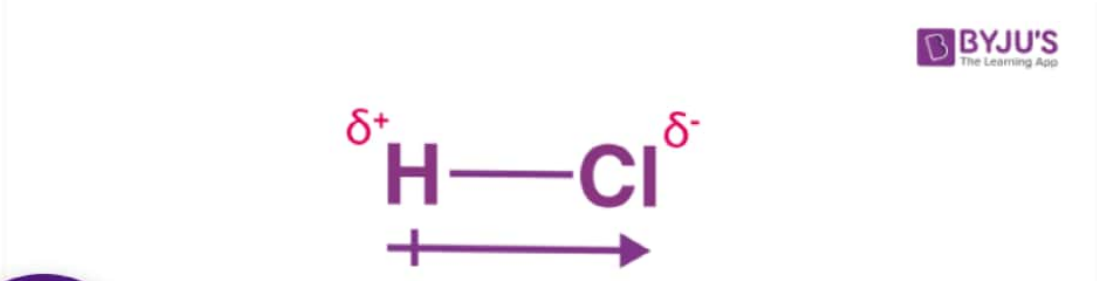
What is Dipole Moment?

A dipole moment arises in any system in which there is a separation of charge. They can, therefore, arise in ionic bonds as well as in covalent bonds. Dipole moments occur due to the difference in electronegativity between two chemically bonded atoms.

A bond dipole moment is a measure of the polarity of a chemical bond between two atoms in a molecule. It involves the concept of electric dipole moment, which is a measure of the separation of negative and positive charges in a system.

The bond dipole moment is a vector quantity since it has both magnitude and direction. An illustration describing the dipole moment that arises in an HCl (hydrochloric acid) molecule is provided below.



It can be noted that the symbols δ^+ and δ^- represent the two electric charges that arise in a molecule which are equal in magnitude but are of opposite signs. They are separated by a set distance, which is commonly denoted by 'd'.

Important Points

- The dipole moment of a single bond in a polyatomic molecule is known as the bond dipole moment and it is different from the dipole moment of the molecule as a whole.
- It is a vector quantity, i.e. it has magnitude as well as definite directions.
- Being a vector quantity, it can also be zero as the two oppositely acting bond dipoles can cancel each other.
- By convention, it is denoted by a small arrow with its tail on the negative center and its head on the positive center.
- In chemistry, the dipole moment is represented by a slight variation of the arrow symbol. It is denoted by a cross

- In the case of a polyatomic molecule, the dipole moment of the molecule is the vector sum of the all present bond dipoles in the molecule.

Dipole Moment Formula

A dipole moment is the product of the magnitude of the charge and the distance between the centers of the positive and negative charges. It is denoted by the Greek letter 'μ'.

Mathematically,

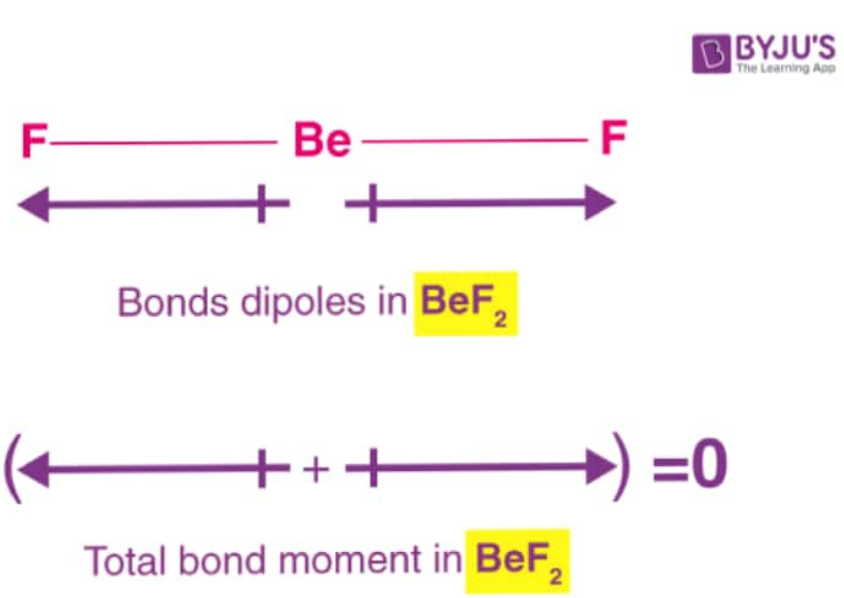
Dipole Moment (μ) = Charge (Q) * distance of separation (r)

It is measured in Debye units denoted by 'D'. 1 D = 3.33564×10^{-30} C.m, where C is Coulomb and m denotes a meter.

The bond dipole moment that arises in a chemical bond between two atoms of different electronegativities can be expressed as follows:

Dipole moment of BeF_2

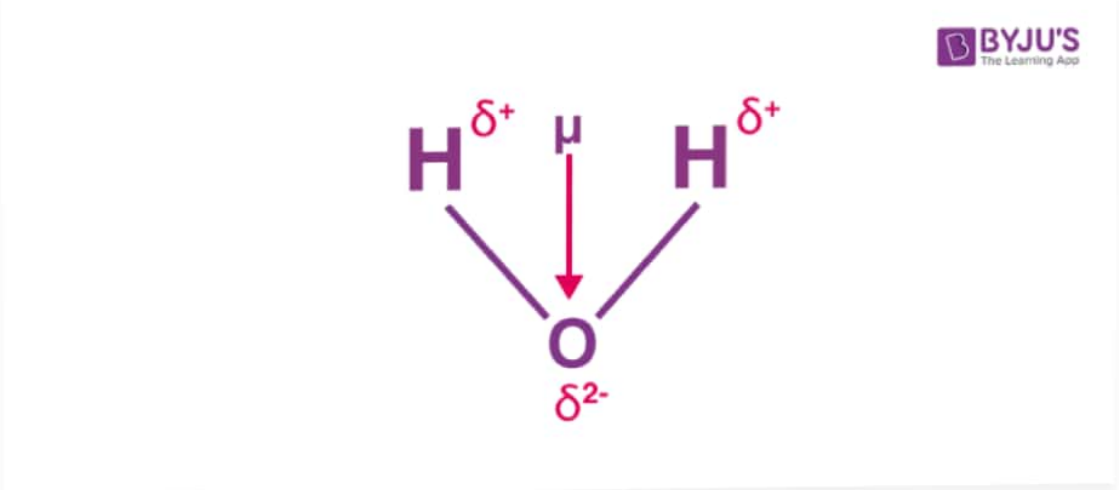
In a beryllium fluoride molecule, the bond angle between the two beryllium-fluorine bonds is 180°. Fluorine, being the more electronegative atom, shifts the electron density towards itself. The individual bond dipole moments in a BeF_2 molecule are illustrated below.



From the illustration provided above, it can be understood that the two individual bond dipole moments cancel each other out in a BeF_2 molecule because they are equal in magnitude but are opposite in direction. Therefore, the net dipole moment of a BeF_2 molecule is zero.

Dipole moment of H_2O (Water)

In a water molecule, the electrons are localized around the oxygen atom since it is much more electronegative than the hydrogen atom. However, the presence of a lone pair of electrons in the oxygen atom causes the water molecule to have a bent shape (as per the VSEPR theory). Therefore, the individual bond dipole moments do not cancel each other out as is the case in the BeF_2 molecule. An illustration describing the dipole moment in a water molecule is provided below.



The bond angle in a water molecule is 104.5°. The individual bond moment of an oxygen-hydrogen bond is 1.5 D. The net dipole moment in a water molecule is found to be 1.84D.