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28

CARBON AND ITS COMPOUNDS

In lesson 27, you have studied about the metals and non-metals. Carbon is an important non –metallic element. The chemistry of carbon and its compounds is an equally important field about which you will learn in this lesson. Carbon is the sixth most abundant element in the universe. It can exist in the free state or in the form of its compounds. It is the major chemical constituent of most organic matter. Carbon is the second most common element in the human body after oxygen. Carbon is present in coal, oil and natural gas. Main natural sources of carbon and its compound which are industrially important are coal, petroleum and natural gas which contribute to our national economy in a big way. Carbon also occurs in a numbers of minerals. You might have seen that when kerosene oil lamp burns it produces black soot which contains carbon particles. You might have also seen that when any some materials like wood, paper are burnt, a black residue is left which contains carbon.

Carbon atoms can form compounds by combining with other carbon atoms as well as atoms of other elements. Carbon has the unique property of forming long chains of carbon atoms. These long chains serve as a backbone on which various groups can attach to give a large variety of compounds. These compounds have a variety of structures, properties and uses in our life. You will study about some such compounds like alcohol, acetic acid, acetone etc. in this lesson.

We will begin this lesson with the discussion on the properties of carbon. Then, various allotropic forms of carbon-viz. *diamond, graphite* and *fullerenes* will be explained. We will also study about *hydrocarbons* which are compounds containing carbon and hydrogen. Here, we will cover various aspects of hydrocarbons such as their *classification, homologous series, isomerism* etc.

We will also give you a brief idea about some simple functional groups which can attach onto the hydrocarbon backbone to yield a large number of compounds. Further, the rules for naming the hydrocarbons and their derivatives will be explained. Finally, some compounds of daily use will be discussed.

OBJECTIVES

After completing this lesson, you will be able to:

- *recognize carbon as a constituent of all living matter and physical world;*
- *appreciate the existence of large number of carbon compounds;*
- *identify various sources of carbon compounds;*
- *explain various allotropes of carbon and compare their properties;*
- *describe the preparation of oxides of carbon and mention their properties;*
- *recognize catenation as the unique property of carbon i.e. its ability to form chains, branches and rings leading to the formation of large number of compounds of carbon;*
- *classify the hydrocarbons as saturated and unsaturated;*
- *describe various homologous series and identify various homologues;*
- *recognize different functional groups (alcohol, aldehyde, keto, carboxylic acid, halogen, double bond (alkene) and triple bound (alkyne) present in common organic compounds:*
- *appreciate that organic compounds have unique names as per IUPAC nomenclature;*
- *name simple organic compounds; and*
- *describe the nature, properties and uses of some useful organic compounds of daily uses i.e. ethanol and acetic acid.*

28.1 CARBON AND ITS PROPERTIES

You have studied in lesson 6 that carbon belongs to Group 14 of the periodic table.

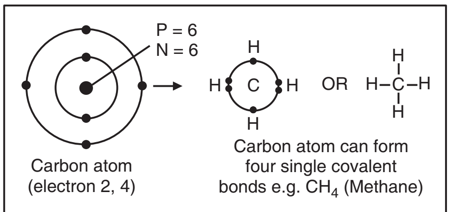
Group → / ↓ Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	**57 La**	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**89 Ac**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

Lanthanoids	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinoids	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

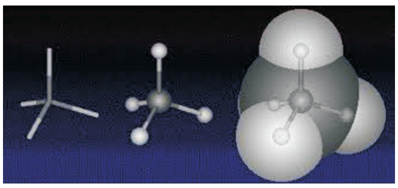
Carbon is abundant in the universe i.e. in Sun, planets, and atmosphere of the Earth. It is present in carbonate rocks i.e. limestone, dolomite, marble etc. It is also a major constituent of fossil fuels such as coal, petroleum and natural gas. It is present in the form of its compounds in all living organisms. Some such compounds are carbohydrates, proteins, fats etc.In combination with oxygen, it occurs as carbon monoxide and carbon dioxide. You are quite familiar with these compounds. Our atmosphere also contains some pollutants arising from these carbon compounds.

In the structure of a carbon atom, there are 4 electrons in the second shell. The electronic configuration of carbon is 2,4 . To complete its octet, carbon requires four more electrons. But due to unfavorable energy considerations, it cannot gain four electrons by ion formation and hence attain the electronic configuration of neon. Due to the same reason, it is also not possible for carbon to lose these four electrons and attain the noble gas configuration of helium. However, it can form covalent bonds by sharing these four electrons.

There are three naturally occurring isotopes of carbon – ^{12}C, ^{13}C, ^{14}C. ^{14}C is a radioactive and its half life is 5730 years. It is used in radio carbon -dating to determine the age of formerly living things.

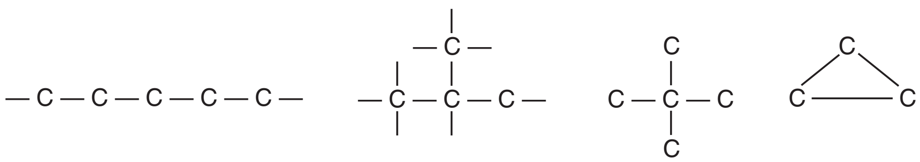


Tetra Covalency of Carbon



It can form four covalent bonds, *i.e.* it is tetravalent in nature. It has a valency of four which is according to the rule you have learnt in lesson 5 i.e. Group No.14 – 10 = 4. The sharing of four more electrons from other atoms completes the octet of carbon atom and it attains the stability by forming four covalent bonds.

Carbon can form bonds with atoms of other elements such as hydrogen (H), nitrogen (N), oxygen (O), sulphur(S) and halogens etc. It also has the property of self combination i.e. bond formation with the other carbon atoms. Thus, carbon can form long chains of carbon atoms. This unique property of forming long chains is known as **catenation.**



The carbon-carbon covalent bond is strong in nature. As you will study later in this lesson, the long carbon chains can act as a backbone to which various groups can attach and give a large number of compounds. The total number of compounds formed by carbon exceeds the total number of compounds formed by all other elements of the periodic table. In addition to the single covalent bonds, carbon can also form multiple bonds, i.e. double or triple bonds with other carbon, oxygen or nitrogen atoms to give a large variety of compounds. The number of compounds formed is so large that a separate branch of chemistry, called **organic chemistry**, is devoted to the study of these compounds.

Before proceeding further, you can check your progress by answering the following questions.

INTEXT QUESTIONS 28.1

1. What is the valency of carbon?
2. What is the nature of bonds formed by carbon?
3. Why carbon forms a large number of compounds?
4. Name the branch of chemistry which is devoted to the study of carbon compounds.
5. How many electrons are needed by a carbon atom to complete its octet?

28.2 ALLOTROPES OF CARBON

Carbon occurs in free state (*i.e.* not combined with any other element) in three allotropic forms. Allotropes are different forms of the same element in the same physical state, earlier only two allotropic forms *i.e. graphite* and *diamond* were known. Another allotropic form – fullerene – has, been discovered few years back. Let us now study about them in detail.

28.2.1 Diamond

Diamonds are formed inside the earth under the conditions of high temperature (about 1500^{o}C) and high pressure (about 70,000 atmospheres).

South Africa is the leading producer of natural diamonds. In India, diamonds are found in Panna in Madhya Pradesh and in Wajrakarur in Andhra Pradesh.

In a diamond crystal, each carbon atom is linked to four other carbon atoms by covalent bonds in a tetrahedral fashion. This results in a three dimensional arrangement as shown in Fig. 28.1

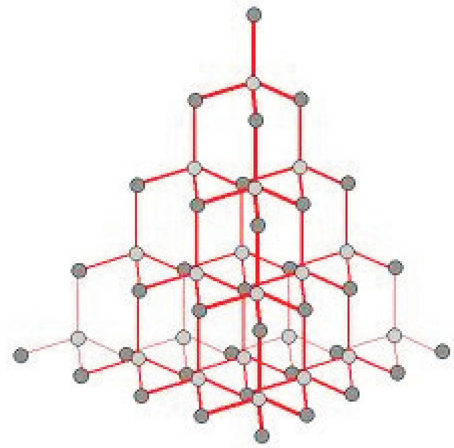


Fig. 28.1 *Three dimensional network of carbon atoms in diamond*

The three-diamensional network of covalently bonded carbon atoms provides a rigid structure to diamonds. This rigidity makes diamond a very hard substance. It is, in fact, the hardest natural substance known. The only other substance harder than diamond is silicon carbide which is also known as carborandum but note that diamond is a natural substance whereas carborandum is a synthetic one.

Diamonds are basically colourless. However, some impurities impart colour to them.

The density of diamond is high. It has a value of 3.51 g cm^{-3}. The melting point of diamond (in vacuum) is also very high, i.e. 3500^oC because a large amount of heat energy is required to break the three-dimensional network of covalent bonds.

Since all the four electrons are covalently bonded and there are no *free electrons* in diamond, hence it does not conduct electricity. But diamond is a good conductor of heat. Its thermal conductivity is five times that of copper. Thus, it can easily dissipate the heat energy released by friction when it is used as an abrasive.

Because of its above-mentioned properties, diamond has the following uses:

(i) It is used in cutting and grinding of other hard materials.

(ii) It is also employed in instruments used for cutting of glass and drilling of rocks.

(iii) It is used in jewellery. Beautiful ornaments are made with diamonds. The high refractive index of diamond (2.5) makes it very brilliant when it is properly cut and polished.

Synthetic Diamonds

Because of their importance diamonds worth millions of dollars are synthesized. In 1950's diamonds were synthesized by the scientist at General Electric in New York. They heated graphite to 1500^oC in the presence of a metal such as nickel and iron under a pressure of 50000 to 65000 atmospheres. Most of the diamonds so produced are used as abrasives and for making diamond coated cutting tools used for drilling.

Most synthetic diamonds lack the size and clarity of natural diamonds and are generally not used in jewellery. Gem quality diamonds can be produced but they are costly.

28.2.2 Graphite

In contrast to diamond, graphite is soft, black and slippery solid. It has a metallic luster. It is also a good conductor of electricity and heat.

Both graphite and diamond contain only carbon atoms, then why do they exhibit such different properties? We can find an answer to this question if we look at the structure of graphite as given below in Fig.28.2.

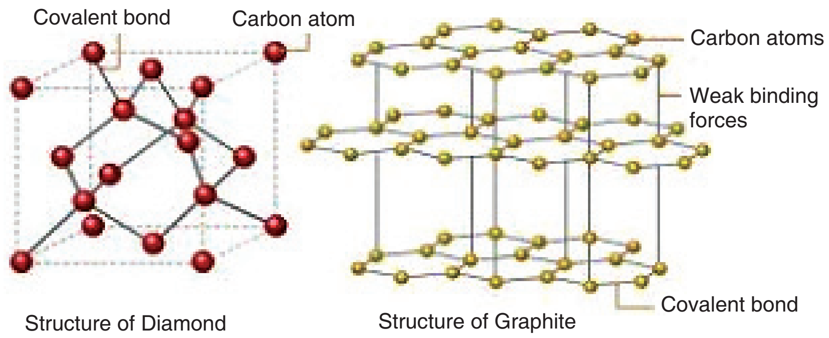


Fig.28.2 *Structures of Diamond and graphite*

You can see that in contrasts to diamond, which has a three-dimensional tetrahedral arrangement of carbon atoms, graphite contains layers of carbon atoms. In each layer, a particular carbon atom is linked to three other carbon atoms in a trigonal planar arrangement with a bond angle of 120^o. Thus, three electrons of carbon are covalently bonded to the other three carbon atoms. The fourth electron, which does not participate in bonding, is free. These electrons of various carbon atoms are free to move along between the layers and hence are able to conduct electricity.

The bonding between these layers of carbon atoms is weak. Hence, these layers can slide one over the other. This property makes graphite a good solid lubricant. The density of graphite is less than that of diamond. It has a value of 2.2g cm^{-3}. The melting point of graphite (in vacuum) is about 3700^oC. Graphite can be converted to diamond by applying very higher atmospheric pressure and temperature.

Because of the above properties, graphite has the following uses:

(i) It is used as a dry lubricant for moving machine parts which operate at a high temperature and where other ordinary oil lubricants cannot be used.

(ii) It is used for making electrodes in dry cells and in electric arcs.

(iii) It is used for making pencil leads. Because of its soft nature and layered structure, it leaves black marks on paper. Hence, it is used for writing as leads in pencils.

(iv) It is used for making containers which are used for melting metals.

28.2.3 Fullerenes

Fullerenes were discovered in 1985 by Robert F. Curl, Harold W. Kroto and Richard E. Smalley. They were awarded the Nobel Prize in Chemistry in 1996 for this discovery. Fullerenes have closed structures like a football. A typical fullerene, named as buckminsterfullerene has 60 carbon atoms. Its structure is shown below in Fig. 28.3.

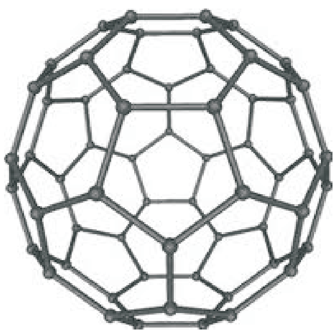


Fig. 28.3 *Buckminsterfullerene,* C_{60}

Fullerenes are formed when vaporized carbon condenses in an atmosphere of an inert gas. The discovery of fullerenes has opened up a new field in Chemistry. Fullerenes of various other sizes are being synthesized and their properties and uses are being studied. New materials, which contain metals enclosed in the fullerenes are being synthesized. It is hoped that these materials would find uses as superconducting materials, new catalysts, polymers etc.

In addition to the above three allotropic forms, carbon also exists in three microcrystalline or amorphous forms of graphite. They are **charcoal, coke** and **carbon black**.

- *Charcoal* is formed when wood is heated strongly in the absence of air. It has a large surface area. Activated charcoal is a pulverized form whose surface has been made free from any adsorbed materials by heating with steam. It is widely used for adsorbing coloured impurities and bad odours from water and other substances.

- *Coke* is an impure form of carbon. It is formed when coal is strongly heated in the absence of air. It is used as a reducing agent in metallurgy.

Coke

ACTIVITY 28.1

Take samples of graphite, coal, charcoal and compare their properties.

- *Carbon black* is formed by heating hydrocarbons in limited supply of oxygen. For example,

$$CH_4\,(g) + O_2(g) \longrightarrow C(s) + 2\,H_2O\,(g)$$

ACTIVITY 28.2

Find out places in India which have rich resources of coal, petroleum and natural gas.

Mark these places on the map of India.

Carbon black

It is used as a pigment in black inks. It is also used in making rubber tyres for automobiles.

INTEXT QUESTIONS 28.2

1. Which allotropic form of carbon has been discovered few years back?
2. Each carbon atom is linked to how many carbon atoms in
   (i) Diamond
   (ii) Graphite
3. Why diamond has high melting point?
4. Is diamond a conductor of electricity? Give reason for your answer.
5. Why is graphite a good lubricant?
6. Give two uses of graphite.
7. What kind of structure is possessed by fullerenes?
8. Name the three microcrystalline forms of carbon and give their use.

28.3 COMPOUNDS OF CARBON

The compounds of carbon can be classified as *organic* and *inorganic* compounds. Earlier the **organic compounds** were defined as those compounds which originated from living organisms but it is now possible to synthesize organic compounds in the laboratory, therefore, they are now defined as compounds of carbon.

The compounds of carbon, which are not organic compounds, are called **inorganic compounds**. Most of the inorganic compounds are obtained from various

Notes

minerals. For example, limestone, marble and dolomite contain carbon as *carbonates*. The other inorganic compounds are carbides of metal (e.g. CaC_2, calcium carbide), HCN, CS_2 and oxides of carbon such as CO_2 and CO.

The organic compounds are obtained from natural sources such as *plants* and *animals, coal* and *petroleum*. You have studied in lesson ** that plants and animals are sources of complex organic compounds such as carbohydrates, starch, oils, proteins, drugs etc. Coal gives us benzene, phenol, naphthalene etc. whereas petroleum is source of petrol, diesel, kerosene, lubricating oils, wax and other compounds. In addition, a large variety of synthetic organic compounds exists and there number is increasing daily. Thus, the number of organic compounds as compared to the inorganic ones is very large.

The properties of organic and inorganic compounds are different from each other. Organic compounds are generally low melting solids or liquids. They dissolve in organic solvents such as benzene, alcohol, chloroform etc. but are generally insoluble in water. The inorganic compounds are generally solids which have high melting and boiling points. They generally dissolve in water but are insoluble in organic solvents.

After having a general idea about the nature of compounds, let us now study the oxides of carbon. But before that why don't you answer the following questions to check your understanding.

INTEXT QUESTIONS 28.3

1. Classify the following compounds as organic or inorganic:
   (i) Sugar
   (ii) calcium carbide
   (iii) kerosene
   (iv) carbon dioxide
   (v) carbon disulphide
2. Give two differences between organic and inorganic compounds.

28.4 OXIDES OF CARBON

The two important oxides of carbon are carbon monoxide (CO) and carbon dioxide (CO_2).

Carbon monoxide is formed when carbon or hydrocarbons are burned in a limited supply of oxygen.

$$2C(s) + O_2\,(g) \longrightarrow 2\,CO\,(g)$$

It is a colourless and odourless gas. It has a melting point of –199°C and boiling point of –192°C.

It is a major air pollutant and is released in large quantities from automobile engines. Its low level poisoning causes headache and drowsiness whereas its large amounts can cause even death. It is toxic because it reduces the oxygen carrying capacity of blood by binding with heamoglobin, the red pigment of blood.

Carbon monoxide has many uses which are given below:

(i) It is used as a reducing agent in metallurgical processes to reduce metal oxides. For example, in the blast furnace, it used to reduce iron oxide to iron.

$$Fe_2O_3\ (s) + 3CO\ (g) \longrightarrow 2Fe\ (s) + 3CO_2(g)$$

(ii) In the presence of a catalyst, it can combine with hydrogen to give methanol (CH_3OH).

(iii) It forms carbonyl compounds. The nickel carbonyl $Ni(CO)_4$ is used in the refinement of nickel.

(iv) It is used as a fuel.

(v) It is used in the synthesis of several organic compounds.

Carbon dioxide is formed when carbon containing substances are burnt in excess of oxygen.

$$C\ (s) + O_2\ (g) \longrightarrow CO_2\ (g)$$

$$CH_4\ (g) + 2\ O_2\ (g) \longrightarrow CO_2\ (g) + 2\ H_2O\ (l)$$

It is also produced by heating of carbonates.

$$CaCO_3\ (s) \longrightarrow CaO(s) + CO_2\ (g)$$

It is also released as a by product in the fermentation of sugar to produce alcohol (ethanol).

$$\underset{\text{Glucose}}{C_6H_{12}O_6\ (aq)} \longrightarrow \underset{\text{ethanol}}{2C_2H_5OH\ (aq)} + 2CO_2\ (g)$$

Carbon dioxide is colourless and odourless gas. It is present in very small amount (0.03%) in the atmosphere. It is a major contributor to the green house effect about which you will study in lesson ——.

The main uses of carbon dioxide are as follows:

(i) Solid carbon dioxide also called *dry ice* is used as a refrigerant because when it is cooled at atmospheric pressure, it condenses into a solid rather than as a liquid. This solid sublime at –78°C

(ii) It is used in the production of *carbonated drinks*.

(iii) It is used in the production of washing soda ($Na_2CO_3.10H_2O$) and baking soda ($NaHCO_3$).

INTEXT QUESTIONS 28.4

1. What is dry ice?
2. Which gas, carbon monoxide or carbon dioxide, is a major air pollutant?
3. Which gas is used in carbonated drinks?
4. Name the gas which is a major contributor to the green house effect.
5. Name the products obtained by the fermentation of sugar.

28.5 HYDROCARBONS

As the name suggests, hydrocarbons are compounds which contain only carbon and hydrogen. As you have studied in lesson —— the main source of hydrocarbons is petroleum.

Hydrocarbons can be divided into various classes as show in Fig. 28.4.

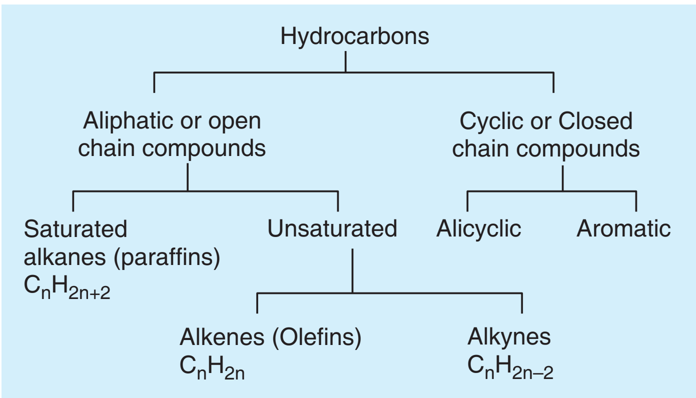


Fig.28.4 *Classification of hydrocarbons*

ACTIVITY 28.3

Why are sources of hydrocarbons getting scarce? What should be done to save these resources?

Aliphatic hydrocarbons: The word aliphatic is derived from the Greek word aleiphar meaning fat. Aliphatic hydrocarbons were named so because they were derived from fats and oils.

Hydrocarbons can be *acyclic* compounds, which are straight chain compounds, or cyclic compounds, which have rings of carbon atoms.

Aromatic hydrocarbons: The word aromatic is derived from the word *aroma* meaning fragrance. The aromatic compounds have a characteristic smell. Structurally, they include benzene and its derivative.

The *aliphatic hydrocarbons* can be divided into two categories: **saturated hydrocarbons** and **unsaturated hydrocarbons.** In *saturated hydrocarbons*, carbon atoms are linked to each other by single bonds whereas in *unsaturated hydrocarbons*, multiple bond (double and triple bonds) are present between carbon atoms.

Let us now study about them in details.

28.5.1 Saturated hydrocarbons (Alkanes)

Methane (CH_4) is the simplest alkane in which four hydrogen atoms are linked to the carbon atom in a tetrahedral fashion as shown in Fig.28.5.

Fig.28.5 *Structure of methane*

If instead of a hydrogen atom, the carbon atom is further linked to another carbon atom, we get another alkane, namely ethane (C_2H_6), Fig 28.6.

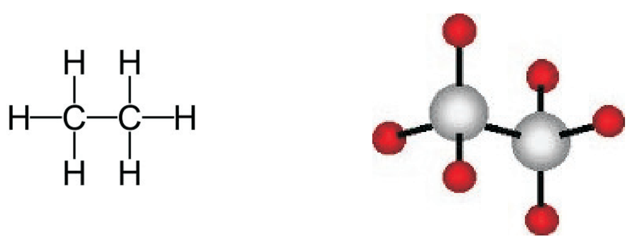


Fig.28.6 *Structure of Ethane*

Similarly, more carbon atoms can link with each other and the carbon chain can further extend to give a variety of hydrocarbons.

The general formula of alkanes is C_nH_{2n+2} where n is the number of carbon atoms in the alkane molecule. First ten alkanes corresponding to n = 1 to n = 10 are given in Table 28.1.

Table 28 .1 Some alkanes and their physical properties

No. of Carbon atoms	Name	Molecular formula	Molecular Mass (u)	Melting point (°C)	Boiling point(°C)	No. of structural isomers
1	Methane	CH_4	16	–183	–162	1
2	Ethane	C_2H_6	30	–172	–89	1
3	Propane	C_3H_8	44	–187	–42	1
4	Butane	C_4H_{10}	58	–138	0	2
5	Pentane	C_5H_{12}	72	–130	36	3
6	Hexane	C_6H_{14}	86	–95	68	5
7	Heptanes	C_7H_{16}	100	–91	98	9
8	Octane	C_8H_{18}	114	–57	126	18
9	Nonane	C_9H_{20}	128	–54	151	35
10	decane	$C_{10}H_{22}$	142	–30	174	75

Alkanes are colourless and odorless compounds. They have very low reactivity. Many of these compounds are gases or liquids as shown in Table 28.1.

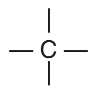
You can also see in Table 28.1 that each compound differs from the previous one by a $–CH_2$ unit. Such a series of compounds is known as **homologous series.** Each homologous series has a general formula. We have mentioned above the general formula for alkanes as CnH_{2n+2} which is the general formula for the homologous series of alkanes, i.e. all the compounds of the homologous series of alkanes can be represented by this general formula.

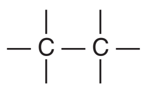
You will see later that similar homologous series also exist for the unsaturated hydrocarbons and derivatives of hydrocarbons.

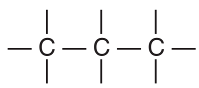
28.5.1a Isomerism in alkanes

So far we have not mentioned anything about the last column of Table 28.1. It mentions the number of isomers for various alkanes. ***Isomers*** *are compounds which have the same molecular formula but have different structures.*

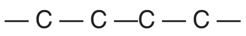
The first three hydrocarbons have only one isomer because there is only one way in which one, two or three carbon atoms can link to each other i.e.


Methane

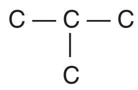

Ethane


Propane

But when there are four carbon atoms, they can join in two different ways as follows:

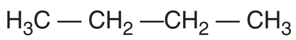


or



(straight chain arrangement) (branched chain arrangement)

Corresponding to the above two carbon skeletons, there are two hydrocarbons- butane and *iso*butane as shown below:



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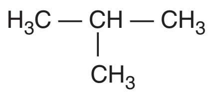


Butane *iso*butane

They are the isomers of butane as they have the same molecular formula (C_4H_{10}) but have different structures.

The number of possible structures in which different carbon atoms can link to each other increases with the increase in number of carbon atoms in the alkane molecules. Hence, the number of isomers of alkanes increases with the increase in the number of carbon atoms as is shown in Table 28.1.

After knowing about the structures of alkanes, let us now study how they are named.

20.5.1b IUPAC Nomenclature of Alkanes

Earlier organic compounds were known by their popular or common names which mostly originated from the sources of these compounds. But as the number of these compounds increased, it became difficult to correlate the structure and name of the compound. This let to the need of a systematic nomenclature of compounds.

In 1892, 'International Union of Chemists' met in Geneva, Switzerland and framed the rules for nomenclature. Later, this organization was named as International Union of Pure and Applied Chemistry (IUPAC) and the names approved by it are called IUPAC names of compounds.

The systematic names are called IUPAC names. For IUPAC naming, we must have idea about **word root** of carbon skeleton. The word root for different carbon skeletons are given below:

No. of Carbon atom	Word root	No. of Carbon atom	Word root
1	meth	5	pent
2	eth	6	hex
3	prop	7	hept
4	but	8	oct

The rules for the IUPAC nomenclature of alkanes are as follows:

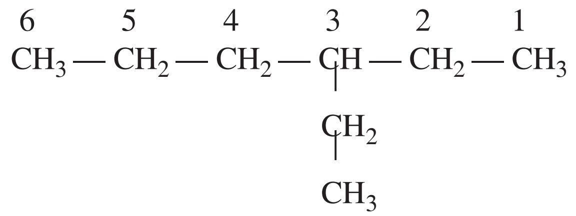
1. Upto butane, the common names are listed in Table 28.1, have been adopted by IUPAC. For straight chain alkanes higher than butane, the suffix-*ane* is added to the Greek root for the number of carbon atoms, *i.e. pent* – for five, *hex* – for six and so on.

   For example CH_4, word root + ane ⟶ Meth + ane ⟶ Methane

   C_3H_8, word root + ane ⟶ Prop + ane ⟶ Propane, and so on.

   The names of alkanes so obtained are listed in Table 28.1.

2. For branch chain alkanes, the longest continuous chain of carbon atoms is selected as the main chain which gives the root name of the hydrocarbon. For example, in the following compounds the longest chain consists of 6 carbon atoms.



   Hence, this compound is a hexane derivative.

3. Then, the substituent alkyl groups are identified and named. The alkyl groups are named by replacing *-ane* suffix of the alkane with *–yl* suffix. Some examples of the names of alkyl groups so obtained are given below.

Table 28.2 : Naming of alkyl groups

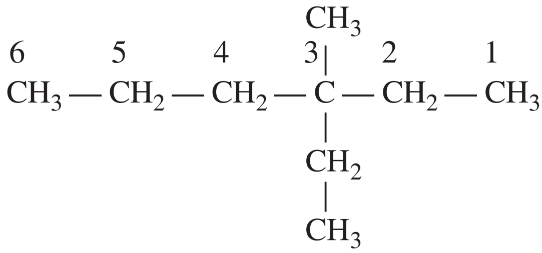
Alkyl group	Derived from Alkane	Name of Alkyl group
— CH_3	methane	meth*yl*
— C_2H_5	ethane	eth*yl*
— C_3H_7	propane	prop*yl*
and so on		

   You can see that in the above compound, the substituent alkyl group is an ethyl group.

4. The location of the substituent alkyl group on the main chain is specified by counting its number from that end of the carbon chain which gives it the lowest possible number. If we count from the end as shown in point No.2, we see that the ethyl group is attached to the third carbon atom of the main chain. Hence, we write the IUPAC name of the above alkane as 3 –ethylhexane.

   Note that the number and alphabets are separated by a hyphen (-) and there is no space between the substituent and the root name.

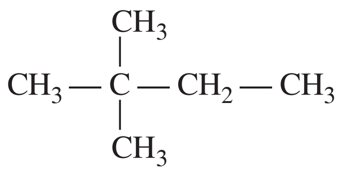
5. When more than one substituent is present on the carbon chain, then they are listed in alphabetical order.



3-ethyl-3-methylhexane

6. The identical substituents are indicated by the prefixes *di* (two), *tri* (three), *tetra* (four) etc.

   The prefixes *di, tri, tetra* etc. are not considered while arranging the substituent's in the alphabetical order.



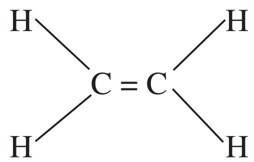
2,2-dimethylbutane

28.5.2 Unsaturated Hydrocarbons

Unsaturated hydrocarbons contain carbon-carbon double or triple bonds. Unsaturated hydrocarbons having carbon -carbon double bonds (—C=C—) are called alkenes bond whereas those having carbon – carbon triple bonds (— C ≡ C —) are known as **alkynes.**

(a) Alkenes

The simplest alkene, ethene has two carbon atoms joined by a double bond. Its molecular formula is C_2H_4. Its structure is as shown below:



Ethene

Similar to alkanes, alkenes also form a homologous series of compounds in which each member differs from the next one by a $-CH_2$ unit. The homologous series of alkenes is shown below in Table 28.3.

Table 28.3 Homologous series of alkenes

No. of carbon atoms	Name of the Alkene	Molecular formula
2	ethene	C_2H_4
3	propene	C_3H_6
4	butene	C_4H_8
5	pentene	C_5H_{10}
And so on		

You can see that the homologous series of alkenes can be represented by the general formula C_nH_{2n} where *n* represents the number of carbon atoms in the alkene molecule.

IUPAC name of an alkene can be given as

Ex C_2H_4 , Word root + ene = eth + ene = Ethene

The names of alkenes are given by replacing the *–ane* suffix of alkanes by *–ene*. The other rules for the nomenclature of alkenes are same as those of alkanes. However, the position of the double bond is indicated by the smaller number of the two carbon atoms forming the double bond. For example, in the following alkene

$$\overset{1}{H_2C} = \overset{2}{CH} — \overset{3}{CH_2} — \overset{4}{CH_3}$$

1-butene

The double bond is between the carbon atoms numbered as 1 and 2 and hence ,it is called 1-butene.Similarly,in another alkene shown below,

$$\overset{1}{H_3C} — \overset{2}{CH} = \overset{3}{CH} — \overset{4}{CH_3}$$

2-butene

The double bond is between the carbon atoms numbered as 2 and 3 and hence it is called 2-butene.

Note that these two butenes *i.e.* 1 – butene and 2 – butene are *isomeric* in nature.

(b) Alkynes

The simplest alkyne is *ethyne* and it has molecular formula C_2H_2. Its common name is acetylene. It is used to ripen the fruits such as banana, mango etc. It is also used along with oxygen in oxy-acetylene torch which is used for welding purposes. Its structure is as shown below:

$$H — C \equiv C — H$$

The homologous series of alkynes is shown below in table 28.4

Table 28.4 : Homologous series of alkynes

No. of carbon atoms	Name of the Alkyne	Molecular formula
2	ethyne	C_2H_2
3	propyne	C_3H_4
4	butyne	C_4H_6
5	pentyne	C_5H_8

You can see from the above table that the general formula for the homologous series of alkynes is $C_n H_{2n-2}$ where *n* is the number of carbon atoms in the alkyne molecule.

IUPAC Name of alkyne = Word root + yne , eg C_2H_2 = eth + yne = Ethyne

Alkynes are named by replacing *–ane* suffix of alkanes by *–yne* suffix. The other rules of nomenclature of alkynes are similar to those of alkanes. The names of some simple alkynes are given below:

$$\overset{1}{HC} \equiv \overset{2}{C} - \overset{3}{CH_3}$$

propyne

$$\overset{1}{HC} \equiv \overset{2}{C} - \overset{3}{CH_2} - \overset{4}{CH_3}$$

1-butyne

$$\overset{1}{CH_3} - \overset{2}{C} \equiv \overset{3}{C} - \overset{4}{CH_3}$$

2-butyne

INTEXT QUESTIONS 28.5

1. What is the difference between saturated and unsaturated compounds?
2. Give two examples each of (i) saturated compounds and (ii) unsaturated compounds.
3. Name the alkane which has three carbon atoms.
4. Define isomers.
5. What is the full form of IUPAC?
6. Name the following alkyl groups:

   (i) $-CH_3$ (ii) $-C_2H_5$
7. Give IUPAC name of these compounds

   (a) $CH_3 - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$ (b) $CH_3 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$

28.6 FUNCTIONAL DERIVATIVES OF HYDROCARBONS

Functional derivatives of hydrocarbons are those compounds which are derived from hydrocarbons by replacing one or more hydrogen atoms with the *functional groups*.

A **functional group** *is an atom or a group of atoms which is responsible for characteristic properties of a compound.* The double and triple bonds which respectively give the alkenes and alkynes their characteristic properties are functional groups. The other examples of functional groups are halogens (— F, — Cl, — Br, — I etc.), — OH (hydroxyl group and > C = O (carbonyl group).

Since each of these functional groups exhibits the characteristic properties and reactions, all the compounds having the same functional group show the same chemical reactions and constitute one class of compounds. For example, *haloalkanes* such as chloromethane, chloroethane, chloropropane which have the *halo* (chloro) functional group show the characteristic reactions of the halo (chloro) group and hence,constitute the class of compounds known as *haloalkanes.*

CH_3Cl	Chloromethane
C_2H_5Cl	Chloroethane
C_3H_7Cl	Chloropropane

Similarly, the *alcohols* – methanol, ethanol, propanol *etc.* which have — OH functional group show characteristic properties and reactions due to the — OH group and they constitute another class called alcohols which is different from that of haloalkanes.

CH_3OH	Methanol
CH_3CH_2OH	Ethanol
$CH_3CH_2\ CH_2OH$	Propanol

Table 28.5 shows the common functional groups and their classes.

Table 28.5 : Some common functional groups

Functional group	Class	General formula	Example
$>C=C<$	alkene	C_nH_{2n}	$H_2C=CH_2$
$-C\equiv C-$	alkyne	C_nH_{2n-2}	$HC\equiv CH$
— X (F, Cl, Br, I)	haloalkanes	R — X	CH_3-Cl
— OH	alcohols	R — OH	CH_3OH
$-\overset{\overset{\displaystyle O}{\parallel}}{C}-H$	aldehydes	$R-\overset{\overset{\displaystyle O}{\parallel}}{C}-H$	CH_3CHO

Notes

$-\overset{\overset{O}{\Vert}}{C}-$	ketones	$R-\overset{\overset{O}{\Vert}}{C}-R$	$CH_3-\overset{\overset{O}{\Vert}}{C}-C_2H_5$
$-\overset{\overset{O}{\Vert}}{C}-OH$	carboxylic acids	$R-\overset{\overset{O}{\Vert}}{C}-OH$	$CH_3-\overset{\overset{O}{\Vert}}{C}-OH$ acetic acid
$-\overset{\overset{O}{\Vert}}{C}-O-$	esters	$R-\overset{\overset{O}{\Vert}}{C}-OR$	$CH_3-\overset{\overset{O}{\Vert}}{C}-O-CH_3$

ACTIVITY 28.4

Take some simple organic compounds available around you which contain the simple functional groups and study their properties .You can take help of your teacher for this activity.

INTEXT QUESTIONS 28.6

1. Identify the functional groups present in the following compounds:

   (i) CH_3CH_2OH (ii) CH_3Cl (iii) C_2H_2 (iv) CH_3 — COOH

   In the next section, you will study about some simple compounds which contain some of the above mentioned functional groups.

28.7 COMPOUNDS OF DAILY USE

We daily use many organic compounds such as alcohol, vinegar, vanillin, acetone etc. Let us now study about some of them in more details.

28.7.1 Alcohols

You have read earlier that alcohols contain the hydroxyl (— OH) functional group. They are named by replacing final *e* of the parent alkane by *ol*. Some examples of alcohols are given below:

CH_3OH	C_2H_5OH	$CH_3-\underset{}{\overset{\overset{OH}{|}}{CH}}-CH_3$
Methanol	Ethanol	2-propanol (rubbing alcohol)

$$\begin{array}{ccccc} OH & & OH & & OH \\ | & & | & & | \\ CH_2 & — & CH & — & CH_2 \end{array}$$

1, 2, 3-propanetriol (Glycerin)

Alcohols are soluble in water because they can form hydrogen bonds with water molecules.

(a) Methanol (CH_3OH)

Methanol is also called wood alcohol because it was earlier obtained by heating wood in the absence of air. It is prepared by heating carbon monoxide and hydrogen under pressure and by using a catalyst.

$$CO(g) + 2H_2\ (g) \xrightarrow[200–300\ atm\ \ ZnO/Cr_2O_3]{400°C} CH_3OH\ (g)$$

It has many industrial uses. It is used in the synthesis of acetic acid and many adhesives, fibers and plastics. It is also used as an additive to petrol and also as a fuel.

(b) Ethanol (C_2H_5OH)

Ethanol is present in beer, wine and medicines. It is produced by the fermentation of carbohydrates such as glucose and starch present in grapes, barley etc. The reaction is catalyzed by the enzymes present in yeast.

$$\underset{\text{Glucose}}{C_6H_{12}O6\ (aq)} \xrightarrow{\text{Yeast}} \underset{\text{Ethanol}}{2CH_3CH_2OH\ (aq)} + 2\ CO_2\ (g)$$

It is used as solvent for organic compounds. It is also used as sprit (95% Ethanol)

28.7.2 Aldehydes and Ketones

IUPAC name of aldehyde- Suffix “al” is added by replacing “e” from the parent alkane. For example

For HCHO, parent alkane ⟶ Methane ⟶ replace “e” by “al” ⟶ Methanal

For CH_3CHO, parent alkane ⟶ Ethane ⟶ replace “e” by “al” ⟶ Ethanal

$$\begin{array}{ccccc} & & O & & \\ & & \| & & \\ H & — & C & — & H \end{array} \qquad\qquad \begin{array}{ccccc} & & O & & \\ & & \| & & \\ CH_3 & — & C & — & H \end{array}$$

Methanal (Formaldehyde) Ethanal (Acetaldehyde)

IUPAC naming of ketone - Suffix “one” is added by replacing “e” from the parent alkane. For example

$$\begin{array}{ccccc} & & O & & \\ & & \| & & \\ CH_3 & — & C & — & CH_3 \end{array}$$

Parent alkane ⟶ Propane ⟶ replace “e” by “one” ⟶ Propanone

In ketones, the carbonyl group is attached to two carbon atoms as given below:

$$CH_3 - \overset{\overset{\displaystyle O}{||}}{C} - CH_3$$

(Propanone) Acetone

An aqueous solution of formaldehyde, called *formalin* is used to preserve biological specimens in the laboratories. Vanillin which is used as a flavour, also has the aldehyde functional group.

Acetone is used as a solvent and also in nail polish removers.

28.7.3 Carboxylic Acids

Carboxylic acids contain the carboxyl ($- \overset{\overset{\displaystyle O}{||}}{C} - OH$) functional group. Their general formula is R — COOH. Vinegar which is also called acetic acid has the formula CH_3COOH.

It is obtained by the oxidation of ethanol in the presence of conc. H_2SO_4 and $K_2Cr_2O_7$

$$CH_3 - CH_2 - OH + 2[O] \xrightarrow{\text{conc. } H_2SO_4 + K_2Cr_2O_7} CH_3 - COOH + H_2O$$

It is soluble in water as it forms hydrogen bond with water molecule. It is used as preservative .

Some common carboxylic acids are given below:

$$H - \overset{\overset{\displaystyle O}{||}}{C} - OH$$

Formic acid (from ants)
'In Latin *formica* means ant"

$$CH_3CH_2CH_2 - \overset{\overset{\displaystyle O}{||}}{C} - OH$$

Butyric acid
(present in rancid butter)

$$CH_3 - \overset{\overset{\displaystyle OH}{|}}{CH} - COOH$$

Lactic acid

(present in sour milk, also produced in muscles during heavy exercise)

Similarly, citric acid present in citrus fruits and ascorbic acid present in Vitamin C are carboxylic acids.

INTEXT QUESTIONS 28.7

1. What is wood alcohol?
2. What is glycerin? Which functional group is present in it.
3. How is ethanol produced?

4. Give two examples of compounds having aldehyde functional group.
5. What is the use of acetone?
6. Which acid is present in vinegar?
7. Name the compound which has an aldehyde group and is used as a flavour.
8. Give IUPAC Name of the following compounds
   (a) C_2H_5OH (b) CH_3COOH
   (c) HCHO (d) $CH_3 — CO — CH_3$
9. Name the functional group present in the following compounds
   (a) C_2H_5OH (b) CH_3COOH
   (c) HCHO (d) CH_3-CO-CH_3

WHAT YOU HAVE LEARNT

- In this lesson, you have learnt that carbon is tetravalent in nature and has the unique property of catenation,
- The number of compounds formed by carbon is very large.
- The allotropic forms of carbon are diamond, graphite and fullerene.
- Diamond has a three-dimensional network of covalently bonded carbon atom. It is hard and colourless. It has high melting and boiling point and is a good conductor of heat but poor conductor of electricity.
- Graphite is soft, black, and slippery in nature and has a layered structure. It is a good conductor of electricity.
- Fullerenes contain carbon atoms arranged in closed structures similar to football.
- Charcoal, coke and carbon black are micro-crystalline forms of carbon.
- The compounds of carbon can be classified as organic and inorganic.
- Carbon monoxide and carbon dioxide are two important inorganic compounds of carbon.
- Organic compounds of carbon are hydrocarbons and their derivatives.
- The hydrocarbons can be classified as saturated and unsaturated. The saturated hydrocarbons contain carbon-carbon single bonds whereas the unsaturated hydrocarbons contain carbon-carbon multiple bonds.
- Isomers have same molecular formula but different structure.

- Organic compounds are systematically named according to IUPAC system of nomenclature.
- Some simple functional groups include halo-, hydroxyl-, carbonyl, carboxylic acid etc.
- Compounds containing the above functional groups exhibit characteristic properties and have important uses in our daily life.

TERMINAL EXERCISES

1. Why carbon cannot form ionic bonds?
2. What is catenation?
3. What types of bonds are formed by the carbon atom?
4. Name the three allotropic forms of carbon.
5. How do natural diamonds form?
6. Name two places where diamonds are found.
7. Why is diamond hard?
8. Give two uses of diamond.
9. Compare the physical properties of diamond and graphite.
10. How can graphite be converted into diamond?
11. Create a flow chart as shown below to compare the various allotropes of carbon

C

G....... D....... F.......

1. Names of Allotropes	....	....	....
2. Place where found	....	....	....
3. One use	....	....	....
4. Appearance	....	....	....
5. Arrangement of C atoms	....	....	....

12. What is activated charcoal? How is it prepared?
13. Given below are pictures of three microcrystalline or amorphous form of graphite. Name them and write one use of each.

Picture of Charcoal from book	Picture of Coke from Book	Picture of Carbon Black from book
A	B	C

Name ....
Use ....

14. Name the products formed when
    (i) Wood is strongly heated in absence of air.
    (ii) Coal is strongly heated in the absence of air.
    (iii) Hydrocarbons are heated in limited supply of oxygen.
15. Why is CO toxic in nature?
16. Give two uses of CO and CO_2.
17. For the following state one point of differences between the following pairs of terms
    (i) Organic compounds and inorganic compounds
    (ii) Carbon Monoxide and carbon dioxide
    (iii) Aliphatic and aromatic compounds
18. What is a homologous series?
19. Name 10 carbon compounds of a homologous series. Write their molecular formula and derive a general formula for the series.
20. What is general formula for the homologous series of
    (i) alkanes (ii) alkenes (iii) alkynes?
21. What is the molecular formula for ethane?
22. Give here four prefixes: But- , Eth- , Meth- , Prop- , and Suffix –ane to develop the names of alkanes. How many carbon atoms do each of these alkanes contain?
23. Draw the Chemical Structure of Butane and Isobutane and based on it justify that they are isomers.
24. Give IUPAC name of the following compounds:
    (i) $CH_3 — CH = CH_2$
    (ii) $CH_3 — HC = CH — CH_3$
    (iii) $CH_3 — OH$
25. Give an example of a compound which has carboxylic (-COOH) functional group.
26. (a) Of the following which has single bond, double bonds and triple bonds between C, C atoms? Alkynes, alkane, alkene
    (b) Name their simplest compounds and write the molecular formula.

27. Give one use of each of the following:
    (i) Methanol (ii) ethanol (iii) glycerin
28. What is the difference between the structure of an aldehyde and a ketone?
29. What is (i) dry ice (ii) wood alcohol (iii) formalin (iv) vinegar
30. To which group of carbon compounds do each of the carbon compounds used for the following belong?
    (i) To ripen fruits
    (ii) In oxy-acetylene torch
31. Name the carboxylic acid present in vitamin C.
32. Which acid is present in citrus fruits?
33. Your teacher has asked you to procure sources of formic acid and butyric acid. Which two sources will you collect and bring?
34. Name the carboxylic acids found in :
    (i) Lemon (ii) Vitamin C (iii) Sour milk
    (iv) Rancid butter (v) Ants

ANSWERS TO INTEXT QUESTIONS

28.1

1. 4
2. Covalent
3. Because of catenation, possibility of existence of isomers and presence of various functional groups.
4. Organic chemistry
5. 4

28.2

1. Fullerenes
2. (i) 4 (ii) 3
3. Because a large amount of heat energy is required to break the three – dimensional network of covalent bonds.
4. No. Because there are no free electrons.
5. Because of weak bonding forces between layers of carbon atoms in graphite, they can slide over each other.

6. As electrodes, lubricant, pencil leads, vessels for melting metals (any two).
7. Closed structure similar to foot ball.
8. Charcoal, coke and carbon black

   Uses: Charcoal – absorption of coloured impurities

   Coke – reducing agent in metallurgy

   Carbon black – pigment in inks or in automobile typres

28.3

1. (i), (iii) – Organic

   (ii), (iv) – inorganic
2. (i) Organic compounds have low melting and boiling points whereas inorganic compounds have high melting and boiling points.

   (ii) Organic compounds dissolve in organic solvents whereas inorganic compounds dissolve in water and not in organic solvents.

28.4

1. Carbon dioxide
2. Carbon monoxide
3. Carbon dioxide
4. Carbon dioxide
5. Carbon dioxide and ethanol

28.5

1. In saturated compounds, single bonds are present between carbon atoms whereas in unsaturated compounds double or triple bonds are present between carbon atoms.
2. Saturated: methane, ethane   Unsaturated: ethene, propyne
3. Propane.
4. Isomers are compounds which have the same molecular formula but have different structures.
5. International Union of Pure and Applied Chemistry.
6. (i) methyl   (ii) ethyl
7. (a) 2-methylbutane   (b) 2,3-dimethylbutane

28.6

1. (i) hydroxyl (— OH) (ii) — Cl (iii) Alkyne (iv) Carboxylic

28.7

1. Methanol
2. Glycerin is 1,2,3-propanetriol. It contains the hydroxyl functional group
3. It is produced by the fermentation of carbohydrates such as glucose and starch present in grapes, barley etc.
4. Formaldehyde, acetaldehyde
5. It is used as a solvent.
6. Acetic acid
7. Vanillin
8. (a) Ethanol (b) Ethanoic acid (c) Methanal (d) Propanone
9. (a) Alcohol (b) Carboxylic (c) Aldehyde (d) Ketone

MODULE - 7
HUMANS AND ENVIRONMENT