## Sixth Form Chemistry

## Bridge the gap between GCSE and A Level

## Introduction

Before you start the A Level Chemistry course in September you should have completed this new bridging course for Chemists. It has been written for students to give them a head start to their A Level studies. It is the important information from GCSE plus some more to make you think like an A level Chemist. Over the summer holidays you should find time to go through this booklet and become confident with the concepts covered.

Good luck and see you all in September.

## Atomic structure

As you all know the atom is the fundamental unit of all elements. It is not the smallest thing that can exist. Scientists keep on coming up with smaller and smaller things. But we shall consider the atom as the building block of all elements.

Bromine contains bromine atoms. Iron contains iron atoms. Sodium contains sodium atoms etc.

However, not all bromine atoms are the same and not all carbon atoms are the same but more of that later. (isotopes)

Atoms contain electrons and protons and neutrons


The electrons stay in shells surrounding the nucleus and the protons and neutrons stay in the nucleus. Chemistry is basically to do with what happens to the electrons in an atom. Here is a table that you need to remember

| Particles | Symbol | Charge | Location |
| :--- | :--- | :--- | :--- |
| Protons | p | Positive charge | Found in the nucleus |
| Neutrons | N | Neutral (no) charge | Found in the nucleus |
| Electrons | $\mathrm{e}^{-}$ | Negative charge | Found orbiting the <br> nucleus |

The periodic table gives us all the information that we need to work out the structure of an atom i.e. the number of electrons, protons and neutrons in any atom----and where the electrons are.

Look up carbon and put the symbol and the little numbers next to it Carbon


The smallest number is the number of protons in the atom. Since all atoms have an overall neutral charge the number of electrons must be the same. The big number is the atomic mass and is the number of all the bits in the nucleus. That is the number of protons and neutrons added together.

Now this is known you should be able to work out the number of protons, neutrons and electrons in the carbon atom


Repeat this for the following atoms.
Use the periodic table at the back of the booklet to work out the number of protons neutrons and electrons in the following atoms

1. helium
2. Calcium
3. Lithium
4. Oxygen
5. sulphur


Now you should be confident on working out the number of protons neutrons and electrons in atoms but where do they go?

Electrons are arranged in shells and this simple Bohr model that we are using helps us understand a lot of chemistry. The shells can take certain amounts of electrons before they are full. They always fill up from the closest shell to the nucleus.


Shell diagram of a neutral atom. The positively charged nucleus is
surroundedby clouds of negatively charged electrons, arranged
in successive shells. The first (inner) shell holds a maximum of 2
electrons; the second and third shells can hold 8 outer electrons each
(www.chem.ox.ac.uk/vrchemistry/chapter6/Page2.htm)
So in the oxygen atom the first two electrons fill up the first shell which leaves 6 left and these go into the second shell. They are usually grouped in two s. If we don't draw the atom we can put down in a shorthand way the electronic configuration------ 2,6.

Fill in the following shells for the elements given
Na



F


That's straightforward then.
Now what about those isotopes mentioned earlier.
Work out the number of protons neutrons and electrons in chlorine.
Not so easy as you can't have halves of neutrons- they come in ones only.

So where does the 35.5 come from.
Actually there are number of different types of atoms for each element and the mass number that you see in the periodic table is the average of all the different types of atoms for that element. In chlorine for example there are $25 \%$ of chlorine- 37 and $75 \%$ of chlorine- 35 which gives an average of 35.5 .

Each element has isotopes. Carbon has a number which you have probably heard of already.

Carbon-12, carbon-11 and carbon-14 (that's the one to do with carbon dating)

Don't forget though that all atoms of an element have the same number of electrons and protons in their atoms. The number of protons tells you which element the atom is.

One last point here Hydrogen doesn't have any neutrons. It has one proton and one electron and if it loses its electron to become the hydrogen ion it is just a proton!

## HOW ATOMS COMBINE

Elements usually combine with other elements to produce compounds.

We like to think that they do this in one of two ways but in truth it isn't always that straight forward. But what you need to know at this point is that elements combine in one of two ways called ionic bonding and covalent bonding.

## Ionic Bonding

Atoms are quite stable when they have a full outer shell. They will combine with other atoms to get a full outer shell either by donating electrons or accepting them from other atoms.

Atoms need the same number of electrons in their nucleus as they have protons in their nucleus which makes them neutral.

Think about Lithium. It has one electron in its outer shell. If it looses this electron it will have a full outer shell which means it is stable. It also means that there are more protons in its nucleus than there are electrons. Now the atom is positive but it isn't called an atom anymore. It is now a positive ion.
(The atom wondering down the road said "Oh dear, l've lost an electron. Yes, I'm positive).

Think about fluorine. It has seven electrons in its outer shell. If it gains an electron, it will have a full outer shell which means it is stable. It also means that there are less protons in its nucleus than there are electrons. Now the atom is negative, but it isn't called an atom anymore. It is now a negative ion.

The following diagram shows what happens when sodium and chlorine combine.

revisionworld $\because$

## (http://www.revisionworld.com)

Notice that the sodium and chlorine ions are now in brackets and each one has a charge.

Some atoms want to give away or accept more than one electron. In this case the ions have either $2+$ or 2 -.

You now need to do a few of these diagrams.

Lithium will combine with fluorine to form lithium fluoride. Draw a similar diagram to the above to show how this happens in the box below.
$\square$
sodium combines with oxygen to form sodium oxide. Draw a similar diagram to the above to show how this happens in the box below. Don't forget that the oxygen needs two electrons to get a full outer shell and so needs two sodiums to do this.

Calcium combines with oxygen to form calcium oxide. Draw a similar diagram to the above to show how this happens in the box below. Don't forget that the oxygen needs two electrons to get a full outer shell and calcium wants to give away two electrons.
$\square$

## Covalent bonding

Atoms in the middle of the periodic table can't give away all the electrons in the outer shell and so they have to get a full outer shell by some other method. Oxygen needs two more electrons to complete its outer shell and it exists uncombined with other elements, so how does it do this?
(Just a point here.... atoms don't think. They don't have desires and career plans. Whether they give electrons away or take them is just to do with energies and what is most stable. Well as far as I know!)

Let's take hydrogen as a starting point. A hydrogen atom has one proton and an electron. Draw the diagram of the hydrogen atom in the box below


Notice that the hydrogen has got half a shell full of electrons and yet hydrogen can exist on its own. It needs another electron. Hydrogen will share its electron with another hydrogen atom so that they both have a full outer shell. Hydrogen bonds to another hydrogen by covalent bonding. This is why hydrogen gas is $\mathrm{H}_{2}$.


The line between the hydrogens represents a single covalent bond. A double line- a double bond and three lines a triple bond.

Here is a diagram showing water $\mathrm{H}_{2} \mathrm{O}$ which also has covalent bonding. Notice the shape.


It is not a linear molecule, in other words it is not straight.

Now you need to draw some covalent molecules. Include all the electrons even though the inner electrons do not have anything to do with the bonding.
$\mathrm{O}_{2}$ Oxygen
$\square$
$N_{2}$ Nitrogen


HCl hydrogen chloride
$\square$
$\mathrm{CH}_{4}$ Methane
$\square$
$\mathrm{C}_{2} \mathrm{H}_{4}$ ethene

You should now have a good understanding of how atoms join to form compounds by either ionic or covalent bonding .

Which type of bonding would you expect in the following compounds?
You will need to look at your periodic table.

1. potassium oxide
2. propane
3. lithium chloride
4. chlorine
5. barium oxide

## Naming compounds and writing their formulae.

This is a really important section, and you need to know it well.
For two element compounds all you need is the periodic table

| +1 | +2 | +3 | $+o r-4$ | -3 | -2 | -1 | 0 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |


| H |  |  |  |  |  | He |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Li | Be | B | C | N | O | F | Ne |
| Na | Mg | Al | Si | P | S | Cl | Ar |

You need to look at the number above the groups. Groups go down. (Periods go across). The total +'s and -'s for a compound need to be zero.

So the compound of lithium and fluorine is $\mathrm{Li}(+1)$ and $\mathrm{F}(-1)$. One lithium cancels out the fluorine and so the formula is LiF. This is called lithium fluoride. Notice the metal name stays the same but the nonmetal part gets an -ide.

Next Beryllium and oxygen. $\mathrm{Be}(+2)$ and $\mathrm{O}(-2)$. One beryllium cancels out the oxygen and so the formula is BeO. Beryllium oxide. Oxygen produces oxides when combined with other elements.

Again Sodium and oxygen. $\mathrm{Na}(+1)$ and $\mathrm{O}(-2)$. In this case we need two lots of Na and so the formula is $\mathrm{Na}_{2} \mathrm{O}$. Sodium oxide.

Try these. Give the formulae and the names of the compounds they form.

| elements and | formula | name |
| :--- | :--- | :--- |
| Hydrogen <br> chlorine |  |  |
| Lithium and oxygen |  |  |
| Magnesium and <br> chlorine |  |  |
| Hydrogen and carbon |  |  |
| Aluminium and <br> chlorine |  |  |
| Aluminium and <br> oxygen |  |  |

Often there are groups of elements that go together to form an ion. Here are the more common groups of elements ions.

## $\mathrm{OH}^{-}$hydroxide

$\mathrm{SO}_{4}{ }^{2-}$ sulphate
$\mathrm{NO}_{3}{ }^{-}$nitrate

## $\mathrm{CO}_{3}{ }^{2-}$ carbonate

$\mathrm{MnO}_{4}{ }^{\mathbf{2 -}}$ manganate
(notice ion names - when an element is combined with oxygen to form an ion it ends with -ate)

And one positive ion $-\mathrm{NH}_{4}{ }^{+}$ammonium.

These groups should be treated exactly the same as a single element when combining them with other elements to form a compound.

Magnesium hydroxide is made up of $\mathrm{Mg}^{2+}$ and $\mathrm{OH}^{-}$. One $\mathrm{Mg}^{2+}$ needs two hydroxides to balance the charges and so the compound's formula is

## $\mathbf{M g}(\mathrm{OH})_{2}$

Note the use of the brackets to ensure that there are two lots of OH required. $\mathrm{MgOH}_{2}$ would be wrong as it would look like there was two hydrogens and one oxygen. Make sure that brackets are used to indicate numbers of the groups that are being used.

Sodium nitrate is made up of $\mathrm{Na}^{+}$and $\mathrm{NO}_{3}{ }^{-}$. One $\mathrm{Na}^{+}$needs one nitrate to balance the charges and so the compound's formula is

## $\mathrm{NaNO}_{3}$

Notice that brackets are not needed here. Try the following

| Elements /groups | name | formula |
| :--- | :--- | :--- |
| Sodium and <br> hydroxide |  |  |
| Lithium and sulphate |  |  |
| Magnesium and <br> carbonate |  |  |
| Potassium and <br> manganate |  |  |
| Calcium and nitrate |  |  |
| Ammonium and <br> nitrate |  |  |
| Aluminium and <br> nitrate |  |  |
| Aluminium <br> sulphate |  |  |

You also need to know the names of some acids. These ones need to be remembered.

- $\mathrm{H}_{2} \mathrm{SO}_{4}$ sulphuric acid
- $\left.\mathrm{HCl}_{(\mathrm{aq}}\right)$ hydrochloric acid
- $\mathrm{HNO}_{3}$ nitric acid
- $\mathrm{H}_{2} \mathrm{CO}_{3}$ carbonic acid
- $\mathrm{CH}_{3} \mathrm{CO}_{2} \mathrm{H}$ ethanoic acid (acetic acid).


## Equations to know

During your study of chemistry at GCSE you will have come across a number of important chemical equations that you will need for $A$ level. If you understand the generic equations you will be able to apply these to all sorts of situations. Listed below are the ones you should already know

| Acid + reactive metal | $\rightarrow$ | salt + hydrogen |
| :--- | :--- | :---: |
| Acid + alkali | $\rightarrow$ | salt + water |
| Acid + carbonate | $\rightarrow$ | salt + water + carbon dioxide |
| Carbon compound + oxygen | $\rightarrow$ carbon dioxide + water |  |

The carbon compound could be a hydrocarbon or a carbohydrate.
Don't forget to balance equations. This is when you make sure that the number of atoms in the reactants is the same as the number of atoms in the products. Like this......

$$
2 \mathrm{CO}_{(\mathrm{g})}+\mathrm{O}_{2(\mathrm{~g})} \rightarrow 2 \mathrm{CO}_{2(\mathrm{~g})}
$$

Write the following equations using the information above. You will need to remember to make sure that the formulae are correct using the rules given earlier on. You also need to make sure that the equations are balanced and that state symbols are given.

1. Magnesium + hydrochloric acid
2. Zinc + sulphuric acid
3. Sodium hydroxide + nitric acid
4. Potassium hydroxide + sulphuric acid
5. Citric acid + magnesium
6. Hydrochloric acid + calcium carbonate
7. Sulphuric acid + copper carbonate
8. Burning methane in oxygen ( complete combustion)
9. Burning ethanol in oxygen (complete combustion)
10. The complete combustion of glucose (where else does this equation crop up)

| 1 |  |
| :--- | :--- |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |
| 6 |  |
| 7 |  |
| 8 |  |
| 9 |  |
| 10 |  |

## Moles and chemical calculations

This is a very important section. You need to become competent with these calculations as soon as possible.

## The mole

A dozen means twelve of something
A gross means one hundred and forty four of something
A brace means two of something
A score is twenty of something
A mole is $6.02 \times 10^{23}$ of atoms, ions, molecules, electrons etc.
Although the number is important in chemistry it is really only used to work out masses and concentrations at A level.

You need to follow this section very carefully and complete all the questions.

## Relative atomic mass $A_{r}$

The mass number for any atom is the large number that you will find next to every element in the periodic table. The small number as we have already seen is the proton number or atomic number. Write down the mass numbers for the following elements. You will need a periodic table

| element | Atomic mass | element | Atomic mass |
| :--- | :--- | :--- | :--- |
| Ca |  | U |  |
| P |  | Be |  |
| N |  | B |  |
| O |  | I |  |
| K |  | Ra |  |

## Relative molecular mass $\mathrm{M}_{\mathrm{r}}$

Relative molecular mass is simply all the relative atomic masses in a molecule added together. However there are a few thing that may catch you out.

Brackets- anything inside a bracket is multiplied by the little number outside the bracket

Water of crystallisation- Some compounds have . $\mathrm{x}_{2} \mathrm{O}$ such as Cu $\mathrm{SO}_{4} .5 \mathrm{H}_{2} \mathrm{O}$. When you work out the relative molecular mass of the compound you must remember to add on the correct number of water molecules, in the example above 5 lots of 18 which is 90.

Complete the following

| compound | $\mathrm{M}_{r}$ | compound | $\mathrm{M}_{r}$ |
| :--- | :--- | :--- | :--- |
| NaCl |  | $\mathrm{NH}_{4} \mathrm{NO}_{3}$ |  |
| CuCO |  |  |  |
| $\mathrm{Cu}(\mathrm{Cl})_{2}$ |  | $\left(\mathrm{NH}_{4}\right)_{2} \mathrm{SO}_{4}$ |  |
| $\mathrm{Ca}\left(\mathrm{NO}_{3}\right)_{2}$ |  | $\mathrm{CuSO}_{4} .5 \mathrm{H}_{2} \mathrm{O}$ |  |

## Moles of compounds

Now you have worked out the relative atomic and molecular masses it is very easy to state the mass of a mole of a specific substance.

A mole of a substance is simply the atomic or molecular mass expressed in grams.

A mole of calcium carbonate has a mass of 100 g . A mole of carbon atoms has a mass of 12 g . Half a mole of calcium carbonate has a mass of 50 g and a tenth of a mole of carbon has a mass of 1.2 g

The mass therefore is the number of moles $x$ the atomic or molecular mass
Work out the gaps in the following table

| item | Atomic or <br> molecular mass | Number of <br> moles | Mass in grams |
| :--- | :--- | :--- | :--- |
| C |  | 2 |  |
| Ca |  | 0.1 |  |
| $\mathrm{H}_{2}$ |  | 0.125 |  |
| $\mathrm{~N}_{2}$ |  |  | 2.8 |
| $\mathrm{H}_{2} \mathrm{O}$ |  | 2.5 | 2 |
| $\mathrm{CaCO}_{3}$ |  | 0.16 | 0.6 |
| $\mathrm{C}_{2} \mathrm{H}_{6}$ |  | $1.4 \times 10^{-3}$ |  |
| $\mathrm{C}_{2} \mathrm{H}_{4} \mathrm{O}_{2}$ |  |  |  |
| NaCl |  |  |  |
| $\mathrm{CuSO}_{4}$ |  |  |  |

## Solutions and their concentrations

Concentrations are expressed as so many moles in a $\mathrm{dm}^{3}$ of solution and the correct unit is $\mathrm{mol} \mathrm{dm}^{-3}$. $\mathrm{Adm}^{3}$ is the same as a litre.

1mole of a substance dissolved in $1 \mathrm{dm}^{3}$ of solution gives a concentration of $1 \mathrm{~mol} \mathrm{dm}^{-3}$.
0.5 mol of a substance dissolved in $0.5 \mathrm{dm}^{3}$ of solution gives a concentration of $1 \mathrm{~mol} \mathrm{dm}^{-3}$.

2 mol of a substance dissolved in $0.5 \mathrm{dm}^{3}$ of solution gives a concentration of $4 \mathrm{~mol} \mathrm{dm}^{-3}$.

Fill in the spaces in the table below.

| No. of mols | Vol. of solution <br> $\mathrm{dm}^{3}$ | Concentration <br> $\mathrm{mol} \mathrm{dm}^{-3}$ |
| :--- | :--- | :--- |
| 1 | 1 |  |
| 1 | 1 | 0.5 |
| 0.5 | 1 | 2 |
| 0.1 | 1 |  |
| 0.2 | 0.5 | 1 |
| 0.25 | 0.2 | 0.56 |
| 0.15 | 2 | 2.5 |
| 0.125 |  |  |

Now you can work out the mass of solute to use in a specific volume in order to obtain a solution of specific concentration.

1mole of a substance dissolved in $1 \mathrm{dm}^{3}$ of solution gives a concentration of $1 \mathrm{~mol} \mathrm{dm}^{-3}$. (as above)

If we needed to make $1 \mathrm{dm}^{3}$ of NaCl solution at a concentration of 1 $\mathrm{mol} \mathrm{dm}^{-3}$. then we would need to dissolve 1 mol of NaCl in $1 \mathrm{dm}^{3}$ of solution. That is $23+35.5=58.5 \mathrm{~g}$.

If we needed to make $0.5 \mathrm{dm}^{3}$ of NaOH solution at a concentration of $0.5 \mathrm{~mol} \mathrm{dm}^{-3}$. then we would need to dissolve 0.25 mol of NaOH in $0.5 \mathrm{dm}^{3}$ of solution. That is $23+16+1=40 / 4$ or $40 \times 0.25$. Either way we get 10 g . So 10 g of NaOH dissolved in $0.5 \mathrm{dm}^{3}$ of solution gives a concentration of $0.5 \mathrm{~mol} \mathrm{dm}^{-3}$.

Answer the following questions.

1. How much potassium hydroxide do you need to dissolve in 1000 $\mathrm{cm}^{3}$ in order to obtain a concentration of $2 \mathrm{~mol} \mathrm{dm}^{-3}\left(1000 \mathrm{~cm}^{3}\right.$ is the same as $1 \mathrm{dm}^{3}$ )?
2. How much potassium hydroxide do you need to dissolve in 500 $\mathrm{cm}^{3}$ in order to obtain a concentration of $0.1 \mathrm{~mol} \mathrm{dm}^{-3}$ ?
3. How much potassium hydroxide do you need to dissolve in 250 $\mathrm{cm}^{3}$ in order to obtain a concentration of $0.2 \mathrm{~mol} \mathrm{dm}^{-3}$ ?
4. How much anhydrous copper sulphate do you need to dissolve in $2000 \mathrm{~cm}^{3}$ in order to obtain a concentration of $0.25 \mathrm{~mol} \mathrm{dm}^{-3}$ ?
5. 10 g of NaOH dissolved in $100 \mathrm{~cm}^{3}$ of solution gives what concentration?
6. 5 g of NaOH dissolved in $500 \mathrm{~cm}^{3}$ of solution gives what concentration?
7. 10 g of $\mathrm{CuSO}_{4}$ dissolved in $100 \mathrm{~cm}^{3}$ of solution gives what concentration?
8. 0.167 g of $\mathrm{KMnO}_{4}$ dissolved in $1.5 \mathrm{dm}^{3}$ of solution gives what concentration?
9. 0.1 g of $\mathrm{KMnO}_{4}$ dissolved in $0.1 \mathrm{dm}^{3}$ of solution gives what concentration?
10. 0.25 g of KOH dissolved in $250 \mathrm{~cm}^{3}$ of solution gives what concentration?

## Final words

You should have answered all the questions covered in these pages and you should now be well prepared to take on AS level chemistry. These calculations will become easier as you progress through the course but you will need to understand the information covered in this booklet straight away.

On starting the course we will be going through these notes to make sure that you have understood the areas covered before preceding with the actual AS level course. There will be a test on the material covered in this booklet early on in September.

