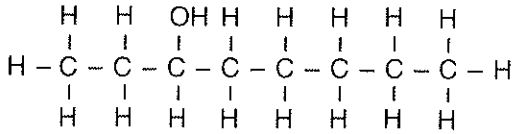
25 Revision of Alkanols

You will recall from the first module you studied this year that **alkanols** are a homologous group of organic compounds which contain the **hydroxyl group (–OH)** as their functional group attached to an alkyl group. You should recall the following points:

- alkanols have the **general formula** ROH, where R stands for a saturated carbon chain with the formula C_nH_{2n+1}
- the name of the alkanol depends on the number of carbon atoms and the position of the hydroxyl group.

3-octanol



2-pentanol

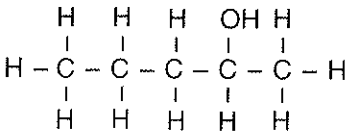


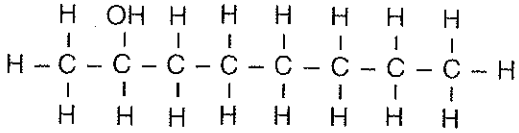
Figure 25.1 Naming alkanols

- alkanols are **polar** molecules as they contain the polar hydroxyl (OH) group
- **hydrogen bonding** occurs because of the presence of the hydroxyl (OH) group
- they are soluble in water but, as with alkanoic acids, the longer the carbon chain, the higher their melting and boiling points and the less soluble they are
- alkanols **react with alkanoic acids to form esters**

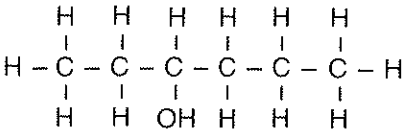
For You To Do

1. Name and write molecular and structural formulas for the alkanols from C1 to C8. Tabulate your answer.
2. Write structural formulas for
   (a) 2-propanol
   (b) 3-octanol
   (c) 1-pentanol
3. Explain what is meant by
   (a) organic compound
   (b) hydrogen bonding
   (c) hydroxyl group
   (d) homologous group
   (e) alkyl group
4. Explain why C_2H_5OH is soluble in water but $C_{15}H_{31}OH$ is insoluble.
5. Identify each of the following substances:

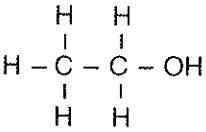
   (a)

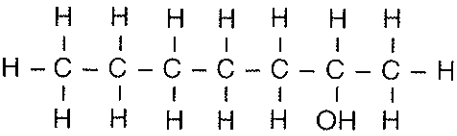
   (b)

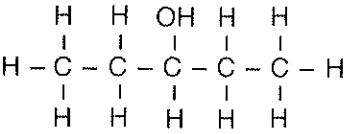
   (c)

   (d)

   (e)

6. Check your knowledge with this quick quiz.
   (a) Write structural formulas for the following substances.
      (i) methanol
      (ii) ethanol
      (iii) 2-pentanol
      (iv) 3-octanol
      (v) 2-hexanol
   (b) Identify the functional group of alkanols.
   (c) State the general formula for alkanols.
   (d) Identify the term for the attractive force between the hydrogen in one molecule and an oxygen, fluorine or nitrogen in another molecule.
   (e) Describe the relationship between the solubility of alkanols in water and the size of the alkanol.
   (f) Identify the group in alkanols that makes them polar.

26 Alkanoic Acids

Most of the acids you have dealt with so far have been inorganic acids. There is also a very large family of organic acids called alkanoic (or carboxylic) acids. Things you should know about alkanoic acids are:

- **alkanoic acids** are organic compounds containing a **carboxyl group (–COOH)** as the functional group, attached to the end of an alkyl group

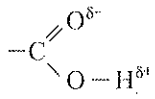


Figure 26.1 Carboxyl group in alkanoic acids

- the **general formula** of alkanoic acids is **RCOOH**, where R stands for an alkyl chain with the formula C_nH_{2n+1}. For example, ethanoic acid is CH_3COOH.
- the carboxyl group in alkanoic acids makes them **polar**
- they form strong **hydrogen bonds** (see Figure 26.2) due to the presence of the carboxyl group. As they have two O atoms, they can form two hydrogen bonds between nearby molecules.

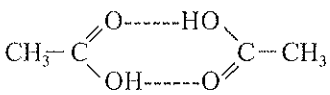


Figure 26.2 Hydrogen bonds between carboxyl groups

This hydrogen bonding means that they are **soluble** in water and have **higher boiling points** than other similar sized alkanes, alkenes, alkynes and alkanols.

- alkanoic acids are **weak acids**; they only partly dissociate in water. For example, ethanoic acid partly dissociates in water as shown by the equation

$$CH_3COOH(aq) \Leftrightarrow CH_3COO^-(aq) + H^+(aq)$$

but the equilibrium lies to the left.

- the salts of long-chain alkanoic acids (such as sodium stearate, $C_{17}H_{35}COONa$) are soaps
- alkanoic acids **react with alkanols** (alcohols) to form esters. This process is called **esterification**.

Figure 26.3 compares the boiling points of a number of hydrocarbons, alkanols and alkanoic acids.

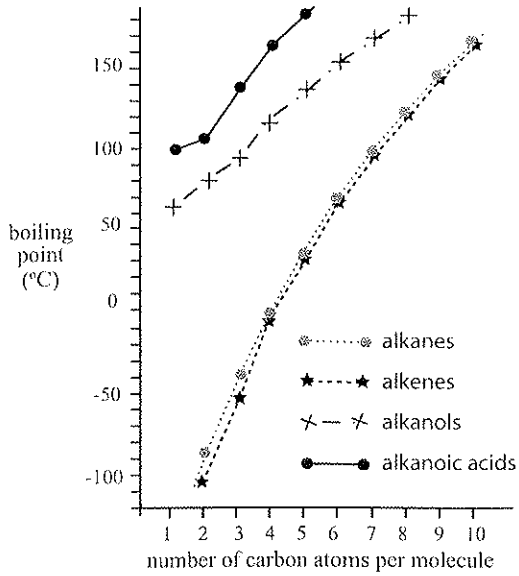
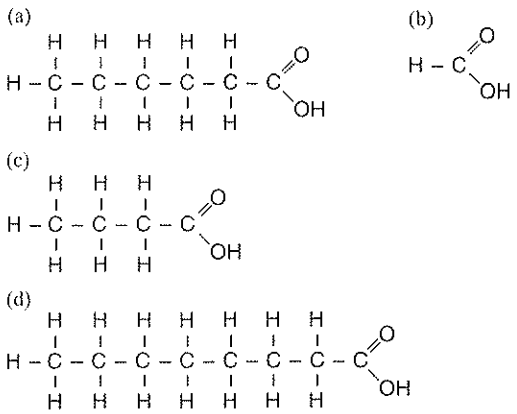


Figure 26.3 Boiling points of organic compounds

For You To Do

1. Name and write molecular and structural formulas for the alkanoic acids from C1 to C8. Tabulate your answer.
2. The graph in Figure 26.3 shows that the boiling points of carbon compounds increase as the chain becomes longer. Outline a reason for this trend.
3. Use the graph in Figure 26.3 to compare boiling points of hydrocarbons, alkanols and alkanoic acids. Explain the differences in terms of bonding.
4. Write the structural formula for 2-chloropentanoic acid.
5. Identify the following substances:



6. Explain why ethanoic acid is soluble in water but stearic acid is insoluble.
7. Check your knowledge with this quick quiz.
   (a) Write formulas for substances (i) to (iii).
      (i) methanoic acid
      (ii) ethanoic acid
      (iii) pentanoic acid
   (b) Identify the functional group of alkanoic acids.
   (c) State the general formula for alkanoic acids.

27 Esters

Esters are organic compounds with the general formula R COOR′ where R and R′ are carbon chains. Short-chain esters are volatile liquids. As the carbon chain increases in size, the liquid esters become less volatile, more oily and more viscous. Long-chain esters are soft solids or waxes.

Figure 27.1 shows the general formula of an ester.

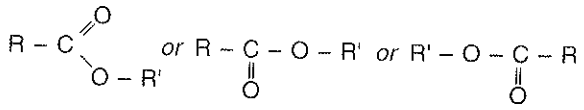
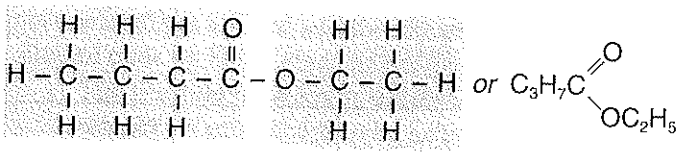


Figure 27.1 General formula of ester

An example of an ester is ethyl butanoate.



Naming Esters

- The first part of the name comes from the alkanol. This is named as an alkyl group. It is shown in the general formula above as R′.
- The second part of the name comes from the alkanoic acid. When naming the ester, the suffix '-oic acid' is changed to 'anoate'.

Thus propyl pentanoate comes from a 3-carbon alkanol (propanol) and a 5-carbon acid (pentanoic acid).

Table 27.1 shows some examples of esters formed from alkanols and alkanoic acids. Some names and formulas have been left out — fill in the spaces.

Uses of Esters

Esters occur naturally in living things. Fats and oils are esters, and esters give perfume and taste to flowers and fruits. Esters tend to have strong flavours and odours, so they are manufactured for use as flavours and perfumes in processed foods and in cosmetics. They are also useful as solvents. Some examples are shown in Table 27.2 (see p. 40).

Table 27.1 Esters

Alkanol	Alkanoic acid	Ester
Methanol CH_3OH	Methanoic acid HCOOH	Methyl methanoate H – C(=O) – O– CH_3
Ethanol C_2H_5OH	Methanoic acid HCOOH	Ethyl methanoate H – C(=O) – O– C_2H_5
Propanol C_3H_7OH	Methanoic acid HCOOH	Propyl methanoate H – C(=O) – O– C_3H_7
Butanol C_4H_9OH	Methanoic acid HCOOH	
Hexanol $C_6H_{13}OH$	Methanoic acid HCOOH	Hexyl methanoate H – C(=O) – O– C_6H_{13}
Methanol CH_3OH	Ethanoic acid CH_3COOH	Methyl ethanoate $CH_3C(=O)$ – O–CH_3
Ethanol C_2H_5OH	Ethanoic acid CH_3COOH	Ethyl ethanoate $CH_3C(=O)$ – OC_2H_5
Propanol C_3H_7OH	Ethanoic acid CH_3COOH	
Butanol C_4H_9OH	Ethanoic acid CH_3COOH	Butyl ethanoate $CH_3C(=O)$ – O–C_4H_9
	Ethanoic acid CH_3COOH	Octyl ethanoate $CH_3C(=O)$ – O–C_8H_{17}
Pentanol $C_5H_{11}OH$	Methanoic acid HCOOH	
Pentanol $C_5H_{11}OH$	Ethanoic acid CH_3COOH	
Pentanol $C_5H_{11}OH$	Propanoic acid C_2H_5COOH	
Pentanol $C_5H_{11}OH$	Octanoic acid $C_7H_{15}COOH$	

Table 27.2 Uses of esters

Name	Structure	Use
Ethyl ethanoate	$CH_3COOC_2H_5$	Nail polish remover
Ethyl butanoate	$C_3H_7COO\ C_2H_5$	Pineapple ester
Pentyl ethanoate	$CH_3COOC_5H_{11}$	Banana ester
Glyceryl tristearate (monooctadecanoate)	$C_{17}H_{35}COOCH_2$ | $CHOH$ | CH_2OH	An animal fat

For You To Do

1. What is meant by the terms
   (a) volatile
   (b) viscous
   (c) ester
2. Write structural formulas for the following esters:
   (a) methyl propanoate
   (b) propyl methanoate
   (c) butyl ethanoate
   (d) ethyl butanoate
3. Name the following esters:

(a) $C_7H_{15}C(=O)-O-C_2H_5$

(b) $C_3H_7C(=O)-O-CH_3$

(c) $C_4H_9C(=O)-O-C_3H_7$

(d) $CH_3C(=O)-O-C_6H_{13}$

4. Identify two esters and outline a use of each.
5. Identify one use of esters and a property that makes them suitable for this use.
6. Complete the following table to summarise the homologous series of carbon compounds that you have studied.

Name of homologous series	Functional group	General formula	Name and formula of an example
Alkene			
	Single C–C bonds		
Alkanol			
Alkanoic acid			Propanoic acid
Ester			

7. Check your knowledge with this quick quiz.
   (a) State two uses of esters.
   (b) Identify a use for pentyl ethanoate.
   (c) Name the ester made from pentanoic acid and butanol.
   (d) Write the structural formula for pentyl propanoate.
   (e) Identify a use for ethyl ethanoate.

28 Production of Esters

Esters are made by a condensation reaction between an alkanol and an alkanoic acid. This process is called **esterification.**

alkanoic acid + alkanol → ester + water

RCOOH + R'OH → RCOOR' + H_2O

This is also called a **condensation** reaction, as a molecule of water condenses out.

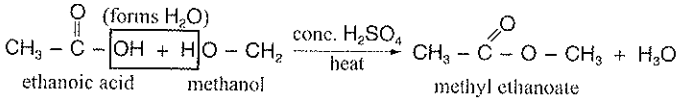


Figure 28.1 Esterification

Notice that the bridging oxygen atom in the ester comes from the alkanol and the oxygen atom of the alkanol ends up in the ester, not in the water.

The reaction between an alkanol and an alkanoic acid to make an ester needs to be heated to speed it up.

Concentrated sulfuric acid is used as a catalyst. It absorbs water, pushing the equilibrium to the right. The reaction is carried out by **reflux**.

Refluxing is the process of heating a reaction mixture in a container with a cooling condenser attached vertically. This prevents the loss of volatile reactants and products to the environment and allows the reaction to be carried out at a higher temperature than would otherwise be possible.

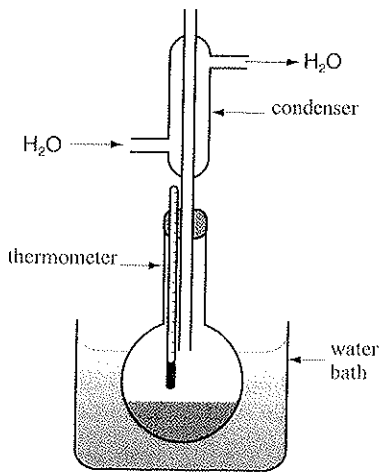


Figure 28.2 Esterification

For You To Do

1. (a) Outline the meaning of the term 'refluxing'.
   (b) Why is the water shown entering the bottom of the condenser jacket?
   (c) Explain the advantage of using the technique of refluxing.
   (d) What is the purpose of the water in the condenser jacket?
   (e) Does the water in the condenser jacket mix with the vapour coming out of the flask? Explain.
2. Name the esters produced by the following reactions:
   (a) propanol and ethanoic acid
   (b) methanol and butanoic acid
   (c) ethanol and propanoic acid
3. Compare the reaction of an alkanol and an alkanoic acid with the polymerisation of glucose to form cellulose. What do these reactions have in common?
4. An ester will undergo hydrolysis in the presence of excess water and a catalyst to produce an alkanol and an alkanoic acid.

   ester + water ⇔ alkanol + alkanoic acid

   If the alkanol is removed from the resulting mixture as it forms, by distilling the mixture, in which direction will the reaction go? Justify your answer.
5. During this topic you performed a first-hand investigation in which you prepared an ester using reflux.
   (a) Use a diagram to show the equipment you chose.
   (b) Identify the reactants used and the products formed.
   (c) Explain the need for reflux during this reaction.
   (d) Outline safety precautions necessary for this procedure.
   (e) Describe the role of concentrated sulfuric acid in this experiment.
   (f) How does the use of the condenser differ in the processes of reflux and distillation?
6. Identify the reactants you would use to manufacture a product with the following flavours:
   (a) banana
   (b) pineapple
7. Check your answers with this quick quiz.
   (a) Name the process of making an ester.
   (b) Identify the catalyst used in this process.
   (c) Identify the piece of equipment shown below.
   (d) In the diagram does water go in through A or B?