Edexcel GCSE Chemistry

Your notes

Alcohols & Carboxylic Acids

Contents

Alcohols

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Alcohols

- All alcohols contain the hydroxyl (**–OH**) functional group which is the part of alcohol molecules that is responsible for their **characteristic reactions**

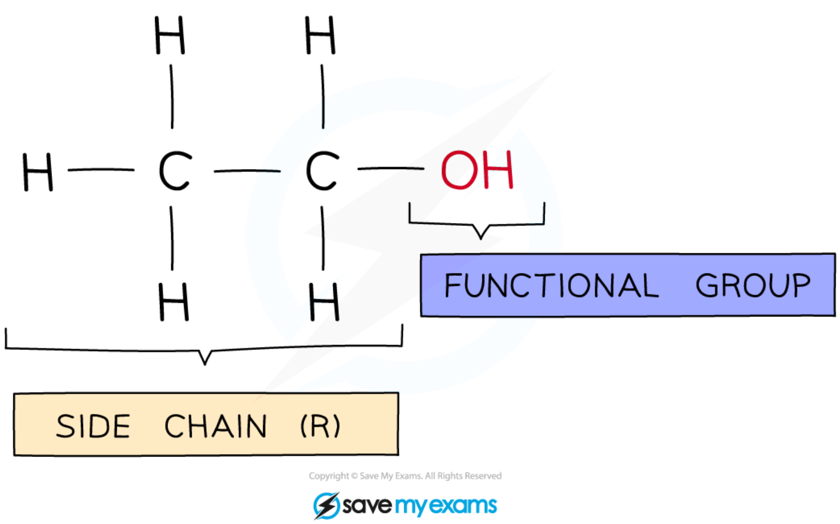
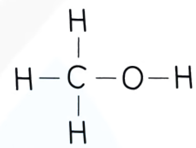
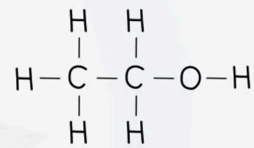
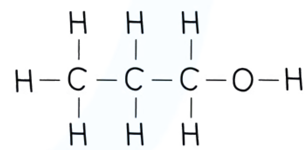
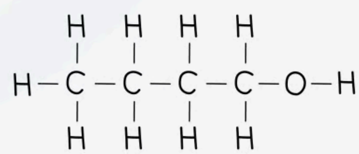


Diagram of the side chain and –OH group in ethanol which characterizes its chemistry

- Alcohols are colourless liquids that dissolve in water to form **neutral** solutions
- The first four alcohols are commonly used as **fuels**
- Methanol and ethanol are also used extensively as **solvents**
- This is because they can dissolve many substances that water cannot such as **fats** and oils, but can also dissolve most of the substances that water can
- The names and structures of the first four alcohols are shown below
- In terms of naming, the same system is used as for alkanes and alkenes, with the final '**e**' being replaced with '**ol**'

Table Showing the Formulae and Structures of the First Four Alcohols

ALCOHOL	STRUCTURAL FORMULA	DISPLAYED FORMULA
METHANOL	CH_3OH	
ETHANOL	CH_3CH_2OH	
PROPANOL	$CH_3CH_2CH_2OH$	
BUTANOL	$CH_3CH_2CH_2CH_2OH$	

Examiner Tips and Tricks

It is standard practice to write the functional group on the end as it shows what the molecule is. E.g. Methanol is CH_3OH, not CH_4O.

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Core Practical: Heat of Combustion of Alcohols

- Alcohols can be used as **fuels** as they readily undergo **combustion** and release heat energy
- Ethanol for example combusts in excess oxygen:

$$CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

- Some alcohols are **better fuels** than others i.e. they release more heat energy per mole than other alcohols
- Calorimetry studies can be performed to investigate the efficiency of alcohol fuels by measuring how much of each alcohol is needed to raise the temperature of a **fixed amount** of water by a **set number** of degrees

Heat of Combustion of Alcohols

Aim:

- To investigate the heat of combustion of four alcohols

Materials:

- Copper calorimeter can with lid, thermometer, water, spirit burner, balance
- Supply of ethanol, propanol, butanol and pentanol

Diagram:

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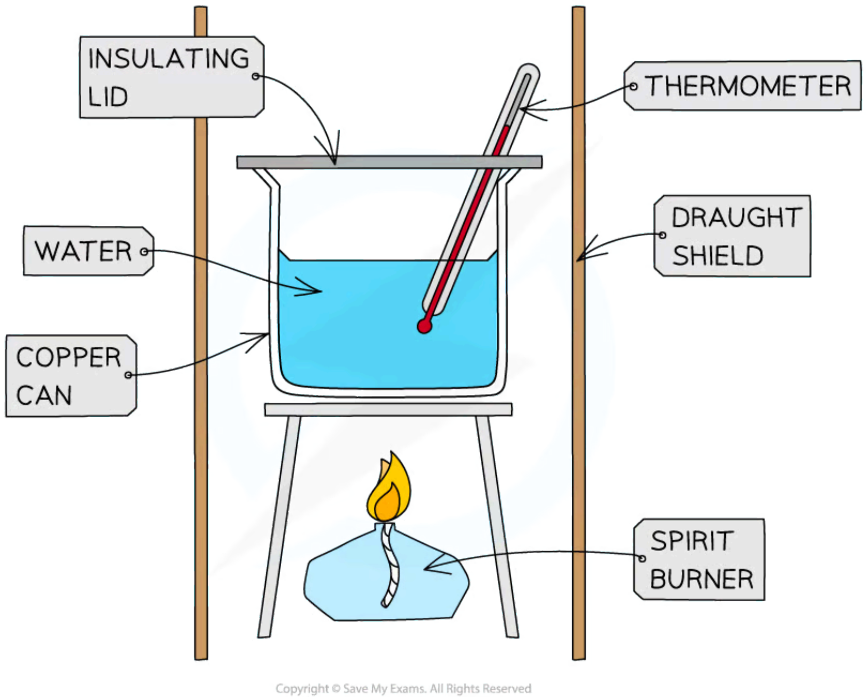

A simple combustion calorimeter

Method:

- Using a measuring cylinder, place 100 cm^3 of water into a copper can
- Record the **initial temperature** of the water and the **mass** of the empty burner
- Fill the burner with the test alcohol and record its **new mass**
- Place the burner under the copper can, light the wick and place the **lid** on
- Stir the water constantly with the thermometer (calorimeter lids allow for this) and continue heating until the temperature rises by **25 °C**
- Immediately extinguish the flame and measure and record the **mass** of the spirit burner
- Repeat procedure for other alcohols, making sure the variables are kept the same:
  - **Volume** of water (water should be changed each time)
  - **Distance** between wick and bottom of stand
- Record your results neatly in tabular format

Results:

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- Different amounts of the four alcohols will be needed to achieve the same temperature rise
- Calculate the mass change for each alcohol in the spirit burner
- Use the calorimetry equation to find the heat of combustion of the alcohols in kJ per gram or kJ per mole:

Enthalpy change equation: Q = m x c x ΔT

where:

- Q – energy transferred to water
- m – mass of water heated
- c – the specific heat capacity – is the amount of heat needed to raise the temperature of 1 gram of a substance by 1 °C.
    - For water, the value is 4.18 J g^{-1} C^{-1} (Joules per gram per degree Celsius).
- ΔT – change in temperature
- When you have found Q you have calculated amount of heat released to burn the mass of alcohol in the experiment
- You can then work out:
    - The amount of heat released per 1 g of substance = Q/mass of substance burnt
    - The amount of heat released per 1 mole of substance = (Q/mass of substance burnt) x molar mass of substance

Sample results

Sample results for combustion of alcohols

Alcohol	Ethanol	Propanol	Butanol	Pentanol
Energy released per gram of alcohol burned (kJ/g)	29.8	33.5	36.3	37.6
Mass of alcohol to produce a 40 °C rise in temperature 100 cm^3 of water (g)	0.56	0.51	0.45	0.42
Mass of alcohol to produce a 1 °C rise in temperature 100 cm^3 of water (g)	0.0140	0.0128	0.0113	0.0105

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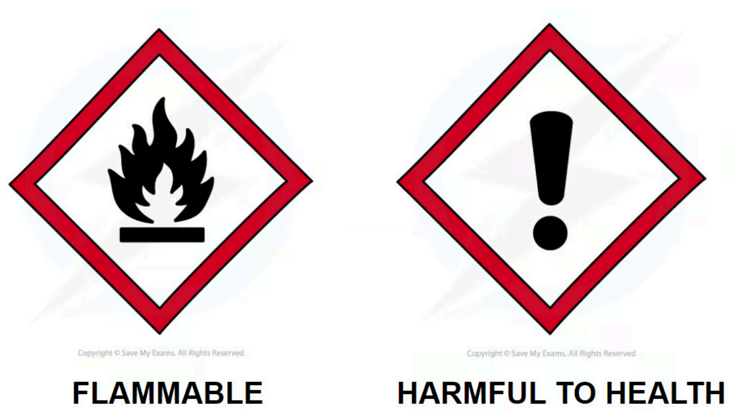
- The results show that alcohols that are larger make better fuels as they produce the **most energy per gram**
- Therefore, the order of energy density is:
  - Pentanol, $C_5H_{11}OH$ > butanol > C_4H_9OH > propanol C_3H_7OH > ethanol C_2H_5OH

Hazards, risks and precautions



Hazard symbols to show substances that are flammable and harmful to health

- The alcohols used are flammable and often harmful to health, e.g, propan-1-ol, butan-1-ol, pentan-1-ol
- The alcohols should be kept away from naked flames, e.g. a Bunsen burner
- Avoid contact with the skin and breathing in the vapour
- A fume cupboard can be used for harmful alcohols

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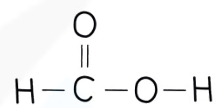
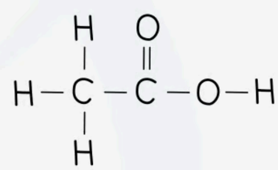
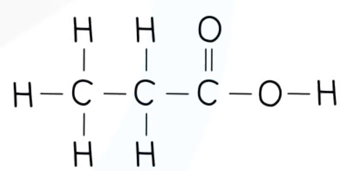
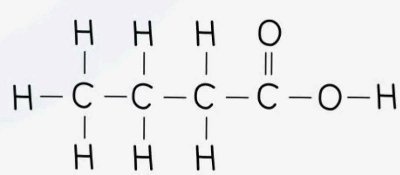
Carboxylic Acids

Carboxylic Acids

- **Carboxylic acids** is the name given to compounds containing the functional group **carboxyl, -COOH**
- The naming of a **carboxylic acid** follows the pattern **alkan + oic acid**
- The names and structure of the first four carboxylic acids are shown below

The Names and Structures of the First Four Carboxylic Acids

ALKENE	STRUCTURAL FORMULA	DISPLAYED FORMULA
METHANOIC ACID	HCOOH	
ETHANOIC ACID	CH_3COOH	
PROPANOIC ACID	CH_3CH_2COOH	
BUTANOIC ACID	$CH_3CH_2CH_2COOH$	

Examiner Tips and Tricks

Vinegar is an aqueous solution of ethanoic acid and contains about 5% of the acid by volume.

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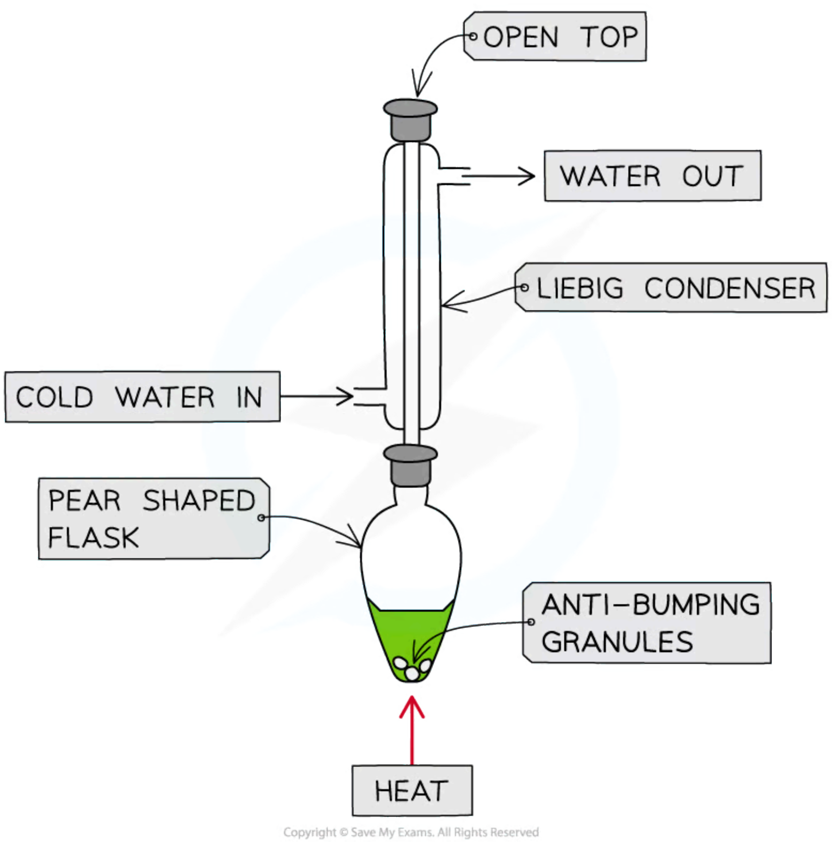
Making Ethanoic Acid

Preparation of ethanoic acid

- Alcohols undergo oxidation to produce carboxylic acids when treated with oxidising agents
- When ethanol is heated with acidified potassium dichromate solution the ethanol oxidises to ethanoic acid
- The equation for the reaction is:

$$CH_3CH_2OH + [O] \rightarrow CH_3COOH + H_2O$$

- The oxidising agent is represented by the symbol for oxygen in square brackets
- The reaction is slow so the mixture is heated to its boiling point for about an hour; to avoid the substances evaporating a condenser is placed above the reaction flask that prevents volatile liquids from escaping
- During the reaction the potassium dichromate turns from orange to green



Ethanol can be oxidised by heating it with potassium dichromate in sulfuric acid. The solution turns from orange to green during the reaction

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Examiner Tips and Tricks

Other carboxylic acids can be prepared from the oxidation of corresponding alcohols with the same carbon chain length.

Predicting Products

- Organic molecules that belong to the same homologous series react in the same way, so the products of those reactions can be predicted
- Homologous series are **families** or **groups** of organic compounds that have similar **features** and chemical **properties** due to them having the same **functional group**
- All members of a homologous series have:
  - The same **general formula**
  - The difference in the molecular formula between one member and the next is **CH_2**
  - Gradation in their **physical** properties
  - Same functional group
  - Similar **chemical properties**
- The chemistry of homologous series is therefore determined by the functional group
- We can use this to **predict** how other molecules in a homologous series will react
- Previously we have seen that ethanol can be oxidised to ethanoic acid using acidified potassium dichromate
- The next member of the series is propanol, so we can predict the reaction would be:

$$CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2COOH + H_2O$$

propanol **propanoic acid**

- Although the homologous series allows us to predict **what** the reaction products should be, it tells us nothing about the **rate** or **extent** of the reaction
- For example, as the chain length increases in alcohols the combustion or oxidation reactions may be slower or incomplete as the carbon chain influences the reactivity of the functional group

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Fermentation

Fermentation

- Ethanol (**C_2H_5OH**) is one of the most important alcohols
- It is used as **fuel** (for vehicles in some countries) and as a **solvent**
- It is the type of alcohol found in **alcoholic drinks** such as wine and beer
- It can be produced by fermentation where sugar or starch is dissolved in water and yeast is added
- The mixture is then fermented between **15** and **35 °C** with the **absence** of oxygen for a few days
- Yeast contains enzymes that break down sugar to alcohol
- If the temperature is too **low** the reaction rate will be too slow and if it is too **high** the enzymes will become denatured
- The yeast respires anaerobically using the glucose to form ethanol and carbon dioxide:

$$C_6H_{12}O_6 + \text{enzymes} \rightarrow 2CO_2 + 2C_2H_5OH$$

- The yeast is killed off once the concentration of alcohol reaches around 15%, hence the reaction vessel is emptied and the process is started again
- This is the reason that ethanol production by fermentation is a **batch** process

Examiner Tips and Tricks

Fermentation is an anaerobic process. Oxygen is not required for ethanol to be produced by fermentation.

Purifying the Product

- Fermentation produces a **dilute solution** of ethanol which needs to be **separated** from the reaction mixture.
- This is done using **fractional distillation**.
- The mixture is heated to **78 °C** which is the **boiling point** of ethanol but below that of water (100 °C).
- The ethanol **evaporates** and its vapours pass through a **condenser**, where they cool and **condense**, forming liquid ethanol.

- The water and any other impurities remain behind in the reaction flask.
- When the temperature starts to increase to 100 °C heating should be stopped. The water and ethanol have now been separated.

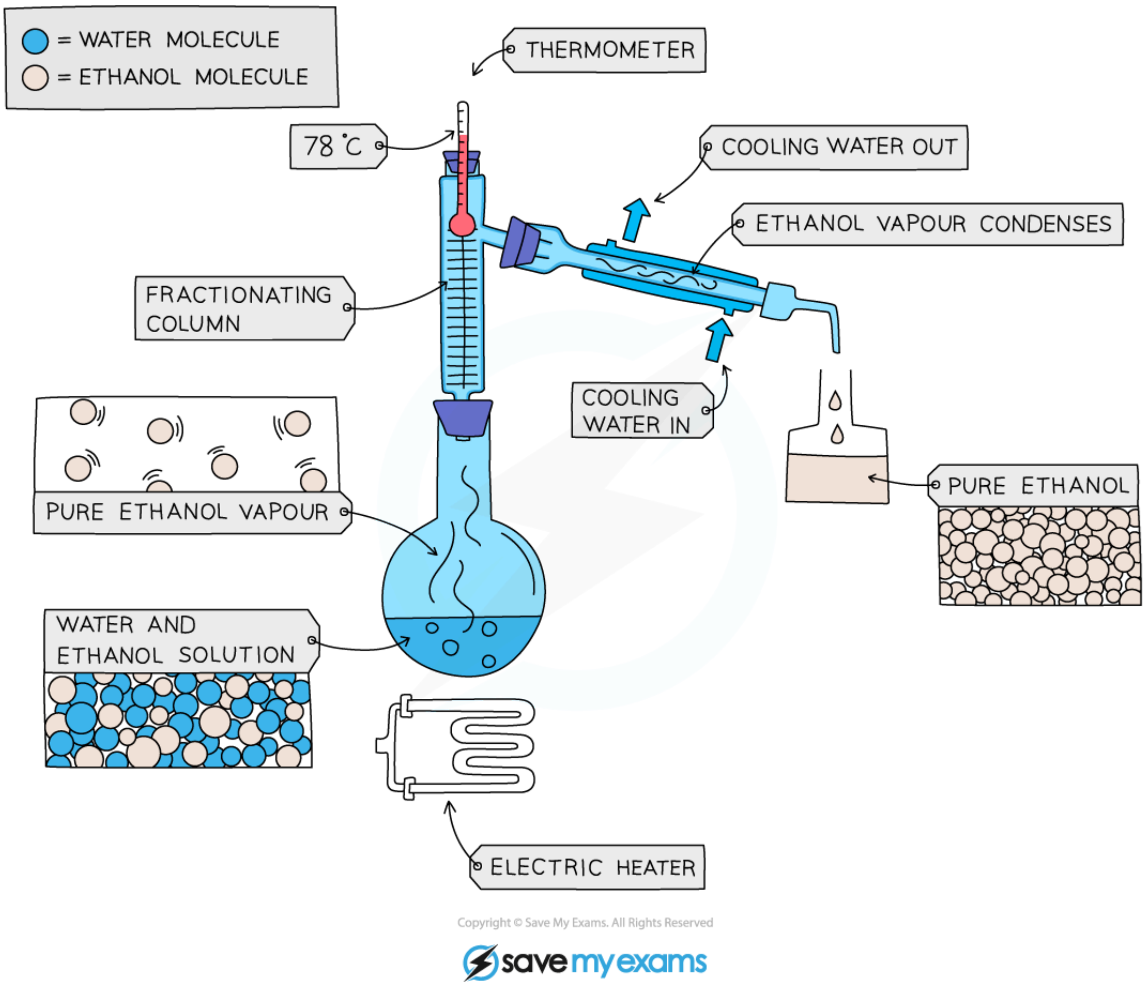

Diagram showing how fractional distillation is used to separate ethanol from water in the laboratory

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