

# Edexcel IAL Chemistry A-level

## Topic 19: Organic Nitrogen Compounds: Amines, Amides, Amino Acids and Proteins

Detailed notes

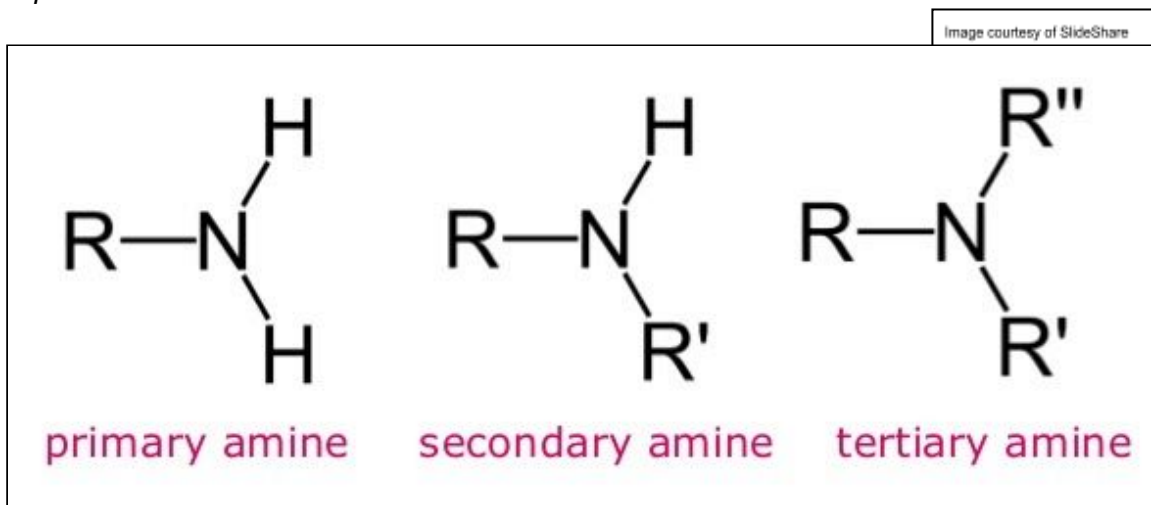
This work by [PMT Education](https://www.pmt.education) is licensed under [CC BY-NC-ND 4.0](https://creativecommons.org/licenses/by-nc-nd/4.0/)



## Aliphatic Amines

Amines are produced when one or more of the hydrogen atoms in ammonia is **replaced with an alkyl group**. They can be classified as **primary, secondary or tertiary amines**, depending on how many alkyl groups are bonded to the nitrogen atom. Amines are **miscible** with water as a result of the **hydrogen bonding** which occurs between water molecules and the  **$\delta^+$  hydrogen atoms** in the amine group.

*Example: Classification of amines*

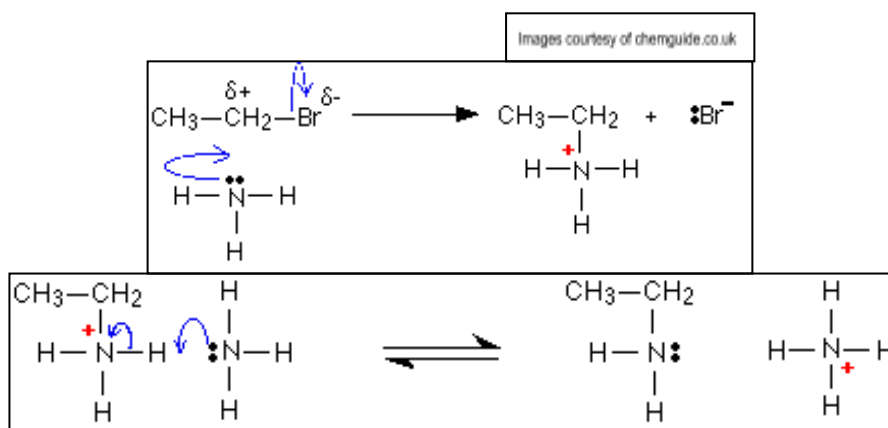


Amines can be produced by **nucleophilic substitution** or by the **reduction of nitriles**:

### Nucleophilic Substitution

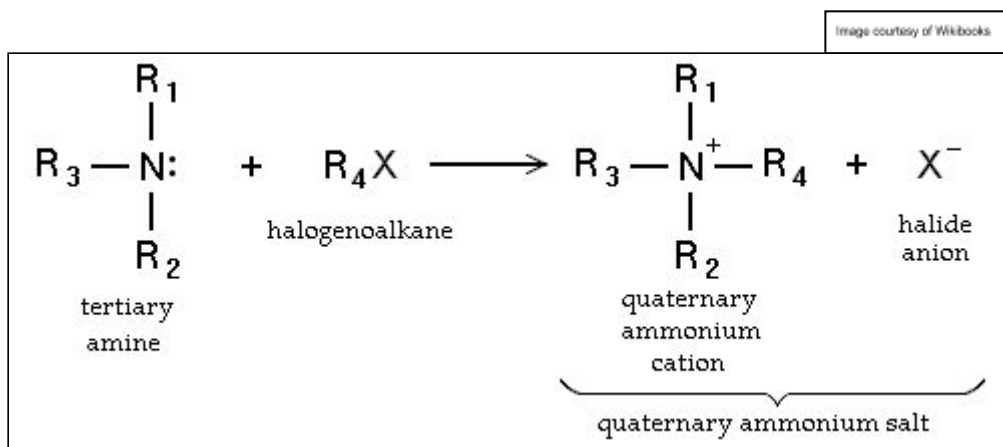
Amines can be produced from the nucleophilic substitution reaction between a **halogenoalkane with ammonia** in a sealed tube. One mole of halogenoalkane reacts with two moles of ammonia, producing a **primary amine** and an **ammonium salt (ammonium ion and halide ion)**.

*Example: Nucleophilic substitution of bromoethane with ammonia*



This substitution reaction can continue until **all the hydrogen atoms have been replaced** with amine groups. Following this, an additional substitution can occur, producing a **quaternary ammonium salt**.

Example:

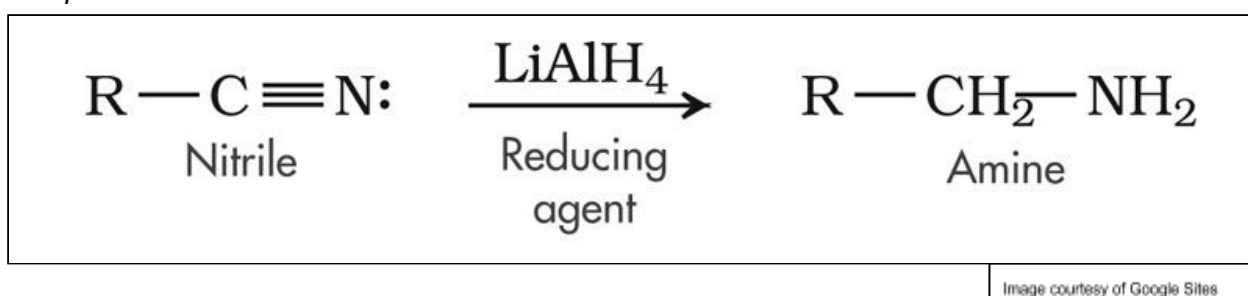


The multiple possible substitutions mean that a **mixture of products** is produced. Therefore, the reaction has **low efficiency** and the reaction **conditions** have to be changed so that only a single substitution occurs. Ammonia can be added **in excess** in order to achieve only the primary amine, or the mixture of products can be **separated using fractional distillation**.

### Reduction of Nitriles

Amines can be produced by the reduction of nitriles by **hydrogenation**. This reduction requires the reducing agent **LiAlH<sub>4</sub>**, and **acidic conditions**, or a combination of **hydrogen with a nickel catalyst** (catalytic hydrogenation).

Example:



### Amine Base Properties

Amines are **weak bases** because the **lone electron pair** on the nitrogen atom can accept protons. The base strength of amines depends on **how available** the electron pair is on the nitrogen atom.



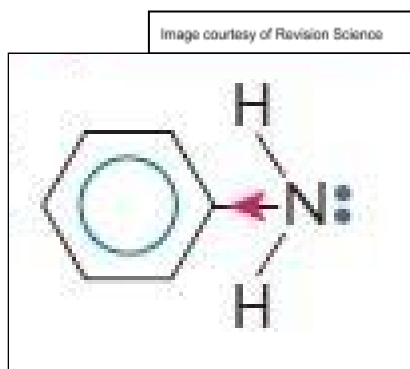
The more available the electron pair is, the more likely it is to accept a proton, meaning the amine is a stronger base.

### The Inductive Effect

In an organic molecule, different functional groups can affect how available a lone electron pair is by changing **electron density** around the bond.

1. **Benzene rings** - draw electron density **away** from the nitrogen making the lone pair 'less available'

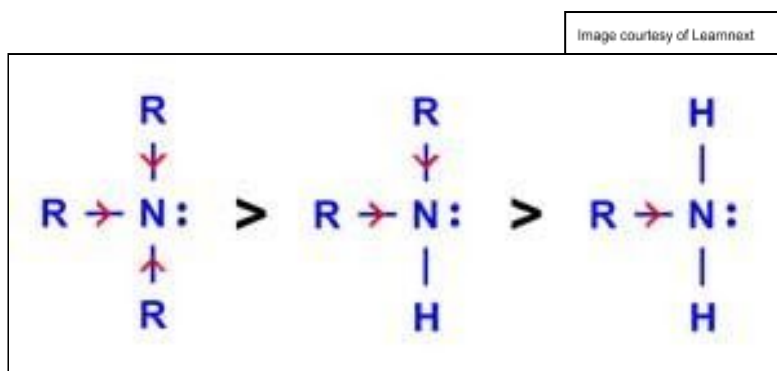
*Example:*



**Negative inductive effect**

2. **Alkyl groups** - push electron density **towards** the nitrogen atom making the lone pair 'more available'. More alkyl groups means more 'pushing'.

*Example:*



**Positive inductive effect**

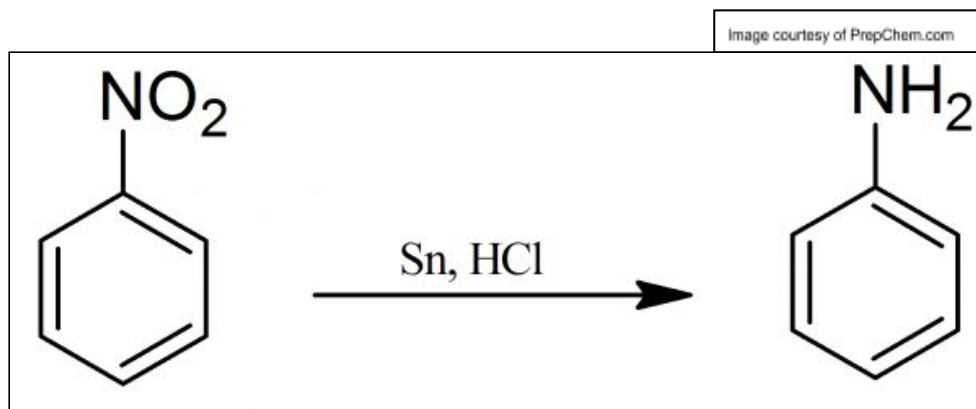
Therefore, **aliphatic amines are stronger** bases and **aromatic amines are weaker bases**.



## Aromatic Amines

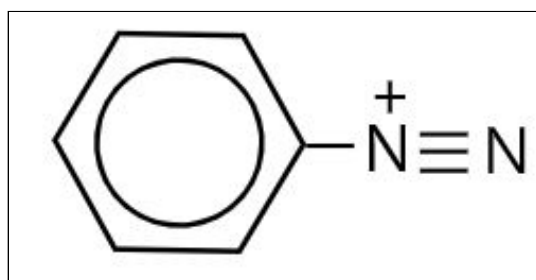
Aromatic amines can be produced from the **reduction of nitrobenzene** using **concentrated hydrochloric acid** (HCl) and a **tin catalyst**. Aromatic amines consist of an amine group and a benzene ring.

Example:



## Reactions of Aromatic Amines

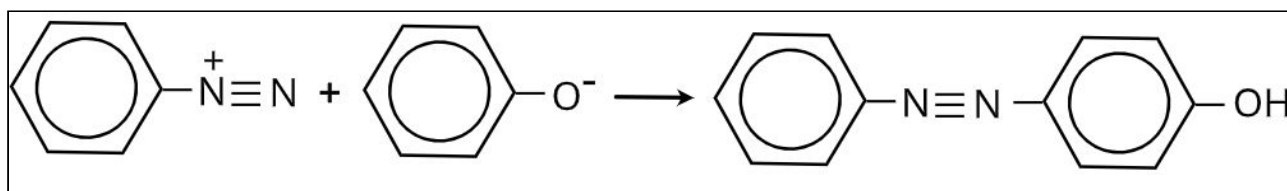
**Benzenediazonium ions** are formed when primary aromatic compounds react with **nitric(III) acid (nitrous acid)** at temperatures **below 10°C**. Diazonium ions are ions that contain an **N<sub>2</sub><sup>+</sup> group**.



*Structure of a benzenediazonium ion*

Benzenediazonium chloride reacts with phenol in a **coupling reaction**. Coupling reactions are organic reactions that involve the joining together of two chemical species in an **alkaline solution**.

First, a solution of sodium phenoxide is produced by dissolving phenol in sodium hydroxide. Next, the solution is cooled and added to benzenediazonium chloride. A **yellow-orange solution/precipitate** is formed. The product is known as an **azo compound**.



*The coupling reaction between a benzenediazonium ion and a phenoxide ion*



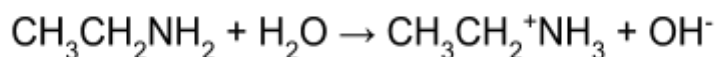
Azo compounds form **brightly coloured compounds**, so they are regularly used in dyes.

## Reactions of Primary Aliphatic Amines and Aromatic Amines

### Amines as Bases

Amines react with water to form an **alkaline solution**. The lone pair of electrons on the amine's nitrogen atom can **accept a hydrogen** from a water molecule, therefore acting as a base. This releases **OH<sup>-</sup> ions** into the solution.

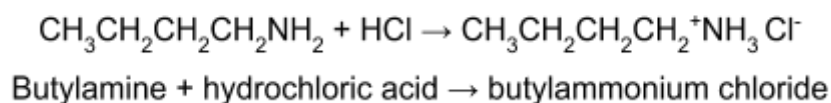
*Example:*



### To produce Salts

Amines react with acids to form an ammonium salt. Again, the amine acts as a base and accepts a proton to form a **quaternary ammonium salt**.

*Example:*



### Reaction with Copper(II) ions

In topic 18 it was learnt that ammonia can react with copper aqua ions to form an **octahedral complex**. Similarly, aliphatic and aromatic amines can react in the same way. In solution, the copper ions will react with water to form a **copper aqua ion**. The amine then acts as a base to **accept protons** from the water ligands to give a **blue precipitate** of  $\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4$  along with an ammonium salt.

*Example:*

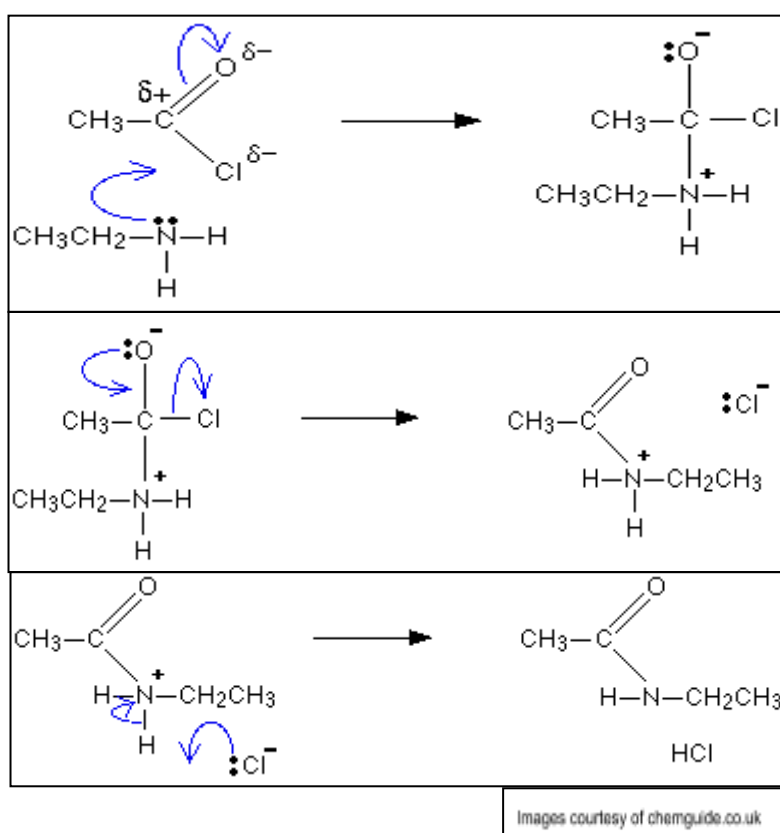
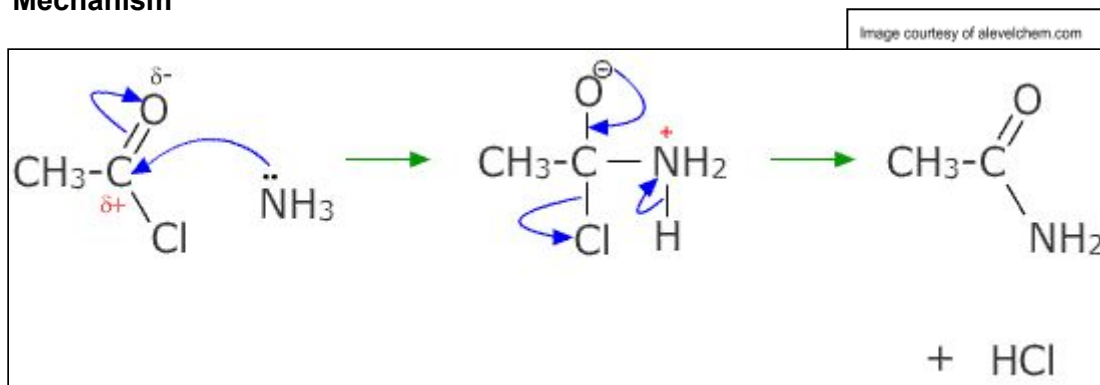


## Amides



Amines can undergo **nucleophilic addition-elimination** reactions with **acyl chlorides** to produce **amides** and **N-substituted amides**.

### Mechanism



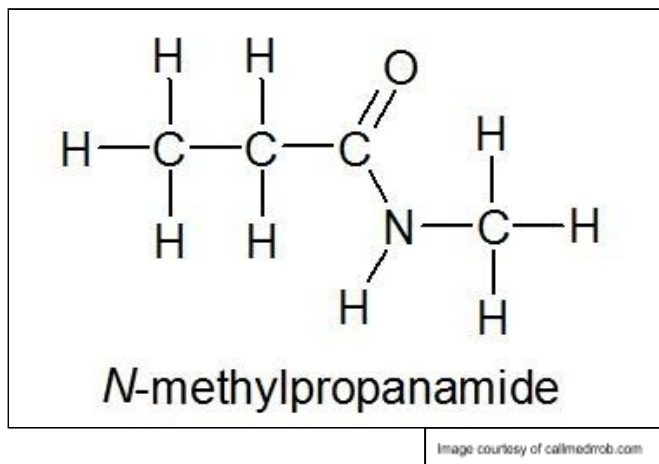
This same reaction mechanism can also occur with **acid anhydrides** to produce an amide and a carboxylic acid.

### N-substituted Amides

When **naming** N-substituted amides, they are treated in a similar way to **esters**. The **prefix** indicates the length of the carbon chain bonded to the **nitrogen** atom only and the **suffix** indicates the carbon chain which contains the **carbonyl** bond.



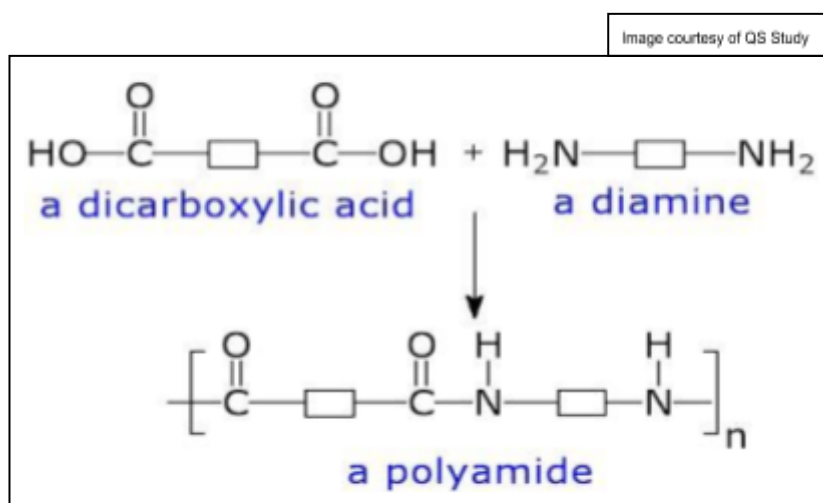
Example:



## Polyamides

Polyamides are condensation polymers generally formed in a reaction between a **dicarboxylic acid** and a **diamine**. A molecule of water is removed, leaving an **amide linkage**.

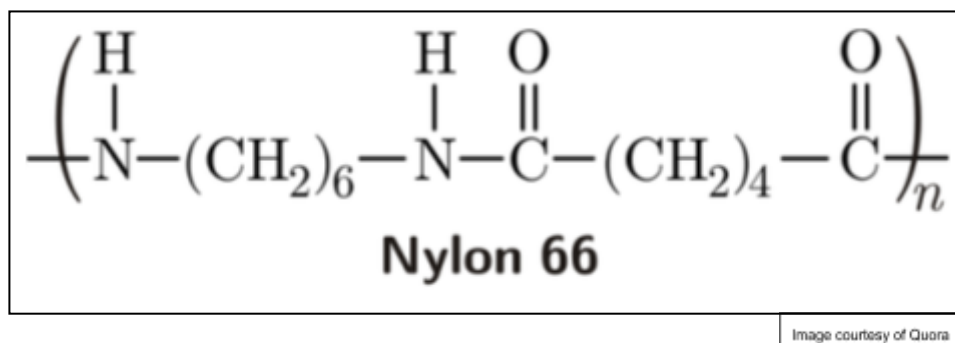
Example:



**-CONH-** is the amide linkage

Examples of polyamides include **nylon-6,6** made from 1,6-diaminohexane and hexanedioic acid.

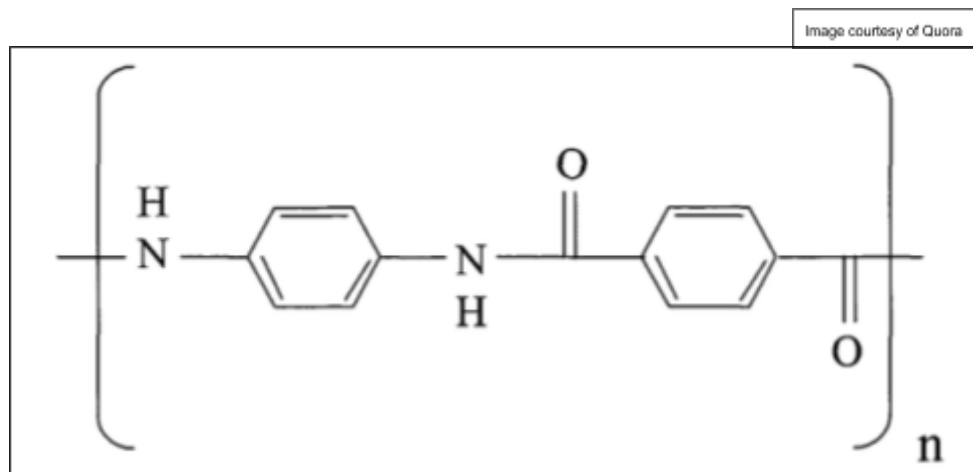
Example:





**Kevlar** is another common polyamide made from benzene-1,4-dicarboxylic acid and 1,4-diaminobenzene.

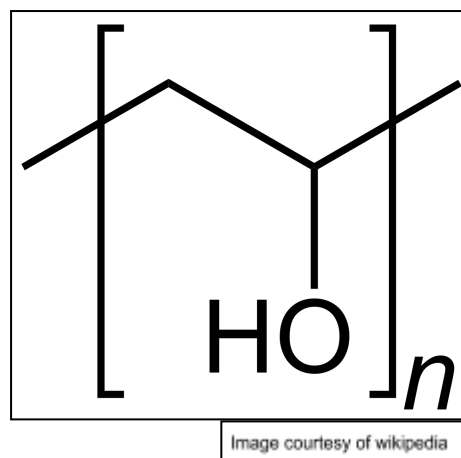
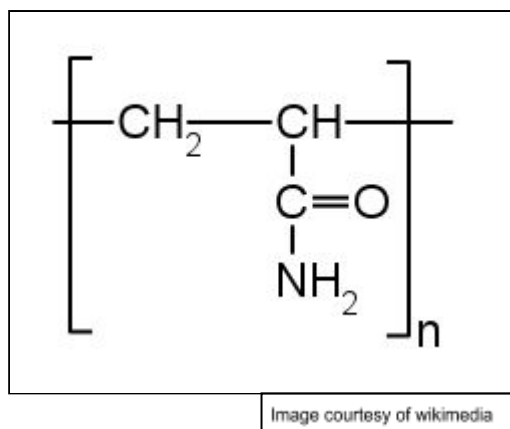
*Example:* Repeat unit of kevlar



Polyamides are commonly formed from **long chain molecules** which makes them **strong**.

Polyamides may also be formed by **addition polymerisation** reactions of monomers that contain both an **amide functional group** and **unsaturated carbon bonds**.

*Examples:* The repeat unit of the polymers poly(propenamide) (left) and poly(ethenol) (right).



### Properties

Polyamides have **high strength** and **resilience**. They are commonly used in carpets, clothing and plastics, amongst other things. They are generally **soluble** in water, since the amide functional group can form **hydrogen bonds** with water.

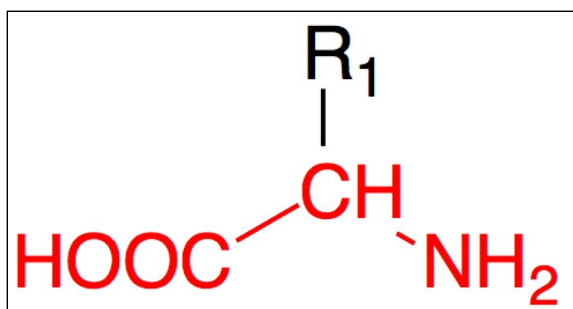


Poly(ethenol) is also a water-soluble polymer. This is due to the presence of the alcohol group which can also form **hydrogen bonds** with water. This property, along with its high tensile strength, means it is used in **soluble laundry bags** and **liquid-detergent capsules**.

## Amino Acids

### Chirality

**α-amino acids** are organic molecules containing a **carboxylic acid group** and an **amine group** bonded to the same carbon atom. Their general structure is shown below, where different amino acids have different chemical groups as the 'R' side chain.



All amino acids, except **glycine**, contain a **chiral carbon** atom bonded to four separate groups. The R group on aminoethanoic acid (glycine) is just a hydrogen atom so the carbon is not bonded to four separate groups.

Since all other amino acids are chiral, they are **optically active**, so a solution of amino acids will **rotate plane-polarised monochromatic light**.

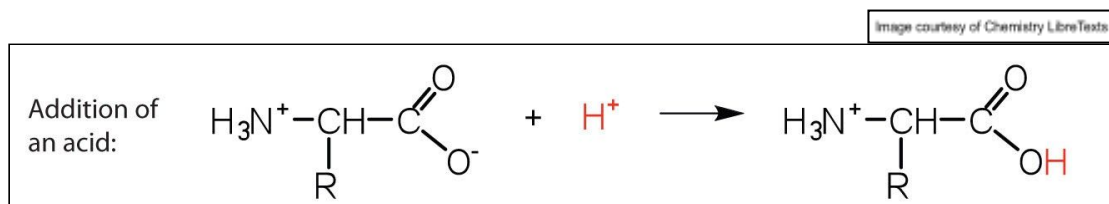
### Zwitterions

The two functional groups within a single molecule mean that amino acids can **react as both acids and bases**, depending on the conditions of the reaction.

A zwitterion is a **dipolar ion**. This means it has a positive charge in one part of the molecule and a negative charge in another part of the molecule. The zwitterionic form of an amino acid is the state in which the amine group has a **positive charge (+NH<sub>3</sub>)** and the carboxyl group has a **negative charge (COO<sup>-</sup>)**.

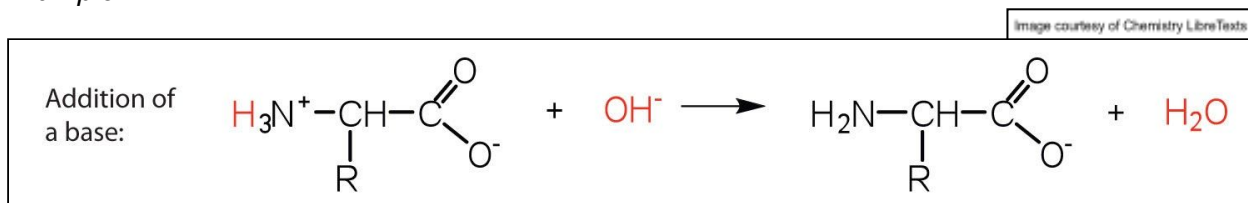
In **acidic conditions (low pH)**, the COO<sup>-</sup> group is more likely to accept a hydrogen ion, producing a **positive (acidic) end** to the molecule.

*Example:*



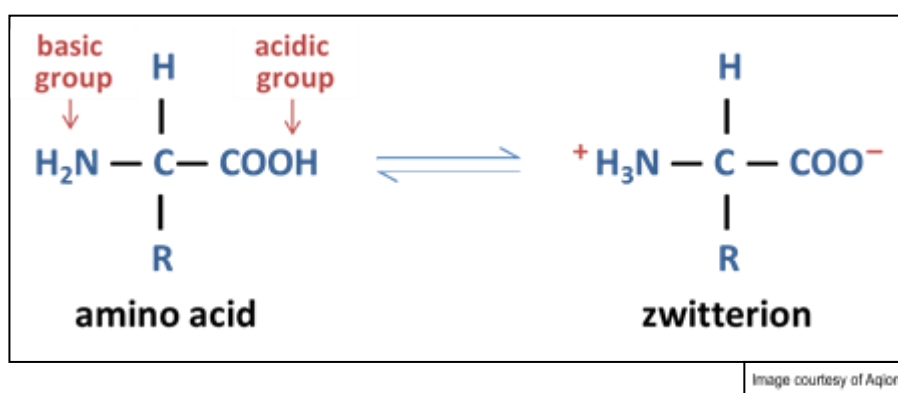
In **basic conditions (high pH)**, the hydrogen ion in the  $\text{NH}_3^+$  group is more likely to be lost, producing a **negative (basic) end** to the molecule.

*Example:*



**Zwitterions** form at the **isoelectric** point. This is the pH at which the overall charge of the molecule is **zero**.

*Example:*

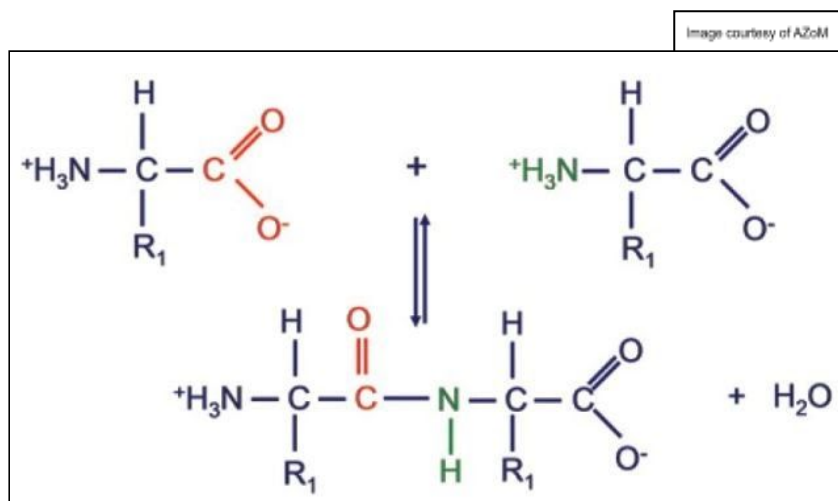


**Thin-layer chromatography** can be used to identify unknown amino acids. UV light is used to help view the traces on the silica plate.

## Proteins

Proteins are another form of condensation polymer formed from sequences of amino acids joined together by **peptide bonds**.

*Example:*



**-CONH-** is the peptide bond/amide linkage

