CHEMISTRY GRADE 11
UNIT 3

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CHEMICAL BONDING AND STRUCTURE

UNIT – THREE

CHEMICAL BONDING AND STRUCTURE

Octet Rule

- States that during the formation of a chemical compound, each atom has an octet (8) electrons in its highest occupied energy level by gaining, losing, or sharing electrons. The noble gases have
- Very stable electron configuration
- High ionization energies
- Low electron affinity
- Lack of reactivity

Types of chemical Bonding

-The force of attraction that hold atoms

together are called Chemical bonds.
These forces of attraction can be categorized as intermolecular forces.
This affects the chemical properties of the species.

There are three main types of chemical bonds

1 Ionic bonding
2 Covalent bonding
3 Metallic bonding

1 - IONIC BONDING

-Is formed by electron transfer from a metal to a non-metal with different electronegative values.

Examples of ionic compounds are:

LiCl , CsI, NaCl, KF, KCl, MgF_2,

$MgCl_2$, $FeCl_2$, $ScBr_3$,CuCl, ….

Properties of Ionic Compounds

- Crystalline solids at room temperature
- The fundamental units are positive and negative ions
- Crystalline ionic solids are not conduct heat and electricity
- In aqueous solution or molten state conduct electricity
- Have high melting and boiling points
- Non volatile
- Very resistant to heat but easily broken by

2 COVALENT BONDING

-Is formed by sharing of electron between

two atoms.

- A compound that contain covalent bond is

called covalent compounds

Examples of covalent compounds are:

H_2O, NH_3, CO_2, CS_2, $SiCl_4$, CH_4, C_2H_6, CF_4, ….

The representation of covalent bonding through Lewis symbols and shared

Coordinate covalent bonding

-Is a bond in which both shared electrons are donated by only one atom .

Examples: O_3, CO, NH_3BF_3, H_3O^+, NH_4^+, ...

Resonance structures

-Are a molecule or ion that can be represented by two or more Lewis structures.

-Differ only in the distribution of electrons

Examples: O_3, N_2O_4, HNO_3, NO_2F, NO_3^-, CO_3^{2-}, …

Exceptions to the octet rule in covalent bonding

Three groups of molecules that are exceptions to the Octet rule

- Less than Octet
- More than octet
- Odd number of total valence electrons

Properties of Covalent Compounds

Covalent compounds are

-Molecular substances

-Have low melting and boiling points

-**Volatile** because many covalent compounds are found in gaseous state at room temperature.

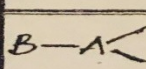
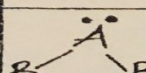
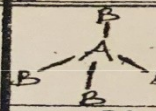
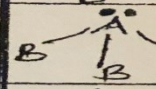
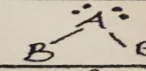
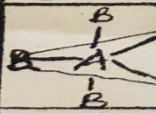
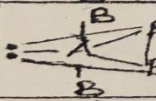
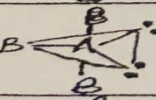
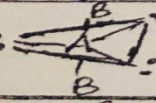
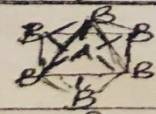
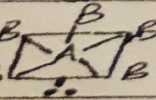
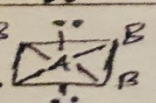
-Generally insoluble in water

Molecular Geometry

-The spatial arrangement of atoms around a central atom of a molecule or a poly atomic molecule.

- Valence shell electron pair repulsion (VSEPR) theory predicting the shapes of molecules and ions.

-The general formula for predicting molecular shapes is AX_nE_m

No. of e⁻ pairs	Molecular formula	Molecular structure or sketch	Molecular Geometry	e⁻-pair (set) geometry	Bond angle	Examples
2	AX_2	B—A—B	Linear	Linear	180°	CO_2, HCN, CS_2, C_2H_2, ... COS, $BeCl_2$
3	AX_3		Trigonal planar	Trigonal planar	120°	BF_3, BCl_3, NO_3^-, CO_3^{2-}, HCOH, NF_3^{2+}, $COCl_2$, ...
	AX_2E		V-shape bent Angular	Trigonal planar	< 120°	O_3, $SnCl_2$, SO_2, GeF_2, ...
4	AX_4		Tetrahedral	Tetrahedral	109.5°	CH_4, CF_4, CCl_4, $SiCl_4$, PH_4^+, NH_4^+, SO_4^{2-}, ...
	AX_3E		Trigonal Pyramidal	〃	< 109.5°	NH_3, PCl_3, H_3O^+, PH_3, H_3S^+, ...
	AX_2E_2		Bent (V-shape) Angular	〃	< 109.5°	H_2O, H_2S, H_2Se, NH_2^-, OF_2, ...
5	AX_5		Trigonal bipyramidal	Trigonal bipyramidal	90°, ±120	PCl_5, SbF_5, ...
	AX_4E		See Saw	〃		SF_4, $SeCl_4$, PF_4^-, IF_4^+, ...
	AX_3E_2		T-shape	〃		ClF_3, BrF_3, ICl_3, OCl_3^-, ...
	AX_2E_3		Linear	〃	180°	XeF_2, I_3^-, IF_2^-, ...
6	AX_6		Square bi pyramidal (Octahedral)	Octahedral (Square bi pyramidal)	90°	SF_6, $AlCl_6^{3-}$, ...
	AX_5E		Square pyramidal	〃		BrF_5, TeF_5^-, ICl_5
	AX_4E_2		Square planar	〃		XeF_4, ICl_4^-, $BrCl_4^-$, ...

Intermolecular Forces in covalent compounds

Intermolecular forces

- Force of attraction between atoms or molecules
- Affect the physical properties of the species
- Not chemical bonds
- Relatively weak

The common intermolecular forces are

- ✓ London force
- ✓ dipole- dipole force
- ✓ H-bonding

Strength and polarity of intermolecular forces

Intermolecular force	Strength	Polarity
Hydrogen Bonding	The Strongest	Polar
Dipole-dipole Forces	Moderate	Polar
London Dispersion Forces	The Weakest	Non-polar

3. METALLIC BONDING

-Is formed by the force of attraction between freely moving electrons
and metallic nuclei.

-Is referred to as bonding in metal atoms.

-the strength of metallic bonding depends on the number of contribution electrons and size of the atoms.

Examples: Na , K , Li , Cs , Mg , Be, Ca , Fe, Cu , Co, W, Zn, Al, ……..

Properties of Metals

- A high degree of electrical conductivity
- A high degree of thermal conductivity
- luster(shiny)
- High density
- Malleable and ductile
- High melting and boiling point

Chemical Bonding Theories

The two modern chemical bonding theories are **Valence Bond Theory (VBT)** and **Molecular Orbital Theory (MOT)**

1 - Valence Bond Theory (VBT)

explains the bonding between two atoms caused

by the overlap of half-filled atomic orbitals.

Overlap of Atomic orbitals (Sigma and pi bonds).

The three simple types of overlaps are:-

I. S-S
II. S-P
III. P-P

Hybridization of orbitals

Hybridization is mixing up of two or more different atomic orbitals of the same atom.

Valence bond theory employs the concept of hybridization.

In hybridization the number of hybrid orbital depends on the number of atomic orbital

The five common types of hybrid orbitals are SP, SP^2, SP^3, SP^3d and SP^3d^2

2 - Molecular Orbital Theory (MOT)

- as atoms approach each other and their atomic orbitals overlap, molecular orbitals are formed
- the two types of molecular orbitals are **Bonding** and **Anti-bonding** molecular orbitals

Bonding molecular orbital

- have a region of high electron charge density between the two nuclei
- denoted by
- stable
- exist at lower energy level

Anti bonding molecular orbital

-have a region of zero electron density between two nuclei
-denoted by *
-away from the region between the two nuclei
-unstable
-exist at highest energy level

Electron configuration of diatomic species

The order of energy of molecular orbitals has been determined mainly from spectroscopic data.

a In simple homonuclear diatomic molecules (total electrons = 14 or less) the order is:

$$\sigma_{1s}\sigma^{*}_{1s}\sigma_{2s}\sigma^{*}_{2s}\left(\pi_{2p_y}=\pi_{2p_z}\right)\sigma_{2p_x}\left(\pi^{*}_{2p_y}=\pi^{*}_{2p_z}\right)\sigma^{*}_{2p_x}$$

b For simple homonuclear diatomic molecules (total electrons greater than 14) the $\left(\pi_{2p_y}=\pi_{2p_z}\right)$ comes after σ_{2p_x} and the order is:

$$\sigma_{1s}\ \sigma^{*}_{1s}\ \sigma_{2s}\ \sigma^{*}_{2s}\ \sigma_{2p_x}\ (\pi_{2p_y}=\pi_{2p_z})\ (\pi^{*}_{2p_y}=\pi^{*}_{2p_z})\ \sigma^{*}_{2p_x}.$$

Bond Order

-refers to the number of bonds that exist between two atoms

-It is a measure of stability of molecules or molecular ions

$$B.O = (n_b - n_a)$$

- If bond order increases then stability and

bond energy increases but bond length decreases

Magnetic Properties

The two types of magnetic properties are Para magnetic and diamagnetic species

Example: 1. H_2 total number of electron=2

$_{1S}{}^{2}$(diamagnetic)

Bond order =1/2(2-0) = 1

2. C_2total number of electron=12

$_{1S}{}^{2}{}_{1S}{}^{2}{}_{2S}{}^{2}{}_{2S}{}^{2}{}_{2P}{}^{2}{}_{2P}{}^{2}$ (diamagnetic)

Bond order =1/2(8-4) = 2

3. N_2total number of electron=14

$_{1S}{}^{2}{}_{1S}{}^{2}{}_{2S}{}^{2}{}_{2S}{}^{2}{}_{2P}{}^{2}{}_{2P}{}^{2}{}_{2P}{}^{2}$(diamagnetic)

Bond order =1/2(10-4) = 3

4. O_2total number of electron=16

$_{1S}{}^{2}{}_{1S}{}^{2}{}_{2S}{}^{2}{}_{2S}{}^{2}{}_{2P}{}^{2}{}_{2P}{}^{2}{}_{2P}{}^{2}{}_{2P}{}^{1}{}_{2P}{}^{1}$(paramagnetic)

Bond order =1/2(10-6) = 2

5. CN^- total number of electron=14

$_{1S}{}^{2}{}_{1S}{}^{2}{}_{2S}{}^{2}{}_{2S}{}^{2}{}_{2P}{}^{2}{}_{2P}{}^{2}{}_{2P}{}^{2}$(diamagnetic)

Bond order =1/2(10-4) = 3

Types of Crystals

-A crystal is a piece of a solid substance that has plane surface, Sharpe edge and a regular geometric shape

1-Ionic crystals

-the fundamental units are ions.

- consist of cations and anions held together by electrical attraction of opposite charges.

Example: NaCl , KNO_3 ,$CaCO_3$,…

2-Molecular crystals

- the fundamental unit of a molecular solid is molecule

- consist of atoms or molecules held together by intermolecular forces.

-non conductors of heat and electricity.

Example: sugar, dry ice , glucose , aspirin,….

3-**Covalent network crystals**

-the fundamental units are atoms.

-consist of atoms held together in large networks by covalent bonds.

-The whole is one giant molecule .

Example: quartz(SiO_2), diamond , graphite,

4-**Metallic crystals**

- the fundamental units are atoms.

- consist of atoms held together by metallic bonding.

- conduct heat and electricity

Example: Cu , Ag , Au , Al , Fe