ChemFactsheet

April 2001 **Number 15**

Organic Chemistry I - Nomenclature

To succeed with this topic you need to

- **Learn thoroughly the terms introduced in this Factsheet**
- **Learn thoroughly the rules for nomenclature**
- **Practice naming compounds until you are fully competent at applying the nomenclature rules**

After working through this Factsheet you will be able to

- **Identify the functional groups in compounds**
- **Give the systematic names of the carbon compounds you will meet at AS level**

Introduction

There are millions upon millions of carbon-based (organic) compounds, and thousands more are created (or discovered) every year.

In this context it is vital that an agreed world-wide system of naming these compounds is used so that scientists from different countries know which compound is which. This is called systematic nomenclature. This Factsheet gives you the basics of this international system.

1. Functional group

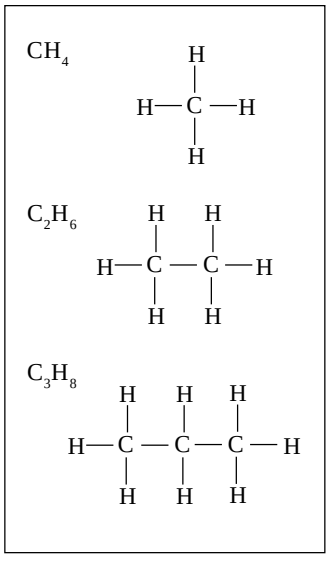
*The **functional group** is the reactive part of the molecule*

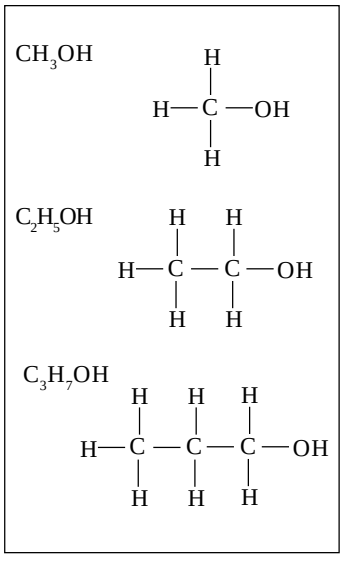
2. Family of compounds

*A **family of compounds** contains the same functional group*

3. Homologous series

A homologous series of compounds is one in which the compounds belong to the same family and only differ by a $-CH_2-$ i.e the length of the carbon chain





***Exam Hint** - The ability to name carbon compounds correctly is fundamental to any question on this topic. Remember – if you can identify and name it you have solved half the problem. In addition, you gain marks for these "basic" skills.*

4. General formula (of a homologous series)

*The **general formula** is the formula representing a homologous series of a family of compounds.*

E.g.

Family	General Formula (examples)	Homologous series
Alkanes	C_nH_{2n+2}	CH_4, C_2H_6, C_3H_8 etc
Alkenes	C_nH_{2n}	C_2H_4, C_3H_6, C_4H_8 etc
Alcohols	$C_nH_{2n+1}OH$	CH_3OH, C_2H_5OH, C_3H_7OH etc

***Exam hint** - Learn the general formula for the hydrocarbons (compounds containing only carbon and hydrogen) alkanes and alkenes.*

Questions will often give a formula – eg C_7H_{14} – and expect you to spot that it matches C_nH_{2n}, so it is an alkene. Similarly, C_8H_{18} is an alkane, because it matches C_nH_{2n+2}

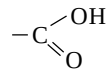
Systematic nomeclature

1. The length of the carbon chains

Name	Number of carbons	
Meth-	1	C
Eth-	2	C_2
Prop-	3	C_3
But-	4	C_4
Pent -	5	C_5
Hex-	6	C_6
Hept-	7	C_7
Oct-	8	C_8
Non-	9	C_9
Dec-	10	C_{10}

Many of the terms you will remember from maths – eg pentagons have 5 sides, hexagons 6 side etc. Candidates usually remember meth- and eth- but it is prop- and but- that are most commonly mixed up!

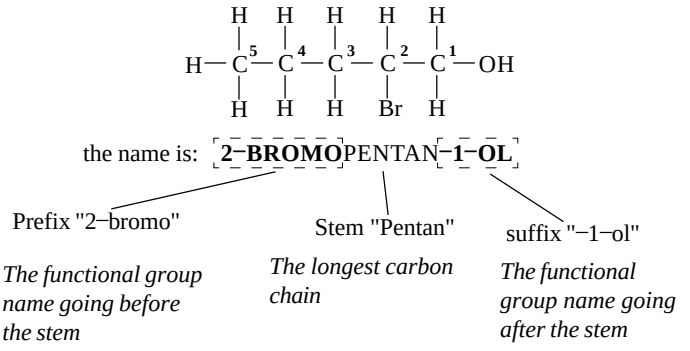
2. Functional Groups

Family	Functional Group	Systematic Name
Alkane	C – C	-ane
Alkene	C=C	-ene
Alcohol	-OH	-ol
Halogenoalkane	-Cl -Br -I	chloro- bromo- iodo-
Ketone		-one
Aldehyde		-al
Carboxylic Acid		-oic acid

These functional groups are the ones in the AS-level course. More are introduced in A2.

Notice where the dash is on the systematic name. If it is behind eg bromo-, then other names follow it, and the reverse if the dash is in front e.g. –ene.

3. Naming Compounds – the method
Look at the example below:



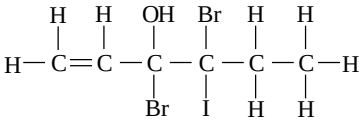
Notice particularly the numbering of the carbon chain. If it was numbered the other way, the compound would be 4-bromopentan-5-ol, so we number it to get the **lowest** combination in the name.

Also see how pent becomes “pentan” because there are only carbon-carbon single bonds, like an alkane, so the “an” appears to reflect this fact. If there were only C=C bonds, the "an" would not appear

The box below shows the standard method for naming compounds

Method
1. Find the longest carbon chain and so identify the stem name
2. Identify where the functional groups are on the chain and number the chain based on their positions to get the lowest numbers possible
3. Identify the names of the functional groups and whether they go before or after the stem name
4. Write the name of the compound using the order: – stem, numbers of prefixes and suffixes in alphabetical order

Worked example

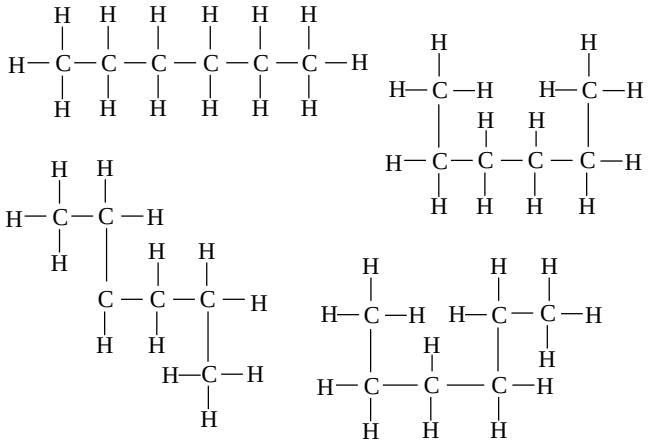


1. Six carbons in longest chain ⇒ hex
2. 5 functional groups. To get lowest numbers, start on the left of chain
3. Br ⇒bromo-; I⇒iodo- OH⇒ -ol; C=C ⇒ -ene
4. The name is **3,4-dibromo-4-iodohex-1-ene-3-ol**

Note:
1. Two lots of Br ⇒”dibromo” (3 lots would be tribromo). Both numbers are given.
2. Alphabetical so dibromo then iodo, and ene before ol.
3. The double bond (C=C) covers C atoms 1 and 2, but we only need to give the 1.
4. “hex” not “hexan” because it has the alkene group C=C in it.

Exam hint *- Many candidates lose marks when using the nomenclature system through a common error: it is not the longest straight chain of carbon atoms, it is the longest chain. Remember that the displayed formula is a way of representing a 3 dimensional molecule, so it can be written in different ways. This is used in questions to examine whether or not a candidate understands this concept.*

Study the following displayed formulae; they are all hexane!



Before continuing, you should attempt questions 1 and 2 at the end of the Factsheet to ensure you are confident with naming organic compounds

Branching of the carbon chain

When smaller carbon chains come off the longest carbon chain, they are called **side-chains** and the molecule is said to be **branched**. It is the ability to have side-chains that is partly responsible for the large number of carbon compounds.

The side chains are called **alkyl groups** and their names reflect their number of carbon atoms:

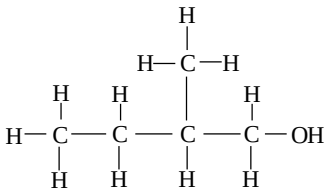
Number of carbons	Alkyl group	Name
1	CH_3-	methyl
2	C_2H_5-	ethyl
3	C_3H_7-	propyl
4	C_4H_9-	butyl
5	C_5H_{11}-	pentyl

Points about branching

1. The nomenclature method now has to be slightly changed to take in side-chains as well as functional groups.

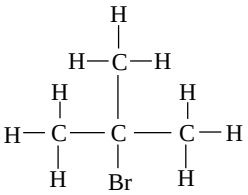
   Method: side chains are treated as functional groups in that they are prefixes, and go in the name alphabetically

   e.g.



   is 2-methylbutan-1-ol

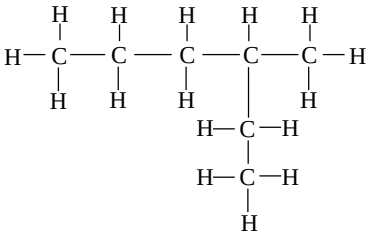
   e.g.



   is 2-bromo-2methylpropane

2. Looking for the longest chain on a branched molecule must be done very carefully

   e.g.



   is 3-methylhexane not 2-ethylpentane

Questions 3 and 4 will provide you with practice in naming branched molecules

Isomerism

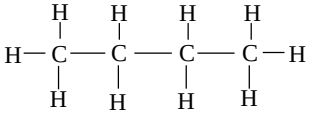
Isomerism is the term used for compouds with the same molecular formula (i.e. the same number of atoms of each type) that have diferent arangements of these atoms. The different forms are called isomers. At AS level there are two types of isomerism to learn about:

1. Structural isomerism

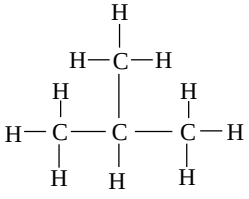
Structural isomerism is when the same number and type of atoms can be arranged in different ways to form structural isomers

Examples

1. C_4H_{10} has two structural isomers

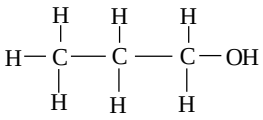


Butane

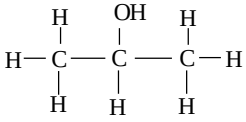


2-methylpropane

2. C_3H_7OH has two structural isomers



Propan-1-ol



Propan-2-ol

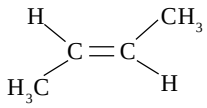
Exam Hint *- A very common question at AS level is to give a formula e.g. C_5H_{12} and ask you to give some structural isomers of it. This is where the ability to name compounds really comes into its own because if you correctly name the isomers you draw, you will avoid duplicating the isomers.*

Question 5 gives you some practice in drawing and naming structural isomers

2. Geometric isomerism

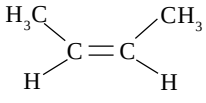
Geometric isomerism is caused by the presence of a carbon-carbon double bond (C=C). There is no rotation about the C=C because rotating would require breaking the π bond. The two forms are called ***stereoisomers.***

But-2-ene, C_4H_8 is the smallest molecule showing geometric isomerism



Trans-but-2-ene

The H-atoms are diagonally **across** (hence "trans") the double bond



Cis-but-2-ene

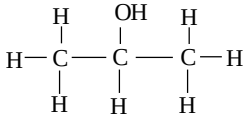
The H-atoms are **same** side (hence "cis") the double bond

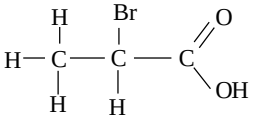
Geometric isomers can only form if both carbons involved in the double bond have two different groups attached to them.

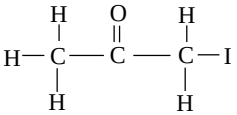
Question 6 provides practice on geometric isomerism.

Condensed formula

Examination questions and textbooks use a mixture of displayed formulae and 'condensed' formulae for example:

 is $CH_3CH(OH)CH_3$

 is $CH_3CH(Br)CO_2H$

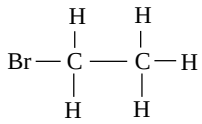
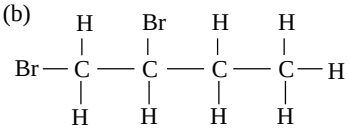
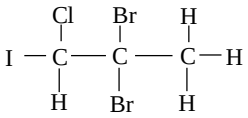
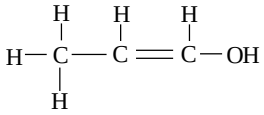
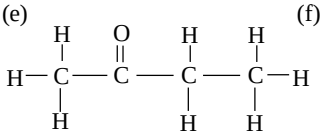
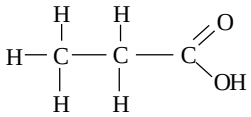
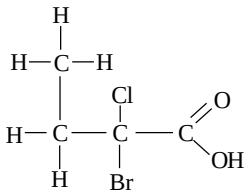
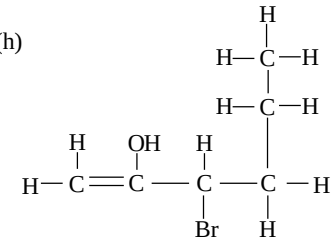
 is $CH_3\overset{\overset{O}{\|}}{C}CH_2I$

Exam Hint *- You must be able to use condensed formulae and the golden rule for all candidates is never try working out answers from just "condensed" formulae – always convert condensed formulae to displayed formulae.The reason for this is that it is easier to see the functional groups and the longest carbon chain for naming the compound.*

Question 7 provides practice on condensed and displayed formulae.

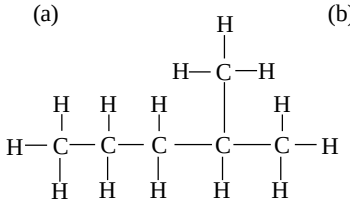
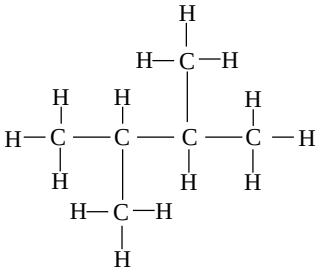
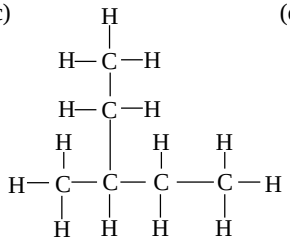
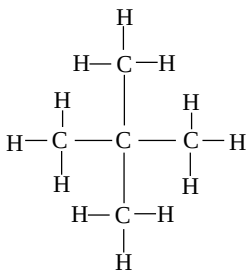
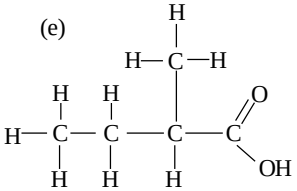
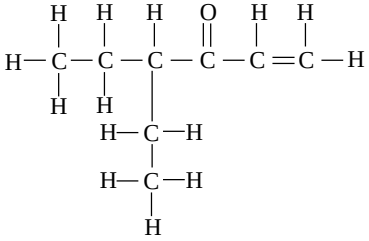
Practice Questions

Give the systematic names of these compounds:

1. (a) 
(b) 
(c) 
(d) 
(e) 
(f) 
(g) 
(h) 

2. Draw the displayed formulae for these compounds
   (a) Pentanoic acid (b) Butanone
   (c) 3-chloropentan-1-ol (d) 1,1,1-tribromoethane
   (e) 1-iodobut-1-ene (f) 3-chlorohexanal
   (g) 1-iodobutan1,2diol (h) hex-1-ene-3-ol

3. Give the systematic names of the following compounds

(a) 
(b) 
(c) 
(d) 
(e) 
(f) 

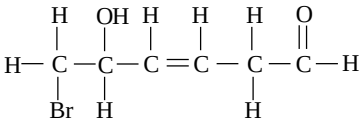
4. Draw the displayed formulae for the following componds:
   (a) 2-methylbutan-2-ol (b) 2,2-dimethylhex-3-ene
   (c) 2-methyl-2-iodopropanoic acid (d) 3-bromo-3-ethylpentanal
   (e) 2,3,4-trimethylpentane (f) 3-ethylhex-2-ene-1-ol

5. C_4H_9OH has several structural isomers. Draw the displayed formulae for <u>all</u> the isomers and give their systematic names.

6. Pentene has two structural isomers called pent-1-ene and pent-2-ene. Only one of these isomers forms geometric isomers. Which isomer forms geometric isomers and what are their displayed formulae and names?

7. Draw the displayed formulae for the following compounds:
   (a) $CH_3CH(OH)CH(Br)CH_3$
   (b) $CH_2(I)CH_2C(=O)CH_3$
   (c) $CH_3CH_2CH_2CH(OH)CH(OH)CO_2H$
   (d) $CH_2(OH)CH(Br)CH_3$

8. This question is about the molecule shown below.

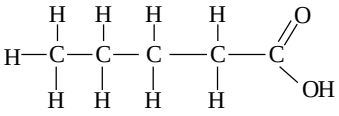
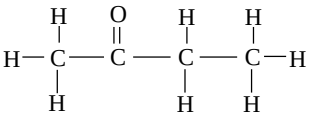
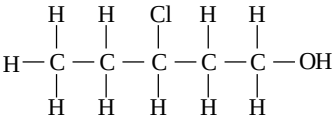
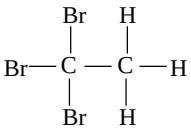
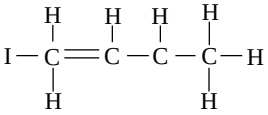
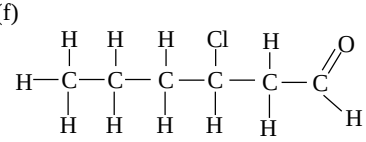
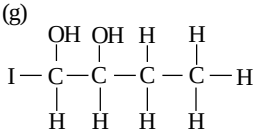
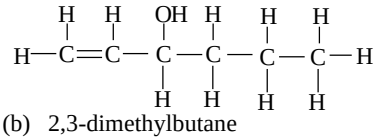


   (a) Identify the four functional groups present in the molecule.

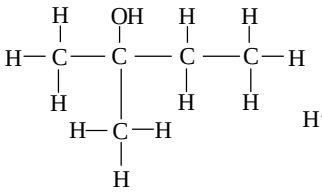
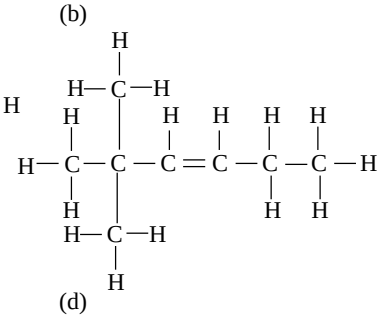
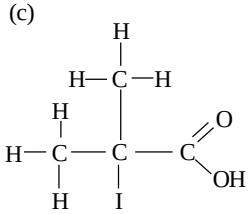
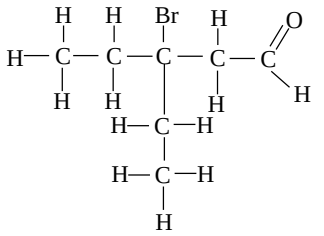
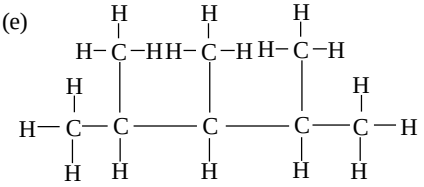
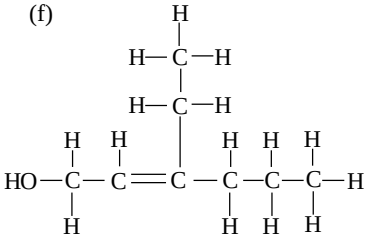
   (b) Draw the two geometric isomers of the molecule.

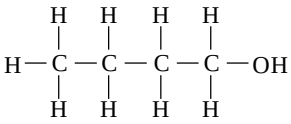
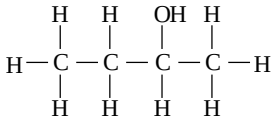
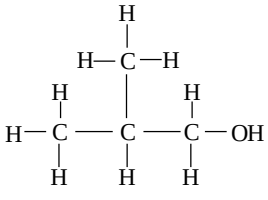
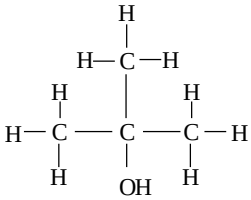
Answers

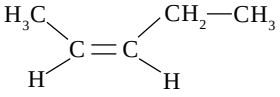
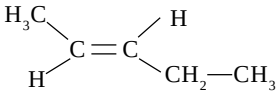
1. (a) bromoethane (b) 1,2-dibromobutane
   (c) 1-chloro-2,2dibromo-1-iodopropane
   (d) prop-1-ene-1-ol (e) butanone
   (f) propanoic acid (g) 2-bromobutanic acid
   (h) 3-bromohex-1-ene-2-ol

2. (a) 
   (b) 
   (c) 
   (d) 
   (e) 
   (f) 
   (g) 
   (h) 

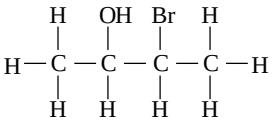
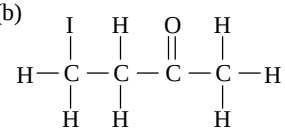
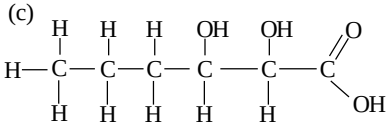
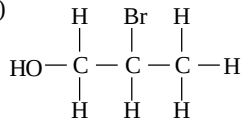
3. (a) 2-methylpentane (b) 2,3-dimethylbutane
   (c) 3-methylpentane (d) 2,2-dimethylpropane
   (e) 2-methylbutanoic acid (f) 4-ethylhex-1-ene-3-one

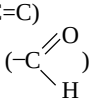
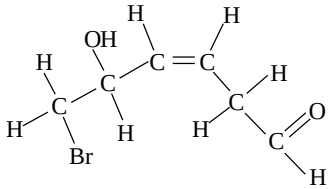
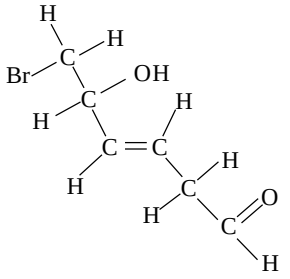
4. (a) 
   (b) 
   (c) 
   (d) 
   (e) 
   (f) 

5. 
   butan-1-ol
   
   butan-2-ol
   
   2-methylpropan-1-ol
   
   2-methylpropan-2-ol

6. pent-2-ene
   
   Cis
   
   Trans

Pent-1-ene does not form geometric isomers because one of the carbons involved in the double bond has two identical groups (hydrogen atoms) joined to it

7. (a) 
   (b) 
   (c) 
   (d) 

8. (a) bromoalkane (Br)
   alcohol (OH)
   alkene (C=C)
   aldehyde ()
   (b) 'Cis' 
   'Trans' 

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