Formation and function of molecules depending on chemical bonding

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Introduction

A very warm greeting to all the viewers. Today we are going to discuss about the different kinds of chemical bonds that are responsible for the formation of various molecules.

As we know most of the substances in nature exists in the form of molecules which are the cluster of atoms of same or different kind.

For example, hydrogen, oxygen, ammonia, water, etc., consist of

small group of atoms mutually held together by some attractive force.

The attractive forces which holds various constituents like atoms, ions, etc. together in different chemical species is called **Chemical bond**. The bond is caused by the electrostatic force of attraction between opposite charges, either between electrons and nuclei, or due to a dipole attraction.

The strength of chemical bonds varies considerably.

The chemical bonds can be classified in to various types like:

Ionic bond, Covalent bond, Co-ordinate covalent

bond, Hydrogen bond and Van der Waals forces.
Let us begin, bystudyingthe different kinds of bonds. The first bond that we will study about is the ionic bond.

Ionic Bond

Ionic bond is formed by the transfer of one or more electrons from one atom to another. This type of bond comes into existence between a metal and a non- metal atom. The metallic atom losses its valence electron and changes into a positive ion (cation) while a non-metallic atom gains electron and gets converted in to negative ion (anion). The oppositely charged ions are held together by electrostatic force of attraction. Thus ionic bond may be defined as electrostatic force of attraction holding the oppositely charged ions.

Ionic bonding is observed because metals have few electrons in their outer-most orbitals. 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 their valence shells tend to

readily
accept electrons to achieve noble gas configuration. In ionic bonding, more than 1 electron can be donated or received to satisfy the octet rule. The charges on the anion and cation correspond to the number of electrons donated or
received. In ionic bonds, the net charge of the compound must be zero.

To understand ionic bonding let us study the formation of Sodium Chloride as an example. Sodium atom has only one electron in its valence shell. In order to gain the noble gas configuration of Neon it has to lose its valence electron. Whereas, chlorine atom has seven electrons in its valence shellandto acquire its nearest noble gas configuration of Argon, it has to gain one electron. Thus Sodium molecule donates the lone electron in its valence orbital and becomes a positively charged cation (electro-positive atom) due to the loss of electron while the chlorine atom receives one electron and becomes negatively charged anion (electro negative atom).

Ionic compounds generally have high melting and

boiling points due to strong electro static force of attraction between oppositely charged ions. Hence a large amount of energy is required to overcome strong attractive forces. They cannot conduct electricity in solid state because the ions occupy fixed positions and are not able to move. However, they can conduct electricity in their aqueous solutions because the ions are in free state. Also, they are soluble in water and other polar solvents but they are insoluble in non-polar solvents.

Covalent Bond

Covalent bonding is the sharing of electrons. It occurs between two atoms of the same element or of elements close to each other in the periodic table. This bonding occurs primarily between nonmetals; however, it can also be observed between nonmetals and metals. Thus a force which binds atoms of same or different elements by mutual sharing of electrons is called a covalent bond. In covalent bonding, because both atoms have the same affinity for

electrons neither has a tendency to donate them, they share electrons in order to achieve octet configuration and become more stable. The atoms involved in bond formation contribute equal number of electrons for sharing. The shared electrons become a common property of both the atoms and constitute a bond between them. The shared pair of electrons which is responsible for the bond formation is also called bond pair of electrons.

Let us now see the formation of PCl_3 In PCl_3, Phosphorous shares three of its valence electrons with three Chlorine atoms. In the end product, all four of these molecules have 8 valence electrons and satisfy the octet rule. The valence electrons not involved in sharing are known as non-bonding electrons or lone pairs. Thus each chlorine atom has three lone pairs and the phosphorous atom has one lone pair.

When atoms share one electron pair the bond formed is called Single covalent bond. If two electron pairs are shared by the atoms, the bond formed is Double covalent bond.

Similarly, when the atoms share three electron

pairs, the bond is called Triple covalent bond. The double and triple covalent bonds are collectively called multiple covalent bonds.

Now, here is an example of formation of Double covalent bond.

Oxygen atom has six electrons in its valence shell. It has a tendency to attain the configuration of the noble gas Neon. The two oxygen atoms contribute two electrons each and share four electrons that is two bond pairs. Thus, the oxygen atoms in oxygen molecule (O_2) are held by a double covalent bond.

While for the formation of Triple bond example of formation of Nitrogenmoleculecan be studied.

Nitrogen atom has 5 electrons in its valence shell and to acquire a configuration of Neon, it can contribute 3 electrons each to share three pairs of electrons. Thus, the nitrogen atoms in Nitrogen molecule (N_2) are held by Triple Covalent Bonds.

Covalent compounds are joined together by mutual sharing of electrons and therefore exist as individual molecules. The intermolecular forces in these compounds are usually weak.

Therefore, they exist in liquid or gaseous state.

However, a few exception compounds to exist in solid state are urea, sugar, etc.

These compounds are generally poor conductor of electricity in the fused or dissolved state due to non -existence of ions.

Covalent compounds have low melting and boiling points because the attractive force between these compounds are usually weak and require less amount of energy to overcome intermolecular forces.

These compounds have low solubility in water and in other polar solvents. However, they are more soluble in non-polar solvents. Also they do not produce ions in aqueous solutions. Hence, their reactions are not ionic in nature. Their reactions involve breaking of covalent bonds in reacting molecules and forming new covalent bonds to give molecules of the products. These reactions are therefore, relatively slow.

Now let us throw some light on one type of Covalent bond which is **Polar covalent bond**. But before that, it is necessary to understand what electronegativity is. Electronegativity is defined as

the tendency of an atom to attract the bonding or shared pair of electrons towards itself in a molecule. If a covalent bond is formed between two dissimilar atoms, one of which has a larger value of electronegativity, the bonding pair of electrons is displaced towards more electro negative atom. In other words, electron cloud containing the bonding electrons gets distorted and the charge density concentrates around the more electro negative atom. Due to these unequal distributions of electron charge density the more electro negative atom acquires a partial negative charge indicated as delta negative (δ^-) whereas the less electro negative atom acquires a partial positive charge indicated as delta positive (δ^+). Thus, a covalent bond develops a partial ionic character as a result of the difference of electronegativities of the atoms comprising the bond. Such a bond is called a Polar Covalent bond. One of the examples is the bond between Hydrogen and Chlorine atoms in HCl molecule. It is polarbecause the shared electron pair is

displaced towards Clatom which is more electronegative.

Now moving towards the next bond which is Co -ordinate Covalent Bond

Co-ordinate Covalent Bond

Co-ordinate bond is a special case of covalent bond. It is formed by mutual sharing of electrons between the two atoms but the shared pair of electrons is contributed only by one of the two atoms, the other atom simply participates in sharing. The atom which donates an electron pair for sharing is called donor and has its octet completed.

The atom which accepts the electron pair in order to complete its octet is called acceptor.The bond is represented by an arrow pointing from donor towards acceptor. Let us understand this bond by formation of Ozone Molecule (O_3) A molecule of oxygen contains two oxygen atoms which share 4 electrons and complete their octet. Now if an atom of oxygen having 6 valence electrons comes close to oxygen molecule, it shares a lone pair of electrons with one of the oxygen atoms of

the molecule and acts as the donor.

This is how the ozone molecule is formed.

Now we will discussabout the next bond that is the Hydrogen bond

Hydrogen Bond

When a hydrogen atom is bonded to a highly electro negative atom by a covalent bond, the bond paired of electrons is displaced towards the electro negative atom. When lone electron of hydrogen atom lies away from it, its nucleus gets exposed and behaves as a bare proton. Such a bare hydrogen nucleus exerts a strong electro static attraction on the electro negative atom of the neighboring molecule. This interaction between hydrogen atom of one molecule and electro negative atom of the other molecule is referred to as Hydrogen Bond. Thus, hydrogen bond is defined as the electro static force of attraction which exists between the covalently bonded hydrogen of one molecule and the electro negative atom of the other molecule. The Hydrogen bond is represented by a dotted line. Hydrogen bonding can

be understood by the example of water. In a distinct water molecule, there are two hydrogen atoms and one oxygen atom. Two molecules of water can form a hydrogen bond between them; the simplest case, when only two molecules are present, it is called the water dimer and is often used as a model system. When more molecules are present, as is the case with liquid water, more bonds are possible because the oxygen of one water molecule has two lone pairs of electrons, each of which can form a hydrogen bond with a hydrogen on another water molecule. This can repeat such that every water molecule is H-bonded with up to four other molecules. Hydrogen bond has a major influence on the properties of various substances as follows: The hydrogen bonds link up molecules of the same substance to form large aggregates which is known as association of molecules. Also, abnormally high melting and boiling points are seen in compounds whose molecules are associated with one another by hydrogen bonds. Hence, large amount of energy is needed to overcome

intermolecular hydrogen bonds to separate the molecules.

The solubility of certain compounds in water can also be explained by hydrogen bonding. Compounds whose molecules can form H-bonds with water molecules are soluble in water. Sugar, honey, lower alcohols, etc., are soluble in water because their molecules can form H-bonds with water molecules.
Now before we move to another bond, it is important to know about dipole moment and its interactions. It has been pointed out earlier that a covalent bond between two atoms acquires a partial polar character if the values of electronegativity of the two bonded atoms differ.
The two charged ends of the bond behave as an electric dipole and the degree of polarity is measured in terms of dipole moment. Dipole moment can thus be defined as the product of magnitude of charge on any one of the atoms and the distance between them.
The molecules having dipole moment are called polar molecules like for e.g. HF, HCl, NH_3, H_2O,

etc. whereas molecules having zero dipole moment are said to be non-polar molecules like H_2, N_2, O_2, and Cl_2. Dipole moment gives an idea about the ionic character in a bond or a molecule. The value of dipole moment also helps to predict the shape of molecules.

I hope so far you have understood the different kinds of bonds that have been discussed. Now, let's talk about the next bond which is based on dipole dipole interaction which is Van derWaals forces.

Van Der Waals Forces

Van der Waals forces include attractions and repulsions between atoms, molecules, and surfaces, as well as other intermolecular forces. They occur between permanent and induced dipoles. The attraction between molecules is greatest at a distance called Van derWaals radius. If molecules approach each other more closely, a repulsive force develops. The magnitude of Van derWaals forces depends on how easily an atom is polarized. Electronegative atoms with unshared pairs of electrons are easily polarized. There are three types

of Van der Waals forces:

Dipole-Dipole interactions

These forces occur between molecules containing electronegative atoms. They cause molecules to orient themselves so that the positive end of one molecule is directed toward the negative end of another.

Dipole-induced dipole interactions

A permanent dipole induces a transient dipole in a nearby molecule by distorting its electron distribution.

Induced dipole-Induced dipole interaction

In this type, the motion of electrons in nearby non-polar molecules results in transient charge imbalances in adjacent molecules. A transient dipole in one molecule polarizes the electrons in neighboring molecule. This attractive interaction, often called London Dispersion forces which is

extremely weak. Van der Waals forces are relatively weak forces than the other bonds due to its transient electrostatic interactions.

So, here we conclude the different types of bond formations.

Summary

In today's lecture, we discussed about different kinds of chemical bonds that are responsible for the formation of various molecules. We learnt that there are majorly five types of bonds which are Ionic Bond, Covalent bond, Co-ordinate Covalent bond, Hydrogen bond and Van der Waals Forces. We got a brief idea on why do atoms combine and what is the nature of the force existing between the combining atoms. We understood why a definite number of atoms are used to make up a particular molecule. I hope you found this lecture fruitful in understanding the different types of bonds. Thank you!