TACKLING WORD EQUATIONS AND BALANCED SYMBOL EQUATIONS IN CHEMISTRY EXAM PAPERS

Learning outcomes

At the end of this, you should be able to:

- State how you know a reaction has taken place

-Write a word equation for a given reaction

- Write a balanced symbol equation for a reaction, given the symbols for the reactants

- Write a balanced symbol equation for a reaction when you have to look up the symbols from a table and/or using the Periodic table (Higher only)

What you should already know

- What an element is
- What a compound is
- The difference between ionic and covalent compounds
- What a molecule is
- How to write the formula for a molecule or compound using symbols

Word equations and balanced symbol equations

A reaction may happen when two or more chemicals are mixed. Sometimes you have to add heat (energy) before the reaction will occur.

Not all chemicals react together when they are mixed. We can tell a reaction has taken place if we see bubbles of gas, a change in colour, a change in temperature or a precipitate (a layer of solid in the bottom of the test tube that wasn't there when you started). So vinegar (an acid) reacts with sodium bicarbonate – there are bubbles of gas and the test tube gets warm – but it doesn't react with table salt (sodium chloride). The salt dissolves but nothing else happens, even if you heat the mixture.

A word equation helps us work out what has happened during a reaction.

Let's look at the word equation for the reaction between sulphuric acid and calcium carbonate (limestone or marble).

We know a reaction happens because we see bubbles of gas and the test tube gets warm.

The clue to what the gas is is in the name of the reactants; if you add acid to a carbonate you always get carbon dioxide. (You could also test the gas; we know it is carbon dioxide because if we bubble it through limewater, the limewater goes 'milky'.) In addition, if you react an acid with an alkali or base, like a carbonate, an oxide or a hydroxide, you always get water. (You need to know this for the chemistry exam.) The name of the acid gives you a clue to the name of the salt it forms.

Calcium carbonate + sulphuric acid calcium sulfate + carbon dioxide + water

Let's look at another reaction. This is one you learn about in biology; respiration.

The reactants are glucose and oxygen, the products are carbon dioxide and water.

Glucose + oxygen carbon dioxide + water (+energy)

(This is almost the same as burning a hydrocarbon; you get the same products.)

Some reactions are very hard to describe in any other way than by a word equation. Not all substances have a chemical formula you can write down, for example, wood or a chocolate biscuit. Or the chemical formula may be one you don't know, such as vinegar which is mainly a solution of something called ethanoic acid.

Word equations describe what is happening, but it is often more useful to know what each of the atoms, molecules or ions is doing. To do this, we use a balanced symbol equation. Sometimes you will have to look up the formulas for the compounds or even work them out using the Periodic Table.

'Balancing' just means making sure you have the same number of each sort of atom on each side.

This is important. We do not lose or gain mass during a chemical reaction. This is called 'Conservation of mass'. You may have come across this idea already in Physics.

Let's see how to write a balanced formula equation for the reaction between magnesium and hydrochloric acid. You know a reaction happens because there is fizzing. If you test the gas with a lighted splint, you get a 'squeaky pop', telling you hydrogen has been produced.

The word equation is

magnesium + hydrochloric acid hydrogen + magnesium chloride.

If you look in the table of ions, you will see that magnesium makes ++ ions and chloride ions are – , so you need 2 chlorine ions to each ion of magnesium. You could also work this out by looking at the Periodic Table. Magnesium is in the second column of the Periodic table and chlorine is in the next-to-last column, so magnesium has 2 electrons in its outer shell to give away, and chlorine has 7 electrons in its outer shell, so needs 1 to make a full shell.

To write the symbol equation, first write down the reactants and products in symbol form: Mg + HCl $MgCl_2$ + H_2

This doesn't balance; we have 1 H and 1 Cl on the left-hand side and two of each on the right-hand side. So we need to add another HCl to make the equation balance:

Mg + 2HCl $MgCl_2$ + H_2

The hydrochloric acid is in solution, and so is the magnesium chloride. You can show this by writing a little 'aq' (short for aqueous, which means 'in water') under the HCl and $MgCl_2$. You could also show that the magnesium chloride is ionic and in solution by writing Mg^{++} $(Cl^-)_2$ instead of MgCl.

You have probably seen the reaction between a group I metal and water; for example sodium and water. The sodium races around fizzing and there is a yellow flame too.

The fizzing tells us there is a gas being produced. The flame tells us there is also a lot of heat being produced; enough to ignite the gas. There is definitely a reaction going on!

The only substances involved are sodium and water and if you test the water afterwards with pH or litmus paper, you will find it is alkaline. The gas gives a 'squeaky pop' if it is tested with a lighted splint; it must be hydrogen.

Sodium + water hydrogen + sodium hydroxide.

In symbols:

$Na + H_2O \rightarrow H_2 + NaOH$

This doesn't balance, there are too many H's on the right-hand side. If we add another Na, we also need another H_2O to make sure we have enough OH.

So we have:

$2Na + 2H_2O \rightarrow 2NaOH + H_2$

This is an example of a very important reaction; make sure you learn it, and the one for Group II metals. You'll find that in the 'some to try for yourself' section.

Another reaction you might have seen or done is the reaction between copper II oxide and dilute sulphuric acid. This is a reaction requiring heat (and a lot of stirring) to make it happen. Copper II oxide (CuO) is a black insoluble powder. Dilute sulphuric is a clear liquid. The products are copper II sulfate and water. Copper II sulfate is a pretty blue colour. You can tell this reaction has happened because you have a change in colour.

Copper II oxide + dilute sulphuric acid → copper sulfate + water

Write the symbols:

$Cu\,O + H_2SO_4 \rightarrow CuSO_4 + H_2O$

There is the same number of atoms on each side; the equation is balanced. The dilute sulphuric acid and copper sulfate are both in solution, so you could write 'aq' underneath or show them as ions.

Let's look at something which needs more balancing: the reaction between iron and chlorine. These are both elements and you aren't adding anything else, so the product will be iron III chlorides, as long as you have lots of chlorine. Chlorine makes Cl- ions and iron III ions are +++.

Chlorine always comes as Cl2 molecules.
Iron + chlorine → iron III chloride
Write a formula equation:

$Fe + Cl_2 \rightarrow FeCl_3$

This doesn't balance: you have 2 chlorines on the left-hand side and 3 on the right-hand side. You need to use a bit of clever maths here; 2 x 3 = 6. If you put a 3 in front of the Cl_2 and a 2 in front of the $FeCl_3$, you have 6 chlorines on both sides. However, you now also have to put a 2 in front of the Fe on the left-hand side because you have 2 irons on the right-hand side:

$2Fe + 3Cl_2 \rightarrow 2FeCl_3$

You will find this 'balancing trick' with 2 and 3 useful for a lot of iron and also aluminium compounds. (The only — ion you are likely to come across is phosphate.) There is one to try in the 'some to try for yourself' section. But first here's another example.

Let's look at the reaction between aluminium hydroxide and sulphuric acid.
It's a reaction between an alkali and an acid, so we will get water as well as salt.

The salt is aluminium sulfate, and we can use the balancing trick to work out it is $Al_2(SO_4)_3$.

Aluminium hydroxide + sulphuric acid → aluminium sulfate + water.

Begin by writing down the symbols:

$Al(OH)_3 + H_2SO_4$ $Al_2(SO_4)_3 + H_2O$

We can see straight away that we need 2 aluminium ions and 3 molecules of sulphuric acid on the left-hand side to make the aluminium sulfate.

$2Al(OH)_3 + 3H_2SO_4$ $Al_2(SO_4)3 + H_2O$

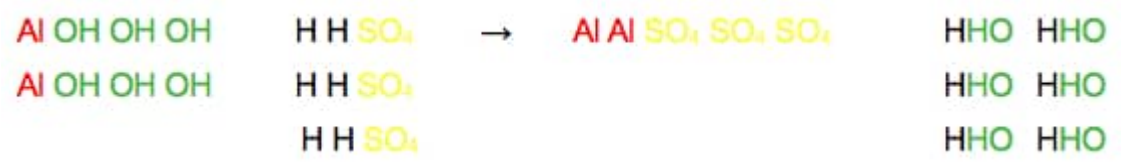
Now we have 6 OH's and 6 H's on the left. Each O needs 2 H's to make water, so we have the right amount to make 6 H_2O with nothing left over.

The final balanced equation is:

$2Al(OH)_3 + 3H_2SO_4$ $Al_2(SO_4)_3 + 6H_2O$

Take your time and remember to make sure you have the same number of each element or ion on each side.

You might find it helps to write the symbols in groups and cross them off as you use them:



These symbol equations all involve elements and ions, but we can write balanced symbol equations for other reactions, too.

If we burn the hydrocarbon gas propane in oxygen (or in the air), we get carbon dioxide and water.

Propane + oxygen carbon dioxide + water

The formula for propane is C_3H_8.
Write down a symbol equation:

$C_3H_8 + O_2$ $CO_2 + H_2O$

You can see straight away that there are 3C's on the left and 1 on the right, so you know there must be 3 CO_2's. The 8 H's will make 4 water molecules. So you need 4O's for the water and 6 for the CO_2's; 10 O's or 5 O_2's.

The balanced equation is:
$C_3H_8 + 5O_2$ $3CO_2 + 4H_2O$

Sometimes you end up with an odd number of O's or H's. If this happens, you just double everything up.

Propane's cousin ethane C2H6 needs this:
$2C_2H_6 + 7O_2$ $4CO_2 + 6H_2O$

Summary

- You know a reaction has happened because you get bubbles of gas, a change in colour, a change in temperature or a precipitate.
- You can write a reaction as a word equation. This is useful if you don't know the formula or for complicated compounds/substances.
- You can also write a reaction as a balanced symbol equation. Balanced means having the

same number of atoms of each element on each side of the equation.
- You might need to use the Periodic Table or a table of ions to work out the formulas of the things you are reacting.
- You need to know what happens when you react an acid with an oxide, a hydroxide or a carbonate.
- You need to know what happens when you react to a Group I or II metal with water.
- You need to know what happens when you burn a hydrocarbon.
- You need to be able to write word equations for respiration and photosynthesis.

Some to try for yourself

1. Write a word equation for the reaction that occurs when a candle is burned. (Candle wax is a hydrocarbon.)
2. Write a word equation for the reaction between potassium and water.
3. Write a balanced formula equation for the reaction between calcium metal and water.
4. Write a balanced formula equation for the reaction between magnesium carbonate ($MgCO_3$) and sulphuric acid (H_2SO_4).
5. Write a balanced formula equation for the reaction between iron II oxide (FeO) and nitric acid (HNO_3).
6. Write a balanced formula equation for the reaction between sodium carbonate and hydrochloric acid.
7. Ammonia (NH_3) is made by reacting together nitrogen and hydrogen.
8. Write a balanced formula equation for this reaction.
9. Iron is extracted from haematite iron ore (Iron III oxide) by heating with carbon. Write a balanced formula equation for this reaction. Write a balanced formula equation for the reaction between aluminium oxide and nitric acid.
10. Quicklime is made by heating limestone, calcium carbonate. A gas is given off during the reaction. Quicklime is alkaline and reacts with water to form calcium hydroxide. Write balanced formula equations for these two reactions?

Answers

Remember to write a word equation before you write the balanced formula equation to make sure you don't forget anything.

Answer 1

candle wax + oxygen carbon dioxide + water

Answer 2

potassium + water potassium hydroxide + hydrogen

Answer 3

calcium + water calcium hydroxide + hydrogen

$Ca + 2H_2O \; Ca(OH)_2 + H_2$

Calcium is Group II so it is ++. Otherwise, it's the same as the reaction between sodium and water. The calcium fizzes and the test tube gets warm.

Answer 4

magnesium carbonate + sulphuric acid magnesium sulfate + carbon dioxide + water
$MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + CO_2 + H_2O$
In the acid/carbonate reaction, the carbonate ion gives an oxygen atom to the hydrogen from the acid to form a water molecule.
Magnesium carbonate is the chemical name for gypsum, a soft white rock.

Answer 5

Iron II oxide + nitric acid iron II nitrate + water
$FeO + 2HNO_3 \rightarrow Fe(NO_3)_2 + H_2O$
Transition metals like iron and copper often have more than one 'oxidation state' - they can have different numbers of +. Watch out for things like iron II and copper I.

Answer 6

Sodium carbonate + hydrochloric acid sodium chloride + carbon dioxide + water
$Na_2 CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$
Something alkaline + an acid gives a salt. This reaction gives 'table salt'. Sodium carbonate is washing soda.

Answer 7

$N_2 + 3H_2 \rightarrow 2NH_3$
This is an important reaction because it is used to make ammonia for fertiliser.
It is what is called an 'equilibrium' reaction; not all the reactants are turned into a product. You will learn more about this reaction in a later unit of your course.

Answer 8

Iron III oxide + carbon iron + carbon dioxide
$2Fe_2O_3 + 3C \rightarrow 2Fe + 3CO_2$
You will learn about the extraction of metals later in your course.

Answer 9

Aluminium oxide + nitric acid aluminium nitrate + water
$Al_2O_3 + 6HNO_3 \rightarrow 2Al(NO_3)_3 + 3H_2O$
Aluminium reacts in a similar way to group II metals but forms +++ ions.
Since there are 2 Al ions there need to be $6NO_3$ ions.

Answer 10

The gas given off is carbon dioxide. This means that the first reaction is
$CaCO_3 \rightarrow CO_2 + CaO$
This tells you that quicklime is calcium oxide.
The calcium oxide is reacted with water. Nothing is given off, so the product must be calcium hydroxide. This is known as slaked lime.
$CaO + H_2O \rightarrow Ca(OH)_2$
These are very important reactions.
Calcium oxide is used in the manufacture of cement, concrete and mortar (used to stick bricks together). A lot of heat is given out by the second reaction (it is exothermic) – if you've ever mixed cement you will know it gets hot. This is why.
Lime is also used to 'sweeten' clay soils to make them easier to work and more productive.
Slaked lime is dissolved in water to make lime water, which you use to test for carbon dioxide. The

milkiness is due to the particles of insoluble calcium carbonate formed when calcium hydroxide reacts with carbon dioxide.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$