TOPIC 8: ORGANIC CHEMISTRY

Prescribed content

Organic molecules
- Define organic molecules as molecules containing carbon atoms.

Molecular and structural formulae
- Write molecular formulae and structural formulae for organic compounds of up to six carbon atoms for alkanes, alkenes, alkynes, alkyl halides, aldehydes, ketones, alcohols, carboxylic acids and esters.

Functional group
- Define functional group as a bond or an atom or group of atoms that determine the chemistry of a molecule.

Homologous series
- Define homologous series as a series of compounds that have the same general formula and where each member differs from the next by $–CH_2$.
- Distinguish between different homologous series.

Saturated hydrocarbons
- Saturated hydrocarbons contain ONLY single covalent bonds between the carbon atoms.
- Unsaturated hydrocarbons contain covalent double or triple bonds between the carbon atoms.
- Distinguish between saturated and unsaturated homologous series.

Isomers
- Organic molecules with the same molecular formula but with different structures are called isomers.
- Write structural formulae for given isomers and name the isomers.

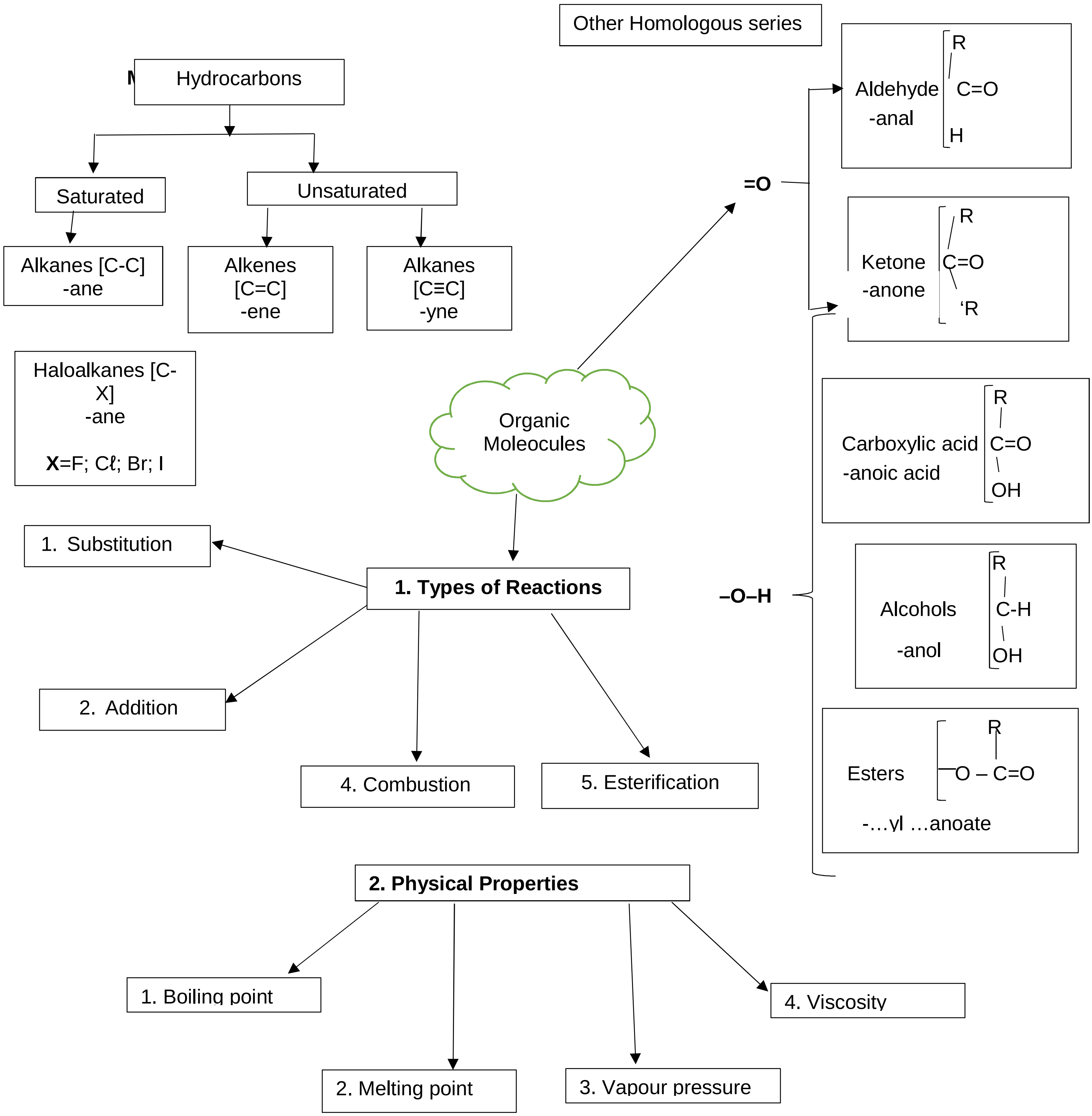
IUPAC naming and formulae
- Give the IUPAC name when given the formula for alkanes, alkenes, alkynes, alkylhalides, aldehydes, ketones, alcohols, carboxylic acids and esters.
- Give the formula when given the IUPAC name for alkanes, alkenes, alkynes, alkylhalides, aldehydes, ketones, alcohols, carboxylic acids and esters.

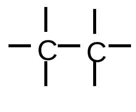
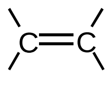
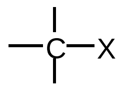
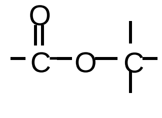
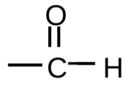
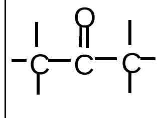
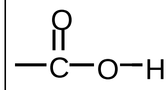
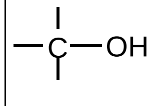
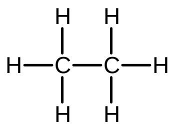
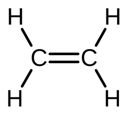
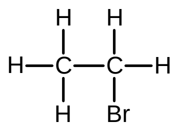
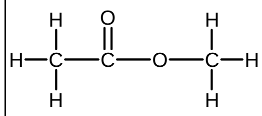
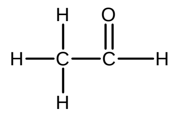
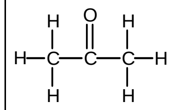
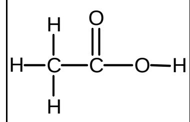
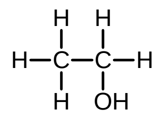
Physical properties of organic compounds
- Discuss physical property relationships (boiling point, melting point, vapour pressure and viscosity) in alkanes, alkenes, alkynes, alkylhalides, aldehydes, ketones, alcohols, carboxylic acids and esters.
- Compare physical properties of different homologous series.

Reactions of organic compounds
- Oxidation
- Substitution
- Addition
- Halogenations
- Hydrohalogenation
- Balance equations for the above reactions using molecular and structural formulae.

Plastics and polymer

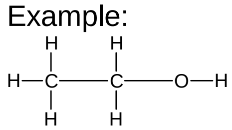
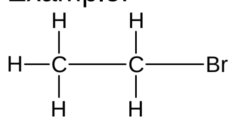
- Describe the terms polymer, macromolecule, chains and monomers.
- Define plastics and polymers.
- Discuss the industrial use of polythene as a basic application of organic chemistry.

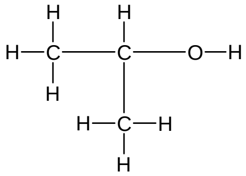
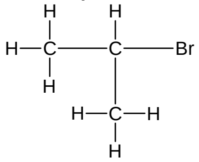
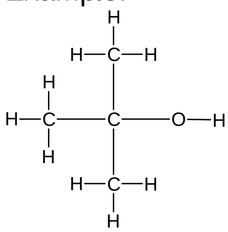
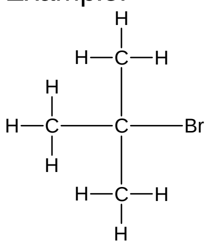


ORGANIC MOLECULES									
Homologous series	**Hydrocarbons**			Haloalkanes	Esters	Aldehydes	Ketones	Carboxylic acids	Alcohols
	Alkanes	Alkenes	Alkynes						
General formula	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}	$C_nH_{2n+1}X$	$C_nH_{2n}O_2$	$C_nH_{2n}O$	$C_nH_{2n}O$	$C_nH_{2n}O_2$	$C_nH_{2n+1}OH$
Functional group									
Example structural formula									
Example IUPAC name	Ethane	Ethene	Ethyne	Bromoethane	Methyl ethanoate	Ethanal	Propanone	Ethanoic acid	Ethanol
Intermolecular forces	**London forces**								
				Dipole-dipole forces					
								Hydrogen Bonding	
Chemical reactions	Oxidation Cracking Substitution	Addition		Substitution Elimination				Esterification	Elimination Substitution Esterification

Important terms/definitions

Addition reaction	A reaction in which a double bond in the starting material is broken and elements are added to it.
Addition polymer	A polymer formed when monomers (usually containing a double bond) combine through an addition reaction
Addition polymerisation	A reaction in which small molecules join to form very large molecules by adding on double bonds
Alcohol	An organic compound in which H atoms in an alkane have been substituted with hydroxyl groups (-OH groups). General formula: $C_nH_{2n+1}OH$
Aldehydes	Organic compounds having the general structure RCHO where R = H or alkyl. General formula: RCHO (R = alkyl group)
Alkane	An organic compound containing only C-H and C-C single bonds. General formula: C_nH_{2n+2}
Alkene	A compound of carbon and hydrogen that contains a carbon-carbon double bond. General formula: C_nH_{2n}
Alkyl group	A group formed by removing one H atom from an alkane.
Alkyne	A compound of carbon and hydrogen that contains a carbon-carbon triple bond.
Boiling point	The temperature at which the vapour pressure of a liquid equals atmospheric pressure.
Carbonyl group	Functional group of ketones (>C=O)
Carboxyl group	Functional group of carboxylic acids (-COOH)
Carboxylic acid	An organic compound containing a carboxyl group (-COOH group). General formula: $C_nH_{2n+1}COOH$ (or RCOOH)
Chain isomers	Compounds with the same molecular formula, but different types of chains.
Cracking	The chemical process in which longer chain hydrocarbon molecules are broken down to shorter more useful molecules.
Dehydration	Elimination of water from a compound usually such as an alcohol.
Dehydrohalogenation	The elimination of hydrogen and a halogen from a haloalkane.
Dipole-dipole force	Intermolecular forces found between polar molecules i.e. molecules in which there is an uneven distribution of charge so that the molecule has a positive and a negative side.
Elimination reaction	A reaction in which elements of the starting material are “lost” and a double bond is formed.
Esterification	The preparation of an ester from the reaction of a carboxylic acid with an alcohol.
Functional group	A bond or an atom or a group of atoms that determine(s) the physical and chemical properties of a group of organic compounds.
Functional isomers	Compounds with the same molecular formula, but different functional groups.
Haloalkane (Alkyl halide)	An organic compound in which one or more H atoms in an alkane have been replaced with halogen atoms. General formula: $C_nH_{2n+1}X$ (X = F, Cℓ, Br or I)
Halogenation	The reaction of a halogen (Br_2, $C\ell_2$) with a compound.
Homologous series	A series of organic compounds that can be described by the same general formula.

	OR A series of organic compounds in which one member differs from the next with a CH_2 group.
Hydration	The addition of water to a compound.
Hydrocarbon	Organic compounds that consist of hydrogen and carbon only.
Hydrogenation	The addition of hydrogen to an alkene
Hydrogen bond	A strong intermolecular force found between molecules in which an H atom is covalently bonded to wither an N, O or F atom.
Hydrohalogenation	The addition of a hydrogen halide to an alkene
Hydrolysis	The reaction of a compound with water
Intermolecular force	Forces between molecules that determine physical properties of compounds.
IUPAC name	A chemical nomenclature (set of rules) created and developed by the International Union of Pure and Applied Chemistry (IUPAC) to generate systematic names for chemical compounds.
London force	A weak intermolecular force between non-polar molecules.
Macromolecule	A molecule that consists of a large number of atoms
Melting point	The temperature at which the solid and liquid phases of a substance are at equilibrium.
Molecular formula	A chemical formula that indicates the type of atoms and the correct number of each in a molecule.
Monomer	Small organic molecules that can be covalently bonded to each other in a repeating pattern.
Organic chemistry	Chemistry of carbon compounds.
Plastics	
Polymer	A large molecule composed of smaller monomer units covalently bonded to each other in a repeating pattern
Polymerisation	A chemical reaction in which monomer molecules join to form a polymer
Positional isomer	Compounds with the same molecular formula, but different positions of the side chain, substituents or functional groups on the parent chain.
Primary alcohol	One C atom is bonded to the C atom bonded to hydroxyl group. Example: 
Primary haloalkane	One C atom is bonded to the C atom bonded to the halogen. Example: 
Saturated compounds	Compounds in which there are no multiple bonds between C atoms in their hydrocarbon chains. OR Compounds with only single bonds between C atoms in their hydrocarbon chains.
Secondary alcohol	Two C atoms bonded to the C atom that is bonded to hydroxyl

	group. Example: 
Secondary haloalkane	Two C atoms bonded to the C atom bonded to the halogen. Example: 
Structural formula	A structural formula of a compound shows which atoms are attached to which within the molecule. Atoms are represented by their chemical symbols and lines are used to represent ALL the bonds that hold the atoms together.
Structural isomer	Organic molecules with the same molecular formula, but different structural formulae.
Substituent (branch)	A group or branch attached to the longest continuous chain of C atoms in an organic compound.
Substitution reaction	A reaction in which an atom or a group of atoms in a molecule is replaced by another atom or group of atoms.
Tertiary alcohol	Three C atoms bonded to carbon that is bonded to hydroxyl group. Example: 
Tertiary haloalkane	Three C atoms bonded to the C atom bonded to the halogen. Example: 
Unsaturated compounds	Compounds in which there are multiple bonds (double or triple bonds) between C atoms in their hydrocarbon chains.
Van der Waals forces	A combined name used for the different types of intermolecular forces.
Vapour pressure	The pressure exerted by a vapour at equilibrium with its liquid in a closed system.
Viscosity	
Volatile	A property that describes how easily a compound can evaporate at normal temperatures. Substances with high vapour pressures are volatile
Volatility	The tendency of a substance to vaporize. Volatility is directly related to a substance's vapour pressure. At a given temperature, a

	substance with higher vapour pressure vaporizes more readily than a substance with a lower vapour pressure.

8.1 Structure of organic molecules

Organic Chemistry is the **chemistry of carbon compoun**ds.

8.1.1 Homologous series

A family of organic compounds is referred to as a homologous series. Per definition a **homologous series** is a group of organic compounds that can be described by the same general formula and have the same functional group OR in which one member differs from the next with a $-CH_2$ group.

8.1.2 General formulae

A **general formula** can be used to determine the molecular formula of any member in a homologous series.

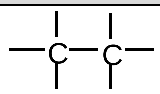
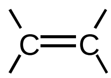
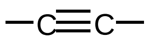
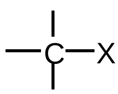
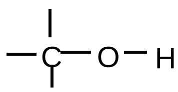
Table 1: General formulae of organic compound

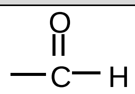
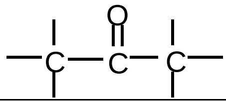
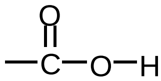
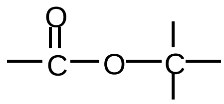
Homologous series	General formula
Alkanes	C_nH_{2n+2}
Alkenes	C_nH_{2n}
Alkynes	C_nH_{2n-2}
Haloalkanes	$C_nH_{2n+1}X$
Alcohols	$C_nH_{2n+1}OH$
Aldehydes	$C_nH_{2n}O$
Ketones	$C_nH_{2n}O$
Carboxylic acids	$C_nH_{2n}O_2$
Esters	$C_nH_{2n}O_2$

8.1.3 Functional groups

A functional group is a bond, an atom or a group of atoms that determine(s) the physical and chemical properties of a group of organic compounds. The functional groups of the nine homologous series' that you must learn are listed in table 2 below.

Table 2: Functional groups of organic compounds

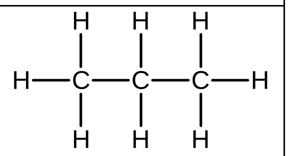
Homologous series	Structure of functional group	
	Structure	Name/Description
Alkanes		Only C-H and C-C single bonds
Alkenes		Carbon-carbon double bond
Alkynes		Carbon-carbon triple bond
Haloalkanes	 (X = F, Cℓ, Br, I)	Halogen atom bonded to a saturated C atom
Alcohols		Hydroxyl group bonded to a saturated C atom

Homologous series	Structure of functional group	
	Structure	**Name/Description**
Aldehydes		Formyl group
Ketones		Carbonyl group bonded to two C atoms
Carboxylic acids		Carboxyl group
Esters		-

8.1.4 Representing organic molecules

When representing organic molecules, different types of formulae and structures may be used. Table 3 below summarises the different types of formulae and structures that can be used.

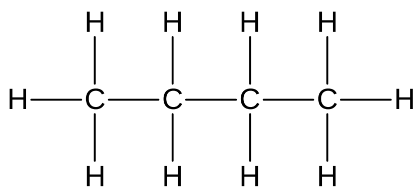
Table 3: Representation of organic molecules

Type of formula	Definition	Example
Molecular formula	A chemical formula that indicates the type of atoms and the correct number of each in a molecule.	C_3H_8
Structural formula	A structural formula of a compound shows which atoms are attached to which within the molecule. Atoms are represented by their chemical symbols and lines are used to represent ALL the bonds that hold the atoms together.	

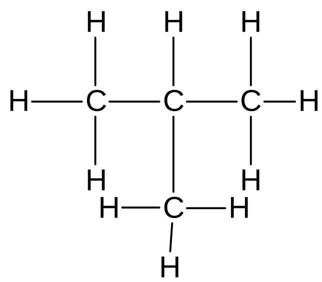
8.1.5 Isomerism

Isomers are compounds with the same molecular formula, but different structures.

Structural isomers are compounds with the same molecular formula, but different structural formulae.



Butane



2-methylpropane

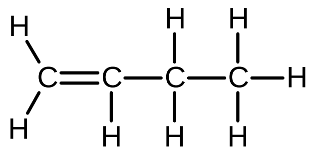
These two compounds have the same number and type of atoms, but are different compounds due to the different arrangement of the atoms.

Structural isomers can be further divided into chain isomers, positional isomers and functional isomers.

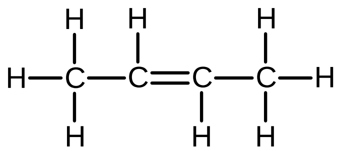
- **Chain isomers**
  Chain isomers have the same molecular formula, but different types of chains. Butane and 2-methylpropane are chain isomers.

- **Positional isomers**
  Positional isomers have the same molecular formula, but different positions of the side chain, substituents or functional groups on the parent chain. Examples of positional isomers are shown below.

Different positions of the functional group

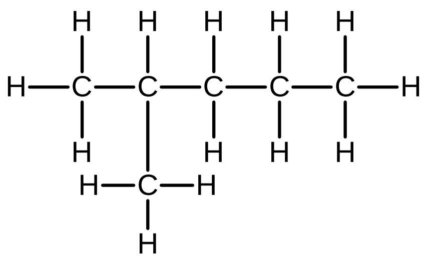


But-1-ene

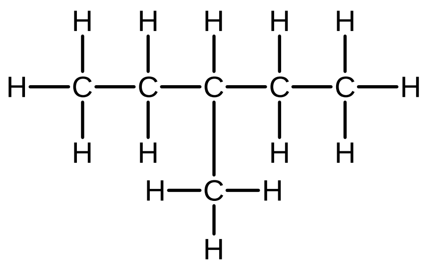


But-2-ene

Different positions of the side chain or substituent

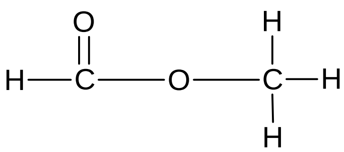


2-methylpentane

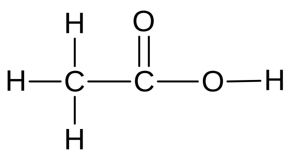


3-methylpentane

- **Functional isomers**
  Functional isomer have the same molecular formula, but different functional groups, e.g. methyl methanoate and ethanoic acid.



methyl methanoate



ethanoic acid

8.1.6 Nomenclature of organic compounds

The IUPAC name of every organic molecule has three parts:

- The **parent name** indicates the number of C atoms in the longest continuous carbon chain in the molecule.
- The **suffix** indicates what functional group is present.

- The **prefix** reveals the identity, location and number of substituents attached to the carbon chain.

prefix	parent	suffix
What and where are the substituents?	How many carbons?	What is the functional group/homologous series?

Functional groups are indicated in Table 1. Table 4 shows the parent names used for compounds containing one to six carbon atoms in the parent chain.

Table 4: Parent name for one to eight carbon atoms

Number of carbon atoms	Parent name	Number of carbon atoms	Parent name
1	meth	4	but
2	eth	5	pent
3	prop	6	hex

8.1.6.1 IUPAC names of hydrocarbons

Hydrocarbons are compounds consisting of carbon and hydrogen only. These compounds include alkanes, alkenes and alkynes.

(a) Alkanes

Fast facts

- Alkanes are organic compounds containing ONLY C-H and C-C single bonds.
- General formula: C_nH_{2n+2}
- Functional group: Only C-H and C-C single bonds
- Alkanes are saturated hydrocarbons
  Why hydrocarbons? They consist of hydrogen and carbon atoms only.
  Why saturated? They have only C-C single bonds or each C atom is bonded to the maximum number of atoms i.e. four.
- Many alkanes occur in nature, mainly as natural gas and petroleum, which are both non-renewable sources of energy. Natural gas is mainly methane, the first alkane in the series. Petrol consists mainly of the alkanes containing from six to twelve carbon atoms.

RULES for naming Alkanes

Step 1: Name the parent hydrocarbon.

- Use the longest continuous chain as parent containing the functional group.
- If two chains of the same length, choose one with larger number of substituents.
- Choose the parent name, e.g pent for 5 C atoms in longest chain.
- Add the suffix –ane

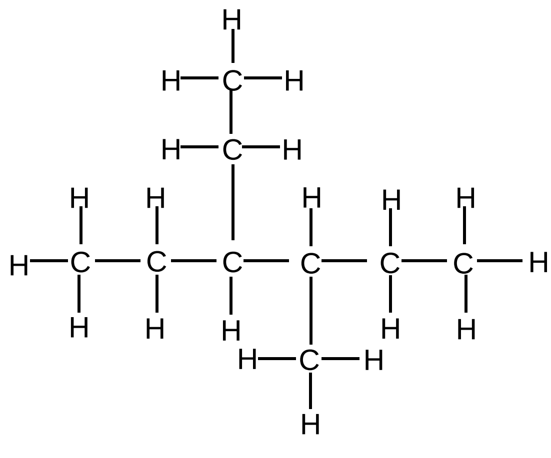
Step 2: Number the atoms in the parent chain.

- Begin at the nearest to the first substituent, number each C atom in parent chain.
- If two substituents are an equal distance away from both ends, begin numbering at the end nearer to the second substituent.
- If two different substituents can have the same number, alphabetically first substituent obtains the lower number.

Step 3: Identify and number substituents.

- Name substituents according to number of C atoms, add suffix –yl. (CH_3 – methyl group, CH_3CH_2 – ethyl).
- Assign number to each substituent according to its point of attachment to the parent chain.
- If two substituents on the same Carbon, they get the same number.
- I more than on type of substituent present, arrange them alphabetically in front of the parent name'.
- If two or three identical substituents are present, use *di* or *tri* as prefix. Do not use these prefixes for alphabetic purposes.
- Use hyphens to separate numbers and prefixes, commas to separate numbers.

Example 1



The IUPAC name of the accompanying compound can be determined as follows:

- The compound is a hydrocarbon with only C-C single bonds – an alkane. The name ends on *–ane*.
- The longest chain contains 6 C atoms - the parent name is *hex-*.
- One substituent has 1 C atom - *methyl* group. Another substituent contains 2 C atoms - an *ethyl* group.
- Numbered from the left, the *methyl* group is on C4 and the *ethyl* group on C3. Numbered from the right, the *methyl* group is on C3 and the *ethyl* group on C4. Numbering from either side gives the same result, but alphabetically *ethyl* comes before *methyl.* Commas separate numbers, while hyphens separate numbers and prefixes.

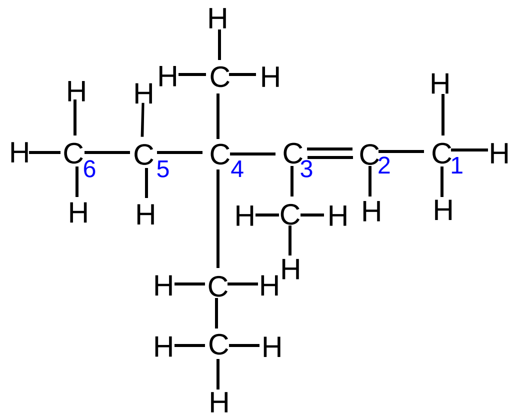
The compound is **3-ethyl-4-methylhexane**.

(b) Alkenes

Fast facts

- An alkene is a compound of carbon and hydrogen that contains a **carbon-carbon double bond.**
- General formula: C_nH_{2n}
- Functional group: carbon-carbon double bond
- Alkenes are **unsaturated hydrocarbons.**
  Why hydrocarbons? They consist of hydrogen and carbon atoms only.
  Why unsaturated? They have carbon-carbon double bonds.

Example 2



The IUPAC name of the accompanying compound can be determined as follows:

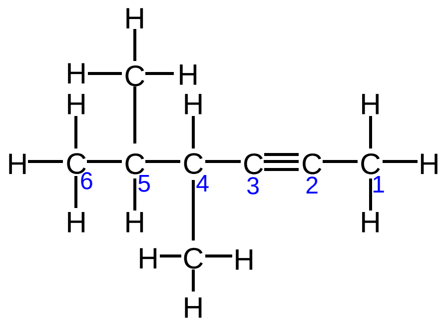
- The compound is a hydrocarbon with a carbon-carbon double bond – an alkene. The name ends on *–ene*.
- The longest chain containing the double bond has 6 C atoms - the parent name is *hex-*.
- If numbered from the right, the double bond is after C2. If numbered from the left, the double bond is after C4. The former gives the double bond the lower number.
- Place the number -2- of the double bond between the parent name and the suffix. Use a hyphen between the number and the suffix and between the number and the parent name.
- The substituents are on C3 and C4. *Ethyl* before *methyl* and *two methyl* groups become *dimethyl*. The compound is **4-ethyl-3,4-dimethylhex-2-ene**.

(c) Alkynes

Fast facts

- An alkyne is a compound of carbon and hydrogen that **contains a carbon-carbon triple bond.**
- General formula: C_nH_{2n-2}
- Functional group: carbon-carbon triple bond
- Alkynes are **unsaturated hydrocarbons.**
  Why hydrocarbons? They consist of hydrogen and carbon atoms only.
  Why unsaturated? They have carbon-carbon triple bonds.
- The **first alkyne** in the homologous series, **ethyne** (acetylene, H−C≡C−H) is a colourless gas that burns in oxygen to form CO_2 and H_2O. The combustion of acetylene releases more energy per mole of product formed than any other hydrocarbons. It burns with a very hot flame and is an excellent fuel.

Example 3



The IUPAC name of the accompanying compound can be determined as follows:

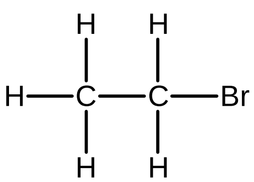
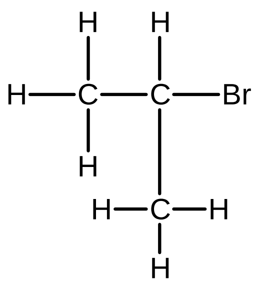
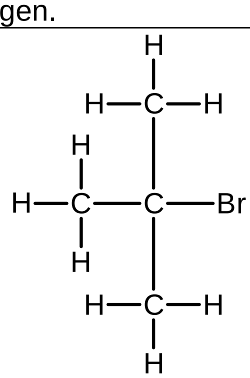
- The compound is a hydrocarbon with a carbon-carbon triple bond – an alkyne. The name ends on *–yne*.
- The longest chain containing the triple bond has 7 C atoms - the parent name is *hex*-.
- Numbered from the other end of the chain, the triple bond is after C2. Numbered from the left, the triple bond is after C5. The former gives the lower number.
- Place the number -2- of the triple bond between the parent name and the suffix. Use a hyphen between the number and the suffix and between the number and the parent name.
- The substituents, two *methyl* groups, are on C4 and C 5.
  The compound is **4,5-dimethylhex-2-yne**.

8.1.6.2 IUPAC names of other homologous series

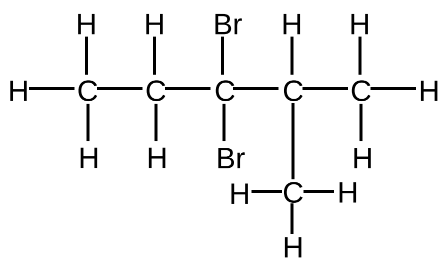
(a) Haloalkanes

Fast facts

- A haloalkane (or an alkyl halide) is an organic compound in which **one or more H atoms in an alkane have been replaced with halogen atoms.**
- General formula: $C_nH_{2n+1}X$ (X = F, Cℓ, Br or I)
- Functional group: a halogen bonded to a saturated C atom i.e. a C atom forming four single bonds
- Haloalkanes can be classified as primary, secondary or tertiary depending on the number of C atoms bonded to the carbon with the halogen.

Primary haloalkane	**Secondary haloalkane**	**Tertiary haloalkane**
One C atom is bonded to the C atom bonded to the halogen.	Two C atoms bonded to the C atom bonded to the halogen.	Three C atoms bonded to the C atom bonded to the halogen.
		

Example 4



The IUPAC name of the accompanying compound can be determined as follows:

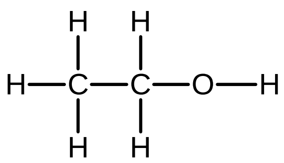
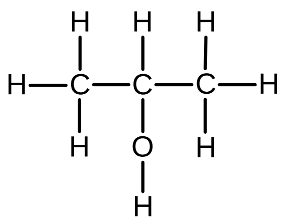
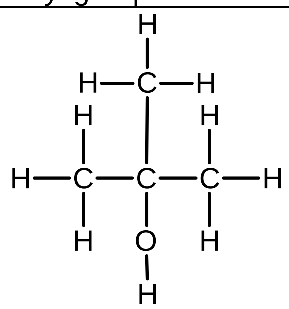
- The compound is an alkane containing two halogen atoms – a haloalkane. The longest chain contains 5 C atoms - the parent name is *pentane*.

- Three substituents are present: a *methyl* group and two bromine atoms. Numbered from the left, the *methyl* group is on C4, and the Br atoms on C3. Numbered from the right, the *methyl* group is on C2, and the Br atoms on C3. The latter gives the lower numbers.
- Alphabetically *bromo* comes before *methyl*. The compound is **3,3-dibromo-2-methylpentane**.

(b) Alcohols

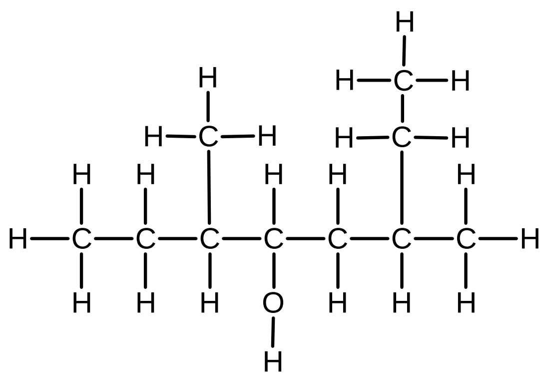
Fast facts

- An alcohol (or alkanol) is an organic compound in which **H atoms in an alkane have been substituted with hydroxyl groups (-OH groups).**
- General formula: $C_nH_{2n+1}OH$
- Functional group: a hydroxyl group (- OH) bonded to a saturated C atom (sp^3 C atom)
- Alcohols are regarded as organic derivatives of water in which one H atom of water is replaced by an organic group.
- Methanol (CH_3OH) and ethanol (CH_3CH_2OH) are two of the most important industrial chemicals. Methanol is toxic to humans and causes blindness in small doses. Ethanol is, apart from numerous other industrial uses, used in alcoholic beverages.
- Alcohols can be classified as **primary, secondary or tertiary** depending on the number of C atoms bonded to the carbon atom containing the hydroxyl group.

Primary alcohol	Secondary alcohol	Tertiary alcohol
One C atom is bonded to the carbon bonded to hydroxyl group.	Two C atoms bonded to the carbon that is bonded to hydroxyl group.	Three C atoms bonded to carbon that is bonded to hydroxyl group
		

Example 5

The IUPAC name of the accompanying compound can be determined as follows:



- The compound is an alkane containing a *hydroxyl* group – an alcohol. The suffix *–ol* replaces the *-e* in the corresponding alkane.
- The longest chain containing the hydroxyl group has 8 C atoms - the parent name is *oct-.*
- Numbered from the right, the *hydroxyl* group is on C5. Numbered from the left it is on C4. The latter gives the lower number. The number is written between the parent name and the suffix. Hyphens separate the number from the parent name and from the suffix i.e. octan-4-ol.
- Two substituents are present: two *methyl* groups on C3 and C6. The compound is **3,6-dimethyloctan-4-ol**.

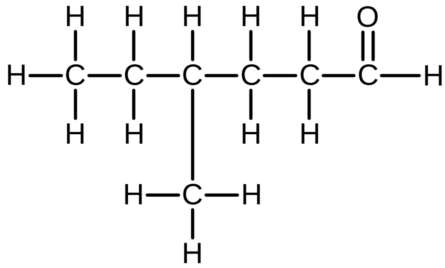
(c) Aldehydes

Fast facts

- Aldehydes are organic compounds having the general structure RCHO where R = H or alkyl.
- General formula: RCHO (R = alkyl group)
- Functional group: -CHO i.e. a carbonyl group (>C=O, pronounced car-bo-**neel**) with at least one H atom bonded to the carbonyl C atom. The -CHO group is called a formyl group.
- The **first aldehyde** in the homologous series, **methanal,** is an important industrial chemical. It is used in the production of many plastics. Its common name is **formaldehyde** and its aqueous solution is sold as formalin used as preservative for biological specimens.

Example 6

The IUPAC name of the accompanying compound can be determined as follows:



- The compound contains a –CHO group – an aldehyde. The suffix *–al* replaces the *-e* in the name of the corresponding alkane.
- The longest chain containing the –CHO group has 6 C atoms - the parent name is *hex-.* The compound is a *hexanal.*
- One substituent is present: a *methyl* group on C4 (the carbonyl C atom is always C1). The compound is **4-methylhexanal**.

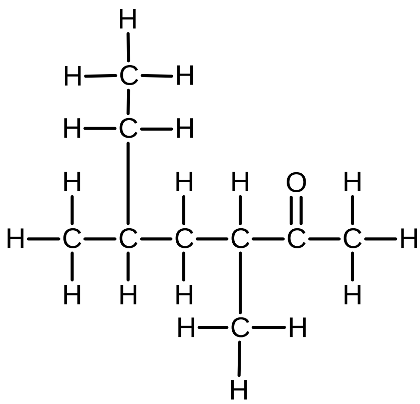
(d) Ketones

Fast facts

- Ketones are organic compounds with two alkyl groups (R and R') bonded to the carbon atom of a carbonyl group.
- General formula: RCOR' (R & R' = alkyl groups)
- Functional group: a carbonyl group (>C=O, pronounced car-bo-**neel**) with two alkyl groups bonded to it (keto group)
- The **first third ketone** in the homologous series, **propan-2-one** (or just propanone), is well known as **acetone**. It is an industrial solvent.

Example 7

The IUPAC name of the accompanying compound can be determined as follows:



- The compound contains a RCOR' group – a ketone. The *–e* in the corresponding alkane is replaced with *-one*.
- The longest chain containing the carbonyl group has 7 C atoms - the parent name is *hept.*
- Numbered from the left, the carbonyl C atom is C6. Numbered from the right it is C2. The latter gives the lower number. The number is written between the parent name and the suffix. Hyphens separate the number from the parent name and from the suffix, i.e. heptan-2-one.
- Two substituents are present: two *methyl* groups on C3 and C5.
- The compound is **3,5-dimethylheptan-2-one.**

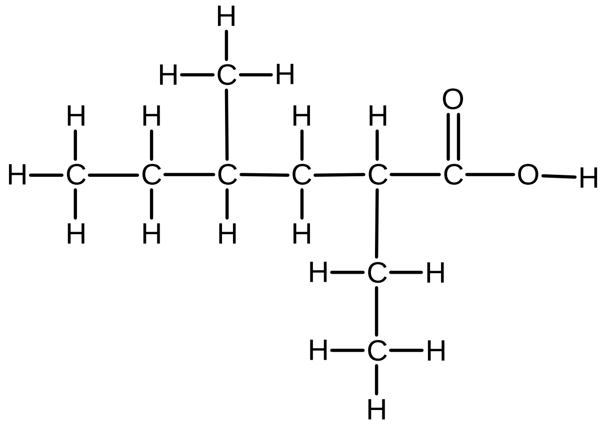
(e) Carboxylic acids

Fast facts

- A carboxylic acid is an organic compound containing a carboxyl group (-COOH group). Carboxylic acids have the general structure RCOOH.
- General formula: $C_nH_{2n+1}COOH$ (or RCOOH)
- Functional group: a carboxyl group (-COOH) bonded to a saturated C atom (sp^3 C atom)
- Many carboxylic acids are found in nature. Methanoic acid (HCOOH), the first carboxylic acid in the homologous series, has a biting taste and is responsible for the sting of some ants. Ethanoic acid (CH_3COOH), the second carboxylic acid, is sour component of vinegar. Oxidation of ethanol to ethanoic acid causes "bad" wine to taste sour.

Example 8

The IUPAC name of the accompanying compound can be determined as follows:



- The compound contains a –COOH group – a carboxylic acid. The suffix *–oic acid* replaces the *-e* in the corresponding alkane.
- The longest chain containing the carboxyl group has 6 C atoms – the parent name is *hex-*.
- Two substituents are present. The carboxyl C atom is always C1, but the number is not shown in the name. An ethyl group is on C2 and a methyl group on C4. Hyphens separate numbers and prefixes.

The compound is **2-ethyl-4-methylhexanoic acid.**

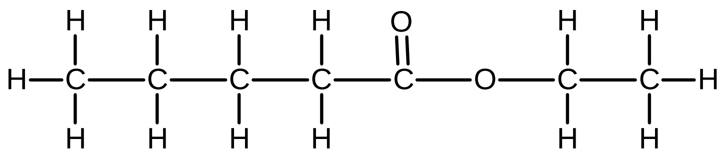
(f) Esters

Fast facts

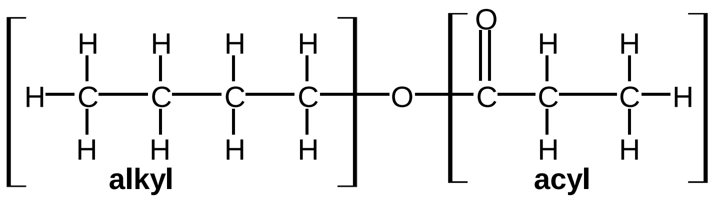
- An ester is an organic compound with the general structure RCOOR' (R = H or alkyl group; R' = alkyl group).
- General formula: RCOOR'
- Functional group: –COOR' (R'= alkyl group)
- Esters are derivatives of carboxylic acids and can be prepared by the reaction of an alcohol and a carboxylic acid.
- Many esters have pleasant and very characteristic odours.
- The name of an ester has two parts: the first part comes from the alcohol and the last part from the carboxylic acid from which it is derived.

Example 9

The IUPAC name of the accompanying compound can be determined as follows:



- The compound contains a --COOR group – an ester.
- The ester has two groups, an alkyl and an acyl, that are named separately:



- The **alkyl group** (originally form butanol) has 4 C atoms. The parent alkane, butane, is changed to an alkyl group, i.e. *butyl*. This is the first part of the name of the ester.
- The **acyl group** (originally from propanoic acid) has 3 C atoms. The parent acid is propanoic acid. The *–ic* in the name is changed to *–ate*, i.e. propanoate. This is the second part of the name of the ester.
- The name of the compound is **butyl propanaoate**.

8.2 Physical Properties.

8.2.1 Boiling point.

8.2.2 Melting point.

8.2.3 Vapour pressure.
8.2.4 Viscosity.

8.3 Plastics and Polymers.

- Recycling.
- Polymerisation.
- Industrial use of polythene.

Activity 8.1

Question 1

Give one word or term for each of the following statements.

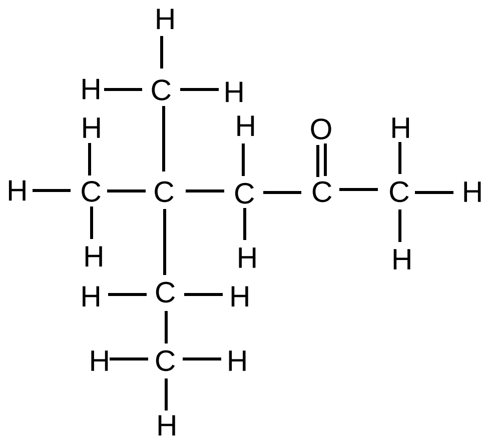
1.1 Organic compounds with the functional group –OH
1.2 The homologous series to which propan-2-one belongs
1.3 The IUPAC name of the alkene with two carbon atoms
1.4 The homologous series to which the compound $CH_3C\ell$ belongs
1.5 The general term that describes compounds that consist of hydrogen and carbon atoms only
1.6 The homologous series to which H – C Ξ C – H belongs
1.7 The IUPAC name of the first aldehyde in the homologous series
1.8 Atoms, groups of atoms or bonds that give a homologous series its characteristic properties
1.9 The IUPAC name of the first alkyne in the homologous series
1.10 The IUPAC name of the first ketone in the homologous series
1.11 A group of organic compounds with the carbonyl group as functional group
1.12 An atom or a group of atoms that gives an organic compound its chemical properties
1.13 Hydrocarbons containing triple bonds
1.14 Alkanes in which a hydrogen atom has been substituted by a halogen atom
1.15 Compounds with the same molecular formula but different structural formulae

QUESTION 2

Consider the organic compounds labelled **A – C**.

A $CH_3CH_2CH_2CH_2CH_2CH_3$

B



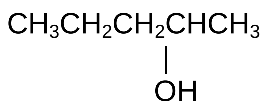
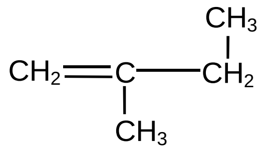
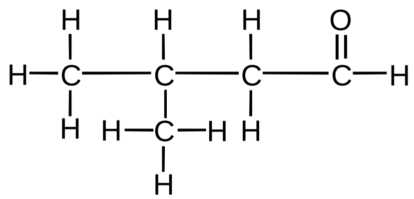
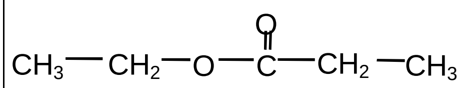
C CH_2CH_2

2.1 To which homologous series does compound **C** belong?
2.2 Compound **C** reacts with chlorine gas in an inert solvent. Using structural formulae, write a balanced equation for the reaction that takes place.
2.3 Write down the IUPAC name for compound **B**.
2.4 Write down the structural formula of an isomer of compound **A** that has only FOUR carbon atoms in the longest chain.

Activity 8.2

Question 1

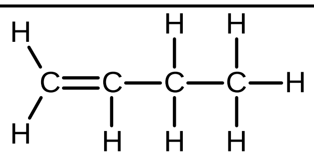
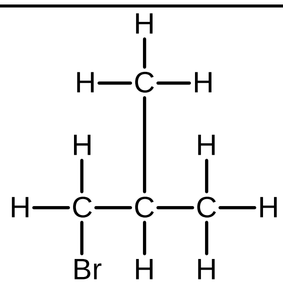
The letters **A** to **F** in the table below represent six organic compounds.

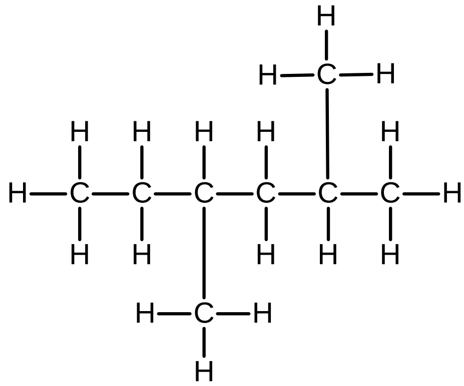
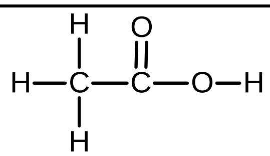
A	$CH\equiv C-CH_2-CH_2-CH_3$	**B**	
C		**D**	Pentanoic acid
E		**F**	

1.1 Write down the letter(s) that represent(s) each of the following:
1.1.1 An alkyne
1.1.2 Two compounds that are structural isomers
1.1.3 A compound containing a carboxyl group
1.1.4 An aldehyde
1.1.5 An alcohol
1.2 Write down the:
1.2.1 IUPAC name of compound **C**
1.2.2 Structural formula of compound **D**
1.3 Compound **F** is prepared in the laboratory.
1.3.1 How can one quickly establish whether compound **F** is indeed being formed?
1.3.2 Write down the IUPAC name of the alcohol needed to prepare compound **F**.
1.3.3 Write down the IUPAC name of compound **F**.

Question 2

The chemical properties of organic compounds are determined by their functional groups. The letters **A** to **F** in the table below represent six organic compounds.

A		**B**	

C		**D**	Methanal
E		**F**	Methyl methanoate

2.1 Write down the LETTER that represents the following:
2.1.1 An alkene
2.1.2 An aldehyde
2.2 Write down the IUPAC name of the following:
2.2.1 Compound **B**
2.2.2 Compound **C**
2.3 Write down the structural formula of compound **D**.
2.4 Write down the IUPAC name of the carboxylic acid shown in the table.
2.5 Write down the structural formula of compound **F**.

Activity 8.3

QUESTION 1

Four compounds of comparable molecular mass are used to investigate the effect of functional groups on vapour pressure. The results obtained are shown in the table below.

COMPOUND		VAPOUR PRESSURE (kPa at 20 °C)
A	Butane	204
B	Propan-2-one	24,6
C	Propan-1-ol	2
D	Ethanoic acid	1,6

1.1 Define the term functional group of an organic compound.
1.2 Which ONE of the compounds (A, B, C or D) in the table has the:
1.2.1 Highest boiling point
(Refer to the vapour pressures in the table to give a reason for the answer.)
1.2.2 Weakest intermolecular forces.
1.3 Refer to the type of intermolecular forces to explain the difference between the vapour pressure of compound **A** and compound **B**.

1.4 The vapour pressures of compounds **C** and **D** are much lower than those of compounds **A** and **B**. Name the type of intermolecular force in **A** and **B** that is responsible for this difference.
1.5 Briefly explain the difference in vapour pressure between compound **C** and compound **D**.

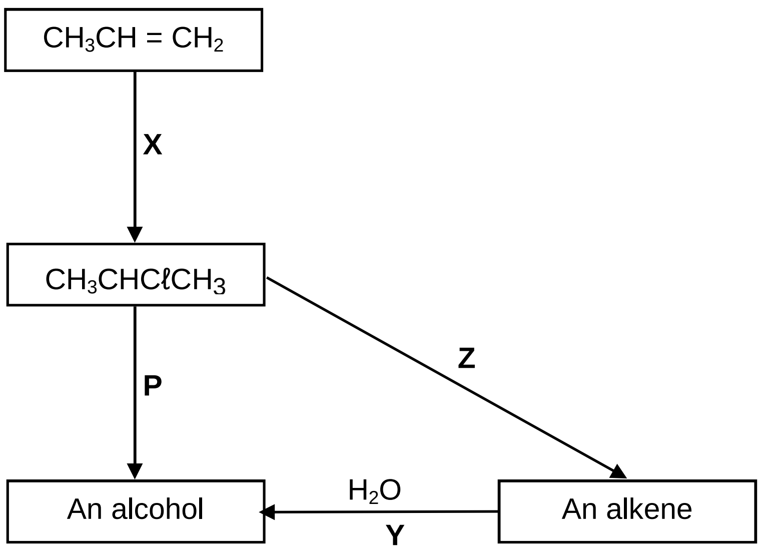
QUESTION 2
The table below shows the results obtained from experiments to determine the boiling points of some alkanes and alcohols of comparable molecular masses.

Compound	Relative molecular mass	Boiling point (°C)
CH_3CH_3	30	-89
CH_3OH	32	65
$CH_3CH_2CH_3$	44	-42
CH_3CH_2OH	46	78
$CH_3CH_2CH_2CH_3$	58	0
$CH_3CH_2CH_2OH$	60	97
$CH_3CH_2CH_2CH_2CH_3$	72	36
$CH_3CH_2CH_2CH_2CH_2OH$	74	117

2.1 Define the term boiling point.
2.2 Consider the boiling points of the four alkanes given in the above table.
2.2.1 Describe the trend in their boiling points.
2.2.2 Fully explain the trend in QUESTION 2.2.1.

Activity 8.4

QUESTION 1
The flow diagram below shows the preparation of different organic compounds using $CH_3CH = CH_2$ as starting material. **X**, **Y**, **Z** and **P** represent different organic reactions.



1.1 To which homologous series does $CH_3CH = CH_2$ belong?
1.2 Write down the:
1.2.1 Type of reaction of which **X** is example
1.2.2 Structural formula and IUPAC name of the alcohol produced during reaction **P**.

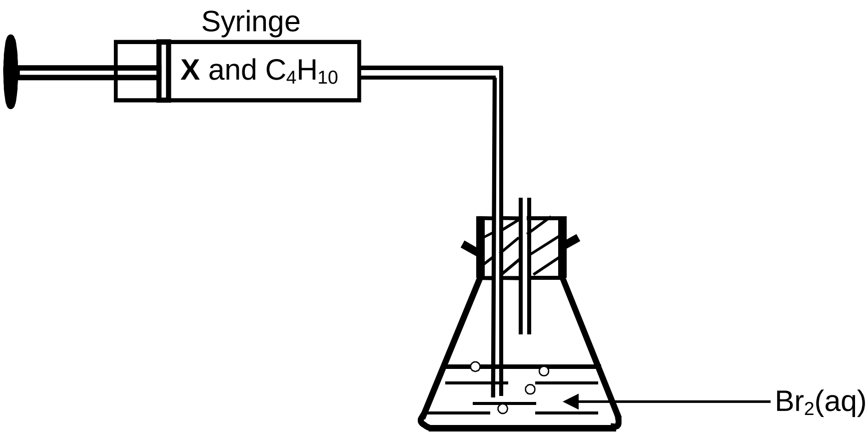
1.2.3 Type of reaction of which **Y** is example
1.2.4 Is the Alcohol produced by reaction **Y,** Primary, Secondary or Tertiary?
2.3 For reaction **Y**, write down:
2.3.1 The NAME of the other reagent needed
2.3.2 A balanced equation for the production of the alcohol, using structural formulae.
2.4 To which homologous series does $CH_3CHC\ell CH_3$ belong?
2.5 Give the IUPAC name of $CH_3CHC\ell CH_3$.

QUESTION 2

Butane (C_4H_{10}) is produced in industry by the THERMAL cracking of long-chain hydrocarbon molecules, as shown in the equation below. **X** represents an organic compound that is produced.

$$C_{10}H_{22} \rightarrow \mathbf{X} + C_4H_{10}$$

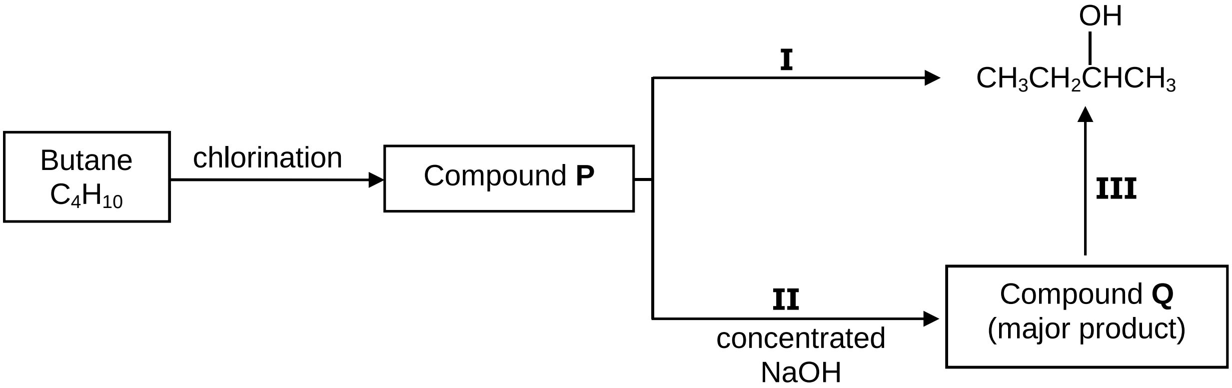
2.1 Write down:
2 .1.1 The balanced chemical equation for the complete combustion of $C_{10}H_{22}$ in excess oxygen.
2.1.2 ONE condition required for THERMAL cracking to take place.
2.1.3 The molecular formula of compound **X.**
2.1.4 The homologous series to which compound **X** belongs.
2.2 A mixture of the two gases, compound **X** and butane, is bubbled through bromine water, $Br_2(aq)$, in a conical flask, as illustrated below. THE REACTION IS CARRIED OUT IN A DARKENED ROOM.



The colour of the bromine water changes from reddish brown to colourless when the mixture of the two gases is bubbled through it.

2.2.1 Which ONE of the gases (**X** or BUTANE) decolourises the bromine water? Explain the answer.
2.2.2 Write a balanced chemical equation using structural formula for reaction in QUESTION 2.2.1

2.3 Study the flow diagram below, which represents various organic reactions, and answer the questions that follow.



Write down the:

2.3.1 Structural formula and IUPAC name of compound **P**
2.3.2 Type of reaction labelled **I**
2.3.3 Structural formula of compound **Q**
2.3.4 The type of addition reaction represented by reaction **III**