ELEMENTS and COMPOUNDS

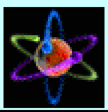
MIXTURES and their separation

CHEMICAL REACTIONS and EQUATIONS

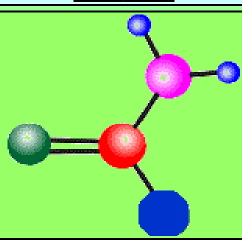
KEYWORDS ... atom ... chemical change ... chromatography ... compound ... covalency ... distillation (simple/fractional) ... element ... equations - (word, picture, symbol, quizzes) ... formula ... impure/pure ... ionic equations ... ionic valency ... magnet ... mixture ... molecule ... physical change ... products ... reactants ... separating mixtures ... chemical symbols - (elements, formula, in equations) ... state symbols ... valency ... working out formulae ...

Introduction and Some keywords (pictures)

ATOM



An **ATOM is the smallest particle of a substance which can have its characteristic properties**. BUT remember atoms are built up of even more fundamental sub-atomic particles - the electron, proton and neutron.



A **MOLECULE** is a **larger particle formed by the chemical combination of two or more atoms**. The molecule may be an element or a compound eg hydrogen H_2 or carbon dioxide CO_2 and the atoms are held together by covalent bonds.

ELEMENT and symbols

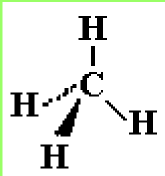
$^{60}_{27}Co$

H I Na Al Fe C Ag U?

- **An ELEMENT is a pure substance made up of only one type of atom***, 92 in the Periodic Table naturally occur from hydrogen H to uranium U.
- Note that **each element has symbol which is a single capital letter like H** or U **or a capital letter + small letter eg cobalt Co**, calcium Ca or sodium Na.
- Each element has its own unique set of properties but the Periodic Table is a means of grouping similar elements together. They may exist as atoms like the Noble Gases eg helium He or as molecules eg hydrogen H_2 or sulphur S_8. (**more examples applied to equations** and see note about '**formula of elements**')
- *** At a higher level of thinking, all the atoms of the same element, have the same atomic or proton number. This number determines how many electrons the atom has, and so ultimately its chemistry. Any atom with 27 protons and electrons is cobalt!**

COMPOUND and FORMULA

- **A COMPOUND is a pure substance formed by chemically combining at least two different elements** by ionic or covalent bonding



CH_4

- Compounds can be represented by a **FORMULA**, eg **sodium chloride NaCl** (ionic, 2 elements,1of sodium and 1 of chlorine), **methane CH_4** (covalent, shown on the left has 2 elements in it, 4 of carbon and 1 of hydrogen*****) and **glucose $C_6H_{12}O_6$** (covalent, 3 elements, 6 atoms of carbon, 12 of hydrogen and 6 of oxygen). **There must be at least two different types of atom (elements) in a compound**.(*** the 1 is never written in the formula, no number means 1**)
- Compounds have a **fixed composition** and therefore a **fixed ratio of atoms** represented by a **fixed formula**, however the compound is made or formed.
- In a compound the **elements are not easily separated by physical means**, and quite often not easily by chemical means either.
- The **compound has properties quite different from the elements it is formed from**.
    - For example soft silvery reactive sodium + reactive green gas chlorine ==> colourless, not very reactive crystals of sodium chloride.
- The **formula of a compound summarises the 'whole number' atomic ratio of what it is made up of** eg **methane CH_4** is composed of **1 carbon atom** combined with **4 hydrogen atoms**. **Glucose** has **6 carbon** : **12 hydrogen** : **6 oxygen** atoms, **sodium chloride** is **1 sodium** : **1 chlorine atom**.
- When there is **only one atom of the element, there is no subscript number**, the 1 is assumed eg Na in NaCl or C in CH_4.
- When there is more than 1 atom of the same element, a subscript number is used eg the 4 in CH_4 meaning 4 hydrogen atoms.
- Sometimes, a compound (usually ionic), is partly made up of two or more identical groups of atoms. To show this more accurately ( ) are used eg
    - calcium hydroxide is $Ca(OH)_2$ which makes more sense than CaO_2H_2 because the OH group is called hydroxide and exists in its own right in the compound.
    - Similarly, **aluminium sulphate** has the formula
        - **$Al_2(SO_4)_3$** rather than $Al_2S_3O_{12}$, because it consists of **two aluminium** ions **Al^{3+}** and **three sulphate** ions **SO_4^{2-}**.
- **The word formula can also apply to elements**. eg hydrogen H_2, oxygen O_2, ozone O_3 (2nd unstable form of oxygen), phosphorus P_4, sulphur S_8, have 2, 2, 3, 4 and 8 atoms in their molecules. Elements like helium He are referred to as 'monatomic' because they exist as single uncombined atoms.

MIXTURE

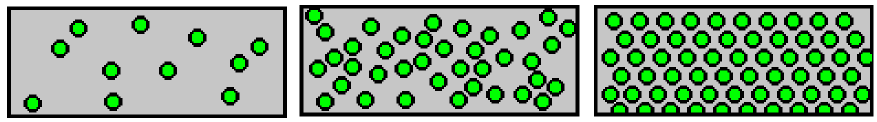
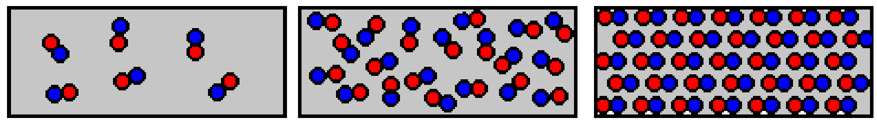
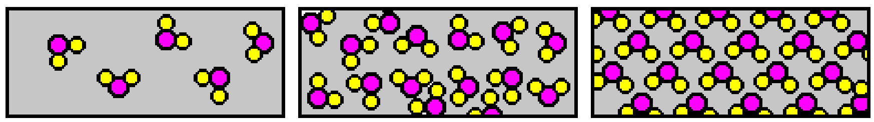
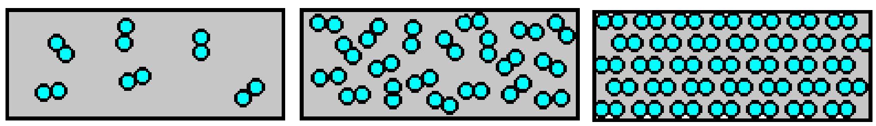
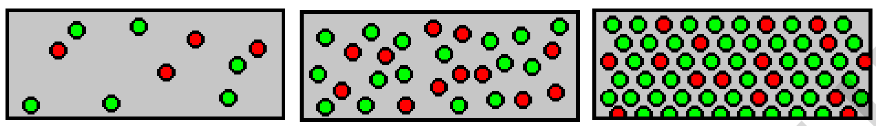
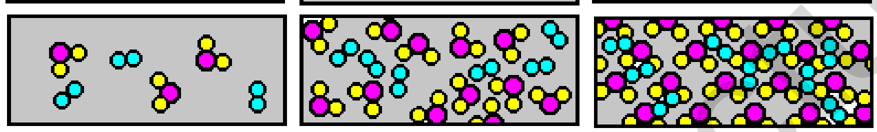
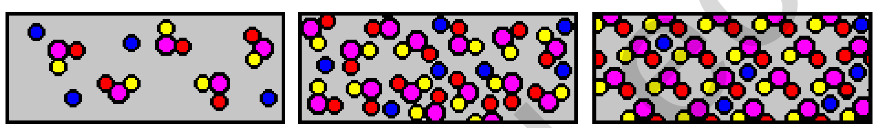
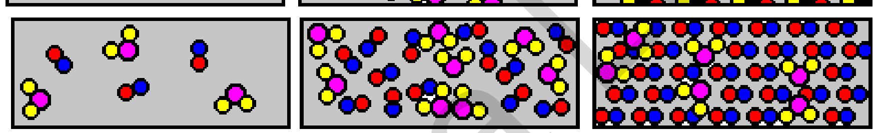
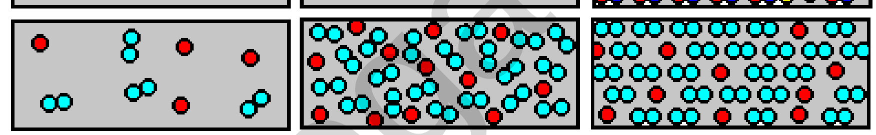
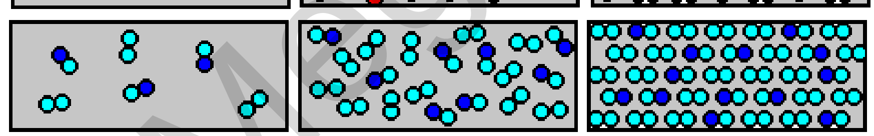
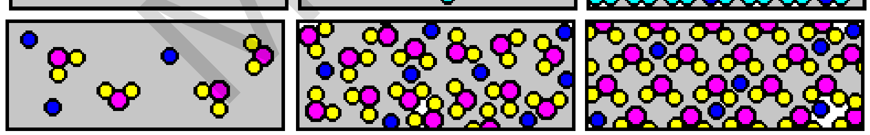
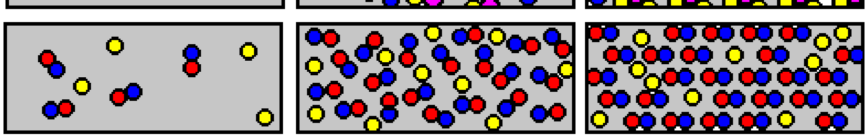
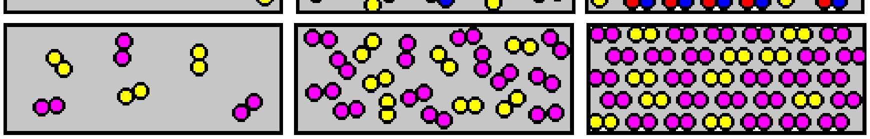
A **MIXTURE** is a material made up of at least two substances which may be elements or compounds. They are usually easily separated by physical means eg filtration, distillation, chromatography etc. Examples: air, soil, solutions.

PURE

- **PURE** means that only one substance present in the material and can be an element or compound.
- A simple physical test for purity and helping identify a compound is to measure the boiling point of a liquid. Every pure substance melts and boils at a fixed temperature.
    - If a liquid is pure it may boil at a constant temperature (boiling point).
    - An impure liquid could boil higher or lower than the expected boiling point and over a range of temperature.

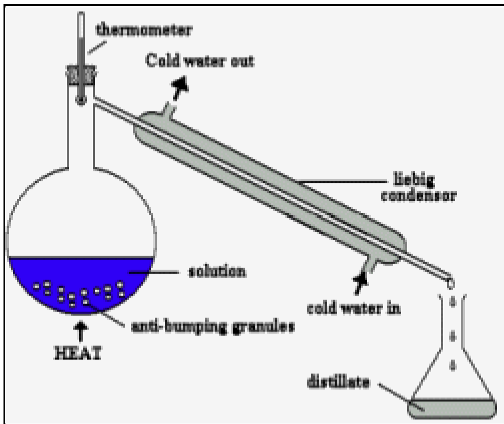
	○ If a solid is pure, it will quite sharply at the melting point. ○ An impure solid melts below its expected melting point and more slowly over a wider temperature range.
IMPURE	• **IMPURE** usually means a mixture of mainly one substance plus one or more other substances physically mixed in. • The % purity of a compound is important, particularly in drug manufacture. Any impurities present are less cost-effective to the consumer and they may be harmful substances.
PURIFICATION	• Materials are purified by various separation techniques. • The idea is to separate the desired material from unwanted material. • they include: ○ **Filtration** to separate a solid from a liquid. You may want the solid or the liquid or both! ○ **Simple distillation** to separate a pure liquid from dissolved solid impurities which have a very high boiling point. ○ **Fractional distillation** to separate liquids with a range of different boiling points, especially if relatively close together. ○ **Crystallisation** to get a pure solid out of a solvent solution of it. ○ **Chromatography** can be used on a larger scale than spots' to separate out pure samples from a mixture.

Picture examples of Elements, Compounds and Mixtures

GAS / LIQUID / SOLID	COMMENTS	
	one pure element of single atoms	eg He helium
	one pure compound of diatomic molecules	eg HCl hydrogen chloride
	one pure compound of molecules	eg H_2O water
	one pure element of diatomic molecules	eg H_2 hydrogen
	mixture of two elements, both are single atoms	eg He Ne helium and neon
	mixture of a compound and an element, both molecules	eg N_2 H_2O nitrogen and water
	a mixture of a molecular compound and element atoms	eg Kr NOCl krypton and nitrosyl chloride
	a mixture of two compounds, both molecules	eg ClF H_2O chlorine monofluoride and water
	a mixture of element atoms and molecules of an element	eg He O_2 helium and oxygen
	a mixture of an element and a compound, both diatomic molecules	eg N_2 NO nitrogen nitrogen monoxide
	a mixture of compound molecules and element atoms	eg Ar H_2O argon and water
	a mixture of a diatomic molecule compound and element atoms	eg He HCl helium and hydrogen chloride
	a mixture of two diatomic elements	eg O_2 N_2 oxygen and nitrogen

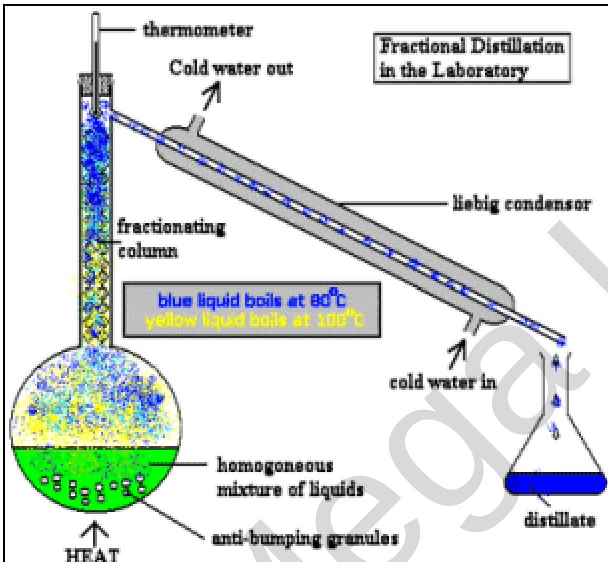
METHODS of SEPARATING MIXTURES

Simple Distillation



- **Distillation** involves 2 stages and both are physical state changes.
- (1) The liquid or solution mixture is **boiled to vaporise** the most volatile component in the mixture (**liquid ==> gas**). The ant-bumping granules give a smoother boiling action.
- (2) The vapour is cooled by cold water in the condenser to **condense** (**gas ==> liquid**) it back to a liquid (the distillate) which is collected.
- This can be used to purify water because the dissolved solids have a much higher boiling point and will not evaporate with the steam.
- BUT it is too simple a method to separate a mixture of liquids especially if the boiling points are relatively close.

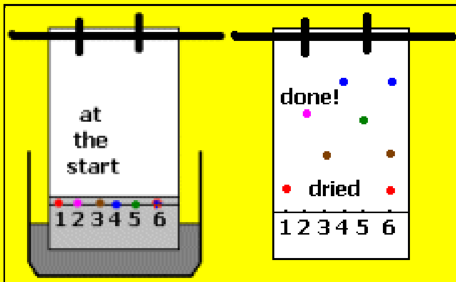
Fractional Distillation



- **Fractional distillation** involves 2 main stages and both are physical state changes. **It can only work with liquids with different boiling points**.
- (1) The liquid or solution mixture is **boiled to vaporise** the most volatile component in the mixture (**liquid ==> gas**). The ant-bumping granules give a smoother boiling action.
- (2) The vapour passes up through a **fractionating column**, where the separation takes place (theory at the end). This column is not used in the simple distillation described above.
- (3) The vapour is cooled by cold water in the condensor to **condense** (**gas ==> liquid**) it back to a liquid (the distillate) which is collected.
- This can be used **to separate alcohol from a fermented sugar solution**.
- It is used on a large scale **to separate the components of crude oil**, because the different hydrocarbons have different boiling and condensation points
- **FRACTIONAL DISTILLATION THEORY**:
  - Imagine green liquid is a mixture of a blue liquid (but. 80°C) and a yellow liquid (bpt. 100°C), As the vapour from the boiling mixture enters the fractionating column it begins to cool and condense. The highest boiling or least volatile liquid tends to condense more ie the yellow liquid (water). The lower boiling more volatile blue liquid gets further up the column. Gradually up the column the blue and yellow separate from each other so that yellow condenses back into the flask and pure blue distills over to be collected. The 1st liquid, the lowest boiling point, is called the 1st fraction and each liquid distills over when the top of the column reaches its particular boiling point to give the 2nd, 3rd fraction etc.
  - **To increase the separation efficiency of the tall fractionating column**, it is usually packed with glass beads, short glass tubes or glass rings etc. which greatly increase the surface area for evaporation and condensation.
  - In the **distillation of crude oil** the different fractions are condensed out at different

points in a huge fractionating column. At the top are the very low boiling fuel gases like butane and at the bottom are the high boiling big molecules of waxes and tar.

Paper Chromatography

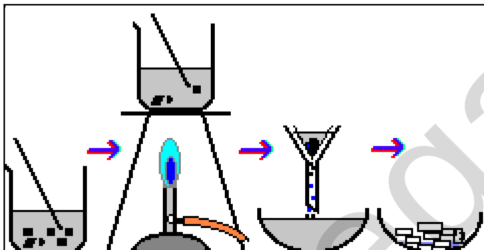


This method of separation is used to see what coloured materials make up eg a food dye analysis.

- The material to be separated eg a food dye (6) is dissolved in a solvent and carefully spotted onto chromatography paper alongside known colours on a 'start line' (1-5).
- The paper is carefully dipped into a solvent, which is absorbed into the paper and rises up it.
- Due to different solubilities and different molecular 'adhesion' some colours move more than others up the paper, so effecting the separation of the different coloured molecules.
- Any colour which **horizontally matches** another is likely to be the same molecule ie red (1 and 6), brown (3 and 6) and blue (4 and 6) match, showing these three are all in the food dye (6).

It is possible to analyse colourless mixture if the components can be made coloured eg protein can be broken down into **amino acids** and **coloured purple** by a chemical **reagent called ninhydrin** and many **colourless organic molecules fluoresce** when **ultra-violet light is shone on them**.

FILTRATION	EVAPORATION	CRYSTALLISATION

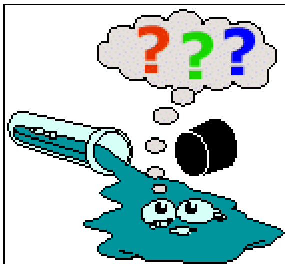


- **Filtration** use a filter paper or fine porous ceramic to separate a solid from a liquid. It works because the tiny dissolved particles are too small to be filtered BUT any non-dissolved solid particles are too big to go through!
- **Evaporation** means a liquid changing to a gas or vapour. In separation, its removing the liquid from a solution, usually to leave a solid. It can be done quickly with gentle heating or left out to 'dry up' slowly. The solid will almost certainly be less volatile than the solvent and will remain as a crystalline residue.
- **Crystallisation** can mean a liquid substance changing to its solid form. However, the term usually means what happens when the liquid from a solution has evaporated to a point beyond the solubility limit. Then solid crystals will 'grow' out of the solution.
- All three of these separation methods are involved in (1) separation of sand and salt mixtures or (2) **salt preparations** eg from dissolving an insoluble base in an acid.

Miscellaneous Separation Methods

MAGNET	This can be used to separate iron from a mixture with sulphur (see below). It is used in recycling to recover iron and steel from domestic waster ie the 'rubbish' is on a conveyer belt that passes a powerful magnet which pluck's out magnetic materials.

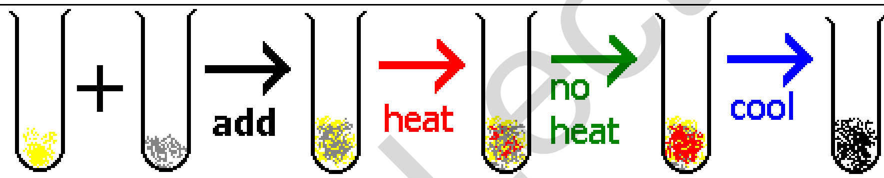
PHYSICAL CHANGES



These are changes which do not lead to new substances being formed. Only the physical state of the material changes. The substance retains exactly the same chemical composition. Examples ...

- **melting**, solid to liquid, easily reversed by cooling eg ice and liquid water are still the same H_2O molecules.
- **dissolving**, eg solid mixes completely with a liquid to form a solution, easily reversed by evaporating the liquid eg dissolving salt in water, on evaporation the original salt is regained.
- So **freezing, evaporating, boiling, condensing** are all physical changes.
- **separating a physical mixture eg chromatography**, eg a coloured dye solution is easily separated on paper using a solvent, they can all be re-dissolved and mixed to form the original dye.
- So **distillation, filtering** are also physical changes.

CHEMICAL CHANGES - REACTIONS - reactants and products



- **Heating iron and sulphur is classic chemistry experiment**.
- A mixture of silvery grey iron filings and yellow sulphur powder is made.
- The iron can be plucked out with a magnet ie an easily achieved physical separation because the iron and sulphur are not chemically combined yet!
- They are still the same iron and sulphur.
- On heating the mixture, it eventually glows red on its own and a dark grey solid called iron sulphide is formed. Both observations indicate a chemical change is happening ie a new substance is being formed.
- We no longer have iron or sulphur BUT a **new compound** with **different** physical **properties** (eg colour) and chemical properties (unlike iron which forms hydrogen with acids, iron sulphide forms toxic nasty smelling hydrogen sulphide!).
- **iron + sulphur ==> iron sulphide** or in symbols: **Fe + S ==> FeS**
- AND it is no longer possible to separate the iron from the sulphur using a magnet!
- So **signs that a chemical reaction has happened** include:
  - **colour changes**,
  - **temperature changes**,
  - **change in mass** eg
    - some solids when burned in air gain mass in forming the oxide eg magnesium forms magnesium oxide
    - some solids lose mass when heated, eg carbonates lose carbon dioxide in thermal decomposition
- Therefore a **chemical change is one in which a new substance is formed, by a process which is not easily reversed and usually accompanied by an energy (temperature) change**. This is **summarised as reactants ==> products** as expressed in **chemical equations** in words or symbols.

THE CONSTRUCTION OF CHEMICAL EQUATIONS

"How to write and understand chemical equations"

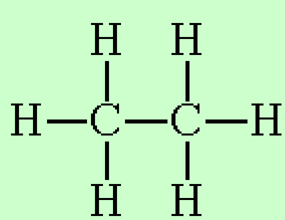
- **Seven equations are presented, but approached in the following way**
  - **(1a-7a) the individual symbols and formulae are explained**
  - **(1b-7b) the word equation is presented to summarise the change of reactants to products**
  - **(1c-7c) a balanced 'picture' equation which helps you understand reading formulae and atom counting to balance the equation**
  - **(1d-7d) the fully written out symbol equation with state symbols (often optional for starter students)**

Chemical Symbols and Formula

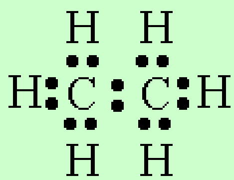
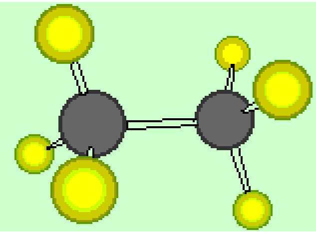
- For any reaction, what you start with are called the **reactants**, and what you form are called the **products**.
  - So any **chemical equation** shows in some way the overall chemical change of **...**
  - **REACTANTS ==> PRODUCTS**, which can be written in **words or symbols/formulae**.
- **It is most important you read about formula in an earlier section of this page.**
- **empirical formula and molecular formula** are dealt with on another page.
- In the equations outlined below several things have been deliberately simplified. This is to allow the 'starter' chemistry student to concentrate on understanding formulae and balancing chemical equations. Some teachers may disagree with this approach BUT my simplifications are:
  - the word 'molecule' is sometimes loosely used to mean a 'formula',
  - the real 3D shape of the 'molecule' and the 'relative size' of the different element atoms is ignored
  - if the compound is ionic, the ion structure and charge is ignored, its just treated as a formula

Molecular and Structural Formulas

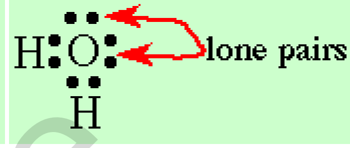
A molecular formula gives the types and the count of atoms for each element in a compound. An example of a molecular formula is ethane, C_2H_6. Here the formula indicates carbon and hydrogen are combined in ethane. The subscripts tell us that there are 2 carbon atoms and 6 hydrogen atoms in a formula unit.



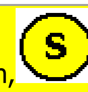
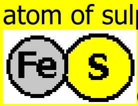
The structural formula shows the atoms in a formula unit and the bonds between atoms as lines. Single bonds are one line, Double bonds are two lines. Triple bonds are three lines. The Lewis dot structure shows the number of valence electrons and types of bonds in the molecule.

Lewis dot structure	Ball and stick model
	

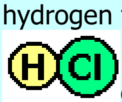
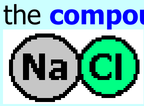
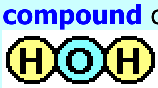
Electron pairs that are shared are physically between the symbols for the atoms. Electron pairs that are unshared are called lone pairs. Lone pairs are not between atom symbols.



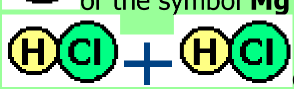
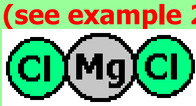
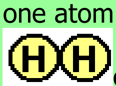
1a

- A single symbol means an uncombined **single atom** of the **element**,  or **Fe** 1 atom of iron,  or **S** 1 atom of sulphur (2Fe would mean two atoms, 5S would mean five atoms etc.)
-  or the formula **FeS** means one atom of iron is chemically combined with 1 atom of sulphur to form the **compound** called **iron sulphide**

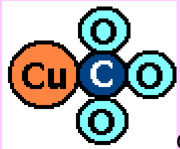
2a

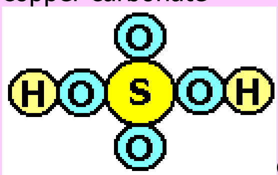
-  or the formula **NaOH** means 1 atom of sodium is combined with 1 atom of oxygen and 1 atom of hydrogen to form the **compound** called **sodium hydroxide**
-  or the formula **HCl** means 1 atom of hydrogen is combined with 1 atom of chlorine to form 1 molecule of the **compound** called **hydrochloric acid**
-  or the formula **NaCl** means 1 atom of sodium are combined with 1 atom chlorine to form the **compound** called **sodium chloride**
-  or the formula **H_2O** means 2 atoms of hydrogen are chemically combined with 1 atom of oxygen to form the **compound** called **water**.

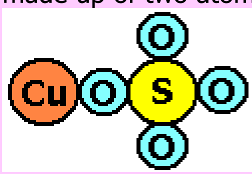
3a

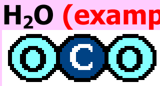
-  or the symbol **Mg** means **1 atom** of the **element** called **magnesium**
-  or **2HCl** means **two separate molecules** of the **compound** called **hydrochloric acid** **(see example 2)**
-  or the formula **$MgCl_2$** means **1 formula** of the **compound** called **magnesium chloride**, made of one atom of magnesium and two atoms of chlorine.
-  or the formula **H_2** means **1 molecule** of the **element** called **hydrogen** made up of two joined hydrogen atoms

4a

- 

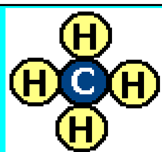
or the formula $CuCO_3$ means **one formula** of the **compound** called **copper carbonate**, made up of one atom of copper is combined with one atom of carbon and three atoms of oxygen to form the compound copper carbonate
- 

or the formula H_2SO_4 means **one formula** of the **compound** called sulphuric acid, which is made up of two atoms of hydrogen, one atom of sulphur and four atoms of oxygen
- 

or the formula $CuSO_4$ means **one formula** of the **compound** called copper sulphate which is made up of one atom of copper, one atom of sulphur and four atoms of oxygen
- **H_2O (example 2)**
- 

or the formula CO_2 means **one molecule** of the **compound** called **carbon dioxide** which is a chemical combination of one atom of carbon and two atoms of oxygen.

5a

- 

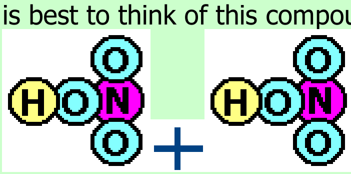
or the formula CH_4 means **one molecule** of the **compound** called **methane** which is made of one atom of carbon combined with four atoms of hydrogen
- 

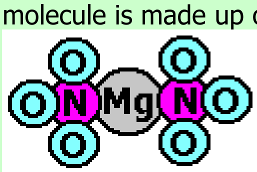
or **$2O_2$** means **two separate molecules** of the **element** called **oxygen**, and each oxygen molecule consists of two atoms of oxygen
- **CO_2 (see also example 4)**
- 

or **$2H_2O$** means **two separate molecules** of the **compound** called **water (see also example 2)**

6a

- 

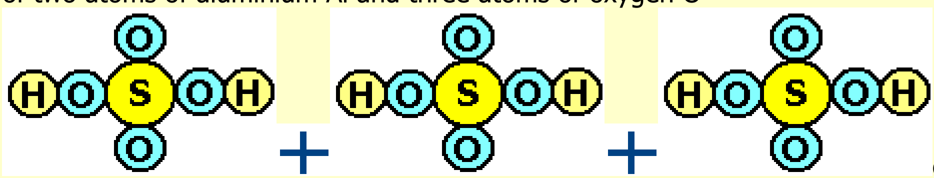
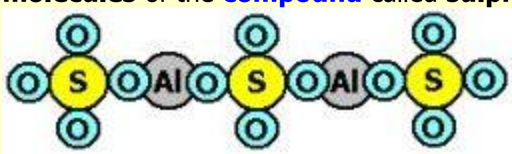
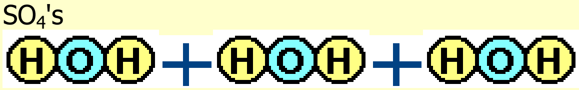
or the formula $Mg(OH)_2$ is the **compound** magnesium hydroxide made up of one magnesium, two oxygen and two hydrogen atoms BUT the OH is a particular combination called hydroxide within a compound, so it is best to think of this compound as a combination of an Mg and two OH's, hence the use of the ( ).
- 

or **$2HNO_3$** means **two separate molecules** of the **compound nitric acid**, each molecule is made up of one hydrogen atom, one nitrogen atom and three oxygen atoms.
- 

or the formula $Mg(NO_3)_2$ is the **compound magnesium nitrate**, it consists of a magnesium (ion) and two 'nitrates' (ions), each nitrate consists of one nitrogen and three oxygen atoms, again the nitrate is a particular combination of atoms within a compound and hence the use of ( ) again.

-  or $2H_2O$ meaning **two molecules** of the **compound water** **(see also examples 2 and 5)**

7a

-  or the formula Al_2O_3 means **one formula** of the **compound** called **aluminium oxide**, made up of two atoms of aluminium Al and three atoms of oxygen O
-  or $3H_2SO_4$ meaning **three molecules** of the **compound** called **sulphuric acid** **(see also example 4)**
-  or the formula $Al_2(SO_4)_3$ means **one formula** of the **compound** called **aluminium sulphate**, it consists of two aluminium, three sulphur and twelve oxygen atoms BUT the SO_4 is a particular grouping called sulphate, so it is best to think of the compound as a combination of two Al's and three SO_4's
-  or $3H_2O$ means **three separate molecules** of the **compound** called **water** **(see also examples 2 and 5)**

Chemical word equations

- **==>** means the direction of change from **reactants =to=> products**
- **no symbols or numbers are used in word equations**
- **always try to fit all the words neatly lined up from left to right, especially if its a long word equation** eg for clarity in example 4, some names are split in two parts using two lines, one under the other, this 'style' helps understanding when it comes to revision!

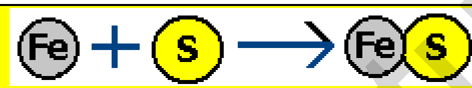
1b	**iron + sulphur ==> iron sulphide**
2b	**sodium hydroxide + hydrochloric acid ==> sodium chloride + water**
3b	**magnesium + hydrochloric acid ==> magnesium chloride + hydrogen**
4b	**copper carbonate + sulphuric acid ==> copper sulphate + water + carbon dioxide**
5b	**methane + oxygen ==> carbon dioxide + water**
6b	**magnesium hydroxide + nitric acid ==> magnesium nitrate + water**
7b	**aluminium oxide + sulphuric acid ==> aluminium sulphate + water**

Chemical picture equations

There are three main points to writing and balancing equations

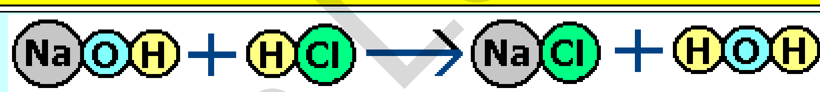
- **Writing the correct symbol or formula for each equation component.**
- **Using numbers if necessary to balance the equation.**
- **if all is correct, then the sum of atoms for each element should be the same on both side of the equation arrow .....**
    - **in other words: atoms of products = atoms of reactants**
        - **This is a chemical conservation law of atoms and later it may be described as the 'law of conservation of mass.**
    - **the 7 equations are first presented in 'picture' style and then written out fully with state symbols**
    - **The individual formulas involved and the word equations have already been presented above.**
- **PRACTICE QUESTIONS - words and symbols**
    - **Multiple choice quiz on balancing numbers**
    - **Word-fill exercises**
    - **Reactions of acids** with metals, oxides, hydroxides and carbonates.

1c



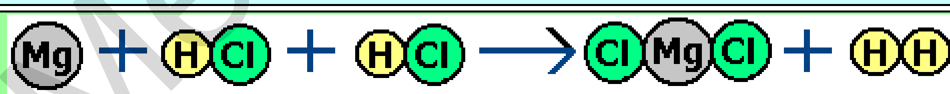
- **on average one atom of iron chemically combines with one atom of iron forming one molecule of iron sulphide**
- **atom balancing, sum left = sum right: 1 Fe + 1 S = (1 Fe + 1S)**
- **two elements chemically combining to form a new compound**

2c



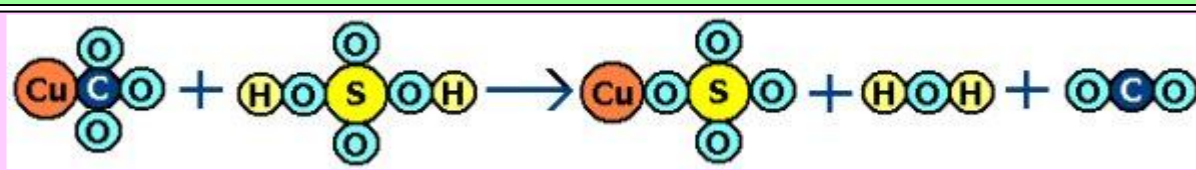
- **the reactants are one molecule of sodium hydroxide and one molecule of hydrochloric acid**
- **the products are one molecule of sodium chloride and one molecule of water**
- **all chemicals involved are compounds**
- **atom balancing, sum left = right: (1 Na + 1 O + 1 H) + (1 H +1 Cl) = (1 Na + 1 Cl) + (2 H's + 1 O)**

3c



- **one atom of magnesium reacts with two molecules of hydrochloric acid**
- **the products are one molecule of magnesium chloride and one molecule of hydrogen**
- **Mg and H-H are elements, H-Cl and Cl-Mg-Cl are compounds**
- **atom balancing, sum left = right: (1 Mg) + (1 H + 1 Cl) + (1 H + 1 Cl) = (1 Mg + 2 Cl's) + (2H's)**

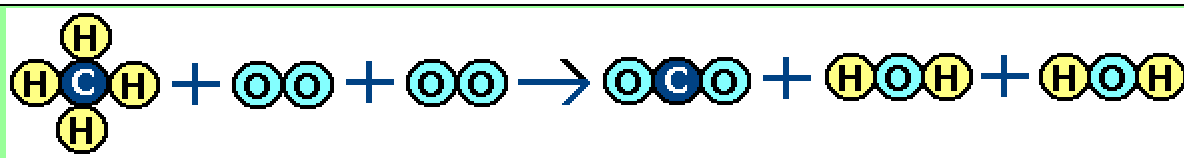
4c



- **the reactants are one formula of copper carbonate and one molecule of sulphuric acid**
- **the products are one formula of copper sulphate, one molecule of water and one molecule of carbon dioxide**
- **all molecules are compounds in this reaction**

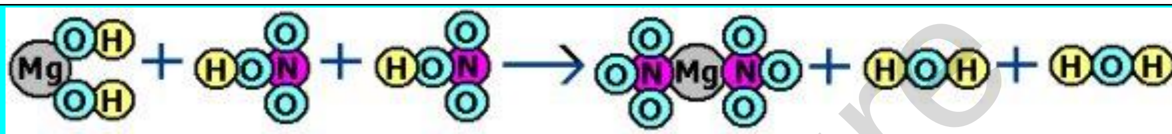
- **atom balancing, sum left = sum right: (1 Cu + 1 C + 3 O's) + (2 H's + 1 S + 4 O's) = (1 Cu + 1 S + 4 O's) + (2 H's + 1 O) + (1 C + 2 O's)**

5c



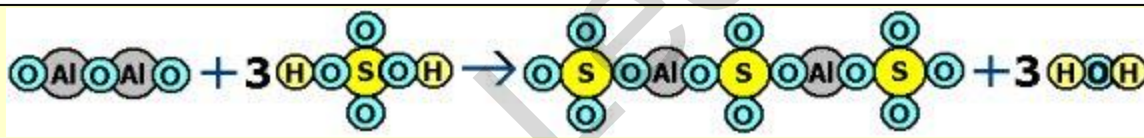
- **one molecule of methane is completely burned by two molecules of oxygen**
- **to form one molecule of carbon dioxide and two molecules of water**
- **atom balancing, sum left = sum right: (1 C + 4 H's) + (2 O's) + (2 O's) = (1 C + 2 O's) + (2 H's + 1 O) + (2 H's + 1 O)**

6c



- **one formula of magnesium hydroxide reacts with two molecules of nitric acid to form one formula of magnesium nitrate and two molecules of water (all compounds)**
- **atom balancing, sum left = sum right: (1 Mg + 2O's + 2 H's) + (1 H + 1 N + 3O's) + (1 H + 1 N + 3O's) = (1 Mg + 2 N's + 6 O's) + (2 H's + 1 O) + (2 H's + 1 O)**

7c



- **one formula of aluminium oxide reacts with three molecules of sulphuric acid**
- **to form one formula of aluminium sulphate and three molecules of water**
- **note the first use of numbers (3) for the sulphuric acid and water!**
- **so picture three of them in your head, otherwise the picture gets a bit big!**
- **atom balancing, sum left = sum right: (2 Al's + 3 O's) + 3 x (2 H's + 1 S + 4 O's) = (2 Al's + 3 S's + 12 O's) + 3 x (2 H's + 1 O)**

Chemical symbol equations (rules already stated above)

1d

- **$Fe_{(s)} + S_{(s)}$ ==> $FeS_{(s)}$**
- **atom balancing, sum left = sum right: 1 Fe + 1 S = (1 Fe + 1S)**
- **all the reactants (what you start with) and all the products (what is formed) are all solids in this case.**
- **When first learning symbol equations you probably won't use state symbols at first (see end note).**

2d

- **$NaOH_{(aq)} + HCl_{(aq)}$ ==> $NaCl_{(aq)} + H_2O_{(l)}$**
- **atom balancing, sum left = right: (1 Na + 1 O + 1 H) + (1 H +1 Cl) = (1 Na + 1 Cl) + (2 H's + 1 O)**

3d

- **$Mg_{(s)} + 2HCl_{(aq)}$ ==> $MgCl_{2(aq)} + H_{2(g)}$**
- **atom balancing, sum left = right: (1 Mg) + 2 x (1 H + 1 Cl) = (1 Mg + 2 Cl's) + (2H's)**

4d	• **$CuCO_{3(s)} + H_2SO_{4(aq)}$ ==> $CuSO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$** • **balancing sum left = sum right: (1 Cu + 1 C + 3 O's) + (2 H's + 1 S + 4 O's) = (1 Cu + 1 S + 4 O's) + (2 H's + 1 O) + (1 C + 2 O's)**
5d	• **$CH_{4(g)} + 2O_{2(g)}$ ==> $CO_{2(g)} + 2H_2O_{(l)}$** • **atom balancing, sum left = sum right: (1 C + 4 H's) + 2 x (2 O's) = (1 C + 2 O's) + 2 x (2 H's + 1 O)**
6d	• **$Mg(OH)_{2(aq)} + 2HNO_{3(aq)}$ ==> $Mg(NO_3)_{2(aq)} + 2H_2O_{(l)}$** • **atom balancing, sum left = sum right: (1 Mg + 2O's + 2 H's) + 2 x (1 H + 1 N + 3 O's) = (1 Mg + 2 N's + 6 O's) + 2 x (2 H's + 1 O)**
7d	• **$Al_2O_{3(s)} + 3H_2SO_{4(aq)}$ ==> $Al_2(SO_4)_{3(aq)} + 3H_2O_{(l)}$** • **atom balancing, sum left = sum right: (2 Al's + 3 O's) + 3 x (2 H's + 1 S + 4 O's) = (2 Al's + 3 S's + 12 O's) + 3 x (2 H's + 1 O)**

- **NOTE 1: $\rightleftharpoons$ means a reversible reaction**, it can be made to go the 'other way' if the conditions are changed. Example:
  - nitrogen + hydrogen $\rightleftharpoons$ ammonia
  - **$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$**
  - balancing: 2 nitrogen's and 6 hydrogen's on both sides of equation

Note 2 on the state symbols $X_{(?)}$ of reactants or products in equations

- **(g)** means **gas**, **(l)** means **liquid**, **(s)** means **solid**
- and **(aq)** means **aqueous solution** or **dissolved in water**
- **eg** carbon dioxide gas **$CO_{2(g)}$**, liquid water **$H_2O_{(l)}$**, solid sodium chloride 'salt' **$NaCl_{(s)}$**
- and copper sulphate solution **$CuSO_{4(aq)}$**

VALENCY - COMBINING POWER - FORMULA DEDUCTION

- **(2nd draft)** The **valency** of an atom or group of atoms is its **numerical combining power** with other atoms or groups of atoms.
- **The theory behind this, is all about stable electron structures!**
  - **The combining power or valency is related to the number of outer electrons.**
  - **You need to consult the page on "Bonding" to get the electronic background.**
- A **group of atoms**, which is **part of a formula**, with **a definite composition**, is sometimes referred to as a **radical**.
- In the case of ions, the **charge on the ion is its valency** or combining power (list below).
- **To work out a formula** by combining 'A' with 'B' the rule is:
  - number of 'A' x valency of 'A' = number of 'B' x valency of 'B',
- **However it is easier perhaps? to grasp with ionic compound formulae**.
  - In the **electrically balanced stable formula**, the total positive ionic charge must equal the total negative ionic charge. Example:
  - Aluminium oxide consists of aluminium ions **Al^{3+}** and oxide ions **O^{2-}**
  - number of Al^{3+} x charge on Al^{3+} = number of O^{2-} x charge on O^{2-}
  - the simplest numbers are 2 of Al^{3+} x 3 = 3 of O^{2-} x 2 (total 6+ balances total 6-)
  - so the simplest whole number formula for aluminum oxide is Al_2O_3

Positive Ions (cations) Name	Formula	Negative Ions (anions) Name	Formula
Hydrogen	H^+	Chloride	Cl^-
Sodium	Na^+	Bromide	Br^-
Silver	Ag^+	Fluoride	F^-
Potasssium	K^+	Iodide	I^-
Lithium	Li^+	Hydroxide	OH^-
Ammonium	NH_4^+	Nitrate	NO_3^-
Barium	Ba^{2+}	Oxide	O^{2-}
Calcium	Ca^{2+}	Sulphide	S^{2-}
Copper(II)	Cu^{2+}	Sulphate	SO_4^{2-}
Magnesium	Mg^{2+}	Carbonate	CO_3^{2-}
Zinc	Zn^{2+}		
Lead	Pb^{2+}	Hydrogencarbonate	
Iron(II)	Fe^{2+}		HCO_3^-
Iron(III)	Fe^{3+}		
Aluminium	Al^{3+}		

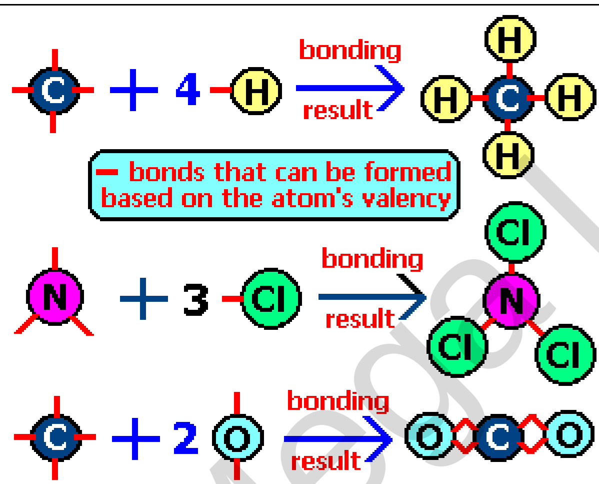
Examples of ionic combining power of ions (left, valency = numerical charge value)

Examples of covalent combining power of atoms (valencies below)

- **Hydrogen H (1)**
- **Chlorine Cl and other halogens (1)**
- **Oxygen O and sulphur S (2)**
- **Boron B and aluminium Al (3)**
- **Nitrogen (3, 4, 5)**
- **Carbon C and silicon Si (4)**
- **Phosphorus (P 3,5)**

Examples of working out covalent formulae

'A' (valency)	'B' (valency)	deduced formula
1 of **carbon C (4)**	balances 4 of **hydrogen H (1)**	1 x 4 = 4 x 1 = **CH_4**
1 of **nitrogen (3)**	balances 3 of **chlorine Cl (1)**	1 x 3 = 3 x 1 = **NCl_3**
1 of **carbon C (4)**	balances 2 of **oxygen O (2)**	1 x 4 = 2 x 2 = **CO_2**



The diagram on the left illustrates the three covalent examples above for

methane CH_4

nitrogen trichloride NCl_3

carbon dioxide CO_2

Examples of working out ionic formulae

'A' (charge=valency)	'B' (charge=valency)	deduced formula
2 of **Na^+ (1)**	balances 1 of **O^{2-} (2)**	2 x 1 = 1 x 2 = **Na_2O**
1 of **Mg^{2+} (2)**	balances 2 of **Cl^- (1)**	1 x 2 = 2 x 1 = **$MgCl_2$**
1 of **Fe^{3+} (3)**	balances 3 of **F^- (1)**	1 x 3 = 3 x 1 = **FeF_3**
2 of **Fe^{3+} (3)**	balances 3 of **SO_4^{2-} (2)**	2 x 3 = 3 x 2 = **$Fe_2(SO_4)_3$**