WJEC Wales Chemistry GCSE

2.1: Bonding, structure and properties

Detailed notes

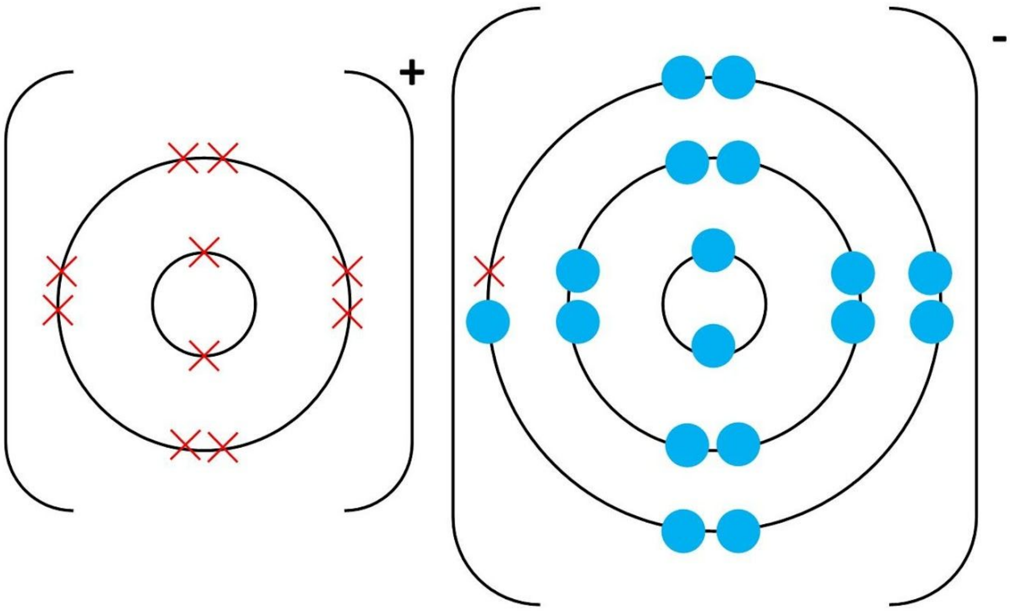
Bonding

- Compounds - substances in which 2 or more elements are chemically combined.
- There are 3 types of strong chemical bonds:
  - Ionic - the bonding present in ionic compounds
  - Metallic - the bonding present in metals
  - Covalent - the bonding present in giant covalent structures and simple covalent molecules
- The type of bonding accounts for many of the physical and chemical properties of the compound / molecule.

Ionic compounds

Bonding and structure

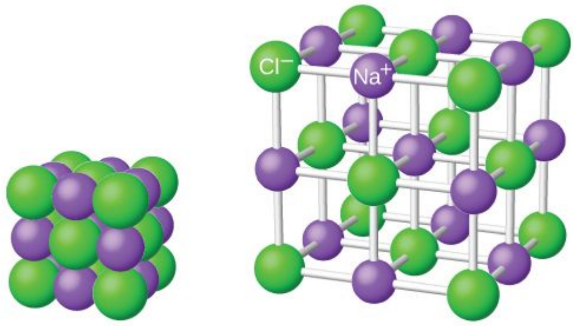
- Bonding occurs between metals and non-metals
- Ionic bonds are electrostatic attractions between oppositely charged ions
- The ions form a giant ionic lattice
- Electrons in the outer shell of the metal are transferred
  - Metal atoms lose electrons to become positively charged ions
  - Non-metal atoms gain electrons to become negatively charged ions
- Electron transfer during the formation of an ionic compound can be represented by a dot and cross diagram
  - An example is shown for sodium chloride:



Na + [2,8] +

Cl - [2,8,8] -

- An ionic lattice can be represented diagrammatically as shown:



(a) (b)

Image from: https://courses.lumenlearning.com/boundless-chemistry/chapter/types-of-crystals/

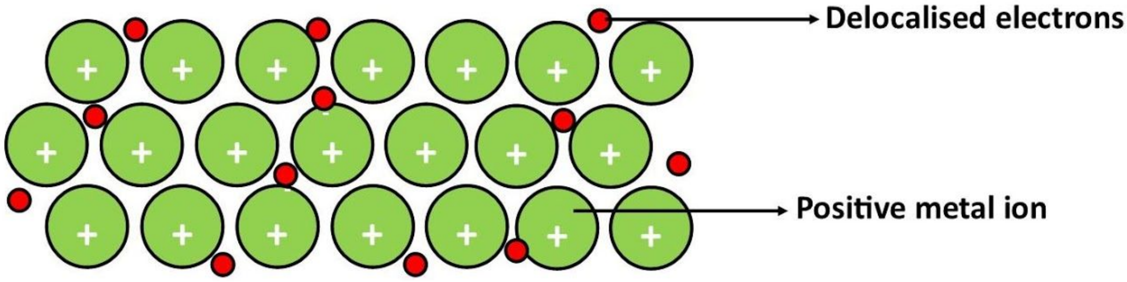
Properties

- The strong electrostatic attraction between oppositely charged ions means ionic compounds have high melting and boiling points
- When solid, ionic compounds don't conduct electricity because the ions are fixed in place.
    - However, the ions can move when molten/dissolved so then ionic compounds conduct electricity
- Ionic compounds are brittle

Metallic compounds

Bonding and structure

- Metals consist of giant structures of positive metal ions
- The electrons in the outer shell of metal atoms are delocalised and so are free to move through the whole structure – 'sea' of delocalised electrons
- Metallic bonds form due to the electrostatic attraction between the positively charged metal ions and negative delocalised electrons



Properties

- The layers of ions in metals are able to slide over each other, so metals can be bent and shaped making them malleable and ductile
- The delocalised electrons can move through the metal and carry charge, so metals conduct electricity and heat
- The metallic bonds are very strong and require large amounts of energy to be broken, so most metals have very high melting and boiling points.

Covalent bonding

When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong.

- Some covalently bonded compounds consist of small molecules e.g. HCl, H_2, O_2, Cl_2, NH_3, CH_4.
- Some have very large molecules, such as polymers.
- Some have giant covalent structures (macromolecules) e.g diamond, silicon dioxide.
- To show covalent bonding you can draw: dot and cross diagrams, repeat units for polymers, ball and stick and two- and three-dimensional diagrams. An example dot and cross diagram for the covalent bonding in water is shown:

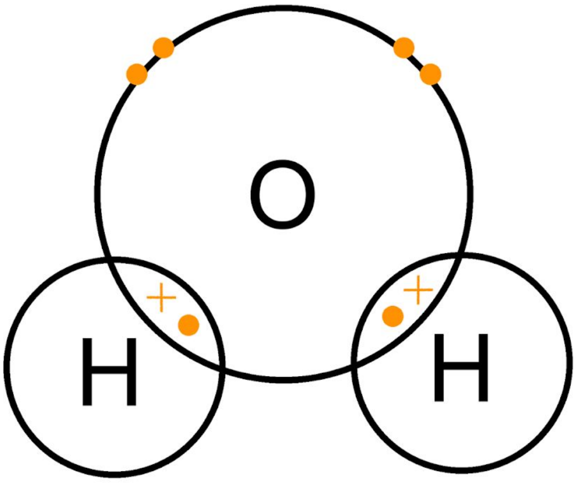


Image source: Benjah-bmm27 [Public domain]

Different covalent structures

Both simple molecules and giant covalent structures have covalent bonding however their structures and properties are very different.

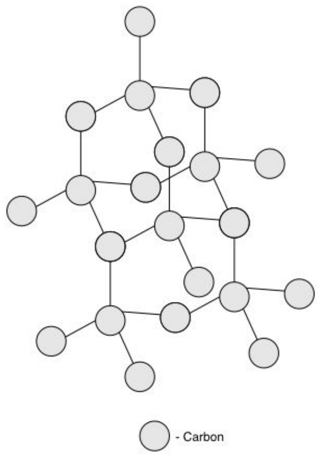
- Simple molecules
    - Substances that consist of simple molecules are usually gases or liquids that have low boiling and melting points.
    - Substances that consist of simple molecules have weak intermolecular forces between the molecules. These are broken in boiling or melting - not the covalent bonds.
        - The intermolecular forces increase with the size of the molecules, so larger molecules have higher melting and boiling points.
    - Substances that consist of simple molecules don't conduct electricity, because simple molecules do not have an overall electric charge
- Giant covalent structures
    - 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.

Types of giant covalent structures

The giant covalent structures looked at below are all allotropes of carbon. Allotropes are different forms elements can exist in - the structures are all made of atoms of the same element, yet do not have the same properties. Carbon atoms on their own do not have the properties exhibited by any one of the different structures.

Diamond

- In diamond, each carbon is joined to 4 other carbons covalently.
    - This is the maximum number bonds each carbon atom can make – 4.
    - It's very hard, has a very high melting point and does not conduct electricity.



Graphite

- In graphite, each carbon is covalently bonded to 3 other carbons, forming layers of hexagonal rings which have no covalent bonds between the layers.
    - The layers can slide over each other due to no covalent bonds between the layers, but weak intermolecular forces (meaning that graphite is soft and slippery).
- One electron from each carbon atom is delocalised.
    - This makes graphite similar to metals, because of its delocalised electrons.
    - It can conduct electricity – unlike Diamond.

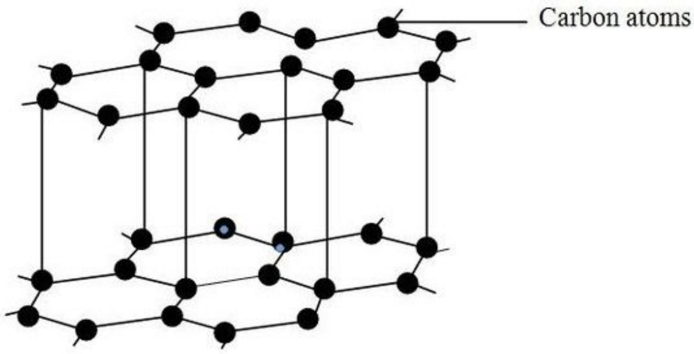


Image from: https://chemistry.stackexchange.com

Graphene and fullerenes

A huge number of natural and synthetic organic compounds we use today occur due to the ability of carbon to form families of similar compounds, chains and rings.

- Graphene
  - Single layer of graphite
  - Has properties that make it useful in electronics and composites
- Carbon can also form fullerenes with different numbers of carbon atoms.
  - Molecules of carbon atoms with hollow shapes
  - They are based on hexagonal rings of carbon atoms, but they may also contain rings with five or seven carbon atoms
  - The first fullerene to be discovered was Buckminsterfullerene (C_{60}), which has a spherical shape
- Carbon nanotubes
  - Cylindrical fullerenes with very high length to diameter ratios
  - Their properties make them useful for nanotechnology, electronics and materials
- Examples of uses
  - Fullerenes can be used as lubricants, to deliver drugs in the body and catalysts.
  - Nanotubes can be used for reinforcing materials, for example tennis rackets.

Nanoparticles

Properties

- Milli- (10^{-3}), micro- (10^{-6}) and nano- (10^{-9})
- Nanoparticles are 1-100 nanometers across
- They contain a few hundred atoms
- As the side of cube decreases by a factor of 10 the surface area to volume ratio increases by a factor of 10
- Nanoparticles include fullerenes.
- A nanoparticle has different properties to the 'bulk' chemical it's made from, because of their high surface area to volume ratio. It may also mean that smaller quantities are needed to be effective than for materials with normal particle sizes. e.g fullerenes have different properties to big lumps of carbon.
  - For example silver nano-particles have very different properties to silver metal.

Nano-particle uses

- Nano-silver:
  - Kills bacteria, so used in wound dressings and deodorants; also used to line socks and fridges to kill bacteria that cause bad smells.
- Nano-titanium dioxide:
  - Titanium dioxide nanoparticles are so small they do not reflect visible light, so cannot be seen. They are used in sunblock creams to block harmful ultraviolet light without appearing white on the skin.
  - Used in self-cleaning windows as they help break down dirt.

HIGHER TIER ONLY: Risks of nano-particles

- **Nanoparticles are so small that they could potentially enter the bloodstream. Many people feel the risks of them aren't yet known, so more testing should be done before they are used.**
- **They are a relatively new material so long term effects are not known.**
- **Could enter and potentially damage the environment**

Smart materials

Smart materials are responsive to certain stimuli, such as temperature and moisture. Some examples include:

- Shape memory alloys and shape memory polymers -
  - These materials can be bent and deformed but return to their original shape when heated
  - Uses for shape memory polymers include sports equipment, such as gum shields and medical stitches
  - Uses for shape memory alloys include car bodies and plates for bone fractures
- Thermochromic materials -
  - Change colour when they reach a certain temperature
  - Used in mugs and spoons which change colour when their contents are hot
- Photochromic pigments -
  - These pigments change colour when exposed to light
  - An application of this is sunglasses that darken when in bright sun
- Polymer gels -
  - Hydrogels absorbs up to 1,000 times their volume in water
  - Certain stimuli (changes in pH and temperature) can cause the water to be released
  - Used in nappies, fake snow and hair gel