AQA Chemistry A-level

Organic Chemistry II

Definitions

Selected Definitions modified or taken from: [AQA Specification for GCSE Chemistry, 8462, Version 1.1 04 October 2019](#) & [AQA Specification for AS & A-Level Chemistry, 7404 & 7405, Version 1.1, December 2015](#)

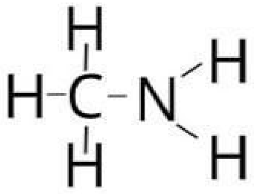
Definitions and Concepts for AQA Chemistry A-level

Organic Chemistry II

3.7 Optical Isomerism

Chiral Carbon: an asymmetric carbon atom/ a carbon atom bound to 4 different groups. This may also be called a chiral centre.

Displayed Formula: shows all the bonds between every atom in the compound. E.g:



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

Optical isomerism: a type of stereoisomerism that occurs as a result of the presence of a chiral centre in a molecule. Optical isomers have different effects on a plane of polarised light.

Racemic Mixture (racemate): a mixture containing equal amounts of enantiomers.

Stereoisomers: compounds that only differ in their arrangement of atoms in space.

Structural Formula: shows the arrangement of atoms in a molecule without the bonds drawn between them. E.g. $CH_3CH_2COCH_3$.

3.8 Aldehydes and Ketones

Aldehyde: a molecule containing the C=O functional group at the end of the molecule. Aldehydes can be distinguished from ketones using Fehling's solution or Tollens' reagent. Aldehydes produce a silver mirror with Tollens' and a red precipitate with Fehling's solution. Ketones do not react with either of these reagents.

Carbonyl group: a functional group with a C=O double bond.

Curly Arrow: used in mechanisms to show the movement of a pair of electrons.

Enantiomers: molecules which are non-superimposable mirror images of one another.

Hydroxynitrile: a molecule containing an alcohol group (OH) and a nitrile group (C≡N) bound to the same carbon. These can be formed in a nucleophilic addition reaction between a carbonyl and KCN followed by dilute acid (this reaction forms a mixture of enantiomers if an aldehyde or an unsymmetrical ketone is used).

Ketone: a molecule containing the C=O functional group in the middle of the molecule. Ketones can be distinguished from aldehydes using Fehling's solution or Tollens' reagent. Ketones do not react with either of these reagents while aldehydes produce a silver mirror with Tollens' and a red precipitate with Fehling's solution.

Nucleophile: an electron pair donor.

Nucleophilic Addition: a reaction in which an electrophilic π bond reacts with a nucleophile, breaking the π bond and forming 2 new σ bonds.

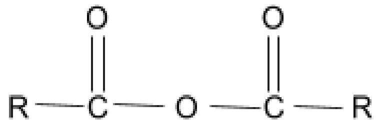
Oxidation of Aldehydes: aldehydes can be oxidised using acidified potassium dichromate to form carboxylic acids.

Reduction of Aldehydes: aldehydes can be reduced to primary alcohols in a nucleophilic addition reaction with $NaBH_4$ in aqueous solution.

Reduction of Ketones: ketones can be reduced to secondary alcohols in a nucleophilic addition reaction with $NaBH_4$ in aqueous solution.

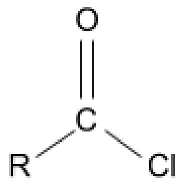
3.9 Carboxylic Acids and Derivatives

Acid Anhydride: a molecule containing the functional group below.



$$R-\overset{\overset{\displaystyle O}{\|}}{C}-O-\overset{\overset{\displaystyle O}{\|}}{C}-R$$

Acyl Chloride: a molecule containing the functional group below.



Alcohol: a molecule containing the OH functional group.

Biodiesel: a mixture of methyl esters of long-chain carboxylic acids. Biodiesel is produced by reacting vegetable oils with methanol in the presence of a catalyst.

Carboxylic Acids: molecules containing the -COOH functional group. Carboxylic acids are weak acids that form CO_2 when reacted with carbonates.

Esters: molecules containing the R-COO-R' functional group which can be formed when carboxylic acids and alcohols react in the presence of an acid catalyst. Esters of glycerol (propane-1,2,3-triol) naturally occur in vegetable oils and animal fats and these esters can be hydrolysed in alkaline conditions to produce soaps and glycerol. Esters can be used to create solvents, plasticisers, perfumes and food flavourings.

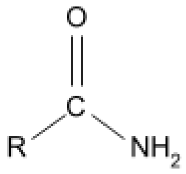
Hydrolysis of esters: under acidic conditions, esters will be hydrolysed to form alcohols and carboxylic acids. Under alkaline conditions, esters will be hydrolysed to form alcohols and carboxylate salts.

Melting Point Apparatus: a piece of apparatus used to determine the melting point of a sample. The recorded melting point range is compared with known values to determine whether the sample is pure.

Nucleophile: an electron pair donor

Nucleophilic addition-elimination: a reaction in which a nucleophile is added to a molecule by breaking a π bond then a leaving group is removed to reform the π bond.

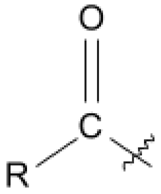
Primary Amide: a molecule containing the functional group shown below.



Recrystallisation: a technique used to purify a compound. A sample is dissolved in the minimum volume of hot solvent then filtered. The filtrate is then cooled before being filtered under reduced pressure. The residue on the filter paper is the purified compound.

3.10 Aromatic Chemistry

Acyl Group: a group with the structure shown below, where R is an alkyl group.



Addition Reaction: a reaction in which molecules combine to form a single product.

Aromatic Compound: a compound containing at least one benzene ring.

Benzene: a 6 membered carbon ring (C_6H_6) containing a delocalised π system. Benzene has a planar structure and a bond length between a single and double bond. Delocalisation of the p electrons into the π system makes benzene more stable than expected.

Delocalisation of p electrons: in benzene, the empty p orbital on each carbon atom overlaps with the others to form a delocalised π system which contains 6 electrons.

Electrophile: an electron pair acceptor.

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

Enthalpy of Hydrogenation: the enthalpy change that takes place when one mole of an unsaturated compound reacts completely with hydrogen to form a saturated compound. Comparing the enthalpy of hydrogenation of benzene with that of the theoretical molecule cyclohexa-1,3,5-triene shows that benzene is more thermodynamically stable as more energy is needed to hydrogenate benzene.

Friedel-Crafts Acylation: an important synthetic reaction involving an electrophilic aromatic substitution reaction between benzene and acyl chlorides or anhydrides, used to form monoacylated benzene rings. $AlCl_3$ is used as a catalyst.

Monosubstituted benzene ring: a benzene ring with one hydrogen replaced by another group, e.g. $C_6H_5NO_2$

Nitration: Nitration is important for synthesis, particularly for manufacturing explosives and for forming amines. Benzene can undergo nitration via an electrophilic substitution reaction, using concentrated nitric acid and a concentrated sulfuric acid catalyst at 50°C.

Substitution Reaction: a reaction in which one atom/ group of atoms is replaced by another atom / group of atoms.

3.11 Amines

Aliphatic: organic compounds with carbon atoms joined in chains.

Alkyl group: a group based on an alkane, where one hydrogen has been removed (this allows the group to attach to another atom in a chain).

Amines: compounds based on ammonia where hydrogen atoms have been replaced by alkyl or aryl groups. Amines are weak bases that can act as nucleophiles.

Aromatic: a compound containing at least one benzene ring.

Aromatic Amines: an organic compound with the structure $R\text{-}NH_2$, where R is an aromatic ring. Aromatic amines can be prepared by the reduction of nitro compounds and they are important for the manufacture of dyes.

Aryl group: a group based on a benzene ring, where one hydrogen has been removed (this allows the group to attach to another atom in a chain).

Lone Pair: a pair of valence electrons (outer-shell electrons) not involved in bonding.

Nucleophile: an electron pair donor.

Nucleophilic addition-elimination: a reaction in which a nucleophile is added to a molecule by breaking a π bond then a leaving group is removed to reform the π bond.

Nucleophilic substitution: a reaction in which an electron-rich nucleophile attacks a positive charge or partial positive charge to replace an atom/ group of atoms. One example of this is the reaction between ammonia and halogenoalkanes, which forms a primary ammonium salt.

Primary aliphatic amines: an organic compound with the structure $R\text{-}NH_2$ (where R is an alkyl group). Primary aliphatic amines can be prepared by reacting ammonia with halogenoalkanes or by reducing nitriles.

Primary ammonium salt: an organic compound formed when a halogenoalkane is reacted with ammonia. These salts have the general formula $RNH_3^+X^-$ (where R is an alkyl group and X^- is the halide ion).

Quaternary ammonium salts: an organic compound formed when a halogenoalkane reacts with a tertiary amine. These salts have the general formula $R_4N^+X^-$ (where R is an alkyl group and X^- is the halide ion). Quaternary ammonium salts can be used as cationic surfactants.

Secondary ammonium salt: an organic compound formed when a halogenoalkane reacts with a primary amine. These salts have the general formula $R_2NH_2^+X^-$ (where R is an alkyl group and X^- is the halide ion).

Tertiary ammonium salt: an organic compound formed when a halogenoalkane reacts with a secondary amine. These salts have the general formula $R_3NH^+X^-$ (where R is an alkyl group and X^- is the halide ion).

3.12 Polymers

Addition Polymer: a long chain molecule formed when many monomers join together, where the polymer is the only product.

Biodegradable: a substance that can be decomposed by bacteria or other living organisms.

Condensation Polymer: a long chain molecule formed when monomers react together with the release of small molecules such as water. These polymers can be formed by a reaction between dicarboxylic acids and diols, dicarboxylic acids and diamines or between amino acids.

Hydrolysis: a reaction which uses water to break down a compound.

Intermolecular Forces: forces which act between molecules. These include permanent dipole-dipole forces, induced dipole-dipole forces and hydrogen bonding.

Monomer: a small molecule that is used to form polymers.

Polyalkene: a type of addition polymer formed when many alkene monomers are joined together. These polymers are chemically inert and non-biodegradable.

Polyamide: a type of condensation polymer formed by the linkage of an amino group in one monomer and a carboxylic acid group of another (e.g. nylon 6,6 and Kevlar). These polymers can be broken down by hydrolysis and are biodegradable.

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.

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

Repeating Unit: a structure within a polymer that appears over and over again. Joining many repeat units together would form the polymer.

3.13 Amino acids, Proteins and DNA

Active Site: the region of an enzyme where the substrate binds.

Amino Acid: an organic compound containing both a carboxyl group (-COOH) and an amino group (-NH_2).

Catalyst: a substance which speeds up the rate of a reaction without being used up. Enzymes are biological catalysts.

Cisplatin: a complex of Pt(II) which is used as an anticancer drug. Cisplatin prevents DNA replication in cancer cells by a ligand replacement reaction with DNA (during this reaction, a bond forms between platinum and a nitrogen atom in guanine).

Developing Agents: these are used to locate amino acids on a chromatogram (e.g. ninhydrin and ultraviolet light).

DNA (deoxyribonucleic acid): a polymer of nucleotide linked by covalent bonds between the phosphate group of one nucleotide and the 2-deoxyribose of another nucleotide. The resulting polymer has a sugar-phosphate-sugar-phosphate chain with the bases (adenine, cytosine, guanine and thymine) attached to the sugars in the chain. DNA has a double helix structure which is made up of 2 complementary strands.

Enantiomers: molecules that are non-superimposable mirror images of one another.

Enzyme: a biological catalyst made of 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 which blocks the active site, preventing a substrate molecule binding.

Hydrogen Bonding: a type of intermolecular bond formed between a hydrogen atom in one molecule and an electronegative atom in another. Hydrogen bonding between base pairs leads to complementary strands of DNA.

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

Ligand: an ion or molecule that binds to a metal atom by donating a pair of electrons and forming a coordinate bond.

Nucleotide: a molecule made from a phosphate ion bound to 2-deoxyribose which is bonded to one of the 4 bases of DNA (adenine, cytosine, guanine and thymine).

Pentose Sugar: a sugar molecule that contains 5 carbon atoms.

Peptide Link: a bond which forms between the carboxyl group (-COOH) of one amino acid and the amino group ($-NH_2$) of another in a protein. When peptide links are hydrolysed, the constituent amino acids are formed.

Primary Protein Structure: the sequence of a chain of amino acids that make up a protein, contains peptide bonds.

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

Secondary Protein Structure: the structure of a protein when hydrogen bonds form between the amino acid chains. There are 2 types of secondary protein structure: α-helix and β-pleated sheet.

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

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

Thin Layer Chromatography: a technique which uses a solvent and a plastic sheet coated in silica to separate and identify compounds such as amino acids.

Zwitterion: a molecule which has separate positively and negatively charged groups.

3.14 Organic Synthesis

Atom Economy: The measure of the amount of starting materials that end up as useful products.

$$\text{Percentage atom economy} = \frac{\textit{Molecular mass of desired product}}{\textit{Sum of molecular masses of all reactants}} \times 100$$

Organic Compound: a carbon-containing compound.

Solvent: a liquid which can dissolve other substances.

Synthesis: combining different elements and compounds to build new molecules.

3.15 Nuclear Magnetic Resonance Spectroscopy

Aliphatic Compound: an organic compound that is made up of straight or branched chains.

CCl_4: a solvent commonly used in ^{1}H NMR spectroscopy.

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

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

Deuterated Solvent: a solvent in which all hydrogen atoms are replaced with deuterium.

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

Equivalent protons: protons that are in the same environment.

Integrated NMR Spectrum: shows the area under each peak on a ^{1}H NMR spectrum, indicating the relative number of ^{1}H atoms in each environment.

n+1 rule: used to determine spin-spin 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}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}C or ^{1}H nuclei are analysed. ^{13}C NMR spectra are generally simpler than ^{1}H NMR spectra.

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

Singlet: a signal on a ^{1}H NMR spectra made up of 1 peak, indicating that there are no 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}H NMR spectrum is split into a multiplet according to the n+1 rule.

TMS (tetramethlysilane): the standard for calibrating chemical shift values in NMR.

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

3.16 Chromatography

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

Column Chromatography (CC): a type of chromatography in which a column is packed with a solid and a solvent moves down the column.

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 be used to analyse components separated by GC.

Mass Spectrometry: a technique that measures the mass to charge ratio of gaseous ions. Mass spectrometry may be used after a mixture has been separated by GC to identify the compounds present.

Mobile Phase: a substance that moves through the chromatography system to separate the mixture. This may be a gas (GC) or a liquid (TLC and CC).

Retention Time: The time taken for a sample to travel from the inlet to the detector in GC. The recorded retention time can be compared with standards to identify the substances in the mixture.

R_f Value: in TLC, the R_f values can be calculated as shown below then compared with standards to identify what substances present in a mixture.

$$R_f = \text{distance moved by substance} \div \text{distance moved by solvent}$$

Stationary Phase: a substance through which the mobile phase moves in chromatography. This is typically a solid although a solid coated in a liquid may be used in GC.

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