Bonding in compounds

Ionic bonding

When non-metals react with metals, there is a transfer of electrons. The metal atoms tend to donate electrons from the outermost energy level to the non-metal atoms in order that both gain a more stable electronic structure, similar to a noble gas (complete outermost shell of electrons). Resultantly, metal atoms form positively charged ions (cations) and non-metals form negatively charged ions (anions).

- **How bonds form -** The unlike charges between the ions result in strong electrostatic forces of attraction that hold the metal and non-metal ions together in an ionic bond. The electrostatic attraction of oppositely charged ions overcomes any repulsion between ions of the same charge, holding together ionic lattice structures (including those of hydrated salts).

When ion charges don't balance (e.g. Cl^- + Mg^{2+}): since the reactions form products in a stoichiometric manner, more ions of a particular reactant become involved in the reaction in order to form a stable product with no charge and a structure similar to a noble gas. i.e. $MgCl_2$

Properties of Giant ionic structures.

- **State, melting point -** Ionic compounds are typically solid at room temperature and pressure and have lattice structures; they are formed from a large number of oppositely charged ions that are held together in a regular arrangement in a giant ionic lattice where there are strong electrostatic forces acting equally in all directions. Therefore a great deal of energy is required to overcome/break these bonds and split the lattice up meaning they have high melting/boiling points.

- **Shape -** The electrostatic forces between unlike charged ions act in all direction equally. This results in an arrangement called a giant ionic lattice. Because of the regular shape, ionic compounds form regularly shaped crystals.

- **Electrical conductivity –** Ionic compounds are usually solid at room temperature and pressure so all the ions are held tightly by electrostatic forces of attraction that act equally in all direction within the giant ionic lattice structure. Because of this, the charged ions are not free to move throughout the structure so can't carry an electrical charge (there are also no delocalised electrons to do so). In solid form, they don't conduct electricity.

  Most are soluble in water and so when in a solution the lattice split as the compound dissolves dissociating into ions that are free to move and carry electrical current. Likewise, when in a molten state, the ions are free to move and carry a charge.

- **Strength –** Ionic compound have giant ionic lattices made up of oppositely charged ions that are bonded tightly by electrostatic forces that act equally in all direction and overcome the repulsion of like charged ions. Lots of energy is required to break these strong ionic bonds.

  However, When enough energy is provided to overcome the electrostatic bonds, the layers of ions slide and distort the lattice so that unlike charge ions will come into alignment. They have a strong repulsion which splits the compound causing it to shatter with brittle failure.

What substances form this?	Metals & Non-metals
Examples	Sodium chloride/NaCl, Calcium oxide, CaO
What type of particles formulate?	Ions (cations + /anions -)
How are particles bonded?	Strong ionic bonds; electrostatic attraction
Typical melting & boiling point:	High
Strength	Hard but brittle
Electrical conductivity	No, except when in solution with water or molten
Solubility (water)	Often soluble
Solubility (non-polar solvent e.g. hexane)	Insoluble

Metallic bonding

Metals also have a lattice structure. A popular/simple model is the electron-sea model.
Every metal atom has free (**valence**) electrons in their outermost shell which become delocalised and metal cations form surrounded by a sea of free electrons. This causes a lattice of metal cations that have a positive charge which are held strongly in a regular arrangement by the electrostatic forces of attraction between the negatively charged sea of delocalised electrons that surround them.

<u>Properties of Giant metallic structures.</u>

- **State, melting point -** Metallic compounds are typically solid at room temperature and pressure and have lattice structures; they are formed from a large number positively charged metal ions (cations) which are arranged in a regular lattice structure and held by strong electrostatic forces of attraction between the sea of delocalised electrons surrounding them. The strong electrostatic forces require a great deal of energy to overcome and break. Therefore the melting and boiling points are high.

- **Shape -** The electrostatic forces between metal cations and the sea of delocalised electrons act equally in all direction so the metal cations are arranged in regular rows that form a crystal lattice.

- **Electrical conductivity –** In the metallic structure, there is a lattice of metal cations arranged regularly and surrounded by a sea of delocalised electrons. This is so because every metal particle has electrons that are not involved in bonding (**valence electrons**) in their outermost shell which are free to move to form a sea of delocalised electrons. These can move throughout the structure and carry an electrical charge.

- **Heat conduction –** Moreover, the sea of delocalised electrons allows for efficient dissipation of heat energy, carrying kinetic energy throughout the structure while also colliding with ions. The closely packed metal cations also vibrate and so kinetic energy is quickly passed through the structure. This makes metals good conductors of heat.

- **Strength –** Metallic compounds have a giant metallic lattice; the positive metal cations are held in a regular arrangement by strong electrostatic forces of attraction to their sea of delocalised electrons**.** These strong metallic bonds require a great deal of energy to overcome and break. Therefore metallic structures are hard.

  Much less energy is needed to distort a metal than brake it. When the force is applied, the structure does not necessarily shatter. The regular rows of metal cations are able to slide over each other. Since the delocalised electrons are not associated with any particular ion, they can accommodate for the distortion and continue to surround the cations, providing the electrostatic attraction that holds the cations in the structure. This means metals are malleable & ductile and show plastic deformation.

  If a large enough force is applied then the rows of metal cations will jolt over each other and the sea of delocalised electrons may not surround the structure at all points causing the metal to shatter. (This is more common in alloys where the irregular arrangement of different sized ions (and different bonding types) causes a build-up of stress which is released in a brittle failure as the layers jolt out of place).

What substances form this?	Metals & Alloys
Examples	Copper, Gold , Bronze (Copper + Tin), Brass (copper + zinc)
What type of particles formulate?	Cations surrounded by delocalised electrons
How are particles bonded?	Strong metallic bonds; electrostatic attraction between positive nuclei and electrons
Typical melting & boiling point:	Generally high except mercury
Electrical conductivity	High, solid or liquid
Strength	Hard but malleable (except mercury)
Solubility (water)	Insoluble (some even react)
Solubility (non-polar solvent e.g. hexane)	Insoluble