

13.5: Formation of Binary Ionic Compounds

Ionic bonding is the complete transfer of valence electron(s) between atoms and is a type of chemical bond that generates two oppositely charged ions. It is observed because metals with few electrons in its outer-most orbital. By losing those electrons, these metals can achieve noble-gas configuration and satisfy the **octet rule**. Similarly, nonmetals that have close to 8 electrons in its valence shell tend to readily accept electrons to achieve its noble gas configuration.

Introduction

In ionic bonding, electrons are transferred from one atom to another resulting in the formation of positive and negative ions. The electrostatic attractions between the positive and negative ions hold the compound together. The predicted overall energy of the ionic bonding process, which includes the **ionization energy** of the metal and **electron affinity** of the nonmetal, is usually positive, indicating that the reaction is endothermic and unfavorable. However, this reaction is highly favorable because of their electrostatic attraction. At the most ideal inter-atomic distance, attraction between these particles releases enough energy to facilitate the reaction. Most ionic compounds tend to dissociate in polar solvents because they are often polar. This phenomenon is due to the opposite charges on each ions.

At a simple level, a lot of importance is attached to the electronic structures of noble gases like neon or argon which have eight electrons in their outer energy levels (or two in the case of helium). These noble gas structures are thought of as being in some way a "desirable" thing for an atom to have. One may well have been left with the strong impression that when other atoms react, they try to organize things such that their outer levels are either completely full or completely empty.

✓ Example: Bonding in NaCl

Sodium Chloride:

- Sodium (2,8,1) has 1 electron more than a stable noble gas structure (2,8). If it gave away that electron it would become more stable.
- Chlorine (2,8,7) has 1 electron short of a stable noble gas structure (2,8,8). If it could gain an electron from somewhere it too would become more stable.

The answer is obvious. If a sodium atom gives an electron to a chlorine atom, both become more stable.



The sodium has lost an electron, so it no longer has equal numbers of electrons and protons. Because it has one more proton than electron, it has a charge of 1+. If electrons are lost from an atom, positive ions are formed. Positive ions are sometimes called **cations**.

The chlorine has gained an electron, so it now has one more electron than proton. It therefore has a charge of 1-. If electrons are gained by an atom, negative ions are formed. A negative ion is sometimes called an **anion**.

The nature of the bond

The sodium ions and chloride ions are held together by the strong electrostatic attractions between the positive and negative charges. You need one sodium atom to provide the extra electron for one chlorine atom, so they combine together 1:1. The formula is therefore NaCl.

✓ Example 1: Bonding in MgO

Magnesium Oxide:

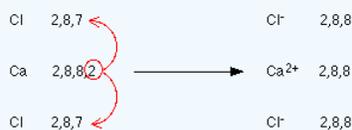


Again, noble gas structures are formed, and the magnesium oxide is held together by very strong attractions between the ions. The ionic bonding is stronger than in sodium chloride because this time you have 2+ ions attracting 2- ions. The greater the

charge, the greater the attraction. The formula of magnesium oxide is MgO.

✓ 2

Calcium Chloride:



This time you need two chlorines to use up the two outer electrons in the calcium. The formula of calcium chloride is therefore CaCl_2 .

✓ ○

Potassium Oxide:



Again, noble gas structures are formed. It takes two potassiums to supply the electrons the oxygen needs. The formula of potassium oxide is K_2O .

Some Stable Ions do not have Noble Gas Configurations

You may have come across some of the following ions, which are all perfectly stable, but not one of them has a noble gas structure.

Fe^{3+}		$[\text{Ar}]3\text{d}^5$
Cu^{2+}		$[\text{Ar}]3\text{d}^9$
Zn^{2+}		$[\text{Ar}]3\text{d}^{10}$
Ag^+		$[\text{Kr}]4\text{d}^{10}$
Pb^{2+}		$[\text{Xe}]4\text{f}^{14}5\text{d}^{10}6\text{s}^2$

What needs modifying is the view that there is something magic about noble gas structures. There are far more ions which do not have noble gas structures than there are which do.

- Noble gases (apart from helium) have an outer electronic structure ns^2np^6 . Apart from some elements at the beginning of a transition series (scandium forming Sc^{3+} with an argon structure, for example), all [transition metal](#) elements and any metals following a transition series (like tin and lead in Group 4, for example) will have structures like those above.
- That means that the only elements to form positive ions with noble gas structures (apart from odd ones like scandium) are those in groups 1 and 2 of the Periodic Table and aluminum in group 3 (boron in group 3 does not form ions).
- Negative ions are tidier! Those elements in Groups 5, 6 and 7 which form simple negative ions all have noble gas structures.

If elements are not aiming for noble gas structures when they form ions, what decides how many electrons are transferred? The answer lies in the energetics of the process by which the compound is made.

Contributors and Attributions

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