Kirkcaldy High School

Chemistry

National 5

Unit 2 – Nature's Chemistry

NOTES

Course Overview

Contents

The National 5 Chemistry Course is split into three units. *Italic* shows the contents of this notes booklet.

Assessment

- There is a **final exam** for National 5 Chemistry. It lasts for **2 h 30 mins** and contains **100 marks**. There are:
  - 25 marks of multiple-choice questions
  - 75 marks of written answer questions
- There is an **Assignment** (essay on a Chemistry topic) to write for National 5 Chemistry.
  - The Assignment is **externally marked** by an SQA marker (NOT your teacher)
  - The Assignment contains **20 marks,** but these are scaled to 25 marks such that the assignment is worth one quarter of the total marks.
  - You have unlimited **time to research** and gather data for your Assignment.
  - You can **1 h 30 mins to write** the Assignment.

(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**

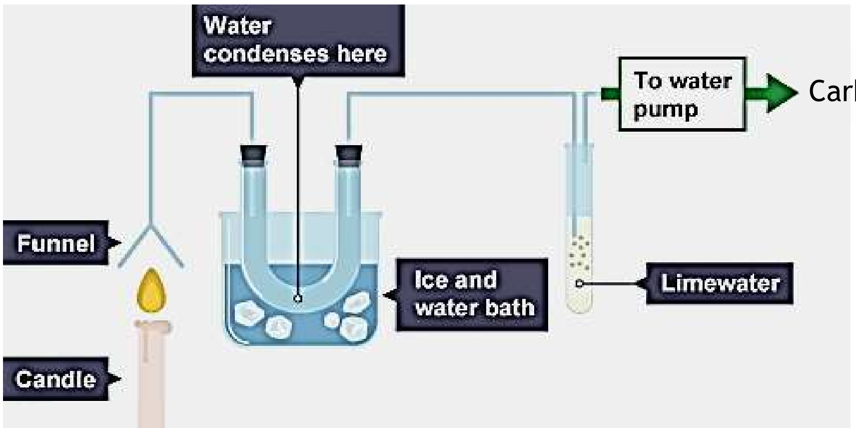
Hydrocarbon + Oxygen → Water + Carbon Dioxide

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

e.g.

	$\mathbf{C_2H_6 + O_2 \rightarrow CO_2 + H_2O}$
Carbon first:	$\mathbf{C_2H_6 + O_2 \rightarrow \underline{2}CO_2 + H_2O}$
Hydrogen next:	$\mathbf{C_2H_6 + O_2 \rightarrow 2CO_2 + \underline{3}H_2O}$
Oxygen last:	$\mathbf{C_2H_6 + \underline{3.5}O_2 \rightarrow 2CO_2 + 3H_2O}$

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



Carbon Dioxide

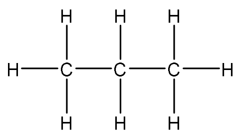
Hydrocarbon
+ Oxygen

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: $CH_3CH_2CH_3$
    - 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: $CH_3CH_2CH(CH_3)CH_2CH_3$
  - Branches are shown in **brackets**
- Molecular formula C_6H_{14}

- Straight chained and branched chained alkanes are isomers of each other

Cycloalkanes

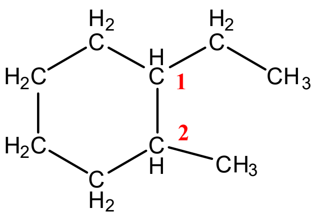
- Names end in -ane and start with cyclo-
- Start of name represents the number of carbon atoms (some of these names are also given in the data booklet page 9)

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

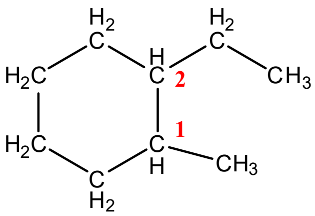
Naming Cycloalkanes

- 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.*



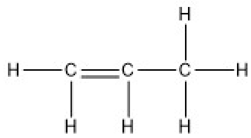
1-ethyl-2-methylcyclohexane

NOT



2-ethyl-1-methylcyclohexane

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

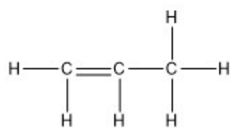


Alkenes

- 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.*

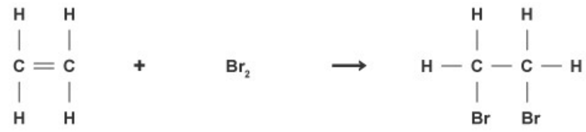
But-1-ene　　　　　　　　　　　　But-2-ene

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

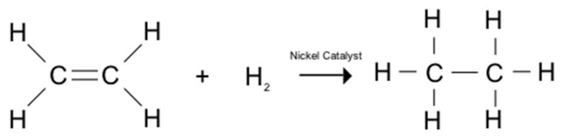
Addition reactions

- 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.*

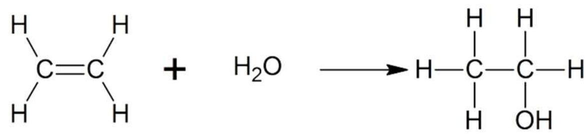
Alkene + Bromine (Br_2) → dibromoalkane (bromination)



Alkene + Hydrogen (H_2) → Alkane (hydrogenation)



Alkene + Water (H_2O) → 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	C_nH_{2n+2}	Saturated	No
Alkene	C_nH_{2n}	Unsaturated	Yes
Cycloalkane	C_nH_{2n}	Saturated	No

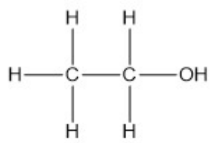
(b) Everyday Consumer Products

(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: CH_3CH_2OH
- Molecular formula: C_2H_5OH or C_2H_6O

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.

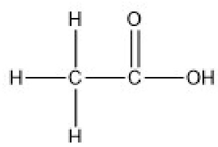
Carboxylic acids

- 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

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

- 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

Acid + Metal carbonate → Salt + Water + Carbon dioxide

- 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).

$$C_2H_5OH \quad + \quad O_2 \rightarrow CH_3COOH \quad + \quad H_2O$$

- 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 kJ kg^{-1} $°C^{-1}$) = energy needed to raise the temperature of 1 kg of a substance by 1 °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 (°C)

Rearrangement of the equation

$$E_h = cm\Delta T$$

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

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

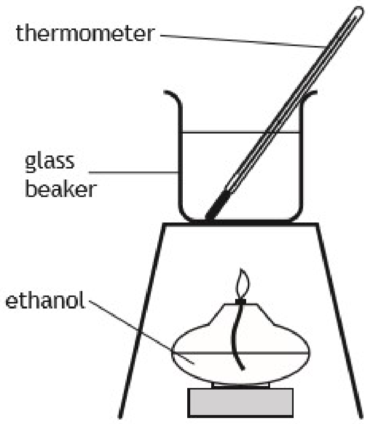
$$\mathbf{E_h = cm\Delta T}$$

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

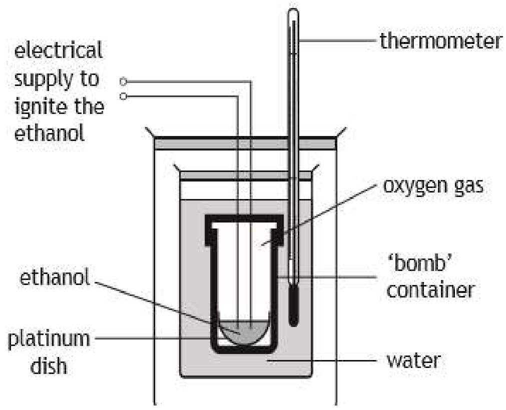
$$E_h = 25.08 \text{ kJ}$$

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/mass (g) = kJ/g]