# National 5 Chemistry

## Unit 2:

### Nature's Chemistry

**Student:**

---

## Topic 6

### Consumer Products

<table>
<thead>
<tr>
<th>Topics</th>
<th>Sections</th>
<th>Done</th>
<th>Checked</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6.1 Alkanol Family</strong></td>
<td>1. Alkanol Molecules</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Properties of Ethanol</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Uses of Ethanol</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Properties of Alkanols</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Self-Check Questions 1 - 3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.2 Alcohol Structures</strong></td>
<td>1. Straight-Chain Isomers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Branched-Chain Isomers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Other Alcohols</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.3 Carboxylic Acids</strong></td>
<td>1. Ethanoic Acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. General Formula</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Self-Check Questions 1 - 4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.4 Esters - Flavour Molecules</strong></td>
<td>1. Esters</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Formulae &amp; Names</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Condensation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Self-Check Questions 1 - 4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.5 Condensation Polymerisation</strong></td>
<td>1. Addition Polymerisation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Condensation Polymerisation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Natural Polymers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Self-Check Questions 1 - 4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.6 Energy From Fuels</strong></td>
<td>1. Alcohol Biofuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Specific Heat Capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Measuring Energy from Fuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Combustion Equations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Self-Check Questions 1 - 5</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Consolidation Work**

<table>
<thead>
<tr>
<th>Score:</th>
<th>%</th>
<th>Grade:</th>
</tr>
</thead>
</table>

**End-of-Topic Assessment**

<table>
<thead>
<tr>
<th>Consolidation A</th>
<th>Score:</th>
<th>/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consolidation B</td>
<td>Score:</td>
<td>/</td>
</tr>
<tr>
<td>Consolidation C</td>
<td>Score:</td>
<td>/</td>
</tr>
<tr>
<td>Consolidation D</td>
<td>Score:</td>
<td>/</td>
</tr>
</tbody>
</table>

---

KHS Feb 2014
6.1 Alkanol Family

Alkanol Molecules

In the last Topic you learnt that alk can be made by the addition of a water molecule across the double bond in an alkene.

The functional group in alkanols is the hydroxyl group.

\[
\text{ethene} + \text{water} \rightarrow \text{ethanol}
\]

\[
\text{H}_2\text{C} = \text{C} + \text{H} - \text{OH} \rightarrow \text{H} - \text{C} = \text{C} - \text{OH}
\]

The alkene can be thought of as ‘substituted alkanes’ - a hydrocarbon chain with the hydroxyl group replacing one of the hydrogen atoms.

As well as sharing the same general formula, the physical properties of the alkanols such as melting point (increases), boiling point (increases) and solubility in water (decreases) show a steady trend as the molecular size increases. For these reasons, the alkanols can be described as a homologous series.

<table>
<thead>
<tr>
<th>Name</th>
<th>Functional Molecular Formula</th>
<th>Full Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanol</td>
<td>CH$_3$OH</td>
<td></td>
</tr>
<tr>
<td>propan-1-ol</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Properties of Ethanol

The aim of this activity is to investigate some of the properties of ethanol.

Ethanol has a short hydrocarbon chain, like an alkane, with the hydroxyl functional group at the end.

<table>
<thead>
<tr>
<th>Property</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td></td>
</tr>
<tr>
<td>Solubility</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
</tr>
<tr>
<td>Conduction</td>
<td></td>
</tr>
<tr>
<td>Burning</td>
<td></td>
</tr>
</tbody>
</table>

Like water, ethanol is a covalent molecule and, as a result, is a very poor conductor of electricity.

Like water, ethanol has a polar O—H bond which allows for stronger attractions between molecules. As a result, water and ethanol will ‘dissolve’ in each other as the strength of their attractions are very similar.
**Uses of Ethanol**

Historically, *eth* has often been used as a *fu*, often as methylated spirits.

It releases *more en* (per kg) than *wood* but *less en* than *pet*.

**Word equation:** ethanol + → +

**Formulae equation:** $C_2H_5OH + \rightarrow +$

Like *wa*, ethanol is an excellent *solv* able to *diss* a variety of substances.

*Eth* is widely used as the *solv* for many ink based pens and is, therefore, the ideal chemical to be used when attempting to remove ink stains.

In industrial and consumer products, *eth* is the second most important *solvent* after *wa*. Ethanol is the *least toxic* of the alcohols (it is only *pois* in large amounts), which makes it more suitable for use in *industry* and consumer products.

*Eth* is a *sol* in:

- **Cos** such as *perfumes*.
- **Food col** and flav such as *vanilla*.
- **Med preparations** such as *antiseptics*.
- Some *clea* agents.
- **Industry**.
Properties of Alkanols

Most properties of the Alkanols are a result of the interactions between the molecules.

However, there are significant differences between the properties of the polar hydrocarbons such as anes and enes.

ethene
name methanol
C₂H₄
formula CH₃OH
28 amu mass 32 amu
non-polar type polar
-104 BPt (°C) 65

Melting & Boiling Pts

as usual, the melting and boiling points increase as the size of the molecules increase.

Flammability

as usual, the flammability increases as the size of the molecules decrease.

Solubility

small alkanol molecules are very soluble (miscible) in water, solubility will decrease as the hydrocarbon chain gets bigger.
Q1.

Ethanol is one member of the alkanol family.

a) Draw the full structural formula for ethanol.

b) Circle the functional group of the molecule.

c) State the name of this functional group.

d) Some people mistakenly expect ethanol to be alkaline.

i) Why would they think this?

ii) Explain why ethanol is, in fact, neutral.

Q2.

Ethanol has many different uses, for example.

A making vinegar
B burning in spirit burners
C manufacturing chloroform
D removing marker pen graffiti
E extracting chlorophyll from leaves
F an alternative to mercury in thermometers

a) In which two examples is ethanol being used as a solvent?

b) In which two examples is ethanol being used as a feedstock?

c) When pure, ethanol is a clear colourless liquid. State two other properties of ethanol.

d) Draw the full structural formula for an isomer of ethanol that is not an alcohol.

Q3.

The above compound could be formed by adding water to

A

B

C

D

The above compound could be formed by adding water to

A

B

C

D
# 6.2 Alcohol Structures

## Straight-Chain Isomers

The position of the hydroxyl group can change to produce *iso*mers without the need to introduce *branched* structures.

<table>
<thead>
<tr>
<th>Full Structural</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>— C — C — C —</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shortened Structural</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>— C — C — C —</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Straight-Chain Alkanols

<table>
<thead>
<tr>
<th>Name:</th>
<th>heptan-4-ol</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shortened Structural Formula:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Shortened Structural Formula:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Shortened Structural Formula:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Shortened Structural Formula:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
</tr>
</thead>
</table>

| Shortened Structural Formula: | CH₃CH₂CH₂CH₂CH₂CH₂CH₂OH |
This activity considers how to use systematic names to indicate both the position of the hydroxyl group and the branch position in isomers of branched-chain alkanols.

The ‘longest chain’ must include the functional group.

The chain is numbered from the end nearest the functional group.

### Branched-Chain Alkanols

<table>
<thead>
<tr>
<th>Name:</th>
<th>2-methylpentan-1-ol</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
</tr>
<tr>
<td>Name:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Name:</td>
<td>2-methylpentan-1-ol</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Name:</td>
<td>2-methylpentan-1-ol</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full Structural Formula:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td></td>
</tr>
<tr>
<td>Shortened Structural Formula:</td>
<td></td>
</tr>
</tbody>
</table>
The alkanols are based on alkanes - chains (and branches) with single carbon to carbon bonds (C — C) only. There are many other possible alcohols.

Cycloalkanols - rings with single carbon to carbon bonds (C — C) only.

Cyclohexanol is used in the production of nylon, paints, plastics, detergents, textiles and pesticides. It's also used as a solvent in some specialist inks.

Alkenols - chains (and branches) with a double carbon to carbon bond (C = C)

Ethenol (often called VinylAlcohol) is used to make a water soluble plastic, polyethenol (better known as PolyVinylAlcohol or PVA) used as a glue but can also make soluble sutures (for stitching) and soluble laundry bags for use in hospitals.

Diols & Triols - molecules with two or three hydroxyl groups (— OH).

Ethane-1,2-diol (often called ethylene glycol) is an odorless, colourless, syrupy, sweet-tasting liquid mainly used to make polyesters but is also an ingredient in antifreeze.

Propane-1,2,3-triol (often called glycerol or glycerine) is an odorless, colourless, viscous, sweet-tasting liquid mainly used to make medicinal solutions but also has many uses in food production.
6.3 Carboxylic Acids

**Ethanoic Acid**

*Ethanoic acid* is normally manufactured from *eth* in a two-step reaction called *oxid*.

\[
\begin{align*}
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{O} & \quad \text{H} \\
\| & & & & \\
\text{H} & \quad \text{C} & \quad \text{=O} & \quad \text{H}
\end{align*}
\]

\[
\begin{align*}
\text{H} & \quad \text{C} & \quad \text{=O} & \quad \text{H} \\
\| & & & & \\
\text{H} & \quad \text{C} & \quad \text{H}
\end{align*}
\]

The smell of acids can be *unpleasant* (sometimes described as 'like vomit') which is not surprising as *fatty acids* are formed during *dig*.

The *cov carb group* (—COOH) will *diss* in *water* to produce *hy ions*, $\text{H}^+\text{(aq)}$ so they will have *typical acid reactions*.
acids are substances which dissolve in water to produce hydrogen ions, $H^+_{(aq)}$.

**ethanoic acid**

$$H^+_{(aq)} + Cl^-_{(aq)} \rightarrow HCl_{(aq)}$$

**hydrochloric acid**

$$H^+_{(aq)} + CH_3COO^-_{(aq)} \rightarrow HCH_3COO_{(aq)}$$

**ethanoic acid**

e.g. magnesium + sulfuric acid $\rightarrow$ magnesium sulfate + hydrogen

$$Mg_{(s)} + H_2SO_4_{(aq)} \rightarrow MgSO_4_{(aq)} + \text{gases}$$

magnesium + ethanoic acid $\rightarrow$ magnesium ethanoate + hydrogen

$$Mg_{(s)} + CH_3COOH_{(aq)} \rightarrow Mg(CH_3COO)_{2(aq)} + \text{gases}$$

**Properties**

Most properties of the Carboxylic acids are a result of the stronger than normal attractions between the molecules.
as usual, the **melting and boiling points increase** as the size of the molecules increase.

small acid molecules are very **soluble** (miscible) in water, **solubility will decrease** as the hydrocarbon chain gets bigger.

**Flammability**

as usual, the **flammability increases** as the size of the molecules decrease.

**General Formula**

The **gen** for **for the alk acids** is:-

\[ \text{C}_n \text{H}_{2n+1} \text{COOH} \]

Notice that one of the **car** atoms is not included in the C\(_n\) ‘chain’. This is to enable the **carboxyl func group** to be emphasised. **WARNING !** - this means that for each acid \( n \) is one less than you'd expect; **methanoic** \( n = 0 \), **ethanoic** \( n = 1 \), etc.

From all this it can be seen that the **alk acids** have:

1. **sim chem properties**
2. **phy properties** that show a steady **tre**

and 3. a **common gen formula**,

so they belong to a **homo series**
Q1. Int2
A student carefully measured the boiling points of some alcohols. The results are shown in the following table.

<table>
<thead>
<tr>
<th>Alcohol</th>
<th>Boiling Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>propan-1-ol</td>
<td>97</td>
</tr>
<tr>
<td>propan-2-ol</td>
<td>81</td>
</tr>
<tr>
<td>butan-1-ol</td>
<td>117</td>
</tr>
<tr>
<td>butan-2-ol</td>
<td>100</td>
</tr>
<tr>
<td>pentan-1-ol</td>
<td>137</td>
</tr>
<tr>
<td>pentan-2-ol</td>
<td>119</td>
</tr>
</tbody>
</table>

a) What is the effect on the boiling point of an alkanol of moving the hydroxyl group from an end-of-chain position to the next carbon along?

b) Predict the boiling point of hexan-2-ol.

c) Give the shortened structural formula for pentan-2-ol.

Q2. Higher
The structures for molecules of four liquids are shown below.

Which liquid will be the most viscous?

A
\[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{OH} \\
\text{H} \\
\end{array}
\]

B
\[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{H} \\
\end{array}
\]

C
\[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{H} \\
\text{OH} \\
\end{array}
\]

D
\[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{OH} \\
\text{H} \\
\text{OH} \\
\end{array}
\]

Q3.
Many medicines are available as tablets which dissolve readily in water.
These tablets contain solid citric acid and sodium hydrogencarbonate.

a) When the tablet is added to water the citric acid reacts with the sodium hydrogencarbonate giving off a gas.
   Name the gas produced.

b) The structure of citric acid is shown below.

\[
\text{HO} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{OH} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \\
\]

i) Circle the functional groups responsible for the acidic nature of this molecule.

ii) Name the other functional group present.

iii) Write the molecular formula for citric acid.

c) Draw the structure of the dissociated form of citric acid.

d) How many moles of NaOH would react with one mole of citric acid?

Q4.
Potassium permanganate can be used to convert alkenes into two molecules.
The conversion of pent-1-ene is shown.

\[
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{H} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{OH} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \\
\]

a) Name molecule X.

b) State the test for carbon dioxide.
An ester is a substance which is formed by the reaction of an alcohol with a carboxylic acid.

Each ester can thought of as having a ‘parent alc’ from which it is formed. The ‘parent alc’ provides the ‘christian name’ of the ester. The alc name has the ‘—ol’ ending replaced with an ‘—yl’ ending.

<table>
<thead>
<tr>
<th>‘parent alcohol’</th>
<th>ester ‘christian name’</th>
</tr>
</thead>
<tbody>
<tr>
<td>meth</td>
<td>methyl</td>
</tr>
<tr>
<td>eth</td>
<td>eth</td>
</tr>
<tr>
<td>prop</td>
<td>prop</td>
</tr>
<tr>
<td>but</td>
<td>but</td>
</tr>
</tbody>
</table>

Each ester also has a ‘parent carb acid’ from which it is formed. The ‘parent acid’ provides the ‘surname’ of the ester. The acid name has the ‘—oic’ ending replaced with an ‘—oate’ ending.

<table>
<thead>
<tr>
<th>‘parent acid’</th>
<th>ester ‘surname’</th>
</tr>
</thead>
<tbody>
<tr>
<td>meth</td>
<td>methanoate</td>
</tr>
<tr>
<td>eth</td>
<td>eth</td>
</tr>
<tr>
<td>prop</td>
<td>prop</td>
</tr>
<tr>
<td>but</td>
<td>but</td>
</tr>
</tbody>
</table>

For example,

pentyl ethanoate

parent alcohol = CH₃–CH₂–CH₂–CH₂–CH₂–OH

parent acid = C–C–C–C–C–O–C–C

CH₃–CH₂–CH₂–CH₂–CH₂–OH

O

C–C–C–C–C–O–C–C

H–O

C–CH₃
The ‘best’ way to think about an ester is to consider it as an acid molecule which has had its hydrogen atom replaced by a carbon chain (an alkyl group).

Learn to draw acids and you should find esters easy.

As is often the case, we ‘start’ at the end of the name.

Identify the acid (look for the carbonyl C = O) and give the ester its surname by changing the -oic ending to -oate.

The carbon chain (derived from the parent alcohol) is the ‘christian’ name, -ol changed to -yl.

### Ester Structures & Names

<table>
<thead>
<tr>
<th>Name:</th>
<th>Full Structural Formula:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethyl propanoate</td>
<td>H H O</td>
</tr>
<tr>
<td></td>
<td>H—C—C—C—O</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
<th>pentyl propanoate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td>CH₃CH₂COOCH₂CH₂CH₂CH₂CH₃</td>
</tr>
</tbody>
</table>
The 3 main uses of esters are as:

1. **flav** - in foodstuffs
2. **solv** - e.g. used in nail varnish
3. **perf** - are volatile, so quickly release vapour

Being **vol** often makes them very **flam**.

<table>
<thead>
<tr>
<th>parent alcohol</th>
<th>parent carboxylic acid</th>
<th>ester name</th>
<th>ester flavour</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethanol</td>
<td>methanoic acid</td>
<td>rum</td>
<td></td>
</tr>
<tr>
<td>ethanol</td>
<td>ethanoic acid</td>
<td>sweet wine</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>pentyl ethanoate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ethyl butanoate</td>
<td>pineapple</td>
</tr>
</tbody>
</table>

**Condensation**

To *join together*, each molecule must *lo* some of the existing atoms attached to the *car* atom with the *func* group.

The **hydr** group on the **alc** will have to lose its hydrogen atom, —**H**.

The **carb** group on the **ac** loses its —**OH** group.

The whole reaction is helped by the fact that an —**OH** group and an —**H** atom will then be able to form a **sta** molecule, water (H₂O).

**Condensation reaction:** reaction in which two molecules join together, usually in the presence of a catalyst, with elimination of water or some other simple molecule.
Q1. Int2

Artificial flavourings added to foods are often esters. The following ester gives an orange flavour.

\[
\begin{array}{c}
\text{H} \quad \text{O} \\
\text{H} \quad \text{C} \quad \text{O} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H}
\end{array}
\]

a) Name this ester.

b) Draw the original parent acid

c) Draw and name an isomer of the original parent alcohol

Q2. Int2

Sweets, such as pineapple cubes, contain the artificial flavouring methyl butanoate.

a) To which family of compounds does methyl butanoate belong?

b) Methyl butanoate can be made from an alkanol and an alkanoic acid.
   i) Name this type of chemical reaction.

   ii) Draw the full structural formula for the alkanoic acid used to make methyl butanoate.

   iii) Draw the full structural formula for the alkanol used to make methyl butanoate.

Q3. Int2

Ethanol is a member of the alkanol family of compounds.

a) Ethanol can be manufactured from ethene as shown in the following addition reaction.

\[
\text{H} \quad \text{H} \\
\text{C} = \text{C} + \text{H}_2\text{O} \xrightarrow{\text{catalyst}} \text{H} \quad \text{C} \quad \text{C} \quad \text{H} \\
\text{H} \quad \text{H} \quad \text{O} \quad \text{H} \quad \text{H}
\]

What other name is given to this type of addition?

b) Ethanol can be used to make esters which can be used as flavourings for food. The following ester is used to give ice cream a rum flavour.

\[
\begin{array}{c}
\text{H} \quad \text{C} \quad \text{C} \quad \text{O} \quad \text{C} \quad \text{C} \quad \text{C} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H}
\end{array}
\]

Name this ester.

c) Butan-2-ol is another member of the alkanol family

\[
\begin{array}{c}
\text{H} \quad \text{H} \quad \text{H} \\
\text{H} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \\
\text{H} \quad \text{O} \quad \text{H} \quad \text{H}
\end{array}
\]

Draw the full structural formula for an isomer of butan-2-ol.

Q4. Higher

An ester has the following structural formula

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{COOCH}_2\text{CH}_3
\]

The name of this ester is

A  propyl propanoate
B  ethyl butanoate
C  butyl ethanoate
D  ethyl propanoate
6.5 Condensation Polymers

**Addition Polymerisation**

This activity revises the polymerisation reaction met in the previous Topic:

A **polymer** is a long chained molecule made up from lots of small molecules called **monomers**.

If the **monomers** contain $C = C$ double bonds, e.g ethene, then the polymers will be formed by the reaction known as **addition polymerisation**.

An **initiator** will start the reaction by causing the **double bond** in some of the **monomers** to open up. These molecules react with other molecules to continue the ‘chain reaction’.

A **long chain** made from **hundreds** or even **thousands** of **monomers** will result. It can be identified as an **addition polymer** because it will have only carbon atoms in the chain.

The same unit is **repeated** over and over so structure of poly(ethene) can be shown as:

$(-CH_2-CH_2-)_n$$

Depending on **reaction conditions**, different forms of polythene can be made with slightly **different properties** and, as a result, different uses.

<table>
<thead>
<tr>
<th>LDPE (0.92 g cm$^{-3}$)</th>
<th>HDPE (0.96 g cm$^{-3}$)</th>
<th>LLDPE (0.92 g cm$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>low density poly(ethene)</strong></td>
<td><strong>high density poly(ethene)</strong></td>
<td><strong>linear low density poly(ethene)</strong></td>
</tr>
<tr>
<td>very high pressures 150°—300°C initiator</td>
<td>lower pressures lower temperatures Ti/Cr catalyst</td>
<td>lower pressures lower temperatures catalyst</td>
</tr>
<tr>
<td>extensive branching more flexible material</td>
<td>fewer branches stronger, more rigid</td>
<td>side chains butene co-polymer</td>
</tr>
<tr>
<td>film packaging electrical insulation</td>
<td>pipes, gutters, bottles industrial packaging</td>
<td>film packaging electrical insulation</td>
</tr>
</tbody>
</table>
Other poly can be made from eth by replacing some or all of the hydr atoms with other atoms or groups. Examples include:

\[
\begin{align*}
\text{H} & \quad \text{CN} \\
\text{C} & \quad \text{C} \\
\text{H} & \quad \text{H}
\end{align*}
\]

acrylonitrile

\[
\begin{align*}
\text{C} & \quad \text{C} \\
\text{H} & \quad \text{H}
\end{align*}
\]

chloroethene

\[
\begin{align*}
\text{F} & \quad \text{F} \\
\text{C} & \quad \text{C}
\end{align*}
\]

tetrafluoroethene

\[
\begin{align*}
\text{H} & \quad \text{H}
\end{align*}
\]

phenylethene (styrene)

Pro is also a very important monomer used to make poly(propene).

<table>
<thead>
<tr>
<th>Monomer</th>
<th>Polymer Name</th>
<th>Trade Name</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{F}_2\text{C}═\text{CF}_2)</td>
<td>polytetrafluoroethylene</td>
<td>Teflon, Gore-Tex</td>
<td>Non-stick coating for cooking utensils, chemically-resistant specialty plastic parts, Gore-Tex waterproofing</td>
</tr>
<tr>
<td>(\text{H}_2\text{C}═\text{CCl}_2)</td>
<td>polydichloroethylene</td>
<td>Saran</td>
<td>Cling Film food wrap</td>
</tr>
<tr>
<td>(\text{H}_2\text{C}═\text{CH(CN)})</td>
<td>polyacrylonitrile</td>
<td>Orlon, Acrilan, Creslan</td>
<td>Fibers for textiles, carpets, upholstery</td>
</tr>
<tr>
<td>(\text{H}_2\text{C}═\text{CH(OCOCH}_3\text{)})</td>
<td>polyvinyl acetate</td>
<td></td>
<td>Elmer's glue - Silly Putty</td>
</tr>
<tr>
<td>(\text{H}_2\text{C}═\text{CH(OH)})</td>
<td>polyvinyl alcohol</td>
<td></td>
<td>Dissolving sutures, Hospital laundry bags, Wood Glue - Slime</td>
</tr>
</tbody>
</table>
Condensation Polymerisation

This activity shows how the condensation reaction met earlier can be used to make polymers.

Polyesters

Earlier it was shown how the carb (acid) group could take part in a cond reaction with the hyd group to form an ester link.

Man-made polyesters tend to make use of two monomers. One will have an acid group at both ends (a diacid), while the other molecule will have two hydroxyl groups (a diol). For example, when ethane-1,2-diol and benzene-1,4-dicarboxylic acid react the polymer known as Terylene is formed.

By themselves, the main use of Polyesters is in clothing.

Mixed in with other plastics, however, and they have a wide-range of useful properties and a wide range of uses.
Consumer Products

Polyamides

The carb (acid) group (—COOH) can also take part in a cond reaction with the am group (—NH₂) to form an am link.

Amino acids use the am (or pep) link to form cond poly called pro.

Man-made polyamides such as Nylon tend to make use of two monomers. One will have an acid group at both ends (a diacid), while the other molecule will have two am groups (a diamine). For example, when 1,6-diaminohexane and hexan-1,6-dioic acid react the polymer known as Nylon 6,6 is formed.

As usual, long chains are formed though the rep unit, in these examples, is a two monomer unit.

Polyamides can set up extra attractions between the pol chains so Nylon, for example, has many uses as an 'Engineering Plastic'.

More numerous attr make the polyamide Kevlar stronger than steel.
Natural Polymers

There are also many Polymers found in Nature and many man-made Polymers are based on their structures.

Rubber

Rubber is made from the sap of the rubber tree and the monomer is 2-methyl-1,3-butadiene, often called isoprene:

\[
\text{CH}_3 - \text{C} = \text{C} - \text{CH}_2 - \text{CH}_3
\]

The presence of a C = C double bond and the 'carbon only' backbone is evidence that rubber is an addition polymer.

Cellulose

The monomer used to make cellulose is the sugar glucose.

\[
\text{CH}_2\text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{CH}_2\text{OH}
\]

The presence of oxygen atoms in the backbone is evidence that cellulose is a condensation polymer.

Keratin

Keratin is a family of proteins making up skin, hair and nails.

The monomers used to make proteins are amino acids.

The presence of the amine link in the backbone is evidence that keratin is a condensation polymer.
**Q1.**

Some waterproof clothing contains a thin layer of the plastic PTFE.

PTFE is a polymer made from the monomer shown above

* a) Draw a section of the PTFE polymer, showing three monomer units joined together.

* b) Name this type of polymerisation reaction.

---

**Q2.**

Kevlar is a polymer which is used in the manufacture of body armour.

* a) What property of Kevlar makes it suitable for use in body armour?

* b) Kevlar is made from the following monomers.

i) Draw the structure of the repeating unit formed from these two monomers.

ii) Name the type of link formed.

ii) Name the type of polymer formed.

---

**Q3.**

What functional group is always found in a protein molecule?

A
\[
\text{A} \quad -\text{N} \quad \text{H}
\]

B
\[
\text{B} \quad -\text{C} \quad \text{C}
\]

C
\[
\text{C} \quad \text{O} \quad \text{H}
\]

D
\[
\text{D} \quad -\text{C} \quad -\text{N} \quad -
\]

---

**Q4.**

Synthetic nappies contain hydrogel polymers which attract and absorb water molecules.

* a) The following is part of the structure of a hydrogel polymer.

\[
\text{H} \quad \text{COOH} \quad \text{H} \quad \text{COOH} \quad \text{H} \quad \text{COOH}
\]

\[
\text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C}
\]

\[
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H}
\]

i) Name the type of polymer formed.

ii) Draw the monomer from which this polymer is made.

* b) The diagram below shows how water molecules are attracted to the hydrogel.

What type of bonding must be present in the water molecules, which allows them to be attracted to the hydrogel?
6.6 Energy From Fuels

Alcohol Biofuels

Whilst ethanol can be made from alkenes by the addition of water (hydration), it has also always been made by the fermentation of sugars.

Traditionally the microorganism yeast has been used to make ethanol but, recently, other microorganisms like bacteria have been used to make mixtures of ethanol and butanol.

Ethanol and butanol are greener fuels than petrol and diesel but butanol has advantages over ethanol that mean that a lot of work is going into developing bacterial fermentation.

Advantages of ethanol and butanol

- Can be produced sustainably and are renewable fuel sources
- Adds oxygen to petrol/diesel blends – reducing greenhouse gas and unburned hydrocarbon emissions
- Blend with petrol and diesel as a fuel extender
- Higher octane rating than petrol/diesel which increases engine performance

Butanol versus ethanol

- Not hygroscopic (does not pick up water)
- Completely miscible with diesel (separation under cold and damp conditions is a problem with ethanol-diesel blends requiring emulsifier addition)
- Low vapour pressure (easier and safer to handle) means less evaporation in comparison to ethanol, highly flammable vapours are a problem with ethanol
- Blend with petrol to any per cent (ethanol limited to 85%)
- No engine modifications required (less corrosive than ethanol) which means it can be added to any vehicle on the road.
- Can be handled & stored in current infrastructure for petrol
- More similar properties to petrol and diesel therefore makes it easier to blend, it has a higher viscosity, reducing pump and injector leakage (observed with ethanol) which is important for fuel delivery in the vehicle
- A longer hydrocarbon chain = more energy from its combustion compared to ethanol
Ferm is a chem reaction that certain pla can use to produce ene whenever the supply of oxy is too poor to allow normal resp.

Yeast is a plant (a fun) that is particularly well suited to living in conditions where oxy is in po supply. Long ago, bakers and brewers learnt to use yea for their own purposes. Bakers used the car dio gas produced during ferm to help their dough to ‘rise’.

Resp

\[ \text{Glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy} \]

Ferm

\[ \text{Glucose} \rightarrow \text{carbon dioxide} + \text{ethanol} + \text{energy} \]

Almost anything, fru, vege, gra etc, can be used for ferme, hence, the wide variety of alco drinks made all around the world.

Yeast contains a biological catalyst, an enz, called zymase. In be making the yea is grown and added to the ho, wheras gra have yea present on their skin making wi particularly easy to make. Most bak is done using ‘yeast extracts’, in other words, zym.

### Specific Heat Capacity

\[ \Delta H = \text{energy gained or lost by the water} \]

\[ c = \text{specific heat capacity of the water} \]

\[ m = \text{mass of the water} \]

\[ \Delta T = \text{rise or fall in temperature} \]

\[ \Delta H = c \times m \times \Delta T \]

During chem reactions en is rel to the surr, thermic, or tak in from the surr, thermic.

Often, the surr are the wa that the chemicals are diss in or we can arrange things so that water absorbs the heat.

We know exactly how much energy it takes to heat, or cool down, 1kg of water by exactly 1°C. This is the specific heat capacity, 

\[ c = 4.18 \text{ kJ kg}^{-1} \text{°C}^{-1} \]  
(Data Book)

**Remember:** the density of water is 1.00 g cm\(^{-3}\) and 1cm\(^3\) = 1ml so:-  
1ml of water = 1g
Measuring Energy from Fuels

copper can
200 cm$^3$ water
thermometer
alkanol

Consumer Products

KHS Feb 2014

page 27

National 5
Combustion Equations

This reaction is effectively the same for all organic molecules including **alcohols, acids** and **esters**.

- **carbon** \(\rightarrow\) **carbon dioxide**: as shown by the **lime** water turning **milk** / **clo**

- **hydrogen** \(\rightarrow\) **water**: as shown by the **blue** Cobalt Chloride paper turning **pink**

\[
\begin{align*}
\text{methanol} & + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} \\
CH_3OH & + \rightarrow +
\end{align*}
\]

\[
\begin{align*}
\text{butanoic acid} & + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} \\
C_3H_7COOH & + \rightarrow +
\end{align*}
\]

\[
\begin{align*}
\text{methylethanoate} & + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} \\
CH_3COOCH_3 & + \rightarrow +
\end{align*}
\]

Combustion equations are particularly suitable for practising how to do 'calculations based on balanced equations' - Section 5 (page 8) of your Chemistry Calculations Booklet 1.
The alkanals are a homologous series of compounds that all contain the elements carbon, hydrogen and oxygen.

a) What is meant by the term homologous series?

b) The combustion of alkanals releases heat energy.

<table>
<thead>
<tr>
<th>Name of alkanal</th>
<th>Heat energy released when one mole burns (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanal</td>
<td>510</td>
</tr>
<tr>
<td>ethanol</td>
<td>1056</td>
</tr>
<tr>
<td>propanal</td>
<td>1624</td>
</tr>
<tr>
<td>butanal</td>
<td>2304</td>
</tr>
</tbody>
</table>

i) Make a general statement linking the amount of heat energy released and the number of carbon atoms in the alkanal molecules.

ii) Predict the amount of heat energy released, when 1 mole of pentanal burns.

Fats and oils are made by reacting the alcohol glycerol with 3 molecules of a fatty acid.

a) What type of molecules are Fats and Oils?

b) What name is given to the reaction that forms Fats and Oils?

c) The equation below shows the breakdown of glyceryl tristearate to form glycerol and stearic acid.

\[
\text{C}_{57}\text{H}_{110}\text{O}_6 + 3\text{H}_2\text{O} \rightarrow \text{C}_3\text{H}_8\text{O}_3 + 3\text{C}_{18}\text{H}_{36}\text{O}_2
\]

glycerol + stearic acid

GFM = 890g
GFM = 284g

Calculate the mass of stearic acid produced from 8.9 g of glyceryl tristearate.

Ethanoic acid is a member of the alkanoic acid family.

a) The functional group in ethanoic acid has been highlighted.

b) Ethanoic acid can be prepared by reacting methanol with carbon monoxide.

\[
\text{CH}_3\text{OH} + \text{CO} \rightarrow \text{CH}_3\text{COOH}
\]

Calculate the mass of ethanoic acid produced from 16 g of methanol.

When 1 mole of methanol (CH₃OH) is burnt, 727 kJ of energy is released.

What mass of methanol has to be burned to produce 72.7 kJ?

A 3.2 g  
B 32 g  
C 72.7 g  
D 727 g

Which of the following compounds fits the general formula, \(\text{C}_x\text{H}_{2x}\), and will rapidly decolourise bromine solution?

A cyclopentane  
B pentane  
C pentene  
D cyclopentene
Homologous Series

- A homologous series is a group of compounds with:
  - similar chemical properties
  - the same general formula
  - a gradual change in physical properties such as melting and boiling point.

- Examples of homologous series include families of compounds called the alkanols and alkanic acids.

Alkanols

- The alkanols are the family of alcohols which have the hydroxyl group —OH on a chain of carbon atoms with single (C — C) bonds only

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Shortened Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanol</td>
<td>CH₃OH (l)</td>
<td>CH₃OH</td>
</tr>
<tr>
<td>ethanol</td>
<td>C₂H₅OH (l)</td>
<td>CH₃CH₂OH</td>
</tr>
<tr>
<td>propanol</td>
<td>C₃H₇OH (l)</td>
<td>CH₃CH₂CH₂OH</td>
</tr>
<tr>
<td>butanol</td>
<td>C₄H₉OH (l)</td>
<td>CH₃CH₂CH₂CH₂OH</td>
</tr>
<tr>
<td>pentanol</td>
<td>C₅H₁₁OH (l)</td>
<td>CH₃CH₂CH₂CH₂CH₂OH</td>
</tr>
<tr>
<td>hexanol</td>
<td>C₆H₁₃OH (l)</td>
<td>CH₃CH₂CH₂CH₂CH₂CH₂OH</td>
</tr>
<tr>
<td>heptanol</td>
<td>C₇H₁₅OH (l)</td>
<td>CH₃CH₂CH₂CH₂CH₂CH₂CH₂OH</td>
</tr>
<tr>
<td>octanol</td>
<td>C₈H₁₇OH (l)</td>
<td>CH₃CH₂CH₂CH₂CH₂CH₂CH₂CH₂OH</td>
</tr>
</tbody>
</table>

- The general formula for the alkanols is CₙH₂ₙ₊₁OH
- Most alkanols will be made by the addition of water (hydration) to alkenes
- Ethanol can be made by the yeast fermentation of sugars
- Other alcohols can be made by the bacterial fermentation of sugars
- The alkanols have weak attractions between their molecules and the early (smaller) members of the family
  - have very low melting & boiling points
  - are volatile, flammable and non-viscous (runny)
- The alkanols, however, have stronger attractions same as water so the smaller members are soluble (miscible) in water
- The alcohols are used in a wide variety of consumer products
Alkanols can be **straight chained** or **branched** and the **hydroxyl** group can change position.

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Shortened Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanoic acid</td>
<td>HCOOH (_{(l)})</td>
<td>HCOOH</td>
</tr>
<tr>
<td>ethanoic acid</td>
<td>CH(<em>3)COOH (</em>{(l)})</td>
<td>CH(_3)COOH</td>
</tr>
<tr>
<td>propanoic acid</td>
<td>C(_2)H(<em>5)COOH (</em>{(l)})</td>
<td>CH(_3)CH(_2)COOH</td>
</tr>
<tr>
<td>hexanoic acid</td>
<td>C(<em>5)H(</em>{11})COOH (_{(l)})</td>
<td>CH(_3)CH(_2)CH(_2)CH(_2)COOH</td>
</tr>
</tbody>
</table>

Alkanols can be **named** systematically according to rules set down by the International Union of Pure and Applied Chemistry (IUPAC).

- **butan-1-ol**
- **2-methylpropan-1-ol**
- **butan-2-ol**
- **2-methylpropan-2-ol**

The alkanols burn to give carbon dioxide and water on **complete combustion**

---

**Alkanoic acids**

- **The alkanoic acids** are the family of **organic acids** which have the **carboxyl group** —COOH on a chain of carbon atoms with single (C — C) bonds only

- The general formula for the **alkanoic acids** is C\(_n\)H\(_{2n+1}\)COOH (n = 0, 1 etc)
- Most alkanoic acids will be made by the **oxidation** of an **alkanol**
- The alkanoic acids burn to give carbon dioxide and water on **complete combustion**
- The alkanoic acids have **weak attractions** between their molecules and the early (smaller) members of the family
  - have **very low melting & boiling points**
  - are **volatile, flammable** and **non-viscous** (runny)
- The alkanoic acids, however, have **stronger attractions** same as water so
  - the smaller members are **soluble** (miscible) in water
- The alkanoic acids **dissociate** in water to produce H\(^+\)\(_{(aq)}\) ions and will
  - react with **metals** to produce **hydrogen gas**
  - react with **carbonates** to produce **carbon dioxide gas**
  - be **neutralised** by the addition of **alkali** (OH\(^-\)\(_{(aq)}\) ions)
• **Straight chained acids** can be named systematically according to rules set down by the International Union of Pure and Applied Chemistry (IUPAC).

\[
\begin{align*}
\text{but-1-ene} & \quad \text{but-2-ene} & \quad \text{2-methylpropene} \\
\end{align*}
\]

• The acids burn to give carbon dioxide and water on **complete combustion**

• The acids are used in a wide variety of **consumer products**

**Esters**

• The *esters* are formed by a **condensation** reaction between an *organic acid* and an *alcohol*

\[
\text{methyl ethanoate, } \quad \begin{array}{c}
H_3C - O \\
\big/ \\
C - CH_3 \\
\end{array}
\]

• **Condensation** is the **joining together** of two molecules involving the **elimination of a small molecule**, usually water.

• An ester can be named given the names of the the parent alkanol and alkanoic acid

\[
\begin{align*}
\text{methyl ethanoate, } & \quad \begin{array}{c}
H_3C - O \\
\big/ \\
C - CH_3 \\
\end{array} \\
\text{methanol } & \quad \begin{array}{c}
H_3C - OH \\
\big/ \\
O \\
\end{array} \quad \text{ethanoic acid}
\end{align*}
\]

• The *esters* have very **weak attractions** between their molecules and the early (smaller) members of the family
  
  ❖ **have very low melting & boiling points**
  ❖ are **volatile, flammable** and **non-viscous (runny)**
  ❖ are **insoluble (immiscible)** in water

• Esters burn to give carbon dioxide and water on **complete combustion**

• Esters are used in a wide variety of **consumer products**

**Polymers**

• **Polymers** can be made by joining together many small molecules (**monomers**) by either **addition** or **condensation** reactions

• **Polymers** can be both **natural** or **synthetic** (**man-made**)

• **Monomers** suitable for **addition** polymerisation will have \( C = C \) double bonds

• **Monomers** suitable for **condensation** polymerisation can have groups like

  - hydroxyl (\( \text{—OH} \))
  - carboxyl (\( \text{—COOH} \))
  - amino (\( \text{—NH}_2 \))
• **Addition Polymers** have a backbone of carbon atoms only
• **Condensation Polymers** will have an *ester link* or *amide link* or *non-carbon* atoms in the backbone

![Diagram of polymer structures]

• **Condensation Polymers** with an *ester link* are known as *polyesters*
• Polymers are used in a wide variety of *consumer products*

**Energy from Fuels**

• Organic molecules release energy (*exothermic*) when they burn (*combustion*)
• Alkanes and alcohols are of particular use as fuels
• Alcohol can be made from any fruit or vegetable containing starch or sugars e.g. grapes (glucose) → wine, barley (starch) → whisky, rice (starch) → saki
• If starch is used, it must first be broken down to glucose using enzymes
• The alcohol in alcoholic drinks is *ethanol*, the second member of a family called the *alkanols*
• Alcohol (*ethanol*) is obtained from glucose by a process called *fermentation*
• **Fermentation** is the breakdown of glucose to form ethanol and carbon dioxide. An enzyme in *yeast*, a living organism, acts as a catalyst for the reaction:

\[
\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide}
\]

\[
C_6H_{12}O_6 \rightarrow 2 \text{C}_2\text{H}_5\text{OH} + 2 \text{CO}_2
\]
• There is a limit to the alcohol concentration of fermented drinks because yeast cells die if the concentration rises above 12 %
• Like all enzymes, those used in fermentation have a pH and a temperature at which they work best (their optimum pH and temperature)
• Since water boils at 100 °C and ethanol boils at 78 °C, the two can be separated by *distillation*. This enables high alcohol drinks such as whisky to be made (spirits)
• Typically: - beer/lager 3 - 7 %, wine 10 - 12 %, spirits 40 %
**CONSOLIDATION QUESTIONS**

**Q1.** A bottle of whisky contains 40% ethanol by volume. Which line in the table is the correct description of the mixture?

<table>
<thead>
<tr>
<th>Solute</th>
<th>Solvent</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ethanol</td>
<td>whisky</td>
</tr>
<tr>
<td>B</td>
<td>ethanol</td>
<td>water</td>
</tr>
<tr>
<td>C</td>
<td>water</td>
<td>ethanol</td>
</tr>
<tr>
<td>D</td>
<td>whisky</td>
<td>water</td>
</tr>
</tbody>
</table>

**Q2.** When a compound is burned completely, the products are carbon dioxide and water. From this information, it can be concluded that the compound must contain

A carbon only  
B hydrogen only  
C carbon and hydrogen  
D carbon, hydrogen and oxygen

**Q3.** Ethanol can be produced from sugar cane by

A oxidation  
B fermentation  
C polymerisation  
D catalytic hydration

**Q4.** Propan-1-ol can be dehydrated.

Which of the following compounds is a product of the reaction?

A Propanoic acid  
B Propyl propanoate  
C Propene  
D Propane

**Q5.** Polyamides and polyesters are always made from monomers

A which are unsaturated  
B with one functional group per molecule  
C containing a hydroxyl group  
D with two functional groups per molecule

**Q6.** The flow chart shows some of the stages in the manufacture of ethanoic acid.

- A) In the mashing process, some of the starch (polymer) is broken down into glucose (monomer). What type of polymer is starch?

- B) Name process X.

- C) Draw the full structural formula for ethanoic acid.

- D) Ethanoic acid can be reacted with methanol to form an ester, which is used as a solvent in nail varnish remover. Draw the structure, and name this ester.
The table shows the result of heating two compounds with acidified potassium dichromate solution.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Acidified potassium dichromate solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>H - C - C - C - C - H</td>
<td>stays orange</td>
</tr>
<tr>
<td>H - H - H - O - O - H</td>
<td>turns green</td>
</tr>
</tbody>
</table>

Which of the following compounds will not turn acidified potassium dichromate solution green?

A

B

C

D

Which of the following groups can react together to form an amide (peptide) link?

A

B

C

D

Esters are formed by the reaction between which two functional groups?

A a hydroxyl group and a carboxyl group

B a hydroxyl group and a carbonyl group

C a hydroxide group and a carboxyl group

D a hydroxide group and a carbonyl group

Ethanol can be manufactured in different ways from different raw materials.

Select the appropriate processes from the following list to complete the two flowcharts below.

fermentation cracking hydration distillation dehydration oxidation

a) sugar solution


ethanol solution


pure ethanol

b) naphtha fraction


ethene gas


pure ethanol
CONSOLIDATION QUESTIONS

Q1. The shortened structural formula for an organic compound is
\[ CH_3CH(CH_2)CH(OH)C(CH_3)_3 \]
Which of the following is another way of representing this structure?

A
\[ \begin{array}{c}
H \quad H \quad OH \quad CH_3 \\
H \quad C \quad C \quad C \quad C \quad CH_3 \\
H \quad CH_3 \quad H \\
\end{array} \]

B
\[ \begin{array}{c}
H \quad H \quad H \quad OH \quad CH_3 \\
H \quad C \quad C \quad C \quad C \quad C \quad CH_3 \\
H \quad H \quad H \quad CH_3 \\
\end{array} \]

C
\[ \begin{array}{c}
H \quad H \quad H \quad CH_3 \quad CH_3 \\
H \quad C \quad C \quad C \quad C \quad C \quad CH_3 \\
H \quad CH_3 \quad OH \quad H \quad H \\
\end{array} \]

D
\[ \begin{array}{c}
H \quad H \quad H \quad OH \quad CH_3 \\
H \quad C \quad C \quad C \quad C \quad C \quad CH_3 \\
H \quad CH_3 \quad OH \quad H \quad H \\
\end{array} \]

Q2. methanol + ethanoic acid → methyl ethanoate + water
This reaction is an example of

A addition
B dehydration
C condensation
D neutralisation.

Q3. Chemicals in food provide flavour and smell. Ketones are responsible for the flavour in blue cheese.
Two examples of ketones are shown below.

\[ \begin{array}{c}
H \quad H \quad H \quad OH \\
H \quad C \quad C \quad C \quad C \quad CH_3 \\
\end{array} \quad \text{pentan-2-one} \]
\[ \begin{array}{c}
H \quad H \quad H \quad OH \\
H \quad C \quad C \quad C \quad C \quad CH_3 \\
\end{array} \quad \text{pentan-3-one} \]

a) Draw a structure for hexan-3-one.

b) Suggest a name for the ketone shown below.
\[ \begin{array}{c}
H \quad H \quad H \quad OH \\
H \quad C \quad C \quad C \quad C \quad C \quad CH_3 \\
\end{array} \]

c) Information about the boiling points of four ketones is shown in the table.

<table>
<thead>
<tr>
<th>Ketone</th>
<th>Boiling point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_4H_9O</td>
<td>56</td>
</tr>
<tr>
<td>C_5H_10O</td>
<td>80</td>
</tr>
<tr>
<td>C_6H_12O</td>
<td>102</td>
</tr>
<tr>
<td>C_7H_14O</td>
<td>127</td>
</tr>
</tbody>
</table>

Predict the boiling point of C_7H_14O. ___________ °C

Q4. Poly(ethenol) is one of the substances used to cover dishwasher tablets. A section of the poly(ethenol) polymer is shown.

- \[ -CH_2-CH-CH_2-CH-CH_2- \]

OH \quad OH \quad OH

a) Name the functional group in this polymer

b) Draw the structure of the repeating unit for this polymer.

c) A dishwasher tablet, complete with its poly(ethenol) cover, can be added to a dishwasher.

What property of the poly(ethenol) makes it suitable as a cover for a dishwasher tablet?
Alcohols are widely used in antifreeze and de-icers.

\[
\begin{align*}
\text{ethane-1,2-diol} & : \quad \text{molecular mass} = 62, \quad \text{boiling point} = 197 °C \\
\text{propan-1-ol} & : \quad \text{molecular mass} = 60, \quad \text{boiling point} = 98 °C
\end{align*}
\]

\textbf{a)} Why is the boiling point of ethane-1,2-diol much higher than the boiling point of propan-1-ol?

\textbf{b)} Ethane-1,2-diol can be produced industrially from ethene in a two stage process:

\textit{Stage one} \quad \textit{Stage two}

Name the alkene required to produce butane-2,3-diol.

Diols are widely used in the manufacture of polyester polymers.

Polyethylene naphthalate is used to manufacture food containers. The monomers used to produce this polymer are shown.

\[
\begin{align*}
\text{naphthalenedicarboxylic acid} & : \quad \text{HO} - \text{C} - \text{C}_{10}\text{H}_6 - \text{C} - \text{O} - \text{OH} \\
\text{ethane-1,2-diol} & : \quad \text{HO} - \text{CH}_2 - \text{CH}_2 - \text{OH}
\end{align*}
\]

\textbf{a)} Draw the repeating unit for polyethylene naphthalate

\textbf{b)} Ethane-1,2-diol is produced in industry by reacting glycerol with hydrogen.

\[
\begin{align*}
\text{glycerol (GFM} = 92) & \quad + \quad \text{H}_2 & \quad \rightarrow & \quad \text{ethane-1,2-diol (GFM} = 62)
\end{align*}
\]

Calculate how much ethane-1,2-diol would be produced by reacting 4.6 kg of glycerol with excess hydrogen.