3.11 Amines

Naming Amines

See 3.7 revision guide : naming and isomerism for discussion of naming Amines

Base Properties

Primary aliphatic amines act as Bronsted-Lowry Bases because the lone pair of electrons on the nitrogen is readily available for forming a dative covalent bond with a H⁺ and so accepting a proton.

\[ \text{CH}_3\text{NH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{NH}_3^+ + \text{OH}^- \]

Primary aliphatic amines are stronger bases than ammonia as the alkyl groups are electron releasing and push electrons towards the nitrogen atom and so make it a stronger base.

\[ \text{NH}_3 (aq) + \text{H}_2\text{O} (l) \rightarrow \text{NH}_4^+ (aq) + \text{OH}^- (aq) \]

Secondary amines are stronger bases than primary amines because they have more alkyl groups that are substituted onto the N atom in place of H atoms. Therefore more electron density is pushed onto the N atom (as the inductive effect of alkyl groups is greater than that of H atoms). One might expect using the same trend that tertiary amine would be the strongest amine base but the trend does not hold. The tertiary amines and corresponding ammonium salts are less soluble in water and this makes them less strong bases than the secondary amines. (This point will not be examined)

Base strength of aromatic amines

Primary aromatic amines such as Phenylamine do not form basic solutions because the lone pair of electrons on the nitrogen delocalise with the ring of electrons in the benzene ring. This means the N is less able to accept protons.

Overall order of base strength

Aromatic amines < ammonia < primary amines < tertiary amines < secondary amines

Reactions with acids

All amines will react with acids to become ammonium salts

\[
\begin{align*}
\text{CH}_3\text{NH}_2 (aq) + \text{H}^+ (aq) & \rightarrow \text{CH}_3\text{NH}_3^+ (aq) \\
(\text{CH}_3\text{CH}_2)_2\text{NH} (aq) + \text{H}^+ (aq) & \rightarrow (\text{CH}_3\text{CH}_2)_2\text{NH}_2^+ (aq) \\
(\text{CH}_3\text{CH}_2)_3\text{N} (aq) + \text{H}^+ (aq) & \rightarrow (\text{CH}_3\text{CH}_2)_3\text{NH}^+ (aq)
\end{align*}
\]

Amines as bases react with acids to form ammonium salts.

CH₃NH₂(aq) + HCl(aq) → CH₃NH₃⁺Cl⁻(aq)

Methylamine methy lammonium chloride

The ionic salts formed in this reaction means that the compounds are soluble in the acid.
e.g. Phenylamine is not very soluble in water but pheny lammonium chloride is soluble

Addition of NaOH to an ammonium salt will convert it back to the amine

These ionic salts will be solid crystals, if the water is evaporated, because of the strong ionic interactions.

Making a basic buffer from an amine

Basic buffers can be made from combining a weak base with a salt of that weak base
e.g. Ammonia and ammonium chloride
Methylamine and methy lammonium chloride
Ethylamine and ethyl ammonium chloride
Nucleophilic properties

**Forming a primary amine in a one step reaction of halogenoalkanes with ammonia**

Primary amines can be formed by the nucleophilic substitution reaction between halogenoalkanes and ammonia in a one step reaction. However, as the lone pair of electrons is still available on the N in the amine formed, the primary amine can react in the same nucleophilic way in a successive series of reactions forming secondary, tertiary amines and quaternary ammonium salts. This is therefore not a good method for making a primary amine because of the further reactions. It would mean the desired product would have to be separated from the other products.

\[
\text{CH}_3\text{CH}_2\text{Br} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Br}
\]

Ammonia dissolved in ethanol is the initial nucleophile

In the first step of the mechanism the nucleophile attacks the halogenoalkane to form an intermediate.

In the second step of the mechanism a second ammonia removes a proton from the intermediate (acts as base) to form the amine.

Using an excess of Ammonia can limit the further subsequent reactions and will maximise the amount of primary amine formed.

**Further reactions**

**Reaction forming secondary amine**

The primary amine formed in the reaction above has a lone pair of electrons on the nitrogen and will react further with the halogenoalkane.

In this second step of the mechanism either ammonia or the amine can remove a proton from the intermediate (acts as base) to form the amine.

**Reaction forming a tertiary amine**

The same reaction mechanism occurs with the secondary amine reacting to form a tertiary amine.

Using an excess of Ammonia can limit the further subsequent reactions and will maximise the amount of primary amine formed.
Reaction forming a quaternary ammonium salt

\[
\begin{align*}
\text{H}_3\text{C}-\text{CH}_2-\text{N}^+\text{CH}_2\text{CH}_3 & \quad \text{Br} \\
\text{Tetraethylammonium ion} & \\
\end{align*}
\]

Using an excess of the halogenoalkane will promote the formation of the quaternary salt

Only the first step of the mechanism occurs when forming the quaternary salt

Quaternary ammonium salts are not amines

Overall scheme of reactions

Where RX is the haloalkane

Using a large excess of Ammonia will maximise the amount of primary amine formed

Using an excess of the halogenoalkane will promote the formation of the quaternary salt

Quaternary Salts can be used as cationic surfactants

Surfactants reduce the surface tension of liquids

The positive nitrogen is attracted toward negatively charged surfaces such as glass, hair, fibres and plastics.

This helps in their uses as fabric softeners, hair conditioners and sewage flocculants

Some questions will involve substituting an amine onto a halogenoalkane which has a different length of carbon chain from the amine

propylamine \quad N\text{-methylpropylamine} \quad \text{N,N-dimethylpropylamine}

Using excess bromomethane would promote the final quaternary salt
Preparing Amines from Nitriles in a 2 step reaction

Using the method above of reacting halogenoalkanes and ammonia is not an efficient method for preparing a high yield of the primary amine because of the further substitution reactions that occur.

A better method is to use the following 2 step reaction scheme

Step 1. convert halogenoalkane to nitrile by using KCN in ethanol (heat under reflux)

\[
\text{CH}_3\text{CH}_2\text{Br} + \text{CN}^- \rightarrow \text{CH}_3\text{CH}_2\text{CN} + \text{Br}^-
\]

Step 2. reduce nitrile to amine by using LiAlH}_4 in ether or by reducing with H\textsubscript{2} using a Ni catalyst

\[
\text{CH}_3\text{CH}_2\text{CN} + 4\text{[H]} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2
\]

A disadvantage of this method is that it is a two step reaction that may therefore have a low yield. Also KCN is toxic.

Reducing nitroarenes to aromatic amines

The nitro group on an arene can be reduced an amine group as follows

**Reagent:** Sn and HCl or Fe and HCl  
**Conditions:** Heating  
**Mechanism:** reduction

\[
\begin{align*}
\text{NO}_2^- + 6\text{[H]} & \rightarrow \text{NH}_2^- + 2\text{H}_2\text{O} \\
\text{nitrobenzene} & \rightarrow \text{phenylamine}
\end{align*}
\]

As the reaction is carried out in HCl the salt C\textsubscript{6}H\textsubscript{5}NH\textsubscript{3}^+Cl^- will be formed. Reacting this salt with NaOH will give phenylamine.

This reduction reaction can also be done with catalytic hydrogenation (H\textsubscript{2} using a Ni catalyst).

Other reactions of amines

Aliphatic amines and phenylamine can react with acyl chlorides and acid anhydrides to form amides in a nucleophilic addition-elimination reaction- see previous chapter on reactions of C=O bond for more details.

<table>
<thead>
<tr>
<th>Change in functional group: acyl chloride \rightarrow secondary amide</th>
<th>Change in functional group: acid anhydride \rightarrow secondary amide</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reagent:</strong> primary amine</td>
<td><strong>Reagent:</strong> primary amine</td>
</tr>
<tr>
<td><strong>Conditions:</strong> room temp.</td>
<td><strong>Conditions:</strong> room temp.</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
\text{RCOCl} + 2\text{CH}_3\text{NH}_2 & \rightarrow \text{RCONHCH}_3 + \text{CH}_3\text{NH}_2\text{Cl}^- \\
\text{CH}_3\text{C}=\text{O} + 2\text{CH}_3\text{NH}_2 & \rightarrow \text{CH}_3\text{C}=\text{N}\text{HCH}_3 + \text{CH}_3\text{NH}_2\text{Cl}^- \\
& \text{N-methylethanamide}
\end{align*}
\]

\[
\begin{align*}
(\text{RCO}_2\text{O})_2 + 2\text{CH}_3\text{NH}_2 & \rightarrow \text{RCONHCH}_3 + \text{RCO}_2\text{CH}_3\text{NH}_2^- \\
\text{CH}_3\text{C}=\text{O} + 2\text{CH}_3\text{NH}_2 & \rightarrow \text{CH}_3\text{C}=\text{N}\text{HCH}_3 + \text{CH}_3\text{CO}_2\text{CH}_3\text{NH}_2^- \\
& \text{N-methylethanamide}
\end{align*}
\]