

(a) Homologous Series

Systematic Carbon Chemistry

- **Hydrocarbons** are compounds containing only hydrogen and carbon atoms
- Homologous series: is a family of compounds with the same general formula and similar chemical properties
- Bonding: carbons must make 4 bonds, hydrogen must make 1 bond
- **Full structural formula** - draw out all the atoms and bonds
- **Shortened structural formula** - sequence of atoms (look at each carbon and write how many hydrogens are attached)
- **Molecular formula** - the number of carbon atoms and hydrogen atoms in each molecule
- **General formula** - formula including 'n' for each family (allows you to work out individual molecular formulas for the molecules in that family)
- **Isomers**: molecules with the same molecular formula but different structures.

Physical Properties

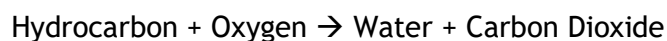
- A physical property is something that can be observed and measured (e.g. boiling point and melting point).
- As alkanes, alkenes or cycloalkanes increase in size (increase in number of carbon atoms) there is a gradual increase in the melting points and boiling points.
- Molecules with more carbons **have stronger forces of attraction between the molecules** therefore it takes more energy to separate these molecules.
- These molecules have stronger **intermolecular forces**.
- Isomers have different physical properties including melting and boiling point

Uses

- Hydrocarbons are used in **fuels** - especially branched chain alkanes
- Alkenes (branched chain) - used in **plastics** - they are monomers in polymerisation reactions
- Cycloalkanes - used as **solvents** for compounds that do not dissolve in water

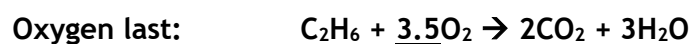
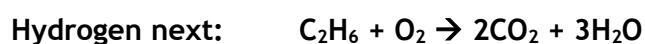
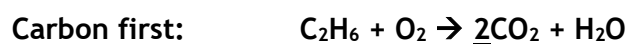
Combustion

- Is the reaction of burning a fuel in oxygen
- It is an exothermic reaction
- A fuel is a substance that burns to release energy
- Complete combustion - burning in a plentiful supply of oxygen to produce **carbon dioxide and water**

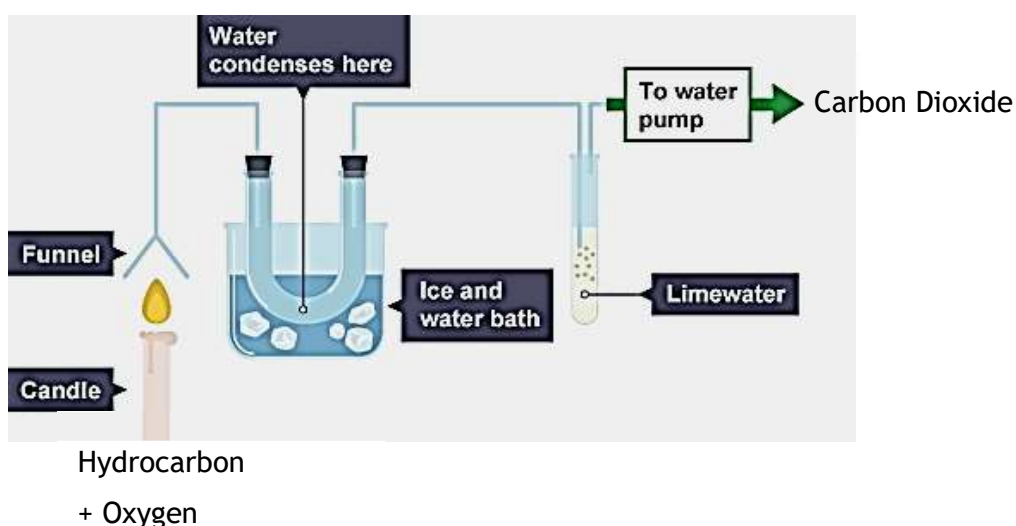


- Balancing a combustion equation - use the 'CHO' rule

e.g.



- Testing for the products of combustion - water and carbon dioxide



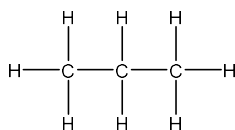
Alkanes

- Names end in -ane
- Start of name represents the number of carbon atoms (these names are also given in the data booklet pg 9)

Number of carbons	Name
1	Methane
2	Ethane
3	Propane
4	Butane
5	Pentane
6	Hexane
7	Heptane
8	Octane

- They are **saturated** - the carbon to carbon bonds are all single bonds
- General formula: C_nH_{2n+2}
- e.g. Propane

- Full structural formula:



- Shortened structural formula: $\text{CH}_3\text{CH}_2\text{CH}_3$
- Molecular formula: C_3H_8

Branched Chained Structures - Systematic Naming Rules:

- The **longest chain** is the main chain and the last part of the name.
- **Numbering** of the main chain starts from the end that gives the lower overall number position for side groups (branches).
- **Side branch** names end in 'yl' and depend on the number of carbon atoms in them: methyl for 1 carbon, ethyl for 2 carbons, propyl for 3 carbons, etc.
- **Prefixes** 'di', 'tri' etc... are used when the same branch is present more than once
- **Alphabetical** order is used if different side branches appear in the same structure e.g. ethyl before methyl
- **Hyphens** are used before or after numbers that come next to letters within a name e.g. 2-ethyl-3-methyl.....
- **Commas** are used between numbers if there is more than one of the same side branch e.g. 2,3,3-trimethyl..... (remember if there are 2 branches on one carbon you must write the position number twice)
- e.g. 3-methylpentane
- Full structural formula:
 - Shortened structural formula: $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$
 - Branches are shown in **brackets**
 - Molecular formula C_6H_{14}
- Straight chained and branched chained alkanes are isomers of each other

Cycloalkanes

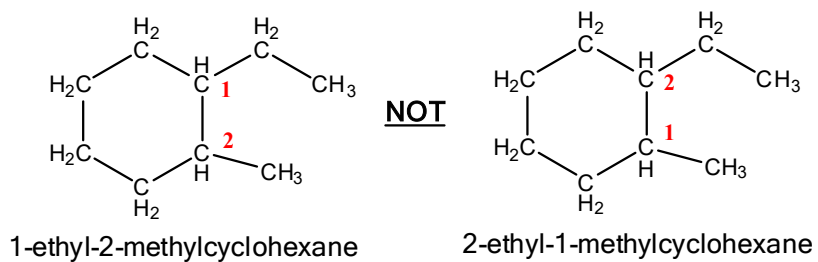
- Names end in -ane and start with cyclo-
- Start of name represents the number of carbon atoms (some of these names are also given in the data booklet page 9)

Number of carbons	Name
3	Cyclopropane
4	Cyclobutane
5	Cyclopentane
6	Cyclohexane
7	Cycloheptane
8	Cyclooctane

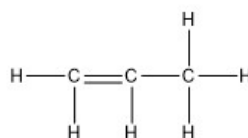
- They are **saturated** - made up of only carbon-to-carbon single bonds
- Cycloalkanes are made up of carbon atoms that form a **ring**
- General formula: C_nH_{2n}
- e.g. Cyclopropane
 - Full structural formula:
 - Shortened structural formula:
 - Molecular formula: C_3H_6

Naming Cycloalkanes

- Choose one of the branches to be 1 and ensure the branches have the lowest possible numbers
- If two different branches number in alphabetical order
- *e.g.*



- Cycloalkanes and alkene are isomers of each other
- *e.g.* cyclopropane and propene are both C_3H_6 but they have a different structure:

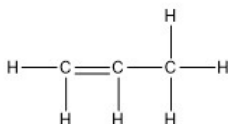


Alkenes

- Names end in -ene
- Start of name represents the number of carbon atoms (some of these names are also given in the data booklet page 9)

Number of carbons	Name
2	Ethene
3	Propene
4	Butene
5	Pentene
6	Hexene
7	Heptene
8	Octene

- Alkenes are made up of chains of carbon atoms that contain at least one double bond
- They are **unsaturated** - this means that the molecule contains at least one double (or triple) carbon to carbon bond
- General formula: C_nH_{2n}
- e.g. Propene
- Full structural formula



- Shortened structural formula: $CH_2=CHCH_3$
- Molecular formula: C_3H_6

Naming Alkenes

- When naming alkenes, the position of the double bond **MUST** be given
- Numbering of a molecule starts at the end closest to the double bond - the double bond takes priority over branches
- e.g. 4-methylpent-2-ene

- The number for the double bond is the number of the carbon where the bond starts
- e.g.

But-1-ene

But-2-ene

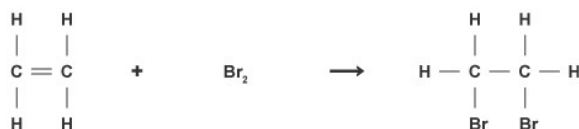


- These structures are isomers of each other as the double bond is in a different position

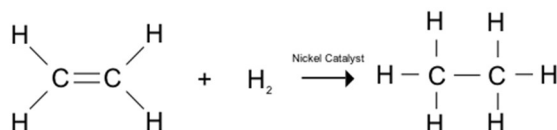
Addition reactions

- The chemical test for unsaturation - a double bond (e.g. an alkene) is it **decolourises bromine water**
- Alkenes undergo addition reactions: the addition of a small molecule across a double bond.
- e.g.

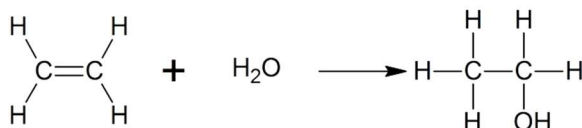
Alkene + Bromine (Br_2) $\rightarrow$ dibromoalkane (bromination)



Alkene + Hydrogen (H_2) $\rightarrow$ Alkane (hydrogenation)



Alkene + Water (H_2O) $\rightarrow$ Alcohol (hydration)



Other small molecules include HX (X = halogen) e.g. HBr , HCl , HI

Summary:

Homologous Series	General Formula	Saturated or Unsaturated	Decolourises bromine?
Alkanes	$\text{C}_n\text{H}_{2n+2}$	Saturated	No
Alkene	C_nH_{2n}	Unsaturated	Yes
Cycloalkane	C_nH_{2n}	Saturated	No

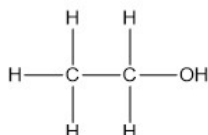
(b) Everyday Consumer Products

(i) Alcohols

- Homologous series with a similar chemical structure to alkanes however one of the hydrogen atoms is replaced with an -OH group.
- Functional group = **Hydroxyl group** (-OH group)
- Name ends in -ol
- Start of name represents the number of carbon atoms (some of these names are also given in the data booklet pg 9)

Number of carbons	Name
1	Methanol
2	Ethanol
3	Propan-1-ol
4	Butan-1-ol
5	Pentan-1-ol
6	Hexan-1-ol
7	Heptan-1-ol
8	Octan-1-ol

- General formula: $C_nH_{2n+2}O$
- e.g. Ethanol
- Full structural formula:



- Shortened structural formula: $\text{CH}_3\text{CH}_2\text{OH}$
- Molecular formula: $\text{C}_2\text{H}_5\text{OH}$ or $\text{C}_2\text{H}_6\text{O}$

Naming

- The position of the OH group **MUST** be stated. The number carbon the OH is attached to goes in front of the -ol in the name, the lowest possible number is used:

e.g.

- These structures are isomers as the OH is in a different position

Physical Properties

- The melting point and boiling point of alcohols increase as the molecules increase in size. There are more/stronger **intermolecular forces of attraction** in bigger molecules so it takes more energy to separate bigger molecules
- As the length of the hydrocarbon chain **increases**, the solubility of alcohols in water **decreases**

Chemical Properties

- They are flammable
- They react with carboxylic acids to form esters

Uses

- **Solvents** - they dissolve a variety of compounds and evaporate easily meaning they are used in cleaning e.g. baby wipes, alcohol gels
- **Fuels** - because they are highly flammable and burn with very clean flames

Production of Ethanol

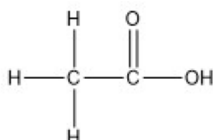
- Ethanol is produced from **fermentation**, but alcohols can be produced from reacting an alkene with water - addition reaction.

Carboxylic acids

- Functional group = **Carboxyl group** (-COOH group)
- Name ends in -oic acid
- Start of name represents the number of carbon atoms (some of these names are also given in the data booklet pg 9)

Number of carbons	Name
1	Methanoic acid
2	Ethanoic acid
3	Propanoic acid
4	Butanoic acid
5	Pentanoic acid
6	Hexanoic acid
7	Heptanoic acid
8	Octanoic acid

- General formula: $C_nH_{2n}O_2$
- e.g. Ethanoic acid
- Full structural formula:



- Shortened structural formula: CH_3COOH
- Molecular formula: $C_2H_4O_2$

Naming

- When naming the -COOH carbon **MUST** be counted as one of the carbons
- When numbering the -COOH carbon is always carbon 1

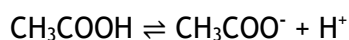
Physical Properties

- The boiling point of carboxylic acid increase as the molecules increase in size. There are more/stronger **intermolecular forces of attraction** in bigger molecules, so it takes more energy to separate bigger molecules.

- Smaller carboxylic acids (C1-5) are soluble in water whereas larger carboxylic acids are less soluble.

Chemical Properties

- Carboxylic acids are **weak** acids (pH 3-5) they partially ionise when added to water



- They react with metals, oxides, hydroxides, and carbonates - neutralisation reactions
- Example: vinegar = ethanoic acid is good at removing metal carbonates from kettles, showerheads and taps

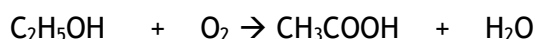


- They react with alcohols to form esters

Uses

- Vinegar is a solution of ethanoic acid. Vinegar is used:
- In **household cleaning products** designed to remove lime scale (insoluble metal carbonates removed by neutralisation)
- As a **preservative** in the food industry - the low pH of vinegar prevents bacteria and fungi growing. Examples: pickling eggs or vegetables

- Formation of vinegar
- Vinegar is a solution of ETHANOIC ACID.
- Vinegar can be made by reacting alcohol, such as wine or beer, with oxygen (oxidation).



- It is the ethanoic acid that gives vinegar its characteristic smell and taste.

(c) Energy from Fuels

Fuels

- Combustion reactions are exothermic - fuels release energy during combustion reactions
- Exothermic reactions: release energy to their surroundings (often in the form of heat - e.g. a heat pack)
- Endothermic reactions: take in (absorb) energy from their surroundings (often resulting in the surrounding cooling down)

Equation

$$E_h = cm\Delta T$$

- equation and c given in data booklet page 3
- E_h = energy released (kJ)
- c = specific heat capacity of water ($4.18 \text{ kJ kg}^{-1} \text{ }^\circ\text{C}^{-1}$) = energy needed to raise the temperature of 1 kg of a substance by $1 \text{ }^\circ\text{C}$
- m = mass of **water** (kg) [we assume that 1 litre = 1 kg] (if given volume in cm^3 must divide by 1000)
- ΔT = temperature change ($^\circ\text{C}$)

Rearrangement of the equation

$$E_h = cm\Delta T$$

$$\Delta T = \frac{E_h}{cm} \quad c = \frac{E_h}{m\Delta T} \quad m = \frac{E_h}{c\Delta T}$$

- e.g. 500 cm^3 of water at $10 \text{ }^\circ\text{C}$ is heated by burning alcohol. Calculate the energy, in kJ required to increase the temperature of water to $22 \text{ }^\circ\text{C}$.
 - $c = 4.18 \text{ kJ kg}^{-1} \text{ }^\circ\text{C}^{-1}$
 - $m = 0.5 \text{ kg}$ (from $500 \text{ cm}^3/1000$)
 - $\Delta T = 22 - 10 = 12 \text{ }^\circ\text{C}$

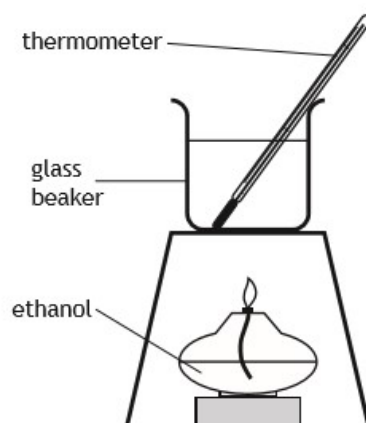
$$E_h = cm\Delta T$$

$$E_h = 4.18 \times 0.5 \times 12$$

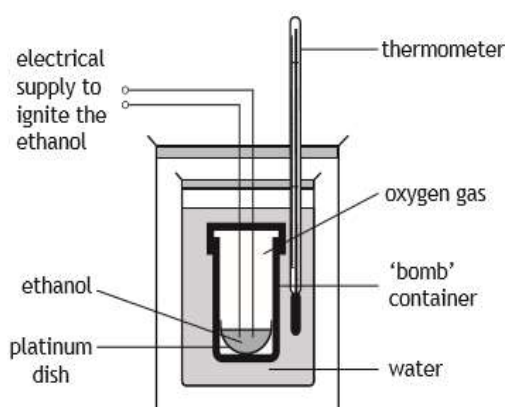
$$E_h = 25.08 \text{ kJ}$$

Experimental set up to calculate energy released

- Fuel is burned in a spirit burner
- The heat released is used to heat water in a beaker
- Mass of water in the beaker is measured before and the change in temperature is measured in the experiment
- The mass of fuel used to heat the water can be calculated by measuring the mass of the spirit burner at the start and at the end
- Must ensure the distance between the flame and the beaker is kept constant
- Light burned under the beaker to ensure as much energy as possible is transferred to the water



- There are two problems with this experimental set up:
 - Heat is lost to the surroundings.
 - Incomplete combustion occurs
- A copper can and draught shield may be used instead of a glass beaker to minimise heat loss
- The bomb calorimeter - improvement:



- Heat no longer lost to surroundings - water surrounds the container
- Complete combustion: calorimeter is attached to an oxygen cylinder.

Energy released per gram

- By comparing how much energy is released per 1g of fuel burned you can make an assessment as to which would be the most efficient fuel. [$E_h/\text{mass (g)} = \text{kJ/g}$]