4.2 Bonding, structure and the properties of matter

GCSE Chemistry

4.2.1 Chemical bonds, ionic, covalent and metallic

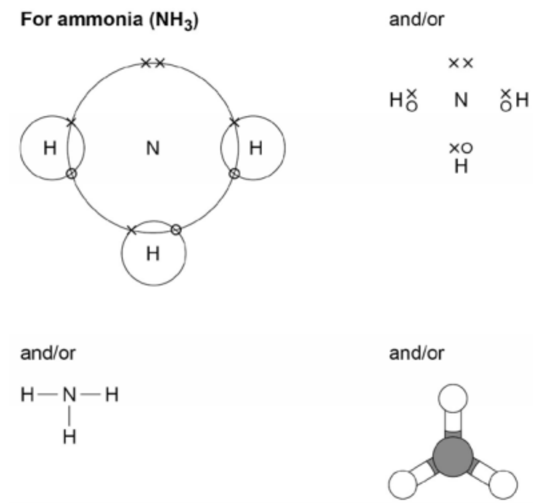
There are three types of strong chemical bond – ionic, covalent and metallic.

There are also weak intermolecular bonds which hold molecules close to each other.

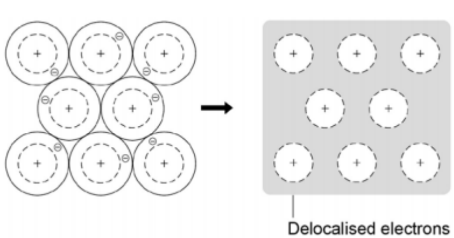
Type of bond	**What happens to electrons?**
Covalent	Electrons are shared
Ionic	Electrons are transferred
Metallic	Electrons are delocalised between positive metal ions

Metallic Bond	Non-metal & Non-metal
Ionic Bond	Metal & Metal
Covalent Bond	Metal & Non-metal

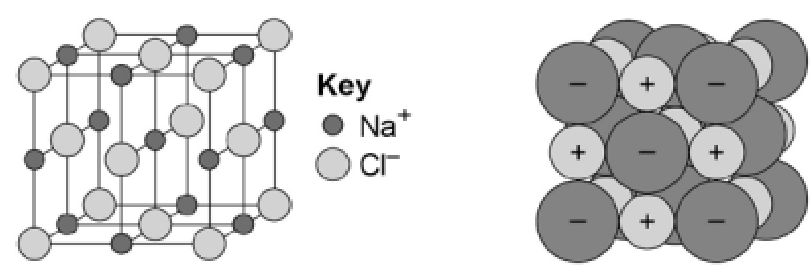
Covalent bonding



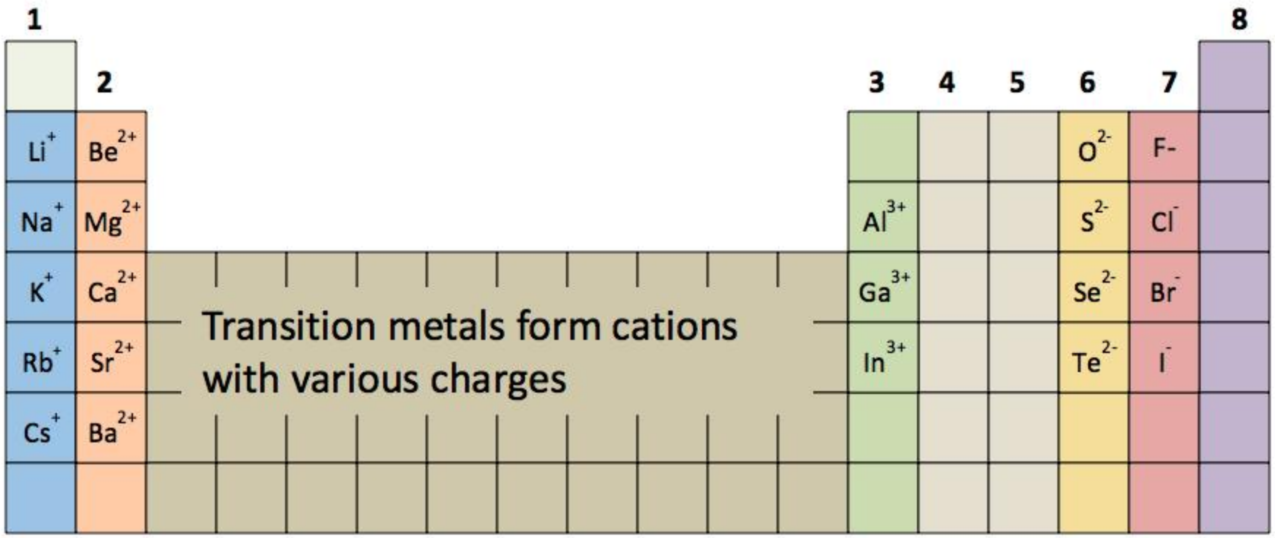
Metallic bonding



Ionic bonding



4.2.1 Chemical bonds, ionic, covalent and metallic

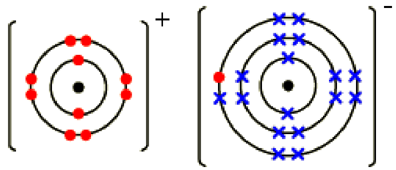
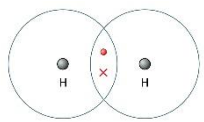
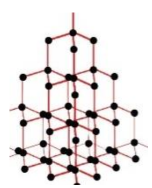
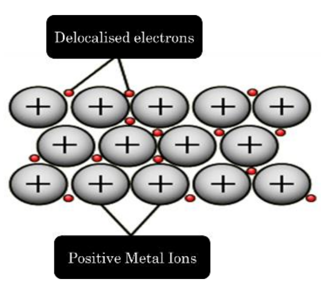


Element	**What happens to the electrons?**	**Ion formed**
Metal	Lost	Positive ion (cation)
Non-metal	Gained	Negative ion (anion)

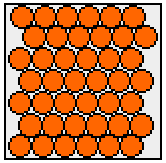
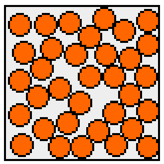
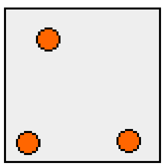
Ionic compound	**Ratio of ions in the compound**	**Formula of the compound**
Sodium chloride	$Na^+ : Cl^-$ 1 : 1	$NaCl$
Magnesium oxide	$Mg^{2+} : O^{2-}$ 1 : 1	MgO
Calcium chloride	$Ca^{2+} : Cl^-$ 1 : 2	$CaCl_2$

Name of ion	**Formula of ion**
Hydroxide	OH^-
Nitrate	NO_3^-
Carbonate	CO_3^{2-}
sulfate	SO_4^{2-}

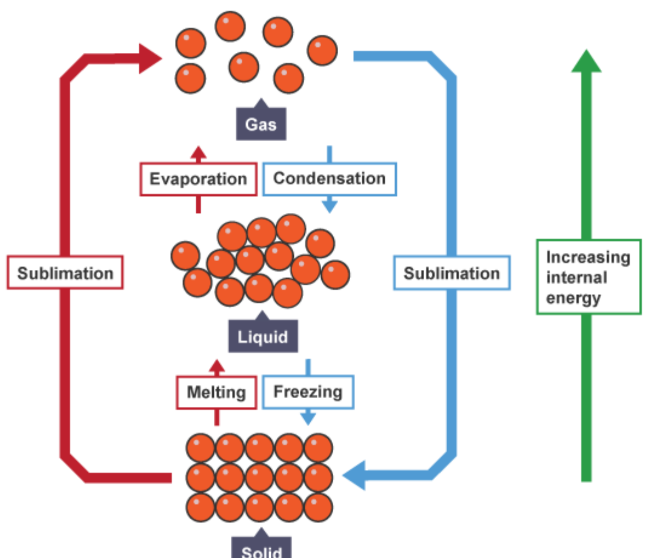
4.2.1 Chemical bonds, ionic, covalent and metallic

Type of chemical bond	Exists between	Example	Properties
Ionic bonding	Metal and non-metal	NaCl  sodium ion, Na^+ $[2,8]^+$ chloride ion, Cl^- $[2,8,8]^-$	<u>Ionic compounds</u> • Giant lattice structure. • Strong electrostatic forces of attraction between oppositely charged ions. • High melting and boiling points. • Do not conduct as a solid – ions cannot move • Do conduct when melted/dissolved – ions can move.
Covalent bonding	Non-metals	<u>Simple covalent molecules</u> H_2 	<u>Simple covalent molecules</u> • Do not conduct electricity. • Strong covalent bonds between atoms but weak intermolecular forces between molecules – low melting and boiling points.
		<u>Giant covalent molecules (macromolecules)</u> 	<u>Giant covalent molecules (macromolecules)</u> • Do not conduct electricity – no ions or delocalised electrons (exceptions include graphite). • Strong covalent bonds and all atoms bonded to each other – high melting and boiling points.
Metallic bonding	Metals	Sodium 	• Delocalised electrons carry current and thermal energy well - conduct electricity and heat. • Strong electrostatic forces of attraction between positive ions and electrons - high melting/boiling points. • Layers can move around so metal is malleable/ductile. • Each metal puts in electrons, the more electrons in the cloud = stronger bonding. • Alloys (a metal mixed with another element) – stronger as the different sized atoms distort the layers so they cannot slide over each other.

4.2.2 How bonding and structure are related to the properties of substances

State	**Diagram**	**Properties**
Solid		• Strong forces of attraction between particles. • Particles are close together in lattice arrangement. • The particles don't move from their positions so solids keep a definite shape. • The particles vibrate in their positions – the hotter the solid, the more they vibrate (solids expand when hot).
Liquid		• Weak force of attraction between particles. They are randomly arranged and free to move past each other (but they stick closely together). • Liquids have a definite volume but not a definite shape – they can flow. • The particles are constantly moving with random motion. The hotter the liquid gets, the faster they move (liquids expand when hot).
Gas		• Very weak force of attraction between particles. They are free to move and are far apart. The particles in gases travel in straight lines. • Gases don't keep a definite shape or volume. • The particles move constantly with random motion. The hotter the gas gets, the faster they move. Gases either expand when heated, or their pressure increases.

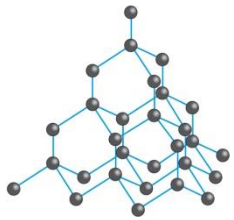
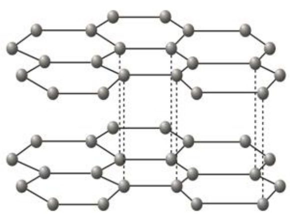
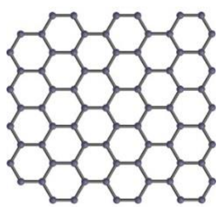
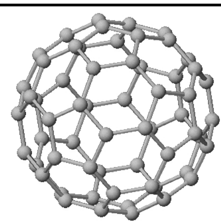
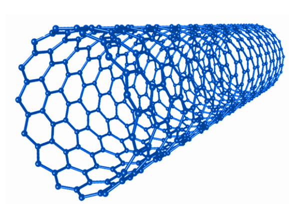
State	**Symbol**
Solid	s
Liquid	l
Gas	g
Aqueous	aq



Heating a substance up gives the particles more energy. More energy means the particles are moving more and break away from each other because they overcome the bonds.

The amount of energy needed for a substance to change state depends on how strong the forces between the particles are. The stronger the forces, the more energy is needed to break them, and so the higher the melting and boiling points of the substance.

4.2.3 Structure and bonding of carbon

Allotrope of carbon	Structure	Properties	Use
Diamond		• Each carbon atom has 4 covalent bonds – diamond is very hard • These strong bonds take a lot of energy to break – diamond has a very high melting point. • It doesn't conduct electricity as there are no free electrons or ions.	• In drill bits.
Graphite		• Each carbon atom has 3 covalent bonds (each atom has 1 delocalised electron) – the delocalised electron allows graphite to conduct electricity and thermal energy. • The covalent bonds take a lot of energy to break – graphite has a high melting point. • There aren't any bonds between layers – this makes graphite soft and slippery.	• As lubricants.
Graphene		• Graphene is on one atom think – it is a 2D compound. • The network of covalent bonds makes it very strong and very light – it can be added to materials to improve their strength without adding much weight. • It contains delocalised electrons so can conduct electricity through the whole structure.	• In electronics.
Fullerenes		• Fullerenes are molecules of carbon, shaped like closed tubes or hollow balls. • They are arranged in hexagons (or pentagons or heptagons). • They can trap molecules inside them. • They have a huge surface area. • The first fullerene to be discovered was the Buckminsterfullerene (C_{60}).	• For drug delivery. • To make carbon nanotubes.
Fullerenes as nanotubes		• Nanotubes are tiny carbon cylinders. • The ratio between the length and the diameter of nanotubes is very high. • They can conduct both electricity and thermal energy. • They have high tensile strength.	• In electronics. • For tennis rackets.

4.2.4 Bulk and surface properties of matter including nanoparticles

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

Type of particles	**Size in nm**	**Size in m**
Nanoparticles	1-100	1×10^{-9} to 1×10^{-7}
Fine particles ($PM_{2.5}$)	100-2500	1×10^{-7} to 2.5×10^{-6}
Coarse particles (PM_{10})	2500-10000	1×10^{-5} to 2.5×10^{-6}

Surface area to volume ratio

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

Surface area to volume ration = surface area ÷ volume

Use	**Why? (property)**
Catalysts	Due to their huge surface area to volume ratio.
Medicine (to deliver drugs)	They are small and more easily absorbed into the body.
Computer chips	Some nanoparticles conduct electricity.
Surgical masks and wound dressings	Silver nanoparticles have antibacterial properties.
Cosmetics	To improve moisturisers without making them oily.

Although nanoparticles are useful, the way they effect the body isn't fully understood so there may be some risks. Products containing nanoparticles should be labelled so that consumers can choose whether to use them or not.