Writing and Balancing Equations

Reaction Equations Show How Chemicals React Together

1) A reaction equation shows what happens during a chemical reaction.
The **reactants** are shown on the **left hand side**, and the **products** on the **right hand side**.
2) **Word equations** just give the **names** of the components in the reaction.
For example: propane + oxygen → carbon dioxide + water
3) **Symbol equations** give the chemical formulae of all the different components.
They show all the **atoms** that take part in the reaction, and how they rearrange.
For example: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
4) Symbol equations have to **balance** — there has to be the **same number** of each **type** of atom on each side of the equation. The big numbers in front of each substance tell you how much of that particular thing there has to be for all the atoms to balance.

Writing Balanced Equations

To write a balanced symbol equation for a reaction there are 4 simple steps:

1) Write out the **word equation** first.
2) Write the correct **formula** for each substance below its name.
3) Go through each element in turn, making sure the **number of atoms** on each **side** of the equation **balances**. If your equation isn't balanced, you can only add more atoms by adding **whole reactants** or **products**.
4) If you changed any numbers, do step 3 again, and repeat until **all** the elements **balance**.

Doing the third step:
If the atoms in the equation don't balance you **can't** change the **molecular formulae** — only the numbers in **front** of them.
For example: $CaO + HCl \rightarrow CaCl_2 + H_2O$
There are **two Cl** atoms on the **right-hand side** of the equation, so we need to have **two HCl** on the **left-hand** side: $CaO + 2HCl \rightarrow CaCl_2 + H_2O$
This also doubles the number of **hydrogen atoms** on the left-hand side, so that the hydrogens **balance** as well.

EXAMPLE: Write a balanced equation for the reaction of magnesium with hydrochloric acid.

Step 1 — Write the word equation:
magnesium + hydrochloric acid → magnesium chloride + hydrogen

Step 2 — Write the symbol equation: $Mg + HCl \rightarrow MgCl_2 + H_2$

Step 3 — Go through the equation and balance the elements one by one:
$Mg + \mathbf{2}HCl \rightarrow MgCl_2 + H_2$
(the Mgs balance, but there are different amounts of H and Cl on each side. Put a 2 in front of HCl to balance the Hs and Cls. Check everything still balances.)

Writing and Balancing Equations

In **Ionic Equations** Make Sure the **Charges** Balance

1) In some reactions, particularly those in solution, not all the particles take part in the reaction.
2) **Ionic equations** are chemical equations that just show the **reacting particles**.
3) As well as having the same number of **atoms** of each element on each side of the equation, in ionic equations you need to make sure the **charge** is the same on both sides.

EXAMPLE: Balance the following ionic equation: $Na + H^+ \rightarrow Na^+ + H_2$

First, balance the **number of atoms** of each element using the method on the last page:

$$Na + \mathbf{2}H^+ \rightarrow Na^+ + H_2$$

Then check the **charge** is the same on both sides of the equation:

- On the left hand side, each H^+ ion contributes +1, so the charge is 2 × +1 = **+2**.
- On the right hand side, the sodium ion contributes +1, so the charge is 1 × +1 = **+1**.

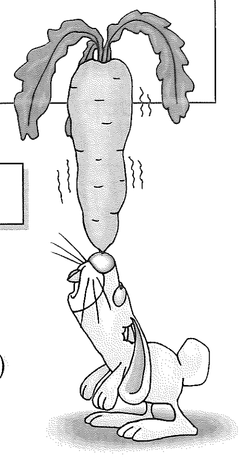
To get the charges to balance, you need another positive charge on the right-hand side. One way of doing this is by adding another sodium ion to the products:

$$Na + 2H^+ \rightarrow \mathbf{2}Na^+ + H_2$$

Now check that the number of atoms still balances:
The Hs balance, but there are 2Nas on the right-hand side, and only one on the left.
So put a 2 in front of the left-hand side Na:

$$\mathbf{2}Na + 2H^+ \rightarrow 2Na^+ + H_2$$

The atoms **and** charges on each side balance, so that's your final answer.



Chemical Equations Sometimes Include **State Symbols**

State symbols show the **physical state** that a substance is in.
The state symbols you need to know about are in the box below:

(l) — liquid (g) — gas (s) — solid (aq) — aqueous (dissolved in water)

So the balanced equation for the reaction between hydrochloric acid and magnesium, including state symbols is: $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$.

Hold one ear and stare at something still — it'll help you balance...

1) Write a balanced symbol equation for the combustion of methane (CH_4) in oxygen.
   Step 1 has been done for you.
   Step 1: Methane + oxygen → carbon dioxide + water
2) Write balanced symbol equations for the following reactions.
   a) The complete combustion of ethanol (C_2H_5OH) in oxygen (O_2) to give carbon dioxide (CO_2) and water (H_2O).
   b) The reaction of calcium hydroxide ($Ca(OH)_2$) with hydrochloric acid (HCl) to give calcium chloride ($CaCl_2$) and water (H_2O).
3) Balance the following ionic equation: $Cl_2 + Fe^{2+} \rightarrow Cl^- + Fe^{3+}$.
   Include state symbols given that Cl_2 is a gas and everything else is aqueous.

Group 2

Trend in **Reactivity** Down the Group

During their reactions, Group 2 metals **donate** their **two outer electrons** to another atom. The reactivity of Group 2 metals depends on how **easily** the outer electrons can be donated. The **easier** the electrons can be donated, the **more reactive** the metal will be. You will find that:

Reactivity **increases** as you go **down** Group 2.

To see why, think about the factors that affect how strongly an electron is held by the nucleus:

1) The first is the **positive nuclear charge** — how **positive** the nucleus is. A **greater** nuclear charge provides a **stronger** force of attraction between the nucleus and electrons, and makes it more difficult for the atom to donate its outer electrons. As you go down the group, the nuclear charge **increases** as more **protons** are added to the nucleus, so if this was the **only** factor, reactivity would decrease down Group 2. But that **isn't** the case.
2) The second factor is that in **larger atoms**, the outer electrons are **further away** from the nucleus. The electrostatic attraction **decreases** in strength with **distance** from the source.
3) The third factor is **electron shielding**. As the atoms in Group 2 get **larger**, the number of **full electron shells** round the nucleus **increases**. These negative charges **shield** the two outer electrons from the attraction of the positive nucleus.

The increase in the **distance** between the outer electrons and the nucleus, and the increased **shielding** as you go down the Group, far **outweigh** the increase in nuclear charge.

4) You may have noticed that these are the **same factors** that affect the **ionisation enthalpy** (page 6). This is because both the reactivity of Group 2 and ionisation are to do with **removing electrons**.

Trend in the **Melting Points** of Group 2 Metals

You can see from the table that:

As you go **down** Group 2, **melting point decreases.**

Magnesium doesn't fit in with the general trend. It behaves a bit oddly because it has a slightly different structure to the other Group 2 metals.

	Melting Point (°C)
Beryllium (Be)	1278
Magnesium (Mg)	651
Calcium (Ca)	839
Strontium (Sr)	769
Barium (Ba)	727

This is also due to the increase in **electron shielding** as you go down the group.

Group 2 metals, like all other metals, are held together in a lattice structure by **metallic bonds** (page 16).

The **strength** of the metallic bonds depend on how strong the **attraction** is between the positive ions and the free electrons. The **more shielded** the positive nuclei are, the **weaker** the attraction will be, and so the **less energy** will be required to break the bond and melt the metal.

I love the Group 2 Metals — they're really trendy...

1) The following are descriptions of the reactions of Be and Ca with cold water. Use them to predict the reactions of Mg and Sr.
   - Beryllium will not react with cold water at all.
   - Calcium reacts steadily with cold water to produce hydrogen gas and calcium hydroxide.
2) Predict, with reasoning, the trend in boiling points of the Group 2 metals.

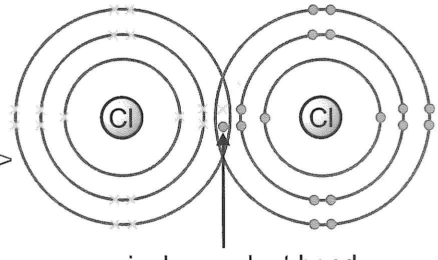
Group 7

Some **General Properties** of Group 7 Elements

Group 7 elements all have **7 electrons** in their outer shell. As a result these elements either:

1) Form **ionic compounds** by gaining an **extra electron** or,
2) **share** a pair of electrons and form a **covalent bond**.

In their elemental state, the halogens bond **covalently**, forming diatomic molecules (two atoms joined with a single covalent bond). In each case the atoms share an electron pair.



The halogen elements all have **coloured vapours**:

- **Chlorine** (Cl_2) is a **yellow/green gas** at room temperature.
- **Bromine** (Br_2) is a **brown liquid** at room temperature.
- **Iodine** (I_2) is a **grey solid** at room temperature (and sublimes to produce a **purple** vapour).

As you go down the group, the **melting points** and the **boiling points** of the elements **increase**. This is because the **strength** of the weak intermolecular bonds **between** molecules **increases** as the number of **electrons** in the molecules increases (see page 9).

Trend in **Reactivity** Down Group 7

During their reactions, Group 7 elements accept an **extra electron** from another atom. The reactivity of Group 7 elements depends on how **strongly** the nucleus can attract electrons. The **stronger** the attraction, the **more reactive** the element will be.

Reactivity **decreases** as you go **down** Group 7.

1) As with the Group 2 elements, **nuclear charge increases** as you go down the group. A greater nuclear charge will attract the extra electron required to fill the outer shell more strongly. This works to increase the reactivity of the elements as you go down the group.
2) However, as the atoms get bigger, the **extra shells** of electrons **shield** the nuclear charge more effectively. So the nucleus is **less able** to attract the extra electron the atom wants.

In Group 7 this **shielding** outweighs the effect of increasing nuclear charge. The elements at the **top** of the group are best able to attract an extra electron, and are more **reactive**.

Group 7 Reactivity and **Displacement Reactions**

You can show the relative reactivity of the Group 7 elements using **displacement reactions**. If you mix a **halogen** with a solution containing **halide ions**, a **more reactive** halogen will **displace** a **less reactive** halide ion (one below it in the group) from solution. For example:

Fluorine is more reactive than chlorine.

$$F_{2\,(aq)} + 2Cl^-_{(aq)} \rightarrow Cl_{2\,(aq)} + 2F^-_{(aq)}$$

The chloride ions have been **displaced** from the solution.

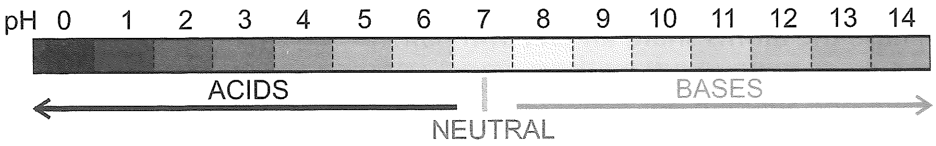
I met a friend for coffee today — I said 'Hallo, Jen'...

1) Predict, with reasoning, what would happen if you mixed the following halogens and halide solutions.
   a) Cl_2 and Br^-, b) I_2 and Cl^-, c) I_2 and Br^-, d) Cl_2 and I^-.
2) Draw a diagram to show the bonding between atoms in a fluorine molecule.

Acids and Bases

The pH Scale

1) The **pH** scale goes from **0** to **14** and measures how **acidic** or **basic** something is. **Acids** have a pH **less** than 7, while **bases** have a pH **greater** than 7. The **more acidic** something is, the **lower** the pH, so strong acids have a pH of between **0** and **1**. By contrast, the more **basic** something is, the **higher** its pH will be. **Strong bases** have a pH of **14**.
2) **Neutral** substances (such as water) have a pH of **7**. They are neither acidic nor basic.



Acids are **Proton Donors** and Bases are **Proton Acceptors**

1) Acids are **proton donors**. They **release hydrogen ions** (H^+) when mixed with water.

$$HCl_{(g)} \xrightarrow{water} H^+_{(aq)} + Cl^-_{(aq)}$$

2) The reverse happens with **bases** — they're proton acceptors so they **take H^+ ions**. **Alkalis** are bases that are **soluble** in water. They release **OH^-** ions in solution.

$$NaOH_{(s)} \xrightarrow{water} Na^+_{(aq)} + OH^-_{(aq)}$$

3) When an acid reacts with an alkali, a **salt** and **water** are formed — this is called a **neutralisation** reaction.

acid + alkali → salt + water

You can show neutralisation just in terms of H^+ and OH^- ions. The hydrogen ions (H^+) from the acid will react with hydroxide ions (OH^-) from the base to produce water.

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

EXAMPLE: Write a balanced equation for the reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH).

This reaction is a **neutralisation reaction** — a hydrogen ion from HCl combines with a hydroxide ion from NaOH to form water. The remaining ions combine to form the salt:

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$$

Some **Common Acids and Bases**

Acid	**Formula**
Hydrochloric acid	HCl
Sulfuric acid	H_2SO_4
Nitric acid	HNO_3
Ethanoic acid	CH_3COOH

Base	**Formula**
Sodium hydroxide	$NaOH$
Potassium hydroxide	KOH
Ammonia	NH_3

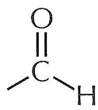
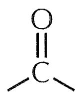
Siobhan always tells the truth, but Alka lies...

1) Write a balanced equation for the reaction between nitric acid and potassium hydroxide.
2) Write equations to show what happens when the following substances are mixed with water:
   a) sulfuric acid, b) potassium hydroxide, c) nitric acid.

Organic Molecules

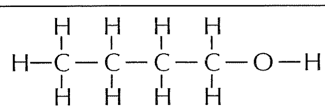
There are Lots of **Families** of Compounds in Organic Chemistry

Organic Chemistry is the study of organic compounds — these are just substances that contain **carbon**. Carbon compounds can be split up into different **groups** which have similar **properties** and **react** in similar ways. These groups are called **homologous series**. All the compounds in a homologous series contain the same **functional group** — a certain group of atoms that is responsible for the **properties** of the molecule. Here are some **common homologous series**:

HOMOLOGOUS SERIES	FUNCTIONAL GROUP	EXAMPLE
alkanes	-C–C-	propane — $CH_3CH_2CH_3$
alkenes	-C=C-	propene — $CH_3CH{=}CH_2$
alcohols	-OH	ethanol — CH_3CH_2OH
aldehydes		ethanal — CH_3CHO
ketones		propanone — CH_3COCH_3
carboxylic acids	-COOH	ethanoic acid — CH_3COOH

There are Different Ways of **Representing** a Molecule's **Structure**

Chemists have a few different ways of representing an organic molecule's **formula**.
Here are a few ways that you'll need to be able to interpret:

FORMULA	WHAT IT SHOWS YOU	FORMULA FOR BUTANOL (an alcohol)
General formula	This describes **any member** in a homologous series. The number of carbons is represented by 'n' and the number of hydrogens in terms of 'n'.	$C_nH_{2n+1}OH$ (this is true for all alcohols.)
Molecular formula	This shows the number of **atoms** of each **element** in a molecule.	$C_4H_{10}O$
Structural formula	This shows the molecule **carbon by carbon**, with all attached hydrogens and functional groups.	$CH_3CH_2CH_2CH_2OH$
Skeletal formula	The **bonds** of the carbon skeleton are drawn, with any **functional groups**. The carbon atoms and attached hydrogens aren't shown.	
Displayed formula	All the **atoms** and **bonds** are drawn to show how the molecule is arranged.	

Organic Chemistry — no pesticides, no added sugars, no flavourings...

1) Draw the skeletal and displayed formulae for the molecule with the structural formula $CH_3CHOHCH_2CH_3$.
2) What is the molecular formula of the compound with the structural formula CH_3CH_2COOH?