2.20 Introduction to Bonding

This chapter looks briefly at the main types of bonding you should be familiar with from your GCSE courses. It goes on to introduce the ideas that will be further explained in the subsequent bonding chapters. I think it helps to start with the big picture in mind then look at the details. I am assuming here you have a basic GCSE knowledge of ionic and covalent bonding.

What is bonding?

Bonding is what holds particles together.

All bonding is caused by electrostatic forces of attraction between particles with different charges. I use the word particle here as a general word for ions, electrons, nuclei. Different types of bonding have these forces of attraction between different types of particles, but all involve something positively charged being attracted to something negatively charged. This is an important idea that may conflict with existing ideas about bonding that you may have. It is common for students (and sometimes teachers) to have misconceptions about what an ionic or covalent bond is. Let us look now at what ionic and covalent bonds are.

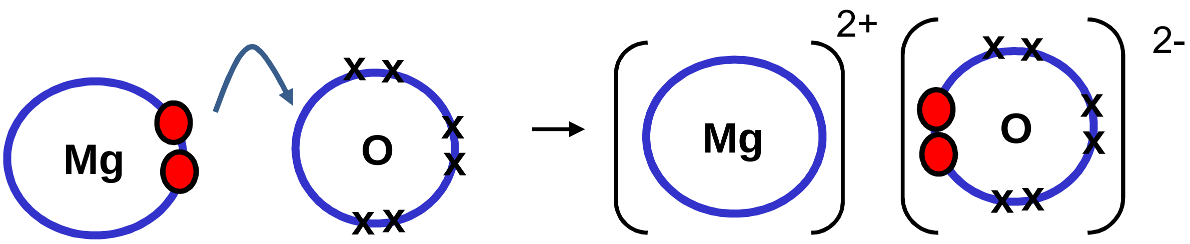
An Ionic bond is the electrostatic force of attraction between oppositely charged ions in a lattice.

A covalent bond is caused by the electrostatic force of attraction between the bonding pair of electrons and the nuclei.

Are these the definitions you would have given from your GCSE knowledge? Probably not.

Ionic Bonding

You will probably remember that ions are formed by a transfer of electrons between atoms and that ions have full shells of electrons. You will also have probably drawn diagrams like the ones below to show this process.



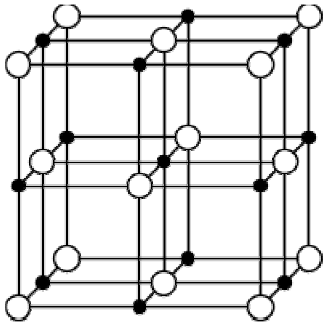
Just showing outer shell electrons

Is there anything wrong with this diagram representing ionic bonding? It does represent how electrons are transferred to produce ions but it can lead to misconceptions about what an ionic bond is. The ionic bond is the electrostatic force of attraction between the positively charged magnesium ions and the negatively charged oxide ions. How those ions are formed is almost irrelevant to the nature of the bond. It is certainly incorrect to say an ionic bond is somehow defined as the act of transferring electrons.

New ionic substances can be formed in reactions from other ionic substances and no electrons need be transferred.

$MgCO_3 \rightarrow MgO + CO_2$

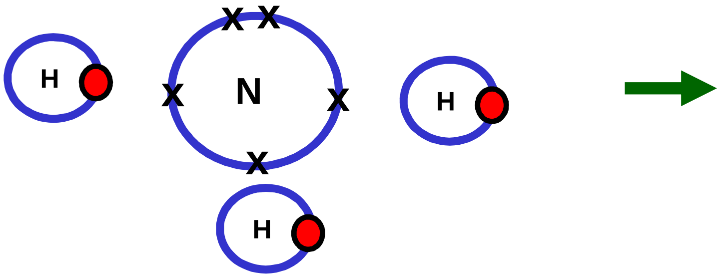
In this thermal decomposition reaction the magnesium ion was 2^+ in the reactant and product. No electrons have been transferred but we do have a new ionic substance in the magnesium oxide.



The dot and cross diagram on the previous page can also make it look like the ionic bond is just between two ions. When we look at the structure of ionic substances we can see that ionic bonding is between ions and all their surrounding oppositely charged ions. Each sodium ion in this structure is surrounded and equally attracted by six chloride ions. The ionic bond is the attraction between all these ions. It is actually not easy to define what 'one' ionic bond is. We generally measure the strength of ionic bonding by the energy needed to to form **one mole** of an ionic lattice from its gaseous ions (called the lattice enthalpy of formation) rather than trying to measure the strength of one bond.

Covalent Bonding

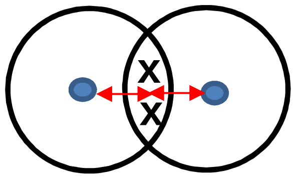
For Covalent bonding you will probably remember that electrons are shared and have drawn diagrams like the one below.



Is this diagram an accurate depiction of the formation of a covalent bond? Not really. Covalent compounds like ammonia do not form from gaseous elemental atoms. Ammonia actually forms from molecules of N_2 and H_2. The ability, however, to draw a quick 'dot and cross' diagram of molecules like ammonia is a useful skill that we will need for working out shapes of molecules later on.

Should we define the covalent bond as a shared pair of electrons? Some exam boards actually do define it this way. It is a weak definition though because it does not really get to the nature of why the atoms stick together in this molecule.

It is better to think of a covalent bond being the electrostatic force of attraction between the negative charge of the shared bonding pair of electrons and the positive charge of the two nuclei on either side



It is useful to think of one shared pair of electrons as representing one covalent bond but we need to remember they do not just float between nuclei through magic!

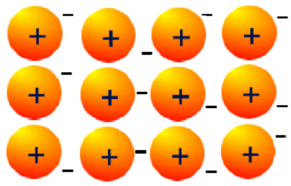
Full shells of electrons

One last misconception we should deal with is the idea that atoms react to gain a full shell of electrons. People often give atoms human like desires where they want to achieve a full shell, like it is some searched for Nirvana. It is a mistake to think that this is the goal that atoms try to achieve through reacting. Atoms don't have feelings. Many substances do have full shells of electrons but they have often been formed from other substances with full shells of electrons so this can't be the driving force.
What actually drives reactions to occur is if the products are more thermodynamically stable than the reactants. (more on this in later chapters); it is nothing to do with gaining a full shell.

Metallic bonding

We should briefly consider metallic bonding at this point. This is the type of bonding found in metals and alloys. It too Is bonding caused by electrostatic forces of attraction.

> A **metallic bond** is the **electrostatic force** of attraction between the **positive metal ions** and the **delocalised electrons**

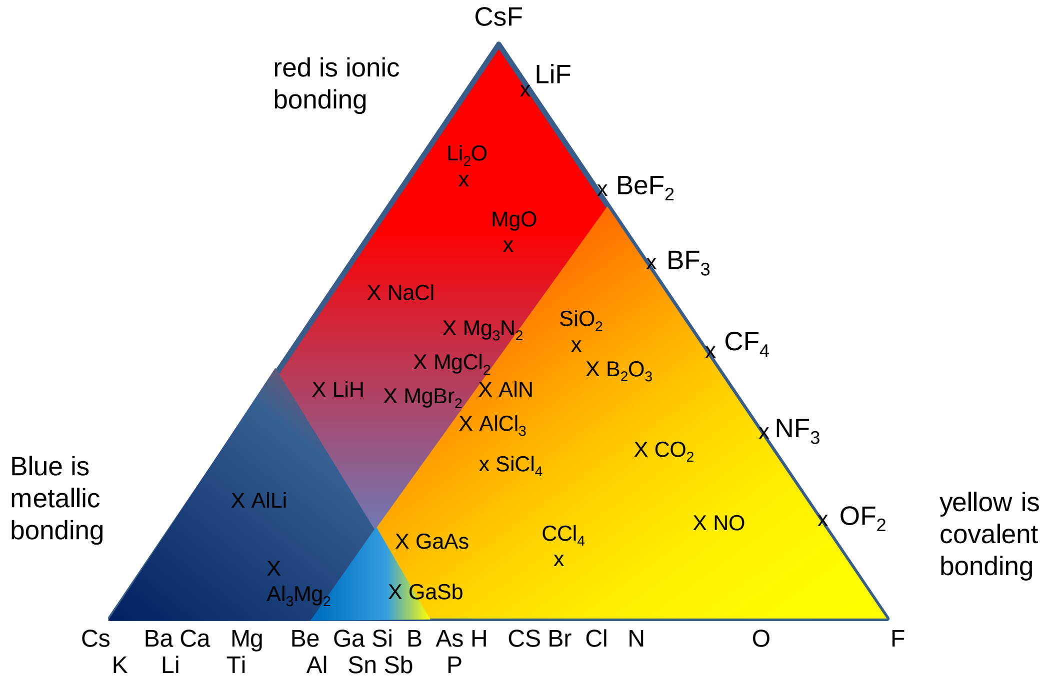


sodium

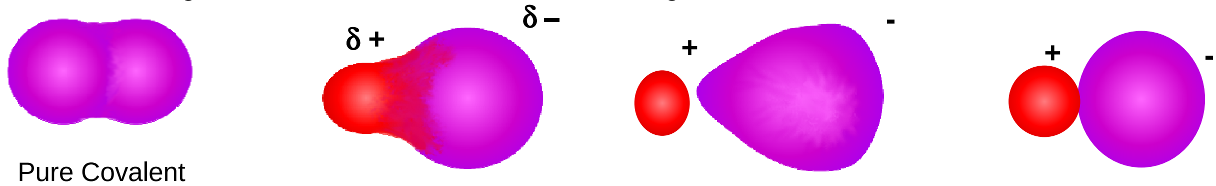
The positive ions are formed when the outer electrons become detached from the atom, leaving a positive ion behind. The electrons that leave the atom, join in the sea of delocalised electrons. The metal ions are arranged in a lattice.

Intermediate Bonding

Before we look at these three types of bonding in more detail we should understand that these three types of bonding are actually extremes on a scale of intermediate bonding. Most compounds are not on the extremes. This diagram below shows this scale. The corners of the triangles represent 100 % characteristic of each of the three types of bonding. The compounds nearer the middle of the triangle have characteristics of intermediate bonding. E.g. $AlCl_3$ has bonding that is intermediate between covalent and ionic.



The diagrams below represent how the charge clouds of electrons vary on the transition from covalent bonding to ionic bonding. These represent how bonding can exist on a sliding scale between extremes. In the chapter on intermediate bonding we will look at the reasons for this change.



Pure Covalent

Electrons are shared equally. The charge cloud is symmetrical

Covalent with ionic character

There are still electrons shared. The charge cloud is not symmetrical

Ionic with covalent character

The ions are separate. The charge clouds are not spherical

Pure Ionic

The ions are separate. The charge clouds are spherical