

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: $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$
- 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: $\text{CaO} + \text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}$

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**: $\text{CaO} + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}$

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: $\text{Mg} + \text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$

Step 3 — Go through the equation and balance the elements one by one:

$\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$

(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.)

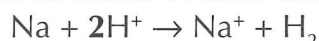
Writing and Balancing Equations

*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: $\text{Na} + \text{H}^+ \rightarrow \text{Na}^+ + \text{H}_2$

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

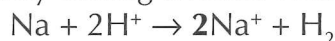


Then check the **charge** is the same on both sides of the equation:

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

To get the charges to balance, you need another positive charge on the right-hand side.

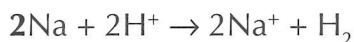
One way of doing this is by adding another sodium ion to the products:



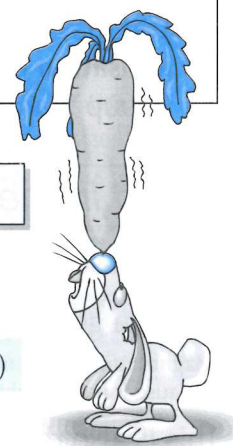
Now check that the number of atoms still balances:

The Hs balance, but there are 2Na on the right-hand side, and only one on the left.

So put a 2 in front of the left-hand side Na:



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: $\text{Mg}_{(s)} + 2\text{HCl}_{(aq)} \rightarrow \text{MgCl}_{2(aq)} + \text{H}_{2(g)}$.

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 \rightarrow carbon dioxide + water
- 2) Write balanced symbol equations for the following reactions.
 - a) The complete combustion of ethanol ($\text{C}_2\text{H}_5\text{OH}$) in oxygen (O_2) to give carbon dioxide (CO_2) and water (H_2O).
 - b) The reaction of calcium hydroxide ($\text{Ca}(\text{OH})_2$) with hydrochloric acid (HCl) to give calcium chloride (CaCl_2) and water (H_2O).
- 3) Balance the following ionic equation: $\text{Cl}_2 + \text{Fe}^{2+} \rightarrow \text{Cl}^- + \text{Fe}^{3+}$.
Include state symbols given that Cl_2 is a gas and everything else is aqueous.

Trends in Properties Across the Periodic Table

Structure and Bonding Change Across the Periodic Table

You should have seen from this section how much the **properties** of a compound depend on its **bonding** and **structure**. You also know that the type of bonding that occurs depends on the **number of electrons** in the outer shells of the elements making up the compound, and so their **positions** in the periodic table.

A good way to compare the way that different elements bond is by looking at the properties of a series of similar compounds across a **period**.

Look at the information in the table below about all the Period 3 oxides.

You can see that there are clear **patterns** in the data.

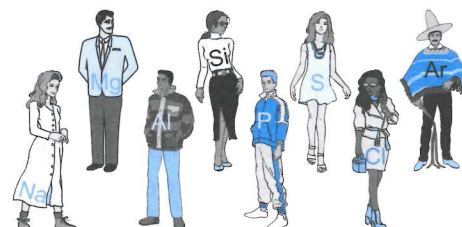
Trends Across Period Three

(Period 3 is studied because it is a simple case.

There are no d-block elements to confuse matters.)

The table below shows some of the physical properties of Period 3 oxides.

The final row has been deduced from these physical properties.



	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀	SO ₂
State (at room temperature and standard pressure)	solid	solid	solid	solid	solid	gas
Melting point (°C) (at standard pressure)	1275	2800	2072	1650	570	-73
Electrical conductivity (when molten)	good	good	good	none	none	none
Bonding	ionic lattice	ionic lattice	ionic lattice	giant covalent structure	small covalent molecule	small covalent molecule

You can see from this data that there is a change in the properties of the Period 3 oxides as you move from left to right across the periodic table.

The trend is from **ionic bonding** to **small covalent molecules** via a **giant covalent structure**.

These trends across a period are **more subtle** than the trends going down a group that you saw at GCSE. However they are extremely useful as they allow you to make **predictions** about the reactions and properties of unknown compounds.

There are of course **exceptions** to the rules/trends, but on the whole they allow links between physical properties and atomic structure to be made.

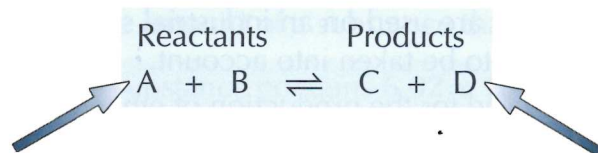
Trending now — #Arewedoneyet? #Dontworryitstheendofthesection...

- 1) Explain how the data in the first three rows of the table above supports the idea that the bonding type changes from ionic to covalent as you move across Period 3.
- 2) Use the information on Period 3 oxides to predict the trend in the melting points of the elements as you go across Period 3.
- 3) Predict the type of bonding you would expect in the chlorides of:
 - a) sodium
 - b) phosphorus

Le Chatelier's Principle

Position of Equilibrium

The **position** of equilibrium tells you the amount of **reactants compared** to the amount of **products** that are present when the reaction reaches an **equilibrium**.



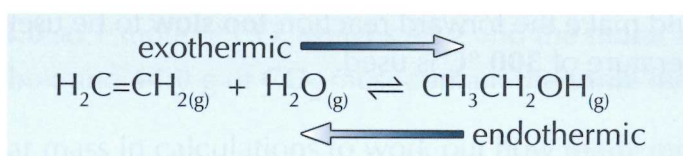
If the position of equilibrium lies on the **left-hand side**, there are **more reactants** than products in the reaction mixture.

If the position of equilibrium lies on the **right-hand side**, there are more **products** than reactants in the reaction mixture.

Changing Conditions Changes the Equilibrium Position

Altering the conditions of a reversible reaction can **move** the position of equilibrium in one direction or the other. Careful control of the conditions can result in a higher yield (more of the products).

Look at the production of ethanol from ethene again as an example:



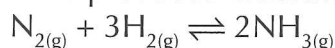
- 1) If you increase the **pressure**, conditions will favour the forward reaction and **more ethanol** ($\text{CH}_3\text{CH}_2\text{OH}$) will be formed.
This is because there are **more molecules** of gas on the **left-hand side** than on the right-hand side — two molecules of $\text{H}_2\text{C}=\text{CH}_2/\text{H}_2\text{O}$ react to form **only one** molecule of $\text{CH}_3\text{CH}_2\text{OH}$. This **reduces** the pressure.
- 2) Raising the **temperature** favours the **reverse** reaction. This is because it's **endothermic** (see page 41) and **absorbs** the extra heat energy, **lowering** the temperature.
- 3) **Removing ethanol** from the container as it forms will push the equilibrium to the **right** to try and make up for the change in concentration between the reactants and products.

These observations can be summarised by an important rule known as **Le Chatelier's Principle**:

A reversible reaction will move its equilibrium position to resist any change in the conditions.

Equilibrium reactions are so stubborn — always resisting change...

- 1) You are making ethanol from ethene and steam using the reaction shown above. What will happen to the yield of ethanol if you increase the amount of steam in the reaction mixture?
- 2) Ammonia is produced industrially using the following reversible reaction:



The forward reaction is exothermic and the backwards reaction is endothermic.

How will the position of the equilibrium change if you:

- a) Increase the temperature of the reaction?
- b) Remove some ammonia from the reaction?

The Mole

A Mole is a Number of Particles

If you had a sample of a substance, and you wanted to **count** the number of atoms that were in it, you'd have to use some very **big numbers**, and spend a very long time counting. So you need a **unit** to describe the **amount** of a substance that you have — that unit is the **mole**.

One mole of a substance contains 6.02×10^{23} particles.
 $6.02 \times 10^{23} \text{ mol}^{-1}$ is known as **Avogadro's constant**.

The particles can be **anything** — e.g. atoms or molecules (or even giraffes). So 6.02×10^{23} atoms of **carbon** is 1 mole of carbon, and 6.02×10^{23} molecules of CO_2 is 1 mole of CO_2 .

No, I'm not getting on there. That joke's far too obvious...



Molar Mass is the Mass of One Mole

One mole of atoms or molecules has a **mass in grams** equal to the **relative formula mass** (A_r or M_r) of that substance.

For **carbon**, $A_r = 12.0$ so 1 mole of carbon weighs **12 g** and the **molar mass** is 12 g mol^{-1} .

For CO_2 , $M_r = 44.0$ so 1 mole of CO_2 weighs **44 g** and the **molar mass** of CO_2 is 44 g mol^{-1} .

So, **12.0 g of carbon** and **44.0 g of CO_2** must contain the **same number of particles**.

You can use molar mass in calculations to work out how many moles of a substance you have.

Just use this formula:

$$\text{Number of moles} = \frac{\text{Mass of substance (g)}}{\text{Molar mass (g mol}^{-1}\text{)}} \quad \leftarrow \text{g mol}^{-1} \text{ is the same as g/mol.}$$

EXAMPLE: How many moles of sodium oxide are present in 24.8 g of Na_2O ?

$$\text{Molar mass of Na}_2\text{O} = (2 \times 23.0) + (1 \times 16.0) = 62.0 \text{ g mol}^{-1}$$

$$\text{Number of moles of Na}_2\text{O} = 24.8 \text{ g} \div 62.0 \text{ g mol}^{-1} = \mathbf{0.400 \text{ moles}}$$

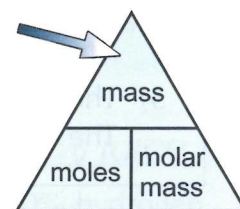
You can **rearrange** the formula above and use it to work out the mass of a substance or its relative formula mass (see page 3). It can help to remember this triangle:

EXAMPLE: What is the mass of 1.30 moles of magnesium oxide (MgO)?

$$\text{Molar mass of MgO} = (1 \times 24.3) + (1 \times 16.0) = 40.3 \text{ g mol}^{-1}$$

Rearranging the formula, $\text{mass} = \text{moles} \times \text{molar mass}$

$$\text{So mass of MgO} = 1.30 \times 40.3 = \mathbf{52.4 \text{ g (3 s.f.)}}$$



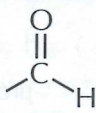
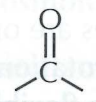
Avocado's constant: how much I need to satisfy my guacamole craving...

- 1) Find the molar mass of sulfuric acid, given that 0.700 moles weighs 68.6 g.
- 2) How many moles of sodium chloride are present in 117 g of NaCl ?
- 3) I have 54.0 g of water (H_2O) and 84.0 g of iron (Fe). Do I have more moles of water or of iron?

Organic Molecules


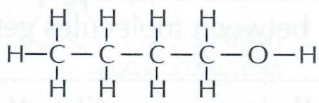
There are Lots of **Families** of Compounds in Organic Chemistry

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 — $\text{CH}_3\text{CH}_2\text{CH}_3$
alkenes	-C=C-	propene — $\text{CH}_3\text{CH}=\text{CH}_2$
alcohols	-OH	ethanol — $\text{CH}_3\text{CH}_2\text{OH}$
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'.	$\text{C}_n\text{H}_{2n+1}\text{OH}$ (this is true for all alcohols.)
Molecular formula	This shows the number of atoms of each element in a molecule.	$\text{C}_4\text{H}_{10}\text{O}$
Structural formula	This shows the molecule carbon by carbon , with all attached hydrogens and functional groups.	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
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 $\text{CH}_3\text{CHOHCH}_2\text{CH}_3$.
- 2) What is the molecular formula of the compound with the structural formula $\text{CH}_3\text{CH}_2\text{COOH}$?