# INDEX

S.No.	Торіс	Page No.		
PHYSICAL CH	IEMISTRY			
1.	Atomic Structure	1		
2.	Stoichiometry	2		
3.	Gaseous State	6		
4.	Thermodynamics	8		
5.	Chemical Equilibrium	12		
6.	Ionic Equilibrium	15		
7.	Electrochemistry	18		
8.	Solution & Colligative Properties	22		
9.	Solid State	27		
10.	Chemical Kinetics & Radioactivity	30		
INORGANIC (	CHEMISTRY			
11.	Periodic Table & Periodicity Chemical	34		
12.	Bonding Coordination Compounds	42		
13.	Metallurgy s-Block Elements & their	53		
14.	compounds p-Block Elements & their	66		
15.	compounds d-Block Elements & their	73		
16.	compounds Qualitative Analysis	77		
17.		95		
18.		101		
ORGANIC CH	EMISTRY			
	Points to remember in			
19.	Nomenclature	109		
20.	Structure Isomerism	114		
21.	General Organic Chemistry	119		
22.	Alk ane	126		
23.	Alkene & Alkyne	126		
24.	Alkyl Halide	127		
25.	Alcohol	127		
26.	Grignard Reagent	129		
27.	Reduction	130		
28.	Oxidation Reaction	132		
29.	Aldehyde & Ketones	135		
30.	Carboxylic acid & Derivatives	139		
31.	Aromatic Compounds	141		
32.	Polym ers	145		

# PHYSICAL CHEMISTRY ATOMIC STRUCTURE

# Planck's Quantum Theory :

Energy of one photon =  $h \mathbb{Z} = \frac{hc}{TT}$ 

## **Photoelectric Effect :**

$$h? = h?0 + \frac{1}{2} me?$$

# Bohr s Model for Hydrogen like atoms :

**1.** 
$$mvr = n \frac{h}{27}$$
 (Quantization of angular momentum)

2. En = 
$$\frac{E_1}{n^2} z \approx 2.178 \times 10^{-18} \frac{z^2}{n^2}$$
 J/atom =  $\frac{z^2}{13.6 n^2}$  eV  
E1 =  $\frac{222}{n^2}$  me4

**3.** 
$$rn = \frac{n^2}{Z} \times \frac{h^2}{4\mathbb{Z}^2 e^{\frac{n^2}{2}}} = \frac{0.529\mathbb{Z} n^2}{Z} Å$$

4. 
$$v = \frac{2 \boxtimes ze^{-2}}{nh} = \frac{2.18 \boxtimes 10^{-6} \square z}{n} m/s$$

De Broglie wavelength :

$$2 = \frac{h}{mc} \Box \frac{h}{p}$$
 (for photon)

### Wavelength of emitted photon :

$$\begin{array}{c} 1 \\ \hline \end{array} = \begin{array}{c} \square = \mathbb{RZ2} \\ \square \begin{array}{c} \square 1 \\ \square 1 \end{array} \begin{array}{c} 1 \\ \square 2 \\ \square 1 \end{array} \begin{array}{c} 1 \\ \square 2 \\ \square 1 \end{array} \begin{array}{c} \square 2 \\ \square 2 \\ \square 1 \end{array} \begin{array}{c} \square 2 \\ \square 2 \\ \square 1 \end{array} \begin{array}{c} \square 2 \\ \square 2 \\ \square 2 \\ \square 2 \end{array} \begin{array}{c} \square 2 \\ \square 2$$

## No. of photons emitted by a sample of H atom :

2n(2n21) 2

#### Heisenberg s uncertainty principle :

h or m 2x.2v 2 42 h or ⊓x.v ? ₂

#### Quantum Numbers :

\*

- Brincipal quantum number (n) electron in any to Pit = \*
- Azimuthal quantum number  $(\square) = 0, 1, \dots$  to  $(n \ 1)$ . \* nh
- \* Number of orbitals in a subshell = 22 + 1
- Maximum number of electrons in particular subshell =  $2 \times (22)$ \*

Orbital angular momentum L =  $\frac{h}{2 - \sqrt{2(221)}} = \sqrt{2(221)}$ 

# STOICHIOMETRY



Mass

## Density :

Specific gravity = density of the substance density of water at 42C

#### For gases :

Absolute density (mass/volume) = Molar massof the gas Molar volume of the gas

$$\Box = \frac{PM}{RT}$$

Vapour density V.D.=  $\frac{d_{gas}}{d_{H_2}} = \frac{PM_{gas}_{RT}}{PM_{H_2}_{RT}} = \frac{M_{gas}}{M_{H_2}} = \frac{M_{gas}}{2}$ 

Mgas = 2 V.D.

## Mole-mole analysis :



### **Concentration terms :**

# Molarity (M) :

 $\square Molarity (M) = \frac{w@1000}{(Mol. wt of solute)@Vinml}$ 

# Molality (m) :

number of moles of solute Molality = <u>mass of solvent in gram</u> 21000 = 1000 w1 / M1w2

# Mole fraction (x) :

- □ Mole fraction of solution (x 1) =  $\frac{n}{\square N}$
- □ Mole fraction of solvent (x2) =  $\frac{N}{n \square N}$ x1 + x2 = 1

# % Calculation :

(i) % w/w =	mass of solute in gm mass of solution in gm-12100
(ii)% w/v =	mass of solute in gm Volume of solution in ml <sup></sup> 100
(iii)% v/v =	Volume of solute in ml Volume of solution

# Derive the following conversion :

1.	x2221000 Mole fraction of solute into molarity of solution M = x1M1 2 M2 x 2									
2.	MM1 $\boxed{2}$ 1000 Molarity into mole fraction x 2 = $\boxed{2210002MM}_{2}$									
3.	Mole fraction into molality m = $\frac{x2 21000}{x1M1}$									
4.	mM1 Molality into mole fraction x 2 = $1000@mM_{1}$									
5.	Molality into molarity M =	m221000 1000 2mM2								
6.	Molarity into Molality m =	M 2 1000 10002 2MM2								
	M1 and M2 are molar mas	sses of solvent and solute.	. 🛙 is density of solution							

(gm/mL) M = Molarity (mole/lit.), m = Molality (mole/kg), x 1 = Mole fraction of solvent, x2 = Mole fraction of solute

# Average/Mean atomic mass :

Mean molar mass or molecular mass :

$$M_{avg.} = \frac{n1M1 \ @ n2M2 \dots n nMn}{n1 \ @ n2} \quad \text{or} \quad M_{avg.} = \frac{\overset{j_{\square}n}{\textcircled{0}} njMj}{\overset{j_{\square}n}{\textcircled{0}} njMj}$$

Page 🚕 ٤

# Calculation of individual oxidation number : Formula :Oxidation Number = number of electrons in the valence shell number of electrons left after bonding Concept of Equivalent weight/Mass : For elements, equivalent weight (E) = Atomic weight Valency-factor М For acid/base. **E**? Basicity / Acidity Where M = Molar massМ **E**? For O.A/R.A. no.of moles of e gained/lost Equivalent weight (E) = <u> Atomic or moleculear weight</u> <u> v.f.</u> (v.f. = valency factor) Concept of number of equivalents : No. of equivalents of solute = $\frac{Wt}{Eq.wt.} = \frac{Wt}{M/n}$ No. of equivalents of solute = No. of moles of solute $\times$ v.f.

# Normality (N) :

Normality (N) = <u>
Number of equivalents of solute</u> Volume of solution(inlitres)

Normality = Molarity  $\times$  v.f.

### Calculation of valency Factor :

n-factor of acid = basicity = no. of H+ ion(s) furnished per molecule of the acid.

n-factor of base = acidity = no. of OH ion(s) furnised by the base per molecule.

### At equivalence point :

N1V1 = N2V2n1M1V1 = n2M2V2

#### Volume strength of H2O2 :

20V H2O2 means one litre of this sample of H2O2 on decomposition gives 20 It. of O2 gas at S.T.P.

Normality of H2O2 (N) =  $\frac{\text{Volume, strengthof H2O2}}{5.6}$ 

Molarity of H2O2 (M) =  $\frac{11.2}{11.2}$ 

**Measurement of Hardness :** 

Hardness in ppm = \_\_\_\_\_massof CaCO3 Total mass of water 210<sup>6</sup>

Calculation of available chlorine from a sample of bleaching powder :

% of Cl2 =  $\frac{3.557x7V(mL)}{W(g)}$  where x = molarity of hypo solution

and v = mL. of hypo solution used in titration.

# **GASEOUS STATE**

#### **Temperature Scale :**

 $CPO = RP273 = PP32 = R(100)^{10} R(O)$ where R = Temp. on unknown scale. Boyle s law and measurement of pressure : At constant temperature, V ??? p P1V1 = P2V2Charles law : At constant pressure, V I V2 T or T1 I T2 Gay-lussac s law : P2 At constant volume, P 🛛 T  $T_1 \square T_2$  temp on absolute scale Ideal gas Equation : PV = nRT $PV = \frac{W}{m}RT$  or  $P = \frac{d}{m}RT$  or Pm = dRTPage 🚕 ٦

#### Daltons law of partial pressure :

$$\mathsf{P}_1^{\texttt{m}} \xrightarrow[]{} \frac{\mathsf{n}_1^{\texttt{RT}}}{\mathsf{v}}, \qquad \mathsf{P}_2 \xrightarrow[]{} \frac{\mathsf{n}_2^{\texttt{RT}}}{\mathsf{v}}, \qquad \mathsf{P}_3^{\texttt{m}} \xrightarrow[]{} \frac{\mathsf{n}_3^{\texttt{RT}}}{\mathsf{v}} \text{ and so on.}$$

Total pressure =  $P1 + P2 + P3 + \dots$ 

Partial pressure = mole fraction X Total pressure.

### Amagat s law of partial volume :

 $V = V1 + V2 + V3 + \dots$ 

#### Average molecular mass of gaseous mixture :

Total mass of mixture = n1M1 @n2M2 @n3M3 Mmix = Totalno.ofmolesinmixture = n1 @n2 @n3M3

#### Graham s Law :

Rate of diffusion r 2  $\frac{1}{\sqrt{d}}$ ; d = density of gas

$$\frac{r1}{r^2} = \frac{\sqrt{d2}}{\sqrt{d^{\dagger}}} = \frac{\sqrt{M2}}{\sqrt{M1}} = \sqrt{\frac{V. D_2}{V. D1}}$$

#### Kinetic Theory of Gases :

 $PV = \frac{3}{2}$  mN U2 Kinetic equation of gases

Average K.E. for one mole = 
$$N\mathbb{Z}_{A} \stackrel{\boxed{2}}{\mathbb{Z}_{2}} \frac{-2}{m}\mathbb{Z}_{2} = \frac{3}{2} K N_{A}T = \frac{3}{2} RT$$

 $\square$  Root mean sugare speed

Urms =  $\sqrt{\frac{3RT}{M}}$ 

molar mass must be in kg/mole.

□ Average speed Uav = U1 + U2 + U3 + ...... UN

Uavg. = 
$$\sqrt{\frac{8RT}{2M}} = \sqrt{\frac{8KT}{2m}}$$

K is Boltzmman constant

 $\square$  Most probable speed

$$UMPS = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2KT}{m}}$$

Page 🚕 v

Van der Waal s equation :

$$\frac{1}{V2} \frac{an2}{V2} (V \text{ nb}) = nRT$$

□ Critical constants :

Vc = 3b, PC = 
$$\frac{a}{27b2}$$
, TC =  $\frac{8a}{27Rb}$ 

# THERMODYNAMICS

#### Thermodynamic processes :

Isothermal process : 1. T = constant dT = 0?T = 0 V = constant 2. **Isochoric process :** dV = 0?V = 0 P = constant 3. **Isobaric process :** dP = 0?P = 0 q = 04. Adiabatic process : or heat exchange with the surrounding = 0(zero)

### IUPAC Sign convention about Heat and Work :

Work done on the system = Positive Work done by the system = Negative

#### 1st Law of Thermodynamics

 $\Box U = (U 2 \ U 1) = q + w$ 

Law of equipartion of energy :

 $U = \frac{f}{2} nRT$  (only for ideal gas)

 $\mathbb{P}E = \frac{f}{2} nR (\mathbb{P}T)$ 

f = degrees of freedom for that gas. (Translational + Rotational)

- f = 3 for monoatomic
- = 5 for diatomic or linear polyatmic
- = 6 for non linear polyatmic

## Calculation of heat (q) : Total heat capacity :

$$C_{T} = \frac{\Box q}{\Box T} \Box \frac{dq}{dT} = J/^{2}C$$

Molar heat capacity :

$$C = \frac{\Box q}{n \Box T} \Box \frac{dq}{n dT} = J \text{ mole } 1 \text{ K } 1$$
$$CP = \frac{\Box R}{\boxtimes 1} \qquad C_{v} = \frac{R}{\boxtimes 1}$$

Specific heat capacity (s) :

$$S = \frac{2q}{m2T} \Box \frac{dq}{mdT} = J gm 1 K 1$$

WORK DONE (w) :

Isothermal Reversible expansion/compression of an ideal gas : W = nRT ln (V f/Vi)

Reversible and irreversible isochoric processes.

Since dV = 0SodW = P ext. dV = 0.

Reversible isobaric process :

W = P(Vf Vi)

Adiabatic reversible expansion :

2 T 2V2 = 1 = T1V1 = 1

**Reversible Work :** 

$$W = \frac{P2V2 \ @P1V1}{\Box \ \Box \ 1} = \frac{nR \ (T2 \ @T1)}{\Box \ \Box \ 1}$$

Irreversible Work :

$$W = \frac{P2V2 @P1V1}{\square \square \square} = \frac{nR (T2 @T1)}{\square \square \square} = nCv (T2 T1) = Pext (V2 \vee 1)$$

Free expansion Always going to be irrerversible and since  $P_{ext} = 0$ sodW = P ext. dV = 0 If no. heat is supplied q = 0 then  $\Box E = 0$  so  $\Box T = 0$ .

## Application of Ist Law :

2U = 2Q + 2W □ 2W = P 2V □ 2U = 2Q P2V

## Constant volume process

Heat given at constant volume = change in internal energy 2 du = (dq) $du = nQvdT^{v}$ 

$$C_v = \frac{1}{n} \cdot \frac{du}{dT} = \frac{f}{2}R$$

#### Constant pressure process :

H  $\square$  Enthalpy (state function and extensive property) H = U + PV

## $\bigcirc C p \quad Cv = R \text{ (only for ideal gas)}$

#### Second Law Of Thermodynamics :

S universe = S system + 22 surrounding a 9pontaneous process.

### Entropy (S) :

## Entropy calculation for an ideal gas undergoing a process :

State A

State B T2

P1, V1, T1

 $\mathbb{S} \text{system} = \text{ncv} \frac{\text{T2}}{\text{In}} + \text{IR} \ln \frac{\text{V2}}{\text{In}}$ 

(only for an ideal gas)

#### Third Law Of Thermodynamics :

The entropy of perfect crystals of all pure elements & compounds is zero at the absolute zero of temperature.

Gibb *s free energy* **G**: (State function and an extensive property) Gsystem = H system TS system

### Criteria of spontaneity :

- (i) If ☑G system is (ve) < 0 (ii) If ☑G system is > 0
- (iii) If 2G system = 0

process is spontaneous system is at equilibrium.

# Physical interpretation of 2G :

**212** The maximum amount of non-expansional (compression) work which can be performed. **213** G = dw non-exp = dH TdS.

Standard Free Energy Change (2G<sup>2</sup>) :

- 1. ⊠G° = 2.303 RT log 10 K
- 2. At equilibrium 2 G = 0.
- 3. The decrease in free energy ( 2G) is given as :

<sup>1</sup>/<sub>2</sub>G = W ≞<sup>2</sup>.303 nRT lo g10√2

- 4.  $\square G^{\circ}$  for elemental state = 0
- 5.  $\boxtimes G^{\circ} = Gp^{\circ} oducts G^{\circ}_{Beactants}$

#### Thermochemistry :

Change in standard enthalpy  $\square H^{\circ} = H^{\circ} \square D^{\circ}$ 

= heat added at constant pressure.

= Cp?T.

If Hproducts > Hreactants

- Reaction should be endothermic as we have to give extra heat to reactants to get these converted into products and if Hproducts < Hreactants</li>
- Reaction will be exothermic as extra heat content of reactants will be released during the reaction.
   Enthalpy change of a reaction :
   PHreaction = Hproducts Hreactants
   PH° reactions = H° products H° reactants

= positive endothermic

= negative exothermic

### Temperature Dependence Of **2H** : (Kirchoff's equation) :

For a constant pressure reaction  $\square H2^\circ = \square H1^\circ + \square CP (T2 T1)$ where  $\square CP = CP$  (products)  $\square CP$  (reactants). For a constant volume reaction



## Enthalpy of Reaction from Enthalpies of Formation :

The enthalpy of reaction can be calculated by <sup>(2)</sup>Hr° = <sup>(2)</sup> 2B <sup>(2)</sup>Hf°, products <sup>(2)</sup> 2B <sup>(2)</sup>Hf°, reactants B is the stoichiometric coefficient.

#### Estimation of Enthalpy of a reaction from bond Enthalpies :

■ PEnthalpy required to 2
②H ②break resources

Enthalpy released to

 Image: Sector of the sector

#### **Resonance Energy**:

 $\boxtimes$ H° resonance =  $\boxtimes$ H°f, experimental  $\boxtimes$ H°f, calclulated

= 2H° c, calclulated 22 2H°c, experimental

# CHEMICAL EQUILIBRIUM

#### At equilibrium :

- Rate of forward reaction = rate of backward reaction (i)
- Concentration (mole/litre) of reactant and product becomes constant. (ii)
- (iii) 2G = 0.
- Q = K(iv) eq.

#### Equilibrium constant (K) :

 $\label{eq:K} \begin{array}{l} \mbox{rateconstant of forward reaction} & \mbox{Kf} \\ \mbox{rateconstant of backward reaction} = K \hfill \h$ 

### Equilibrium constant in terms of concentration (KC) :

$$\frac{Kf}{K_{b}} = KC = \frac{\begin{bmatrix} C \\ A \end{bmatrix} \begin{bmatrix} C \\ B \end{bmatrix} \begin{bmatrix} D \\ B \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \end{bmatrix} \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \end{bmatrix} \begin{bmatrix} C \\ C \\ C \end{bmatrix} \end{bmatrix} \begin{bmatrix} C \\ C \end{bmatrix} \end{bmatrix} \end{bmatrix} \begin{bmatrix} C$$

Equilibrium constant in terms of partial pressure (KP):

$$\mathsf{KP} = \frac{[\mathsf{P}]\mathsf{c}[\mathsf{P}]\mathsf{d}_{\mathsf{D}}}{[\mathsf{P}]\mathsf{a}[\mathsf{P}]\mathsf{b}_{\mathsf{B}}}$$

### Equilibrium constant in terms of mole fraction (Kx) :

$$Kx = \frac{x c x d}{x a x B}$$

# Relation between Kp & KC :

Relation between Kp & KX : K = K (P)

$$\log \frac{K^2}{K_1} = \frac{\Box H}{2.303R} \frac{\Box 1}{\Box 1} \frac{\Box 1}{T^2}; \Box H = \text{Enthalpy of reaction}$$

Relation between equilibrium constant & standard free energy change :

⊠G° = 2.303 RT log K

Reaction Quotient (Q) :

The values of expression  $Q = \begin{bmatrix} C \\ A \\ a \\ B \end{bmatrix} b$ 

# Degree of Dissociation (2) :

 $\square$  = no. of moles dissociated / initial no. of moles taken = fraction of moles dissociated out of 1 mole.

Note :2% dissociation = 2 x 100

## Observed molecular weight and Observed Vapour Density of the mixture :

#### Observed molecular weight of An(g)

molecular weight of equilibrium mixture

= total no. of moles

□ D 2 d M<sub>T</sub> 2 M<sub>o</sub> □ (n21)2d 2 (n21)M0

# External factor affecting equilibrium :

#### Le Chatelier's Principle:

It a system at equilibrium is subjected to a disturbance or stress that changes any of the factors that determine the state of equilibrium, the system will react in such a way as to minimize the effect of the disturbance.

#### Effect of concentration :

\* If the concentration of reactant is increased at equilibrium then reaction shift in the forward direction .

If the concentration of product is increased then equilibrium shifts in the backward direction

### Effect of volume :

- \* If volume is increased pressure decreases hence reaction will shift in the direction in which pressure increases that is in the direction in which number of moles of gases increases and vice versa.
- \* If volume is increased then, for

- n < 0 reaction will shift in the backward direction
- 2n = 0 reaction will not shift.

#### Effect of pressure :

If pressure is increased at equilibrium then reaction will try to decrease the pressure, hence it will shift in the direction in which less no. of moles of gases are formed.

#### Effect of inert gas addition :

Constant pressure : (i)

If inert gas is added then to maintain the pressure constant, volume is increased. Hence equilibrium will shift in the direction in which larger no. of moles of gas is formed

- reaction will shift in the forward direction 2n > 0
- reaction will shift in the backward direction 2n < 0
- reaction will not shift. n = 0
- (ii) Constant volume :

Inert gas addition has no effect at constant volume.

#### Effect of Temperature :

Equilibrium constant is only dependent upon the temperature.

If plot of 2nk vs  $\frac{1}{\tau}$  is plotted then it is a straight line with slope =  $\Box H \Box$ R

- and intercept =  $\frac{\Box S \Box}{R}$ For endothermic ( $\Box H > 0$ ) reaction value of the equilibrium constant \*
- increases with the rise in temperature \*
- For exothermic ( $\mathbb{D}H < 0$ ) reaction, value of the equilibrium constant
- decreases with increase in temperature
- For  $\mathbb{D}H > 0$ , reaction shifts in the forward direction with increase in
- tem peratutre
- \* For 2H < 0, reaction shifts in the backward direction with increases in tem perature.

If the concentration of reactant is increased at equilibrium then reaction shift in the forward direction .

If the concentration of product is increased then equilibrium shifts in the backward direction

#### Vapour Pressure of Liquid :

PartialpressureofH2Ovapours Vapour pressureofH2Oat that temp. Relative Humidity =

# Thermodynamics of Equilibrium :

2G = 2G0 + 2.303 RT log<sup>10Q</sup>

Page 🔬 🗤

# **IONIC EQUILIBRIUM**

#### **OSTWALD DILUTION LAW :**

 $\Box$  Dissociation constant of weak acid (Ka),



#### Acidity and pH scale :

 $pH = \log a H (where a H ) is the activity of H ions = molar concentration for dilute solution).$ 

#### [Note :pH can also be negative or > 14]

pH = log [H	l+];	[H+] = 10 pH
pOH = log	[OH ] ;	[OH] = 10 pOH
pKa = log ł	Ka ;	Ka = 10 pKa
pKb = log ł	<b>≺</b> b ;	Kb = 10 pKb
$p(x) = \log x$	ω,	RD = 10 pRD

### **PROPERTIES OF WATER :**

- 1. In pure water [H+] = [OH] so it is Neutral.
- 2. Molar concentration / Molarity of water = 55.56 M.
- 3. Ionic product of water (KW): K = [H+][OH] = 10 <sup>14</sup> at 25 (experimentally) pH = 7 = pOH neutral pH < 7 or pOH > 7 acidic pH > 7 or pOH < 7 Basic
- 4. Degree of dissociation of water :

no. ofmolesdissociated 10<sup>™</sup> □ □ TotalNo.ofmolesinitiallytaken 155.55 18x10210 or 1.8x1027%

5. Absolute dissociation constant of water :

 $Ka = Kb = \frac{[H][OH]}{[H2O]} = \frac{1027 \ 21027}{55.55} \ 21.8210^{-216}$  $pK_a = pKb = \log (1.8 \times 10^{-16}) = 16 \log 1.8 = 15.74$ 

Page 🚕 🗤

Ka × K = [H+] [OH] = Kw

**2**Note: for a conjugate acid- base pairs

 $pK_a + pK_{\overline{B}} \quad pKw = 14$  at 25°C.  $pK_a of HQ_s + ions = 1.74$  $pK_b of OH \quad ions = 1.74.$ 

#### pH Calculations of Different Types of Solutions:

#### (a) Strong acid solution :

- (i) If concentration is greater than 10 6 M In this case H+ ions coming from water can be neglected,
- (ii)If concentration is less than 10 6 M In this case H+ ions coming from water cannot be neglected

#### (b) Strong base solution :

Using similar method as in part (a) calculate first [OH ] and then use  $[H+] \times [OH] = 10.14$ 

#### (c) pH of mixture of two strong acids :

Number of H+ ions from 2-solution = NV1 Number of H+ ions from 22-solution = 2V2

 $[H_{-}] = N = \frac{N1V1 @ N2 V2}{V1@V2}$ 

(d) pH of mixture of two strong bases :

 $[OH] = N = \frac{N1V1 ? N2 V2}{V1?V2}$ 

#### (e) pH of mixture of a strong acid and a strong base :

If N1V1 > N2V2, then solution will be acidic in nature and

N1V1 ☑ N2 V2 [H+] – N –

$$[\Box +] = N = - V1 @ V2$$

If N2V2 > N1V1, then solution will be basic in nature and

### (f) pH of a weak acid(monoprotic) solution :

 $Ka = \frac{[H2] [OH2]}{[HA]} = \frac{C22}{1-2}$ if 22<1 2221 22222 2 1

$\Box \Box \Box = \sqrt{\frac{K_a}{C}} $ (is valid	if ᠌ < 0.1 or	10%)							
On increasing the dilution									
C C C C C C C C C C C C C C C C C C C									
RELATIVE STRENGTH OF TWO ACIDS :									
[H <sup>[2]</sup> ] furnished by acid [H <sup>[2]</sup> ] furnished by acid $\Box \frac{c_1 \square 1}{c_2 \square 2} \Box \sqrt{\frac{k_{a_1} c_1}{k_{a_2} c_2}}$									
SALT HYDROLYSIS	:								
Salt of	Type of hydrolysis	kh	h	рН					
(a) weak acid & strong base	anionic	kw K <sub>a</sub>	$\sqrt{\frac{k_w}{kac}}$	1 1 7+ <u>२</u> pka+ <u>२</u> logc					
(b) strong acid & weak base	cationic	k <sub>w</sub> Kb	$\sqrt{\frac{k_w}{kbc}}$	$7  \frac{1}{2} \text{pk}_{b}  \frac{1}{2} \log c$					
<ul><li>(c) weak acid &amp; weak base</li><li>(d) Strong acid &amp; strong base</li></ul>	both	kw kakb	$-\sqrt{\frac{k}{-ka}}$	$\frac{1}{6}$ 7+ $\frac{1}{2}$ pka $\frac{1}{2}$ p kb					
	do	o not nyo	arolysed-	pH = /					

Hydrolysis of ployvalent anions or cations

For [Na3PO4] = C. Ka1 × Kh3 = Kw Ka1 × Kh2 = Kw Ka3 × Kh1 = Kw

Generally pH is calculated only using the first step Hydrolysis

$$K_{h1} = \frac{Ch2}{12h} \Box Ch^{2}$$

$$h = \sqrt{\frac{Kh1}{c}} \qquad \boxed{22}[OH] = ch = K\sqrt{h12c} \qquad \boxed{22}[H+] = \sqrt{\frac{K\sqrt{2}K}{c}}$$

$$SopH = \frac{1}{2}[pKw2pKa3 \log C]$$

#### **BUFFER SOLUTION :**

(a) Acidic Buffer : e.g. CH3 COOH and CH3COONa. (weak acid and salt of its conjugate base).

[Salt ] pH= pKa + log <del>[Acid]</del>

[Henderson's equation]

(b) Basic Buffer : e.g. N#OH + NH4CI. (weak base and salt of its conjugate acid).

pOH = pKb + log [Salt] [Base]

## **SOLUBILITY PRODUCT :**

 $K_{cp} = (xs)x (ys)y = xx.yy.(s)x+y$ 

### **CONDITION FOR PRECIPITATION :**

If ionic product KI.P > KSP precipitation occurs,

if KI.P = KSP saturated solution (precipitation just begins or is just prevented).

# ELECTROCHEMISTRY

#### **ELECTRODE POTENTIAL**

For any electrode  $\square$  oxidiation potential = Reduction potential Ecell = B.B of cathode, B.P. of anode, Ecell is always a +ve quantity & Anode will be electrode of low R.P E

 $E^{\circ}Cell = SRP$  of cathode SRP of anode.

## Greater the SRP value greater will be oxidising power. GIBBS FREE ENERGY CHANGE :

 $\square G = nFE_{cell}$  $\square G^{o} = nFE^{o}_{cell}$ 

NERNST EQUATION : (Effect of concentration and temp on emf of cell)

$$\begin{split} &\boxtimes G = \boxtimes G^\circ + RT \, \overline{\boxtimes nQ} \qquad (\text{where } Q \text{ is raection quotient}) \\ &\boxtimes G^\circ = RT \, \boxtimes n \, K_{eq} \\ &\text{Ecell} = E^\circ \text{cell} \, \frac{RT}{nF} \, \overline{\boxtimes} n \, Q \\ & 2.303RT \\ &\text{Ecell} = E^\circ \text{cell} \, \frac{nF}{nF} \, \log Q \end{split}$$

Ecell = E<sup>o</sup>cell 
$$\frac{0.0591}{n} \log Q$$
 [At 298 K]  
At chemical equilibrium  
 $\square G = 0$ ; Ecell = 0.  
 $\log \text{Keq} = \frac{nE_{O}}{0.0591}$ .  
E<sup>o</sup>cell  $\frac{0.0591}{n} \log K_{eq}$   
For an electrode M(s)/Mn+.  
 $E_{Mn\square/M} \square e^{-nE} \log [Mn\square]$ .

#### **CONCENTRATION CELL:**

#### A cell in which both the electrods are made up of same material.

For all concentration cell  $E^2$ cell = 0.

(a) Electrolyte Concentration Cell : eg.  $Zn(s) / Zn2+ (t) \parallel Zn+(c2) / Zn(s)$ 

$$E = \frac{0.0591}{2} \log \frac{C2}{C1}$$

(b) Electrode Concentration Cell : eg.Pt, H(P 1 atm) / H+(1M) / H2 (P2 atm) / Pt  $E = \frac{0.0591}{2} \log \frac{PP1P2}{P}$ 

#### **DIFFERENT TYPES OF ELECTRODES :**

1. Metal-Metal ion Electrode M(s)/Mn+ . Mn+ + ne 222M(s)

$$E = E^{\circ} + \frac{0.0591}{n} \log[Mn+]$$

2. Gas-ion Electrode Pt /H2(Patm) /H+(XM)

as a reduction electrode

3. Oxidation-reduction Electrode Pt / Fe2+, Fe3+ as a reduction electrodeFe3+ + e 222 Fe2+

> [Fe22] E = E° 0.0591 log [Fe32]

4. Metal-Metal insoluble salt Electrode eg. Ag/AgCl, Cl as a reduction electrode AgCl(s) + e 2222Ag(s) + Cl

ECI2/AgCI/Ag = ECI2/AgCI/Ag 0.0591 log [CI].

### **ELECTROLYSIS:**

(a)K+, Ca+2, Na+, Mg+2, Al+3, Zn+2, Fe+2, H+, Cu+2, Ag+, Au+3.

Increasing order of deposition.

(b)Similarly the anion which is strogner reducing agent(low value of SRP) is liberated first at the anode.

SO24, NO3, OH, CI, Br, I Increasingorderofdiposition

## FARADAY S LAW OF ELECTROLYSIS : First Law :



#### Specific conductance or conductivity : Π K = . ⊢ (Reciprocal of specific resistance) K = specific conductance Equivalent conductance : Π K21000 □E □ Normality unit : -ohm cm eq 1 Molar conductance : K21000 □m □ Molarity unit:-ohm cm maole 1 specific conductance = conductance $\times \square$ а KOHLRAUSCH S LAW : Variation of 2eq / 2M of a solution with concentration : Strong electrolyte (i)

⊔<sub>M</sub>° = ⊠M b √c

(ii) Weak electrolytes :  $\square = n \square \square + n \square \square$ where  $\square$  is the molar conductivity

n+= No of cations obtained after dissociation per formula unit n = No of anions obtained after dissociation per formula unit

# APPLICATION OF KOHLRAUSCH LAW :

1. Calculation of 20M of weak electrolytes : 20<sub>M(CH3COOH)</sub> = 2M(CH3COONâ) + 2M(HCI) 20M(NaCI)

2. To calculate degree of diossociation of a week electrolyte

$$\mathbb{P} = \frac{\mathbb{P}_{G_1}}{\mathbb{P}_{O_1}} \qquad ; \qquad \qquad \mathsf{K}_{eq} = \frac{\mathsf{c}_{\square}^2}{(1\mathbb{P}_{O_1})^-}$$

3. Solubility (S) of sparingly soluble salt & their K

$$\square_{\mathbf{M}} = \square \mathbf{M}^{\mathbf{p}} = \square \times \text{solubility} \\ \mathbf{K}^{\mathrm{sp}} = \mathbf{S2}$$

# Transport Number :

Where tc = Transport Number of cation & ta = Transport Number of anion

Page 🍙 🗤

# **SOLUTION & COLLIGATIVE PROPERTIES**

# **OSMOTIC PRESSURE :**



**Relation between i &** 2 (degree of dissociation) :

i=1+(n 1)2

Where, n = x + y.

Relation b/w degree of association 2 & i.

# **RELATIVE LOWERING OF VAPOUR PRESSURE (RLVP) :**

Vapour pressure : P Soln. < P Lowering in VP = P P  $^{s}$  =  $\square$ P Relative lowering in vapour pressure

$$\mathsf{RLVP} = \frac{\mathbf{P}}{\mathbf{P}}$$

Raoult's law : (For non volatile solutes)

Experimentally relative lowering in V.P = mole fraction of the non volatile solute in solutions.

$$RLVP = \frac{P - P_s}{P} = X = \frac{n}{n \boxtimes N}$$

$$\frac{P - Ps}{P_s} = \frac{n}{N}$$

$$\frac{P - Ps}{P_s} = (\text{ molality }) \times \frac{M}{1000}$$

(M = molar mass of solvent)

If solute gets associated or dissociated

$$\frac{P - Ps}{P_s} = \frac{i.n}{N}$$

$$\frac{P - Ps}{P_s} = i \times (\text{molality}) \times \frac{M}{1000}$$

According to Raoult s law

 $\square$ 

(i)  $p = p1 \times 1$ . where X1 is the mole fraction of the solvent (liquid).

(ii) An alternate form 2  $\frac{p012p1}{p1} = X2.$ 

## **Elevation in Boiling Point :**



RT2 RTfM

Kf = molal depression constant =  $\frac{10002 \text{Lfusion}}{10002 \text{Lfusion}} = \frac{100022 \text{H}_{\text{fusion}}}{10002 \text{Lfusion}}$ 

## Raoult s Law for Binary (Ideal) mixture of Volatile liquids :

PA = XAPA<sup>e</sup> if P<sup>o</sup> > P<sup>o</sup> A B

PB = XBPB

A is more volatile than B B.P. of A < B.P. of B According to Dalton's law

#### PT = PA + PB = XAPA + XBPB

 $\overset{x}{B} = \underset{x}{H}$  in vapour above the liquid / solution.

P\_= XP&A = XA' PT PB = XB' PT = XBPB<sup>e</sup>

$$\frac{1}{P_{T}} = \frac{xA'}{P_{A^{\circ}}} + \frac{xB'}{P_{B^{\circ}}}.$$

 $\square$ 

 $\square$ 

# **Graphical Representation :**



# Ideal solutions (mixtures) :

eg.

(a)

eg.

(b)

Mixtures which follow Raoul'ts law at all temperature.

A ----- A A ----- B.  $\square$ B ----- B 2Hmix = 0:  $\mathbb{P}Vmix = 0$  $\boxed{2}Smix = +ve$  as for process to proceed 2Gmix = ve(1) Benzene + Toluene. (2) Hexane + heptane. (3) C2H5Br + C2H52. Non-Ideal solutions : Which do not obey Raoult's law. Positive deviation : (i)  $PT.exp > (XAP^{\circ}A + XBPB^{\circ})$ (ii) A . . . . A . . . . B . . . . . B ? Force of attraction (iii) <sup>(2</sup>H mix = +vænergy absorbed (iv) <sup>(2</sup>V mix = +ve (v) 2S mix = +ve (vi) 2G mix = ve H2O + CH3OH. H2O + C2H5OH C2H5OH + hexane C2H5OH + cyclohexane. CHCI3 + CCI4 2 dipole dipole interaction becomes weak. Р POA > POBXA = 1 XB = 0 XA = 0 XB = 1 **Negative deviation** (i)  $PT exp < XAPA^{\circ} + XBP^{\circ}B$ 

> ADDDDA B< A ----- B. (ii) Вппп strength of force of altraction.



B.P. of solution is less than the individual B.P. s of both the liquids.

#### Henry Law :

This aw deals with dissolution of gas in liquid i.e. mass of any gas in any solvent per unit volume is proportional to pressure of gas in

#### equilmio®upm withnliquikdp

m 2 weight of gas Volume of liquid

# SOLID STATE

# **Classification of Crystal into Seven System**

П

Crystal	SystemUnit	Bravais Lattices Example							
	an	d Angles		SC, E	BCC, FC	C			
Cubic		= b = c ; ? = ? = !	?] = 90°	SC,	BCC,	end	NaCl		
Orthorho	ombic a 🛙	b ? c ; ? = ? = ?	2 = 90°	centr					
				SC,	BCC	SC,	S <sub>R</sub>		
Tetragor	nal a =	= b ? c ; 📋 = ? =	? = 90°	SC	Sn, ZnO 2				
Monoclinic a 🛛 b 🖾 c ; 🛛		]b?c; _= ? =	90° ? ?	SC			S <sub>M</sub>		
Rhombohedral a =		= b = c ;	? [? <b>90</b> °	SC			Quartz		
Triclinic a 🛛 b 🖾 c 📋 🍕				00			Н ЗВОЗ		
Hexago	nal a =	= b ? c ; ? = ? =	90°;? = 120°				Graphite		
	ANALYSIS	S OF CUBICA	L SYSTEM						
	Prope	rty	SC	всс	;		FCC		
(i)	atomic rad	ius (r)	a 2	<u>√</u> 3 4	l		$\frac{a}{2\sqrt{2}}$		
	a = edge le	ength							
(ii)	No. of ator	ns per		_					
(iii)	unit cell (Z	)	1	2 8			4 12		
(iii) (iiv)	Packing ef	ficiency	52%	68%			74%		
$(\mathbf{v})$	No. voids	licitity					/ -		
(-)	(a) octahee	dral (Z)					4		
	(b) Tetraho	leral (2Z)					8		
	NEIGHBO	UR HOOD OF	A PARTICLE :						

Simple Cubic (SC) Structure : (I) Type of neighbour Distance no.of neighbours nearest 6 (shared by 4 cubes) а (next)1 12 (shared by 2 cubes) а √2<sup>-</sup> (next)2 8 (unshared) а √3

(II)	<b>Body Centered Cubic</b>	(BCC) Structur	e :					
	Type of neighbour	Distance	no.of neighbours					
	(next)1	$2r - 2\sqrt{3}$	0					
	(next)2	$=a^{-2}$	6					
		= a	12					
(111)	Ease Contered Cubic	$\sqrt{2}$	<b>、</b> .					
(111)	Type of neighbour	Distance	, no. of neighbours					
	nearest	а						
		$\frac{2}{}$	$12 = \mathbb{P} \stackrel{3}{=} \frac{3}{2} $					
	(next)1	а						
	(next)2	$a\sqrt{\frac{3}{2}}$	24					
	DENSITY OF LATTICE MATTER (d) = $\frac{Z}{N^A}$ as a							
	where N A = Avogadro	s No. M = atomic	c mass or molecular mass.					
	IONIC CRYSTALS							
	C.No. Limiti	ng radius rati	2r ा □ 0-12912					
	4 0.155 0.225 (T	riangular)						
	6 0.225 0.414 (T	etrahedral)						
	8 0.414 0.732 (0 0.732 0.999 (0	Octahedral) Cubic)						
	(a) Rock Salt (NaCl) C (b) CsCl C.No. (8 : 8)	oordination nu	mber (6 : 6)					
	$a_{sc} = \frac{2}{\sqrt{3}} (r_{12}r)$							
	(c) Zinc Blende (ZnS)	C.No. (4 : 4)	afcc = $\frac{4}{\sqrt{3}}$ (r <sub>Zn27</sub> $\Box$ r <sub>s<sup>2</sup>0</sub> )					
	(d) Fluorite structure (	(CaF) C.No. (8 :	4) $a_{fcc} = \frac{4}{3} (rCa2 r_F)$					

Page 🚓 ۲۸





# **CHEMICAL KINETICS & REDIOACTIVITY**

### **RATE/VELOCITY OF CHEMICAL REACTION :**

Rate =  $\frac{@c}{@t}$  =  $\frac{\text{mol/lit.}}{\text{sec}}$  = mol lit 1 time 1 = mol dm 3 time 1

#### Types of Rates of chemical reaction :

For a reaction R 222 P

Average rate = Total change in concentration Total time taken



# RATE LAW (DEPENDENCE OF RATE ON CONCENTRATION OF REACTANTS) :

**Rate = K (conc.)order** differential rate equation or rate expression Where K = Rate constant = specific reaction rate = rate of reaction whenconcentration is unityunit of <math>K = (conc)1 order time 1

#### Order of reaction :

m1A + m2B ??? products.

 $R \square [A]P [B]q$  Where p may or may not be equal to m 1 & similarly q may or may not be equal to m 2.

p is order of reaction with respect to reactant A and q is order of reaction with respect to reactant B and (p + q) is **overall order of the reaction**.

#### **INTEGRATED RATE LAWS :**

C0 or 'a' is initial concentration and Ct or a x is concentration at time 't'



#### METHODS TO DETERMINE ORDER OF A REACTION (a) Initial rate method :

)

r = k [A]a [B]b [C]c

[B] = constant [C] = constant

then for two different initial concentrations of A we have

if

$$r_{0_1} = k [A]_{A_1}, \quad r_{02} = k [A_0]_{A_2}$$

$$\Box \quad \frac{\mathbf{r}_{0_1}}{\mathbf{r}_{0_2}} \stackrel{[\mathbf{A}]_{0_1}}{\longrightarrow} \begin{bmatrix} \mathbf{A}_{0_1} \\ \mathbf{A}_{0_2} \end{bmatrix}^{\mathbf{a}}$$

(b

**Using integrated rate law :** It is method of trial and error.

# Method of half lives :

(C for nth order reaction )

(d) Ostwald Isolation Method :  
rate = k [A]a [B]b [C]c = 
$$k_0$$
[A]a

## METHODS TO MONITOR THE PROGRESS OF THE REACTION :

(a) Progress of gaseous reaction can be monitored by measuring total pressure at a fixed volume & temperature or by measuring total volume of mixture under constant pressure and temperature.

 $= \frac{2.303}{1 \text{ log}} = \frac{1000 \text{ PO}(\text{n})}{1000 \text{ PO}(\text{n})}$ 

{Formula is not applicable when n = 1, the value of n can be fractional also.}

- (b) By titration method :
- $2a 2V_{0}$   $a x 2Vt_{1}$   $k = \frac{2.303}{t} \log \frac{V0}{Vt}$ 1.

Study of acid hydrolysis of an easter. 2.

> 2.303 V2 V0 k = \_\_\_t log <del>∨@ @ ∨t</del>

By measuring optical rotation produced by the reaction mixture : (C)

 $k = \frac{2.303}{1} \log \frac{1}{100}$ 

#### EFFECT OF TEMPERATURE ON RATE OF REACTION.

T.C. = 
$$\frac{K_{till10}}{K_{t}}$$
  $\Box$  2 to 3 ( for most of the reactions)

## Arhenius theroy of reaction rate.



SHR = Summation of enthalpies of reactants SHP = Summation of enthalpies of reactants DH = Enthalpy change during the reaction Ea1 = Energy of activation of the forward reaction Ea2 = Energy of activation of the backward reaction

#### **Arhenius equation**

 $\square$ 

Π

k 🛛 AeEaRT

r = k [conc.]order

$$\frac{dlnk}{dT} = \frac{Ea}{RT2} \qquad \qquad \boxed{\log k = \boxed{2}} \frac{Ea}{2.303 R^{2}} \boxed{2} \log A$$

If k1 and k2 be the rate constant of a reaction at two different temperature T1 and T2 respectively, then we have

$$\log \frac{k_2}{k_1} = \frac{Ea}{2.303 \text{ RegT}} = \frac{1}{T_2}$$

$$\ln k = \ln A \quad Ea \quad \ln A \quad \ln A \quad \int \frac{Ea}{\ln K} \quad \ln A \quad \int \frac{1}{1/T_2} = \frac{Ea}{R} \quad Ea \boxtimes O$$

$$\ln K = \frac{1}{1/T_2} \quad \ln A \quad \int \frac{Ea}{1/T_2} = \frac{Ea}{R} \quad Ea \boxtimes O$$

Page 🚕 ۳۳

# INORGANIC CHEMISTRY PERIODIC TABLE & PERIODICITY

# **Development of Modern Periodic Table :**

(a) Dobereiner *s Triads*: He arranged similar elements in the groups of three elements called as triads (b) Newland *s Law of Octave*: He was the first to correlate the chemical properties of the elements with their atomic masses. (c) Lother Meyer *s Classification*: He plotted a graph between atomic masses against their respective atomic volumes for a number of elements. He found the observations ; (i) elements with similar properties occupied similar positions on the curve, (ii) alkali metals having larger atomic volumes occupied the crests, (iii) transitions elements occupied the troughs, (iv) the halogens occupied the ascending portions of the curve before the inert gases and (v) alkaline earth metals occupied the positions at about the mid points of the concluded that the atomic volumes (a physical property) of the elements are the periodic functions of their atomic masses.

## (d) Mendeleev s Periodic Table :

#### Mendeleev s Periodic s Law

the physical and chemical properties of the elements are the periodic functions of their atomic masses.

Periods	Number of Elements	Called as
(1)st n = 1	2	Very short period
(2)nd n = 2	8	Short period
(3)rd n = 3	8	Short period
(4)th n = 4	18	Long period
(1)th n = 1 (5)th n = 5	18	l ong period
(3)th n = 5	32	Very long period
(0)(1)(1) = 0	10	Incomplete period
<del>(/)(() n = /</del>	.9	incomplete period

#### Merits of Mendeleev s Periodic table:

- It has simplified and systematised the study of elements and
- their compounds.

It has helped in predicting the discovery of new elements on the basis of the blank spaces given in its periodic table.

## Demerits in Mendeleev s Periodic Table :

- $\square$  Position of hydrogen is uncertain .It has been placed in IA and VIIA groups
- $\square$  No separate positions were given to isotopes.
- $\square$  Anomalous positions of lanthanides and actinides in periodic table.
- $\Box$  Order of increasing atomic weights is not strictly followed in the arrangement
- $\square$  of elements in the periodic table.
- $\square$  Similar elements were placed in different groups.

It didn t explained the cause of periodicity.

# (e) Long form of the Periodic Table or Moseley *s Periodic Table :*

# MODERN PERIODIC LAW (MOSELEY S PERIODIC LAW) :

If the elements are arranged in order of their increasing atomic number, after a regular interval, elements with similar properties are repeated.

## **PERIODICITY :**

The repetition of the properties of elements after regular intervals when the elements are arranged in the order of increasing atomic number is called periodicity.

## **CAUSE OF PERIODICITY :**

The periodic repetition of the properties of the elements is due to the recurrence of similar valence shell electronic configurations after certain regular intervals.

The modern periodic table consists of horizontal rows (periods) and vertical column (groups).

### Periods :

 $\square$ 

There are seven periods numbered as 1, 2, 3, 4, 5, 6 and 7.

Each period consists of a series of elements having same valence shell.

Each period corresponds to a particular principal quantum number of the valence shell present in it.

Each period starts with an alkali metal having outermost electronic configuration as ns1.

Each period ends with a noble gas with outermost electronic configuration ns2np6 except helium having outermost electronic configuration as 1s2.

Each period starts with the filling of new energy level.

The number of elements in each period is twice the number of atomic orbitals available in energy level that is being filled.

# Groups :

There are eighteen groups numbered as 1, 2, 3, 4, 5, ...... 13, 14, 15, 16, 17, 18.

Group consists of a series of elements having similar valence shell electronic configuration.

6.	~		6		00			0			ŋ	[ <sup></sup>							
18 VIII A	4.002	10	20.17	18	Ar 39.94	36	¥	83.8	54	×e	132.2	86	R	222		_			
	17 VII A	<b>ი</b> ს	18.998	17	CI 35.452	35	Б	79.904	53	-	126.904	85	At	210					
)	16 VI A	∞ (	15.999	16	S 32.006	34	Se	78.96	52	Те	127.60	84	8	209					
	15 V A	~ 4	14.006	15	Р 30.973	33	As	74.921	51	с С Р	121.757	83	ā	207.980				nte)	(6)
	14  < A	ي ق	12.011	4	\$i 28.085	32	Ge	72.61	50	Sn	118.710	82	8	207.2	111		h	alama	
	13 13	5	10.811	13	AI 26.981	31	Ga	69.723	49	5	114.82	8	F	204.383				Block	-0104
			1	ţ	2 8	30	Ŋ	65.39	48	B	112.411	80	БН	200.59				atole (f	
				÷	<u> </u>	29	C	63.546	47	Ag	107.868	62	Au	196.666				M	
				0	2 III	28	ī	58.693	46	Pd	106.42	78	٤	195.08	110	nn	269	rancit	
	nents			c	e IIIV	27	ő	55.933	45	Rh	102.905	11	-	192.22	109	Mt	266	Pr -	-
	( Eler	)		a	° III	26	Fe	55.84	44	Ru	101.07	76	ő	190.2	108	Η	265	4	
	-Block	Ì		٢	VII B	25	Mn	54.938	43	Tc	98	76	Re	186.207	107	Bh	262.12		
	P			u	VI B	24	ວັ	51.996	42	Mo	95.94	74	≥	183.85	106	Sg	263.118		
				ų	28	23	>	50.9415	41	qN	92.906	73	Та	180.947	105	нa	262.114		
					t ≥	22	F	47.88	40	z	91.224	72	Ŧ	178.49	104	Ł	261.11		
				~	°≣	21	S	44.959	39	≻	88.905	67	La*	138.905	89	Ac**	227		
	z H	4 0	9.012	12	Mg 24.30	20	Ca	40.078	38	ي ا	87.62	<del>66</del>	Ba	137.27	88	Ra	226		
- ₹	1 H 1.007	е	ы 6.941	7	Na 22.98	19	¥	39.08	37	Rb	85.46	66	ő	132.90	87	Ľ	223		
	A VIII A	1  A  A    A 	1     1     1       1A     1     2       1A     1     1       1     2     1       1     1     2       1     1     1       3     4     1       3     4     1	1     1     18     14     15     16     17     18       1     1     2     1     1     16     17     18       1     1     1     1     1     16     17     16       1     1     1     1     1     1     17     16       3     4     5     6     7     8     9     10       10311     12.011     14.006     15.999     18.998     20.179	1     1     1     18     14     15     16     17     18       1     1     2     13     14     15     16     17     18       1     1007     11A     10A     VA     VIA     VIA     VA       3     4     9012     5     6     7     8     9     100       11     12     13     14     15     16     17     16	1     1     1     1     1     1     1       1     2     1     1     1     1     1     1       1007     1     A     1     1     1     1     1       1007     1     A     VA     VIA     VA     VIA     VIA       1007     1     A     VA     VIA     VIA     VIA     VIA       3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     20.179       11     12     3     4     5     6     7     8     20.179       11     12     3     14     15     16     17     18       11     12     3     14     15     16     17     18       2238     2430     35307     323091     353042     39422     39422	1     1     1     1     1     1     1       1     1     2     1     1     1     1     1       1     1     2     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10       11     12     13     14     15     16     17     18     16     17     18       19     20     21     25     26     27     28     206     35.45     39.48       19     20     21     28     26     27     28     30.73     32.06     35.45     36.48	1     1     1     1     1     1     1     1     1       1     1     2     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1 <th>1     1     2     13     14     15     16     17     18       1     1     2     1007     1A     13     14     15     16     17     16       1     1     2     1     1     1     1     1     1     1     1       3     4     5     6     7     8     9     10     11     12     14     15     16     17       1     12     3     4     5     6     7     8     9     10     11     12       1     12     3     4     5     6     7     8     9     10     11     12       1     12     3     4     5     6     7     8     9     10     11       1     12     3     4     5     6     7     8     9     17     18       1     12     3     4     16     11     12     13     14     15     16     17     18       1     12     3     4     5     2     13     14     15     16     17     18       1     12     2     2     2     2</th> <th>1     1     2     13     14     15     16     17     18       1007     1A     1A     1A     1A     1A     1A     1A     1A       1007     1A     1A     1A     1A     15     16     17     18       1007     1A     1A     1A     15     16     17     14       1007     1A     5     6     7     8     9     10       3     26     7     8     9     10     11     12     14     15     16     17     18       11     12     3     4     5     6     7     8     9     20179       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     20179       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     10       11     12     13     14     15     16     17     18       19     20     21     23     32     32</th> <th>1     1     2     d-Block Elements     13     14     15     16     17     18       1007     1     1     2     d-Block Elements     13     14     15     16     17     4       3     4     1007     1     12     3     4     100     10     11     12     14     15     16     17     4       3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     13     14     15     14     15     16     17     18       13     23     24     55     25     25     27     28     20     16     17     18       13     22     23     24<th>1     1     2     1<th>1     1     2     1     1     1     1     1     1     1       1     1     2     1     1     1     1     1     1     1       1     1007     1     1     1     1     1     1     1     1       3     8     1     1     1     1     1     1     1     1       3     8     1     1     1     1     1     1     1     1       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     4     6     7     8     9     17     18       1     12     2     2     2     2     2     2     3     3     3     3       1     12     12     2     2     2     2     2     3     3</th><th>1     1     2     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1<th>1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1<th>1     1     2     d-Block Elements     13     14     15     16     17     4       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VA     VIA     VIA     VIA     VIA       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     11     12     11     12     14     15     16     17     18       11     12     21     22     23     24     25     26     27     20     14     15     16       13     34     45     65     27     28     29     39     30     30     30</th><th>1     1     2     d-Block Elements     13     14     15     16     17     2       1007     107     10     1     1     1     1     1     1     2       1007     107     10     1     1     1     1     1     1     1     1       107     107     107     1     1     1     1     1     1     1     1       107     10     1     1     1     1     1     1     1     1     1       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     1     12     1     12     14     15     16     17     18       13     20     21     22     23     26</th><th>1     1     2     d-Block Elements     13     14     15     16     17     2       107     107     107     107     107     107     107     107     10     11     12     2       3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     8       107     11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     100       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     16       11     12     3     24     45     45     45     45     45     46     47     48     56     17     106     17     10     17     10<th>1     1     2     d-Block Elements     13     14     15     16     17     16       1007     11A     1</th></th></th></th></th></th>	1     1     2     13     14     15     16     17     18       1     1     2     1007     1A     13     14     15     16     17     16       1     1     2     1     1     1     1     1     1     1     1       3     4     5     6     7     8     9     10     11     12     14     15     16     17       1     12     3     4     5     6     7     8     9     10     11     12       1     12     3     4     5     6     7     8     9     10     11     12       1     12     3     4     5     6     7     8     9     10     11       1     12     3     4     5     6     7     8     9     17     18       1     12     3     4     16     11     12     13     14     15     16     17     18       1     12     3     4     5     2     13     14     15     16     17     18       1     12     2     2     2     2	1     1     2     13     14     15     16     17     18       1007     1A     1A     1A     1A     1A     1A     1A     1A       1007     1A     1A     1A     1A     15     16     17     18       1007     1A     1A     1A     15     16     17     14       1007     1A     5     6     7     8     9     10       3     26     7     8     9     10     11     12     14     15     16     17     18       11     12     3     4     5     6     7     8     9     20179       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     20179       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     10       11     12     13     14     15     16     17     18       19     20     21     23     32     32	1     1     2     d-Block Elements     13     14     15     16     17     18       1007     1     1     2     d-Block Elements     13     14     15     16     17     4       3     4     1007     1     12     3     4     100     10     11     12     14     15     16     17     4       3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     13     14     15     14     15     16     17     18       13     23     24     55     25     25     27     28     20     16     17     18       13     22     23     24 <th>1     1     2     1<th>1     1     2     1     1     1     1     1     1     1       1     1     2     1     1     1     1     1     1     1       1     1007     1     1     1     1     1     1     1     1       3     8     1     1     1     1     1     1     1     1       3     8     1     1     1     1     1     1     1     1       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     4     6     7     8     9     17     18       1     12     2     2     2     2     2     2     3     3     3     3       1     12     12     2     2     2     2     2     3     3</th><th>1     1     2     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1<th>1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1<th>1     1     2     d-Block Elements     13     14     15     16     17     4       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VA     VIA     VIA     VIA     VIA       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     11     12     11     12     14     15     16     17     18       11     12     21     22     23     24     25     26     27     20     14     15     16       13     34     45     65     27     28     29     39     30     30     30</th><th>1     1     2     d-Block Elements     13     14     15     16     17     2       1007     107     10     1     1     1     1     1     1     2       1007     107     10     1     1     1     1     1     1     1     1       107     107     107     1     1     1     1     1     1     1     1       107     10     1     1     1     1     1     1     1     1     1       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     1     12     1     12     14     15     16     17     18       13     20     21     22     23     26</th><th>1     1     2     d-Block Elements     13     14     15     16     17     2       107     107     107     107     107     107     107     107     10     11     12     2       3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     8       107     11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     100       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     16       11     12     3     24     45     45     45     45     45     46     47     48     56     17     106     17     10     17     10<th>1     1     2     d-Block Elements     13     14     15     16     17     16       1007     11A     1</th></th></th></th></th>	1     1     2     1 <th>1     1     2     1     1     1     1     1     1     1       1     1     2     1     1     1     1     1     1     1       1     1007     1     1     1     1     1     1     1     1       3     8     1     1     1     1     1     1     1     1       3     8     1     1     1     1     1     1     1     1       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     4     6     7     8     9     17     18       1     12     2     2     2     2     2     2     3     3     3     3       1     12     12     2     2     2     2     2     3     3</th> <th>1     1     2     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1<th>1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1<th>1     1     2     d-Block Elements     13     14     15     16     17     4       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VA     VIA     VIA     VIA     VIA       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     11     12     11     12     14     15     16     17     18       11     12     21     22     23     24     25     26     27     20     14     15     16       13     34     45     65     27     28     29     39     30     30     30</th><th>1     1     2     d-Block Elements     13     14     15     16     17     2       1007     107     10     1     1     1     1     1     1     2       1007     107     10     1     1     1     1     1     1     1     1       107     107     107     1     1     1     1     1     1     1     1       107     10     1     1     1     1     1     1     1     1     1       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     1     12     1     12     14     15     16     17     18       13     20     21     22     23     26</th><th>1     1     2     d-Block Elements     13     14     15     16     17     2       107     107     107     107     107     107     107     107     10     11     12     2       3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     8       107     11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     100       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     16       11     12     3     24     45     45     45     45     45     46     47     48     56     17     106     17     10     17     10<th>1     1     2     d-Block Elements     13     14     15     16     17     16       1007     11A     1</th></th></th></th>	1     1     2     1     1     1     1     1     1     1       1     1     2     1     1     1     1     1     1     1       1     1007     1     1     1     1     1     1     1     1       3     8     1     1     1     1     1     1     1     1       3     8     1     1     1     1     1     1     1     1       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     5     6     7     8     9     10       1     12     3     4     4     6     7     8     9     17     18       1     12     2     2     2     2     2     2     3     3     3     3       1     12     12     2     2     2     2     2     3     3	1     1     2     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1 <th>1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1<th>1     1     2     d-Block Elements     13     14     15     16     17     4       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VA     VIA     VIA     VIA     VIA       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     11     12     11     12     14     15     16     17     18       11     12     21     22     23     24     25     26     27     20     14     15     16       13     34     45     65     27     28     29     39     30     30     30</th><th>1     1     2     d-Block Elements     13     14     15     16     17     2       1007     107     10     1     1     1     1     1     1     2       1007     107     10     1     1     1     1     1     1     1     1       107     107     107     1     1     1     1     1     1     1     1       107     10     1     1     1     1     1     1     1     1     1       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     1     12     1     12     14     15     16     17     18       13     20     21     22     23     26</th><th>1     1     2     d-Block Elements     13     14     15     16     17     2       107     107     107     107     107     107     107     107     10     11     12     2       3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     8       107     11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     100       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     16       11     12     3     24     45     45     45     45     45     46     47     48     56     17     106     17     10     17     10<th>1     1     2     d-Block Elements     13     14     15     16     17     16       1007     11A     1</th></th></th>	1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1 <th>1     1     2     d-Block Elements     13     14     15     16     17     4       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VA     VIA     VIA     VIA     VIA       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     11     12     11     12     14     15     16     17     18       11     12     21     22     23     24     25     26     27     20     14     15     16       13     34     45     65     27     28     29     39     30     30     30</th> <th>1     1     2     d-Block Elements     13     14     15     16     17     2       1007     107     10     1     1     1     1     1     1     2       1007     107     10     1     1     1     1     1     1     1     1       107     107     107     1     1     1     1     1     1     1     1       107     10     1     1     1     1     1     1     1     1     1       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     1     12     1     12     14     15     16     17     18       13     20     21     22     23     26</th> <th>1     1     2     d-Block Elements     13     14     15     16     17     2       107     107     107     107     107     107     107     107     10     11     12     2       3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     8       107     11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     100       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     16       11     12     3     24     45     45     45     45     45     46     47     48     56     17     106     17     10     17     10<th>1     1     2     d-Block Elements     13     14     15     16     17     16       1007     11A     1</th></th>	1     1     2     d-Block Elements     13     14     15     16     17     4       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VIA     VIA     VIA     VIA     VIA       1007     IIA     1001     IIA     VA     VA     VA     VIA     VIA     VIA     VIA       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     11     12     11     12     14     15     16     17     18       11     12     21     22     23     24     25     26     27     20     14     15     16       13     34     45     65     27     28     29     39     30     30     30	1     1     2     d-Block Elements     13     14     15     16     17     2       1007     107     10     1     1     1     1     1     1     2       1007     107     10     1     1     1     1     1     1     1     1       107     107     107     1     1     1     1     1     1     1     1       107     10     1     1     1     1     1     1     1     1     1       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10       11     12     1     12     1     12     14     15     16     17     18       13     20     21     22     23     26	1     1     2     d-Block Elements     13     14     15     16     17     2       107     107     107     107     107     107     107     107     10     11     12     2       3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     8       107     11     12     3     4     5     6     7     8     9     10       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     18       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     100       11     12     3     4     5     6     7     8     9     10     11     12     13     14     15     16     17     16       11     12     3     24     45     45     45     45     45     46     47     48     56     17     106     17     10     17     10 <th>1     1     2     d-Block Elements     13     14     15     16     17     16       1007     11A     1</th>	1     1     2     d-Block Elements     13     14     15     16     17     16       1007     11A     1

71	Р	174.967	103	۲	260
70	đ	173.04	102	٩	259
69	ш	168.934	101	pM	258
68	ш	167.26	100	En	257
67	우	164.930	66	<mark>В</mark>	252
66	2	162.50	98	້ວ	251
65	đ	158.925	26	鮝	247
64	B	157.25	<del>96</del>	g	247
63	П	151.965	96	Am	243
62	Sm	150.36	64	Ъ	244
61	БВ	145	93	d	237
60	PN	144.24	92	⊃	238.028
59	ፚ	140.907	91	Ра	231
58	o	140.115	60	f	232.038

\*Lanthanides \*\*Actinides

# **CLASSIFICATION OF THE ELEMENTS :**

### (a) s-Block Elements

Group 1 & 2 elements constitute the s-block. General electronic configuration is [inert gas] ns1-2

s-block elements lie on the extreme left of the periodic table.

## (b) p-Block Elements

Group 13 to 18 elements constitute the p-block. General electronic configuration is [inert gas] ns2 np1-6

#### (c) d-Block Elements

Group 3 to 12 elements constitute the d-block. General electronic configuration is [inert gas] (n 1) d1-10 ns1-2

#### (d) f-Block Elements

General electronic configuration is (n 2) f1-14 (n 1) d0-1 ns2. All f-block elements belong to 3rd group.

Elements of f-blocks have been classified into two series. (1) Ist inner transition or 5 f-series, contains 14 elements  $\int_{90}^{58}$  to  $\int_{103}^{71}$  Lr.

# Prediction of period, group and block :

- Period of an element corresponds to the principal quantum number of the valence shell.
- ☐ The block of an element corresponds to the type of subshell which receives the last electron.
- The group is predicted from the number of electrons in the valence shell or/and penultimate shell as follows.

(a)) Gipms-blottle elementerivistion ce electrons Group no. = 10 + no. of valence (b); From (b); Koelenbeorts; elements; Group no. = no. of electrons in (n 1) d sub shell + no. of electrons in valence shell.

# Metals and nonmetals :

The metals are characterised by their nature of readily giving up the electron(s) and from shinning lustre. Metals comprises more than 78% of all known elements and appear on the left hand side of the periodic table. Metals are usually solids at room temperature (except mercury, gallium). They have high melting and boiling points and are good conductors of heat and electricity. Oxides of metals are generally basic in nature (some metals in their higher oxidation state form acid oxides e.g. CrO).

□ Nonmetals do not lose electrons but take up electrons to form corresponding anions. Nonmetals are located at the top right hand side of the periodic table. Nonmetals are usually solids, liquids or gases at room temperature with low melting and boiling points. They are poor conductors of heat and electricity. Oxides of nonmetals are generally acidic in nature.

# Metalloids (Semi metals) :

The metalloids comprise of the elements B, Si, Ge, As, Sb and Te.

# Diagonal relationship :

2nd period Li Be B C 3rd period Na Mg Al Si Diagonal relationship arises because of ;

- (i) on descending a group, the atoms and ions increase in size. On moving from left to right in the periodic table, the size decreases. Thus on moving diagonally, the size remains nearly the same. (Li = 1.23 Å & Mg = 1.36 Å; Li+ = 0.76 Å & Mg2+ = 0.72 Å)
- (ii)it is sometimes suggested that the diagonal relationship arises because of diagonal similarity in electronegativity values.

(Li = 1.0 & Mg = 1.2; Be = 1.5 & Al = 1.5; B = 2.0 & Si = 1.8)

# The periodicity of atomic properties :

# (i) Effective nuclear charge :

The effective nuclear charge (Z) = Z  $(\mathbb{Z})$ , (where Z is the actual nuclear charge (atomic number of the element) and  $(\mathbb{Z})$  is the shielding (screening) constant). The value of  $(\mathbb{Z})$  i.e. shielding effect can be determined using the Slater s rules.

- (ii) Atomic radius :
- (A) **Covalent radius :** It is one-half of the distance between the centres of two nuclei (of like atoms) bonded by a single covalent bond. Covalent radius is generally used for nonmetals.
- (B) Vander Waal s radius (Collision radius) : It is one-half of the internuclear distance between two adjacent atoms in two nearest neighbouring molecules of the substance in solid state.

# (C) Metallic radius (Crystal radius) : It is one-half of the distance between the nuclei of two adjacent metal atoms in the metallic crystal lattice. Thus, the sevelent, wander Wall a and metallic radius magnitude wise follows.

□ Thus, the covalent, vander Wall s and metallic radius magnitude wise follows the order,

$$r_{covalent} < r_{crystal} < r_{vander Walls}$$

Variation in a Period	Variation in a Group
In a period left to right :	In a group top to bottom :
Nuclear charge (Z) increases by one unit	Nuclear charge (Z) increases by more than one unit
Effective nuclear charge (Z <sub>eff</sub> ) also increases	Effective nuclear charge (Zeff) almost remains constant because of increased screening effect of inner shells electrons.
But number of orbitals (n) remains constant	But number of orbitals (n) increases.
As a result, the electrons are pulled closer to the nucleus by the increased Zeff. rn $\Box \Box \frac{1}{2}$	The effect of increased number of atomic shells overweighs the effect of increased nuclear charge. As a result of this the size of atom increases from top to bottom in a given group.
Hence atomic radii decrease with increase in atomic number in a period from left to right.	

#### (iii)

#### Ionic radius :

The effective distance from the centre of nucleus of the ion up to which it has an influence in the ionic bond is called ionic radius.

Cation	Anion
It is formed by the lose of one of more electrons from it is to the valence shell of an atom of an element. Cations are smaller than the parent atoms because, (i) the whole of the outer shell of electrons is usually (i) anis removed. (ii)inacation,thenumberofpositivechargesonthemagnitude o nucleus is greater than number of orbital electrons (ii) nuc leading to incresed inward pull of remaining electrons elect causing contraction in size of the ion.	valence shell of an atom of an element. Anions are larger than the parent atoms because on is formed by gain of one or more electrons in the neutral atom and thus number of electrons increases but of nuclear charge remains the same. ear charge per electrons is thus reduced and the trons cloud is held less tightly by the nucleus leading to theexpansionoftheoutershell.Thussizeofanionis inc rea se d.
(iv) Ionisation Energy : Ionisation energy (IE) is defi to remove the most loosely bound electror cation. M(g) 220印2 M+(g) + e ; M2+ (g) + IE 222 M+3 (g) + e	ned as the amount of energy required n from an isolated gaseous atom to form a $M+(g) + IE_{2}$ M2+ (g) + e

IE, IE & IE are the lst, IInd & IIIrd ionization energies to remove electron from a neutral atom, monovalent and divalent cations respectively. In general, (IE)  $_{1}$  (IE)  $< _{2}$  (IE)  $< ...._{3}$ 

# ☐ Factors Influencing Ionisation energy

- (A Size of the Atom : Ionisation energy decreases with increase in atomic size.
- (B) Nuclear Charge : The ionisation energy increases with increase in the nuclear charge.

- (C) Shielding or screening effect : The larger the number of electrons in the inner shells, greater is the screening effect and smaller the force of attraction and thus ionization energy (IE) decreases. Penetration effect
- (D) of the electron : Penetration effect of the electrons follows the order s > p > d > f for, the same energy level. Higher the penetration of electron higher will be the ionisation energy. Electronic Configuration : If an
- (E) atom has exactly half-filled or completely filled orbitals, then such an arrangement has extra stability. Electron Gain Enthalphy :

(V) (CHANGED TOPIC NAME) The electron gain enthalpy 2H2, is the change in standard molar enthalpy

when a neutral gaseous ato $\overset{\ensuremath{\texttt{g}}}{m}$  gains an electron to form an anion.

X (g) + e (g) ?? X (g)

The second electron gain enthalpy, the enthalpy change for the addition of a second electron to an initially neutral atom, invariably positive because the electron repulsion out weighs the nuclear attraction.

- Group 17 elements (halogens) have very high negative electron gain enthalpies (i.e. high electron affinity) because they can attain stable noble gas electronic configuration by picking up an electron.
- Across a period, with increase in atomic number, electron gain enthalpy becomes more negative
- As we move in a group from top to bottom, electron gain enthalpy becomes less negative
- $\square$  Noble gases have large positive electron gain enthalpies
- $\square$  Negative electron gain enthalpy of O or F is less than S or Cl.
- $\square$  Electron gain enthalpies of alkaline earth metals are very less or positive
- $\square$  Nitrogen has very low electron affinity

### Sic) Engrigement (it) Stability of half filled and

completely filled orbitals of a subshell is comparatively more and the addition of an extra electron to such an system is difficult and hence the electron affinity value decreases.

# (VI) Electronegativity :

А

Electronegativity is a measure of the tendency of an element to attract shared electrons towards itself in a covalently bonded molecules.

(a)

□ = X X =<sub>B</sub>O.208

Pauling s scale :

E.A?B ? EA?A ?EB?B

 $E_{A^{-B}} = \text{Bond enthalpy/ Bond energy of A} \quad B \text{ bond.} \\ E_{A^{-A}} = \text{Bond energy of A} \quad A \text{ bond} \\ E_{B B}^{A^{-A}} = \text{Bond energy of B} \quad B \text{ bond} \\$ **(All bond energies are in kcal / mol)**

 $\mathbb{Q} = X_A X = 0.1017 \qquad \sqrt{E.A\mathbb{Q}B \mathbb{Q} \text{ FADA } \mathbb{Q}EB\mathbb{Q}B}$ All bond energies are in kJ / mol.

(b) Mulliken s scale :

Π

[E ] EA 2\_\_\_\_\_2

Paulings s electronegativity  $\boxtimes$  is related to Mulliken s electronegativity  $\boxtimes_{_{M}}$  as given below.

□= 1.35 (□)1/2 1.37

Mulliken s values were about 2.8 times larger than the Pauling s values.

# (VII) Periodicity of Valence or Oxidation States :

There are many elements which exhibit variable valence. This is particularly characteristic of transition elements and actinoids.

## (VIII) Periodic Trends and Chemical Reactivity :

In a group, basic nature of oxides increases or acidic nature decreases. Oxides of the metals are generally basic and oxides of the nonmetals are acidic. The oxides of the metalloids are generally amphoteric in nature. The oxides of Be, Al, Zn, Sn, As, Pb and Sb are amphoteric.

 $\Box$  In a period the nature of the oxides varies from basic to acidic.

Rad	MgO	AIO	SiO	4 10
SÓ		2 3	2	4 10
Strongly basic	Basic	amphoteric	Weakly acidic	Acidic
Acidic	Strong	ly acidic	-	

# CHEMICAL BONDING

# **Chemical Bond :**

In the process each atom attains a stable outer electronic configuration of inert gases.

### Ionic or Electrovalent Bond :

The formation of an ionic compound would primarily depends upon :

\* The ease of formation of the positive and negative ions from the respective neutral atoms.

\* The arrangement of the positive and negative ions in the solid, that is the lattice of the crystalline compound.

## Conditions for the formation of ionic compounds :

- Electronegativity difference between two combining elements must be (i) larger.
- Ionization enthalpy  $(M(g) \square M+(g) + e)$  of electropositive element must be (ii) low.
- Negative value of electron gain enthalpy (X (g) + e 2 X (g)) of (iii) electronegative element should be high.
- Lattice enthalpy  $(M+(g) + X (g) \square MX (s))$  of an ionic solid must be high. (iv)

# Lattice Enthalpy :

The lattice enthalpy of an ionic solid is defined as the energy required to completely separate one mole of a

solid ionic compound into gaseous constituent ions.

# Factors affecting lattice energy of an ionic compound :

- Lattice energy  $\mathbb{Z} \xrightarrow[r_{\neg} \mathbb{Z}r_{\neg}]{r_{\neg}}$  where  $(r_{+} + r)_{\mathbb{F}}$  Inter-ionic Distance. (i)
- Lattice energy 2 Z, Z (ii)

Z I charge on cation in terms electronic charge.

 $Z^{\dagger}$  charge on anion in terms electronic charge.

# Determination of lattice energy :

### **Born-Haber Cycle :**

It inter relates the various energy terms involved during formation of an ionic compound.

It a thermochemical cycle based on the Hess s law of constant heat sum m ation.

# Hydration :

All the simple salts dissolve in water, producing ions, and consequently the solution conduct electricity. Since Li+ is very small, it is heavily hydrated. This makes radius of hydrated Li+ ion large and hence it moves only slowly. In contrast, Cs+ is the least hydrated because of its bigger size and thus the radius of the Cs+ ion is smaller than the radius of hydrated Li+, and hence hydrated Cs+ moves faster, and conducts electricity more readily.

# Hydrolysis :

**Hydrolysis** means reaction with water molecules ultimately leading to breaking of O-H bond into H+ and OH ions.

Hydrolysis in covalent compounds takes place generally by two mechanisms

(a) By Coordinate bond formation : Generally in halides of atoms having vacant d-orbitals or of halides of atoms having vacant orbitals.

(b) By H-bond formation : For example in Nitrogen trihalides

# General properties of ionic compounds :

- (a) **Physical state :** At room temperature ionic compounds exist either in solid state or in solution phase but not in gaseous state.
- (b) Simple ionic compounds do not show isomerism but isomorphism is their important characteristic.

e.g. , FeSO .7HO l

MgSO, 7HQ

### (c) Electrical conductivity :

All ionic solids are good conductors in molten state as well as in their aqueous solutions because their ions are free to move.

## (d) Solubility of ionic compounds :

Soluble in polar solvents like water which have high dielectric constant

# Covalent character in ionic compounds (Fajan s rule) :

Fajan s pointed out that greater is the polarization of anion in a molecule, more is covalent character in it.

Cation anion

More distortion of anion . more will be polarisation then covalent character increases.

Fajan s gives some rules which govern the covalent character in the ionic compounds, which are as follows:

- (i) Size of cation : Size of cation 2 1 / polarisation.
- (ii) Size of anion : Size of anion 🛛 polarisation
- (iii) Charge on cation : Charge on cation 2 polarisation.
- (iv) Charge on anion : Charge on anion 2 polarisation.
- (v) Pseudo inert gas configuration of cation :

# **Covalent Bond :**

It forms by sharing of valence electrons between atoms to form molecules e.g., formation of  $Cl_molecule$ :



Covalent bond between two CI atoms

The important conditions being that : Each bond Is formed as a result of

- (i) sharing of an electron pair between the atoms. Each combining atom
- (ii) contributes at least one electron to the shared pair. The combining atoms
- (iii) attain the outer- shell noble gas configurations as a result of the sharing of electrons.

# Coordinate Bond (Dative Bond):

The bond formed between two atom in which contribution of an electron pair is made by one of them while the sharing is done by both.



# Valence bond theory (VBT) :



#### **Orbital Overlap Concept**

according to orbital overlap concept, the formation of a covalent bond between two atoms results by pairing of electrons present, in the valence shell having opposite spins.

## Types of Overlapping and Nature of Covalent Bonds

The covalent bond may be classified into two types depending upon the types of overlapping :

(i) sigma(2) bond, and (ii) pi (2) bond

(i) Sigma (2) bond : This type of covalent bond is formed by the end to end (head-on) overlap of bonding orbitals along the internuclear axis.
 2 s-s overlapping



Page 🔬 ٤٦

(ii) **pi**(2) **bond**: In the formation of 2 bond the atomic orbitals overlap in such a way that their axes remain parallel to each other and perpendicular to the internuclear axis.



#### Strength of Sigma and pi Bonds :

In case of sigma bond, the overlapping of orbitals takes place to a larger extent. Hence, it is stronger as compared to the pi bond where the extent of overlapping occurs to a smaller extent.

# Valence shell electron pair repulsion (VSEPR) theory : The main postulates of VSEPR theory are as follows:

- (i) The shape of a molecule depends upon the number of valence shell electron pairs [bonded or nonbonded) around the central atom.
- (ii) Pairs of electrons in the valence shell repel one another since their electron
- (iii) clouds are negatively charged.
- These pairs of electrons tend to occupy such positions in space that
- (iv) minimise repulsion and thus maximise distance between them.
- (v) The valence shell is taken as a sphere with the electron pairs localising on
- the spherical surface at maximum distance from one another.
- (vi) A multiple bond is treated as if it is a single electron pair and the two or three electron pairs of a multiple bond are treated as a single super pair. Where two or more resonance structures can represent a molecule, the VSEPR model is applicable to any such structure.

# The repulsive interaction of electron pairs decreases in the order :

lone pair ( $\square p$ ) - lone pair ( $\square p$ ) > lone pair ( $\square p$ ) - bond pair (bp) > bond pair (bp) - bond pair (bp)

# Hybridisation :

Salient features of hybridisation : The number of hybrid orbitals is
equal to the number of the atomic orbitals that get hybridised. The hybridised orbitals are always equivalent in energy and shape. The hybrid orbitals are more effective in forming stable bonds than the pure atomic orbitals. These hybrid orbitals are directed in space in some preferred direction to have minimum repulsion between electron pairs and thus a stable arrangement is obtained. Therefore, the type of hybridisation indicates the geometry of the molecules.

4

#### Important conditions for hybridisation :

- (i) The orbitals present in the valence shell of the atom are hybridised.
- (ii) The orbitals undergoing hybridisation should have almost equal energy.
- (iii) Promotion of electron is not essential condition prior to hybridisation.
- (iv) It is the orbital that undergo hybridization and not the electrons.

# Determination of hybridisation of an atom in a molecule or ion: Steric number rule (given by Gillespie) :

Steric No. of an atom = number of atom bonded with that atom + number of lone pair(s) left on that atom.

Table-3			
Steric Number	Types of Hybridisation	<b>Geometry</b> Trigonal planar	
2	sp	Tetrahedral	
3	sp2	Trigonal bipyramidal	
4	sp3	Octahedral	
5	sp3 d	Pentagonal bipyramidal	
6	sp3 d2	· ····································	
7	sp3 d3		

# Hybridization Involving d-orbital :

Type of d	orbital involved
gp3	d <sub>z2</sub>
sp3	dx2 y2 & d <sub>Z2</sub>
d2	dx2 <sub>y2</sub> , d Z2 & dxy

dx2y2?

# Molecular Orbital Theory (MOT) :

developed by F. Hund and R.S. Mulliken in 1932. Molecular orbitals are tosmed by the combination of atomic orbitals of comparable energies (i) and proper symmetry. An electron in an atomic orbital is influenced by ggeonucleus, while in a molecular orbital it is influenced by two or more (ii) nuclei depending upon the number of the atoms in the molecule. **Thus** an atomic orbital is monocentric while a molecular orbital is polycentric. The number of molecular orbitals formed is equal to the (iii) number of combining atomic orbitals. When two atomic orbitals combine, two molecular orbitals called bonding molecular orbital and antibonding molecular orbital are formed. The molecular orbitals like the atomic orbitals are filled in accordance with the Aufbau principle (iv) obeying the Pauli Exclusion principle and the Hund s Rule of Maximum Multiplicity. But the filling order of these molecular orbitals is always experimentally decided, there is no rule like (n + l) rule in case of atomic orbitals.

#### Conditions for the combination of atomic orbitals :

- 1. The combining atomic orbitals must have the same or nearly the same
- 2. energy.
- 3. The combining atomic orbitals must have the same symmetry about the molecular axis.

The combining atomic orbitals must overlap to the maximum extent.

#### Energy level diagram for molecular orbitals :

The increasing order of energies of various molecular orbitals for O and F is given below :

 $221 s < 2^* 1 s < 22 s < 2^* 2 s < 22 p < (22 p = 22 p) < (2^* 2 p = 2^* 2 p) < 2^* 2 p$ 

The important characteristic <sup>z</sup> feature <sup>x</sup> of this order is that the **energy of** <sup>[7</sup>2pz molecular orbital is higher than that of <sup>[7</sup>2px and <sup>[7</sup>2py molecular orbitals.

### Bond Order

#### Bond order (b.o.) = $\frac{1}{2}$ (Nb Na)

A positive bond order (i.e., N > N) means a stable molecule while a negative (i.e., N < N) or zero (i.e., N = N) bond order means an unstable m olecule.

#### Nature of the Bond :

Integral bond order values of 1, 2 or 3 correspond to single, double or triple bonds respectively.

#### **Bond-Length:**

The bond order between two atoms in a molecule may be taken as an approximate measure of the bond length. The bond length decreases as bond order increases.

#### Magnetic Nature :

If all the molecular orbitals in a molecule are doubly occupied, the substance is diamagnetic (repelled by magnetic field) e.g., N molecule.

### Dipole moment :

Dipole moment ( $\mu$ ) = Magnitude of charge (q) × distance of separation (d)

Dipole moment is usually expressed in Debye units (D). The conversion

factors are  $_{\Box}$   $\,$  1 D = 3.33564  $\times$  10 30 Cm, where C is coulomb and m is meter.

1 Debye = 1 × 10 18 e.s.u. cm.

For example the dipole moment of HF may be represented as

The shift in electron density is represented by crossed arrow (+----) above the Lewis structure to indicate the direction of the shift. a molecule will have a dipole moment if the summation of all of the individual moment vector is non-zero.



 $\mathsf{R} = \sqrt{\mathsf{P2}_{\square} \mathsf{Q2}^{\square} \mathsf{P2} \mathsf{Qcos}^{\square}},$ 

where R is resultant dipole moment.

# **Resonance :**

**Definition :** Resonance may be defined as the phenomenon in which

two or more structures involving in identical position of atom, can be written for a particular compound.

Sprickaeplenthe crown Omovecule can be equally represented by the



**Resonance Hybrid :** It is the actual structure of all different possible structures that can be written for the molecule without violating the rules of maximum covalance for the atoms.



# Hydrogen Bond :

H⊠+ F⊠ H⊠+ F⊠ H⊠+ F⊠⊠

# Conditions required for H-bond :

(i) Molecule should have more electronegative atom (F, O, N) linked to H-atom.

- (ii) Size of electronegative atom should be smaller.
- (iii) A lone pair should be present on electronegative atom.



# TYPES OF H-BONDS :

Π

#### (A) Intramolecular H-Bonding :

it is formed when hydrogen atom is present in between the two highly electronegative (F, O, N) atoms within the same molecule.



o-hydroxy benzaldehyde

It has lower boiling point (i.e. more volatile) than its para-derivative

#### Necessary conditions for the formation of intramolecular hydrogen-bonding:

(a) the ring formed as a result of hydrogen bonding should be planar.

(b) a 5- or 6- membered ring should be formed.

(c) interacting atoms should be placed in such a way that there is minimum strain during the ring closure.

#### (B) Intermolecular H-Bonding :

it is formed between two different molecules of the same or different com pounds.

#### (a) In water molecules



(b) The hydrogen bonds in HF link the F atom of one molecule with the H-atom of another molecule, thus forming a zig-zag chain (HF) in both the solid and also in the liquid.



# Intermolecular forces (Vander Waals Forces) :

Intermolecular attractions hold two or more molecules together. These are weakest chemical forces and can be of following types.

(b) Dipole-dipole attraction

(a) Ion-dipole attraction

(c) Ion-induced dipole attraction (d) Dipole-induced dipole attraction

(e) Instantaneous dipole- Instantaneous induced dipole attraction :

(Dispersion force or London forces)

Strength of vander waal force 2 molecular mass.

van der Waal s force 🛛 boiling point.

# Metallic bond :

Two models are considered to explain metallic bonding: (A) Electron see model (B) Band model

(A) Electron-sea model(B) Band model

## Some special bonding situations :

(a) Electron deficient bonding: There are many compounds in which some electron deficient bonds are present apart from normal covalent bonds or coordinate bonds. These electron deficient bonds have less number of electrons than the expected such as three centre-two electron bonds (3c-2e) present in diborane BH, Al(CH), BeH(s) and bridging metal carbonyls.

(b) Back Bonding : Back bonding generally takes place when out of two bonded atoms one of the atom has vacant orbitals (generally this atom is from second or third period) and the other bonded atom is having some non-bonded electron pair(generally this atom is from the second period). Back bonding increases the bond strength and decreases the bond length. For example, in BF<sub>3</sub>



## **ADDITION COMPOUNDS:**

They are formed by the combination of two or more stable compounds in stoichiometric ratio. These are (1) Double salts and (2) Coordination compounds

#### **DOUBLE SALTS :**

Those addition compounds which lose their identity in solutions eg. K2SO4 , Al2(SO4)3

#### **COORDINATION COMPOUNDS :**

Those addition compounds which retain their identity (i.e. doesn t lose their identity) in solution are

or

#### **Central Atom/Ion :**

In a coordination entity the atom/ion to which are bound a fixed number of ligands in a definite geometrical arrangement around it.

#### Ligands :

The neutral molecules, anions or cations which are directly linked with central metal atom or ion in the coordination entity are called ligands.

## **Chelate ligand :**

Chelate ligand is a di or polydentate ligand which uses its two or more donor atoms to bind a single metal ion producing a ring.

#### **Ambidentate Ligand :**

Ligands which can ligate through two different atoms present in it

 $M \leftarrow N \leqslant_{O}^{O}$  nitrito-N ;  $M \boxtimes O N=O$ nitrito-O M 2 SCN thiocyanato or thiocyanato-S; M I NCS isothiocyanato or thiocyanato-N

#### **Coordination Number :**

The number of ligand donor atoms to which the metal is directly attached.

#### **Oxidation number of Central Atom :**

The oxidation number of the central atom is defined as the charge it would carry if all the ligands are removed along with the electron pairs that are shared with the central atom. [Fe(CN)]3 is +3 and it is written as Fe(III).

# **DENTICITY AND CHELATION :**

# Table : 1

# **Common Monodentate Ligands**

Common Name	IUPAC Name	Formula
methyl isocyanide	methylisocyanide	CH3NC
triphenyl phosphine	triphenyl phosphine/triphenyl phosphane	PPh3
pyridine	pyridine	C5H5N (py)
ammonia	ammine	NH3
methyl amine	methylamine	MeNH2
water	aqua or aquo	H2O
carbonyl	carbonyl	со
thiocarbonyl	thiocarbonyl	CS
nitrosyl	nitrosyl	NO
fluoro	fluoro or fluorido*	F
chloro	chloro or chlorido*	Cl
bromo	bromo or bromido*	Br
iodo	iodo or iodido*	1
cyano	cyanido or cyanido-C* (C-bonded)	CN
isocyano	isocyanido or cyanido-N* (N-bonded)	NC
thiocyano	thiocyanato-S(S-bonded)	SCN
isothiocyano	thiocyanato-N(N-bonded)	NCS
cyanato (cyanate)	cyanato-O (O-bonded)	OCN
isocyanato (isocyanate)	cyanato-N (N-bonded)	NCO
hydroxo	hydroxo or hydroxido*	ОН
nitro	nitrito N (N bonded)	NO 2
nitrito	nitrito O (O bonded)	ONO
nitrate	nitrato	NO 3
amido	amido	NH 2
imido	imido	NH2
nitride	nitrido	N3
azido	azido	N 3
hydride	hydrido	н
oxide	oxido	02
peroxide	peroxido	O2 2
superoxide	superoxido	02
acetate	acetato	
	sulphato	CH3COO
sulphate	thiosulphato	SO2 4
thiosulphate	sulphito	S2O3
sulphite	hydrogensulphito	SO2 3
hydrogen sulphite	sulphido or thio	HSO 3
sulphide	hydrogensulphido or mercapto	S2
hydrogen sulphide	thionitrito	HS
thionitrito	nitrosylium or nitrosonium	(NOS)
nitrosylium	nitronium	NO+
nitronium		NO+2
* TI 0004 II ID 10 1		
<sup>-</sup> The 2004 IUPAC draf	recommends that anionic ligands will end wit	n-1d0.

# Table : 2Common Chelating Amines

Chelating Points	Common Name	IUPAC Name	Abbreviation	Formula
bidentate	ethylenediamine	1,2-ethanediamine/ ethane-1,2-diamine	en	$NH_{23}CH_2CH_2NH_2$
bidentate	propanediamine	1,2-propanediamine	pn	NH <sub>2</sub> -CH-CH <sub>2</sub> -NH <sub>2</sub>   CH <sub>3</sub>
tridentate	diethylenetriamine	[N-(2-aminoethyl)-1 2-ethanediamine or diethylenetriamine	dien	NH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> NHCH <sub>2</sub> CH <sub>2</sub> NH <sub>2</sub>
tetradenate	triethylenetetraamine	[N, N'-bis-(2-aminoethyl)-1 2-ethanediamine	, trien	NH2CH2CH2NHCH2CH2NHCH2CH2NH2
	triaminotriethylamine	or triethylenetetraamine $\beta$ , $\beta'$ , $\beta''$ -tris(2-aminoe-thyl) amine.	tren	NH,CH,CH,NCH,CH,NH,   CH,CH,NH2
pentadentate	tetraethylenepentaamine	1,4,7,10 pentaazatrideca or tetraethylenepentaami	ne	$NH_2CH_2CH_2NHCH_2CH_2NHCH_2CH_2NHCH_2CH_2NH_2$
hexadentate	ethylenediaminetetraacetate	1,2–ethanediyl (dinitrilo) tetraacetate or ethylenediaminetetraa	EDTA acetate	-00CH2C CH2COO-

# Table : 3 Common Multidentate (Chelating) Ligands

Common Name	IUPAC Name	Abbreviation	Formula	Structure
ac et y lac et onat o	2, 4-pent anedi ono or acetylacetonato	acac	СНСОНЮСЗ	
2,2'-bipyridine	2,2'-bipyridyl	bipy	C10H8N2	$(\mathbf{x}) \to (\mathbf{x})$
ox alat o	ox alat o	ox	C2Q4 <sup>2</sup>	
dimethylglyoximato	butanedienedioxime or dimethylglyoximato	DMG	HONC(CH3)C(CH3)O	H <sup>s</sup> C CH <sub>s</sub> N C F
et hy lenediam inet et raac et a	1, 2-et hanediy l (dinitrilo)tetraacetato or et hy lenedi am inet et raac et at	EDTA o	(OOCCH)22NB2H2(HBMO CO )2	

## Homoleptic and heteroleptic complexes

Complexes in which a metal is bound to only one type of donor groups, e.g.,  $[Cr(NH)]_{3}^{3}$ +, are known as homoleptic. Complexes in which a metal is bound to more than one type of donor groups, e.g.,  $[Co(NH)]_{4}^{3}$ +, are known as heteroleptic.

# Nomenclature of Coordination Compounds

#### Writing the formulas of Mononuclear Coordination Entities : The centrial atom is placed first.

The ligation are then placed in alphabetical order. The placement of a ligation in the list does not depend on its charge.

Polydentate ligands are also placed alphabetically. In case of abbreviated ligand, the first letter of the abbreviation is used to determine the position of the ligand in the alphabetical order.

The form(iv) for the entire coordination entity, whether charged or not, is enclosed in square brackets. When ligands are polyatomic, their formulas are enclosed in parentheses. Ligands abbreviations are also enclosed in parentheses.

There  $sh(\mathbf{w})$  and b = no space between the ligands and the metal within a  $(\mathbf{w})$  rdination sphere.

When the formula of a charged coordination entity is to be written without that of the counter ion, the charge is indicated outside the square brackets as a right superscript with the number before the sign. For example, [Co(HO)]3+, [Fe(CN)]3 etc.

(vii) The charge of the cation(s) is balanced by the charge of the anion(s).

# Writing the name of Mononuclear Coordination Compounds :

- (i) Like simple salts the cation is named first in both positively and negatively charged coordination entities.
- (ii) The ligands are named in an alphabetical order (according to the name of ligand, not the prefix) before the name of the central atom/ion.
- (iii) Names of the anionic ligands end in o and those of neutral ligands are the same except aqua for HO, ammine for NH, carbonyl for CO, thiocarbonyl for CS and nitrosyl for NO. But names of cationic ligands end in ium.
- (iv) Prefixes mono, di, tri, etc., are used to indicate the number of the one kind of ligands in the coordination entity. When the names of the ligands include a numerical prefix or are complicated or whenever the use of normal prefixes creates some confusion, it is set off in parentheses and the second set of prefixes is used.

2	di	bis
3	tri	tris
4	tetra	tetrakis
5	penta	pentakis
6	hexa	hexakis
7	hepta	heptakis

- (v) Oxidation state of the metal in cation, anion or neutral coordination entity is indicated by Roman numeral in the parentheses after the name of metal.
- (vi) If the complex ion is a cation, the metal is named same as the element. For example, Co in a complex cation is called cobalt and Pt is called platinum. If the complex ion is an anion, the game of the metal ends with the suffix - ate. For example, Co in complex anion, [Co(SCN)]2 is called cobaltate. For some the Latin names are used in the complex anions. metals, iron (Fe) ferrate lead (Pb) plumbate silver (Aq) tin (Sn) argentate stannate gold (Au) aurate
- (vii) The neutral complex molecule is named similar to that of the complex cation.

# Werner's Theory :

 According to Werner most elements exhibit two types of valencies : (a) Primary valency and (b) Secondary valency. Primary valency : This corresponds to oxidation state of the metal ion. This is also called principal, ionisable or ionic valency. It is satisfied by negative ions and its attachment with the central metal ion is shown by dotted lines.
 Secondary or auxiliary valency : It is also termed as coordination number (usually abbreviated as CN) of the central metal ion. It is nonionic or non-ionisable (i.e. coordinate covalent bond type). In the modern terminology, such spatial arrangements are

called coordination polyhedra and various possibilities are

C.N. = 2	linear	C.N. = 3	Triangular
C.N. = 4 tetrahe	dral or square planar	C.N. = 6	octahedral.

# Effective Atomic Number Rule given by Sidgwick :

Effective Atomic Number (EAN) = Atomic no. of central metal Oxidation state of central metal + No. of electrons donated by ligands.

# Valence Bond Theory :

The model utilizes hybridisation of (n-1) d, ns, np or ns, np, nd orbitals of metal atom or ion to yield a set of equivalent orbitals of definite geometry to account for the observed structures such as octahedral, square planar and tetrahedral, and magnetic properties of complexes. The number of unpaired electrons, measured by the magnetic moment of the compounds determines which d-orbitals are used.

#### TABLE :

Coordiantion number of metal	Type of hybridisation	Shape of complex
4	sp3	Tetrahedral
4	dsp2	Square planer
5	sp3d	Trigonal bipyramidal
6	sp3d	Octahedral
ô	2	Octahedral
	d2sp	

## Coordination Number Six :

In the diamagnetic octahedral complex,  $[Co(NH)]_{3}^{6}$ , the cobalt ion is in +3 oxidation state and has the electronic configuration represented as shown below.

3

The complex [FeF]4 is paramagnetic and uses outer orbital (4d) in hybridisation (sp3d2); it is thus called as outer orbital or high spin or spin free complex. So,

sp3d2 hybrid orbitals

## **Coordination Number Four :**

In the paramagnetic and tetrahedral complex [NiCl]2, the nickel is in +2 oxidation state and the ion has the electronic configuration 3d8. The hybridisation scheme is as shown in figure.



sp3 hybrid orbitals

Similarly complex [Ni(CO)] has tetrahedral geometry and is diamagnetic as it contains no unpaired electrons. The hybridisation scheme is as shown in figure.

sp3 hybrid orbitals

The hybridisation scheme for [Ni(CN)]2 is as shown in figure.

[Ni(CN)<sub>4</sub>]2



dsp2 hybrid orbitals

#### The expressions filed on phieting ds produced by the

ligand and charge on the metal ion. Ligands can be arranged in a series in the orders of increasing field strength as given below :

I < Br < SCN < CI < S2 < F < OH < CO2 < HO < NCS < edta4 \$ NH  $_{2}$  < en < NO  $_{2}$  < CN \$ < CO \$  $^{2}$   ${}^{4}$   ${}^{2}$ 

Such a series is termed as spectrochemical series. It is an experimentally determined series based on the absorption of light by complexes with different ligands.

#### Calculation of Crystal Field stabilisation energy (CFSE)

 Formula : CFSE = [ 0.4 (n) t 2g + 0.6 (n<sup>2</sup>) eg] 20 + \*nP.

 where n & n = [ 0.4 (n) t 2g + 0.6 (n<sup>2</sup>) eg] 20 + \*nP.

 where n & n = [ 0.4 (n) t 2g + 0.6 (n<sup>2</sup>) eg] 20 + \*nP.

 number of extra electron pairs formed because of the ligands in comparison to normal degenerate configuration.

### (b) Crystal field splitting in tetrahedral coordination entities :

In tetrahedral coordination entity formation, the d orbital splitting is inverted and is smaller as compared to the octahedral field splitting. For the same metal, the same ligands and metal-ligand distances, it can be shown that  $\Box t = (4/9)$ [20.



Figure showing crystal field splitting in tetrahedral complex.

#### Colour in Coordination Compounds :

According to the crystal field theory the colour is due to the d-d transition of electron under the influence of ligands. We know that the colour of a substance is due to the absorption of light at a specific wavelength in the visible part of the electromagnetic spectrum (400 to 700 nm) and transmission or reflection of the rest of the wavelengths.

## Limitations of crystal field theory

(1)It considers only the metal ion d-orbitals and gives no consideration at all to other metal orbitals (such as s, p, p and p orbitals).

(2) t is unable to account satisfactorily for the relative strengths of ligands. For example it gives no explanation as to why HO is a stronger ligand than OH in the spectrochemical series.

(3)According to this theory, the bond between the metal and ligands are purely ionic. It gives no account on the partly covalent nature of the metal ligand bonds.

(4)The CFT cannot account for the 2-bonding in complexes.

#### Stability of Coordination Compounds :

The stability of a coordination compound [ML] is measured in terms of the stability constant (equilibrium constant) given by the expression,

□ = [ML]/[M(HO<sub>2</sub>)][L]n

for the overall reaction : $M(HQ) + nL \longrightarrow ML + nHQ$ By convention, the water displaced is ignored, as its concentration remains essentially constant. The above overall reaction takes place in steps, with a stability (formation) constant, K, K, K, ..., K for each step as represented below :

, the stability constant, is related to thermodynamic stability when the system has reached equilibrium.

### **ISOMERISM**:

#### (1) Structural isomerism :

#### (A) Ionisation isomerism :

This type of isomerism occurs when the counter ion in a coordination compound is itself a potential ligand and can displace a ligand which can then become the counter ion.

[Co(NH)SO]NO and [Co(NH)NO]SO

### (B) Solvate / hydrate isomerism :

Complex It occurs when water forms a part of the coordination entity or is outside it. Reaction with conc. HSO(dehydrating agent) Reaction with AgNO

 No water molecule is  $l_{ost}^{2}$  of no reaction one mole of water is lost per mole of complex two mole of water are lost per mole of complex