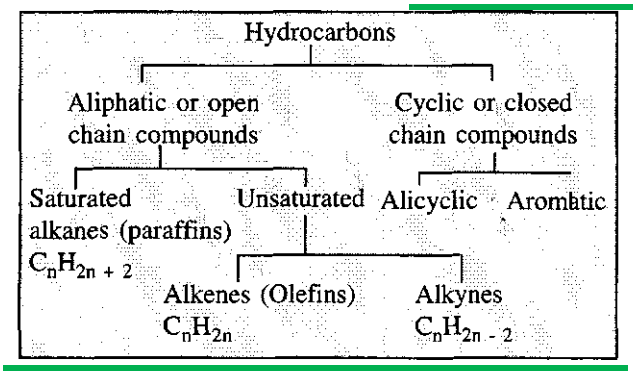
GRADE 10 chemistry 2nd note

ORGANIC COMPOUNDS

HYDROCARBONS



Organic Compound	Functional Group	General Structure	Example
Alkane	R — CH — CH 2 3	H C — C — CH 3 2 3 H Propane	C C (single bond)
Alkene	(double bond) C C	R — CH CH 2	CH H_2C 2 Ethene
Alkyne	(triple bond) C C	R — C C—R	H — C C — H Ethyne

Aromatic	(benzene ring)	Toluene H_3C	R
Alcohols	— OH	R — OH	CH OH $_3CH_2$ Ethanol
Aldehydes	— CHO groupHO C	R — CHOHO CR	Ethanal C — CH H_3 OH_3C HO C
Ketone	— CO — group O C	CH C $H_{3\,3}$ OCPropanone O CH C_3 CH_3	
Carboxylic Acid	— COOH group O C OH	O C R OH R — COOH	O C H OH $_3C$ Ethanoic acid

Major Organic Chemistry Functional Groups



Alkane



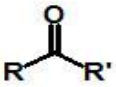
Alkene



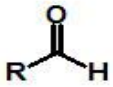
Conjugated Alkene



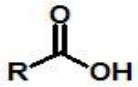
Alkyne



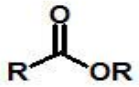
Ketone



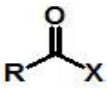
Aldehyde



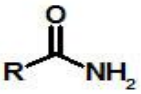
Carboxylic Acid



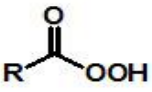
Ester



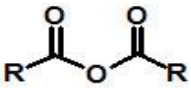
Acid Halide



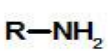
Amide



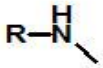
Peroxy Acid



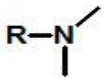
Anhydride



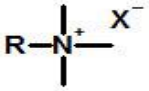
Primary Amine



Secondary Amine



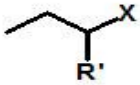
Tertiary Amine



Quaternary Ammonium Salt



Primary Alkyl Halide



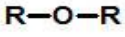
Secondary Alkyl Halide



Tertiary Alkyl Halide



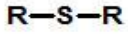
Alcohol



Ether



Thiol



Thioether

SATURATED HYDROCARBONS

Hydrocarbons are organic compounds composed of the elements carbon and hydrogen only. Hydrocarbons are subdivided into two groups, based on the type of bonding between carbon atoms, as saturated hydrocarbons and unsaturated hydrocarbons. Saturated Hydrocarbons are those compounds of carbon and hydrogen containing only carbon-carbon single bonds. Methane, ethane, and propane are typical examples of this group.Unsaturated Hydrocarbons are those compounds of carbon and hydrogen possessing one or more multiple bonds (*double or triple bonds*) between carbon atoms. Alkenes, alkynes and aromatic hydrocarbons are examples of unsaturated hydrocarbons.

A formula that shows all the bonds and atoms is called a detailed structure. The shorter structure is called condensed structure.

ALKALINE OR PARAFINS

Alkanes have the general formula C*n*H2*n*+2, where, *n* = 1, 2, 3 . . . Using this general formula, we can write the molecular formula of any alkane containing a specific number of carbon atoms. For example, the chemical formulas of alkanes containing one, two and three carbon atoms are C 1H2×1+2= CH4, C2H2×2 + 2 =C2H6, and C3H2×3 + 2 =C3H8, respectively.

When we compare the formulas of CH4 and C2H6or C2H6and C3H8, they differ by one carbon and two hydrogen atoms or – CH2– group called the methylene group. A group of

compounds in which each member of the group differs from the next member by a –CH2, is called a homologous series. Compounds in the same homologous series can be represented
by the same general formula. The individual members of the group are called homologues.
Alkanes contain carbon-carbon single bonds (— C — C —) as their functional group.

1.2.2 Physical Properties of Alkanes

Explain why the boiling points and melting points of alkanes increase with increasing number of carbon atoms.

At room temperature, the first four alkanes, methane to butane, are gases; whereas pentane C5H12 to heptadecane (C17H36) are liquids, and the alkanes containing eighteen and more carbon atoms are solids. Alkanes are nonpolar organic compounds. Weak intermolecular forces called Van der Waal's forces hold their molecules together. The strength of these forces increases with the increasing surface area (*molecular mass*) of the alkanes. Since alkanes are non-polar, they are almost insoluble in polar solvents like water, but, they are soluble in non-polar solvents like benzene, toluene, ether and carbon tetrachloride.
The density, melting point, and boiling point of the homologous series of alkanes increase as the carbon number increases. For alkanes of the same carbon number, branched-chain
isomers have lower boiling points than the straight-chain (*normal*) alkanes. The reason is, as branching increases, there is a decrease in surface area and the strength of the intermolecular force, which, in turn, results in a decrease in boiling point; e.g., the boiling points of n-pentane, iso-pentane and neo-pentane are 36°C, 28°C and 9.5°C, respectively.
Alkanes containing all the carbon atoms in one continuous chain are called normal or straight-chain alkanes and those containing chains with branches are known as branchedchain alkanes.
Example
In alkanes (*branched* or *straight-chain*) each carbon atom is tetrahedrally bonded to four atoms with a bond angle of 109.5°.

In alkanes containing a continuous chain of carbon atoms, the carbon atoms are not linked
in straight line but in zigzag chains to keep the tetrahedral distribution of atoms.

Nomenclature (naming) of Alkanes

Organic chemistry uses a simplified and systematic way of naming organic compounds. The
names of alkanes and most of the organic compounds are derived from:
i) a prefix- indicating the number of carbon atoms (listed inTable 1.3)and
ii) a -suffix indicating the type of the functional group present in the molecule.
The following table introduces the prefixes that are used to indicate the presence of one to ten carbon atoms in the longest continuous carbon chain.
you can note that the names of all alkanes contain the suffix '-ane', which indicates that their functional group is a carbon — carbon single bond. Thus, to name an alkane, you should use the appropriate prefix that indicates the number of carbon atoms and
the suffix '-ane'. For example, to name the alkane C6H14, use the prefix 'Hex' that indicate the presence of six carbon atoms and add the suffix '-ane' so that the name becomeshexane.

Common Names of Alkanes

Lower members of the alkane homologous series have common names. The prefixes used in the common names are
n- (*normal*), 'iso-' and 'neo-'. The prefix *n*- is used when all the carbon atoms form a continuous chain.
Iso- is used when all of the carbon atoms form a continuous chain, except for the one next to the last carbon.
Neo- is used when the central carbon is bonded to four other carbon atoms.

IUPAC System of Nomenclature of Alkanes

It is difficult to have common names for the more branched and complex alkanes. In naming such alkanes, the more systematic, convenient and appropriate one is the International Union of Pure and Applied Chemistry (IUPAC) system. In order to apply this system, it is very important to know the rules to be followed, what alkyl radicals are, and how they are named.

Alkyl radicals are obtained by removing one hydrogen atom from the corresponding alkanes. Their general formula is C*n*H2*n*+1, where *n* = 1, 2, 3 . . . . The names of alkyl radicals are derived from the names of the corresponding parent alkanes by changing the suffix -ane to -yl.

Formulas, names and structures of some alkyl groups.

Formula of alkane	Formula of alkyl radical	Condensed structure of alkyl radical	Common name of alkyl radical
CH_4	CH – 3	Methyl	CH – 3
C_2H_6	$–C_2H_5$	H C C H – 3 2	Ethyl
C_3H_8	$–C_3H_7$	H C 3 2 2 C H CH – CH CH 3 — — CH 3	-Propyl *n* Isopropyl
C_4H_{10}	$–C_4H_9$		

The system of naming organic compounds is based on the recommendations of IUPAC. The following are the rules established by IUPAC to name branched-chain hydrocarbons.

1. Select the longest continuous chain of carbon atoms in the molecule as the *parent structure*. The name of the straight-chain alkane possessing the same number of carbon atoms is used as the name of this longest chain. The groups attached to the parent structure are called side chains or substituents. There are seven carbon atoms in the longest chain (*the parent structure*). Therefore, it gets the name "heptane".

2. Assign numbers to the carbon atoms of the longest chain starting from one end to the other so that the carbon atoms to which side chains are attached get the lowest possible number.

To check which direction of numbering is correct; add the locants (*numbers assigned to the carbon atoms to which substituents are attached*). The sum of locants in the first case is 3 + 4 = 7 and in the second case, 4 + 5 = 9. So numbering should be done from left to right in this case. Thus, the first option is correct.

3. Indicate the position of the side chain by using the number assigned to the carbon atom to which it is attached. If the same substituents appear more than once, use the. prefix *di-*, *tri-*, *tetra-* etc. before the name of the substituent to show *two*, *three*, *four,* etc. substituents, respectively.

4. Numbers are separated from each other by commas while they are separated from substituent names by hyphens.

5. Arrange the names of the side chains before the parent name in alphabetical order. The complete name of the alkane given in the above example will then be 4-ethyl-3- methylheptane (substituents in *alphabetical order*). The longest chain has six carbon atoms and the parent name is hexane. There are two methyl groups at carbon-2 and another two methyl groups on carbon-4 and one chlorine atom at carbon-3. Therefore, the correct name of the compound is 3-chloro-2,2,4,4-tetramethylhexane. The longest chain contains eight carbon atoms. Hence, the parent name of the given molecule
is octane. There are three methyl groups attached to carbon number 3, 4 and 6; one bromine atom is attached to carbon-4 and two chlorine atoms are attached to carbon-3

and carbon-5. Thus, the correct name of the compound is 4-bromo-3,5-dichloro-3,4,6- trimethyloctane. When F, Cl, Br and I appear as substituents, change the names fluorine, chlorine, bromine and iodine to fluoro, chloro, bromo and iodo, respectively.

There are seven carbon atoms in the parent structure, so it takes the name heptane. There are two methyl groups at carbon-2 and two methyl groups at carbon-4 and carbon-5 and one fluorine at carbon-3. So the name of the compound is 3-fluoro-2,2,4,5-tetramethyl heptane.

Exercise 1.2

1. Write any three possible structures for octane, C_8H_{18}, and give their IUPAC names.
2. Write the structure of 2,2-dimethyl butane.
3. Write the structure of 2,3-dimethylpentane.
4. When F, Cl, Br and I appear as substituents in an organic compound, how are they named?

Isomerism

There is only one possible structure for each of the first three alkanes, namely, methane (CH4), ethane (C2H6) and propane (C3H8). Those alkanes containing four or more carbon atoms have more than one structure. The existence of two or more chemical compounds with the same molecular formula but different structures is called isomerism. The compounds that have the same molecular formula but different structures are called isomers. Alkanes exhibit a type of structural isomerism called chain or skeletal isomerism. These structures differ in the arrangement of the carbon atoms and hydrogen atoms. To understand what isomers are, consider the isomers of butane (C4H10) and pentane (C5H12).

1. Isomers of butane (C4H10**)**

Butane has two isomers:

2. Isomers of pentane (C5H12**)**

Pentane has three isomers.

Summary of the Straight-Chain Alkanes

Name	Formula	Melting Point (°C)	Boiling Point (°C)	Number of Structural Isomers
Methane	CH_4	-182.5	-164.0	1
Ethane	C_2H_6	-183.3	-88.6	1
Propane	C_3H_8	-189.7	-42.1	1
Butane	C_4H_{10}	-138.4	-0.5°	2
Pentane	C_5H_{12}	-129.7	36.1	3
Hexane	C_6H_{14}	-95	68.9	5
Heptane	C_7H_{16}	-90.6	98.4	9
Octane	C_8H_{18}	-56.8	125.7	13
Nonane	C_9H_{20}	-51	150.8	36
Decane	$C_{10}H_{22}$	-29.7	174.1	75
Undecane	$C_{11}H_{24}$	-25.6	195.9	
Dodecane	$C_{12}H_{26}$	-9.6	216.3	
Tridecane	$C_{13}H_{28}$			
Tetradecane	$C_{14}H_{30}$			
Pentadecane	$C_{15}H_{32}$			
Hexadecane	$C_{16}H_{34}$			
Heptadecane	$C_{17}H_{36}$			
Octadecane	$C_{18}H_{38}$			
Nonadecane	$C_{19}H_{40}$			
Eicosane	$C_{20}H_{42}$	36.8	343.0	366,319 (!)
Heneicosane	$C_{21}H_{44}$			
Docosane	$C_{22}H_{46}$			
Tricosane	$C_{23}H_{48}$			
Triacontane	$C_{30}H_{62}$	66	449.7	4,111,846,763 (!!)
Hentriacontane	$C_{31}H_{64}$			
Tetracontane	$C_{40}H_{82}$			62,481,801,147,341 (!!!)
Pentacontane	$C_{50}H_{102}$	92		
Hexacontane	$C_{60}H_{122}$			
Heptacontane	$C_{70}H_{142}$			
Octacontane	$C_{80}H_{162}$			

Nonacontane	$C_{90}H_{182}$			
Hectane	$C_{100}H_{202}$			

Exercise 1.3

1. Which of the following statements are true about isomers:

a They have the same molecular formula.

b They are different compounds.

c They have different boiling and melting points.

d They have similar chemical properties.

2. Draw all the possible structural isomers for hexane and name them.

Preparation of Alkanes

Alkanes are the major constituents of petroleum and natural gas. They are mainly obtained by fractional distillation of petroleum. Alkanes can also be prepared in the laboratory.

Some methods of their preparation are as follows:

1. Hydrogenation of alkenes with a metal catalyst.

General Reaction:

Example

2. **Wûrtz** Synthesis (*reaction*). This method involves the reaction of a halogenated alkane with sodium and the reaction is somewhat exothermic.

3. Heating sodium salt of an organic acid with soda lime (*mixture of sodium hydroxide and calcium oxide*); the reaction brings about the removal of the carboxylate group from the sodium salt of the carboxylic acid. This type of reaction is calleddecarboxylation.

Methane

Methane is the main constituent (*about 90%*) of natural gas. It is obtained during fractional distillation of petroleum. Methane is also formed by the decay and

decomposition of animal and plant remains in swampy or marshy lands. Discuss the following points in groups, and present your ideas to the class.

1. Have you ever walked near a marshy or swampy area? Which characteristic smell do you observe?
2. In most parts of Ethiopia, the walls of houses are constructed from wood and mud. The mud for this purpose is usually prepared by mixing soil, water and hay or straw. After two or three weeks of decay and decomposition, an unusual smell is perceived. What do you think is the cause of this?
3. If Ethiopia introduces the technology of producing biogas to its residents, what benefits will be obtained by the country? What materials can be used to generate biogas?

The materials that can be used to produce biogas include dung from cattle, pigs, chickens, chopped green plants and plant wastes. The advantages of biogas technology include saving on fuel such as kerosene, wood and charcoal, and decrease in local deforestation.The residue obtained after preparing the biogas can be used as fertilizer.

Chemical Properties of Alkanes

Alkanes are generally not considered to be very reactive organic compounds. The name paraffin for alkanes arose from two Latin words 'parum' meaning *little* and 'affinis' means *affinity*. Thus, paraffin means little affinity. This name was suggested because alkanes are inert towards many reagents like acids, bases, oxidizing and reducing agents. However, they undergo several reactions under suitable conditions.

The major reactions of alkanes are the following:

1. Combustion Reactions: If alkanes are burned with limited supply of oxygen, they will form water and carbon monoxide and will liberate lesser amounts of heat

energy. Alkanes burn in excess oxygen to form carbon dioxide and water, liberating
a greater amounts of heat. **2. Substitution Reaction:** This is a reaction that involves the replacement of one
atom or a group of atoms by another atom or group of atoms.

Halogenation of alkanes is a very good example of substitution reaction. This reaction involves reacting alkanes with chlorine and bromine. The reaction of chlorine and bromine with alkanes proceeds in presence of heat or sunlight. This type of reaction is called photochemical reaction. The reaction of alkanes with chlorine and bromine proceeds in a sequence of steps. For example, let us consider the photochemical reaction of methane with chlorine (*chlorination*):

***i*) Chain Initiating Step:** This step involves absorption of energy to generate
reactive particles known as free radicals. A free radical is an atom or a group of atoms possessing unpaired electron. A free radical is electrically neutral. A chlorine molecule absorbs light and decomposes into two chlorine atoms:

***ii*) Chain Propagating Step:**This is a step which consumes a reactive particle (*free radical*) produced in the chain initiation step and generates another free radical.

***iii*) Chain Terminating Step:** In the chain terminating step reactive particles (*free radicals*) are consumed but not generated.

In this step, 'side reactions' that do not lead to the formation of the desired products often take place.

Such a detailed step by step description of a chemical reaction is called a reaction mechanism

Chlorination of methane may produce different products depending on the relative
amounts of methane and chlorine.

CH 4(g)	+ Cl2(g) Æ CH3Cl (g) + HCl (g) *Methyl chloride*

$CH_3Cl(g) + Cl_2(g) \rightarrow CH_2Cl_2(g) + HCl(g)$
Methylene chloride (*dichloromethane*)
$CH_2Cl_2(g) + Cl_2(g) \rightarrow CHCl_3(g) + HCl$
Chloroform (*trichloromethane*)
$CHCl_3(g) + Cl_2(g) \rightarrow CCl_4(g) + HCl(g)$
Carbontetrachloride (*tetrachloromethane*)
The chlorination of methane is an example of a chain reaction that involves a series of steps.

3. Elimination reaction: This type of reaction involves the removal of smaller molecules from a compound and leads to the formation of a compound containing a multiple bond (unsaturated compound). It can also involve the removal of hydrogen atoms from adjacent carbon atoms at relatively high temperatures.

Cycloalkanes

Cycloalkanes are saturated hydrocarbons in which the carbon atoms are linked in such a
manner as to form closed chains or ring structures. They are represented by the general formula, C_nH_{2n}, where $n \geq 3$. Cycloalkanes are isomeric with open-chain alkenes. Their names are obtained by prefixing "cyclo" to the name of an alkane containing the same number of carbon atoms. The following structures represent some examples of cycloalkanes.

Uses of Alkanes

Alkanes are primarily used as fuels. They are also used as solvents, raw materials for making alkenes, alcohols, soaps, detergents and plastics.

Exercise 1.4

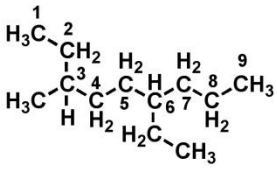
1. Write the balanced equation for the complete combustion of octane.
2. How many chain isomers are there for an alkane that contains 7 carbon atoms?
3. Give IUPAC names to each of the following.
4. Write the structural formulas of the following compounds.

a 2,3-dimethylbutane
b 2-bromo-3,3,4,4-tetramethylhexane.

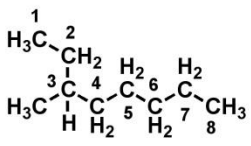
c 2-chloro-4-ethyl-2,3-dimethylhexane.

Additional questions

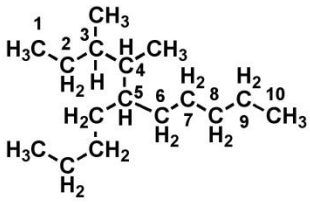
Write the condensed formula of the following structures.



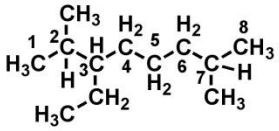
6-ethyl-3-methylnonane



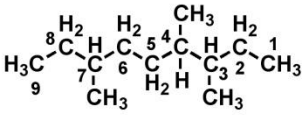
3-methyloctane



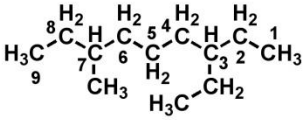
5-butyl-3,4-dimethyldecane



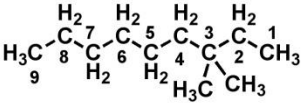
3-ethyl-2,7-dimethyloctane



3,4,7-trimethylnonane



3-ethyl-7-methylnonane



3,3-dimethylnonane