science

chemistry

Topic 2– Structure & Bonding

What is an ion?
An ion is a charged atom. It becomes charged by gaining or losing electrons. If they lose electrons (metals) they become positive ions. If they gain electrons (non-metals) they become negative ions.

Ionic Bonding
An ionic bond is an electrostatic force of attraction between 2 or more oppositely charged ions.
Ionic compounds are formed in reactions between metals and non-metals.
e.g.
Group 1 elements lose one electron to form 1+ ions (e.g. Na^{+})
Group 2 elements lose two electrons to form 2+ ions (e.g. Mg^{2+})
Group 7 elements gain one electron to form 1- ions (e.g. Cl^{-})
Group 6 elements gain two electrons to form 2- ions (e.g. O^{2-})
When a metal reacts with a non-metal, the metal gives electrons to the non-metal.
The ions attract each other to form an ionic lattice, which is a regular 3D arrangement of ions. The ionic lattice is held together by the strong attraction between positive and negative ions (This is called “electrostatic attraction”):

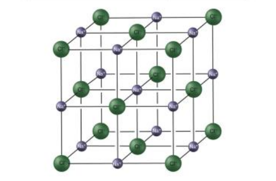
Properties of ionic substances:
High melting points because lots of energy is needed to break all the strong electrostatic forces between ions.
They do not conduct electricity when solid but **do conduct if they are either molten or dissolved in water** as the ions can move freely & carry the current.

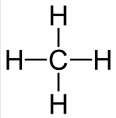
Metallic bonding
Metals have a structure which contains a regular 3D arrangement of layers of positive ions held together by a sea of delocalised electrons.

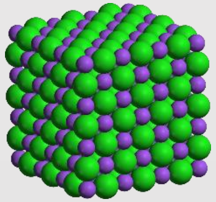
Properties of metals:
They are malleable & ductile because they the layers of metal ions can slide over each other and still be held together by the delocalised electrons.
They conduct electricity because the delocalised electrons can move through the whole structure (remember an electric current is moving charge and electrons are negative) and carry the charge.

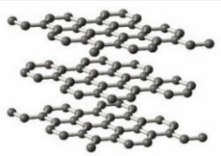
Using models to represent structures of compounds
- Simple particle model (s,l,g) assumes particle made up of solid spheres with no forces between them.
- Dot and cross model (shows where electrons come from but electrons identical, doesn’t always show 3D shape).
- Ball and stick model (limited as spheres are shown to be solid and inelastic and does not show true shape).
- Close packed model (difficult to see arrangement in 3D).

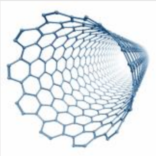
Sodium Chloride Crystal Lattice





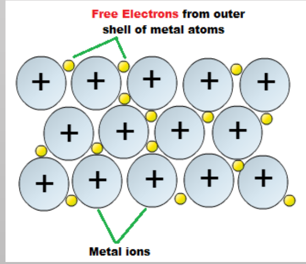


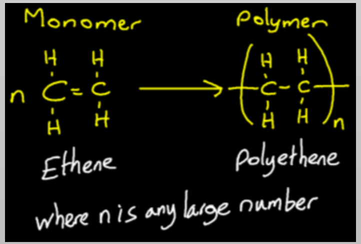




Graphene & fullerenes
Graphene is a single layer of graphite, so it is referred to as a 2D material as it is only one atom thick.
Carbon atoms can also form hollow balls or ring structures called fullerenes. Buckminster fullerene (C_{60}) has a spherical shape like a football – can roll so useful as a catalyst.
Carbon nanotubes can also form which are used in medicine.

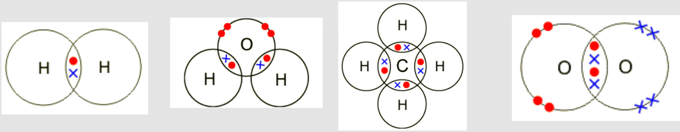
Polymers – Polymers are made up of many small molecules that bond to each other forming a long chain. Most common and simplest example is polyethene.





What is a molecule?
2 or more atoms joined together by covalent boning (sharing electrons)

Covalent Bonding
Covalent bonding occurs when two non-metals are chemically joined together.
A covalent bond is a pair of electrons shared between two atoms.
Covalent bonding can either result in either:
A molecule, e.g. hydrogen (H_2), oxygen (O_2) or water (H_2O). A molecule is “a group of two or more atoms held together by covalent bonds”. Substances containing molecules are called “simple molecular”.
Or a giant 3D lattice held together by covalent bonds. These substances are called “giant covalent” structures.



Properties of simple molecules such as the ones above:
They have low melting points and boiling points because there are only weak forces (“intermolecular forces”) between the molecules (Don’t forget that the actual covalent bonds holding the atoms together are strong). Little energy is needed to break these forces.
They do not conduct electricity because the molecules do not have a charge – there are no ions or free electrons to carry the current.

Giant Molecules (diamond and graphite)
Diamond has a **giant covalent** structure with every carbon atom joined to 4 others by lots of strong covalent bonds. Lots of energy is needed to break all these bonds which make diamonds very hard and useful as cutting tools / drill bits.
Graphite is the more common black form of carbon. It contains layers of carbon atoms with each carbon joined to 3 others by strong covalent bonds. This means that each carbon has an unused electron. ***Graphite conducts electricity because these delocalised electrons are free to move through the structure and carry the charge.*** Pencils and some lubricants contain graphite because the layers of carbon atoms can slide over each other as they are held together by weak forces (intermolecular) of attraction.

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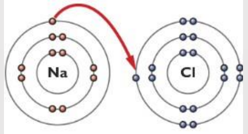
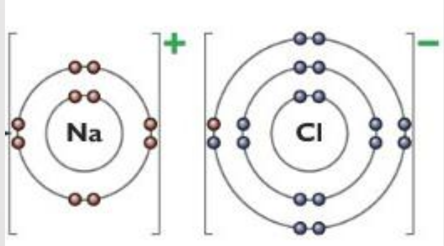
Topic 2– Structure & Bonding

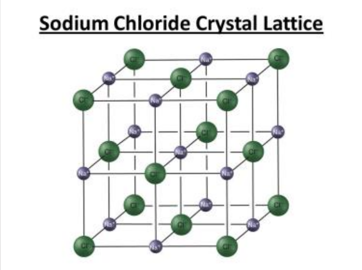
Ionic Bonding

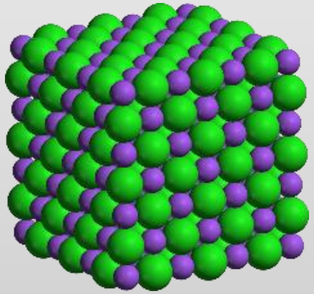
- An ionic bond is an electrostatic force of attraction between 2 or more oppositely charged ions.
- Forms between metals and non-metals.
- Metals give their electrons to the non-metals.





- **The ions attract each other to form an ionic lattice, which is a regular 3D arrangement of ions.**



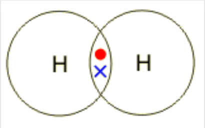


Properties of ionic substances:

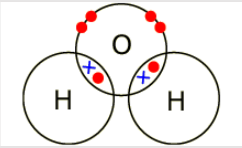
- High melting points - lots of energy needed to break all the strong electrostatic forces between ions.
- Do not conduct electricity when solid
- Can conduct when liquid (molten or aqueous) as the ions are free to move & carry the current.

Covalent Bonding

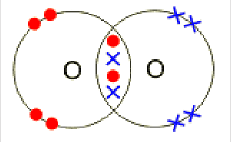
- A covalent bond is a pair of electrons shared between two atoms.
- Occurs between two or more non-metals.
- Forms either simple molecules (see below) or giant molecules (see right).
- A simple hydrogen molecule (H_2)



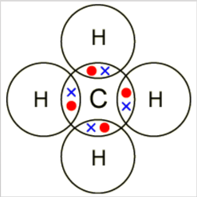
- A simple water molecule (H_2O)

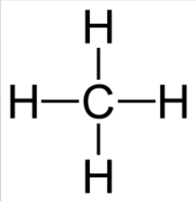


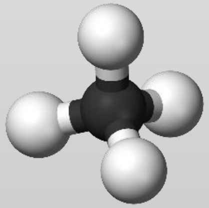
- A simple oxygen molecule (O_2)



- A simple molecule of methane (CH_4)





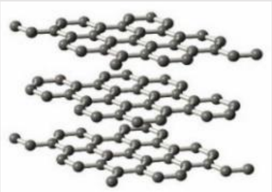


Properties of simple molecules:

- Low melting points and boiling points - Little energy is needed to break the weak forces ("intermolecular forces") of attraction between the molecules.
- Do not conduct electricity because the molecules do not have an overall electric charge.

Giant Molecules (diamond and graphite)

- Substances that consist of giant covalent structures are solids with very high melting points.
- All of the atoms in these structures are linked to other atoms by strong covalent bonds.
- These bonds must be overcome to melt or boil these substances.
- Diamond has a **giant covalent** structure with every carbon atom joined to 4 others by lots of strong covalent bonds (lots of energy is needed to break all these bonds which make diamonds very hard).
- Graphite contains layers of carbon atoms with each carbon joined to 3 others by strong covalent bonds. It is soft as these layers can slide over each other (weak forces of attraction).



Nanoparticles (SINGLE CHEMISTRY ONLY):

1nm = 1×10^{-9}m

Nanoscience refers to structures that are 1–100 nm in size, of the order of a few hundred atoms.

Nanoparticles, are smaller than fine particles, which have diameters between 100 and 2500 nm (1×10^{-7} m and 2.5×10^{-6} m). Coarse particles (PM10) have diameters between 1×10^{-5} m and 2.5×10^{-6} m. Coarse particles are often referred to as dust.

As the side of cube decreases by a factor of 10 the surface area to volume ratio increases by a factor of 10.

Nanoparticles may have properties different from those for the same materials in bulk because of their high surface area to volume ratio. Smaller quantities are needed to be effective compared to normal particle sizes.

Nanoparticles have many applications in medicine, in electronics, in cosmetics and sun creams, as deodorants, and as catalysts. New applications for nanoparticulate materials are an important area of research.

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Bonding involves changes to the outer electrons by…

Transfer		Sharing	
Ionic	**Metallic**	**Covalent**	
Electrostatic force of attraction between oppositely charged ions	Layers of metal ions held together by a sea of delocalised electrons (layers can slide so metals are malleable & ductile)	The sharing of a pair of electrons between two or more non-metals	
Giant lattice structure	Giant lattice structure	Simple molecules	Giant covalent structure (lattice)
High mpt due to strong forces of attraction between ions which requires lots of energy to break them	High mpt due to strong forces of attraction between the metal ions and electrons which requires lots of energy to break them	Low mpt due to weak intermolecular forces between molecules as little energy needed to break them	V. high mpt due to large number of strong bonds so lots of energy needed to break them.
Only conduct when aqueous / molten as ions free to move and carry the current	Always conduct due to delocalised electrons moving throughout the whole structure in the direction of the current	Never conduct as no ions and no free electrons	Only graphite due to delocalised electrons moving in the direction of the current

Topic 3 – Quantitative Chemistry

science chemistry

Conservation of mass – In any chemical reaction no atoms are lost or made during a chemical reaction so the mass of the products equals the mass of the reactants.
If an element is heated in the air, it's mass may appear to go up as it is reacting with the oxygen in the air.
Metal carbonates, when heated, undergo thermal decomposition (breaking down using heat). The equation for the reaction is:
Calcium carbonate → Calcium oxide + Carbon dioxide.
$CaCO_{3\,(s)} \rightarrow CaO_{(s)} + CO_{2\,(g)}$
The mass might appear to go down but that is because one of the products made is a gas and this will escape into the environment.

Relative Atomic Mass (Ar)
The relative atomic mass of an element (Ar) is the average mass of the isotopes of that element compared to 1/12th the mass of carbon 12.

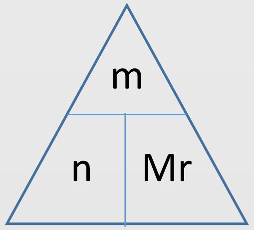
Relative Formula / Molecular Mass (Mr)
The relative formula mass (Mr) of a compound is the sum of the relative atomic masses of the atoms in the chemical formula. (e.g. Mr of NaOH = 23 + 16 + 1 = 40)
The relative mass of any substance, in grams, is known as one mole of that substance. A mole is basically a number of particles.

Isotopes – Elements **with the same number of protons but different number of neutrons** (so they will have different relative masses).

% by mass of an element
To calculate what percentage of a compound is made from a particular element:
e.g.
% of Mg in MgO
$\% \text{ Mg} = \frac{Mr\ of\ Mg}{Mr\ MgO}\ x\ 100 \quad = \frac{24}{40} x100 \ = 60\%$

Avogadro and the mole
One mol of any substance will contain the same number of particles, atoms, molecules or ions - 6.02×10^{23} per mol.
1 mol of H_2O will contain 6.02×10^{23} molecules.
This is known as Avogadro's number.

Calculating moles (HT only)



n = no. of moles (mols)

m = mass (grams)

Mr = Relative atomic mass

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

If you have a 60g of Mg, what mass of HCl do you need to convert it to $MgCl_2$?

A_r : Mg =24 so mass of 1 mole of Mg = 24g
M_r : HCl (1 + 35.5) so mass of 1 mole of HCl = 36.5g

So 60g of Mg is 60/24 = 2.5 moles

Balanced symbol equation tells us that for every one mole of Mg, you need two moles of HCl to react with it.

So you need 2.5x2 = 5 moles of HCl

You will need 5 x 36.5g of HCl= 182.5g

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

Alternatively you could work this out relative masses and scaling.
If you have a 60g of Mg, what mass of HCl do you need to convert it to $MgCl_2$?
A_r of Mg = 24, M_r of 2HCl = (2 x 36.5) = 73
Scale it down to 1g (divide both sides by 24)
1g Mg needs 72/24 = 3.04g HCl (then scale it back up to what you need)

60g of Mg needs 3.04 x 60 = 182.5g of HCl

Uncertainty - determine whether the mean value falls within the range of uncertainty of the result
1. Calculate the mean
2. Calculate the range of the results
3. Estimate of uncertainty in mean would be half the range.

e.g.
Mean value is 46.5s
Range of results is 44s to 49s = 5s
So the time taken was 46.5s $\pm$2.5s

Using moles to balance equations (HT only)
Convert the masses in grams to amounts in moles and convert the number of moles to simple whole number ratios.
e.g. 8.5g of sodium nitrate is heated in a test tube, it forms 6.9g of sodium nitrite and the remainder is oxygen. Balance the equation

	$NaNO_3$	→	$NaNO_2$	+	O_2
Work out mols	8.5/85		6.9/69		1.6/32
	=0.1		= 0.1		= 0.05

then divide each by smallest

Equation is **2**$NaNO_3 \rightarrow$ **2**$NaNO_2 + O_2$

Limiting reactants
The reactant that is used up first (the other one will be in excess). This limits the amount of product that is made and ensures that one of the reactants is completely used up. Work out the moles of each that you have & using the equation you can determine which one you have less moles of.

Concentration of solutions
Worked out by knowing the mass of solid dissolved and the volume of liquid it's dissolved in
$\text{Conc} = \frac{mass\ (g)}{volume\ (dm^3)}$ or $\text{conc} = \frac{mass\ (g)}{volume\ (cm^3)} x1000$

$1dm^3 = 1000cm^3$

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Topic 3 – Quantitative Chemistry (Single Chemistry)

Yield – The amount of a product in a reaction is known as the yield.

Percentage yield

This compares the actual mass you obtained in an experiment with the mass you should have got if all the reactants reacted together and there was no loss. This is know as the theoretical yield & is calculated from doing a moles calculation as before:

$$\% \text{ Yield} = \frac{actual\ mass\ of\ product}{\text{max}\ theoretical\ mass} \times 100$$

Factors affecting percentage yield

- Reaction may be reversible
- Unwanted / competing reactions
- Loss of product in handling / separation
- Reactants may not be pure.

Atom economy

This is a measure of how green /environmentally friendly the reaction is as it compares how much of your reactants are converted into useful products:

$$\text{Atom economy} = \frac{Mr\ of\ useful\ products}{\text{Mr of all the reactants}} \times 100$$

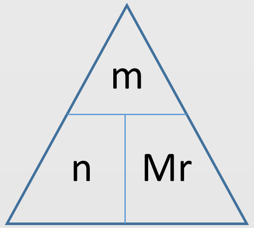
Remember Mr is also know as **relative formula mass** or relative molecular mass

Volumes of gases

1mol of any gas has a volume of $24dm^3$ (24litres or $24000cm^3$)

So if you have 0.5mols of O_2 gas then it would have a volume of $12dm^3$

Calculating moles



n = no. of moles (mols)

m = mass (grams)

Mr = Relative atomic mass

$$n = \frac{CV}{1000} \qquad \text{or} \qquad n = CV$$

n= no. of moles (mols)	n= no. of moles (mols)
C = concentration (mol/dm^3)	C = concentration (mol/dm^3)
V = Volume (cm^3)	V = Volume (dm^3)

Titration calculations

What is the concentration of hydrochloric acid if $21.33cm^3$ of acid were needed to neutralise $25cm^3$ of $0.5mol/dm^3$ solution of sodium hydroxide?

e.g.

$HCl + NaOH \rightarrow NaCl + H_2O$

From the equation 1mol HCl needs 1mol of HCl

Using $n = \frac{CV}{1000}$ work out moles of NaOH

Moles NaOH = $\frac{0.5 \times 25}{1000}$ = 0.0125

So from the equation the same amount of HCl would be needed so we have 0.0125mols of HCl.

Rearrange the equation to get the concentration:

$$\text{Conc} = \frac{1000 \times n}{V\ (acid)} = \frac{1000 \times 0.0125}{21.33} = 0.59mol/dm^3$$

Titrations

- The volumes of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator.
- If the concentration of one of the reactants is known, the results of a titration can be used to find the concentration of the other reactant.
- You should be able to calculate the chemical quantities in titrations involving concentrations (in moles per dm^3) and masses (in grams per dm^3).
- Acid is usually placed in the burette and a known volume of known concentration of alkali is measured out using a pipette.
- The pipette is filled with a pipette filler and then emptied under gravity into a conical flask.
- 2-3 drops of a suitable indicator (e.g. phenolphthalein) is added which will go pink in alkali and then colourless at end point.
- The flask is placed on a white tile so the colour change is clearer to see.
- The unknown acid is then added slowly from the burette to the alkali until the last drop of pink disappears. This is called the end-point.
- The reading on the burette is taken at eye level (to reduce any errors).
- The experiment is then repeated until you obtain **concordant** results (within ± $0.1cm^3$ of each other)
- Looking at the results in the table below, you would use your two concordant results which would be from experiments 2 & 3. The average would be $21.33cm^3$.

Attempt	1	2	3
Initial burette reading (cm^3)	0.00	0.00	0.00
Final burette reading (cm^3)	22.50	21.30	21.35
Titre value (cm^3)	22.50	21.30	21.35