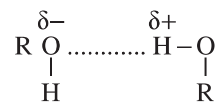
Hydrogen Bonding :

Molecules that contain F–H, O–H, N–H bonds (e.g., Water, Alcohols, Organic acids, Amines, Aromatic alcohols, etc.) show a strong tendency to associate, i.e., to link up to form larger molecules. This feature exists in solid form and as well as in solutions in certain solvents. In all of such compounds, OH, or N–H or F–H, bond is highly polar due to large difference in electronegativity. The electrostatic attraction between such molecules should be quite strong. The *positive end* of one molecule attracts and is strongly attracted by the *negative end* of the neighbouring molecule. In this manner a large number of molecules are associated to form a cluster of molecules. Since in each case the hydrogen atom is responsible for the formation of linkages, this is known as *Hydrogen bond* or H-bond. It is impossible for hydrogen to form a second covalent bond so the additional linkage is shown by a *dotted line*. Hydrogen bonds are always of type : –A–H....B– , where A and B may be atoms of O, F, N. Hydrogen bonds are comparatively weak, with bond energies of 10-100 kJ/mol, but they are widespread and have important effect on many physical properties of many Organic and Inorganic compounds.



Hydrogen Bonding is of two types :

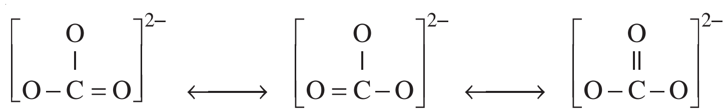
(i) Intermolecular H-bonding **(ii)** Intramolecular H-bonding

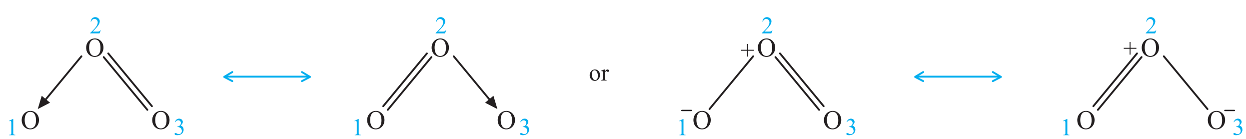
You will learn more about Hydrogen Bonding in the Chapter Chemical Bonding-II.

RESONANCE Section 8

There are certain molecules whose properties cannot be explained by a single structure.

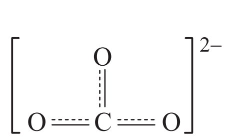
For example : The molecules of CO_3^{2-} ion, three Lewis dot structures are possible. Similarly Lewis structure for ozone (O_3) shows that one of O atom is bounded to a O atom by a double bond and by a coordinate covalent bond to the other O atom and there are two possible structures for it.



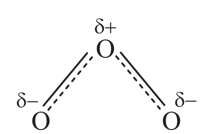


The length of three bonds in CO_3^{2-} ions and two bonds in O_3 is expected to be different. However from spectroscopic analysis, it is observed that the lengths of bonds are equal and lie somewhere between that of a single and double bond. Hence a particular structure is not sufficient to account for the observed facts.

The actual structure of CO_3^{2-} ion and O_3 molecule has neither of these Lewis structures. The real structure is an average (midway between) of these structures. This phenomenon of representing the actual structure in such a manner is called as Resonance. The individual structures are known as *Canonical forms* or *Resonance structures*. The actual structure is called as Resonance hybrid.



Resonance Hybrid of Carbonate ion

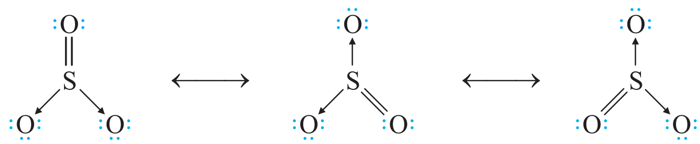


Resonance Hybrid of Ozone

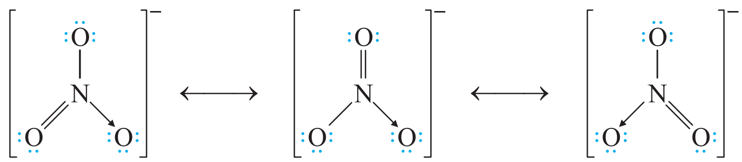
Thus resonance hybrid may be defined as the actual structure of all the canonical forms that are possible for a given molecule without changing the relative positions of its atoms. The resonance hybrid is more stable than any of the other canonical forms. The difference in the energy between the resonance hybrid and the most stable canonical form is called as Resonance energy. *The more the number of possible resonating forms, the higher is the resonance energy and hence more is the stability of the compound.*

The resonating structure of a few more molecules and ions are shown below :

(i) SO_3 molecule :



(ii) Nitrate ion NO_3^- :



Note : Bond order (B.O.) $= \dfrac{\text{Total number of bonds}}{\text{Number of resonating structure}}$

Effects of Resonance :

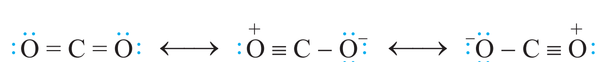
- It imparts stability to the molecule and hence decreases its reactivity. The reactivity of the molecule is decreased due to delocalisation of electrons over the entire surface of the molecule.
- Since the electrons are not localised between any particular atoms, and are uniformly distributed in the resonance hybrid, all the bond are similar and are of equal bond lengths. *The bond length of a single covalent is decreased as a result of resonance.*

Note : *Detailed study of concept of resonance will be taken later in Introduction to Organic Chemistry (IOC).*

Illustration - 8 *The bond length of normal C = O double bond is 121 pm. However each carbon to oxygen bond length in CO_2 is found to be 115 pm. Explain the structure of CO_2 molecule.*

SOLUTION :

If we consider only structure I for CO_2 molecule there should be two carbon to oxygen double bonds. As per question the bond length of normal C = O double bond is 121 pm. However, each carbon to oxygen bond length in CO_2 is found to be 115 pm which is in between that of C = O double bond (121 pm) and C ≡ O triple bond (110 pm). Hence, CO_2 is considered a resonance hybrid of the following three Lewis structures.



[I] [II] [III]