Alcohols

4.7.2.3 · Organic chemistry · revision notes

The alcohols: the –OH functional group, the first four alcohols, their reactions with sodium, air, water and oxidising agents, their uses, and making ethanol by fermentation. GCSE Chemistry only. Expect naming, observations, combustion equations, fermentation conditions and evaluate questions based on data.

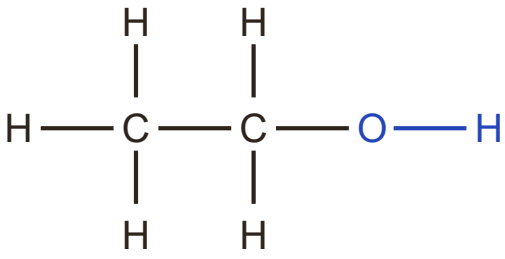
Key facts

- Functional group of the alcohols: –OH
- Methanol CH_3OH, ethanol C_2H_5OH, propanol C_3H_7OH, butanol C_4H_9OH
- Alcohol + sodium: fizzing, hydrogen given off
- Alcohol + water: dissolves, neutral solution (pH 7)
- Alcohol + oxidising agent → carboxylic acid (ethanol → ethanoic acid)
- Complete combustion: alcohol + oxygen → carbon dioxide + water
- $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$
- Fermentation: sugar solution + yeast, about 30 °C, no air
- $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$
- Uses: fuels, solvents; ethanol in alcoholic drinks

Notes

The alcohols

- Alcohols contain the **–OH** functional group. They are not hydrocarbons, because they contain oxygen.
- The first four: **methanol** CH_3OH, **ethanol** CH_3CH_2OH, **propanol** $CH_3CH_2CH_2OH$ and **butanol** $CH_3CH_2CH_2CH_2OH$. You may see ethanol written as C_2H_5OH.
- Ethanol:



- Recognise an alcohol by the name ending **-ol**, or by an –OH group bonded to a carbon chain.

Reactions of the first four alcohols

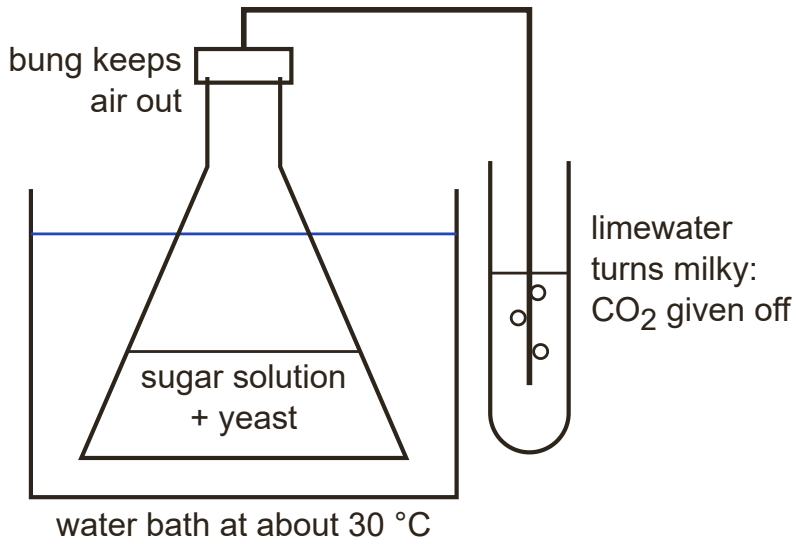
- **Sodium**: fizzing, as bubbles of **hydrogen** are given off, and the sodium gets smaller. It is less vigorous than sodium with water.
- **Burning in air**: complete combustion gives carbon dioxide and water and releases energy: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$.
- **Added to water**: they dissolve to form a **neutral** solution (pH 7). Methanol, ethanol and propanol mix completely with water; butanol is less soluble.
- **Oxidising agent**: the alcohol is oxidised to a **carboxylic acid**, e.g. ethanol → ethanoic acid.
- You only need to write balanced equations for combustion. For the other reactions, know what you would see and name the products.

Uses

- **Fuels**: e.g. ethanol, which can be mixed with petrol.
- **Solvents**: e.g. ethanol in perfumes, cosmetics and hand gels.
- Ethanol is the main alcohol in **alcoholic drinks**.

Fermentation

- Aqueous solutions of ethanol are made by **fermenting** sugar solutions using **yeast**.
- Conditions: sugar dissolved in water, yeast, a warm temperature (about 30 °C) and **no air** (anaerobic).



Fermentation: warm, no air, yeast. The carbon dioxide turns limewater milky.

- glucose → ethanol + carbon dioxide: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$
- If it is too hot, the enzymes in the yeast are denatured and fermentation stops; if it is too cold, fermentation is very slow. Air is kept out because oxygen would oxidise the ethanol to ethanoic acid. Grade 7+ only
- The product is a dilute solution of ethanol, which can be concentrated by fractional distillation.

How to answer each type of question

Describe what you would see

2 to 4 marks | Grade 5

1. Give observations, not just product names: fizzing, bubbles, the sodium getting smaller.
2. Name any gas produced: hydrogen with sodium.
3. With water, say that the alcohol dissolves and that the solution is neutral.

Example. A student tests ethanol in two ways.
(a) Ethanol is added to water containing universal indicator. What colour is the indicator? Give a reason.
(b) A small piece of sodium is added to ethanol. Describe **two** things the student would see.

Model answer.

(a) Green (1), because ethanol forms a neutral solution, pH 7 (1).
(b) Fizzing or bubbles of gas (1). The sodium gets smaller and disappears (1).

Write a balanced equation for the combustion of an alcohol

2 marks | Grade 6

1. Write the formulae: alcohol + $O_2 \rightarrow CO_2 + H_2O$.
2. Balance C, then H. Count all the H atoms, including the one in –OH.
3. Balance O last, remembering that the alcohol already contains one O atom.

Example. Write a balanced equation for the complete combustion of butanol, C_4H_9OH.

Model answer.

Correct formulae: $C_4H_9OH + O_2 \rightarrow CO_2 + H_2O$ (1)

Balanced: $C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$ (1)

(Check the O atoms: 1 + 12 = 13 on the left; 8 + 5 = 13 on the right.)

Give and explain the conditions for fermentation

2 to 4 marks | Grade 6

1. List the conditions: sugar solution, yeast, warm (about 30 °C), no air.
2. Explain the temperature: too hot denatures the enzymes in the yeast; too cold is slow.
3. Explain why air is kept out: oxygen would oxidise the ethanol to ethanoic acid.

Example. Ethanol for use as a fuel is made by fermenting sugar cane juice.
(a) Name the substance added to the sugar solution to ferment it.
(b) The mixture is kept at about 30 °C. Explain why it is not heated to 60 °C.
(c) Air is kept out of the fermentation tank. Give a reason.

Model answer.

(a) Yeast (1)
(b) At 60 °C the enzymes in the yeast would be denatured (1), so fermentation would stop (1).
(c) Oxygen would oxidise the ethanol to ethanoic acid (1).

6-mark: evaluate two ways of making ethanol

6 marks | Grade 5

1. Compare the raw materials: sugar from crops is renewable; ethene comes from crude oil, which is finite.
2. Compare the conditions: about 30 °C and normal pressure, against about 300 °C and high pressure (more energy, more expensive).
3. Compare the rate and the product: slow, in batches, giving a dilute solution, against fast and continuous, giving much purer ethanol.
4. Finish with a conclusion that follows from your points.

Example. Ethanol can be made by fermenting sugar, or by reacting ethene with steam.
Evaluate the two methods. You should use your own knowledge.

Model answer.

Marked in levels, not 1 mark per point. A top-level answer (5 to 6 marks) makes several clear comparisons and reaches a justified conclusion, for example:

Fermentation uses sugar from crops, which is renewable, but ethene comes from crude oil, which is finite.

Fermentation runs at about 30 °C and normal pressure, so it needs less energy; the ethene method needs about 300 °C and a high pressure, which cost more.

The ethene method is fast and continuous and gives much purer ethanol; fermentation is slow, is done in batches and makes a dilute solution that must be distilled.

Conclusion: fermentation is more sustainable, but reacting ethene with steam is better for making large amounts of ethanol quickly.

Don’t lose marks

- Calling ethanol a hydrocarbon. It contains oxygen.

- Saying alcohols form acidic or alkaline solutions. Their solutions are neutral (pH 7).
- Saying sodium and an alcohol give oxygen or carbon dioxide. The gas is hydrogen.
- Forgetting the H in the –OH when counting hydrogen atoms for a combustion equation.
- Saying fermentation needs a high temperature. It needs a warm temperature; too hot denatures the enzymes.

More tips

Memory tricks

- '-ol' means alcohol: methanol, ethanol, propanol, butanol.
- Counting hydrogens: C_2H_5OH has 5 + 1 = 6 H atoms, which make $3H_2O$.
- Alcohol combustion: an alcohol with n carbon atoms needs 1.5n molecules of O_2. Ethanol needs 3; butanol needs 6.
- Oxidising an alcohol gives the acid with the same number of carbons: ethanol → ethanoic acid, propanol → propanoic acid.
- Fermentation needs a warm, airless, sugary home for the yeast.

Exam technique

- In 'describe what you would see' questions, give observations (fizzing, the sodium disappears), not just 'hydrogen is made'.
- Balanced equations are only expected for alcohol combustion. For other reactions, word equations and names are enough.
- In evaluate questions, give points for and against each method and finish with a conclusion that follows from them.
- Give the fermentation temperature as a number (about 30 °C) as well as the word 'warm'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Name the functional group of the alcohols**
The –OH group.

Grade 3 — **Give the main uses of alcohols**
As fuels and solvents; ethanol is the main alcohol in alcoholic drinks.

Grade 4 — **Name and draw the first four alcohols**
Methanol, ethanol, propanol and butanol; ethanol is CH_3CH_2OH.

Grade 4 — **State the conditions for fermentation**
Sugar solution, yeast, a warm temperature (about 30 °C) and no air.

Grade 5 — **Describe the reactions of alcohols**
Sodium: fizzing (hydrogen). Water: dissolves, neutral solution. Oxidising agent: a carboxylic acid forms.

Grade 6 — **Write balanced equations for alcohol combustion**
For example, $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$.

Grade 7 — **Explain the conditions used for fermentation**
Too hot denatures the enzymes in yeast; oxygen would oxidise the ethanol to ethanoic acid.

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