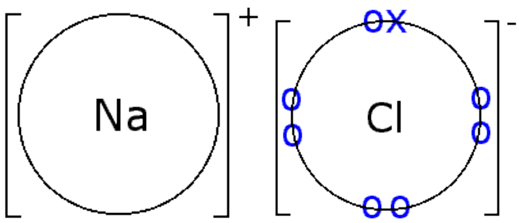
Topic 5 – Bonding and Structure
Revision Notes

1) Introduction

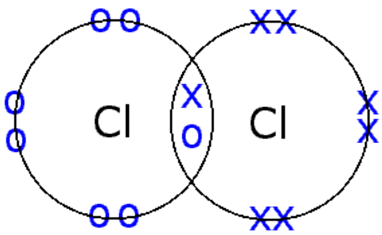
- Atoms form bonds to get a full outer shell of electrons
- There are three types of bonding: ionic, covalent and metallic
- The structures produced by forming bonds are either giant or simple
- The possible combinations of structure and bonding are giant ionic, simple covalent, giant covalent and giant metallic
- Simple covalent is sometimes called simple molecular
- Giant covalent is sometimes called giant molecular or macromolecular
- To melt a substance the forces holding the particles together need to be broken
- To conduct electricity there must something charged that can move (ions or electrons). Technically this is called a mobile charged species
- To dissolve in a particular solvent the substance must interact with the solvent

2) Types of Bonding

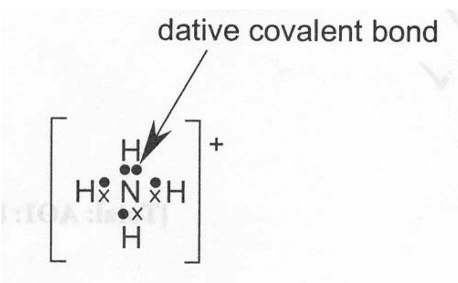
- Ionic bonding – metals transfer electrons to non-metals producing positive metal ions and negative non-metal ions. An ionic bond is an electrostatic attraction between oppositely charged ions. Dot-cross diagrams show outer electrons only e.g. NaCl



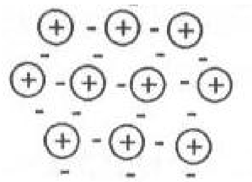
- Covalent bonding – A covalent bond is a shared pair of electrons. Only non-metals can get a full shell by sharing electrons. The bond is the attraction of the shared electrons for the two nuclei. Dot-cross diagrams show outer electrons only e.g. Cl_2



- In dative covalent bonds, one atom provides both of the shared pair of electrons e.g. formation of an ammonium ion, NH_4^+, from ammonia, NH_3, and H^+



- Metallic bonding – metals lose their outer shell electrons to produce a lattice of positive metal ions surrounded by delocalised (free) electrons.



3) <u>Types of Structure</u>

a) Giant ionic lattices e.g. sodium chloride

- Lattice of oppositely charged ions.
- High melting and boiling points (strong forces of attraction between **ions** need to be broken).
- Do not conduct when solid (ions not free to move).
- Conduct when molten or dissolved in water (ions then free to move).
- Most are soluble in polar solvents like water. The ions interact with the dipoles in the solvent molecules
- Tend not to dissolve in non-polar organic solvents like cyclohexane. The ions do not interact with non-polar solvents

b) Simple covalent lattices e.g. iodine and ice

- Consists of molecules held together by weak intermolecular forces (see section 5 below)
- Low melting and boiling points (weak forces of attraction between **molecules** are easily broken)
- Do not conduct (no mobile charge carriers)
- Most are insoluble in polar solvents, like water, because they do not interact with the dipoles in the solvent. Alcohols, however, can hydrogen bond to water molecules
- Tend to dissolve in non-polar organic solvents, like cyclohexane, because the solvent can interact with the simple covalent substance

c) Giant metallic lattices e.g. magnesium, copper

- Lattice of metal ions surrounded by delocalised electrons.
- High melting and boiling points usually (strong forces of attraction between metal ions and free electrons need to be broken).
- Conduct when solid (free electrons).
- Insoluble in all solvents (some react with water)

d) Giant covalent lattices e.g. diamond, graphite

- Lattice of non-metal atoms joined by strong covalent bonds
- Very high melting and boiling points usually (many strong covalent bonds to be broken)
- Diamond doesn't conduct (no mobile charge carriers). Graphite is the only non-metal that conducts as a solid (structure contains delocalised electrons)
- Insoluble in polar solvents, like water, because they do not interact with the dipoles in the solvent in water

4) Electronegativity and bond polarity

- Electronegativity is the ability of an atom to attract the electrons in a covalent bond.
- If there is a big difference in electronegativity between the atoms at either end of a covalent bond the electrons will be pulled towards the more electronegative atom creating a polar covalent bond (the bond has a permanent dipole)
- For example, chlorine is more electronegative than hydrogen so the H-Cl bond is polar

$$\overset{\delta+}{H}-\overset{\delta-}{Cl}$$

- Polar molecules have permanent dipoles that don't cancel out (e.g. H_2O) because the dipoles are at an angle
- Non-polar molecules either have no dipoles (e.g. Cl_2) or dipoles that cancel out (e.g. CO_2) because the dipoles are at 180°

5) Intermolecular Forces

- Three types of weak force hold simple covalent molecules together.

a) Van der Waal's

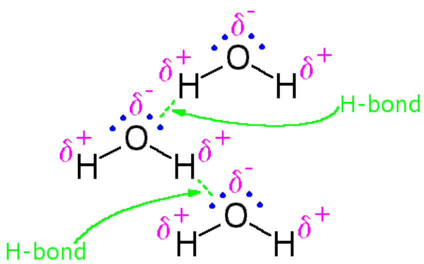
- Arise from temporary dipole (uneven distribution of electrons) in one molecule that induces dipole in another molecule.
- The more electrons, the stronger the van der Waal's forces
- Occur in all simple covalent substances

b) Dipole-dipole

- Attraction between molecules with permanent dipoles
- δ+ ends attracted to δ- ends

c) Hydrogen bonds

- Need H attached to N/O/F (highly electronegative elements).
- Exposed H nucleus is strongly attracted to lone pair on N/O/F
- Diagram must show lone pairs, dipoles and H-bond shown by dotted line e.g. water



d) Anomalous properties of water

- Water has some unusual properties due to the presence of hydrogen bonding
- Ice is less dense than water because ice has an open structure caused by hydrogen bonding
- Water has a higher melting and boiling point than expected due to the strength of hydrogen bonds that have to be broken

6) Shapes of Molecules

The following procedure allows the shape of a molecule to be worked out.

- Draw a dot-cross diagram
- Count number of electron pairs round the central atom
- **Pairs of electrons repel each other and get as far apart as possible**
- Lone pairs repel more than bonding pairs so bonds are pushed closer together e.g. 107° in ammonia compared with the tetrahedral bond angle of 109.5° in methane

Number of pairs	Examples	Name of shape	Bond angle
3 bonding pairs (repel equally)	BF_3	Trigonal planar	120°
4 bonding pairs (repel equally)	CH_4, NH_4^+	Tetrahedral	109.5°
6 bonding pairs (repel equally)	SF_6	Octahedral	90°
3 bonding, 1 lone (lone pair repels more than bonds)	NH_3	Pyramidal	107°
2 bonding , 2 lone (lone pair repels more than bonds)	H_2O	Non-linear	104.5°
2 double bonds (repel equally)	CO_2	Linear	180°

OCR seems quite keen on SO_2 where S has 2 double bonds and 1 lone pair. Repulsion is roughly equal for double bonds and lone pairs so bond angle is 120°, shape non-linear