

# WJEC (Wales) Chemistry A-level

## Unit 4: Organic Chemistry and Analysis Definitions and Concepts

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## Definitions and Concepts for WJEC (Wales) Chemistry A-level

### Unit 4: Organic Chemistry and Analysis

#### 4.1 Stereoisomerism

**Cahn-Ingold-Prelog (CIP) Priority Rules:** A set of rules used to identify whether a stereoisomer is E or Z. Atoms with a higher atomic number have a higher priority. If the highest priority substituents are on the same side of the double bond (both above or below), it is the Z isomer, whereas if the highest priority groups are on the opposite sides (one above and one below), it is the E isomer.

**Chain isomers:** Structural isomers that have carbon backbones of differing lengths. These occur due to the branching in the carbon chain.

**Chiral centre:** A carbon atom that is bonded to four different atoms/groups of atoms.

**Functional group isomers:** Structural isomers that contain different functional groups. This means they belong to different homologous series.

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

**E/Z isomerism:** A type of stereoisomerism that occurs due to the restricted rotation around the carbon double bond. This results in two different groups on either end of the double bond. If the highest priority groups for each carbon are found on the same side of the molecule, then it is the Z-isomer. If the highest priority groups for each carbon are found on opposite sides of the molecule, then it is the E-isomer.

**Optical activity:** The ability of a molecule to rotate plane polarised light.

**Optical isomerism:** A type of stereoisomerism present in compounds that are non-superimposable mirror images of one another, caused by the presence of a chiral centre. They have the same molecular formula but have different arrangements of atoms in space.

**Position isomer:** Structural isomers that differ in their position of one or more functional groups. The carbon backbone of the molecules are the same.

**Racemic mixture (racemate):** A mixture containing equal amounts of enantiomers, a 50:50 mix of a pair of enantiomers.

**Stereoisomers:** Two or more molecules who differ only by their spatial arrangement of atoms.





**Structural isomer:** Structural isomers are compounds which have the same molecular formula but a different structural formula. Structural isomers include chain isomers, functional group isomers and position isomers.

## 4.2 Aromaticity

**Addition:** Joining two or more molecules together to form a larger molecule. *Hydration* is the addition of a  $\text{H}_2\text{O}$  molecule. *Halogenation* involves the addition of a halogen. *Hydrogenation* is the addition of H. *Electrophilic addition* describes all the above examples.

**Aromatic compound/Arene:** A compound containing at least one benzene ring.

**Benzene:** A 6 membered carbon ring ( $\text{C}_6\text{H}_6$ ) containing a delocalised  $\pi$  electron system. Benzene has a planar structure and an intermediate bond length between a single and double bond. Delocalisation of the p electrons into the  $\pi$  system makes benzene more stable than expected.

**Electrophile:** An electron pair acceptor.

**Electrophilic substitution:** A reaction in which an electrophile replaces an atom/group of atoms in a compound.

**Friedel–Crafts alkylation:** An important synthetic reaction involving an electrophilic aromatic substitution reaction between benzene, a haloalkane and aluminium chloride.

**Halogenation:** A type of reaction that involves the addition of a halogen.

**Monosubstituted benzene ring:** A benzene ring with one hydrogen replaced by another atom/group of atoms. E.g. Nitrobenzene,  $\text{C}_6\text{H}_5\text{NO}_2$ .

**Nitration:** A type of reaction that involves the addition of a nitro group.

## 4.3 Alcohols and Phenols

**Carbonyl:** The  $\text{C}=\text{O}$  functional group. Aldehydes and ketones are carbonyl compounds.

**Carboxylic acid:** An organic compound containing the  $-\text{COOH}$  functional group.





**Halogenoalkane:** An organic compound containing a halogen atom attached to an alkyl chain.

**Phenol:** A benzene ring where one of the hydrogen atoms has been substituted for a hydroxyl group.

**Primary alcohol:** An alcohol in which the -OH is attached to a primary carbon atom (i.e.  $\text{RCH}_2\text{OH}$ ). Primary alcohols can be oxidised with  $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$  to form either an aldehyde or a carboxylic acid, depending on the conditions.

**Secondary alcohol:** An alcohol in which the -OH is attached to a secondary carbon atom (i.e.  $\text{R}_2\text{CHOH}$ ). Secondary alcohols can be oxidised under reflux with  $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$  to form a ketone.

**Tertiary alcohol:** An alcohol in which the -OH is attached to a tertiary carbon atom (i.e.  $\text{R}_3\text{COH}$ ).

#### **4.4 Aldehydes and Ketones**

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

**Carbonyl:** The  $\text{C}=\text{O}$  functional group. Aldehydes and ketones are carbonyl compounds.

**Fehling's solution:** A deep blue solution used to identify aldehydes from ketones. When aldehydes are present the solution forms a brick-red precipitate. When ketones are present the solution remains blue.

**Ketone:** A compound containing the  $\text{C}=\text{O}$  functional group within an alkyl chain. Ketones cannot be oxidised further.

**Nucleophile:** An atom or molecule that donates an electron pair to form a covalent bond. Attracted to electron-deficient areas.

**Nucleophilic addition:** A reaction in which an electrophilic  $\pi$  bond reacts with a nucleophile, breaking the  $\pi$  bond and forming two new  $\sigma$  bonds. Examples include carbonyl compounds reacting with  $\text{NaBH}_4$  to form alcohols, or with  $\text{HCN}$  to form hydroxynitriles.

**Oxidation:** The loss of electrons/increase in oxidation number.

**Primary alcohol:** An alcohol in which the -OH is attached to a primary carbon atom (i.e.  $\text{RCH}_2\text{OH}$ ). Primary alcohols can be oxidised with  $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$  to form either an aldehyde or a carboxylic acid, depending on the conditions.

**Reduction:** The gain of electrons/decrease in oxidation number.



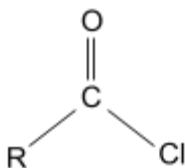


**Secondary alcohol:** An alcohol in which the -OH is attached to a secondary carbon atom (i.e.  $R_2CHOH$ ). Secondary alcohols can be oxidised under reflux with  $Cr_2O_7^{2-}/H^+$  to form a ketone.

**Tollens' Reagent:** Also known as ammoniacal silver nitrate, this reagent forms a silver mirror in the presence of an aldehyde and can be used to distinguish between aldehydes and ketones. An aldehyde is oxidised to a carboxylic acid while silver ions in Tollens' are reduced to silver, forming a silver mirror on the wall of the test tube.

#### **4.5 Carboxylic acid and Derivatives**

**Acid chloride:** A compound containing the functional group  $COCl$ . Acyl chlorides are a derivative of carboxylic acids, but the -OH is substituted by -Cl.



**Alcohol:** An organic compound containing the -OH functional group.

**Aldehyde:** A compound containing the -CHO functional group at the end of an alkyl chain. Aldehydes can be oxidised to carboxylic acids by heating them under reflux with  $Cr_2O_7^{2-}/H^+$ .

**Amide:** A molecule containing the functional group  $-CONR_2$ , where R can be an alkyl chain or a hydrogen atom.

**Aromatic compound/Arene:** A compound containing at least one benzene ring.

**Carboxylic acid:** An organic compound containing the -COOH functional group.

**Decarboxylation:** A type of reaction that involves the removal of a carboxyl group, releasing  $CO_2$ .

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

**Halogenoalkane:** A saturated molecule where one or more of the hydrogen atoms in an alkane have been substituted for a halogen.

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





**Hydroxynitrile:** A molecule with a  $-CN$  functional group and an  $-OH$  functional group bonded to the same carbon atom.

**Nitrile:** A molecule with a  $-CN$  functional group.

**Oxidation:** Process involving the loss of electrons. Results in an increase in oxidation number.

**Phenol:** A benzene ring where one of the hydrogen atoms has been substituted for a hydroxyl group.

**Reduction:** The gain of electrons/decrease in oxidation number.

## 4.6 Amines

**Aliphatic amine:** An amine which only contains straight or branched alkyl chains. Aliphatic amines can be formed via a substitution reaction of haloalkanes with either ammonia or amines in ethanol solvent.

**Amines:** Compounds that contain the  $NR_3$  functional group (where R could be hydrogen atoms or alkyl chains). Amines are basic as the nitrogen atom has a lone pair of electrons that can accept a proton. In a reaction between amines and dilute acids, salts are formed.

**Aromatic amine:** An amine which contains a benzene ring directly attached to the nitrogen atom. Aromatic amines can be formed by reducing nitroarenes with tin and concentrated HCl.

**Azo compound:** A molecule which contains the functional group  $R-N=N-R'$ .

**Chromophore:** The part of a molecule which gives a compound its colour.

**Ethanoylation:** A reaction that involves the addition of an acetyl group to a molecule.

**Halogenoalkane:** A saturated molecule where one or more of the hydrogen atoms in an alkane have been substituted for a halogen.

**Nitrile:** A molecule with a  $-CN$  functional group.

**Nitrobenzene:** A molecule with the molecular formula  $C_6H_5NO_2$ , it is made up of a benzene ring where one of the hydrogen atoms has been substituted with a nitro group ( $NO_2$ ).

**Phenol:** A benzene ring where one of the hydrogen atoms has been substituted for a hydroxyl group.





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

#### **4.7 Amino acids, Peptides and Proteins**

**$\alpha$ -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 can react with alkalis or can be used to form esters. The amine group of an amino acid can react with acids.

**Amino acid:** An organic compound containing both a carboxyl group ( $-\text{COOH}$ ) and an amino group ( $-\text{NH}_2$ ).

**Amphoteric:** A substance that is able to react as both an acid and a base.

**Dipeptide:** A compound made up of two amino acids linked by a peptide bond.

**Enzyme:** A biological catalyst.

**Melting temperature:** The melting point of a substance is the temperature at which it changes from solid state to liquid state.

**Polypeptides:** A polymer made up of lots of amino acids.

**Primary protein structure:** The sequence of amino acids in a polypeptide chain.

**Protein:** A large molecule formed when a polypeptide folds into its 3D shape.

**Secondary protein structure:** The initial folding of the polypeptide chains, these are usually alpha-helix or beta-pleated sheets. These arise due to hydrogen bonding between peptide bonds.

**Solubility:** The ability of a given substance to dissolve in a solvent.

**Tertiary protein structure:** The three dimensional shape of the protein.

**Zwitterion:** A dipolar ion with 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 ( $^+\text{NH}_3$ ) and the carboxyl group has a negative charge ( $\text{COO}^-$ ).





## 4.8 Synthesis and Analysis

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

**Chromatography:** A technique used to separate and identify components in a mixture. There are several different types of chromatography, including thin layer chromatography and gas chromatography. Separation during chromatography depends on the balance between each individual compound's solubility in the mobile phase and retention by the stationary phase.

**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).

**Gas Chromatography (GC):** A type of chromatography in which a column is packed with a solid (or a solid coated in a liquid) and a gas is passed through the column under pressure at high temperature. Mass spectrometry may then be used to analyse the components separated by GC.

**High Performance Liquid Chromatography (HPLC):** A type of column chromatography where a solvent is the mobile phase and tightly packed absorbent material is the stationary phase.

**Nuclear Magnetic Resonance (NMR):** A technique that uses the absorption of electromagnetic radiation by an atomic 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.

**Melting temperature:** The melting point of a substance is the temperature at which it changes from solid state to liquid state.

**Organic compound:** A carbon-containing compound.

**Polyamide:** A type of condensation polymer formed by the linkage of an amine group in one monomer with a carboxylic acid group of another. These polymers can be broken down by hydrolysis and are biodegradable. The bond between each monomer is called an amide linkage.

**Polyester:** A type of condensation polymer formed by the linkage of an alcohol group in one monomer with a carboxylic acid group of another (e.g. Terylene). These polymers can be broken down by hydrolysis and are biodegradable. The bond between each monomer is called an ester linkage.

**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 represent the environments. 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.

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

**Purification:** The process of removing impurities or contaminants from a product.

**Separation:** A method of getting distinct separate products from a mixture.

**Synthesis:** Combining different elements and compounds to build new molecules.

**Thin Layer Chromatography (TLC):** A type of chromatography in which a plate is coated with a solid and a solvent moves up the plate.

