Edexcel International A Level (IAL) Chemistry

Your notes

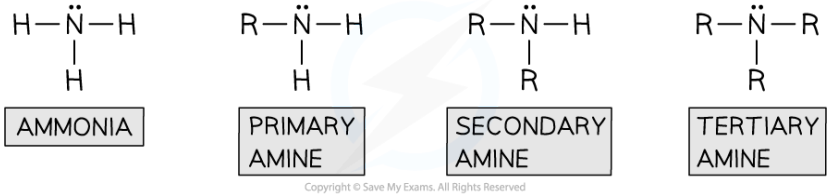
Organic Chemistry: Nitrogen Compounds

Contents

Your notes

Amines, Amides & Amino Acids – Introduction

- **Amines** can be thought of as derivates of ammonia, in which one or more of the hydrogens is replaced by an alkyl or aryl group
- The number of substituted hydrogens is the basis of classifying amines



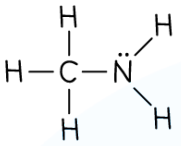
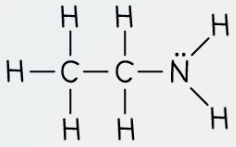
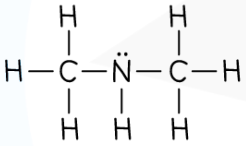
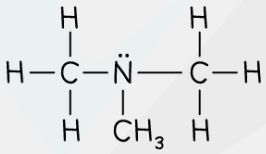
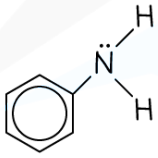
Classification of amines

- Notice the classification is not the same as in alcohols and haloalkanes, where the designation primary, secondary and tertiary is based on the substituents on the *carbon* atom rather than the *nitrogen* atom
- If the R group is an alkyl group (methyl, ethyl, etc) then then it is an **aliphatic amine;** if it is an aryl group (benzene ring or phenyl) then it is an **aromatic amine**
- Aliphatic and aromatic amines share similar chemical reactions and the aryl group can strongly influence the chemistry and reactivity of the amine group

Naming Amines

- Amines can be named using common names or IUPAC systematic names
- The common way to name amines is to use the alkyl (or aryl) prefix followed by **-amine**
- The IUPAC systematic name uses the numbered prefix **amino-** followed by the alkane (or aromatic) stem

Nomenclature of Aliphatic and Aromatic Amines Table

Structural Formula	Name	Molecular Formula
	methylamine or aminomethane	CH_5N
	ethylamine or aminoethane	C_2H_7N
	dimethylamine or N–methyl aminomethane	C_2H_7N
	trimethylamine or N,N–dimethyl aminomethane	C_3H_9N
	phenylamine or aminobenzene	C_6H_7N

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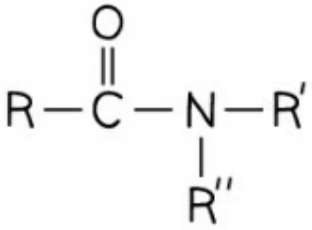
Amides

- **Amides** are formed from the **condensation reaction** of **carboxylic acids** or **acyl chlorides** with **ammonia** or **amines**
- Amides are common in nature such as in proteins where the amine and carboxylic acid groups of amino acids bond together
- Amides have a general structure of $RCONR_2$



The general structure of an amide

- Amides can be classified as primary, secondary or tertiary amides
- Like amines, this is done as a comparison to ammonia, depending on the number of substitutions on the amide nitrogen
  - Primary amide - one carbon bonded to the amide nitrogen
    - R' and R'' are both hydrogen atoms so one "ammonia" hydrogen has been substituted with the carbonyl group from the RCO portion of the molecule
  - Secondary amide - two carbons bonded to the amide nitrogen (one MUST be the carbonyl carbon)
  - Tertiary amide - three carbons bonded to the amide nitrogen (one MUST be the carbonyl carbon)

Naming primary amides

- For primary amides, we simply add -amide to the stem name
  - e.g. CH_3CONH_2
    - Contains two carbons with a C-C (ethan-) and an amide group (-amide)
    - This gives us ethanamide

Naming secondary amides

- For secondary amides, the alkyl chain attached to the nitrogen is added at the start of the chemical name
- This alkyl chain is prefixed with N-
- The chain containing the carbonyl group is named the same as a primary amide
  - e.g. CH3CONH(C_3H_7)
    - Contains a propyl group on the nitrogen (N-propyl)
    - Contains two carbons with a C-C (ethan-) and an amide group (-amide)
    - This gives us N-propylethanamide

Naming tertiary amides

- For tertiary amides, there are two alkyl chains attached to the nitrogen
- The naming of these chains is the same as secondary amides
- As with standard nomenclature, these chains are listed in alphabetical order and the prefix 'di-' is used if necessary
  - e.g. CH3CONCH$_3$(C_3H_7)
    - Contains a methyl group on the nitrogen (N-methyl)
    - Contains a propyl group on the nitrogen (N-propyl)

Your notes

- Contains two carbons with a C-C (ethan-) and an amide group (-amide)
- This gives us N-methyl-N-propylethanamide

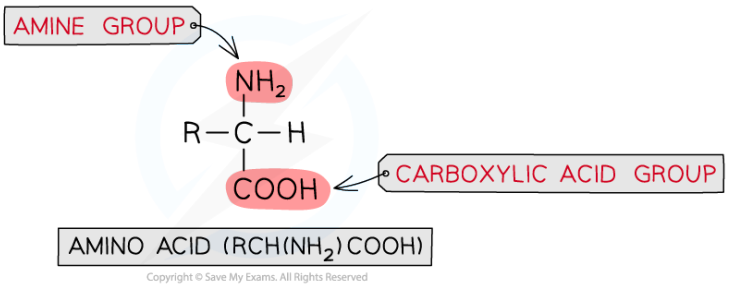
Your notes

Amino acids

- **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

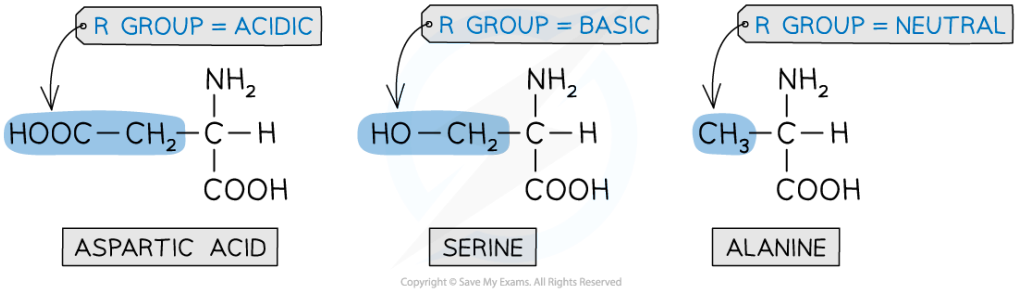
- 2–aminocarboxylic acids are a type of amino acids in which the amine ($-NH_2$) group is bonded to the carbon atom next to the -COOH group
- These type of amino acids form the 'building blocks' that make up **proteins**
- There are 20 naturally occurring amino acids with the general structural formula of **RCH(NH2)COOH**



General structural formula of amino acids

General structural formula of amino acids

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



The R group varies in different amino acids

Your notes

Your notes

Primary Aliphatic Amines – Reactions

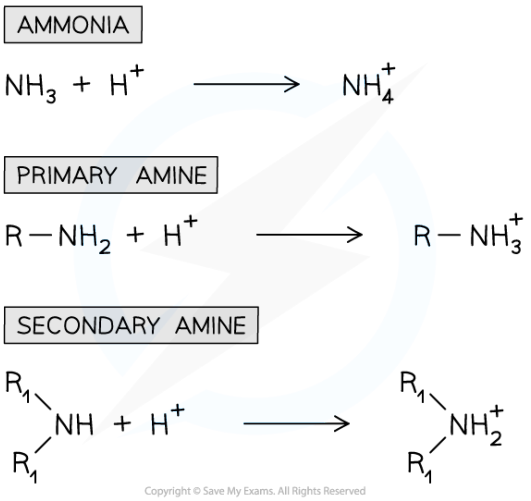
Reactions with water

- The first few members of the homologous series of primary aliphatic amines are miscible with water
  - However as the hydrocarbon part of the molecule becomes longer, the solubility decreases
  - Phenylamine is only slightly soluble in water
- They dissolve in water as they are able to form hydrogen bonds with water molecules
- Amines also react slightly with water to form alkaline solutions

$$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$$

Amine basicity

- The nitrogen atom in ammonia and amine molecules can **accept** a **proton** (H^+ ion)
- They can therefore act as Bronsted-Lowry **bases** in aqueous solutions by **donating** its lone pair of electrons to a proton and form a **dative bond**

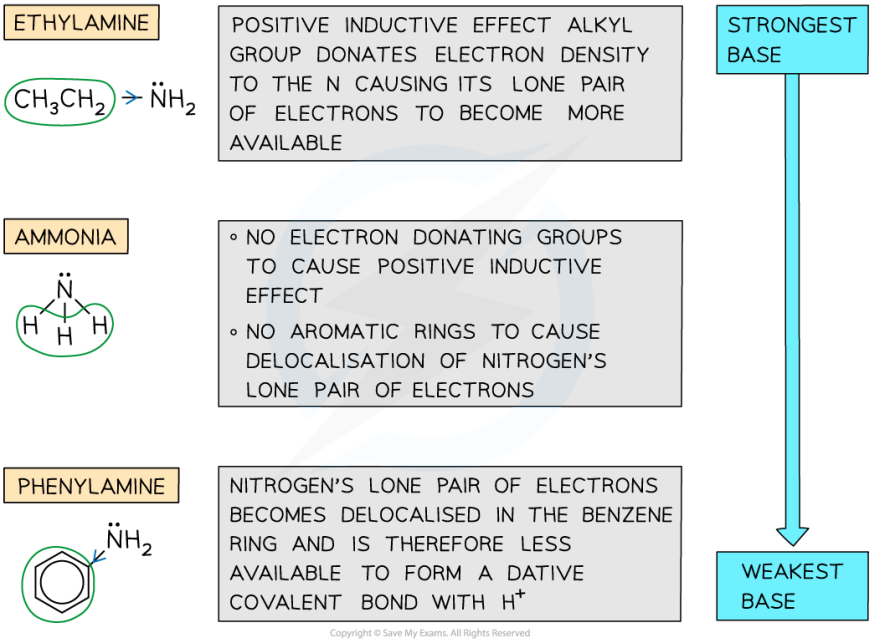


The nitrogen atom in ammonia and amines can donate its lone pair of electrons to form a bond with a proton and therefore act as a base

- The **strength** of amines depends on the **ability** of the lone pair of electrons on the nitrogen atom to accept a proton and form a dative covalent bond
- The **more readily** a proton is attracted, the **stronger the base** is
- Factors that may affect the **basicity** of amines include:

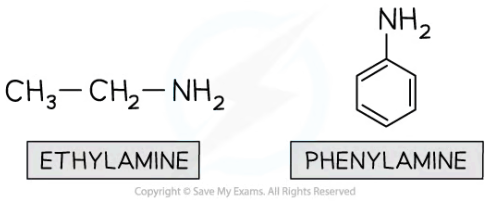
- **Positive inductive effect** - Some groups such as **alkyl groups** donate electron density to the nitrogen atom causing the lone pair of electrons to become more available and therefore **increasing** the amine's **basicity**
- **Delocalisation** - The presence of aromatic rings such as the **benzene ring** causes the lone pair of electrons on the nitrogen atom to be **delocalised** into the benzene ring
- The lone pair becomes **less available** to form a dative covalent bond with ammonia and hence **decreases** the amine's **basicity**

- 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
- Secondary amines are stronger bases than primary amines because they have more alkyl groups that are substituted onto the nitrogen atom in place of hydrogen atoms
  - Therefore more electron density is pushed onto the nitrogen atom (as the inductive effect of alkyl groups is greater than that of hydrogen atoms)



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 nitrogen is less able to accept protons
- Ethylamine (which has an electron-donating ethyl group) is **more basic** than **phenylamine** (which has an electron-withdrawing benzene ring)



Your notes

Ethylamine is more basic than phenylamine due to electron donating ethyl group which increases electron density on the nitrogen and makes it more attractive to protons

Reactions with acids

- Amines react with strong acids to form ionic ammonium salts

$CH_3NH_2\ (aq) + HCl\ (aq) \rightarrow CH_3NH_3^+Cl^-\ (aq)$ Methylamine methylammonium chloride

- 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
- 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 phenylammonium chloride is soluble

Reactions with ethanoyl chloride

- This reaction type is addition-elimination reaction meaning two molecules join together, and then a small molecule is eliminated - in these examples, hydrogen chloride
  - You do not need to know the mechanism of these reactions
- The organic product contains a new functional group - amide - in which a carbonyl group is next to an NH group
- The equation for the reaction of butylamine with ethanoyl chloride is

$$CH_3COCl + CH_3CH_2CH_2CH_2NH_2 \rightarrow CH_3CONHCH_2CH_2CH_2CH_3 + HCl$$

Reaction with halogenoalkanes

- Again you do not need to know the mechanism for these reactions
- The electron-deficient carbon atom in the halogenoalkane and the electron-rich atom nitrogen atom in the amine causes these two species to react together
- The general formula for this reaction would be

$$R'NH_2 + R''X \rightarrow R'NHR'' + HX$$

- Where R' is the alkyl group in the amine and R" is the alkyl group in the halogenoalkane
- This reaction is an example of a substitution reaction

- The organic product is a secondary amine and the inorganic product is a hydrogen halide, often hydrogen chloride
- As an example, the equation for the reaction of butylamine and chloroethane is

$$CH_3CH_2CH_2CH_2NH_2 + CH_3CH_2Cl \rightarrow CH_3CH_2CH_2CH_2NHCH_2CH_3 + HCl$$

- The organic product contains an electron-rich nitrogen atom, so can also react with chloroethane

$$CH_3CH_2CH_2CH_2NHCH_2CH_3 + CH_3CH_2Cl \rightarrow CH_3CH_2CH_2CH_2N(CH_2CH_3)_2 + HCl$$

- The organic product of this reaction is a tertiary amine
- The organic product also contains an electron-rich nitrogen atom, so can also react with chloroethane

$$CH_3CH_2CH_2CH_2N(CH_2CH_3)_2 + CH_3CH_2Cl \rightarrow CH_3CH_2CH_2CH_2N^+(CH_2CH_3)_3Cl^-$$

- In this reaction HCl is not formed because this would require the loss of H from the nitrogen from the organic reactant, which the tertiary amine doesn't have
- The product is an ionic compound related to ammonium chloride except that all the hydrogens in the ammonium ion have been replaced by alkyl groups
  - This is known as a quaternary ammonium salt

Reactions with copper(II) ions

- Ammonia can act as a lone pair donor in its reactions with transition metal ions
- For example the overall equation for the reaction of ammonia with hexaaquacopper(II) ions is

$$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_20$$

- Amines also have a lone pair of electrons on the nitrogen, so can take part in similar reactions
- The observations are the same as with ammonia
  - A blue precipitate forms
  - With excess butylamine the precipitate dissolves to give a blue solution
- Formation of the pale blue precipitate

$$[Cu(H_2O)_6]^{2+} + 2CH_3CH_2CH_2CH_2NH_2 \rightarrow [Cu(H_2O)_4(OH)_2] + 2CH_3CH_2CH_2CH_2NH_3^+$$

- Formation of the deep blue solution

$$[Cu(H_2O)_4(OH)_2] + 4CH_3CH_2CH_2CH_2NH_2 \rightarrow [Cu(CH_3CH_2CH_2CH_2NH_2)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$$

Primary Aliphatic Amines – Preparation

Preparing Amines

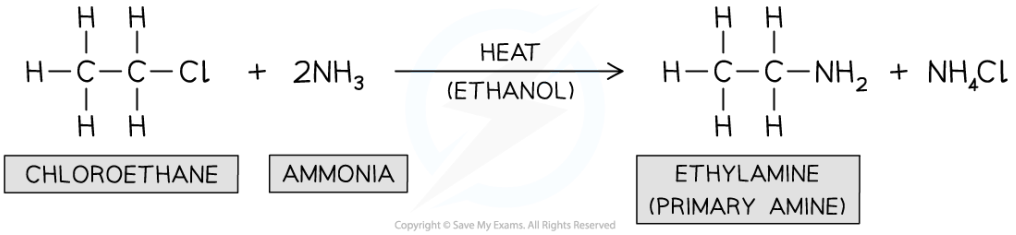
Your notes

- Primary amines can be prepared from different reactions including:
  - The reaction of halogenoalkanes with ammonia
  - The reduction of nitriles

Your notes

Reaction of halogenoalkanes with ammonia

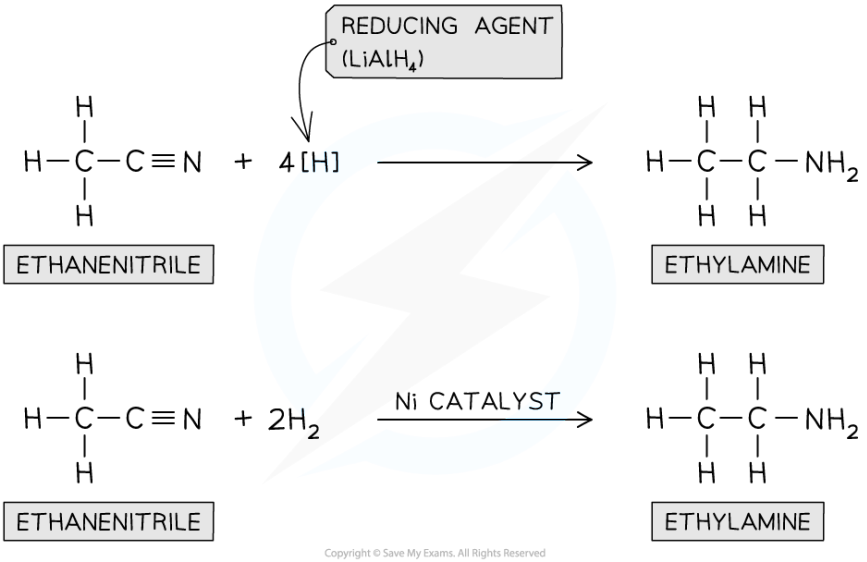
- This is a **nucleophilic substitution** reaction in which the nitrogen lone pair in ammonia acts as a **nucleophile** and **replaces** the halogen in the halogenoalkane
- When a halogenoalkane is reacted with **excess, hot ethanolic ammonia under pressure** a **primary amine** is formed



Formation of primary amine

Reduction of nitriles

- Nitriles contain a -CN functional group which can be **reduced** to an -NH_2 group
- The nitrile vapour and **hydrogen gas** are passed over a **nickel catalyst** or **$LiAlH_4$** in **dry ether** can be used to form a **primary amine**

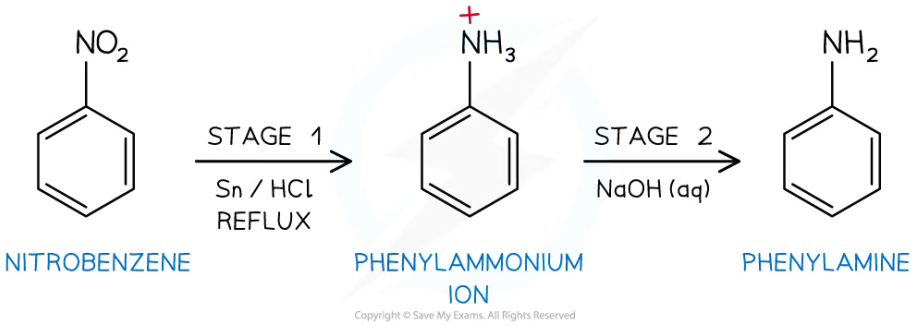


Nitriles can be reduced with $LiAlH_4$ or H_2 and Ni catalyst

Your notes

Aromatic Amine – Formation

- **Phenylamine** is an organic compound consisting of a benzene ring and an **amine** (NH_2) functional group
  - Phenylamine is sometimes known as aminobenzene or aniline
- Nitrobenzene, $C_6H_5NO_2$, can be reduced to phenylamine, $C_6H_5NH_2$, according to the following two-stage reaction:



The two-stage reduction reaction of nitrobenzene to phenylamine

Stage 1 – Reduction of nitrobenzene

- Nitrobenzene, $C_6H_5NO_2$, is reacted with tin, Sn, and concentrated hydrochloric acid, HCl
  - The combination of tin and hydrochloric acid acts as a reducing agent
- The reaction mixture is heated under reflux in a boiling water bath
- The nitrobenzene has been reduced, in the presence of acid, by gaining electrons from tin
  - The tin is oxidised to a mixture of tin(II), Sn^{2+}, and tin(IV), Sn^{4+}
- The reduction reaction of nitrobenzene does not form phenylamine directly
- Due to the acidic conditions, the reduction reaction forms the phenylammonium ion, $C_6H_5NH_3^+$

Stage 2 – Formation of phenylamine

- Excess sodium hydroxide solution, NaOH (aq), is added to the phenylammonium ions, $C_6H_5NH_3^+$
  - This causes them to deprotonate and form the desired phenylamine product
  - A mixture of tin compounds, including tin(II) hydroxide and tin(IV) hydroxide is also formed from reactions between the sodium hydroxide solution and the tin ions in stage 1

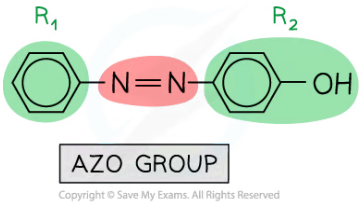
Stage 3 – Purification of phenylamine

- The crude phenylamine product undergoes steam distillation to produce a cloudy distillate
- Sodium chloride is added to the distillate before the mixture is added to a separating funnel
- Ether is added to the separating funnel resulting in an aqueous layer at the bottom and an organic layer, containing the phenylamine, on the top
  - The sodium chloride aids separation by increasing the polarity of the aqueous layer causing the phenylamine to "salt out" into the organic layer
- The aqueous layer is discarded and the organic layer is distilled
  - The ether will boil off easily and is discarded
  - The phenylamine fraction that boils off at 180 - 185 °C is retained and can have its boiling point tested to check the purity of the product

Your notes

Aromatic Amine – Reactions

- **Azo** (or **diazonium**) **compounds** are organic compounds that have an R_1-N=N-R_2 group
- They are often used as **dyes** and are formed in a **coupling reaction** between the **diazonium ion** and an **alkaline solution** of **phenol**



Azo compounds are characterized by the presence of an R_1-N=N-R_2 group

Coupling of benzenediazonium chloride with phenol in NaOH

- Azo compounds can be formed from the coupling reaction of a **benzenediazonium chloride salt** with **alkaline phenol**
- Making an azo dye is a **multi-step process**

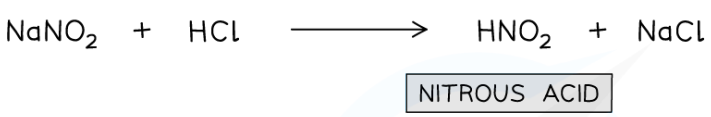
Formation of Azo Compounds Table

Step	Description	Reaction Conditions
1. Formation of nitrous acid	Nitrous acid is very unstable so has to be made in a test tube using sodium nitride (NaNO2) and hydrochloric acid	N/A

2. Diazotization	The reaction between nitrous acid and phenylamine to form the diazonium ion is called diazotization	The reaction mixture must be kept below 10°C using ice as otherwise the diazonium ion will thermally decompose to benzene and nitrogen (N_2) Dilute acid (such as HCl)
3. Coupling reaction	The diazonium ion acts as an electrophile and substitutes into the benzene ring of the phenol at the 4th position	Alkaline conditions are required to deprotonate the organic product and form the azo compound

Your notes

STEP 1: FORMATION OF NITROUS ACID



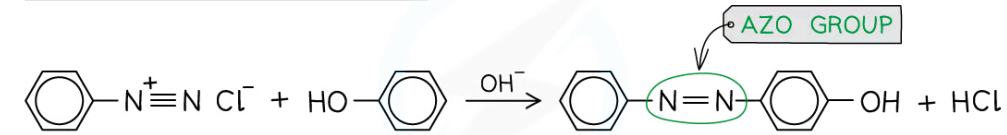
NITROUS ACID

STEP 2: DIAZOTIZATION

PHENYLAMINE

BENZENEDIAZONIUM CHLORIDE

STEP 3: COUPLING REACTION



BENZENEDIAZONIUM CHLORIDE

PHENOL

AZO DYE

Reaction mechanism of the formation of azo compounds

- The **delocalised** electrons in the π bonding systems of the two benzene rings are **extended** through the -N=N- which acts as a **bridge** between the two rings
- As a result of the delocalisation of electrons throughout the compound, azo compounds are **very stable**

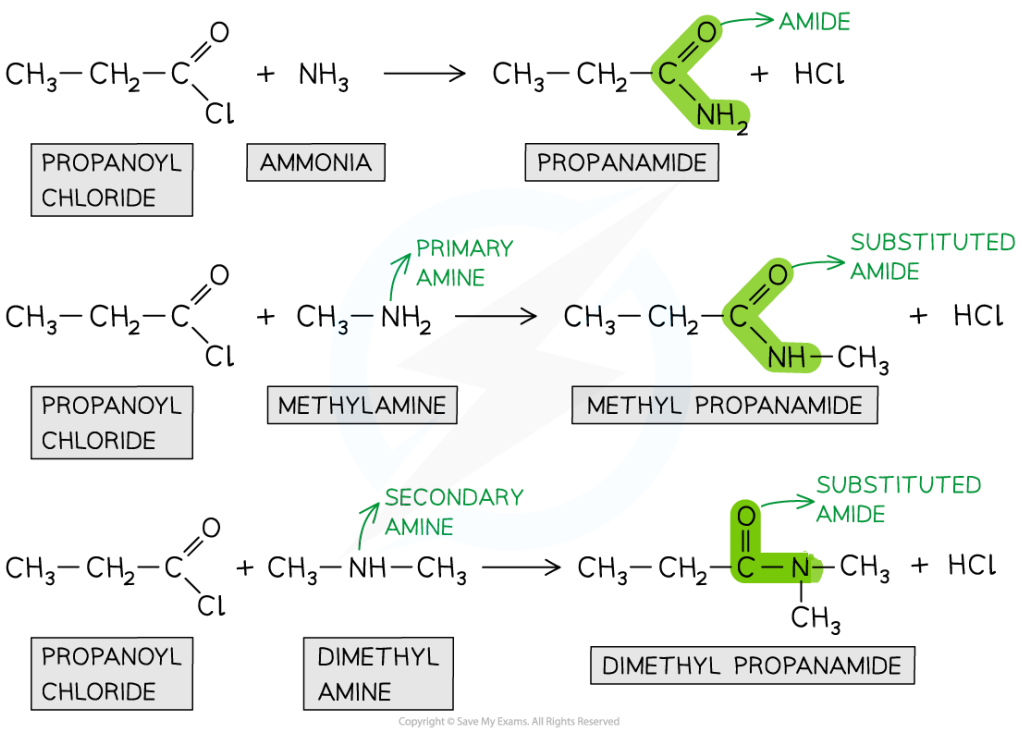
Your notes

Amide Formation

- **Amides** are organic compounds with an -$CONR_2$ functional group
- They can be prepared from the **condensation reaction** between an **acyl chloride** and **ammonia** or **amine**
- In a **condensation** reaction, two organic molecules **join together** and in the process **eliminate** a small molecule
- In this case, the acyl chlorides and ammonia or amine **join together** to form an **amide** and **eliminate** an HCl molecule

Condensation reaction

- The chlorine atom in acyl chlorides is **electronegative** and draws electron density from the carbonyl carbon
- The carbonyl carbon is therefore **electron-deficient** and can be attacked by **nucleophiles**
- The nitrogen atom in ammonia and amines has a lone pair of electrons which can act as a **nucleophile** and attack the carbonyl carbon
- As a result, the C-Cl bond is **broken** and an **amide** is formed
- Whether the product is a **substituted** amide or not, depends on the nature of the **nucleophile**
  - Primary and secondary amines will give a **substituted amide**
  - The reaction of acyl chlorides with ammonia will produce a **non-substituted amide**



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Acyl chlorides undergo condensation reactions with ammonia and amines to form amides

- Note that ammonia is basic and the inorganic product is acidic, so there will be a reaction between the two molecules

$$NH_3 + HCl \rightarrow NH_4Cl$$

- We can therefore write the overall equation for the reaction of propanoyl chloride and ammonia as

$$CH_3CH_2COCl + 2NH_3 \rightarrow CH_3CH_2CONH_2 + NH_4Cl$$

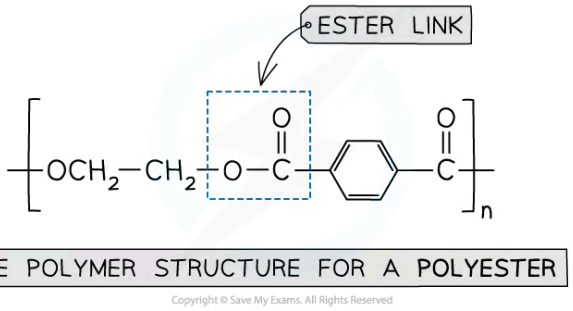
Your notes

Condensation & Addition Polymerisation

- Addition polymerisation has been covered in reactions of alkenes
  - They are made using monomers that have C=C double bonds joined together to form polymers such as polyethene
- Condensation polymerisation is another type of reaction whereby a polymer is produced by repeated condensation reactions between monomers
- Natural condensation polymers are all formed by **elimination of water**
  - Although the process of **condensation** polymerisation involves the **elimination of a small molecule**
- **Condensation polymers** can be identified because the monomers are linked by **ester** or **amide bonds**
- Condensation polymers can be formed by:
  - dicarboxylic acids and diols
  - dicarboxylic acids and diamines
  - amino acids

Polyester

- Is formed by the reaction between **dicarboxylic acid monomers** and **diol monomers**
- Polyester is produced by linking these monomers with **ester bonds / links**

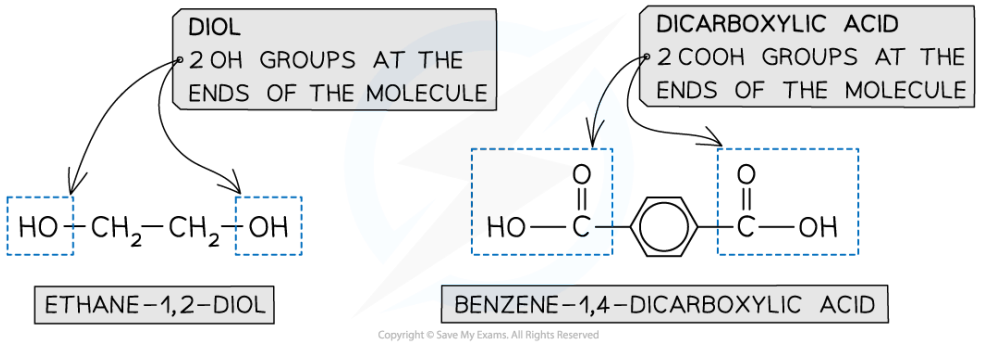


THE POLYMER STRUCTURE FOR A POLYESTER

This polymer structure shows an ester functional group linking monomers together

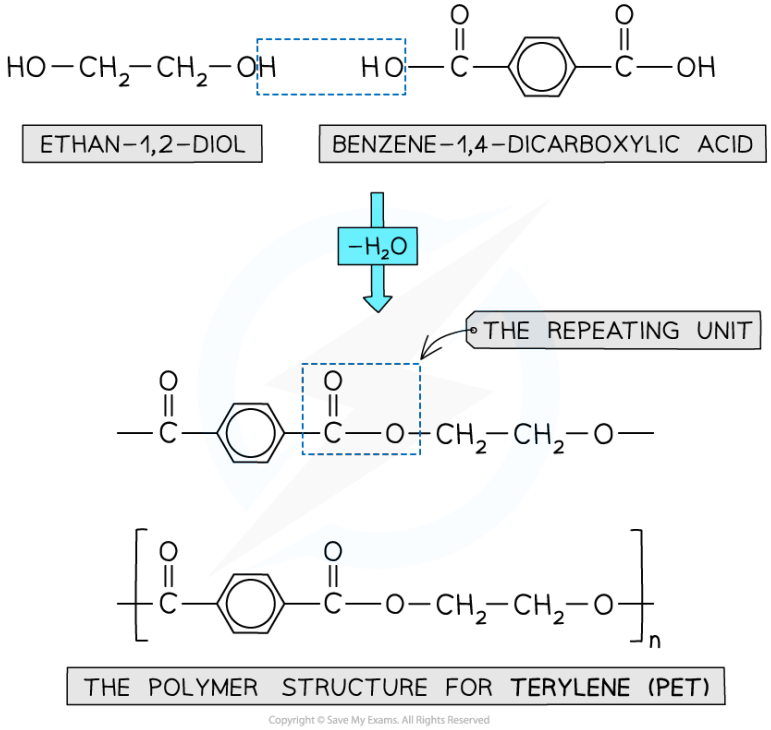
Formation of polyesters

- A diol and a dicarboxylic acid are required to form a polyester
  - A diol contains 2 -OH groups
  - A dicarboxylic acid contains 2 -COOH groups



The position of the functional groups on both of these molecules allows condensation polymerisation to take place effectively

- When the polyester is formed, one hydrogen atom from the diol and one of the -OH group from the -COOH are expelled as a water molecule (H_2O)
- The resulting polymer is a polyester
  - In this example, the polyester is **poly(ethylene terephthalate)** or PET, which is sometimes known by its brand names of Terylene or Dacron



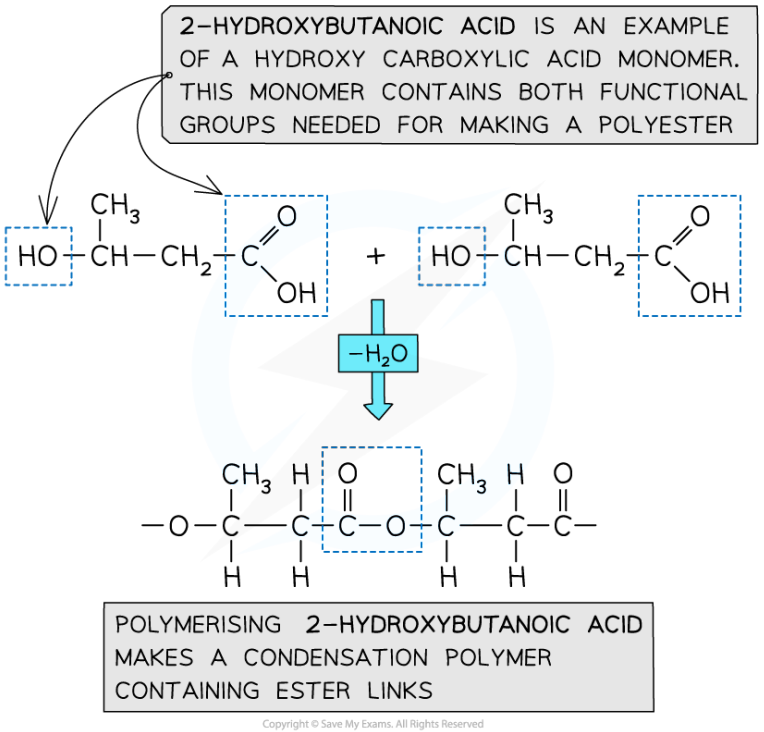
Expulsion of a water molecule in this condensation polymerisation forms the polyester called (ethylene terephthalate) (PET)

Formation of polyesters – hydroxycarboxylic acids

- So far the examples of making polyesters have focused on using 2 separate monomers for the polymerisation

Your notes

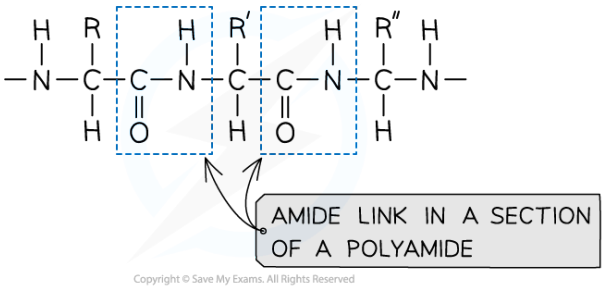
- There is another route to making polyesters
- A single monomer containing both of the key functional groups can also be used
- These monomers are called hydroxycarboxylic acids
  - They contain an alcohol group (-OH) at one end of the molecule while the other end is capped by a carboxylic acid group (-COOH)



Both functional groups that are needed to make the polyester come from the same monomer

Polyamides

- Polyamides are polymers where repeating units are bonded together by amide links
- The formula of an amide group is -CONH



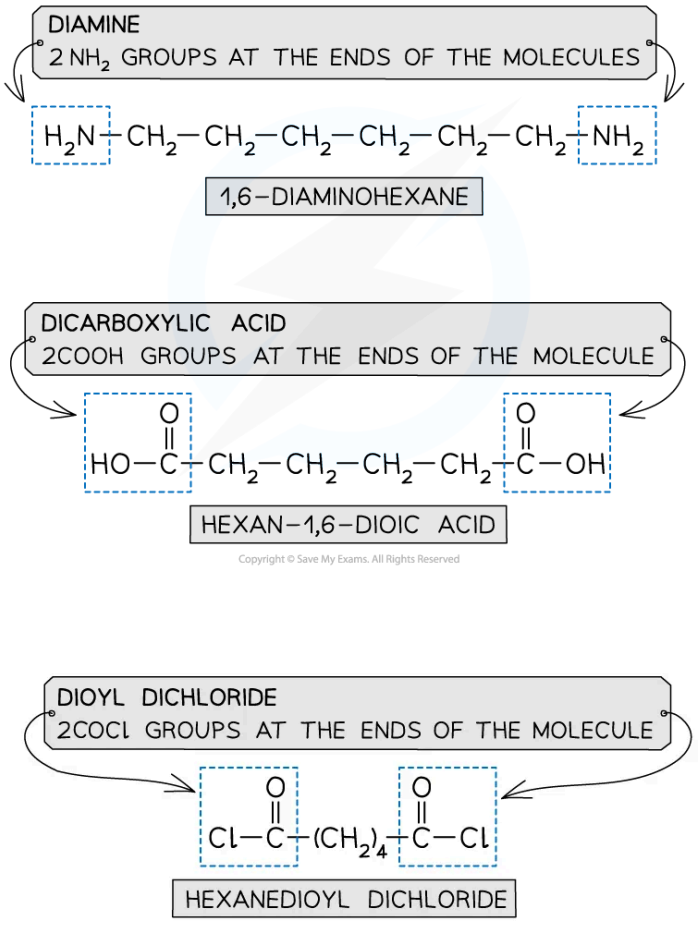
An amide link - also known as a peptide link - is the key functional group in a polyamide

Your notes

Polyamide monomers

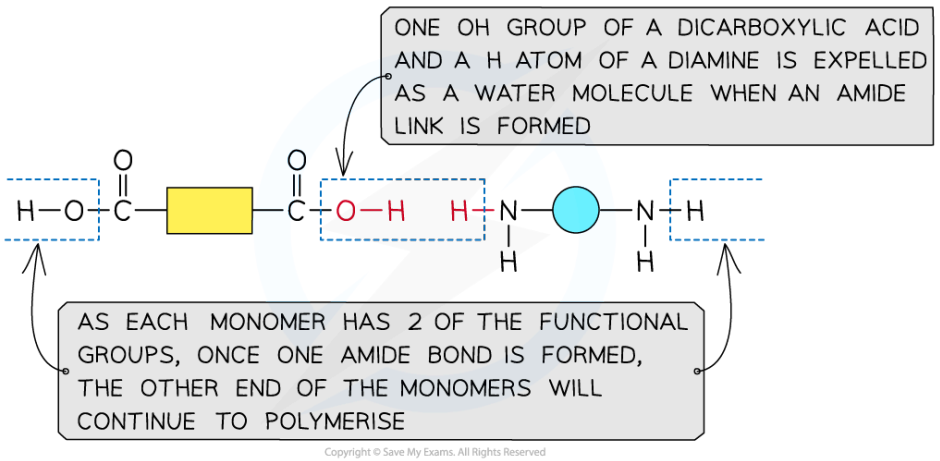
Your notes

- A diamine and a dicarboxylic acid are required to form a polyamide
  - A diamine contains 2 -NH_2 groups
  - A dicarboxylic acid contains 2 -COOH groups
- Dioyl dichlorides can also used to react with the diamine instead of the acid
  - A dioyl chloride contains 2 -COCl groups
  - This is a more reactive monomer but more expensive than dicarboxylic acid



The monomers for making polyamides

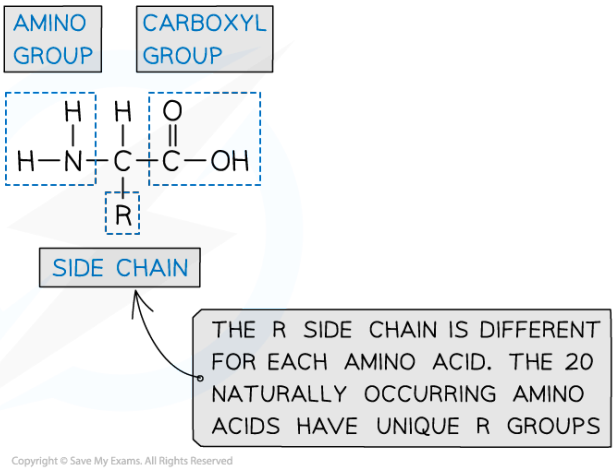
Formation of polyamides



This shows the expulsion of a small molecule as the amide link forms

Amino acids – formation of proteins

- Proteins are vital biological molecules with varying functions within the body
- They are essentially polymers made up of amino acid monomers
- Amino acids have an aminocarboxylic acid structure
- Their properties are governed by a branching side group - the R group



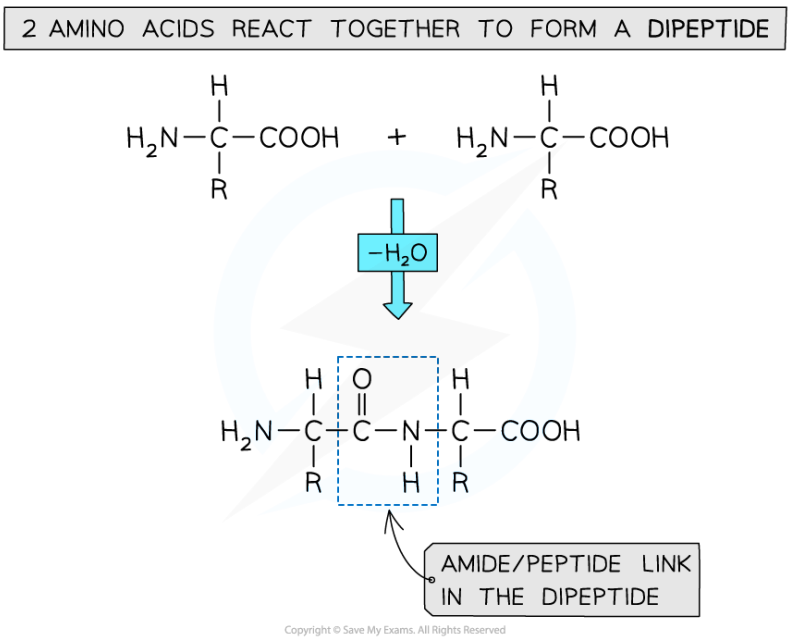
Amino acids contain an amine group, an acid group and a unique R group

- Different amino acids are identified by their unique R group
- The names of each amino acid is given using 3 letters
- For example Glutamine is known as 'Gln'
- Dipeptides can be produced by polymerising 2 amino acids together

Your notes

- The amine group ($-NH_2$) and acid group (-COOH) of each amino acid is used to polymerise with another amino acid

- Polypeptides are made through polymerising more than 2 amino acids together



Dipeptides and polypeptides are formed by polymerising amino acid molecules together

Examiner Tips and Tricks

Become familiar with the structures of the different monomers that can be used to make condensation polymers.

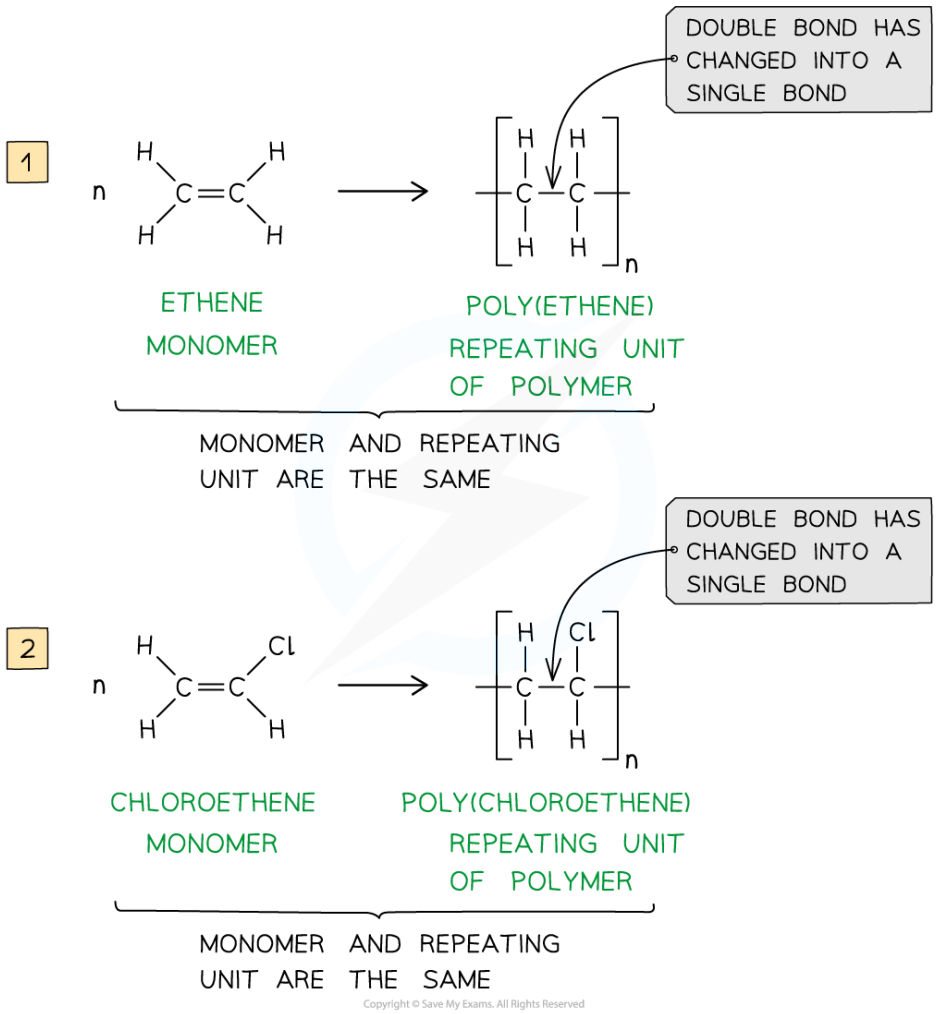
Also, remember that exam questions will require you to identify the monomers and also draw the repeating units

Repeating Units

Deducing repeat units

- A **repeat unit** is the smallest group of atoms that when connected one after the other make up the polymer chain
  - It is represented by **square brackets** in the displayed and general formula
- In **poly(alkenes)** (such as poly(ethene)) and **substituted poly(alkenes)** (such as PVC) made of **one type of monomer** the repeating unit is the same as the monomer except that the C-C double bond is changed to a C-C single bond

Your notes



The repeating units of poly(ethene) and poly(chloroethene) are similar to their monomer except that the C=C bond has changed into a C-C bond

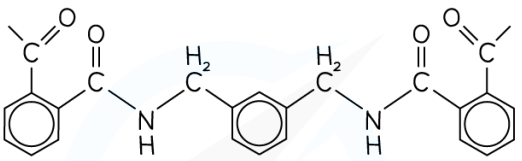
Worked Example

Draw the repeating unit and identify the monomers used to make the following polymers

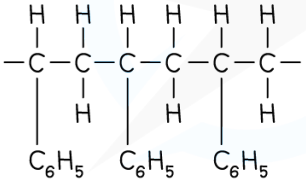
Your notes

Your notes

a)

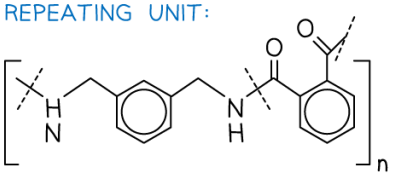


b)

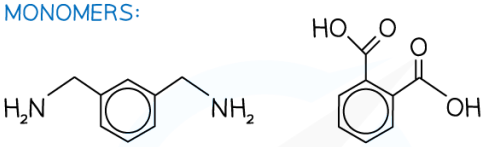


Answer:

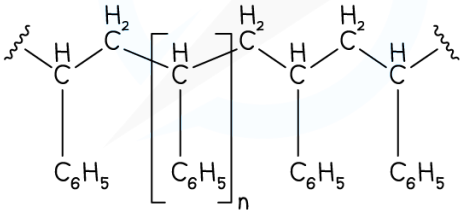
a) REPEATING UNIT:



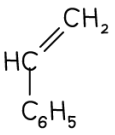
a) MONOMERS:



b) REPEATING UNIT:



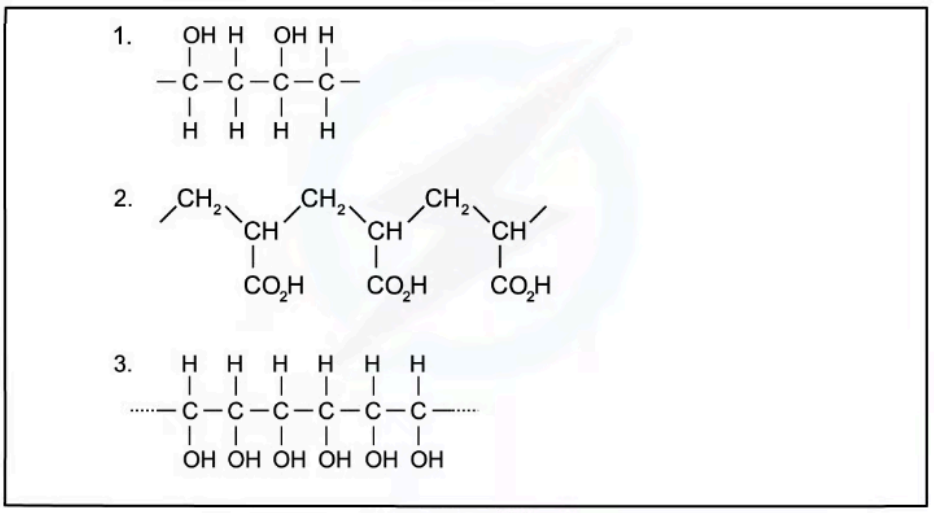
b) MONOMERS:



Worked Example

Identifying monomers

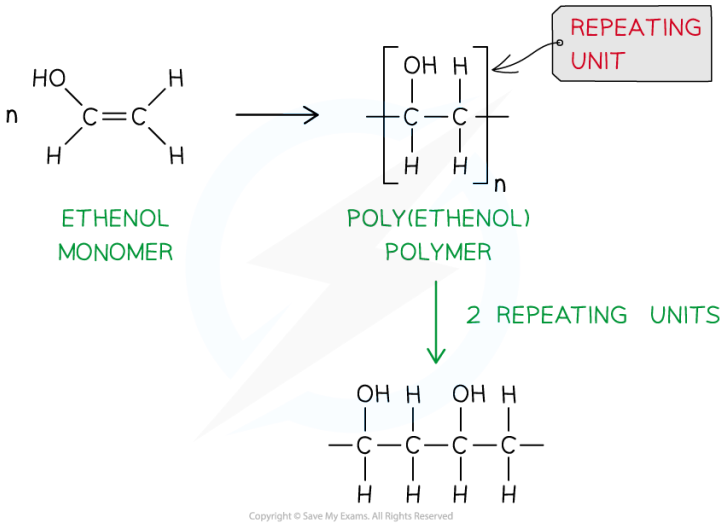
- Identify the monomers present in the given sections of addition polymer molecules



Your notes

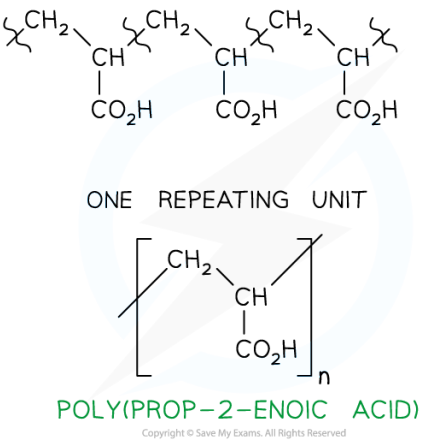
Answer 1:

- When ethenol ($CH(OH)=CH_2$) is polymerised, the C-C double bond opens to produce a repeating unit of $CH(OH)-CH_2$. This gives the polymer poly(ethenol)

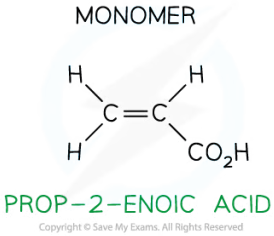


Answer 2:

- To find the monomer, first the repeating unit should be deduced. Repeating units have only 2 carbons in the polymer main chain

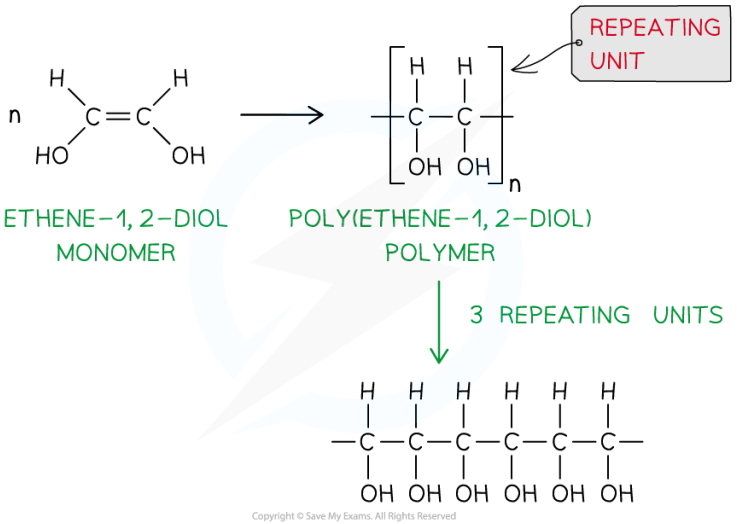


- Since the repeating unit is now found, it can be concluded that the monomer is prop-2-enoic acid



Answer 3:

- Again, the repeating unit only has 2 carbons in the polymer chain which in this case are two carbon atoms that each contain one OH group
  - Thus, when ethene-1,2-diol (CH(OH)=CH(OH)) is polymerised, the C-C double bond opens to produce a repeating unit of CH(OH)-CH(OH) which gives the polymer poly(ethene-1,2-diol)



Your notes

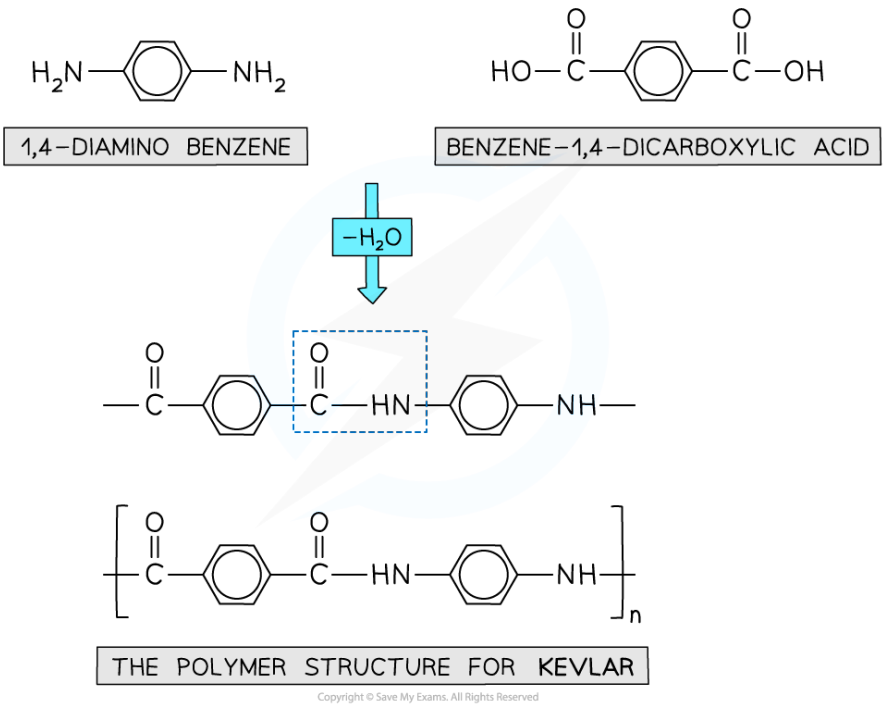
Your notes

Polyamides – Physical Properties

Examples of polyamides

Kevlar

- Kevlar is an example of a polymer formed through condensation polymerisation
- The polymer chains are neatly arranged with many hydrogen bonds between them
- This results in a strong and flexible polymer material with fire resistance properties
- These properties also lend Kevlar to a vital application in bullet-proof vests
- The monomers used to make Kevlar are:
  - 1,4–diaminobenzene
  - Benzene-1,4–dicarboxylic acid
- As seen with Nylon, a dioyl dichloride can be used instead of the acid as well (benzene-1,4–dioyl chloride)

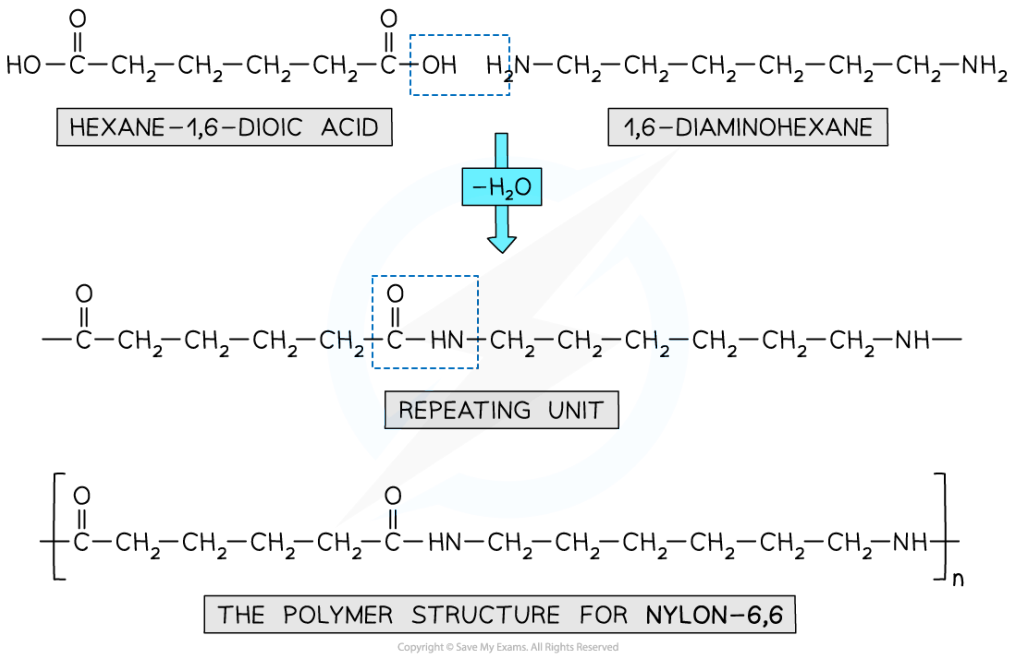


Kevlar is made using a diamine and dicarboxylic acid monomers

Nylon 6-6

- Nylon 6,6 is a synthetic polyamide

- Its monomers are 1,6-diaminohexane and hexane-1,6-dioic acid
  - The '6,6' part of its name arises from the 6 carbon atoms in each of Nylon 6,6 monomers



Nylon 6,6 is a synthetic polyamide made using diamine and dicarboxylic acid monomers

Properties of polyamides

- Most polyamides (nylons) tend to be semi-crystalline
- They are generally very tough with good thermal and chemical resistance
- Polyamides tend to absorb moisture from their surroundings
  - This absorption increases until equilibrium is reached
- The impact resistance and flexibility of polyamides increases with water content whilst strength and stiffness decrease
- The strong bonds in polyamides make the polyamide chains strong allowing them to be made into strong fibres for clothing
  - E.g. Kevlar shown above
- Polyamide film (cling film) is used in food packaging due to its toughness and the fact it prevents gas molecules from passing through
- Polyamide film is also used for 'Boil in the bag' foods due to its high-temperature resistance

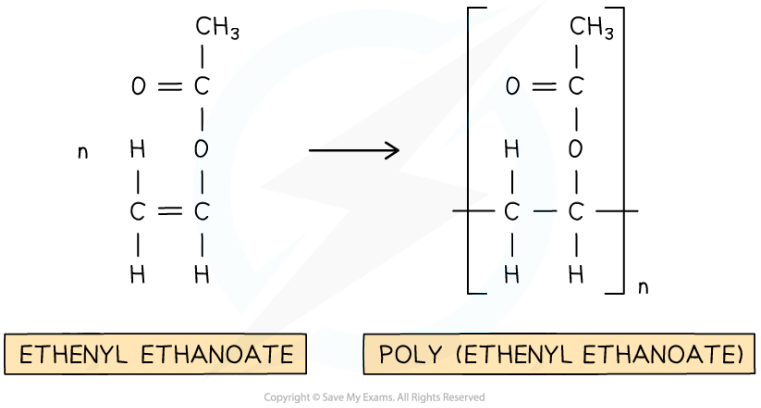
Poly(ethenol)

- Poly(ethenol) is another addition polymer, sometimes called poly(vinyl alcohol)

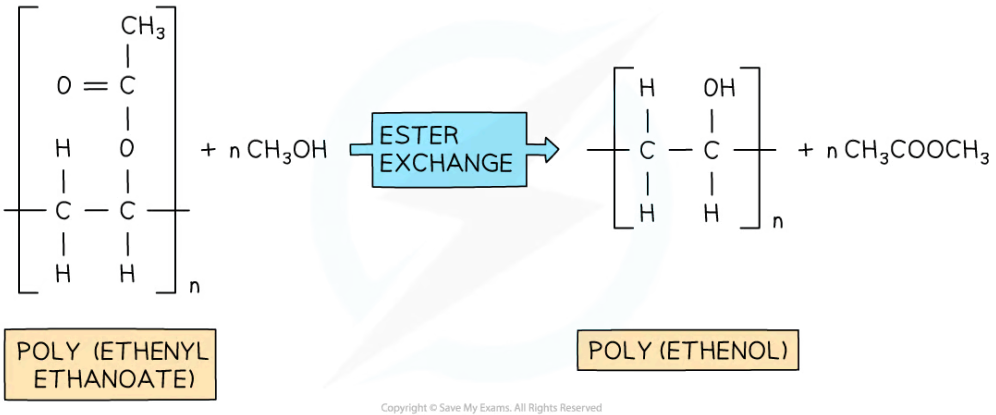
Your notes

- It is not made in the usual way by directly polymerising a monomer
- Instead, it is made in two stages:

Your notes



Stage 1: polymerisation of ethenyl ethanoate



Stage 2: poly(ethenyl ethanoate) reacts with methanol forming poly(ethenol) and methyl ethanoate (this process is known as ester exchange)

- The amount of ester exchange is controlled by varying the temperature

Solubility

- Poly(ethenol) contains many OH groups
- These groups can form hydrogen bonds with water making poly(ethenol) soluble in water
- The degree of solubility depends on how many ester groups have been replaced with OH groups
    - Solubility ranges from insoluble, to soluble in warm/hot water, to soluble in cold water

Uses

- Poly(ethenol) is used to make disposable laundry bags for use in hospitals
  - These laundry bags are soluble in water
- Dirty bedding and clothing, which may be covered in microorganisms from patients, are put in the laundry bags
- The bag is then placed in the washing machine without hospital workers having to touch the dirty fabrics
- During washing the bag dissolves and the fabrics are washed clean
- Poly(ethenol) is also used to make liquid-detergent capsules that contain measured quantities of detergent for use in washing machine and dishwashers
  - The capsule dissolves during use

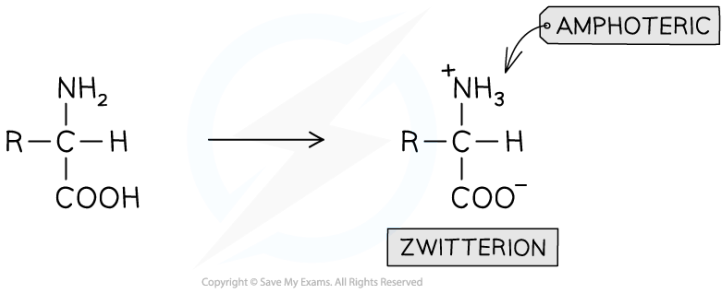
Your notes

Your notes

Characteristic Behaviour of Amino Acids

Acid / base properties of amino acids

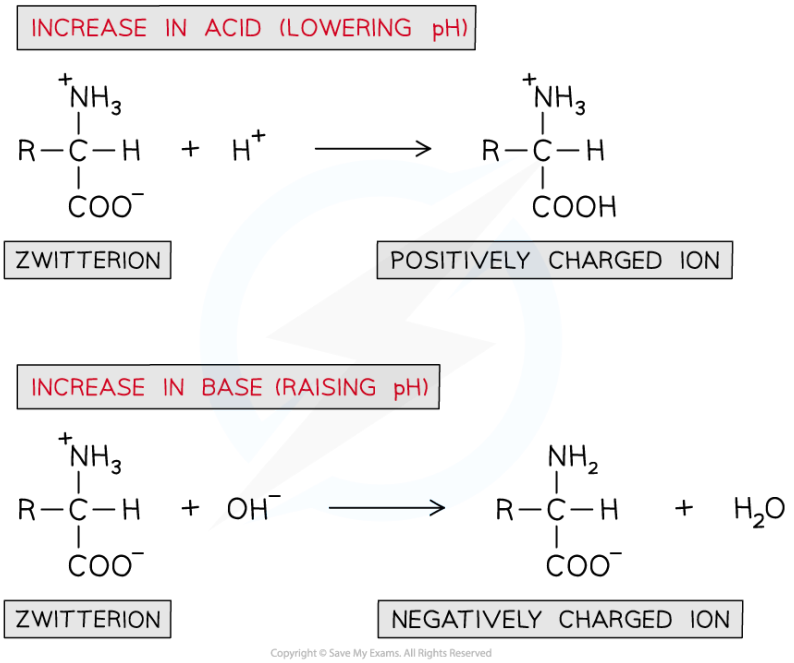
- Amino acids will undergo most reactions of amines and carboxylic acids including acid-base reactions of:
  - Amines with acids
  - Carboxylic acids with bases
- However, they can also interact **intramolecularly** (within themselves) to form a **zwitterion**
- A zwitterion is an ion with both a **positive** ($-NH_3^+$) 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**



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

Isoelectric point

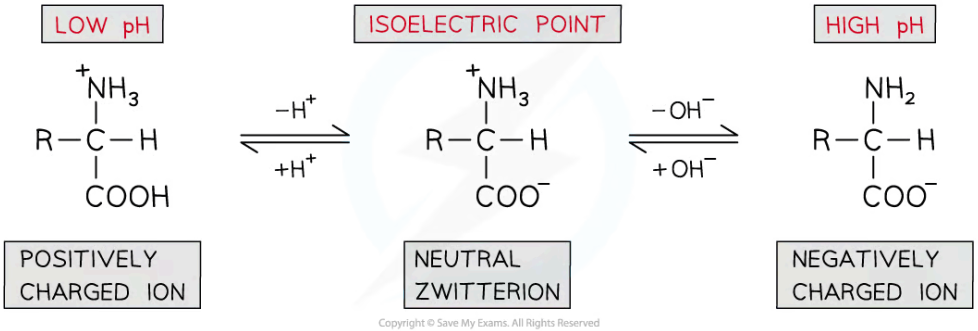
- A solution of amino acids in water will exist as **zwitterions** with both **acidic** and **basic** properties
- They act as **buffer solutions** as they resist any changes in pH when **small** amounts of acids or alkali are added
- If an acid is added (and thus the pH is **lowered**):
  - The $-COO^-$ 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**



Your notes

A solution of amino acids 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 amino acids is the pH at which the amino acid exists as a neutral zwitterion

Reactions of the amine group

- The amine group is basic and reacts with acids to make salts
- For example, a general amino acid reacts with hydrochloric acid to form the ammonium salt:

$$H_2NCHRCOOH + HCl \rightleftharpoons H_3N^+CHRCOOH + Cl^-$$

Reactions of the carboxylic acid group

Your notes

Reaction with aqueous alkalis

- An amino acid reacts with aqueous alkali such as sodium or potassium hydroxide to form a salt and water
- For example, a general amino acid reacts with sodium hydroxide to form a sodium salt:

$$H_2NCHRCOOH + NaOH \rightleftharpoons H_2NCHRCOO^- Na^+ + H_2O$$

Esterification with alcohols

- Amino acids, like carboxylic acids, can be esterified by heating with alcohol in the presence of concentrated sulfuric acid
- The carboxylic acid group is esterified whilst the basic amine group is protonated due to the acidic conditions:

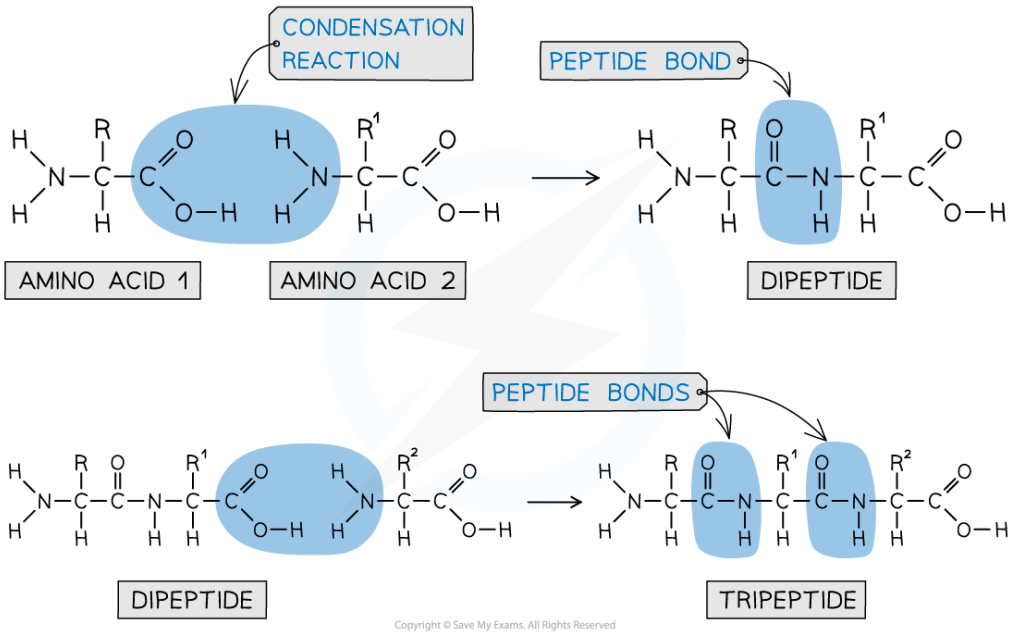
$$H_2NCHRCOOH + C_2H_5OH + H^+ \rightleftharpoons H_3N^+CHRCOOC_2H_5 + H_2O$$

Optical activity

- Almost all 2–amino acids contain a chiral centre (the C of the CH group), and so are optically active
  - The only exception is glycine, which has a CH_2 group instead
- Aqueous solutions of the enantiomers rotate the plane of polarisation of plane-polarised light
  - Dextrorotatory (+)
  - Laevorotatory (-)
- If an amino acid is synthesised in the lab, a racemic mixture is formed

Peptide bonds

- Each amino acid contains an amine (-NH_2) and carboxylic acid (-COOH) group
- The new **amide bond** between two amino acids is also called a **peptide link** or **peptide bond**
- 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**
- 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**



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

Your notes