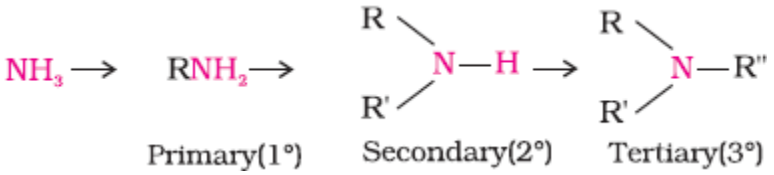
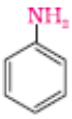
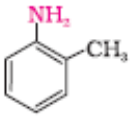
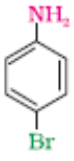
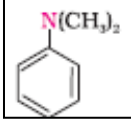
Chapter- 13: Amines

1. Introduction: Amines are derivatives of ammonia in which one, two or all three hydrogen atoms are replaced by alkyl or aryl group.



2. Nomenclature of Amines:

Amine	Common name	IUPAC name
CH_3–CH_2–NH_2	Ethylamine	Ethanamine
CH_3–CH_2–CH_2–NH_2	*n*-Propylamine	Propan-1-amine
$CH_3-CH(NH_2)-CH_3$	Isopropylamine	Propan-2-amine
$CH_3-N(H)-CH_2-CH_3$	Ethylmethylamine	N-Methylethanamine
$CH_3-N(CH_3)-CH_3$	Trimethylamine	N,N-Dimethylmethanamine
$C_2H_5-N(C_2H_5)-CH_2-CH_2-CH_2-CH_3$	*N,N*-Diethylbutylamine	N,N-Diethylbutan-1-amine
$NH_2-CH_2-CH=CH_2$	Allylamine	Prop-2-en-1-amine
$NH_2-(CH_2)_6-NH_2$	Hexamethylenediamine	Hexane-1,6-diamine
	Aniline	Aniline or Benzenamine
	*o*-Toluidine	2-Aminotoluene
	*p*-Bromoaniline	4-Bromobenzenamine or 4-Bromoaniline
	*N,N*-Dimethylaniline	N,N-Dimethylbenzenamine

3. Preparation of Amines:

1) Ammonolysis of alkyl halides:

- The process of cleavage of C–X bond by ammonia is called ammonolysis. When ammonia is taken in excess, primary amine is formed as main product.

$$R\text{-}X + 2NH_3 \longrightarrow R\text{-}NH_2 + NH_4X$$

- If alkyl halide is in excess, the amine formed further reacts with alkyl halide to form 2°, 3° amines and finally quaternary ammonium salts is formed as main product.

$$\underset{(1^0)}{RNH_2} \xrightarrow{RX} \underset{(2^0)}{R_2NH} \xrightarrow{RX} \underset{(3^0)}{R_3N} \xrightarrow{RX} \underset{\text{Quaternary ammonium salt}}{R_4\overset{+}{N}\,\overset{-}{X}}$$

- The order of reactivity of alkyl halide is RI > RBr > RCl

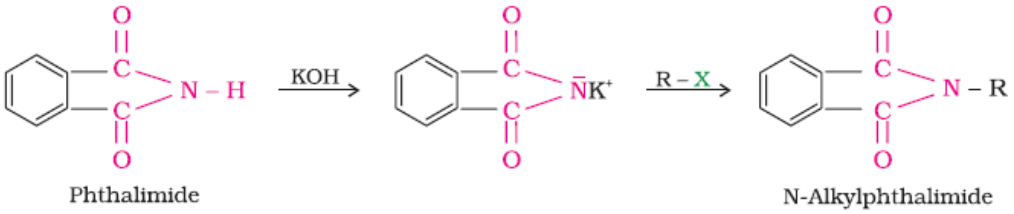
2) Reduction of Nitriles:

$$R{-}C{\equiv}N + 2H_2 \xrightarrow[Na(Hg)/C_2H_5OH]{Ni\ /} R{-}CH_2{-}NH_2$$

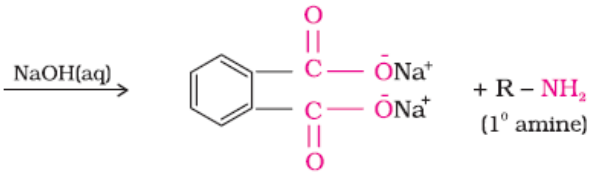
3) Reduction of Amides:

$$R{-}\underset{\underset{O}{\|}}{C}{-}NH_2 + 2H_2 \xrightarrow[(ii)\ H_2O]{(i)\ LiAlH_4} R{-}CH_2{-}NH_2$$

4) Gabriel phthalimide synthesis:



Phthalimide N-Alkylphthalimide

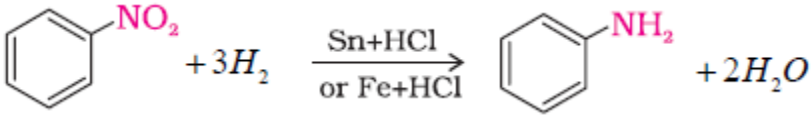


Aromatic amines cannot be prepared by this method b/c aryl halides do not undergo nucleophilic substitution with the anion formed by phthalimide.

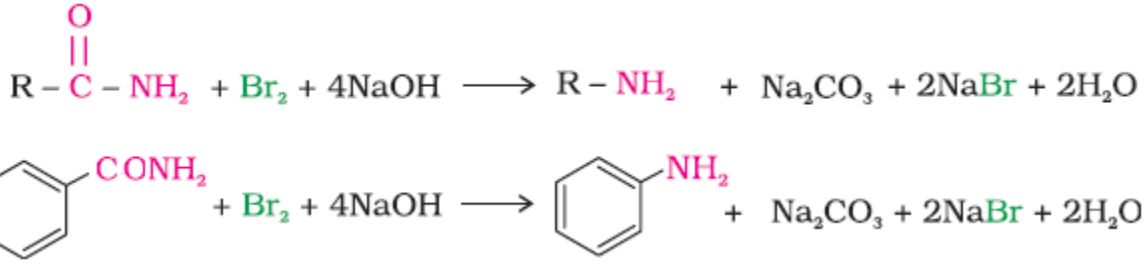
5) Reduction of nitro compounds: Alkyl and aryl (aniline) both type amines can be prepared by this method.

$$a)\ R-NO_2 + 3H_2 \xrightarrow{Ni, Pt \text{ or } pd} R-NH_2 + 2H_2O$$

$$b)\ R-NO_2 + 3H_2 \xrightarrow{Sn/HCl \text{ or } Fe/HCl} R-NH_2 + 2H_2O$$

c) 

6) Hoffmann bromamide degradation reaction: Alkyl and aryl (aniline) both type amines can be prepared by this method.



4. Physical Properties:

1) Solubility: Lower aliphatic amines are soluble in water b/c they can form hydrogen bond with water. Solubility with water decreases with increases in molar mass of amines due to increase in size of hydrophobic group. Higher aliphatic amines and aromatic amines are soluble in organic solvent.

2) Boiling Point: In isomeric amines primary and secondary amines have high boiling point b/c they can form hydrogen bonding while tertiary amine cannot form the hydrogen bond. So order of boiling point of isomeric amines is Primary > Secondary > Tertiary

Amines have lower boiling points than the comparable molecular masses of alcohols or carboxylic acids b/c as comparatively hydrogen bond is weak in amines so order of boiling point should be: carboxylic acid > alcohol > amine

5. Basic character of Amines: Amines have a lone pair of electrons on nitrogen atom due to which they behave as Lewis base. Basic character of amines can be better understood in terms of their Kb and pKb values like as

$$R-NH_2+H_2O \Leftrightarrow R-\overset{+}{N}H_3+\overset{-}{O}H$$

$$K=\frac{[R-\overset{+}{N}H_3][\overset{-}{O}H]}{[R-NH_2][H_2O]}$$

$$K_b=\frac{[R-\overset{+}{N}H_3][\overset{-}{O}H]}{[R-NH_2]}$$

$$pK_b=-\log K_b$$

Larger the value of Kb or smaller the value of pkb, stronger is the base.

Comparison of basic strength of amines with other substances:

1) Amine vs alcohols, ethers and esters: Since nitrogen is less electronegative than oxygen, it is in a better position to provide accommodating the positive charge of the proton. Therefore, amines are stronger basic than alcohol, ethers, esters etc.

Amines > ethers > alcohol > esters

2) Alkyl amines vs ammonia: Alkyl amines are stronger base than ammonia due to +I effect of alkyl groups leading to high electron density on the nitrogen atom.

3) Basic strength of Primary, secondary and tertiary amines in gaseous phase: Amines in the gaseous phase follows the expected order on the basis of +I effect is:

$$3°\text{amine} > 2°\text{ amine} > 1°\text{ amine} > NH_3$$

4) Basic strength of Primary, secondary and tertiary amines in aqueous solution: In aqueous solution it is observed that tertiary amines are less basic than either primary or secondary amines. This can be explained on the basis of following factors:

i) Solvation factor (stability of ammonium cation): Greater is the stability of substituted ammonium cation formed, corresponding amine is stronger as a base. Tertiary ammonium ion is less hydrated than secondary ammonium ion which is less hydrated than primary amine. Thus tertiary amines have fewer tendencies to form ammonium ion and consequently are least basic.

$$1°\text{amine} > 2°\text{ amine} > 3°\text{ amine}$$

ii) Steric factor: Due to increases number of alkyl group from primary to tertiary amine hindrance to bonding with hydrogen increases so decreases the basic strength. The basic strength of amines in aqueous solution is a combination of the +I effect, H-bonding and steric factor which decide the stability of the ammonium cations in solution and the basic strength of alkyl amines in the aqueous state.

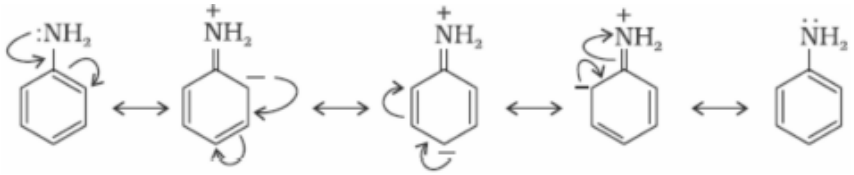
When the alkyl group is small like CH3 there is no steric hindrance to H-bonding. In this case order of basicity in aqueous medium is

$$(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$$

When the alkyl group is ethyl then order of basicity in aqueous medium is

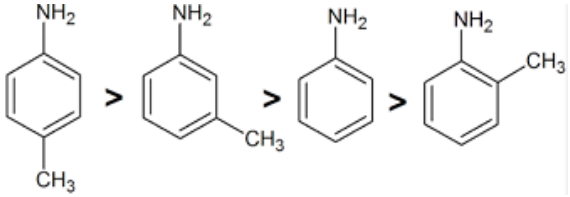
$$(C_2H_5)_2NH > (C_2H_5)_3N > C_2H_5NH_2 > NH_3$$

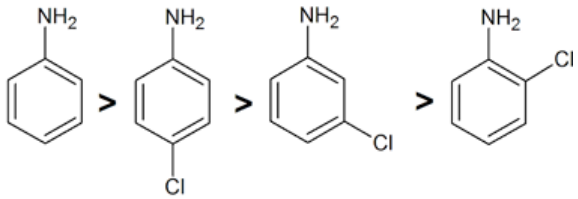
5) Comparision of basic strength of aryl amines and alkyl amines: Aryl amines are weaker bases than alkyl amines. In aromatic amine (like aniline) due to resonance, the lone pair electrons on the N-atom are delocalised over the benzene ring so it is less available for sharing with a proton (H^+ ions).



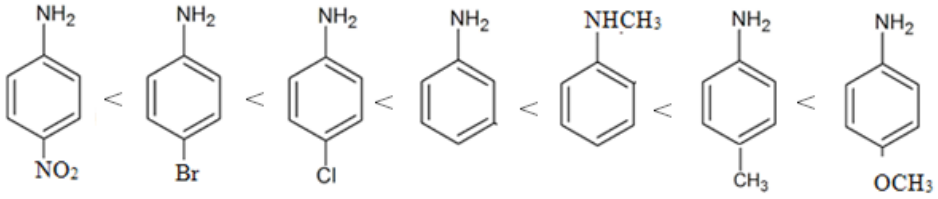
On the other hand, in alkyl amine (CH_3NH_2) due to +I effect of CH_3 group increases the electron density on nitrogen atom. Thus alkyl amine is strong base than aryl amines.

6) Effect of substituent on the basicity of aromatic amines: Electron donating group (electron releasing group such as $–CH_3$, - OCH_3, $-NH_2$ etc.) increases basic strength while electron withdrawal group ($–NO_2$, -CN, Halogens etc.) decreases basic strength. The effect of this substituent is more at p- than m- positions for examples the isomeric toluidines, the basic strength with respect to aniline decreases as:





Here ortho substituted anilines are weaker bases than aniline due to combination of steric and electronic factors.



6. Chemical Properties of Amines:

1) Acylation: Carried out in the presence of strong base (pyridine) which removed formed HCl. Tertiary amines do not go acylation reaction due to unavailability of replaceable H-atom.

$$R-NH_2 + \underset{\text{Acid chloride}}{RCOCl} \xrightarrow{\text{pyridine}} \underset{\text{Substituted amide}}{RNHCOR} + HCl$$

$$R'-NH_2 + R-\underset{\text{Acid anhydride}}{\overset{O}{\overset{\|}{C}}-O-\overset{O}{\overset{\|}{C}}-R} \xrightarrow{\text{pyridine}} \underset{\text{Substituted amide}}{R'NHCOR} + RCOOH$$

$$R_2NH + RCOCl \xrightarrow{\text{pyridine}} R_2NCOR + HCl$$

2) Carbylamine reaction (Isocyanide test): Only primary amines (aliphatic as well as aromatic) on heating with chloroform and alcoholic KOH form foul smelling of isocyanides or carbylamines. Secondary and tertiary amines do not give this test.

$$R-NH_2 + CHCl_3 + 3KOH \xrightarrow{\text{Heat}} R-NC + 3KCl + 3H_2O$$

3) Reaction with Nitrous acid: Primery aliphatic amine on reaction with nitrous acid form aliphatic Diazonium salt (unstable) which decompose and form alcohol.

$$R-NH_2 + HNO_2 \xrightarrow{NaNO_2 + HCl} \underset{\text{unstable}}{[R-\overset{+}{N_2}Cl^-]} \xrightarrow{H_2O} ROH + N_2 + HCl$$

While aromatic amines (aniline) form Diazonium salt (benzene di azonium chloride) like as

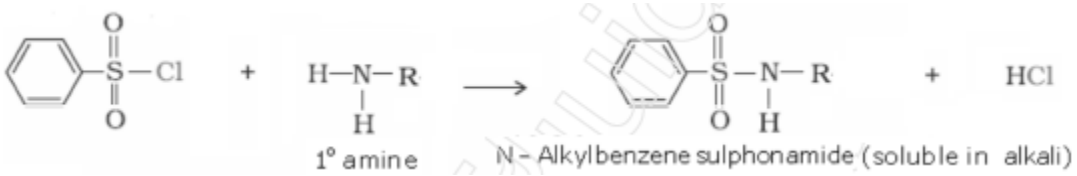
$$C_6H_5-NH_2 \xrightarrow[273-278\ K]{NaNO_2 + 2HCl} C_6H_5-\overset{+}{N_2}Cl^- + NaCl + 2H_2O$$

Secondary amines form a yellow green oily layer of N- Nitrosoamines.

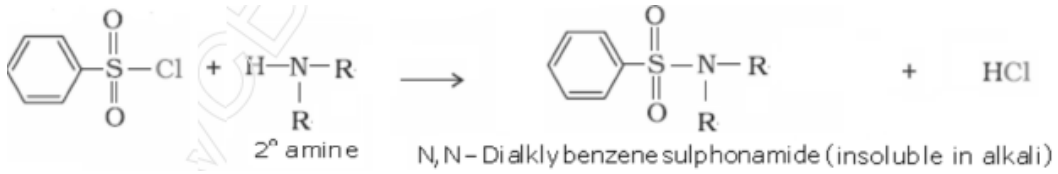
$$R_2NH + HNO_2 \rightarrow R_2N\text{-}N{=}O + H_2O$$

4) Reaction with aryl sulphonyl chloride (Hinsberg's test): In this test, the unknown amine is first treat with Hinsberg's reagent (benzene sulphonyl chloride) and then shaken with aqueous KOH soln, the three amines behave in different ways.

i) Primary amine form sulphonamide which is strongly acidic due to the presence of strong electron withdrawing sulphonyl group and the H atom attached to nitrogen. Hence it is soluble in alkali solution.



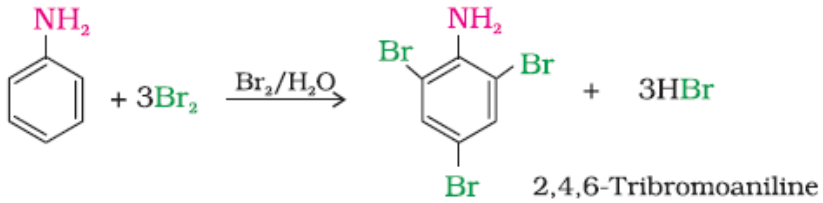
ii) Secondary amine also form sulphonamide but it is not acidic b/c it does not contain any H atom attached to nitrogen. Hence it is insoluble in alkali solution.



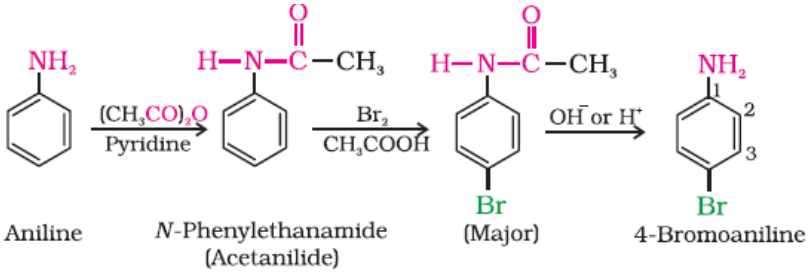
iii) Tertiary amine does not react at all.

5) Electrophilic substitution: Aniline is more reactive than benzene and undergoes electrophilic substitution reaction at ortho and para position.

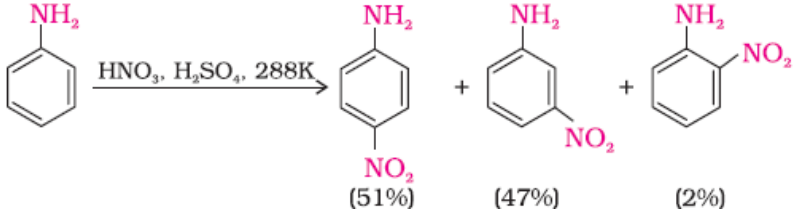
i) Bromination:



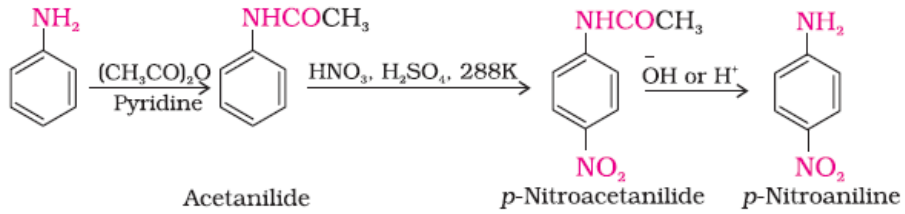
In order to stop reaction at mono substitution activating effect of $-NH_2$ group is reduced by acetylation. Acetyl group is removed by hydrolysis.



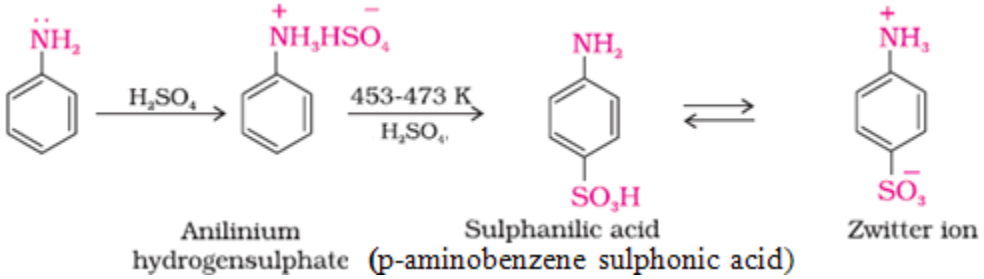
ii) Nitration: In strongly acidic medium significant amount of meta isomer also obtained. This is due to the formation of anilinium ion which is meta directing.



Aromatic amines cannot be nitrated directly b/c HNO3 being a strong oxidising agent. The p-nitro derivative can be obtained as the major product by protecting the $-NH_2$ group by acetylation reaction.



iii) Sulphonation:



iv) Friedel-Craft reaction: Aniline being a lewis base, react with lewis acid $AlCl_3$ to form a salt.

$$C_6H_5NH_2 + AlCl_3 \longrightarrow C_6H_5\overset{+}{N}H_2AlCl_3^-$$

As a result, N of aniline acquires positive charge and hence its act as a strong deactivating group for electrophilic substitution reaction. Consequently, aniline does not undergo Friedel craft reaction.

Diazonium Salts

1. General formula: RN_2X, where R is an aryl group and X^- ion may be Cl^-, Br^-, HSO_4^-, BF_4^- etc. The $\overset{+}{N}_2$ $(-\overset{+}{N}\equiv N)$ is called the Diazonium group.

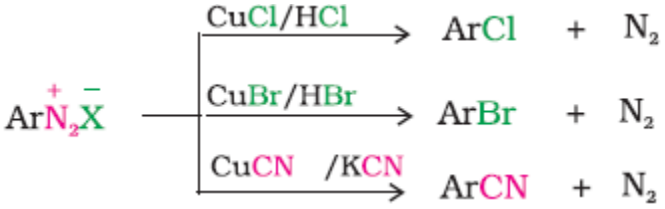
2. Chemical Properties of Diazonium salts: The reaction of Diazonium salts can be divided into two categories, namely

1) Reaction involving displacement of nitrogen.

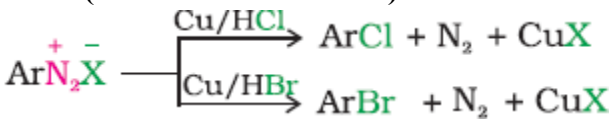
2) Reaction involving retention of diazo group.

1) Reaction involving displacement of nitrogen:

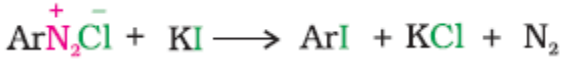
i) Replacement by halide or cyanide ion (Sandmeyer's reaction):



ii) Replacement by halide ion (Gatterman's reaction):

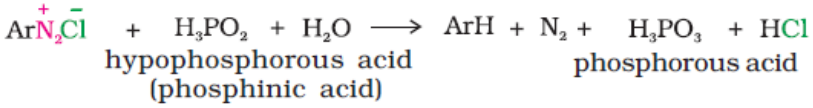


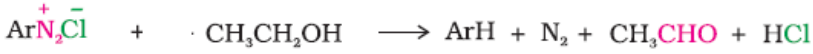
iii) Replacement by iodide ion:



iv) Replacement by fluoride ion:

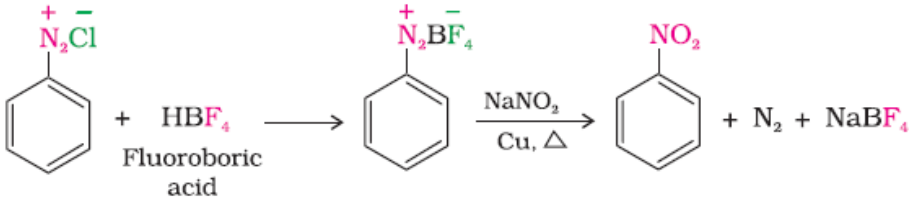
v) Replacement by hydrogen:





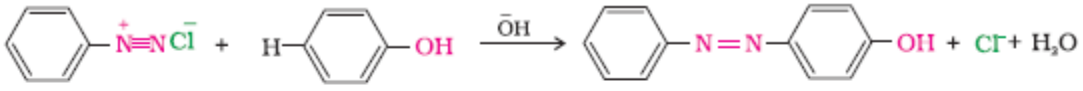
vi) Replacement by hydroxyl group:

vii) Replacement by nitro group:

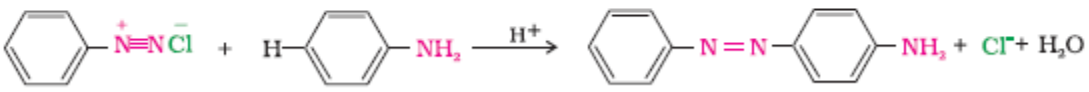


2) Reaction involving retention of diazo group:

Coupling reaction: The reaction of Diazonium salt with phenol and aniline to form azo compounds of the general formula Ar-N=N-Ar is called coupling reaction. The reaction is electrophilic substitution reaction where the Diazonium ion is act as electrophile. Coupling generally occurs at the p-position, w.r.t. the hydroxyl or the amino group, if free, otherwise it takes place at the o-position.



p-Hydroxyazobenzene (orange dye)



p-Aminoazobenzene (yellow dye)