# 4.1 - Basic concepts and hydrocarbons

## 4.1.1 - Basic concepts of organic chemistry

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| **Define hydrocarbon** | A compound consisting of **ONLY** hydrogen and carbon. | |
| **Define saturated and unsaturated** | * Saturated means **ONLY** single carbon-carbon bond. * Unsaturated means multiple carbon-carbon bonds (e.g., C=C and C≡C).   *Remember, s in saturated for single.* | |
| **Test for unsaturated compounds** | Add bromine water which turns the solution from orange to colourless. | |
| **Define molecular formula** | The **ACTUAL** number of atoms of **EACH ELEMENT** in an element/compound. | |
| **Define empirical formula** | The **SIMPLEST** ratio of atoms of **EACH ELEMENT** in an element/compound. | |
| **Define general formula** | The algebraic formula for homologous series (e.g., CnH2n). | |
| The arrangement of atoms in compound (e.g., CH3(CH2)2CH3). | |
| **Difference between displayed and skeletal formulae** | * Displayed - every bond is drawn. * Skeletal - carbon to hydrogen bonds aren’t drawn.   *Every bond means -OH should be drawn as -O-H.* | |
| **Define aliphatic** | An organic compound joined in straight or branched chains, or non-aromatic rings.    *Cyclohexane is more specifically alicyclic yet also aliphatic.* | |
| **Define alicyclic** | An organic compound that is both aliphatic and cyclic. | |
| **Define aromatic compounds / arenes** | Containing benzene ring(s). | |
| **Define homologous series** | A family of compounds with the same functional group yet each successive member differs in the addition of a -CH2- group. | |
| **Functional group, prefix, and suffix of an alcohol** | * Functional group: OH. * Prefix: hydroxy-. * Suffix: -ol (more common). | |
| **Functional group and prefixes of haloalkanes** | * Functional group: C-X. * Prefix: fluro-, chloro-, bromo-, iodo-.     *E,g., 1-chloropropane* | |
| **Functional group, prefix, and suffix of aldehydes** | * Functional group:      * Prefix: formyl-. * Suffix: -al.     *E.g., ethanal.* | |
| **Functional group, prefix, and suffix of ketones** | * Functional group:      * Prefix: oxo-. * Suffix: -one (more common).     *E.g., propone.* | |
| **Functional group and suffix of carboxylic acids** | * Functional group:      * Suffix: -oic acid.     *E.g., ethanoic acid.* | |
| **Functional group and suffix of esters** | * Functional group:      * Suffix: -yl-oate.     *E.g., methyl ethanoate.* | |
| **What takes precedence when naming with branched chains?** | * Functional groups. * E.g., 3-methylbut-1-ene is right, 2-methylbut-3-ene is wrong.     *Begin counting carbons from the functional group.* | |
| **Define structural isomers** | Same molecular formula but **different structural formula**. E.g.,    *This has the subsets of chain isomers, positional isomers, and functional group isomers.* | |
| **Define chain isomers** | Same molecular formula but **different arrangement of carbon atoms**. | |
| **Define positional isomers** | Same molecular formula but **different position of functional group** (e.g., propan-1-ol and propan-2-ol). | |
| **Define functional group isomers** | Same molecular formula but **different functional group** (e.g., but-2-one and butan-1-ol). | |
| **What is homolytic fission and what does it form?** | A **COVALENT BOND BREAKS** (1) with each bonded atom getting an electron forming radicals (1). | |
| **Define free radical** | A reactive species with an unpaired electron. | |
| **What is heterolytic fission?** | When a **COVALENT BOND BREAKS** (1) with one bonded atom getting both electrons forming ions (1). | |
| **Where must curly arrows start?** | At a lone pair or the centre of a bond. | |

## 4.1.2 - Alkanes

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| **Which important bonds are freely rotating in organic chemistry?** | Single C-C and C-H bonds. |
| **What 2 factors affect the boiling points of a homologous series?** | 1. Length of the main chain:    * Longer ∴ **MORE** London forces ∴ stronger the attraction ∴ more energy required to overcome. 2. Surface area of contact:    * Greater ∴ **MORE** London forces ∴ stronger the attraction ∴ more energy required to overcome.    * Branching reduces this. |
| **Give 2 reasons why organic compounds are mostly unreactive** | * C-C and C-H have high bond enthalpies. * Very low bond polarity (essentially nonpolar).   *However, they can react with radicals or anything else as reactive as a radical.* |
| **What is incomplete combustion, what does this form, and what does this mean in terms of energy?** | * Combustion under limited oxygen forming CO and/or C (soot). * Produces less energy per mole (as less energy is released from bond making.) |
| **What is cracking?** | * Converting long chain hydrocarbons to smaller ones. * High Mr alkane → small Mr alkane + alkene. |
| **Describe the 3 steps of the synthesis of chloroalkanes (using methane)** | 1. Initiation - UV light is supplies enough energy to break Cl-Cl bonds by homolytic fission. 2. Propagation - chlorine radicals remove H atoms from methane to form methyl radicals. These react with Cl2 molecules to form a chloromethane and Cl•. The new radical continues the chain reaction. 3. Termination - when all radicals meet other radicals. |
| **Give 2 problems with synthesising haloalkanes by free radical substitution** | * Lots of termination steps lead to impurities (e.g., 2 •CH3 meeting). * Further substitution of termination products. |
| **Describe the process of fractional distillation** | 1. Heat the crude oil to the highest boiling point. 2. Funnel the vapours into a fractionating column which is cooler further up. 3. Let the hydrocarbons will rise up and condense and their respective b.p.’s. |

## 4.1.3 - Alkenes

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| **Define electrophile** | A species that accepts a lone pair of electrons.  *Think of ‘phile’ as meaning loving. It loves electrons.* |
| **What is a π bond? (with diagram)** | The sideways overlapping of p-orbitals.    *Draw the full reaction with the arrows.* |
| **Give 2 differences between σ and π bonds** | 1. π bonds have a lower bond enthalpy than σ bonds. 2. σ bonds have electron density between bonding atoms **WHEREAS** π bond have electron density above and below bonding atoms (so are more exposed/prone to attack). |
| **What are stereoisomers?** | Same structural formulae but different spatial arrangement of atoms. |
| **What is required for E-Z stereoisomerism to arise?** | 1. A double C=C bond (which provides limited rotation). 2. Two different groups on each carbon atom around the double bond. |
| **Describe the Cahn-Ingold-Prelog (CIP) priority rule** | * Identify the priority groups on either side (the atom with the larger atomic mass). * If the priorities are on the same (**zame**) side, it is a Z-isomer. If the priorities are on opposite sides (**epposite**), it is a E-isomer. * If the directly attached atoms are the same, move onto the next atom. |
| **What is E/Z isomerism?** | An example of stereoisomerism where...   * There is restricted rotation about the C=C. * Two different groups attached to each 12C of the C=C group. |
| **What is cis-trans isomerism?** | A special case of E/Z isomerism (and thus stereoisomerism) where a substituent group on one 12C of the C=C group is the same as the other 12C.  Eg,    The left is cis **whereas** the right is trans.  *Note that above, they only need 2 of the same groups, both groups on each carbon* ***don't*** *have to be the same. This also counts as E/Z isomerism as it can be named using the CIP convention too. It's just the cis-trans is a most specific form.*  *Cis for same and trans for opposite.* |
| **What is the hydration of alkenes and its conditions?** | * Forming alcohols from alkenes. * Conditions:   + Steam.   + Phosphoric acid catalyst.   + Around 300°C * Example:   + C2H4 + H2O → C2H5OH |
| **What is hydrogenation of alkenes and its conditions?** | * C2H4 + H2 → C2H6. * With **hydrogen** in the presence of a **nickel catalyst** at around **150°C**. |
| **Describe and draw the electrophilic addition between bromine and ethene** | 1. Br2 molecule approaches alkene. 2. Electrons in the π bond induce a temporary dipole the Br2 thus causing the Brδ+ to attack the electron dense π bond whilst the Br-Br bond breaks by heterolytic fission. 3. The positive carbon on the carbocation intermediate attracts the Br- ion |
| **Describe the electrophilic addition of hydrogen bromide and butene** | 1. As the HBr (polar molecule) approaches the double bond, the Hδ+ attacks the electron dense π bond whilst the hydrogen-halogen bond breaks by heterolytic fission. 2. This forms a carbocation intermediate which attracts the Br- atom. |
| **What is Markovnikov's rule and what is used to do? (both with and without 1H)** | * That the Hδ+ in the hydrogen halide will attach to the carbon with more hydrogens attached. * It’s used to determine the major and minor products of electrophilic addition between hydrogen halides and asymmetric alkenes. * For ICl, the Iδ+ will bond with the carbon with more hydrogens attached to it since it is less electronegative (just like Hδ+). |
| **What conditions are required for polymerisation?** | * High temperature. * High pressure. * A catalyst.   *The specifics depend on the product you want to form.* |
| **Draw the polymerisation of monomers into a polymer** | *The bracket with the ethane inside is a repeat unit.* |
| **What limits biodegradable plastics?** | Not having the right conditions to decompose (i.e., moisture and oxygen). |
| **Give 3 ways of dealing with waste polymers** | 1. Separating and recycling. 2. Used as feedstock for cracking. 3. Combusting for energy production. |
| **What are the problems of combusting polymers?** | Can lead to toxic fumes (e.g., HCl). |
| **Give examples of homogeneous catalysis** | * Acid catalyst in esterification. * Depletion of atmospheric ozone by chlorine radicals. |

# 4.2 Alcohols, haloalkanes and analysis

## 4.2.1 - Alcohols

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| **What dangers are there with some alcohols?** | Methanol, ethanol, and propanol are very flammable. |
| **Why do alcohols have a low volatility and high b.p.?** | As they can form hydrogen bonds which require more energy to overcome. |
| **Why are shorter chain alcohols more soluble in water?** | The functional group, which forms hydrogen bonds with water molecules making it soluble, forms a greater proportion of the molecule. |
| **What are the 3 degrees of alcohols?** | * Primary (1°):     *The carbon which the functional group is attached to is only attached to one other carbon.*   * Secondary (2°):      * Tertiary (3°): |
| **What are the reagents for the oxidation of primary and secondary alcohols and where are they from?** | * An excess of…   + Cr2O72-.   + H+. * From solution of potassium dichromate (VI) and dilute sulfuric acid.   *Something such as hydrochloric acid cannot be used as the dichromate ions would rather oxidise this.* |
| **What is the equation for the partial oxidation of primary alcohols?** | A primary alcohol reacts with [O] (the oxidising agent) to form an aldehyde and water.    *E.g., propan-1-ol to propanal.* |
| **What are the reaction conditions for the partial oxidation of primary alcohols and why?** | Distilling the aldehyde as it forms otherwise it will continue onto form a carboxylic acid. |
| **What is observed (colour-wise) under the oxidation of alcohols?** | **Orange** to **green** colour change. |
| **Describe the setup for distillation with an explanation for the key points** | *Some setups may have a receiver at the end of the condenser.*   * Bulb of thermometer at T-junction - to display the correct b.p. * Water entering via bottom of condenser - entire condenser will fill up before water exits. * Electric heater - prevents highly flammable organic compounds setting alight under a live flame.   *If water enters via the top of the condenser, it would trickle down and leave without filling the whole condenser.* |
| **What is the equation for the full oxidation of a primary alcohol? Explain it** | Primary alcohol + 2[O] → carboxylic acid + water     1. Two lots of oxidising agent is required; one for each stage 2. The water was produced at the first stage (when forming aldehyde)   *You can distill afterwards to remove any unreacted alcohol molecules.* |
| **What are the reaction conditions for the full oxidation of primary alcohols and oxidation of secondary alcohols? Why?** | Heating under reflux to prevent evaporation. |
| **Describe reflux setup** | * Open end - prevents build up of gas that can cause explosion * Anti-bumping granules - prevents vigorous and uneven boiling by forming smaller bubbles |
| **When is the reflux setup most often used?** | When heating organic reaction mixtures for long periods. |
| **What is the equation for oxidation of secondary alcohols?** | Secondary alcohol + [O] → ketone + water |
| **Why won’t tertiary alcohols oxidise?** | As you need to remove a 1H atom from the carbon the -OH is bonded to (alongside the 1H from the -OH substituent group). Yet, no 1H is bonded to said carbon. |
| **What are the products and conditions for the dehydration of alcohols and why?** | * Forms an alkene and water. * **HEAT** under reflux. * Concentrated sulphuric or phosphoric acid. * As we don’t want any water to form alcohols again.   *In short, the same catalyst, however, without water.* |
| **What is an elimination reaction?** | A reaction involving the elimination of leaving group to form an unsaturated compound. |
| **What type of reaction is the dehydration of alcohols? And why?** | * Acid-catalysed **elimination**. * The -OH group (and a 1H on an adjacent carbon) is eliminated forming an unsatured molecule. |
| **When and why are isomers formed from the dehydration of alcohols?** | * From secondary or tertiary alcohols. * As an H is removed from either one of the two/three adjacent carbons to the carbon the -OH is bonded to. |
| **How are haloalkanes formed from alcohols safely, and why? (conditions) (using hydrogen bromide and ethanol as an example)** | 1. Form the hydrogen halide in a substitution reaction between NaBr and H2SO4.   NaBr + H2SO4 → NaHSO4 + HBr   1. React the alcohol with the hydrogen halide.   CH3CH2OH + HBr → CH3CH2Br + H2O   * This is by nucleophilic substitution **UNDER REFLUX**. * The HBr is highly toxic so has to be produced within the reaction mixture and reacted instantly.     *You can write an overall reaction for this.* |

## 4.2.2 - Haloalkanes

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| **What is a nucleophile (with examples)?** | * A species that donates lone pair of electrons. * HO-, H2O, and NH3. |
| **What makes HO- a better nucleophile than H2O?** | Its full charge. |
| **Describe and draw the general nucleophilic substitution of a haloalkane** | *Substitution here is swapping the halogen for another atom.*   1. The nucleophile attacks the delta positive carbon in the carbon-halogen polar bond to form a covalent bond. 2. At the same time, the carbon-halogen bond breaks by heterolytic fission forming a halide ion. 3. The geometry of the product switches.  * The nucleophile approaches from behind as its repelled by the delta negative halogen.   *For a tertiary haloalkane, this is a 2-step process because the carbocation intermediate is stable on its own.* |
| **What is hydrolysis?** | A **type of reaction** involving the splitting of a molecule by water. |
| **What are the conditions and products for the hydrolysis of halogenoalkanes?** | * Heating under reflux with NaOH (aq) or KOH (aq). * The product is an alcohol and a compound of the halogen (e.g., NaBr or KBr for the hydrolysis of bromoalkanes).   *The NaOH and KOH is needed so it dissociates into HO- nucleophiles. You can’t just have a pure solution of OH ions.* |
| **What 2 things does the rate of the hydrolysis of haloalkanes depend on and how?** | * The bond enthalpy (i.e., strength) of the carbon-halogen bond; the weaker, the faster. * The degree of the haloalkane; tertiary is faster than secondary which is faster than primary. |
| **Why does the degree of haloalkane affect the rate of hydrolysis?** | The higher the degree, the more stable the carbocation intermediate formed. |
| **How does the strength of the carbon-halogen bond vary between different haloalkanes and why?** | * Bond enthalpy (i.e., strength) decreases for halogens further down the group ∴ **broken more easily**. * Due to decreased attraction between the bonding pair of electrons and the nuclei of bonding pairs due to increased shielding and atomic radius.   *This factor overrides the polarity of the bonds.* |
| **How can the rate of the hydrolysis of haloalkanes be measured and why?** | * By adding AgNO3 (aq) and timing how long it takes for a precipitate for form. The quicker it does, the faster the rate of reaction. * As soon as the halide ion is formed from nucleophilic substitution, it can react with the silver ion: Ag+ (aq) + X- (aq) → AgX (s). |
| **What are CFCs, what are they used as and why?** | * Chlorofluorocarbons (thus containing only carbon, chlorine, and fluorine). * Used as propellants, aerosols, and refrigerants because of their stability/low-reactivity, non-toxicity, and volatility. |
| **What is in equilibrium in the upper atmosphere and how?** | * The formation and destruction of ozone. * O2 → 2O (broken by UV light to form diradicals). * O3 ⇌ O2 + O. |
| **Describe how CFCs lead to the destruction of ozone and explain why this is so effective** | * The weaker C-Cl bond is broken by homolytic fission under UV light forming Cl• which catalyses the breakdown of ozone:   + Cl• + O3 → ClO• + O2   + ClO• + O• → O2 + Cl• * The overall equation is O3 + O• → 2O2 * The chlorine radical is reproduced so they have a long residence time.   *Nitrogen oxides work in a similar way.* |
| **What does the destruction of the ozone mean?** | Exposed to UV light which can cause skin cancer. |

## 4.2.3 - Organic synthesis

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| *Most of the techniques are covered earlier on.* | |
| **What is redistillation?** | Changing the beaker as soon as the b.p. on the thermometer changes as another substance is about to exit the condenser. |
| **How is a separating funnel used?** | 1. Shake the reaction mixture then allow to settle into a dense aqueous layer (containing the impurities) and a less dense organic layer. 2. Open the tap to run off the aqueous layer. |

## 4.2.4 - Analytical techniques

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| **Give an everyday use of IR spectroscopy** | Breathalyzers. |
| **How does mass spectroscopy work?** | By ionising atoms/molecules, accelerating them via an electric field, deflecting them by varying degrees using a magnetic field, and detecting. |
| **What are the lines on a mass spectrum?** | * If analysing elements, they’re isotopes. * If analysing compounds, they’re fragment ions. |
| **What is fragmentation under mass spectroscopy?** | When a bond breaks in a molecular ion (due to instability) forming fragment ions.  *The electron can go onto either side of the double bond. E.g., for CH3CH2OH, it may form [CH3CH2]+ (with the positive charge on the second carbon) or HO+.* |
| **What absorbs IR in the atmosphere, what happens, and what can this lead to?** | * The bonds of gaseous molecules such as CO2 and H2O. * They vibrate **MORE**. * Global warming. |
| **Give 3 things the Greenhouse Effect of a gas depends on** | * Its atmospheric concentration. * Its ability to absorb IR. * Its residence time (how long it’s in the atmosphere). |