Amines

[TOPIC 1] Introduction, Methods of Preparation and Physical Properties (Including Basic Character of Amines)

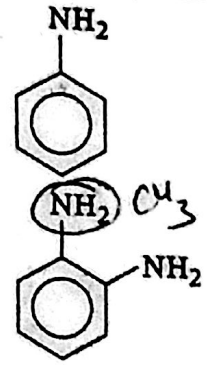
Amines constitute one of the most important class of organic compounds. In nature, they occur in proteins, vitamins, hormones etc. Synthetic examples include drugs, polymers and dyestuffs.

- Amines can be considered as derivatives of ammonia obtained by the replacement of hydrogen atoms with alkyl or aryl groups.
- All amines RNH_2 (1°), R_2NH (2°) and R_3N (3°) have one unshared pair of electrons on nitrogen atom due to which they behave as **Lewis bases.**

Nomenclature

In IUPAC system, amines are named as alkanamines derived by replacement of 'e' of alkane by the word amine. In case more than one amino group is present at different position in the parent chain, their positions are specified by giving numbers to the carbon atom bearing $—NH_2$ group and suitable prefix such as di, tri etc. is attached to the amine. In arylamines suffix 'e' of arene is replaced by amine. Common and IUPAC names of some alkylamines and arylamines are given below.

Amine	Common name	IUPAC name
$CH_3CH_2CH_2NH_2$	*n*-propylamine	propan-1-amine
$CH_3-\underset{\displaystyle NH_2}{\underset{\vert}{CH}}-CH_3$	Isopropylamine	Propan-2-amine
$NH_2-\overset{1}{C}H-\overset{2}{C}H=\overset{3}{C}H_2$	Allylamine	Prop-2-en-1-amine
$NH_2-(CH_2)_6-NH_2$	Hexamethylene-diamine	Hexane-1, 6-diamine

Amine	Common name	IUPAC name
	Aniline	Aniline
	o-toluidine	2-aminotoluene

1.1 Preparation of Amines

(i) Ammonolysis

$NH_3 + R—X \longrightarrow$ (Mixture of 1°, 2°, 3° amines are obtained)

$\xrightarrow[393\ K]{NaOH}$

(ii) Reduction

$R—C\equiv N \xrightarrow[Na/\ C_2H_5OH]{H_2\ /\ Ni}$ $R—NH_2$ (R = aliphatic group/aryl group)

[Gives only 1° amines] [Mendius reaction]

$R—CONH_2 \xrightarrow{H_2/Ni/Pd} RCH_2NH_2$ (R= aliphatic group/aryl group)

$R—NO_2 \xrightarrow[\text{or } H_2/Ni/Pd \text{ or } Fe/Sn/HCl]{LiAlH_4}$ $R—NH_2$

[Gives 1° amine]

(iii) Hydrolysis of isocyanides

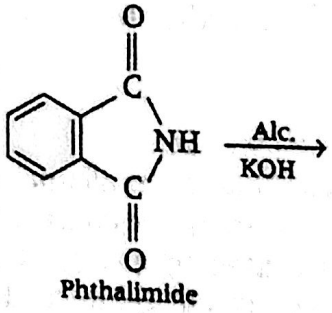
$R—NC \xrightarrow{H^+/H_2O}$ $R—NH_2$

(iv) Hofmann bromamide degradation

$R—CONH_2 + Br_2 + 4NaOH \longrightarrow$ $R—NH_2$

Hoffmann bromamide degradation reaction

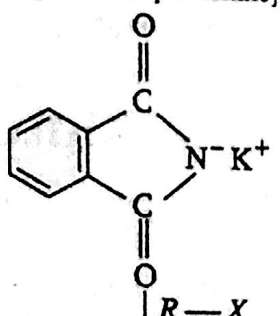
(v) Gabriel phthalimide reaction



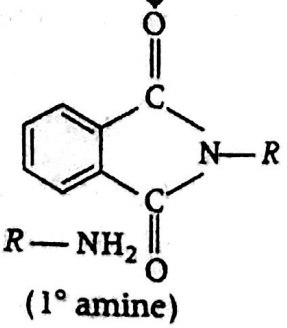
Phthalimide

$\xrightarrow[KOH]{Alc.}$

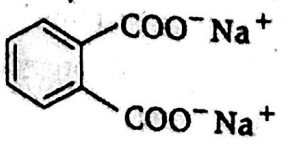
[Gives only 1° amine]



$\xrightarrow{R—X}$



$\xrightarrow{NaOH(aq)}$



$+ R—NH_2$ (1° amine)

NOTE (a) **Gabriel phthalimide synthesis** cannot be used for the preparation of 2° and 3° amines. Also, aromatic primary amines cannot be prepared by this method because aryl halides do not undergo nucleophilic substitution with the anion formed by phthalimide.

(b) **Hofmann bromamide reaction** gives 1° amine having one carbon atom less than parent primary amide.

Physical Properties of Amines

(*i*) **Solubility** Aliphatic amines (1° and 2°) form H-bonds with water and hence, are soluble in water 3° amines do not have intermolecular association due to the absence of hydrogen atom available for hydrogen bond formation. Aromatic amines are however insoluble in water due to large hydrocarbon part.

(*ii*) **Boiling points** Boiling point of 1° amine is higher than 2° and 3° amine due to the presence of two H-atoms attached directly with N, which results in greater extent of H-bonding in 1° amines.

Basic Character of Amines

Aliphatic Amines

(*i*) All aliphatic amines are more basic than ammonia.

(*ii*) In gaseous phase, the order of basicity is 3°> 2°> 1° amine.

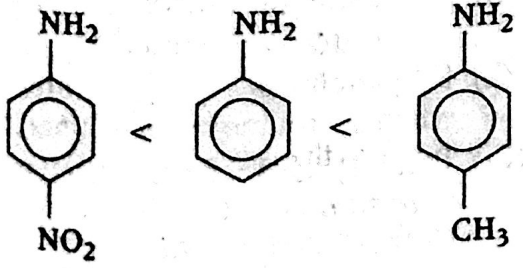
(*iii*) Greater the value of K_b or smaller the value of pK_b, stronger is the base.

(*iv*) In aqueous solution the basicity of methylamines follow the order $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N$ (i.e. 2°> 1°> 3°) but for ethylamines and all other higher amines, basicity follows the order $R_2NH > R_3N > RNH_2$ (i.e. 2°> 3°> 1°)

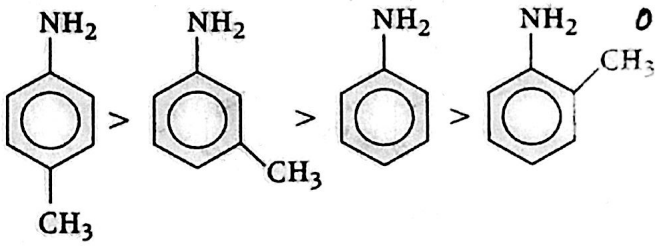
Aromatic Amines

(*i*) In aniline or any other arylamines unshared electron pair on nitrogen atom is in conjugation with the benzene ring and making, it less available for protonation.

(*ii*) Electron donating groups such as — CH_3, — OCH_3, — NH_2 increase the basicity while electron withdrawing groups such as — NO_2, — CN, —(halogens) decrease the basicity of amines. The effect of these substituents is more pronounced at *p*- than at *m*-positions.



(*iii*) *o*-substituted anilines are weaker bases than aniline regardless of the nature of the substituent whether electron-donating or electron-withdrawing. This is called *ortho* effect and is due to steric hindrance.



NOTE Aliphatic amines are more basic than aromatic amines. As in aromatic amines, lone pair of electrons present on nitrogen takes part in resonance, hence not available for donation whereas in aliphatic amines, it is available.

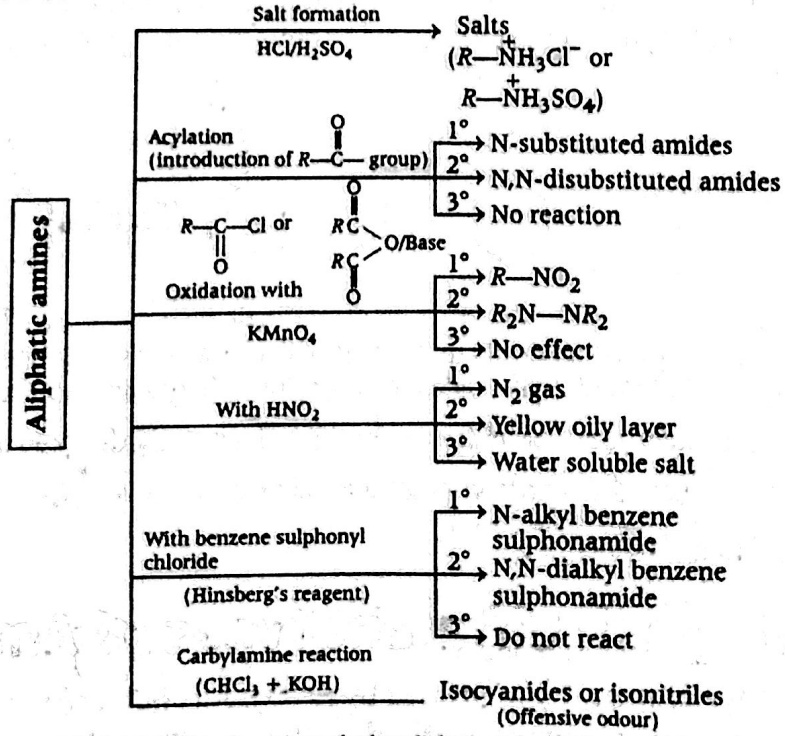
Topic 2 Chemical Reactions of Amines and Diazonium Salts

Amines are highly reactive due to difference in electronegativity between nitrogen and hydrogen atoms. These are also reactive due to presence of lone pair of electrons over N-atom. They show variety of reactions. Some important are as follows :

2.1 Chemical Reactions of Amines

For Aliphatic Amines

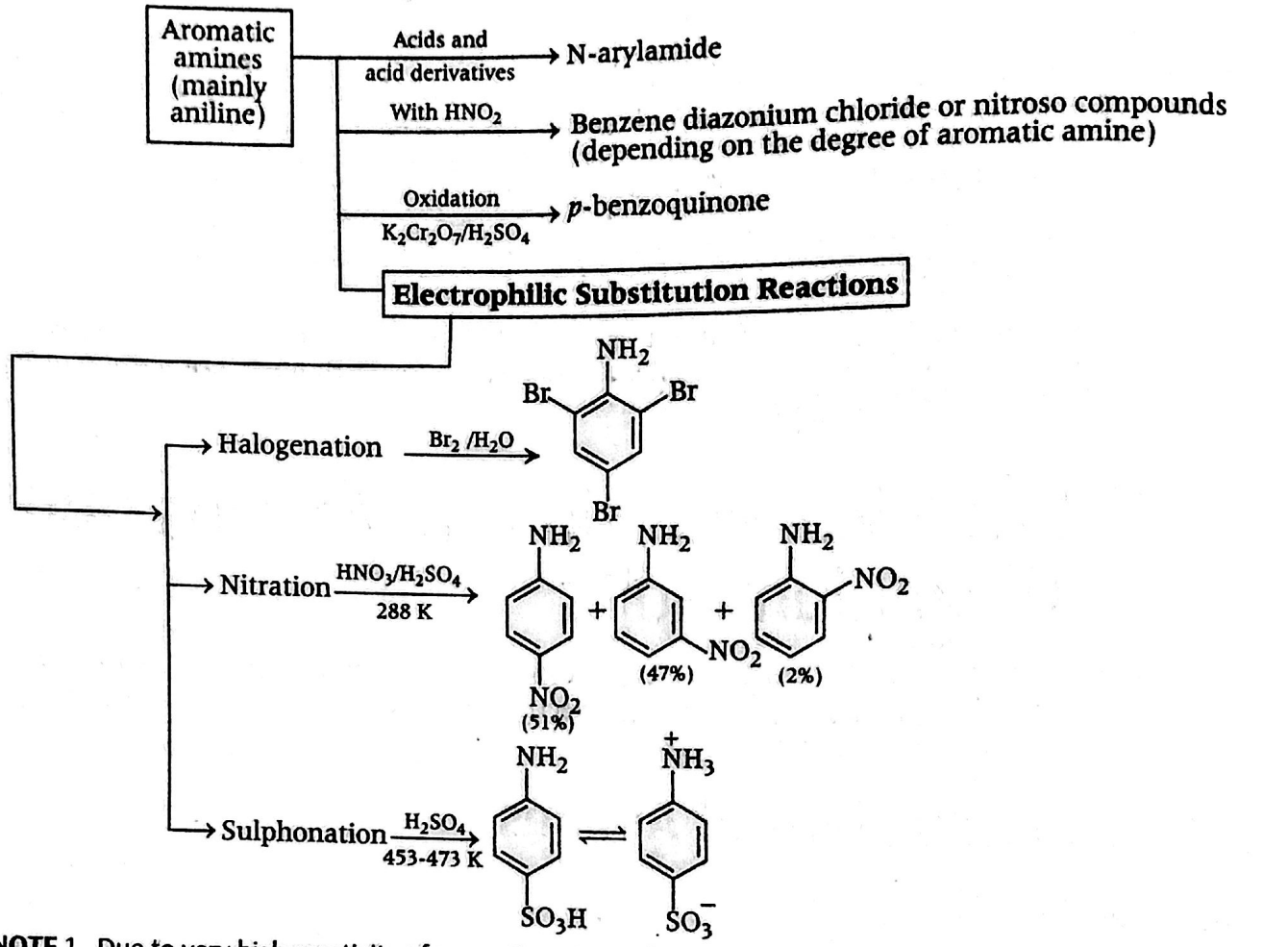
These can be summarised as:



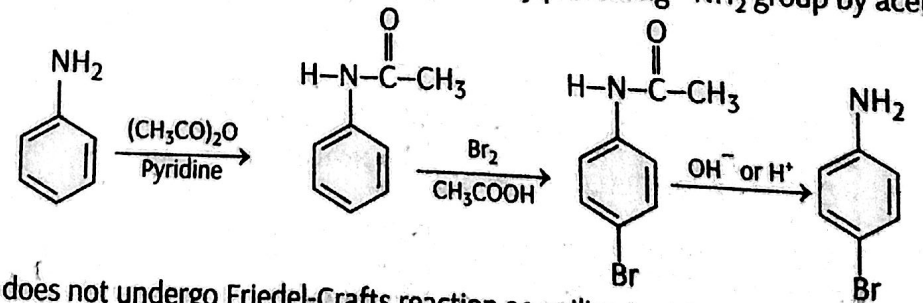
(Only 1° amines gives whether aliphatic and aryl primary amines)

For Aromatic Amines

Some important reactions of aromatic amines are as follows :



NOTE 1. Due to very high reactivity of aromatic amines, electrophilic substitution occurs at *o* and *p*-positions. Thus, monosubstituted product can be prepared by protecting $-NH_2$ group by acetylation.



2. Aniline does not undergo Friedel-Crafts reaction as aniline is a Lewis base and forms salt with Lewis acid ($AlCl_3$). As a result, N-atom of aniline acquires a positive charge and acts as a deactivating group for electrophilic substitution reaction. $\overset{+}{N}_2$(i.e. $-\overset{+}{N}\equiv N$) is known as diazonium-group. One of the most important diazo-compound is benzene diazonium chloride $[C_6H_5-\overset{+}{N}_2Cl^-]$. Aromatic diazonium salts have the general formula $[Ar.\overset{+}{N}_2.\bar{X}]$.

2.2 Test to Distinguish Different Types of Amines

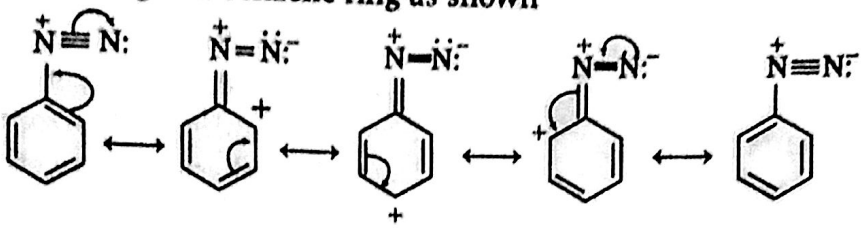
Aliphatic and aromatic 1° amines can be distinguished by HNO_2. Alcohols are obtained on reaction of aliphatic 1° amine with nitrous acid, whereas diazotised product is formed in case of aromatic amines,

i.e $C_6H_5N_2^+Cl^-$. The **Schiff's bases** formed by the reaction of aldehydes and 1° amines are called **anils**. The 2° amines shows a distinguish test, known as **Liebermann's nitroso reaction,** in which the N-nitrosoamine formed by the reaction of 2° amine with HNO_2 on treatment with phenol and conc. H_2SO_4 forms green coloured solution which becomes blue coloured on adding aqueous NaOH and further on dilution turns red. 1°, 2° and 3° amines can be distinguished by **Hinsberg's test** in which Hinsberg's reagent is benzene sulphonyl chloride ($C_6H_5SO_2Cl$). Carbylamine reaction is only given by aliphatic and aromatic primary amines.

2.3 Aromatic Diazonium Salts

(*i*) Aromatic diazonium salts are prepared by adding a cold aqueous solution of $NaNO_2$ in the presence of HCl at 273-278K. This reaction is called **Diazotisation.**

(*ii*) Aromatic diazonium salts are much more stable than aliphatic diazonium salts due to the dispersal of positive charge on benzene ring as shown



Flow Chart for the Preparation and Chemical Reactions of Benzene Diazonium Chloride

Preparation

$C_6H_5NH_2 + NaNO_2 + 2HCl$

Diazotisation, 273-278 K

$C_6H_5N_2^+Cl^-$

Chemical Properties

- H_3PO_2/H_2O (Hypophosphorous acid) → $C_6H_6 + N_2 + H_3PO_3 + HCl$
- CH_3CH_2OH, Δ → $C_6H_6 + N_2 + HCl + CH_3CHO$
- Cu_2Br_2/HBr → $C_6H_5Br + N_2$
- Cu_2Cl_2/HCl → $C_6H_5Cl + N_2$ } (Sandmeyer's Reaction)
- $KCN/CuCN$ → C_6H_5CN (benzonitrile) $+ N_2$
- $-N_2, -KCl$
- Cu/HCl → $C_6H_5Cl + N_2 + CuCl$
- Cu/HBr → $C_6H_5Br + N_2 + CuBr$ } (Gattermann's Reaction)
- KI → $C_6H_5I + N_2 + KCl$
- HBF_4, $-HCl$ → $C_6H_5\overset{+}{N}_2(BF_4)^-$ → $C_6H_5F + BF_3 + N_2$ (Balz-Schiemann's Reaction; Fluorobenzene)
- $NaNO_2$, Cu/Δ → $C_6H_5NO_2 + N_2 + NaBF_4$
- H_2O/H_2SO_4, Boiling → $C_6H_5OH + N_2 + HCl$ (Phenol)
- $-OH, OH^-$, pH 9-10, cold (Coupling reaction) → *p*-hydroxyazobenzene (Orange dye)
- $C_6H_5NH_2/H^+$, pH 9-10, cold → *p*-aminoazobenzene (Yellow dye)