

**CHEMISTRY - FORMULA**

**NEET/MH-CET**



## Chemistry

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# 1. SOME BASIC CONCEPTS OF CHEMISTRY

$$(1). \text{ Number of molecules in } W(\text{g}) \text{ of substance} = \frac{W(\text{g}) \times N_A}{\text{GMM}}$$

$$(2). \text{ Molality (m)} = \frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}}$$

$$(3). \text{ Number of molecules in } V \text{ litre of gas at S.T.P.} = \frac{VN_A}{22.4}$$

$$(4). \text{ Number of gram atoms} = \frac{W(\text{g})}{\text{GAM}} \text{ (GAM} \rightarrow \text{gram atomic mass)}$$

$$(5). \text{ Number of gram molecules} = \frac{W(\text{g})}{\text{Gram molecular mass}}$$

$$(6). \text{ Dilution formula : } M_1 V_1 = M_2 V_2$$

For mixing two solutions of the same substance

$$M_1 V_1 + M_2 V_2 = M_3 (V_1 + V_2)$$

Molarity can be directly calculated from % by mass (w/w) if density is known

$$\text{Molarity} = \frac{\% \times 10 \times d}{\text{GMM}}$$

$$(7). \text{ Mass of 1 atom of element} = \frac{\text{GAM}}{N_A}$$

$$(8). \text{ Mass of 1 molecule of substance} = \frac{\text{MM}}{N_A} \text{ (MM} \rightarrow \text{Molar mass)}$$

$$(9). T(K) = T(^{\circ}\text{C}) + 273.15$$

$$(10). \text{ Relative atomic mass} = \frac{\text{Mass of an atom of the element}}{\frac{1}{12} \times \text{Mass of an atom of carbon (C-12)}}$$

$$(11). \text{ Number of molecules in } n \text{ moles of substance} = n \times N_A$$

$$(12). \text{ Mass \% of an element in a compound} = \frac{\text{Mass of that element in 1 mole of the compound}}{\text{Molar mass of the compound}} \times 100$$

$$(13). \text{ Mass percent} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

(14).  $\frac{X_B}{1-X_B} = \frac{\text{molality} \times M_A}{1000}$  where  $M_A$  - mass of solvent

(15). Molarity (M) =  $\frac{\text{No. of moles of solute}}{\text{Volume of solution in litres}}$  mole / L

(16). Avogadro's No.  $N_A = 6.022 \times 10^{23}$

(17).  $T(^{\circ}\text{F}) = \frac{9}{5}T(^{\circ}\text{C}) + 32$

(18). Molecular mass =  $2 \times$  vapour density

(19). Mole fraction of A =  $\frac{\text{No. of moles of A}}{\text{No. of moles of solution}}$

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## 2. STRUCTURE OF ATOM

(1). Wavelength of matter wave

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{h}{p}$$

$$\lambda = \frac{h}{\sqrt{2Em}}$$

Where, E = Kinetic energy

(2). Total number of nodes =  $n - 1$

Radial nodes =  $n - l - 1$

Angular nodes =  $l$

(3). Number of neutrons =  $A - Z$

(4). Number of subshells in  $n^{\text{th}}$  shell =  $n$

Number of orbitals in  $n^{\text{th}}$  shell =  $n^2$

Number of electrons in  $n^{\text{th}}$  shell =  $2n^2$

Number of orbitals in subshell =  $2l + 1$

Number of electrons in subshell =  $2(2l + 1)$

(5). Energy of quantum of radiation according to Planck's quantum theory

$$E = hv$$

(6).

$$hv = hv_0 + \frac{1}{2}m_e v^2$$

Einstein's photoelectric equation.

(7). **Line spectrum of hydrogen**

$$\bar{v} = 109677 \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \text{cm}^{-1} \text{ where } \bar{v} \text{ is wave number and } \bar{v} = \frac{1}{\lambda}.$$

Where  $n_1 = 1, 2, \dots$

$n_2 = n_1 + 1, n_1 + 2, \dots$

(8). **Bohr's model of hydrogen atom**

(a) **Frequency** of radiation absorbed or emitted during transition ;  $v = \frac{\Delta E}{h}$

$$v = \frac{E_2 - E_1}{h}$$

$E_1$  = Energy of lower energy state

$E_2$  = Energy of higher energy state.

(b) **Orbit angular momentum** of an electron,

$$m_e vr = n \cdot \frac{h}{2\pi}$$

Where,  $n = 1, 2, 3, \dots$

(c) **Energy** of stationary states

$$E_n = -2.18 \times 10^{-18} \left( \frac{Z^2}{n^2} \right) \text{J}$$

(d) **Radii** of the stationary states/orbits

$$r_n = 52.9 \times \left( \frac{n^2}{Z} \right) \text{pm}$$

(9). Energy gap between the two orbits

$$\Delta E = R_H \left( \frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

Where  $R_H = 2.18 \times 10^{-18}$

Where,  $n_i$  = initial orbit

$n_f$  = final orbit

(10). **Atomic number (Z)** = Number of protons in the nucleus of an atom

= Number of electrons in a neutral atom

(11). Heisenberg's uncertainty principle

$$\Delta x \times \Delta p \geq \frac{\hbar}{4\pi};$$

$$\Delta x \times m\Delta v \geq \frac{\hbar}{4\pi}$$

(12). Speed of light is equal to the product of frequency and wavelength of light

$$c = \nu\lambda$$

(13). **Mass Number (A)** = Number of protons + Number of neutrons

### 3. STATE OF MATTER

(1). **Van der Waals Equation :**  $\left( P + \frac{an^2}{V^2} \right) (V - nb) = nRT$

(2). **Combined Gas Equation :**  $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}; \quad (n, R \text{ constant})$

(3). **Dalton's Law of partial pressures :**  $P_{\text{Total}} = P_1 + P_2 + P_3 + \dots$

(4) **Ideal gas equation :**  $PV = nRT$

$$M = \frac{dRT}{P}$$

(5) **Charles's Law** :  $\frac{V_1}{T_1} = \frac{V_2}{T_2}$  (at constant P and n)

(6). **Avogadro's Law** :  $V = kn$  (at constant P and T)

(7). **Partial Pressure in Terms of Mole Fraction** :  $P_i = x_i P_{\text{total}}$

(8). **Boyle's Law** :  $P_1 V_1 = P_2 V_2$  (at constant T and n)

(9). Compressibility factor  $Z = \frac{PV}{RT}$  (for 1 mole of Gas)

## 4. THERMODYNAMICS

- **First law of thermodynamics**  
 $\Delta U = q + W$
- **Enthalpy of reaction**

$$\Delta H = \sum \Delta_i H^\circ (\text{products}) - \sum \Delta_i H^\circ (\text{reactants})$$

By convention heat of formation of every element in its standard state is arbitrarily assumed to be zero.

$$\Delta_{\text{sub}} H^\circ = \Delta_{\text{fus}} H^\circ + \Delta_{\text{vap}} H^\circ$$

- **Heat Capacity**      Specific heat capacity  $c_s = \frac{q}{m\Delta T}$

$$C = \frac{q}{\Delta T} \quad \text{molar heat capacity } c_m = \frac{q}{n\Delta T}$$

- **Energy changes**       $q_v \rightarrow$  heat exchange at constant volume  
 $\Delta U = q_v, \Delta H = q_p$        $q_p \rightarrow$  heat exchange at constant pressure

- **Enthalpy**

$$H = U + pV$$

- **Relation between  $\Delta H$  and  $\Delta U$**

$$\Delta H = \Delta U + p\Delta V \quad \text{Or}$$

$$\Delta H = \Delta U + \Delta n_g RT$$

- $C_p - C_v = R$

$$\Delta S = \frac{q_{rev}}{T}$$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G^\circ = -RT \ln K$$

Atomicity	$\gamma$	$C_p$	$C_v$
Monoatomic	5/3	5R/2	3R/2
Diatomeric	7/5	7R/2	5R/2
Triatomic non linear	4/3	4R	3R

## 5. EQUILIBRIUM

(1).  $K_w = K_a \times K_b$

(2).  $K_i = \frac{[A^+][B^-]}{[AB]}$

(3).  $K_{sp} = [A^{y+}]^x [B^{-x}]^y$

(4).  $\Delta G^\circ = -2.303 RT \log K$

(5).  $K_a = \frac{[A^-][H_3O^+]}{[HA]}$

$$K_b = \frac{[B^-][OH^-]}{[BOH]}$$

$$(6). K_w = [H^+] [OH^-] = 10^{-16} \text{ at } 25^\circ C$$

$$(7). pH = -\log [H^+]$$

$$(8). pK_w = pH + pOH = 14 \text{ at } 25^\circ C$$

$$(9). K_p = K_c (RT)^{\Delta n}$$

(10). Hydrolysis of salts

(i) For a salt of strong acid and weak base

$$pH = \frac{1}{2} [pK_w - pK_b - \log c]$$

(ii) for a salt of weak acid and strong base

$$pH = \frac{1}{2} [pK_w + pK_a + \log c]$$

(iii) For salts of weak acid and weak base

$$pH = \frac{1}{2} [pK_w + pK_a - pK_b]$$

$$(11). \text{Equilibrium constant, } K_{eq} = \frac{K_a}{K_b}$$

$$(12). K_a \text{ or } K_b = c\alpha^2$$

$$(13). \text{Concentration quotient, } Q = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

## 6. SOLID STATE

### (1). Density of Cubic Crystal System

$$\rho \text{ (or } d) = \frac{Z \times M}{a^3 \times N_A} \text{ g.cm}^{-3}$$

Where, Z = number of atoms per unit cell

$N_A$  = Avogadro's Number

M = Gram atomic weight of element (g. mol<sup>-1</sup>)

a = edge – length

### (2). Radius-ratio in ionic solids

Voids	Triangular	Tetrahedral	Octahedral	Cubical
Radius-ratio	$0.155 \leq \frac{r^+}{r^-} < 0.225$	$0.255 \leq \frac{r^+}{r^-} < 0.414$	$0.414 \leq \frac{r^+}{r^-} < 0.732$	$0.732 \leq \frac{r^+}{r^-} < 0.999$

### (3).

Crystal	Radius of atom (r)	No. of atoms per unit cell	p.f.
Simple cubic	$\frac{a}{2}$	1	52.4 %
F.C.C.	$\frac{a}{2\sqrt{2}}$	2	74 %
B.C.C	$\frac{\sqrt{3}}{4}a$	2	68 %

$$(4). \text{Packing Fraction (p.f.)} = \frac{\text{Volume occupied by particles (per unit cell)}}{\text{Volume of unit cell}}$$

$$\text{Contribution of each atom present on the corner} = \frac{1}{8}$$

$$\text{Contribution of each atom present on the centre of face} = \frac{1}{2}$$

$$\text{Contribution of each atom present on the body centre} = 1$$

Contribution of each atom present on the edge centre =  $\frac{1}{4}$

(5). Seven crystal system with dimensions :

- (a) Cubic :  $\alpha = \beta = \gamma = 90^\circ$ ,  $a = b = c$
- (b) Tetragonal :  $\alpha = \beta = \gamma = 90^\circ$ ,  $a = b \neq c$
- (c) Orthorhombic :  $\alpha = \beta = \gamma = 90^\circ$ ;  $a \neq b \neq c$
- (d) Monoclinic :  $\alpha = \gamma = 90^\circ$ ;  $\beta \neq 90^\circ$  ;  $a \neq b \neq c$
- (e) Hexagonal :  $\alpha = \beta = 90^\circ$ ;  $\gamma = 90^\circ$  ;  $a = b \neq c$

(f) Rhombohedral or trigonal :  $\alpha = \beta = \gamma \neq 90^\circ$  ;  $a = b = c$

(g) Triclinic :  $\alpha \neq \beta \neq \gamma \neq 90^\circ$  ;  $a \neq b \neq c$

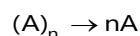
## 7. SOLUTIONS

(1). Depression in freezing point

$$\Delta T_f = K_f \times m$$

$$K_f = \frac{RT_0^2}{1000 l_{\text{fusion}}} = \frac{M_A RT_0^2}{1000 \Delta H_{\text{fusion}}}$$

(2) Dissociation of solute



$$i = \frac{1 + (n - 1)\alpha}{1} \quad \{\alpha = \text{degree of dissociation}\}$$

$$(3). P_{\text{sol}} = \frac{P_A^0 X_A + P_B^0 X_B}{(P_B^0 - P_A^0)X_B + P_A^0} \left. \begin{array}{l} \\ \end{array} \right\} \text{Raoult's law}$$

#### (4). Osmotic pressure

$$\pi = CRT$$

For isotonic solution,  $\pi_1 = \pi_2$

$$(5) \frac{1}{P_{\text{sol}}} = \frac{Y_A}{P_A^0} + \frac{Y_B}{P_B^0}$$

#### (6). Relative lowering of vapour pressure

$$\frac{P_A^0 - P}{P_A^0} = \chi_B \quad \{ \chi_B = \text{mole fraction of solute} \}$$

$$(7) Y_A = \frac{P_A}{P_T}; Y_B = \frac{P_B}{P_T}$$

Where  $Y_A$  and  $Y_B$  are mole fractions in vapour phase and  $P_A = P_A^0 X_A : P_B = P_B^0 X_B$

#### (8). Elevation of boiling point

$$\Delta T_b = K_b \times m$$

$$K_b = \frac{RT_0^2}{100 I_{\text{vapour}}} = \frac{M_A RT_0^2}{1000 \Delta H_{\text{vapour}}}$$

Where,  $m$  = molality

$M_A$  = molecular mass of solvent

(9).

$$\text{Molality (m)} = \frac{\text{Number of moles of solute}}{\text{Weight of solvent (kg)}} \text{ mole / kg}$$

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (L)}} \text{ mole / L}$$

Normality (N) =  $\frac{\text{Number of gram equivalent of solute}}{\text{Volume of solution (L)}}$  g equiv / L

Formality (F) =  $\frac{\text{Number of gram formula mass}}{\text{Volume of solution (L)}}$

#### (10). Van't Hoff factor

$$i = \frac{\text{Experimental colligative property (observed)}}{\text{Calculated (normal) colligative property}}$$

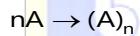
$$\frac{P_A^B - P}{P_A^B} = \frac{(i \times n_B)}{(i \times n_B) + n_A}$$

$$\Delta T_b = i \times K_b \times m$$

$$\Delta T_f = i \times K_f \times m$$

$$\pi = iCRT$$

#### (11). Association of Solute



$$i = \frac{(1 - \alpha) + \frac{\alpha}{n}}{1} \quad \{ \alpha = \text{degree of association} \}$$

#### (12). Henry's Law

$$p = K_H \cdot X \left\{ \begin{array}{l} p = \text{partial pressure of gas in vapour phase} \\ K_H = \text{Henry's law constant} \\ X = \text{Mole fraction of gas} \end{array} \right.$$

## 8. ELECTROCHEMISTRY

(1). **Ohm's law**  $\Rightarrow V = RI$

$$R = \rho \frac{\ell}{a}$$

$V$  = Potential difference

$R$  = Resistance

$I$  = Current

$\rho$  = Specific resistance (resistivity)

$\ell$  = length of conductor

$a$  = cross-section area of conductor

(2). **Conductance**  $G = \frac{1}{R}$

Specific conductance (conductivity)  $\kappa = \frac{1}{\rho}$

(3). **Cell constant**  $\sigma = \frac{\ell}{a}$

$$\kappa = G \cdot \sigma$$

(4). **Molar conductance**  $\Lambda_M$  (or  $\phi_C$ )  $= \frac{1000 \times \kappa}{C}$  (or M) {C = concentration of electrolyte in terms of molarity}

(5). **Equivalent conductance**  $\Lambda_M$  (or  $A_C$ )  $= \frac{1000 \times \kappa}{C}$  (or N) {C = concentration (normality)}

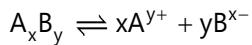
$$\Lambda_M = \Lambda_N \times (n - \text{factor})$$

$$\Lambda_0 = \lim_{C \rightarrow 0} \Lambda_C \quad \{ \Lambda_0 = \text{equivalent conductance at infinite dilution (or zero concentration)} \}$$

(6) For weak electrolyte,  $\Lambda_C \propto \frac{1}{\sqrt{C}}$

For strong electrolyte,  $\Lambda_C = \Lambda_0 - B(C)^{1/2}$  {B = constant}

(7). At infinite dilution, for an electrolyte  $A_x B_y$



$$\Lambda_{A_x B_y}^{\circ} = x \lambda_A^{\circ} + y \lambda_B^{\circ} \quad \{\lambda_A^{\circ}, \lambda_B^{\circ} = \text{equivalent conductance at infinite dilution of cation and anion}\}$$

$$= x \lambda_+^{\circ} + \lambda_-^{\circ}$$

$$\lambda_C^{\circ} = k \mu_c^{\circ} \quad \{\mu = \text{ionic mobility, } K = 96500 \text{ coulomb}\}$$

$$\mu = \frac{\text{Ionic velocity}}{\text{Potential gradient}}$$

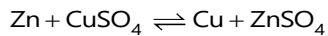
(8). For a weak electrolyte, ( $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$ )

**Degree of dissociation,**  $\alpha = \frac{\Lambda_M}{\Lambda_0}, K_{eq} = \frac{C(\Lambda_M / \Lambda_0)^2}{1 - (\Lambda_M / \Lambda_0)}$

(9). For solubility of salt ( $\text{AgCl} \rightleftharpoons \text{Ag}^+ + \text{Cl}^-$ )

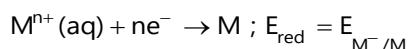
$$K_{sp} = \left( \frac{1000 K}{\Lambda_0} \right)^2$$

(10). For a cell reaction in an electrochemical cell,



Cell representation  $\Rightarrow \text{Zn} | \underset{\text{Anode}(-)}{\text{Zn}^{2+}(\text{aq.})} || \underset{\text{Cathode}(+)}{\text{Cu}^{2+}(\text{aq.})} | \text{Cu}$

(11). For half cell reaction  $M \rightarrow M^{n+}(\text{aq.}) + n e^- ; E_{ox} = E_{M/M^-}$



emf of cell,  $E_{cell}^{\circ} = E_{right}^{\circ} - E_{left}^{\circ}$

$$= E_{cathode}^{\circ} - E_{anode}^{\circ} \quad \{\text{R.P.} = \text{Reduction potential}\}$$



$$(12). \Delta G = -nFE_{\text{cell}}$$

$$= -W$$

$$= -\Delta G^{\circ} + 2.303 RT \log Q$$

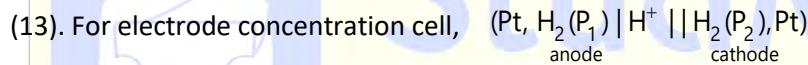
$$\Delta G^{\circ} = -nFE_{\text{cell}}^{\circ}$$

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{2.303 RT}{nF} \log Q$$

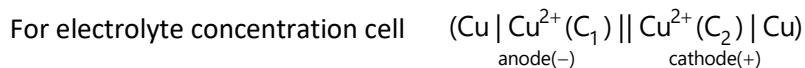
$\Delta G$  = Change in free energy  
 $W$  = Useful work done  
 $n$  = Number of electrons exchanged  
 $F$  = Faraday constant (96500 coulomb)  
 $Q$  = Reaction quotient

At room temperature (25°C)

$$\Rightarrow \text{Nernst's equation} \Rightarrow E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{n} \log Q$$



$$E_{\text{cell}} = \frac{0.0591}{2} \log \frac{P_1}{P_2} \quad (\text{P} = \text{Pressure})$$



$$E_{\text{cell}} = \frac{0.0591}{2} \log \frac{C_2}{C_1}$$

For concentration cells,  $E_{\text{cell}}^{\circ} = 0$

(14). At equilibrium,  $E_{\text{cell}} = 0$  (as  $\Delta G = 0$ )

$$(15). \text{Temperature coefficient (T.C.)} = \left( \frac{\partial}{\partial T} E_{\text{cell}} \right)_P$$

Change in entropy,  $\Delta S = +nF \times (\text{T.C.})$  { $\Delta H$  = heat of cell-reaction}

$$E_{\text{cell}} = \left( \frac{-\Delta H}{nF} \right) + T \cdot (\text{T.C.})$$

$T.C. > 0 \Rightarrow$  Cell-reaction is endothermic and vice-versa.

(16). Faraday's 1<sup>st</sup> law of electrolysis

$$m = Zit$$

$m$  = mass of substance deposited

$Z$  = electrochemical equivalent

$i$  = current

$t$  = time

$$Z = \frac{\text{Atomic mass}}{n \times F}$$

Faraday's 2<sup>nd</sup> law of electrolysis

$$\frac{m_1}{m_2} = \frac{E_1}{E_2} \quad (E = \text{equivalent weight})$$

(17). Oxidation potential for half-cell reaction :  $M \rightarrow M^{+n} + ne^-$

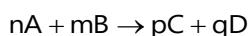
$$E_{\text{ox}} = E_{\text{ox}}^{\circ} - \frac{2.303}{nF} \log [M^{+n}]$$

Reduction potential for half-cell reaction :  $M^{+n} + ne^- \rightarrow M$

$$E_{\text{red}} = E_{\text{red}}^{\circ} + \frac{2.303 RT}{nF} \log [M^{+n}]$$

## 9. CHEMICAL KINETICS AND NUCLEAR CHEMISTRY

(1). For a general chemical transformation

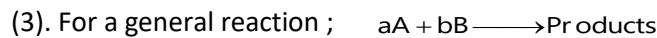


$$\text{Rate} = \frac{-1}{n} \frac{d[A]}{dt} = \frac{-1}{m} \frac{d[B]}{dt} = + \frac{1}{p} \frac{d[C]}{dt} = \frac{1}{q} \frac{d[D]}{dt}$$

(2). For elementary chemical reaction



$$\text{Theoretical rate} = \frac{dx}{dt} = k[A]^m \times [B]^n$$



$$\text{Rate} = \frac{dx}{dt} = k[A]^m \times [B]^n$$

Order of reaction w.r.t. A = m overall order of reaction =  $(m + n)$

Order of reaction w.r.t. B = n

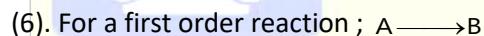
(4). Unit of rate constant = (mole) $^{1-n}$  (litre) $^{n-1}$  time $^{-1}$

Where, n = order of reaction



$$\text{Rate} = \frac{-d[A]}{dt} = k[A]^B = k \text{ (constant)}$$

$$K = \frac{[A_0] - [A]}{K}$$



$$\text{Rate} = \frac{-d[A]}{dt} = k[A]$$

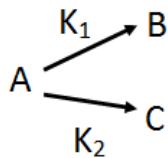
$$k = \frac{2.303}{t} \log_{10} \frac{[A]_0}{[A]_1} = \frac{2.303}{t} \log_{10} \left( \frac{a}{a-x} \right)$$

$$(7). \text{For a zero order reaction, } t_{1/2} = \frac{[A]_0}{2k}$$

$$\text{For a first order reaction, } t_{1/2} = \frac{0.693}{k}$$

$$\text{For an } n^{\text{th}} \text{ order reaction, } t_{1/2} \propto \frac{1}{[A]_0^{n-1}} \text{ (for } n \geq 2\text{)}$$





$$\frac{-d[A]}{dt} = (k_1 + k_2)[A]$$

(9). For a first order reaction :  $A \longrightarrow B + C$ , a reagent reacts with all A, B and C

$$k = \frac{2.303}{t} \log_{10} \left( \frac{V_\infty - V_t}{V_\infty - V_0} \right) \quad \{V = \text{vol. of reagent}\}$$

$$(10). \text{Temperature coefficient} = \frac{k_{T+10^{\circ}\text{C}}}{k_T}$$

Arrhenius equation,  $k = Ae^{-E_a/RT}$

$$\log_{10} \frac{k_2}{k_1} = \frac{E_a}{(2.303 R)} \left( \frac{T_2 - T_1}{T_2 T_1} \right)$$

$$\log_{10} k = \log_{10} A - \frac{E_0}{2.303 RT}$$

$\left\{ \begin{array}{l} A = \text{Arrhenius's constant} \\ E_a = \text{Activation energy} \end{array} \right.$

$$\log_{10} k = \log_{10} A - \frac{E_0}{2.303 RT}$$

(12). Binding energy, B.E. =  $\Delta m \times 931.5 \text{ MeV}$

$\Delta m$  = mass defect = calculated At. Mass – observed At. Mass

$$\text{B.E. per nucleon} = \frac{\text{B.E. (total)}}{\text{mass number}}$$

$$1 \text{ MeV} = 9.6 \times 10^{10} \text{ Joule mol}^{-1}$$

$$(13). \text{Packing fraction. P.F.} = \frac{\text{Isotopic atomic mass-mass no.}}{\text{mass numer}} \times 10^6$$

$$(14). \text{In a radioactive decay, } N_t = N_0 e^{-\lambda t}$$

Amount of radioactive substance after 'n' half-life periods

$$N = \left(\frac{1}{2}\right)^n N_0$$

(15). Activity,  $A_t = A_0 e^{-\lambda t}$ ,  $A = \lambda N$

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## 10. SURFACE CHEMISTRY

(1). Freundlich Adsorption isotherm

$$\left(\frac{x}{m}\right) = K_p^{\left(\frac{1}{m}\right)} ; n \geq 1$$

(2). Langmuir Adsorption isotherm

$$\theta = \frac{K' P_A}{1 + K P_A}$$

Or,  $\frac{x}{m} = \frac{aP}{1 + bP}$  or  $\frac{m}{x} = \frac{1}{aP} + \frac{b}{a}$

$$(3) \frac{x}{m} = K C^{\left(\frac{1}{n}\right)} ; C = \text{Concentration of solute in solution.}$$

$$(4). \text{Zeta potential, } Z = \frac{4\pi\eta\mu}{D}$$


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## 11. HYDROGEN

$$(1) \text{ At. Wt. of H} = \frac{\% {}^1\text{H} \times 1 + \% {}^2\text{H} \times 2 + \% {}^3\text{H} \times 3}{100}$$

$$(2) \text{ Vapour density of a gas} = \frac{\text{molar mass of gas}}{\text{molar mass of H}_2}$$

LHS and RHS both are unitless

$$(3). \text{ Molecular wt.} = 2 \times (\text{V.D.})$$

$$(4). \text{ Vol. Strength of H}_2\text{O}_2 = \text{Molarity} \times 11.2$$

$$= \text{Normality} \times 5.6$$



## 12. S-BLOCK ELEMENTS

- (1) General Electronic Configuration  $ns^{1-2}$ .
- (2) Atomic Radii increases down the group.
- (3) Hydration enthalpy decreases down the group.
- (4). Ionization enthalpy decreases down the group.
- (5). On reaction with oxygen give oxide, peroxide and superoxides.
- (6) On reaction with water produces hydroxide and hydrogen.
- (7). Some important compounds and their general names.

Name	Chemical Formula	Prepared by
Caustic Soda	NaOH	Electrolysis in costner kellner cell
Washing Soda	Na <sub>2</sub> CO <sub>3</sub> , 10H <sub>2</sub> O	Solvay's process
Baking Soda	NaHCO <sub>3</sub>	Solvay's process
Glauber's Salt	Na <sub>2</sub> SO <sub>4</sub> , 10H <sub>2</sub> O	NaCl + H <sub>2</sub> SO <sub>4</sub>
Microcosmic salt	Na(NH <sub>4</sub> )HPO <sub>4</sub>	NH <sub>4</sub> Cl + Na <sub>2</sub> HPO <sub>4</sub>

Potash or Pearl Ash	$K_2CO_3$	Leblanc Process
Caustic potash	KOH	Electrolysis of KCl
Quick lime	CaO	Decomposition of $CaCO_3$
Slaked lime	$Ca(OH)_2$	Hydrolysis of CaO
Gypsum	$CaSO_4, 2H_2O$	$CaCl_2 + H_2SO_4$
Plaster of Paris	$CaSO_4, \frac{1}{2} H_2O$	By heating gypsum

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## 13. P-BLOCK ELEMENTS

(1). In general metallic character, electropositive character, atomic radii, basic character, reducing character decreases on moving left to right in a period and increases down the group.

(2). Some important compound of p-block elements

i.	Borax (Tincal)	$Na_2B_4O_7, 10H_2O$
ii.	Colomonite	$Ca_2B_6O_{11}, 5H_2O$
iii.	Kemite	$Na_2B_4O_7, 4H_2O$
iv.	Sassolite or boric acid	$H_3BO_3$
v.	Diborane	$B_2H_6$
vi.	Borazole	$B_3N_3H_6$
vii.	Alumina	$Al_2O_3$
viii.	Lithium aluminium hydride	$LiAlH_4$
ix.	Potash Alum	$K_2SO_4, Al_2(SO_4)_3, 24 H_2O$

## 14. COORDINATION COMPOUND

(1). Magnetic moment,  $\mu = \sqrt{n(n+2)} \text{ B.M}$

$$(2) \Delta_0(\text{CFSE}) = \left[ \left( -4 \times n_{\substack{e^- \\ (t_{2g})}} \right) + \left( +6 \times n_{\substack{e^- \\ (e_g)}} \right) \right] Dq$$

$$(3). \Delta_t(\text{CFSE}) = \left[ \left( +4 \times n_{\substack{e^- \\ (t_{2g})}} \right) + \left( -6 \times n_{\substack{e^- \\ (e_g)}} \right) \right] Dq$$

$$(4). \Delta_t = \frac{4}{9} \Delta_0$$

(5). For the reaction :  $M + 4L \rightleftharpoons ML_4$ , overall stability constant of complex ( $ML_4$ ) is  $\beta_4 = \frac{[ML_4]}{[M][L]^4}$

$$(6). \text{EAN}_{\substack{\text{(of metal atom/ion)}}} = Z - \text{O.N.} + 2(\text{C.N.})$$



**StudMonk**

## 15. ORGANIC CHEMISTRY

Relations for the estimation of elements in organic compounds.

$$\% \text{ of C} = \frac{12}{44} \times \frac{\text{Mass of } CO_2 \text{ formed}}{\text{Mass of the compound}} \times 100$$

$$\% \text{ of H} = \frac{2}{18} \times \frac{\text{Mass of } H_2O \text{ formed}}{\text{Mass of the compound}} \times 100$$

$$\% \text{ of N}_{\substack{\text{(Dumas's method)}}} = \frac{28}{22400} \times \frac{\text{Volume of } N_2 \text{ at NTP}}{\text{Mass of compound}} \times 100$$

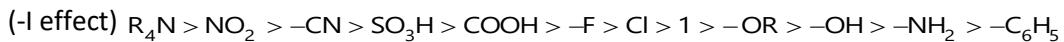
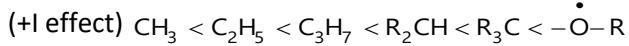
$$\% \text{ of N}_{\substack{\text{(kjeldahl's method)}}} = \frac{1.4 \times \text{Normality of acid used} \times \text{Volume of acid used}}{\text{Mass of the compound}}$$

$$\% \text{ of } X(\text{Halogens}) = \frac{\text{At. mass of } X}{(108 + \text{At. mass of } X)} \times \frac{\text{Mass of AgX formed}}{\text{Mass of the compound}} \times 100$$

$$\% \text{ of } S = \frac{32}{233} \times \frac{\text{Mass of BaSO}_4 \text{ formed}}{\text{Mass of the compound}} \times 100$$

$$\% \text{ of } P = \frac{62}{222} \times \frac{\text{Mass of Mg}_2\text{P}_2\text{O}_7 \text{ formed}}{\text{Mass of the compound}} \times 100$$

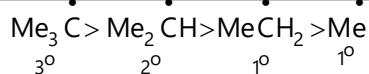
(1). Inductive effect



(2). Relative basic strength in aqueous medium.

$\text{R} = \text{CH}_3$	$2^\circ > 1^\circ > 3^\circ > \text{NH}_3$
$\text{R} = \text{C}_2\text{H}_5$	$2^\circ > 3^\circ > 1^\circ > \text{NH}_3$
$\text{Me}_2\text{CH}^-$	$1^\circ > \text{NH}_3 > 2^\circ > 3^\circ$
$\text{M}_2\text{C}$	$\text{NH}_3 > 1^\circ > 2^\circ > 3^\circ$

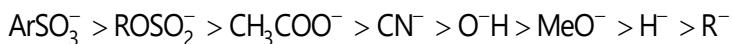
(3). Stability of free radical



(4) Heat of hydrogenation of alkenes



(5). Leaving nature in Nucleophilic substitution reaction



(6). Number of product formed during crossed aldol condensation

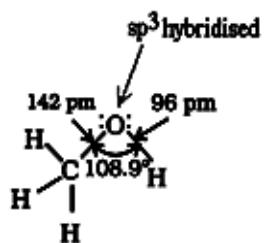
S. No.	Carbonyl compound (I)	Carbonyl compound (II)	Self Condensation Product	Cross Condensation Product	Total Product
1.	One type of similar $\alpha$ -H-atom	One type of similar $\alpha$ -H-atoms	2	2	4

	O    CH <sub>3</sub> – C – H	CH <sub>3</sub> – CH <sub>2</sub> – CHO			
2.	Two different types of dissimilar $\alpha$ -H-atoms CH <sub>3</sub> – COCH <sub>2</sub> CH <sub>3</sub>	One type of similar $\alpha$ -H-atoms CH <sub>3</sub> – CH <sub>2</sub> – CHO	3	3	6
3	Two different types of dissimilar $\alpha$ -H-atoms CH <sub>3</sub> CO – CH <sub>2</sub> – CH <sub>3</sub>	Two different types of dissimilar $\alpha$ -H-atoms PhCH <sub>2</sub> – CO – CH <sub>2</sub> – CH <sub>3</sub>	4	4	8

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## 16. ALCOHOLS, PHENOLS AND ETHERS

Structure of Alcohols :

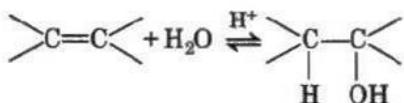


**Methanol**  
**(Alcohol)**

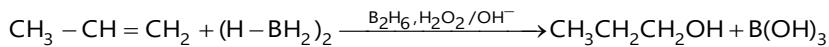
### Preparation of Alcohols

(i) From alkenes

(a) By acid catalysed hydration in accordance with Markownikoff's rule.

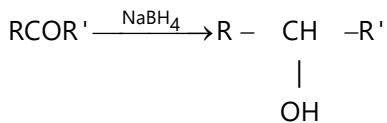
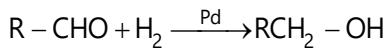


(b) By hydroboration-oxidation

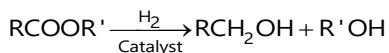
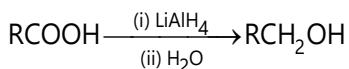


(ii) From carbonyl compounds

(a) By reduction of aldehydes and ketones

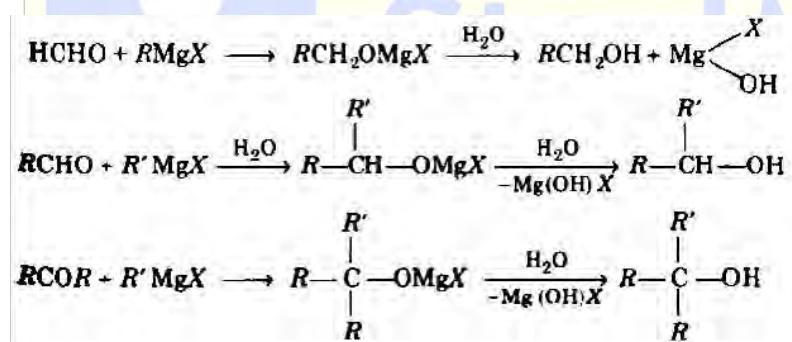


(b) By reduction of carboxylic acids and ester

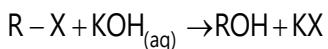


Reduction of aldehyde, ketones and esters with No alcohol is called Bouveault-blanc reduction.

**Reaction of carbonyl compound with Grignard Reagent.**

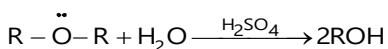


(iv) Hydrolysis of alkyl halides

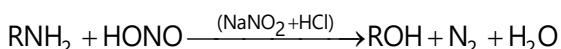


Ease of hydrolysis of alkyl halides  $\text{RI} > \text{RBr} > \text{RCI} >$  and  $3^\circ > 2^\circ > 1^\circ$  alkyl halides.

(v) Hydrolysis of ethers

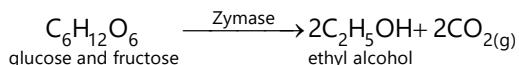
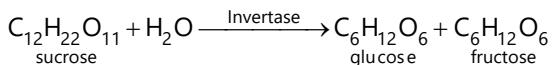


(vi) From primary amines by treatment with nitrous acid



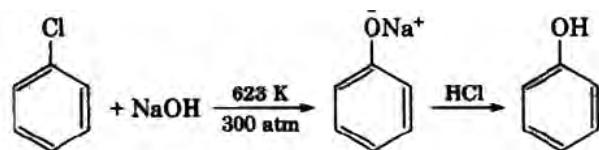
Methylamine does not give methyl alcohol when treated with  $\text{HNO}_2$ . It gives  $\text{CH}_3\text{OCH}_3$  and  $\text{CH}_3\text{ONO}$ .

(vii) By alcoholic fermentation

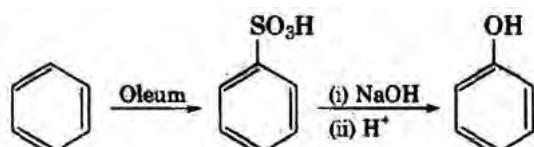


### Preparation of Phenols

(i) From haloarenes



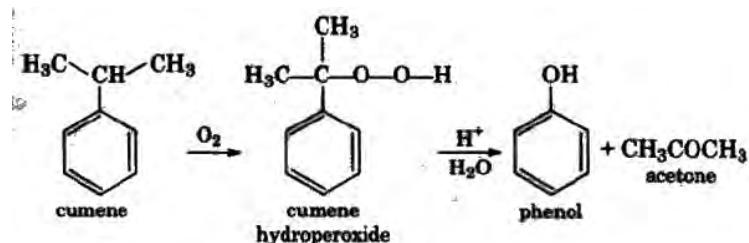
(ii) From benzene sulphonic acid



(iii) From diazonium salts



(iv) From cumene

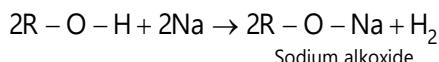


### Chemical properties of alcohols :

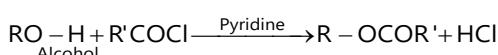
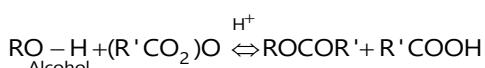
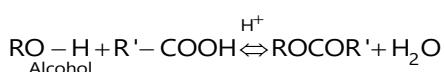
1. Reaction involving cleavage of O-H bond :

Alcohols react as nucleophiles :

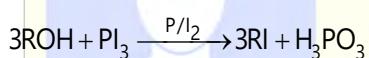
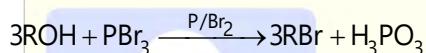
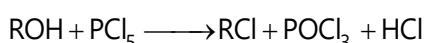
(a) Reaction with metals



(b) Esterification reaction



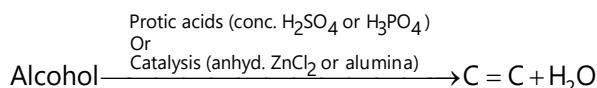
(b) Reaction with phosphorus halides



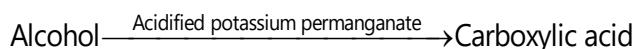
(c) Reaction with thionyl chloride



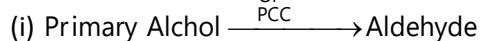
(c) Dehydration reaction



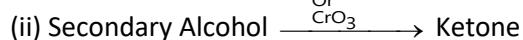
(d) Oxidation reaction



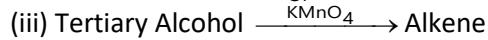
Cu, 573k  
Or  
CrO<sub>3</sub>  
Or  
PCC



Cu, 573k  
Or  
CrO<sub>3</sub>

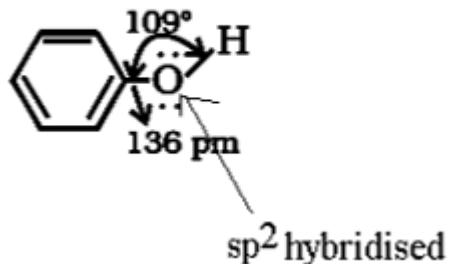


Cu, 573k  
Or  
KMnO<sub>4</sub>



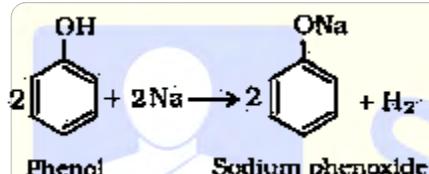
## Phenols

### Structure of Phenols :

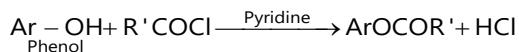
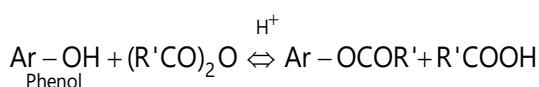
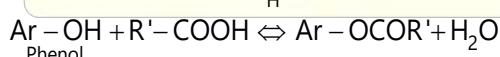


### Chemical properties of phenols :

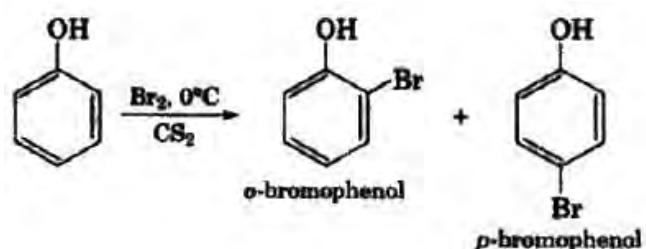
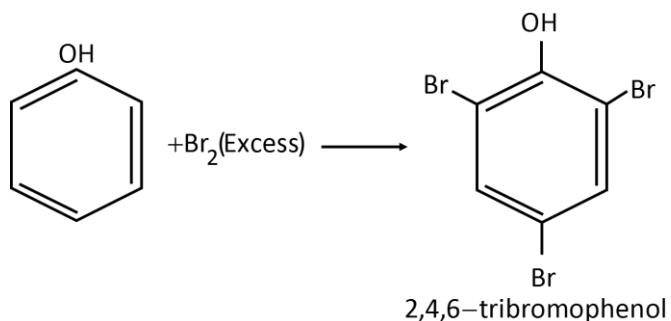
#### (a) Reaction with metals



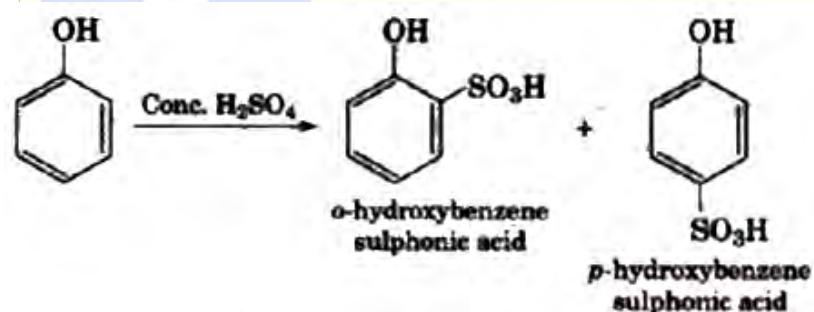
#### (b) Esterification reaction



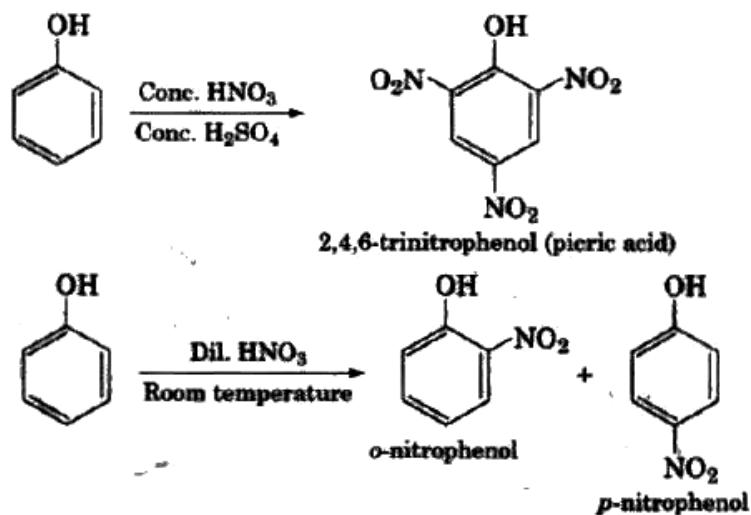
#### (a) Halogenation



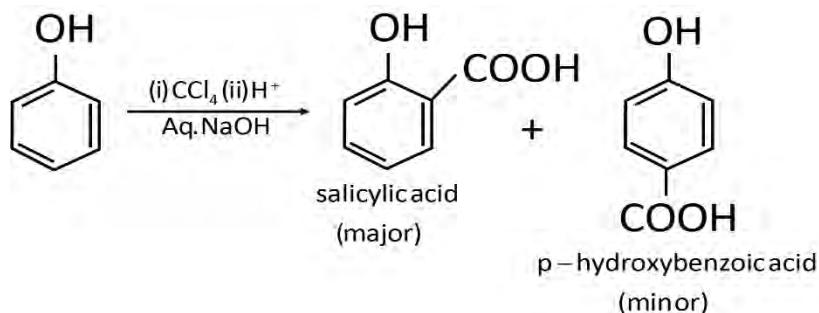
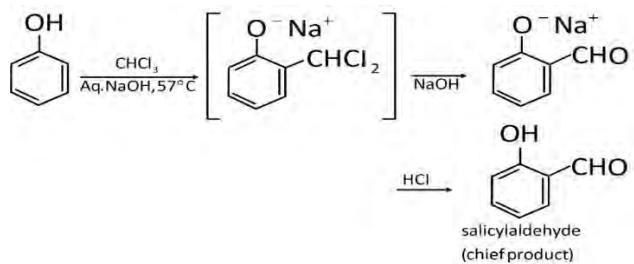
(b) Sulphonation



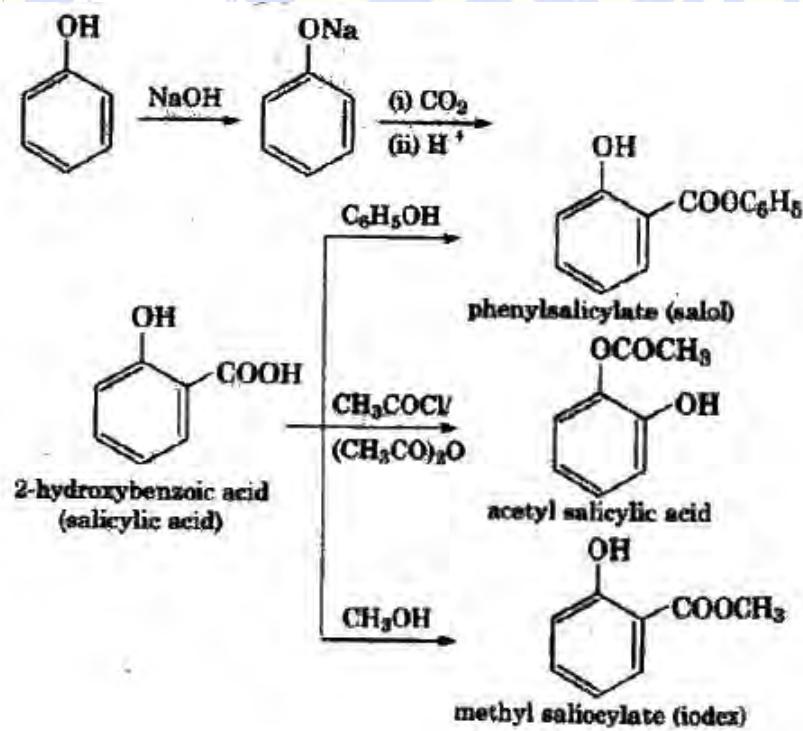
(c) Nitration



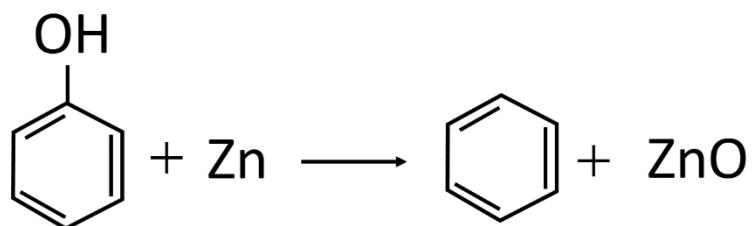
(d) Reimer-Tiemann reaction



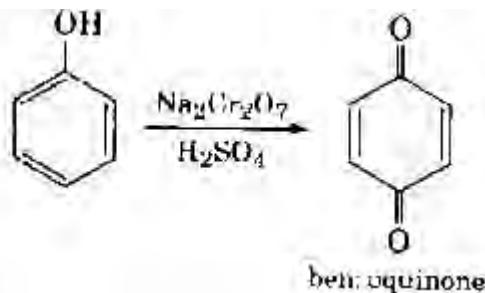
(ii) Kolbe's reaction



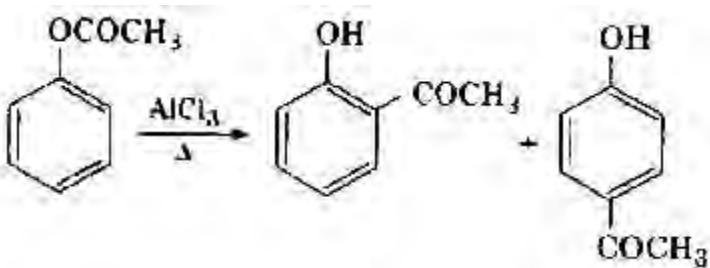
iii) Reaction with zinc dust



(iv) Oxidation

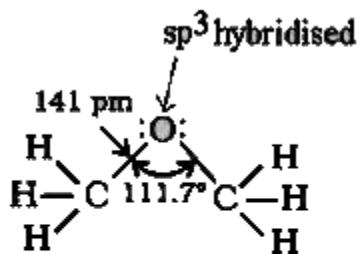


(v) Fries rearrangement



## Ethers

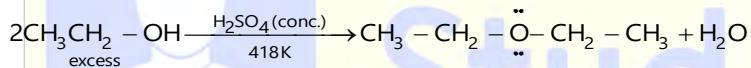
### Structure of Ethers



## Methoxymethane (Ether)

### Preparation of Ethers

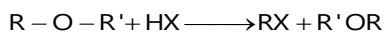
#### (i) By dehydration of alcohols



**Williamson's Synthesis** Only primary alkyl halides when react with sodium alkoxide give ether while tertiary alkyl halides give alkene due to steric hindrance.



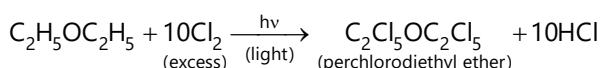
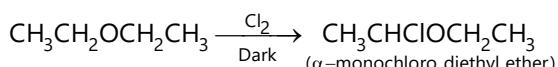
### Chemical Reactions of Ether



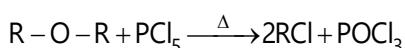
The order of reactivity of hydrogen halides is as follows



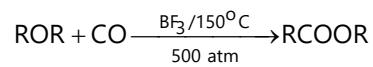
#### (ii) Halogenation



#### (iii) Reaction with $\text{PCl}_5$



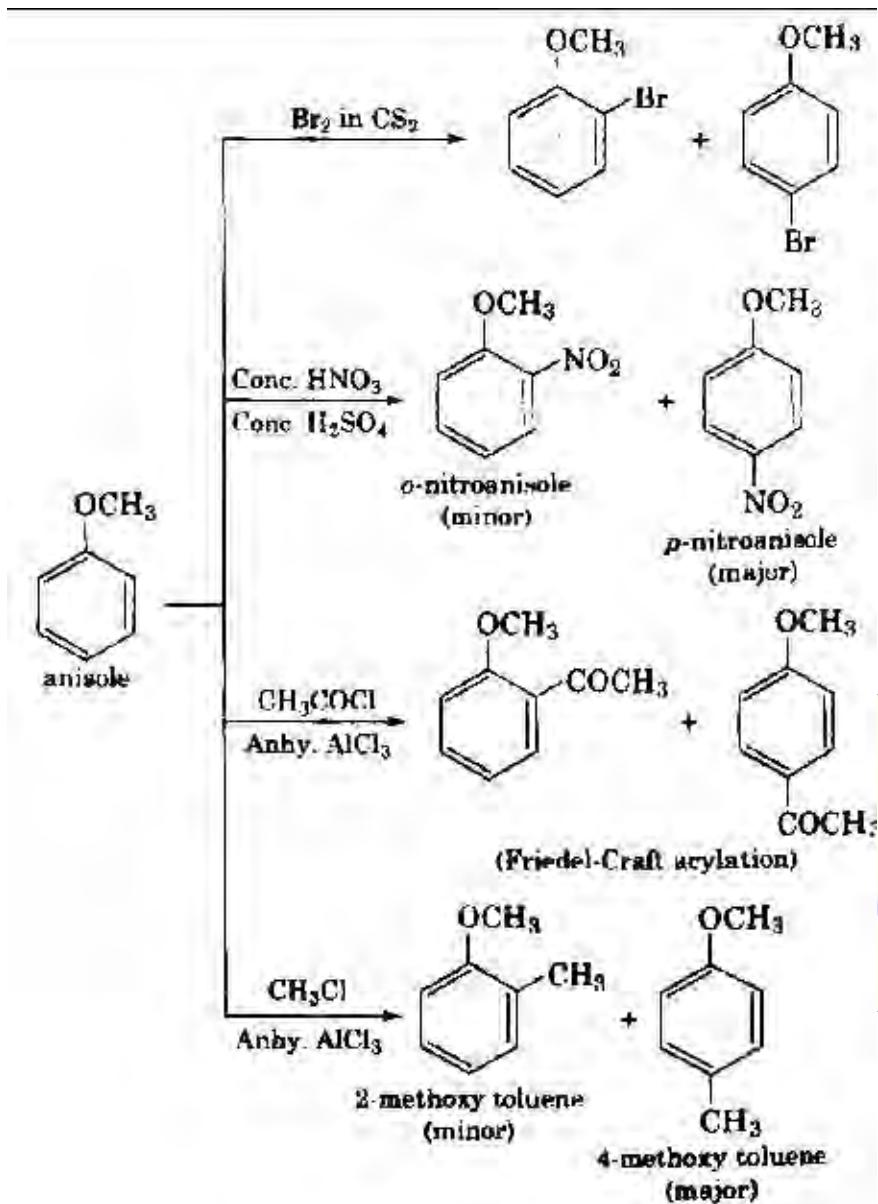
(iv) Reaction with CO



#### Electrophilic Substitution reactions

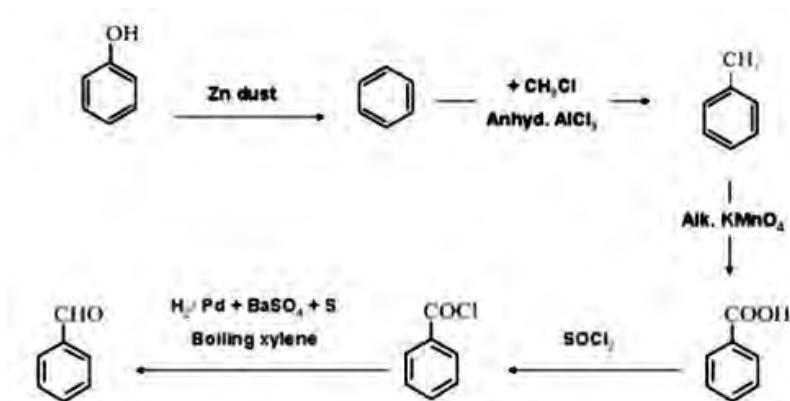


# StudMonk

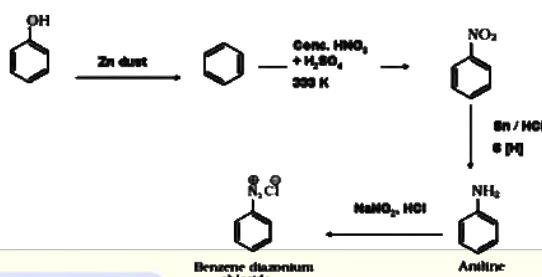


onk

- Other conversion reactions :
  - (a) Phenol to salicylaldehyde



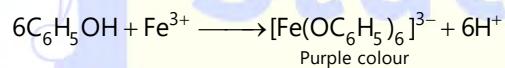
(b) Phenol to benzene diazonium chloride



Differentiate between organic compounds :

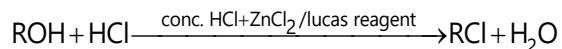
## (a) Alcohols and phenols

Phenol on reaction with neutral  $\text{FeCl}_3$  gives purple colour whereas alcohols do not give purple colour.



## (b) Primary, secondary and tertiary alcohols

Lucas reagent test :



If it is a primary alcohol, no turbidity appears at room temperature. Turbidity appears only on heating. If it is a secondary alcohol, turbidity appears in 5 minutes. If it is a tertiary alcohol, turbidity appears immediately.

## (c) Methanol and ethanol

Iodoform test : Ethanol when reacted with ( $\text{I}_2$  and  $\text{NaOH}$ ) or  $\text{NaOI}$  gives yellow ppt of iodoform since it has the presence of  $\text{CH}_3\text{-CH(OH)}$ -group.

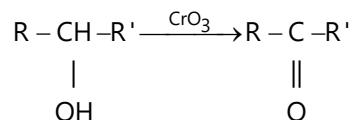
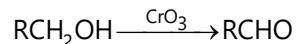


## 17. ALDEHYDES, KETONES AND CARBOXYLIC ACIDS

### Preparation of Aldehydes and Ketones

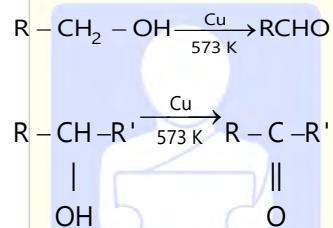
#### (i) By oxidation of alcohols

Aldehydes and ketones are generally prepared by oxidation of primary and secondary alcohols, respectively.

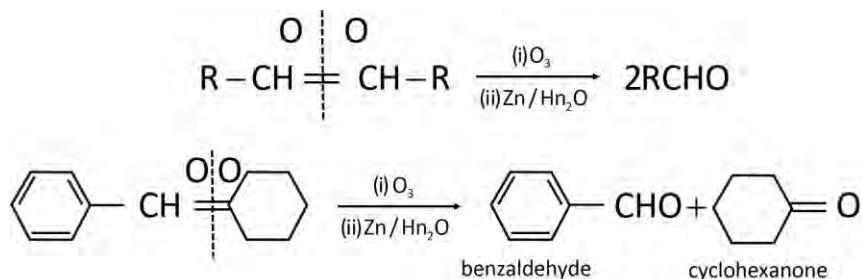


#### By dehydrogenation of alcohols

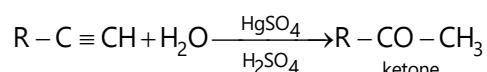
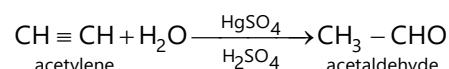
Primary and secondary alcohols give aldehydes and ketones, respectively.



#### (iii) By ozonolysis of alkenes

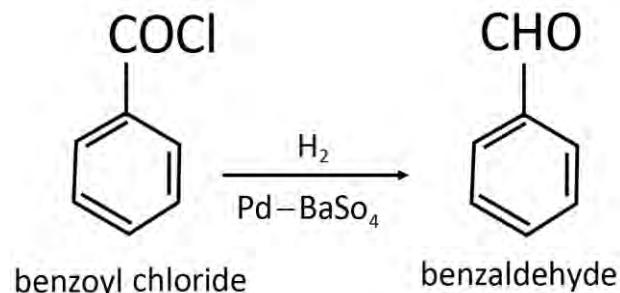


#### (iv) By hydration of alkynes



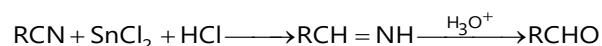
### Preparation of Aldehydes

(i) Rosenmund reduction



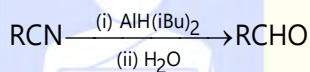
Formaldehyde cannot be prepared by this method as  $\text{HCOCl}$  is highly unstable.

(ii) From nitriles

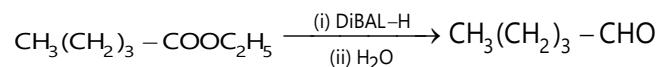


This reaction is called **Stephen reaction**.

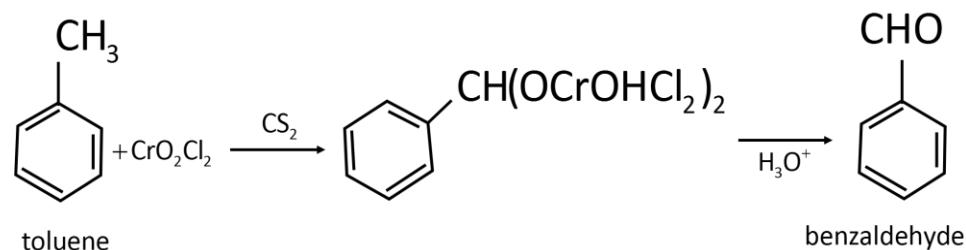
Alternatively, nitriles are selectively reduced by diisobutylaluminium hydride, [DiBAL-H] to imines which on hydrolysis give aldehydes.



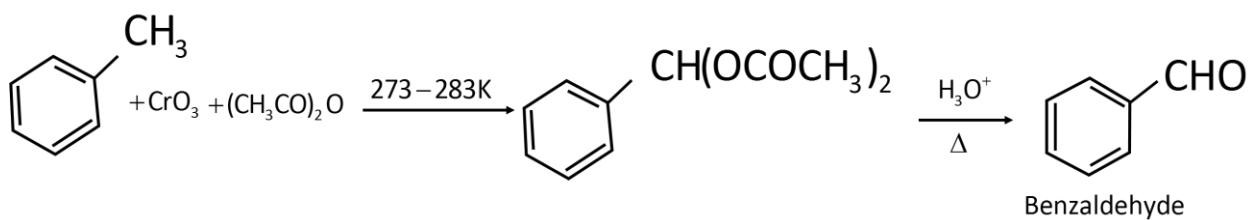
Similarly, esters can also be reduced to aldehydes with DiBAL-H.



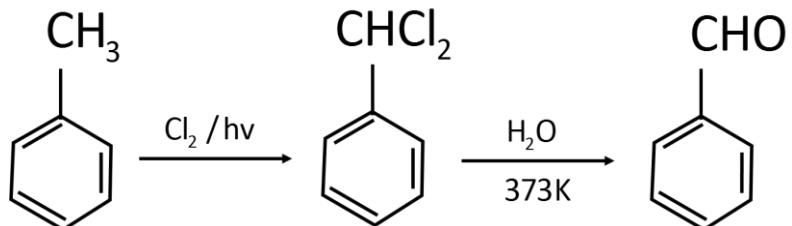
(iii) Etard reaction



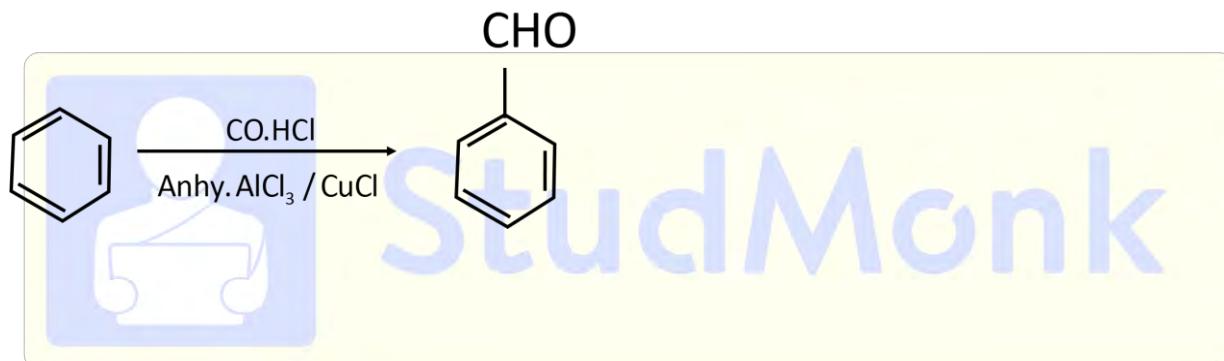
Using chromium oxide ( $\text{CrO}_3$ ) : Toluene or substituted toluene is converted to benzaldehyde in presence of chromic oxide in acetic anhydride.



(iv) Side chain halogenation is followed by hydrolysis of toluene

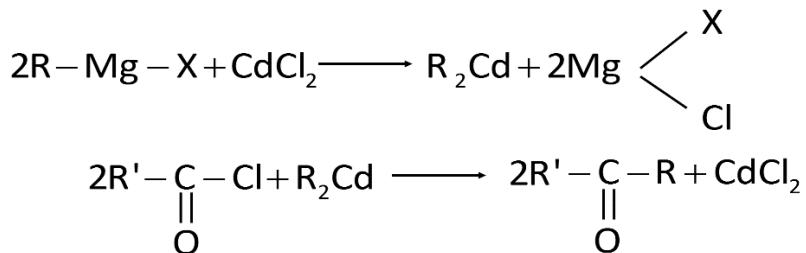


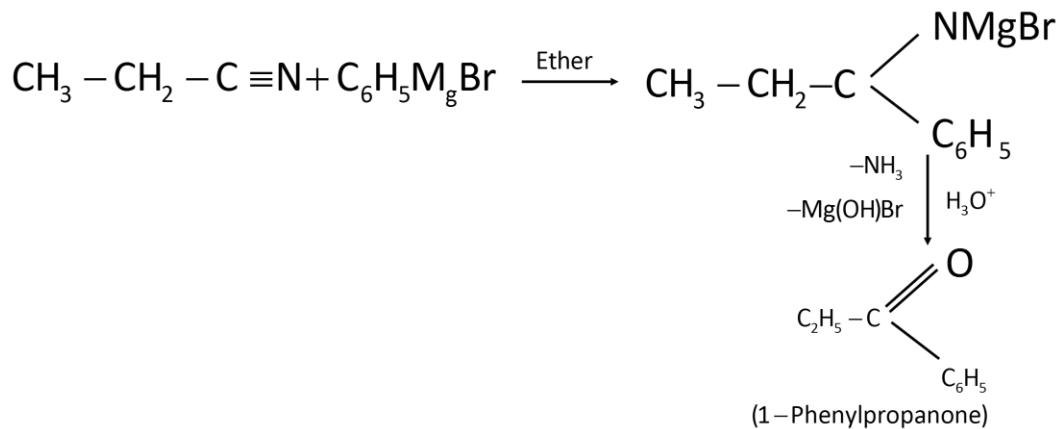
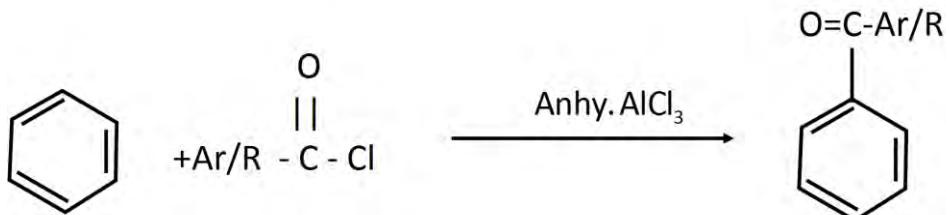
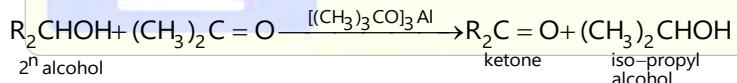
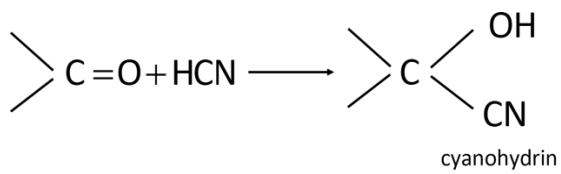
(v) Gattermann-Koch synthesis



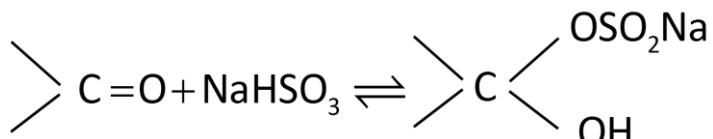
### Preparation of Ketones

#### (i) From acyl chlorides

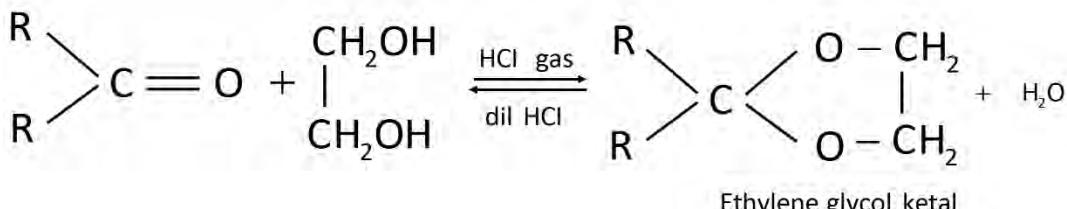
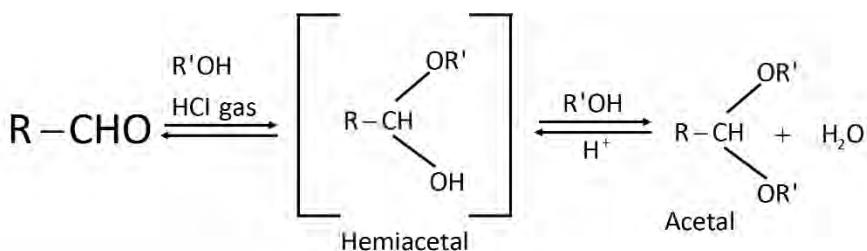
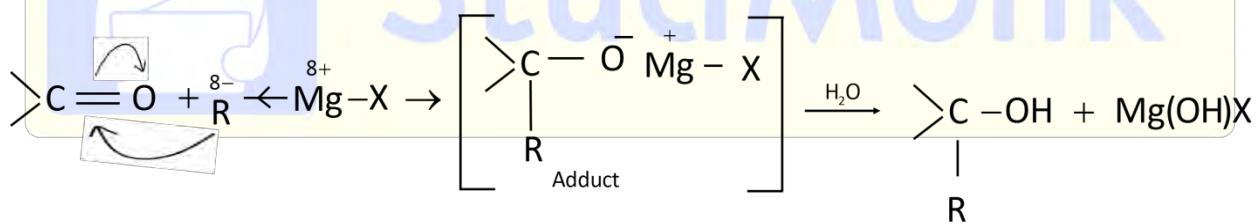


**(ii) From nitriles**

**(iii) Friedel-Crafts acylation**

**(iv) Oppenauer oxidation**

**Chemical Reactions of Aldehydes and Ketones**
**(i) Addition of hydrogen cyanide**


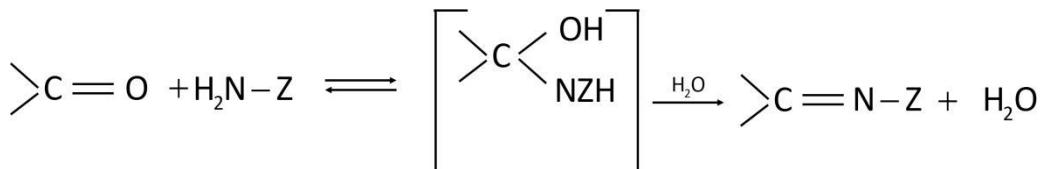
## (ii) Addition of sodium hydrogen sulphite

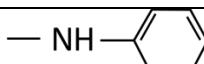
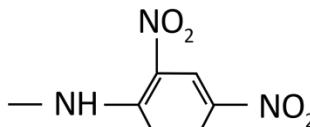
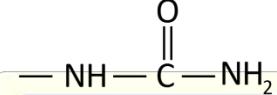


white crystalline solid

(iii) Addition of Grignard reagent ( $\text{RMgX}$ ) to form alcohol

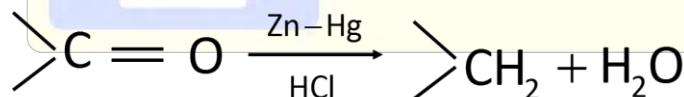
## (iv) Addition of ammonia and its derivatives

 $\text{Z} = \text{Alkyl, aryl, OH, NH}_2, \text{C}_6\text{H}_5\text{NH, NHCONH}_2, \text{etc}$

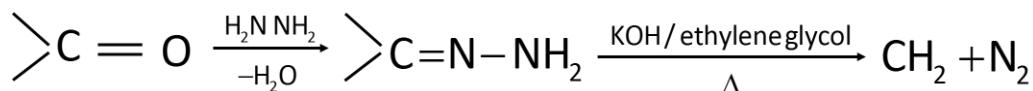
Z	Reagent name	Carbonyl derivative	Product Name
-R	Amine	$\text{--C}=\text{NR}$ 	Substituted imine (Schiff's base)
-OH	Hydroxyl amine	$\text{--C}=\text{N--OH}$ 	Oxime
-NH <sub>2</sub>	Hydrazine	$\text{--C}=\text{N--NH}_2$ 	Hydrazone
	Phenyl-hydrazine	$\text{>C}=\text{N--NH--C}_6\text{H}_5$	Phenylhydrazone
	2, 4-dinitrophenyl hydrazine	$\text{>C}=\text{N--NH--C}_6\text{H}_3(\text{NO}_2)_2$	2, 4-dinitrophenyl hydrazone
	Semi-carbazide	$\text{>C}=\text{N--NH--C}(=\text{O})\text{--NH}_2$	Semi-carbazone

### Reduction

#### (1). Clemmensen reduction

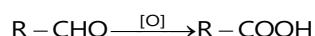


#### (2). Wolff-Kishner reduction



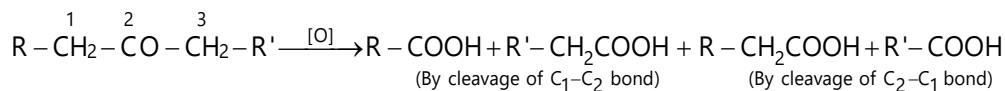
#### (3). Oxidation

(i) Aldehydes are oxidized to acids in presence of mild oxidizing agents  $\text{HNO}_3$ ,  $\text{K}_2\text{Cr}_2\text{O}_7$ ,  $\text{KMnO}_4$

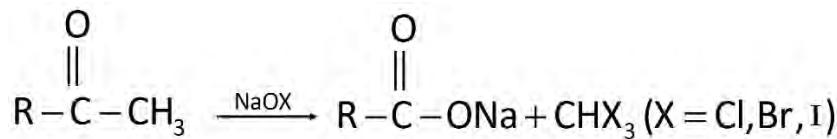


(ii) Ketones are oxidized under drastic conditions i.e. with powerful oxidizing agents like

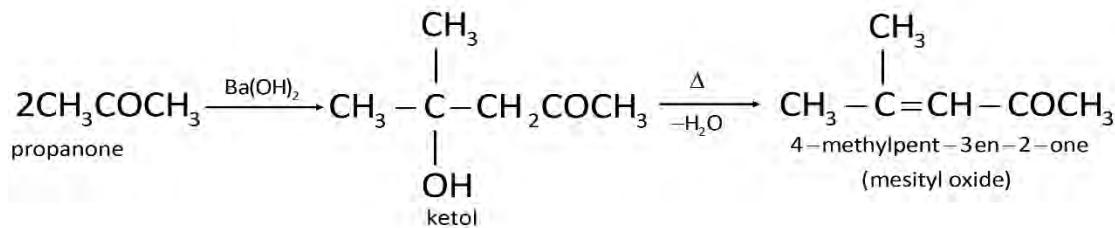
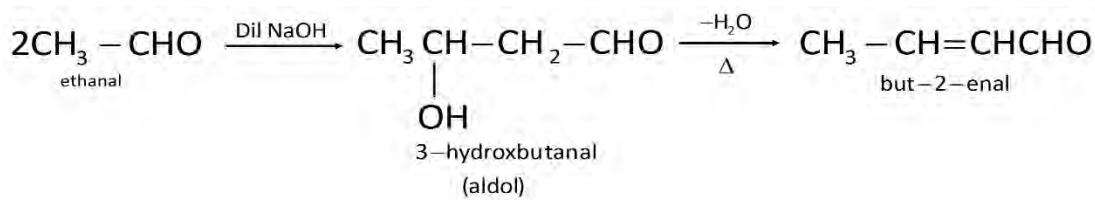
$\text{HNO}_3$ ,  $\text{K}_2\text{Cr}_2\text{O}_7 / \text{H}_2\text{SO}_4$ ,  $\text{KMnO}_4 / \text{H}_2\text{SO}_4$  at higher temperature.



(iii) Haloform reaction :

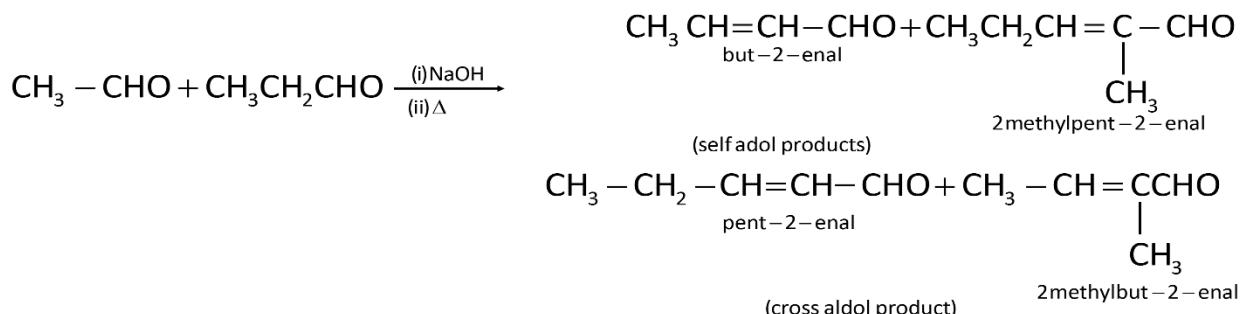


(v) Aldol condensation

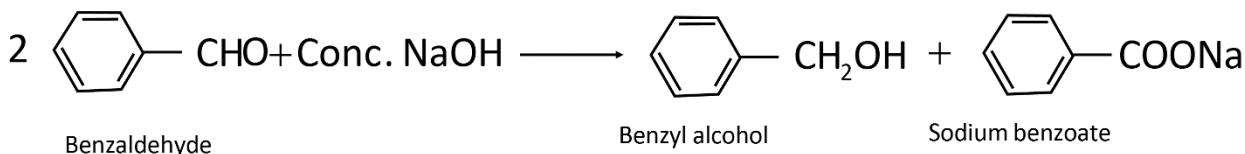
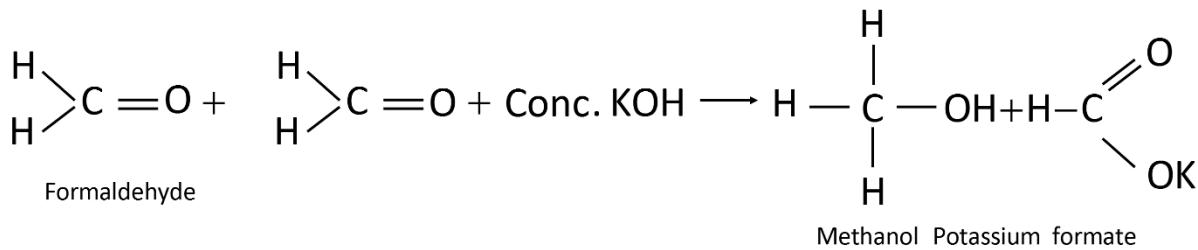


### Cross aldol condensation

Base catalysed crossed aldol condensation between an aromatic aldehyde and an aliphatic aldehyde or ketone is called **Claisen-Schmidt condensation** or **Claisen reaction**.



Cannizzaro reaction



Test to distinguish aldehydes and ketones :

**(1) Tollen's test :** When an aldehyde is heated with Tollen's reagent it forms silver mirror.

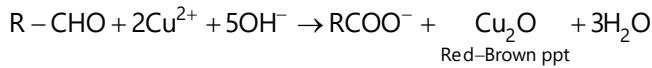
Tollen's reagent is ammoniacal solution of  $\text{AgNO}_3$



Ketones do not form silver mirror and hence do not give this test.

**(2) Fehling's test :** When an aldehyde is heated with Fehling's reagent it forms reddish brown precipitates of cuprous oxide.

Fehling's reagent : Fehling solution A (aqueous solution of  $\text{CuSO}_4$ ) + Fehling solution B (alkaline solution of sodium potassium tartarate)

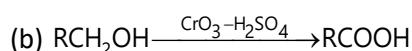


Ketones do not give this test.

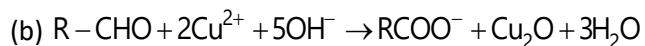
## Carboxylic Acids

### Methods of Preparation of carboxylic Acids

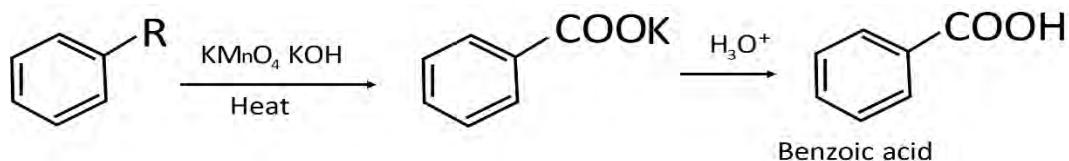
#### From primary alcohols and aldehydes



### From aldehydes

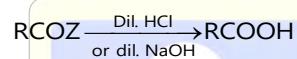


### From alkyl benzenes



### From acid derivatives

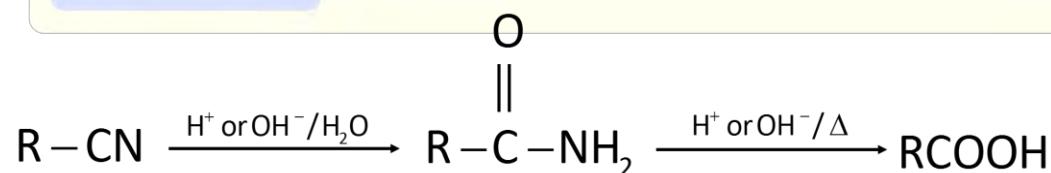
All acid derivatives like amides ( $\text{RCONH}_2$ ), acid halides ( $\text{RCOCl}$ ), esters ( $\text{RCOOR}'$ ), acid anhydrides ( $\text{RCO-O-COR}'$ ) on hydrolysis give carboxylic acids. All acid derivatives break from  $\text{RCO}^+$ .



$Z = -\text{NH}_2, -\text{X} (\text{X} = \text{Cl}, \text{Br}, \text{I}), \text{OR}', \text{RCOO} - \text{etc.}$

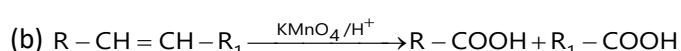
Ease of hydrolysis :  $\text{RCOCl} > (\text{RCO})_2\text{O} > \text{RCOOR}' > \text{RCONH}_2$

### From nitriles and amides

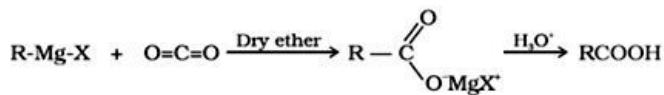


### From alkenes

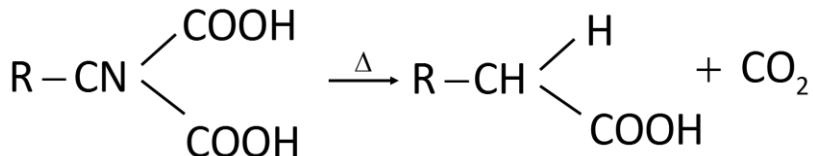
Suitably substituted alkenes are oxidized to carboxylic acids on oxidation with acidic potassium permanganate or acidic potassium dichromate.



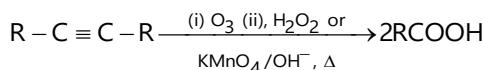
### From Grignard reagents



**By heating germinal dicarboxylic acids**

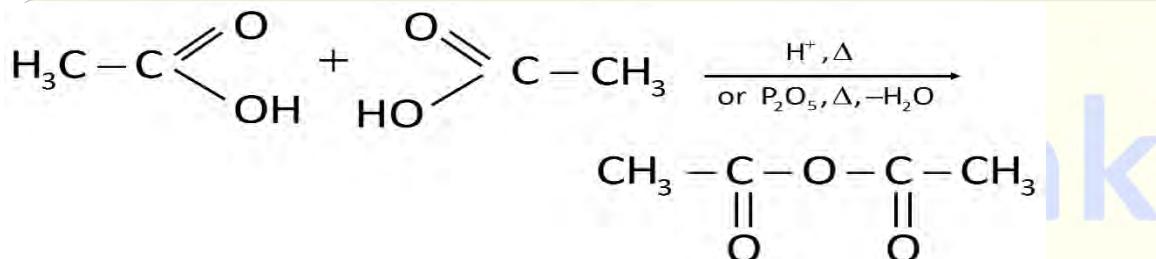


**From alkynes**

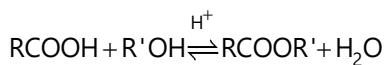


**Reactions of Carboxylic acids**

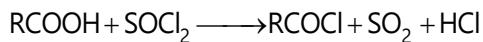
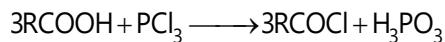
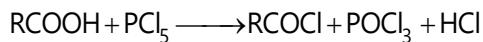
**Formation of anhydride**



**Esterification**

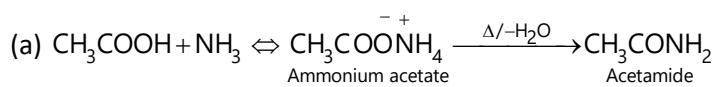


**Reactions with  $\text{PCl}_5$ ,  $\text{PCl}_3$  and  $\text{SOCl}_2$**

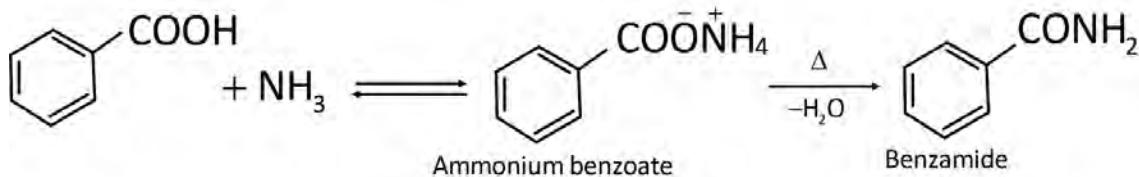


**Reaction with ammonia ( $\text{NH}_3$ )**

Carboxylic acids react with ammonia to give ammonium salt which on further heating at high temperature gives amides.

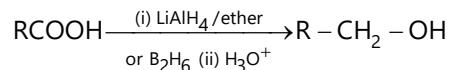


(b)

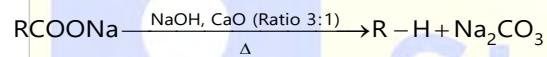


### Chemical reactions involving – COOH group

#### (a) Reduction

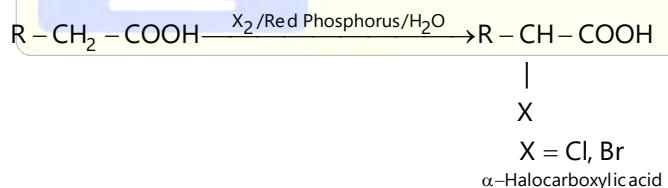


#### (b) Decarboxylation

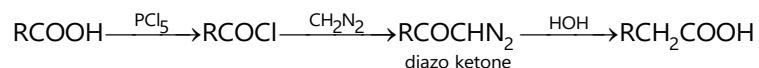


Substitution reactions in the hydrocarbon part

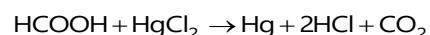
#### Hell-Volhard-Zelinsky reaction



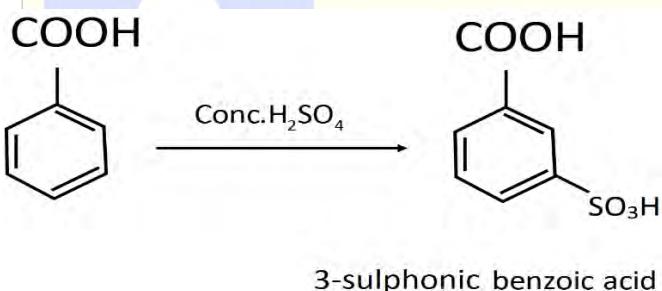
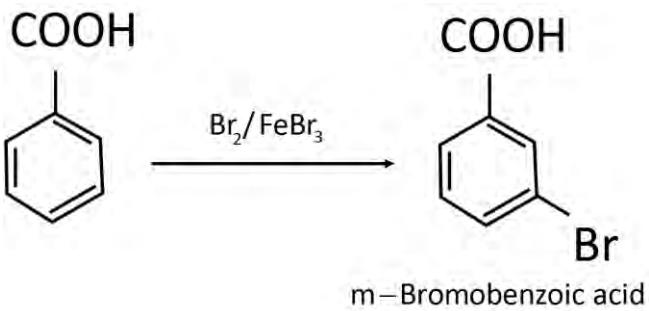
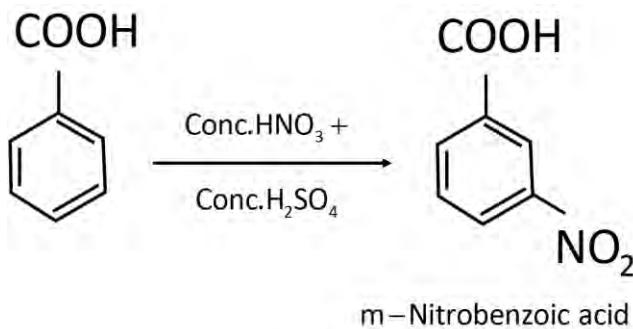
#### Arndt-Eistert reaction



#### Reducing property



#### Electrophilic substitution reactions of aromatic acids



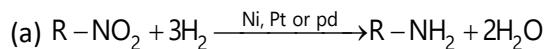
Monk

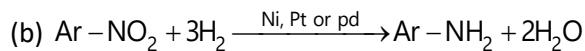
## 18. AMINES

### Methods of Preparation of Amines

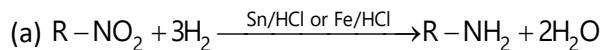
#### (i) By reduction of nitro compounds :

Nitro compounds can be catalytically reduced by passing hydrogen gas in presence of Raney Ni, finely divided Pt or Pd as catalyst at room temperature.

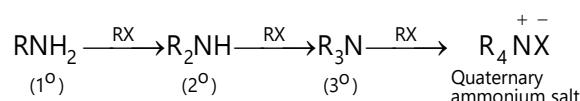




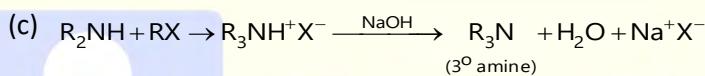
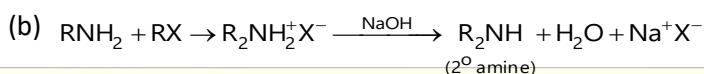
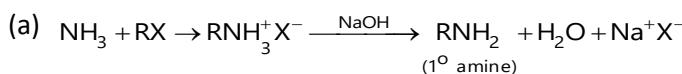
Nitro compounds can also be reduced with active metals such as Fe, Sn, Zn etc. with conc. HCl.



(ii) By Hoffmann's method (Ammonolysis of alkyl halides):



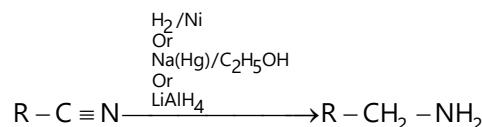
- The free amine can be obtained from the ammonium salt by treatment with a strong base :



- Order of reactivity of halides is :  $\text{RI} > \text{RBr} > \text{RCI}$

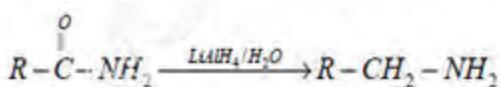
(iii) By reduction of nitriles :

Nitriles can be reduced to amines using  $\text{H}_2/\text{Ni}$ ,  $\text{LiAlH}_4$  or  $\text{Na(Hg)}/\text{C}_2\text{H}_5\text{OH}$

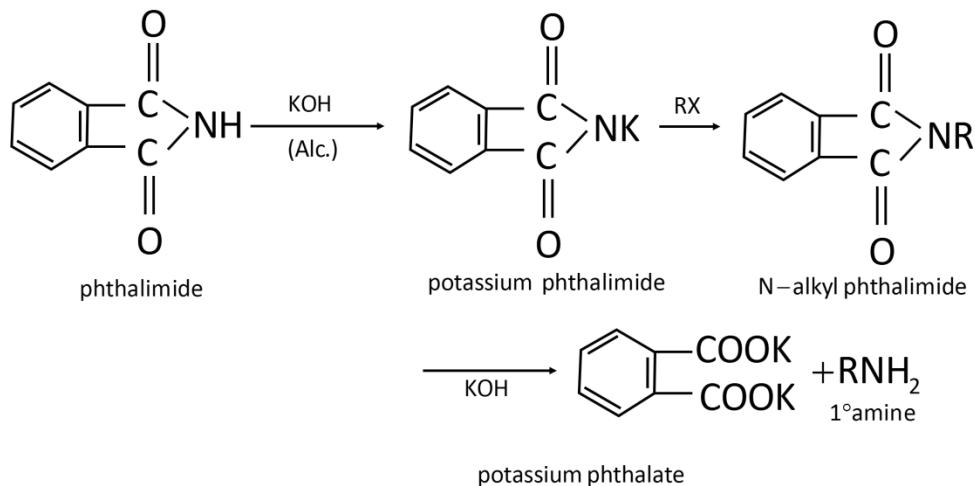


(iv) By reduction of amides :

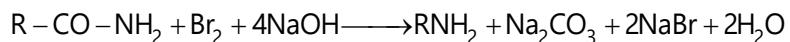
Amides are reduced to corresponding amines by  $\text{LiAlH}_4$



(v) Gabriel's phthalimide reaction

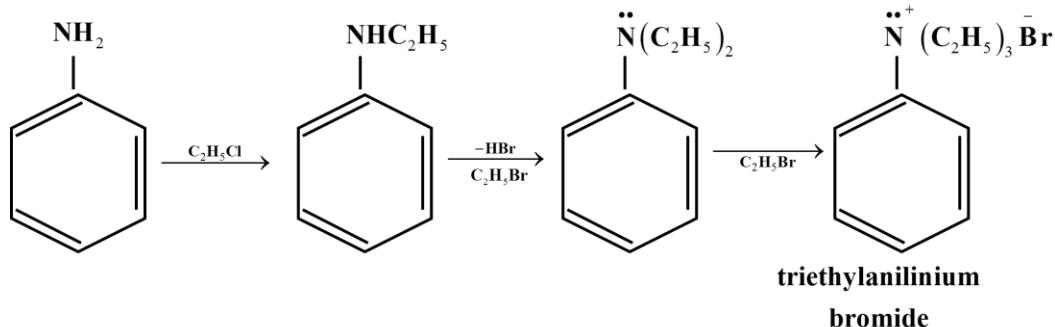
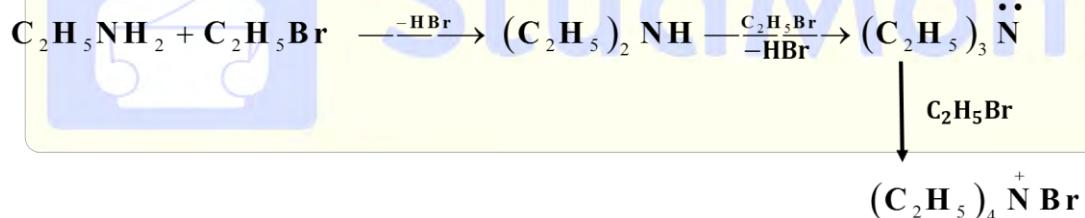


(vi) Hofmann bromamide degradation reaction

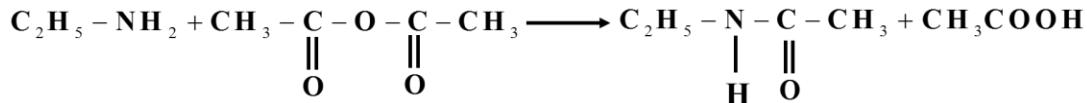
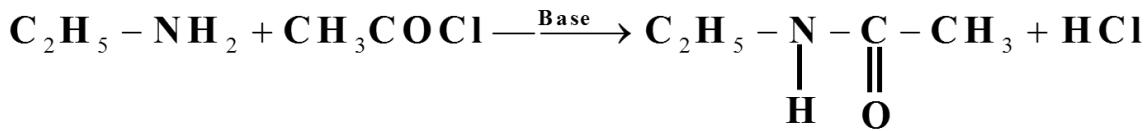


### Reactions of Amines

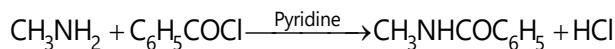
(i) Alkylation



(ii) Acylation

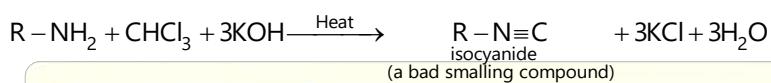


(iii) Benzoylation



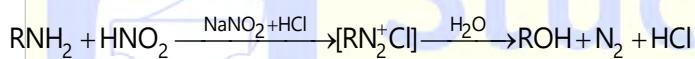
Benzoylation of aniline is known as Schotten Baumann reaction.

(iv) Carbonylamine reaction [only by 1° amines]

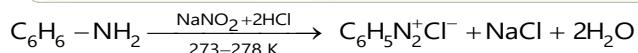


Methyl isocyanide gas ( $\text{CH}_3 - \text{N} = \text{C} = \text{O}$ ) was responsible for Bhopal gas tragedy in December 1984.

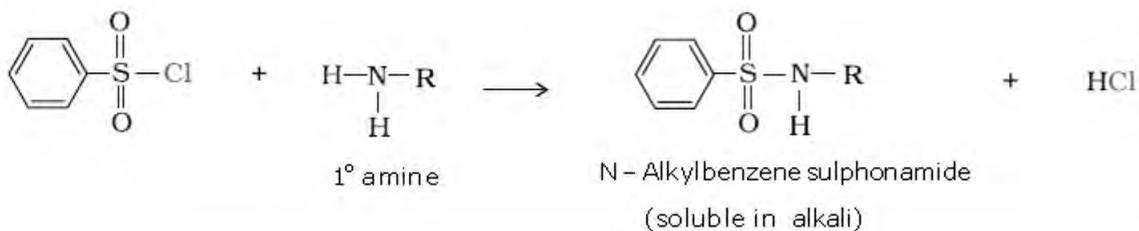
(v) Reaction with nitrous acid

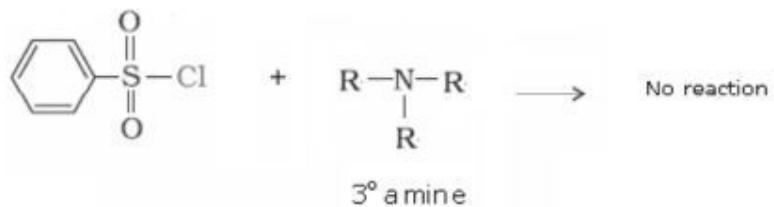
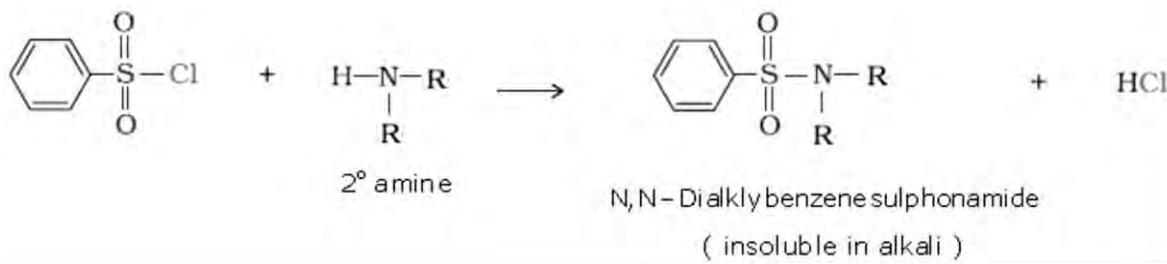


Quantitative evolution of nitrogen is used in estimation of amino acids and proteins.



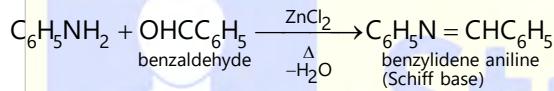
**Reaction with aryl sulphonyl chloride [Hinsberg reagent]**





### Reaction with aldehydes

Schiff base is obtained.

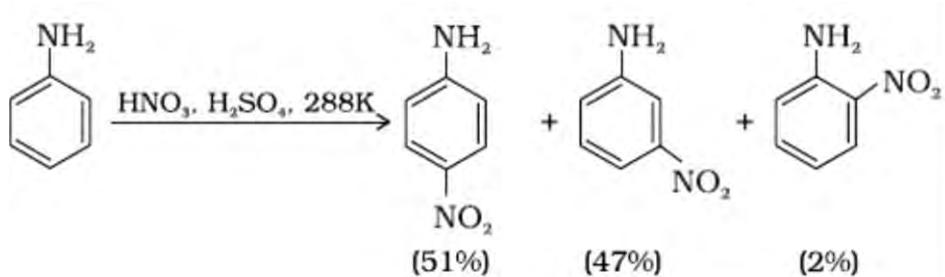


### Electrophilic substitution reactions



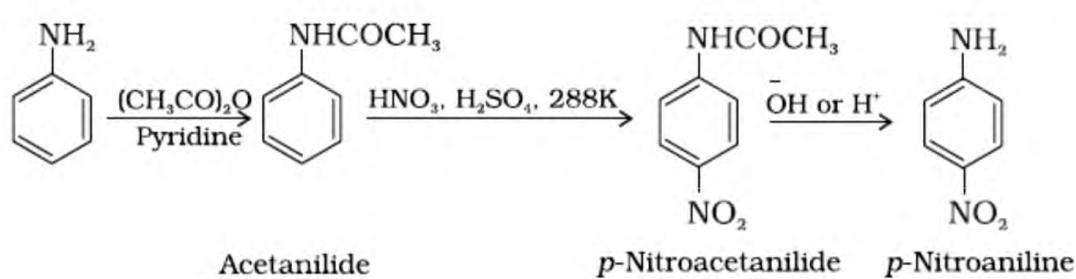
### Nitration

(a) Under strongly acidic medium aniline gets protonated to form anilinium ion, which is deactivating group and is meta directing. Hence m-nitroaniline is also formed in 47 % along with ortho and para products.

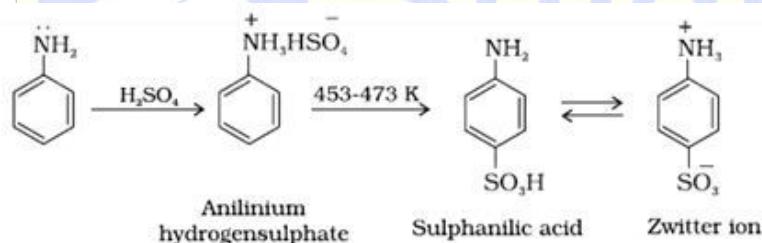


Aromatic amines cannot be nitrated directly because  $\text{HNO}_3$  being a strong oxidizing agent oxidizes it forming black mass.

(b) Nitration by protecting the  $-\text{NH}_2$  group by acetylation reaction with acetic anhydride :



(c) Sulphonation On sulphonation, aniline gives sulphanilic acid, as the major product.

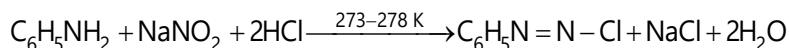


### Oxidation

Oxidising agent	Product
Acidified $\text{KMnO}_4$ (or $\text{Na}_2\text{Cr}_2\text{O}_7 + \text{CuSO}_4 + \text{dill acid}$ )	Aniline back (a dye)
Chromic acid ( $\text{Na}_2\text{Cr}_2\text{O}_7 + \text{Conc H}_2\text{SO}_4$ )	$p$ -benzoquinone
Caro's acid ( $\text{H}_2\text{SO}_5$ )	Nitrobenzene and nitrosobenzene
Conc. Nitric acid	decomposes

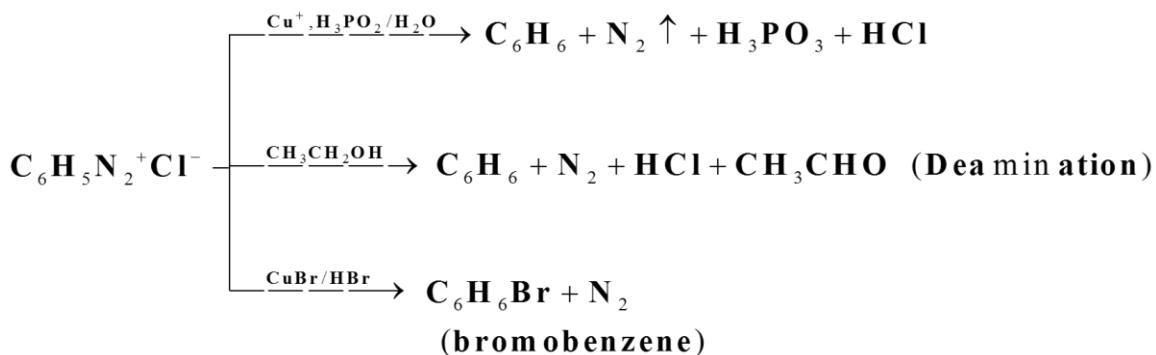
**Benzene Diazonium Chloride** ( $\text{C}_6\text{H}_5\text{N}_2^+ ; \text{Cl}^-$ )

**Preparation** (Diazotisation reaction)

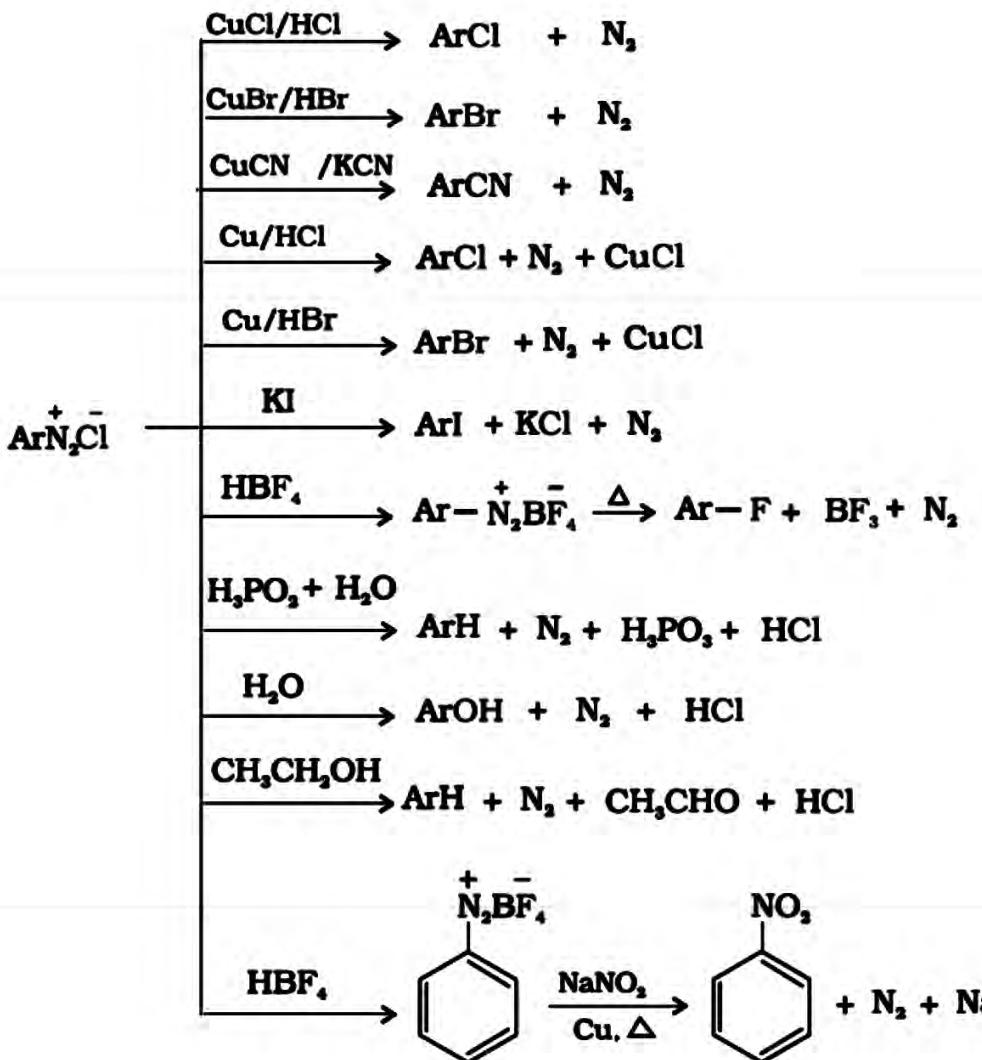




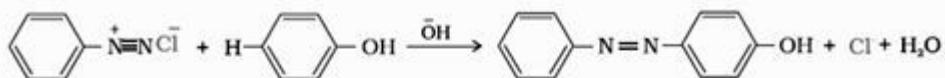
## Chemical reactions



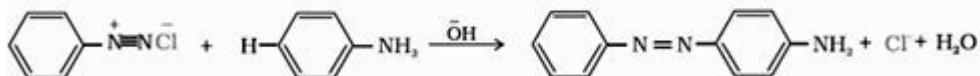
(a) Reactions involving displacement of nitrogen :



### Azo coupling reactions



*p*-Hydroxyazobenzene (orange dye)

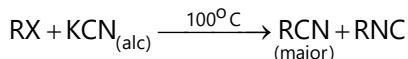


*p*-Aminoazobenzene  
(yellow dye)

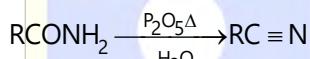
### Alkyl Cyanides

#### Methods of Preparation

##### (i) From alkyl halides

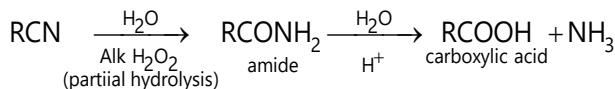


##### (ii) From acid amides

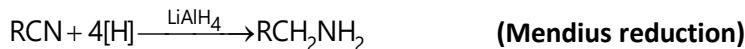
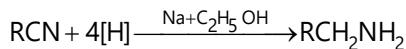


#### Reactions of Alkyl Cyanides

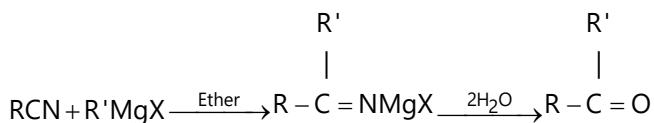
##### (i) Hydrolysis



##### (ii) Reduction



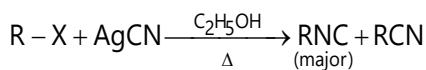
##### (iii) Reaction with Grignard reagent



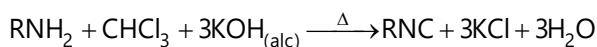
## Alkyl isocyanides

### Methods of Preparation

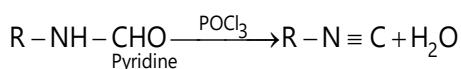
#### (a) From alkyl halides



#### (b) Carbylamine reaction

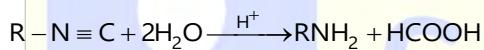


#### (c) From N-alkyl formamide

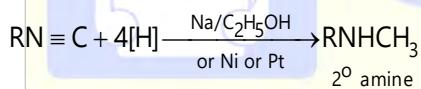


### Reactions of Alkyl isocyanides

#### Hydrolysis



#### (ii) Reduction



#### (iii) Addition reaction

Due to the presence of unshared pair of electrons on C atom, alkyl isocyanides give addition reaction.



#### (iv) Isomerisation

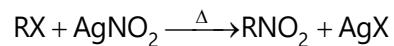
At 250°C, it isomerizes to nitrile.



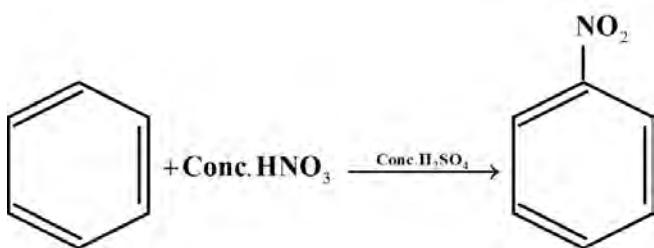
## Nitro Compounds

### Methods of Preparation

#### (i) From alkyl halides



#### (ii) Nitration: Nitrating mixture is conc HNO<sub>3</sub> + conc H<sub>2</sub>SO<sub>4</sub>



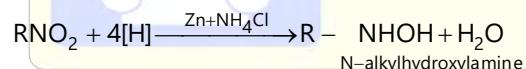
### Reactions of Nitro Compounds

#### Reduction

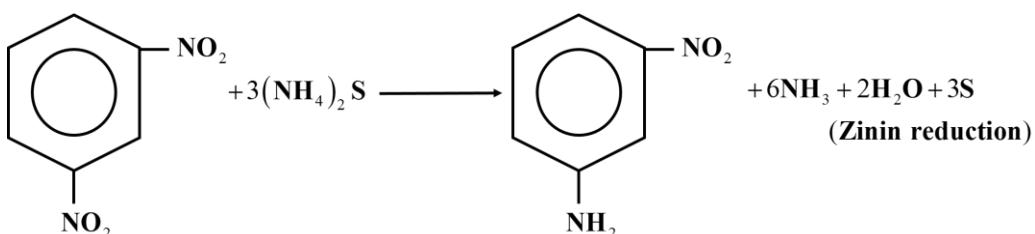
With Sn/HCl or catalytic hydrogenation, nitroalkanes are reduced to amines.



If neutral reducing agent like Zn dust + NH<sub>4</sub>Cl is used, hydroxylamines are obtained as major product.



In the presence of (NH<sub>4</sub>)<sub>2</sub>S or Na<sub>2</sub>S, selective reduction takes place.



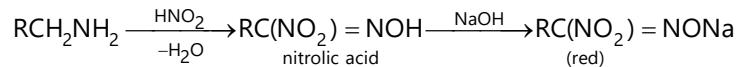
Nitrobenzene gives different products with different reagents and in different mediums.

Medium	Reagent	Product
Acid	Sn/HCl	Aniline
Neutral	Zn/NH <sub>4</sub> Cl Na <sub>3</sub> AsO <sub>3</sub> /NaOH	N-phenyl hydroxylamine  ↑ Azoxbenzene (C <sub>6</sub> H <sub>5</sub> N = NC <sub>6</sub> H <sub>5</sub> )

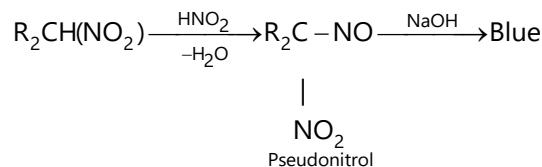
Alkaline	Zn/NaOH, CH <sub>3</sub> OH Zn/NaOH, C <sub>2</sub> H <sub>5</sub> OH	Azobenzene hydrazobenzene
Metallic hydride	LiAlH <sub>4</sub>	aniline
Electrolytic	dil H <sub>2</sub> SO <sub>4</sub>	p-aminophenol

### Action of HNO<sub>2</sub>

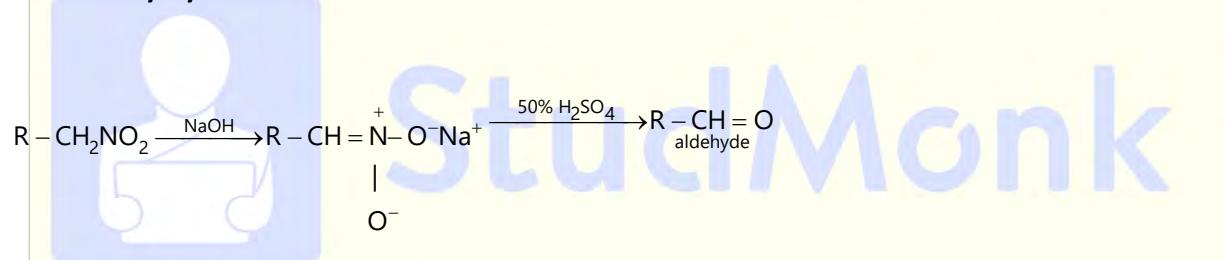
1° nitroalkane gives nitrolic acid which gives red colour with NaOH.



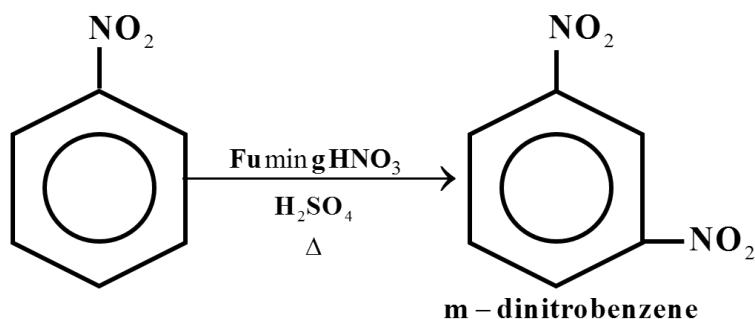
2° nitroalkanes give pseudonitrol with HNO<sub>2</sub>



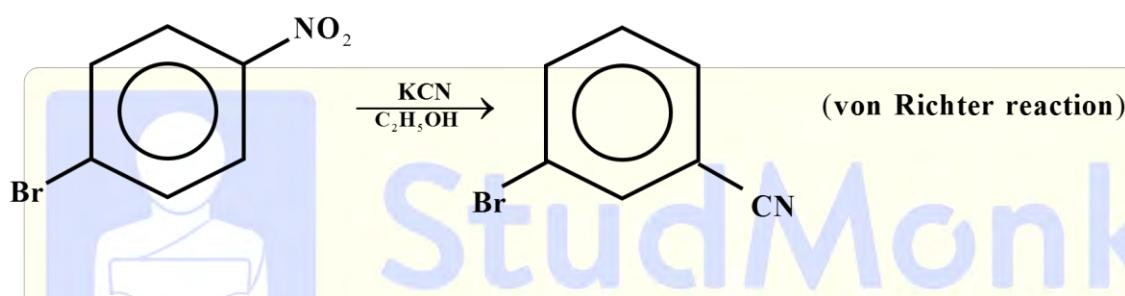
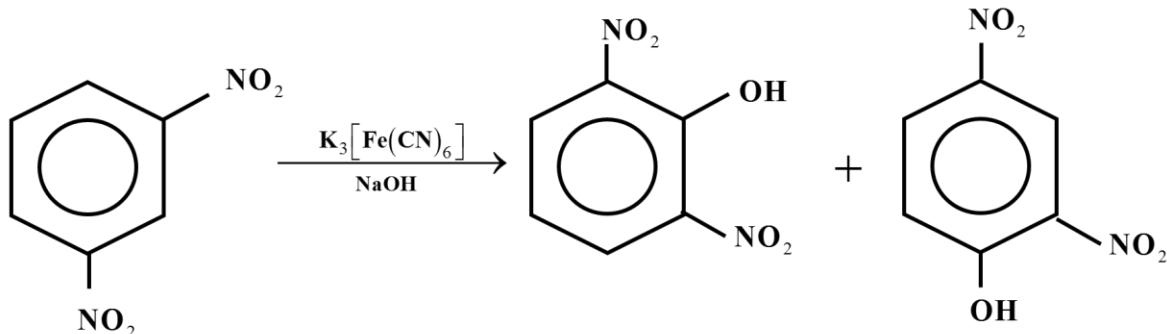
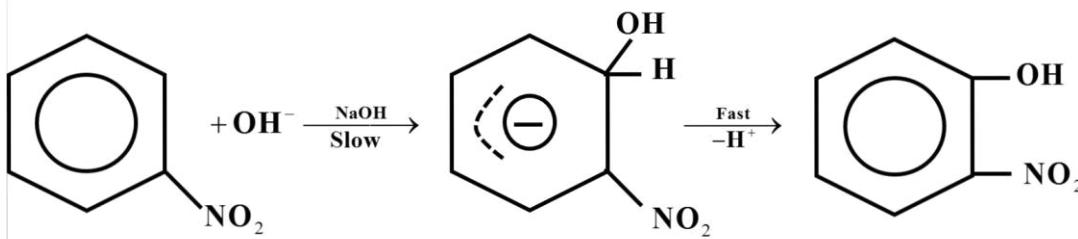
### Nef carbonyl synthesis



Electrophilic substitution On nitration



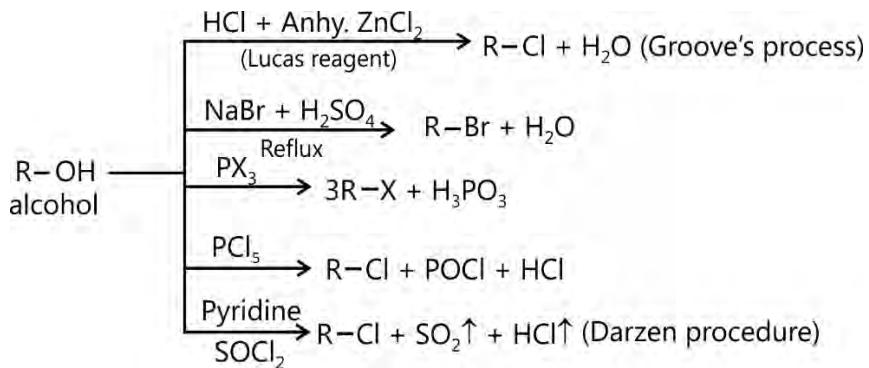
**Nucleophilic substitution reaction** -NO<sub>2</sub> group activates the ring towards nucleophilic substitution.

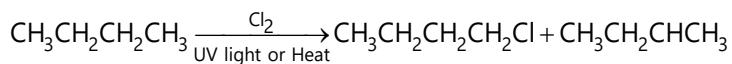


## 19. HALOALKANES AND HALOARENES

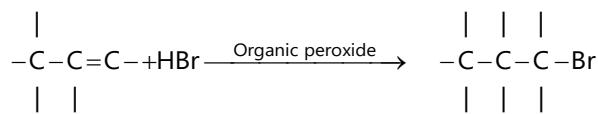
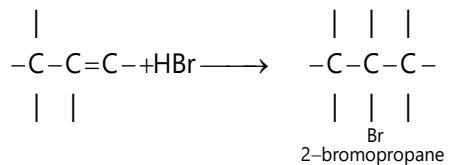
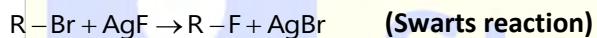
### General Methods of Preparation of Haloalkanes

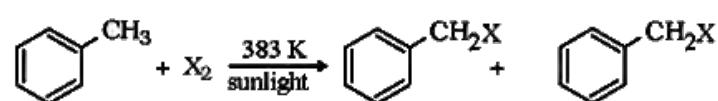
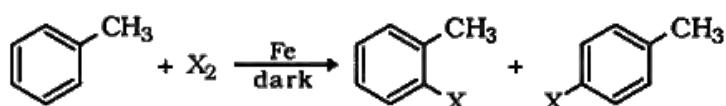
#### From Alcohols

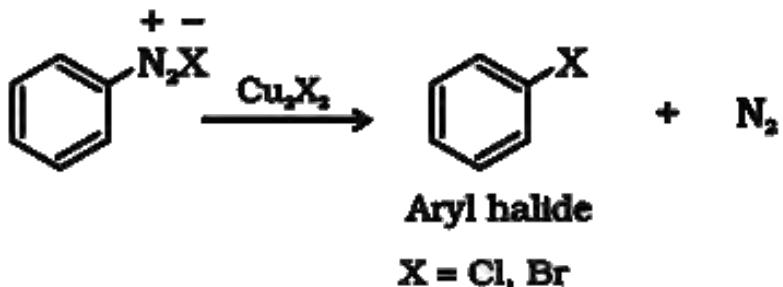
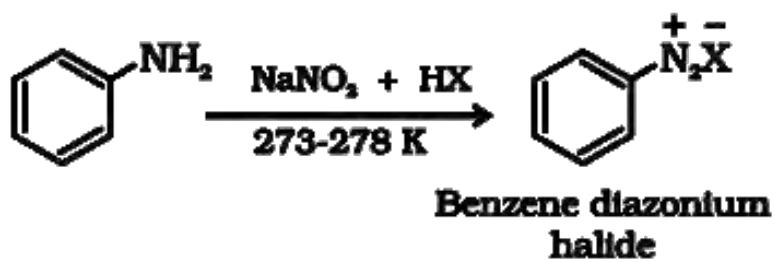


**Free Radical Halogenation of Alkanes**

|  

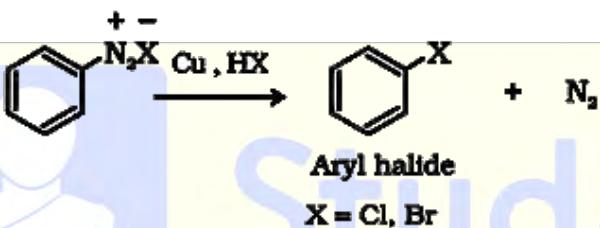
Cl

**Addition of hydrogen Halides on Alkenes**

**(i) Halogen Exchange method :**

**Hunsdiecker Reaction**

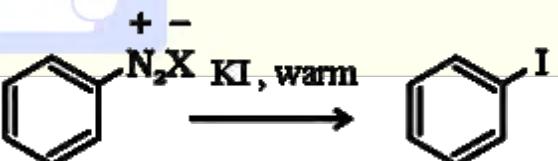
**Preparation of haloarenes :**
**(a) By electrophilic substitution reaction :**

**(b) Sandmeyer's reaction :**



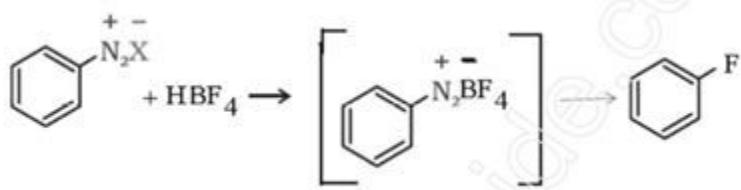
(c) Gattermann reaction :



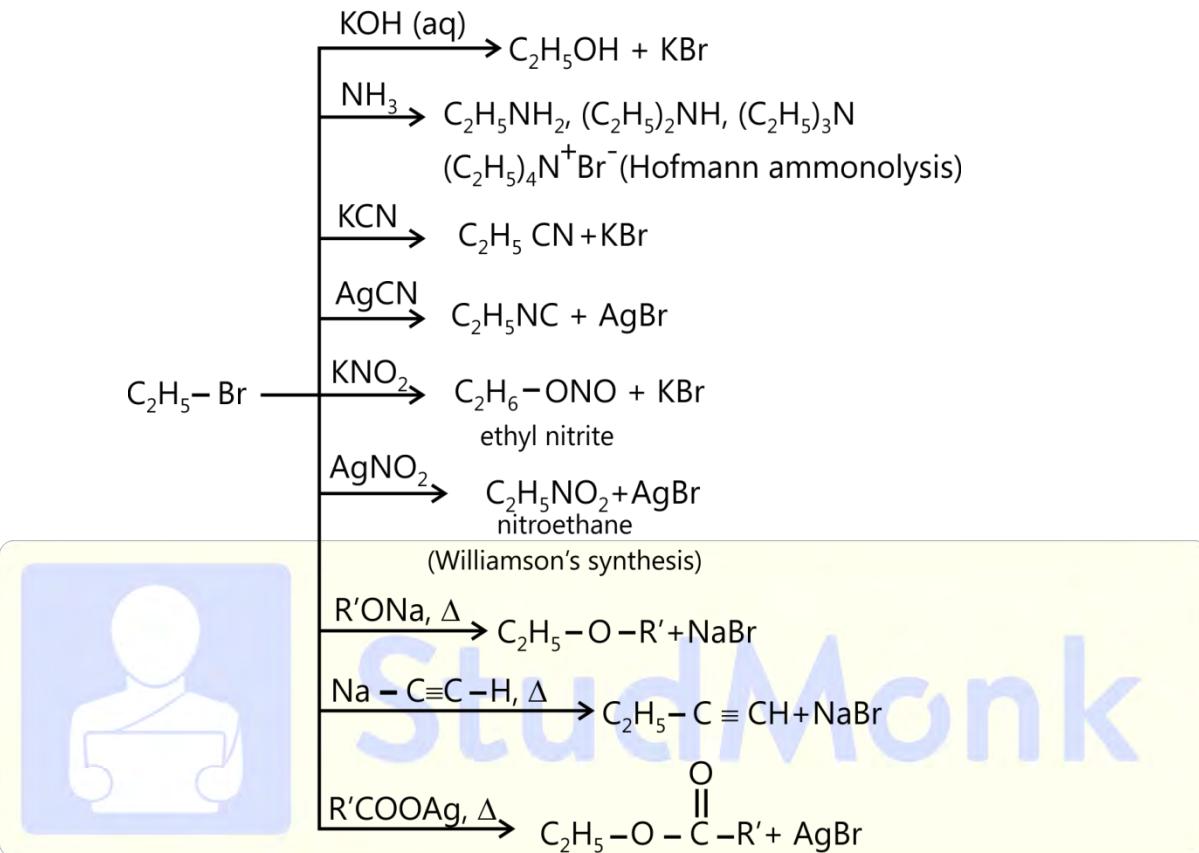
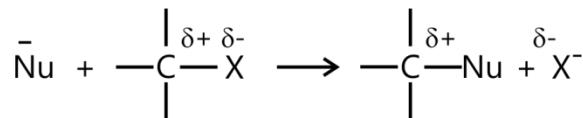
(d) From Diazonium Chloride :



(e) Balz-Schiemann reaction :

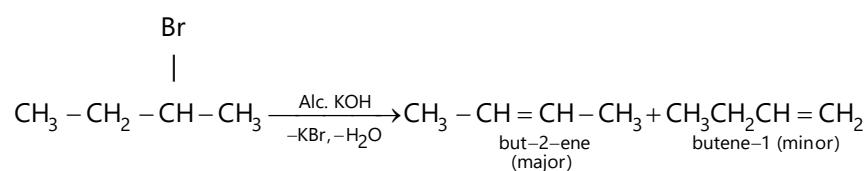


### Nucleophilic Substitution Reactions

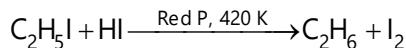
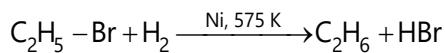


## 2. Elimination Reactions

Dehydrohalogenation is a  $\beta$ -elimination reaction in which halogen is from  $\alpha$ -carbon atom and the hydrogen from the  $\alpha$ -carbon according to Saytzeff rule, e.g.

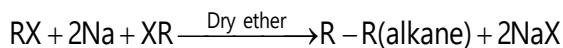


## Reduction

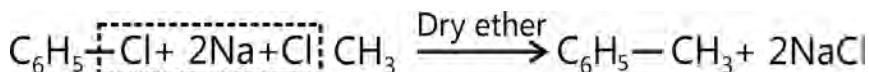


### Reaction with Metals

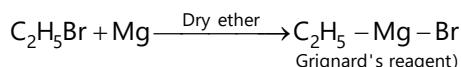
#### (i) Wurtz reaction



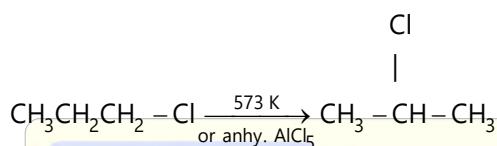
#### (ii) Wurtz-Fitting reaction



#### (iii) Reaction with Mg



### Isomerisation



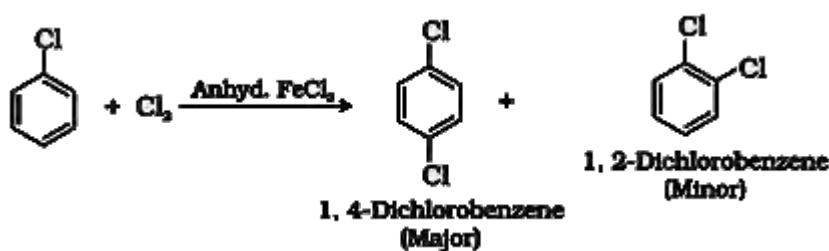
### Chemical properties of haloarenes :

#### (a) Dow's Process



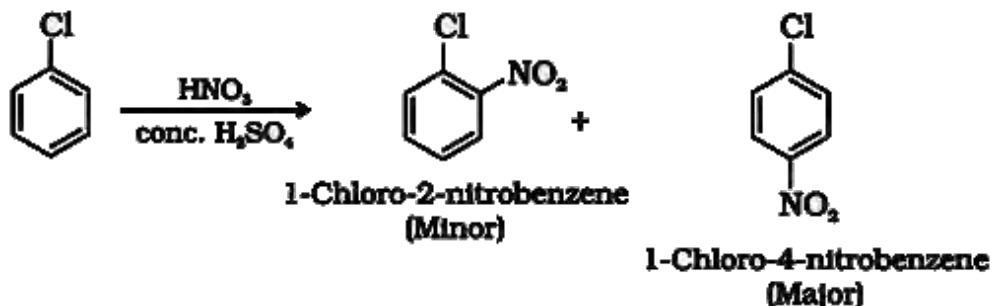
### Electrophilic substitution Reactions

#### (b) With halogens





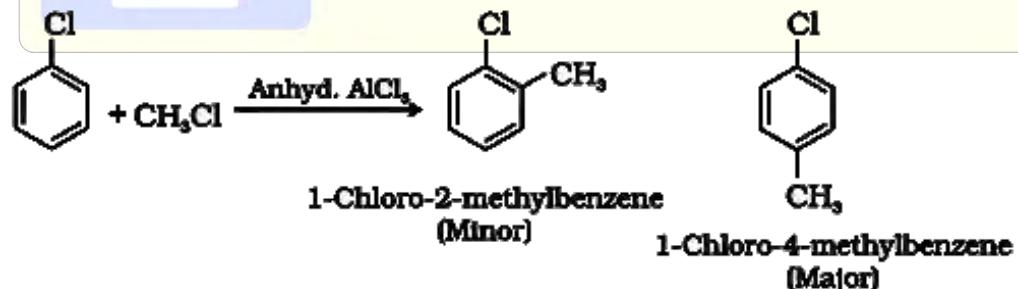
(c) With conc. sulphuric acid and nitric acid



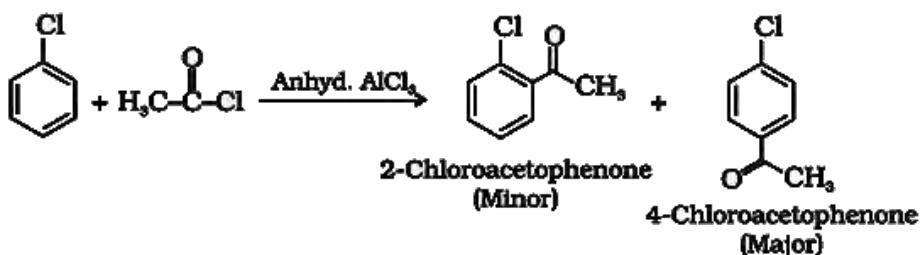
(d) On heating with conc. sulphuric acid



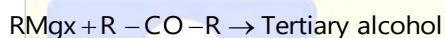
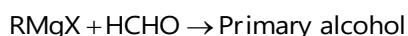
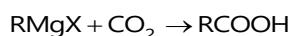
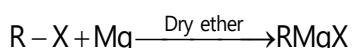
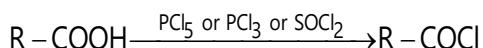
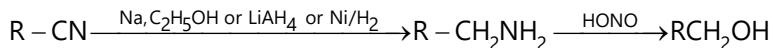
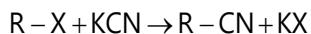
(e) With methyl chloride



(f) With acetyl chloride

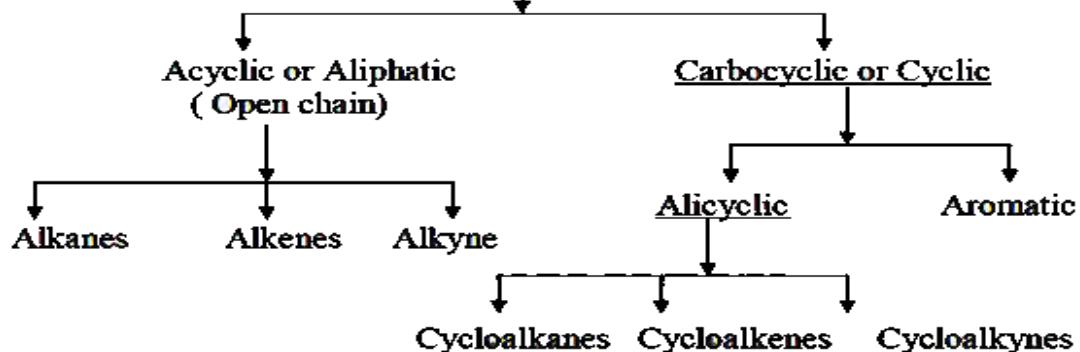


**(i) Other conversions :**



## 20. HYDROCARBONS

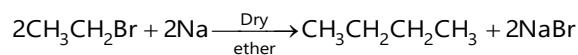
### CLASSIFICATION OF HYDROCARBONS: HYDROCARBON



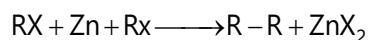
## Alkanes

### Preparation of Alkanes

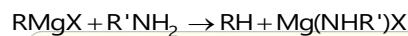
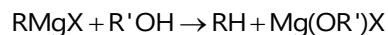
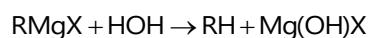
(1) Wurtz reaction :



Frankland reaction

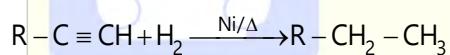


(2) From Grignard reagent ( $\text{RMgX}$ )



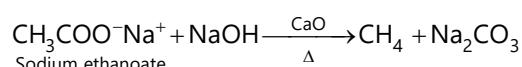
(3) From unsaturated hydrocarbons :-

Sabatier-Senderens reduction

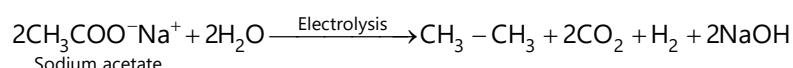


4. From carboxylic acids-

Decarboxylation –



Kolbe's electrolytic method –

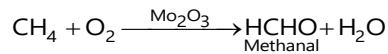
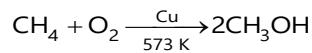
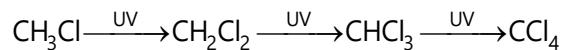
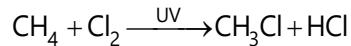


### Reactions

Combustion :-

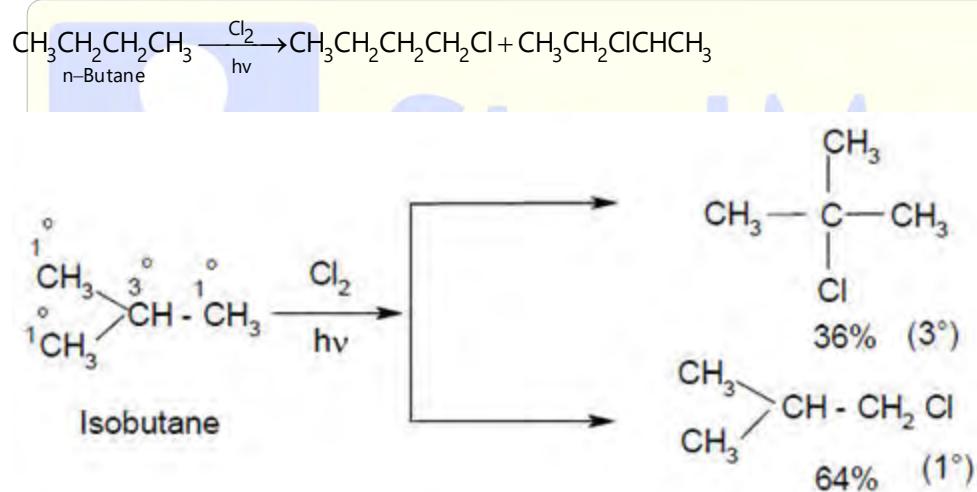
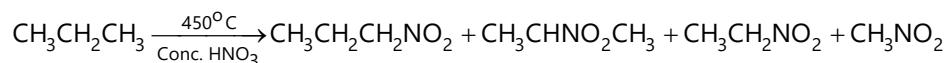


Oxidation :-


**Substitution :-**
**Halogenation :-**


(i) The reactivity of Halogens :  $\text{F}_2 > \text{Cl}_2 > \text{Br}_2 > \text{I}_2$

(ii) The rate of replacement of Hydrogens of alkanes is :  $3^\circ > 2^\circ > 1^\circ$


**Nitration**


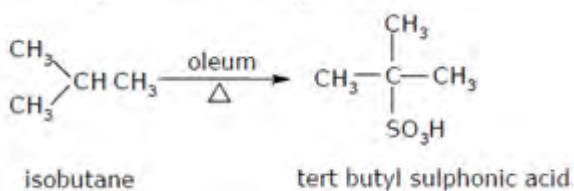
25 %

40 %

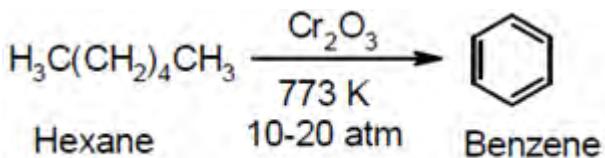
10 %

25 %

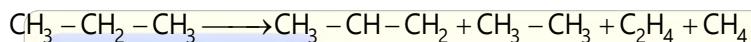
**Sulphonation** : - replacement of hydrogen atom of alkane by  $-\text{SO}_3\text{H}$  group.



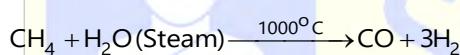
Aromatization :-



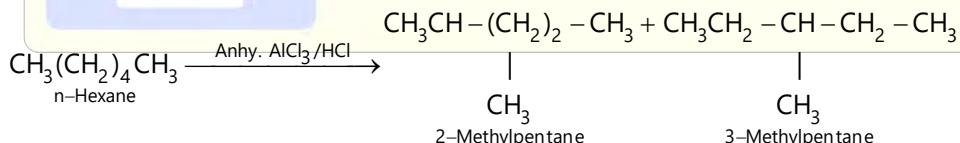
(6) Thermal decomposition or Pyrolysis or cracking or Fragmentation : - when higher alkanes are heated at high temp (about 700 – 800 K) in the presence of alumina or silica catalysts, the alkanes break down to lower alkenes and alkanes.



(7) Action of steam : - Catalyst : nickel, alumina  $\text{Al}_2\text{O}_3$



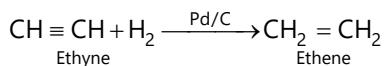
Isomerization



## Alkenes

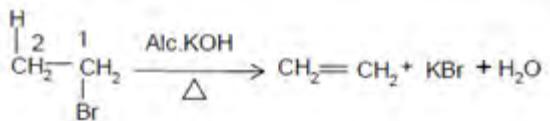
**Preparation :**

1. From Alkynes : - Alkynes on partial reduction with partially deactivated palladised charcoal known as Lindlar's catalyst give alkynes.

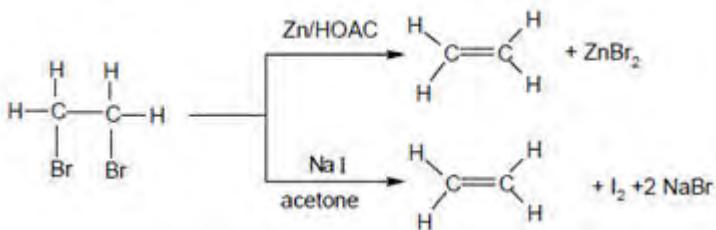


2. From Haloalkanes : - dehydrohalogenation ( $E_2$  or 1, 2-elimination or Beta-elimination)

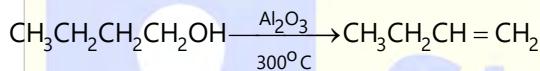
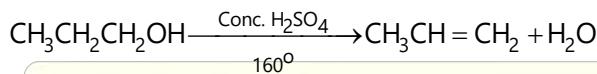




### 3. From Dihaloalkanes :- Dehalogenation



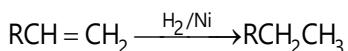
### 4. From Alcohols :- Dehydration (E1 – elimination)



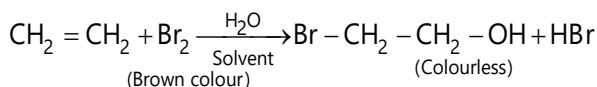
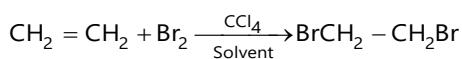
## Reactions of Alkenes

(1) Addition Reaction :- Alkene show electrophilic addition reaction.

### 1. Addition of Hydrogen :-

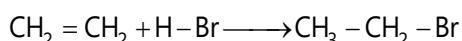


### 2. Addition of Halogens :-



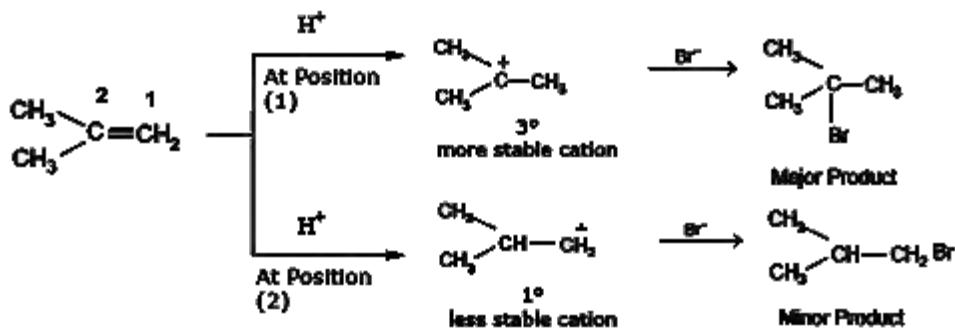
### 3. Addition of hydrogen halides –

Addition reaction of HBr to symmetrical alkenes

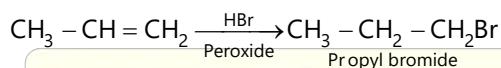


Addition reaction of HBr to unsymmetrical alkenes takes place according to Markovnikov Rule

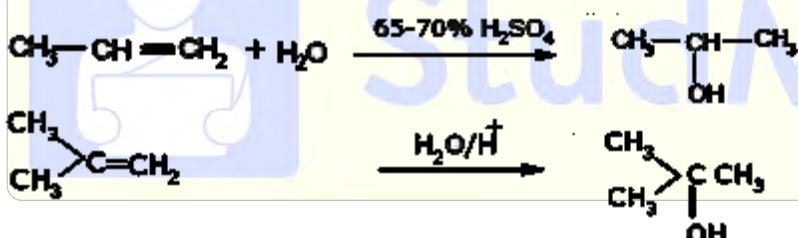
Markownikov rule :- negative part of the addendum (adding molecule) gets attached to that carbon atom which possesses lesser number of hydrogen atoms. E.g.



Peroxide effect or Kharasch (Anti Markownikoff's addition) :- In 1933 Kharasch and Mayo observed that when HBr is added to an unsymmetrical double bond in the presence of organic peroxide, the reaction takes place opposite to the Markownikov rule.



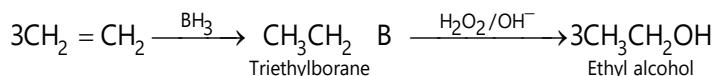
4. Addition of water (Hydration):- Acid catalyzed addition of water



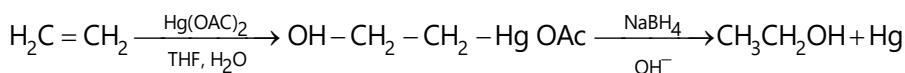
2. Oxidation :-

1. Combustion :  $\text{CO}_2 + \text{H}_2\text{O}$

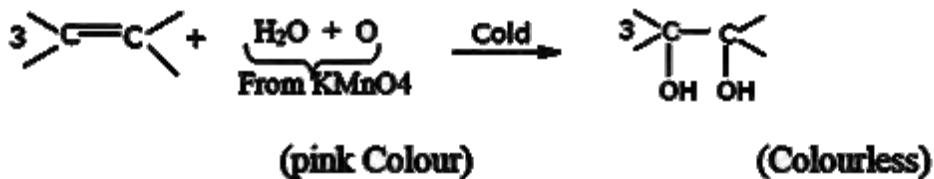
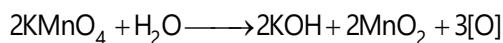
2. Hydrocarboration-oxidation:- Alkenes react with diborane to form trialkyl boranes which on oxidation with alkaline  $\text{H}_2\text{O}_2$  give alcohols.



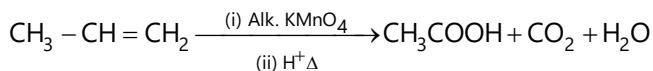
3. Oxymercuration-demercuration :-



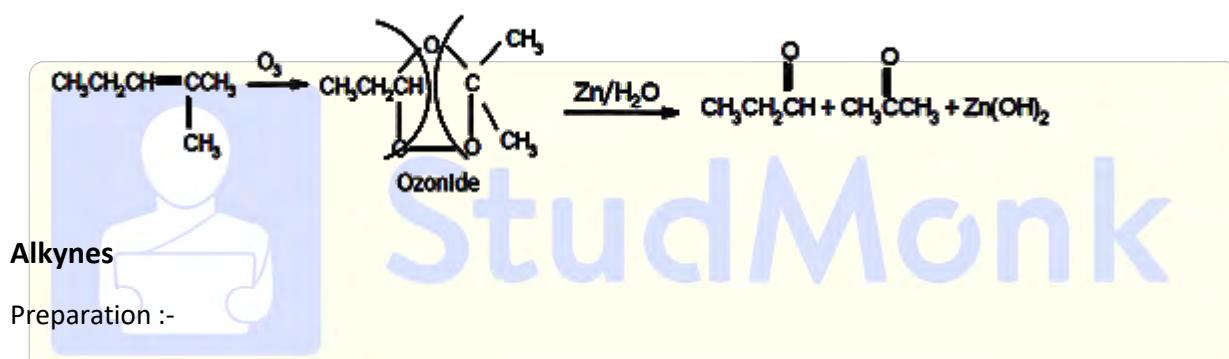
4. Oxidation with potassium permanganate :-



### Bayer's Test

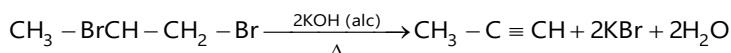


Oxidation with Ozone :- Ozonolysis-give carbonyls compounds



Preparation :-

From vicinal dihalides :- dehalogenation



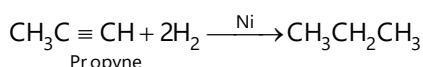
By the action of water on calcium carbide :-



### Reactions

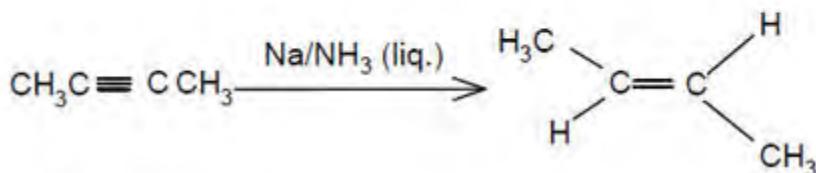
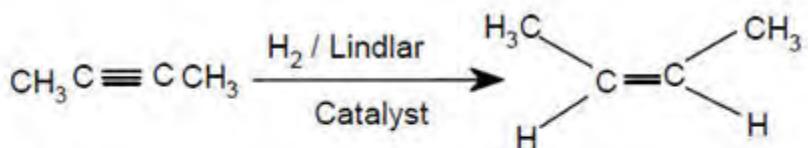
(1) Addition Reaction : Alkyne show electrophilic addition reaction.

1. Addition of Hydrogen – Hydrogenation.

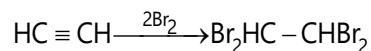




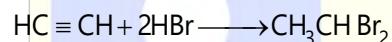
## Birch Reduction



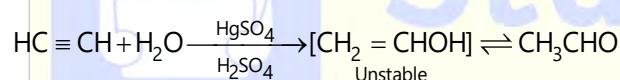
## 2. Addition of Halogens :-



## 3. Addition of hydrogen halides :-



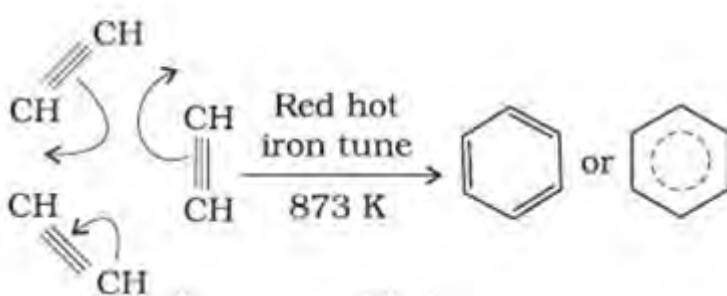
## 4. Addition of water (Hydration):- Acid catalyzed addition of water



## 5. Polymerisation –

(a) Linear polymerization : of ethyne gives polyacetylene or polyethyne which is a high molecular weight polyene containing repeating units of  $(\text{CH} = \text{CH} - \text{CH} = \text{CH})$  and can be represented as –  $(\text{CH} = \text{CH} - \text{CH} = \text{CH})_n$

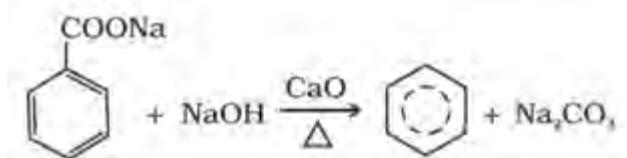
(b) Cyclic polymerization-results in the formation of aromatic compound.



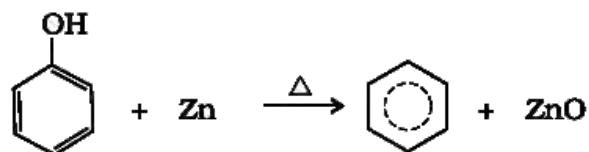
## Aromatic Hydrocarbon

### Preparation of Benzene

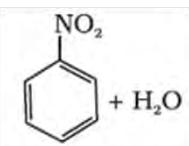
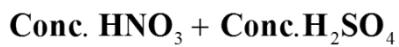
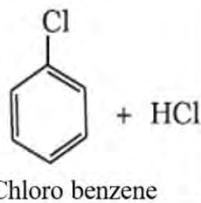
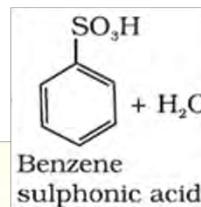
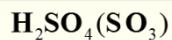
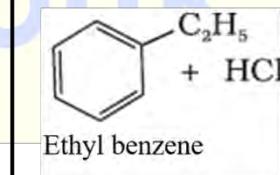
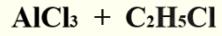
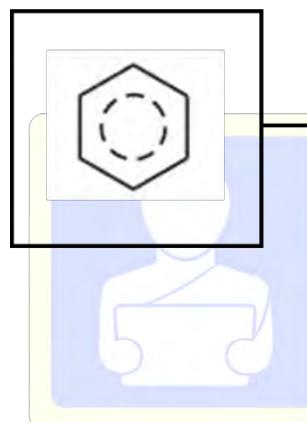
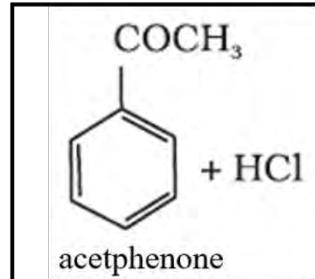
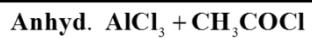
(i) Decarboxylation of aromatic acids.



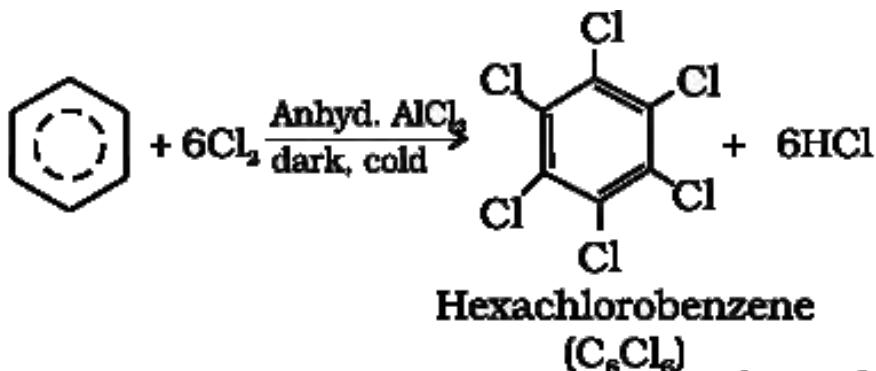
(ii) Reduction of phenol: Phenol is reduced to benzene by passing its vapours over heated zinc dust



# StudMonk

**Nitration****Halogenation****Sulphonation****Friedel-Crafts alkylation****Friedel-Crafts acylation**

Benzene on treatment with excess of chlorine in the presence of anhydrous  $\text{AlCl}_3$  in dark yields hexachlorobenzene ( $\text{C}_6\text{Cl}_6$ )



Directive influence of a functional group in monosubstituted benzene :-

1. Ortho and para directing groups and activating

–OH, –NH<sub>2</sub>, –NHR, –NHCOCH<sub>3</sub>, –OCH<sub>3</sub>, –CH<sub>3</sub>, –C<sub>2</sub>H<sub>5</sub> etc.

2. Meta directing group and deactivating :- –NO<sub>2</sub>, –CN, –CHO, –COR, –COOH, –COOR, –SO<sub>3</sub>H,

3. Ortho and para directing groups and deactivating – Halogens because of their strong – I effect, overall electron density on benzene ring decreases. However due to resonance the electron density on o- and p- position is greater than that at the m-position. Hence, they are also o- and p- directing groups.

## 21. POLYMERS

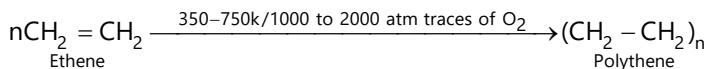
Important Addition Polymers

### Polyolefins

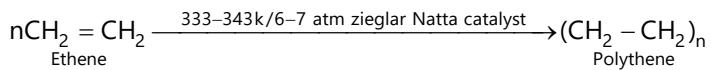
#### 1. Polythene

Polymer of ethylene or ethene.

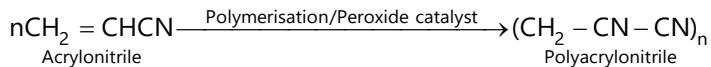
(a) Low density polythene (LDP)



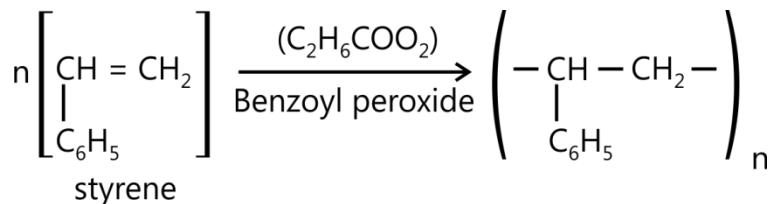
(b) High density polythene (HDP)



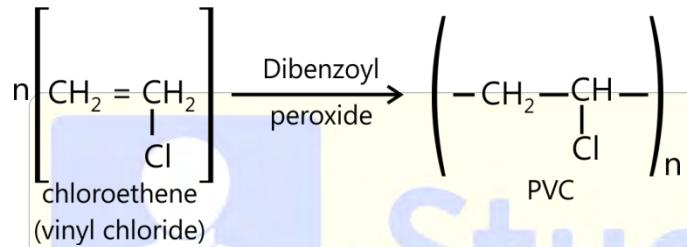
(d) Polyacrylonitrile



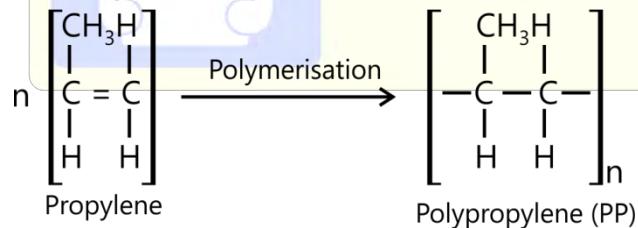
2. Polystyrene (Styrene)



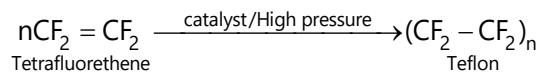
3. Polyvinylchloride (PVC)



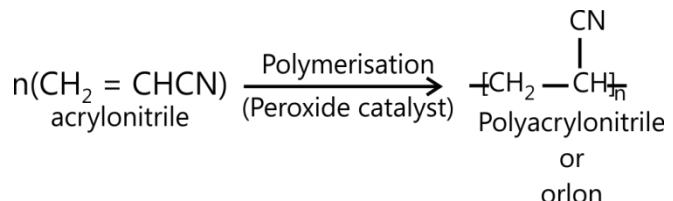
4. Polypropylene (PP)



5. Polytetrafluoroethylene (Teflon)



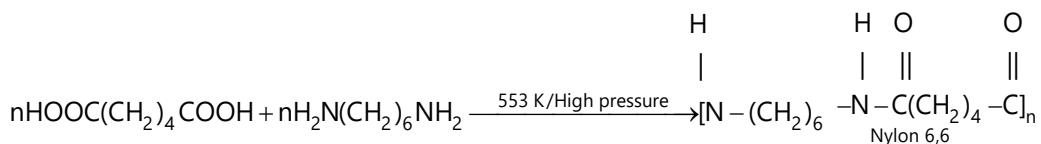
6. Polyacrylonitrile



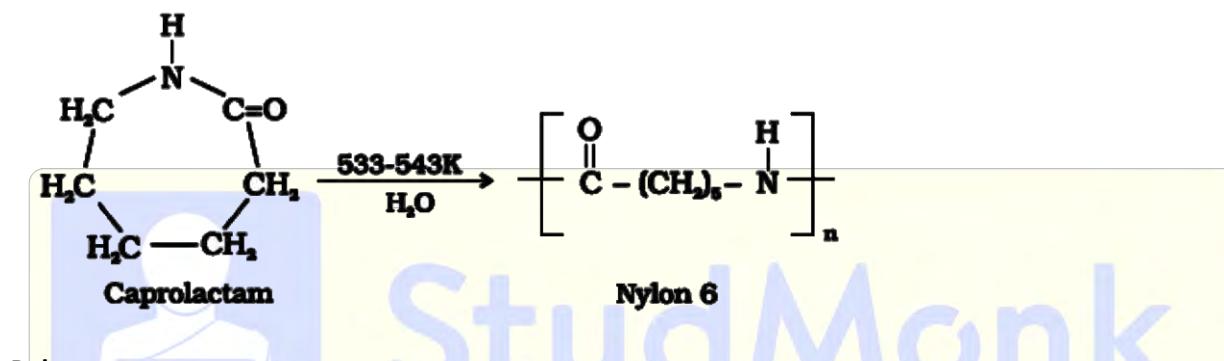
## Condensation polymers

### Polyamides

(a) Nylon 6, 6 : It is prepared by the condensation polymerization of hexamethylenediamine with adipic acid under high pressure and at high temperature.

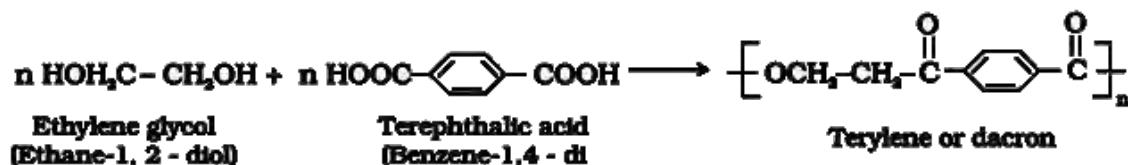


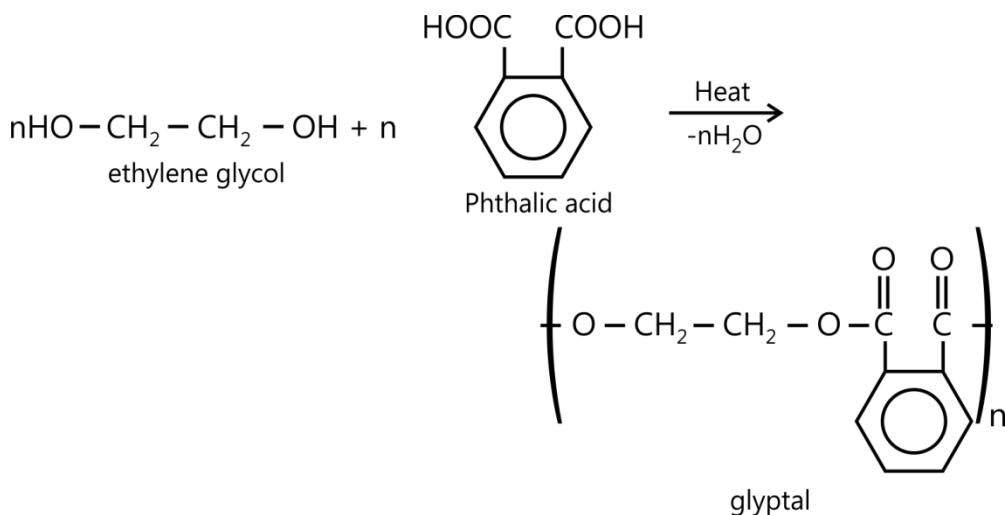
(b) Nylon 6 : It is obtained by heating caprolactam with water at a high temperature



### Polyesters

(a) Terylene or Dacron : It is manufactured by heating a mixture of ethylene glycol and terephthalic acid at 420 to 460 K in the presence of zinc acetate-antimony trioxide catalyst.

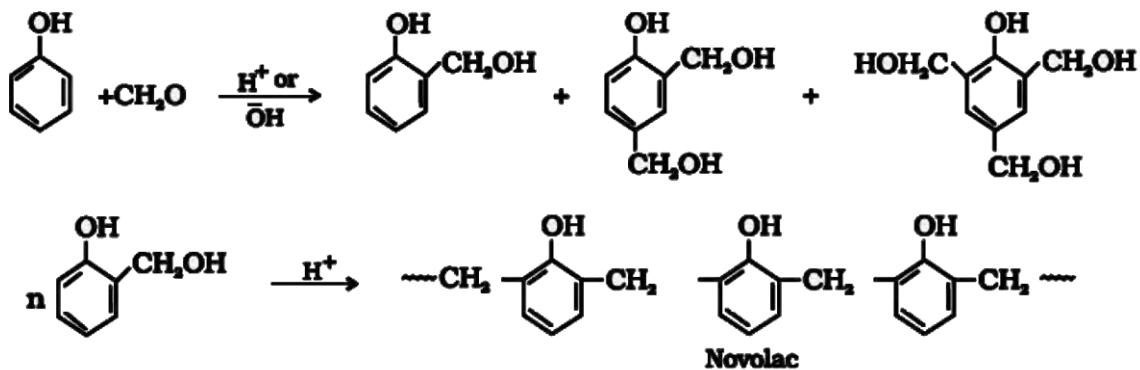


**2. Glyptal**

**Polymethylmethacrylate (PMMA)**

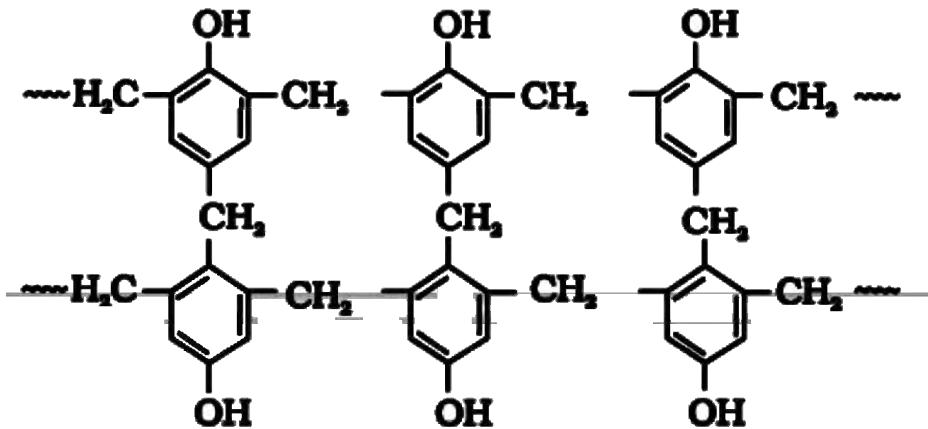
The polymer is known by several commercial names such as lucite, acrylite, plexiglass and perspex.

**Resins**
**1. Phenol-Formaldehyde Polymer**

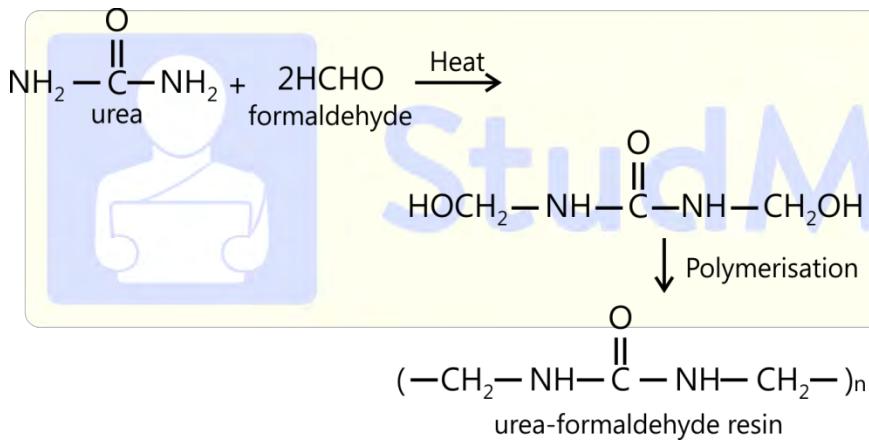
These polymers are obtained by the condensation reaction of phenol with formaldehyde in the presence of either acid or a base catalyst. The reaction involves the formation of methylene bridge at ortho, para or both ortho and para positions. A linear or cross linked material is obtained depending upon the condition of reaction.



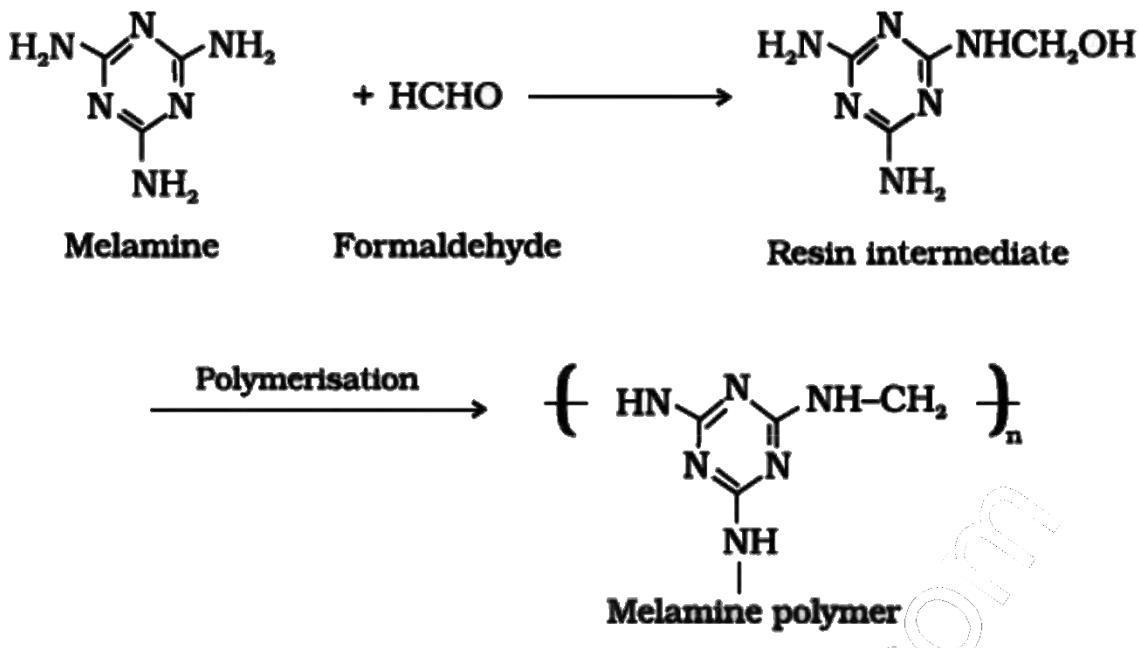
(b) Novolac on heating with formaldehyde forms Bakelite



## 2. Urea-Formaldehyde Resin

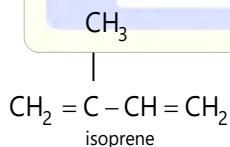


4. Melamine – formaldehyde polymer : Melamine formaldehyde polymer is formed by the condensation polymerization of melamine and formaldehyde

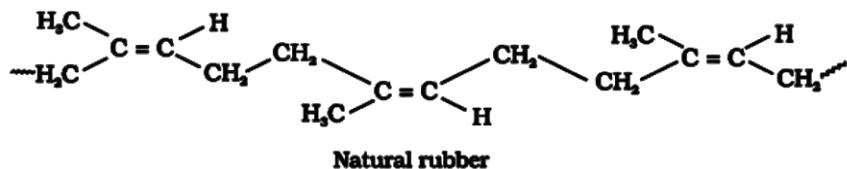


#### 4. Natural Rubber

Natural rubber is a coiled linear 1, 4-polymer of isoprene.



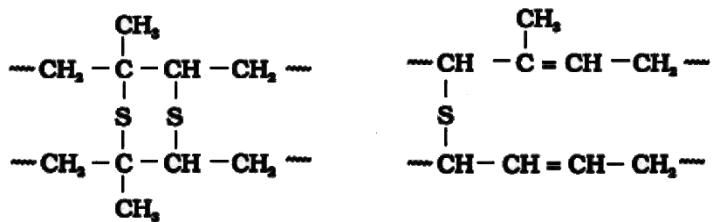
(a) Natural rubber : Natural rubber is a linear polymer of isoprene (2-methyl-1, 3-butadiene) and is also called as cis-1, 4-polyisoprene.



#### Vulcanisation of Rubber

The properties of natural rubber can be modified by introducing -S-S- polysulphide crosslinks in its structure.

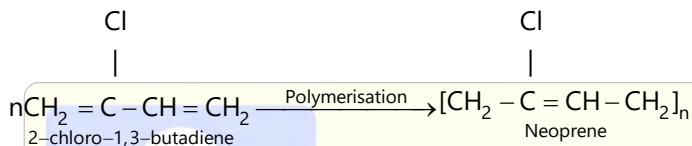
The process of heating a mixture of raw rubber with sulphur and an appropriate additive in a temperature range between 373 K to 415 K to improve upon physical properties like elasticity, strength etc.



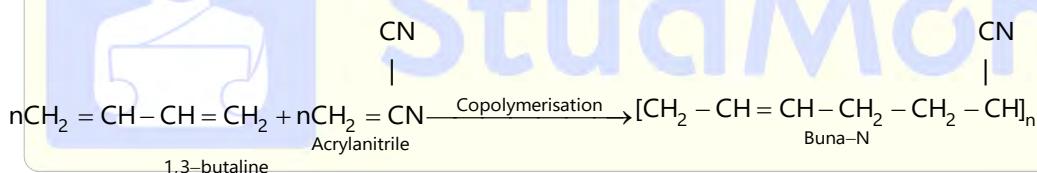
Sulphur cross links in vulcanised rubber

### Synthetic rubber

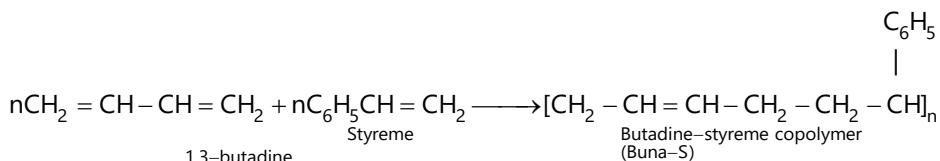
#### (A) Neoprene or polychloroprene



#### (B) Buna – N



#### (C) Buna – S



## Biopolymers and Biodegradable Polymers

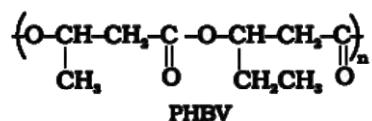
Aliphatic polyesters are the common examples of biodegradable Polymers.

#### (a) Poly- $\beta$ -hydroxybutyrate-co- $\beta$ -hydroxy valerate (PHBV):

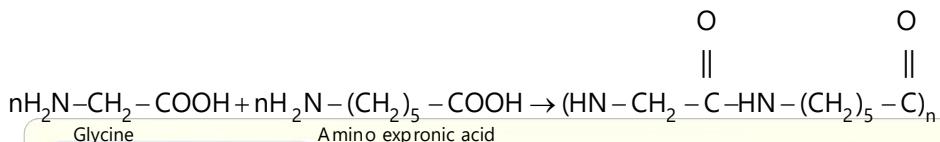
It is obtained by the copolymerization of 3-hydroxybutanoic acid and 3-hydroxypentanoic acid



3-Hydroxybutanoic acid      3-Hydroxypentanoic acid



(b) Nylon 2-nylon 6 : It is an alternating polyamide copolymer of glycine ( $\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$ ) and amino caproic acid ( $\text{H}_2\text{N}(\text{CH}_2)_5\text{COOH}$ )



Some polymers:

S.N	Name of polymer	Class of polymer	Name/s of monomer/s	Uses
1.	Dynel	Copolymer	Vinyl chloride and acrylonitrile	Human hair wigs
2.	Glyptal	Copolymer	Ethylene glycol and phthalic acid	In paints
3.	Thiokol	Condensation	Ethylene chloride and sodium (Polysulphide rubber)	Rubber tetra sulphide
4.	Superglue	Homopolymer	Methyl $\alpha$ -cyanoacrylate	Glue
5.	Kevlar	Polyamide condensation	Terephthalic acid chloride and p-phenylene diamine	Bullet proof vests and helmets
6.	Nomex	Polyamide condensation	m-phthalic acid and m-dinitrobenzene	Protective clothes for race car drivers and fire fighters.
7.	Lexan	Polycarbonate	Diethylcarbonate and bisphenol Ester condensation	Bullet proof windows and helmets
viii)	Polyurethane or Thermocole	Copolymer glycol	Toluene diisocyanate and ethylene	For padding and building insulation
ix)	Saran	Copolymer chloride	Vinyl chloride and vinylidene	Bumpers