FARJANA YEASMIN
LECTURER, DEPT. OF FSE

INORGANIC CHEMISTRY

Chemical bonding

Atoms tend to arrange themselves in the most stable patterns possible, which means that they have a tendency to complete or fill their outermost electron orbits. They join with other atoms to do just that. The force that holds atoms together in collections known as molecules is referred to as a chemical bond.

The strength of chemical bonds varies considerably; there are "strong bonds" or "primary bond" such as metallic, covalent or ionic bonds and "weak bonds" or "secondary bond" such as dipole–dipole interactions, the London dispersion force and hydrogen bonding.

Why form chemical bonds?

The basic answer is that atoms are trying to reach the most stable (lowest-energy) state that they can. Many atoms become stable when their valence shell is filled with electrons or when they satisfy the octet rule (by having eight valence electrons) to attain the configuration of the nearest noble gas. Because noble gas configuration is the most stable. If atoms don’t have this arrangement, they’ll “want” to reach it by gaining, losing, or sharing electrons via bonds.

Valence Electrons and Electronegativity

All the elements possess a certain charge, which is expressed as the number of electrons they carry in the outermost or valence shell of their orbit. These electrons are termed as valence electrons, and they play a key role in bond formation. The electronegativity of every element depends on the number of valence electrons it carries. Owing to the fact that each element will have a different number of valence electrons, they can exhibit different number of valence states.

Types of Chemical Bonds

These elements form a bond by either donating, accepting, or sharing electrons. This is the basic principle of chemical bonding. The most common types of chemical bonds include:

1. Ionic bond
2. Covalent bond
3. Metallic Bond

1.Ionic bond

Ionic bonding is nothing but a type of chemical bond formation that involves complete transfer of electrons from one atom to another. When the atoms lose or gain electrons, they become differentially charged ions or oppositely charged ions. The charged ions are then attracted towards each other due to the electrostatic force, which brings the oppositely charged ions together, resulting in the formation of an ionic bond.

Example

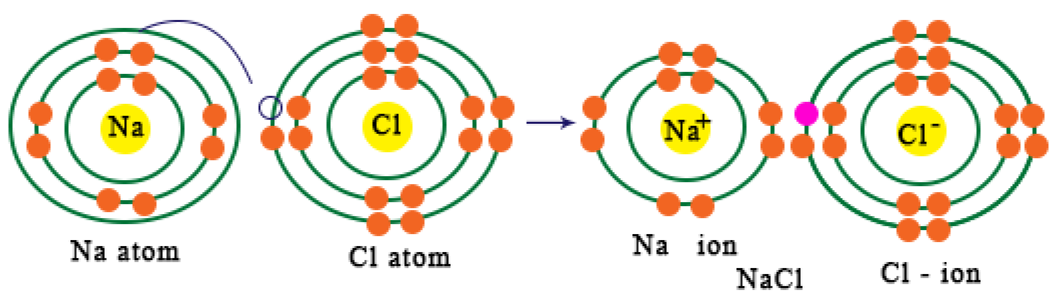
The most common example of ionic bonding is the formation of sodium chloride in which an atom of sodium combines with a chlorine atom.

The electronic configurations of each:

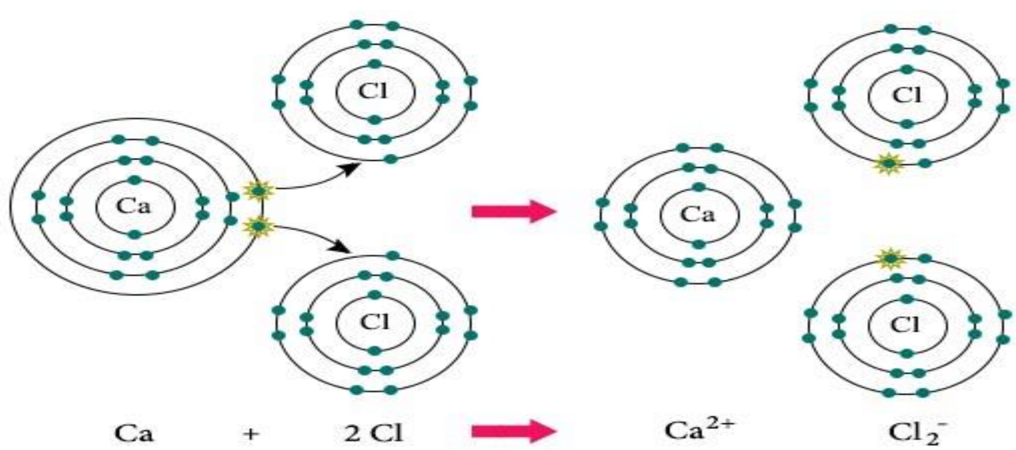
Sodium (Na) : 2,8,1 and Chlorine (Cl) : 2, 8, 7.

Thus, we see that an atom of chlorine requires only one electron to attain the configuration of the nearest noble gas, i.e., Argon (2,8,8). An atom of sodium, on the other hand, requires to get rid of the single electron in its outermost shell to acquire the configuration of the nearest noble gas, i.e., Neon (2,8).

In such a scenario, the sodium atom donates its outermost electron to the chlorine atom, which requires only one electron to attain octet configuration. The sodium ion becomes positively charged due to the loss of an electron, whereas the chloride ion becomes negatively charged due to gain of an additional electron. The oppositely charged ions, thus formed, are attracted to each other and result in the formation of an ionic bond.



Another example is CaCl:



Characteristics

The presence of ionic bonds affects the chemical and physical properties of the resulting compounds. There exist several prominent characteristics of ionic bonds and here is a list of the same.

» Owing to the fact that metals tend to lose electrons and non-metals tend to gain electrons, ionic bonding is common between metals and non-metals. Hence, unlike covalent bonds that can only be formed between non-metals, ionic bonds can be formed between metals and non-metals.

» While naming these compounds, the name of the metal always comes first and the name of the non-metal comes second. For instance, in case of sodium chloride (NaCl), sodium is the metal, whereas chlorine is the non-metal.

» Compounds that contain ionic bonds readily dissolve in water as well as several other polar solvents. These bonds, thus, have an effect on the solubility of the resultant compounds.

» When ionic compounds are dissolved in a solvent to form a homogeneous solution, the solutions tends to conduct electricity.

» Ionic bonding has an effect on the melting point of the compounds as well, as such compounds tend to have higher melting points, which means that these bonds remain stable for a greater temperature range.

Three dimensional structure called an ionic lattice.

Examples of Ionic Compounds and Their Uses

There are many ionic compounds which are brought into use on a daily basis. Some of them are so common that we do not even take notice of such compounds. But the presence of these compounds is inherent to our very existence.

***Ferric oxide:**

The cation in this case is ferric or Fe (III) which forms a compound with anion oxide to form ferric oxide which a common ingredient for ceramic industry.

***Potassium permanganate:**

The cation in this case is Potassium K, which reacts with anion manganate to form potassium manganate which is usually used as anti-bacterial formulations. These are used for bacterial infection of athlete's feet as well as using these for cleaning water resources.

Electrolytic solutions made up of various vital ionic compounds are given either orally or is administered intravenous to help overcome emergency situation during cases like diarrhoea and vomiting which usually results in loss of water and minerals.

***Barium chloride:**

Many of the pyro techniques used by modern day fire cracker industries use barium chloride to bring in the green colour during the actual fire cracker display.

***Calcium chloride:**

In most of the North European countries and North America the use of calcium chloride during winter snow fall goes up. Calcium chloride helps in lowering the freezing point of water and hence the sprinkling of this crystals help in melting the snow and clear roads.

***Potassium iodide:**

The use of potassium chloride tablets for those who work in nuclear plants or areas where the danger of radiation is high is common. Potassium iodide helps in protecting the workers from these hazardous radiation especially the thyroid glands.

***Cobalt chloride:**

The use of cobalt chloride paper in lab to test the presence of water is well known. These papers are also used to detect the presence of moisture in other research units as well. Cobalt chloride when exposed to moisture turn from blue to pink which confirms the presence or the liquid as water. Higher level of moisture turns the paper from light blue to purple and then to deep pink.

***Lithium iodide:**

The lithium iodide paste is used as the main ingredient for all kinds of dry cells where it helps in excellent conduction of electricity.

***Anion and cation resin:**

The use of cation and anion resins help in removing the heavy metallic salts of calcium and magnesium from hard water. The presence of these heavy metals makes the water unusable for drinking as well as washing.

The use of these resins helps in removing only the heavier metals (Ca2+)(Ca2+) and Mg2+)Mg2+) and not metals like Na+.

***Sodium hypochlorite:**

The use of this compound is prevalent in bleaching powder. The chlorite helps in releasing the chlorine when exposed to moisture / water and that helps in bleaching.

***Sodium fluoride:**

Sodium fluoride is used in most of the toothpaste as this helps in maintaining the good health of teeth.

***Sodium nitrate:**

The use of sodium nitrate is mainly for agriculture fields and is considered to be one of the main ingredients of chemical fertiliser.

***Ammonium nitrate:**

This chemical is also used as fertiliser in agricultural fields.

There are several ionic compounds which are brought into use on a daily basis. Some of these are very important as we get to use them on a regular basis and few are used occasionally but these are helpful for a healthy body. Too much of these chemicals in food can also cause serious health issues.

***Sodium Benzoate:**

Sodium benzoate is used for the treatment of multiple sclerosis. These are also used to help reduce the ammonia level decline from our body system. The downside of this chemical is that too much of consumption can cause blood in urine and malignancy.

***Sodium bisulphite**

The use of sodium bisulphite as a preservative of items rich in vitamin C. These chemicals help in preventing of vitamin C breaking down. The downside is breaking down of vitamin B1.

***Sodium chloride (NaCl):**

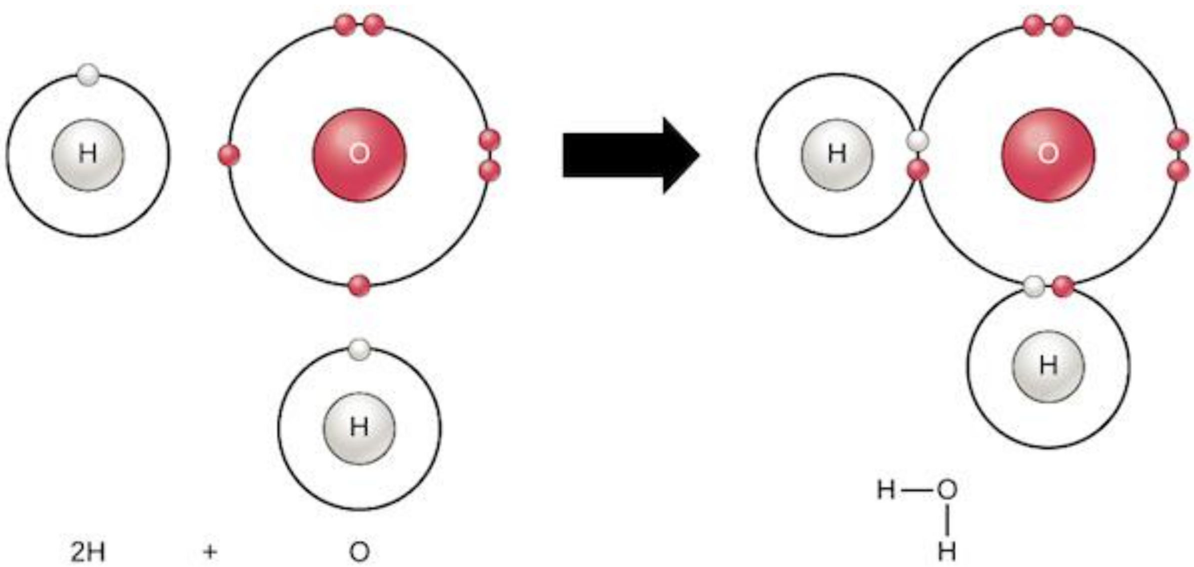
Use of sodium chloride as table salt is household and for any type of food the use of this salt is necessary to make it tasty. Downside is heart related problem in case taken in high amount.

***Sodium phosphate**

This salt is used to treat the prevention of specific type of kidney stones. Moreover, this also helps in lowering the blood pressure. Downside is that it can cause upset stomach and diarrhoea.

2.Covalent bond

The most common bond in organic molecules, a covalent bond involves the sharing of electrons between two atoms. The pair of shared electrons forms a new orbit that extends around the nuclei of both atoms, producing a molecule.

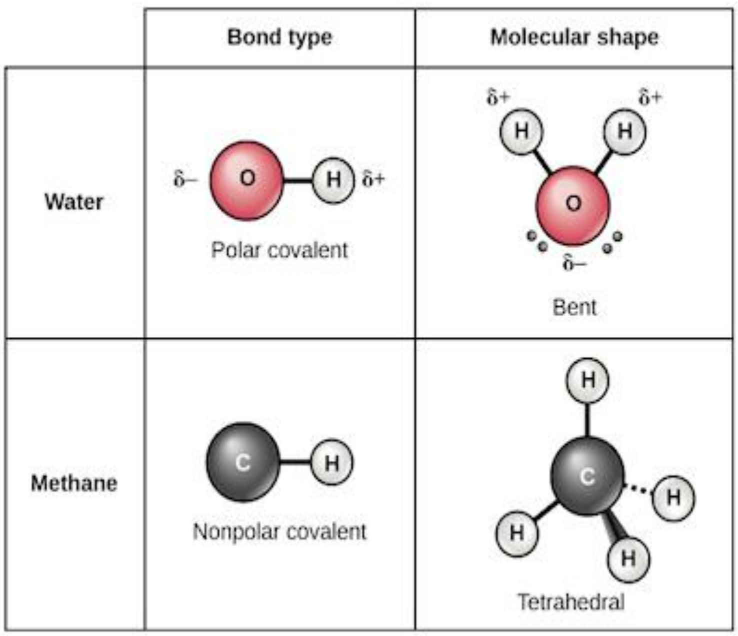


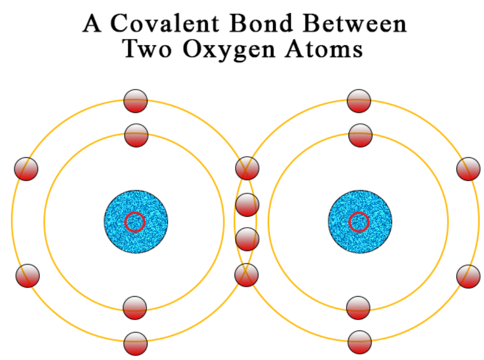
There are two basic types of covalent bonds: polar and nonpolar.

Polar covalent bonds

In a polar covalent bond, the electrons are unequally shared by the atoms and spend more time close to one atom than the other. Because of the unequal distribution of electrons between the atoms of different elements, slightly positive (δ+) and slightly negative (δ–) charges develop in different parts of the molecule.

In a water molecule, the bond connecting the oxygen to each hydrogen is a polar bond. Oxygen is a much more electronegative atom than hydrogen, meaning that it attracts shared electrons more strongly, so the oxygen of water bears a partial negative charge (has high electron density), while the hydrogens bear partial positive charges (have low electron density).





Nonpolar covalent bonds

Nonpolar covalent bonds form between two atoms of the same element, or between atoms of different elements that share electrons more or less equally. For example, molecular oxygen (O_2) is nonpolar because the electrons are equally shared between the two oxygen atoms.

Another example of a nonpolar covalent bond is found in methane (CH_4). Carbon has four electrons in its outermost shell and needs four more to achieve a stable octet. It gets these by sharing electrons with four hydrogen atoms, each of which provides a single electron. Reciprocally, the hydrogen atoms each need one additional electron to fill their outermost shell, which they receive in the form of shared electrons from carbon. Although carbon and hydrogen do not have exactly the same electronegativity, they are quite similar, so carbon-hydrogen bonds are considered nonpolar

c**haracteristics of covalent compounds:**

(i) Low melting and boiling points:

Covalent compounds consist of molecules held by weak forces. These can be easily overcome by heat. Thus, covalent compounds have low melting points and low boiling points.

(ii) Non-conducting nature:

Covalent compounds do not conduct electricity, i.e., electricity does not pass through the covalent compounds. This is because the covalent compounds do not contain ions, or free electrons. Sugar is a covalent compound, and its solution does not conduct electricity. Solutions of polar covalent compounds, e.g., HCl, conduct electricity due to the presence of ions in solutions.

(iii) Solubility:

Covalent compounds are usually insoluble not polar solvents like water. The covalent compounds however, dissolve in non-polar solvents, like benzene, toluene, etc.

(iv) Slow rate of reaction:

The reactions of the covalent compounds are quite slow. This is because the covalent compounds take part in reactions as molecules, and the molecular reactions are slow.

(v) Isomerism:

Covalent bonds are rigid and directional. Therefore, these can give different arrangements of atoms in space. So, a single molecular formula may represent a number of different compounds with different properties. This phenomenon is called isomerism.

Some common covalent compounds with their names and chemical formulae are listed below.

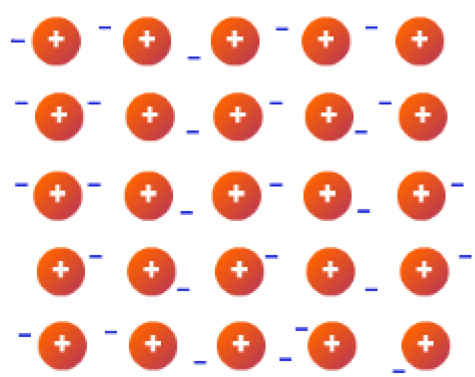
Covalent compound	**Name of covalent compound**
CH_3CH_2OH	Ethanol
O_3	Ozone
H_2	Hydrogen
CO_2	Carbon dioxides
CO	Carbon monoxide
CH_4	Methane
NH_3	Ammonia
ClF_3	Chlorine trifluoride
PCl_3	Phosphorus trichloride
PCl_5	Phosphorus pentachloride
SO_2	Sulfur dioxide
SF_6	Sulfur hexafluoride
SeO	Selenium monoxide
H_2O	Water
HCl	Hydrogen chloride
BrF_5	Bromine pentafluoride
N_2O_5	Dinitrogen pentoxide
NO_2	Nitrogen dioxide
O_2F_2	Dioxygen difluoride
AsO_3	arsenic trioxide
XeF_6	xenon hexafluoride
S_2F_2	Disulfur difluoride

ICl_3	iodine trichloride
ClF_3	Chlorine trifluoride
S_2Br_2	disulfur dibromide

3.Metallic bond

Metallic bond is a type of chemical bond formed between positively charged atoms in which the free electrons are shared among a lattice of cations. In contrast, covalent and ionic bonds form between two discrete atoms. Metallic bonding is the main type of chemical bond that forms between metal atoms.

The schematic representation of metallic bonding is shown below. The valence electrons become dissociated with their atomic core and form an electron "sea" that acts as the binding medium between the positively charged ions.



Examples for materials having metallic bonds are most metals such as Cu, Al, Au, Ag etc. Transition metals (Fe, Ni etc) form mixed bonds that are comprised of covalent bonds (involving their 3d-electrons) and metallic bonds. This is one of the reasons why they are less ductile than Cu, Ag and Au. Metallic bonds are seen in pure metals and alloys and some metalloids. For example, graphene (an allotrope of carbon) exhibits two-dimensional metallic bonding. Metals, even pure ones, can form other types of chemical bonds between their atoms.

Characteristics of metallic bond:

Metallic Luster

- The bright luster of metals is due to the presence of delocalised mobile electrons.
- When light falls on the surface of the metal, the loosely held electrons absorb photons of lights.
- They get promoted to higher energy levels (excited state), oscillating at a frequency equal to that of the incident light.
- These oscillating electrons readily return from the higher to the lower levels of energy by releasing energy, thus becoming a source of light radiations.
- Light appears to be reflected from the metal surface and the surface acquires a shining appearance, which is known as metallic luster.

Electrical conductivity

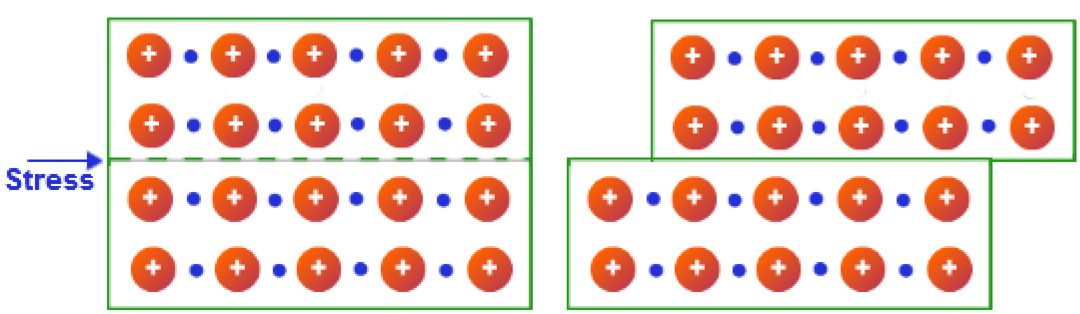
- The presence of mobile electrons causes electrical conductivity of a metal. When a potential difference is applied to the metal sheet, the free mobile electrons in the metallic crystal start moving towards the positive electrode.
- The electrons coming from the negative electrode simultaneously replace these electrons.
- Thus, the metallic sheet maintains the flow of electrons from the negative electrode to positive electrode. This constitutes **electrical conductivity.**

Thermal conductivity

- When a part of the metal is heated, the kinetic energy of the electrons in that region increases.
- Since the electrons are free and mobile, these energetic electrons move rapidly to the cooler parts and transfer their kinetic energy by means of collisions with other electrons.
- Therefore, the heat travels from hotter to cooler parts of the metals.

Malleability and ductility

- Metals can be beaten into sheets (malleability) and drawn into wires (ductility). Metallic bonds are nondirectional in nature.
- Whenever any stress is applied on metals, the position of adjacent layers of metallic kernels is altered without destroying the crystal.
- The metallic lattice gets deformed but the environment of kernels does not change and remains the same as before.
- The deforming forces simply move the kernels from one lattice site to another.



High tensile strength

- Metals have high tensile strength. Metals can resist stretching without breaking.
- A strong electrostatic attraction between the positively charged kernels and the mobile electrons surrounding them is the reason for tensile strength.

Hardness of metals

- The hardness of metals is due to the strength of the metallic bond. In general, the strength of a metallic bond depends upon:
- The greater the number of valence electrons for delocalisation the stronger is the metallic bond.
- Smaller the size of the kernel of metal atom, greater is the attraction for the delocalised electrons. Consequently, stronger is the metallic bond.
- For example, alkali metals have only one valence electron and larger atomic kernels, which makes the metallic bonds weak. Consequently, these metals are soft metals.

Opaqueness

- The light that falls on metals is either reflected or completely absorbed by the delocalised electrons.
- Because of this, no light is able to pass through metals and they are termed as opaque.

Melting and boiling points

- Metals have metallic bond strengths, which is intermediate to that of covalent and ionic bonds.

- Therefore in general, metals have boiling and melting points in between to that of covalent and ionic compounds.

Hydrogen bond

Because they're polarized, two adjacent H_2O (water) molecules can form a linkage known as a hydrogen bond, where the (electronegative) hydrogen atom of one H2O molecule is electrostatically attracted to the (electropositive) oxygen atom of an adjacent water molecule.

Consequently, molecules of water join together transiently in a hydrogen-bonded lattice. Hydrogen bonds have only about 1/20 the strength of a covalent bond, yet even this force is sufficient to affect the structure of water, producing many of its unique properties, such as high surface tension, specific heat, and heat of vaporization. Hydrogen bonds are important in many life processes, such as in replication and defining the shape of DNA molecules.

In a polar covalent bond containing hydrogen (e.g., an O-H bond in a water molecule), the hydrogen will have a slight positive charge because the bond electrons are pulled more strongly toward the other element. Because of this slight positive charge, the hydrogen will be attracted to any neighboring negative charges. This interaction is called a hydrogen bond.

The comparison of ionic bond, covalent bond, and metallic bond is discussed below.

Ionic Bond	Covalent Bond	Metallic Bond
The transfer of electrons between two atoms having different electronegativities forms this bond.	This bond is formed by the mutual sharing of electrons between same or different elements.	This bond is formed due to the attraction between kernels and the mobile electrons in a metal lattice.
This is a strong bond due to electrostatic force of attraction.	This is also a fairly strong bond because the electron pair is strongly attracted by two nuclei.	This is a weak bond due to the simultaneous attraction of the electrons by a large number of kernels
This is a non-directional bond.	This is a directional bond.	This is a non-directional bond.
This bond makes substances hard and brittle.	This bond makes substances hard and incompressible.	This bond makes substances malleable and ductile.