



# OCR (B) Chemistry A-level

## Storyline 7: Polymers and Life

### Definitions and Concepts

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## Definitions and Concepts for OCR (B) Chemistry A-level

### Polymers and Life

#### Structure and Bonding

**$\alpha$ -Amino acid:** A compound with the general formula  $\text{RCH}(\text{NH}_2)\text{COOH}$ , where an amino group and a carboxylic acid group are bonded to the same carbon atom. The carboxylic acid group of an amino acid reacts with alkalis or can be used to form esters. The amine group of an amino acid reacts with acids.

**Active site:** The region on an enzyme where the substrate binds.

**Base pairing:** The bases in DNA form hydrogen bonds to complementary bases in a second strand of DNA, which then twist into a helix.

**Condensation:** A type of reaction where two molecules react to form a larger molecule, this usually produces a small molecule like  $\text{H}_2\text{O}$  as a by-product.

**Condensation polymerisation:** A long chain molecule formed when monomers react together with the release of small molecules, such as water. Types of condensation polymers are polyamides (formed from carboxylic acids/acyl chlorides and amines) and polyesters (formed from carboxylic acids/acyl chlorides and alcohols).

**DNA:** Deoxyribonucleic acid. A molecule that contains genetic information stored in sequence of bases. It is a double helix of polynucleotide chains. A DNA nucleotide contains a nitrogenous base, deoxyribose sugar and a phosphate group.

**Double helix:** Describes the structure of DNA: two complementary strands of DNA that twist around each other like a helix.

**Hydrogen bonding:** A type of intermolecular bond formed between a hydrogen atom in one molecule and an electronegative atom in another. This atom is usually nitrogen, oxygen or fluorine. Hydrogen bonding between complementary base pairs results in the helix shape of DNA.

**Hydrolysis:** A reaction in which water is used to break a bond.

**Intermolecular forces:** The forces which exist between molecules. The strength of the intermolecular forces impacts physical properties like boiling/melting point. Types of intermolecular forces including permanent dipole-dipole interactions, induced dipole-dipole interactions (these are also known as van der Waals forces) and hydrogen bonding.





**Pentose sugar:** A sugar molecule that contains 5 carbon atoms.

**Peptide link:** A bond between the carboxyl group ( $\text{-COOH}$ ) of one amino acid and the amino group ( $\text{-NH}_2$ ) of another in a protein. When peptide links are hydrolysed, the constituent amino acids are formed.

**Pharmacophore:** The part of a molecule that is responsible for a specific pharmaceutical or biological activity.

**Primary protein structure:** The sequence of a chain of amino acids that make up a protein, contains peptide bonds.

**Protein:** A large molecule made up of amino acids joined by peptide bonds. Hydrogen bonding and sulfur-sulfur bonds are important to maintain the structure of proteins.

**Receptors:** Proteins in the membrane of a cell that will recognise and bind to specific molecules.

**RNA:** A single polynucleotide strand consisting of ribonucleotides formed from a base, phosphate group and ribose sugar.

**Secondary protein structure:** The folding of a polypeptide chain when hydrogen bonds form between the amino acid chains. There are 2 types of secondary protein structure:  $\alpha$ -helix and  $\beta$ -pleated sheet.

**Substrate:** A molecule that binds to the active site of an enzyme during a reaction.

**Sugar-phosphate backbone:** DNA and RNA chains are made of a repeating backbone of phosphate and sugar. In DNA the sugar is deoxyribose and in RNA the sugar is ribose.

**Tertiary protein structure:** The three-dimensional structure of a protein. This contains ionic bonds, disulfide bridges, hydrogen bonding and induced dipole-dipole interactions.

## Kinetics

**Catalyst:** A substance that speeds up the rate of a reaction without being used up. They speed up the rate of reaction by providing an alternative reaction pathway with a lower activation energy. Enzymes are biological catalysts.



**Competitive enzyme inhibitor:** An inhibitor which resembles the substrate and will bind to the active site of an enzyme. This means the substrate can no longer bind, reducing the enzyme's activity.

**Enzyme:** A biological catalyst made of one or more proteins. Enzymes have stereospecific active sites that bind to a certain substrate molecule.

**Enzyme inhibitor:** A substance that reduces the activity of an enzyme. This might be a drug that blocks the active site, preventing a substrate molecule binding.

**Specificity:** A measure of how specific an enzyme is for its substrate, they will only catalyse a very small number of reactions.

### Equilibria (Acid-Base)

**Carbonate:** An ion with the formula  $\text{CO}_3^{2-}$ . Carboxylic acids react with the carbonate ion, causing effervescence (release of  $\text{CO}_2$ ).

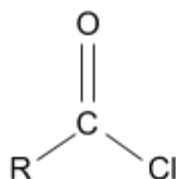
**Carboxylic acid:** An organic compound containing the  $-\text{COOH}$  functional group. Carboxylic acids react with  $\text{CO}_3^{2-}$ , causing effervescence (release of  $\text{CO}_2$ ).

**Zwitterion:** A molecule that has separate positively and negatively charged groups.

### Organic Functional Groups

**Acid anhydride:** A compound with the functional group  $\text{R}-(\text{CO})\text{O}(\text{CO})-\text{R}'$ .

**Acyl chloride:** A compound containing the functional group shown below. They are used to form esters, carboxylic acids and primary and secondary amides.



**Aldehyde:** A compound containing the  $-\text{CHO}$  functional group at the end of an alkyl chain. Aldehydes can be oxidised to carboxylic acids using  $\text{Cr}_2\text{O}_7^{2-} / \text{H}^+$ .





**Amines:** Compounds that contain the  $\text{NR}_3$  functional group (where R could be hydrogen atoms or alkyl chains). Amines are basic as the nitrogen lone pair can be used to accept a proton. In a reaction between amines and dilute acids, salts are formed.

**Carboxylic acid group:** The  $\text{-COOH}$  group in an organic compound.

**Diamine:** A molecule that contains two amine functional groups ( $\text{-NH}_2$ ).

**Dicarboxylic acid:** A molecule that contains two carboxylic acid functional groups ( $\text{-COOH}$ ).

**Diol:** An molecule that contains two hydroxyl groups.

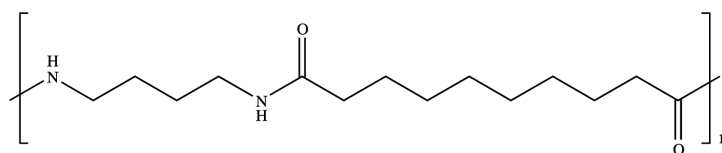
**Ester:** A compound containing the  $\text{R-COO-R'}$  functional group (where R and R' are alkyl groups).

**Homologous series:** A series of compounds with the same functional group and similar chemical properties. For example, all alkanes belong to the same homologous series.

**Ketone:** An organic compound containing the  $\text{C=O}$  functional group in the middle of an alkyl chain. Ketones can be formed by the oxidation of a secondary alcohol.

**Nomenclature:** The naming of a molecule.

**Nylon:** A polyamine that is commonly used in textiles. An example of a nylon repeat unit is shown below.



nylon-6,10

**Phenol:** Phenol has an aromatic ring with an  $\text{-OH}$  group attached. Phenol can undergo electrophilic substitution reactions more easily than benzene as the lone pair in the p-orbital of oxygen is donated into the  $\pi$  system of phenol, increasing its electron density. As a result of this electron donation, phenol is more susceptible to electrophilic attack than benzene.

**Primary amine:** An organic compound that contains the functional group  $\text{RNH}_2$  (where R is an alkyl chain).

**Secondary amine:** An organic compound that contains the functional group  $\text{R}_2\text{NH}$  (where R is an alkyl chain).



## Organic Reactions

**Ester hydrolysis:** Esters can either be hydrolysed with hot aqueous acid (forming carboxylic acids and alcohols) or with hot aqueous alkali (forming carboxylate salts and alcohols). Polyesters can be hydrolysed in a similar way.

## Polymers

**Addition polymerisation:** The formation of a long chain molecule when many monomers join together (the polymer is the only product).

**Condensation polymerisation:** A long chain molecule formed when monomers react together with the release of small molecules such as water. Types of condensation polymers are polyamides (formed from carboxylic acids/acyl chlorides and amines) and polyesters (formed from carboxylic acids/acyl chlorides and alcohols).

**Monomer:** A small molecule that is used to form polymers.

**Polymer:** A large molecule made from many small units that have been bonded together.

**Polymerisation:** The process of making a polymer from its monomers. There are two types: addition polymerisation and condensation polymerisation.

**Repeat unit:** A structure within a polymer that appears over and over again. Joining many repeat units together would form the polymer.

## Isomerism

**Chiral centre:** A carbon atom that is bonded to 4 different groups.

**Enantiomers:** Molecules which are non-superimposable mirror images of one another. Enantiomers have opposite effects on a plane of polarised light.

**Optical isomerism:** A type of stereoisomerism in which compounds are non-superimposable mirror images of one another (caused by the presence of a chiral centre).

**Racemic mixture (racemate):** A mixture containing equal amounts of enantiomers.

**Stereoisomers:** Compounds with the same structural formula but a different arrangement of atoms in space.



## **Modern Analytical Techniques**

**Carbon-13 NMR spectroscopy:** A type of NMR spectroscopy which analyses  $^{13}\text{C}$  nuclei. The number of peaks in the spectrum shows the number of different environments and the chemical shifts show what environments are present.

**Chemical shift:** The shift of a carbon or proton environment relative to standard (TMS). The chemical shift value ( $\delta$ ) depends on the molecular environment of the proton/carbon atom.

**Coupling:** Interactions between adjacent non-equivalent protons during NMR spectroscopy.

**D<sub>2</sub>O exchange:** As O-H and N-H peaks can appear across a wide range of chemical shift values on a proton NMR spectrum, D<sub>2</sub>O exchange can be used to identify which peaks are caused by O-H and N-H protons. Firstly, a proton NMR is run on a sample. The sample is then shaken with D<sub>2</sub>O and a second proton NMR is run. Any peaks that are due to O-H or N-H protons will disappear on the second spectrum as these hydrogen atoms will be exchanged for deuterium.

**Deuterated solvent:** A solvent, such as CDCl<sub>3</sub>, in which all of the hydrogen atoms have been replaced by deuterium ( $^2\text{H}$ ). Deuterated solvents are used in order to prevent the appearance of a solvent peak on the  $^1\text{H}$  NMR spectrum.

**Doublet:** A signal on a  $^1\text{H}$  NMR spectra made up of 2 peaks, indicating that there is 1 adjacent non-equivalent proton.

**Elemental analysis:** A sample is analysed to determine the proportion of elements that make up the compound present. This is done by converting a known amount of an unknown sample into simple known compounds.

**Environment:** In NMR spectroscopy, a proton or carbon environment considers the atoms/groups that are adjacent to that hydrogen/carbon atom. If two protons/carbons are surrounded by different groups of atoms, they are in different environments.

**Equivalent protons:** Protons that are in the same environment.

**Infrared (IR) spectroscopy:** A technique used to identify particular bonds and functional groups within a molecule. Infrared radiation is absorbed by covalent bonds in molecules, causing them to vibrate at a specific frequency.

**Mass spectrometry:** A technique used to identify compounds and determine their relative molecular mass.

**Molecular formula:** The total number of atoms of each element in the compound.





**Molecular ion peak:** The peak on a mass spectrum with the highest  $m/z$  value, used to determine the molecular mass of a compound.

**$M^{+1}$  peak:** A small peak on a mass spectrum caused by the presence of a small proportion of carbon-13.

**$M/Z$  ratio:** The mass to charge ratio on a mass spectrum. For  $1+$  ions, this is equivalent to the mass of the ion.

**$n+1$  rule:** Used to determine splitting patterns of adjacent non-equivalent protons. A proton with ' $n$ ' adjacent non-equivalent protons will have a signal made up of ' $n+1$ ' peaks on a  $^1\text{H}$  NMR spectrum.

**Nuclear Magnetic Resonance (NMR):** A technique that uses the absorption of electromagnetic radiation by a nucleus in an external magnetic field to analyse the structure of a compound. Typically, either  $^{13}\text{C}$  or  $^1\text{H}$  nuclei are analysed.  $^{13}\text{C}$  NMR spectra are generally simpler than  $^1\text{H}$  NMR spectra.

**Proton NMR spectroscopy:** A type of NMR spectroscopy which analyses  $^1\text{H}$  nuclei. The number of peaks on the spectrum shows the number of proton environments and the chemical shifts show the type of environments. The integration trace (equivalent to the area under each peak) shows the relative number of protons in each environment. The splitting pattern can be used to work out the number of adjacent protons.

**Quartet:** A signal on a  $^1\text{H}$  NMR spectra made up of 4 peaks, indicating that there are 3 adjacent non-equivalent protons.

**Spin-spin splitting:** An interaction between adjacent non-equivalent protons. When protons couple (interact with one another), the signal on the  $^1\text{H}$  NMR spectrum is split into a multiplet according to the  $n+1$  rule.

**Tetramethylsilane (TMS):** The standard for chemical shift measurement in NMR spectroscopy.

**Triplet:** A signal on a  $^1\text{H}$  NMR spectra made up of 3 peaks, indicating that there are 2 adjacent non-equivalent protons.

