WJEC England GCSE Chemistry

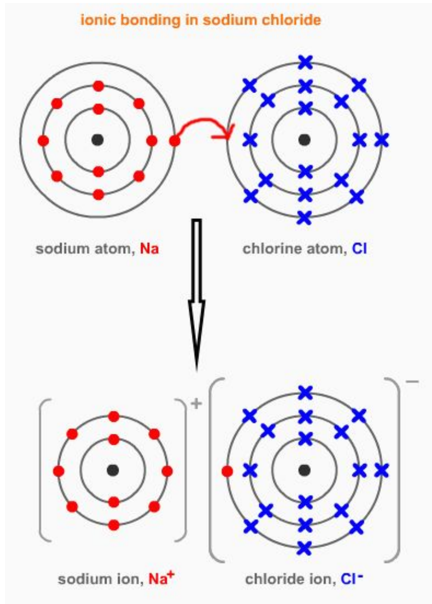
Topic 5: Bonding, structure and properties

Notes

(Content in bold is for Higher Tier only)

Chemical bonds

- **Compounds**- substances in which 2 or more elements are chemically combined.
- There are 3 types of strong chemical bonds: ionic, covalent and metallic.
- **Ionic**
    - Particles are oppositely charged ions
    - Occurs in compounds formed from metals combined with non-metals
- **Covalent**
    - Particles are atoms which share pairs of electrons
    - Occurs in most non-metallic elements and in compounds of non-metals
- **Metallic**
    - Particles are atoms which share delocalised electrons
    - Occurs in metallic elements and alloys

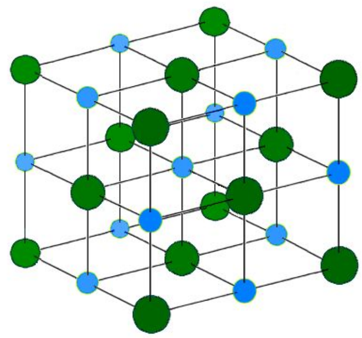


Ionic bonding

- Metal + Non-metal: electrons in the outer shell of the metal atom 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 (see eg for NaCl)

Ionic compounds

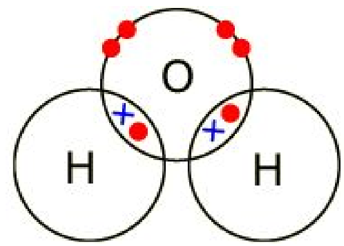
- A giant structure of ions.
- Held together by strong electrostatic forces of attraction between oppositely charged ions
- The forces act in all directions in the lattice, and this is called ionic bonding.
- because of the strong electrostatic forces, ionic compounds have high melting points
- when solid, ionic compounds don't conduct electricity because the ions are fixed in place. The ions can move when molten/dissolved so then ionic compounds can conduct electricity.



An example is sodium chloride (salt):
Na^+ (small blue particles) and Cl^- (larger green ones)

Covalent bonding

- A covalent bond is formed when 2 atoms share a pair of electrons in order to gain full outer shells. These bonds between atoms are strong.
- Covalently bonded substances may consist of small molecules e.g. HCl, H_2, O_2, Cl_2, NH_3, CH_4. These simple molecules have low melting and boiling points,because it is their weak intermolecular forces not their strong covalent bonds that are broken during melting/boiling.
- Some have very large molecules, such as polymers.
- Some have giant covalent structures (macromolecules) e.g diamond, silicon dioxide.
- Diagrams to show these substances could be dot and cross (right), shown as repeat units for polymers using a single line to represent a single bond, ball and stick and two- and three-dimensional diagrams.



Properties of 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.

Polymers

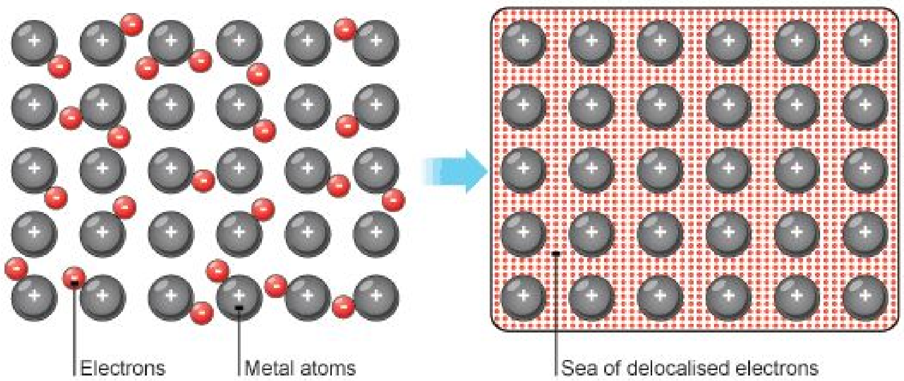
- Have very large molecules
- Atoms in the polymer molecules are linked to other atoms by strong covalent bonds
- Intermolecular forces between polymer molecules are relatively strong and so these substances are solids at room temperature

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.

Metallic bonding

- Metals consist of giant structures of atoms arranged in a regular pattern.
- The electrons in the outer shell of metal atoms are delocalised and so are free to move through the whole structure – 'sea' of electrons
- The sharing of delocalised electrons gives rise to strong metallic bonds.



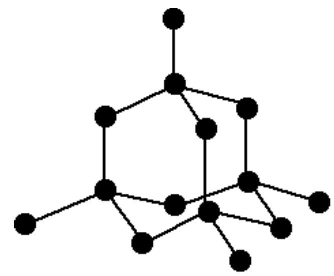
Properties of metals

- Metals have giant structures of atoms with strong metallic bonding.
    - o Therefore, most metals have high melting and boiling points.
    - o They can conduct heat and electricity because of the delocalised electrons in their structures.
    - o Conduction depends on the ability for electrons to move throughout the metal.
    - o The layers of atoms in metals are able to slide over each other, so metals can be bent and shaped.

limitations of the different representations and models of bonding

- dot and cross diagrams: shows how atoms are bonded and electrons, but doesn't show the 3D arrangement of molecules
- ball and stick models: show how atoms are bonded and the 3D shape, but doesn't show the electrons or the chemical symbols
- 2D/3D: generally, 2D models don't show the 3D arrangement and 3D models don't give details of bonding or electrons
- All: do not include intermolecular forces, which are the ones that are broken when boiling and melting simple molecules

Diamond



- In diamond (right), 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.

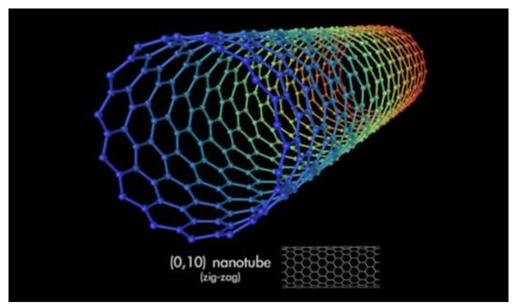
Graphene and fullerenes

- 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 (C60), 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
    - They 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

- milli- (10^{-3}), micro- (10^{-6}) and nano- (10^{-9})
- Nanoparticles are 1-100 nanometers across.
- They contain a few hundred atoms.
- Nanoparticles, are smaller than fine particles (PM2.5), 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 involve 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.

Their uses



- They have a high surface area to volume ratio, and therefore would make good catalysts.
- They can also be used to produce highly selective sensors.
- Nanotubes could make stronger, lighter building materials.
- New cosmetics, e.g sun tan cream and deodorant. They make no white marks.
    - 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
- Lubricant coatings, as they reduce friction. These can be used for artificial joints and gears.
- Nanotubes conduct electricity, so can be used in small electrical circuits for computers.
- risks of using nanoparticles: nanoparticles are so small that they could potentially enter the bloodstream and many people feel the risks of them aren't yet known, so more testing should be done before they are used

surface area to volume

- smaller particles have a larger surface area to volume ratio. This relatively large surface area leads to particles being incredibly reactive