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Valency

The term 'valency' has been derived from the Latin word 'valentia' meaning 'combining power' or 'combining capacity'. Thus,

"The combining capacity of an atom is called its valency."

Valency of an element depends upon its electronic configuration and especially upon the number of electrons in its outermost shell (valence shell) and is determined using following rules-

(1) If an atom contains 8 electrons in its outermost shell i.e. it has complete octet (ns^2, np^6), then its valency is zero. For example, inert gases like Ne, Ar, Kr etc.

Ne (10) - $1s^2$, $2s^2$, $2p^6$	**Valency = 0**
Ar (18) - $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$	**Valency = 0**

Helium is its exception, where first shell is outermost shell, which can accommodate only a maximum of two electrons. Hence, for He duplet configuration ($1s^2$) is stable configuration and its valency is zero.

(2) If only outermost shell of an atom is incompletely filled, then its valency depends upon the number of electrons in its outermost shell. Here,

(a) If the outermost shell contains 1 - 4 electrons, then its valency is equal to the number of electrons in the outermost shell. For example,

Li (3) - $1s^2$, $2s^1$	**Valency = 1**
Be (4) - $1s^2$, $2s^2$	**Valency = 2**
B (5) - $1s^2$, $2s^2$, $2p^1$	**Valency = 3**
C (6) - $1s^2$, $2s^2$, $2p^2$	**Valency = 4**
Na (11) - $1s^2$, $2s^2$, $2p^6$, $3s^1$	**Valency = 1**
Mg (12) - $1s^2$, $2s^2$, $2p^6$, $3s^2$	**Valency = 2**
Al (13) - $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^1$	**Valency = 3**

(b) If it contains 4 - 7 electrons, then its valency is equal to (8 - n), where n is number of electrons in the outermost shell of the atom. For example,

N (7) - $1s^2$, $2s^2$, $2p^3$	**Valency = (8-5) = 3**
O (8) - $1s^2$, $2s^2$, $2p^4$	**Valency = (8-6) = 2**
F (9) - $1s^2$, $2s^2$, $2p^5$	**Valency = (8-7) = 1**

(3) If outer two shells of an atom are incompletely filled, then valency of the atom depends upon the number of electrons in both of these two shells. These atoms show variable valencies. For example, transition metals.

Electronic theory of valency
or
Cause of chemical combination
(Octet Theory)

Electronic theory of valency was for the first time proposed by Kossel and Lewis. The main postulates of this theory are as under-

(1) Those elements which contain 8 electrons in their outermost shell i.e. which have complete octet (ns^2, np^6), are highly stable and do not take part in chemical combination e.g. inert gases like Ne, Ar, Kr etc.

Ne (10) - $1s^2$, $2s^2$, $2p^6$

Ar (18) - $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$

Thus, octet configuration (ns^2, np^6) is the stable electronic configuration of the elements. Helium is its exception, where first shell is outermost shell, which cannot accommodate more than two electrons. Hence, for Helium, duplet configuration ($1s^2$) is the stable configuration.

(2) Those elements which do not contain 8 electrons in their outermost shell i.e. which have incomplete octet, are unstable and therefore, they give, take or share electrons to complete their octet. Hence, they have tendency to take part in chemical combination.

Thus, the tendency of elements to complete their octet i.e. to gain stability by acquiring stable electronic configuration of their nearest inert gas, is the principal cause of chemical combination.

Types of chemical bonds

Chemical bonds are mainly of following three types-

(1) Electrovalent bond-

"The bonds formed by transfer of one or more electrons between the atoms are called electrovalent bonds."

The number of electrons given or taken by one atom of an element during the formation of these bonds is called electrovalency of the element."

Here, the atom which gives electron, becomes positively changed while, that which takes electron, becomes negatively changed. The oppositely changed ions thus formed, get bonded together by strong electrostatic force of attraction.

Examples –

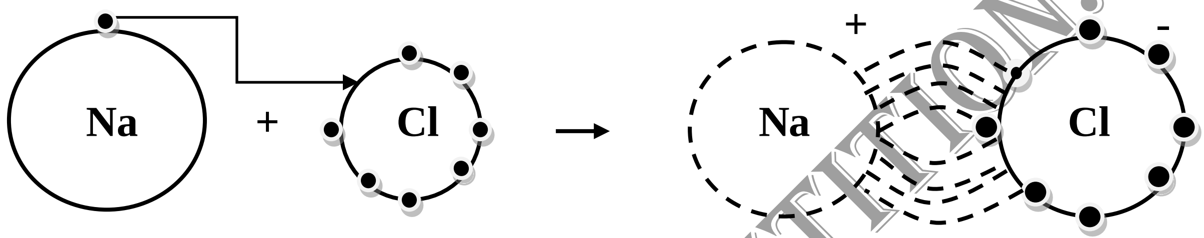
(1) Formation of Sodium chloride (NaCl) -

The electronic configuration of sodium and chlorine atoms are as under-

Na (11) - $1s^2, 2s^2, 2p^6, 3s^1$

Cl (17) -$1s^2, 2s^2, 2p^6, 3s^2, 3p^5$

During formation of NaCl, sodium atom transfers its valence electron to the outermost shell of chlorine atom. It results in the formation of Na^+ and Cl^- ions, which get bonded together by electrostatic force of attraction. Here, the electrovalency of both sodium and chlorine atoms is 1.



Na - atom	Cl - atom	Na^+ ion	Cl^- ion
(2, 8, 1)	(2, 8, 7)	(2, 8)	(2, 8, 8)

Fig.- Formation of NaCl (diagrammatic)

Thus, both sodium and chlorine atoms acquire the stable electronic configuration of their nearest inert gas i.e. Ne and Ar respectively.

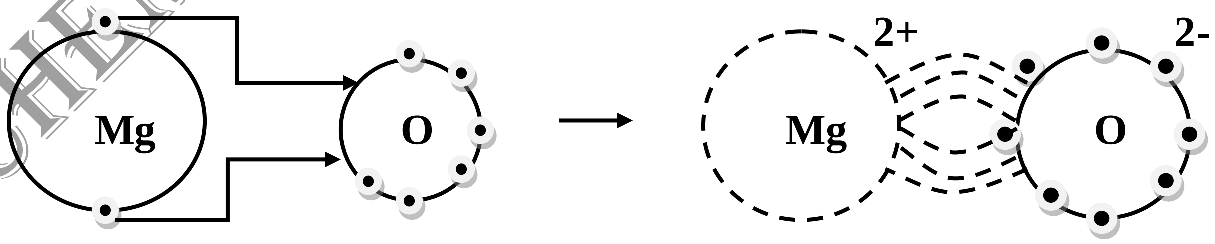
(2) Formation of Magnesium oxide (MgO) -

The electronic configuration of magnesium and oxygen atoms are as under-

Mg (12) - $1s^2, 2s^2, 2p^6, 3s^2$

O (8) -$1s^2, 2s^2, 2p^4$

During formation of MgO, magnesium atom transfers its both the valence electrons to the outermost shell of oxygen atom. It results in the formation of Mg^{2+} and O^{2-} ions, which get bonded together by electrostatic force of attraction. Here, the electrovalency of both magnesium and oxygen atoms is 2.



Mg - atom	O - atom	Mg^{2+} ion	O^{2-} ion
(2, 8, 2)	(2, 6)	(2, 8)	(2, 8)

Fig.- Formation of MgO (diagrammatic)

Thus, both magnesium and oxygen atoms acquire the stable electronic configuration of their nearest inert gas i.e. Ne.

(3) Formation of Magnesium chloride ($MgCl_2$) -

The electronic configuration of magnesium and chlorine atoms is as under-

Mg (12) - $1s^2, 2s^2, 2p^6, 3s^2$

Cl (17) -$1s^2, 2s^2, 2p^6, 3s^2, 3p^5$

During formation of $MgCl_2$, magnesium atom transfers its both the valence electrons to the outermost shell of two chlorine atoms (one each). It results in the formation of Mg^{2+} and Cl^- ions, which get bonded together by electrostatic force of attraction. Here, the electrovalency of magnesium atom is 2 while, that of chlorine atoms is 1.

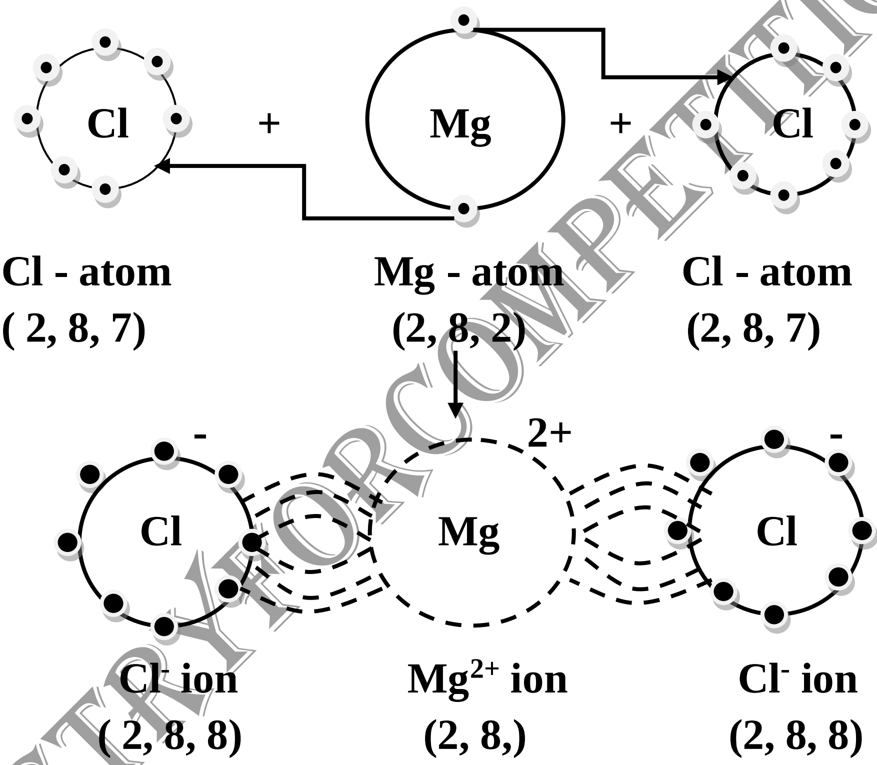


Fig.- Formation of $MgCl_2$ (diagrammatic)

Thus, both magnesium and chlorine atoms acquire the stable electronic configuration of their nearest inert gas.

Conditions of formation of electrovalent bonds-

(1) When a highly electropositive element (metal) combines with highly electronegative element (nonmetal), then electrovalent bond is formed between them.

(2) If an element can complete its octet by giving one or more electrons and other can do so by gaining one or more electrons, then electrovalent bond is formed between them.

(3) If difference in electronegativities of two elements is more than 1.7, then electrovalent bond is formed between them.

Properties of Electrovalent compounds-

(1) Electrovalent compounds are ionic in nature i.e. they are consisting of oppositely charged ions bonded together by strong electrostatic force of attraction.

(2) Since, strong electrostatic force of attraction operates between oppositely charged constituent ions, these compounds have very high melting and boiling points.

(3) These compounds have high thermal stability and therefore, do not decompose on heating.

(4) Being ionic in nature, these compounds are highly soluble in polar solvents like water.

(5) When these compounds are dissolved in water or melted, they get dissociated into their constituent ions. For example,

$$NaCl(s) \xrightarrow{Water} Na^{+}(aq.) + Cl^{-}(aq)$$

This phenomenon is called dissociation.

(6) Due to presence of ions, the aqueous solutions and molten forms of these compounds are good conductor of electricity.

(7) Electrovalent compounds are, in general, solid at room temperature.

(8) Electrovalent bonds are non-directional in nature. Hence, electrovalent compounds do not have a definite geometry.

(2) Covalent bond -

"The bonds formed by equal sharing of electrons between the atoms are called covalent bonds."

The number of electrons shared by one atom of an element for the formation of a covalent bond is called covalency of the atom.

Here, shared electron pair lies simultaneously in the outermost shell of both the bonded atoms and provides them stability.

Depending upon the number of shared electron pairs between the bonded atoms, being 1, 2 and 3, covalent bonds are called single, double and triple bonds respectively and are represented by placing single, double and triple lines between the bonded atoms respectively.

Examples-

(1) Formation of H_2 molecule –

The electronic configuration of hydrogen atom is as under-

H (1) - $1s^1$

Thus, it needs one electron to complete its duplet i.e. stable electronic configuration of its nearest inert gas helium. Hence, two hydrogen atoms share one electron each to form a shared electron pair, which lies simultaneously in outermost shell of both the hydrogen atoms and provides them stability.

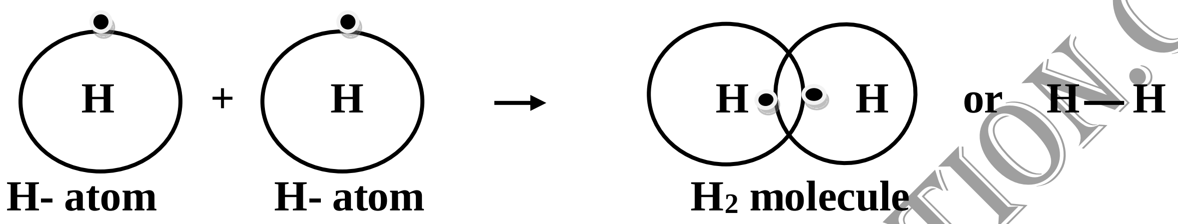


Fig.- Formation of H_2 molecule

Here, both the hydrogen atoms give one electron in shared pair, therefore, their covalency is 1.

(2) Formation of HF molecule –

The electronic configuration of hydrogen and fluorine atoms are as under-

H (1) - $1s^1$

F (9) -$1s^2$, $2s^2$, $2p^5$

Here, both hydrogen and fluorine atoms need one electron to acquire the stable electronic configuration of their nearest inert gas. Hence, they share one electron each to form a shared electron pair, which lies simultaneously in outermost shell of both the atoms and provides them stability.

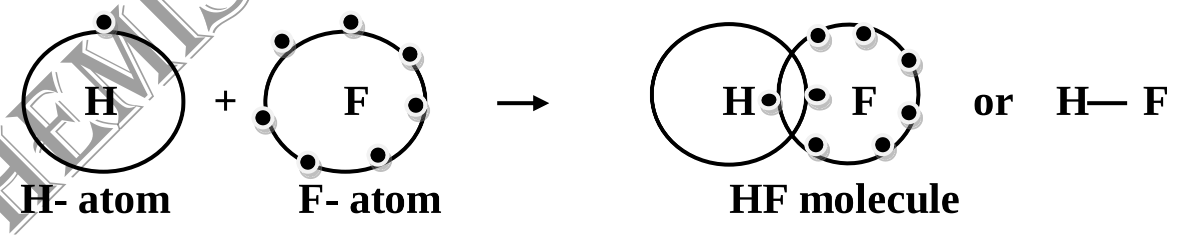


Fig.- Formation of HF molecule

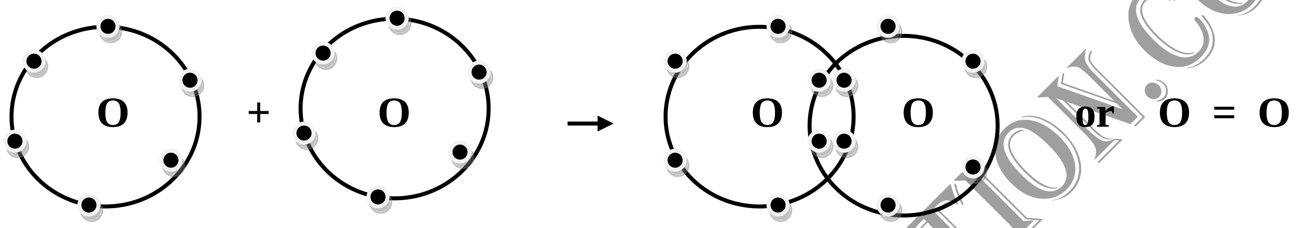
Here, both hydrogen and fluorine atoms give one electron each in shared pair, therefore, their covalency is 1.

(3) Formation of O_2 molecule –

The electronic configuration of oxygen atom is as under-

O (8) -$1s^2$, $2s^2$, $2p^4$

Here, both oxygen atoms need two electrons to acquire the stable electronic configuration of their nearest inert gas i.e. neon. Hence, they share two electrons each to form two shared electron pairs, which lie simultaneously in outermost shell of both the atoms and provide them stability.



O- atom O- atom O_2 molecule

Fig.- Formation of O_2 molecule

Here, both the oxygen atoms give two electrons each in shared pairs,therefore, their covalency is 2.

Conditions of formation of covalent bonds-

(1) When two highly electronegative elements (nonmetals) combine together, then covalent bond is formed between them.

(2) If both the atoms require one or more electrons to complete their octet (ns^2, np^6), then covalent bond is formed between them.

(3) If difference in electronegativities of two elements is less than 1.7, then covalent bond is formed between them.

Properties of Covalent compounds-

(1) Covalent compounds are molecular in nature i.e. they are consisting of neutral molecules, bonded together by weak vander Waal forces.

(2) Since, weak vander Waal forces operate amongst constituent molecules, these compounds have relatively low melting and boiling points.

(3) Covalent compounds are usually insoluble in water. However, they are fairly soluble in non-polar solvents like benzene, carbon tetrachloride, chloroform etc.

(4) Due to absence of ions, the aqueous solutions and molten forms of these compounds are in general, bad conductor of electricity.

(5) These compounds are thermally unstable and therefore, get decomposed on heating.

(6) Covalent bonds are directional in nature i.e. they are formed in some definite directions and provide a definite shape to the molecules. Thus, covalent compounds have a definite geometry.

(3) Co-ordinate bond

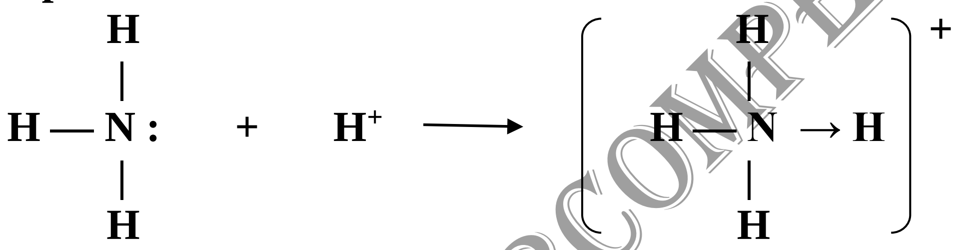
It is a special type of covalent bond, where both the electrons of shared pair are given only by one atom and they are simply shared by another atom. Thus,

"The bonds formed by unequal sharing of electrons between the atoms are called coordinate bonds."

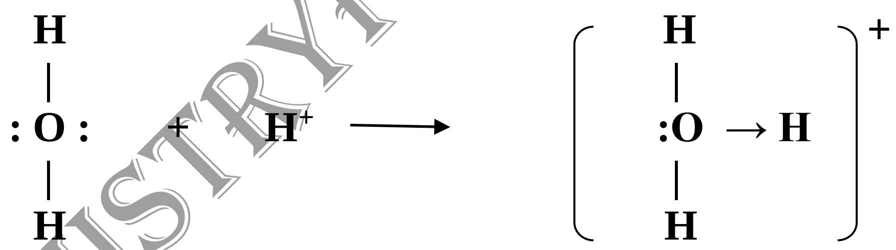
Here, the atom which gives electron pair for sharing is called donor, while that which shares it is called acceptor. Hence, this bond is also called donor – acceptor bond.

Coordinate bonds are represented by arrow (→) directed from donor to acceptor.

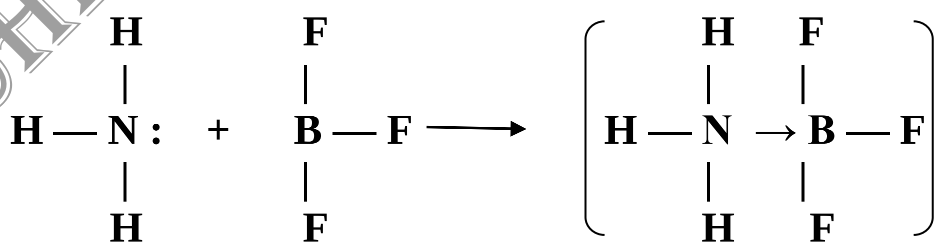
Examples –

(1) 

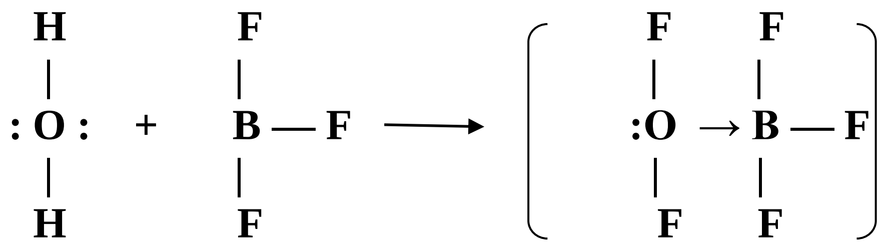
Ammonia (Donor) + Proton (Acceptor) → Ammonium ion

(2) 

Water (Donor) + Proton (Acceptor) → Hydronium ion

(3) 

Ammonia (Donor) + Boron trifluoride (Acceptor) → Addition compound

(4) 

Water (Donor) Boron trifluoride (Acceptor) Addition compound

Co-ordinate bonds are also called semi-polar or dative bonds.

Conditions of formation of co-ordinate bonds-

If an atom contains one or more lone pair of electrons and can donate it to the other atom, while the other atom is electron deficient and can accept one or more lone pair of electrons, then co-ordinate bond is formed between them.

Properties of Co-ordinate compounds-

(1) co-ordinate compounds are molecular in nature i.e. they are consisting of neutral molecules, bonded together by weak vander Waal forces.

(2) Since, weak vander Waal forces operate amongst constituent molecules, these compounds have low melting and boiling points. However, it is higher than those of covalent compounds.

(3) These compounds are usually insoluble or sparingly soluble in water.

(4) Due to absence of ions, the aqueous solutions and molten forms of these compounds are bad conductor of electricity.

(5) These compounds are thermally unstable and therefore, get decomposed on heating.

(6) Co-ordinate bonds are directional in nature i.e. they are formed in some definite directions and provide a definite shape to the molecules. Thus, these compounds have a definite geometry.