JENN

Training and Consultancy

The path to enlightened education

SUBJECT: TECHNICAL SCIENCES

GRADE 12

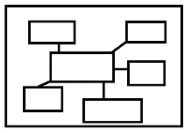
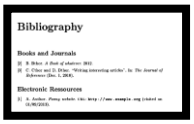
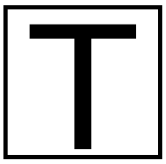
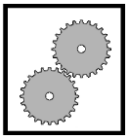
AUTUMN CLASSES

TEACHER AND LEARNER CONTENT MANUAL

ORGANIC CHEMISTRY

1. Organic Molecules and Nomenclature
2. Physical Properties
3. Chemical Properties (Organic Reactions)

ICON DESCRIPTION

 MIND MAP	 EXAMINATION GUIDELINE	 CONTENTS	 ACTIVITIES
 BIBLIOGRAPHY	 TERMINOLOGY	 WORKED EXAMPLES	 STEPS

CONTENTS **PAGE**

1. ORGANIC MOLECULES AND NOMENCLATURE

Examination Guidelines

Matter and Materials: Organic Chemistry
(This section must be read in conjunction with the CAPS, p. 46–47.)

Molecular and structural functional groups, saturated and unsaturated structures, isomers

• Define organic molecules as molecules containing carbon atoms.
• Hydrocarbons are organic compounds containing only carbon atoms and hydrogen atoms.
• Write down molecular and structural formulae of organic compounds of up to six carbons for:
  o Alkanes (no ring structures)
  o Alkenes (no ring structures)
  o Alkynes
  o Alkyl halides (Haloalkanes) (primary, secondary and tertiary haloalkanes; no ring structures)
  o Aldehydes
  o Ketones
  o Alcohols (primary, secondary and tertiary alcohols)
  o Carboxylic acids
  o Esters

Distinguish between:
• Different homologous series
• Saturated and unsaturated hydrocarbons
• Identify compounds up to six carbon atoms that are saturated, unsaturated and are structural isomers.
• Know the general formulae of different homologous series.
• Hydrocarbons are organic compounds that consist of hydrogen and carbon only.
• Saturated hydrocarbons contain only single covalent bonds between carbon atoms.
• Unsaturated compounds contain covalent double or triple bonds between the carbon atoms.

Definitions
• Functional group: An atom or a group of atoms that determine the chemistry of a molecule OR determine(s) the physical and chemical properties of a group of organic compounds.
• Homologous series: A series of organic compounds that can be described by the same general formula and where each member differs from the next by a CH2 group.
• Structural isomers: Organic molecules with the same molecular formula, but different structural formulae.
• Chain isomers, positional isomers and functional isomers.

Chain isomers have the same molecular formula, but different types of chains, e.g. butane and 2-methylpropane.
Positional isomers have the same molecular formula, but different positions of the side chain, substituents or functional groups on the parent chain, e.g. 1-chloropropane and 2-chloropropane or but-2-ene and but-1-ene.
Functional isomers have the same molecular formula, but different functional groups, e.g. methyl methanoate and ethanoic acid.

IUPAC Naming and Formulae
• Write down the IUPAC name when given the structural formula for alkanes, alkenes, alkynes, alkyl halides (haloalkanes), aldehydes, ketones, alcohols, carboxylic acids and esters.
• Write down the structural formula when given the IUPAC name.
• Identify alkyl substituents (methyl- and ethyl-) in a chain to a maximum of TWO alkyl substituents.
• When naming haloalkanes, halogen atoms do not get preference over alkyl groups.
• Substituents appear as prefixes written alphabetically (bromo-, chloro-, ethyl-, methyl-), ignoring di- and tri-.

Physical Properties
• Discuss relationships in physical properties of alkanes, alkenes, alkynes, alkyl halides, aldehydes, ketones, alcohols, carboxylic acids and esters.
• Compare physical properties of different homologous series.
• Explain relationship between physical properties and:
  o Strength of intermolecular forces (hydrogen bonds, dipole-dipole forces, induced dipole forces)
  o Type of functional groups
  o Chain length
  o Branched chains

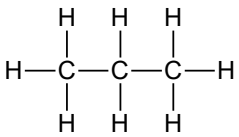
Reactions of Organic Compounds
Oxidation (combustion of hydrocarbons)
• Write down an equation for the combustion of hydrocarbons in excess oxygen.

Substitution and addition reactions
• Identify reactions as substitution or addition.
• Write equations and reaction conditions for addition reactions of alkenes:
  o Hydrohalogenation
  o Halogenation
  o Hydration
  o Hydrogenation
• Write equations and reaction conditions for substitution reactions:
  o Hydrolysis of haloalkanes
  o Hydrolysis (reaction with water)
  o Reactions of HX with alcohols
  o Halogenation of alkanes

Plastics and Polymers
• Macromolecule: A molecule that consists of a large number of atoms.
• Polymer: A large molecule composed of smaller monomer units covalently bonded in a repeating pattern.
• Monomer: Small organic molecules that can be covalently bonded in a repeating pattern.
• Polymerisation: Chemical reaction in which monomer molecules join to form a polymer.
• Plastics: Synthetic materials derived from organic compounds.
• Identify monomers from given addition polymers.
• Discuss industrial uses of polythene.

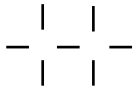
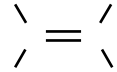
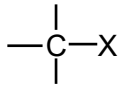
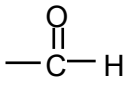
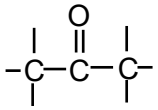
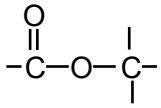
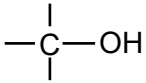
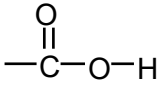
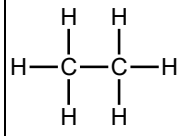
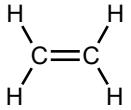
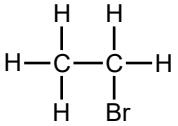
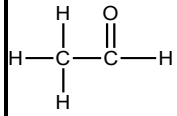
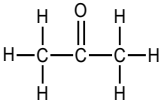
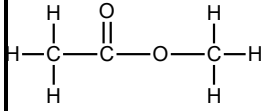
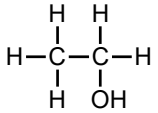
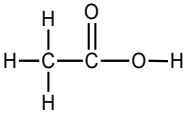
Terms and Definitions

Organic Molecule	molecules containing carbon atoms.
Homologous series	series of organic compounds that can be described by the same general formula and where each member differs from the next by a CH_2 group.
General formula	An expression used to indicate the distribution of atoms in an organic compound in a homologous series.
Functional group	An atom or a group of atoms that determine the chemistry of a molecule OR an atom or a group of atoms that determine(s) the physical and chemical properties of a group of organic compounds.
Hydrocarbon	Organic compounds containing only hydrogen and carbon.
Unsaturated hydrocarbons	contain covalent double or triple bonds between the carbon atoms
Saturated hydrocarbons	contain only single covalent bonds between carbon atoms

Type of formula	**Descriptions**	**Example**	
		Name	***Formula***
Molecular formula	indicate the type of atoms and correct number of each in a molecule.	propane	C_3H_8
Structural formula	show which atoms are attached to which within the molecule. atoms are represented by their chemical symbols lines are used to represent ALL the bonds that hold the atoms together.	propane	

Tips on drawing/writing structural formulae.

- Make sure that carbon atom is surrounded by 4 bonds (not more, not less).
- All bonds must be drawn.
- Hydrogen atoms should not be omitted.
- Functional group should be placed at the correct position.
- Use a general formula to generate the molecular formula.

ORGANIC MOLECULES									
	Hydrocarbons								
Homologous series	Alkanes	Alkenes	Alkynes	Haloalkanes	Aldehydes	Ketones	Esters	Alcohols	Carboxylic acids
General formula	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}	$C_nH_{2n+1}X$ X = F, Cℓ, Br or I	$C_nH_{2n}O$	$C_nH_{2n}O$	$C_nH_{2n}O_2$	$C_nH_{2n+1}OH$	$C_nH_{2n}O_2$
Functional group	 Only C-H and C-C single bonds Saturated	 Carbon-carbon double bond Unsaturated	 Carbon-carbon triple bond Unsaturated	 Halogen atom bonded to a saturated C atom	 Formyl group	 Carbonyl group bonded to two C atoms		 Hydroxyl group bonded to a saturated C atom	 Carboxyl group
Example structural formula									
Example of molecular formula	C_2H_6	C_2H_4	C_2H_2	C_2H_5Br	C_2H_3O	C_3H_6O	$C_3H_6O_2$	C_2H_5OH	$C_2H_4O_2$

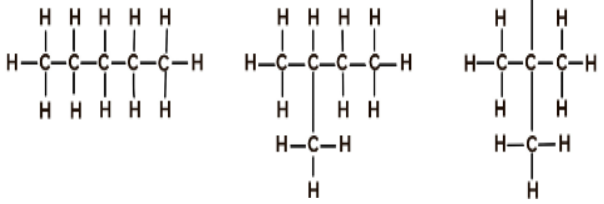
STRUCTURAL ISOMERS

Organic molecule with same molecular formula, different structural formulae.

CHAIN ISOMERS

Same molecular formula, different chains

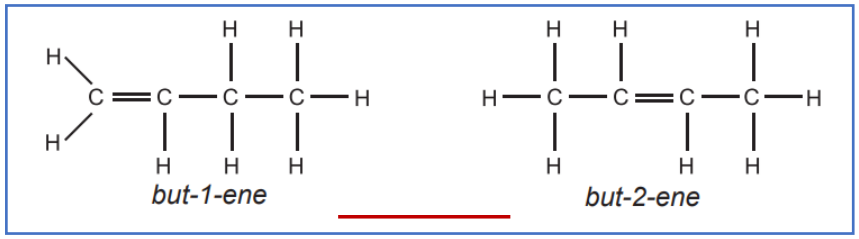
C_5H_{12}



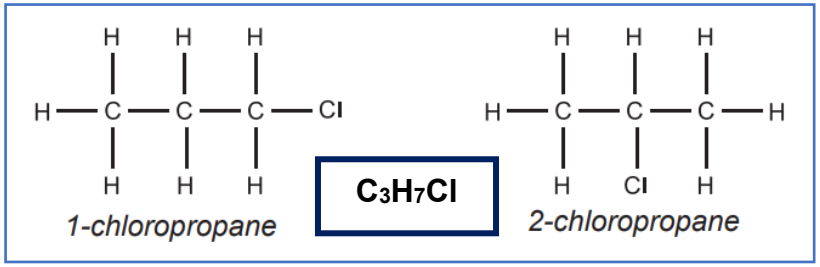
Pentane 2-Methylbutane 2,2 dimethylpropane

POSITIONAL ISOMERS

Same molecular formula, different positions of functional group or side chain.



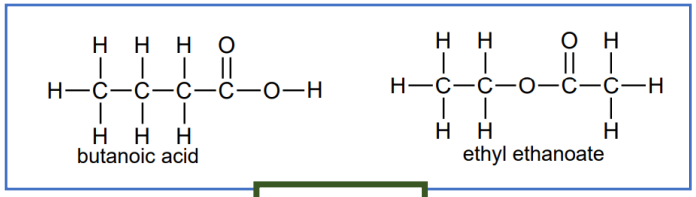
but-1-ene but-2-ene



1-chloropropane C_3H_7Cl 2-chloropropane

FUNCTIONAL ISOMERS

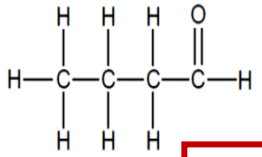
Same molecular formula, different functional groups.



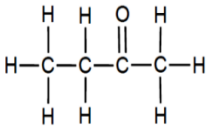
butanoic acid ethyl ethanoate

$C_4H_8O_2$

Butanal



Butan-2-one



C_4H_8O

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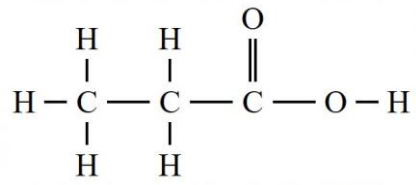
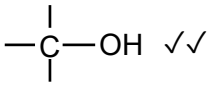
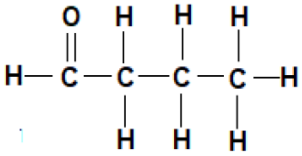
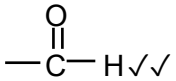
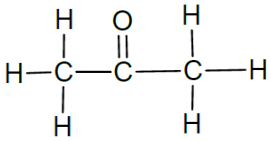
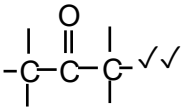
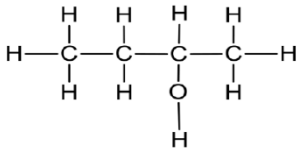
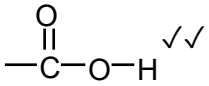
Worked Example 1

Consider the table below and identify **the homologous series** in which each of the following Organic compounds belong, draw the **structure of the functional group** and the name of the **functional group**.

Solutions

		Homologous Series	Functional Group Structure	Name of Functional Group
1.		Carboxylic Acid ✓	 ✓✓	Carboxyl group ✓
2.		Aldehyde ✓	 ✓✓	Formyl group ✓
3.		Ketone ✓	 ✓✓	Carbonyl ✓
4.		Alcohol ✓	 ✓✓	Hydroxyl ✓

Worked Example 2

1.	**Define the following Terms / Concepts**		
	1.1	Homologous Series	(2)
	1.2	Hydrocarbon	(2)
	1.3	Functional group	(2)
	1.4	Chain isomer	(2)
2.	**Distinguish between the following:**		
	2.1	Saturated and unsaturated hydrocarbons	(4)
	2.2	Positional and functional isomer	(4)

Solutions

1. **Define the following Terms / Concepts**
   1.1 **Homologous Series** a series of organic compounds that can be described by the same general formula and where each member differs from the next by a CH_2 group. ✓✓ (2)
   1.2 **Hydrocarbon** are organic compounds containing only carbon atoms and hydrogen atoms. ✓✓ (2)
   1.3 **Functional group** an atom or a group of atoms that determine the chemistry of a molecule. ✓✓ (2)
   1.4 **Chain isomers** have the same molecular formula, but different types of chains.✓✓ (2)

2. **Distinguish between the following:**
   2.1 Saturated and unsaturated hydrocarbons (4)

   2.2 Positional and functional isomer (4)

IUPAC Naming

- Determine the **functional group** in the structure of the given compound or the homologous series to which the compound belongs.
- The number of C atoms in the longest carbon chain that contains the functional group determines the **parent name**.
- Number the C atoms in the longest chain, starting with C nearer to the functional group.
- **Identify substituents** on the parent chain. Substituents can be methyl (*one C atom i.e.* $-CH_3$) or *ethyl* (*2 C atoms i.e.* $-CH_2CH_3$).
- **Use numbers on the parent chain to indicate the position of the substituents** on the parent chain.
- **Arrange substituents in alphabetical order** in the IUPAC name (*bromo, chloro, ethyl, methyl*)
- If two or more of the same substituents occur, use di- and tri- in front of the name of the substituent e.g. dimethyl or tribromo. (*Di- and tri are ignored when arranging substituents in alphabetical order.*)
- When there are two (or more) identical groups on the same C atom, the number of the C atom is repeated with commas between the numbers e.g., **2,4,4-**trimethylhexan-3-one

Alkanes, Alkene and Alkyne	
Number of Carbon Atoms	**Prefix**
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-

Alcohols, Aldehydes, Ketones, Carboxylic Acids	
Number of Carbon Atoms	**Prefix**
1	Methan-
2	Ethan-
3	Propan-
4	Butan-
5	Pentan-
6	Hexan-

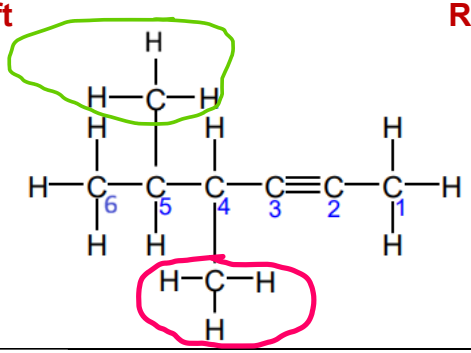
Homologous Series	Suffix
Alkanes	-ane
Alkenes	-ene
Alkynes	-yne
Alcohols	-ol
Aldehydes	-al
Ketones	-one
Carboxylic acids	-oic acid
Esters	-oate

Homologous Series	Prefix
Haloalkane	Bromo-
	Chloro-
	Floro-
Ester	Methyl-
	Ethyl-
	Propyl-

WORKED EXAMPLE

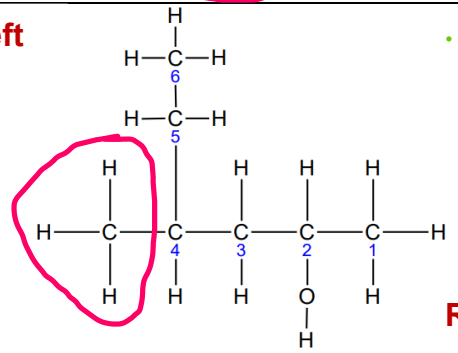
Alkenes, alkynes, alcohols, ketones: Number from the side that will give the functional group the smallest number. The functional group receives a number that is written between parent name and suffix.

Left **Right**



- The compound is an unsaturated hydrocarbon with a carbon-carbon triple bond. The Homologous Series is **Alkyne**. The name ends on –**ene.**
- The longest chain containing the triple bond has 6 C atoms - the parent name is **hex-**.
- Number from the side that will give the functional group the lowest number. Therefore, number from right: **hex-2-yne.**
- The substituents are two methyl groups on C4 and C5. Use di- in front of the name of the substituent.
- IUPAC Name: **4,5-dimethylhex-2-yne.**

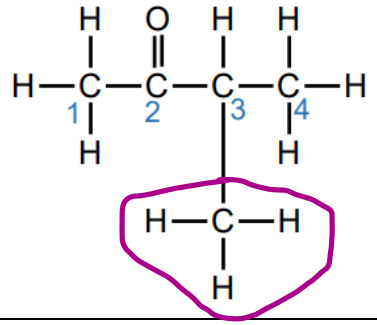
Left



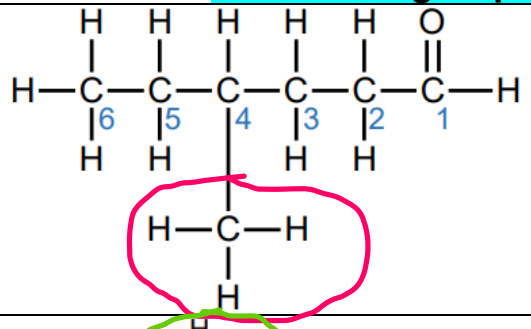
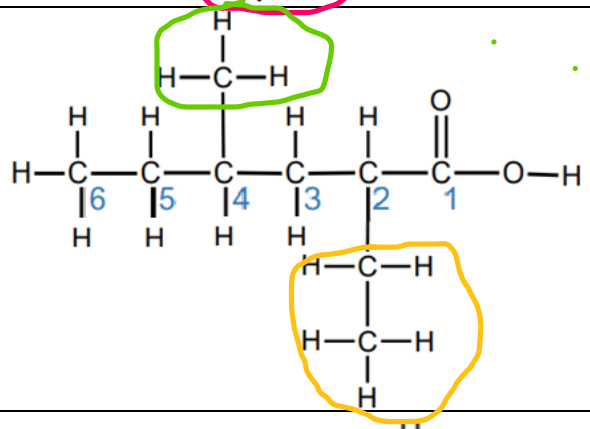
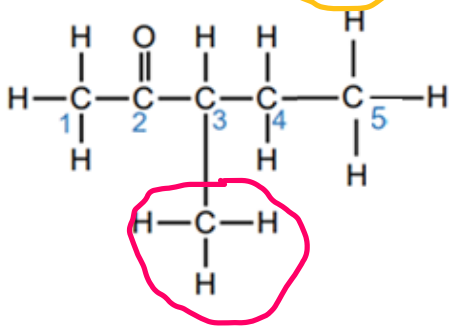
Right

- The compound contains a hydroxyl group. Homologous series is **Alcohol.** The name ends on **–ol.**
- The longest chain containing the hydroxyl group has 6 C atoms - the parent name is **hex-.**
- Number from the side that will give the functional group the lowest number. Therefore, number from right: **hexan-2-ol.**
- The substituent is a methyl group on C4.
- IUPAC Name: **4-methylhexan-2-ol**

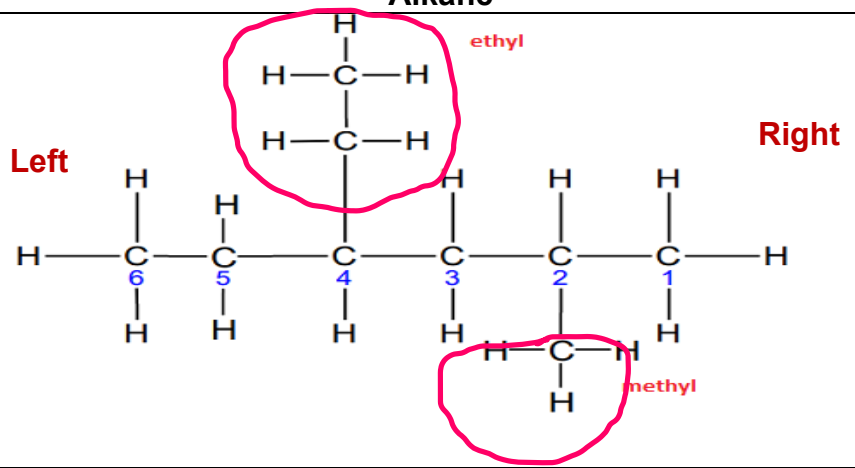
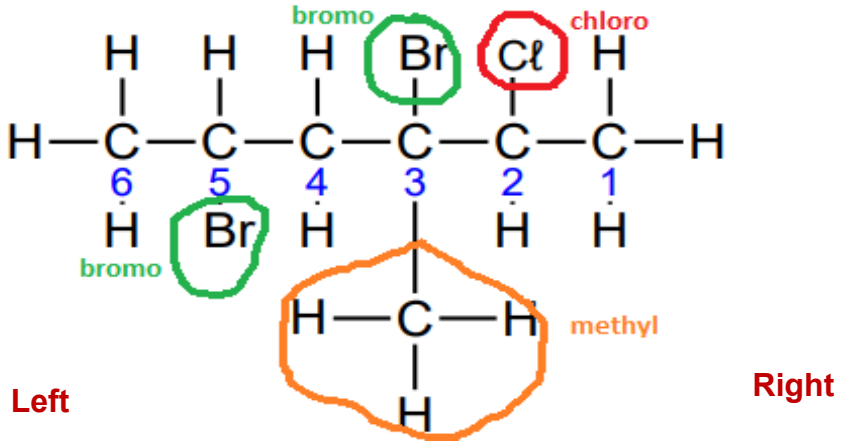
Left **Right**



- A compound contains a carbonyl group. A homologous series is a ketone. The name ends on –**one**
- The longest chain containing the carbonyl group has 4 C atoms - the parent name is but-.
- Number from the side that will give the functional group the lowest number. Therefore, number from left: **butan -2-one.**
- Substituent is methyl group on C3.
- IUPAC Name**:** **3-methylbutan-2-one**

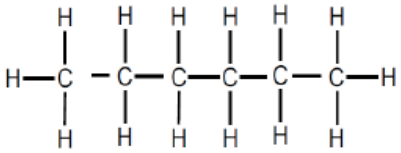
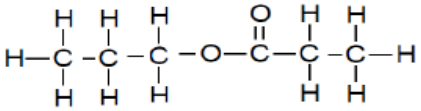
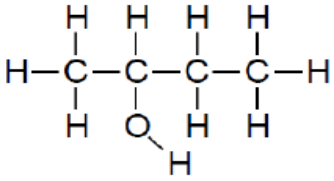
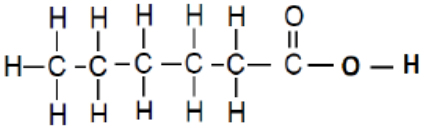
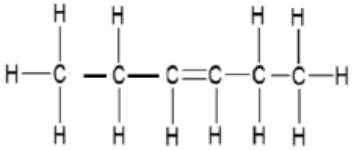
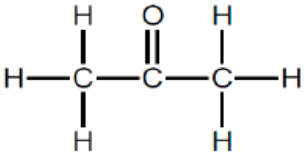
Aldehydes and carboxylic acids: Number from the C atom that forms part of the functional group. **Functional groups of aldehydes, carboxylic acids and esters are not numbered.**	
	• The compound contains a formyl (–CHO) group. The Homologous series is **Aldehyde**. The name ends on –**al.** • The longest chain containing the formyl group has 7 C atoms - the parent name is **hex-**. • Number from the C atom that forms part of the functional group. Therefore, number from right: **hexanal.** • The substituents is a methyl groups on C4. • IUPAC Name: **4-methylhexanal**
	• The compound contains a carboxyl group (-COOH). Homologous series is Carboxylic acid**.** The name ends on **–oic acid.** • The longest chain containing the carboxyl group has 6 C atoms - the parent name is **hex-.** • Number from the C atom that forms part of the functional group. Therefore, number from right: **hexanoic acid** • The substituents are ethyl group on C2 and methyl group on C4. • IUPAC Name: **2-ethyl-4-methylhexanoic acid.**
	• A compound contains a carbonyl group. A homologous series is a ketone. The name ends on –**one** • The longest chain containing the carbonyl group has 5 C atoms - the parent name is pent-. • Number from the side that will give the functional group the lowest number. Therefore, number from left: penta**n -2-one.** • Substituent is methyl group on C3. • IUPAC Name**:** **3-methylpentan-2-one**

Branched Alkanes and haloalkanes:

Alkane	Haloalkane
	
Suffix What is the functional group/homologous series?	
• Homologous series is an **alkane**. • The name ends on – **ane.**	• Homologous series is an **Haloalkane**. • The name ends on – **ane.**
Parent name Number of C atoms in the longest continues carbon chain	
• The longest chain contains 6 C atoms - the parent name is **hex-**.	• The longest chain contains 6 C atoms - the parent name is **hex-**.
Prefix What, where and how many are the substituents attached to the longest carbon chain?	
• ethyl on carbon 4 (**4-ethyl**) • methyl on carbon 2 (**2-methyl**) Numbering should be such that **the substituents have the lowest numbers** • numbering from right to left **2+4 =6** • numbering from left to right **3+5=8** • we number from right with lowest possible numbers for the substituents (**2+4 =6**).	• methyl on carbon 3 (**3-methyl**) • 2 Bromine on carbon 3 and 5 (**3,5-dibromo**) • Chlorine on carbon 2 (**2-chloro**) Numbering should be such that **the substituents have the lowest numbers** • numbering from left to right **3+3+4 =10** • numbering from right to left **3+4 +4 = 11** we number from right with lowest possible numbers for the substituents (**3+3+4 =10**).
2-methyl-3-ethylhexane	**3,5-dibromo-3-chloro-3-methylhexane**

Activity 1

Consider the organic compounds represented by the letters **A** to **G** below and answer the questions that follow.

A	Hex-2-ene	**E**	2-methylpropan-2-ol
B		**F**	
C		**G**	
D		**H**	

1.1 Define the term *hydrocarbon*. (2)

1.2 Write down the letter(s) that represents the following:

- 1.2.1 A secondary alcohol (1)
- 1.2.2 A saturated hydrocarbon (1)
- 1.2.3 Functional isomers (2)
- 1.2.4 Hydrocarbons (1)
- 1.2.5 Positional isomers (2)

1.3 Write down the IUPAC name of the following:

- 1.3.1 D (1)
- 1.3.2 H (1)
- 1.3.2 F (2)

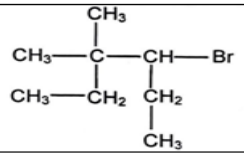
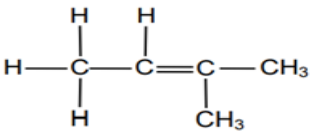
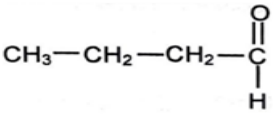
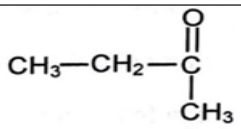
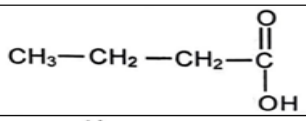
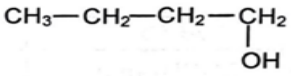
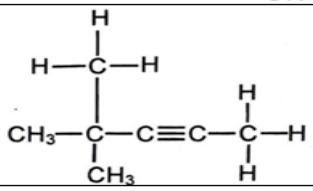
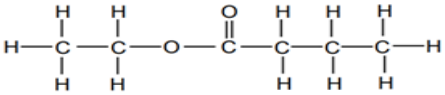
1.4 Write down the:

- 1.4.1 STRUCTURAL formula of compound **A** (2)
- 1.4.2 STRUCTURAL formula for the functional group of compound **D** (1)
- 1.4.3 MOLECULAR formula of compound **B** (1)
- 1.4.4 The name of a ketone (1)
- 1.4.5 STRUCTURAL formula of compound **E** (2)

[20]

Activity 2

The letters A to H in the table below represent eight organic compounds.

A		**B**	
C		**D**	
E		**F**	
G		**H**	

2.1 Write down the IUPAC name of:

2.1.1 Compound **A** (3)

2.1.2 Compound **B** (2)

2.1.3 Compound **C** (2)

2.1.4 Compound **D** (2)

2.1.5 Compound **E** (2)

2.1.6 Compound **F** (2)

2.1.7 Compound **G** (2)

2.1.8 Compound **H** (2)

2.2 Write down the:

2.2.1 HOMOLOGOUS SERIES to which compound **B** belongs. (1)

2.2.2 GENERAL FORMULA of the homologous series to which compound **F** belongs. (1)

2.2.3 NAME of the functional group of compound **C**. (1)

2.2.4 Letters that represent UNSATURATED hydrocarbons. (2)

2.2.5 STRUCTURAL FORMULA of the functional group of compound **C**. (1)

2.2.6 Is compound **A**, a PRIMARY, SECONDARY or TERTIARY haloalkane? Give a reason for the answer.

2.2.7 Letter that represents PRIMARY alcohol. (1)

2.2.8 Letters that represent TWO organic compounds that are isomers of each other. (1)

2.2.9 Type of isomers (CHAIN, FUNCTIONAL or POSITIONAL) identified in QUESTION 2.2.6. (1)

2.2.10 STRUCTURAL FORMULA of the functional isomer of compound **H**. (1)

[26]

Activity 3

3.1 Define the term *functional group* of organic compounds. (2)

3.2 Write down the:

3.2.1 Structural formula of the functional group of aldehydes (1)

3.2.2 Name of the functional group of carboxylic acids (1)

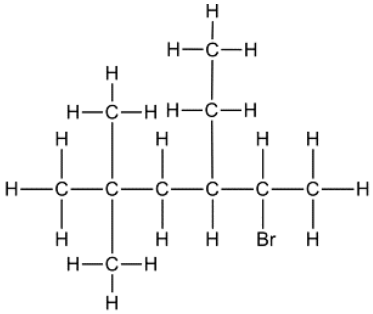
3.3 The IUPAC name of an organic compound is 2,4-dimethylhexan-3-one. For this compound, write down the:

3.3.1 Homologous series to which it belongs (1)

3.3.2 Structural formula (1)

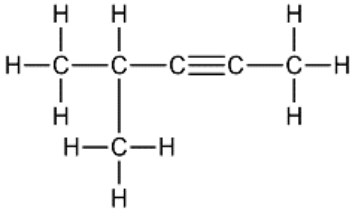
3.4 Write down the IUPAC names of the following compounds:

3.4.1



(3)

2.4.2

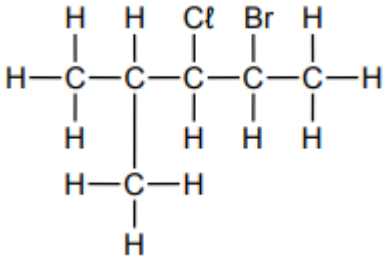


(2)

[8]

Activity 4

Consider the organic compounds represented by the letters A to D in the table below.

A	2,2,4-trimethylhexane	C	$CH_3CH_2CH_2CH_2CHO$
B		D	Pentan-2-one

4.1 Write down the LETTER that represents the following:

4.1.1 An aldehyde (1)

4.1.2 A compound which has a carbonyl group bonded to two carbon atoms as its functional group (1)

4.2 Write down the IUPAC name of compound C. (3)

4.3 Write down the structural formula of:

4.3.1 Compound A (2)

4.3.2 Compound D (2)

4.4 The table contains compounds which are functional isomers.

4.4.1 Define the term *functional isomer*. (2)

4.4.2 Write down the LETTERS that represent two compounds that are functional isomers. (1)

[12]

2. PHYSICAL PROPERTIES

- *A physical property is a characteristic of a substance that can be observed or measured without changing the identity of the substance.*
- *Physical properties include viscosity, vapour pressure, melting and boiling points*

Boiling point

The temperature at which the vapour pressure of a liquid equals atmospheric pressure.

Melting point

The temperature at which the solid and liquid phases of a substance are at equilibrium.

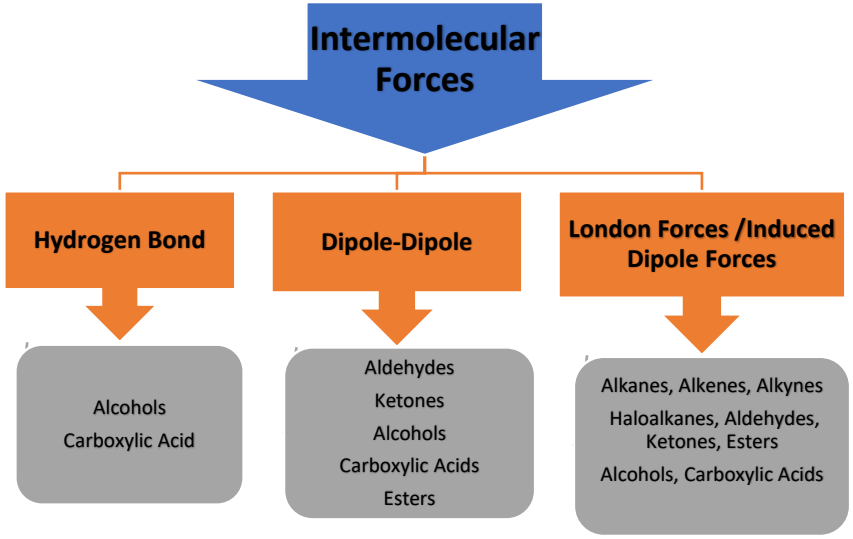
Vapour pressure

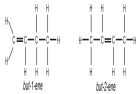
The pressure exerted by a vapour at equilibrium with its liquid in a closed system.

Viscosity

The property of the fluid to oppose relative motion between the two adjacent layers.

Intermolecular Forces





Relationship between Physical Properties and Intermolecular Forces

Intermolecular Forces	Boiling Point	Melting Point	Viscosity	Vapour Pressure
Increases	Increase	Increase	Increase	Decrease
Decreases	Decrease	Decrease	Decrease	Increase

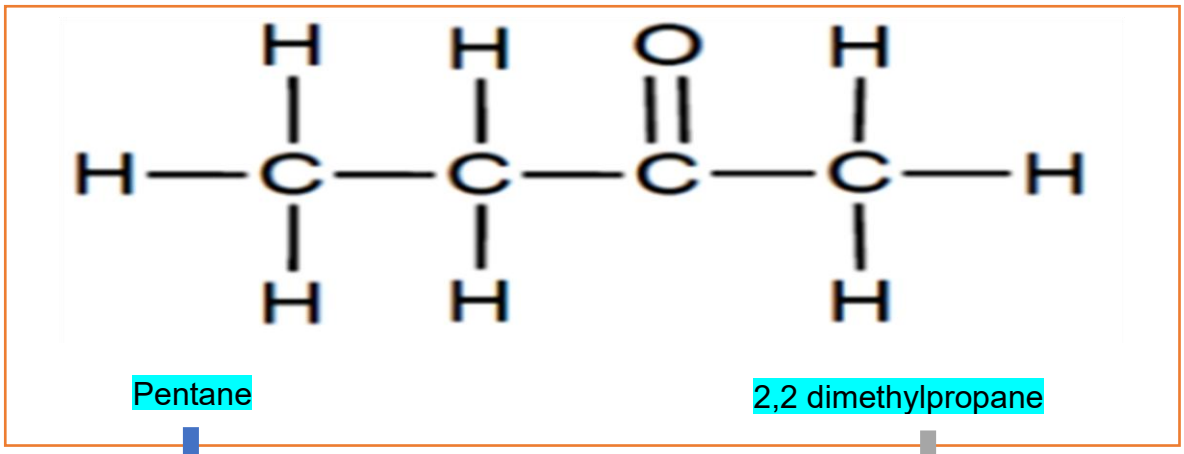
Tips on the trends in **Boiling points**/ **Melting points** / **Viscosity / Vapour pressure.**

- The longer the chain, the higher the viscosity melting point and boiling point.
- Carboxylic Acids have more sites of hydrogen bond than alcohols.
- The stronger the intermolecular forces, the higher the boiling point, viscosity and melting point.
- The stronger intermolecular forces, the weaker the vapour pressure.

Writing Explanations related to Physical Properties:

1. **Comparing two compounds from the same homologous series**
   - Compare the surface areas/chain length/ number of branches of the molecules.
   - Compare the strength of the intermolecular forces.
   - Compare the energy needed to overcome the intermolecular forces.
2. **Comparing two compounds from different homologous series**
   - State the type of IMF in each compound.
   - Compare the strength and "number" of these intermolecular forces.
   - Compare the energy needed to overcome the intermolecular forces.

Comparing two compounds from the SAME HOMOLOGOUS SERIES:



Pentane

2,2 dimethylpropane

Pentane		2,2 dimethylpropane
Longer chain length Larger surface area	STRUCTURE	More branched Shorter surface area
Stronger intermolecular force	STRENGHT OF INTERMOLECULAR FORCES	Weaker intermolecular force
More energy needed	ENERGY NEEDED TO OVERCOME INTER MOLECULAR FORCES	Less energy needed
Higher the Boiling point Higher the Melting point Higher the Viscosity Lower the Vapour pressure		Lower the Boiling Point Lower the Melting Point Lower the Viscosity Higher the Vapour pressure

Worked Example 1

Learners investigate factors that affects the boiling point of organic compounds. In their investigation they determine the boiling point of the first three alkanes.

1. Fully explain why the boiling point increases from methane to propane.

SOLUTION

Structure	Chain length / Surface Area increases from methane to propane
Strength of the Intermolecular forces	The strength of London forces increases from methane to propane
Energy needed	More energy is needed to overcome the intermolecular forces

Worked Example 2

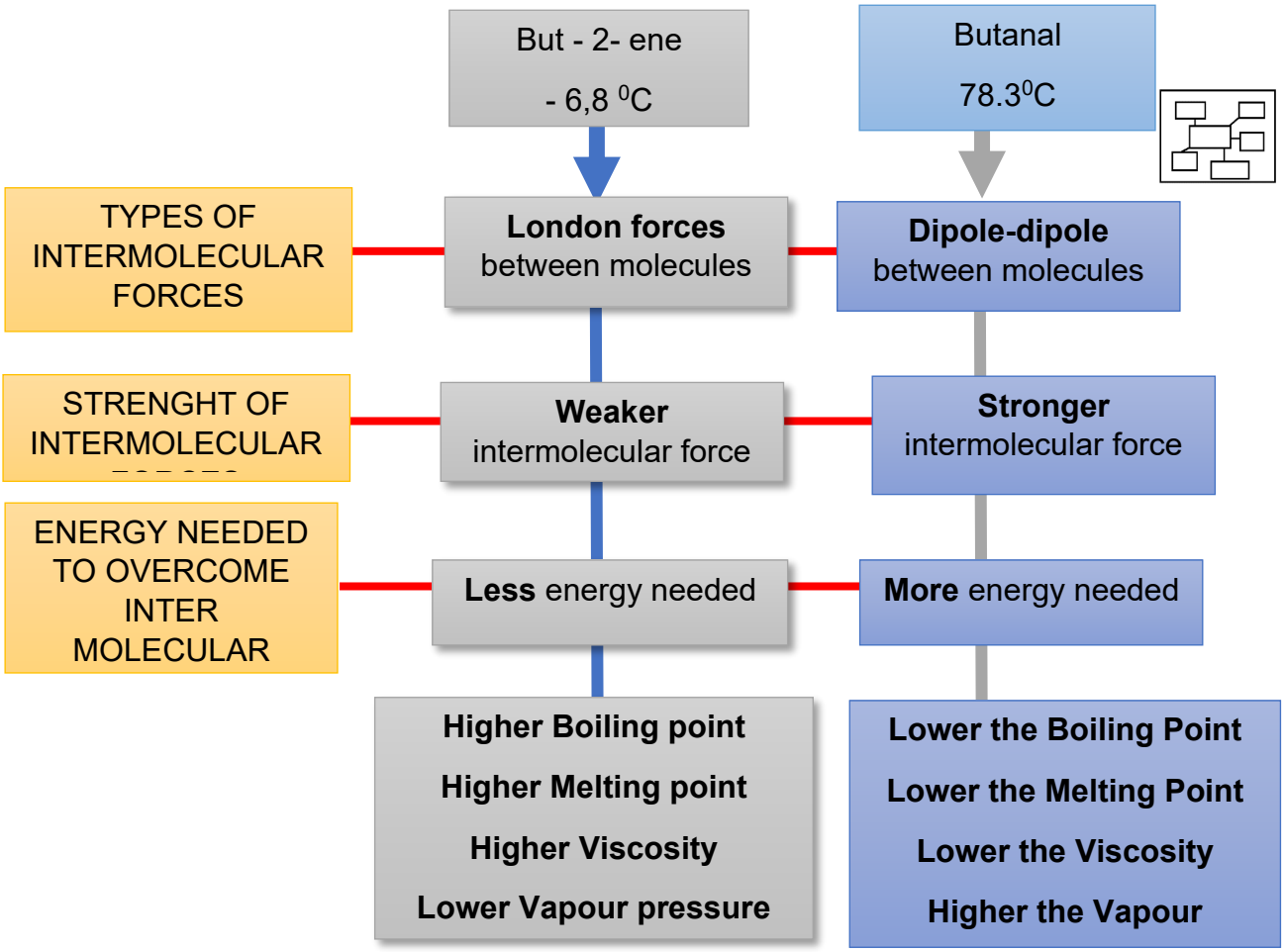
Explain the trend in the boiling point from **compound A** to **compound C**

	Isomer	Boiling Point ºC
A.	2,2-dimethylpropane	9
B.	2-methylbutane	28
C.	Pentane	36

SOLUTION

Structure	From **A** to **C** larger surface area/less branched
Strength of the Intermolecular forces	The strength of London forces increases from **A** to **C**
Energy needed	More energy is needed to overcome the intermolecular forces

Comparing two compounds of the DIFFERENT HOMOLOGOUS SERIES



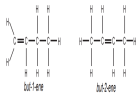
Worked Example 1

Refer to the type of intermolecular forces to explain the difference between the vapour pressure of **compound A** and **compound B**.

COMPOUND		Vapour Pressure (Kpa at 20 ºC)
A	**Butane**	**204**
B	**Propan-2-one**	**24,6**
C	**Propan-1-on**	**2**
D	**Ethanoic Acid**	**1,6**

SOLUTION

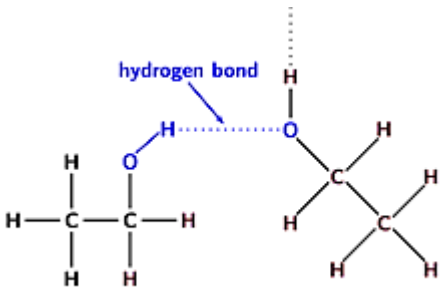
Compound	A	B
TYPE of intermolecular forces	**London forces** between molecules of **compound A**	**Dipole-dipole** between molecules of **compound B**
Strength of the Intermolecular forces	**Weaker** intermolecular forces	**Stronger** intermolecular forces
Energy needed	**Less energy** needed to overcome the intermolecular forces	**More energy** needed overcome the intermolecular forces

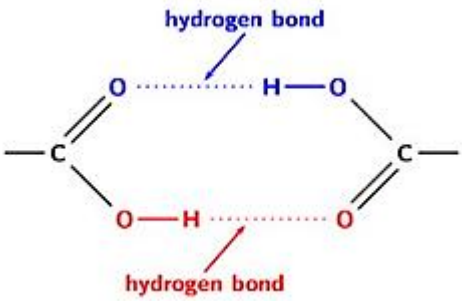


HYDROGEN BONDING

Why do carboxylic acids have stronger intermolecular forces than alcohols?

Alcohol	Carboxylic acid





One site for **Hydrogen Bonding** between Alcohol molecules

T**wo sites for Hydrogen Bonding** between Carboxylic acid molecules

Worked Examples 2

Refer to the type of intermolecular forces to explain the difference between the vapour pressure of Propan - 1 - ol and Ethanoic acid

COMPOUND		Vapour Pressure (Kpa at 20 ºC)
A	**Butane**	**204**
B	**Propan-2-one**	**24,6**
C	**Propan-1-on**	**2**
D	**Ethanoic Acid**	**1,6**

SOLUTION

	Propan-2-ol	Ethanoic acid
TYPE of intermolecular forces	**Hydrogen Bond** between molecules of Propan-2-ol Propan-2-ol has **one site for hydrogen bonding**	**Hydrogen Bond** between molecules of Ethanoic acid Ethanoic acid has **two sites for hydrogen bonding**
Strength of the Intermolecular forces	**Weaker** intermolecular forces	**Stronger** intermolecular forces
Energy needed	**Less energy** needed to overcome the intermolecular forces	**More energy** needed overcome the intermolecular forces

Activity 1

The boiling points of organic compounds **A to E**, were investigated and the results were recorded in the table below. Consider the information that is given in the table below and then answer the questions that follow.

	COMPOUND	BOILING POINT °C
A	Pentane	36,1
B	2- methylbutane	27,9
C	2,2 – dimethylpropane	9,5
D	Pentanol	137,5
E	Pentanoic acid	185

1.1 Consider compounds **A**, **B** and **C** which are isomers.

1.1.1 Define the term structural isomers. (2)

1.1.2 Name and define the type of structural isomers that are represented by these compounds. (3)

1.1.3 Use the information in the table to describe the trend in the boiling points of these compounds? (1)

1.1.4 Explain this trend mentioned in QUESTION 3.1.3 above, thoroughly. (3)

1.2 Consider compounds D and E.

1.2.1 How would the viscosity of compound D compare to that of compound E. Write HIGHER THAN or EQUAL TO or LOWER THAN. (1)

1.2.2 Give an explanation to the answer in QUESTION 3.2.1 above. (2)

[12]

Activity 2

During a practical investigation the boiling points of the first six straight-chain ALKANES were determined and the results were recorded in the table below.

ALKANE	MOLECULAR FORMULA	BOILING POINT (°C)
Methane	CH_4	−164
Ethane	C_2H_6	−89
Propane	C_3H_8	−42
Butane	C_4H_{10}	−0,5
Pentane	C_5H_{12}	36
Hexane	C_6H_{14}	69

2.1 Define Boiling Point. (2)

2.2 Write down the NAME of an alkane that is a liquid at 25 °C. (1)

2.3 Fully explain why the boiling point increases from methane to hexane. (3)

2.4 Is this a fair investigation? Choose YES or NO. (2)
Give a reason for the answer.

2.5 Write down the type of intermolecular forces force that occurs between these organic compounds. (1)

2.6 Which compound has the higher vapour pressure? Give the reason for the answer. (2)

2.7 Does the vapour pressure of the alkanes INCREASE or DECREASE with an increase in the number of carbon atoms? (1)

2.8 Will the boiling points of the structural isomers of hexane be HIGHER THAN, LOWER THAN or EQUAL TO that of hexane? Fully explain the answer (4)

Hexane is now compared to 2,2-dimethylbutane.

2.8.1 Is the molecular mass of hexane GREATER THAN, LESS THAN or EQUAL to that of 2,2-dimethylbutane? (2)
Give a reason for the answer.

2.8.2 Is the boiling point of 2,2-dimethylbutane HIGHER THAN, LOWER THAN or EQUAL TO that of hexane? Fully explain the answer (4)

[22]

Activity 3

Three compounds are used to investigate one of the factors that influences boiling points. The results obtained are shown in the table below.

	COMPOUND	MOLECULAR MASS ($g \cdot mol^{-1}$)	BOILING POINT (°C)
X	Ethyl ethanoate	88	77
Y	Pentan-1-ol	88	137
Z	Butanoic acid	88	165

3.1 For this investigation, write down the following:

3.1.1 Independent variable. (1)

3.1.2 Dependent variable. (1)

3.1.3 Conclusion that can be drawn from the above results. (2)

3.2 Is this a fair investigation? State only YES or NO. (2)
Refer to the data in the table and give a reason for the answer.

3.3 Name the type of Van der Waals forces between molecules of ethyl ethanoate. (1)

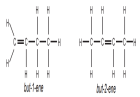
3.4 The boiling point of pentan-1-ol is higher than that of ethyl ethanoate.

Explain this observation by referring to the TYPE of INTERMOLECULAR FORCES present in each of these compounds. (4)

3.5 Refer to the intermolecular forces present in compounds **Y** and **Z**, and FULLY explain the difference in boiling points, as shown in the table. (4)

3.6 Which ONE of the compounds (**X**, **Y** or **Z**) has the highest vapour pressure? Give a reason for the answer. (2)

[23]



3. ORGANIC REACTIONS

Organic compounds take part in different types of reactions which can be grouped into:

- Oxidation (Combustion)
- Substitution and
- Addition reactions

Oxidation (Combustion)

Oxidation of alkanes is also called the combustion of alkanes. In the complete combustion reaction of alkanes, carbon dioxide (CO_2) and water (H_2O) are released along with energy.

An equation for the combustion of an alkane in excess oxygen:

$$Alkane + Oxygen \rightarrow Carbon\ dioxide + water$$

$$Alkane + O_2 \rightarrow CO_2 + H_2O$$

The balanced equation for the complete combustion of methane is:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

How to write a balanced equation for the combustion of alkanes:

Step 1: Balance the carbon atoms

Step 2: Balance the hydrogen atoms

Step 3: Balance the oxygen atoms

Step 4: Make sure all numbers are whole numbers

Worked Example 1

Balance the equation for the combustion of butane:

$$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

Step 1: Balance the carbon atoms

$$C_3H_8 + O_2 \rightarrow 3CO_2 + H_2O$$

Step 2: Balance the hydrogen atoms

$$C_3H_8 + O_2 \rightarrow 3CO_2 + 4H_2O$$

Step 3: Balance the oxygen atoms

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

Step 1: Balance the carbon atoms

3 C atoms on the reactants, 1 C atom on the products balance C atoms by placing 3 in front of CO_2

Step 2: Balance the hydrogen atoms

8 H atoms on the reactants, 2 H atom on the products: balance H atoms by placing 4 in front of H_2O

Step 3: Balance the oxygen atoms

2 O atoms on the reactants, 6+4 =10 O atom on the products: balance O atoms by placing 5 in front of O_2

Worked Example 2

Balance the equation for the combustion of butane:

$$C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$$

Step 1: Balance the carbon atoms

$$C_4H_{10} + O_2 \rightarrow 4CO_2 + H_2O$$

Step 2: Balance the hydrogen atoms

$$C_4H_{10} + O_2 \rightarrow 4CO_2 + 5H_2O$$

Step 3: Balance the oxygen atoms

$$C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O$$

Step 4: Make sure all numbers are whole numbers

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

Step 1: Balance the carbon atoms

4 C atoms on the reactants, 1 C atom on the products balance C atoms by placing 4 in front of CO_2

Step 2: Balance the hydrogen atoms

10 H atoms on the reactants, 2 H atom on the products: balance H atoms by placing 5 in front of H_2O

Step 3: Balance the oxygen atoms

1 O atoms on the reactants, 8+5 =13 O atom on the products: balance O atoms by placing $^{13}/_{2}$ in front of O_2

Step 4: Make sure all numbers are whole numbers

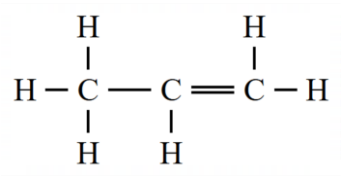
Multiply every coefficient by 2 to eliminate fraction

Flow diagram to show the difference between Addition and Substitution reactions

Unsaturated compound

(Double Bond)

e.g.

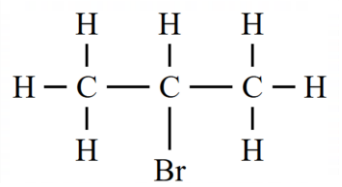


Addition

Saturated compound

(Single Bond)

e.g.

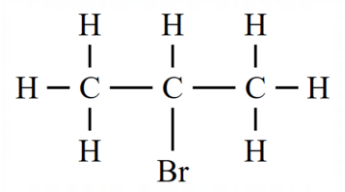


Addition

Saturated compound

(Single Bond)

e.g.



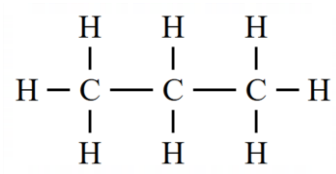
Substitution

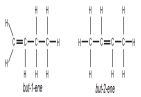
Substitution

Saturated compound

(Single Bond)

e.g.



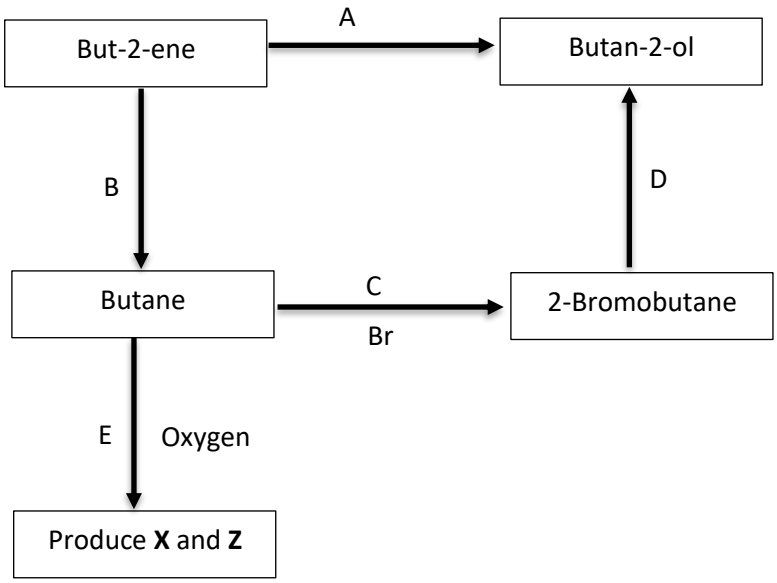


Type of Organic Reaction and Reaction Conditions

Type of Organic Reaction	*Name of Reaction*	*Reactants*	*Reaction Conditions*	*Products*
Substitution	**Halogenation**	Alkane + Halogen	UV light (hv) / Heat (Δ)	Haloalkane + Hydrogen halide
	Hydrolysis (base)	Haloalkane + Base (NaOH/KOH/LiOH)	Dilute strong base; Mild heat	Alcohol + Halide salt
	Hydrolysis (water)	Haloalkane + Water	Add water; Mild heat	Alcohol + Hydrogen halide
	Substitution (Alcohol → Haloalkane)	Alcohol + Hydrogen halide	No water	Haloalkane + Water
Addition	**Hydration**	Alkene + Water	Concentrated H_2SO_4	Alcohol
	Hydrogenation	Alkene + Hydrogen	Pt / Pd / Ni catalyst; non-polar solvent	Alkane
	Halogenation (Alkene)	Alkene + Halogen	-	Haloalkane
	Hydrohalogenation	Alkene + Hydrogen halide	No water	Haloalkane

Worked Example

Study the diagram below.



1.1 Write down the type of organic reaction represented by letters A – E. (10)

A Addition ✓✓
B Addition ✓✓
C Substitution ✓✓
D Substitution ✓✓
E Combustion ✓✓

1.2 Write the name of the Addition or Substitution reaction represented by letters A - C (6)

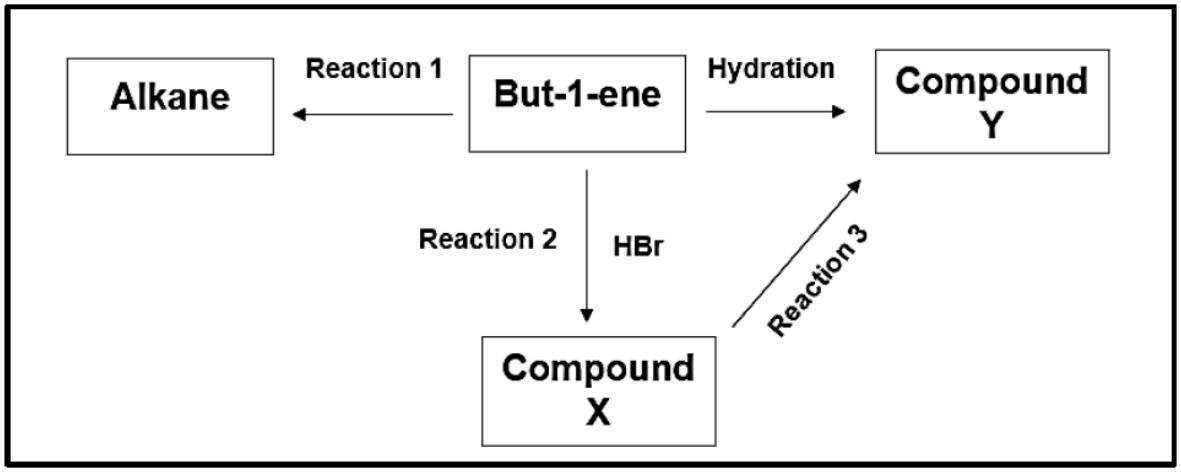
A Hydration ✓✓
B Hydrogenation ✓✓
C Halogenation ✓✓

1.3 Write down a balance chemical reaction for reaction E**.**

$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$ ✓✓✓

Activity 1

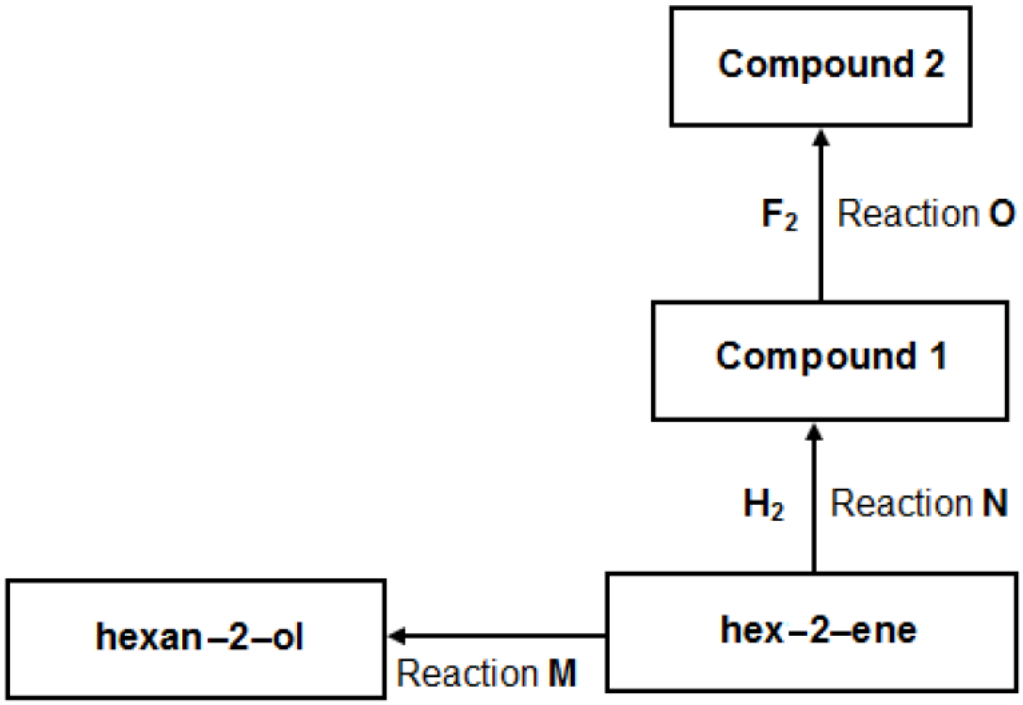
The flow diagram below shows how but-1-ene can be converted into other organic compounds.



1.1	Is the alkane a SATURATED or UNSATURATED hydrocarbon? Explain.	(2)
	Identify the TYPE of reaction represented by the following:	
	1.1.1 Reaction **1**	(1)
	1.1.2 Reaction **3**	(1)
1,2	For reaction **2**, write down a balanced equation using STRUCTURAL FORMULAE for the organic compounds.	(3)
1.3	Write down ONE reaction condition that is required for reaction **2**.	(1)
1.4	Write the NAME of the reactant to be added to but-1-ene to form compound **Y**.	(1)
1.5	Butane is used in kitchen stoves. The gas burns in the presence of excess oxygen. Write down a balanced equation using MOLECULAR FORMULAE for the reaction that will occur.	(3)
1.6	Identify the TYPE of reaction in QUESTION 1.5.	(1)
		[13]

Activity 2

In the flow diagram below hex–2–ene is a starting compound.



2.1 NAME the type of addition reaction represented by:

2.1.1 Reaction **M** (1)

2.1.2 Reaction **N** (1)

2.2 What is the other reactant of reaction **M**? (1)

2.3 Write down a balanced chemical equation for reaction **O** by using STRUCTURAL FORMULAE. (4)

2.4 Write down ONE reaction condition of reaction **M**. (1)

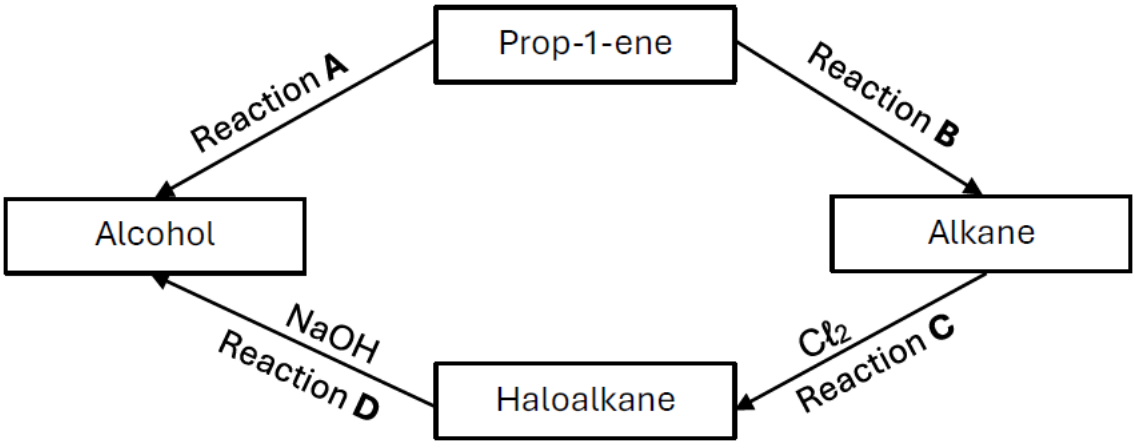
2.5 Hex–2–ene (C_6H_{12}) reacts in excess oxygen.

Write down a balanced chemical equation of this reaction by using MOLECULAR FORMULA. (3)

[11]

Activity 3

Prop-1-ene can be converted to other compounds by means of different organic reactions, represented by **A**, **B**, **C** and **D**, as shown in the flow diagram below.



3.1 Write down the type of reaction represented by:

3.1.1 **B** (1)

3.1.2 **C** (1)

3.2 Write down the:

3.2.1 NAME or FORMULA of the inorganic reactant used in reaction **B** (1)

3.2.2 IUPAC name of the haloalkane formed in reaction **C** (2)

3.2.3 FORMULA of the catalyst needed in reaction **B** (1)

3.3 During reaction **D**, the haloalkane reacts in the presence of a strong base to form an alcohol.

For reaction **D** write down:

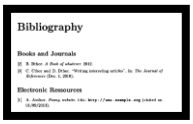
3.3.1 The type of substitution reaction represented by **D**. (1)

3.3.2 A fully balanced chemical equation, using STRUCTURAL FORMULA. (3)

3.4 Rewrite the incomplete chemical equation for the complete combustion of pentane shown below, in your ANSWERBOOK. Complete and balance the equation using MOLECULAR FORMULA. (2)

$$C_5H_{12} + O_2 \rightarrow \_\_\_\_ + \_\_\_\_$$

[12]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