CHEMISTRY OF AMINES

- There many organic nitrogen containing compounds, among which is amines.
- Organic nitrogen compounds are:
    - Amines RNH_2
    - Amide $RCONH_2$
    - Imine R'R C=NR''
    - Nitrile RC≡N
- Generally amines are derivatives of ammonia in which one or more hydrogen atom(s) have been replaced by alkyl or aryl(phenyl) group
- NH_3 Ammonia
- RNH_2 primary
- RR'NH secondary
- RR'R''NH tertiary

Amines

- Primary amine is formed when one hydrogen atom of ammonia is replaced by alkyl or aryl group e.g. methylamine, ethylamine, propylamine, phenylamine (alanine)
- Secondary amine is formed when two hydrogen atoms of ammonia are replaced by alkyl or aryl group e.g. diethylamine, dipropylamine, diphenylamine, ethylmethylamine, methylpropylamine
- Tertiary amine is formed when all (3) hydrogen atoms of ammonia are replaced by alkyl or aryl group e.g. trimethylamine, triethylamine, tripropylamine, triphenylamine, ethylmethylpropylamine.
- When all the alkyl or phenyl groups are the same in secondary and tertiary amines, such amines are called simple amines but when they are not the same they are called mixed amines.
- Examples of simple amines are diethylamine, dipropylamine, diphenylamine, trimethylamine, triethylamine, tripropylamine, triphenylamine
- Examples of mixed amines are ethylmethylamine, methylpropylamine, ethylmethylpropylamine
- **NOTE**: The use of the words “primary, secondary and tertiary” in amines are quite different from the way these words are used in alkanols
- **Classwork: Differentiate the use primary, secondary and tertiary as applied to amines, alkanols and alkylhalides using tert-butylalcohol, tert-butylamine, tert-butylhalides and trimethylamine**

IUPAC NOMENCLATURE OF AMINES

- Amines are known as amino group (containing $–NH_2$).
- Amines are named as alkylamine
- Primary amines' name result from naming the alkyl group bonded to the amino group ($–NH_2$) and adding the suffix "-amine". The entire name is written as one word e.g. $CH_3–NH_2$ Methylamine, $C_4H_7–NH_2$ Butylamine
- Secondary and tertiary amine names are obtained by listing the alkyl groups alphabetically and when two or more identical alkyl groups are present, the prefixes " di, tri" are used e.g.
- $C_2H_5NHCH_3$ Ethylmethylamine
- $C_2H_5NHC_2H_5$ Diethylamine
- $C_2H_5N(CH_3)C_3H_7$ Ethylmethylamine
- $CH_3NH(C_6H_5)$ Methylphenylamine

OCCURRENCE OF ISOMERISM IN AMINES

- Isomerism refers to occurrence of molecules having the same molecular formula but different structural formula
- There are four types of isomerism in amines, viz; (i) Chain isomerism
  (II) Position isomerism (III)Functional isomerism (III)Metamerism isomerism
- **Chain Isomerism:** This is due to the difference in the nature of carbon chain of the alkyl group attached to the amino group e.g.

$CH_3CH_2CH_2CH_2NH_2$ n-Butylamine $CH_3CH(CH_2)CH_2NH_2$ 2-methylpropanamine

- **Position isomerism:** This arises from the position of amino group in the carbon chain e.g. $CH_3CH_2CH_2NH_2$ 1-aminopropane; $CH_3CH(NH_2)CH_3$ 2- aminopropane
- **Functional Isomerism:** This is due to the difference in the nature of class of amino group e.g.$CH_3CH_2CH_2NH_2$ Propylamine (I^0)

$CH_3NHCH_2CH_3$ Ethylmethylamine (2^0)

$(CH_3)_3N$ Trimethylamine (3^0)

- **Metamerism isomerism:** This is due to the difference in the nature of the alkyl group attached to the same functional group (i.e. class of amino group)

$(C_2H_5)_2NH$ Diethylamine (2^0) $C_3H_7NHCH_3$ Methylpropylamine (2^0)

PREPARATION OF AMINES

Ammonolysis of Alkylhalides: This is reaction between alkylhalides and ammonia. All classes of amines can be prepared by this method

$RX + NH_3 \longrightarrow RNH_2 + HX$ (primary amine)

$RX + RNH_2 \longrightarrow R_2NH + HX$ (secondary amine)

$RX + R_2NH \longrightarrow R_3N + HX$ (tertiary amine)

$RX + R_3N \longrightarrow R_4N^+ x^-$ (quaternary ammonium salt)

The order of reactivity of alkylhalide (RX) is RI>RBr>RCl

Reaction of Alcohol with Ammonia (Ammonolysis of simple alcohol)

- Ethanol reacts with ammonia using aluminium oxide/silica gel at 360^0C to produce mixture of primary, secondary and tertiary amines

$$C_2H_5OH + HNH_2 \xrightarrow[360^0C]{Al_2O_3\ /Silica\ gel} C_2H_5NH_2 + H_2O$$

$$C_2H_5OH + C_2H_5NH_2 \xrightarrow[360^0C]{Al_2O_3\ /Silica\ gel} (C_2H_5)_2NH + H_2O$$

$$C_2H_5OH + (C_2H_5)_2NH \xrightarrow[360^0C]{Al_2O_3\ /Silica\ gel} (C_2H_5)_3N + H_2O$$

Assignment: Discuss how the mixture of primary, secondary and tertiary amines can be separated

Reduction Methods

- Amino group represents the most highly reduced state of nitrogen attached to carbon, the reduction of other functional types containing nitrogen atoms linked to one carbon atom will yield primary amines.
- The most useful compounds for reduction to primary amines are:- Nitro compounds (RNO_2); Cyanides/Nitrile (RCN); Amide ($R\text{-}CONH_2$), Oximes (RR'C=NOH)

Reduction of a Nitro compound: This gives primary amine using reducing agents such as hydrogen, catalyst by Raney nickel

$R\text{-}NO_2 + 3H_2 \xrightarrow{\text{Ni as catalyst}} R\text{-}NH_2 + H_2O$ OR $R\text{-}NO_2 \xrightarrow{LiAlH_4} R\text{-}NH_2 + H_2O$

Reduction of Cyanide/Nitrile: Primary amines are formed by the reduction of cyanides using lithiumaluminiumhydride $R\text{-}CN \xrightarrow{LiAlH_4} R\text{-}NH_2$

Reduction of Amide: Using lithiumaluminiumhydride, amide is being reduced to primary amine $R\text{-}CONH_2 \xrightarrow{LiAlH_4} R\text{-}CH_2NH_2 + H_2O$

Hofmann degradation reaction: Primary amine is formed when amide is treated with bromine and alkali, and the resulting amine is distilled off

$R\text{-}CONH_2 + Br_2 + 4NaOH \longrightarrow R\text{-}NH_2 + Na_2CO_3 + 2NaBr + 2H_2O$

NOTE: An amide, $RCONH_2$ is reduced to the amine with the same number of carbon atom, RCH_2NH_2 with $LiAlH_4$ but gives the lower homologue in the Hofmann reaction.

PHYSICAL PROPERTIES OF AMINES

- Lower aliphatic amines (methylamine and ethylamine) are gases at ordinary temperature and pressure and are highly soluble in water
- Higher members are liquids, then solids, their solubility falling off with increasing molecular weight

- Amines have higher boiling points than alkanes of similar molecular weight but lower boiling points than alcohol due to their C-N bond being more polar than C-C bond but less polar than C-OH bond
- Primary and secondary amines can form intermolecular hydrogen bonds because they serve as both hydrogen bond donors and acceptors but tertiary amines have no hydrogen atoms bonded to the nitrogen atom and therefore are not hydrogen bond donor. Hence tertiary amines have lower boiling points than primary and secondary amines of comparable molecular weight.
- Lower alkylamines have notorious “fishy ammonia smells” – a smell rather like bad fish; indeed, a decaying fish produces various amines
- Aromatic amines are liquids or solids with high boiling points and they have similar smell like bad fish and are soluble in organic solvents but almost insoluble in water.
- Aniline is markedly toxic by absorption through the skin.

General Chemical Reactions of Amines

Basic Character of Amine

- All primary amines are bases, undergoing reactions of the general type:

$RNH_2 + HA \longleftrightarrow RN^+H_3 + A^-$

- Simpler alkylamines are only a little stronger as bases than ammonia. The lower members of the series are highly soluble in water, presumably like ammonia on account of hydrogen bonding and their solutions are markedly alkaline e.g.

$C_2H_5NH_2 + H_2O \longleftrightarrow C_2H_5N^+H_3 + OH^-$

- Amine with acids form well defined crystalline salts

$C_2H_5NH_2 + HCl \longleftrightarrow C_2H_5N^+H_3 + Cl^-$

Ethylamine and other volatile amines show the characteristics “white cloud” with hydrogen chloride (or any other acid in the vapour state as ammonia itself)

ALKYLATION OF AMINE

This is conversion of primary amines to secondary amines and possibly to tertiary amine using alkylhalides $RNH_2 \xrightarrow{R'I} RR'NH \xrightarrow{R''I} RR'R''N$

NOTE: The reaction of RI is faster than RBr and RBr is faster than RCl

Acylation of Amines

- This is conversion of amines to amides

$$RNH_2 \longrightarrow RNH.COR'$$

- This reaction achieves the replacement of an hydrogen atom of the $-NH_2$ group by an acyl group R'CO
- Generally acylation can be carried out by four characteristic reagent types, viz;
  - Acylchloride R'COCl
  - Acid anhydride $(R'CO)_2O$
  - Carboxylic acid R'COOH
  - Carboxylate ester $R'COOC_2H_5$

Order of decreasing vigour of reaction

- For acetylation of ethylamine, the four possible reactions would be
- $C_2H_5NH_2 + CH_3COCl \longrightarrow C_2H_5NHCOCH_3 + HCl$
- $C_2H_5NH_2 + (CH_3CO)_2O \longrightarrow C_2H_5NHCOCH_3 + CH_3COOH$
- $C_2H_5NH_2 + CH_3CO_2H \longrightarrow C_2H_5NHCOCH_3 + H_2O$
- $C_2H_5NH_2 + CH_3CO_2C_2H_5 \longrightarrow C_2H_5NHCOCH_3 + C_2H_5OH$

Reaction of Amines with Nitrous acid

- Amines react with nitrous acid in a way which depends on whether they are primary, secondary or tertiary.
- Primary aliphatic amines react to yield gaseous nitrogen. With ethylamine, replacement of $-NH_2$ by $-OH$ with evolution of nitrogen, is among the reaction occurring

$$C_2H_5NH_2 + HONO \longrightarrow C_2H_5OH + N_2 + H_2O$$

- Primary arylamine reacts to give aromatic diazonium salts at a temperature below 10^0C, when phenylamine is treated with HCl and sodium nitrite, it reacts with the nitrous acid formed to give benezenediazonium chloride

$$C_6H_5NH_2 + HONO + HCl \longrightarrow C_6H_5{}^+N{\equiv}NHCl^- + 2H_2O$$

Benezenediazoniumchloride

- Secondary amines (both aliphatic and aromatic) react with nitrous acid to give nitroso compounds which are yellow oils

$$R_2NH + HONO \longrightarrow R_2N\text{-}N{=}O + H_2O$$

A nitrosamine

- Tertiary amines react with nitrous acid to give solutions containing substituted ammonium nitrites $R_3N + HONO \longrightarrow R_3{}^+NHNO^-{}_2$

Reaction of Amines with Chloroform

- Primary amines react with trichloromethane and a solution of potassium hydroxide in ethanol to form isocyano compounds (carbylamine)
- $RNH_2 + CHCl_3 + 3KOH \longrightarrow RN^{+}\equiv C^{-} + 3KCl + 3H_2O$
- Phenylamine forms isocyanobenzene (C_6H_5NC)

AROMATIC AMINES

- They are called arylamine which contain benzene ring. Simplest member of aromatic amine is phenylamine (known as aniline) that is $C_6H_5NH_2$
- Aromatic amine can be primary, secondary or tertiary e.g. phenylamine (1^0), diphenylamine(2^0) and triphenylamine (3^0)
- The presence of amino group on benzene ring directs electrophilic reagents mainly to 2- and 4- positions and renders the compounds far more reactive than benzene towards these reagents.
- For example, during halogenation reaction, benzene requires halogen carrier to form halobenzene but phenylamine reacts rapidly in the absence of halogen carrier to produce 2, 4,6-tribromophenylamine and HBr.
- $C_6H_5NH_2 + 3Br_2 \longrightarrow C_6H_2(Br)_3NH_2 + 3HBr$

USES OF AMINES

- Amines are used in the manufacturing of many pharmaceuticals (Mepacrine- an antimalarial drug)
- Primary aromatic amines are used to make azo dyes
- They are used in production of plastics. 1,6-diaminohexane ($H_2N(CH_2)_6NH_2$) is used in manufacture of nylon 6,6. Other amines are used in the production of isocyanates for polyurethane plastics
- They are used as inhibitors in preventing the deterioration of rubber through oxidation by atmospheric oxygen