	C ₂ H ₆ O =	Butane	C ₄ H ₁₀ =

Using Formula Masses

Once a chemist has worked out a formula mass (RMM) they can use it to start to make predictions about reactions.

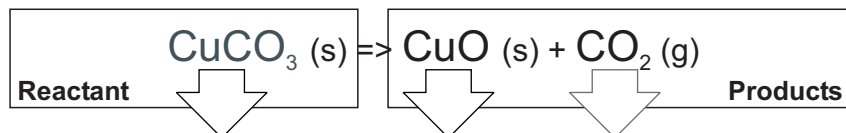


CQ3a HF

To relate RAMs and RMMs to quantities involved in reactions

To collect and interpret masses from experimental data

When green **copper carbonate** is heated strongly, it breaks up into black **copper oxide** and **carbon dioxide** which escapes into the atmosphere.



Formula masses =

Work out and write down the formula mass underneath each of the substances above.

From your formula calculations, you should see that copper carbonate does not split into two equal parts (by mass). Circle the combination which you think best describes the 'split'.

100% \Rightarrow 50:50 60:40 70:30 80:20 90:10

Now calculate the actual percentage of copper oxide as shown opposite and then complete the following.

$$\frac{\text{mass of CuO}}{\text{mass of CuCO}_3} \times 100$$

Prediction
When copper carbonate is heated, it breaks up to form a gas which escapes and a solid. The solid, copper oxide, should weigh about ____ % of the original solid.

Method You must wear goggles at all times

Measure the mass of an empty boiling tube	Add 1 spatula of powdered copper carbonate	Reweigh the tube and starting material	Clamp and then gently heat the tube.	If no further change takes place allow the tube to cool.	Reweigh the cool tube.

Results complete the following calculations

① Mass of empty boiling tube	=	g
② Mass of boiling tube + green carbonate	=	g
③ Mass of boiling tube + black oxide	=	g
Mass of carbonate used	= ② - ①	= g
Mass of oxide produced	= ③ - ①	= g

$$\text{Percentage} \frac{\text{mass of oxide}}{\text{mass of carbonate}} \times 100$$

Conclusion

From my prediction I expected that the solid product would weigh ____ % of the starting solid.
From my practical I found that the percentage was ____ %

Your values should be close; with greater accuracy and more time it is possible to reach the predicted percentage

Using Formula Masses

When chemists carry out experiments to make new materials they need to use the right 'recipe'. It is important that they can predict how much to use and how much product will be made.



CQ3a F

To relate RAMs and RMMs to quantities involved in reactions

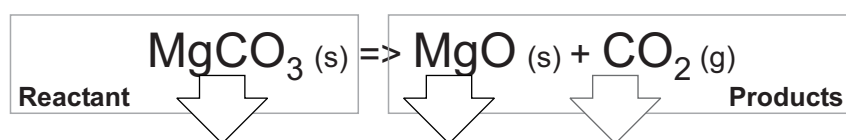
To collect and interpret masses from experimental data

Experiment

When **magnesium carbonate** is heated strongly, it breaks up into **magnesium oxide** and **carbon dioxide** which escapes into the atmosphere.



Using Mg=24, C=12 and O=16 and the equation below, work out the masses of chemicals involved in this experiment.





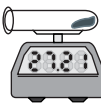



Predicted masses = _____ g _____ g _____ g

Your calculation should show that magnesium carbonate breaks up almost **50:50** with half escaping as a gas. You will now carry out an experiment to see if this is true



Method

You must wear goggles at all times

					
Measure the mass of an empty boiling tube	Add 1 spatula of powdered magnesium carbonate	Reweigh the tube and starting material	Clamp and then gently heat the tube.	Heat for 5 minutes or until no further change seen	Reweigh the cool tube.



Results

① Mass of empty boiling tube	=		=	g
② Mass of boiling tube + white carbonate	=		=	g
③ Mass of boiling tube + heated powder	=		=	g
Mass of carbonate used	=	② - ①	=	g
Mass of oxide produced	=	③ - ①	=	g



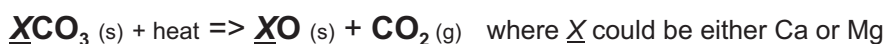
Conclusion

You calculated that about half of the heated powder breaks off as a gas. Explain if your results prove this or not.

Using Percentages

The percentage of solid left after decomposing a substance with a bunsen burner can be easily calculated. This can be useful in identifying substances.

A mineral was thought to be either calcium carbonate (**CaCO₃**) or magnesium carbonate (**MgCO₃**). A small sample was taken and strongly heated to decompose it



The solid left was found to weigh 48% of the starting mineral.



Use the equation opposite to suggest which mineral was involved (Ca=40, Mg=24, C=12, O=16)



CQ3b H

To calculate percentage compositions

To identify substances from percentage compositions

Percentage

$$\frac{\text{RMM of oxide} \times 100}{\text{RMM of carbonate}}$$

Percentage Compositions

Ethane has the formula, C₂H₆; ethane contains two atoms of carbon and six atoms of hydrogen

The relative molecular mass (formula mass) of Ethane = (12 × 2) + (6 × 1)
= 30

The fraction, by mass, of carbon in Ethane = 24 out of 30
= 24/30 × 100%
= 80.0 %

1) Calculate the percentage by mass of carbon in the following molecules (C=12, H=1, O=16)

- | | | | | |
|--------------------------------|---|--|--|-----------------------------------|
| (a) Methane
CH ₄ | (b) Ethene
C ₂ H ₄ | (c) Butane
C ₄ H ₁₀ | (d) Ethanol
C ₂ H ₆ O | (e) Methanol
CH ₄ O |
|--------------------------------|---|--|--|-----------------------------------|

2) Calculate the percentage by mass of nitrogen in the following fertilizers (N=14, S=32)

- | | | |
|---|--|--|
| (a) Ammonium nitrate
NH ₄ NO ₃ | (b) Ammonium sulphate
(NH ₄) ₂ SO ₄ | (c) Ammonium hydroxide
NH ₄ OH |
|---|--|--|

3) Iron (Fe=56) reacts with oxygen to form three possible products, iron (II) oxide **FeO**, iron(III) oxide **Fe₂O₃** and mixed iron oxide **Fe₃O₄**

- Calculate the percentage of oxygen by mass in each of the three oxides
- In one particular experiment, 2.24 grams of iron filings were burnt in pure oxygen. A red product was produced and had a mass of 3.20 grams. Calculate the mass of oxygen which joined with 2.24 grams of iron.
- From your answer to part (b), Calculate the percentage by mass of oxygen in the 3.20 grams of iron oxide.
- From your answers to parts (a) and (c), Suggest which of the three possible oxides was prepared in the experiment.
- Consider the formula given for each of the iron oxides and suggest a reason why Fe₃O₄ is called **mixed** iron oxide

Chemical Percentages

Sometimes it is useful to talk about how a chemical using percentages. For example 24 carat gold is 100% pure but 12 carat only contains half as much gold.



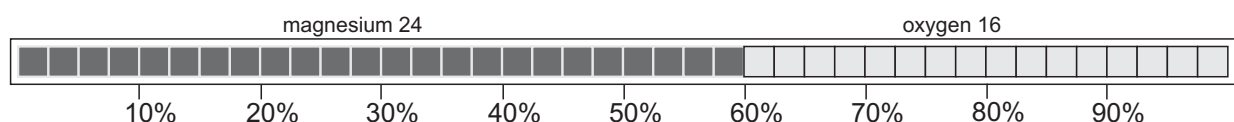
CQ3b F

To calculate percentage compositions

When we calculate percentages for a substance we start by looking at their masses.



The following **40 boxes** show these masses of magnesium (24) and oxygen (16)



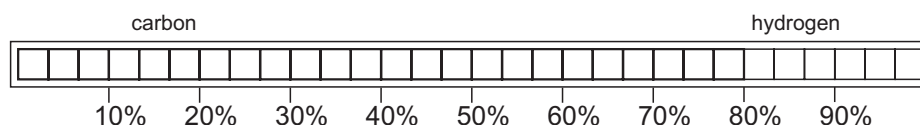
Using this chart, it is easy to see that 60% of the chemical is made up of magnesium.

Calculating Percentages

Ethane has the formula, C_2H_6 ; ethane contains two atoms of carbon and six atoms of hydrogen

$$\begin{aligned} \text{The relative mass of Ethane} &= \text{C} + \text{C} + \text{H} + \text{H} + \text{H} + \text{H} + \text{H} + \text{H} \\ &= 12 + 12 + 1 + 1 + 1 + 1 + 1 + 1 \\ &= 30 \end{aligned}$$

Using **30 boxes**



Colour in the chart above using **blue** for carbon and **red** for hydrogen

What is the percentage of **carbon** in the chemical ethane ?

Instead of using boxes it is often quicker to use a calculator to work out percentages
Propane has the formula, C_3H_8 ; it contains three atoms of carbon and eight atoms of hydrogen

$$\begin{aligned} \text{The relative mass of Propane} &= \text{C} + \text{C} + \text{C} + \text{H} + \text{H} + \text{H} + \text{H} + \text{H} + \text{H} + \text{H} + \text{H} \\ &= 12 + 12 + 12 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 \\ &= 44 \end{aligned}$$

The mass of just carbon in Propane = **36**

Now that we have these two numbers we can calculate the percentage of carbon=>

$$\frac{\text{just carbon} \times 100\%}{\text{whole mass}} = \frac{36 \times 100}{44} = 82\%$$



Calculate the percentage by mass of carbon in the following molecules (C=12, H=1, O=16)

(a) Methane
 CH_4

(b) Ethene
 C_2H_4

(c) Butane
 C_4H_{10}

(d) Ethanol
 $\text{C}_2\text{H}_6\text{O}$

(e) Methanol
 CH_4O

Empirical Formulae

Sometimes chemical formula can be simplified. This leads to its **empirical formula**.

Ethene has the formula, C_2H_4 .

The ratio of carbon : hydrogen in one molecule of ethene = 2 : 4

The ratio of carbon : hydrogen in ethene can be simplified = 1 : 2

Ethene can also be simplified into an empirical formula = C_1H_2

= CH_2

Benzene has the formula, C_6H_6 .

The ratio of carbon : hydrogen in one molecule of benzene = 6 : 6

= 1 : 1

The empirical formula of benzene is therefore = C_1H_1

= CH



Answer the following questions on **lined paper**.

1) Work out the empirical formula for the following molecules

(a) Propene
 C_3H_6

(b) Ethane
 C_2H_6

(c) Butane
 C_4H_{10}

(d) Butene
 C_4H_8

(e) Propane
 C_3H_8

2) Ethane has the molecular formula C_2H_6 and the empirical formula CH_3

(a) Calculate the percentage by mass of carbon in the molecular formula C_2H_6

(b) Calculate the percentage by mass of carbon in the empirical formula CH_3

(c) Comment on the %carbon in the molecular and empirical formulae.

3) A molecule has 75% carbon and 25% hydrogen by mass. If we use these numbers as follows



This gives us the formula as $C_{6.25}H_{25}$ which simplifies into the empirical formula C_1H_4

(a) Work out the empirical formula for the hydrocarbon compound containing 85.7% carbon and 14.3% hydrogen.

(b) Work out the empirical formula for the hydrocarbon compound containing 81.8% carbon and 18.1% hydrogen. (Hint the molecule has an RMM of 44)

(c) Work out the empirical formula for a compound with 60% magnesium and 40% oxygen given that the relative atomic mass of Mg=24 and O=16



CQ3c H

To calculate empirical formulae

To calculate empirical formulae from percentage compositions

Chemical Masses 1

Knowing how to calculate how much molecules weigh can help us to easily predict the amounts of chemicals needed for a successful reaction

**CQ4a H**

To calculate RMMs and convert these into molar quantities

To calculate molar quantities for provided balanced equations

For example it is possible to predict the mass of oxygen needed to completely burn methane gas:

Symbol equation	CH_4 ^{reactants} + 2O_2		=>	CO_2 ^{products} + $2 \text{H}_2\text{O}$	
Atomic masses no units	$12 + (4 \times 1)$ = 16	$2 \times (16 + 16)$ = 64		$12 + 16 + 16$ = 44	$2 \times (1 + 1 + 16)$ = 36
Lab or Molar quantity	16 g	64 g		44 g	36 g

Formula masses have no units; remember they are based on a relative scale where one atom of carbon = 12. But we can easily stick '**grams**' after the numbers we calculate; chemists refer to these amounts as the **molar quantities** for the equation. These amounts involve trillions of atoms (what are known as moles of atoms).

Using your previous sheets to find the relative atomic masses, calculate the mass of each of the substances in the following equations:

Symbol equation	C_2H_4	+	3O_2	=>	2CO_2	+	$2 \text{H}_2\text{O}$
Atomic masses	$24 + 4$		$3 \times (16 + 16)$		$2 \times (12 + 16 + 16)$		$2 \times (1 + 1 + 16)$
Molar quantities							

Symbol equation	2NaOH	+	H_2SO_4	=>	Na_2SO_4	+	$2 \text{H}_2\text{O}$
Atomic masses							
Molar quantities							

Symbol equation	2Na	+	$2 \text{H}_2\text{O}$	=>	2NaOH	+	H_2
Atomic masses							
Molar quantities							

Symbol equation	Mg	+	$2 \text{H}_2\text{O}$	=>	$\text{Mg}(\text{OH})_2$	+	H_2
Atomic masses							
Molar quantities							

Symbol equation			$2 \text{Al}_2\text{O}_3$	=>	4Al	+	3O_2
Atomic masses							
Molar quantities							

Symbol equation			2KNO_3	=>	2KNO_2	+	O_2
Atomic masses							
Molar quantities							

Symbol equation	N_2	+	3H_2	=>	2NH_3
Atomic masses					
Molar quantities					

Chemical Masses 2

When a more reactive metal is added to copper sulphate, the copper is **displaced**. Displacement reactions are often **exothermic** (releasing heat). The greater the amount of chemicals used, the more energy will be released.



CQ4b H

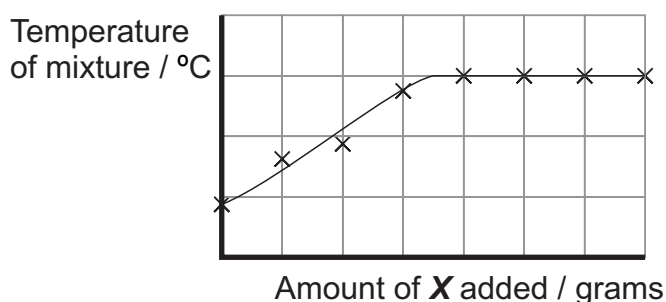
To calculate RMMs and convert these into molar quantities

To calculate molar quantities for provided balanced equations

In the following equation metal **X** is higher up in the reactivity series than copper.



Starting with a small beaker of copper sulphate one spatula at a time, of metal **X**, is added and carefully stirred. If the temperature is measured each time the following graph should be obtained.



Shade in the part of the graph where more than enough (excess) metal has been added

The graph shows that for the experiment there is correct or **optimum** amount of metal **X** to use; this can be used to help identify the metal.

Aim To identify metal X by scaling experiment results up to molar quantities

Method You must wear goggles at all times

- | | |
|--------------|---|
|

 | <ol style="list-style-type: none"> 1 Measure out 25 cm³ of 0.5M copper sulphate solution into a boiling tube 2 Record the initial temperature. 3 Measure out 0.20g** of metal X. 4 Pour all of X into the boiling tube. 5 Swirl and carefully measure the maximum temperature reached. 6 Repeat with 0.40, 0.60, 1.40g of metal X |
|--------------|---|

You could be asked to collate your results as a whole class and will be given a different mass of **X.

Calculation

Using the axis given in the example diagram, plot the determine the optimum mass of metal **X**

25cm³ of 0.5M copper sulphate contains 2.0g of copper sulphate. If you had used a molar quantity, you would have used 160g. Use the following to help you scale up your results to molar quantities.



Experiment quantities

Scaled up
g

2.00 g

Scaled up x 80

160 g

This should give you the RAM of the unknown metal. From a periodic table you should be able to identify **X**.

Molar quantity

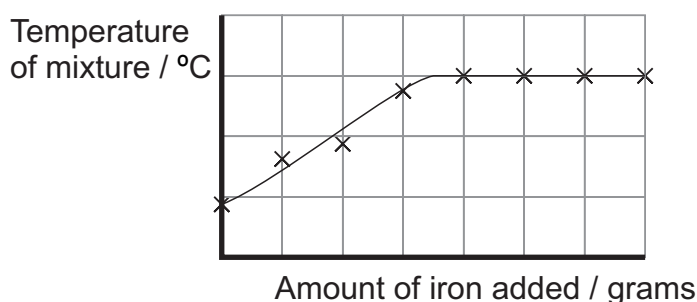
Chemical Masses

When a more reactive metal is added to copper sulphate, the copper is **displaced**. Displacement reactions are often **exothermic** (releasing heat). The greater the amount of chemicals used, the more energy will be released.

Iron is higher up in the reactivity series than copper. It reacts as follows.



When iron, one spatula at a time, is added and stirred with copper sulphate the temperature slowly rises. The following graph should be obtained after several spatulas.



Circle the graph where the enough iron has been added to give a full reaction.

The graph shows that for the experiment there is correct or **optimum** amount of iron to use;

Aim To determine the correct amount of iron needed to react with 2g of copper sulphate

Method You must wear goggles at all times

- 1 Measure out 25 cm³ of 0.5M copper sulphate solution (2g) into a boiling tube
- 2 Record the initial temperature.
- 3 Measure out 0.20g** of iron filings
- 4 Pour all of the iron into the boiling tube.
- 5 Swirl and carefully measure the maximum temperature reached.
- 6 Repeat with 0.40, 0.60, 1.40g of iron.



**You could be asked to collate your results as a whole class and will be given a different mass of iron.

Calculation

Using the axis given in the example diagram, plot and then determine the required mass of iron.

Chemical recipe books give the 'perfect' quantities as **160g** of copper sulphate with **56 g** of iron. The 25cm³ of solution you used contained only 2.0g of copper sulphate (a scaled down experiment).



Perfect quantity



56 g

Scaled down

160 g

Scaled down $\div 80$

Predicted quantities

g

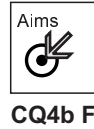
2.00 g

Use this equation to help you work out how much iron (in theory) you needed to add.

How does this compare to your actual experiment ?

Using The Right Mass

We can use (atomic) masses to work out the right amounts to use for a chemical reaction.



CQ4b F

To calculate RMMs and convert these into molar quantities

To calculate molar quantities for provided balanced equations

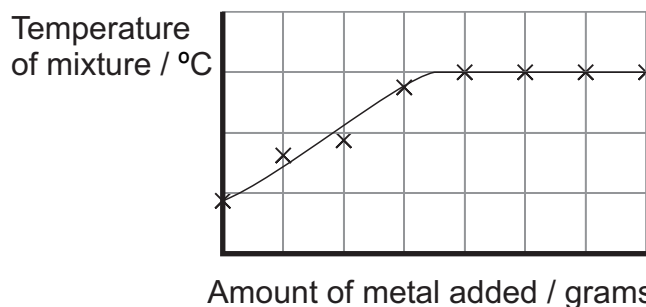
During reactions there are often signs that the right amounts have been used.

Experiment

Iron reacts with copper sulphate to make _____ and _____



If spatula at a time of iron is added to a small beaker of copper sulphate the temperature slowly rises



Circle the graph where exactly the right amount of metal has been added

Aim To find out how much iron needs to be added to 2g of copper sulphate

Method You must wear goggles at all times

- | | | |
|---------|---|---|
| Task | 1 | Measure out 25 cm ³ of 0.5M copper sulphate solution into a boiling tube |
| Exp | 2 | Record the initial temperature. |
| X | 3 | Measure out 0.20g** of iron filings. |
| Goggles | 4 | Pour all of the iron into the boiling tube. |
| | 5 | Swirl and carefully measure the maximum temperature reached. |
| | 6 | Repeat with 0.40, 0.60, 1.40g of iron |

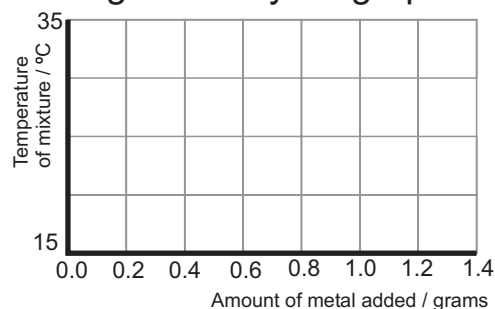
Results



Mass of iron / grams	Maximum temperature reached / °C
0.0	
0.2	
0.4	
0.6	
0.8	
1.0	
1.2	
1.4	

Graph

Use the following axis for your graph



Conclusion

How much iron is needed to completely react with 2g of copper sulphate ?

Chemical Masses 3

Knowing the 'molar quantities' for a reaction makes it easy to calculate and predict the masses for actual experiments.



CQ4c H

To calculate molar quantities for provided balanced equations

To calculate scaled quantities from molar quantities

For example, if **5.0 grams** of **methane** is to be burnt in pure oxygen, predict the mass of **water** (steam) produced. The equation and calculated molar quantities are :

Symbol equation	CH₄	+	2 O ₂	=>	CO ₂	+	2 H₂O
Atomic masses	12 + (4 × 1)		2 × (16 + 16)		12 + 16 + 16		2 × (1 + 1 + 16)
Molar quantity	16 g		64 g		44 g		36 g
	↓ ÷ 16		↓ ÷ 16		↓ ÷ 16		↓ ÷ 16
Scale down	1 g		4 g		2.75 g		2.25 g
	↑ × 5		↑ × 5		↑ × 5		↑ × 5
Scale up	5 g		20 g		13.75 g		answer = 11.25 g

These calculations can be summarized as

- Calculate the **molar quantities** using atomic masses
- Scale down all the quantities so that the **highted chemical** equals just **1 gram**.
- Scale up all the quantities to fit the mass of the highted chemical.

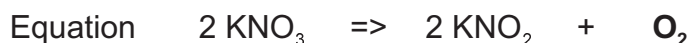
Notice that the same scaling up and down steps are used for all chemicals in the question.

Answer the following questions

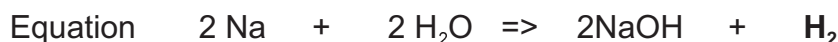
- (1) If **3 grams** of **magnesium** are completely burnt, how much magnesium oxide is made



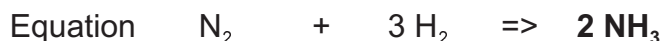
- (2) How much potassium nitrate (KNO₃) is needed to prepare **100 g** of **oxygen** for the reaction :



- (3) How much sodium and water are needed to make **50 g** of **hydrogen** according to the equation :



- (4) **95.2 kg** of **ammonia** can be created using how much hydrogen and nitrogen ?
The equation for the production of ammonia :



- (5) 20 grams of methane and **32 grams** of **oxygen** react to give 22 grams of carbon dioxide and 18 grams of water. Some of the methane is not used up (it is in excess). How much unburnt methane will there be ?



Hint work out how much methane would normally be used first.

Chemical Masses 4

For the following calculate the molar quantities and then scale the equations up or down to amount of substance given in the question.



CQ4d H

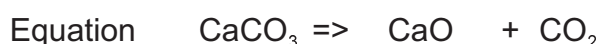
To calculate molar quantities for provided balanced equations

To calculate scaled quantities from molar quantities

1. How much magnesium must be burned to make 4.0g of magnesium oxide ?



2. What mass of calcium oxide (quicklime) is formed when 100g of calcium carbonate (limestone) is heated strongly in a lime kiln ?



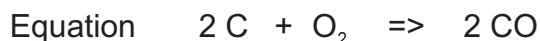
3. During the production of iron in the Blast Furnace, iron(III) oxide is reduced to iron using carbon monoxide.



- (a) What mass of carbon monoxide is needed to react completely with 16 tonnes of iron(III) oxide ? (1 tonne = 1 million grams or simply cross out word *grams* and write *tonnes*)

- (b) What mass of iron would be produced (from the above amounts) ?

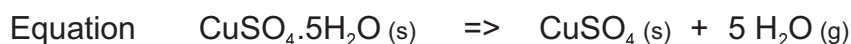
The carbon monoxide is produced in the furnace by the reaction between carbon (coke) and blasts of warm air (oxygen).



- (c) What mass of carbon is required to produce 2.8 tonnes of carbon monoxide ?

4. Copper sulphate is usually blue. This is due to water of crystallisation - when the crystals of copper sulphate are formed, water becomes trapped in the crystals.

If the blue crystals are heated, the crystals turn into a dry (anhydrous) white powder



What is the mass lost when 1.25g of blue copper sulphate crystals are heated and converted in the anhydrous salt ?

5. The mineral Bauxite can be purified to give white aluminium oxide. This can be used to prepare the metal aluminium, by passing electricity through molten aluminium oxide.

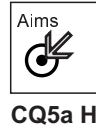


What is the mass of aluminium which can be obtained from 50 tonnes of aluminium oxide ?

RAMs Mg = 24 : O = 16 : Ca = 40 : C = 12 : Fe = 56 : Cu = 64 : S = 32 : H = 1 : Al = 27

Volumes and Masses 1

Chemists can easily calculate the **mass** (in grams) of the **reactants** or **products** for a chemical reaction. This is particularly useful for solid substances. However for gases it is more useful to measure the **volume** (in cm^3).



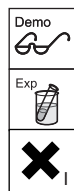
CQ5a H

To observe accurate measurement of gas volumes

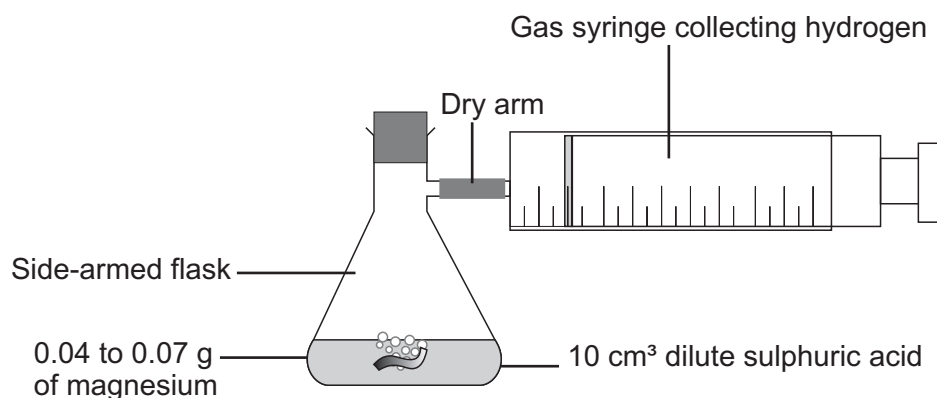
To calculate molar volume of hydrogen from experimental data

Experiment

Aim To find the **molar volume** of hydrogen gas produced according to the equation



In this experiment the hydrogen gas produced is collected and measured in a gas syringe.



The results are then used to predict the volume of gas which would be produced on a molar scale (ie if 24g of magnesium had been used).

Method

- 1 Measure out 10 cm^3 of dilute sulphuric acid in a small measuring cylinder.
- 2 Carefully pour the acid into a side-armed flask - do not let any liquid enter the dry arm
- 3 Attach a gas syringe to the flask and clamp the syringe securely. Ensure that the clamp does not prevent the plunger of the syringe from moving freely.
- 4 Weigh out a small length of magnesium ribbon (about 5cm in length) on a balance.
- 5 Add the magnesium to the flask and quickly cork the apparatus.
- 6 Gently swirl the flask. When all the magnesium has reacted record the final volume of gas.

Calculation



Mass of magnesium used = **g**
in the experiment

Volume of hydrogen collected = **cm^3**
in the experiment

Scaled up.

Scaled up.

Molar quantity = **24 g**

Molar quantity = **cm^3**

The volume predicted from this experiment is often larger than the accepted value **24000 cm^3** (or 24 litres). The reaction between the magnesium and acid is **exothermic**.



What does this mean and how could this alter the volume of the hydrogen collected?

Volumes and Masses 2

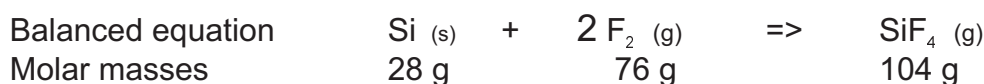
Reacting molar quantities of hydrogen and oxygen creates a spectacular explosion. To use a molar quantity, requires measuring out 2g of H₂.

Hydrogen is lighter than air. You cannot fill and easily weigh a balloon of H₂ - the balloon floats upwards!

However 'one molar quantity' of **any** gas room temperature and pressure (20°C and 1 atmosphere) takes up **24000 cm³** (24 litres or 24 dm³). This is an important fact for chemical calculations.

Example calculation

When solid silicon is tipped into fluorine gas, the product, silicon tetrafluoride, is a gas.

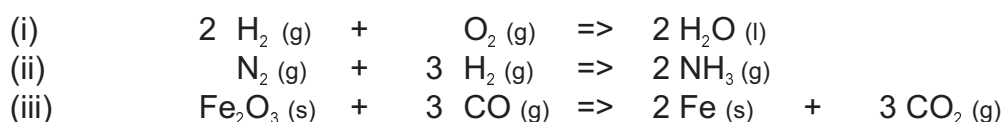


Some important things to note

- Volumes of **gases** are calculated from the *numbers of molecules* in the balanced equation
- The total mass of products **must** equal the total mass of reactants.
- The total volume of products does **not** have to equal the volume of reactants.
- The condition "@ rtp" should also be quoted (your answers would be larger at higher °C).
- Volumes like masses can be scaled up or down

Answer the following questions on lined paper

1) Work out molar quantities, both masses and volumes, for the following equations



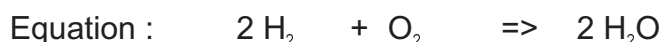
2) If 4.8 grams of magnesium are completely burnt, what volume of oxygen is needed for this reaction at room temperature and pressure ?



3) What volume of hydrogen would be produced if 92 grams of sodium is added to an excess of water ?



4) How many cm³'s of hydrogen and oxygen are needed to form 36 grams of water ?



5) 8 grams of methane gas and 32 grams of oxygen reacted to give 22 grams of carbon dioxide and 18 grams of liquid water. Calculate the total starting volume of gases and the final volume of gases.



CQ5b H

To calculate gas volumes for provided balanced equations

To calculate scaled quantities from molar quantities

Volumes and Masses 3

Molar quantities can also be applied to **electrolysis** reactions. This is however a little complex!



CQ5c H

To calculate gas volumes for provided balanced equations

To calculate scaled quantities from molar quantities

During electrolysis changes take place at the **cathode** and at the **anode**. **Half equations** are used to describe changes taking place.

Molten lithium chloride can be electrolysed to make lithium and chloride gas. During electrolysis the half equations are



The amount of electrons added or removed must be balanced

this equation has been doubled



By using the same quantity of electricity at each electrode we can state that for each 14g of lithium made, there will be 71g (24000cm³) of chlorine. This can be scaled up or down as normal.

Answer the following questions on lined paper

- 1) Sodium chloride contains the ions Na⁺ and Cl⁻. During electrolysis, chlorine is formed at the anode. If 46g of sodium is formed what **volume** of chlorine will be produced ?



- 2) Lead oxide contains the ions Pb²⁺ and O²⁻. What **mass** of lead metal is produced if at the same time 8g of oxygen forms at the anode ?



- 3) Lead bromide contains the ions Pb²⁺ and Br¹⁻. What **mass** of lead metal is produced if at the same time 8g of bromine forms at the anode ?



- 4) Copper chloride contains the ions Cu²⁺ and Cl¹⁻. What **mass** of copper metal is produced if at the same time 12000cm³ of chloride forms at the anode ?



- 5) Aluminium oxide contains the ions Al³⁺ and O²⁻ and is used in the manufacture of aluminium metal - the source of aluminium oxide is a mineral called bauxite (Al₂O₃)

During electrolysis oxygen is formed at the anode

- write the half equation for aluminium ions turning into aluminium atoms
- write the half equation for oxide ions turning into oxygen molecules
- if 54 g of aluminium are formed, what **volume** of oxygen will be formed at the same time ?