Making Ethanol

Indicates a Flash activity.
Indicates an accompanying worksheet.
Indicates a virtual experiment.
Indicates that there are teacher’s notes.
Indicates that ‘How Science Works’ skills are covered.

For more detailed instructions, see the Getting Started presentation.
Making Ethanol

- Fermentation
- Hydration of ethene
- New techniques
- Summary activities
What is ethanol?

Ethanol is a type of alcohol. Alcohols are a group of organic compounds that contain hydrogen, carbon and oxygen. They have the functional group –OH.

Ethanol is a very useful alcohol:

- it is the alcohol present in alcoholic drinks
- it is used in antibacterial hand wipes
- it is used to make vinegar
- bioethanol, made from plant material, is used as a fuel.
Making ethanol by fermentation

Most ethanol is made from glucose by fermentation:

\[
\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide} \\
\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2
\]

The reaction is performed by yeast, which is a type of fungus. The basic steps of ethanol production are:

1. Yeast is added to a solution of glucose and water.
2. The yeast converts the glucose into ethanol.
3. Ethanol is removed from the mixture by distillation.
Yeast is a fungus which produces ethanol when it respires anaerobically.

Drag the spatula of glucose into the conical flask of water to start the process of fermentation.

How is ethanol produced by fermentation?
How does yeast work?

Yeast produces alcohol during a process called **anaerobic respiration**. This means respiration without the presence of oxygen.

\[
\text{glucose} \xrightarrow{\text{yeast enzymes}} \text{ethanol} + \text{carbon dioxide}
\]

The reaction is catalysed by **enzymes** in the yeast.

The reaction releases energy, which is used by the yeast. Ethanol is made in the process.
Changing the conditions of fermentation

The conditions of fermentation have an impact on the amount of ethanol produced.

Press on the buttons to find out more.

- temperature
- oxygen
- pH
What are the conditions needed for fermentation?

Choose which conditions are needed to make ethanol by fermentation.

Press "start" to begin.
Yeast in beer production

How is beer produced?

Press "start" to find out how yeast help to turn barley into beer.
Limits of fermentation

Ethanol is **toxic** to yeast above a certain concentration. This limits the concentration of ethanol that can be made by fermentation.

Ethanol can be concentrated by **distillation**.

Ethanol boils at a lower temperature than water. At 78°C the ethanol boils off leaving the water behind. The ethanol is collected using a condenser.

Distillation is used to make spirits such as whisky and brandy.
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Making ethanol from ethene

Ethanol can also be made by reacting ethene with water.

\[
\begin{align*}
\text{Ethene} & \quad + \quad \text{water} \\
C_2H_4 & \quad + \quad H_2O \\
\text{phosphoric acid} & \quad \rightarrow \\
\text{ethanol} & \quad \rightarrow \\
C_2H_5OH
\end{align*}
\]

Ethene is mixed with high pressure steam in the presence of a **phosphoric acid catalyst**. The reaction is called **hydration**.

Under certain conditions this reaction is reversible, producing ethene and water from ethanol. This is called **dehydration**.
Advantages of hydration

Most of the ethanol used in industrial processes is made from the hydration of ethene.

This process has several advantages over fermentation:

<table>
<thead>
<tr>
<th></th>
<th>fermentation</th>
<th>hydration</th>
</tr>
</thead>
<tbody>
<tr>
<td>rate of reaction</td>
<td>slow</td>
<td>fast</td>
</tr>
<tr>
<td>ethanol purity</td>
<td>impure</td>
<td>pure</td>
</tr>
<tr>
<td>production</td>
<td>batch process</td>
<td>continuous process</td>
</tr>
</tbody>
</table>

In the hydration process, a continuous stream of reactants is passed over a catalyst. This continuous production process is more efficient than fermentation, in which ethanol is produced in separate batches (batch production).
Disadvantages of hydration

The hydration process requires high temperatures and pressures. These conditions are expensive to maintain.

Another major disadvantage of the hydration method is the ethene itself, which is sourced from crude oil.

- Crude oil is a non-renewable resource. Fermentation uses sugar, which can be produced from renewable resources.

- Producing ethene from crude oil is expensive and dependent on volatile oil prices. Fermentation uses raw materials which are cheap and readily available.
Comparing the methods of making ethanol

**Fermentation**

**Hydration**

How does the hydration of ethene compare with fermentation?

Press **start** to begin.
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Making ethanol using bacteria

Scientists are working on new ways of producing ethanol.

One technique uses **genetically modified** bacteria.

Scientists have modified **E. coli** bacteria so that they are able to convert waste biomass into ethanol.

Biomass can be sourced from materials that would otherwise be thrown away, such as waste paper, grass cuttings and wood chippings.

The method may provide an alternative to the production of ethanol from ethene, which relies on crude oil.
Evaluating the new technology

Making ethanol using genetically modified bacteria is similar in some ways to making ethanol by fermentation.

The methods share some advantages, such as low energy costs, but also some disadvantages. The reaction is quite slow and the product is impure.

An additional disadvantage is the high cost of genetically engineering and growing the bacteria.

Can you think of any other advantages or disadvantages?
### Three methods of making ethanol

<table>
<thead>
<tr>
<th></th>
<th>Fermentation with yeast</th>
<th>Production from ethene</th>
<th>Use of modified bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost of raw materials</strong></td>
<td>cheap</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Availability of raw materials</strong></td>
<td>?</td>
<td>?</td>
<td>widely available: wood, paper, etc.</td>
</tr>
<tr>
<td><strong>Energy costs</strong></td>
<td>low</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>Purity of product</strong></td>
<td>?</td>
<td>?</td>
<td>low – needs distilling</td>
</tr>
<tr>
<td><strong>Speed of reaction</strong></td>
<td>slow</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

- **Expensive**
Making Ethanol

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- New techniques

Summary activities
Glossary of keywords: making ethanol

**alcohol** – A family of compounds which contains the –OH functional group.

**anaerobic** – A reaction which takes place without oxygen.

**batch production** – The production of a substance in separate batches. The production of one batch needs to be completed before the production of the next batch can begin.

**catalyst** – A substance which influences the rate of a
Multiple-choice quiz

It's time to see how much you know about making ethanol. Can you make it to the end of this quiz?

Press "start" to begin.

[start]