CHAPTER

11

Organic Chemistry

Students Learning Outcomes

Students will be able to:

- Recognize structural, condensed and molecular formulae of the straight chain hydrocarbons up to ten carbon atoms. (Understanding);
- Identify some general characteristics of organic compounds. (Remembering);
- Explain the diversity and magnitude of organic compounds. (Understanding);
- list some sources of organic compounds (Applying);
- list the uses of organic compounds (Remembering);
- Recognize and identify a molecule's functional groups. (Understanding);
- Convert alkanes into alkyl radicals. (Applying);
- Differentiate between alkanes and alkyl radicals. (Analyzing);
- Define functional group. (Remembering);
- Differentiate between organic compounds on the basis of their functional groups. (Analyzing) and
- Classify organic compounds into straight chain, branched chain and cyclic compounds. (Understanding).

Introduction:

Initially (before 1828), the name organic chemistry was given for the chemistry of compounds obtained from plants and animals, i.e., from living organism. The word organic signifies life. Lavoisier showed that compounds obtained from plants were often made of C, H and O elements while compounds obtained from animals contain elements C, H, N, O, S, P.... etc.

In early 19th century, Swedish chemist Jacob Berzellius put forward the "Vital Force Theory". According to this theory, organic compounds could not be prepared in laboratories because they were supposed to be synthesized under the influence of a mysterious force called Vital Force, inherent only in living things.

The Vital Force theory suffered death blow in 1828 when Wohler synthesized the first organic compound urea from inorganic substance by heating ammonium cyanate (NH_4CNO):

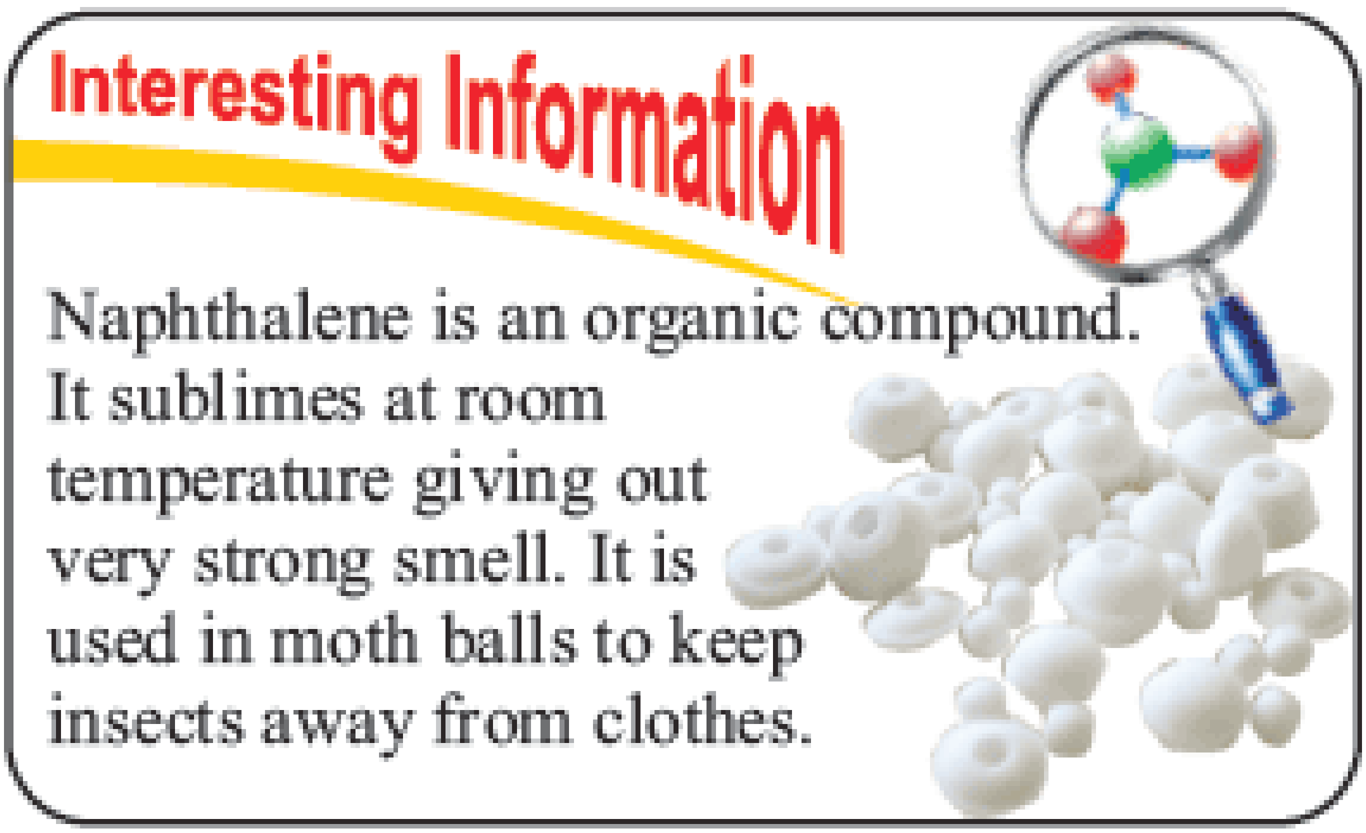
$$NH_4CNO \xrightarrow[\text{Rearrangement}]{\Delta} \underset{\text{urea}}{H_2NCONH_2}$$

Later on Vital Force theory was further negated by Kolbe (1845) when he prepared acetic acid in laboratory.

Organic compounds include carbohydrates, proteins, lipids, enzymes, vitamins, drugs, pharmaceutical products, fertilizers, pesticides, paints, dyes, synthetic rubbers, plastics, artificial fibres and many polymers, etc.

11.1 ORGANIC COMPOUNDS

Today, there are about ten millions of organic compounds and thousands of new organic compounds are being prepared every year. Therefore, the old definition has been rejected. A detailed investigation of organic compounds revealed that all of them contain covalently bonded carbon and hydrogen as their essential constituent. Hence, *organic compounds are hydrocarbons (compounds of carbon and hydrogen only) and their derivatives, in which covalently bonded carbon is an essential constituent. The branch of chemistry which deals with the study of hydrocarbons and their derivatives is known as* ***organic chemistry****.*



Though, the oxides of carbon like carbon monoxide and carbon dioxide, carbonates, bicarbonates and carbides are also carbon compounds, they are not treated as organic compounds because their properties are quite different from those of organic compounds. Each organic compound has specific formula.

There are four types of formulae of organic compounds:

- Molecular formula
- Structural formula
- Condensed formula
- Dot and cross formula

(i) Molecular Formula

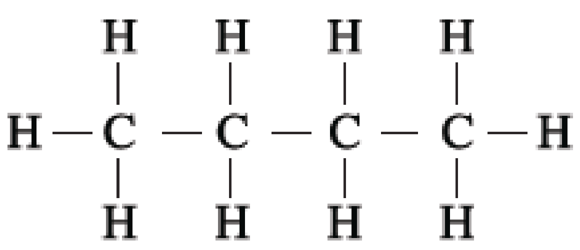
The formula which represents the actual number of atoms in one molecule of the organic compound is called the molecular formula, e.g., molecular formula of butane is C_4H_{10}. It shows:

a. Butane is made up of carbon and hydrogen atoms.

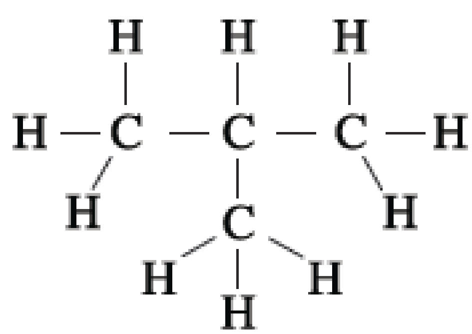
b. Each molecule of butane consists of 4 carbon atoms and 10 hydrogen atoms.

(ii) Structural Formula

Structural formula of a compound represents the exact arrangement of the different atoms of various elements present in a molecule of a substance. In a structural formula, single bond is represented by a single line (-), a double bond by two lines (=) and a triple bond by three lines ( ) between the bonded atoms. Organic compounds may have same molecular formulae but different structural formulae, e.g., structural formulae of butane C_4H_{10} are:



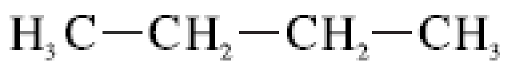
n-Butane



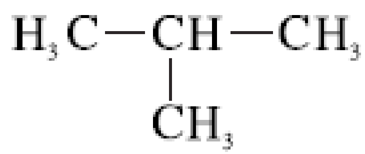
isobutane

(iii) Condensed Formula

The formula that indicates the group of atoms joined together to each carbon atom in a straight chain or a branched chain is called the condensed formula.



n-Butane



isobutane

(iv) Electronic or Dot and Cross Formula

The formula which shows the sharing of electrons between various atoms in one molecule of the organic compound is called dot and cross formula or electronic formula.

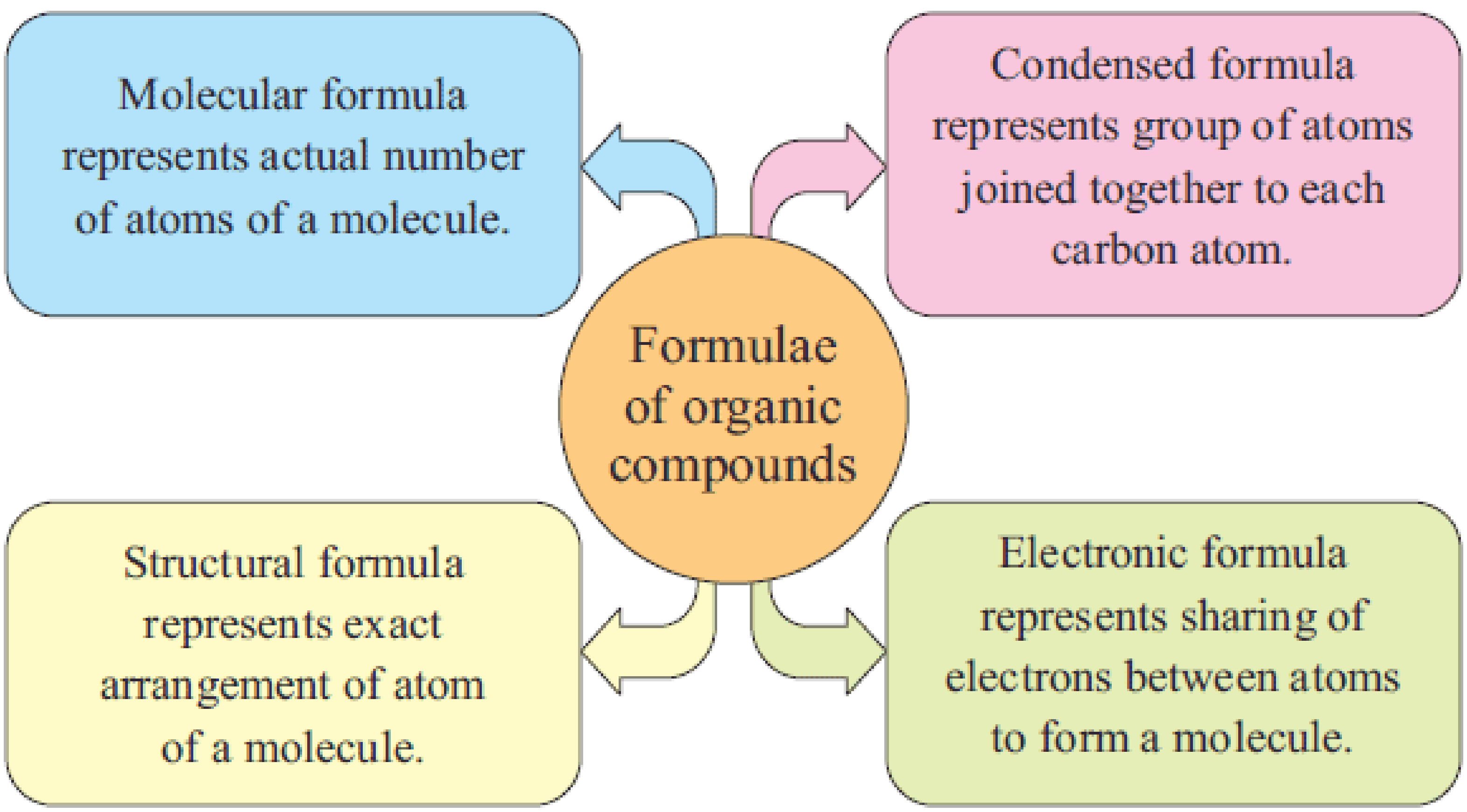
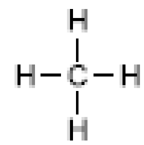
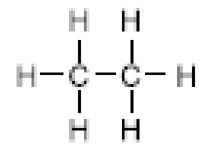
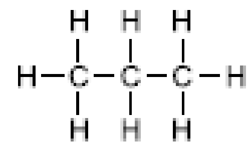
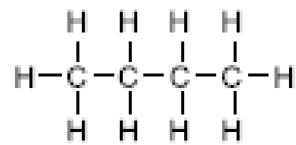
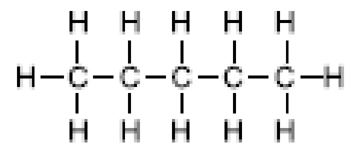
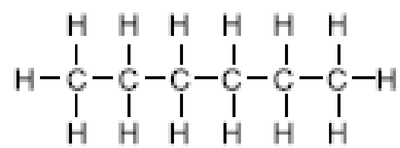
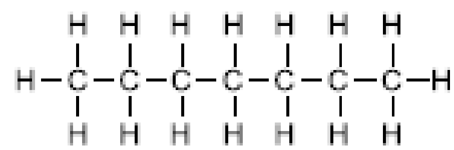
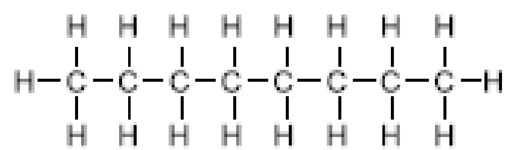
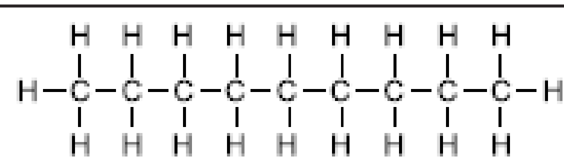
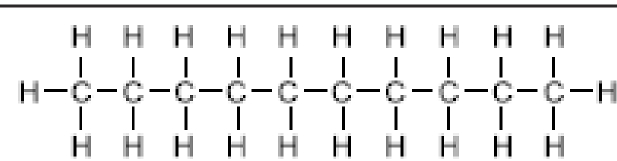


Table 11.1: Names, Molecular, Condensed and Structural Formulae of the first ten Hydrocarbons

Name	Molecular Formula	Condensed Formula	Structural Formula
Methane	CH_4	CH_4	
Ethane	C_2H_6	H_3CCH_3	
Propane	C_3H_8	$H_3CCH_2CH_3$	
Butane	C_4H_{10}	$H_3C\ (CH_2)_2CH_3$	
Pentane	C_5H_{12}	$H_3C(CH_2)_3CH_3$	
Hexane	C_6H_{14}	$H_3C(CH_2)_4CH_3$	
Heptane	C_7H_{16}	$H_3C(CH_2)_5CH_3$	
Octane	C_8H_{18}	$H_3C(CH_2)_6CH_3$	
Nonane	C_9H_{20}	$H_3C(CH_2)_7CH_3$	
Decane	$C_{10}H_{22}$	$H_3C(CH_2)_8CH_3$	

11.1.1 Classification of Organic Compounds

All known organic compounds have been broadly divided into two categories depending upon their carbon skeleton. These are:

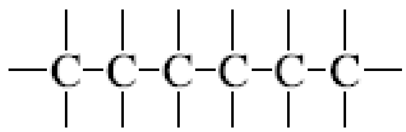
(i) Open chain or acyclic compounds.

(ii) Closed chain or cyclic compounds.

(i) Open chain or Acyclic compounds

Open chain compounds are those in which the end carbon atoms are not joined with each other, in this way they form a long chain of carbon atoms. These chains may be either straight or branched. For example,

(a) Straight chain compounds are those in which carbon atoms link with each other through a single, double or triple bonds forming a straight chain such as;

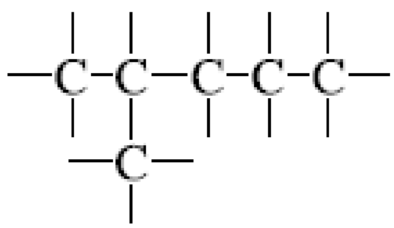


Straight chain

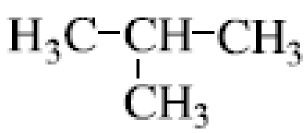
$$H_3C-CH_2-CH_2-CH_3$$

Straight chain (*n*-Butane)

(b) Branched chain compounds are those in which there is a branch along a straight chain, such as:



Branched chain



Branched chain (isobutane)

Open chain compounds are also called aliphatic compounds.

(ii) Closed chain or Cyclic compounds

Closed chain or cyclic compounds are those in which the carbon atoms at the end of the chain are not free. They are linked to form a ring. They are further divided into two classes:

(a) Homocyclic or carbocyclic compounds.

(b) Heterocyclic compounds.

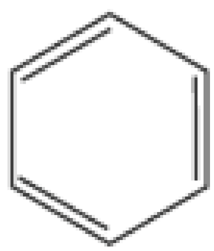
(a) Homocyclic or Carbocyclic compounds.

Homocyclic or carbocyclic compounds contain rings which are made up of only one kind of atoms, i.e., carbon atoms. These are further divided into two classes:

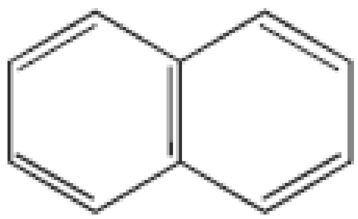
- Aromatic compounds
- Alicyclic compounds

Aromatic compounds:

These organic compounds contain at least one benzene ring in their molecule. A benzene ring is made up of six carbon atoms with three alternating double bonds. They are called aromatic because of aroma or smell they have. For example:



Benzene

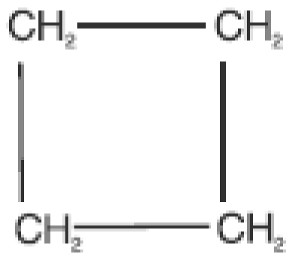


Naphthalene

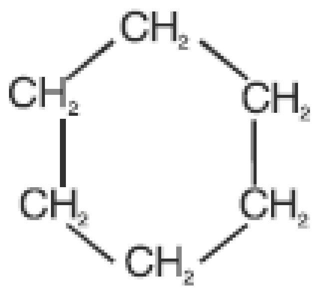
They are also called benzenoid compounds.

Alicyclic or non-benzenoid compounds:

Carbocyclic compounds which do not have benzene ring in their molecules are called alicyclic or non-benzenoid compounds. For example,



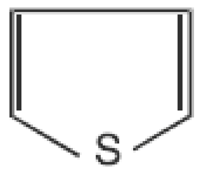
Cyclobutane



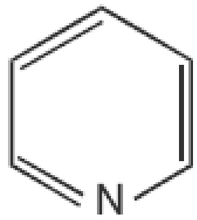
Cyclohexane

(b) Heterocyclic compounds

Cyclic compounds that contain one or more atoms other than that of carbon atoms in their rings are called heterocyclic compounds.

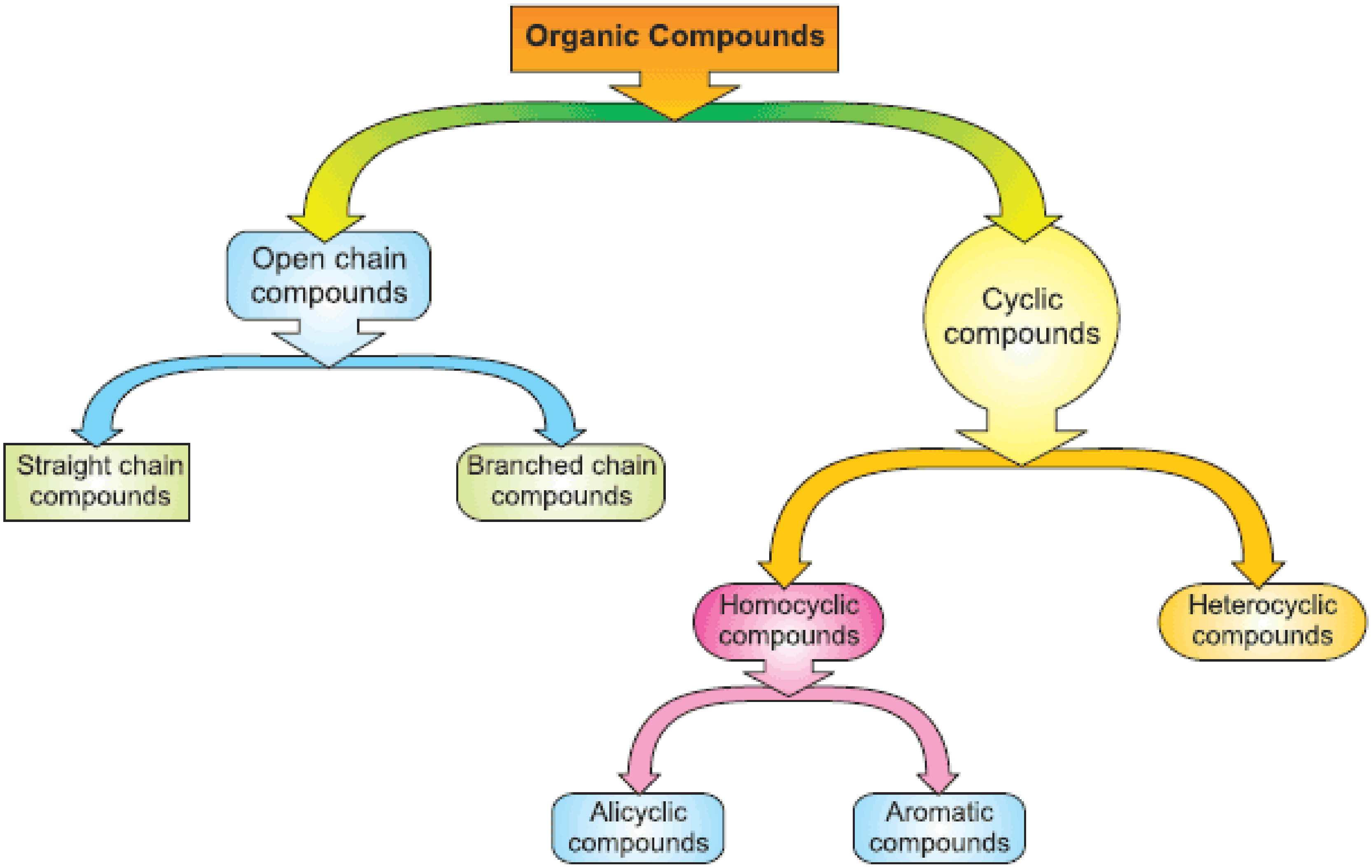


Thiophene



Pyridine

The classification may be summarized as follows:



11.1.2 Diversity and Magnitude of Organic Compounds

There are a total of 118 elements known today. The number of organic compounds (carbon compounds) is more than ten million. This number is far more than the number of compounds of all the remaining elements taken together. The existence of such a large number of organic compounds is due to the following reasons:

Animation 11. 1: benzene
Source & Credit: campbell

(i) Catenation: The main reason for the existence of a large number of organic compounds is that carbon atoms can link with one another by means of covalent bonds to form long chains or rings of carbon atoms. The chains can be straight or branched. The ability of carbon atoms to link with other carbon atoms to form long chains and large rings is called **catenation.**

Two basic conditions for an element to exhibit catenation are:

1. Element should have valency two or greater than two.
2. Bonds made by an element with its own atoms should be stronger than the bonds made by the element with other atoms especially oxygen.

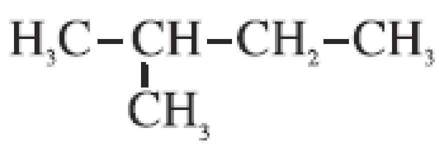
Both silicon and carbon have similar electronic configurations but carbon shows catenation whereas silicon does not. It is mainly due to the reason that C-C bonds are much stronger (355 kJ mol^{-1}) than Si-Si (200 kJ mol^{-}) bonds. On the other hand, Si - O bonds are much stronger (452 kJ mol^{-1}) than C-O bonds (351 kJ mol^{-1}). Hence, silicon occurs in the form of silica and silicates in nature.

(ii) Isomerism:

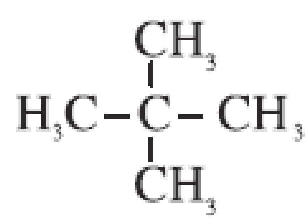
Another reason for the abundance of organic compounds is the phenomenon of **isomerism.** *The compounds are said to be* **isomers** *if they have the same molecular formula but different arrangement of atoms in their molecules or different structural formulae.*

Isomerism also adds to the possible number of structures, e.g., molecular formula C_5H_{12} can be represented by three different structures. Thus, C_5H_{12} has three isomers, as shown below:

n-pentane



iso-pentane



neopentane

Number of isomers increases with the increase in number of carbon atoms in the given molecular formula.

(iii) Strength of covalent bonds of carbon: Due to its very small size, carbon can form very strong covalent bonds with other carbon atoms, hydrogen, oxygen,nitrogen and halogens. This enables it to form a large number of compounds.

(iv) Multiple bonding: In order to satisfy its tetravalency, carbon can make multiple bonds (i.e., double and triple bonds). This further adds to the possible number of structures. For example, two carbons in ethane are linked by a single covalent bond, by a double covalent bond in ethylene and a triple covalent bond in acetylene.

11.1.3 General Characteristics of Organic Compounds:

Organic compounds have the following general characteristics:
(i) Origin: Naturally occurring organic compounds are obtained from plants and animals. On the other hand, inorganic compounds are obtained from minerals and rocks.
(ii) Composition: Carbon is an essential constituent of all organic compounds. They are made up of few elements such as carbon, hydrogen, nitrogen, oxygen, halogen, sulphur, etc. On the other hand, inorganic compounds are made up of almost all the elements of the Periodic Table known so far.
(iii) Covalent linkage: Organic compounds contain covalent bonds, that may be polar or non-polar, while the inorganic compounds mostly contain ionic bonds.

(iv) Solubility:
Organic compounds having non-polar linkages are generally soluble in organic solvents like alcohol, ether, benzene, carbon disulphide etc. On the other hand, the inorganic compounds with ionic bonds are soluble in polar solvents like water.

(v) Electrical conductivity:
Due to the presence of covalent bonds, organic compounds are poor conductors of electricity, whereas inorganic compounds being ionic in nature, are good conductors of electricity in molten state or in aqueous solution.

(vi) Melting and boiling points: Generally, organic compounds have low melting and boiling points and are volatile in nature. Inorganic compounds, on the other hand, have comparatively high melting and boiling points.

(vii) Stability: Since organic compounds have low melting and boiling points, they are less stable than inorganic compounds.

(viii) Combustibility: Organic compounds with high percentage of carbon are generally combustible. On the other hand, inorganic compounds are mostly non-combustible.

(ix) Isomerism: A main characteristic of organic compounds which differentiate them from inorganic substances is their tendency to exhibit the phenomenon of isomerism. Isomerism is rare in inorganic substance.

(x) Rate of reaction: Due to the presence of covalent linkages, the reactions of organic compounds are molecular in nature. They are often slow and require specific conditions such as temperature, pressure or catalyst.

Test YourSelf 11.1

1. Why and how carbon completes its octet?
2. Point out the properties of carbon which are responsible for formation of long chains of carbon atom compounds.
3. Why are the melting and boiling points of organic compounds low?
4. Why are the organic compounds poor conductors of electricity?
5. What are the reasons for the formation of millions of organic compounds?

11.2 SOURCES OF ORGANIC COMPOUNDS

Organic compounds are prepared naturally by animals and plants. Animals synthesize two main groups of organic compounds: proteins and fats. Proteins are meat, mutton, chicken and eggs, etc. Fats are present in milk, butter, etc. Plants synthesize; carbohydrates, proteins, fats, vitamins, etc

Moreover, dead plants buried under Earth's crust are converted through biochemical processes to coal, petroleum and gas. These materials are the main sources of organic compounds. We can get thousands of organic compounds by *the destructive distillation of coal and fractional distillation of petroleum.*

Details of each source are given in figure below:

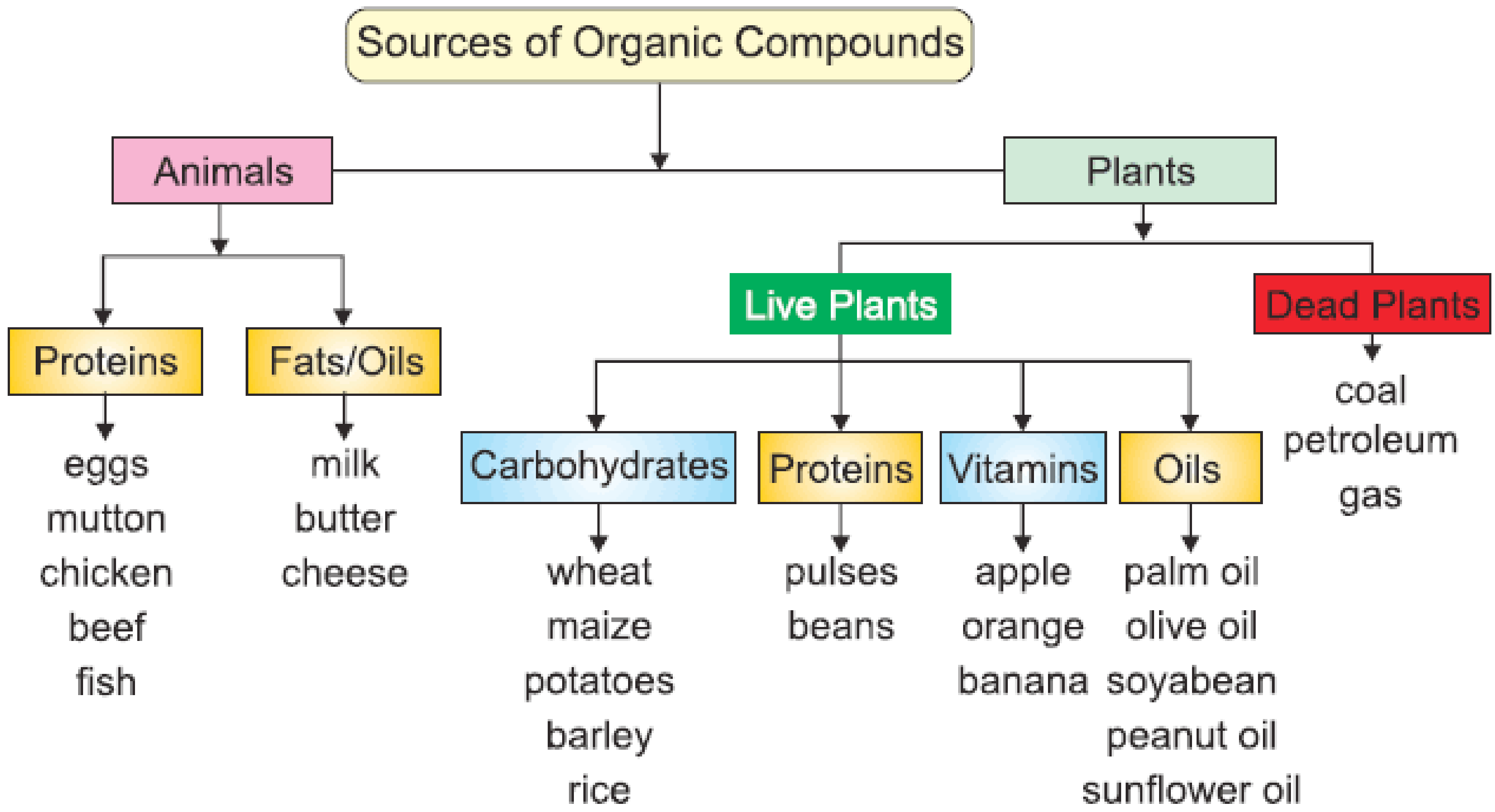


Fig. 11.1 Sources of organic compounds

11.2.1 Coal

Coal is a blackish, complex mixture of compounds of carbon, hydrogen and oxygen. It also contains small amounts of nitrogen and sulphur compounds:

Coal was formed by the decomposition of dead plants buried under the Earth's crust millions of years ago. *Conversion of wood into coal is called carbonization.* It is a very slow biochemical process. It takes place in the absence of air under high pressure and high temperature over a long period of time (about 500 millions of years) as shown in figure 11.2. Wood contains about 40% carbon, so depending upon the extent of carbonization process, four types of coal are found. These types differ with respect to carbon content, volatile matter and moisture. Table 11.2 shows the detail of contents of different types of coal and their uses in daily life and industry.

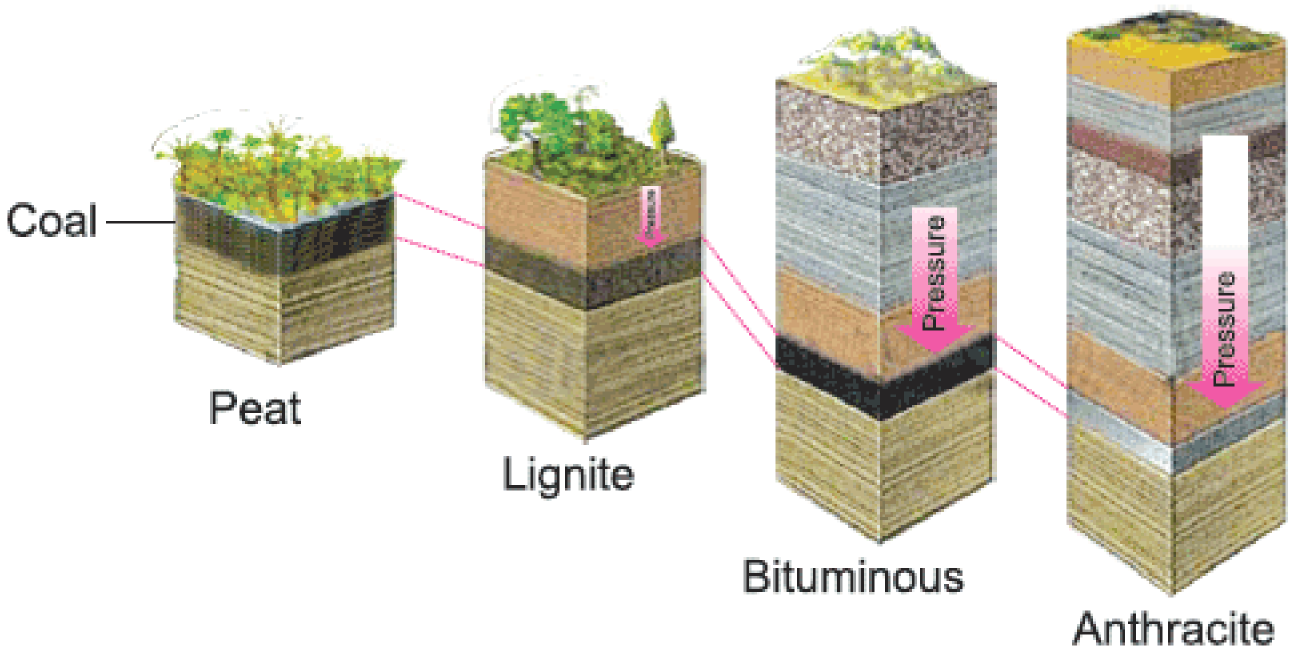


Fig. 11.2 Formation of coal in different stages with the increase of pressure.

Table 11.2 Different types of coal

Type of Coal	Carbon Contents	Uses
Peat	60 %	It is inferior quality coal used in kiln.
Lignite	70 %	It is soft coal used in thermal power stations.
Bituminous	80 %	It is common variety of coal used as household coal.
Anthracite	90 %	It is superior quality hard coal that is used in industry.

Coal has become a major source of organic compounds because of destructive distillation. The strong heating of coal in the absence of air is called destructive distillation. As we know, coal contains elements like carbon, hydrogen, oxygen, nitrogen and sulphur. So destructive distillation of coal provides a large number of organic compounds along with a few inorganic compounds. These products are:

(i) Coal Gas is a mixture of hydrogen, methane and carbon monoxide. It produces heat when burnt in air. Therefore, it is mainly used as a fuel in industry. It is also used to provide an inert or reducing atmosphere in various metallurgical processes.

(ii) Ammonical Liquor is a solution of ammonia gas in water. It is used to prepare nitrogenous fertilizers. For example, when it is treated with sulphuric acid, it produces ammonium sulphate, fertilizer.

(iii) Coal Tar is a thick black liquid. It is a mixture of more than 200 different organic compounds, mostly aromatic. These compounds are separated by fractional distillation. Some of the important aromatic compounds are benzene, phenol, toluene, aniline, etc. These chemicals are used to synthesize drugs, dyes, explosives, paints, varnishes, plastics, synthetic fibre and pesticides. Besides these valuable chemicals, the black residue of the coal tar called pitch is obtained. It is used for surfacing of roads and roofs.

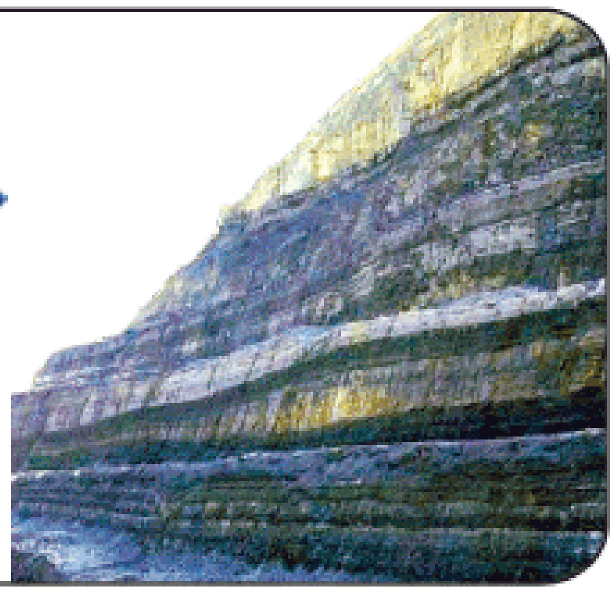
(iv) Coke is 98% carbon. It is left behind residue of coal. When coal is subjected to destructive distillation, it loses all its volatile components and leaves behind a solid *residue* called coke. It is mainly used as a reducing agent in the extraction of metals especially iron. It is also used as fuel.

TestYourSelf 11.2

i. Name the gases which are found in coal gas.
ii. Is coal tar a compound. What is importance of coal tar?
iii. What is coke? For what purpose it is used?
iv. Which is the best quality of coal?
v. What is destructive distillation?

Interesting Information

Scientists are working on ways to convert coal into gas underground so that it will not have to be mined. This will allow us to use small seams of coal or seams that are dangerous to mine because of weaknesses in the surrounding rocks.



11.2.2 Petroleum

Petroleum *is a dark brownish or greenish black coloured viscous liquid.* It is a complex mixture of several solid, liquid or gaseous hydrocarbons in water mixed with salts and earth particles.

Petroleum is a main source of organic compounds. It consists of several compounds mainly hydrocarbons. These compounds are separated by fractional distillation (separation of fractions or components depending upon their boiling point ranges). These fractions and their uses are provided in table 16.1 in chapter 16. Each fraction is not a single compound, rather each of it consists of different organic compounds.

11.2.3 Natural Gas

It is a mixture of low molecular mass hydrocarbons. The main component about 85% is methane, along with other gases: ethane, propane and butane. Its origin is similar to that of coal and petroleum. Therefore, it is found with their deposits as shown in figure 11.3. Natural gas is used as fuel in homes as well as in industries. It is used as fuel in automobiles as compressed natural gas (CNG). Natural gas is also used to make carbon black and fertilizer.

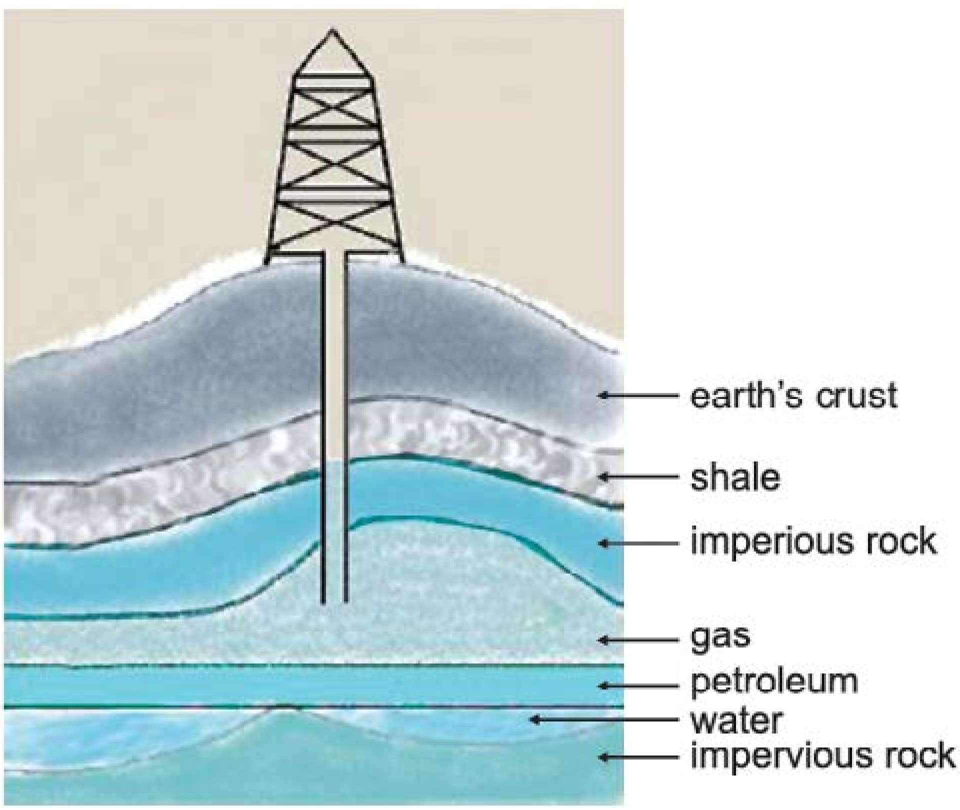


Fig. 11.3 Occurrence and drilling of gas.

11.2.4 Plants

Living plants synthesize macro-molecules, e.g., carbohydrates, proteins, oils and vitamins. The basic unit of all types of carbohydrates is glucose which is synthesized by plants through photosynthesis. Glucose then further polymerizes to form sucrose, starch and cellulose. Proteins are found in the pulses and beans. *Proteins* are prepared by the fixation of nitrogen by bacteria found on the roots of plants. *Oils* are found in the seeds of plants such as sunflower, rapeseed, palm, coconut and groundnut. *Vitamins* are found in apple and citrus fruits. Besides these major food items, plants also give us gums, rubber, medicines, etc.

11.2.5 Synthesis in Laboratory

Just about two hundred years ago, it was considered that organic compounds could be synthesized only by plants and animals because they possess 'Vital Force', which is very essential for synthesis of organic compounds. But the synthesis of urea (NH_2CONH_2) in laboratory by F.M. Wohler in 1828, opened the discipline on field synthesis of organic compounds in laboratory. Uptil now more than ten million organic compounds have been prepared in the laboratories. They range from simple to complex compounds.
They are present in drugs and medicines; flavours and fragrances; plastics and paints; synthetic fibres and rubber, cosmetics and toiletries and detergents, insecticides and pesticides, etc.

11.3 USES OF ORGANIC COMPOUNDS

No doubt, thousands of organic compounds are synthesized naturally by animals and plants, but millions of organic compounds are being prepared in the laboratories by the chemists. These compounds are part of everything from food we eat to the various items we use in daily life to fulfill our needs.

- **Uses as Food:** The food we eat daily such as milk, eggs, meat, vegetables, etc., contain carbohydrates, proteins, fats, vitamins, etc., are all organic stuff.
- **Uses as Clothing**: All types of clothing (we wear, we use as bed sheets etc.) are made up of natural fibres (cotton, silk and wool, etc.) and synthetic fibres (nylon , dacron and acrylic, etc.) all these are organic compounds.
- **Uses as Houses:** Wood is cellulose (naturally synthesized organic compound). It is used for making houses and furniture of all kinds.

- **Uses as Fuel:** The fuels we use for automobiles and domestic purposes are coal, petroleum and natural gas. These are called fossil fuels. All of these are organic compounds.

- **Uses as Medicines:** A large number of organic compounds (naturally synthesized by plants) are used as medicines by us. Most of the life saving medicines and drugs such as antibiotics (inhibit or kill microorganisms which cause infectious diseases) are synthesized in laboratories.
- **Uses as Raw Material:** Organic compounds are used to prepare a variety of materials, such as rubber, paper, ink, drugs, dyes, paints, varnishes, pesticides, etc.

TestYourself 11.3

1. Define petroleum.
2. What types of compounds are synthesized by plants?
3. What is the basic unit of carbohydrates and how is it synthesized?
4. CNG stands for ....
5. Our existence owes to organic compounds, comment.

11.4 ALKANES AND ALKYLRADICALS

Alkanes are saturated hydrocarbons or paraffins (para means little, affin means affinity). Their general formula is C_nH_{2n+2}, where 'n' is number of carbon atoms. In case of alkanes 'n' ranges from 1 to 40. In this way, alkanes form the most important homologous series of compounds.

Homologous Series

Organic compounds are divided into groups of compounds having similar chemical properties. Each group is known as a homologous series. Organic compounds of the same homologous series have the following properties in common:

1. All members of a series can be represented by a general formula for example general formulae of alkane, alkenes and alkynes are C_nH_{2n+2}, C_nH_{2n} and C_nH_{2n-2}, respectively.

2. Successive members of the series differ by one unit of $-CH_2-$ and 14 units in their relative molecular mass.
3. They have similar chemical properties (because they contain the same functional group).
4. There is a regular change in their physical properties; the melting and boiling points increase gradually with the increase of molecular masses.
5. They can be prepared by similar general methods.

Hydrocarbons are regarded as parent organic compounds. All other compounds are considered to be derived from them by substituting one or more hydrogen atoms of a hydrocarbon by one or more reactive atom or group of atoms.

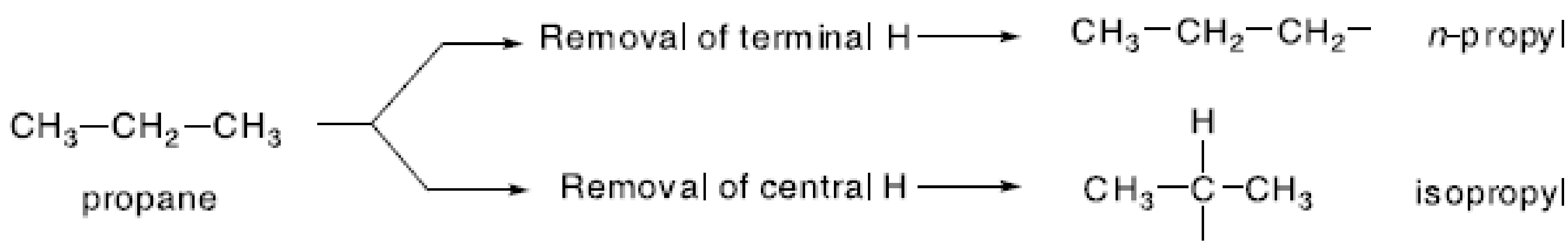
Formation of Alkyl Radicals

Alkyl radicals *are derivatives of alkanes*. They are formed by the removal of one of the hydrogen atoms of an alkane and are represented by a letter 'R'. Their name is written by replacing "ane" of alkane with 'yl' Table 11.3 represents first ten alkanes and their alkyl radicals. Their general formula is C_nH_{2n+1}

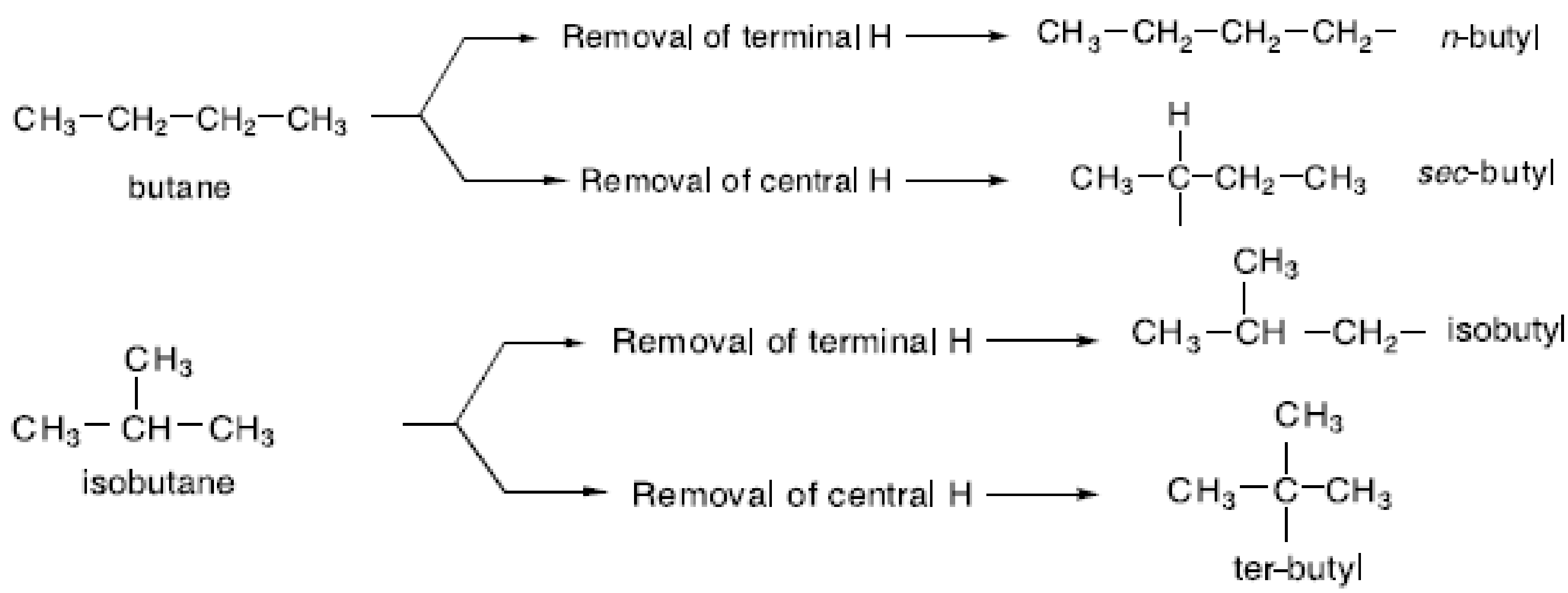
Table 11.3 Names and Molecular Formulae of Alkanes and their Alkyl Radicals

Alkane	Molecular Formula	Alkyl radical	Name
Methane	CH_4	CH_3-	Methyl
Ethane	C_2H_6	C_2H_5-	Ethyl
Propane	C_3H_8	C_3H_7-	Propyl
Butane	C_4H_{10}	C_4H_9-	Butyl
Pentane	C_5H_{12}	$C_5H_{11}-$	Pentyl
Hexane	C_6H_{14}	$C_6H_{13}-$	Hexyl
Heptane	C_7H_{16}	$C_7H_{15}-$	Heptyl
Octane	C_8H_{18}	$C_8H_{17}-$	Octyl
Nonane	C_9H_{20}	$C_9H_{19}-$	Nonyl
Decane	$C_{10}H_{22}$	$C_{10}H_{21}-$	Decyl

It is better to explain the type of radicals of propane and butane. Propane has a straight chain structure. When terminal H is removed, it is called **n-propyl**. When hydrogen from central carbon is removed, it is called **isopropyl**, as explained below:



Similarly, different structures of butyl radicals are explained:



11.5 FUNCTIONAL GROUPS

An atom or group of atoms or presence of double or triple bond which determines the characteristic properties of an organic compound is known as the functional group. The remaining part of the molecule mainly determines the physical properties such as melting point, boiling point, density, etc. For example, -OH *group is the functional group of alcohols, which gives characteristics properties of alcohols.* The characteristic properties of carboxylic acids are due to the presence of -COOH group in them. Therefore, *functional group of carboxylic acids is -COOH group.*

11.5.1 Functional Groups Containing Carbon, Hydrogen and Oxygen

The organic compounds containing carbon, hydrogen and oxygen as functional groups are alcohols, ethers, aldehydes, ketones, carboxylic acids and esters. Their class name, functional group, class formula and examples are given in the Table 11.4.

(i) Alcoholic Group

The functional group of alcohol is -OH. Their general formula is ROH. Where R is any alkyl group.

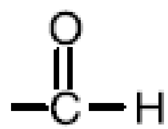
CH_3-OH	CH_3-CH_2-OH	$CH_3-CH_2-CH_2-OH$
Methyl alcohol	Ethyl alcohol	n-Propyl alcohol

(ii) Ether Linkage

The functional group of ether is C - O - C. Their general formula is
R - O - R` where R and R' are alkyl groups.
R and R' may be same or different, such as:

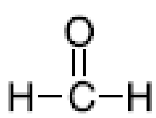
$H_3C-O-CH_3$ Dimethyl ether, $C_2H_5-O-C_2H_5$, Diethyl ether
$H_3C-O-C_2H_5$, Ethyl methyl ether

(iii) Aldehydic Group

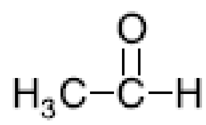
Aldehyde family consists of functional group. 

Their general formula is RCHO.

Where R stands for H or some alkyl group, such as:

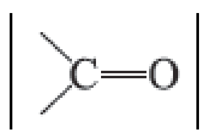


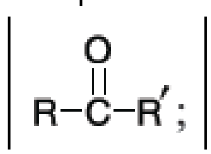
Formaldehyde



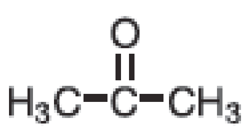
Acetaldehyde

(iv) Ketonic Group

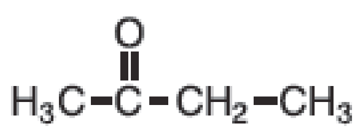
Compounds containing the functional group  are called ketones.

They have the general formula  where R and R' are alkyl groups.

They may be same or different, such as:

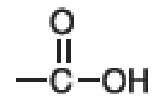


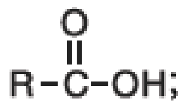
Acetone (Dimethyl ketone)

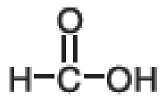


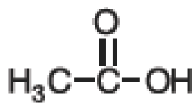
Ethyl methyl ketone

(v) Carboxyl Group

Compounds containing functional group  are called carboxylic acids.

Their general formula is  where R stands for — H or some alkyl group. Such as:


Formic acid

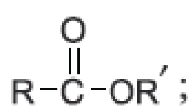

Acetic acid

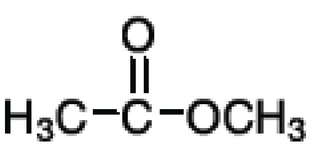
Interesting Information

- Perfumes often contain rose oil, which consist of distinct smell giving organic compound geraniol. Geraniol consist of two functional groups; carbon-carbon double bond and the hydroxyl group.
- A sniffing dog can recognize the characteristic smell of human sweat. Each person's sweat contains a unique blend of carboxylic acids.

(vi) Ester Linkage

Organic compounds consisting of **RCOOR'** functional group are called esters.

Their general formula is where  R and R'are alkyl groups. They may be same or different, such as:


Methyl acetate

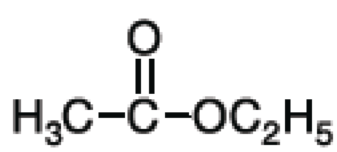
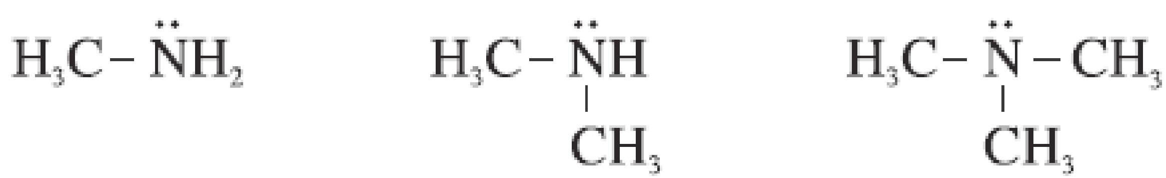

Ethyl acetate

Table 11.4 Functional groups containing carbon, hydrogen and oxygen

Class Name	Functional Group	Class Formula	Examples
Alcohols			
Primary	$-CH_2-OH$	$R-CH_2-OH$	H_3C-CH_2-OH
Secondary	$>CH-OH$	R_2CH-OH	$(H_3C)_2CH-OH$
Tertiary	$-\overset{\mid}{\underset{\mid}{C}}-OH$	R_3C-OH	$(CH_3)_2(H_3C)C-OH$
Ethers	$-O-$	$R-O-R$	$H_3C-O-CH_3$
Aldehydes	$-\overset{O}{\overset{\Vert}{C}}-H$	$R-\overset{O}{\overset{\Vert}{C}}-H$	$H_3C-\overset{O}{\overset{\Vert}{C}}-H$
Ketones	$-\overset{O}{\overset{\Vert}{C}}-$	$R-\overset{O}{\overset{\Vert}{C}}-R$	$H_3C-\overset{O}{\overset{\Vert}{C}}-CH_3$
Carboxylic acids	$-\overset{O}{\overset{\Vert}{C}}-OH$	$R-\overset{O}{\overset{\Vert}{C}}-OH$	$H_3C-\overset{O}{\overset{\Vert}{C}}-OH$
Esters	$-\overset{O}{\overset{\Vert}{C}}-OR$	$R-\overset{O}{\overset{\Vert}{C}}-OR$	$H_3C-\overset{O}{\overset{\Vert}{C}}-OC_2H_5$

11.5.2 Functional Group Containing Carbon, Hydrogen and Nitrogen:

The organic compounds containing carbon, hydrogen and nitrogen as functional group are called as amines. Their functional group is $-NH_2$ and their general formula is $R-NH_2$. Examples of amines are:



Methylamine Dimethylamine Trimethylamine

11.5.3 Functional Group Containing Carbon, Hydrogen and Halogens:

The organic compounds having functional group containing carbon, hydrogen and halogens are called alkyl halides. Their functional group is R-X. 'X' may be F, Cl, Br or I.

Table 11.5 Functional group containing carbon, hydrogen and halogens.

Class Name	Functional Group	Class Formula	Examples
Alkyl Halides a. Primary	$-CH_2-X$	$R-CH_2-X$	H_3C-CH_2-X Ethyl halide
b. Secondary	$>CH-X$	R_2CH-X	$(H_3C)_2CH-X$ *sec*-Propyl halide
c. Tertiary	$-\overset{\vert}{\underset{\vert}{C}}-X$	R_3C-X	$(CH_3)_2(H_3C)C-X$ *ter*-Butyl halide

11.5.4 Double and Triple Bond:

Hydrocarbon consisting of double bonds between two carbon atoms in their molecules are called as alkenes, such as:

$$H_2C = CH_2 \qquad H_3C - HC = CH_2$$

Ethene Propene

Hydrocarbon consisting of triple bonds between two carbon atoms in their molecules are called as alkynes, such as:

$$HC \equiv CH \qquad H_3C - C \equiv CH$$

Ethyne (Acetylene) Propyne

11.6 TESTS OF FUNCTIONAL GROUPS

11.6.1 Test for Unsaturation

$$>C=C< \text{ or } -C\equiv C-$$

(i) Bromine water test:

Dissolve a pinch of the given organic compound in 2.0 cm^3 of carbon tetrachloride (CCl_4). Add 2 cm^3 of bromine water in it and shake.

Result: Bromine will be decolourised.

(ii) Baeyer's test:

Dissolve about 0.2 g of the organic compound in water. Add to it 2-3 drops of alkaline $KMnO_4$ solution and shake.

Result: Pink colour will disappear.

11.6.2 Test for Alcoholic Group —OH

(i) Sodium metal test:

Take about 2-3 cm^3 of the given organic liquid in a dry test tube and add a piece of sodium metal.

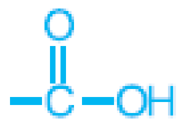
Result: Hydrogen gas will evolve.

(ii) Ester formation test:

Heat about 1.0 cm^3 of the organic compound with 1.0 cm^3 of acetic acid and 1-2 drops of concentrated sulphuric acid.

Result: Fruity smell will be given out

11.6.3 Test for Carboxyl Group



(i) Litmus test:

Shake a pinch of the given compound with water and add a drop of blue litmus solution.

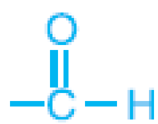
Result: Litmus solution will turn red.

(ii) $NaHCO_3$ solution test:

Take about 2.0 cm^3 of 5% $NaHCO_3$ solution and add a pinch of given compound.

Result: CO_2 gas with effervescence evolves.

11.6.4 Detection of Aldehydic Group



(i) Sodium bisulphite test:

Shake about 0.2 g or 0.5 cm^3 of the given compound with 1-2 cm^3 of saturated solution of sodium bisulphite.

Result: A crystalline white precipitate will be formed.

(ii) Fehling's solution test:

Mix equal volumes of Fehling's solution A and B in a test tube. Add a pinch of organic compound and boil for five minutes.

Result: Red precipitate will be formed.

11.6.5 Test for Ketonic Group $>C=O$

(i) Phenyl hydrazine test:

Shake a pinch of the given organic compound with about 2.0 cm^3 of phenyl hydrazine solution.

Result: Orange red precipitate will be formed

(ii) Sodium nitroprusside test:

Take about 2.0 cm^3 of sodium nitroprusside solution in a test tube and add 2-3 drops of NaOH solution. Now add a pinch of the given compound and shake.

Result: Red colour will be formed.

(iii) With Fehling's solution:

No reaction

11.6.6 Test for Primary Amino Group ($-NH_2$)

(i) Carbyl amine test:

Heat about 0.2 g of the given compound and add 0.5 cm^3 of chloroform and add 2-3 cm^3 of alcoholic KOH.

Result: Extremely unpleasant odour will be given out.

11.6.7 Test for Ester

They are recognized by their fruity smell.

Test Yourself 11.4

i. What is the functional group of an ester?
ii. What is the difference between aldehydes and ketones?
iii. Give the functional groups of alkenes and alkynes.
iv. How is an alcohol tested?
v. How is a ketonic group is tested?

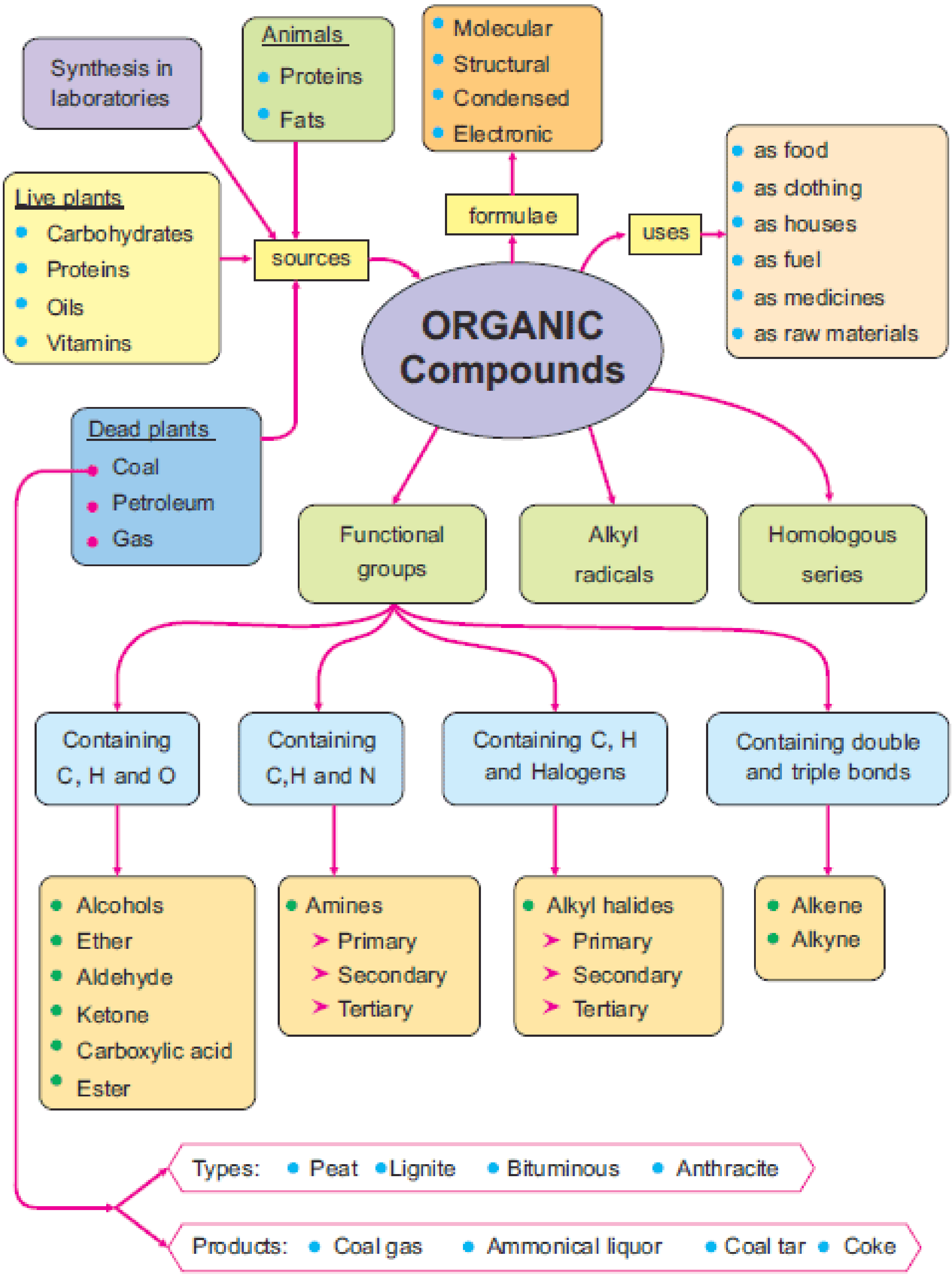
Pharmaceutical chemists work towards the partial and total synthesis of effective drugs

Synthesis of effective drugs to control the epidemics and fatal diseases is the need of the society. The responsibility to synthesize effective drugs is of pharmaceutical chemists. They can evaluate the efficiency and safety of these drugs. They make the drugs more and more effective by reducing their side effects and enhancing potency.

Key Points

- Organic compounds are compounds of carbon and hydrogen and their derivatives.
- Compounds made up of carbon and hydrogen are called hydrocarbons. They are alkanes, alkenes and alkynes.
- Organic compounds are molecular compounds having covalent bonding.
- They form homologous series of compounds, thus their properties resemble within a series.
- Sources of organic compounds are animals, plants, coal, petroleum and natural gas.
- Dead plants buried under Earth's crust are converted into coal; petroleum and gas. Coal is blackish solid material.
- Coal is of four types, i.e peat, lignite, bituminous and anthracite.
- Destructive distillation of coal produces; coal gas, ammonical liquor; coal tar and coke.
- Petroleum is a dark brownish or greenish black coloured viscous liquid consisting of several compounds. These compounds are separated by fractional distillation.
- Natural gas is a mixture of low molecular mass hydrocarbons. It is mainly used as fuel.
- Living plants synthesize macro-molecules (carbohydrates, proteins, fats and vitamins).
- Organic compounds can also be synthesized in laboratories ranging from the simplest compounds to complex ones.
- Organic compounds have wide range of uses. They are used as food, clothing, housing fuel, medicines and to prepare a variety of materials.
- Alkanes are saturated hydrocarbons, alkyl radicals are derivatives of alkanes which are represented by 'R'.
- An atom or a group of atoms that provide characteristic properties to an organic compound is called functional group.
- Depending upon the functional groups, organic compounds are classified as alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, amines and alkyl halides.

CONCEPT DIAGRAM



Short Questions:

1. What is meant by the term catenation? Give an example of a compound that displays catenation.
2. How is coal formed?
3. What is the importance of natural gas?
4. Justify that organic compounds are used as food.
5. How are alkyl radicals formed? Explain with examples.
6. What is the difference between n-propyl and isopropyl radicals ? Explain with structure.
7. Explain different radicals of butane.
8. Define functional group with an example.
9. What is an ester group? Write down the formula of ethyl acetate.
10. Write down the dot and cross formulae of propane and n-butane?
11. Define structural formula. Draw the structural formulae of n-butane and isobutane.
12. Write classification of coal.
13. What are heterocyclic compounds? Give two examples.
14. Why are benzene and other homologous compounds of benzene called aromatic compounds?

Extensive Questions:

1. (a) How is coal formed? What are the different types of coal?
   (b) Write down the composition and uses of different types of coal.
2. (a) What is destructive distillation of coal?
   (b) Name the different types of the products obtained by the destructive distillation of coal.
3. Write a detailed note on functional groups of alkenes and alkynes. How are they identified from other compounds?
4. Give some uses of organic compounds in our daily life.
5. Write down the characteristics of homologous series.
6. Why are organic compounds numerous?
7. What are amines? Explain the different types of amines giving an example of each type. How primary amino group is identified?
8. Describe the functional group of an alcohol. How are alcoholic groups identified?
9. Differentiate between aldehydic and ketonic functional groups. How are both identified from each other?
10. Encircle the functional groups in the following compounds. Also give the names of the functional groups?

(i) $CH_3-\overset{\overset{\displaystyle O}{||}}{C}-CH_3$ (ii) $CH_3-\overset{\overset{\displaystyle O}{||}}{C}-H$

(iii) $HO-\overset{\overset{\displaystyle O}{||}}{C}-CH_2-CH_3$ (iv) $H-\overset{\overset{\displaystyle O}{||}}{C}-CH_2-CH_3$

(v) $H_2C=CH-CH_3$ (vi) $CH_3-O-\overset{\overset{\displaystyle O}{||}}{C}-CH_3$

11. What are the general properties of organic compounds?
12. Write a detailed note on classification of organic compounds.