UTKALMANI GOPABANDHU INSTITUTE OF ENGINEERING, ROURKELA

DEPARTMENT OF CHEMICAL ENGINEERING

LEARNING MATERIAL

OF 4TH SEMESTER

(SAMPLE)

CONTENTS

SI NO	SUBJECT NAME	FACULTY
1	ORGANIC CHEMISTRY	RAGHUNATH MARANDI
2	HEAT TRANSFER	SUBASINI JENA
3	CHEMICAL PROCESS INDUSTRY-I	SOVAN SAHOO
4	MASS-TRANSFER-I	B.K. GANTAYAT SATARUPA SAHU

ORGANIC CHEMISTRY

1.0 IUPAC NOMENCLATURE

INTRODUCTION

There are two main classes of chemical compounds, inorganic and organic. More than a century ago all substances then known were classified on the basis of source from which they were derived. The compounds which were of mineral origin were known as inorganic and those of vegetable or animal origin were called organic. For example, table salt, marble, and carbon dioxide were inorganic, whereas acetic acid (from vinegar), alcohol (from wine), tartaric acid (from grapes), citric acid (from lemons) and sucrose (from sugarcane) were organic. It was assumed that the organic compounds could be produced only by living matter, for living matter was thought to possess a Vital Force. Theory long went unchallenged. In 1828, the German chemist Friedrich Wohler heated ammonium cyanide, derived from inorganic substances, and obtained the organic compound urea. Thus by 1850, the Vital Force Theory was finally and decisively disproved.

1.2 A COMPARISON OF PROPERTIES OF ORGANIC AND INORGANIC COMPOUNDS

Organic 1. Low melting points 2. Low boiling points 3. Low solubility in water; high solubility 4. Flammable 5. Solutions are nonconductors of electricity 6. Exhibit covalent bonding 7. Exhibit isomerism 8. Chemical reactions are usually slow

Inorganic 1. High melting points 2. High boiling points 3. High solubility in water; low in nonpolar solvents solubility in nonpolar solvents 4. Nonflammable 5. Solutions are conductors of electricity 6. Exhibit ionic bonding 7. Isomers are limited to a few exceptions (e.g., the transition elements) 8. Chemical reactions are fast

1.3 Importance of organic Chemistry in modern life.

No field of science is so closely related with our daily activities as is organic chemistry. The food we eat is mainly organic in nature. The changes which this food undergoes in our bodies, are organic chemical reactions. Metabolism, growth and maintenance of our bodily functions involves organic chemistry, as do the analogous changes taking place throughout the entire living world, plant and animal. The clothes we wear, the dyes that color them, the soap and starch used to launder them, the leather in our shoes, as well as the dye and shoe polish, are products of organic chemical industry. Many of the structural materials in our houses and furniture, as well as paints and varnishes used for finishing them, are all organic. Many of the appointments in our motor cars, their fuels and lubricants, and the fuels which power our industrial plants are all organic in nature. The tremendous importance of organic compounds in everyday life is illustrated by the following list: Food: Proteins, fats, carbohydrates Clothing: Cotton, silk, wool, nylon, rayon, dacron Shelter: Wood, paints, varnishes Power and Transportation: Natural gas, petroleum products, coal Medicines and Drugs: Penicillin G, streptomycin, LSD Insecticides: DDT Herbicides: Treflan, 2,4-D Hormones and Steroids Vitamins and Enzymes Antiseptics and Anesthetics Pigments and Dyes Paper and inks Photographic films and Developers Perfumes and Flavors Plastics, Rubber and Resins Propellants and Explosives Soaps and Detergents Refrigerants

1.4 Classification and sources of organic compounds

Historically, as has been mentioned, all organic compounds at one time came from plants or animals. Many of our most important substances are still derived from these sources directly or indirectly.

(1) **Plants and Animals**. Many organic compounds are obtained directly from plant or animal sources by suitable methods of isolation. A few familiar examples are carbohydrates (cellulose, sugars, starches), proteins (silk, wool, casein, food proteins), fats and oils (cottonseed, soybean oils, lard, butter), alkaloids (quinine, morphine, strychnine), hormones, vitamins, perfumes, favors, resins.

2) **Natural Gas and Petroleum**. Natural gas and petroleum are now the major sources of organic compounds. They are used as fuels and also, through synthetic organic reactions, for the production of hundreds of useful organic substances such as solvents, synthetic rubber, explosives, and plastics.

(3) **Coal**. Coal is another major source of organic compounds. It yields coke and coal-tar on pyrolysis or destructive distillation. More than 200 organic compounds have been directly isolated from coal-tar. These coal-tar products form the starting materials for the manufacture of thousands of useful aromatic compounds, including perfumes, drugs, dyes, photographic developers, and others.

(4) **Fermentation**. Fermentation is defined as the production of chemicals by the action of microorganisms. By employing appropriate organisms hosts of useful substances are produced including alcohols, acids, vitamins, and antibiotics.

(5) **Synthesis**. Simple organic compounds derived from petroleum or coal have been converted into thousands of useful materials by synthetic methods. Many examples might be cited of synthetic organic compounds replacing those obtained from natural sources, such as dyes, rubber, fibers, plastics, drugs, vitamins. In many cases the synthetic materials are superior to the natural compounds replaced. For example, synthetic dyes are superior to those of natural origin. In other cases the synthetic materials are entirely unknown in nature and fill the requirements not satisfied from any other source. Examples are ether, glycol, aspirin, and the sulpha drugs. Synthetic organic chemistry touches almost every phase of life.

1.5 IUPAC naming of mono functional and poly functional Organic Compound.

According to the Guidelines set by IUPAC, the nomenclature of compounds must follow these steps:

1. The Longest Chain Rule: The parent hydrocarbon must be identified and subsequently named. The parent chain belonging to the compound in question is generally the longest chain of carbon atoms, be it in the form of a straight chain or a chain of any other shape.
2. The Lowest Set of Locants: The carbon atoms belonging to the parent hydrocarbon chain must be numbered using natural numbers and beginning from the end in which the lowest number is assigned to the carbon atom which carries the substituents.
3. Multiple instances of the same substituent: Prefixes which indicate the total number of the same substituent in the given organic compounds are given, such as di, tri, etc.
4. Naming of different substituents: In the organic compounds containing multiple substituents, the corresponding substituents are arranged in alphabetical order of names in the IUPAC nomenclature of organic compounds in question.
5. The naming of different substituents present at the same positions: In the scenario wherein two differing substituent groups are present at the same position of the organic compound, the substituents are named in ascending alphabetical order.
6. Naming Complex Substituents: Complex substituents of organic compounds having branched structures must be named as substituted alkyl groups whereas the carbon

which is attached to the substituent group is numbered as one. These branched and complex substituents must be written in brackets in the IUPAC nomenclature of the corresponding compounds.

The format of the IUPAC Name of the Compound can be written as: Locant + Prefix + Root + Locant + Suffix

1. Root

The Word root indicates the total number of carbon atoms present in the longest carbon chain belonging to the compound. For example, ‘Meth’ refers to a chain with 1 carbon atom and ‘Pent’ refers to a chain with 5 carbon atoms.

2. Suffix

The suffix in IUPAC nomenclature is usually a functional group belonging to the molecule which follows the root of the name. It can be further divided into the following types.

- A Primary Suffix, which is written immediately after the word root as in the case of alkanes, where the suffix is ‘ane’.
- A Secondary Suffix, which is generally written after the primary suffix is written. For example, compounds having an alkane and alcohol group attached to it will be named as an alkanol, with ‘ol’ being the secondary suffix for the alcohol group.

In accordance with these norms, the suffix of a compound can be written as a part of the IUPAC name of the given compound.

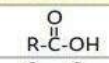
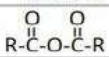
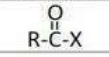
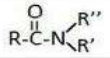
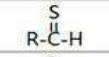
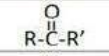
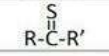
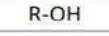
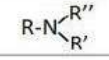
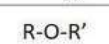
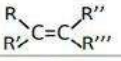
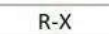
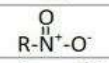
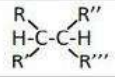
3. Prefix

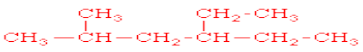
Prefixes are added prior to the root of the compounds IUPAC nomenclature. Prefixes are very useful since they indicate the presence of side chains or substituent groups in the given organic molecule. These prefixes also offer insight into the cyclic or acyclic natures of the compounds in question.

- Primary Prefixes Indicate the cyclic or acyclic nature of the given compound. The prefix ‘cyclo’ is used for cyclic compounds, for example.
- Secondary Prefixes Indicate the presence of side chains or substituent groups. An example of these types of prefixes would be the ‘CH_3’ group, which is called the methyl group.

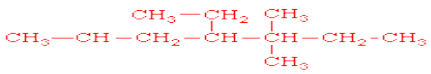
Thus, prefixes in IUPAC nomenclature can be broadly classified into primary prefixes and secondary prefix

POLYFUNCTIONAL GROUP

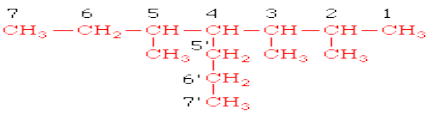
Functional groups listed in *decreasing priority order* for nomenclature			
Functional group	**Prefix***	**Suffix**	**Formula****
Carboxylic Acids	carboxy-	-oic acid -carboxylic acid	
Acid anhydrides		-oic anhydride -carboxylic anhydride	
Esters	*alk*oxycarbonyl	-oate -carboxylate	
Acyl halides	halocarbonyl-	-oyl halide carbonyl halide	
Amides	carbamoyl-	-amide -carboxamide	
Nitriles	cyano-	-nitrile -carbonitrile	
Aldehydes	formyl-	-al -carbaldehyde	
Thioaldehydes	thioformyl-	-thial	
Ketones	oxo-	-one	
Thiones	thioxo-	-thione	
Alcohols	hydroxy-	-ol	
Thiols	mercapto- sulfanyl-	-thiol	
Amines	amino-	-amine	
Ethers	*alk*oxy- oxa-	-ether -ane	
Sulfides	*alk*ylsulfanyl- *alk*ylthio- thia-	sulfide	
Alkenes	*alk*enyl	-ene	
Alkynes	*alk*ynyl	-yne	
Alkyl halides	halo-	-ane	
Nitro	nitro-	-ane	
Alkanes	*alk*yl-	-ane	
* *alk*- in the prefix, represents the number of carbon atoms in the root carbon chain. See list below. ** R, R', R'' and R''' are used to represent generic groups based on C (such as a methyl group) or just H.			



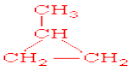
4-ethyl-2-methylhexane



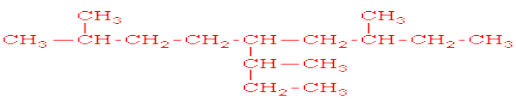
4-ethyl-3,3-dimethylheptane



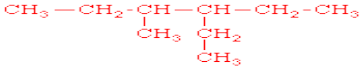
2,3,5-trimethyl-4-propylheptane
(NOT: 2,3-dimethyl-4-sec-butylheptane)



methylcyclopropane



5-sec-butyl-2,7-dimethylnonane



3-ethyl-4-methylhexane

1.6 Concept, type and example of isomerism

Isomerism is the phenomenon in which more than one compounds have the same chemical formula but different chemical structures. Chemical compounds that have identical chemical formulae but differ in properties and the arrangement of atoms in the molecule are called **isomers**. Therefore, the compounds that exhibit isomerism are known as isomers.

Types

There are two primary types of isomerism, which can be further categorized into different subtypes. These primary types are Structural Isomerism and Stereoisomerism. The classification of different types of isomers is illustrated below.

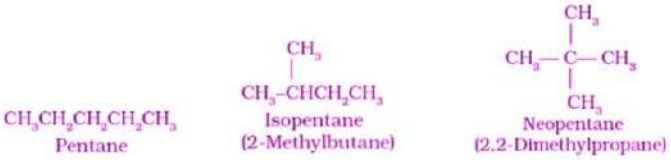
Structural Isomerism

Structural isomerism is commonly referred to as constitutional isomerism. The functional groups and the atoms in the molecules of these isomers are linked in different ways. Different structural isomers are assigned different IUPAC names since they may or may not contain the same functional group.

The different types of structural isomerism are discussed in this subsection.

Chain Isomerism

- It is also known as skeletal isomerism.
- The components of these isomers display differently branched structures.
- Commonly, chain isomers differ in the branching of carbon
- An example of chain isomerism can be observed in the compound C_5H_{12}, as illustrated below



Position Isomerism

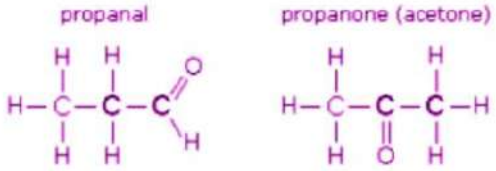
- The positions of the functional groups or substituent atoms are different in position isomers.
- Typically, this isomerism involves the attachment of the functional groups to different carbon atoms in the carbon chain.
- An example of this type of isomerism can be observed in the compounds having the formula C_3H_7Cl



Functional Isomerism

- It is also known as functional group isomerism.

- As the name suggests, it refers to the compounds that have the same chemical formula but different functional groups attached to them.
- An example of functional isomerism can be observed in the compound C_3H_6O.



Metamerism

- This type of isomerism arises due to the presence of different alkyl chains on each side of the functional group.
- It is a rare type of isomerism and is generally limited to molecules that contain a divalent atom (such as sulfur or oxygen), surrounded by alkyl groups.
- Example: $C_4H_{10}O$ can be represented as ethoxyethane ($C_2H_5OC_2H_5$) and methoxy-propane ($CH_3OC_3H_7$).

Tautomerism

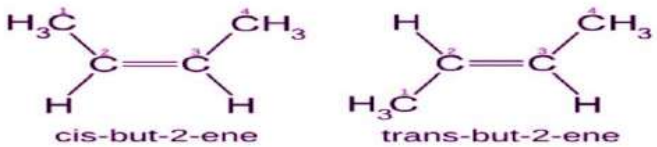
- A tautomer of a compound refers to the isomer of the compound which only differs in the position of protons and electrons.
- Typically, the tautomers of a compound exist together in equilibrium and easily interchange.
- It occurs via an intramolecular proton transfer.
- An important example of this phenomenon is Keto-enol tautomerism.

Stereoisomerism

This type of isomerism arises in compounds having the same chemical formula but different orientations of the atoms belonging to the molecule in three-dimensional space. The compounds that exhibit stereoisomerism are often referred to as stereoisomers. This phenomenon can be further categorized into two subtypes. Both these subtypes are briefly described in this subsection.

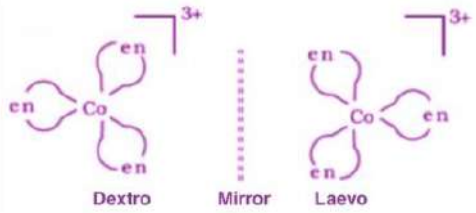
Geometric Isomerism

- It is popularly known as cis-trans isomerism.
- These isomers have different spatial arrangements of atoms in three-dimensional space.
- An illustration describing the geometric isomerism observed in the acyclic But-2-ene molecule is provided below.



Optical Isomerism

- Compounds that exhibit optical isomerism feature similar bonds but different spatial arrangements of atoms forming non-superimposable mirror images.
- These optical isomers are also known as enantiomers.
- Enantiomers differ from each other in their optical activities.
- Dextro enantiomers rotate the plane of polarized light to the right whereas laevo enantiomers rotate it to the left, as illustrated below.



METHANE, CH4 Methane is the first member of the alkane series. It is also called Marsh Gas because it is found bubbling from marshy places where it is produced as a result of bacterial decomposition of dead vegetable matter. It also occurs under pressure in many coal seams. The coal miners call it Fire Damp because it forms explosive mixtures with air. The biggest source of methane is Natural Gas issuing from the petroleum wells and it contains 80-90 per cent methane. It also occurs in Coal Gas up to the extent of 35 per cent.

Preparation.

Methane can be obtained:

(1) By heating anhydrous sodium acetate with soda-lime.

$$CH_3COONa + NaOH \longrightarrow CH_4 + Na_2CO_3$$

Sodium acetate — Methane

The heating can be carried in a pyrex test-tube and the gas collected over water.

(2) By the reduction of methyl iodide, using nascent hydrogen, formed by the action of ethanol on zinc-copper couple.

$$CH_3I + 2[H] \text{ (from couple)} \longrightarrow CH_4 + HI$$

Methyl iodide — Methane

A zinc-copper couple is prepared by allowing zinc to stand in a solution of copper sulphate. The couple is then placed in a round-bottomed flask and a mixture of methyl iodide and 95 per cent ethanol is added from the tap funnel. Methane produced is collected over water.

(3) By treating aluminium carbide with water or dilute acid.

$$Al_4C_3 + 12HCl \longrightarrow 3CH_4 + 4AlCl_3$$

Aluminium carbide — Methane

(4) By hydrolysis of methylmagnesium iodide.

$$CH_3MgI + H_2O \longrightarrow CH_4 + Mg(OH)I$$

Methylmagnesium iodide — Methane

The above methods are used for the preparation of methane on small-scale. Larger quantities of methane are obtained from natural gas, from crude oil, or as by products in the refining of petroleum products.

Properties.

Methane is a colorless gas, insoluble in water but soluble in organic solvents like acetone, ethanol, ether, and benzene. Methane gives all the general reactions of alkanes. Other characteristic reactions are:

(1) In the presence of UV light or on ignition, chlorine reacts with methane with an explosion to form carbon and hydrogen chloride. $CH_4 + 2Cl_2 \xrightarrow{\text{UV light}} C + 4HCl$

(2) When methane is treated with steam in the presence of a nickel catalyst, carbon monoxide and hydrogen are formed. This mixture can be passed under pressure over heated ZnO + Cr2O3 catalyst to yield methanol.

$$CH_4 + H_2O \text{ (steam)} \xrightarrow{\Delta} CO + 3H_2 \text{ Ni}$$

$$CO + 2H_2 \xrightarrow{ZnO\ Cr_2O_3} CH_3OH$$

(3) When methane is heated in the absence of air or oxygen at 1500°C, acetylene is formed.

$$2CH_4 \xrightarrow{1500°C} 2HC\ CH + 3H_2$$

Acetylene

Uses. Methane is used:

(1) as a domestic fuel in the form of natural gas;

(2) in the manufacture of methanol;

(3) in the manufacture of carbon black which is used in printing inks, shoe polishes, gramophone records, and rubber tyres.

ETHANE, CH3–CH3

Ethane occurs to the extent of 10-20 per cent along with methane in Natural Gas. Preparation. Ethane can be prepared:

(1)By heating sodium propionate with soda-lime in a pyrex test-tube.

$$CH_3CH_2COONa + NaOH \xrightarrow{\Delta} CH_3CH_3 + Na_2CO_3$$

Sodium propionate — Ethane

(2) By the reduction of ethyl iodide, using nascent hydrogen, formed by the action of ethanol on zinc-copper couple. $CH_3CH_2I + 2[H]$ (from couple) $\longrightarrow CH_3CH_3 + HI$

Ethyl iodide — Ethane

(3) By the action of sodium metal on methyl iodide in dry ether solution. (Wurtz Reaction)

$CH_3I + 2Na + ICH_3 \longrightarrow CH_3CH_3 + 2NaI$

Methyl iodide — Ethane

Thin slices of sodium metal are suspended in dry ether contained in a small flask fitted with a reflux condenser and a tap-funnel. Methyl iodide is slowly added from the tap-funnel and the ethane evolved is collected over water.

(4) By passing a mixture of ethylene and hydrogen over heated nickel catalyst.

$CH_2\ CH_2 + H_2 \xrightarrow{Ni} CH_3CH_3$

Ethylene — Ethane

(5) By hydrolysis of ethylmagnesium bromide.

$CH_3CH_2MgBr + H2O \longrightarrow CH3CH3 + Mg(OH)Br$

Ethylmagnesium bromide — Ethane

Properties. Ethane is a colorless gas. It is sparingly soluble in water but dissolves in organic solvents like ethanol, ether, and benzene. It gives all the general reactions of alkanes.

2.2 Methods of preparations properties of ethylene

Ethylene is the first member of the alkene series. It is produced in large amounts by the cracking of petroleum. Preparation.

Ethylene can be obtained:

By heating ethanol with excess concentrated sulfuric acid at 170°C. (Laboratory Method)

$CH3CH2OH \xrightarrow{conc\ H2SO4\ 170°C} CH2\ CH2 + H2O$

Ethanol — Ethylene

(2) By heating ethyl iodide with alcoholic KOH.

$CH3\ CH2\ I + KOH \xrightarrow{ethanol\ \Delta} CH2\ CH2 + KI + H2O$

Ethyl iodide — Ethylene

(3) By heating 1,2-dibromoethane with zinc dust in ethanol.

$CH2\ Br\ CH2\ Br + Zn \xrightarrow{ethanol\ \Delta} CH2\ CH2 + ZnBr2$

1,2-Dibromoethane — Ethylene

(4) By controlled addition of hydrogen to acetylene in the presence of Lindlar's catalyst.

$$CH\ CH + H_2 \xrightarrow{Pd/CaCO_3\ quinoline} CH_2\ CH_2$$

Acetylene — Ethylene

(5) By cracking of natural gas and petroleum.

$$CH_3\ CH_3 \xrightarrow{600°C} CH_2\ CH_2 + CH_4 + H_2$$

Ethane — Ethylene

Properties (Physical). Ethylene is a colorless gas with a sweet odor. It is slightly soluble in water but dissolves readily in organic solvents such as ethanol and ether.

Uses. Ethylene is used in the manufacture of many industrially important polymers (e.g., PVC, EPR, Sarans, polyethylene). These polymers are used in the manufacture of floor tiles, shoe soles, synthetic fibres, raincoats, purses, saran wrap, and pipes.

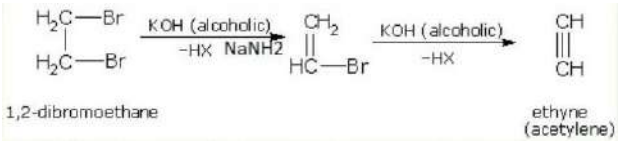
2.3 Methods of preparation, properties and uses of acetylene.

ACETYLENE

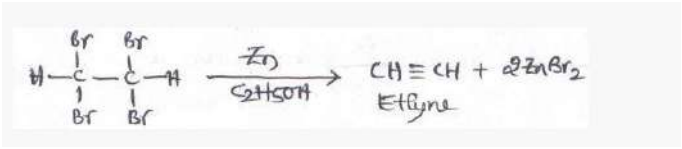
Acetylene is the most important alkyne. It is a link between inorganic and organic chemistry. It is used as a starting material for a very large number of industrially important organic compounds. Preparation.

Acetylene can be obtained:

By treatment of 1,2-dibromoethane with alcoholic KOH followed by NaNH2.



(2) By heating 1,1,2,2-tetrabromoethane with zinc dust in alcohol.



(3) By heating iodoform with silver powder.

$$CHI_3 + 6Ag + I_3CH \xrightarrow{\Delta} HC\ CH + 6AgI$$

Iodoform — Iodoform — Acetylene

Properties

(Physical). Acetylene is a colorless gas, bp –75ºC. It is practically insoluble in water, but very soluble in acetone.

(Chemical). Some of the important reactions of acetylene are given below:

001-364
1st week

Heat Transfer -:

Sunday 01

When two objects at different temperatures are brought into thermal contact. Heat flows from the object at higher temperature to the object at lower temperature.

The mechanisms by which the heat may flow are :-

(i) Conduction

(ii) Convection

(iii) Radiation

Objectives :-

⇒ To Study different modes of heat transfer.

⇒ To determine the rate of heating & cooling.

⇒ To determine the efficiency of existing heat exchange equipment's.

Essential	Job to do	Phone No.

02 Monday

002-363
2nd week

Heat - Transfer - Applications :-

1. Evaporation: Heat is supplied in order to convert a liquid into a vapour.

2. Distillation: Heat is supplied to the liquid mixture for separation of individual vapor component.

3. Drying: For drying the wet granules.

4. Crystallization: Saturated solution is heated to bring out super saturation. which promotes crystallization of drugs.

5. Sterilization: Autoclaves uses steam as heating medium.

Essential | Job to do | Phone No.

Heat Transfer - Mechanism

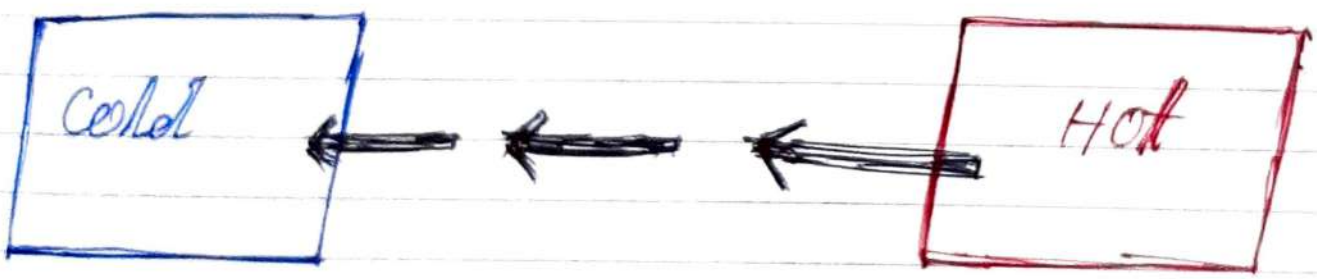
Tuesday 03

Heat transfer from one place to another takes place by three different mechanisms and all three may occur simultaneously.

(1) Conduction (2) convection (3) Radiation

"Heat Transfer is the movement of heat energy from one substance to another."

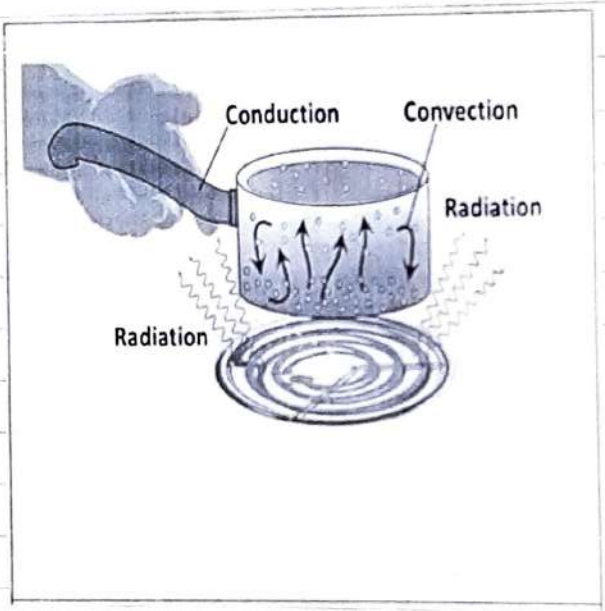
→ Heat (energy) always moves from a warmer substance to a cooler substance.



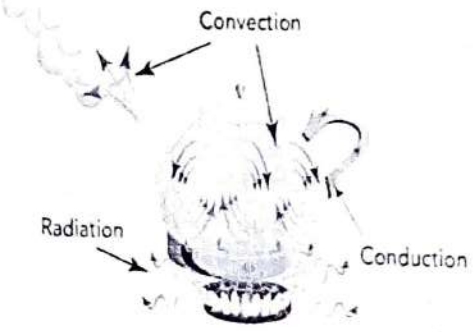
Essential | Job to do | Phone No

04 Wednesday

→ Heat will continue to move until both substances are the same temperature.



Heat Transfer Methods



Essential

Phone No.

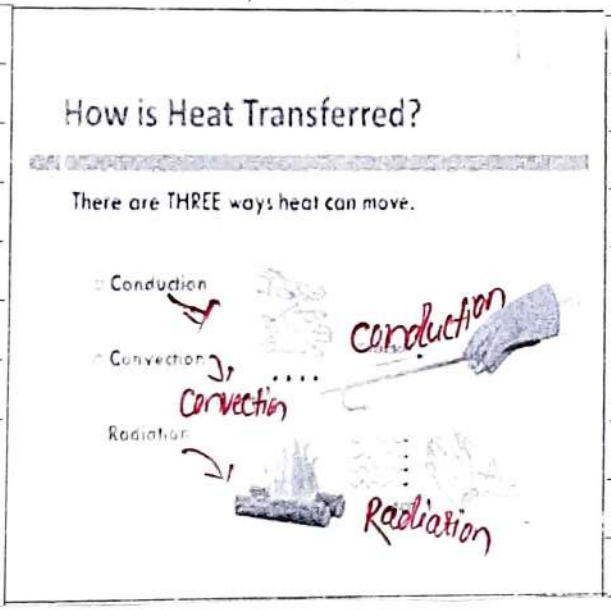
005-360
2nd week

Thursday 05

(I) Heat always move from a warmer place to a cooler place.

(II) Hot objects in a cooler room will cool to room temperature.

(III) Cold objects in a warmer room will heat up to room temperature.



Essential	Job to do	Phone No.

JANUARY

CHAPTER - I

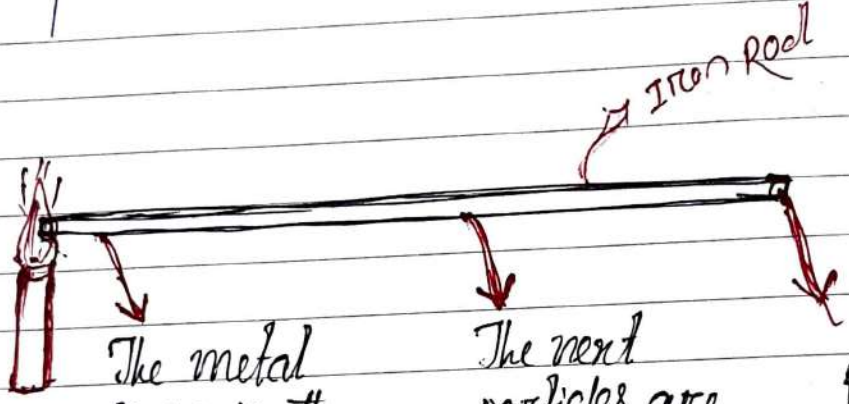
2017

006-359
2nd week

06 Friday

'CONDUCTION'

Conduction is the process by which heat is transmitted through a medium from one particle to another.



The metal particles in the flame gain energy & start to vibrate more vigorously.

The next particles are pushed & pulled about by their vigorously vibrating neighbours, so they start to vibrate faster too.

Eventually the particles at the far end of the rod are made to vibrate vigorously. The end of the rod gets hot.

Example :-

→ when we make tea heat from stove gets transferred to steel pan because of direct contact & thus this is Conduction.

→ when you iron your cloths heat energy gets conducted from iron to cloths.

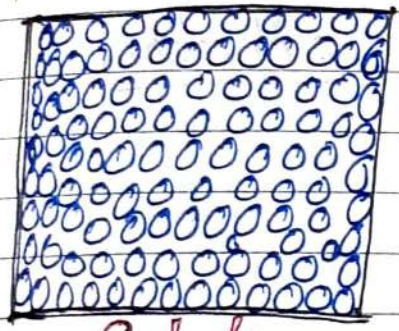
Essential | Job to do | Phone No.

007-358
2nd week

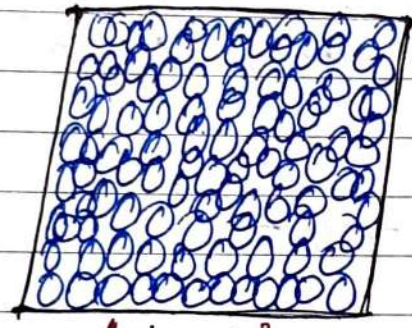
How are the particles arranged in a Solid, a leqeed and a gas?

Saturday 07

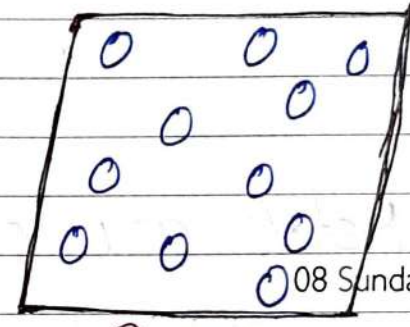
Conduction is the transfer of energy from more energetic particles of a substance to adjacent less energetic ones result of interaction between particles.



Solids



Liquids



Gases

08 Sunday

The flow of heat is depends on the transfer of Vibrational energy from one molecule to another, and in case of metal the movement of free electrons.

Essential	Job to do	Phone No.

09 Monday

Conduction - How it occurs?

When you heat a metal strip at one end, the heat travels to the other end.

As you heat the metal, the particles vibrate, these vibrations make the adjacent particles vibrate, and so on. The vibration are the metals so is the heat. (we call the Conduction)

Metals are different →

→ The outer electrons of metal atoms drift, and are free to move.

→ when the metal is heated, the 'sea of electrons' gain kinetic energy and transfer it throught the metal.

Essential	Job to do	Phone No.

010-355
3rd week

10 Tuesday

→ Insulators, such as wood and plastic do not have this 'sea of electrons' which is they have do not conduct heat as well as the metals.

Why does metal feel colder than wood, if they are both at the same temperature?

'Metal' is a conductor, 'wood' is an insulator.

Metal conducts the heat away from your hands. wood does not conducts the heat away from your hands as well as the metal. So the wood feels warmer than the metal.

Essential | Job to do | Phone No.

(i) Insulators:- Substance which conducts heat slowly.

(ii) Conductors:- Substance which conducts heat quickly.

11 Wednesday

Steady & unsteady heat transfer

011-354
3rd week

There is no change in heat transfer with time at any point in a direction within the medium is called Steady state heat transfer.

or,

If the temperature of a body does not vary with time, it is said to be in Steady State.

But if there is an abrupt change in its surface temperature, it attains an equilibrium temperature or a steady state after some period. During this period, the temperature varies with time and body is said to be in the un-steady or transient state.

This is known as unsteady or transient heat conduction.

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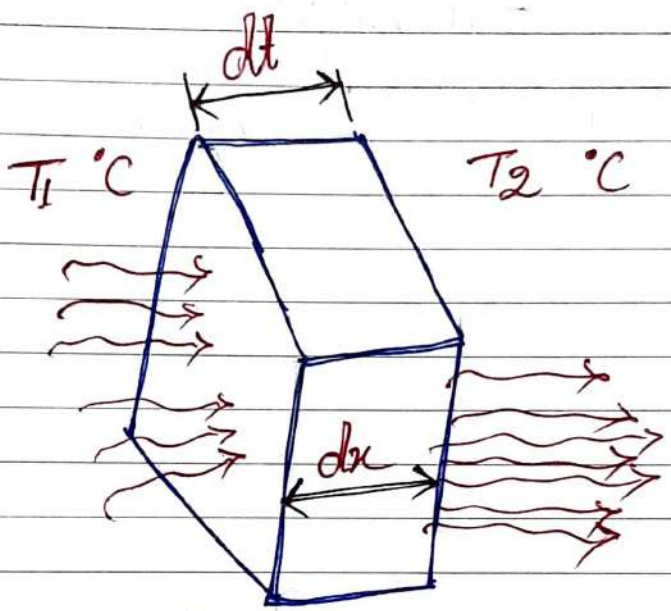
012-353
3rd week

Fourier's Law of Heat Conduction

Thursday | 2

It States that the rate of flow of heat through a solid is directly proportional to the cross sectional area of the section and temperature gradient, in the direction of heat flow per unit time.

$$Q \propto A \frac{dt}{dx}$$



where,

Q = heat flow through a body (watt)

A = Cross-Sectional area of heat flow (m^2)

dt = Temeperature difference across heat flow path (°C)

dx = Thickness of body in direction of heat flow (m)

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013-352
3rd week

13 Friday $Q = -KA \frac{dt}{dx}$

K = Constant of proportionality known as Thermal Conductivity.

Unit ⇒ W/mk or watt/mc.

The -ve sign is the decreasing temperature along with the increasing thickness o path length of heat flow.

Essential	Job to do	Phone No.

014-351
3rd week

Mathematical Expression of Fourier's Law

Saturday 14

Expression of equation of Fourier's law of heat conduction.

$$Q \propto A \frac{dt}{dx}$$

dt = Temperature difference across thickness in °C $(dT = T_2 - T_1)$,

where along heat flow path $T_2 < T_1$.

$$\boxed{Q = -KA \frac{dt}{dx}}$$

15 Sunday

If considering, dt = temperature difference across thickness in °C $(dT = T_1 - T_2)$

$$\boxed{Q = KA \frac{dt}{dx}}$$

Essential	Job to do	Phone No.

16 Monday

016-349
4th week

Assumptions in Fourier's Law:-

(i) Conduction of heat takes place under steady state conditions.

(ii) Heat flow is one-directional.

(iii) The temperature gradient is linear and constant.

(iv) There is no internal heat generation.

(v) The material is homogeneous and isotropic.

Essential | Job to do | Phone No.

017-348
4th week

Tuesday 17

Thermal Conductivity (K):-

It is defined as the heat Conduction rate per unit area normal to the direction of heat flow through unit thickness of the body per unit temperature difference.

we know that the rate of heat transfer

$$Q = K \cdot A \cdot \frac{dt}{dx}$$

$$\Rightarrow \boxed{K = Q/A \times \frac{dx}{dt}}$$

unit of thermal Conductivity :-

$$\text{unit of } K = \frac{W}{m^2} \times \frac{m}{K \text{ or } ^\circ C}$$

$$\boxed{K = W/mK}$$

or $$\boxed{K = W/m\,^\circ C}$$

Essential , Job to do Phone No.

18 Wednesday

Significance of Thermal Conductivity:

Thermal Conductivity is the property of materials, which transfer the heat from one point to another point. It plays a very important role in steady state heat Conduction.

Knowing the value of thermal Conductivity one can categories material into two - Category of thermal conductors or Non-Conductors.

→ Higher thermal conductivity faster the heat is going to transfer between given two points. Generally all metals are good

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019-346
4th week

Thursday 19

thermal conductors, ex- copper, aluminium, iron etc.

→ Lower the thermal conductivity slower the heat is going to transfer between given two points. Generally all non-metals are bad thermal conductors, hence used as thermal insulators, ex- wood, asbestos, plastic etc.

Essential	Job to do	Phone No.

20 Friday

Effect of Various parameters on thermal Conductivity :-

a. Temperature :- In Solids, thermal Conductivity decreases with increase in temperature.

In liquids, thermal Conductivity decreases with increase in temperature.

In gases, thermal Conductivity increases with increase in temperature.

b. Density :- Thermal Conductivity increases with increase in density.

c. Chemical Composition :- It is highest for pure metals and decreases with increase in impurity.

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in impurity. | Fe, Cu, Ag → pure metals
− + adding other component (impure)

021-344
4th week

Saturday 21

d. pressure:- Thermal Conductivity is weakly dependent on pressure.

e. Dampness:- ~~Conductivi~~ Thermal Conductivity for wet material is considerably higher that of dry material.

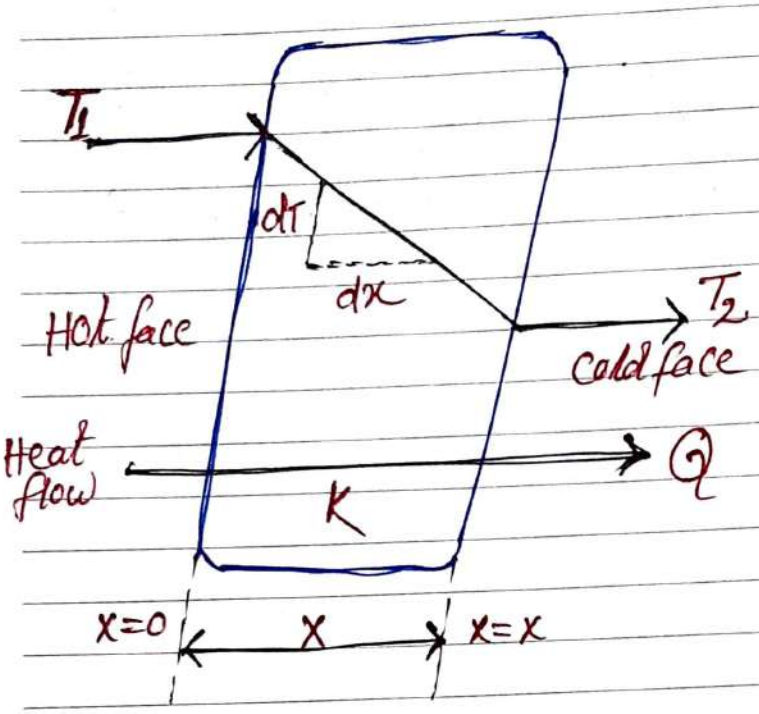
Sunday 22

Essential	Job to do	Phone No.

23 Monday

Heat Conduction through a plane wall / Slab :-

023-342 5th week



Boundary Conditions

(i) At $x=0$, $T=T_1$

(ii) At $x=x$, $T=T_2$

where,

x = Thickness of plane wall (m)

T_1 = Initial temperature (°K)

T_2 = final temperature (°K)

Q = Rate of heat flow (watt)

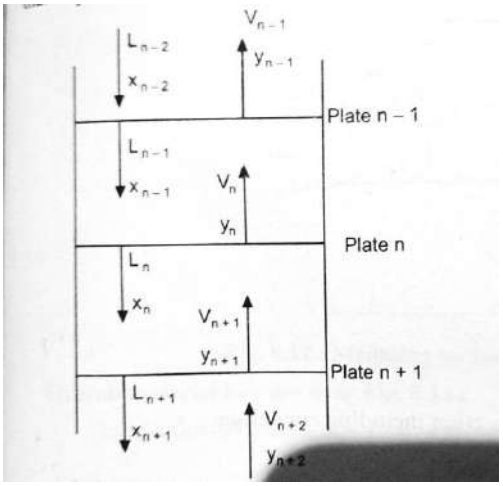
A = Area of wall (m^2)

K = Thermal Conductivity (w/mK)

Essential | Job to do | Phone No.

Rectification on Ideal Plate

- In rectification column, the plates are numbered serially from the top down. Consider the nth plate from the top in the cascade.
- The plate n-1 is immediately above the plate 'n' and plate n+1 is immediately below the plate ‘n’.
- On every plate, two different fluid streams not at equilibrium are brought into intimate contact, mass transfer takes place, phases are separated and finally the two fluid streams leave the plate in equilibrium with each other.
- Thus, the plate under consideration will receive a liquid stream of L_n moles/h of composition x_n and a vapour stream of Vn+1 moles/h of composition y_{n+1} from plate n-1 and n+1 respectively.



- A liquid stream L_n moles/h of composition x_n and a vapour stream V_n moles/h of composition y_n leave this plate for plate n+1 and n-1, respectively in equilibrium with each other.
- When the vapour from plate n+1 is brought into intimate contact on the plate under consideration with the liquid from plate n-1 their compositions tend to change to attain equilibrium values.
- During the interchange process, some of the more volatile component is vaporised from the liquid L_{n+1} is decreasing the liquid concentration from x_{n-1} to x_n and some of the less volatile component is condensed from the vapour V_{n+1} increasing the vapour concentration from y_{n+1} to y_n.
- In the column, as the liquid is at its bubble point and the vapour is at its dew point, the heat to vaporise the more volatile component from the liquid is supplied by the heat released in the condensation of the less volatile component from the vapour.
- Thus, the net effect is that the more volatile component is transferred to the vapour rising up from the liquid running down the column, while the less volatile component is transferred to the liquid running down from the vapour rising up the column.
- Liquid and vapour phase composition increases along the column height with respect to the more volatile component.

Overall Material Balance

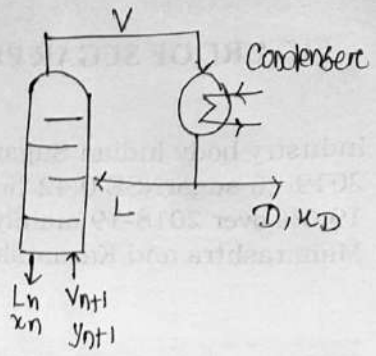
$$F = D + W$$

Material Balance of more volatile component

$$F x_F = D x_D + W x_W$$

External Reflux Ratio $R_E = L/D$

Internal Reflux Ratio $R_I = V/D$



Material Balance Around condenser

$$V = L + D$$

$$\Rightarrow D = V - L \qquad L = V - D$$

Overall Material Balance over Rectifying Section

$$V_{n+1} = L_n + D$$

Component balance of more volatile component 'A'

$$V_{n+1} y_{n+1} = L_n x_n + D \cdot x_D$$

$$\Rightarrow y_{n+1} = \frac{L_n}{V_{n+1}} x_n + \frac{D}{V_{n+1}} x_D$$

$$\Rightarrow \boxed{y_{n+1} = \left(\frac{L_n}{L_n + D}\right) x_n + \left(\frac{D}{L_n + D}\right) x_D}$$ ← operating line for rectifying section

Overall material balance over stripping section

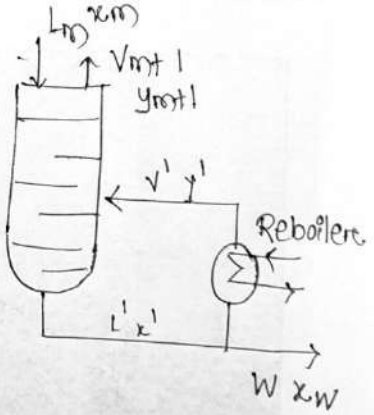
$$L_m = V_{m+1} + W$$

Component balance of more volatile component 'A'

$$L_m x_m = V_{m+1} y_{m+1} + W x_W$$

$$\Rightarrow y_{m+1} = \frac{L_m}{V_{m+1}} x_m - \frac{W}{V_{m+1}} x_W$$

$$\Rightarrow \boxed{y_{m+1} = \frac{L_m}{L_m - W} x_m - \frac{W}{L_m - W} x_W}$$ ← operating line for stripping section



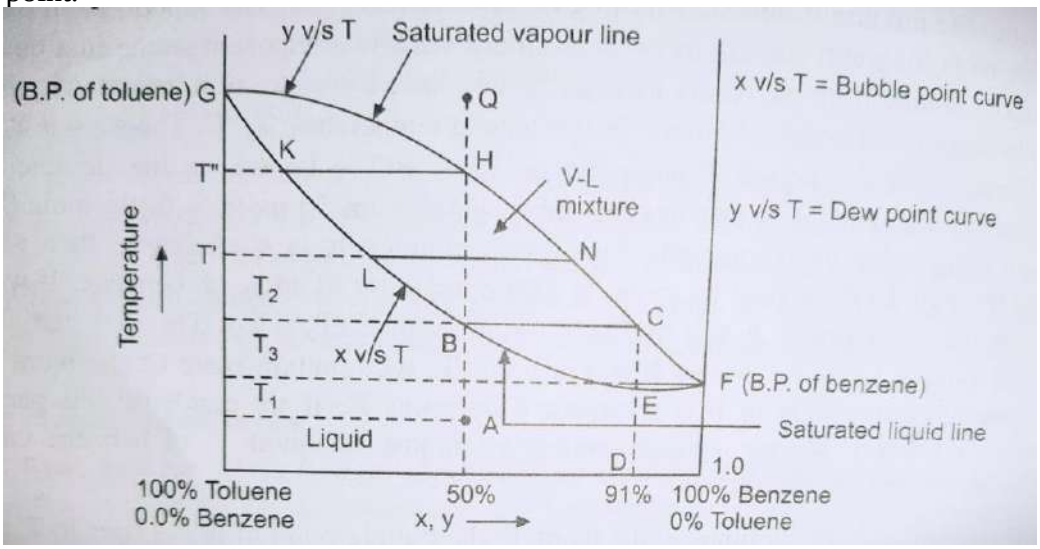
Constant-Pressure Vapour-Liquid Equilibrium

- The compositions of the vapour and liquid phases that are in equilibrium, are usually expressed in terms of mole fractions of the more volatile component in the respective phases (y and x).
- We use mole fractions as a measure of concentrations.
- Equilibrium data for a binary mixture at constant total pressure are represented in graphical forms by means of
    1. The temperature-composition diagram
    2. The x-y diagram where the vapour phase composition (y) is plotted against the liquid phase composition (X).

Boiling Point Diagram:

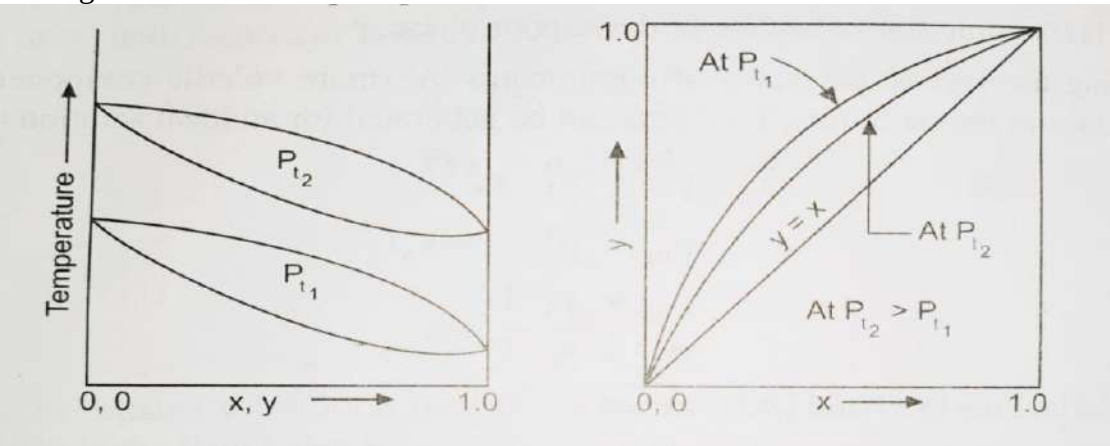
- It is used to show how the equilibrium vapour and liquid phase compositions (y and x) change with temperature.
- With the help of an equilibrium still one can determine experimentally the composition vapour in equilibrium with the liquid of a given composition and the results thus obtained can be shown on a temperature composition diagram.
- Let us follow the whole process of boiling a binary mixture in an equilibrium still. Suppose that the mixture handled consists of benzene (a more volatile component) and toluene (a less volatile / heavier component).
- The composition of the mixture is plotted as abscissa in terms of the mole fraction of the more volatile component and temperature of the mixture is plotted as ordinate.
- The mixture presented by point A is at a temperature of T_1°C and contains 50 mole % of benzene.
- When we apply heating to the mixture it will start boiling at temperature T_2 °C.
- The vapour given off by the mixture on boiling will contain more of the more volatile component so the first quantity of the vapour issuing from the binary mixture 'B' will have a composition indicated by point 'C', i.e., this vapour will contain 91 mole % benzene at temperature T_2, °C.
- The vapour at C is in equilibrium with the liquid at point 'B and thus BC is known as the tie line.
- Hence, considerable enrichment in benzene has taken place from 50 mole % to 91 mole %. If we remove this portion of vapours and condense it completely in a condenser, then we would obtain the liquid represented by point D' still containing 91 mole % benzene.
- If we reheat this portion of the liquid, it will boil at T_3°C at point E (T3, < T2).
- The first portion of the vapours issuing from the boiling liquid at point 'E will contain more of the more volatile component, composition of it is represented by point F.
- If we condense this part of the vapour completely, we get a liquid containing almost 100 mole % of benzene indicating further enrichment in the vapour.
- If we further heat the liquid at the point B the boiling point of liquid rises to T' because of the removal of the majority of the more volatile component by vaporisation.
- At this temperature, the liquid phase composition is represented by L and the vapour phase composition by N and further heating to T" all the liquid get vaporised to give the vapour represented by point H.

- Alternatively, consider a mixture of vapours represented by point Q, when we cool it down to temperature T", condensation will start at point H.
- The first drop of a liquid formed will have a composition represented by point K (i.e., the less volatile component will tend to condense first).
- If we further cool the vapours to T' we will get a liquid represented by point L and the vapour represented by point N.
- This means that the vapour is richer in the more volatile component than the liquid. Hence, we can say that partial vaporisation as well as partial condensation will both tend to enrich the vapour in the more volatile component.
- In the process of boiling, the mixture boils over a temperature range from B to H (from the bubble point to the dew point), so the term boiling point has no meaning for the mixture and the correct term is the bubble point.
- Bubble point is the temperature at which a liquid mixture of a given composition starts to vaporise as the temperature is increased.
- The liquid represented by any point on the lower curve is at its bubble point and hence the lower curve is called as the saturated liquid curve or the bubble point temperature curve (1 v/s x).
- The temperature at which a vapour mixture on cooling first begins to condense is called dew point.

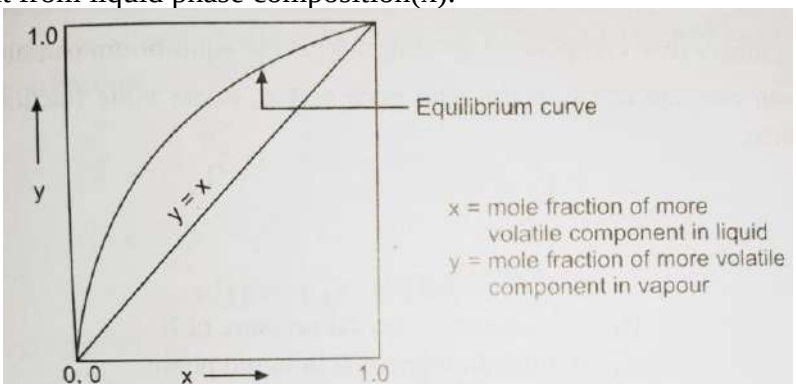


- The condensation starts at any point on the upper curve and hence the upper curve called as the saturated vapour curve or the dew point temperature curve (T VS y).
- For any pure liquid, the bubble point and dew point are identical and equal to the boiling point or liquid, whereas the dew point and bubble point for a binary system are functions of its composition.
- The dew point and bubble point are identical at x, y = 0 and x, y=1 as the compositions indicate pure toluene and pure benzene.
- As the total pressure of the system is increased say, for example, from P_{t1} to P_{t2}, the spread between the bubble point curve and the dew point curve decreases and the separability by distillation becomes less, at high pressure owing to the decrease in the value of the relative volatility at higher pressure.
- A majority of distillation operations are carried out at a constant total pressure.

- For distillation calculations, the equilibrium vapour-liquid composition data can be plotted in the figure.



- The vapour phase composition (y) is plotted as an ordinate and the liquid phase composition (x) is plotted as an abscissa. Such diagram is called as equilibrium diagram.
- As the vapour is richer in more volatile components than the liquid, equilibrium curve lies above the 45^0 diagonal line which is drawn for comparison.
- An equilibrium curve very close to diagonal means vapour phase composition (y) is not much different from liquid phase composition(x).



VAPOUR-LIQUID EQUILIBRIUM

- Separation of a mixture by distillation is based on equilibrium distribution of the components between the liquid and the vapour phases.
- A knowledge of vapour-liquid equilibrium is therefore essential for understanding the principles of distillation.
- Consider an aqueous solution of ethanol taken in a closed vessel.
- The solution is boiled for some time and the vapour along with air in the space above the liquid is expelled through a valve so that the vessel now contains molecules of ethanol and water only.
- The valve is now closed and the vessel is put in a constant temperature bath.
- What do we expect to happen?
- Given sufficient time, the system reaches equilibrium and the liquid and the vapour compositions as well as the total pressure in the vapour space (i.e. the total pressure exerted by the solution) attain unique values.
- Now the vessel is taken out of the bath, some amount of ethanol (or water) is pushed into it and the vessel is again maintained at the same temperature in the bath.
- The system will attain a new equilibrium state, i.e. it will have a different set of liquid and vapour concentrations and a new total pressure in the vapour space.
- Under a given set of conditions, the equilibrium vapour composition is related to the liquid composition, This is called the vapour-liquid equilibrium (VLE).
- But what is meant by a given set of conditions'?
- The answer is given by Gibb's phase rule expressed as
  $F= C- P+2$
- In the above example of equilibrium in the ethanol-water system, the number of components, C=2; the number of phases, P =2 (the vapour and the liquid phase). So F = 2 and the system has two degrees of freedom.
- The total number of parameters and variables is four-temperature, total pressure, liquid composition and vapour composition.
- Since the number of degrees of freedom (F) is 2, two of these four quantities need to be fixed to define the system in equilibrium.
- Thus if temperature and pressure are fixed, the liquid and the vapour compositions will be automatically fixed (i.e. there can be only one set of liquid and vapour compositions for which the total pressure exerted in the vapour space is equal to the given pressure at the given temperature).
- Similarly, if the temperature and the liquid composition are fixed, the total pressure and the vapour compositions will be automatically fixed if the system is in equilibrium.

Fertilizers

- Introduction
- Plant Nutrients and their functions
- Classification of Fertilizers
- Status of Fertilizer Industries
- Nitrogen Fixation
- Ammonia based fertilizers
  - Ammonia
  - Ammonium Chloride
  - Ammonium Phosphate
- Phosphoric Acid
- Potassium Sulphate
- Potassium Chloride
- Superphosphate (Single, Tripple)
- Urea

- As the quantity of additional nutrients required by a particular crop to increase its growth to the optimal level in a given soil. After repeated cultivation the soil reached to a stage where it becomes less productive, if supply of the above nutrients is not provided. Thus, in order to make up this deficiency, certain elements in the form of their compounds have to the added to the soil to make it reproductive. These substances are known as **fertilizers**.
- Hence, we can say that any substance which is organic or inorganic, natural or artificial, supplies one or more of the chemical elements required for plant growth.

- Fertilizers are the products that improve the levels of the available plant nutrients and/or the chemical and physical properties of the soil, thereby directly or indirectly enhancing the growth, yield and quality of the plant.
- Fertilizers are compounds used to promote plants growth. They are usually applied either through the soil, for uptake by plant roots, or uptake through leaves.
- Fertilizers can be organic matter or inorganic chemicals or minerals. They can be naturally occurring compounds such as peat or mineral deposits, or manufactured through natural processes or chemical processes.

- Carbon, oxygen and hydrogen are directly supplied by air and water and therefore not treated as nutrients by the fertilizer industry.
- Fertilizers typically provide, the three major plant nutrients (phosphorous, nitrogen and potassium), the secondary plant nutrients (sulfur, calcium and magnesium), and sometimes trace elements (or micronutrients) with the role in plant nutrition: chlorine, boron, manganese, zinc, iron, copper, and molybdenum.

Fertilizing the land is essential due to following reason

- Provide nutrient essential for growth and better yield.
- Maintain the pH of the soil in the vicinity of 7-8 to facilitate optimum growth
- Provide food supplement to the plants

PLANT NUTRIENTS : Plants require following nutrient elements for their growth

- a) **Natural nutrients** : Carbon, hydrogen and oxygen are derived from air and water and so these are called natural nutrients.
- b) **Primary nutrients** : Nitrogen, phosphorus and potassium are consumed in large amounts by the plants for their growth and so these are called primary nutrients.
- c) **Secondary nutrient** : Calcium, magnesium and sulfur which occur to a limited extent in all soils, are called secondary nutrients.
- d) **Micronutrients** : Zinc, boron, copper, manganese, chlorine, iron and molybdenum are required in little amount by the plants and so these are called micro nutrients.

FUNCTION OF NUTRIENT

- **Nitrogen** : **required during early stages of plant growth to promote development of stems and leaves.** Nitrogen supplied as nitrate ion or ammonium salt is one of the important constituent for synthesis of amino acids which are then converted into proteins and enzymes. Proteins thus formed make part of the protoplasm, while enzymes act as catalysts for various reactions taking place in the plants. Nitrogen is also a special constituent of the chlorophyll, without which photosynthesis is not possible. Nitrogen makes up 16-18% of the plant protein and constitutes 1-4% of the dry weight of plants and is required in large amounts of any of the plant nutrients.

Sources of nitrogen

- Atmosphere
- Organic nitrogen compounds formed in the soil by recurring natural processes
- Fertilizers
- The natural sources are not sufficient for adequate plant growth and so artificial nitrogen compounds in the form of fertilizers are added to the soil.

- **Phosphorus : which stimulates early growth and accelerates seeding or fruit formation in later stages of growth.** It is required in much lesser amounts than nitrogen.
- Most soils contain phosphate in the form of complex calcium phosphate, aluminium and iron complexes and organic compounds. Such sources are insoluble and so the plants can make very little use of them.
- Phosphates are involved in the respiratory and photosynthetic processes which provide energy in some of the plants metabolic processes without which the plant could not live.
- The need of phosphorus is also necessary for the health of the plant as it is constituent of nucleic acids, phytins and phospholipids.
- It is also found in seeds and fruits. The phosphorus has also been found to contribute to the formation of the reproductive parts in the early life of the plant.

- **Potassium : essential to the development of the starches of potatoes and grains, the sugar of fruits and vegetables and the fibrous material of plants; an ample supply of potassium in the soil sometimes helps to prevent disease and to lessen the effects of excessive nitrogen application.**
- It is necessary for healthy growth of plants and cannot be replaced even by closely related elements as sodium and lithium.
- In the plant, it either occurs as a part of the anion of organic acid or as a soluble inorganic salt in the tissues.
- It contributes to formation and movement of carbohydrates in plant.
- Deficiency of potassium quickly reduces the carbohydrate contents.
- The potassium content of plants ranges from about 0.5-2.5% of the dry weight.