Cambridge (CIE) A Level Chemistry

Your notes

Amino Acids

Contents

Your notes

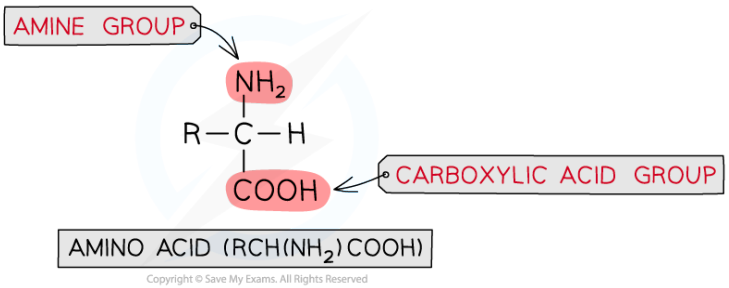
Acid / Base Properties of Amino Acids, Zwitterions & the Isoelectric Point

- **Amino acids** are **organic compounds** that contain two functional groups:
  - A basic **amino** (-NH_2) group
  - An acidic **carboxylic acid** (-COOH) group
- Due to the presence of both a **basic** and **acidic** group in amino acids, they are said to be **amphoteric**
  - They can act as both acids and bases

Naturally occurring amino acids

- **2-aminocarboxylic acids** are a type of amino acid where the amine (-NH_2) group is bonded to the carbon atom **next** to the -COOH group
- These types of amino acid form the 'building blocks' that make up **proteins**
- There are **20** naturally occurring amino acids with the general structural formula of **RCH(NH_2)COOH**

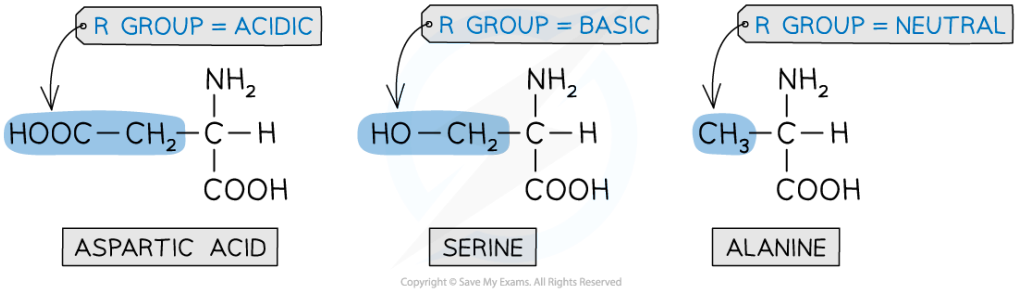
General structural formula of amino acids



In most amino acids, the amine group is bonded to the carbon directly adjacent to the carboxylic acid group

- The **R** group varies in different amino acids and can be:
  - Acidic
  - Basic
  - Neutral

Example amino acids with different R groups

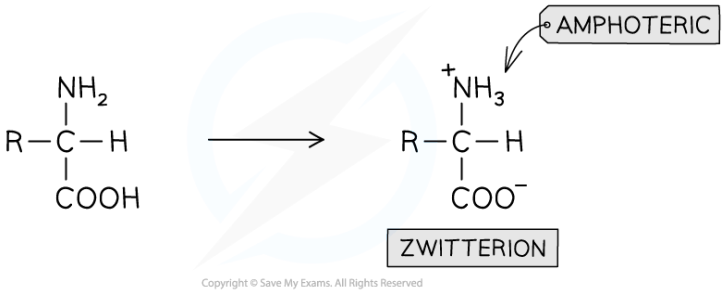


The R group in amino acids can be acidic (aspartic acid), basic (serine) or neutral (alanine)

Acid / base properties of amino acids

- Amino acids will undergo most reactions of amines and carboxylic acids including acid-base reactions of:
  - Amines with acids
  - Carboxylic acids with bases
- However, they can also interact **intramolecularly** (within themselves) to form a **zwitterion**
- A zwitterion is an ion with both a **positive** ($-NH_3^+$) and a **negative** ($-COO^-$) charge
- Because of these charges in a zwitterion, there are **strong intermolecular forces of attraction** between amino acids
  - Amino acids are therefore **soluble crystalline solids**

Zwitterion formation within an amino acid



An amino acid molecule can interact within itself to form a zwitterion

Isoelectric point

- A solution of amino acids in water will exist as **zwitterions** with both **acidic** and **basic** properties
- They act as **buffer solutions** as they resist any changes in pH when **small** amounts of acids or alkali are added

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- If an acid is added (and thus the pH is **lowered**):
  - The -COO^- part of the zwitterion will **accept** an H^+ ion to reform the -COOH group
  - This causes the zwitterion to become a **positively charged ion**
- If a base is added (and thus the pH is **raised**):
  - The -NH_3^+ part of the zwitterion will **donate** an H^+ ion to reform the -NH_2 group
  - This causes the zwitterion to become a **negatively charged ion**

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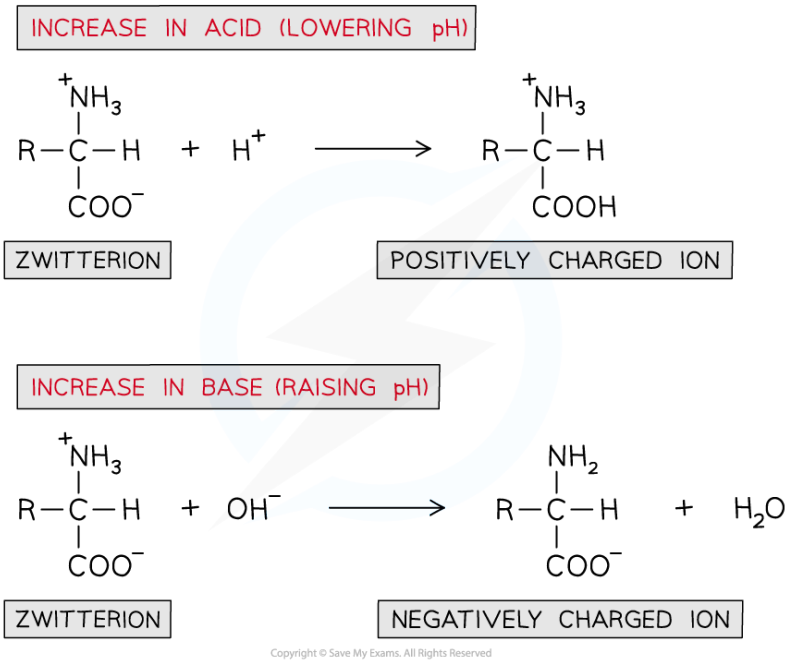
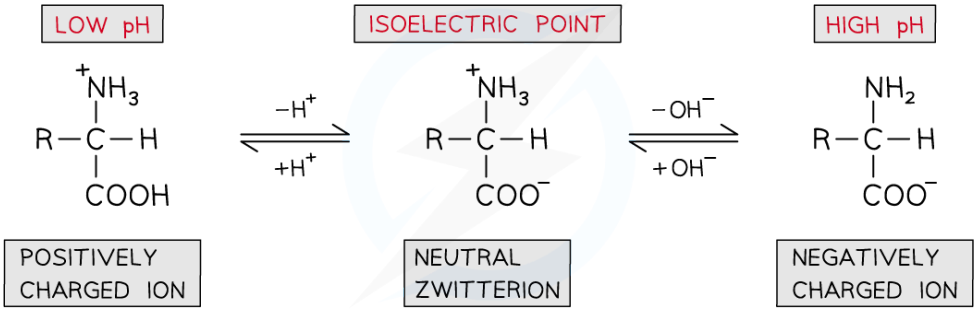
The effect of changing pH on zwitterions



An amino acid solution can act as a buffer solution by resisting any small changes in pH

- The pH can be slightly adjusted to reach a point at which neither the **negatively charged** or **positively charged** ions dominate and the amino acid exists as a **neutral zwitterion**
  - This is called the **isoelectric point** of the amino acid

The isoelectric point of an amino acid



The isoelectric point of amino acids is the pH at which the amino acid exists as a neutral zwitterion

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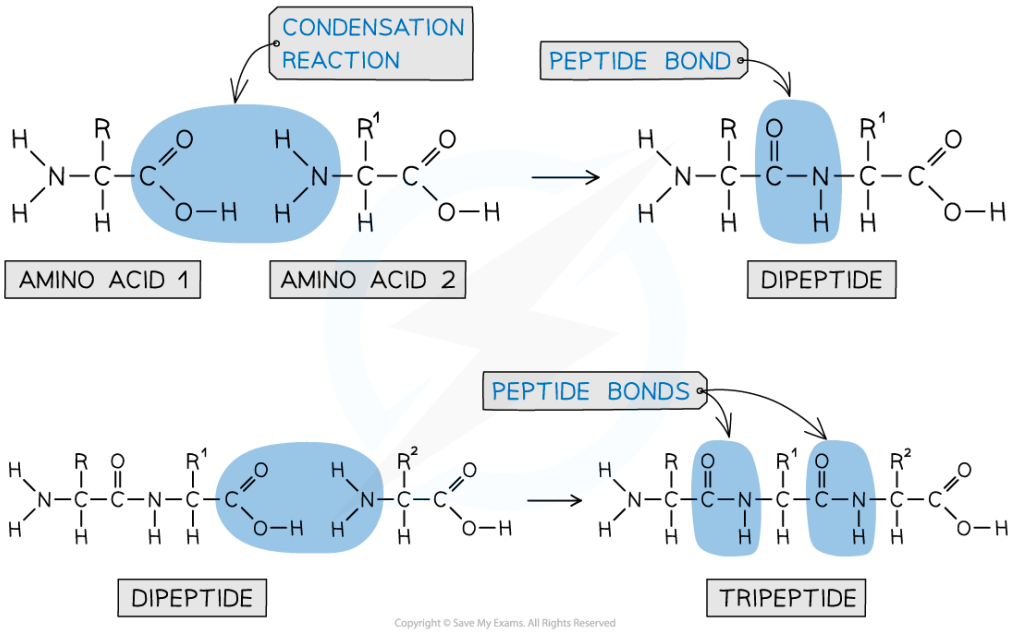
Formation of Peptide Bonds

- Each amino acid contains an amine ($-NH_2$) and carboxylic acid (-COOH) group
- The $-NH_2$ group of **one amino acid** can react with the -COOH group of **another amino acid** in a **condensation reaction** to form a **dipeptide**
  - The new **amide bond** between two amino acids is also called a **peptide link** or **peptide bond**
- Since this is a condensation reaction, a small molecule (in this case H_2O) is **eliminated**
- The **dipeptide** still contains an $-NH_2$ and -COOH group at each end of the molecule which can again participate in a condensation reaction to form a **tripeptide**

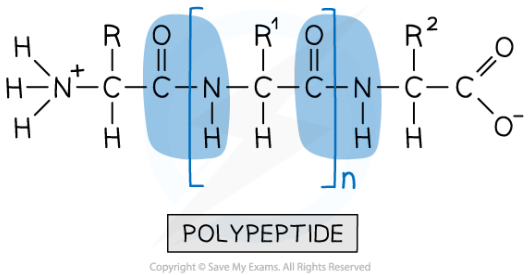
Peptide bonds



A peptide bond is an amide bond between two amino acids

- A **polypeptide** is formed when **many** amino acids join together to form a long chain of molecules

Showing polypeptides



A polypeptide is a long chain of amino acid molecules joined together

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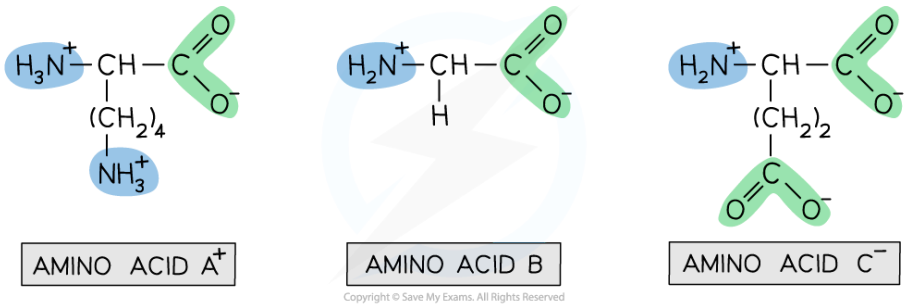
Electrophoresis

- **Electrophoresis** is an **analytical technique** which separates ions by placing them in an electrical field
  - This method is often used in **biochemical analysis** to **identify** and **purify** proteins
- A sample of amino acids is placed between **two oppositely charged electrodes**
  - The positively charged ions will move towards the **negative electrode**
  - The negatively charged ions will move towards the **positive electrode**
- The **rate** (how fast) at which the ions move towards the electrodes depends on:
  - The **size** of the ions: larger ions move **more slowly**
  - The **charge** of the ions: highly charged ions move **more quickly**
- An **electropherogram** is the series of bands which are observed on the paper or gel after **electrophoresis** has occurred
  - Each band in the electropherogram corresponds to a particular species

Separating mixtures of amino acids by varying the pH

- The charge on the **amino acid ions** depends on the pH of the solution
- The movement of the ions to the electrodes during electrophoresis will therefore be affected by the pH
- Consider a sample which consists of a **mixture** of three amino acids at pH 7
  - Amino acid **A**: lysine, side-chain is **positively charged**
  - Amino acid **B**: glycine, side chain is **neutral**
  - Amino acid **C**: glutamic acid, side chain is **negatively charged**

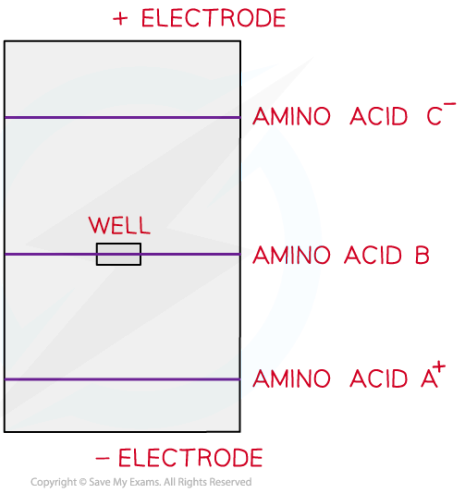
The different amino acids within the sample



The sample consists of a mixture of three amino acids which are separated using electrophoresis

- The amino acids in this mixture can be separated by electrophoresis
  - Amino acid **C** will move towards the **positive** electrode
  - Amino acid **B** will remain in the **well** where the sample is applied to the gel
  - Amino acid **A** will move towards the **negative** electrode
- Since glutamic acid is **larger** than lysine, it will travel towards the positive electrode at a **slower rate** compared to lysine

Separation of a mixture of amino acids by electrophoresis



During electrophoresis, positive amino acids move to the negative electrode and negative amino acids move to the positive electrode

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