What is Co-ordinate Bond ?

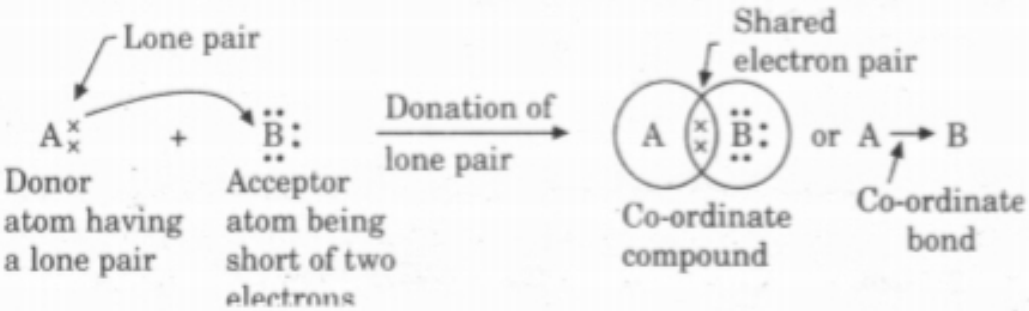
We have seen that in the formation of a normal covalent bond each of the two bonded atoms contributes one electron for the shared pair of electrons which form a covalent bond between the two atoms. However in some compounds the formation of a covalent bond between two atoms takes place by the mutual sharing of two electrons both of which are provided entirely by one of the bonded atoms. This bond is called coordinate bond. Thus :

A covalent bond which is formed by the mutual sharing of two electrons both of which are provided entirely by one of the linked atoms (or ions) is called a co-ordinate bond.

Co-ordinate bond is also sometimes referred to as *co-ordinate covalent bond or dative bond.* The pair of shared electrons is called *lone pair*. The atom which furnishes the electron pair is called *donor* or *ligand* while the other atom which accepts the electron pair is called *acceptor*. A coordinate bond is represented by an arrow which points away from the donor to the acceptor.

Illustration of the Formation of a Coordinate Bond.

The formation of a co-ordinate bond between two atoms, say A and B, can be illustrated as :



The donor atom A has a spare lone pair of electrons on it while the acceptor atom B is short of two electrons than the octet in its valence-shell. A donates its lone pair to B which accepts it. Thus the two electrons of the lone pair which originally belonged to A atom are now shared by both the atoms and this mutual sharing of electron pair results in the formation of a co-ordinate bond between A and B (A → B). Although the arrow head indicates the origin of electrons, once a co-ordinate bond has been established, it becomes quite identical with a normal covalent bond. Both are established by a shared electron pair and have similar properties.

Conditions for the Formation of a Co-ordinate Bond.

Conditions which are necessary for the formation of a coordinate bond are :

(*i*) The atom acting as a donor should have a lone pair of electrons.

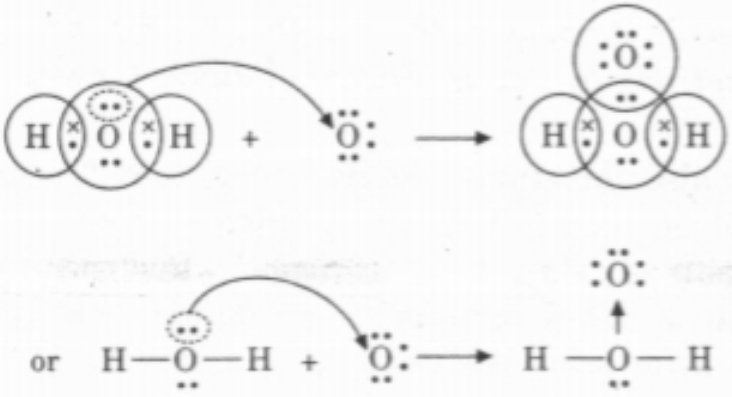
(*ii*) The atom acting as an acceptor should have a vacant orbital to accept the electron pair donated by the donor.

Writing the Electronic Formulae (Lewis Formulae) of the Compounds or Ions Having Co-ordinate Bonds

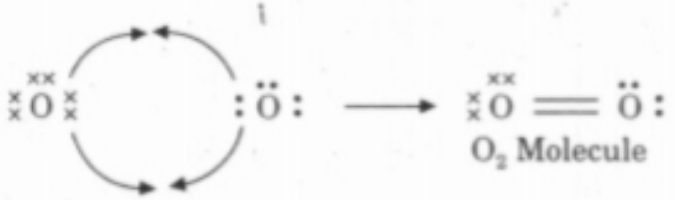
The compounds which contain coordinate bonds are called co-ordinate compounds. Some of them are given below :

1. H_2O_2 molecule. This molecule can be regarded as being formed by the combination of H_2O molecule and oxygen atom. Oxygen atom of H_2O molecule has two lone pairs of electrons on it.

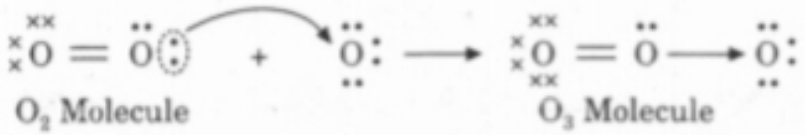
In the formation of H_2O_2 molecule by the combination of H_2O molecule and oxygen atom, one of the two lone pairs on oxygen atom of H_2O molecule is donated to the new oxygen atom and thus a coordinate bond is established between oxygen atom of H_2O molecule and the new oxygen atom.



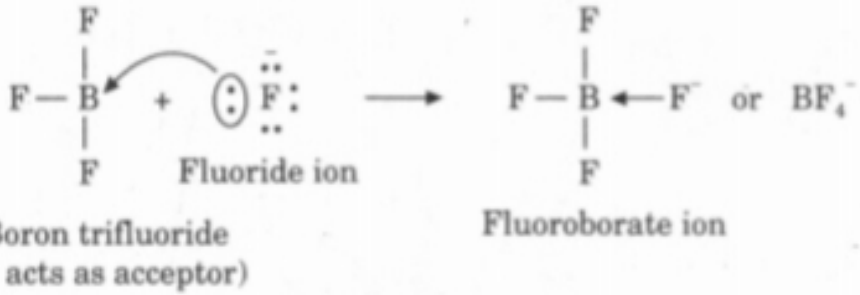
2. O_3 molecule. We know that O_2 molecule is made up of two O-atoms which are joined together by covalent bonds.



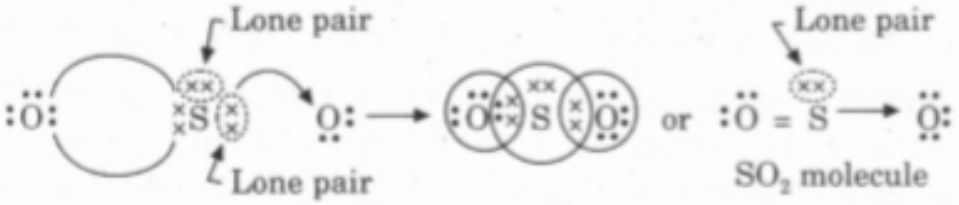
As is evident from the structure of O_2 molecule, each O-atom has two unshared pairs of electrons. When one pair of these is donated to a third O-atom which has six electrons in its valence- shell, a coordinate bond is formed. Thus Lewis structure of O_3 may be shown as :



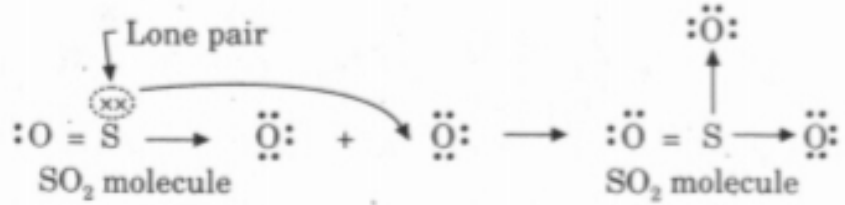
3. Fluoroborate ion, BF_4^-. It is formed when BF_3 molecule shares a pair of electrons supplied by F^- ion.



4. SO_2 and SO_3 molecules. Sulphur achieves its octet by forming two covalent bonds with one O-atom, giving SO species. The S-atom in SO has two lone pairs, one of which is shared with a second O-atom to form SO_2.



S-atom in SO_2 still has one lone pair which it donates to a third O-atom forming SO_3 molecule.



How is a Co-ordinate Bond Formed ?

The formation of a coordinate bond (A → B) between two atoms *viz.* A and B may be regarded to occur in the following two steps :

1st step **:** In this step the donor atom A transfers one electron of its lone pair to the acceptor atom B. This results in that atom A develops *unit positive charge* (+) and atom B develops a *unit negative charge* (–). This charge is known as *formal charge*. This step is similar to the formation of an ionic bond.

2nd step **:** In this step the two electrons, one each with A^+ and B^- are shared by both the ions. This step is similar to the formation of a covalent bond.

$$A\bullet^+ + \bullet B^- \rightarrow A : B \quad or \quad A \rightarrow B$$

Thus we see that a co-ordinate bond is equivalent to a combination of an electrovalent bond (polar bond) and a covalent bond (non-polar bond). It is for this reason that a coordinate bond is also sometimes called a *semi-polar bond.*

Properties of Co-ordinate Compounds.

The main characteristics are given below :

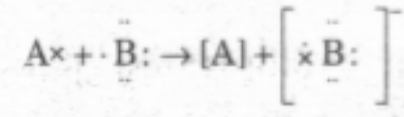
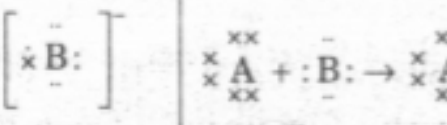
1. ***Melting / boiling points and viscosity.*** We have seen that a co-ordinate bond is, in a way, a combination of an ionic bond and a covalent bond. It is for this reason that coordinate compounds have melting and boiling points, and viscosities which are *higher* than those of purely covalent compounds but *lower* than those of purely ionic compounds.
2. ***Semi-polar character.*** These compounds are semi-polar in character (A^+–B^-), *i.e.* they are more polar than covalent compounds and less polar than the ionic compounds.
3. ***Physical state.*** These compounds are gases, liquids or solids.
4. ***Solubility.*** These are usually insoluble in polar solvents like water but are soluble in non-polar (*i.e.* organic) solvents.
5. ***Conductivity.*** Like covalent compounds, coordinate compounds are also *non-ionic, i.e.* they do not conduct electric current through their *aqueous solutions or fused mass.*

6. ***Molecular reactions.*** Coordinate compounds are molecular and hence undergo molecular reactions which are slow.
7. ***Stability.*** Coordinate compounds are as stable as the covalent compounds. But when they are made up of two different stable molecules (*molecular compounds*), they are not very stable.
8. ***Isomerism.*** Coordinate compounds also show isomerism. Since the coordinate bond is *rigid* and *directional*, different space models (*i.e.* stereoisomers) of a single coordinate compound are possible.

Comparison Between Ionic, Covalent and Co-ordinate Bonds

The comparison between the three bonds is given in Table 7.2.

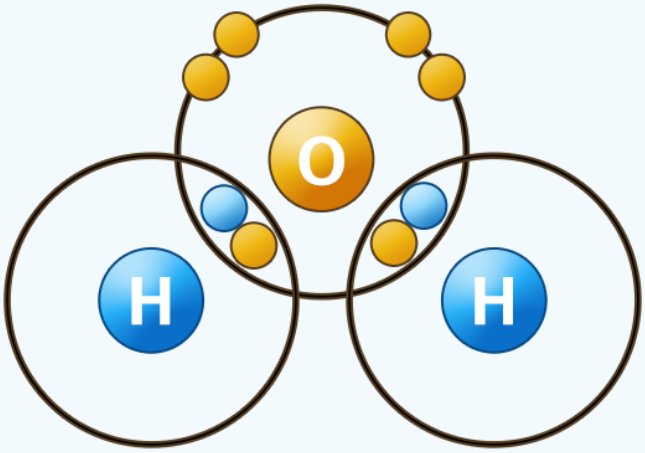
Table 7.2. Comparison between ionic, covalent and co-ordinate bonds

Ionic Bond	Covalent Bond	Coordinate Bond
(*i*) Ionic bond is formed by the transfer of electrons from a metal atom (A) which has 1, 2 or 3 valence-electrons to a non-metal (B) having 5, 6 or 7 valence electrons.  or $A + B^-$	(*i*) Covalent bond is formed by sharing two electrons between non-metal atoms having 1, 4, 5, 6, or 7 valence electrons.  or A–B	(*i*) It is formed by the sharing of two electrons between two atoms, both electrons coming from one atom. or A → B
(*ii*) Ionic bond consists of electrostatic force between cations and anions.	(*ii*) Covalent bond consists of two electrons that hold the atoms together.	(*ii*) It consists of an electron pair between the linked atoms.
(*iii*) It is a weak bond, since the electro-static force can be broken easily.	(*iii*) It is a strong bond, since the paired electrons cannot be separated easily.	(*iii*) It is also a strong bond, since the paired electrons cannot be separated easily.
(*iv*) It is a polar bond (A^+–B^-)	(*iv*) It is a non-polar bond (A–B)	(*iv*) It is a semi-polar bond ($A^+ - B^-$)

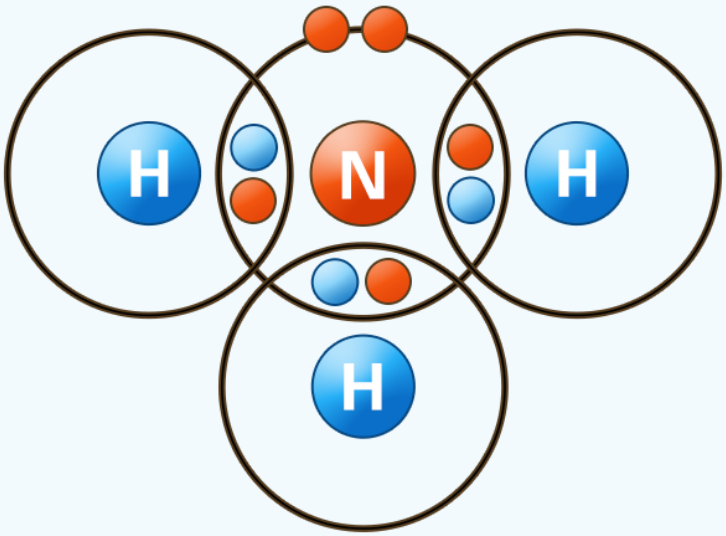
COVALENT BOND
VERSUS
COORDINATE BOND

COVALENT BOND	COORDINATE BOND
A covalent bond is a type of chemical bond that is formed when two atoms share their unpaired electrons with each other	A coordinate bond is a type of chemical bond that is formed due to the donation of a lone electron pair by one atom to another atom
Two atoms donate an equal number of electrons	Only one atom donates a pair of electrons
There should be unpaired electrons	There should be no unpaired electrons
Empty orbitals are not required	Empty orbitals should be present in the electron deficient species
Lone electron pairs are not required	At least one lone electron pair should be present in one of the two atoms
Can be polar or nonpolar according to the electronegativity difference of two atoms	Polar bonds

Examples of Covalent Bond



Water (H_2O)



Ammonia (NH3)