Chapter 8 Organic compounds

8.1 Organic materials

KEY QUESTIONS

Knowledge and understanding

1 Compounds such as petrol, polymers and cosmetics are **carbon**-based compounds. Many of these compounds are currently produced from **crude oil**, which is a mixture made up of the remains of marine microorganisms, such as **bacteria** and plankton that died millions of years ago. The great age of these deposits explains why petrol is called a **fossil** fuel. Crude oil is a **non-renewable** resource because no more carbon is being added to the environment.

2 Organic compounds are carbon-based compounds which typically also have hydrogen and oxygen in them. They may also contain nitrogen, sulfur, phosphorus and halogens (fluorine, chlorine, bromine, iodine).

3 Photosynthesis is the name of the process by which carbon dioxide is changed by plants into glucose. This involves the following reaction:

$$6CO_2(g) + 6H_2O(l) \xrightarrow{\text{UV light, chlorophyll}} C_6H_{12}O_6(aq) + 6O_2(g)$$

Water and carbon dioxide are converted by a series of complex reactions in the presence of UV light and the molecule chlorophyll into glucose and oxygen.

Analysis

4 Organic chemicals that are made from crude oil are non-renewable because crude oil is a fossil fuel and is not being made at a rate that is anywhere close to the rate at which we use it.

5 The glucose comes from photosynthesis in plants. This is a renewable process as the glucose can be replaced at a rate that is similar to the rate at which we use it, so the polyethene made from ethanol derived from glucose is also renewable.

6 **a** If the polymers are recycled, rather than thrown away, the organic compounds are reused, rather than new hydrocarbons being refined from crude oil.

b If the government insists by legislation that petrol and diesel-fuelled cars are replaced by electric cars, then it will have to make this possible by providing infrastructure, while the non-renewable resource, crude oil, will be saved for uses where it cannot be replaced.

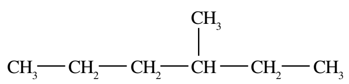
c Since crude oil is a non-renewable resource, it is important to find other ways to make the organic chemicals that we require, so replacement materials, such as plant-based biomass, need to be found.

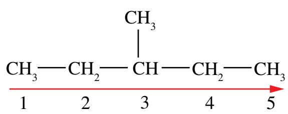
8.2 Hydrocarbons

Worked example: Try yourself 8.2.1

IUPAC NAMING SYSTEM FOR ALKANES

Write the systematic name for the following molecule.



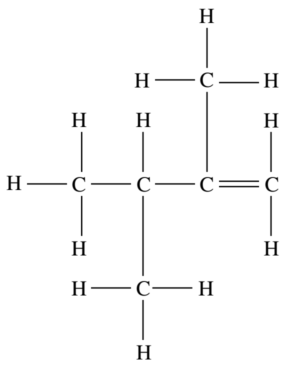
Thinking	Working
Identify the longest carbon chain in the molecule. The stem name of the molecule is based on this longest chain.	There are 5 carbons in the longest chain. The stem name is based on pentane.
Number the carbons, starting from the end closest to the side chain.	 Note: In this molecule, it does not matter at which end the numbering begins as the side branch comes off the central carbon, which is the third carbon.
Identify the side chain and its location.	The side chain is a methyl group on carbon number 3.
Combine all components.	The name of the molecule is 3-methylpentane.

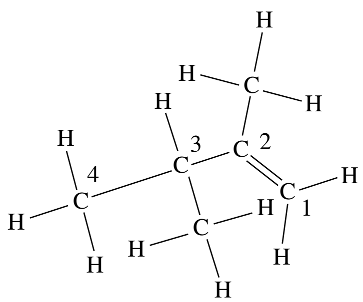
 ISBN 978 0 6557 0006 7

Worked example: Try yourself 8.2.2

IUPAC NAMING SYSTEM FOR ALKENES

Write the systematic name for the following molecule.



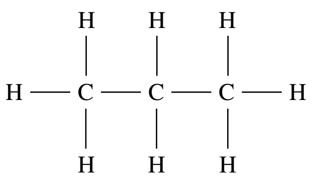
Thinking	Working
Identify the longest carbon chain in the molecule that contains the double bond. The name of the molecule is based on this longest chain.	There are 4 carbons in the longest chain with the double bond. The name is based on butene.
Number the carbon atoms, starting from the end closest to the double bond. Note the position of the double bond.	 There is a double bond on carbon number 1, so the longest chain is but-1-ene.
Identify any side chain and the number carbon that it is on.	The side chains are methyl groups and they are on carbons numbered (from smallest to largest) 2 and 3.
Combine all components.	The name of the molecule is 2,3-dimethylbut-1-ene.

KEY QUESTIONS

Knowledge and understanding

1 **a** Propane. This hydrocarbon contains three carbon atoms, so the stem name is prop-. Its formula fits the general formula of an alkane, C_nH_{2n+2} (n = 3, so 2 × 3 + 2 = 8). Hence the name of the hydrocarbon is propane.

b



c $CH_3CH_2CH_3$

d $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$

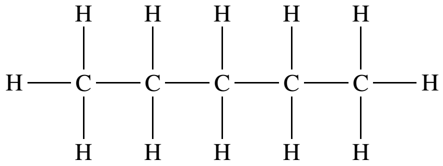
2 **a** alkanes: C_nH_{2n+2}; alkenes: C_nH_{2n}

b Alkanes have only C–C single bonds, so have the largest ratio of hydrogen atoms to carbon atoms; alkenes have one C=C double bond, so have fewer hydrogens per carbon than do alkanes.

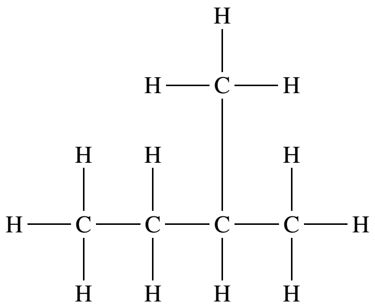
 ISBN 978 0 6557 0006 7

3 **a** Structural isomers of a compound, such as C_5H_{12}, have the same molecular formula, but they differ from each other by having a different arrangement of the carbon atoms in the molecule, and hence a different structure.

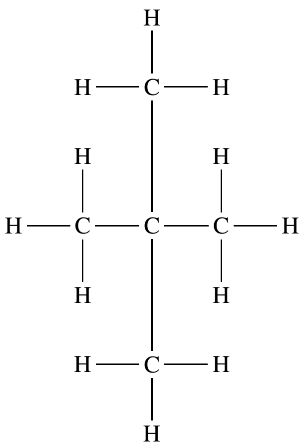
b



pentane



2-methylbutane

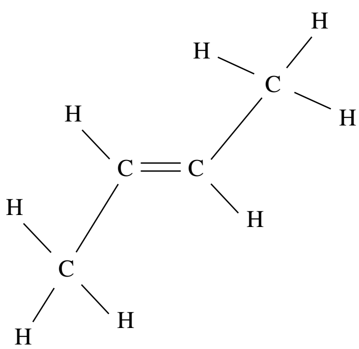


2,2-dimethylpropane

4 **a** pent-1-ene

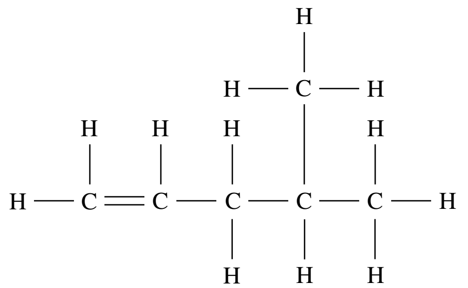
b $CH_2 = CHCH_2CH_2CH_3$ or $CH_3CH_2CH_2CH = CH_2$ or $CH_3CH_2CH_2CHCH_2$ or $CH_2CHCH_2CH_2CH_3$

5 **a** but-2-ene



 ISBN 978 0 6557 0006 7

b 4-methylpent-1-ene



Analysis

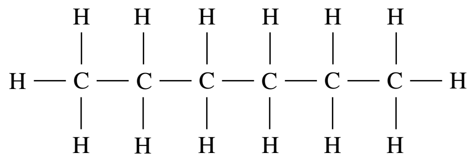
6 **a** hexane. The longest chain of carbon atoms has 6 carbon atoms (hex-) and there are no branches.

b 3-methylhexane. The longest chain of carbon atoms is 6, giving the stem name of hexane, and there is one methyl, $–CH_3$, branch on carbon number 3, when numbered from the end closest to the branch.

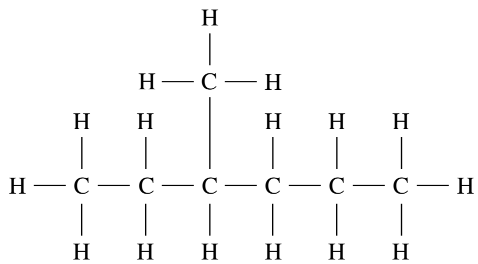
c 2,4-dimethylhexane. The longest chain of carbon atoms is 6, giving the stem name of hexane, and there are two methyl, $–CH_3$, branches on carbons numbered 2 and 4, when numbered from the end closest to the first branch.

d 2,2-dimethylbutane. The longest chain of carbon atoms is 4, giving the stem name of butane, and there are two methyl, $–CH_3$, branches on carbon number 2, when numbered from the end closest to the branches.

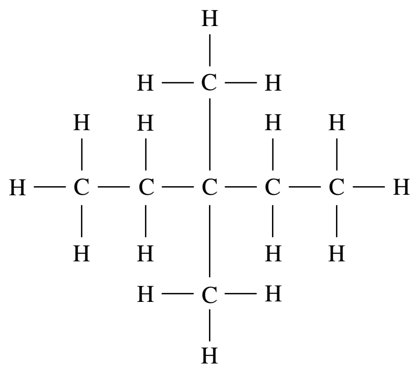
7 **a** hexane



b 3-methylhexane

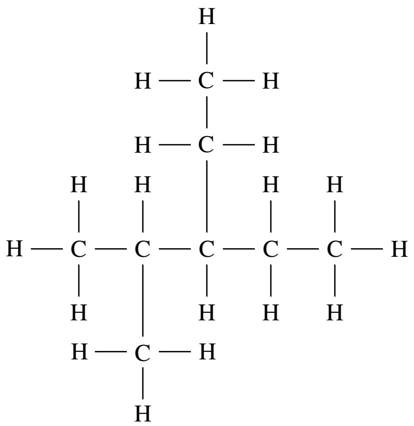


c 3,3-dimethylpentane

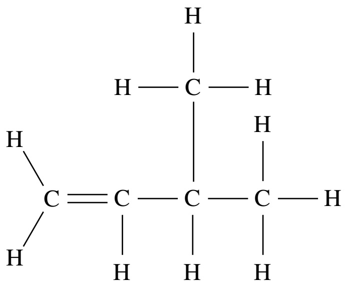


 ISBN 978 0 6557 0006 7

d 3-ethyl-2-methylpentane

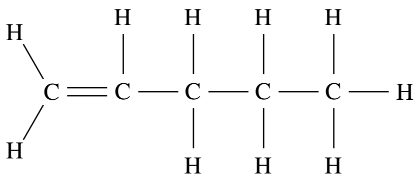


8 **a**

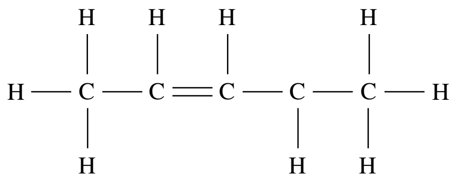


b C_5H_{10}

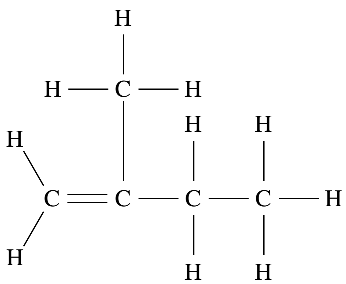
c



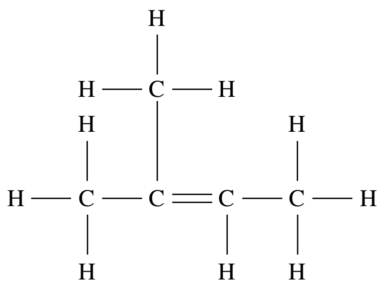
pent-1-ene



pent-2-ene



2-methylbut-1-ene



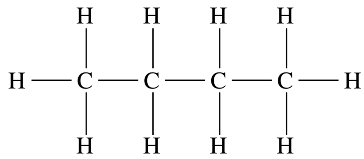
2-methylbut-2-ene

d 3-methylbut-2-ene is actually the same molecule as 2-methylbut-2-ene, but is just being viewed from the other end of the molecule. IUPAC rules specify the the carbon atoms in the chain are numbered from the end of the chain that will give the smallest numbers to double-bonded carbon atoms.

e The molecular formula of this compound is C_5H_{10}, so all isomers must have the same molecular formula. The proposed isomer, dimethylpropene, would have the molecular formula C_5H_{11}, and it would have 5 bonds around the 2nd carbon atom in the chain, which is not possible.

 ISBN 978 0 6557 0006 7

9 **a** **i**

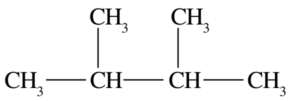


$CH_3(CH_2)_2CH_3$

ii It is not possible to have a methyl branch (or any branch) on the first carbon, so 1-methyl is not a branch, it is the continuation of the main carbon chain.

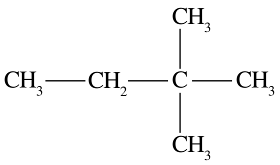
iii butane

b **i**



2,3-dimethylbutane

And

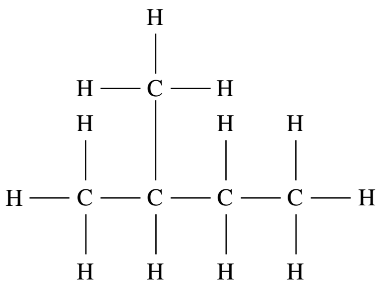


2,2-dimethylbutane

ii The methyl branches are not numbered. These could both be on carbon number 2, or one could be on carbon number 2 and the other on carbon number 3.

iii 2,2-dimethylbutane or 2,3-dimethylbutane

c **i**



ii The smallest possible number should always be selected for numbering a branch. Carbon number 3 from one end of the chain is actually carbon number 2 from the other end.

iii 2-methylbutane

10

Alkene	Incorrect semi-structural formula	Mistake	Correct semi-structural formula
but-2-ene	$CH_2CHCH_2CH_3$	Double bond is in the wrong place. Formula given is for but-1-ene	$CH_3CHCHCH_3$
2-methylprop-1-ene	$CH_2CH(CH_3)_2$	Five bonds around carbon number 2. Extra H on carbon number 2.	$CH_2C(CH_3)_2$
2,3-dimethylpent-2-ene	$CH_3C(CH_3)CCH_2CH_3$	Missing methyl group on carbon number 3.	$CH_3C(CH_3)C(CH_3)CH_2CH_3$

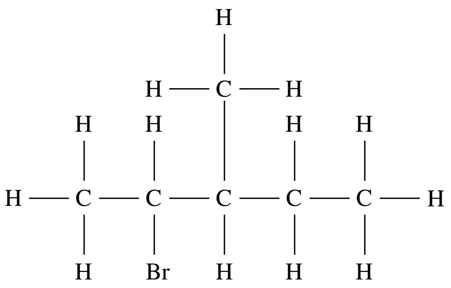
 ISBN 978 0 6557 0006 7

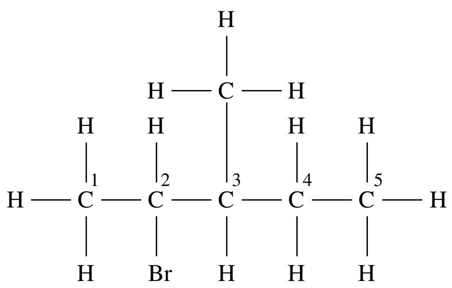
8.3 Haloalkanes

Worked example: Try yourself 8.3.1

IUPAC NAMING SYSTEM FOR HALOALKANES

Write the systematic name for the following molecule.



Thinking	Working
Identify the longest carbon chain in the molecule that contains the halogen atom/s. The name of the molecule is based on this longest chain.	There are 5 carbons in the longest chain with the halogen atom. The name is based on pentane.
Number the carbon atoms, starting from the end closest to the first halogen atom. Note the position of the halogen atom/s.	 There is a bromine atom on carbon number 2, so the longest chain is 2-bromopentane.
Identify each side chain and the number carbon that it is on.	The side chain is a methyl group and it is on carbon number 3.
Combine all components, remembering to list them in alphabetical order.	The name of the molecule is 2-bromo-3-methylpentane.

CASE STUDY: ANALYSIS

Haloalkanes and the ozone layer

Analysis

1 A free radical has an unpaired electron. Covalent bonds are formed when two unpaired electrons are shared between two atoms, so a free radical is very reactive because it has an electron already available to form a bond, whereas before new bonds can be formed in other reactions the existing bonds have to be broken.

2 Because higher energy light is needed to break the bonds in O_2, compared to O_3, this suggests that the bonds in ozone are weaker than the covalent double bond in an oxygen molecule.

3 The preferential breaking of the carbon–chlorine bond suggests that this bond is not as strong as the carbon–fluorine bond, which does not break.

4 CCl_2F_2 is called dichlorodifluoromethane.

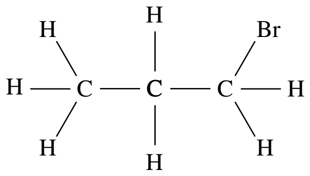
 ISBN 978 0 6557 0006 7

KEY QUESTIONS

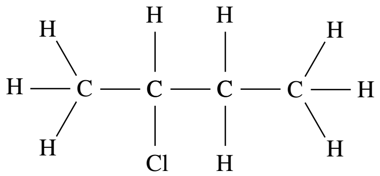
Knowledge and understanding

1 **a** CH_3CH_2Cl
b CH_3Br
c CH_3CHICH_3

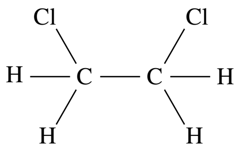
2 **a** 1-bromopropane



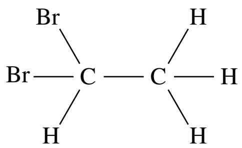
b 2-chlorobutane



c 1,2-dichloroethane



d 1,1-dibromoethane



3 **a** 2-chloro-2-iodopropane
b 1,1,2-tribromoethane
c tetrachloromethane

Analysis

4 The four isomers are 1-chlorobutane, 2-chlorobutane, 1-chloro-2-methylbutane, 2-chloro-2-methylbutane.

5 Because the bromine atom could be bonded to carbon number 1 or carbon number 2, a number must be included in the name of bromobutane. So, it must be either 1-bromobutane or 2-bromobutane.

6 Having two chlorine atoms in the molecule increases the possibilities for isomers significantly. The chlorine atoms may be on the same carbon, on adjacent carbons, or even on the two carbons at either end of the molecule. When there is just one chlorine atom in the molecule, there are only two isomers.

For C_3H_7Cl the isomers are: $CH_3CH_2CH_2Cl$ (1-chloropropane) and $CH_3CHClCH_3$ (2-chloropropane).

For $C_3H_6Cl_2$ the isomers are: $CHCl_2CH_2CH_3$ (1,1-dichloropropane), $CH_2ClCHClCH_3$ (1,2-dichloropropane), $CH_2ClCH_2CH_2Cl$ (1,3-dichloropropane), $CH_2CCl_2CH_3$ (2,2-dichloropropane).

7 **a** The molecule is polar because there is one C–Br bond, which is polar, and so the molecule is asymmetrical.
b The molecule is polar because there is one C–Cl bond, which is polar, and so the molecule is asymmetrical.
c The molecule is polar because there are two C–Br bonds, which are polar, on the same carbon, making the molecule asymmetrical.
d The molecule is polar because the C–Cl bond is more polar than the C–I bond, (chlorine is more electronegative than iodine), so even though there is a polar bond on each carbon, these are not equal, so do not cancel out. The molecule is asymmetrical.

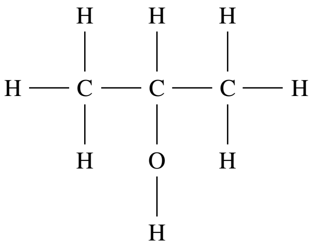
 ISBN 978 0 6557 0006 7

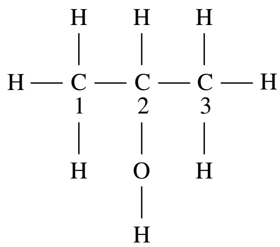
8.4 Alcohols and carboxylic acids

Worked example: Try yourself 8.4.1

IUPAC NAMING SYSTEM FOR ALCOHOLS

Write the systematic name for the following molecule.

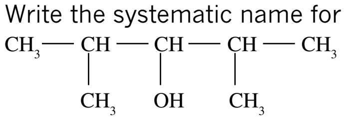


Thinking	Working
Identify the longest carbon chain in the molecule. The name of the molecule is based on this longest chain.	There are 3 carbons in the longest chain. The name is based on propane.
Identify the functional group that is present.	There is a hydroxyl group present.
Number the carbon atoms, starting from the end closest to the functional group.	
Identify the position(s) and the type(s) of side chains.	There are no branches in this molecule.
Combine all components. Place the number for the position of the side chain in front of the prefix, and the number for the position of the hydroxyl group in front of the –ol ending.	The name of the molecule is propan-2-ol.

Worked example: Try yourself 8.4.2

IUPAC NAMING SYSTEM FOR ALCOHOLS

Write the systematic name for the following molecule.



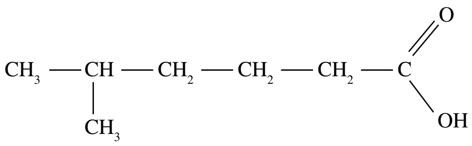
Thinking	Working
Identify the longest carbon chain in the molecule. The name of the molecule is based on this longest chain.	There are 5 carbons in the longest chain. The name is based on pentane.
Identify the functional group that is present.	There is a hydroxyl group present.
Number the carbon atoms, starting from the end closest to the functional group.	The functional group will be on C3.
Identify the position(s) and the type(s) of side chains.	There is a methyl ($–CH_3$) group on C2 and on C4, so the prefix 'dimethyl' will be used.
Combine all components. Place the number for the position of the side chain in front of the prefix, and the number for the position of the hydroxyl group in front of the –ol ending.	The name of the molecule is 2,4-dimethylpentan-3-ol.

 ISBN 978 0 6557 0006 7

Worked example: Try yourself 8.4.3

IUPAC NAMING SYSTEM FOR CARBOXYLIC ACIDS

Write the systematic name for the following molecule.



Thinking	Working
Identify the functional group that is present.	There is a carboxyl group present.
Identify the longest carbon chain that includes the carboxyl carbon. This atom will be C1. The stem name of the molecule is based on this longest chain.	There are 6 carbons in the longest chain, so the stem name is based on hexane.
Number the carbon atoms, starting from the end incorporating the functional group.	The functional group will be on C1.
Identify the position(s) and the type(s) of side chains.	There is a methyl group on C5.
Combine all components. Place the number for the position of the side chain in front of the prefix and using the ending –oic acid.	The name of the molecule is 5-methylhexanoic acid.

KEY QUESTIONS

Knowledge and understanding

1 The hydroxyl, –OH, functional group forms hydrogen bonds with water molecules. Because methanol and ethanol have only one and two carbon atoms respectively, the non-polar (alkyl) part of the molecule is not large enough to overcome this attraction.

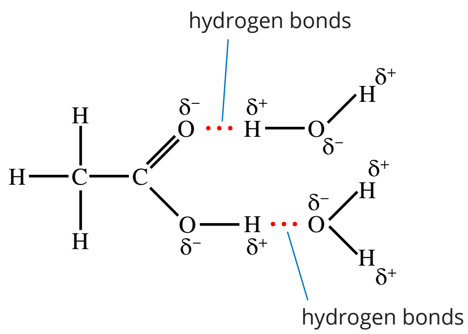
2 **a** The presence of the hydroxyl functional group enables stronger intermolecular forces to be formed between alcohol molecules. This attractive force is stronger than the dispersion forces between alkane molecules, so more energy is required to separate alcohols than alkanes with the same number of carbon atoms, hence the boiling points of alcohols are higher.

b As the length of the carbon chain in alcohols increases, the strength of the dispersion forces between the molecules increases (number of electrons in the molecules increases), so more energy is required to separate the molecules and so the boiling points of the alcohols increase.

3 **a** $C_nH_{2n+1}OH$ or $C_nH_{2n+2}O$

b The molecule $C_5H_{12}OH$ is not a member of the alcohol homologous series because it has too many hydrogen atoms in its formula. With 5 carbon atoms, it should have the formula $C_5H_{11}OH$ to belong to the alcohol homologous series.

4



5 **a** $CH_3CH_2CH_2COOH$

b $CH_3CH(CH_3)COOH$

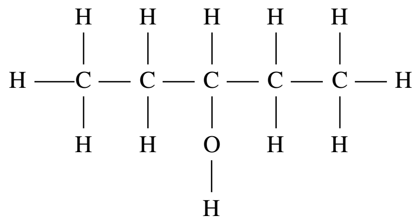
c $CH_3CH_2CH(CH_3)CH(CH_3)COOH$

 ISBN 978 0 6557 0006 7

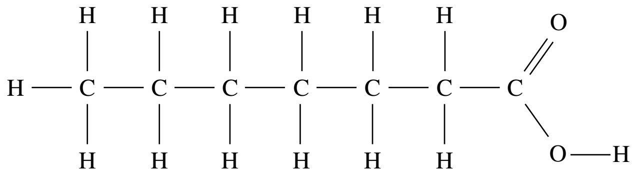
Analysis

6 **a** propan-2-ol
b 2-methylbutan-2-ol
c 2-methylbutanoic acid
d 3,4-dimethylpentanoic acid

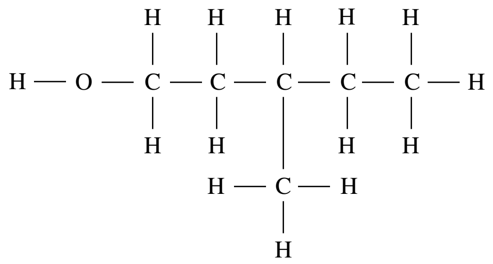
7 **a** pentan-3-ol



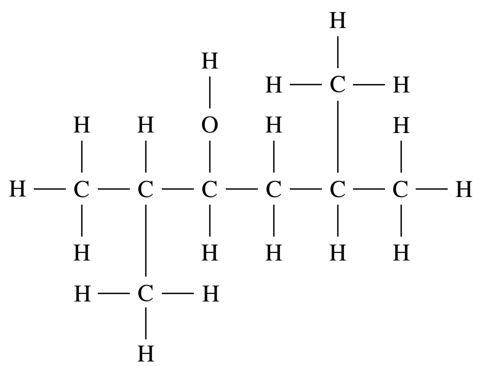
b heptanoic acid



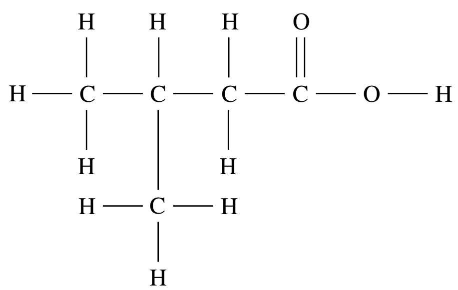
c 3-methylpentan-1-ol



d 2,5-dimethylhexan-3-ol

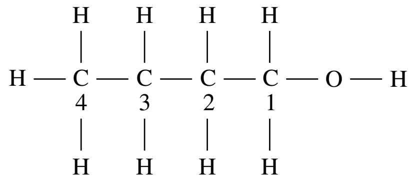


e 3-methylbutanoic acid

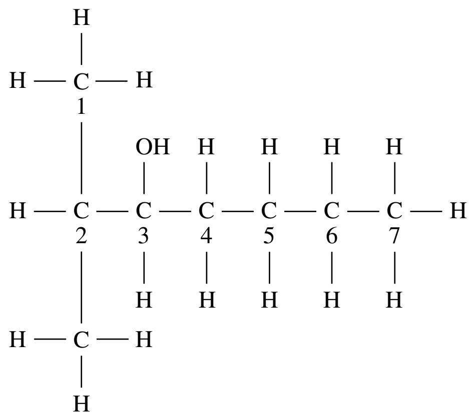


 ISBN 978 0 6557 0006 7

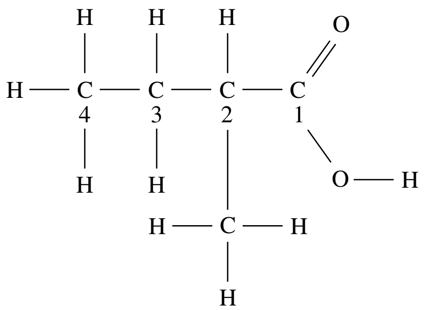
8 **a** The correct name is butan-1-ol. Carbon number 4 should be labelled carbon number 1, as that is the end closest to the hydroxyl group.



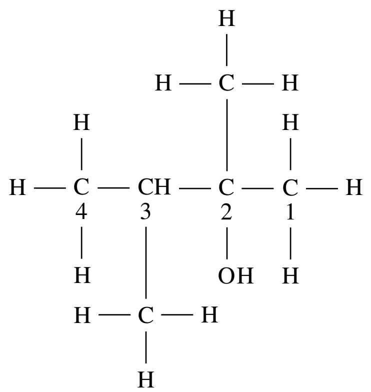
b The correct name is 2-methylheptan-3-ol. One of the mislabeled methyl branches is actually part of the longest carbon chain and the other methyl is actually on carbon number 2. So, what was thought to be carbon number 1 is actually carbon number 2 and, consequently, the hydroxyl group is on carbon number 3.



c The correct name is 3-methylbutanoic acid. The carboxyl group must always be carbon number 1, so the methyl group must be at carbon number 3, since it was 2 carbons away from the carboxyl group in the incorrect name.



d The correct name is 2,3-dimethylbutan-2-ol. Carbon number 3 should be labelled carbon number 2 as that is the end closest to the hydroxyl group.



 ISBN 978 0 6557 0006 7

Chapter 8 Review

REVIEW QUESTIONS

Knowledge and understanding

1 C. While coal is a fossil fuel, it is found in separate locations to crude oil as a solid deposit, so alternative C is correct. During fractional distillation, petrol (alternative A) is derived from crude oil as part of the gasoline fraction, diesel (alternative B) comes from the kerosene fraction, and asphalt (alternative D) is a product of the final fraction referred to as unvapourised residues.

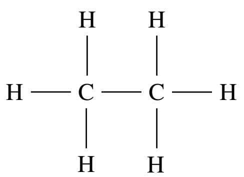
2 D. Unsaturated means that there are one or more carbon–carbon double bonds in the compound. Alternative D, but-2-ene, has one carbon–carbon double bond. Alternative A is a haloalkane, which only has single carbon-carbon bonds, and alternatives B and C are both alkanes, also with only single carbon–carbon bonds.

3 B. This statement is incorrect because it is missing one hydrogen atom. Alkanes have the general formula C_nH_{2n+2}. The correct statements, A, C and D can be found in the chapter in Sections 8.2 and 8.3.

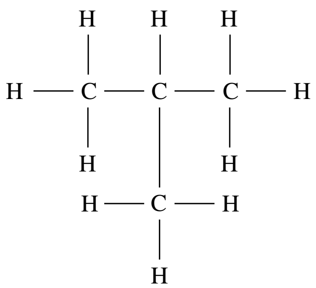
4 D. The weaker the intermolecular forces, the lower the boiling point. The homologous series with the lowest boiling point is the alkanes, because the molecules are non-polar, so only have dispersion forces between them. The next highest is haloalkanes because the presence of the halogen adds a polar bond, enabling some degree of dipole–dipole attraction. The next highest is the alcohol homologous series because there is hydrogen bonding between the molecules, which is a stronger intermolecular force than dipole–dipole attractions. Finally, carboxylic acids have the highest boiling point of the four listed homologous series, as the molecules form dimers, so the dispersion forces between the dimers is equivalent to a molecule with double the molecular mass.

All the other alternatives do not show these homologous series in increasing boiling point order.

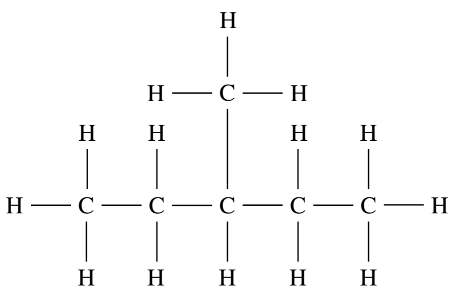
5 **a** ethane



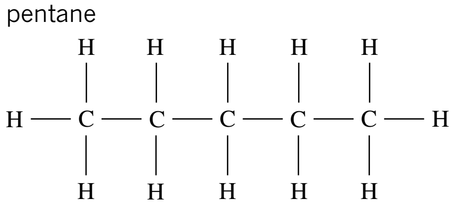
b 2-methylpropane



c 3-methylpentane



d pentane



 ISBN 978 0 6557 0006 7

6 **a** Alkanes have the general formula C_nH_{2n+2}, and for this hydrocarbon $n = 16$, so $2n + 2 = 34$.

b $C_{17}H_{36}$. One more than 16 is 17, so for this hydrocarbon $n = 17$, and $2n + 2 = 36$.

c $C_{15}H_{32}$. One less than 16 is 15, so for this hydrocarbon $n = 15$, and $2n + 2 = 32$.

d $C_{16}H_{32}$. With one carbon–carbon double bond, the compound is an alkene, general formula C_nH_{2n}, so for this hydrocarbon $n = 16$, and $2n = 32$.

7 Remembering that the general formula for alkanes is C_nH_{2n+2} and for alkenes is C_nH_{2n}

a alkene

b alkane

c alkene

d alkane

e alkane

8 **a** An alkene contains one double carbon–carbon bond, which requires two carbon atoms. The first alkene is therefore ethene.

b The carbon atom has four electrons in the outer shell, which are available for sharing with other atoms to produce four covalent bonds.

9 There are four structural isomers of $C_3H_6Br_2$: 1,1-dibromopropane, 1,2-dibromopropane, 2,2-dibromopropane and 1,3-dibromopropane.

10 The following is an example of an answer. There are many possible answers to this question.

Homologous series	Particular compound	Use
alkanes	petrol (octane), diesel	fuel for transport
	methane	gas burnt in Bunsen burners
alkenes	ethene	monomer for making polymers
	but-1-ene	manufacture of polymers
haloalkanes	iodomethane	pesticide

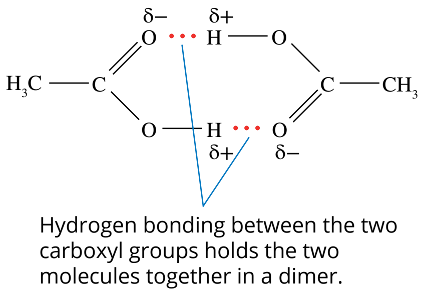
11 **a** $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

b $2C_6H_{14}(l) + 19O_2(g) \rightarrow 12CO_2(g) + 14H_2O(l)$

c C_4H_{10}: $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

12 Renewable means that there is a continuous source of the fuel, so as they are used up they can be replenished. There is only a limited supply of fossil fuels present in the Earth's crust as crude oil, because these were formed from the remains of prehistoric marine microorganisms, such as bacteria and plankton, which have been converted into hydrocarbons over millions of years. Because this process is no longer occurring, our supply of fossil fuels is not renewable.

13 While alcohols have hydrogen bonding between the molecules, carboxylic acid molecules pair up due to the hydrogen bonding between the carboxyl groups, forming dimers. As a result, the dispersion forces between the dimers are equivalent to a molecule with double the molecular mass, so the intermolecular forces are stronger than those between the equivalent alcohols.



 ISBN 978 0 6557 0006 7

Application and analysis

14 C. If you track the molecule from left to right, structure C gives the correct order of carbons and hydrogens. Alternative A is incorrect because it combines the two CH_3 groups into C_2H_6. Alternative B is incorrect because it attributes the wrong number of hydrogens to some of the carbons in the structure and misses other carbons. Alternative D is almost correct, but it does not allow for the double bond between the last two carbons (shown on the right hand side), so it has too many hydrogens.

15 Using polyethene (polyethylene) made from sugarcane instead of from crude oil products means that the non-renewable crude oil products can be saved for use in making other products. Polyethene made from sugarcane is considered renewable and thus sustainable, because the sugarcane can be regrown quickly after it had been used.

16 **a** hex-2-ene. This is an alkene with 6 carbon atoms and the carbon–carbon double bond in the second position from the end.

b 2-methylbutane. The molecule has been drawn with the longest carbon chain bending downwards. The longest chain has 4 carbons and there is a methyl group on the second carbon from the end.

c 2,3-dimethylbut-1-ene. The longest carbon chain, containing the carbon–carbon double bond, which is in the first bonding position, has 4 carbons and there are two methyl groups on the second and third carbon from the end nearest the double bond.

d 2-methylpentan-3-ol. The molecule has been drawn with the longest carbon chain zig-zagging. The longest carbon chain has 5 carbons and there is a methyl group on the second carbon from the end. The hydroxyl group is on the third carbon from the end.

e 3-methylbutanoic acid. The longest carbon chain has 4 carbons and starts with the carboxyl group. There is a methyl group on the third carbon from the carboxyl group.

17 This compound is 3-methylpent-2-ene. The numbering of carbon chain must start at the end nearest the functional group (the carbon-carbon double bond), so the molecule is 3-methylpen-2-ene, rather than 3-methyl pent-3-ene.

18

	Alkanes	Alkenes	Haloalkanes	Alcohols
Solubility in water	does not dissolve	does not dissolve	small haloalkanes dissolve slightly	small alcohols dissolve well in water, due to formation of hydrogen bonds between the hydroxyl group and water molecules
Boiling point	low, increases with size of carbon chain	low, increases with size of carbon chain	higher than alkanes and alkenes, increases with size of carbon chain and with size of halogen atom or number of halogen atoms	higher than haloalkanes due to the strength of the hydrogen bonding between molecules
Bonding between molecules	dispersion forces	dispersion forces	dipole–dipole attraction and dispersion forces	hydrogen bonding and dispersion forces

19 The terms in bold have been corrected.

a **Alkanes** have two more hydrogen atoms per carbon atom than **alkenes**. / Alkenes have two **less** hydrogen atoms per carbon atom than alkanes.

b A haloalkane with five carbon atoms and one chlorine atom bonded to the end carbon could be called **1-chloropentane**. / A haloalkane with **three** carbon atoms and one chlorine atom bonded to the end carbon could be called 1-chloropropane.

c Pentane has **3** structural isomers.

d Alkanes are **saturated** hydrocarbons. / **Alkenes** are unsaturated hydrocarbons.

e The carboxylic acid with seven carbon atoms is called **heptanoic acid**.

f The **hydroxyl** functional group is found in alcohols and has the formula –OH.

g Compounds with the same molecular formula **can have molecules that are structural isomers of each other**.

20 **a** As the number of carbon atoms increases, the number of electrons in the molecules also increases, the attraction between temporary dipoles formed by the random movement of the electrons increases, and so the strength of the dispersion forces between the molecules increases. Because this intermolecular force of attraction has increased, more energy is needed to separate the molecules, and so the boiling point increases.

b Haloalkanes, alcohols or carboxylic acids would all have a higher boiling point than their corresponding alkane. The functional groups in these compounds enable the intermolecular forces to be stronger, so more energy is needed to separate the molecules than would be the case for alkanes, and so the boiling point is higher.

 ISBN 978 0 6557 0006 7

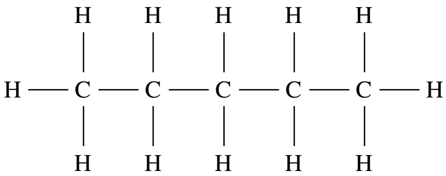
21 a 1-chloropropane is a molecule with three carbon atoms. While the two end (terminal) carbon atoms are equivalent to each other, the second carbon in the chain is not, so the number is required to distinguish whether the chlorine atom is bonded to an end carbon (designated as carbon number 1) or the second carbon in the chain. Chloroethane has only two carbon atoms which are equivalent to each other, so no distinction between the atoms is needed.

b 2,2-dibromopropane has a higher molecular mass, and more electrons than 2-bromopropane, so it has stronger dispersion forces between its molecules. As a result, more energy is needed to separate the molecules when the state changes from liquid to gas, and so it has a higher boiling point.

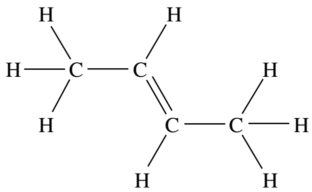
c While the hydroxyl group in ethanol is able to make hydrogen bonds with water molecules and enable the ethanol to dissolve in water, octan-1-ol has a much larger non-polar chain than ethanol (8 carbon atoms, compared to 2 carbon atoms), so the polar hydroxyl group has less influence over its solubility and so octan-1-ol cannot dissolve in water.

d In a carboxylic acid, the carboxyl group is always on carbon number 1 (by convention), so no number is needed for the carboxyl group. In comparison, the hydroxyl group can be anywhere along the carbon chain, so needs to be numbered in molecules larger than ethanol.

22 a

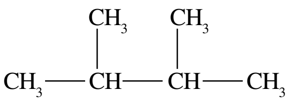


b



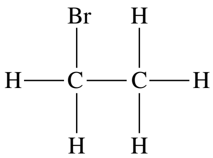
but–2–ene

c



2,3-dimethylbutane

d



 ISBN 978 0 6557 0006 7