

Topic 1.5

INTRODUCTION TO ORGANIC CHEMISTRY

Introduction to Organic Chemistry

Nomenclature

Isomerism

INTRODUCTION TO ORGANIC CHEMISTRY

1. Carbon compounds

Organic chemistry is the chemistry of carbon compounds. Carbon forms a vast number of compounds because it can form strong covalent bonds with itself. This enables it to form long chains (up to 5000 in length) of carbon atoms, and hence an almost infinite variety of carbon compounds are known.

The tendency of identical atoms to form covalent bonds with each other and hence form chains is known as catenation.

All organic compounds contain carbon. Most contain hydrogen.

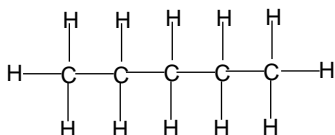
Carbon always forms four covalent bonds and hydrogen one.

The physical and chemical properties of organic compounds depend on two factors:

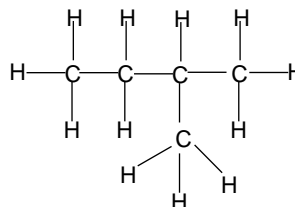
a) The number and arrangement of carbon atoms in the molecule.

A number of important physical properties are determined by the number of carbon atoms in the molecule. The greater the number of carbon atoms, the larger the Van der Waal's forces and the higher the melting points, boiling points and viscosity.

In many cases, all the carbon atoms are arranged in a straight chain. Often, however, there are shorter chains of carbon atoms branching off a longer chain. These are known as branched molecules.

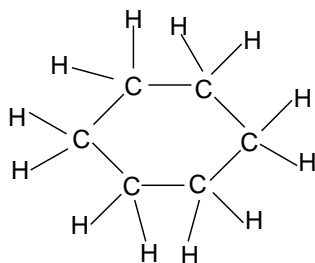


Straight chain molecule



Branched molecule

Carbon atoms can also be arranged to form rings. These are known as cyclic molecules. The most common number of carbon atoms in a ring is 6.



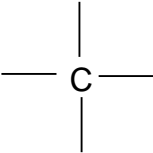
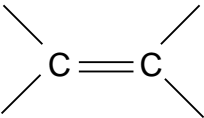
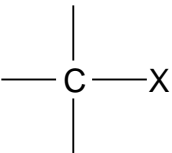
Cyclic molecule

b) The functional groups in the molecule

A functional group is a specific atom or group of atoms which confer certain physical and chemical properties onto the molecule. Organic molecules are classified by the dominant functional group on the molecule.

2. Functional groups

These are the some of the most important functional groups found on organic molecules:

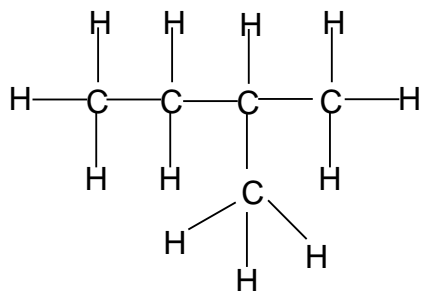
Type of compound	Nature of functional group
Alkane	C-C and C-H single bonds only (ie no functional group) 
Alkene	C=C double bond 
Haloalkane -Chloroalkane -Bromoalkane -Iodoalkane	Cl, Br or I atom attached to a carbon atom 

3. Drawing and writing organic compounds

Organic compounds can be represented in a number of ways:

a) Structural formula showing all covalent bonds

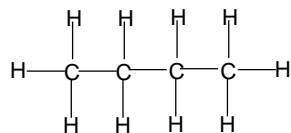
This is also known as the **displayed formula** or **graphical formula**. All covalent and ionic bonds between all atoms are shown:



b) Structural formula, not showing all covalent bonds

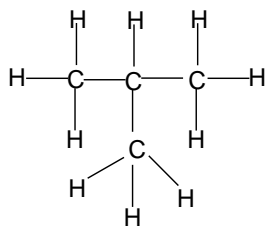
Enough information is shown to make the structure clear, but most of the actual covalent bonds are omitted. Only important bonds are always shown.

Straight chain alkanes are shown as follows:

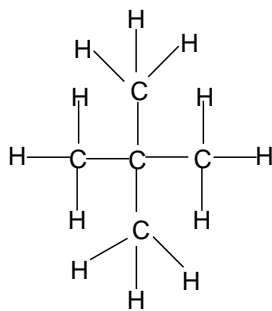


is represented as $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ or $\text{CH}_3(\text{CH}_2)_2\text{CH}_3$.

Branched alkanes are shown as follows:

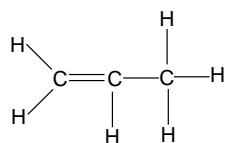


is represented as $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_3$.

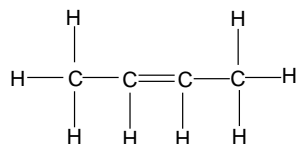


is represented as $\text{CH}_3\text{C}(\text{CH}_3)_2\text{CH}_3$.

Alkenes are shown as follows:



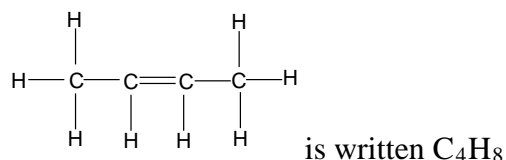
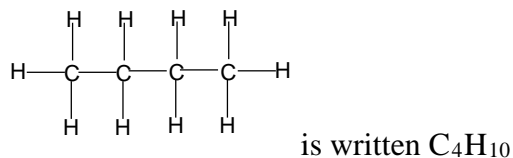
is represented as $\text{CH}_2=\text{CHCH}_3$.



is represented as $\text{CH}_3\text{CH}=\text{CHCH}_3$.

c) Molecular formula

The molecular formula shows the number of each atom in one molecule of the compound. It does not show unequivocally the structure of the molecule.



Alkanes have the general molecular formula $\text{C}_n\text{H}_{2n+2}$.

Alkenes have the general molecular formula C_nH_{2n} .

Haloalkanes have the general molecular formula $\text{C}_n\text{H}_{2n+1}\text{X}$.

d) Empirical formula

The empirical formula is the simplest whole number ratio of the number of atoms of each element in a substance.

4. Homologous series

Organic compounds with the same functional group, but a different number of carbon atoms, are said to belong to the same **homologous series**. Every time a carbon atom is added to the chain, two hydrogen atoms are also added.

A homologous series is a series of organic compounds which have the same functional group, but in which the formula of each successive member increases by $-\text{CH}_2-$.

Eg Homologous series of alkanes:

CH_4 , CH_3CH_3 , $\text{CH}_3\text{CH}_2\text{CH}_3$, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_3(\text{CH}_2)_3\text{CH}_3$, $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$
etc

As a homologous series is ascended, the size of the molecule increases. Therefore the Van der Waal's forces between the molecules become stronger and the boiling point increases.

NOMENCLATURE OF ORGANIC COMPOUNDS

Most organic compounds can be named systematically by the IUPAC method.

In order to describe completely an organic molecule, three features must be described:

- the longest straight carbon chain on the molecule.
- the length and position of any branches on the molecule.
- the nature and position of any functional groups on the molecule.

1. The longest straight chain on the molecule

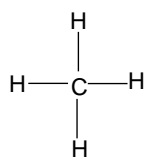
The longest straight chain on the molecule is indicated by one of the following prefixes:

Number of carbon atoms in the chain	Prefix
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-

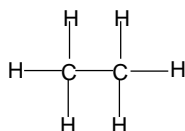
2. The nature and position of any functional groups on the molecule

a) Alkanes

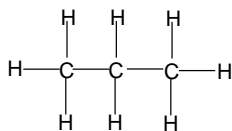
Alkanes are named using the ending -ane:



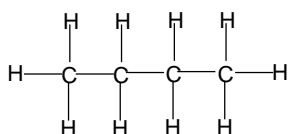
Methane



Ethane



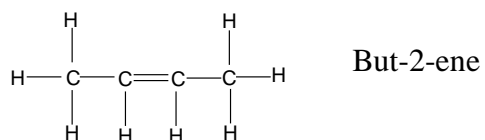
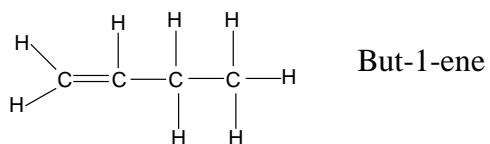
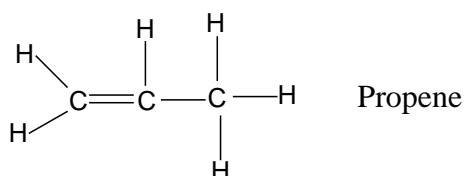
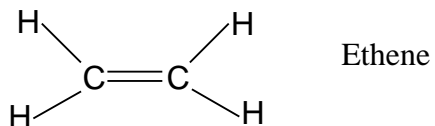
Propane



Butane

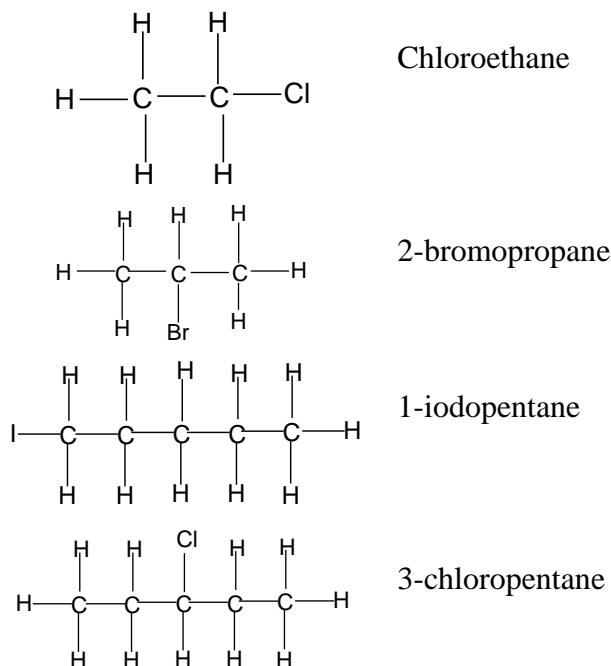
b) **Alkenes**

Alkenes are named using the ending -ene. In molecules with a straight chain of 4 or more carbon atoms, the position of the C=C double bond must be specified. The carbon atoms on the straight chain must be numbered, starting with the end closest to the double bond. The lowest-numbered carbon atom participating in the double bond is indicated just before the -ene:

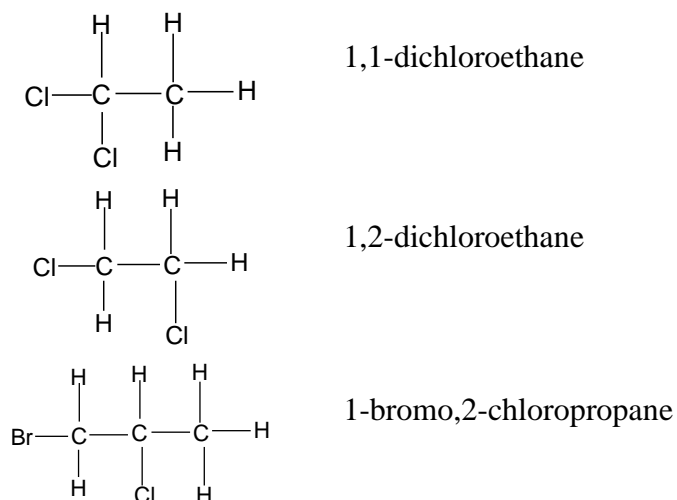


c) **Haloalkanes**

Haloalkanes are named using the prefix chloro-, bromo- or iodo-, with the ending -ane. In molecules with a straight chain of three or more carbon atoms, the position of the halogen atom must also be specified. The carbon atoms on the straight chain must be numbered, starting with the end closest to the halogen atom. The number of the carbon atom attached to the halogen is indicated before the prefix:

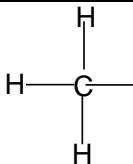
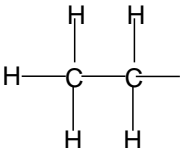


The position of all halogens in dihaloalkanes except those with one carbon atom must be specified. If there is more than one of the same type of halogen atom on the molecule, the di (two), tri (three) or tetra (four) prefixes must also be used.



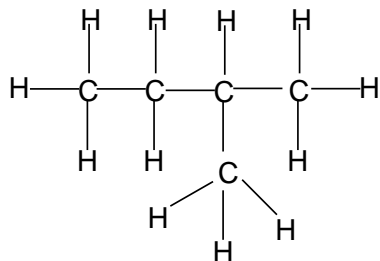
3. The length and position of any branches on the molecule

Many carbon chains are not, in fact straight but are branched. The presence of a branch is indicated one of the following prefixes:

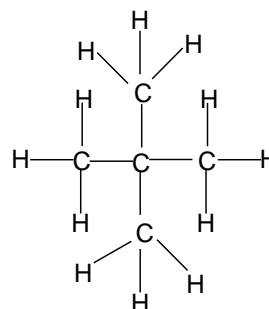
Branch	Prefix
	Methyl
	Ethyl

The position of the branch must be specified according to the number of the carbon on the straight chain to which it is attached. The carbons are always numbered from the carbon at the end of the chain closest to the functional group. If there is no functional group, the carbons are numbered from the carbon at the end of the chain closest to the branch.

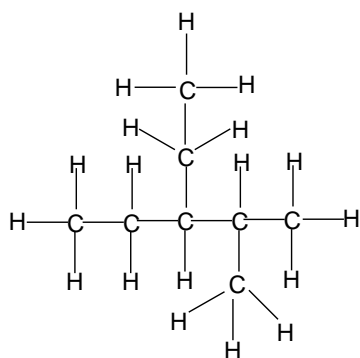
Eg



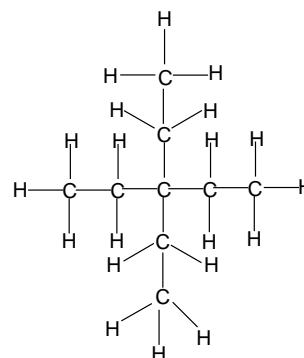
2-methylbutane



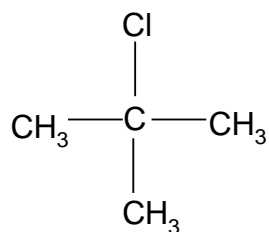
2,2-dimethylpropane



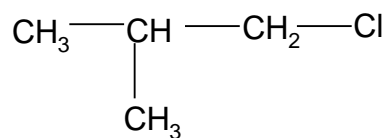
2-methyl,3-ethylpentane



3,3-diethylpentane



2-methyl,2-chloropropane

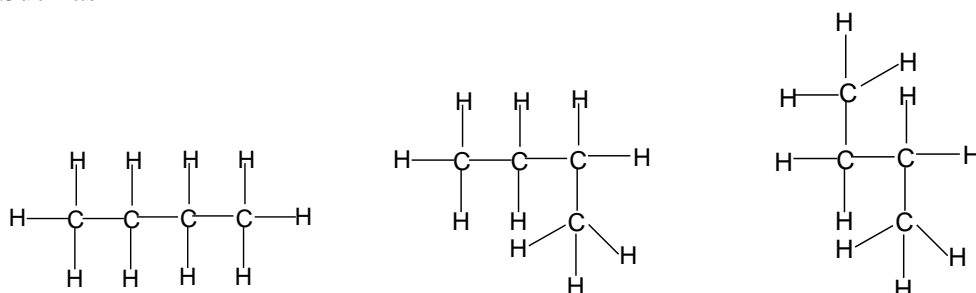


2-methyl,1-chloropropane

Many organic compounds which appear to be different are in fact the same. They appear to be different because different notations are used, or because some of the bonds are simply rotated.

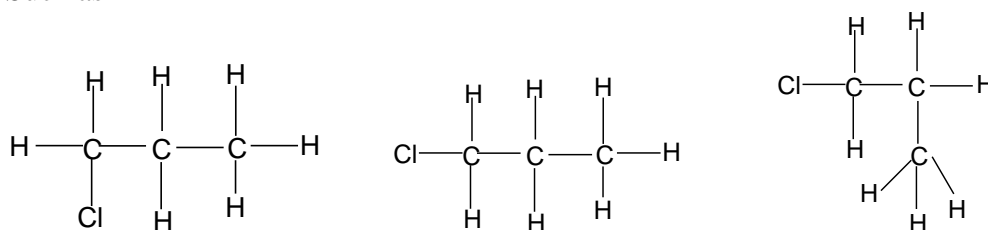
Eg butane can be represented in a number of ways:

Such as



Eg 1-chloropropane can be represented in a number of ways:

Such as



ISOMERISM

Isomers are molecules which have the same molecular formula but different structures.

There are a number of different types of isomerism in organic compounds, but the only type required for AS Chemistry is **structural isomerism**.

Structural isomers are molecules which have the same molecular formula but a different arrangement of covalent bonds.

The different arrangement of covalent bonds can result from:

- i) The functional group being in different positions (**positional isomerism**)
- ii) A different arrangement of the carbon skeleton (**chain isomerism**)
- iii) A different functional group (**functional isomerism**)

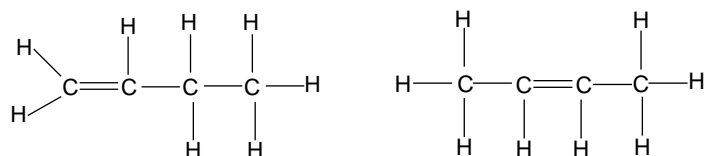
i) **Positional isomerism**

Positional isomers are molecules with the same molecular formula but which have the functional group on different positions in the molecule.

Alkanes do not show functional isomerism as they have no functional group.

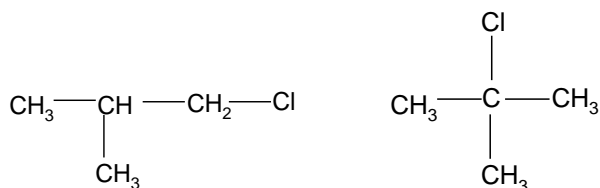
Alkenes with four or more carbon atoms show positional isomerism:

Eg but-1-ene and but-2-ene



Haloalkanes with three or more carbon atoms show positional isomerism

Eg 1-chloromethylpropane and 2-chloromethylpropane

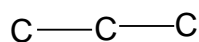


ii) **Chain isomerism**

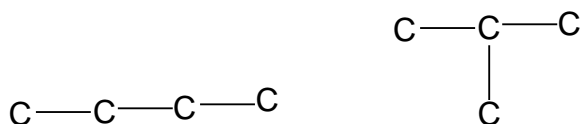
Chain isomers are molecules with the same molecular formula but a different arrangement of carbon atoms.

The arrangement of carbon atoms in an organic molecule is known as the carbon skeleton.

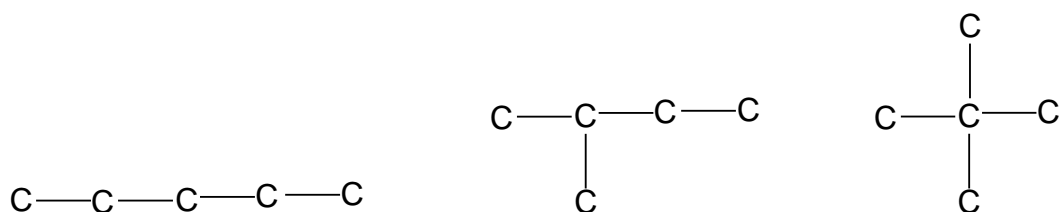
Carbon skeletons containing up to three carbon atoms can only be arranged in one way – i.e. a straight chain with no branching:



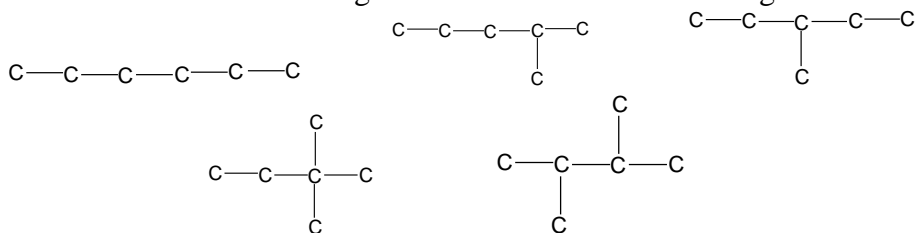
Carbon skeletons containing four carbon atoms can be arranged in two ways:



Carbon skeletons containing five carbon atoms can be arranged in three ways:

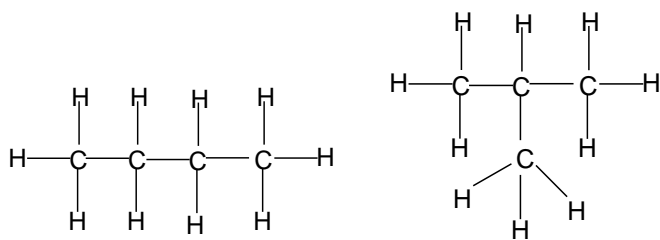


Carbon skeletons containing six carbon atoms can be arranged in five ways:

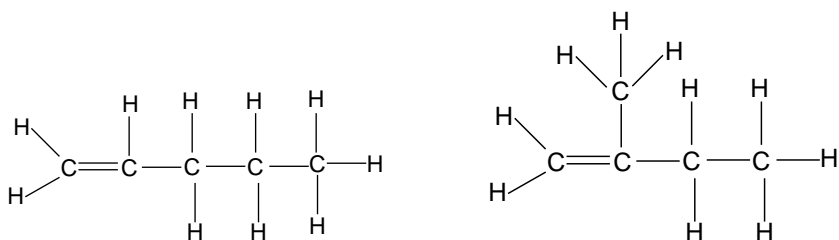


All molecules containing four or more carbon atoms can thus show chain isomerism:

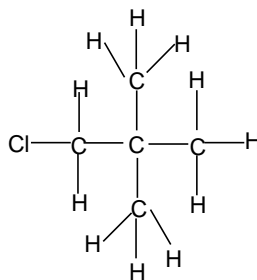
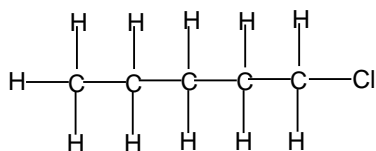
Eg butane and methylpropane



Eg pent-1-ene and 2-methylbut-1-ene



Eg 1-chloropentane and 1-chloro,2,2-dimethylpropane

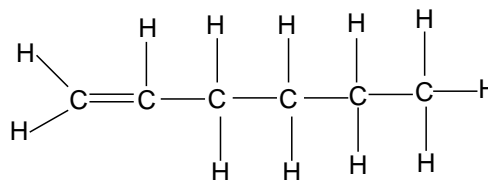
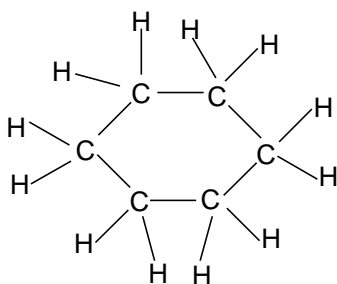


iii) **Functional isomerism**

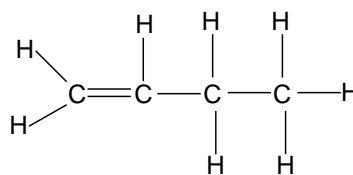
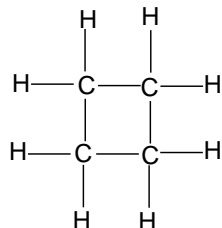
Functional isomers are molecules with the same molecular formula but different functional groups.

eg Alkanes which have a ring rather than a straight chain arrangement are known as cycloalkanes. They have the general formula C_nH_{2n} , which is the same as alkenes. Cycloalkanes and alkenes can thus show functional isomerism.

Eg cyclohexane and hex-1-ene



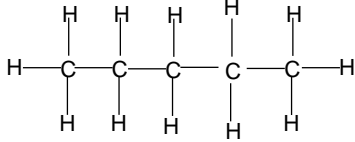
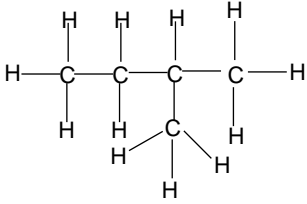
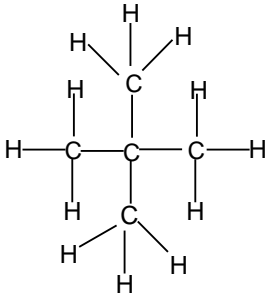
Eg cyclobutane and but-1-ene



3. Distinguishing between isomers

Isomers tend to differ slightly in their melting and boiling points. Molecules with no branching tend to have higher boiling points than isomers with more branching. This is because they have a higher surface area, so they pack together better and so the van der Waal's forces are stronger.

Eg isomers of pentane, C_5H_{12} :

Isomer	Structure	Boiling point/ $^{\circ}C$
Pentane		36
Methylbutane		28
2,2-dimethylpropane		10