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Chemistry

For the IB Diploma

Brighter Thinking
Better Learning

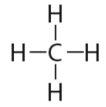
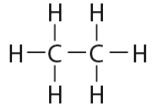
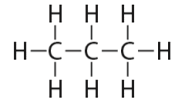
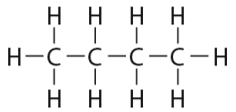
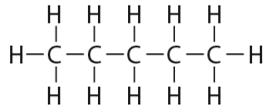
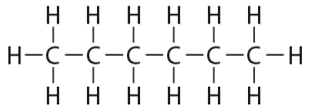
Chapter 11

Functional groups: Classification of organic compounds

Homologous series

- A homologous series is a series of compounds with the same functional group, where each member differs from the next by $–CH_2–$.
- The homologous series can usually be described by a general formula, e.g., C_nH_{2n+2} for alkanes.
- The members of the homologous series show similar chemical properties.
- The members of the homologous series show a gradation in physical properties, such as boiling point.

Complete the table with different types of formulas for the members of the alkane homologous series

Name	Molecular formula	Empirical Formula	Structural formula	
			Condensed	Displayed formula
Methane				
Ethane				
Propane				
Butane				
Pentane				
Hexane				

The general formula of the alkane homologous series is $\mathbf{C_nH_{2n+2}}$. What is the formula of the alkane with 25 C atoms?

Representing molecules

stereochemical formula

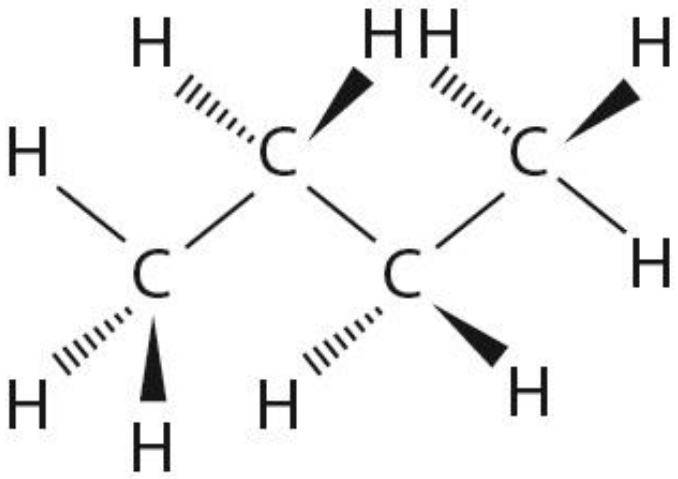


Figure 11.1: The stereochemical formula of butane showing the tetrahedral arrangement around the carbon atoms.

or **skeletal formula**

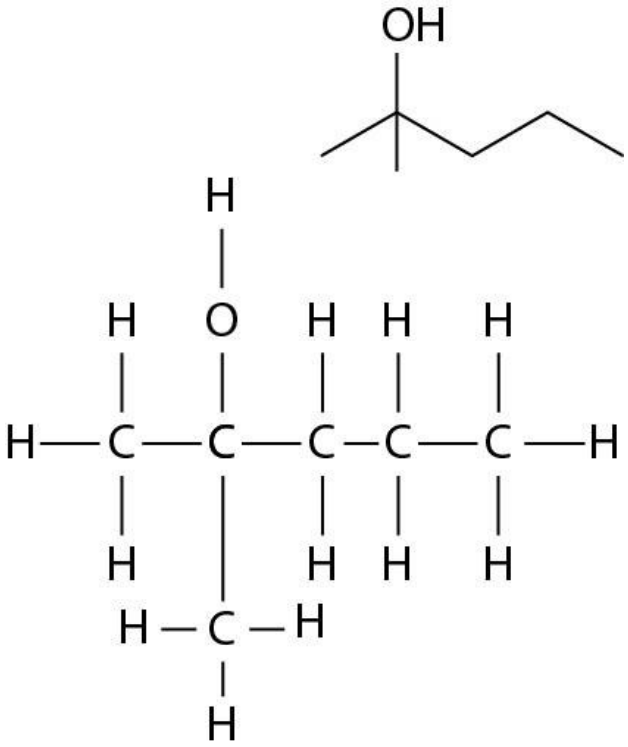


Figure 11.2: A skeletal formula and a displayed formula for 2-methylpentan-2-ol.

Chain isomers

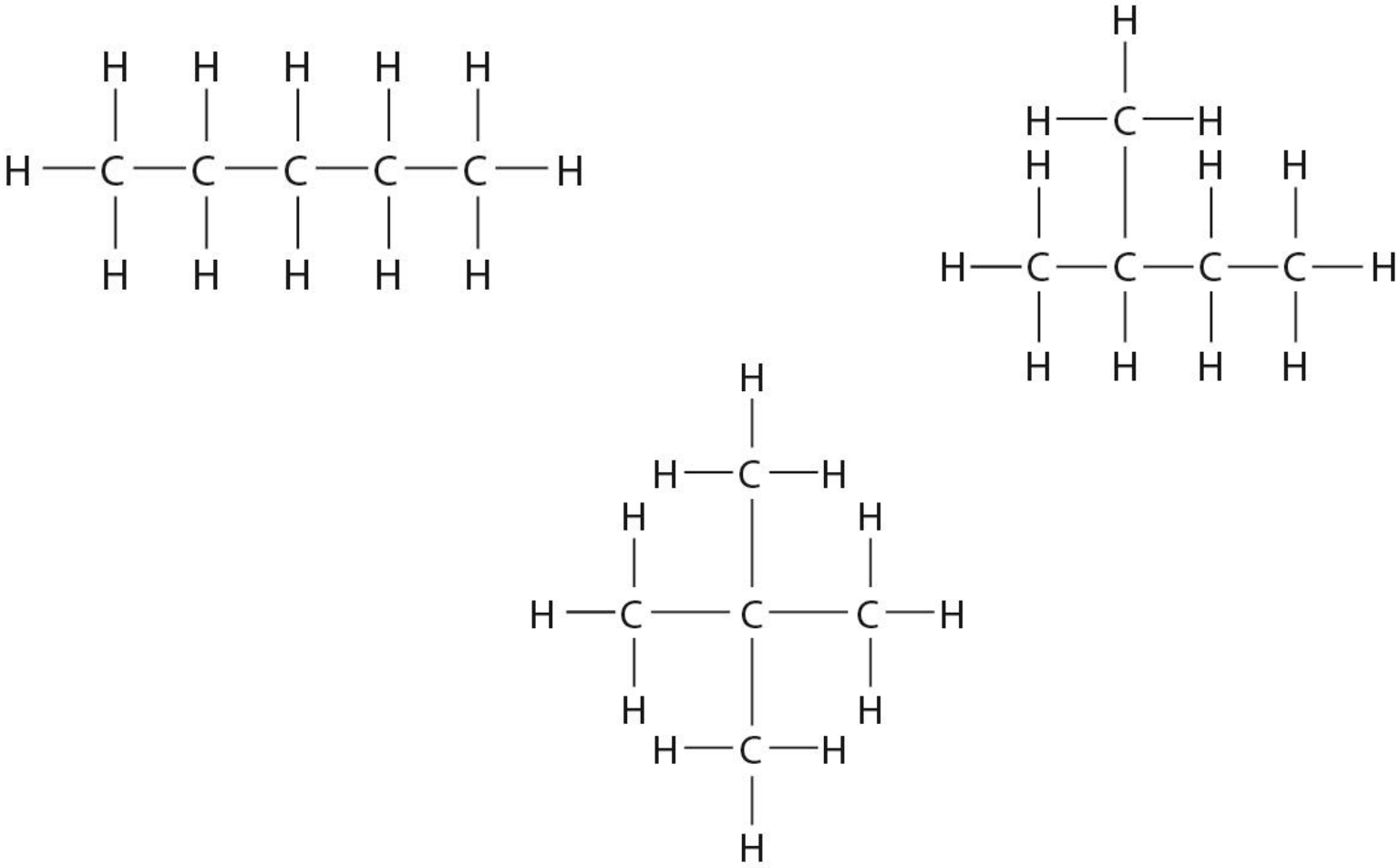


Figure 11.3: Structures of the isomers of C_5H_{12}.

Some isomers of $C_5H_{12}O$

Structural isomers: two or more compounds that have the same molecular formula but different structural formulas; i.e., the atoms are joined together in a different way.

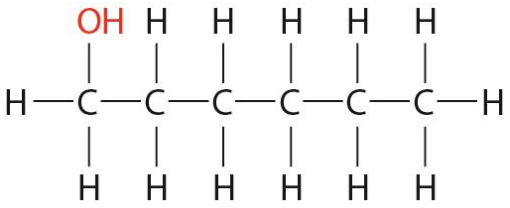
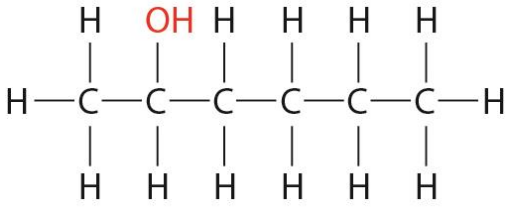
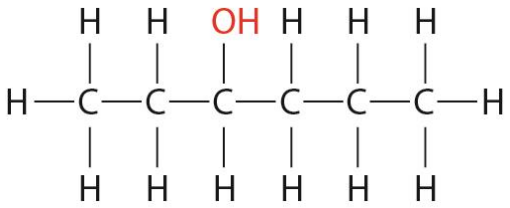
–OH attached to carbon 1	–OH attached to carbon 2	–OH attached to carbon 3
		

Figure 11.4: Positional isomers

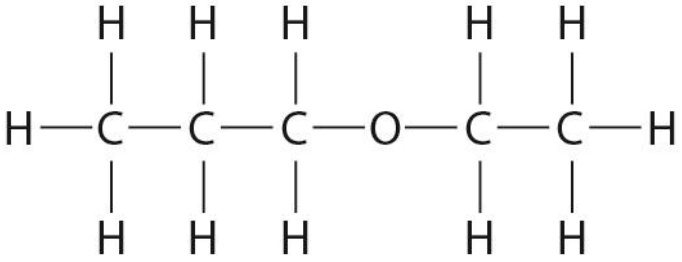


Figure 11.5: Functional group isomers

Naming alkanes

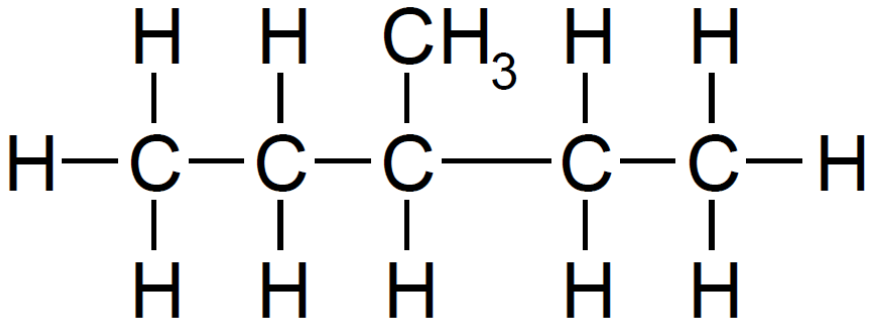


Figure 11.6: 3-methylpentane.

No. C atoms	Prefix
1	meth–
2	eth–
3	prop–
4	but–
5	pent–
6	hex–

$-CH_3$	**methyl**
$-C_2H_5$	ethyl
$-C_3H_7$	propyl

Naming alkenes

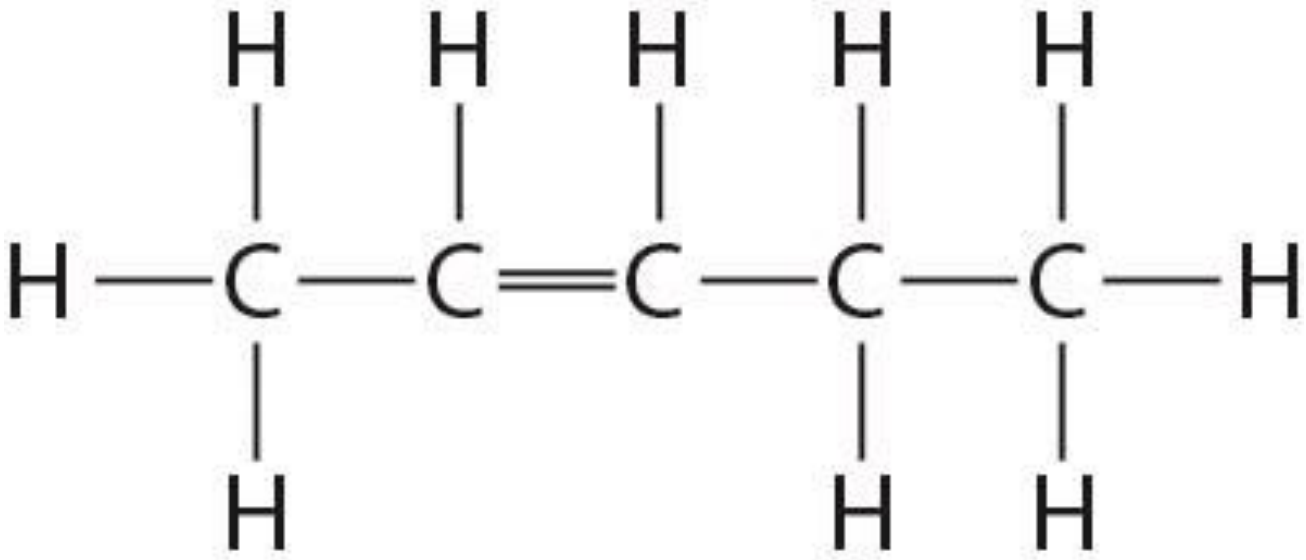


Figure 11.7: Pent-2-ene.

Naming alcohols

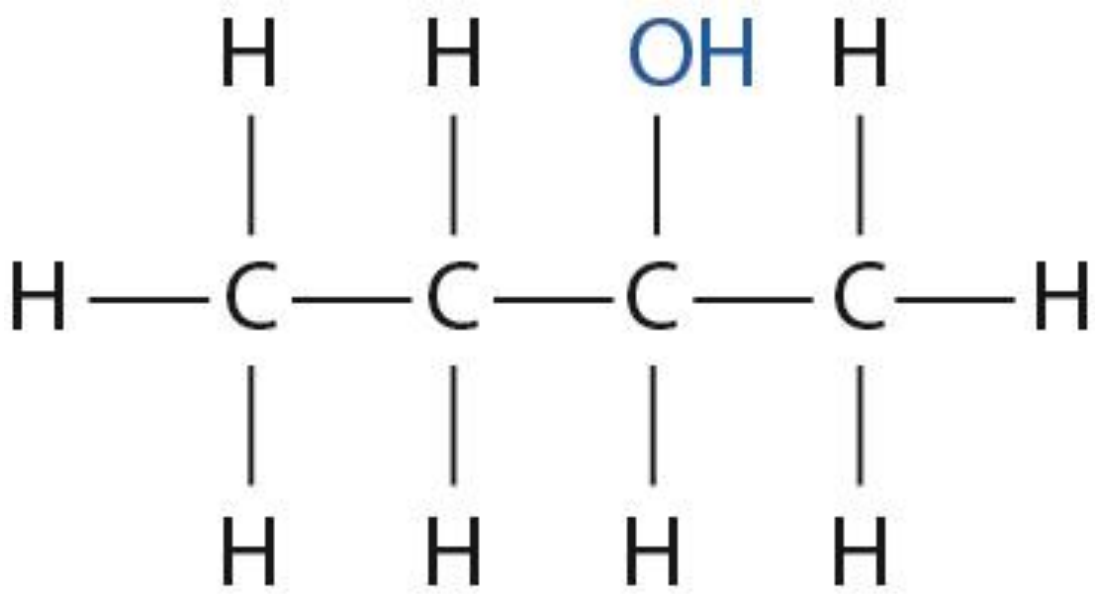


Figure 11.8: Butan-2-ol.

Primary, secondary and tertiary alcohols

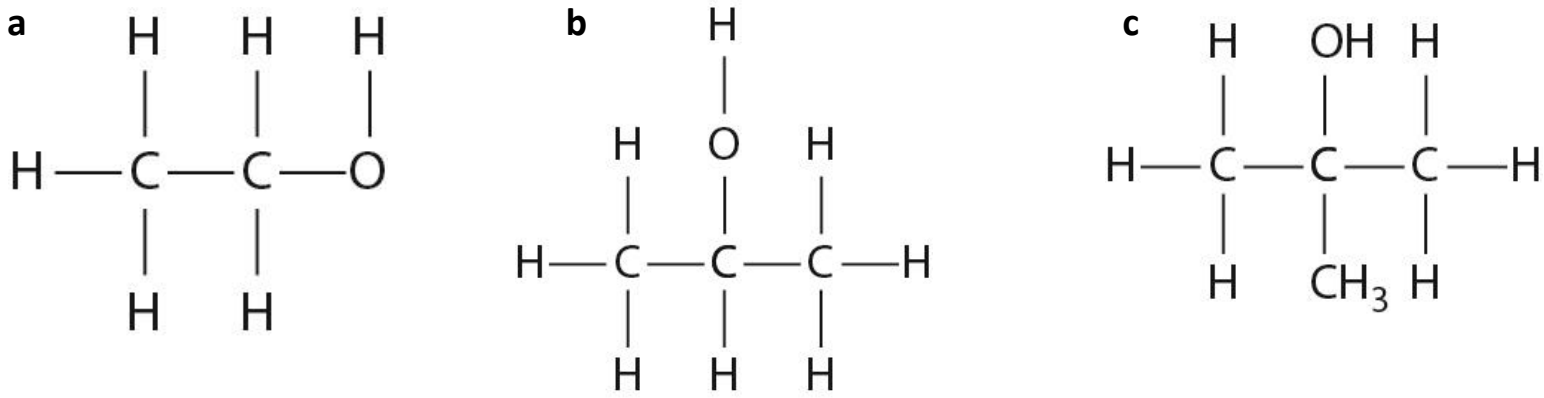


Figure 11.9: Examples of **a** primary, **b** secondary and **c** tertiary alcohols.

Naming carbonyls

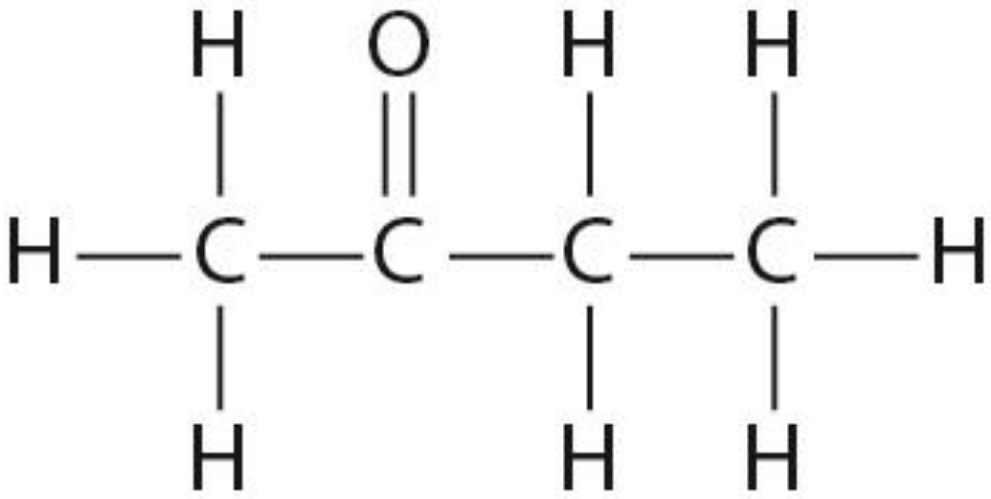


Figure 11.10: Butanone.

Naming carboxylic acids

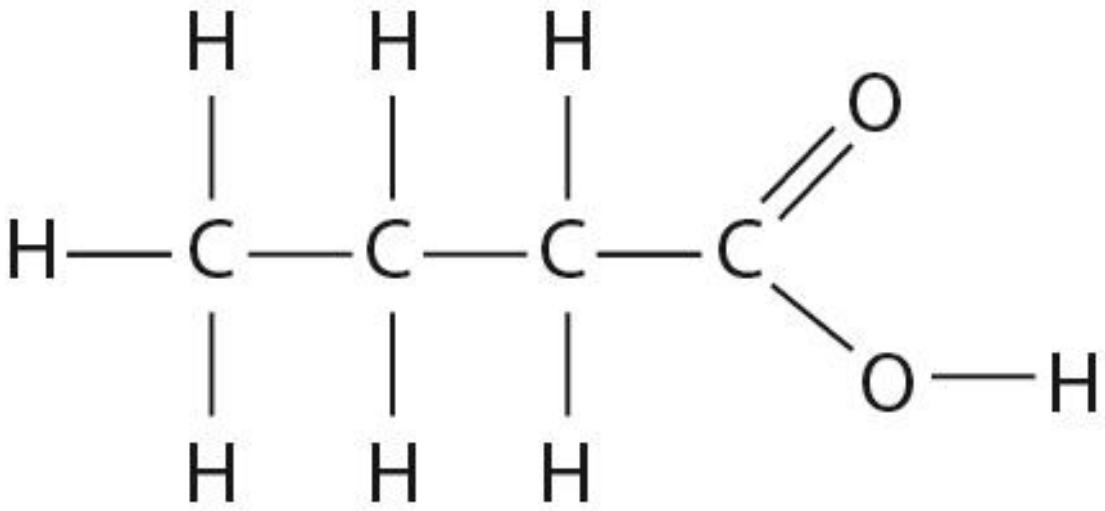


Figure 11.11: Butanoic acid.

Carboxylic acids

RCOOH

RCO_2H

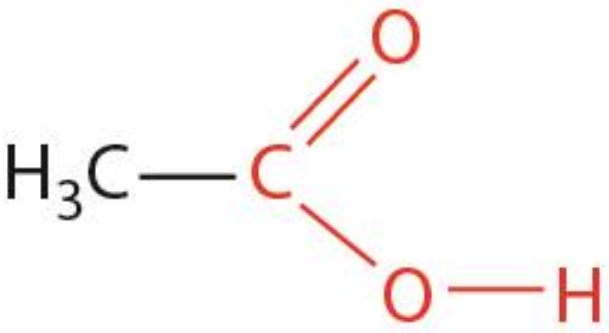


Figure 11.12: Different representations of the carboxyl functional group.

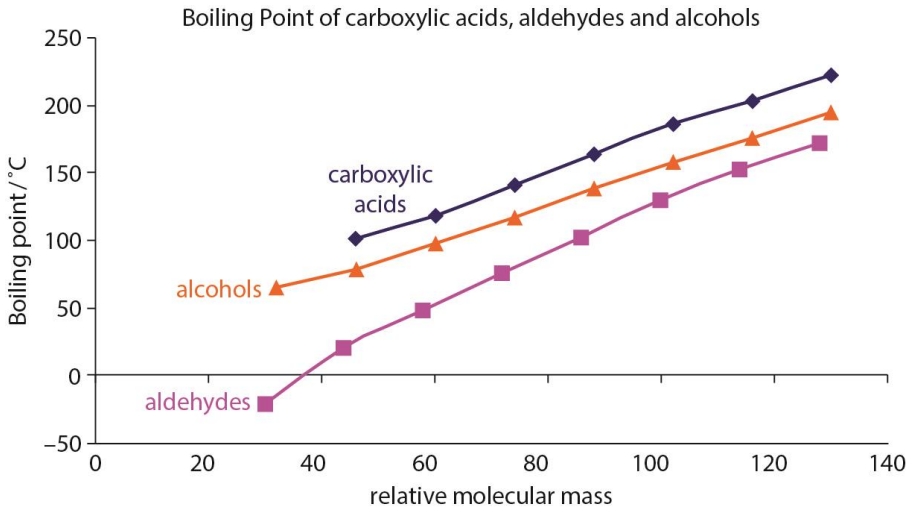


Figure 11.13: Trend in boiling points of alkanes, aldehydes and alcohols.

Naming esters

Ester functional group

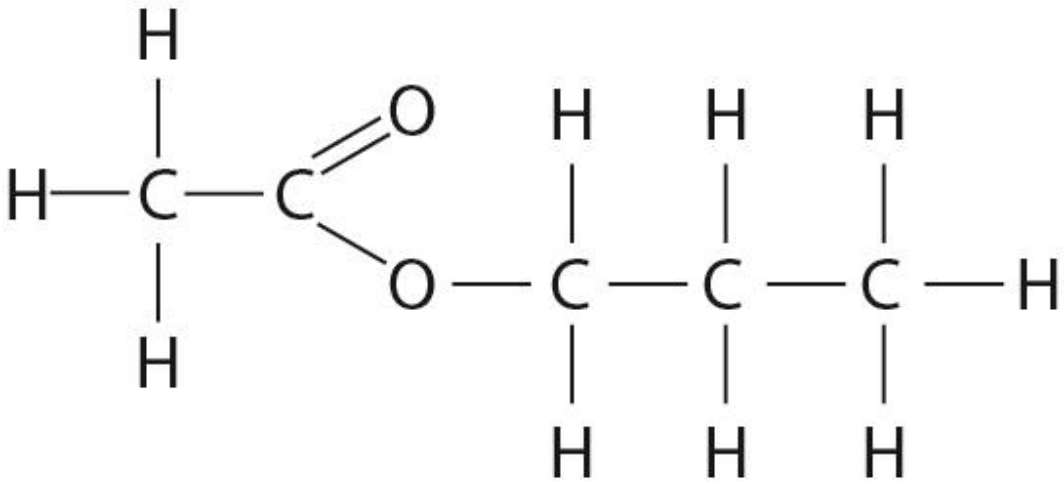
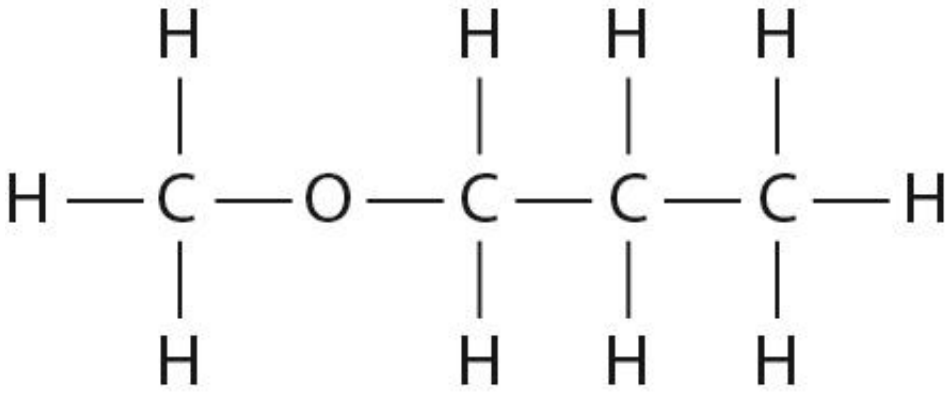


Figure 11.14: Propyl ethanoate.

Alkoxy functional group

Ethers

a



b

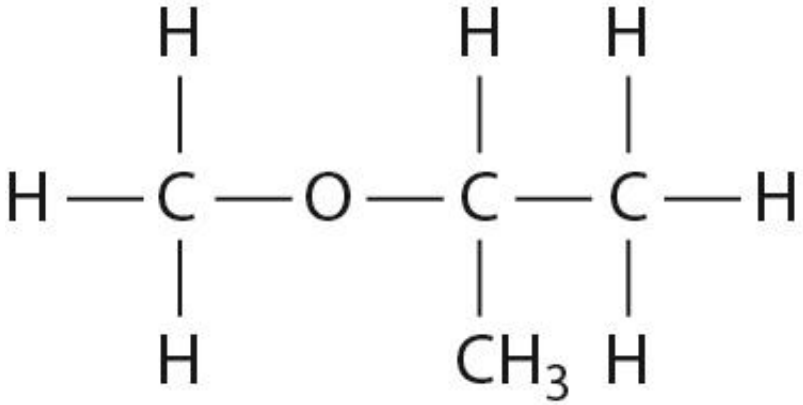


Figure 11.15: **a** 1-methoxypropane and **b** 2-methoxypropane.

Halogenoalkanes

Halogeno functional group

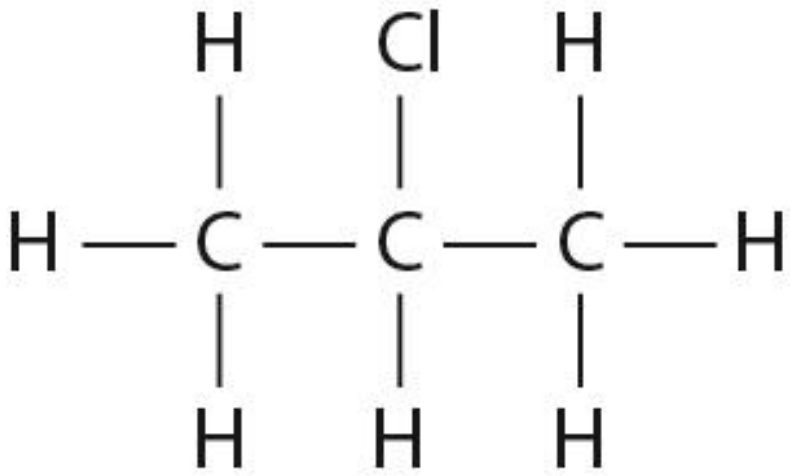


Figure 11.16: 2-chloropropane.

Primary, secondary and tertiary

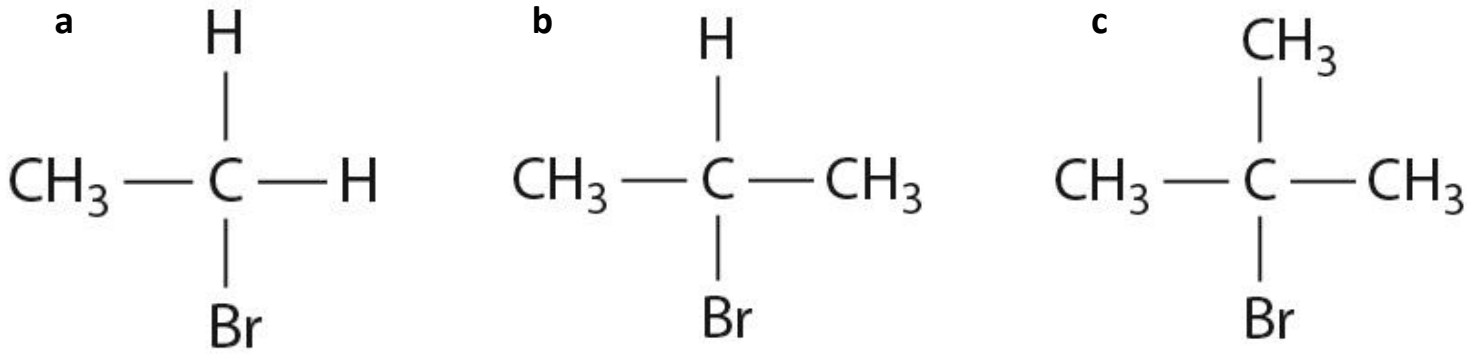


Figure 11.17: **a** Primary, **b** secondary and **c** tertiary bromoalkanes.

Types of compounds

Aromatic compounds are compounds that contain a phenyl group.

Aliphatic compounds are compounds without phenyl groups.

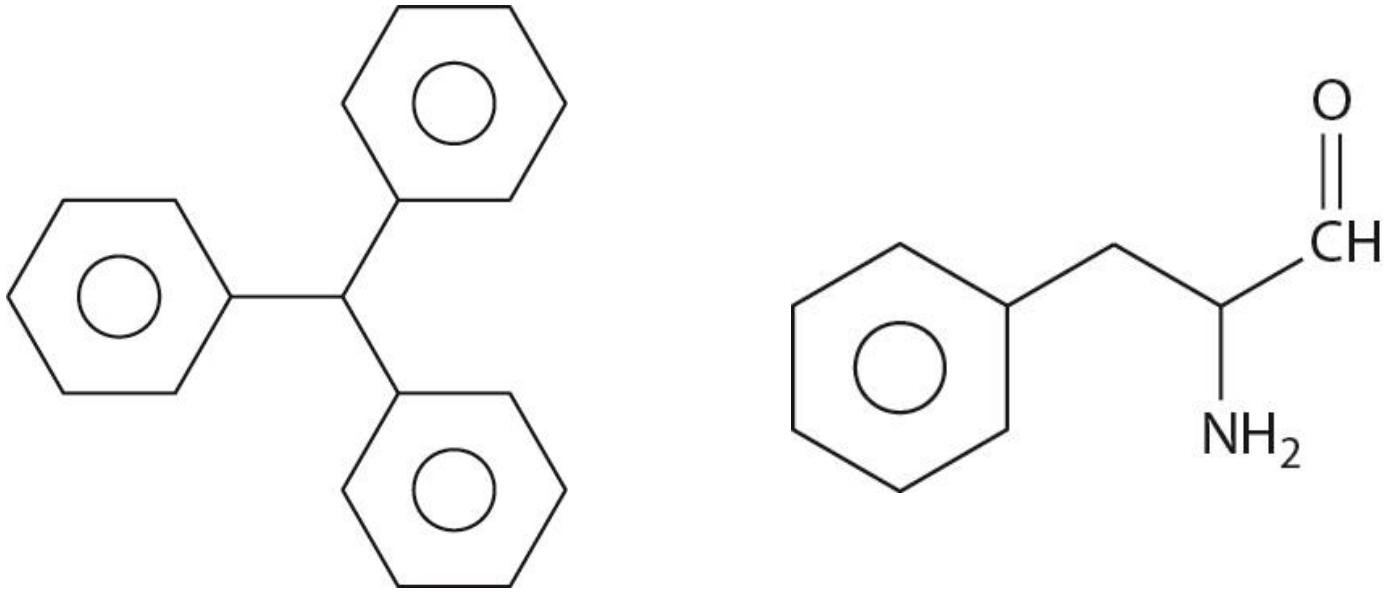


Figure 11.18: Examples of aromatic compounds.

Evidence for the delocalised structure in benzene

Kekulé's structure of benzene

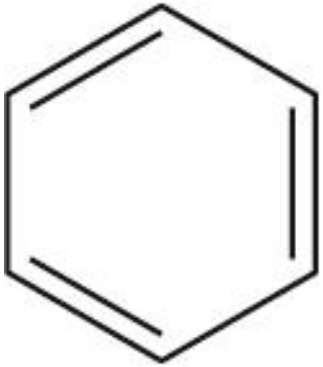


Figure 11.19: Portrait of August Kekulé.

Bond	Compound	Bond length /nm
C=C	ethene	0.133
C—C	ethane	0.154
C—C	benzene	0.140

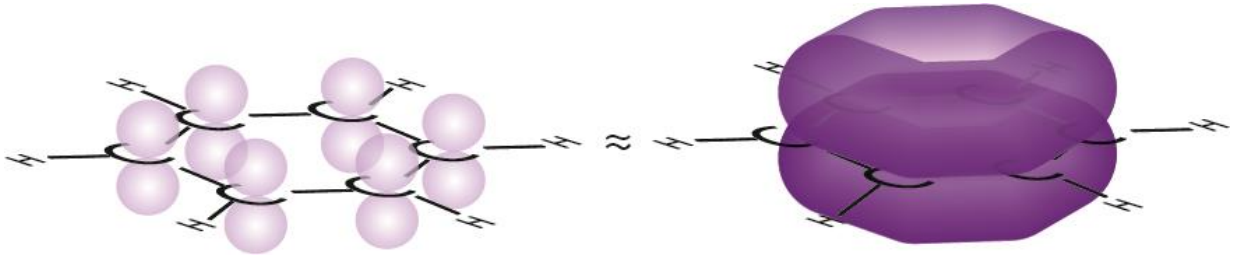
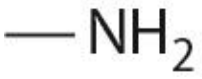
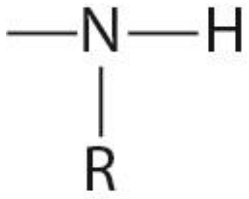
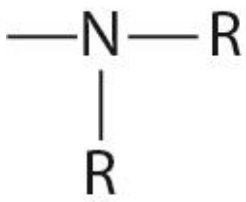


Figure 11.20: Formation of the benzene delocalised system.

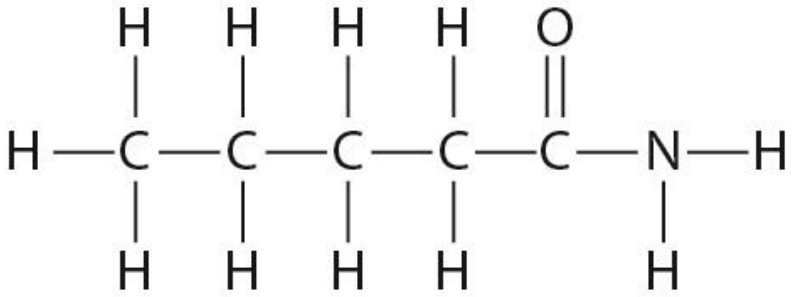
Amines

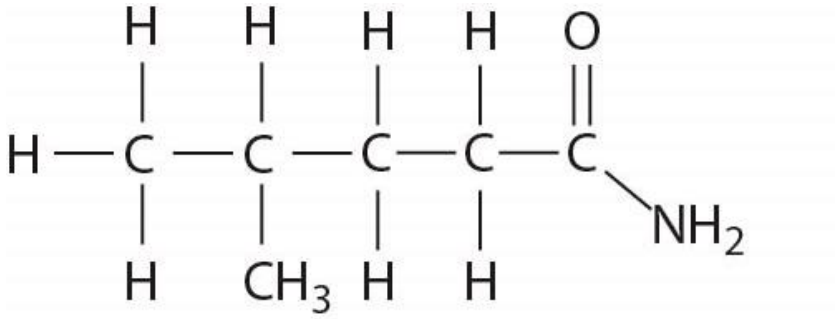
Amino functional group

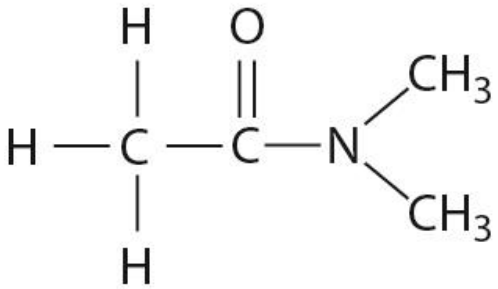
	Primary	Secondary	Tertiary
Functional group			

Amides

Amido functional group







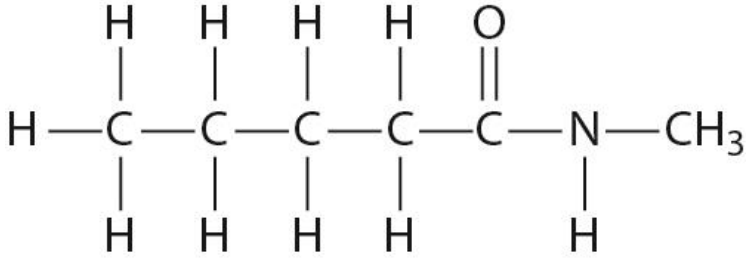
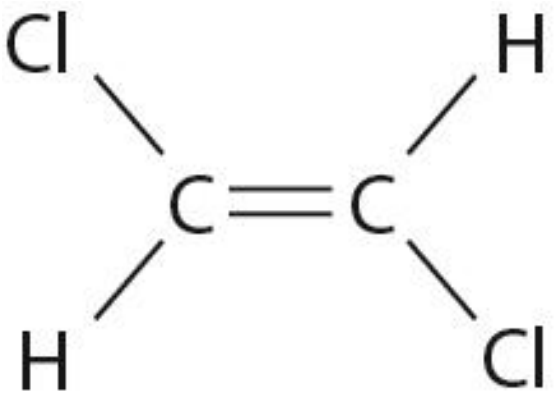


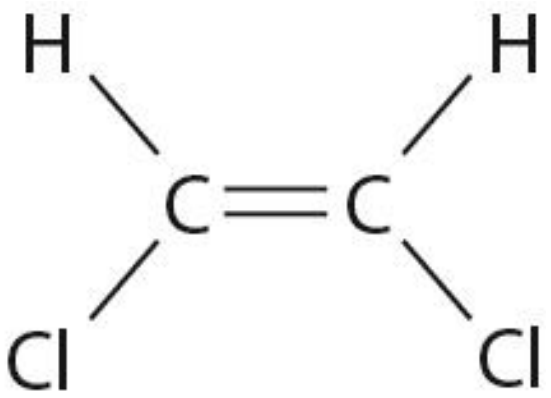
Figure 11.21: Differently substituted amides.

cis–trans isomerism

Stereoisomerism



trans-1,2–dichloroethene

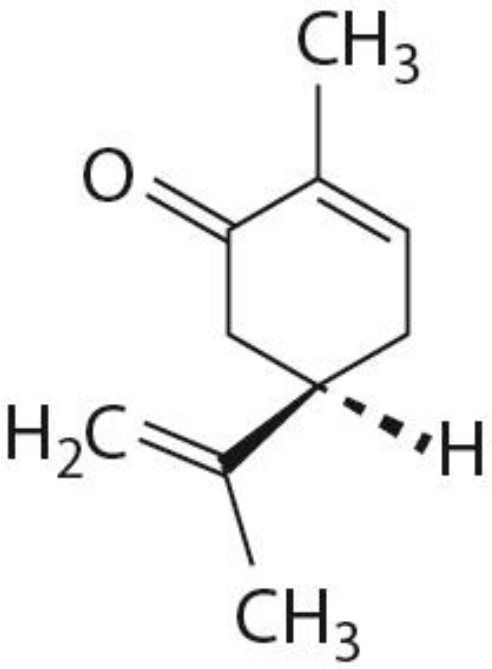


cis-1,2–dichloroethene

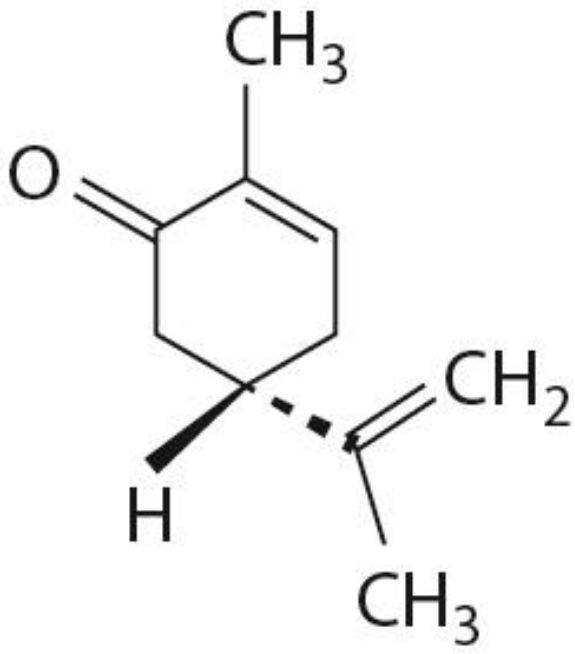
Figure 11.22: Isomers of 1,2-dichloroethene.

Optical isomerism

Stereoisomerism



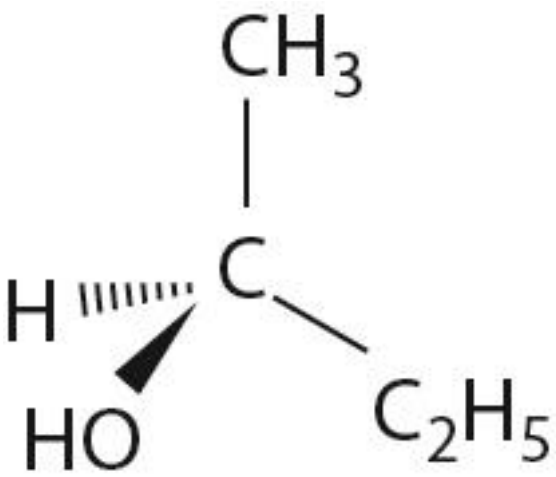
mint

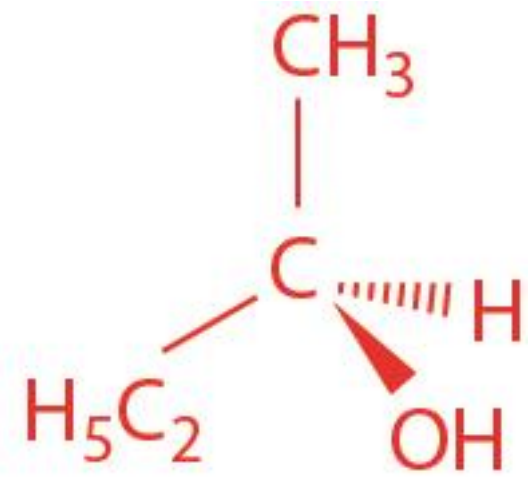


caraway

Figure 11.23: Two of the stereoisomers of carvone.

Types of molecules





Chirality centre (chiral centre): a carbon atom with four different atoms or groups attached to it (sometimes called an asymmetric carbon atom) that makes a molecule chiral.

Enantiomers: the non-superimposable mirror images of a chiral molecule.

Using a polarimeter to determine the direction in which light is rotated

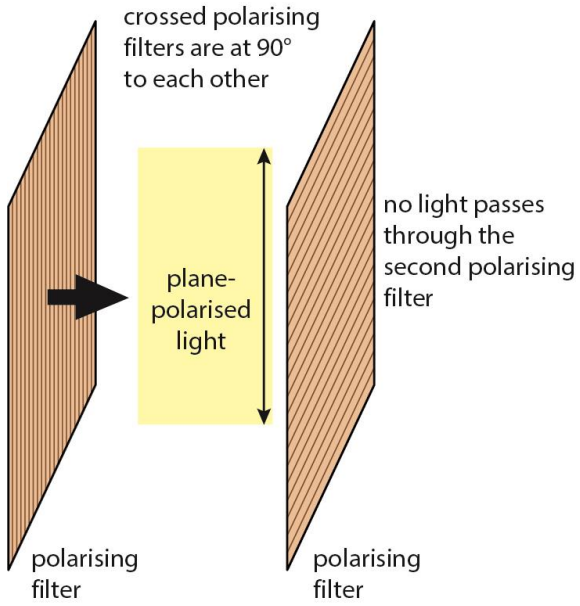


Figure 11.24: When polarising filters are crossed, no light can pass through, unless it has been rotated by an optically active sample between the first and second filters.

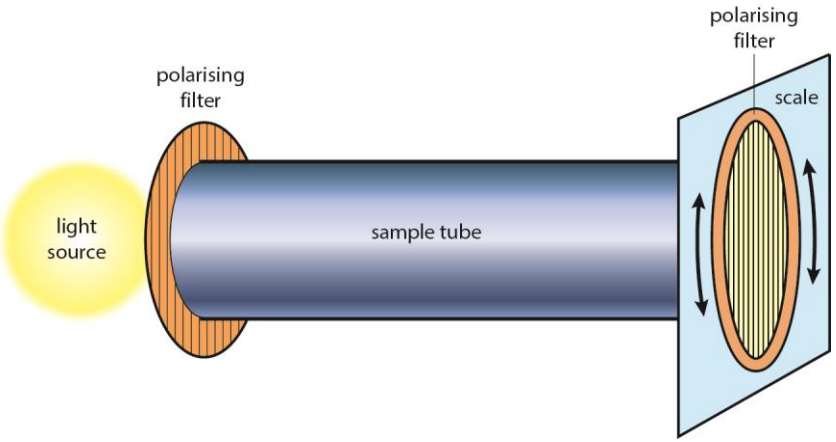


Figure 11.25: A simple polarimeter.

Isomers of propanol can be identified using the fingerprint region of the IR spectra

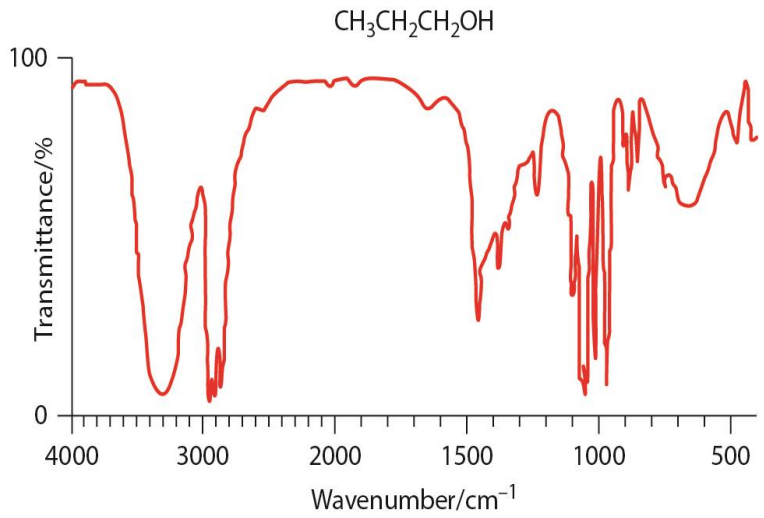


Figure 11.26: Infrared spectrum of propan-1-ol.

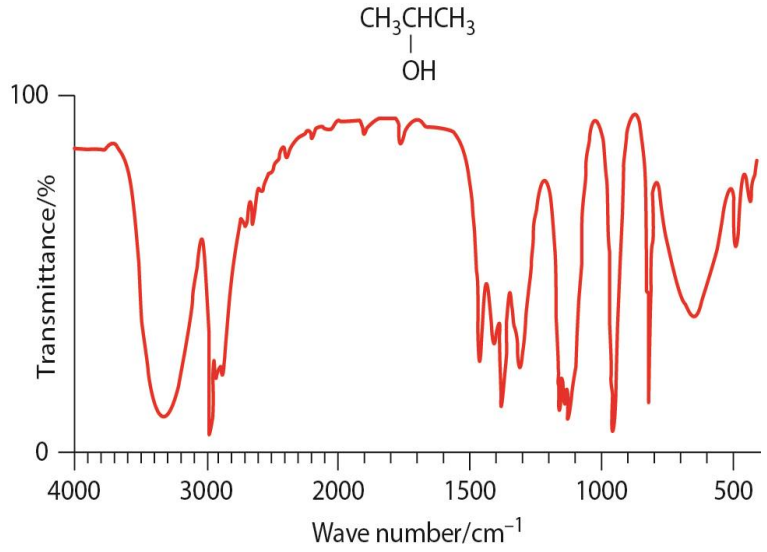
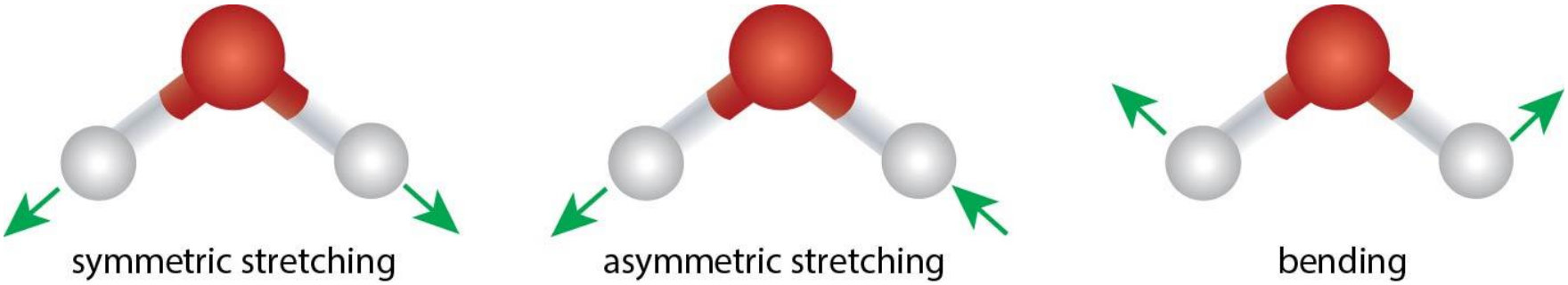


Figure 11.27: Infrared spectrum of propan-2-ol.

Different vibrational modes of water molecules



Video 11.1: Vibrational modes of water molecules.

Mass spectrometry

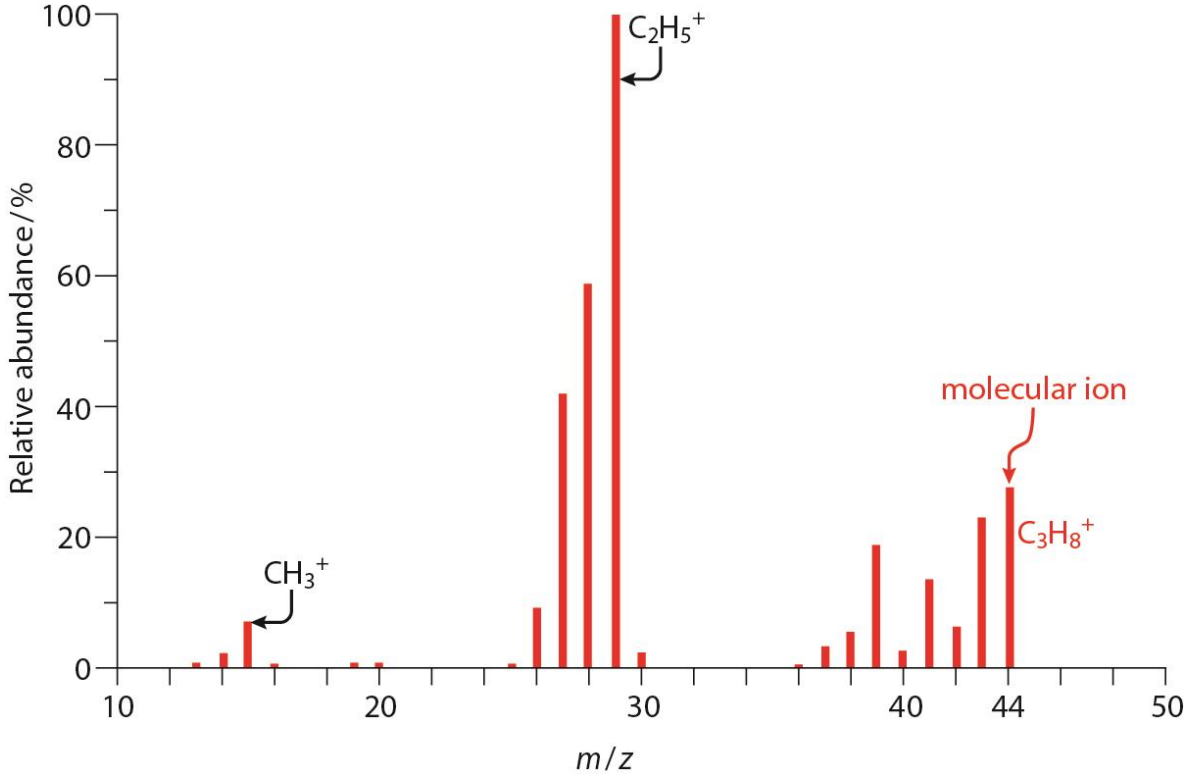


Figure 11.28: The mass spectrum of propane: $CH_3CH_2CH_3$.

^{1}H nuclear magnetic resonance (NMR)

Looking at H atoms in a molecule

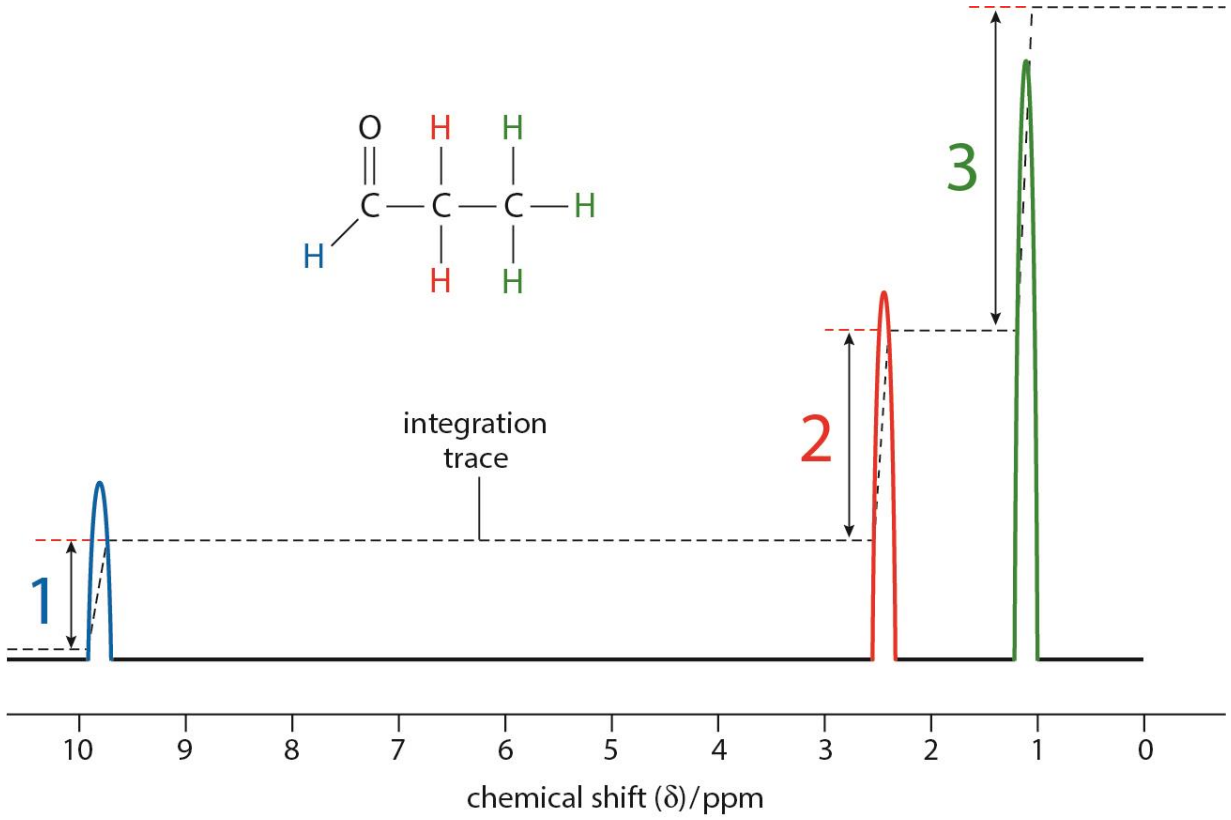


Figure 11.29: The low-resolution NMR spectrum of propanal: CH_3CH_2CHO. The integration trace allows us to work out the ratio of the numbers of protons in each environment.

High-resolution NMR spectrum

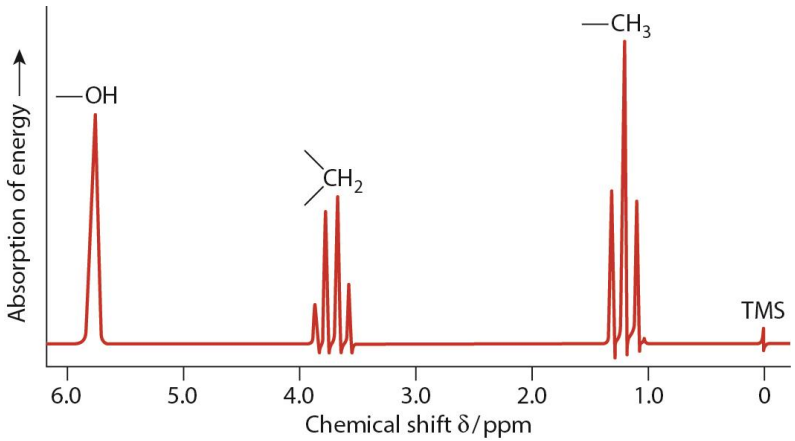
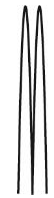


Figure 11.30: High-resolution NMR spectrum of ethanol.

No. of equivalent protons on adjacent C atoms	Pattern	Diagram
1	1:1 doublet	
2	1:2:1 triplet	
3	1:3:3:1quartet