ORGANIC CHEMISTRY

Topic-5

Amines – Classification and separation

VERY SHORT ANSWER QUESTIONS

1. What are amines?

Ans: **Amines** are aliphatic and aromatic derivatives of ammonia. Amines, like ammonia, are weak bases ($K_b = 10^{-4}$ to 10^{-6}). This basicity is due to the unshared electron pair on the nitrogen atom.

2. What are primary amines?

Ans: Those amine compounds that have only one group attached to the nitrogen atom are primary amines.

Ex: $CH_3 – NH_2$ (Methyl Amine)

3. **What are secondary amines?**

Ans: Those amine compounds that have two groups attached to the nitrogen atom are secondary amines.

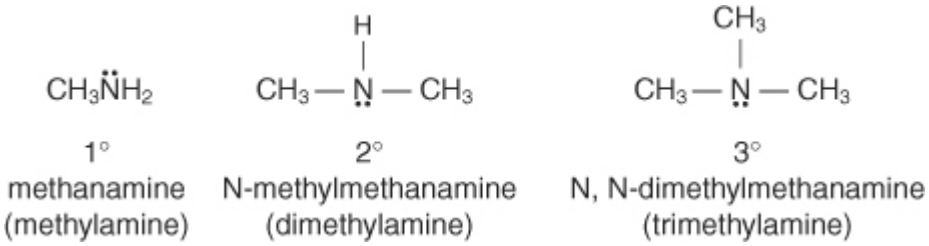
4. What are tertiary amines?

Ans: Those amine compounds that have three groups attached to the nitrogen atom are tertiary amines.

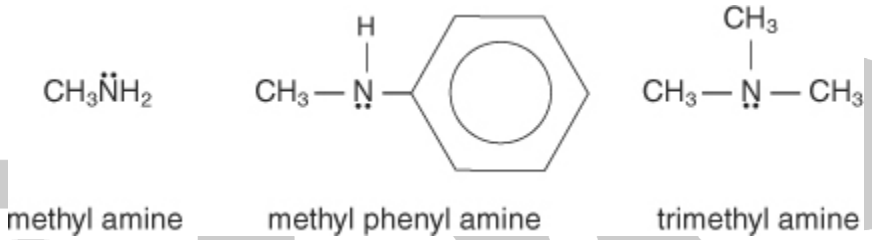
SHORT ANSWER QUESTIONS

1. **Explain the classification of Amines.**

Ans: Classification of amines: Amines are classified as primary, secondary, or tertiary based upon the number of carbon-containing groups that are attached to the nitrogen atom. Those amine compounds that have only one group attached to the nitrogen atom are primary, while those with two or three groups attached to the nitrogen atom are secondary and tertiary, respectively.



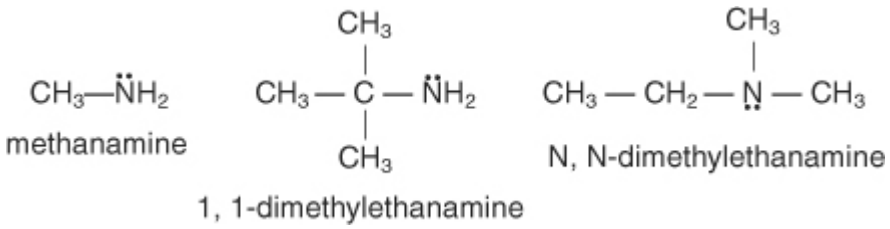
In the common system, you name amines by naming the group or groups attached to the nitrogen atom and adding the word amine.



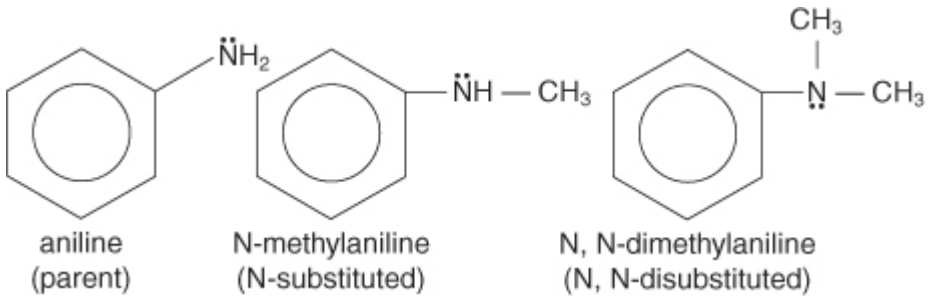
2. **Explain the nomenclature of Amines.**

Ans: In the IUPAC System, apply the following rules to name amines:

1. Pick out the longest continuous chain of carbon atoms. The parent name comes from the alkane of the same number of carbons.
2. Change the -e of the alkane to "amine."
3. Locate and name any substituents, keeping in mind that the chain is numbered away from the amine group. Substituents, which are attached to the nitrogen atom instead of the carbon of the chain, are designated by a capital N.



Aromatic amines belong to specific families, which act as parent molecules. For example, an amino group (—NH_2) attached to benzene produces the parent compound aniline.



3. Explain the basicity of amines.

Ans: Basicity of amines : Amines are basic because they possess a pair of unshared electrons, which they can share with other atoms. These unshared electrons create an electron density around the nitrogen atom. The greater the electron density, the more basic the molecule. Groups that donate or supply electrons will increase the basicity of amines while groups that decrease the electron density around the nitrogen decrease the basicity of the molecule. For alkyl halides in the gas phase, the order of base strength is given below:

$(CH_3)_3 N > (CH_3)_2NH > CH_3NH_2 > NH_3$

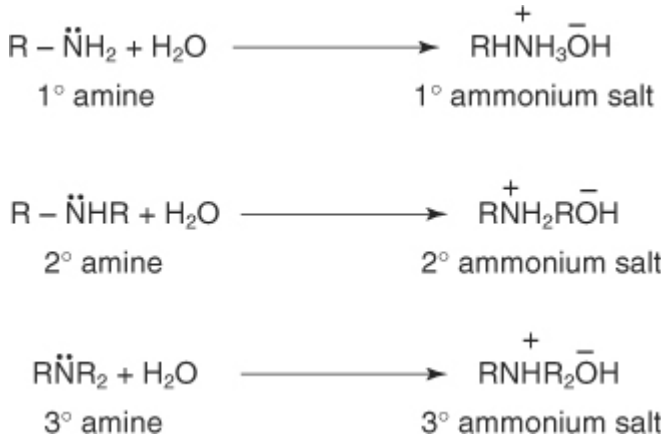
most basic — least basic

However, in aqueous solutions, the order of basicity changes.

$(CH_3)_2 NH > CH_3NH_2 > (CH_3)_3N > NH_3$

most basic — least basic

The differences in the basicity order in the gas phase and aqueous solutions are the result of solvation effects. Amines in water solution exist as ammonium ions.



In water, the ammonium salts of primary and secondary amines undergo solvation effects (due to hydrogen bonding) to a much greater degree than ammonium salts of tertiary amines. These solvation effects increase the electron density on the amine nitrogen to a greater degree than the inductive effect of alkyl groups.

Arylamines are weaker bases than cyclohexylamines because of resonance. Aniline, a typical arylamine, exhibits the resonance structures shown in Figure 1 .

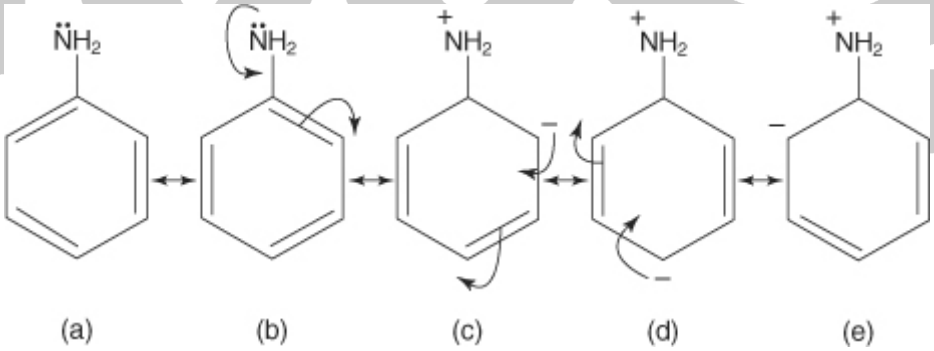


Figure 1

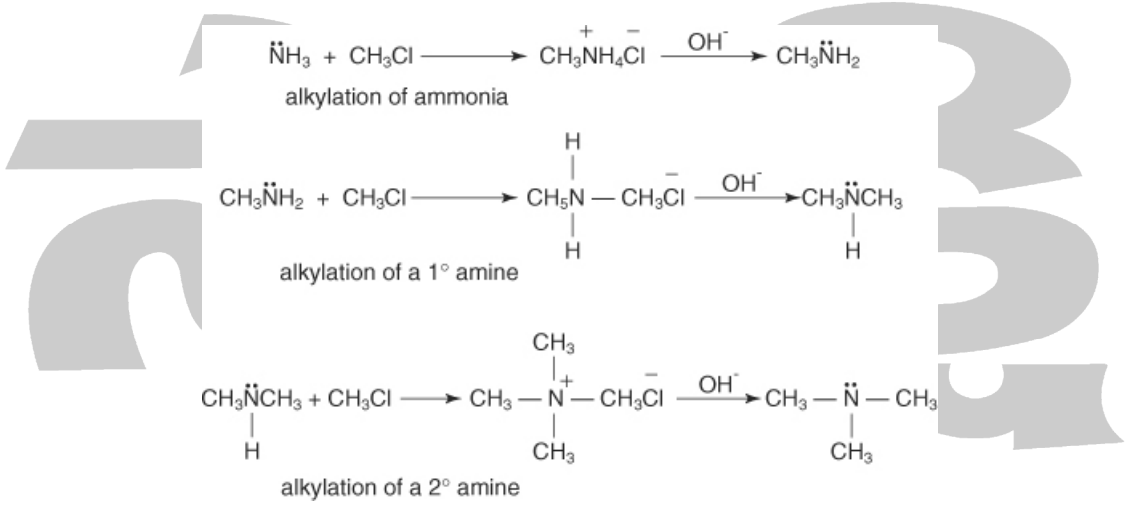
As structures b through e in Figure 1 show, delocalization of the unshared electron pair occurs throughout the ring, making these electrons less available for reaction. As a result of this electron delocalization, the molecule becomes less basic.

LONG ANSWER QUESTIONS

1. Explain the methods of preparation of amines.

Ans: Preparation of Amines: The alkylation of ammonia, Gabriel synthesis, reduction of nitriles, reduction of amides, reduction of nitrocompounds, and reductive amination of aldehydes and ketones are methods commonly used for preparing amines.

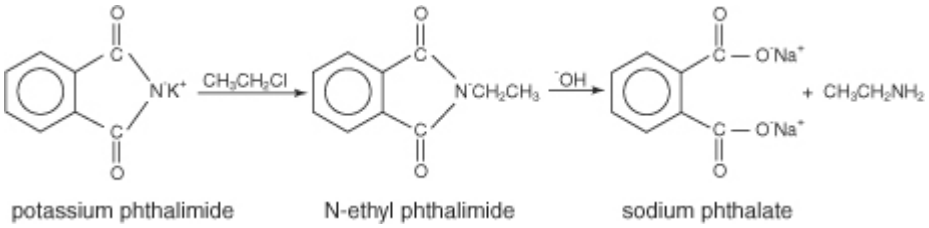
a) Alkylation of ammonia: The reaction of ammonia with an alkyl halide leads to the formation of a primary amine. The primary amine that is formed can also react with the alkyl halide, which leads to a disubstituted amine that can further react to form a trisubstituted amine. Therefore, the alkylation of ammonia leads to a mixture of products.



b) Reduction of alkylazides: You can best prepare a primary amine from its alkylazide by reduction or by the **Gabriel synthesis.**

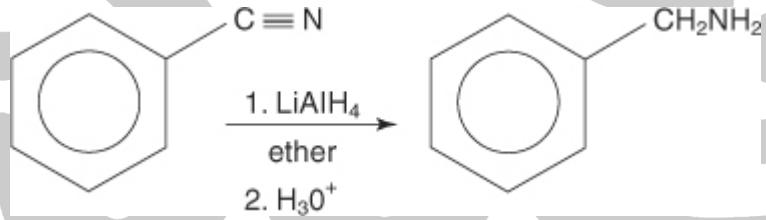
Ethyl Azide

In the **Gabriel synthesis**, potassium phthalimide is reacted with an alkyl halide to produce an N-alkyl phthalimide. This N-alkyl phthalimide can be hydrolyzed by aqueous acids or bases into the primary amine.

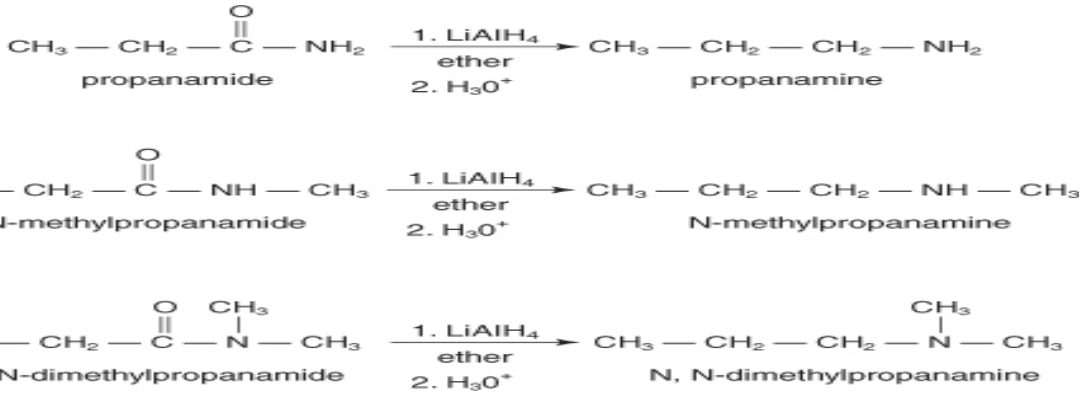


potassium phthalimide N-ethyl phthalimide sodium phthalate

c) Reduction of nitriles : Nitriles can be reduced by lithium aluminum hydride ($LiAlH_4$) to primary amines.

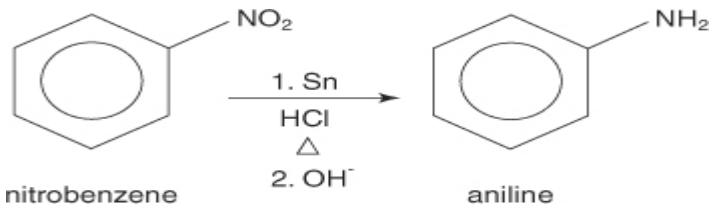


d) Reduction of amides: Amides yield primary amines on reduction by lithium aluminum hydride, while N-substituted and N, N-disubstituted amides produce secondary and tertiary amines, respectively.



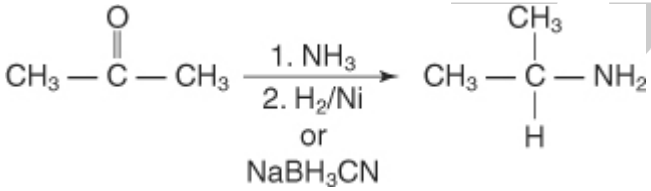
Because amides are easily prepared, their reduction is a preferred method for making all classes of amines.

e) Reduction of nitrocompounds: Aromatic amines are normally prepared by reduction of the corresponding aromatic nitro compound.

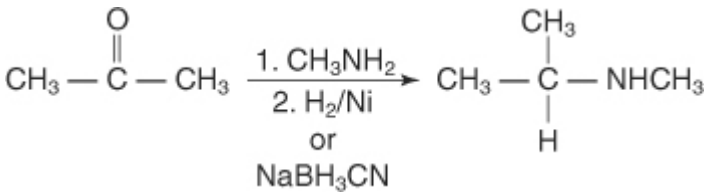


f) Reductive amination of aldehydes and ketones: Aldehydes or ketones can be reduced by catalytic or chemical reductions in the presence of ammonia or primary or secondary amines, producing primary, secondary, or tertiary amines.

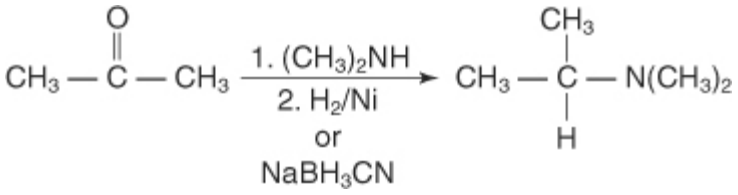
The reaction of a ketone with ammonia, followed by catalytic reduction or reduction by sodium cyanoborohydride, produces a 1° amine.



N-substituted amines are produced by reaction of ketones with primary amines, followed by reduction.



N, N-disubstituted amines can be produced by reaction of 2° amines with ketones followed by reduction.



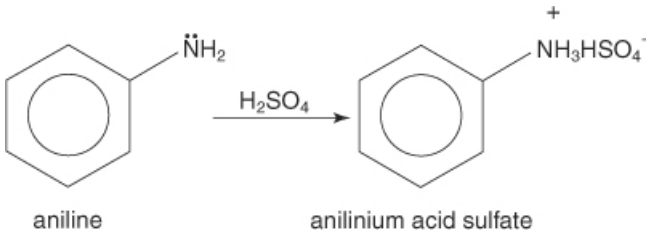
2. Explain the physical and chemical properties of amines.

I. Physical properties of amines: some of the physical properties of amines are as follows.

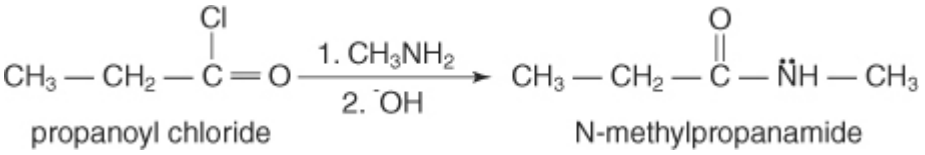
- The lower aliphatic amines are gases with fishy odour.
- Primary amines with three or more carbon atoms are liquid and still higher ones are solid.
- Aniline and other arylamines are usually colourless but get coloured on storage due to atmospheric oxidation.
- Higher amines are essentially insoluble in water.
- Amines are soluble in organic solvents like alcohols, ether benzene.

II. Chemical properties of Amines: Due to the unshared electron pair, amines can act as both bases and nucleophiles.

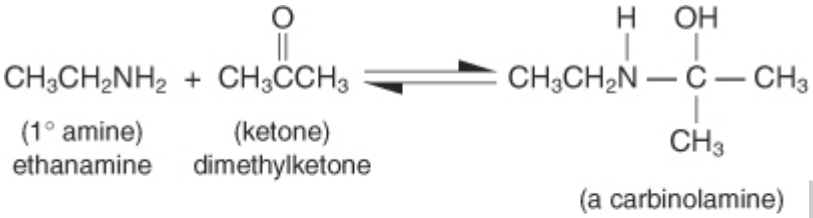
a) Reaction with acids: When reacted with acids, amines donate electrons to form ammonium salts.

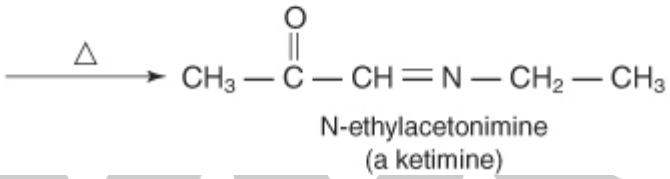


b) Reaction with acid halides: Acid halides react with amines to form substituted amides.

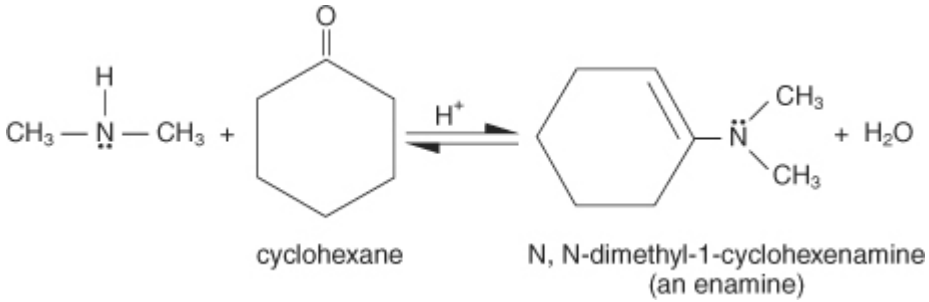


c) Reaction with aldehydes and ketones: Aldehydes and ketones react with primary amines to give a reaction product (a carbinolamine) that dehydrates to yield aldimines and ketimines (Schiff bases).

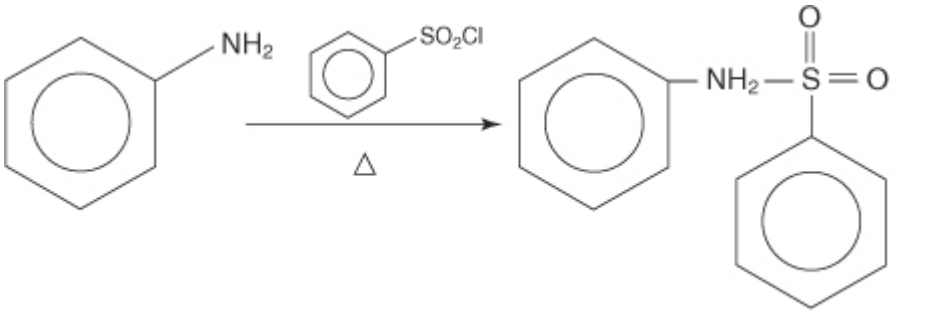




If you react secondary amines with aldehydes or ketones, enamines form.

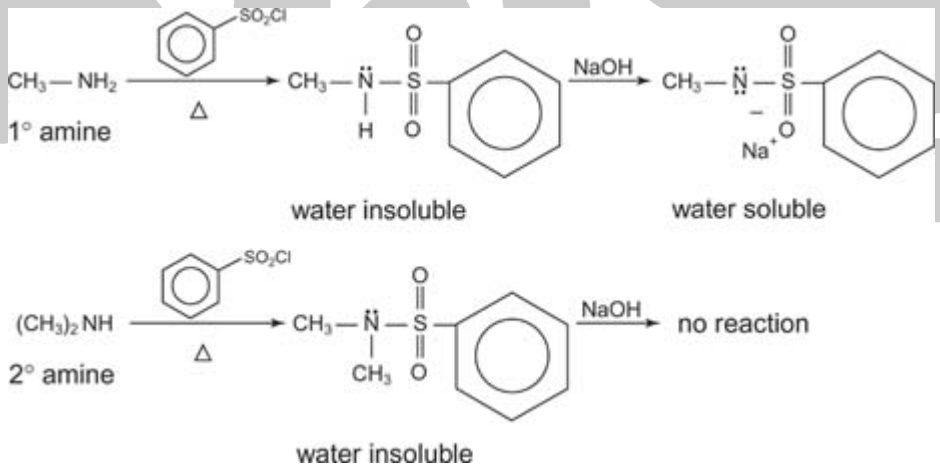


d) Reaction with sulfonyl chlorides: Amines react with sulfonyl chlorides to produce sulfonamides. A typical example is the reaction of benzene sulfonyl chloride with aniline.

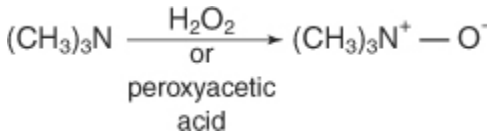


N-phenylbenzenesulfonamide

e) The Hinsberg test: The Hinsberg test, which can distinguish primary, secondary, and tertiary amines, is based upon sulfonamide formation. In the Hinsberg test, an amine is reacted with benzene sulfonyl chloride. If a product forms, the amine is either a primary or secondary amine, because tertiary amines do not form stable sulfonamides. If the sulfonamide that forms dissolves in aqueous sodium hydroxide solution, it is a primary amine. If the sulfonamide is insoluble in aqueous sodium hydroxide, it is a secondary amine. The sulfonamide of a primary amine is soluble in an aqueous base because it still possesses an acidic hydrogen on the nitrogen, which can be lost to form a sodium salt.



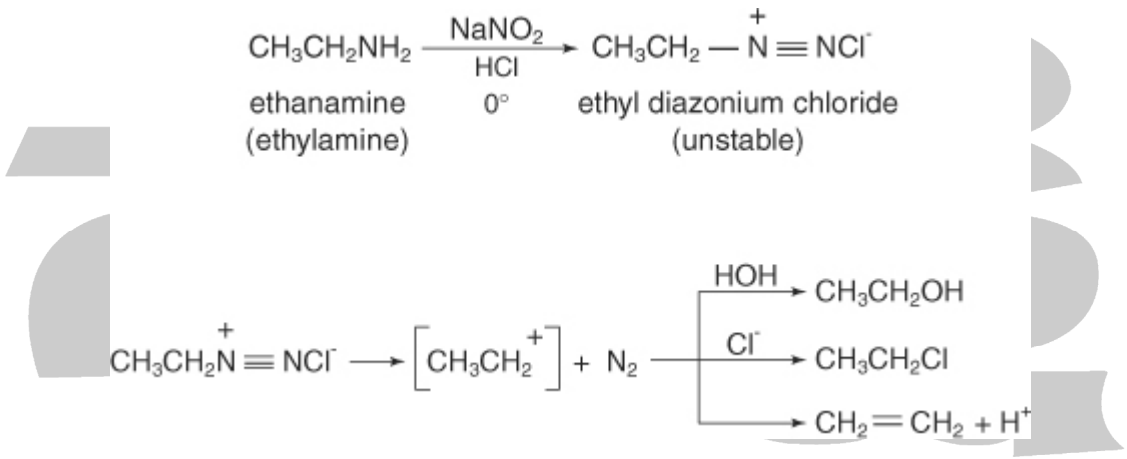
f) Oxidation: Although you can oxidize all amines, only tertiary amines give easily isolated products. The oxidation of a tertiary amine leads to the formation of an amine oxide.



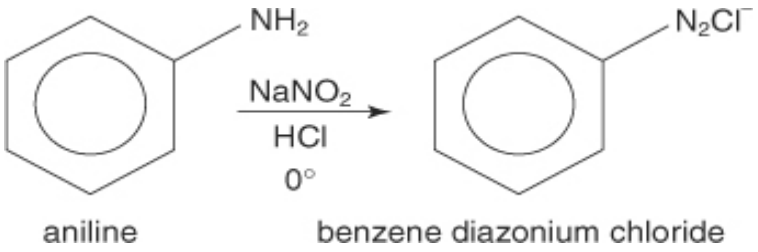
Arylamines tend to be easily oxidized, with oxidation occurring on the amine group as well as in the ring.

g) Reaction with nitrous acid: Nitrous acid is unstable and must be prepared in the reaction solution by mixing sodium nitrite with acid.

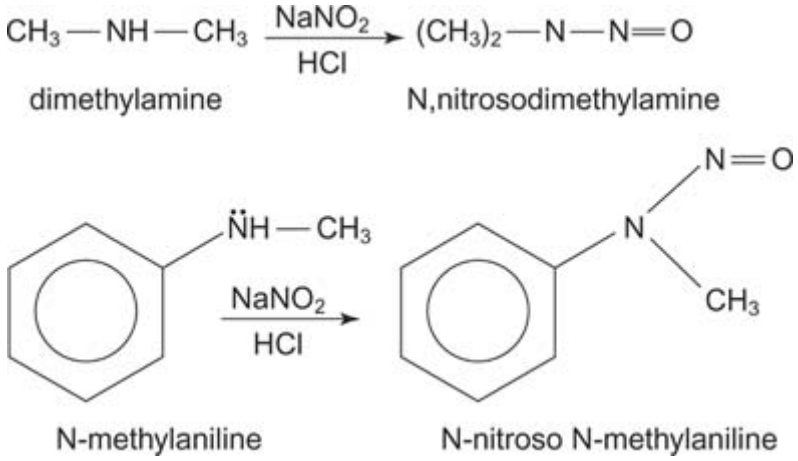
Primary amines react with nitrous acid to yield a diazonium salt, which is highly unstable and degrades into a carbocation that is capable of reaction with any nucleophile in solution. Therefore, reacting primary amines with nitrous acid leads to a mixture of alcohol, alkenes, and alkyl halides.



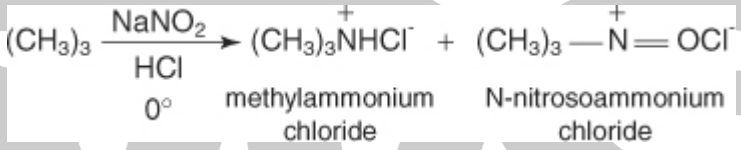
Primary aromatic amines form stable diazonium salts at zero degrees.



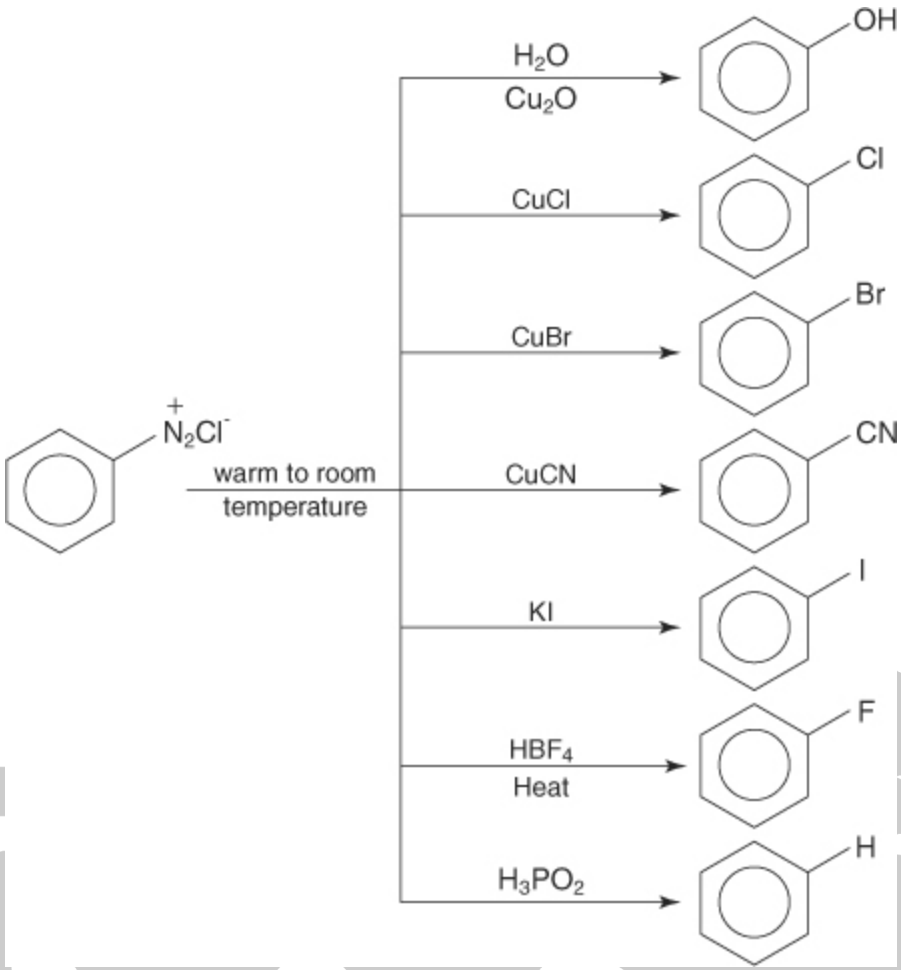
Secondary aliphatic and aromatic amines form nitrosamine with nitrous acid.



Tertiary amines react with nitrous acid to form N-nitrosoammonium compounds.



h) Reactions of aromatic diazonium salts: Diazonium salts of aromatic amines are very useful as intermediates to other compounds. Because aromatic diazonium salts are only stable at very low temperatures (zero degrees and below), warming these salts initiates decomposition into highly reactive cations. These cations can react with any anion present in solution to form a variety of compounds. Figure illustrates the diversity of the reactions.



III. Uses of Amines

1) Dyes

Aromatic amines are mainly used as a starting material for the production of azo dyes. It reacts with nitric (III) acid to form diazonium salt, which goes through coupling reaction to form azo compound. As azo-compounds are highly coloured, they are used broadly in dyeing industries, like: Methyl orange, Direct brown 138, Sunset yellow FCF and Ponceau.

2) Drugs

Many drugs are designed for mimicing or to interfere with the action of natural amine neurotransmitters, can be exemplified by the amine drugs:

Chlorpheniramine is an antihistamine which helps to relieve allergic disorders caused due to cold, hay fever, itchy skin, insect bites and stings.

Chlorpromazine is a tranquillizer which sedates without inducing sleep. It is used to relieve anxiety, excitement, restlessness and sometimes even mental disorder.

Ephedrine and Phenylephrine in form of amine hydrochlorides,are used as decongestants.

Amphetamine, Methamphetamine, and Methcathinone are amines which are listed as controlled substances by the DEA (diethanolamine).

Amitriptyline, Imipramine, Lofepramine and Clomipramine are tricyclic anti-depressants and tertiary amines.

Nortriptyline, Desipramine, and Amoxapine are tricyclic anti-depressants and secondary amines.

3. Industrial uses

Aqueous monoethanolamine (MEA), diglycolamine (DGA), diethanolamine (DEA), diisopropanolamine (DIPA) and methyldiethanolamine (MDEA) are used broadly in industries for removing carbon dioxide (CO2) and hydrogen sulfide (H2S) from natural gas streams and also from refinery process streams. They may also be helpful in removing CO2 from combustion gases / flue gases and may have got potential for abatement of greenhouse gases.

3. How primary, secondry and tertiary amines can be separated?

Ans: Separation of 1^o, 2^o and 3^o amines

- The mixture of amines is reacted with benzene sulphonyl chloride. The product mixture obtained is treated with aqueous HCl and filtered.
- The filtrate contains tertiary amine as its hydrochloride which can be isolated as amine with addition of base.
- The acid insoluble residue contains the 2^o and 1^o amine. This residue is treated with aq KOH solution and filtered.
- The secondary amine sulphonamide is insoluble in alkali so it is obtained as a residue. It is hydrolysed to get secondary amine.
- The filtrate on acidification gives the sulphonamide of the primary amine which is isolated after hydrolysis.