THE CHEMICAL BOND

Principles of Electronic Theory of Chemical Bond

(1) Chemical combination between atoms of the same or different elements takes place due to the tendency by the outermost electron groups to attain the stable arrangement of inert gases.

(2) The attainment of inert gas electron configuration may take place by complete transference of electrons from one atom to another. The resulting electrically charged atoms (or ions) are held together by electrostatic force of attraction. The chemical bond so formed is known as electrovalent or Ionic bond.

(3) The attainment of inert gas configuration may occur by sharing of electrons (in pairs) between two atoms. The chemical bond so formed is called covalent bond.

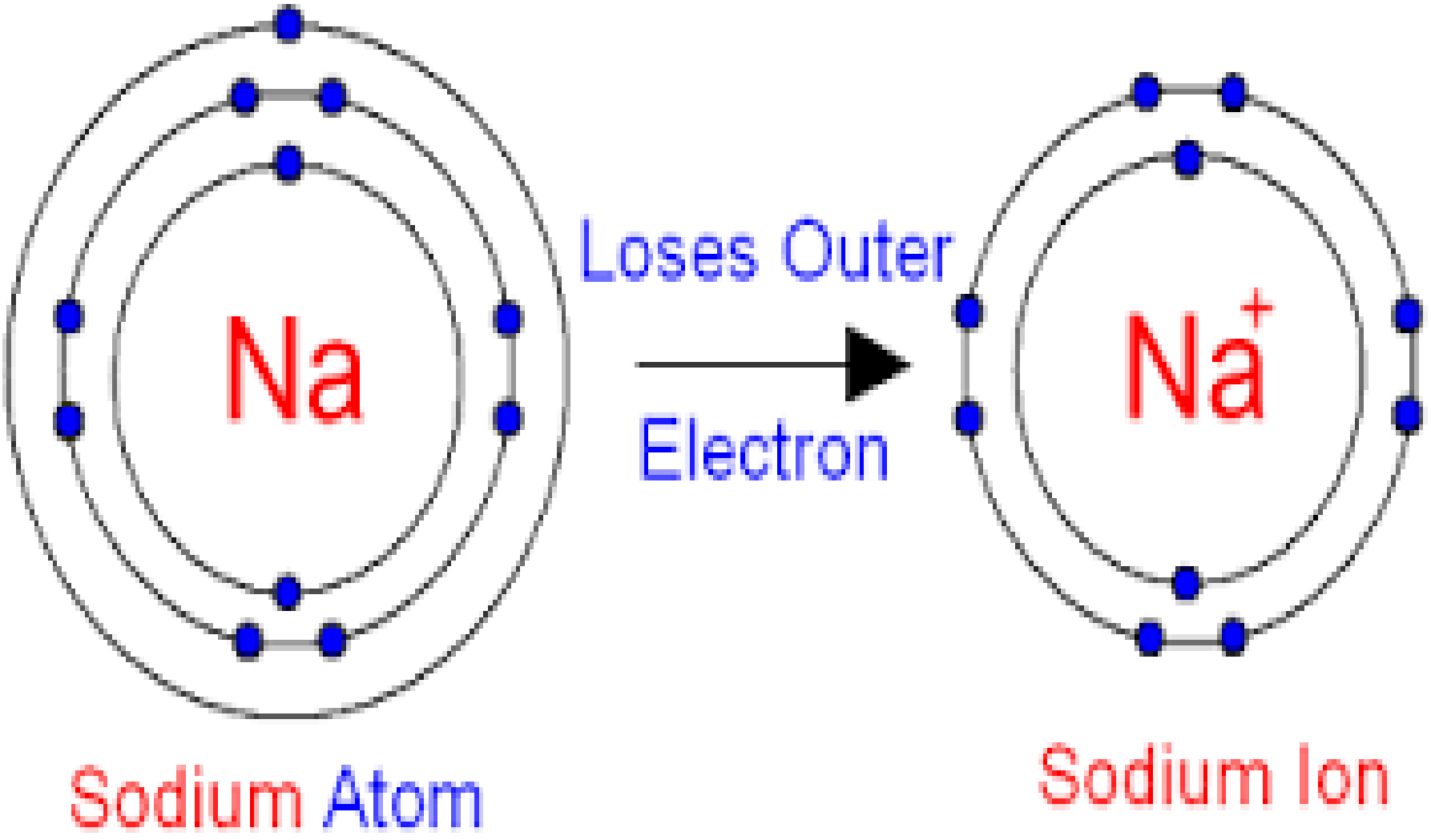
(4) The attainment of electron groupings of inert gases may also happen by both transference and sharing of electrons between atoms in pairs. The bond so formed is known as coordination bond.

The Ionic Bond

The ionic bond is formed when one or more electrons are transferred from one atom to the other to complete the orbital's in each case. In both cases, the electronic arrangements of the resulting ions is identical to that of an atoms of one of the inert gases.

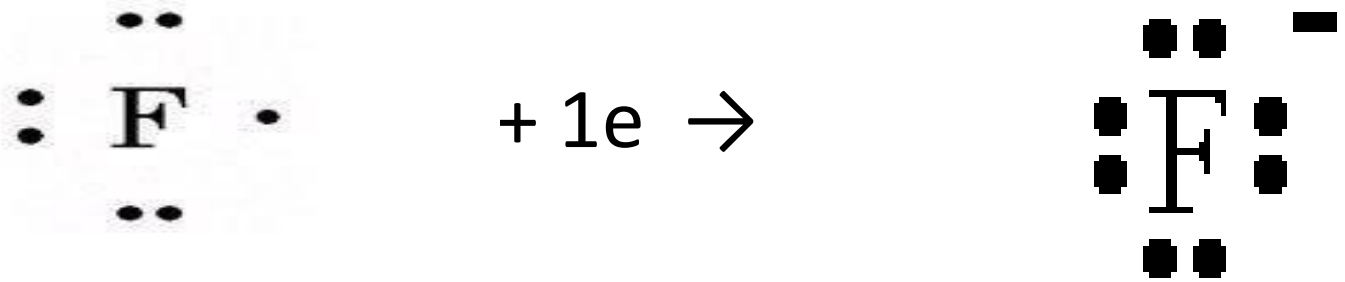
The electronic configuration of Ne(10) and Na(11) is $1s^2 2s^2 2p^6$ and $1s^2 2s^2 2p^6 3s^1$ respectively.

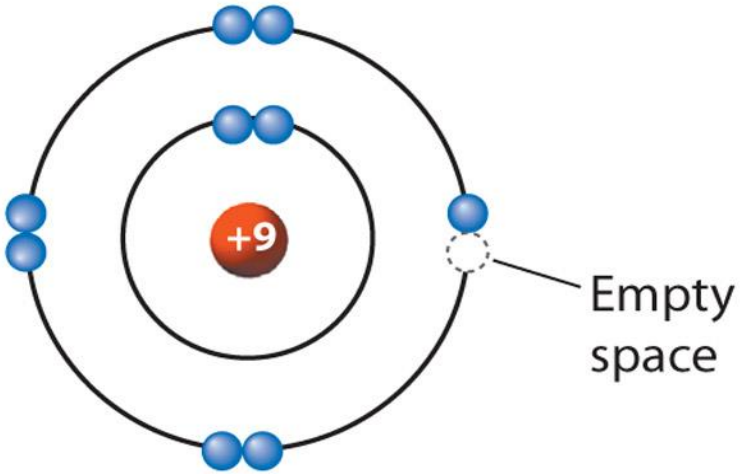
It is noted that the gas neon(Ne) has 8 electrons in its outer energy level.


Na
Loses Outer
Electron
Na+
Sodium Atom
Sodium Ion

Similarly, the formation of negatively charged fluorine ion (F^-) may be illustrated as follows:

$$F(1s^2 2s^2 2p^5) + 1e \rightarrow F^-(1s^2 2s^2 2p^6)$$

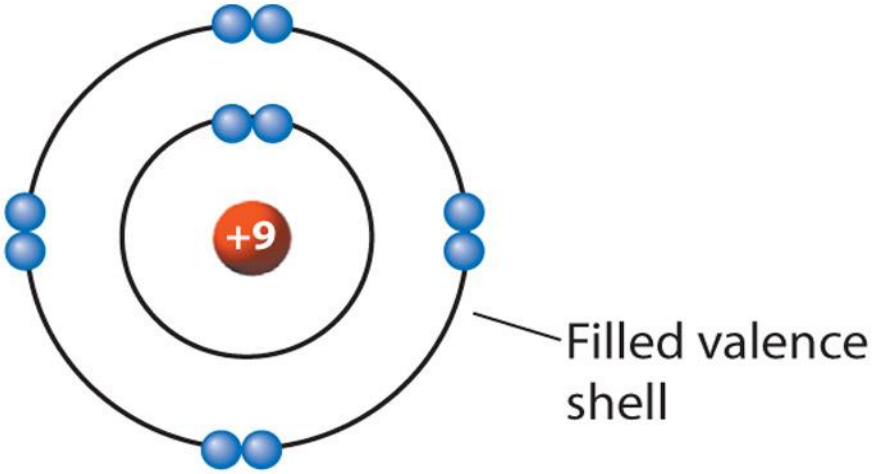




F

9 protons
9 electrons

0 net charge

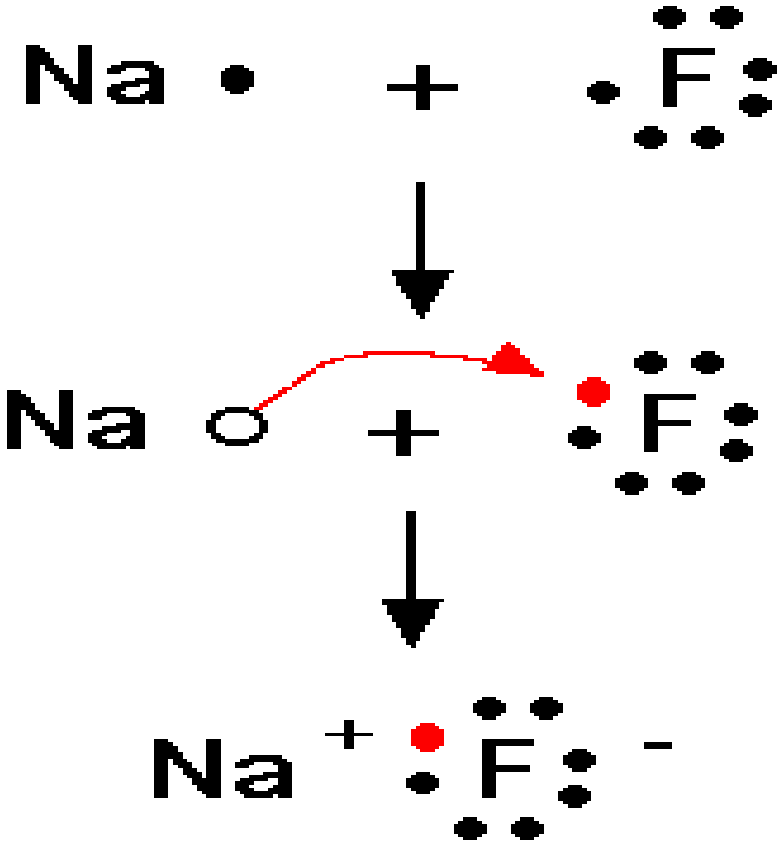


F^{1-} (negative ion)

9 protons
10 electrons

−1 net charge

Formation of an Ionic Compound
Sodium Fluoride, NaF



Similarly, the bond between magnesium and oxygen in magnesium oxide (MgO) involves two electrons.

Mg ($1s^2 2s^2 2p^6 3s^2$)

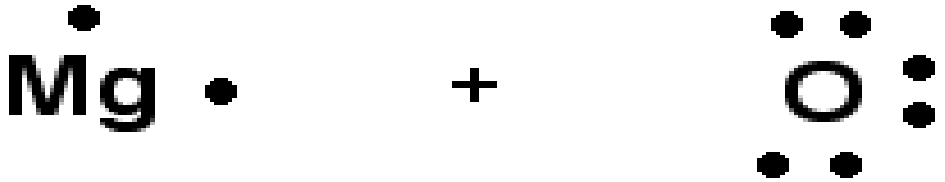
Mg^{+2} ($1s^2 2s^2 2p^6$) Neon structure

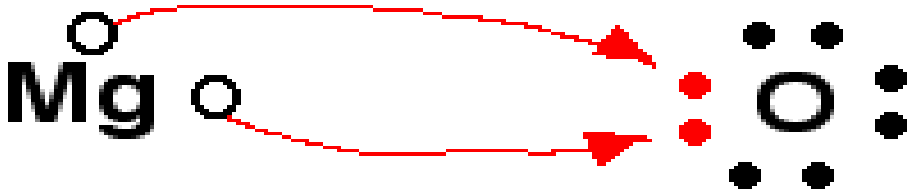
O ($1s^2 2s^2 2p^4$)

O^{-2} ($1s^2 2s^2 2p^6$) Neon structure

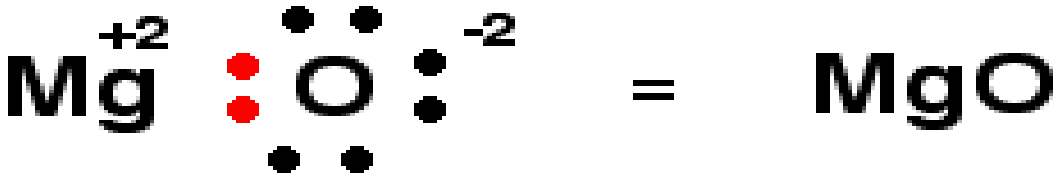
$Mg + O \rightarrow Mg^{+2} + O^{-2} \rightarrow MgO$

Magnesium Oxide





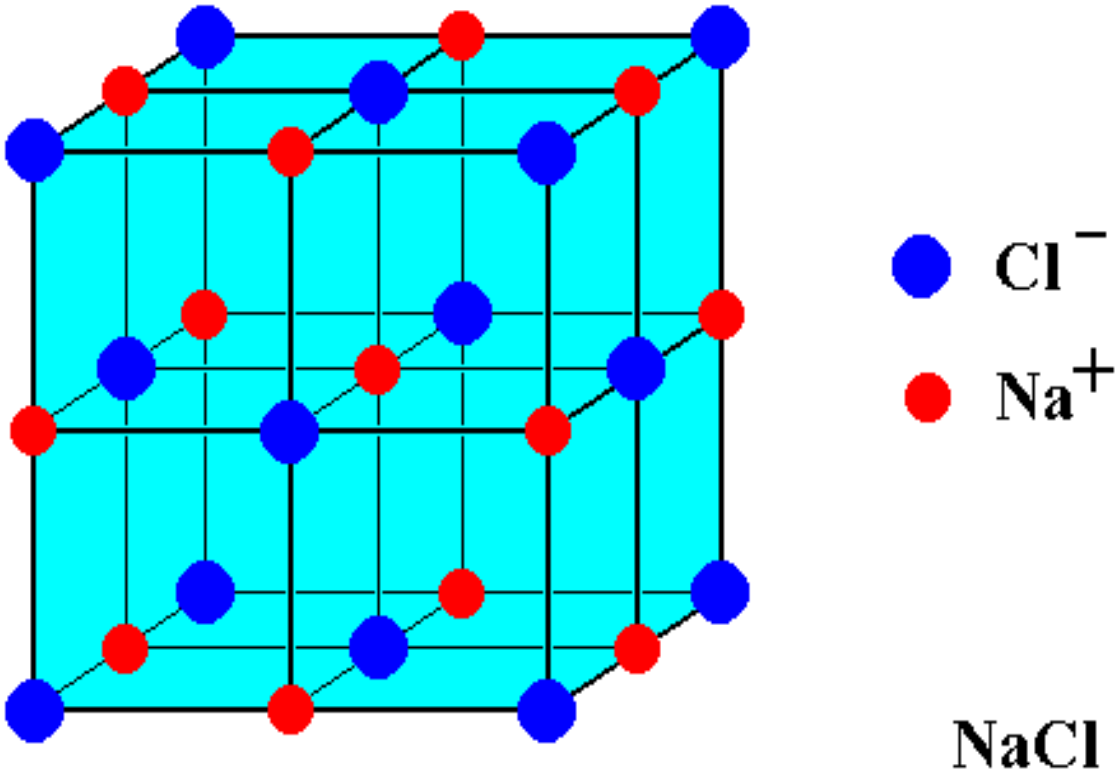
Magnesium loses 2 electrons, and
Oxygen gains 2 electrons to have an Octet.



General Properties of the Ionic Bond

(1) Crystalline State: Ionic compound can form crystalline structure. Crystals are composed of ions in the crystal lattice or the atomic network.

The structure of sodium chloride has been shown in Fig. and gives cubic crystals.



(2) Electrical Conductivity: Ionic compounds either in the fused state or in solutions are good conductors of electricity. The ions are free to move under the influence of electric field.

(3) Isomorphism: The different compounds containing ionic bonds have ions, which assume the same electron arrangements in their molecules and hence show similar crystalline forms.

NaF is isomorphous with MgO, and K_2S has the same crystalline form as that of $CaCl_2$

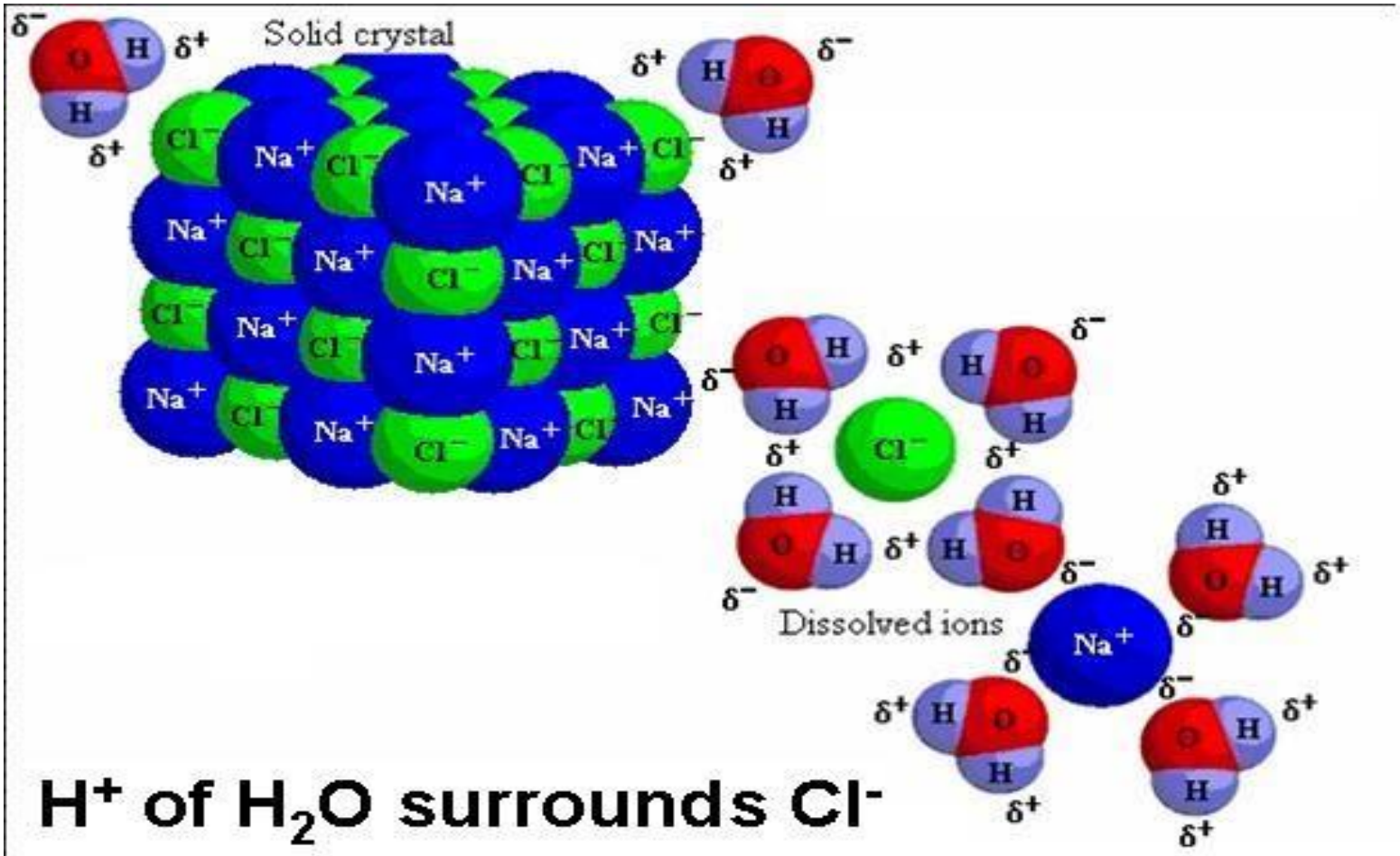
Na^{+} $1s^2 2s^2 2p^6$ F^{-} $1s^2 2s^2 2p^6$

Mg^{+2} $1s^2 2s^2 2p^6$ O^{-2} $1s^2 2s^2 2p^6$

(4) Melting and Boiling Points: In the ionic crystals the ions exert a powerful electrostatic force on each other. A considerable amount of work is needed to separate them from one another. Ionic compounds have high melting and boiling point.

(5) Reactivity: The reactions between ionic compounds generally take place with great speed.

(6) Solubility: Ionic compounds are generally more soluble in polar than in non-polar solvents.

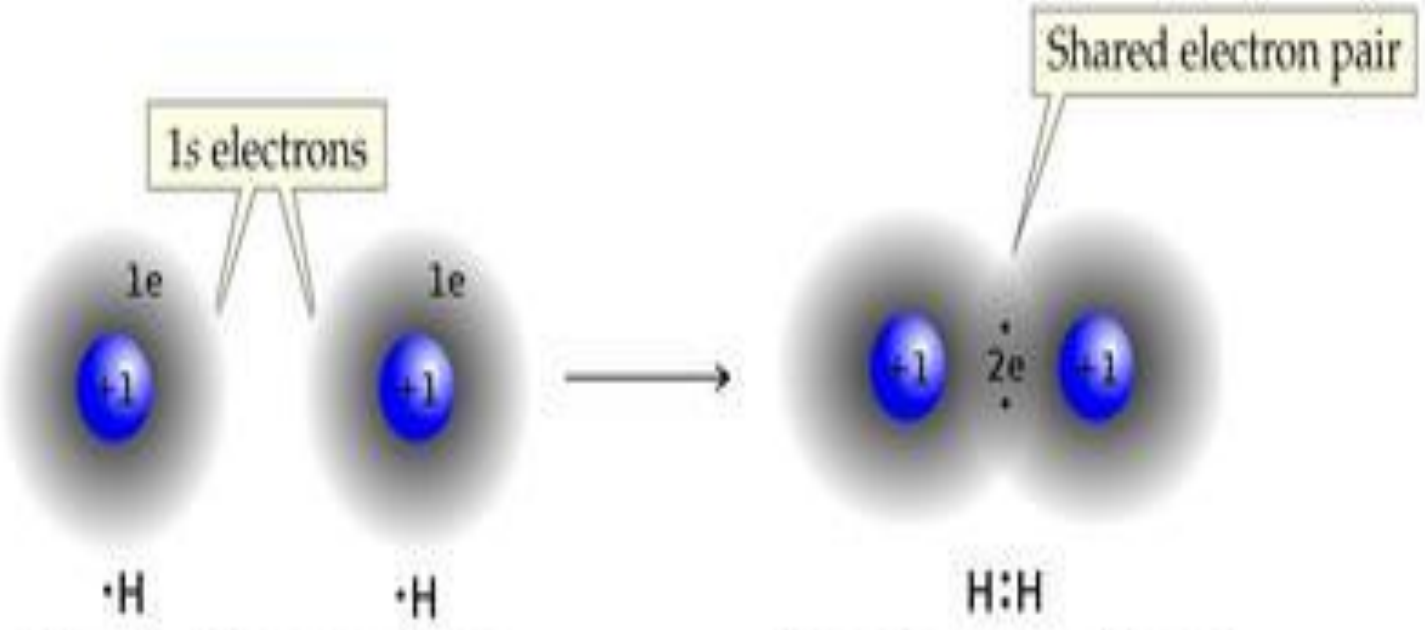


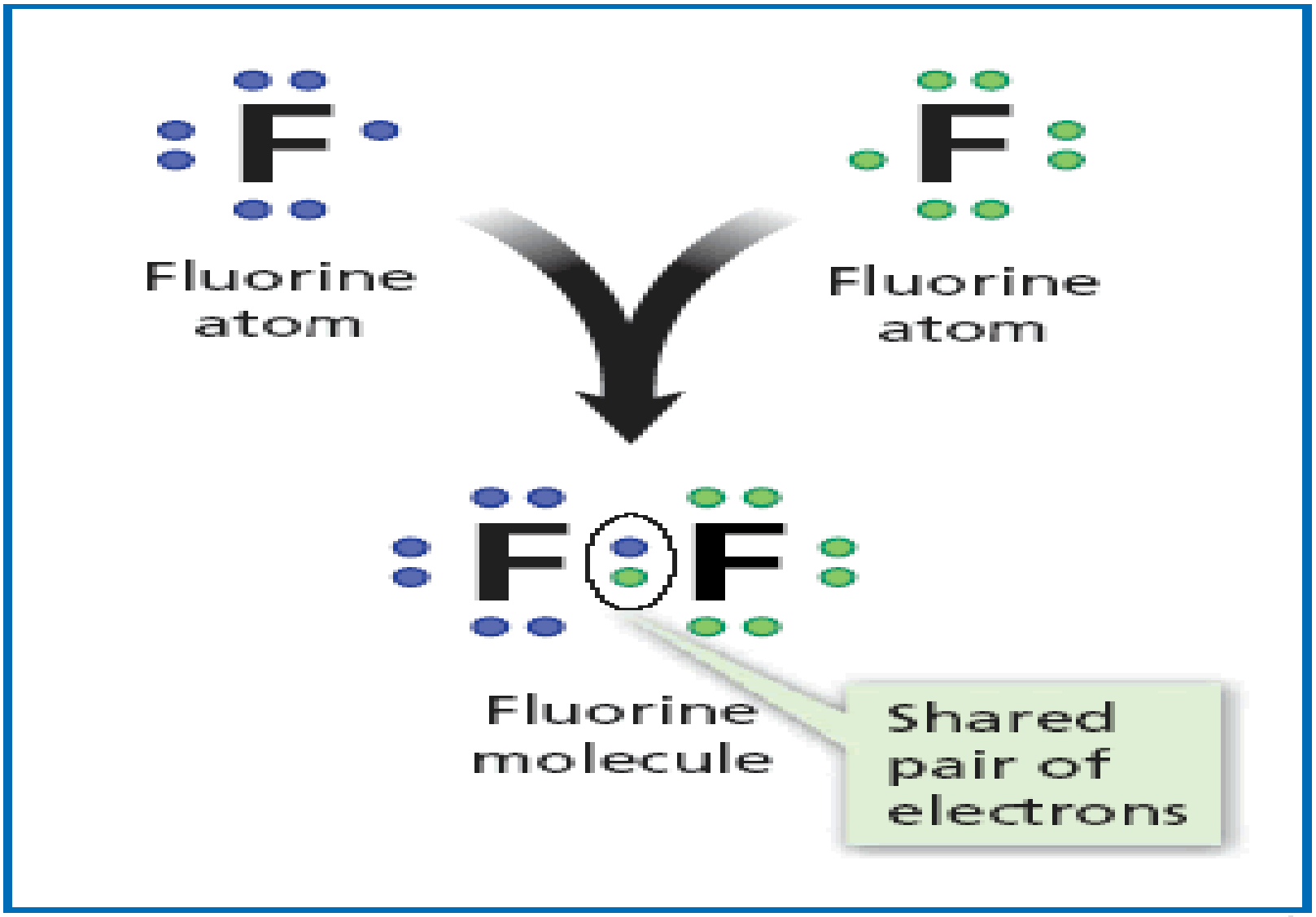
Polar water molecules oriented in one way around sodium ions and another way around chloride ions

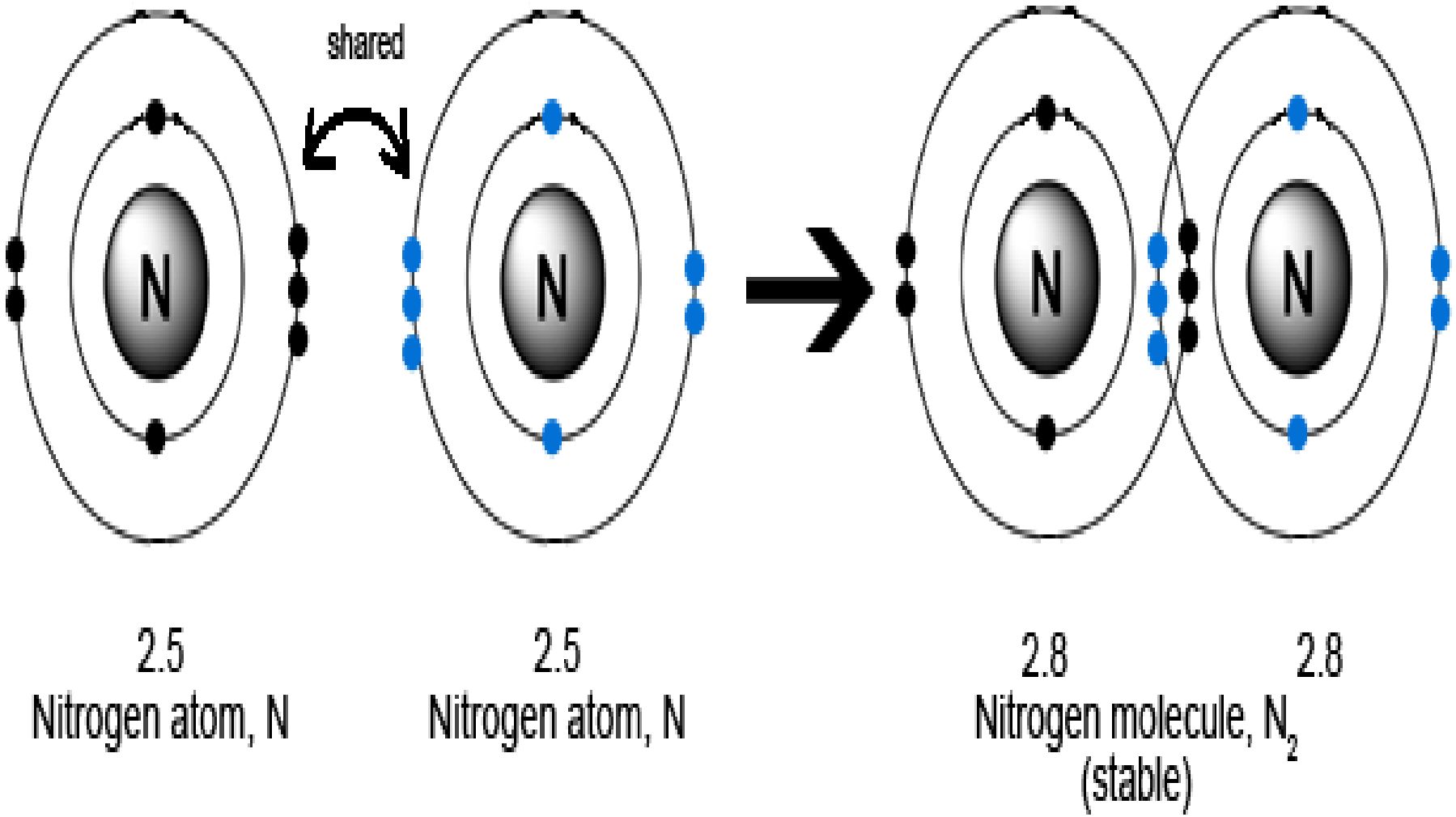
The Covalent Bond

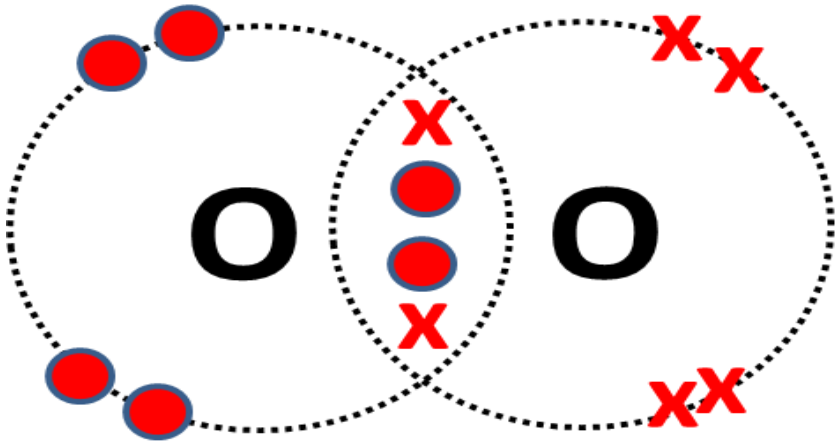
Atoms may combine with each other chemically by sharing of electrons. A chemical bond of this type is called a covalent bond, and compounds containing these bonds are called covalent compounds.

Sharing of electrons between atoms always occurs in pairs, and in each pair of shared electrons one is contributed by each atom. Covalent bonds are, therefore, also known as electron pair bonds.

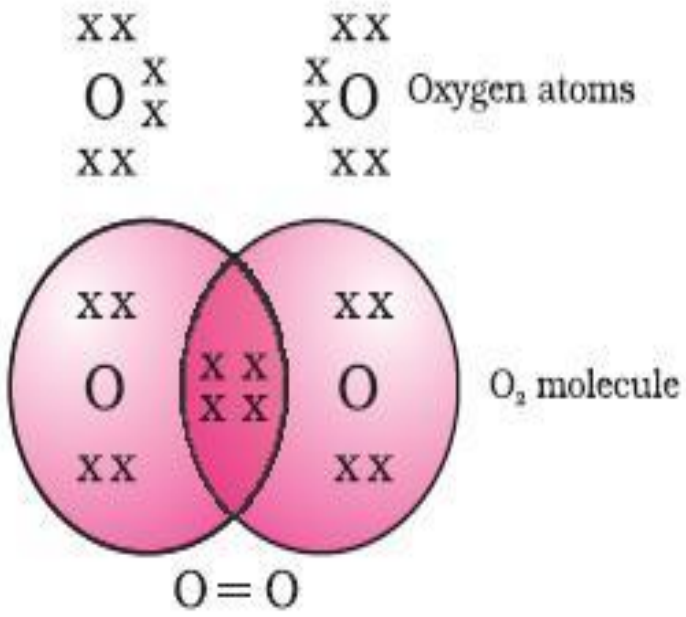

Shared electron pair
1s electrons
1e
1e
+1
+1
2e
+1
+1
·H
·H
H:H
Two hydrogen atoms
A hydrogen molecule
H—H or H2


F
Fluorine atom
F
Fluorine atom
F F
Fluorine molecule
Shared pair of electrons
Morgan Cain & Associates


shared
N
N
N
N
2.5
Nitrogen atom, N
2.5
Nitrogen atom, N
2.8
2.8
Nitrogen molecule, N_2
(stable)



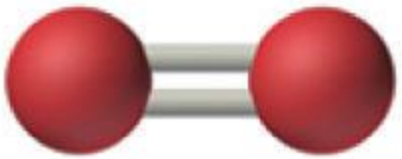
O = O



H—H

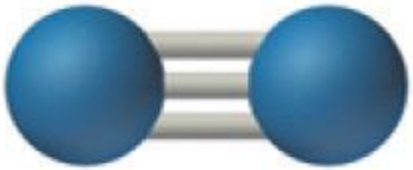
Single bond

O=O



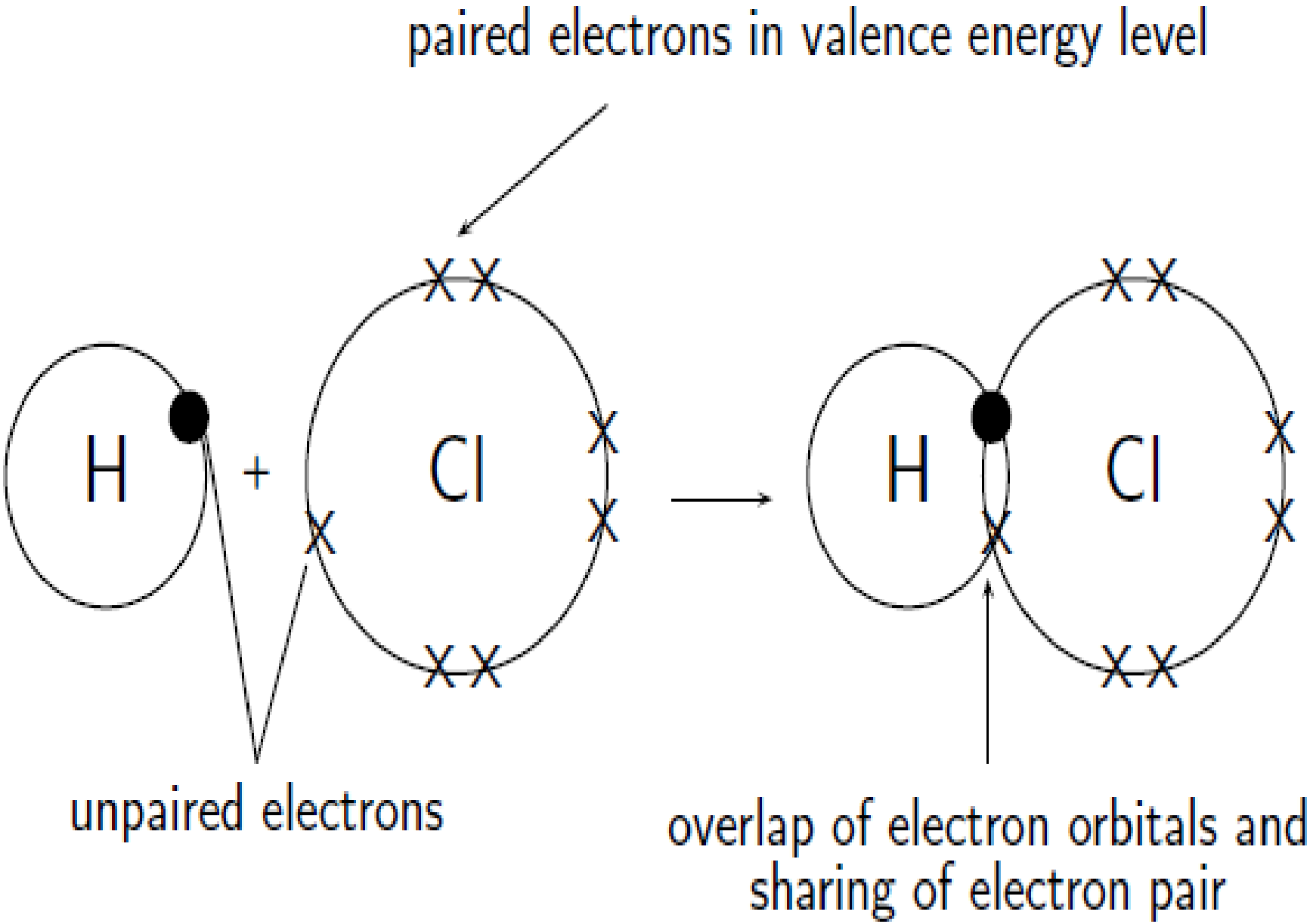
Double bond

N≡N



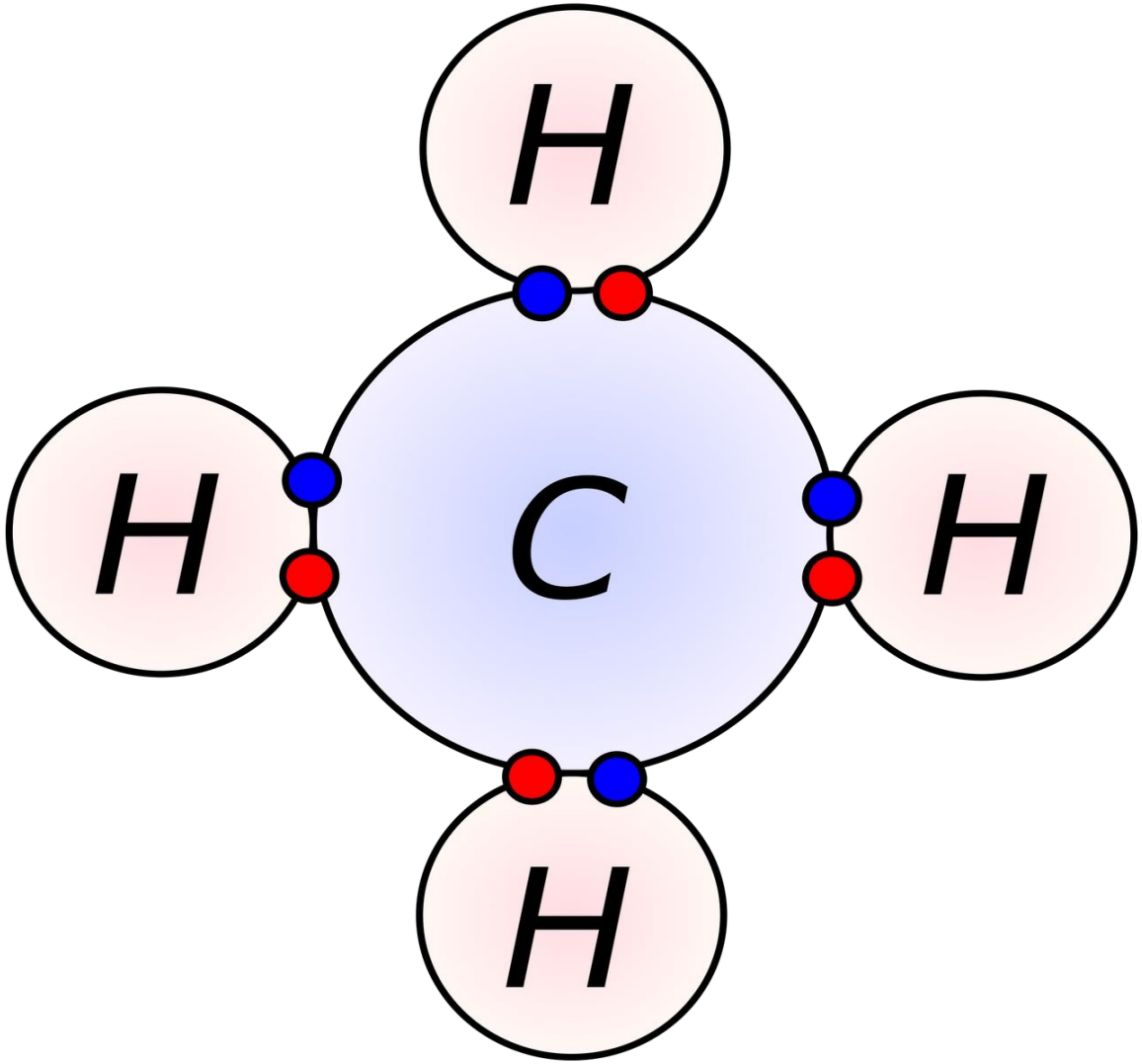
Triple bond

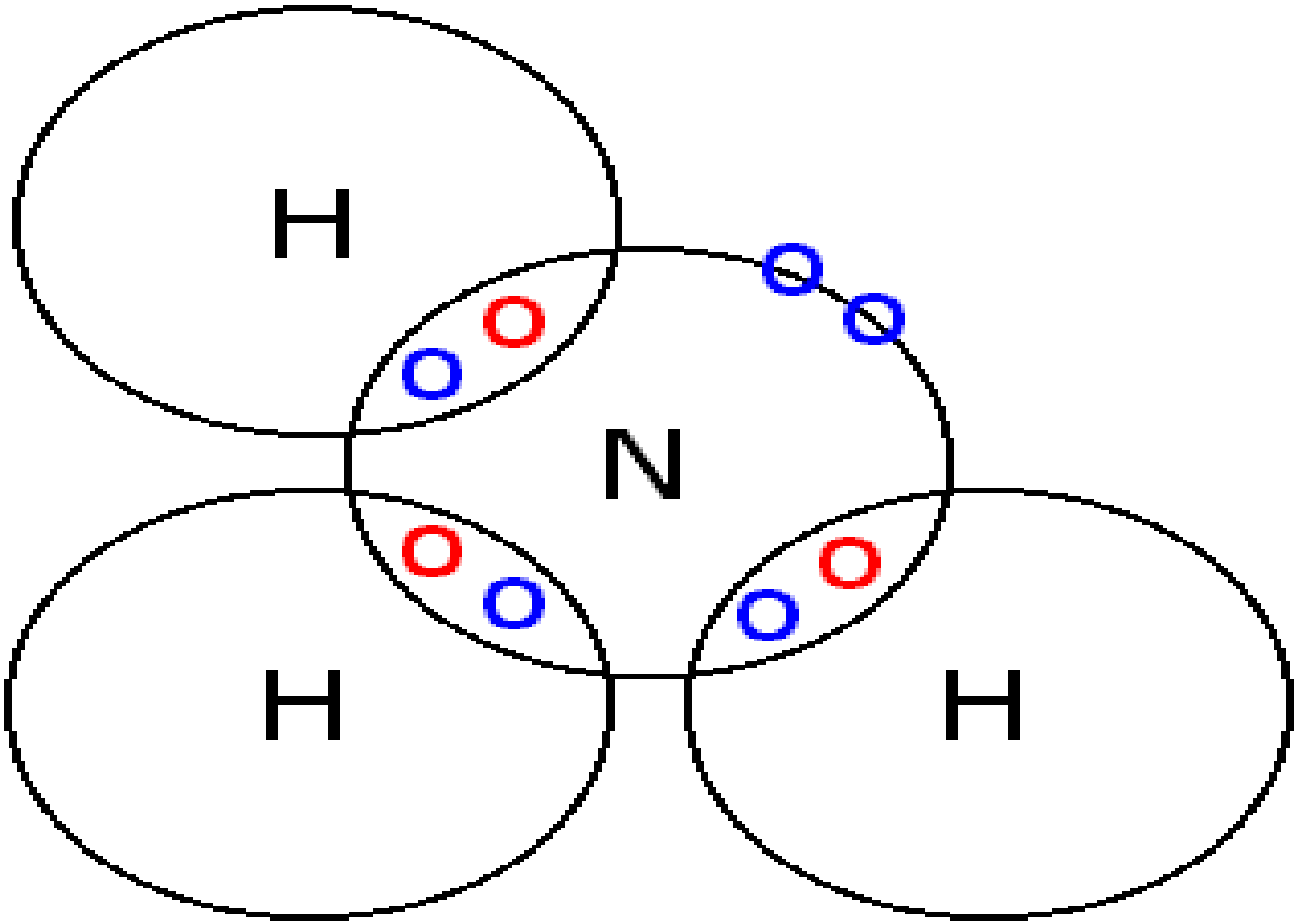
The covalent bond may also link together atoms of different elements to form a molecule of a compound. The combination of hydrogen atom with an atom of chlorine to form a molecule of HCl may be shown as follows:

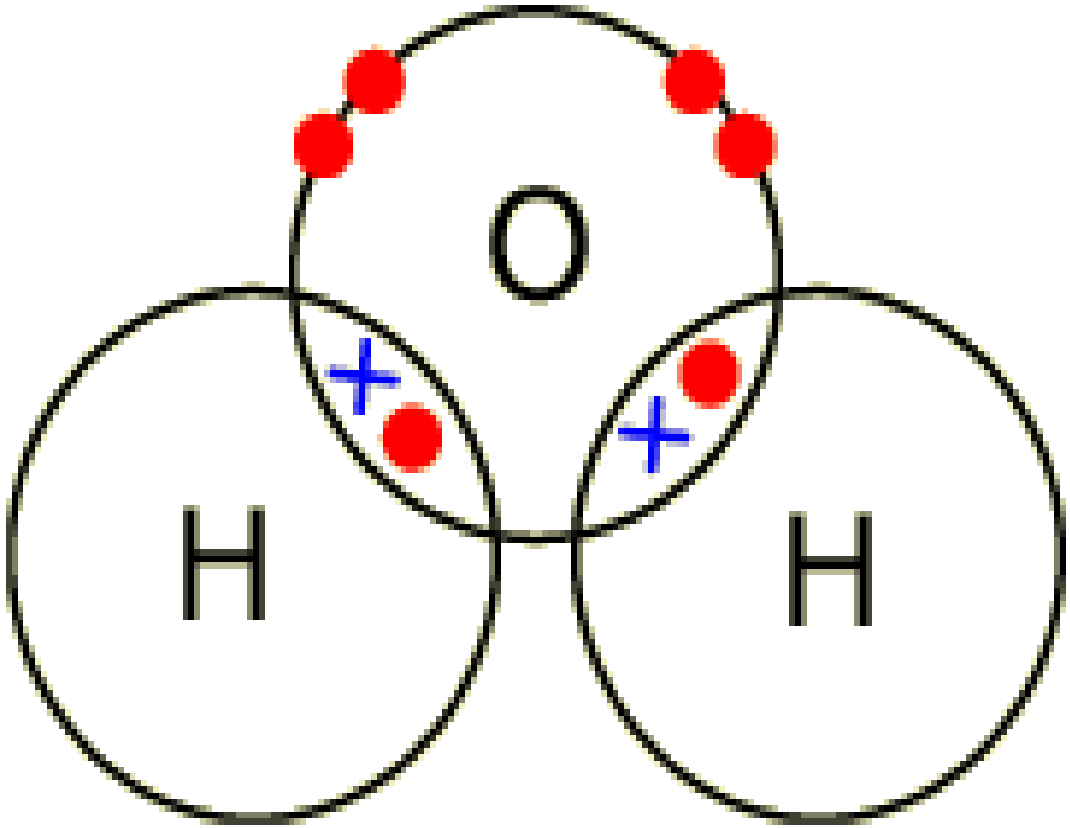

paired electrons in valence energy level
H
+
Cl
H
Cl
unpaired electrons
overlap of electron orbitals and
sharing of electron pair

In the molecule of HCl, both H and Cl are surrounded by an electron cloud like that of helium and argon atoms respectively.

An atom can combine by sharing electrons with more than one atom.


H
H
C
H
H
Electron from hydrogen
Electron from carbon

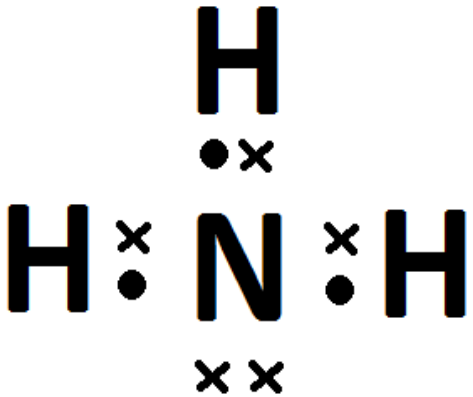

H
N
H
H

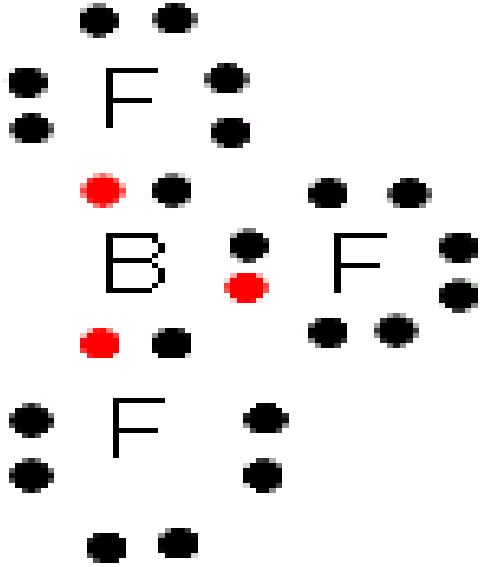

O
H
H

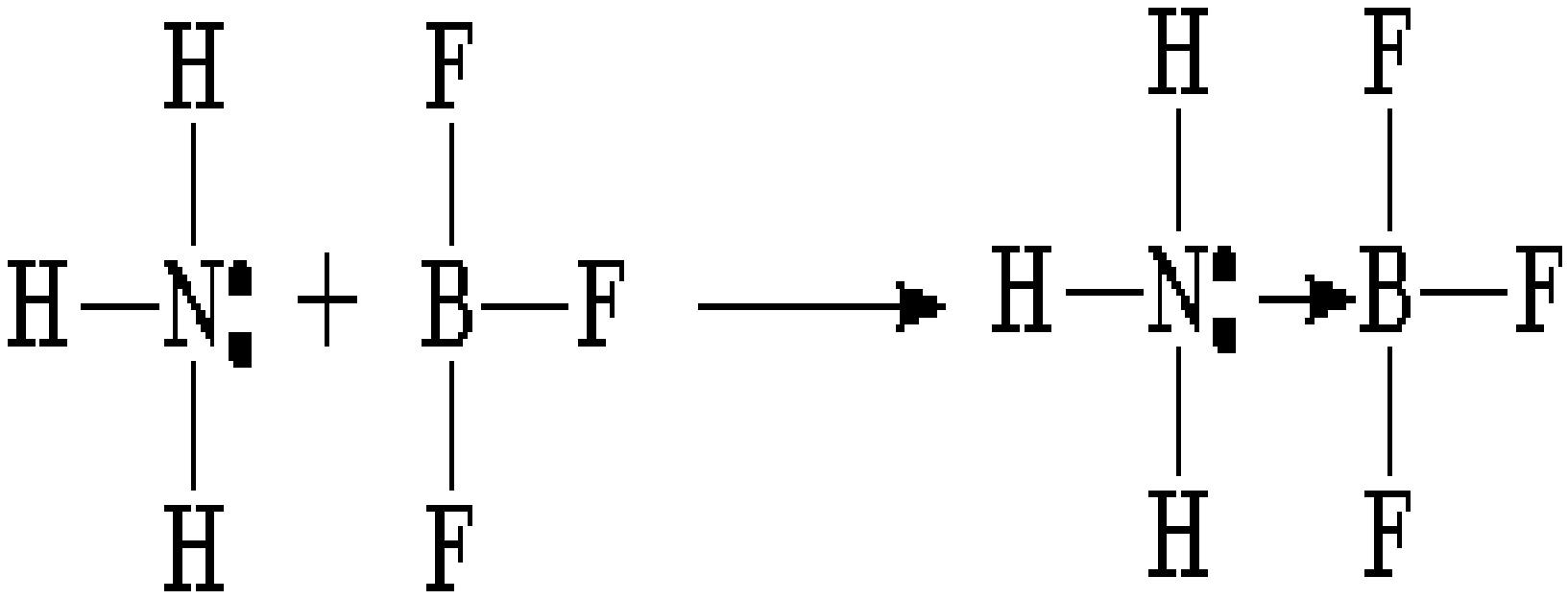
Coordination Bond

In some molecules one of the atoms may supply both electrons, i.e., both shared electrons come from the same atom. A covalent bond formed by the donation of a pair of electrons from one atom to another atom in the molecule is called a coordination bond.

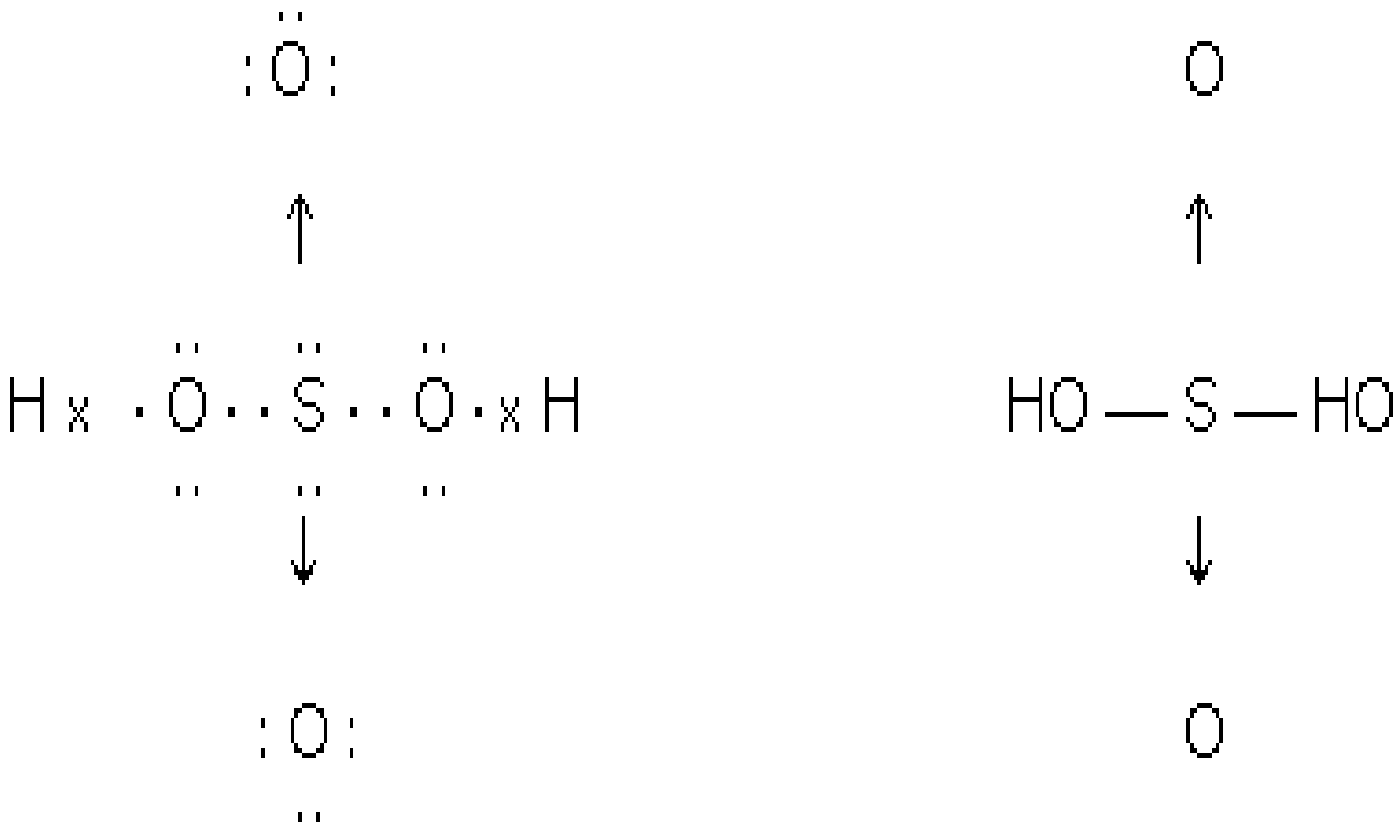
- In this type of bonding, the atom that shares an electron pair from itself is termed as the donor.
- The other atom which accepts these shared pair of electrons is known as a receptor or acceptor.


H
H
N
H


F
B
F
F



Ammonia-boron trifluoride addition compound


O
H O S O H
O
HO S HO
O

Ammonium ion also can be represented as formed by the combination of H^+ ion with ammonia molecule by coordination bond.