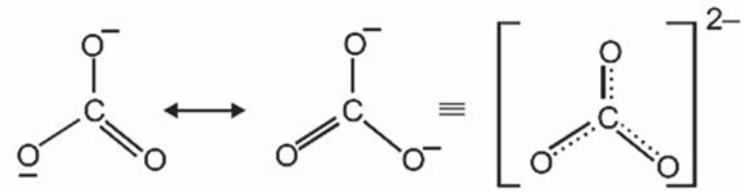
RESONANCE

It is frequently observed that a solitary Lewis structure falls short in adequately representing a molecule in accordance with its experimentally determined properties. A notable example is the ozone (O_3) molecule, which can be equally represented by two distinct structures, denoted as I and II below:



I II III

(Structures I and II depict the two canonical forms, while Structure III serves as the resonance hybrid)
In both structures, an O–O single bond and an O=O double bond is present. The standard O–O and O=O bond lengths are conventionally 148 pm and 121 pm, respectively. However, the experimentally determined oxygen-oxygen bond lengths in the O_3 molecule are identical at 128 pm. This implies that the oxygen-oxygen bonds in the O_3 molecule exist at an intermediate length between a double and a single bond. Remarkably, such a scenario cannot be accurately represented by either of the two Lewis structures presented above.
To address this challenge in depicting precise structures of molecules like O_3, the concept of resonance was introduced. According to this concept, when a single Lewis structure fails to provide an accurate description of a molecule, a set of structures with similar energy, nuclear positions, and arrangements of bonding and non-bonding electron pairs are considered as canonical structures of the hybrid. For O_3, the two structures illustrated above serve as the canonical or resonance structures, and their hybrid—Structure III—more accurately represents the true structure of O_3. This amalgamation is termed the resonance hybrid, symbolized by a double-headed arrow indicating resonance.

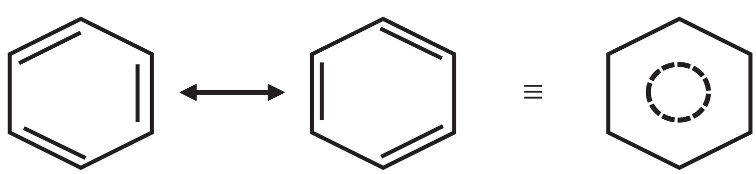
Definition of Resonance:

Resonance can be characterized as the phenomenon where two or more structures, each featuring an identical arrangement of atoms, can be formulated for a specific compound. This occurrence arises when multiple representations are possible for the spatial arrangement of atoms within the compound, highlighting the flexibility and variability inherent in the molecular structure.

$$\text{Bond Order} = \frac{\text{Total Number of Bonds}}{\text{Total Number of Resonating Structures}}$$

Resonance Hybrid:

The resonance hybrid is the definitive representation encompassing all diverse structures conceivable for a molecule, without transgressing the established rules of maximum covalence for the constituent atoms. In essence, it encapsulates the amalgamation of various resonating structures while adhering to the prescribed principles governing the maximum permissible covalent bonding capacities of the individual atoms within the molecule.



Resonance hybrid

Conditions to Writing a Resonating Structure

Conditions for Constructing a Resonating Structure:

Adherence to Maximum Valency:

Ensuring that the maximum valency of an atom is not breached is a fundamental condition for constructing a resonating structure. This criterion maintains the integrity of the structure in accordance with the atom's valency limitations.

Equivalence in π-Bonds and Lone Pair Count: Another critical requirement is that the sum of the number of π-bonds and lone pairs of electrons in each resonating structure must be consistent. This condition ensures a balanced and harmonious distribution of electrons, contributing to the stability and accuracy of the overall resonance hybrid.