Chemical Bonding

Improve your learning

Q. 1. List the factors that determine the type of bond that will be formed between two atoms?

Answer : i. Electronegativity difference between the atoms.

ii. Number of valence electrons present in the valence shell of the atom.

iii. The force of attraction and repulsion between electrons and protons.

iv. Electron affinity

v. Ionization potential

vi. Atomic size

Q. 2. Explain the difference between the valence electrons and the covalence of an element.

Answer :

Sl.no	**Valence electrons**	**Covalence**
1	Number of electrons present in the valence shell.	Capacity of atoms to either gain or lose electrons is covalence.
2	Number of electrons is equal to the group number of the atom.	Number of electrons participating in the bonding.
3	It is always a positive integer.	Covalence may be positive or negative.

Q. 3. A chemical compound has the following Lewis notation:

a) How many valence electrons does element Y have?
b) What is the valency of element Y ?
c) What is the valency of element X ?
d) How many covalent bonds are there in the molecule?

e) Suggest a name for elements X and Y.

Fig-Q3

Answer : (a) Six (all the crosses represent the valence electrons)

(b) Two (two more electrons are required to obtain octet)

(c) One (one more electron needed to obtain stable duplet structure)

(d) Two bonds

X can be Hydrogen and Y can be oxygen

Q. 4. Why do only valence electrons involve in bond formation? Why not electron of inner shells? Explain.

Answer : Electrons in the inner shells are strongly attracted by the nucleus and are stable thereby they don't involve in bond formation. The electrons in the outermost shells of atoms are called valence electrons which are highly active an are weakly attracted by the nucleus of atom. So they are easily transferred or migrated, so undergo chemical reactions.

Q. 5. Explain the formation of sodium chloride and calcium oxide on the basis of the concept of electron transfer from one atom to another atom.

Answer : <u>Sodium chloride</u>

i. Sodium chloride is formed between sodium and chlorine.

ii. Sodium ($_{11}Na^{23}$) configuration is $1s^2 2s^2 2p^6 3s^1$

iii. Chlorine ($_{17}Cl^{35}$) configuration is $1s^2 2s^2 2p^6 3s^2 3p^5$

iv. So, sodium tends to lose a electron i.e. $3s^1$ to obtain octet in its 2^{nd} shell.

v. Chlorine tends to gain a electron to become $3p^6$ to obtain octet in its 3^{rd} shell.

vi. In this way, both sodium and chlorine become stable.

vii. So, sodium loses electron and gains positive charge and is called as sodium ion which is a cation - Na^{+1}

viii. chlorine gains electron and gains negative charge and is called as chloride ion which is a anion – Cl^{-1}

ix. ionic bond is formed by the transfer of electrons and the compound formed is sodium chloride.

x. $Na^{+} + Cl^{-} \rightarrow NaCl$

Calcium oxide

i. Calcium oxide if formed by combination of calcium and oxygen.

ii. Calcium ($_{20}Ca^{40}$) configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$.

iii. Oxygen ($_{8}O^{16}$) configuration is $1s^2 2s^2 2p^4$.

iv. Outer shell of calcium (4^{th}) contains 2 electrons. So it tends to lose these

2 electrons to obtain octet in its 3^{rd} shell which then becomes its outermost shell. Oxygen tends to gain 2 electrons to obtain octet in its outermost 2^{nd} shell.

v. In this way, both calcium and oxygen become stable.

vi. So, calcium loses 2 electrons and gains positive charge and is called as calcium ion which is a cation – Ca^{+2}

vii. oxygen gains 2 electrons and gains negative charge and is called as oxide ion which is an anion – O^{-2}

viii. ionic bond is formed by the transfer of electrons and the compound formed is calcium oxide.

ix. $Ca^{+2} + O^{-2} \rightarrow CaO$

Q. 6. A. B. and C are three elements with atomic number 6, 11 and 17 respectively.

i. Which of these cannot firm ionic bond? Why?
ii. Which of these cannot form covalent bond? Why?
iii. Which of these can form ionic as well as covalent bonds?

Answer : we know that

A is Carbon – $_{6}C^{12}$

B is Sodium – $_{11}Na^{23}$

C is Chlorine – $_{17}Cl^{35}$

(i) The configuration of carbon is $1s^2 2s^2 2p^2$. It has exactly 4 electrons

in its outermost shell. So, it neither loses nor gains electrons to obtain octet. Rather it shares electrons with other atoms and gets stable by obtaining octet structure. So, it forms covalent compounds but not ionic compounds.

(ii) The configuration of sodium is $1s^2 2s^2 2p^6 3s^1$. So, to obtain octet and become stable, it can easily lose an electron which is $3s^1$. Therefore, sodium forms ionic compounds.

(iii) The Chlorine ($_{17}Cl^{35}$) configuration is $1s^2 2s^2 2p^6 3s^2 3p^5$. So, it can

easily gain an electron to obtain octet , thereby forming ionic compounds. But it can also share electrons and form covalent compounds like in the case of HCl. So, chlorine forms both ionic and covalent compounds.

Q. 7. How bond energies and bond length d of molecule helps us in predicting their chemical properties? Explain with the examples.

Answer : Bond length is defined as the distance between the nuclei of 2 atoms which are involved in bonding. Bond energy is defined as the energy required to break the bond between 2 atoms of a diatomic covalent compound in its gaseous state. Bond energy is generally inversely proportional to bond length. For ex. Chlorine has smaller sized atoms, lesser bond length so high bond energy. Iodine has bigger atoms, more bond length, so less bond energy.

The lesser the bond energy, more is the instability and more is the chemical reactivity. The higher the bond energy, more is the stability and less is the chemical reactivity.

Q. 8. Predict the reasons for low melting point for covalent compounds when compared with ionic compound.

Answer : Melting point depends on the force of attraction between molecules and atoms of compounds or elements.

In case of covalent compounds there exists weak vander-waal forces

between molecules. So, lower temperatures are sufficient to break these bonds. But ionic compounds contain strong electrostatic forces which need high energy to break, demanding high melting temperatures. Some exceptions in covalent materials exist like diamond, graphite which demand high melting temperature because of their giant complex structure.

Q. 9. Collect the information about properties and uses of covalent compound and prepare report?

Answer :

Properties –

i. These compounds contain directional covalent bonds which involve sharing of electrons.

ii. They exhibit isomerism.

iii. They are usually liquids or gases in nature, but some are solids.

iv. They are freely soluble in non-polar solvents like benzene and generally insoluble in polar solvents like water.

v. They have lower melting and boiling points.

Uses-

i. Majority constituents in our body are covalent compounds.

ii. Water is a covalent compound and it has many uses.

iii. Most of the organic compounds are covalent compounds.

iv. Sugar, vinegar, cooking gas are all covalent compounds.

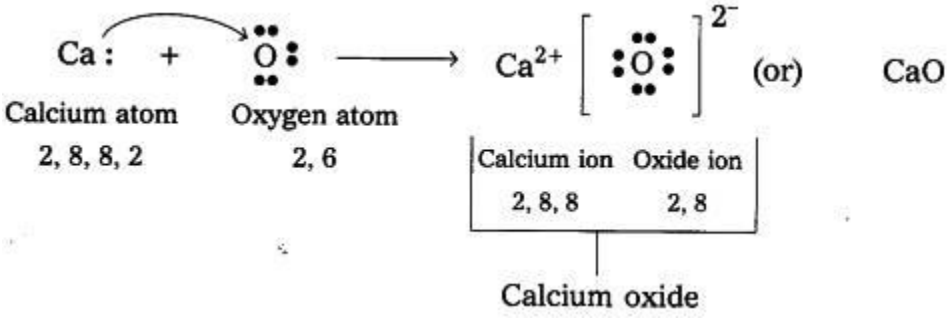
v. Important gases like CO_2, NH_3 are all covalent compounds.

Q. 10. Draw simple diagrams to show how electron are arranged in the following covalent molecules:

a) Calcium oxide (CaO)
(b) Water (H_2O)
(c) Chlorine (Cl_2)

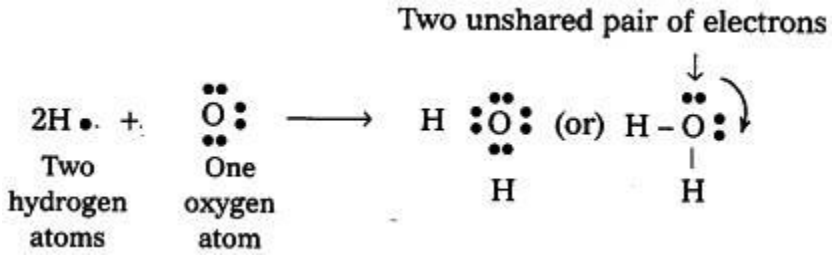
Answer :

(a) Calcium oxide

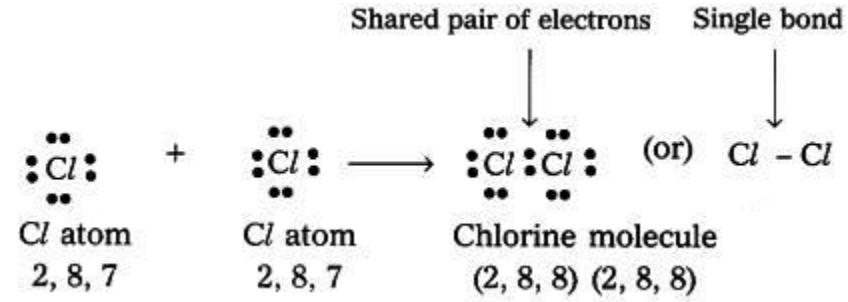


(b) <u>Water Molecule:</u>

One oxygen and 2 hydrogen atoms combine to form water molecule.

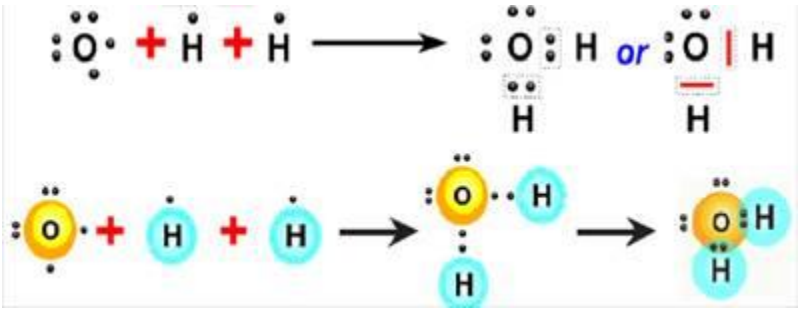


(c) <u>Chlorine</u>



Q. 11. Represent the molecule H_2O using Lewis notation.

Answer :



One atom of oxygen and 2 atoms of hydrogen form 1 molecule of water.

Q. 12. Represent each of the following awns using Lewis notation:

(a) beryllium
(b) calcium
(c) lithium

Answer :

(a) $_4Be^9$ – $1s^2 2s^2$ – lewis notation is

(b) $_{20}Ca^{40}$ – $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ – lewis notation is

(c) $_3Li^6$ – $1s^2 2s^1$ – lewis notation is

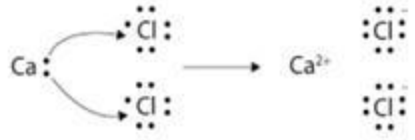
Q. 13. Represent each of the following molecules using Lewis notation:

(a) bromine gas (Br_2)
(b) Calcium chloride ($CaCl_2$)
(c) carbon dioxide (CO_2)
(d) Which of the three molecules listed above contains a double bond?

Answer : (a)

Bromine is a halogen element. It has 7 electrons in its outermost orbit. It needs one more electron to obtain octet and become stable. Hence, in the case of bromine gas, 2 bromine atoms combine to form a molecule (Br_2). Each bromine atom contributes one electron for covalent bond. So, the 2 electrons involved in the bond are shared by both bromine atoms, hence octet is obtained.

(b)



Calcium has 2 electrons in outermost shell. It tends to lose them to get octet structure. Chlorine being halogen element has 7 electrons in the outermost orbit. It needs one more electron to obtain octet and become stable. So, calcium donates its 2 electrons to 2 different chlorine atoms. Hence, calcium cation, chlorine anions are formed and bond forms.

Thus, $CaCl_2$ is formed.

(c)

Oxygen has 6 electrons in its outermost orbit. Carbon has 4 electrons in its outermost orbit. So, oxygen tends to gain 2 electrons to obtain octet. Carbon shares electrons to obtain octet. So, in this case, one carbon and 2 oxygen atoms share electrons. Each oxygen contributes its 2 electrons and carbon contributes 4 electrons. 2 pairs of electrons between each oxygen and carbon form bonds. These electrons are shared by both oxygen and carbon. Both carbon and oxygen obtain octet. Thus, 2 double bonds are formed and CO_2 is formed.

(d) Carbon dioxide – $(O = C = O)$

Q. 14. Two chemical reactions are described below.

• Nitrogen and hydrogen react to firm ammonia (NII)
• Carbon and hydrogen bond to form a molecule of methane (NH_3).
For each reaction, give:
(a) The valency of each of the atoms involved in the reaction.
(b) The Lewis structure of the product that is formed.

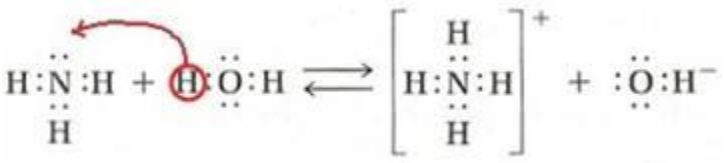
Answer : ● Nitrogen and hydrogen react to form ammonia.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

(a) The electronic configuration of nitrogen is $1s^2 2s^2 2p^3$. Outermost orbit contains 5 electrons. So, it needs 3 more electrons to obtain octet. Valency of nitrogen is 3. Electronic configuration of hydrogen is $1s^1$. Valency of hydrogen is 1. It need to gain one more electron to obtain stable duplet structure. so, one nitrogen contributes its 3 electrons to 3 hydrogen atoms and each hydrogen contributes its one electron for bond

formation. The electrons are shared by both nitrogen and hydrogen. Both become stable and form ammonia.

(b)

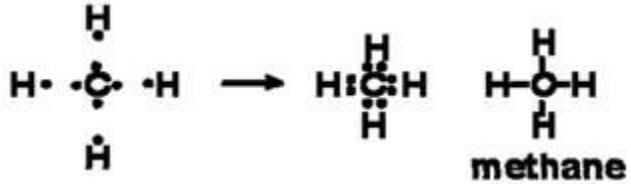


● Carbon and hydrogen react to form methane.

$C + 2H_2 \rightarrow CH_4$

(a) Carbon has 4 electrons in its outermost orbit. Carbon shares electrons to obtain octet. It needs 4 more electrons to obtain octet. So, valency of carbon is 4. Electronic configuration of hydrogen is $1s^1$. Valency of hydrogen is 1. It need to gain one more electron to obtain stable duplet structure. so, carbon contributes its 4 electrons in bond formation with 4 hydrogen atoms. Hydrogen atoms contribute their one electron. So, these electrons are shared by both carbon and hydrogen to form bonds.

(b)



Q. 15. How Lewis dot structure helps in understanding bond formation between atoms?

Answer : In lewis dot structure of atoms of an element, we represent the nucleus and inner shell electrons by the symbol of element and electrons of outer shell by dots.

Based on this we can understand the valence of an element based on which we can predict the type of bond formed between atom. For ex- calcium has electronic configuration -

$_{20}Ca^{40}$ – $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ – lewis notation is

The outermost shell ‘4’ has 2 electrons and they are represented by 2 dots. The inner electrons and nucleus are represented by the symbol Ca.

Q. 16. What is octet rule? How do you appreciate role of the 'octet rule' in explaining the chemical properties of elements?

Answer : Octet rule – it states that atoms of elements are stable with 8 electrons in their outermost shell and they tend to undergo chemical changes (losing or gaining electrons) to get this structure.

Elements after these chemical changes attain noble gas configuration. Chemically active elements don't have 8 electrons in their outermost shell and that's why they lose or gain electrons to obtain stable octet structure.

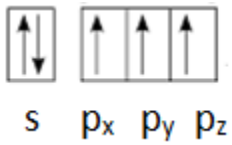
Atoms having more than 4 electrons and less than 8 electrons, already in their outermost shell, tend to gain electrons thereby becoming negatively charged (anions). Atoms having less than 4 electrons and more than 0 electrons, already in their outermost shell, tend to lose electrons thereby becoming positively charged (cations). The ultimate result of this is obtaining octet in outer most shell.

Q. 17. Explain the formation of the following molecules using valence bond theory

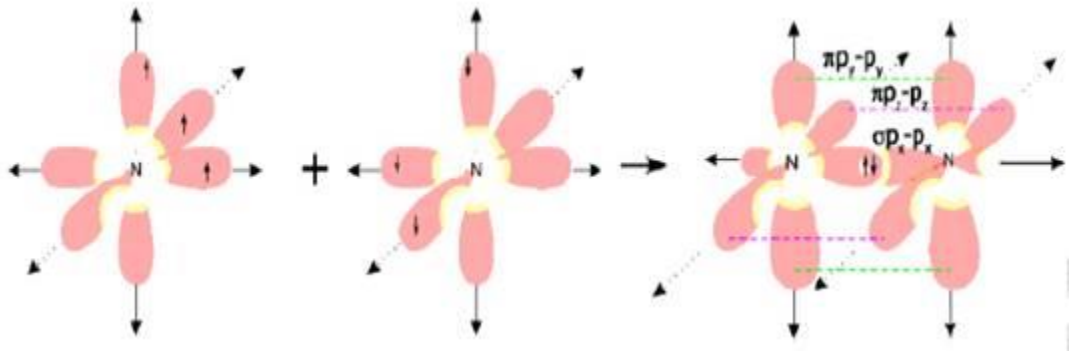
a) N_2 molecule
b) O_2 molecule

Answer : (a) Formation of N_2 molecule

Nitrogen ($_7N^{14}$) has configuration $1s^2 2s^2 2p^3$. Its valence shell contains 5 electrons, i.e. 2 in s and 3 in p orbitals - $2p_x^1 2p_y^1 2p_z^1$

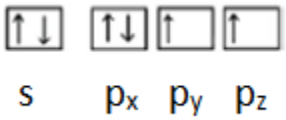


if the p_x orbital of a N atom overlaps with other p_x orbital of another N atom giving ($\sigma p_x - p_x$) bond, along the internuclear axis. Similarly p_y and p_z orbitals of one N atom overlap with p_y and p_z orbitals of another N atom laterally and perpendicularly to internuclear axis given by ($\varpi p_y - p_y$) ($\varpi p_z - p_z$) bonds. So, N_2molecule has a triple bond between 2 nitrogen atoms.



(b) Formation of O_2 molecule.

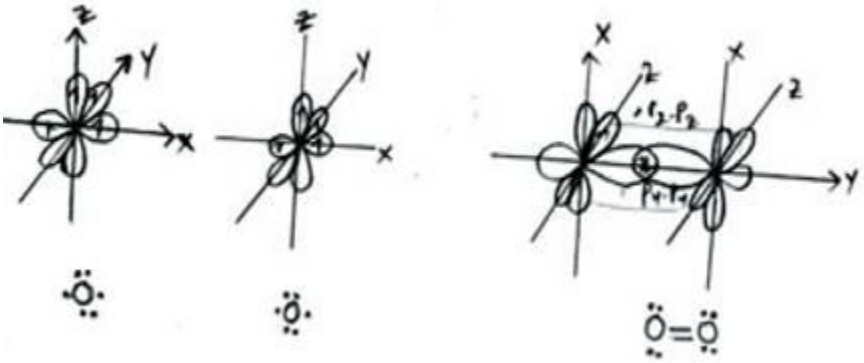
oxygen ($_8O^{16}$) has configuration $1s^2 2s^2 2p^4$. Its valence shell contains 6 electrons, i.e. 2 in s and 4 in p orbitals - $2p_x^2 2p_y^1 2p_z^1$



the p_y orbital of one oxygen atom overlaps with p_y orbital of another oxygen atom along the inter nucleus axis, a sigma $p_y - p_y$ bond is formed.

Similarly, p_z orbital of O atom overlaps with p_z orbital of another O atom laterally, perpendicular to the inter nuclear axis giving pi p_z-p_z bond.

O_2 molecule has a double bond between 2 oxygen atom.



Q. 18. What is hybridisation? Explain the following molecules using hybridisation

a) Be Cl_2
b) BF_3

Answer :

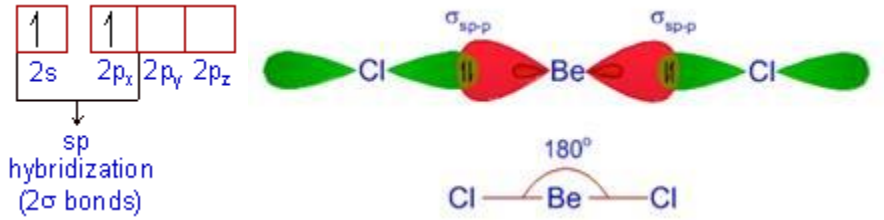
Hybridisation is the concept of mixing atomic orbitals into new hybrid orbitals (with different energies, shapes, etc., than the component atomic orbitals) suitable for the pairing of electrons to form chemical bonds in valence bond theory.

(a) $BeCl_2$

The electronic configuration of 'Be' in ground state is $1s^2\ 2s^2$. Since there are no unpaired electrons, it undergoes excitation by promoting one of its 2s electron into empty 2p orbital.

Thus in the excited state, the electronic configuration of Be is $1s^2\ 2s^1\ 2p^1$.

In the excited state, the beryllium atom undergoes 'sp' hybridization by mixing a 2s and one 2p orbitals. Thus, two half filled 'sp' hybrid orbitals are formed, which are arranged linearly.



These half filled sp-orbitals form two σ bonds with two 'Cl' atoms.

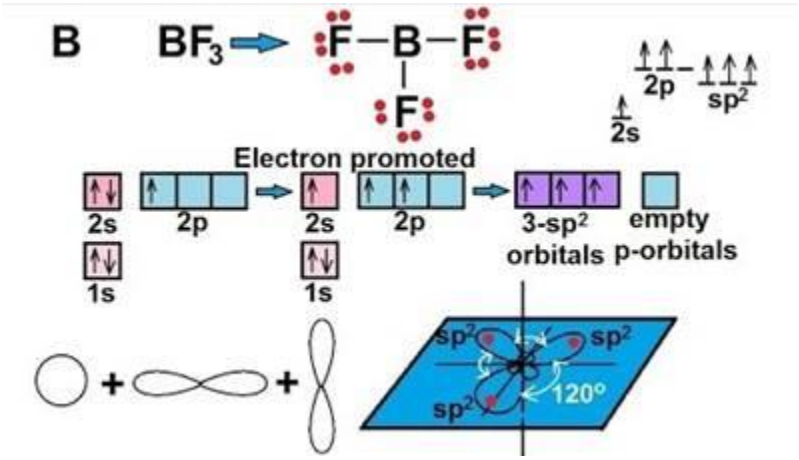
Thus $BeCl_2$ is linear in shape with the bond angle of 180^o.

(b) BF_3

The electronic configuration of 'B' in ground state is $1s^2\ 2s^2\ 2p^1$.

In excited state one electron from s orbital gets excited to p orbital and it becomes

$1s^2\ 2s^1\ 2p_x^1\ 2p_y^1$. This 1 half filled s orbital and 2 half filled p orbitals intermix to give 3 sp^2 hybridised orbitals which overlap with empty p orbitals of 3 fluorine atoms to give BF_3. The shape is trigonal planar.


B
BF3
F
B
F
F
2p
sp2
2s
Electron promoted
2s
2p
2s
2p
3-sp2
orbitals
empty
p-orbitals
1s
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sp2
sp2
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