CHM 1102 (General Chemistry I)

Chemical Bonding and Intermolecular forces

Types of chemical bonding

Ionic bonding is the electrostatic attraction between positiveand negative ions in an ionic crystal lattice. Covalent bondsare formed when the outer electrons of two atoms are shared.The ionic or covalent bonds formed are usually very strong– it takes a lot of energy to break them. There is also a thirdform of strong bonding: metallic bonding.Although the atoms within molecules are kepttogether by strong covalent bonds, the forces between molecules are weak. We call these weak forces *intermolecular forces*. There are several types of intermolecular force:

- van der Waals' forces (also called 'dispersion forces' and'temporary dipole–induced dipole forces')
- permanent dipole–dipole forces
- hydrogen bonds.

An understanding of these different types of chemicalbonding and an understanding of intermolecular forces helps us to explain the structure andphysical propertiesof elements and compounds.

Ionic bonding

One way of forming ions is for atoms to gain or lose one ormore electrons.

- Positive ions are formed when an atom loses one or moreelectrons. Metal atoms usually lose electrons and formpositive ions.
- Negative ions are formed when an atom gains one ormore electrons. Non-metal atoms usually gain electronsand form negative ions.

The charge on the ion depends on the number of electronslost or gained. When metals combine with non-metals, the electronsin the outer shell of the metal atoms are transferred tothe non-metal atoms. Each non-metal atom usually gainsenough electrons to fill its outer shell. As a result of this,the metal and non-metal atoms usually end up with outerelectron shells that are complete – they have an electronicconfiguration of a noble gas.

In Figure 4.2 we can see that:the sodium ion has the electronic structure $[2,8]^{+}$, the sameas that of neonwhereas, the chloride ion has the electronic structure $[2,8,8]^{-}$, thesame as that of argon.

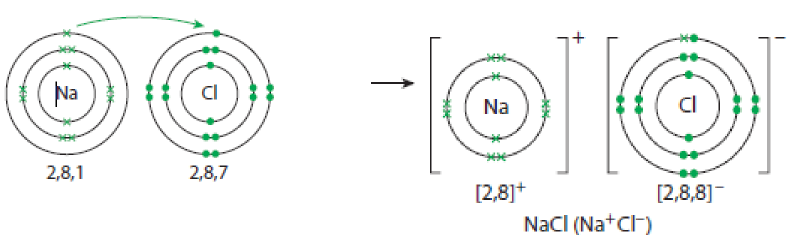


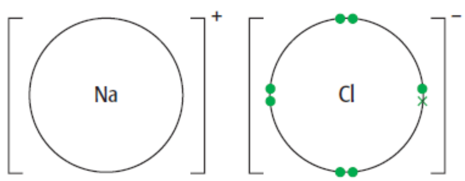
Figure 4.2 The formation of a sodium ion and chloride ionby electron transfer.

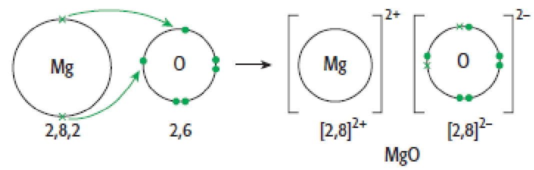
The strong force of attraction between the positive andnegative ions in the ionic crystal lattice results in an **ionic bond**. An ionic bond is sometimes called an electrovalent bond. In an ionic structure, the ions are arranged in a regular repeating pattern. As a result ofthis, the force between one ion and the ions of opposite charge that surround it is very great. In other words, ionicbonding is very strong.

You will notice that in Figure 4.2 we used dots and crosses toshow the electronic configuration of the chloride and sodiumions. This helps us keep track of where the electrons have comefrom. It does not mean that the electron transferred is anydifferent from the others. Diagrams like this are called ***dot-and-cross diagrams***. When drawing a dot-and-cross diagram for an ioniccompound it is usually acceptable to draw the outerelectron shell of the metal ion without any electrons. This is because it has transferred these electrons to the negativeion. Figure 4.4 shows the outer shell dot-and-crossdiagram for sodium chloride.

A dot-and-cross diagram shows:

- the outer electron shells only
- that the charge of the ion is spread evenly, by usingsquare brackets
- the charge on each ion, written at thetop right-hand cornerof the square brackets.





NaCl

Figure 4.4 Dot-and-cross diagram for sodiumchloride.**Figure 4.5** Dot-and-cross diagram for magnesium oxide

Class work: Draw dot-and-cross diagrams for the ions in thefollowing ionic compounds. Show only the outer electron shells. **a.**Potassium chloride, KCl **b.**Calcium Chloride ($CaCl_2$)

Covalent bonding

Single covalent bonds

When two non-metal atoms combine, they share one, or more, pairs of electrons. A shared pair of electrons is called a single covalent bond, or a bond pair. A single covalent bond is represented by a single line between the atoms: for example, Cl-Cl. when chlorine atoms combine not all the electrons are used in bonding. The pairs of outer-shell electrons not used in bonding are called lone pairs. Each atom in a chlorine molecule has three lone pairs of electrons and shares one bonding pair of electrons.

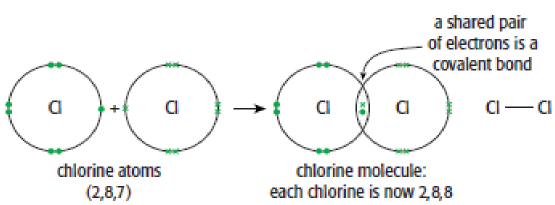
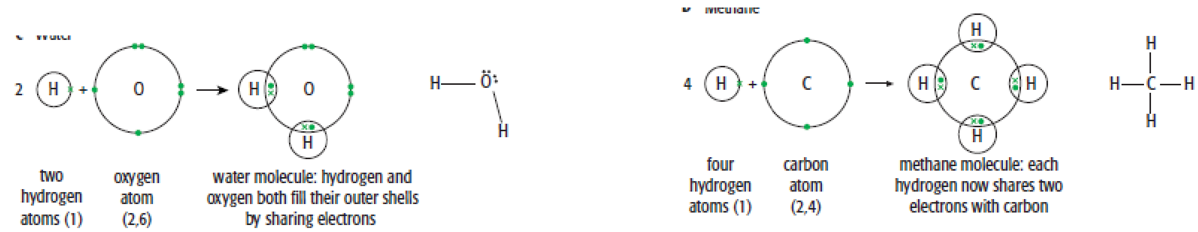


Figure 4.8 Atoms of chlorine share electrons to form a singlecovalent bond.

There are some cases in which the electrons arounda central atom may not have a noble gas configuration.
For example:

▪boron trifluoride, BF_3, has only six electrons aroundthe boron atom; we say that the boron atom is 'electron deficient'

▪sulfur hexafluoride, SF_6, has twelve electrons around thecentral sulfur atom; we say that the sulfur atom has an 'expanded octet' (Figure 4.10).



a. methane **b. water**

Figure 4.9: Dot-and-cross diagrams for covalentcompounds: (**a**)methane, CH_4, (**b**)water, H_2O,

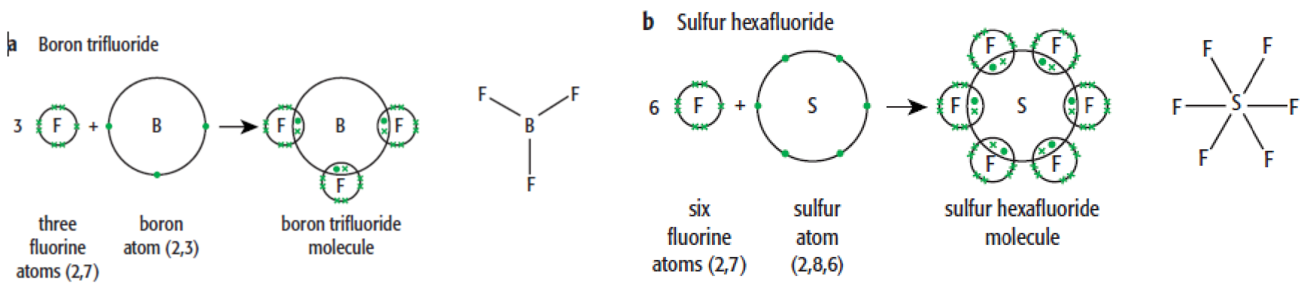
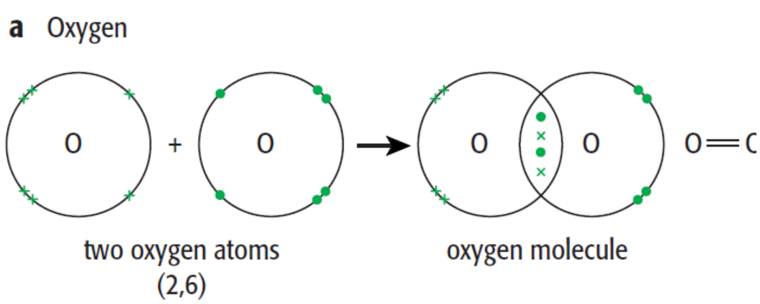


Figure 4.10 Dot-and-cross diagrams for **a** boron trifluoride,BF_3, and **b** sulfur hexafluoride, SF_6.

Multiple covalent bonds

Some atoms can bond together by sharing two pairs ofelectrons. We call this a double covalent bond. A double covalent bond is represented by a double line between the atoms: for example, O-O. The dot-and-cross diagrams for oxygen and carbon dioxide which havedouble covalent bonds, are shown in Figure 4.11.



■ In order to form an oxygen molecule, each oxygen atomneeds to gain two electrons to complete its outer shell. Sotwo pairs of electrons are shared and two covalent bondsare formed.

■For carbon dioxide, each oxygen atom needs to gain twoelectrons as before. But the carbon atom needs to gain fourelectrons to complete its outer shell. So two oxygen atomseach form two bonds with carbon, so that the carbon atomhas eight electrons around it.

■In ethene, two hydrogen atoms share a pair of electronswith each carbon atom. This leaves each carbon atom withtwo outer shell electrons for bonding with each other. Adouble bond is formed.

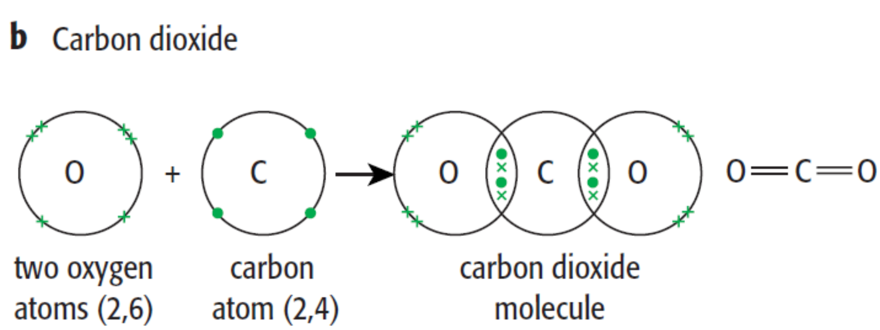
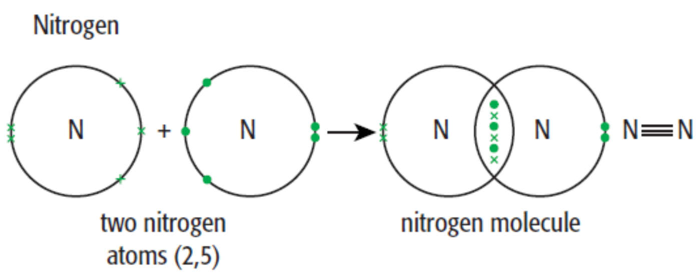


Figure 4.11 Dot-and-cross diagrams for (**a**)oxygen, O_2,(**b**)carbon dioxide, CO_2,

Atoms can also bond together by sharing three pairs of electrons. We call this a triple covalent bond. Figure 4.12shows a dot-and-cross diagram for the triple-bonded nitrogen molecule. In order to form a nitrogen molecule, each nitrogenatom needs to gain three electrons to complete its outershell. So three pairs of electrons are shared and three
covalent bonds are formed.



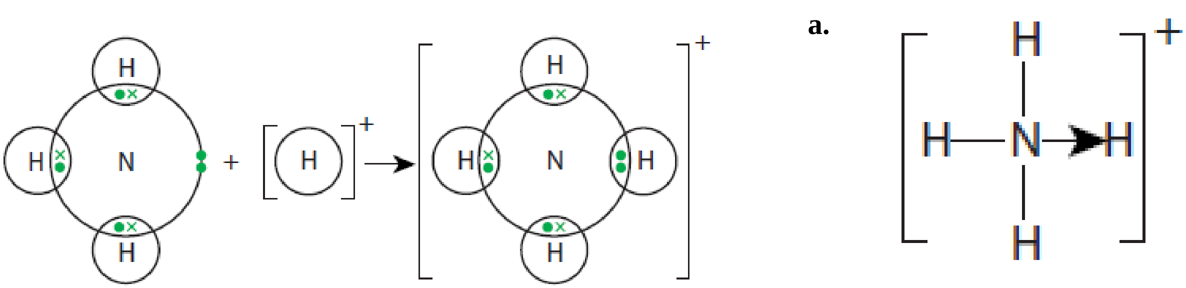
Co-ordinate bonding(dative covalent bonding)

A co-ordinate bond (or dative covalent bond) is formedwhen one atom provides both the electrons needed for a covalent bond.For dative covalent bonding we need:

- *one atom having a lone pair of electrons*
- *a second atom having an unfilled orbital to accept the lonepair; in other words, an electron-deficient compound.*

An example of this is the ammonium ion, NH_4^+, formedwhen ammonia combines with a hydrogen ion, H^+. Thehydrogen ion is electron deficient; it has space for twoelectrons in its shell. The nitrogen atom in the ammoniamolecule has a lone pair of electrons. The lone pair onthe nitrogen atom provides both electrons for the bond(Figure 4.13).

In a displayed formula (which shows all atoms andbonds), a co-ordinate bond is represented by an arrow.The head of the arrow points away from the lone pair thatforms the bond.



b.

Figure 4.13 The formation of a co-ordinate bond in the ammonium ion.