Learning Objectives:

• **recognise** that organic molecules have a hydrocarbon skeleton and can contain functional groups, including alkenes, alcohols, aldehydes, ketones, carboxylic acids, haloalkanes, esters, nitriles, amines, amides and that structural formulas (condensed and extended) can be used to show the arrangement of atoms and bonding in organic molecules

• **deduce** the structural formulas and apply IUPAC rules in the nomenclature of organic compounds (parent chain up to 10 carbon atoms) with simple branching for alkanes, alkenes, alkynes, alcohols, aldehydes, ketones, carboxylic acids, haloalkanes, esters, nitriles, amines and amides

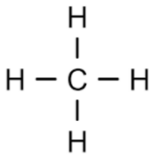
• **identify** structural isomers as compounds with the same molecular formula but different arrangement of atoms; **deduce** the structural formulas and apply IUPAC rules in the nomenclature for isomers of the non-cyclic alkanes up to C6

• **identify** stereoisomers as compounds with the same structural formula but with different arrangement of atoms in space; describe and explain geometrical (cis and trans) isomerism in non-cyclic alkenes.

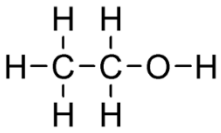
Structure of organic compounds:

Organic compounds are compounds that **contain carbon atoms that are often bonded with** other atoms such as **hydrogen, oxygen and the halogens.**

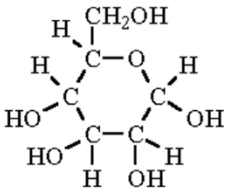
Methane



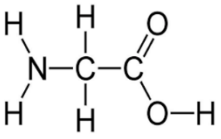
Ethanol



Glucose



Glycine



- There are many different **homologous series** in organic chemistry
- A homologous series is a group of organic compounds with the **same functional group** and **same general formula**
- All compounds in a certain homologous series have **similar chemical properties**

Homologous series:

Homologous Series	General Formula	Functional Group	Example
Alkanes	C_nH_{2n+2}	R-H	Ethane, C_2H_6
Alkenes	C_nH_{2n}	C=C	Ethene, C_2H_4
Alkynes	C_nH_{2n-2}	C≡C	Ethyne, C_2H_2
Alkyl	C_nH_{2n+1}	R(CH_3)	Methylethanoate, $C_3H_6O_2$
Haloalkanes		R-X	Chloroethane, CH_3CH_2Cl
Alcohols	$C_nH_{2n+1}OH$	R-OH	Ethanol, C_2H_5OH
Aldehydes	$C_nH_{2n+1}HO$	R-CHO	Ethanal, CH_3CHO
Ketones		R-CO-R	Propanone, CH_3COCH_3
Carboxylic acids	CnH2n+1COOH	R-COOH	Ethanoic acid, CH_3COOH

Esters		R-COOC-R	Methyl ethanoate, CH_3COOCH_3
Nitriles		R-CN	Ethanenitrile, CH_3CN
Amines		$R\text{-}NH_2$	Methyl amine, CH_3NH_2
Amides		$R\text{-}CONH_2$	Ethanamide, CH_3CONH_2

Drawing organic molecules:

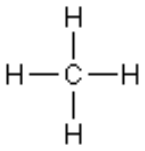
There are many different formulae available in organic chemistry because organic compounds are varied and can therefore be illustrated in different ways depending on the type of formula

Non- Structural - Molecular formula:

- A molecular formula simply counts the numbers of each sort of atom present in the molecule, but tells you nothing about the way they are joined together.
- For example, the molecular formula of butane is C_4H_{10}, and the molecular formula of ethanol is C_2H_6O.

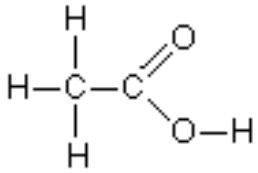
Structural formula – Displayed formula:

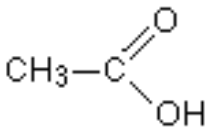
- A displayed formula shows all the bonds in the molecule as individual lines.
- You need to remember that each line represents a pair of shared electrons.
- For example, this is a model of methane together with its displayed formula:



Structural formula – Condensed structural formula

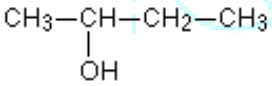
- You can simplify the formula by writing, for example, CH_3 or CH_2 instead of showing all these bonds.
- So for example, ethanoic acid would be shown in a fully displayed form and a simplified form as:

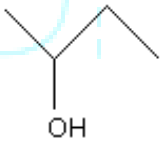




Structural formula – Skeletal formula

- In a skeletal formula, all the hydrogen atoms are removed from carbon chains, leaving just a carbon skeleton with functional groups attached to it.
- In a skeletal diagram there is a carbon atom at each junction between bonds in a chain and at the end of each bond (unless there is something else there already - like the -OH group in the example)
- There are enough hydrogen atoms attached to each carbon to make the total number of bonds on that carbon up to 4.





Your exam will include all the above formula structures, so it is a good idea to practice using them.

General Naming Rules

The name of an organic compound is systematically built from three parts: the stem, suffix, and prefix.

- Step 1: Identify the Suffix

Identify the main functional group to determine the name's ending, or suffix. If multiple functional groups are present, the one with the highest priority determines the suffix.

- Step 2: Identify the Stem

Find the longest continuous carbon chain that contains the principal functional group. This determines the stem name.

- Step 3: Number the Chain

Number the carbons in the stem to give the principal functional group the lowest possible number.

- Step 4: Identify the Prefix

Name any other functional groups or side chains. These prefixes are listed in alphabetical order, with their position indicated by numbers.

    - Use commas (,) to separate numbers.
    - Use hyphens (-) to separate numbers and letters.

Naming stems and suffixes:

Number of carbon atoms	**Stem name**
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex -
7	Hept-
8	Oct-
9	Non-
10	Dec-

Homologous series	Suffix name
Alkane	-ane
Alkene	-ene
Alcohol	-ol
Haloalkane	-ane
Carboxylic acid	-oic acid
Aldehyde	-al
Ketone	-one
Ester	-oate

Other groups	Suffix name
NH_2	Amine
CN	Nitrile

Naming prefixes:

Number of carbon atoms	Alkyl prefix name
1	Methyl
2	Ethyl
3	Propyl

4	Butyl
5	Pentyl-
6	Hexyl

Halogen	**Halogen prefix name**
Fluorine	Fluoro-
chlorine	Chloro-
Bromine	Bromo-
Iodine	Iodo-

Other groups	**prefix name**
OH group	Hydroxy-
NH_2	Amino
NO_2	Nitro

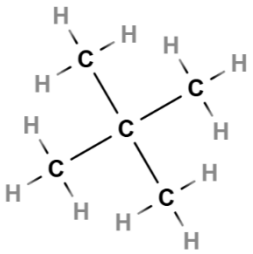
Naming Alkanes

Alkanes are the simplest hydrocarbons, containing only carbon-carbon single bonds.

Step 1:

The principal functional group is an alkane, so the suffix is -ane.

Step 2:



The longest continuous carbon chain contains 3 carbons, so the stem is prop-.

Step 3:

There are two alkyl functional groups (substituents), both are methyl groups. Numbering the chain gives both groups position 2.

Step 4:

The two methyl groups are combined using the prefix di-. The prefix is 2,2-dimethyl.

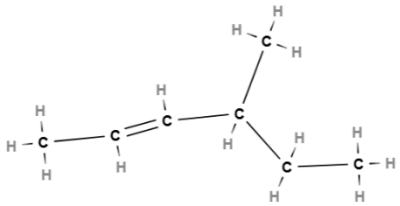
Compound Name: Combining the prefix, stem, and suffix gives the name: 2,2-dimethylpropane.

Naming Alkenes

Alkenes contain at least one carbon-carbon double bond (C=C).

Step 1:

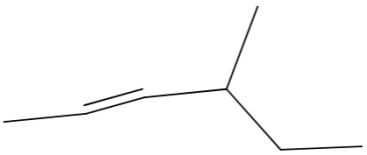
The principal functional group is an alkene (C=C), so the suffix is -ene.



Step 2:

The longest carbon chain containing the double bond has 6 carbons, so the stem is hex-.

Step 3:



Number the chain to give the double bond the lowest possible number, which is position 2.

Step 4:

There is a methyl group substituent at position 4. The prefix is 4-methyl.

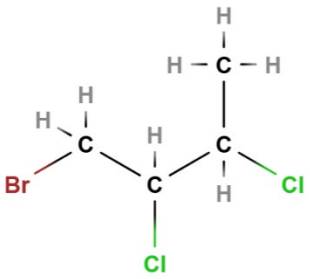
Compound Name: 4-methylhex-2-ene.

Naming Haloalkanes

Haloalkanes have one or more hydrogen atoms replaced by halogens (F, Cl, Br, I).

Step 1:

The molecule is a substituted alkane, so the suffix is -ane.

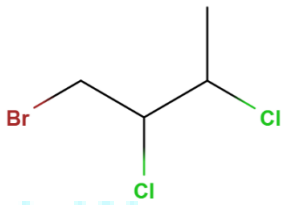


Step 2:

The longest continuous carbon chain has 4 carbons, so the stem is but-.

Step 3:

Number the chain to give the substituents the lowest possible set of numbers.



Step 4:

The prefixes are named alphabetically: bromo- and chloro-. Since there are two chloro groups, we use di-.

- 1-bromo
- 2,3-dichloro

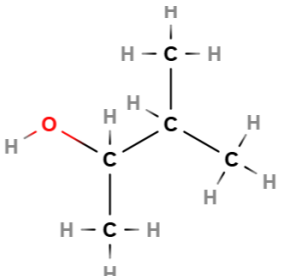
Compound Name: Combining the prefixes alphabetically gives the name: 1-bromo-2,3-dichlorobutane.

Naming Alcohols

Alcohols contain a hydroxyl (-OH) group.

Step 1:

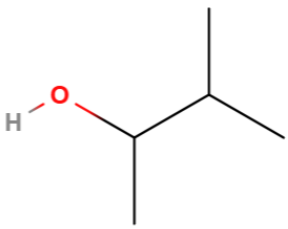
The principal functional group is an alcohol (-OH), so the suffix is -ol.



Step 2:

The longest carbon chain containing the -OH group has 4 carbons, so the stem is but-.

Step 3:Number the chain to give the -OH group the lowest number, which is position 2.



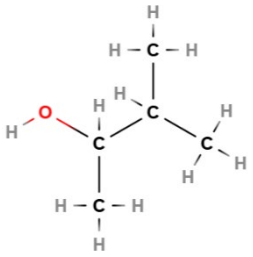
Step 4:

There is a methyl group substituent at position 3. The prefix is 3-methyl.

Compound Name: 3-methylbutan-2-ol.

Naming Aldehydes

Aldehydes contain a carbonyl group (C=O) at the end of a carbon chain.

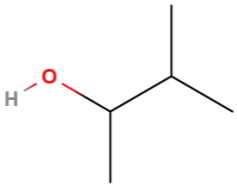


Step 1:

The principal functional group is an aldehyde, so the suffix is -al.

Step 2:

The longest carbon chain containing the aldehyde group has 4 carbons, so the stem is but-.



Step 3:

The aldehyde group is always at position 1, so no number is needed for the suffix.

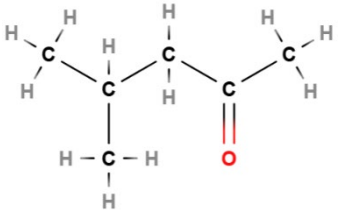
Step 4:

There is a methyl group substituent at position 3. The prefix is 3-methyl.

Compound Name: 3-methylbutanal.

Naming Ketones

Ketones contain a carbonyl group (C=O) within the carbon chain.

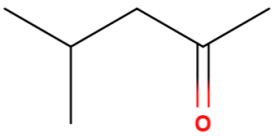


- Suffix: -one

Example: 4-methylpentan-2-one

Step 1:

The principal functional group is a ketone, so the suffix is -one.



Step 2:

The longest carbon chain containing the ketone group has 5 carbons, so the stem is pent-.

Step 3:

Number the chain to give the ketone group the lowest number, which is position 2.

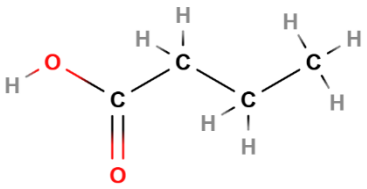
Step 4:

There is a methyl group substituent at position 4. The prefix is 4-methyl.

Compound Name: 4-methylpentan-2-one.

Naming Carboxylic Acids

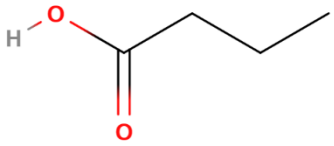
Carboxylic acids contain a carboxyl (-COOH) group.



Step 1:

The principal functional group is a carboxylic acid, so the suffix is -oic acid.

Step 2:



The longest carbon chain containing the -COOH group has 4 carbons, so the stem is but-.

Step 3 & 4:

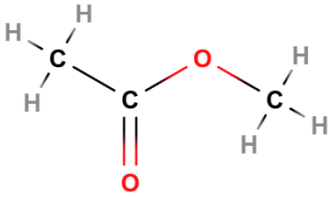
The carboxyl group is always at position 1, and there are no other substituents.

Compound Name: butanoic acid.

Naming Esters

Esters contain the -COO- functional group. Naming is split into two parts.

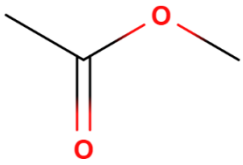
Step 1:



The first part of the name comes from the alkyl group attached to the single oxygen atom. Here, it is a methyl group.

Step 2:

The second part comes from the carbon chain containing the C=O group. It has 2 carbons, so the stem is ethan-.



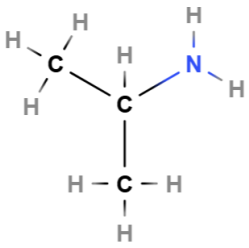
Step 3 & 4:

The suffix for an ester is -oate.

Compound Name:

Combining the two parts gives the name: methyl ethanoate.

Naming Amines



Amines contain a nitrogen atom bonded to alkyl or hydrogen groups.

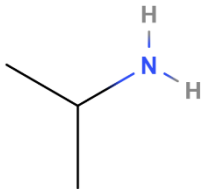
Step 1:

The principal functional group is an amine, so the suffix is -amine.

Step 2:

The longest carbon chain attached to the nitrogen has 3 carbons, so the stem is prop-.

Step 3 & 4:

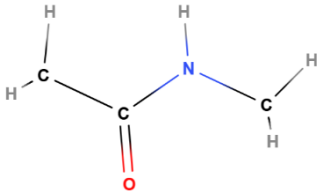


The position of the amine group is indicated by a number. Here, it is at position 2.

Compound Name: propan-2-amine (or 2-aminopropane).

Naming Amides

Amides have a carbonyl group bonded to a nitrogen atom.



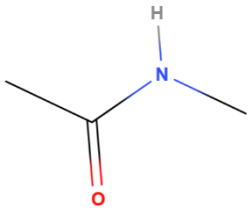
Step 1:

The principal functional group is an amide, so the suffix is -amide.

Step 2:

The carbon chain containing the C=O group has 2 carbons, so the stem is ethan-. This forms the parent amide: ethanamide.

Step 3 & 4:



There is a methyl group attached to the nitrogen atom. This is indicated by the prefix N-methyl.

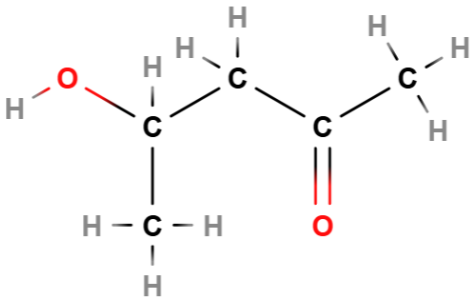
Compound Name: N-methylethanamide.

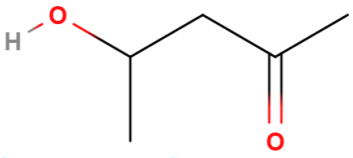
Naming Molecules with Multiple Functional Groups

When a molecule has more than one functional group, one is chosen as the

principal group based on priority, which dictates the **suffix**. All other groups are named as

prefixes. The general order of priority is: Carboxylic acids > Esters > Amides > Nitriles > Aldehydes > Ketones > Alcohols > Amines > Alkenes > Alkynes > Alkanes > Halides.





Step 1: The molecule contains a ketone and an alcohol group. The ketone has higher priority, so the suffix is **-one**.

Step 2: The longest carbon chain containing the ketone has 5 carbons, so the stem is

pent-.

Step 3: Numbering the chain from the end that gives the ketone the lowest number places it at position 2.

Step 4: The lower priority alcohol group is named with the prefix

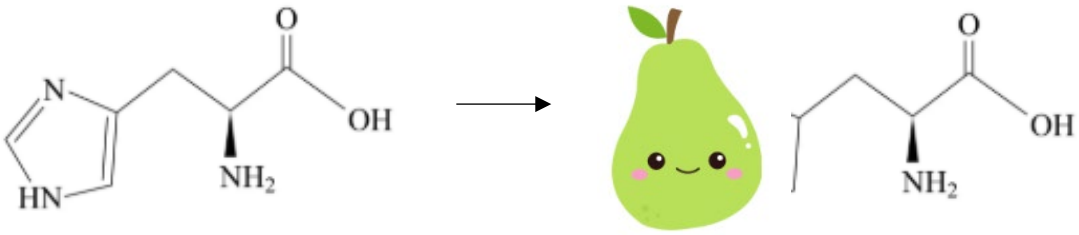
hydroxy-. It is located at position 4. The prefix is

4-hydroxy.

Compound Name: 4-hydroxypentan-2-one.

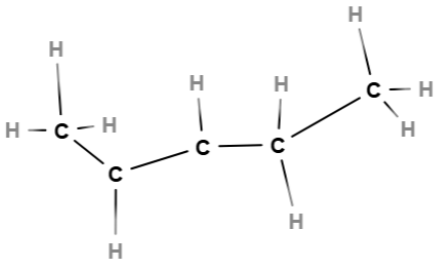
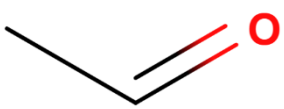
What about cyclic molecules?

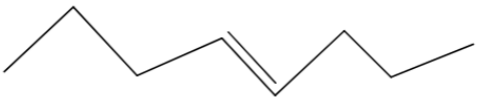
Although these molecules do pop up in exams, you do not have to name them. Ignore the clyclohexane/benzene ring and concentrate on the R group attached.
Cover the ring structure up – it could be a pear for all you care!

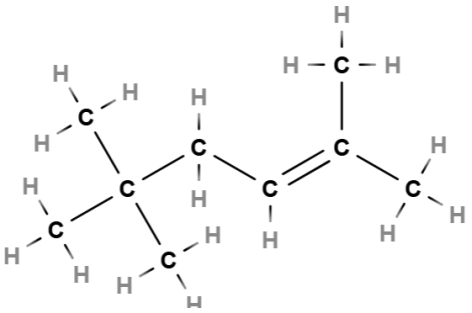


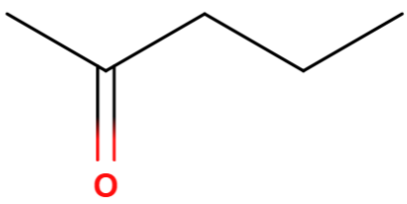
Practice questions:

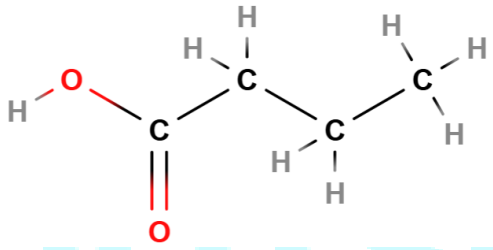
For each of the following compounds, draw the structure if the name is given or vice versa.

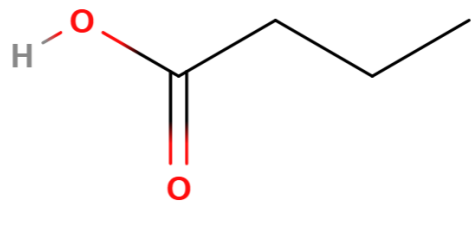
1. pent-1-ene
2. methylpropene
3. methylbut-2-ene
4. 3-methylhexane
5. 2-chloro-3-methylbutane
6. 2,2-dimethylpentane
7. 2,3-dimethylbut-1-ene
8. 2-methyl-3-ethylpentane
9. 2,2-dibromo-3-fluorobutane
10. 1-iodo-2-methylpentane
11. 
12. 

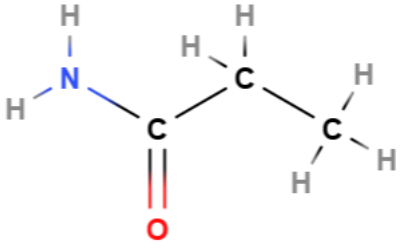
13. 

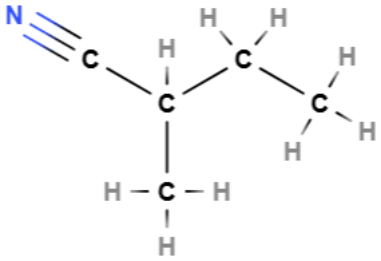
14. 

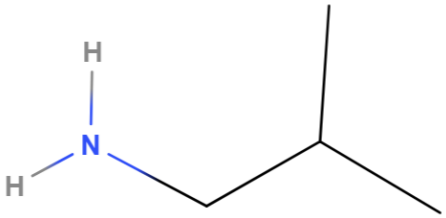
15. 

16. 

17. 



18. 

19. 

20.