Covalent Bond

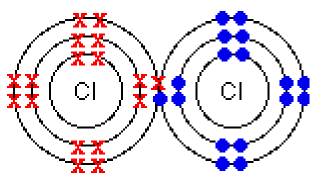
Definition

- Covalent bond (also called electron-pair bond) may be defined as the chemical bond or attractive force between atoms that results from sharing of an electron-pair. Each of the two bonding atoms contributes one electron to the electron-pair (and has equal claim on the shared electron-pair). The shared electron pair is indicated by a dash (─) between the two bonded atoms.
- Two atoms may bind together by one, two or even three covalent bonds.
  H-H, O=O, N≡N.
- The compounds containing a covalent bond are known as **covalent compounds**.

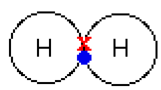
Conditions for Formation of Covalent Bond

1) Combining atoms are non-metals with equal or nearly equal electronegativity.
2) The shared electrons must be unpaired and opposite spin

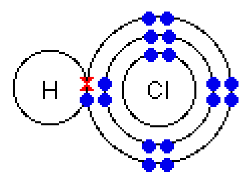
Some very simple covalent molecules



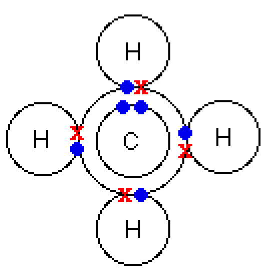
Chlorine



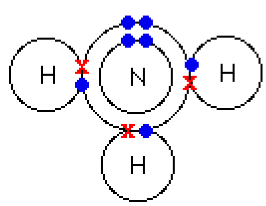
Hydrogen



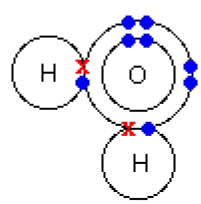
Hydrogen chloride



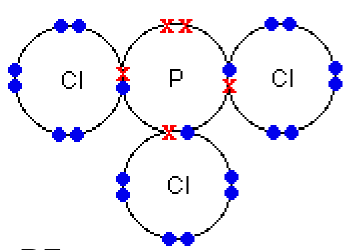
methane



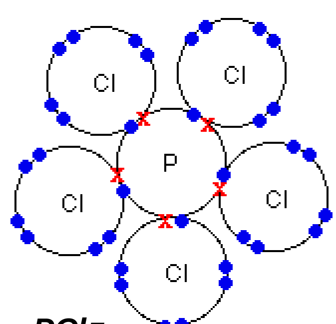
ammonia



water



BF_3



PCl_5

How to draw Lewis dot Structures?
(More examples: General Chemistry by Ebbing, section 9.6 to 9.9)

Simple Rules

You need to follow the following steps:

Step 1 : Calculate the total number of valence electrons.

Example: SF_4 (6+ 4 × 7 = 34)

(i) For polyatomic anions add the number of charges to the total

Example: SO_4^{2-} (6 + 4 × 2 + 2 = 16)

(ii) For polyatomic cations subtract the number of charges from the total

Example: NH_4^+(5 + 4 × 1 -1 = 8)

Step 2 : Divide the total number by 2 to find out the total number of pairs.

Step 3 : Write down the most electropositive atom at the center with other atoms surrounding it. Now distribute the electron pairs so that Octet Rule is followed.

SF_4

Step 4 : If extra pair remains, distribute it to the central atom.

Exception*:* Sometimes formation of multiple bonds may be incorporated to account for the total number of pairs as well as to satisfy the Octet Rule.

$POCl_3$

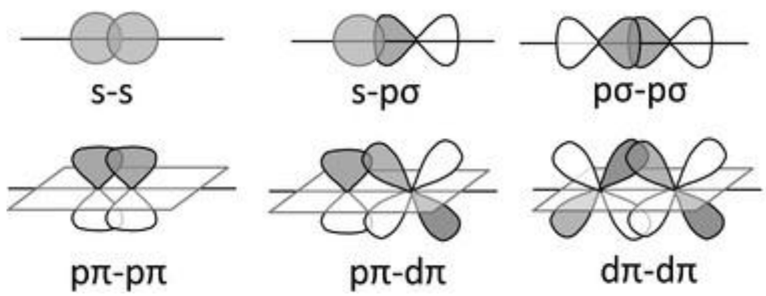
General Properties of Covalent Compounds

- Usually gases, liquids or relatively soft solids at room temperature.
- Low melting points or boiling points.
- Neither hard nor brittle.
- Usually soluble in nonpolar organic solvents (e.g. benzene, ether) and insoluble in water.
- Non-conductor of electricity.
- Exhibit isomerism.
- Molecular reactions are slow

Types of Covalent Bonds

In terms of the molecular orbitals formed, there are two main types of covalent bonds:

Sigma (σ) bonds and **pi (π) bonds**.



Sigma Bonds

- A sigma bond is formed by linear (end-to-end) overlap of orbitals.
- All single covalent bonds and one bond in multiple covalent bonds are sigma bonds.
- It may be obtained by:
- Possible in *s,p,d & hybrid* orbitals

Pi Bonds

- A pi bond is formed by parallel or (side-by-side) overlap of ***p*** orbitals.
- A pi bond has two lobes like ***p*** orbitals □□one half of the bond lies above the plane containing the two nuclei and the other half lies below the plane.
- One bond in double bonds and two bonds in triple bonds are pi bonds.
- Possible in p & d orbitals

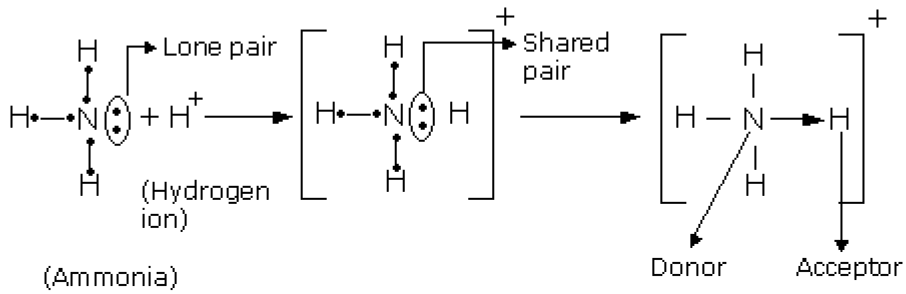
❑Differences between the Sigma and Pi bonds

	Sigma bond	Pi bond
1	It is formed by end-to-end overlapping of half-filled atomic orbitals.	It is formed by the sidewise overlapping of half-filled *p* obitals.
2	Overlapping takes place along the inter-nuclear axis.	Overlapping takes place perpendicular to the inter-nuclear axis.
3	The extent of overlapping is large and the bond formed is stronger.	The extent of overlapping is smaller and the bond formed is weaker.
4	There is free rotation around the sigma bond and so no geometrical isomerism is possible.	There is no free rotation about the pi bond and so geometrical isomerism possible.
5	Possible in ***s,p,d & hybrid*** orbitals	Possible in ***p & d*** orbitals

Co-ordinate covalent bond

If the ion-pair forming the bond is donated by one of the two combining atoms- it is known as Co-ordinate covalent bond, also known as 'dative' bond.

Examples: H_2O (donor) + H^+ (acceptor) → H_3O^+



$:NH_3$ (donor) + H^+ (acceptor) → NH_4^+

$:NH_3$ (donor) + BCl_3 (acceptor) → $H_3N:\rightarrow BCl_3$

- The compounds containing a coordinate bond are called **coordinate compounds** and the molecule or ion that contains the donor atom is called the **ligand**.

Some examples of coordinate compounds or ions

NH_4^+, H_3O^+, BF_4^-, addition compound of NH_3 with BCl_3, CH_3NO_2, SO_2 & SO_3, Al_2Cl_6, SO_4^{2-}, O_3, CO.

Hydrogen bond

A proton or a hydrogen nucleus has a high concentration of positive charge. When a hydrogen atom is bonded to a highly *electronegative* atom, its positive charge will have an attraction for the neighboring electron pairs. This kind of *dipole-dipole* attraction is called a *hydrogen bond*. Hydrogen bond is defined as follows:

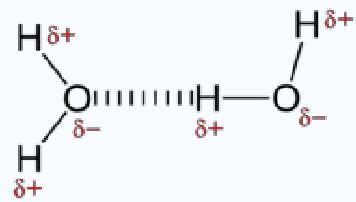
*In compounds where a hydrogen atom is covalently bonded to a highly electronegative atom such as nitrogen, oxygen or fluorine the strong attractive force between hydogen atoms of one molecule for the electronegative atom of another molecule is called the **hydrogen bond**.*

H-bond is of two types::

1. Intermolecular H-bond (e.g H_2O)

2. Intramolecular (e.g nitro phenol)

A common example of *H-bonding* is found in water:



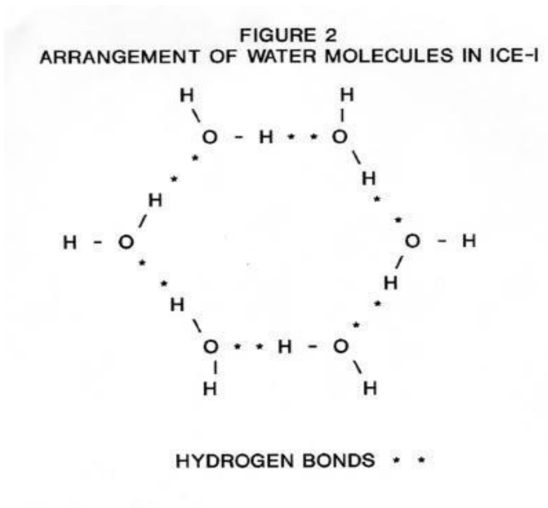
It should be understood that hydrogen bond is an ***intermolecular*** *force and not a bond as is understood in the cases of ionic or covalent bond. No transfer or sharing of electrons occur.*

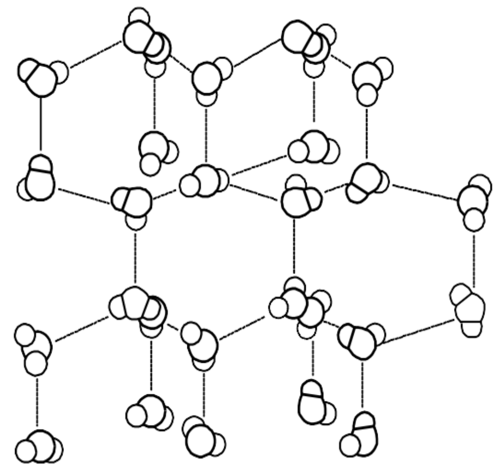
Hydrogen bonding explains **why the *density of ice is less* than that of liquid water.** In the liquid state large number of water molecules joined together by hydrogen bond.

When water starts freezing the hydrogen bonds

between the molecules get fixed and in the solid state, as the molecules cannot move, the

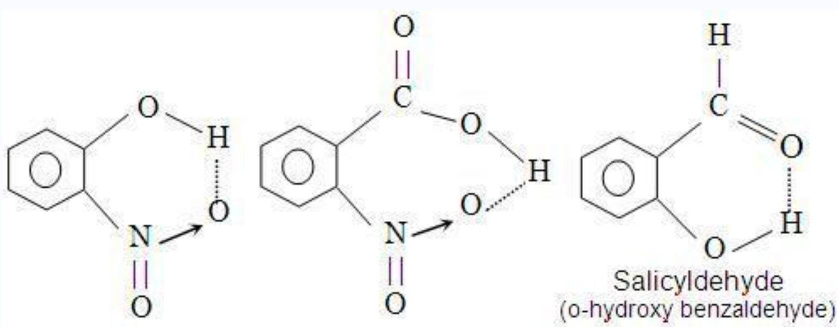
hydrogen bonds between molecules get fixed in position. In the solid state (ice) each oxygen atom is suronded tetrahedrally by four hydrogen atoms: two forming covalent bonds with the *O* atom and are close to it to form H_2O molecule and two from other H_2O molecules farther away from it forming two hydrogen bonds. The result is a three-dimensional structure with empty space. *This is why ice is less dense than water*. When ice melts and liquid is formed again hydrogen bonds are constantly breaking and forming so that molecules can get close to each other giving rise to the liquid. This is a unique property of water and is very important to life on earth.

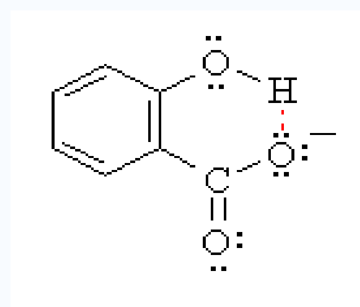




Structure of ice

Intramolecular hydrogen bonding present within a molecule e.g ortho nitro phenol, ortho hydroxyl benzoic acid.



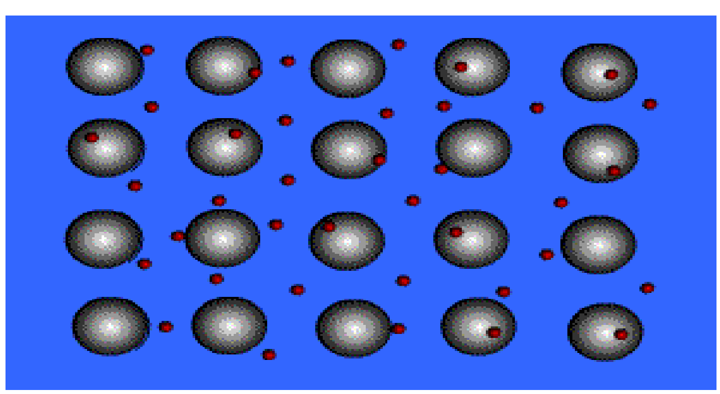


ortho hydroxyl benzoic acid

Metallic Bond

"Bond found in metals; holds metal atoms together very strongly as a result of the attraction between the positive metal cations and surrounding freely mobile negatively electrons."

Examples: Na, Al, Fe, Cu etc.



Physical properties of metal

1. Metals are good conductors of electricity.
2. Metals are good conductors of heat.
3. Metals are opaque and have lusture or colour.
4. Metals are malleable or plastic and ductile.
5. Metals do not combine with metals. They form Alloys which is a solution of a metal in a metal. Examples are steel, brass, bronze and pewter.
6. Metals have elasticity.
7. They possess high tensile strength.
8. They are solid and have high density.
9. Melting and boiling points are higher than covalent compounds.
10. Metals emit electrons.