

Chemical Bonding

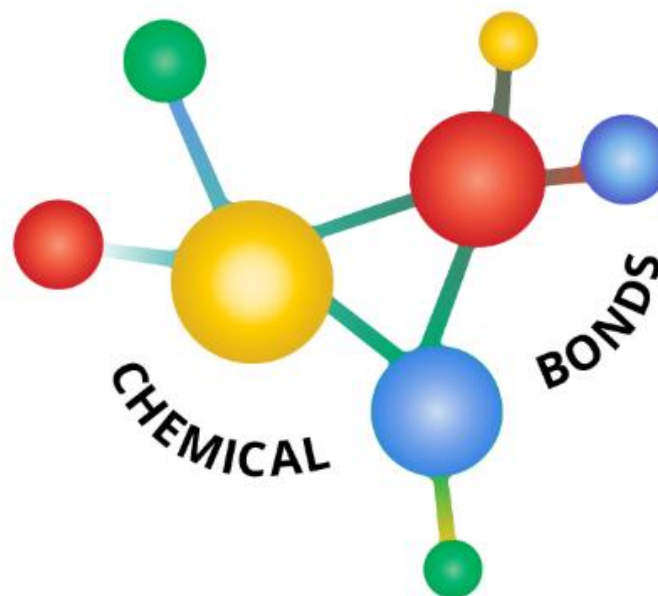
Md. Khairul Islam (PhD)

Applied Chemistry and Chemical Engineering
Rajshahi University

What is Chemical Bonding

A chemical bond is defined as the **attractive forces** that hold two or more atoms together in a molecule or an ion.

- Covalent bonds
- Ionic bonds
- Metallic bonds



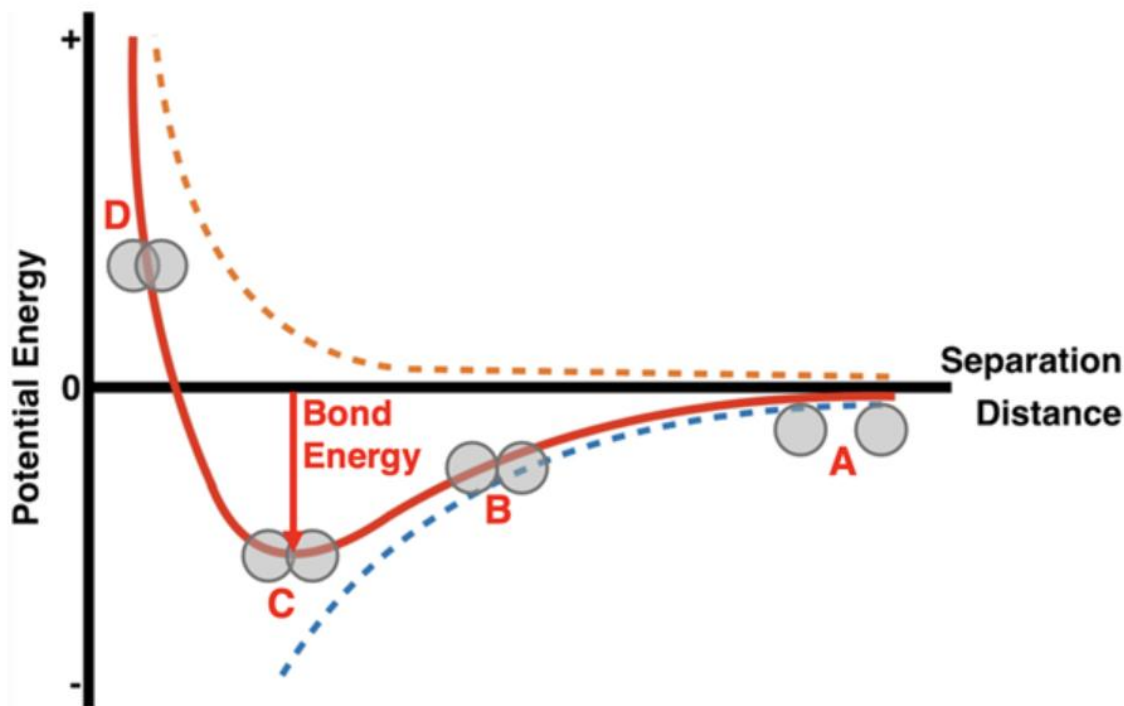
These bonds determine the structure and properties of substances, influencing their physical and chemical behavior.

Why do atom combine?



- Net attractive force
- Octet rule (the tendency of atoms to prefer to have eight electrons in the valence shell)
- Lowering of combining energy of atoms (lowering potential energy)

Why do atom combine?

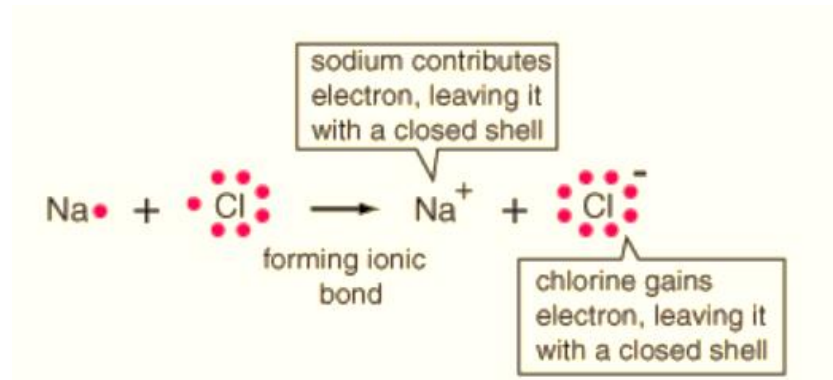


At position C,

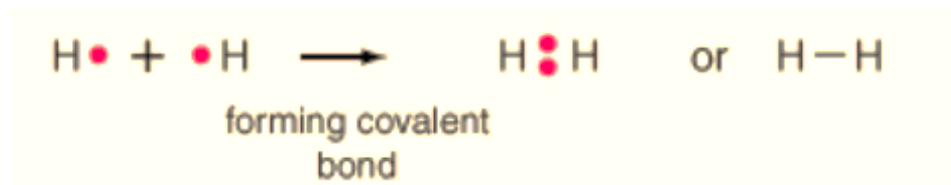
- (1) Attractive and repulsive forces are in equilibrium, hence bond is established.
- (2) Overlapping between orbitals is maximum.
- (3) Energy is minimum, hence stable

How do atom combine?

➤ Transfer of electron

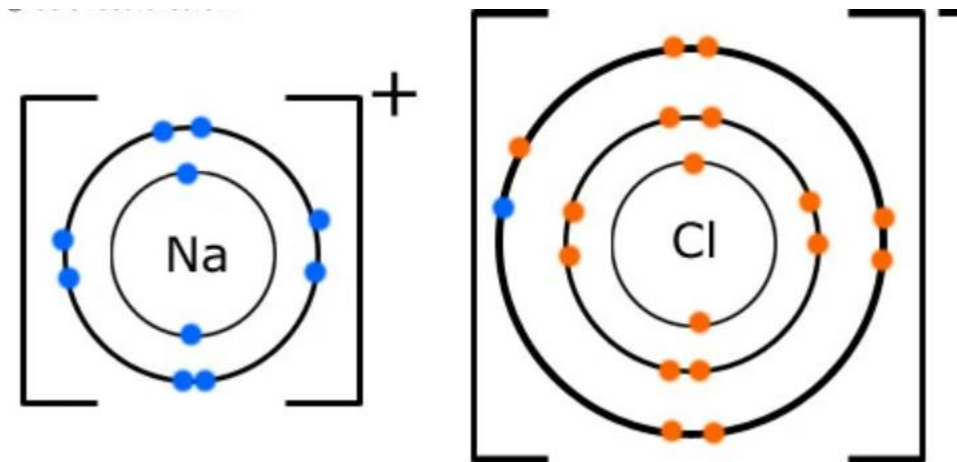


➤ Sharing of electrons (equally or partially)



Ionic bond & compound

Ionic bond is an **electrostatic attraction** between two or more atoms where one atom transfer electron to other atoms. Electron transfer produces negative ions called anions and positive ions called cations.



Factors favouring ionic compound

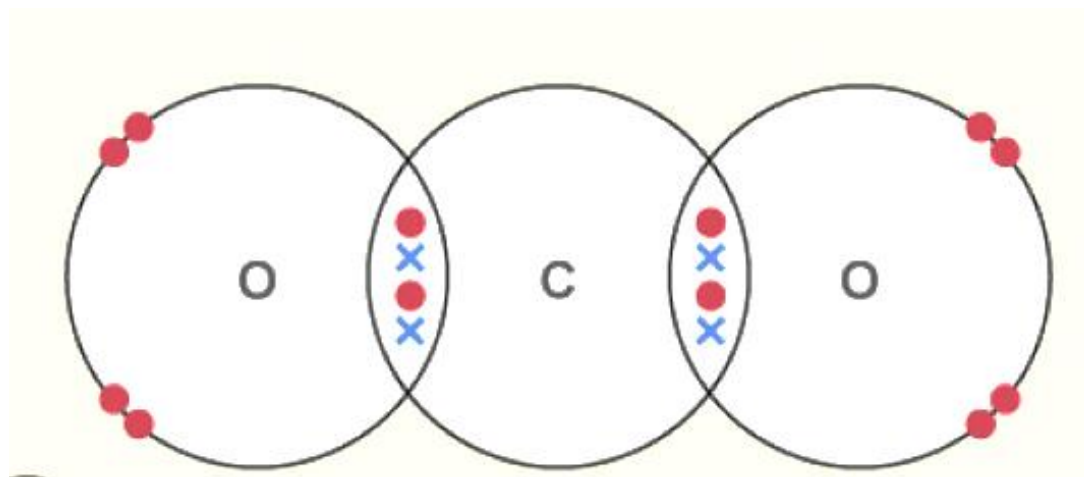
- Number of valence electrons i.e., metal 1,2,3 and non metal 5,6,7
- Low ionization energy of the metal,
- High electron affinity of the non-metal
- High lattice energy
- High electronegativity difference

Properties of ionic compounds

- Physical state (solid, crystalline)
- Electrical conductivity (conduct electricity at molten state)
- High melting and boiling points,
- Hard and brittle
- Soluble in polar solvent but not in non polar solvent
- Highly stable, high density
- Ionic reaction
- Show isomorphism
- Do not show isomerism

Covalent bond & compound

A **covalent bond** consists of the **mutual sharing** of one or more pairs of electrons between two atoms. These electrons are simultaneously attracted by the two atomic nuclei.



Factors favouring covalent compound

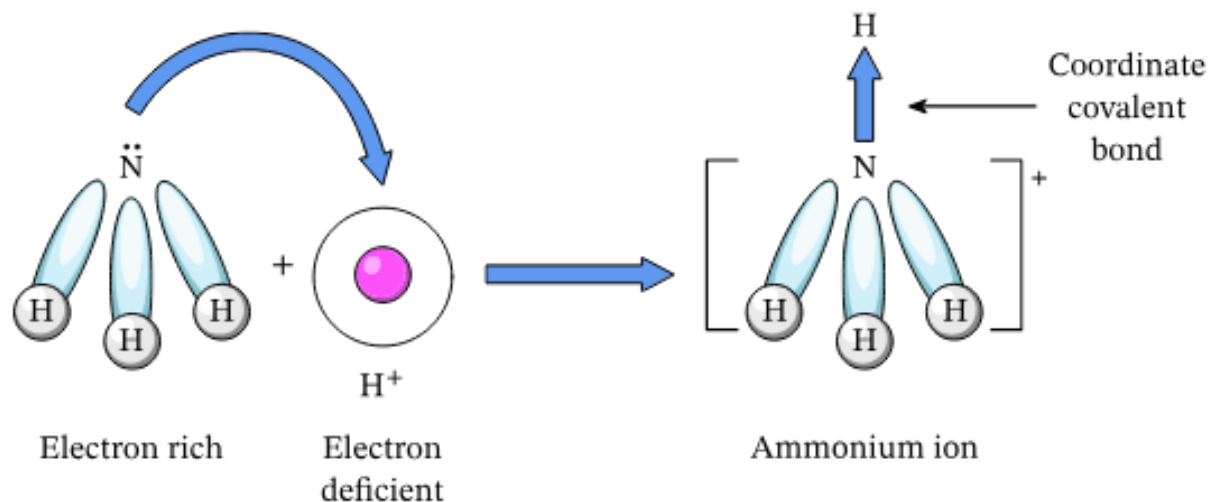
- Small electronegativity difference,
- High ionization energies,
- High electron affinities
- Similar electronegativity's
- Additionally, atoms with 4 to 7 electrons in their valence shell are more likely to form covalent bonds.

Properties of covalent compounds

- Physical state (soft solid, gas, liquid)
- Electrical conductivity (bad conductor)
- Low melting and boiling points,
- Neither hard nor brittle
- Soluble in non-polar solvent but not in polar solvent
- Less stable, less dense
- Molecular reaction
- Do not show isomorphism
- Show isomerism

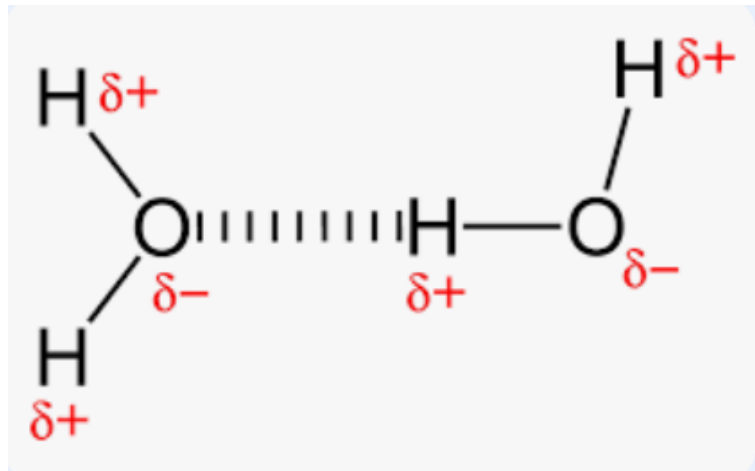
Coordinate bond

A **coordinate bond** (also called a dative covalent bond) is a covalent bond (a shared pair of electrons) in which both electrons come from the same atom. A covalent bond is formed by two atoms sharing a pair of electrons.



Hydrogen bonding

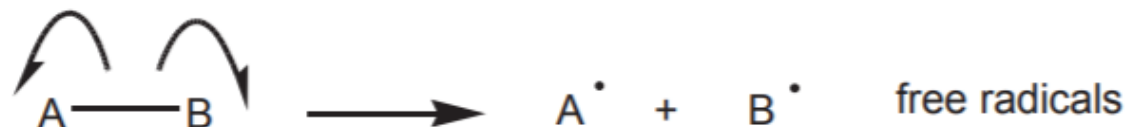
Hydrogen bonding is a special type of dipole-dipole attraction between molecules, not a covalent bond to a hydrogen atom. It results from the attractive force between a hydrogen atom covalently bonded to a very electronegative atom such as a N, O, or F atom and another very electronegative atom.



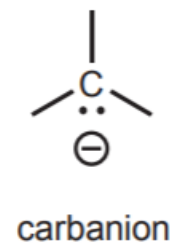
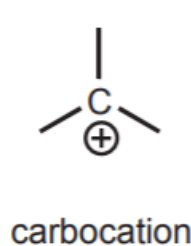
Cleavage of covalent compounds

Covalent bond cleavage is the breaking of a chemical bond, which can occur in two ways:

- In homolytic cleavage, a covalent bond breaks in such a way that each fragment gets one of the shared electrons (equal splitting of electrons, forming free radicals).

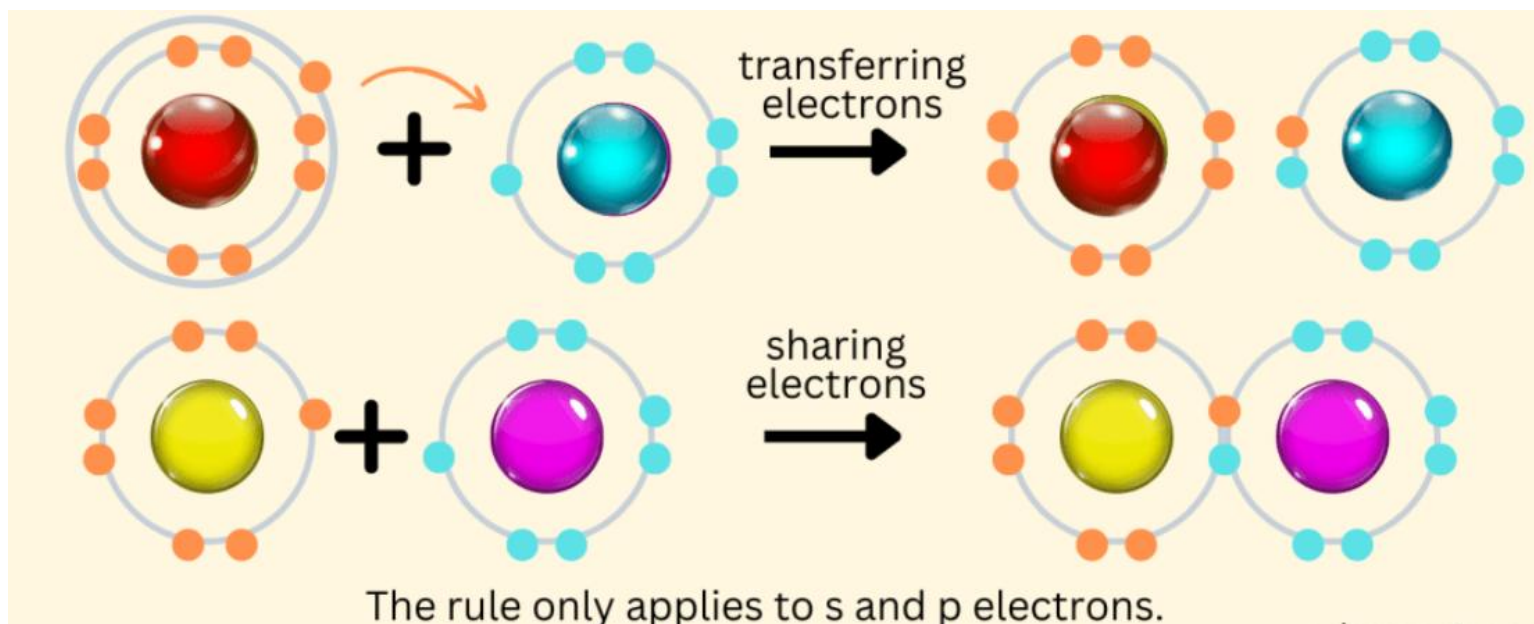


- In heterolytic cleavage, a covalent bond breaks in such a way that one fragment gets both of the shared electrons (unequal splitting of electrons, forming charged ions like carbocations and carbanions).



Octet rule

The octet rule refers to the tendency of atoms to prefer to have eight electrons in the valence shell. When atoms have fewer than eight electrons, they tend to react and form more stable compounds. When discussing the octet rule, we do not consider d or f electrons.



Limitations Octet rule

- Incomplete octet, i.e., BeCl_2 , BF_3
- Odd electron molecules cannot satisfy the octet rule for all atoms, i.e., NO , NO_2
- Expanded octet i.e., PCl_5 , ClF_3
- Duet rule, H , He
- The octet rule doesn't explain the shape and relative stability of molecules. It also doesn't fully account for resonance structures or the behavior of transition metals.

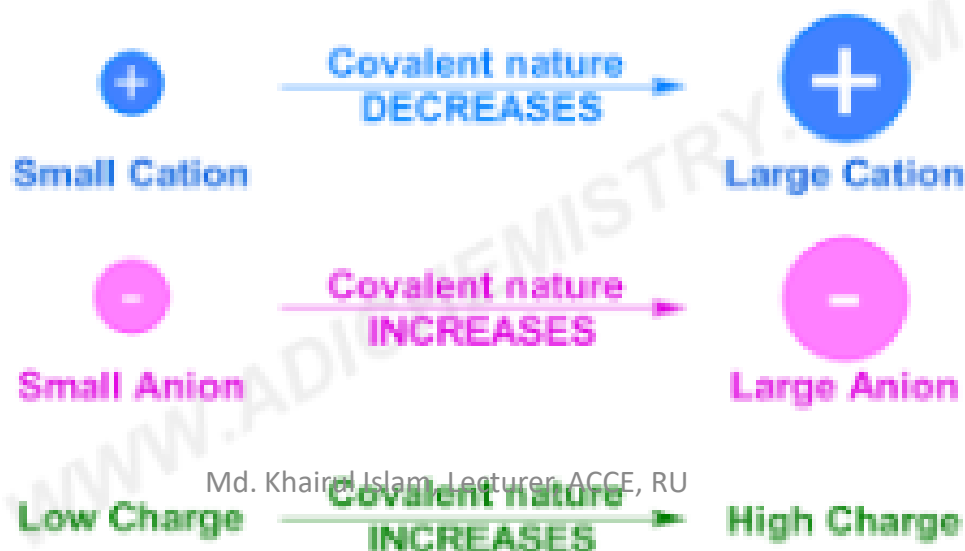
Polarity in covalent compounds

Dipole moment is the **degree of polarity** of a covalent bond/molecule.

Polarization is the **ability of cation to polarize** nearby anion.

The following factors affect polarization-

- The charge and size of the cation,
- The size and charge of the anion,
- Electronic configuration, and
- The resulting covalent character of the bond



Hybridization

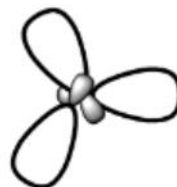
Orbital hybridization is a chemical concept in valence bond theory where atomic orbitals (like s, p, and d) of similar energy within a single atom mix to form new, equivalent hybrid orbitals.

This mixing results in new orbitals with different **shapes, energies, and spatial orientations** compared to the original atomic orbitals, ultimately lowering the overall energy of the resulting molecule and explaining observed molecular geometry.

Equivalent hybrid orbitals are better oriented for forming **stronger, more stable chemical bonds**.



sp
hybrid
orbitals



sp²
hybrid
orbitals

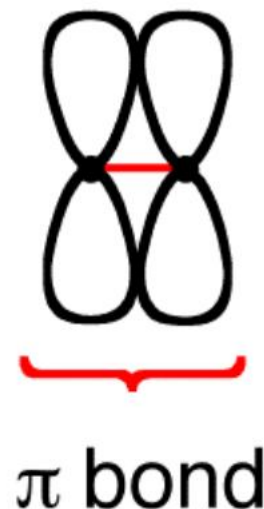
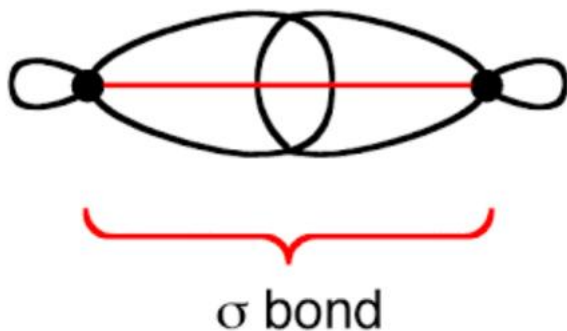


sp³
hybrid
orbitals

Sigma (σ) and Pi (π) bonds

Covalent bonds are formed by the overlapping of atomic orbitals.

Sigma bonds are a result of the head-to-head overlapping of atomic orbitals whereas pi bonds are formed by the lateral overlap of two atomic orbitals.



Difference between σ and π bonds

Sigma bonds	Pi bonds
The overlapping orbitals can be pure or hybrid	The overlapping orbitals must be unhybridized
These bonds are strong and have high bond energies	These bonds are relatively weak
Can exist independently	Must exist along with a sigma bond
Has an impact on the shape of molecules	Has no role in determining the shape of molecules
The bond is rotationally symmetric around the internuclear axis.	The bond is not rotationally symmetric around the internuclear axis.
S as well as p orbitals can form this bond	Only p orbitals can form this bond

Valence bond theory

Electrons in a molecule occupy atomic orbitals rather than molecular orbitals. The overlapping of atomic orbitals results in the formation of a chemical bond and the electrons are localized in the bond region due to overlapping.

Postulates of valence bond theory

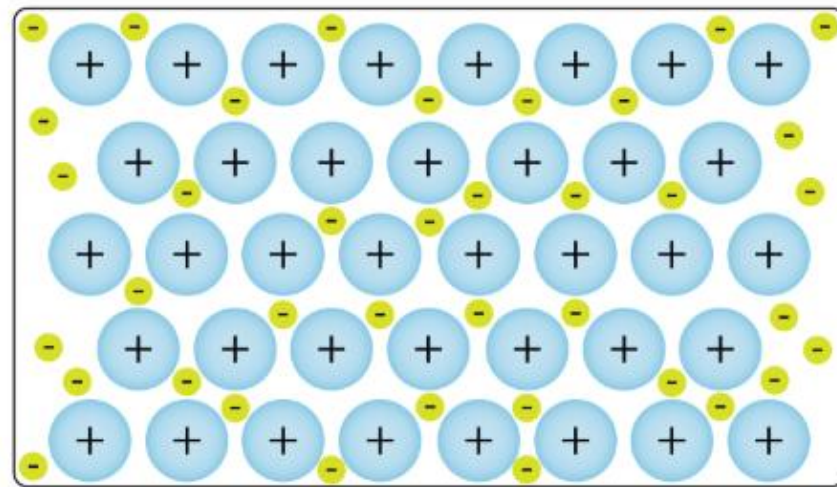
- Covalent bonds are formed when two valence orbitals (half-filled) belonging to two different atoms overlap on each other.
- The presence of many unpaired electrons in the valence shell of an atom enables it to form multiple bonds with other atoms.
- Covalent chemical bonds are directional and are also parallel to the region corresponding to the atomic orbitals that are overlapping.
- Sigma bonds and pi bonds differ in the pattern that the atomic orbitals overlap in, i.e. pi bonds are formed from sidewise overlapping whereas the overlapping along the axis containing the nuclei of the two atoms leads to the formation of sigma bonds.

Limitations of valence bond theory

- Delocalization of electrons over the two nuclei.
- Shielding effect of electrons.
- The essential covalent character of bond.
- The presence of partial ionic nature in a covalent bond.
- The concept of resonance and connection between resonance energy and molecular stability

Metallic bond & compound

Metallic bonding is a type of chemical bonding that arises from the **electrostatic attractive force between conduction electrons** (in the form of an electron cloud of delocalized electrons) and positively charged metal ion.



— Delocalised electrons
+ Metal ions

Factors favouring metallic bond

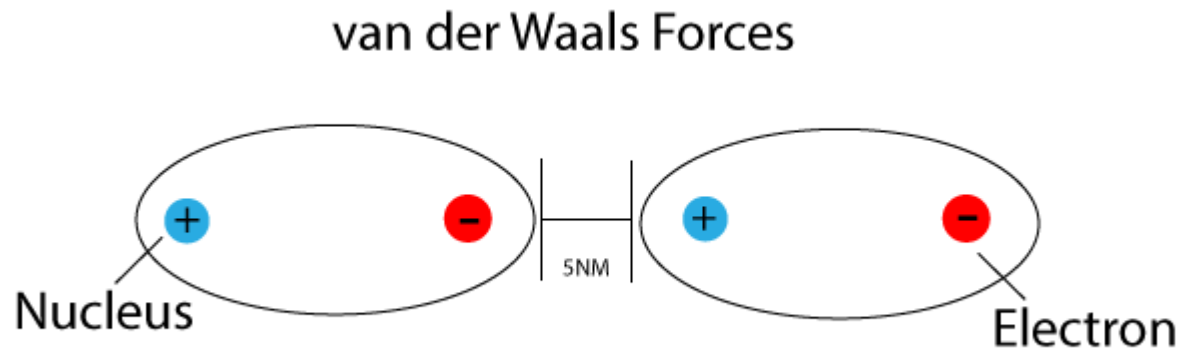
- Low ionization energy, enabling their valence electrons to become delocalized and move freely
- High electro positivity, making them reluctant to gain electrons and form anions, and
- More vacant orbitals than valence electrons, allowing for the easy movement of the mobile electrons.

Properties of metallic compound

- High conductivity of heat and electricity
- Malleability, ductility, and metallic luster.
- High melting and boiling points, and are strong and hard.
- Elasticity and high tensile strength

Van der Waals forces

Van der Waals forces include attraction and repulsions between atoms, molecules, as well as other intermolecular forces. They differ from covalent and ionic bonding in that they are caused by correlations in the fluctuating polarizations of nearby particles (a consequence of quantum dynamics)



Types of Van der Waals forces

- Dipole-dipole interactions
- Ion-dipole interactions
- Dipole-induced dipole interactions
- Instantaneous dipole-induced dipole interactions

Factors affecting Van Der Waals forces

- Large number of electrons in molecules
- Large molecular size
- Molecular shape
- Low temperature
- High Pressure
- Low distance
- Presence of permanent dipoles.

Tutorial

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2.	Why do atom combine to form molecule?	1
3.	Why do ionic compounds have high melting and boiling points than covalent compounds?	2