

Semester	Programme	Course Code	Course Name	L	T	P	C
I	B.E. / B.Tech., Common to all	20CY1T2	ENGINEERING CHEMISTRY	3	0	0	3

COURSE LEARNING OUTCOMES (COs)				
After Successful completion of the course, the students should be able to			RBT Level	Topics Covered
CO1	Explain the properties & working techniques along with potential applications.		K2	1
CO2	Choose the appropriate method for specific application in engineering technology.		K3	2
CO3	Analyse new solutions to problems in materials and energy usage in daily life		K4	3
CO4	Identify the structure of unknown/new compounds with their properties.		K3	4
CO5	Categorize the important features of various materials and methods for burgeoning society.		K4	5

<b>PRE-REQUISITE</b>	-
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CO / PO MAPPING (1 – Weak, 2 – Medium, 3 – Strong)														
COs	Programme Learning Outcomes (POs)												PSOs	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3		2			1			3	3		3		
CO2	3	2				1			3	3		3		
CO3	3	2				1			3	3		3		
CO4	3		2			1			3	3		3		
CO5	3	2	2			1			3	3		3		

COURSE ASSESSMENT METHODS		
<b>DIRECT</b>	1	Continuous Assessment Tests
	2	Lab / Mini Project /Field Work
	3	End Semester Examinations
<b>INDIRECT</b>	1	Course End Survey

**COURSE CONTENT**

<b>Topic - 1</b>	<b>WATER CHEMISTRY</b>	<b>9</b>		
<p>Hardness of water – Types – Units – Boiler troubles (Scale and Sludge, Priming and Foaming and Caustic Embrittlement) – Treatment of boiler feed water – Internal treatment (Phosphate, Colloidal and Calgon conditioning) and External treatment (Ion exchange process and Zeolite process) – Desalination of brackish water – Reverse Osmosis.</p>				
<b>Topic - 2</b>	<b>FUELS</b>	<b>9</b>		
<p>Fuels: Introduction - Classification of fuels – Coal – Analysis of coal (Proximate and Ultimate Analysis) - Carbonization - Manufacture of metallurgical coke (Otto Hoffmann method) - Petroleum – Bergius Process - Knocking - Octane number - Diesel oil - Cetane number - Natural gas - Compressed natural gas (CNG) - Liquefied petroleum gases (LPG) - Power alcohol.</p>				
<b>Topic - 3</b>	<b>ENERGY STORAGE DEVICES</b>	<b>9</b>		
<p>Batteries - Types of batteries – Primary battery - Dry cell. Secondary battery - Lead acid battery, Nickel-Cadmium battery, Fuel cells – Hydrogen - Oxygen fuel cell - Solar energy conversion - Solar cells – Application.</p>				
<b>Topic - 4</b>	<b>SPECTROSCOPY</b>	<b>9</b>		
<p>Introduction – Laws of spectroscopy - Block diagram, Instrumentation, Working and application of Visible spectroscopy and Ultra Violet spectroscopy – Infrared spectroscopy – Flame photometry – Atomic adsorption Spectroscopy.</p>				
<b>Topic - 5</b>	<b>ENGINEERING MATERIALS</b>	<b>9</b>		
<p>Polymer – Types of polymerization – Preparation, properties, uses of Nylon (6, 6), Poly Vinyl Chloride (PVC). Plastics – Types - Rubbers – SBR – Nanomaterial – Synthesis and its applications of Nanomaterial. Abrasives – Classification, Properties- Manufacture of SiC.</p>				
<b>THEORY</b>	<b>45</b>	<b>TUTORIAL 0</b>	<b>PRACTICAL 0</b>	<b>TOTAL 45</b>

**BOOK REFERENCES**

1	S.S Dara and S.S. Umare 'Engineering Chemistry', S.Chand Publication, 2013
2	Jain & Jain 'Engineering chemistry' Dhanpat Rai Publishing Company, 2012
3	Shikha Agarwal , Engineering Chemistry, Cambridge University Press, 2015 edition
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2	<a href="https://nptel.ac.in/course.html">https://nptel.ac.in/course.html</a>
3	<a href="https://www2.chemistry.msu.edu/faculty/reusch/virttxtjml/polymers.htm">https://www2.chemistry.msu.edu/faculty/reusch/virttxtjml/polymers.htm</a>
4	<a href="https://edu.rsc.org/resources/collections/analytical-chemistry-introductions">https://edu.rsc.org/resources/collections/analytical-chemistry-introductions</a>

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## TOPIC - I - WATER TECHNOLOGY

### 1.1 PART –A

#### 1. How is hardness of water removed in Zeolite Process?

Sodium Zeolite absorbs **Ca<sup>2+</sup> and Mg<sup>2+</sup>** ions present in the water and releasing the equivalent amount of sodium ions in exchange

#### 2. Distinguish between hard and soft water.

Hard water: Water which does **not** produce **lather** with soap solution, but produce white precipitate (scum) is called hard water.

Soft water: Water which produce **lather readily** with soap solution is called soft water. Absence of Ca & Mg salts.

#### 3. Define Hardness. Mention the types.

It is property of water which **does not** produce ready lather with soap solution.

##### Types of hardness

Depending upon the types of dissolved salts present in water, hardness of water can be classified into two types.

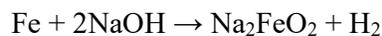
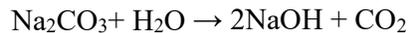
- **Temporary hardness.**(Carbonate Hardness)
- **Permanent hardness.**(Non-Carbonate Hardness)

#### 4. What is desalination?

The process of removing common salt from the water is known as **desalination**.

#### 5. Define caustic embrittlement.

The formation of brittle and intercrystalline cracks in the boiler shell is called caustic embrittlement. In high pressure boilers Na<sub>2</sub>CO<sub>3</sub> present in water undergoes decomposition to give NaOH. This NaOH flows into the minute hair cracks and dissolve the surrounding area of iron as sodium ferroate.



#### 6. Define reverse osmosis. Give its advantages.

- The **life of the membrane** is **high**, and it can be replaced with in few minutes.
- It removes **ionic as well as non –ionic, colloidal impurities**.
- Due to **low capital cost**, simplicity.

#### 7. How the ions are regenerated in Zeolite process?

When the Zeolite bed is exhausted, it can be regenerated by passing **concentrated sodium chloride (brine)** solution.



### 8. Why is Calgon conditioning better than phosphate conditioning?

The complex  $\text{Na}_2[\text{Na}_4(\text{PO}_3)_6]$  is soluble in water and there is no problem of sludge disposal. So Calogen conditioning is better than phosphate conditioning.

### 9. Write a note on colloidal conditioning.

Scale formation can be avoided by adding colloidal conditioning agents like **kerosene, agar-agar, gelatine**, etc. Sludge can be removed by **blow down operation**.

### 10. Why is water softened before using in boiler?

The hard water contains hardness producing ions. So it produces the some troubles in boiler.

### 11. Define boiler feed water.

The water fed into the boiler for the production of steam is known as **boiler feed water**.

### 12. What are the requirements of boiler feed water?

It should free from (i). Suspended solids. (ii). Dissolved salts like  $\text{MgCl}_2$  (iii). Hardness. (iv). Alkalinity. (v). Dissolved gases like  $\text{O}_2$  and  $\text{CO}_2$

### 13. What are the disadvantages using hard water in boiler?

- Scale and sludge formation.
- Caustic Embrittlement.
- Priming and Foaming.
- Boiler corrosion.

### 14. What is meant by internal conditioning of water? Give one example.

Treating the boiler water in the boiler itself by adding chemicals to remove scale forming substance is called **internal conditioning**. Ex: Carbonate conditioning, Phosphate conditioning, Calgon conditioning.

### 15. What is meant by external conditioning of water? Give one example.

Treating the boiler water before feeding it into boiler is called **external conditioning**. Ex: Zeolite process, Demineralisation process

### 16. What is Calgon? How does it function in water treatment?

**Calgon – Sodium Hexa Meta Phosphate**. It interacts with calcium ions forming a highly soluble complex and thus prevents the precipitation of scale forming salt.

### 17. What are the advantages of reverse osmosis method?

- Low capital cost, easy operating.
- RO method is used for converting sea water into drinking water.
- It removes all types of impurities like non-ionic and colloidal.
- The life time of membrane is high and it can be replaced within few minutes.

### 18. What are the methods of expressing the hardness? Or Unit of hardness.

The hardness of water can be expressed by any one of the following two methods.

Units for measuring hardness: mg/litre of  $\text{CaCO}_3$

It is the number of mg  $\text{CaCO}_3$  of present in one litre of water or mg/lit

- part per million of  $\text{CaCO}_3$

It is the number of parts by weight of  $\text{CaCO}_3$  present in million parts of water or ppm.

- 1mg / litre = 1 ppm.

### 19. Write the difference between scale and sludge.

Differentiate between Sludge & Scale			
Sludge		Scale	
1	Due to heating, the salt containing water will get concentrated and changes into loose and slimy precipitates called sludge.	1	When these precipitates becomes hard and adherent called scales.
2	Sludge is not harmful for boiler.	2	Scales is harmful for boiler.
3	Sludge can be removed from the bottom of the boiler time to time.	3	Scale can be removed by either external or internal treatment or hammering.
4	Sludge doesn't cause clogging and corrosion.	4	Scale causes clogging and corrosion.
5	Sludge increases the discarding cost of waste.	5	Scale increases the maintenance and operation cost.

### 20. Write a note on Priming.

**Priming:** Due to rapid boiling the steam may carry some water droplets along with it. This is called wet steam. The process of production of wet steam is called Priming.

Reason for Priming: 1. High steam velocity 2. High water level and 3. Sudden boiling.

### 21. Write a note on Foaming.

**Foaming:** The formation of stable bubbles above the surface of water is called foaming.

Reason for Foaming: This is due to the presence of oil, grease and finely divided particles.

## 1.2. PART-B

### 1.2.1. Explain the Zeolite process for the purification of water.

The name Zeolite is derived from two Greek words (Zien + lithos) which mean "boiling stone". The name was first used by Cronstedt, a Swedish geologist, in 1736, to a certain group of natural minerals, which released their water of hydration (or combination) in the form of steam. Two types of zeolites are in common use

#### a) Natural Zeolites

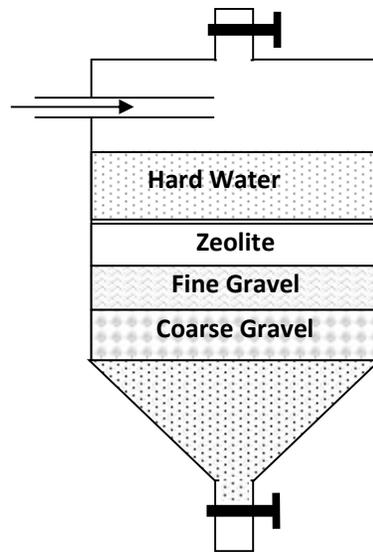
- They are non-porous green sands, amorphous and durable
- They are derived from green sands by washing, heating and treatment with NaOH

## b) Synthetic Zeolites

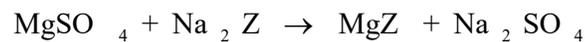
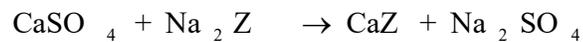
- They are porous and possess a gel structure
- They are prepared from solutions of sodium silicate and aluminium hydroxide
- Sodium Zeolites are commonly used in water softening which is represented as  $\text{Na}_2\text{Z}$ , where Z stands for the insoluble Zeolite radical framework.
- Since these are capable of exchanging basic radicals, these are generally known as base exchangers.

### Process

When hard water passes through a bed containing sodium Zeolite, the  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions are taken up the Zeolite and simultaneously releasing the equivalent sodium ions in exchange for them. The various reactions taking place may be indicated as follows:

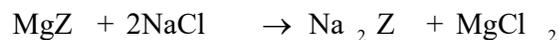


**Fig. Zeolite Process**



### Regeneration:

When the Zeolite bed is exhausted, it can be regenerated by passing concentrated sodium chloride (brine) solution.



[**Note: Brine** is most widely used on account of its cheapness, relatively low molecular weight and also because the products formed by the regeneration reactions are chiefly  $\text{CaCl}_2$  and  $\text{MgCl}_2$  which are highly soluble and can be readily rinsed out from the Zeolite bed]

### Advantages of Zeolite process

- Hardness is completely removed.
- Equipment used is compact and occupies fewer places.
- It automatically adjusts itself to water of different hardness.
- It can work under pressure. Hence the plant can be installed in the water supply line itself, avoiding double pumping.
- In this process, the hardness causing ions are simply exchanged with sodium ions not formed the sludge.
- It is quit clean and rapid process.

### Limitations

- Water should be free from turbidity and suspended matter because the pores of the Zeolite material are blocked.
- It cannot be treated acidity or alkalinity containing water because it may attack the Zeolite.
- It is preferable to have the pH of the water passing through the Zeolite softener around 7.
- Water containing large qualities of  $\text{Fe}^{2+}$  and  $\text{Mn}^{2+}$  cannot be treated because regeneration is difficult.
- Hot water should not be used because Zeolite tends to dissolve in it.
- Acid radicals are not removed by this process. Hence, the temporary hardness present in the raw water is converted to  $\text{NaHCO}_3$  which goes into soft water effluent. If such water is used in the boiler, it dissociates as follows under the boiler conditions.



- This NaOH may cause caustic embrittlement of boiler metal. Further,  $\text{CO}_2$  goes along with the steam and renders the condensed water acidic and corrosive.
- Water treated by the Zeolite process contains about 25% more dissolved solids than that treated by ion exchange process
- Hence, raw water containing large amounts of temporary hardness should be subjected to prolonged boiling or lime treatment to remove temporary hardness, before subjecting to the Zeolite process.

### 1.2.2. What is Desalination? Name the different methods of desalination. Explain any one in detail.

The process of removal of dissolved salts ( $\text{NaCl}$ ) from water is known as **desalination or desalting**. Water containing high concentrations of dissolved salts/solids with salty nature is known as **brackish water or saline water**.

The salinity of raw water is expressed in mg/l or ppm of dissolved salts. Water quality is usually graded as

- Fresh water (less than 1000 mg /l of dissolved salts)
- Brackish water (1000 – 35000 mg /l of dissolved salts)

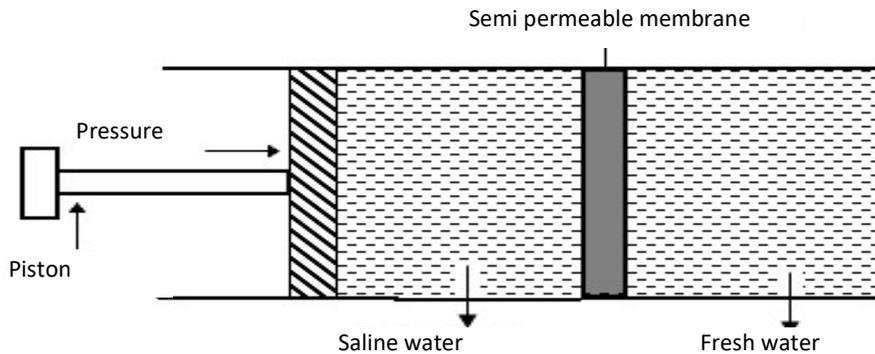
- Sea water (greater than 35000 mg /l of dissolved salts)

The Reverse osmosis techniques are carried out for desalination of sea water and brackish water.

### Reverse Osmosis (RO)

*“When two solutions of different concentrations are separated by a semi-permeable membrane, solvent (water) flows from a region of lower concentration to a region of higher concentration. This process is called osmosis”.*

The driving force or pressure involved in the process of osmosis is known as *osmotic pressure*.



**Fig: Reverse osmosis**

This process can be reversed by applying a pressure higher than the osmotic pressure of the order 15 – 40 kg /cm<sup>2</sup> on the saturated solution side. If a hydrostatic pressure in excess of osmotic pressure is applied on the higher concentration side, the **solvent flows from higher concentration side to lower concentration** through the semi permeable membrane is called **reverse osmosis**. This process is also known as **super-filtration or hyper filtration**.

Cellulose acetate, cellulose butyrate, polyamide and polyimide, polysulphone are the polymers used for the semi-permeable membrane.

### Advantages

- The water obtained by this process is used for high pressure boilers.
- Low capital, operating cost, high reliability and simplicity.
- The life time of the membrane is high and it can be replaced within a short time.
- It also removes ionic, non-ionic and colloidal impurities.
- There is no wastage of water.

### 1.2.3. What do you understand by internal conditioning methods of boiler feed water?

Internal conditioning involves the removal of scale forming substance, by adding chemicals directly into the boiler. The chemicals added to the boiler are called boiler compounds.

Internal conditioning can be done by the following methods

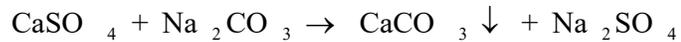
- (i) Colloidal conditioning
- (ii) Carbonate conditioning
- (iii) Phosphate conditioning
- (iv) Calgon conditioning

### (i) Colloidal conditioning

- In low pressure boilers scale formation can be avoided by adding colloidal conditioning agents like kerosene, agar-agar, gelatine, etc.
- These colloidal substances get coated over the scale forming particles and convert them into non-adherent, loose precipitate called sludge
- Sludge can be removed by blow down operation

### (ii) Carbonate conditioning

- Scale formation can be avoided by adding  $\text{Na}_2\text{CO}_3$  to the boiler water
- It is used only in low pressure boilers
- The scale forming salt like  $\text{CaSO}_4$  is converted into  $\text{CaCO}_3$ , which can be removed easily.



### iii) Calgon conditioning

- Calgon is sodium hexametaphosphate with a composition.  $\text{Na}_2 [\text{Na}_4 (\text{PO}_3)_6]$
- This Calgon reacts with the calcium ions of soluble complex of scale forming substances like  $\text{CaSO}_4$ , forming a highly soluble complex.
- Thus they prevent the precipitation of scale forming salt.
- The reaction is as follows  
$$2\text{CaSO}_4 + \text{Na}_2 [\text{Na}_4 (\text{PO}_3)_6] \rightarrow \text{Na}_2 [(\text{Ca}_2 (\text{PO}_3)_6)] + 2\text{Na}_2\text{SO}_4$$
- Since the complex is highly soluble there is no problem of sludge disposal.

### iv) Phosphate conditioning.

In high pressure boilers,  $\text{CaSO}_4$  scale whose solubility decreases with increase of temperature. Such scale can be converted into soft sludge by adding excess of soluble phosphates.



There are three types of phosphates employed for this purpose

S.No	Types of phosphates	Nature of Chemical	uses
1	Tri sodium phosphate	$\text{Na}_3\text{PO}_4$ (too alkaline)	Used for too acidic water.
2	Di sodium hydrogen phosphate	$\text{Na}_2\text{HPO}_4$ (weakly alkaline)	Used for weakly acidic water
3.	Mono sodium di hydrogen phosphate	$\text{NaH}_2\text{PO}_4$ (acidic)	Used for alkaline water.

#### 1.2.4. Discuss the ion-exchange process for water softening?

Demineralization is the process which removes almost all the ions (both cations and anions) present in the hard water. The soft water, produced by lime-soda and Zeolite processes, does not contain hardness producing  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions, but it will contain other ions like  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ , etc.

But the demineralised water does not contain both anions and cations. Hence, it states that a **soft water is not demineralised water whereas demineralised water is a soft water.**

In the demineralised process, the ions present in water are removed by ion exchangers. Ion exchangers are **usually resins with long chain, cross linked, insoluble organic polymers with a micro porous structure.**

The ion exchangers should possess the following properties for effective demineralization process

- It should be non-toxic
- It should possess a high ion-exchange capacity
- It should be resistant to chemical attack
- It should be cheap and commonly available
- It should have a large surface area since ion exchange is surface phenomenon

Based on the acidity or basicity of the functional group, exchangers are classified as cation exchanger and anion exchanger.

##### **Cation exchanger**

Resins containing acidic functional (sulphonic, phenolic) groups are capable of exchanging their  $\text{H}^+$  ions with other cations of hard water. **Cation exchange resin is represented as RH.**

**Example:** i) Sulphonated coals

ii) Sulphonated polystyrene and iii)  $\text{R-SO}_3\text{H}$ ;  $\text{R-COOH}$ .

##### **Anionic Exchanger**

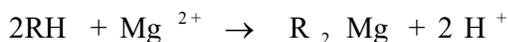
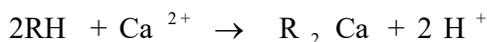
Resins containing basic functional groups are capable of exchanging their anions with other anions of hard water. Anion exchange resin is represented as  $\text{R}(\text{OH})$ .

**Example:** i) Cross-linked quaternary ammonium salts.

ii) Urea-formaldehyde resin iii)  $\text{R-OH}$ ;  $\text{R-NR}_3\text{OH}$

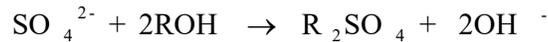
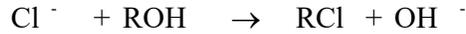
##### **Process:**

The hard water first passing through cation exchanger column, which absorbs all the cations like  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ , etc present in hard water and release hydrogen ions.



Thus sulphates, chlorides and bicarbonates are converted into corresponding acids  $\text{H}_2\text{SO}_4$ ,  $\text{HCl}$  and  $\text{H}_2\text{CO}_3$ .

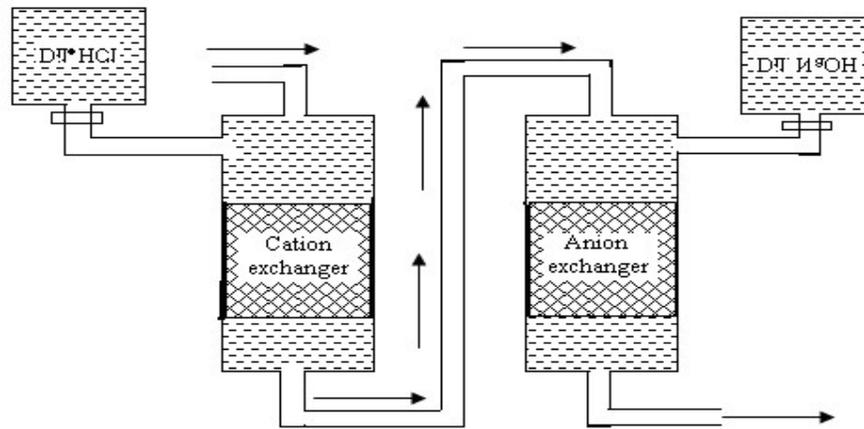
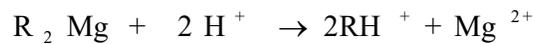
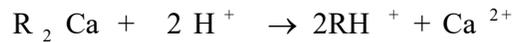
The cation free water is then passed through an anion exchanger column, which absorbs all the anions like  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{HCO}_3^-$ , etc. present in water and acids are converted into water.



The water coming out of the anion exchanger is completely free from cations and anions. This water is known as ***Demineralised water or deionised water.***

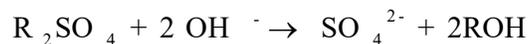
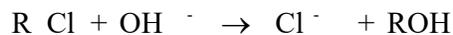
### Regeneration:

When the cation exchange resins get exhausted, they are regenerated by passing a solution of dilute  $\text{H}_2\text{SO}_4$ , or  $\text{HCl}$ .



**Fig. Demineralization process**

Similarly, when the anion exchange resin is exhausted, it can be regenerated by passing a solution of dilute  $\text{NaOH}$ .



### Advantages

- This process can be used to soften highly acidic or alkaline water.
- This process produces water of very low hardness (nearly 2 ppm).

### Disadvantages

- The equipment is costly and more expensive chemicals are needed.
- Water contains turbidity, then the output of the process is reduced.
- The turbidity must be below 10 ppm. If it is more, it has to be removed first by coagulation and filtration.

## **TOPIC-II - FUELS**

### **2.1 PART-A**

#### **1. What is calorific value? Mention its units.**

The calorific value of fuel is defined as the total **amount of heat evolved**, when a **unit mass of the fuel** is completely burnt.

The calorific value of gaseous fuel is expressed in different ways such as Calories, Kilocalories, British Thermal unit (B.T.U) and Centigrade Heat Unit (C.H.U)

#### **2. What is metamorphism or Coalification of coal?**

The process of conversion of vegetable matter to anthracite is called Coalification or metamorphism of coal.

#### **3. What is Metallurgical coke (or) Carbonization of coal?**

When bituminous coal is heated strongly in the absence of air, the volatile matter escapes out and the mass becomes hard, strong, porous and coherent which is called Metallurgical Coke.

#### **4. What is drawback of presence of Sulphur in the coal?**

Sulphur increases the calorific value, but its presence in coal is undesirable because the combustion products of sulphur, i.e.,  $\text{SO}_2$  and  $\text{SO}_3$  are harmful and have corrosion effects on equipments.

#### **5. What is meant by refining of petroleum?**

The process of the petroleum is separated into its components along is called refining of petroleum.

#### **6. What is knocking? How is it to be reduced?**

It is a kind of explosion sound due to rapid pressure raise occurring in an internal combustion engine. It is reduced by adding anti-knocking agents like TEL.

#### **7. What is meant by hydrogenation of coal?**

If coal is heated with hydrogen to high temperature under high pressure, it is converted to gasoline. The preparation of liquid fuels from solid coal is called Hydrogenation of coal

#### **8. Define octane number. How will you improve the octane number?**

Octane number is defined as 'the percentage of iso-octane present in a mixture of iso-octane and n-heptane.

#### **9. What is leaded petrol? Mention its advantages and disadvantages.**

The petrol containing tetra ethyl lead is called leaded petrol.

Advantages : Raise the octane number. It could reduce the knocking of the engine.

Disadvantages : Lead is toxic. It causes a lot of pollution which is not good for human health.

**10. What is LPG? Mention its advantages over other gaseous fuels.**

It consists of propane and butane. It can be readily liquefied under pressure, so it can be economically stored and transported in cylinders. The average composition of LPG is given above table. Its calorific value is about 27,800 Kcal /m<sup>3</sup>

Uses : It is used as a domestic and industrial fuel and motor fuel.

**11. Define Cetane number. How it can be improved? (or) Octane rating**

The Cetane number is defined as ‘the percentage of hexa decane (cetane) present in a mixture of hexa decane and  $\alpha$ -methyl naphthalene.

**12. What is CNG? Mention its primary components.**

CNG is derived from natural gas and the main constituent of CNG is methane. CNG is natural gas compressed to a high pressure of about 3000 or 3600 psi or a steel cylinder containing 15 kg of CNG contains about 20m<sup>3</sup> of natural gas at 1 atmospheric pressure.

Methane is the primary component.

**13. What is caking coals and caking coals?**

When coals are heated strongly, the mass becomes soft, plastic and fused together to large coherent masses. Such types of coals are called Caking Coals. But if the mass so produced is hard, porous and strong then the coals are called Coking coals.

**14. How fuels are classified?**

Fuels are classified into natural or primary fuels and artificial or secondary fuels. Each type is further subdivided into solid, liquid and gaseous fuels.

Sl. No.	State of fuel	Natural	Artificial
1	Solid	Wood, peat, lignite, coal	Wood charcoal, coke
2	Liquid	Crude petroleum	Kerosene, petrol, diesel, alcohol
3	Gaseous	Natural gas	Water gas, producer gas, biogas, coal gas, LPG

**15. Define Combustion of a fuel.**

The chemical reaction of a fuel with oxygen (oxidizing agent) which produces heat and light energy is called combustion of a fuel.



**16. Define Knocking.**

Knocking is a kind of explosion due to rapid pressure rise occurring in an IC engine. Knocking property of the fuel reduces the efficiency of engine.

## 2.2. PART-B

### 2.2.1. Describe proximate analysis of coal with its significance.

Proximate analysis percentage of moisture content, volatile matter, ash content and fixed carbon in coal is determined.

In proximate analysis percentage of moisture content, volatile matter, ash content and fixed carbon in coal is determined.

#### i) Moisture content

**1 gm of powdered coal** sample is taken in a silica crucible, and it is heated at **105-110°C** in an electric hot-air oven for **1 hour** and then cooled. The loss in weight of the sample is calculated % of moisture is calculated as

$$\% \text{ of Moisture in coal} = \frac{\text{loss in weight of the coal}}{\text{Weight of air-dried coal}} \times 100$$

#### ii) Volatile matter

After the analysis of moisture content, the silica crucible **covered with a lid**, and it is heated at **950 ± 20°C** for **7 minutes**. The loss in weight of the sample is calculated % of volatile matter is calculated as

$$\% \text{ of Volatile matter in coal} = \frac{\text{loss in weight of the coal}}{\text{Weight of moisture free coal}} \times 100$$

#### iii) Ash content

After the analysis of volatile matter the crucible, coal sample is heated **without lid at 700 ± 50 °C for 30 minutes** and then the crucible is taken out cooled and weighed. This process is repeated and weight of ash content is observed. From this value the % of ash content is calculated as

$$\% \text{ of ash in coal} = \frac{\text{Weight of ash formed}}{\text{Weight of dried coal}} \times 100$$

#### iv) Fixed carbon

The carbon content can be determined by subtracting the sum total of moisture, volatile and ash contents from **100**.

$$\% \text{ of fixed carbon in coal} = 100 - \% \text{ of (Moisture content + Volatile matter + Ash content)}$$

### Significance (Or) Importance of proximate analysis

#### a) Moisture

- High percentage of moisture content is undesirable because it reduces the calorific value of coal.
- Moisture in coal consumes more heat in the form of latent heat of evaporation and hence more heat is to be supplied to the coal.
- It increases the transport cost.
- Hence lesser the moisture content betters the quality of fuel.

**b) Volatile matter**

- Volatile matters also lower the calorific value of fuel since a large proportion of volatile matter on heating escapes out unburnt.
- Coal with high percentage of volatile matter burns with a long flame with high smoke.
- The coal containing high percentage of volatile matter do not coke well.

**c) Ash content**

- Ash is a useless component present in the coal, which considerably reduces the calorific value.
- Ash causes hindrance to heat flow as well as produces clinkers, which blocks the air supply through the fuel.
- It increases the transporting, handling and storage costs.

**d) Fixed carbon**

- Fixed carbon content is a great asset for the fuel
- Greater the percentage of carbon content, the fuel burns efficient with oxygen of air and greater will be calorific value
- The percentage of fixed carbon helps in designing the furnace and the shape of the fire-box

**e) Volatile matter**

- Volatile matters also lower the calorific value of fuel since a large proportion of volatile matter on heating escapes out unburnt
- The coal containing high percentage of volatile matter do not coke well

**f) Ash content**

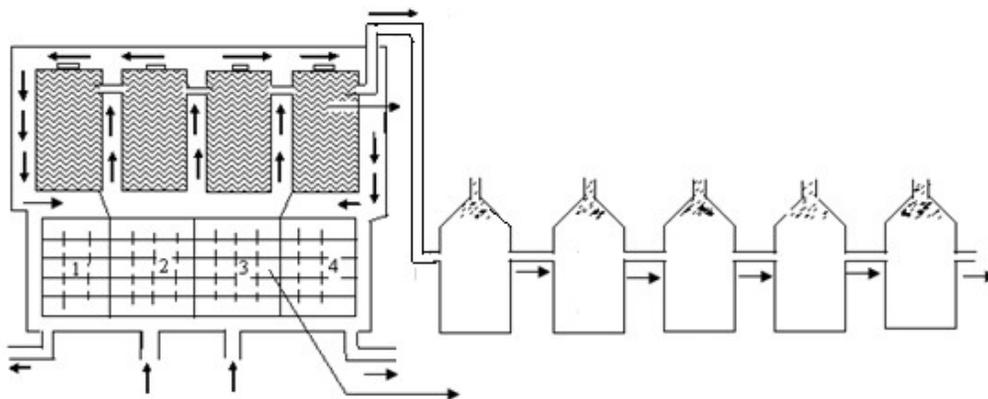
- Ash is a useless component present in the coal, which considerably reduces the calorific value
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**h) Fixed carbon**

- Fixed carbon content is a great asset for the fuel
- Greater the percentage of carbon content, the fuel burns efficient with oxygen of air and greater will be calorific value

**2.2.2. In what ways Otto Hoffmann method is advantageous than the traditional method. Explain the various products and the recovery process.**

There are so many types of ovens used for the manufacture of metallurgical coke. But the important one is **Otto-Hoffman's by product oven**.



**Fig. Otto-Hoffman's by product oven**

Otto-Hoffman's devised a coke oven otherwise known as the by product chamber oven.

- In this oven the thermal efficiency of carbonization process is considerably increased by the regenerative system of heat economy
- By this process most of the valuable by products of coal like coal gas, ammonia, tar, benzol oil, etc. are recovered

The oven consists of a number of **silica chambers**. Each chamber is about **10 – 12 m long, 3 – 4 m height and 0.4 – 0.45 m wide**. Each chamber is provided with a charging door at the top, discharging door at the bottom. The chambers are packed with coal and tightly closed.

Coal is introduced into the silica chamber and the chambers are closed. The chambers are heated to **1200°C** by burning the preheated air and the producer gas mixture in the interspaces between the chambers.

The air and gas are preheated by sending them through **2<sup>nd</sup> and 3<sup>rd</sup>** hot regenerators. Hot flue gases produced during carbonization are allowed to pass through 1st and 4th regenerators until the temperature has been raised to **1000°C**. While **1<sup>st</sup> and 4<sup>th</sup>** regenerators are heated by hot flue gases, the **2<sup>nd</sup> and 3<sup>rd</sup>** regenerators are used for heating the incoming air and gas mixture.

For economical heating, the direction of inlet gases and flue gases are changed frequently. The above system of recycling the flue gases to produce heat energy is known as the regenerative system of heat economy. When the process is complete, the coke is removed and quenched with water.

Time taken for complete carbonization is about **12 – 20 hours**. The yield of coke is about **70%**. The valuable by products like coal gas, tar, ammonia, H<sub>2</sub>S and benzol, etc. can be recovered from flue gas.

## Recovery of by-products

i) **Tar** : The gas coming out of the silica chambers is known as “Coke oven gas” and is mainly consist of coal, tar, ammonia, Hydrogen sulphide, naphthalene, benzene etc. The coke oven gases are first passed through a tower in which **liquor ammonia** is sprayed. Tar and dust get dissolved and collected in a tank below, which is heated by steam coils to recover back the ammonia sprayed.

ii) **Ammonia** : The gases are then passed through another tower in which **water** is sprayed. Here ammonia gets converted to  $\text{NH}_4\text{OH}$  is collected at the bottom.

iii) **Naphthalene** : The gases are then passed through another tower, in which **cooled water** is sprayed and naphthalene gets condensed on the walls of the chambers.

iv) **Benzene**: The remaining gases are passed through another tower, where **petroleum** is sprayed. Benzene and its homologues get condensed to liquid in this chamber.

v) **Hydrogen sulphide** : The finally left out gases are then passed through a purifier packed with moist  $\text{Fe}_2\text{O}_3$ , which absorbs  $\text{H}_2\text{S}$  gas.

The final gas left out is called coal gas which is used as a gaseous fuel.

## Advantages of Otto Hoffman’s process

- Recovery of valuable by products like ammonia, coal gas, Naphthalene etc.
- The time taken for carbonization time is less (about 12-20 Hours)
- Heating is done externally by producer gas

**2.2.3. Explain synthesis of petrol by Bergius process. Or What is Bergius process . What are the advantages of the process?**

Or

**How will you obtain synthetic petrol by Bergius process.**

## Hydrogenation of coal

Coal is a **hydrogen deficient compound**, because it contains **4.5% hydrogen** compared to about **18% in petroleum**.

“If coal is heated with hydrogen to high temperature under high pressure, it is converted to gasoline. The preparation of liquid fuels from solid coal is called **Hydrogenation of coal**”.

## (A) BERGIUS PROCESS

The Bergius process is a method of **production of liquid hydrocarbons** for use as synthetic fuel by hydrogenation of high-volatile bituminous coal at high temperature and pressure. It was first developed by **Friedrich Bergius in 1913**. In 1931 Bergius was awarded the **Nobel Prize in Chemistry** for his development of high-pressure chemistry.

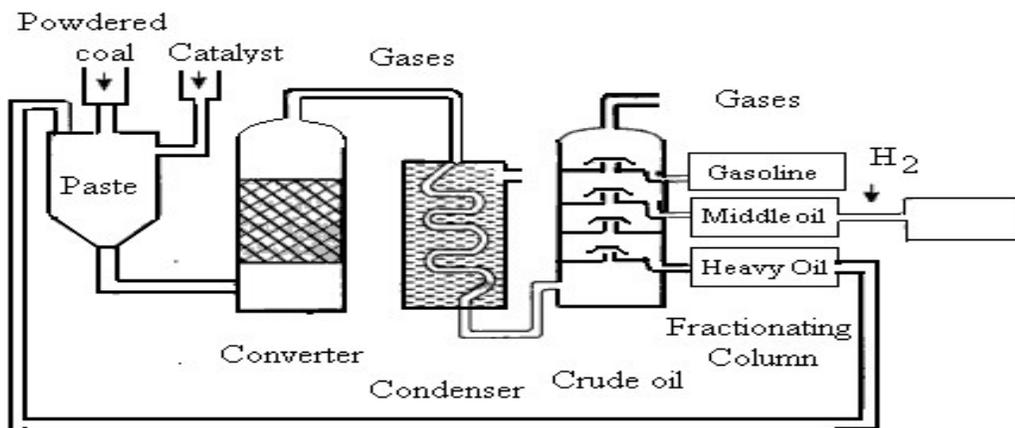
In this process, the finely powdered coal is made into a paste with **heavy oil** and a **catalyst powder (Tin or Nickel Oleate)**. The paste is pumped along with **hydrogen gas** into the converter, where the paste is

heated to **400-450°C** under a pressure of **200-250 atm** for about **1.5 hours**. The Polymerization reaction takes place with the help of the catalyst.

During this process hydrogen combine with coal to form saturated higher hydrocarbons, which undergo further decomposition at higher temperature to yield mixture of lower hydrocarbons. The mixture is passes to a condenser, where the crude oil is obtained.

The crude oil is then fractionated to yield

- i) Gasoline (ii) Middle oil (iii) Heavy oil.



The **middle oil** is further hydrogenated in vapour phase to yield more gasoline. The heavy oil is recycled for making paste with fresh coal dust. The yield of gasoline is about **60%** of the coal used. The heavy oil is used for cracking to get more gasoline.

**2.2.4. Write a note on Compressed Natural Gas (CNG). Mention its advantages.**

**COMPRESSED NATURAL GAS (CNG)**

Constituents	Percentage (%)
Methane	88.5
Ethane	5.5
Propane	3.7
Butane	1.8
Pentane	0.5

CNG is derived from natural gas and the main constituent of CNG is methane. CNG is **natural gas compressed** to a high pressure of about **3000 or 3600 psi** or a steel cylinder containing **15 kg of CNG** contains about **20m<sup>3</sup>** of natural gas at **1 atmospheric pressure**.

Compressed natural gas vehicles require a greater amount of space for fuel storage than convention gasoline power vehicles. Since it is a compressed gas, rather than a liquid like gasoline, CNG takes up more space for each **GGE (Gallon of Gas Equivalent)**.

This makes it difficult to design smaller vehicles that look and operate like the vehicles that people are accustomed to.

CNG is often confused with liquefied natural gas (LNG). While both are stored forms of natural gas, the key difference is that CNG is in **compressed form**, while LNG is in **liquefied form**.

CNG has a lower cost of production and storage compared to LPG as it does not require an expensive cooling process and cryogenic tanks.

CNG requires a much larger volume to store the same mass of natural gas and the use of very high pressures (3000 to 4000 lbf/in<sup>2</sup>, or 205 to 275 bars).

**Properties:**

- CNG is; the cheapest, cleanest and least environmentally impacting alternative fuel.
- Vehicles powered by CNG produce less carbon monoxide and hydrocarbon (HC) emission.
- It is less expensive than petrol and diesel.
- The ignition temperature of CNG is about 550°C. CNG requires more air for ignition.

**Uses:**

- It is cheapest and least environmentally impacting alternative fuel.
- It is used as fuel for all buses, taxis and auto.

**2.2.5. Write a note on Liquefied Petroleum Gas (LPG). Mention its advantages.**

**LIQUEFIED PETROLEUM GAS (LPG)**

Constituents	Percentage (%)
n-Butane	38.5
Iso butane	37
Propane	24.5

**Liquefied Petroleum Gas (LPG) or Auto Gas** is a generic name for mixtures of hydrocarbons which exists as vapor under ambient conditions and can be changed into liquid state by applying moderate pressures.

When stored under pressure it becomes a dense liquid allowing large quantity of gas to be stored in a relatively small space.

Energy content similar to gasoline. Inherently clean burning characteristics. LPG, known world over as Auto gas, gives you a new life as it brings along multiple benefits.

Auto gas is the 3rd most popular automotive fuel and the number # 1 clean fuel alternative in the world.

It is obtained as a by-product during fractional distillation of crude petroleum oil or cracking of heavy oil.

It consists of **propane and butane**.

It can be readily liquefied under pressure, so it can be economically stored and transported in cylinders.

The average composition of LPG is given above table. **Its calorific value is about 27,800 Kcal /m<sup>3</sup>**

### Properties of LPG

- It is like water and cumulative at the deeper places on the ground or somewhere else.
- Non-corrosive.
- It is very light in weight.
- When placed under pressure in cylinders, it is stored as liquid.
- It is in vapour form in atmospheric conditions.
- Large vapour to liquid ratio.
- Stored under pressure as liquid.
- High energy fuel.
- Flammable and heavier than air.

### Uses:

- LPG (liquefied petroleum gas) is used in your home, including cooking, heating, hot water, autogas, aerosol propellant, air conditioning refrigerant.
- Business and industry use LPG fuel for a multitude of processes including steam boilers, kilns, ovens and LPG forklifts.
- LPG products are also employed as a propellant, refrigerant, vehicle fuel and petrochemical feedstock.
- LPG fuel for transport is also a big user of LPG (Autogas).

### 2.2.6. Write a note on Power Alcohol.

When ethyl alcohol is used as fuel in internal combustion engine, it is called as "power alcohol". Generally ethyl alcohol is used as its **5-25%** mixture with petrol.

### Composition of power alcohol

It is a mixture **75-80%** petrol, **20-25%** ethanol, and minute amount of aromatic compounds such as benzene.

### Advantages of Power Alcohol

- Ethyl alcohol has good **antiknocking** property and its octane number is **90**, while the octane number of petrol is about **65**.
- Alcohol has property of absorbing any traces of water if present in petrol. Ethyl alcohol contains 'O' atoms, which helps for complete combustion of power
- Alcohol and the polluting emissions of **CO**, hydrocarbon, particulates are reduced largely.
- Use of ethyl alcohol in petrol reduces our dependence on foreign countries for petrol and saves foreign considerably.
- Power alcohol is **cheaper** than petrol.

### **Disadvantages of power alcohol**

- Ethyl alcohol has calorific value **7000cal/gm** much lower than calorific value of petrol **11500cal/gm**.
- Use of power alcohol reduces power output upto **35%**. Ethyl alcohol has high surface tension and its atomisation, especially at lower temperature, is difficult causing starting trouble.
- Ethyl alcohol may undergo oxidation reaction to form **acetic acid**, which **corrodes** engine parts.
- Use of ethyl alcohol in petrol reduces our dependence for petrol.

## TOPIC - III - ENERGY STORAGE DEVICES

### 3.1. PART-A

#### **1. Write any three applications of solar cells**

Used in calculators, electronic watches, street lights, water pumps to run radios and TVs.

#### **2. Write short notes on wind energy.**

Wind energy is also a renewable energy. Energy recovered from the force of wind is called as wind energy.

#### **3. What are batteries? Mention its types with example.**

It is an arrangement of several electrochemical cells connected in series that can be used as a source of direct electric current.

Primary battery or Primary cells

Secondary battery or secondary cells and Fuel cells.

#### **4. Lithium cells are called solid state battery- why?**

- Its cell voltage is high, 3.0V
- Since Li is a light weight metal, only 7kg material required to produce 1mole of electrons.
- Since all the constituents of the battery are solids, there is no risk of leakage from the battery.
- This battery can be made in a variety of shapes and sizes

#### **5. What are solar cells? Give one example or what are photo galvanic cells?**

It is a device, Converting solar energy directly into electrical energy. It provides power supply for space satellites. Ex: solar water heater, photovoltaic cell

#### **6. What are non-conventional energy sources? Give two examples.**

Non-conventional energy sources are those energy sources which are exposed to use from modern technological advancements; rather than the normal use of conventional fuels as energy sources like gas or oil. Ex: 1. Wind energy 2. Solar energy 3. Tidal energy 4. Hydropower energy.

#### **7. What is a fuel cell? Classify fuel cells.**

It is a device in which the chemical energy of the fuel hydrogen is directly converted into electrical energy without combustion.

Classification of Fuel cells

Fuel cells can be classified into three categories:

(i) Direct fuel cells (ii) Indirect fuel cells (iii) Regenerative fuel cells.



#### **8. What are the advantages of fuel cell? Or what are the advantages of H<sub>2</sub>-O<sub>2</sub> fuel cell?**

- It is used as an auxiliary energy source in space vehicles, submarines.

- Used in military vehicles.
- It is a pollution free one.
- The product is water, so it is a valuable source of fresh water by the astronauts.

**9. What are the applications of lithium batteries?**

Used in cell phones, Digital cameras, Watches, Remote cars, Calculators, Toys, Backup batteries in computers, etc.

**10. List any two advantages of lithium batteries.**

- Its cell voltage is high, 3V.
- Li is a light-weight metal, only 7g (1 mole) material is required to produce 1 mole of electrons.
- It contains solid material so there is no leakage from battery.
- This battery can be made in a variety of sizes and shapes.

**11. Define alkaline battery.**

- It is called as a dry cell. It has the electrolyte of KOH.
- A zinc cylinder is filled with an electrolyte of Zn, KOH and MnO<sub>2</sub>.
- A carbon rod acts as a cathode and zinc body acts as anode.

**12. What is solar energy conversion?**

It is the process of conversion of direct sunlight into more useful forms. It undergoes mainly two types of mechanisms. 1. Thermal conversion. 2. Photo conversion.

**13. What are the merits of wind energy?**

- Non-polluting and sustainable energy source.
- The scope of wind energy is enormous.
- It is a renewable and sustainable energy source.
- It is available in many offshore, onshore and remote areas.

**14. What are the different types of batteries?**

- Primary battery (or) Primary Cells (or) Non- reversible battery.
- Secondary battery (or) Secondary Cells (or) Reversible battery.
- Flow Battery (or) fuel cells.

**15. Write the difference between primary battery and secondary battery.**

S.No	Primary battery	Secondary battery
1.	Cell reaction is irreversible	Cell reaction is reversible.
2.	Must be discarded after use	May be recharged
3.	Have relatively short shelf life	Have long shelf life.
4.	e.g. Dry cell	Li-MnO <sub>2</sub> battery. Lead acid, Ni-Cd battery.

## 3.2. PART B

### **3.2.1. What is solar energy? How it is produced? And mention the applications of solar energy.**

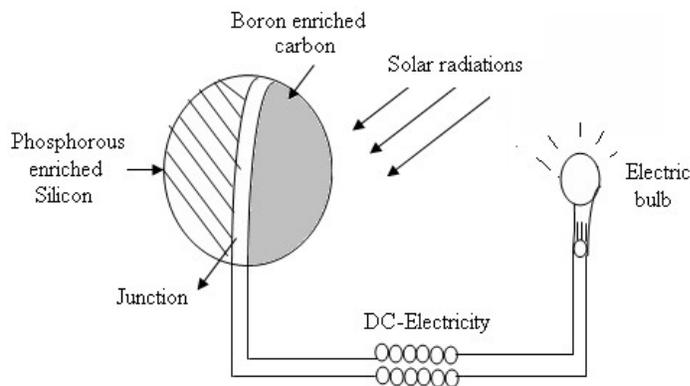
#### **Photo galvanic cell or Solar cell**

##### **Definition**

A solar cell (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect.

##### **Working Principle**

Solar cells consist of a p-type semiconductor (si with B) and n-type semiconductor (si with P). When solar rays fall on the top layer of p-type semiconductor, the electrons from the valence band get promoted to the conduction band and cross the p-n junction into n-type semiconductor. Thereby potential difference between two layers is created, which causes flow of electrons.



Uses: Used in calculators, electronic watches, street lights, water pumps to run radios and TVs.

#### **SOLAR BATTERY**

##### **Working**

When large numbers of solar cells are connected in series it forms a solar battery. Solar battery produces more electricity which is enough to run water pump, street light etc.

##### **Uses:**

They are used in remote areas where conventional electricity supply is a problem.

##### **Advantages of Solar Cell**

- It is a renewable source of energy.
- It's free of charge.
- It doesn't cause pollution.
- They can be use in remote areas.
- The system has long life of 10- 15 years or more.
- The energy cost is very low because the sources are available freely.
- More Solar energy in summer.

##### **Disadvantages of Solar Cell**

- It needs lots of space.

- High initial cost.
- No Solar power at night & cloudy days.
- Less Solar energy in winter.
- DC equipment is expensive.

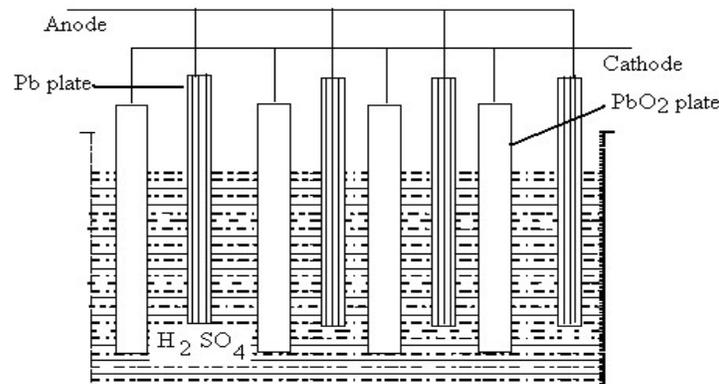
**3.2.2. What is a reversible battery? Describe the construction and working of lead acid battery with cell reaction? Or explain the principle behind Lead acid accumulator.**

**Acid storage battery (Lead storage battery)**

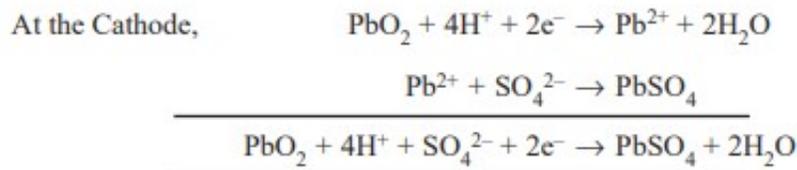
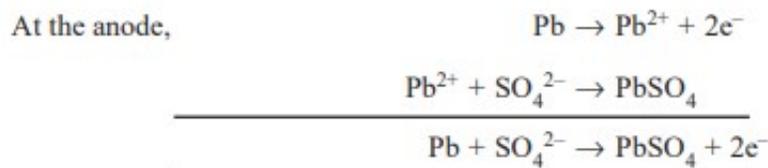
The electrodes are lead grids. The anode grid is filled with spongy lead and the cathode grid is filled with lead dioxide (PbO<sub>2</sub>).

A number of electrode pairs with inert porous partitions in between, are dipped in approximately 20% dilute sulphuric acid, which is the electrolyte.

The battery is encased in a plastic container.



Electrode reactions: The electrode reactions that occur during the discharge of the cell, i.e., on drawing current from the cell, are as follows:



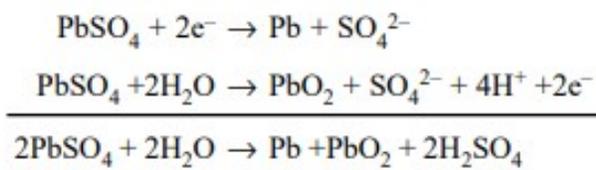
The net cell reaction is,



The product (PbSO<sub>4</sub>) formed during discharge remains adhered on each electrode and is available at the site during recharging.

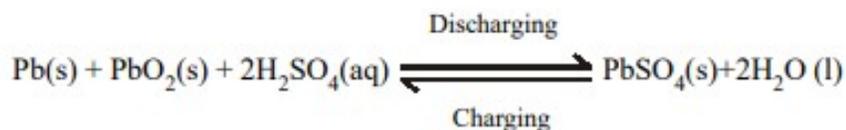
### Recharge reactions:

This is done by reversing the discharge reaction by applying externally a potential higher than that of the cell. The cell acts as an electrolytic cell, depositing lead and lead dioxide on the electrodes.



During charging, sulfuric acid is regenerated in the cell.

The net reaction during charging and discharging can be represented as follows:



### Applications

- Lead storage batteries are extensively used in automobiles to start the engine.
- They are also used for electric supply in telephone exchangers, railway trains, hospitals, laboratories, etc., and for emergency power supplies.

### Limitations:

- The potential decreases with decrease in concentration of sulphuric acid.
- Excessive discharge and quick charging shortens the life of the battery.
- Cell potential and the effectiveness is reduced at low temperature.
- Excessive charging may damage the electrodes and may also lead to explosion.

### 3.2.3. Define a fuel cell. Explain the construction of O<sub>2</sub>-H<sub>2</sub> fuel cells. State its advantages and disadvantages?

**Definition:** A fuel cell is a galvanic cell in which the chemical energy contained in a readily available fuel oxidant system is converted directly into electrical energy by means of electrochemical processes in which the fuel is oxidized at the anode.

A fuel cell reaction:



### HYDROGEN- OXYGEN FUEL CELL

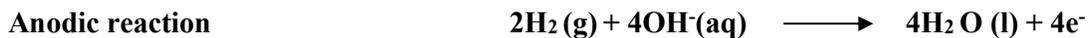
Hydrogen-oxygen fuel cell is the simplest and most successful fuel cell, in which the fuel-hydrogen and the oxidizer-oxygen and the liquid electrolyte are continuously passed through the cell.

### Description

A common type of fuel cell is based on the combustion of H<sub>2</sub> to form water.

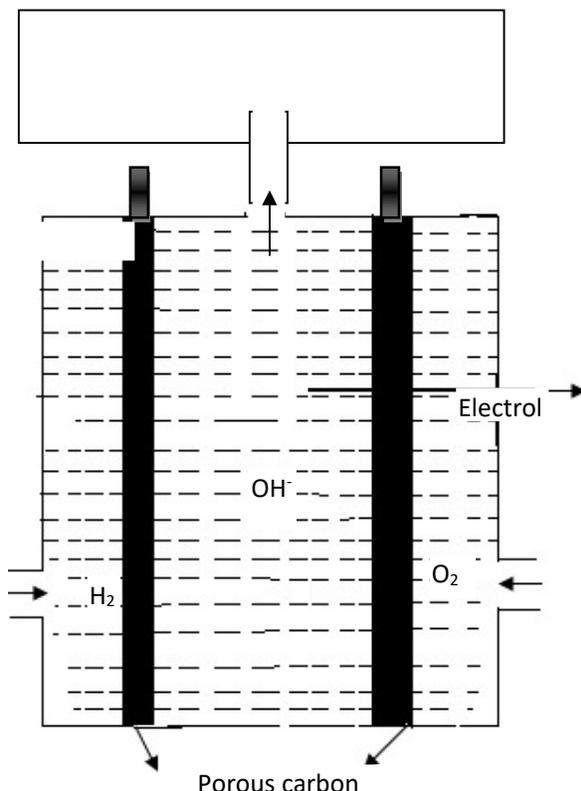


It consists of two porous electrodes anode and cathode. These porous electrodes are made of compressed carbon containing a small amount of catalyst (Pt, Pd, and Ag). In between the two electrodes an electrolytic solution such as 25% KOH or NaOH is filled. Oxygen and Hydrogen are continuously fed into the cell under a pressure of about 50atm. The water produced.



### Fuel Battery

When large number of fuel cells is connected in series, it forms fuel battery. The cell potential is 1.21 V at 25 °C. The acid electrolyte offers the advantage of easy removal of CO<sub>2</sub>, a product of the cell reaction.



### Advantages

- Continuous source of energy
- High Efficiency
- Pollution free working

### Uses

- H<sub>2</sub>-O<sub>2</sub> fuel cells are used as auxiliary energy source in space vehicles, submarines or other military-vehicles and Fuel cell vehicles (FCVs).
- In case of H<sub>2</sub>-O<sub>2</sub> fuel cells, the product of water is proved to be a valuable source of fresh water by the astronauts.

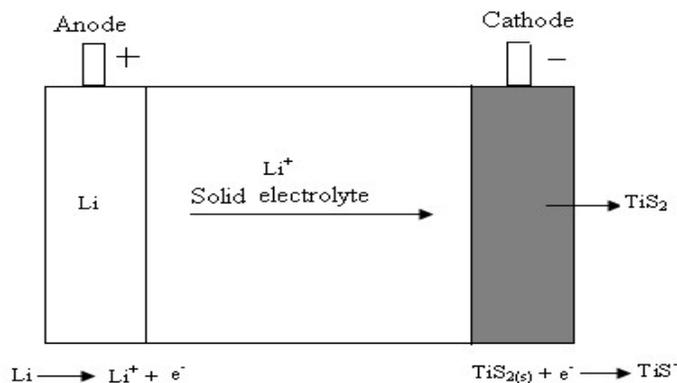
### Disadvantages

- Their initial cost is high.
- Pure hydrogen is costly.

**3.2.4. Write a note on lithium battery. Or Give the importance of Lithium battery. Explain the basic principles of it.**

**Description**

- It consists of a lithium anode and a TiS<sub>2</sub> cathode.
- A solid electrolyte generally a polymer is packed in between the electrodes.
- The electrolyte permits the passage of ions but not electrons.



**Cell reactions at Anode**

Anode (Li) undergoes the oxidation reaction.

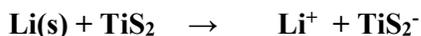


**Cell reactions at At cathode**

Cathode (TiS<sub>2</sub>) undergoes the reduction reaction.



**Overall reaction:**



**Advantages of Li battery (Cell of the Future)**

- Its cell voltage is high, 4.0V
- Since Li is a light weight metal, only 7kg material required to produce 1mole of electrons.
- Since all the constituents of the battery are solids, there is no risk of leakage from the battery.
- This battery can be made in a variety of shapes and sizes.

**Disadvantages of Li battery**

- Li battery is more expensive than other batteries

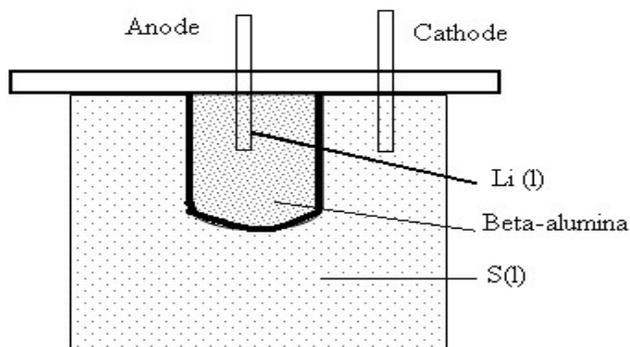
**Uses**

- Button sized batteries are used in calculators, watches, cameras, mobile phones, laptop computers.

## LITHIUM SULPHUR BATTERY

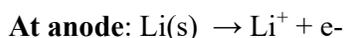
### Description

It consists of a lithium anode and a graphite cathode. Solid electrolyte generally  $\beta$ -Alumina is packed in between the electrodes. Here sulphur is electron acceptor



### Cell reactions At anode

Anode (Li) undergoes the oxidation reaction.

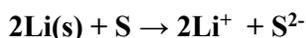


### At cathode

Cathode(S) undergoes the reduction reaction.



### Overall reaction:



The sulphide ions, formed, react with elemental sulphur to form the polysulphide ion.

### Uses

- It is used in electric cars
- Li-S battery has light weight unlike the lead acid battery.
- It possesses a high energy density.

### 3.2.5. Describe the working principle of alkaline storage battery or Nickel-cadmium cell or NiCAD Battery.

The nickel-cadmium battery (commonly abbreviated NiCd or NiCad) is a popular type of rechargeable battery for portable electronics and toys using the metals nickel and cadmium as the active chemicals.

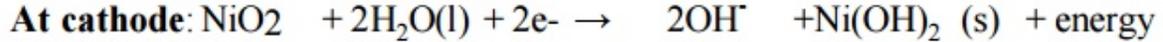
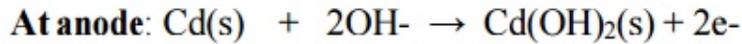
### Description

It consists of a cadmium anode.

A metal grid containing a paste of  $\text{NiO}_2$  acting as a cathode.

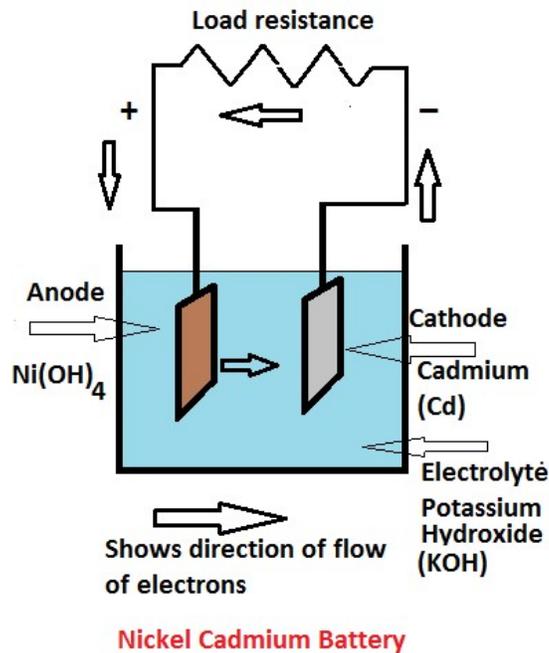
Aqueous KOH is electrolyte.

## Cell reactions



**Applications:** Calculators, digital cameras, pagers, laptops, tape recorders, flash lights, medical devices, electrical vehicles, space applications.

**Advantages:** - Good performance in low temperature long life.



### 3.2.6. What is wind energy? How it is produced? And mention the applications of wind energy.

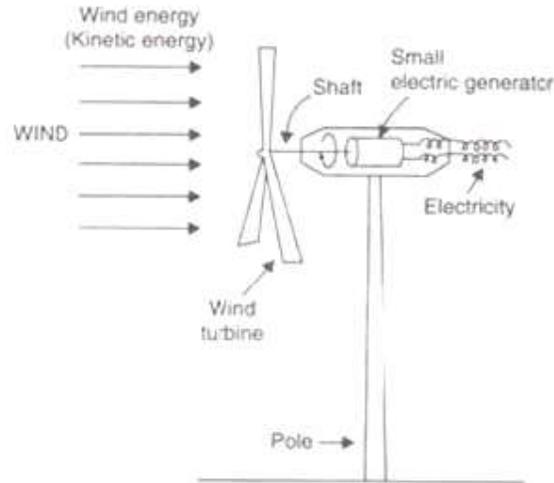
- Wind energy is also a renewable energy. Energy recovered from the force of wind is called as wind energy.
- The strong wind moves the wings of the windmill and this turns the turbines of the electric generator. This mechanical energy is converted to electrical energy.
- The high speed wind has a lot of energy in them as kinetic energy due to their motion. The driving force of the wind is the sun.
- Since the output of a single windmill is very small, many such windmills have to be erected in a carefully chosen place where there is consistent blowing of winds of at least 15km/hr. This is known as wind energy farms which are generally large (2 hectares of land)

#### Methods of Harnessing wind energy

- The wind energy can be harvested mainly two methods such as wind mill and wind form

## 1. Wind mills

The wind energy is harnessed by making use of wind mills. The blades of the wind mill keep on rotating continuously due to the force of the strike of blowing wind. The rotational motion of the blade drives a number of machines like water pump, flour mills and electric generators.



<b>Advantages of Wind energy</b>	<b>Disadvantages of Wind energy</b>
<ul style="list-style-type: none"><li>• It is environment friendly.</li><li>• Renewable source of energy.</li><li>• Only construction expense is involved, but the maintenance (or recurring cost) is less.</li></ul>	<ul style="list-style-type: none"><li>• Initial establishment for construction is high.</li><li>• Also, a lot of open area for wind energy farm is required.</li><li>• Cannot be established everywhere because of requirement of open space and also where winds blow at greater than 15km/hr for most of the year.</li></ul>

## TOPIC- IV - SPECTROSCOPY

### 4.1. PART-A

#### 1. What is meant by monochromatic radiation?

A monochromatic radiation is narrow beam of light which belong to a specific wavelength range of light. It is produced by a special arrangement known as monochromator.

#### 2. Explain the terms “atomic and molecular spectroscopy”?

In “atomic spectroscopy”, the interaction of electromagnetic radiation with atoms which are in the lowest energy state which makes them to shift to the excited state. In “molecular spectroscopy” the interaction of electromagnetic radiation with molecules are in their lower energy state that makes them to shift to the excited higher energy state.

#### 3. Explain electronic transition?

When ultra violet or visible radiation are allowed to pass through a sample under study containing mono atomic particles, very few well defined frequencies are removed as a result of absorption. This is mainly due to the excitation of electrons to higher energy states and when the excited atom reverts back to the ground state, it emits radiation in one step or in several steps in the form of photons of electromagnetic radiation. This can be recorded as spectral lines or very narrow peaks.

#### 4. State Beer- Lambert’s law

When a beam of monochromatic light radiation is passed through a solution of an absorbing substances, the rate of decrease of intensity of transmitted radiation ‘I’ with thickness of the absorbing solution ‘A’ is proportional to the intensity of incident radiation ‘I<sub>0</sub>’ as well as the concentration of the solution ‘C’.

It is mathematically represented as  $\log \frac{I_0}{I} = \epsilon \cdot l \cdot c$  or  $\epsilon = A/c l$

#### 5. What are the disadvantages of Beer-Lambert’s law?

- Beer-Lambert’s law is not obeyed if the radiation used is not monochromatic
- It is applicable only for dilute solutions
- The temperature of the system should not be allowed to a large extent

#### 6. Name the transitions that are responsible for molecular spectra?

The molecular spectra arises from three of transitions, namely rotational transition, Vibrational transition and Electronic transition

#### 7. What is meant by the term ‘absorption spectroscopy’?

An absorption spectroscopy is obtained when a sample selectively absorbs certain frequencies of radiation from a range of frequencies available. The appearance of such a spectrum in the visible region is of a series of dark lines on a coloured background.

#### 8. What is meant by the term ‘emission spectroscopy’?

An emission spectroscopy is obtained when a sample emit a radiation by heating or passing electricity through them.

### 9. Name the important components of UV spectroscopy.

- Light source
- Mono chromators
- Sample cell and reference cell
- Detectors
- Recorder

### 10. What is finger print region? Mention its important uses?

The Vibrational spectral region at 1400-700 cm<sup>-1</sup> gives very rich and intense absorption bands. This region is termed as finger print region. It can be used to detect the presence of functional group and also to identify the compounds.

### 11. What is absorption spectroscopy?

This is the analytical technique based on the phenomenon of light absorption (UV or visible). It is applicable both to qualitative and quantitative analyses

### 12. What are the different electronic transitions that take place on absorption of UV light?

When a molecule absorbs UV radiations the electrons are excited to higher energy levels. In the diagram below the electrons are represented The following electron transitions take place:  $n \rightarrow \pi^*$ ,  $\pi \rightarrow \pi^*$ ,  $\sigma \rightarrow \sigma^*$ ,  $n \rightarrow \sigma^*$ . These electronic transitions are responsible for UV absorption of a molecule

### 13. What are the principles of IR?

The atoms in a molecule bond are in a state of constant vibration and rotation. They may be compared with two balls (atoms) joined by spring (bond). On absorption of IR the bond may stretch, bend etc., as shown below. So stretching and bonding of bonds are responsible for IR absorption

### 14. What are the principles of atomic absorption spectroscopy?

Atomic absorption spectroscopy (AAS) is based upon the principle that free atoms in the ground state can absorb light of a certain wavelength. Absorption for each element is specific, no other elements absorb this wavelength.

### 15. Why is flame photometry not suitable for many elements?

Flame photometry is good only for elements that are easily excited and do not require very high temperatures (Na, K, Li, Ca are the most widely determined atoms by this technique).

### 16. Write the relationship between absorbance and transmittance.

**Absorbance (A):** It is reciprocal of Transmittance

$$\text{Absorbance (A)} = \text{Optical density (D)} = \log \frac{1}{T} \text{ or } \log \frac{I_0}{I}$$

**Transmittance (T):** The fraction of incident light transmitted is known as Transmittance.

## 17. Differentiate UV Spectroscopy and IR Spectroscopy.

UV-VIS spectroscopy	IR-spectroscopy
Electronic spectrum is due to the electronic transitions in atoms and molecules.	Vibrational spectrum is due to the vibrational motions of atoms and molecules.
It arises by the interaction of EMR with matter	It arises by the interaction of EMR with matter.
EMR in the UV-Vis region is responsible for electronic spectrum	EMR in the IR region is responsible for electronic spectrum

### 4.2 PART-B

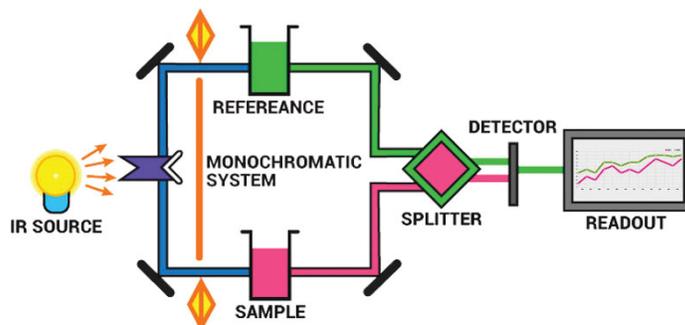
4.2.1. Explain the principle of IR spectroscopy. Give the block diagram of IR Spectrometer and explain the functions of various components and applications.

#### Principle

- The range in the electromagnetic spectrum extending from 12500 to 50  $\text{cm}^{-1}$
- IR spectra is produced by the absorption of energy by a molecule in the infrared region
- The essential requirement for a molecule to produce IR spectrum is that the dipole moment of the molecule must change during vibration. Thus Vibrational spectrum is given by hetero nuclear diatomic molecules.
- Polyatomic molecules with and without dipole moment also produces IR spectrum. Homo nuclear diatomic molecules such as  $\text{O}_2$ ,  $\text{N}_2$ ,  $\text{H}_2$  etc. will not produce IR spectrum, since they have zero dipole moment. But molecules like  $\text{HCl}$ ,  $\text{HBr}$ ,  $\text{NO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{NH}_3$ ,  $\text{CH}_3\text{Cl}$  and  $\text{SO}_2$  can produce IR spectra and they are IR active molecules.
- In the case of polyatomic molecules without dipole moment, the exciting radiations can induce an oscillating dipole moment. Hence they are also IR active.

#### Instrumentation of Infrared (IR) Spectroscopy

The main parts of IR spectrometer are as follows:



1. Radiation source
2. Sample cells and sampling of substances
3. Monochromators
4. Detectors
5. Recorder

## **INSTRUMENTATION**

1. **Radiations source** - Nichrome wire, Nernst glower filament containing oxides of Zr, Th, Ce
2. **Monochromator** - It allows the light of the required wave length to pass through, but absorbs the light of other wavelengths.
3. **Cells (sample cell and reference cell)**-The cells, containing samples or reference for analysis, should fulfil the following conditions.
4. **Detectors**-The detector converts the radiation, falling on which, into current. The current is directly proportional to the concentration of the solution.
5. **Recording system**-The signal from the detector is finally received by the recording system. The recording is done by recorder pen.

### **Working of IR spectrophotometer**

- The radiation from the source is allowed to pass through the Monochromator unit. The Monochromator allows a narrow range of wavelength to pass through an exit slit. The beam of radiation coming out of the Monochromator is split into two equal beams.
- One-half of the beams (the sample beam) is directed to pass through a transparent cell containing a solution of the compound to be analysed.
- Another half (the reference beam) is directed to pass through an identical cell that contains only the solvent. The instrument is designed in such a way that it can compare the intensities of the two beams.
- Graph, which is a plot of wave length Vs absorbance of the light. This graph is known as an absorption spectrum.

### **Applications of Infrared (IR) Spectroscopy**

It has been of great significance to scientific researchers in many fields such as:

- Protein characterization
- Nanoscale semiconductor analysis and
- Space exploration.
- Analysis of gaseous, liquid or solid samples
- Identification of compounds

- Quantitative analysis
- Information regarding functional groups of molecules and constitution of molecules can be deduced from IR spectrum
- To know about interaction among molecules

#### 4.2.2. Explain the principle, instrumentation and working of UV- visible spectrophotometry.

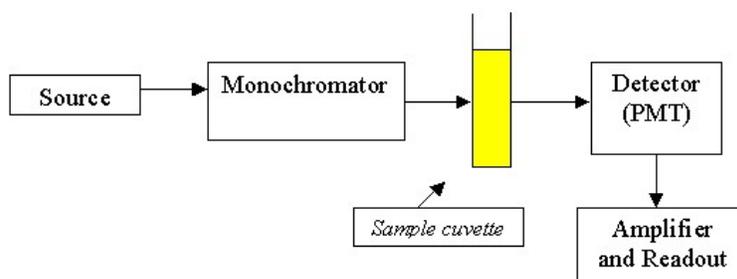
##### Principle

This transition occurs due to the absorption of UV (wavelength 100-400 nm) or visible (wave length 400-750 nm) region of the electronic spectrum by a molecule (or) ion.

##### INSTRUMENTATION

1. **Radiations source** - Hydrogen (or) Deuterium lamps.
2. **Monochromator** - It allows the light of the required wave length to pass through, but absorbs the light of other wavelengths.
3. **Cells (sample cell and reference cell)** - The cells, containing samples or reference for analysis, should fulfil the following conditions.
4. **Detectors** - The detector converts the radiation, falling on which, into current. The current is directly proportional to the concentration of the solution.
5. **Recording system** - The signal from the detector is finally received by the recording system. The recording is done by recorder pen.

##### Instrumentation of UV Spectroscopy



##### Working of visible and UV spectrophotometer

- The radiation from the source is allowed to pass through the Monochromator unit. The Monochromator allows a narrow range of wavelength to pass through an exit slit. The beam of radiation coming out of the Monochromator is split into two equal beams.
- One-half of the beams (the sample beam) is directed to pass through a transparent cell containing a solution of the compound to be analysed.
- Another half (the reference beam) is directed to pass through an identical cell that contains only the solvent. The instrument is designed in such a way that it can compare the intensities of the two beams.

- Graph, which is a plot of wave length Vs absorbance of the light. This graph is known as an absorption spectrum.

### **Applications of UV spectrophotometer**

#### **1. Detection of Impurities**

- It is one of the best methods for determination of impurities in organic molecules.
- Additional peaks can be observed due to impurities in the sample and it can be compared with that of standard raw material.
- By also measuring the absorbance at specific wavelength, the impurities can be detected.

#### **2. Structure elucidation of organic compounds**

- It is useful in the structure elucidation of organic molecules, such as in detecting the presence or absence of unsaturation, the presence of hetero atoms.
- UV absorption spectroscopy can be used for the quantitative determination of compounds that absorb UV radiation.
- UV absorption spectroscopy can characterize those types of compounds which absorbs UV radiation thus used in qualitative determination of compounds. Identification is done by comparing the absorption spectrum with the spectra of known compounds.
- This technique is used to detect the presence or absence of functional group in the compound. Absence of a band at particular wavelength regarded as an evidence for absence of particular group.
- Kinetics of reaction can also be studied using UV spectroscopy. The UV radiation is passed through the reaction cell and the absorbance changes can be observed.
- Many drugs are either in the form of raw material or in the form of formulation. They can be assayed by making a suitable solution of the drug in a solvent and measuring the absorbance at specific wavelength.
- Molecular weights of compounds can be measured spectrophotometrically by preparing the suitable derivatives of these compounds.
- UV spectrophotometer may be used as a detector for HPLC.

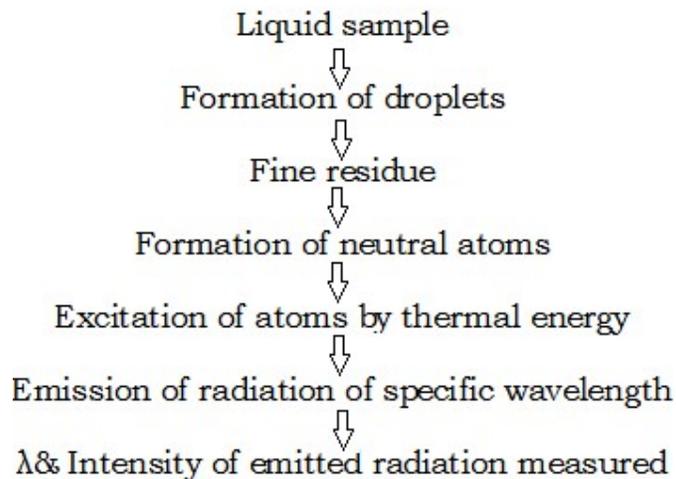
#### **4.2.3. Discuss the principle, construction and working mechanism of flame photometer spectroscopy.**

##### **Flame Photometry Principle, Instrumentation, Application**

**Flame Photometry** is also called as flame emission spectroscopy. Flame Photometry is branch of atomic spectroscopy. It is used to detected certain metal ions like sodium, potassium, magenisum etc.

## PRINCIPLE :-

Sample is sprayed into a flame and it converted to droplets. Due to the thermal energy of the flame the solvent in the droplets evaporate, leaving behind fine residue, which are converted to neutral atoms. This neutral atoms are get energy form thermal energy and go excited state but they are unstable at excited state so they are return to ground state with emission of specific wave length radiation. The wavelength of the radiation emitted is characteristic of the elements and is used to identify the elements (Qualitative Analysis). The intensity of the radiation emitted depends upon the concentration of the element analyzed (Quantitative Analysis).



The wavelength of the radiation emitted is given by the following equation :-

$$\lambda = hc / E_2 - E_1$$

Where,

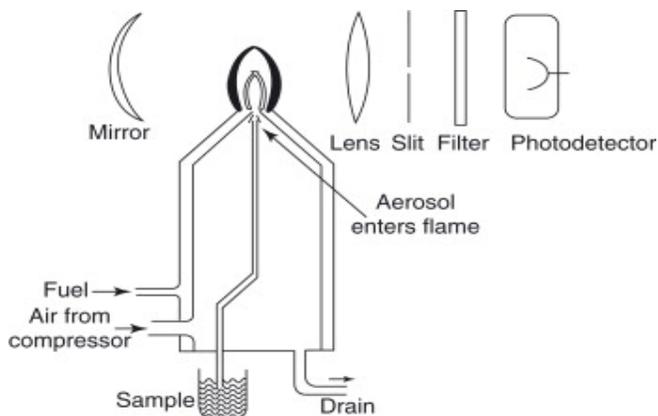
$h$  = Planks constant,  $c$  = Velocity of light

$E_2, E_1$  = energy levels of excited and ground state respectively

## INSTRUMENTATION OF A FLAME PHOTOMETER :-

### *COMPONENTS OF A FLAME PHOTOMETER*

1. Burner (With fuel and oxidant)
2. Filter/Monochromator
3. Detector
4. Read out device



### 1. BURNER :-

There are different burners available which are used to spray the sample solution into fine droplet mix with fuel and oxidant so that a homogenous flame of stable intensity is obtained. The most common ones are mecker burner, total consumption burner and laminar flow burner.

#### TOTAL CONSUMPTION BURNER

- Due to the high pressure of fuel and oxidant the sample solution is aspirated through capillary and burnt at the tip of burner.
- Hydrogen and oxygen are generally employed as fuel and oxidant.
- The advantage over other is the entire consumption of sample, Its disadvantage is the production of non uniform flame and turbulent.

#### PREMIX BURNER

- In this burner the sample, fuel oxidant are thoroughly mixed before aspiration and reaching to flame
- The main advantage of is the uniformity of flame produced.
- The main disadvantage is the heavy loss of mix up to 95%.

### 2. FILTER / MONO CHROMATOR:-

In flame photometry the wavelength as well as intensity of the radiation emitted by the elements has to be monitored. Hence a filter or mono chromator is to be used. A simple flame photometer contains a filter wheel and when a particular element has to be analyzed the specific filter is selected.

### 3. DETECTOR:-

The radiation emitted by the elements is mostly in the visible region. Hence conventional detectors like photo voltaic cell or photo tubes can be used. In a flame spectrophotometer, photomultiplier tube is used as detector.

#### 4. READ OUT DEVICE:-

The signal from the detector is shown as a response in the digital read out device. The readings are displayed in an arbitrary scale (% Flame Intensity).

#### APPLICATION :-

- To estimate sodium, potassium, calcium, lithium etc. level in sample of serum, urine, CSF and other body fluids.
- Flame photometry is useful for the determination of alkali and alkaline earth metals.
- Used in determination of lead in petrol.
- Used in the study of equilibrium constants involving in ion exchange resins.
- Used in determination of calcium and magnesium in cement.

#### 4.2.4. Explain the principle of atomic absorption spectroscopy. Give the block diagram of atomic absorption spectra with uses.

##### Atomic absorption spectroscopy

Atomic absorption is an analytical technique utilizing the principle of spectroscopy for the quantitative determination of chemical elements.

##### **Principle of Atomic absorption spectroscopy**

- Atomic absorption spectroscopy utilizes the principle that free electrons generated in an atomizer absorb radiation of different wavelengths.
- The free electrons absorb UV or visible light, causing the electrons to transfer to higher energy orbits.
- During this process, the absorption spectrum is released, which is detected by the photodetectors.
- The absorption spectrum formed allows the quantification of free electrons in the gaseous state of the matter.
- The amount of photon (radiation) absorbed results in an absorption spectrum which can then be measured in terms of absorbance.
- The absorbance of a sample is dependent on the concentration of molecules in the sample.

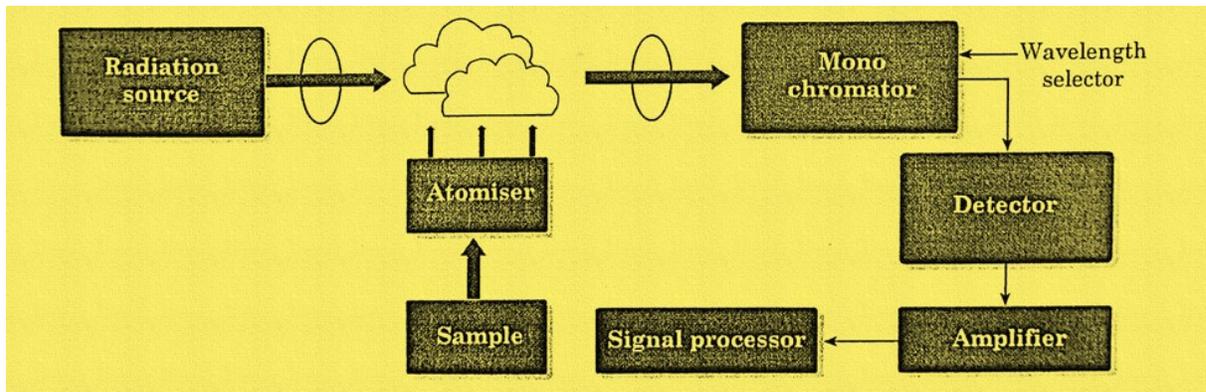
##### **Steps of Atomic absorption spectroscopy**

- The liquid sample is mixed with a particular volume of spirit which is added to a flask which is then vaporized into a gas by a fuel-rich acetylene-nitrous oxide flame.
- A lamp is set with the necessary wavelength as a light source.
- The gas formed from the liquid sample is then passed through a detector that detects the absorbance of the atoms in the gas.

- A similar process is performed for the detection of absorbance of solvent blank and standard solution.
- A graph is plotted for the absorbance against the concentration of the molecules in the sample.

### Uses of Atomic absorption spectroscopy

- Atomic absorption spectroscopy can be used for the quantitative and qualitative determination of metallic elements in biological systems.
- This also helps in the detection of metals as an impurity in alloys and other mixtures.
- Atomic absorption spectroscopy has been utilized for the purification of environmental samples like water and soil.
- Detection of metals in pharmaceutical products and oil products can also be done by this method.



## TOPIC - V - ENGINEERING MATERIAL

### 5.1. PART- A

#### **1. What are abrasives?**

Abrasives are hard substances used for Grinding, cutting, Shaping, drilling, polishing and sharpening operations. Ex: Diamond, Talc

#### **2. How abrasives are classified? Give example for each.**

Abrasives are classified into two types. 1. Natural abrasive Ex: Talc, Diamond. 2. Synthetic abrasive Ex: SiC and B<sub>4</sub>C.

#### **3. What are natural abrasives and synthetic abrasives?**

Natural abrasives: Abrasives are obtained from nature is called natural abrasives. Ex: Talc, Diamond, Topaz.

Synthetic abrasives: Abrasives are prepared from man - made and obtained some chemical reactions. Ex: silicon carbide (SiC)

#### **4. What are Nano materials?**

Nano materials are the materials having components with size less than 100nm atleast in one dimension.

#### **5. What is moh's scale of hardness?**

It is a scale in which common abrasives are arranged in their increasing order of hardness. In this scale, lowest: talc (hardness number is 1) highest: diamond (hardness number is 10)

#### **6. What is hardness of an abrasive? What are its units?**

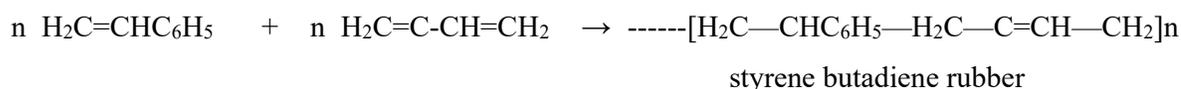
Hardness is one of the most important properties of an abrasive. It is the ability of an abrasive to grind or scratch away other materials. The harder the abrasive, quicker will be its abrading action. Hardness of the abrasive is measured on Moh's scale or Vicker's scale.

#### **7. Mention some important applications of abrasives.**

- To clean the surface prior to coating, abrasive powders are used.
- To prepare smooth wood, metal and plastic surfaces, abrasive paper are used.
- To remove the scales from iron surfaces, grinding wheels are used.

#### **8. What is Co- polymerization?**

Different monomers are combine to form polymer without elimination of small molecules, is called Co-polymerization. Example: SBR



#### **9. What are soft abrasives and hard abrasives? Give examples.**

Abrasives having their hardness 1 – 6 in moh's scale are known as soft abrasives.

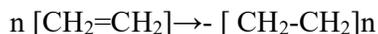
Example: Calcite, Gypsum.

Hard abrasives: Abrasives having their hardness 7 – 10 in moh's scale are known as hard abrasives.

Example: Quartz, Corundum, Emery, Garnet and Diamond.

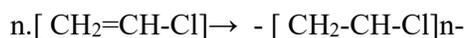
### 10. Define monomer.

Monomer is micro molecule, single unit combines to form polymer. E.g. ethylene combines to form polyethylene.



### 11. What are polymers?

A polymer is macro molecules of high molecular weight and is formed by combination of monomers. e.g. polyvinylchloride formed by combination of vinyl chloride.



### 12. What is polymerization? Give its types.

The process of converting monomer into polymer is called polymerization.

- Addition polymerization
- Condensation polymerization

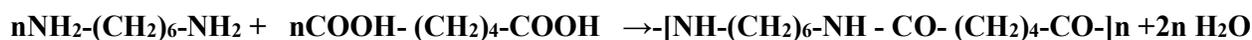
### 13. What are addition polymerizations?

Monomers combine to form polymer without elimination of small molecules like water, acids are called addition polymerization. e.g Polyethylene



### 14. What are condensation polymerizations?

Different monomers are combining to form polymer with elimination of small molecules like water, acids are called condensation polymerization. E.g Nylon



### 15. What is degree of polymerization?

The number of repeating units present in the polymer is known as degree of polymerization.

$$\text{D.P} = \frac{\text{Molecular weight of polymer}}{\text{Molecular weight of monomer}}$$

### 16. Define functionality. Give its types.

The number of bonding sites or reactive sites or functional group present in the polymer is known as functionality. 3 types: Monofunctional, Bifunctional, Trifunctional.

### 17. Difference between Monomer and polymer.

S.N	Monomer	Polymer
1	Monomers are the single units, which collect together to give a polymer	The collection of repetitive units of monomers gives rise to a polymer.
2	The molecular weight of the monomer is lower.	The molecular weight of the polymer is higher.
3	For example, amino acid, ethylene, and vinyl chloride.	For Example, Teflon, polyethylene, and nylon.

**18. What are plastics? Mention the classification.**

- Plastics are high molecular weight organic materials which can be molded into any desired shape by the application of heat and pressure in the presence of a catalyst.
- Classification of plastics:
- The plastic is usually classified depending on the type of resin used for its manufacture. i) Thermoplastic resins and ii) Thermosetting resins.

**19. What is meant by rubber? Mention the classification?**

- Rubbers (or) elastomers are non-crystalline high polymers, which have elastic properties and other – like properties.
- Types of rubber: Natural rubber and Synthetic rubber (elastomers).

**20. Distinguish thermoplastic and thermosetting plastic with suitable example.**

S.N	Thermoplastic	Thermosetting
1	Thermoplastic can be synthesized by the process called addition polymerization.	Thermosetting plastics are synthesized by condensation polymerization.
2	They can be easily soften on heating and hardened on cooling.	It cannot be softened on heating.
3	examples of thermoplastics : <i>Polystyrene, Teflon, Acrylic, Nylon</i>	Examples of thermosetting Vulcanized rubber, Bakelite, Polyurethane, Epoxy resin, Vinyl ester resin

**21. What are nanomaterials?**

- Nanomaterials are the materials having components whose size is less than 100 nm at least in one dimension.
- List any four nano materials. 1. Carbon nanotubes 2. Nanowire 3. pendrive 4. Qauntum dots.

**22. What are Nanoparticles?**

- A nanoparticle is a microscopic particle with at least 1- 100 nm.
- Nanoparticle is of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures.
- They exhibit better physical, chemical and mechanical properties than bulk.
- Examples : Gold and Iron nanoparticles, ZnO, CaO, CdS.

## **5.2. PART- B**

### **5.2.1. Explain the preparation, properties and types of SiC.**

#### **Synthetic Abrasives. Silicon Carbide / Carborundum / Crystolon (SiC)**

##### **Preparation**

Raw materials are

- i. Petroleum Coke (source of carbon)
- ii. Sand (source of Si)
- iii. Saw Dust ( To provide hardness)

All raw materials are sized, dried and mixed along with old charge and fed into the Acheson furnace with little amount of NaCl (flux)

##### **Properties**

- M.Pt. is 2700°C
- Mohs scale hardness is 9.3
- Chemically Inert
- High Thermal Stability
- Brittle hence strength is less

##### **Uses**

- Cutting tools
- Grinding of cast iron, brass, bronze , porcelain marble
- Polishing leather, lenses (Abrasive paper and Cloth)
- Refractory in furnace

##### **Advantages of Synthetic Abrasives**

- Unlike natural abrasive synthetic abrasives possess uniform chemical composition
- Due to uniformity in the composition the hardness at various points also remains uniform.

### **5.2.2. What are abrasives? How they are classified? Name any two natural and synthetic abrasive.**

#### **Application of abrasives**

##### **Definition**

Abrasive is a substance used to wear down ( cut / polish / grind /sharp) the surface of the materials with which it is in contact.

Abrasion is the ability of a substance to wear or tear the surface of other substance

##### **Natural Abrasives**

- Corundum ( $Al_2O_3$ ) [Alundum]
- Diamond (C)
- Emery
- Garnets

- Quartz (SiO<sub>2</sub>)

### **Synthetic Abrasives**

- Silicon Carbide / Carborundum / Crystolon (SiC)
- Boron Carbide / Norbide (B<sub>4</sub>C)

### **Important General Applications of Abrasives.**

- In grinding wheels (Bonded abrasives) abrasives are used to grind and polish the surface of metals and composites, sharpen tools like knife, saw tooth etc.,
- In the form of paper / cloth (abrasive coated on paper / cloth with the help of glue) abrasives are used for cleaning and polishing soft and precious metals (Au, Ag, W etc.,). They are also used to shine leather, clean lens, windscreen etc.,
- In few places abrasives are used in the form of loose powder-for polishing hard metal and wood
- Cleaning products also contain abrasives suspended in a paste or cream.
- For example tooth paste contains calcium carbonate / silica /mica as a "polishing agent" to remove plaque and other matter from teeth as the hardness of the abrasive used is less than that of tooth enamel but more than that of the contaminating agent(plaque material).
- Abrasives may also be used to prepare surfaces for application of paint and varnish.
- Pumice stone (abrasive) is used to remove dead cells from skin (usually to keep the feet crack free).
- Soft abrasives are used in cosmetic industries in various products to rejuvenate skin and maintain a smooth and silky texture.

### **5.2.3. Explain the preparation, properties of natural abrasives.**

#### **Natural Abrasives**

Corundum (Al<sub>2</sub>O<sub>3</sub>) [Alundum]

#### **Properties :**

- Crystalline
- Very Hard
- Moh's scale-9
- Brown to grey in colour.

#### **Corundum is used in :**

- In grinding wheels
- To grind glass/lens/metals,
- Ruby lasers
- Diamond (C)

#### **Diamond exist in three major forms**

- Diamond (gem grade)

- Borts – These are diamonds that are off colour or faulty
- Carbonado – These are black diamonds mined from Brazil. They have good hardness, but due to lack luster, do not find application as jewelry.
- They are commonly used as abrasives.

Abrasive grade diamond has the following properties

- Crystalline
- Chemically inactive
- Moh's scale-10

#### Uses

- In bits of drilling points
- Saw teeth for cutting rocks
- In grinding wheels
- In engraving tools

#### Emery

##### Composition

Alumina (crystalline) 50 - 75% Magnetite 20 - 40% Other minerals 12 %

##### Properties

- Dark grey to black
- Hardness depends upon alumina content
- Moh's scale - 8

#### Uses

- In emery paper and cloth used for polishing.
- In bits of cutting and drilling tools Garnets

##### Properties

- Tri silicates of alumina/ magnesia/ ferrous oxide.
- Common garnet- Calcium aluminium iron silicate
- Moh's scale 6 -7.5

#### Uses

- To paper/cloth to polish wood /metals,
- As bearing pivots in watches
- In glass grinding

#### Quartz (SiO<sub>2</sub>)

##### Properties

- SiO<sub>2</sub> (pure crystalline).
- Moh's scale – 7.

- Hydrated form of  $\text{SiO}_2$  is called Flint.

#### Uses

- Impure grey quartz used in sand paper.
- As granules in grinding.
- Machines used to grind flour, pigments & ores.

#### 5.2.4. Explain the applications of nano material in various fields.

##### Sunscreens and cosmetics

- Nanosized titanium dioxide and zinc-oxide are used in sunscreens. These nanomaterials can absorb and reflect UV rays but remain transparent in visible light
- In some lip sticks, nanosized iron oxide is present as a pigment

##### Coatings and surfaces:

- Nanoparticles are used for scratch-resistant hard coatings as intermediate layers between the hard outer layer and the substrate. Such intermediate layers give excellent bonding and thermal properties to improve adhesion
- Titanium dioxide is used for coating self-cleaning window

##### Clays

- It contains naturally occurring nanoparticles essential for construction materials
- The composites based on clay particles have plastics and nano sized flakes are also used in various applications such as in car bumpers

##### Tougher and harder cutting tools:

- The tougher and harder cutting tools are finding their applications in the drills used to bore holes in circuit boards
- The nano-crystalline materials like tungsten carbide, tantalum carbide, and titanium carbide are used for making cutting tools. The cutting tools made up of these materials are more wear and erosion-resistant and long lasting than conventional tools.

##### Paints

- The performance of paints can be improved by incorporating nanoparticles, thinner paint coatings used on aircraft would reduce their weight

##### Batteries

- There is great demand for light weight, high energy density batteries used in portable electronic equipments such as mobile phones, laptop, computers, and sensors
- A Nickel-metal hydride battery requires less frequent recharging and last longer.

## Catalysis

- As nanoparticles have a large surface area, and hence provide excellent catalytic activity. Rhodium hydrosols used as an effective catalyst for the hydrogenation of olefins dissolved in organic phase
- Metal nanoparticles can be synthesized in solution in the presence of a surfactant to form ordered mono disperse films of catalyst on the provided surface. This film is uniform in size and chemical structure leads to high catalytic activity

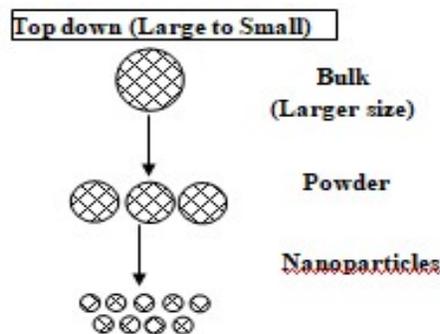
## Lubricants

- Nanospheres made up of inorganic materials can be used as lubricants by acting as nanosized 'ball bearings'.
- Nanoparticles reduces friction between metal surfaces particularly at high loads.

### 5.2.5. Explain the synthesis of nano particles by top down method.

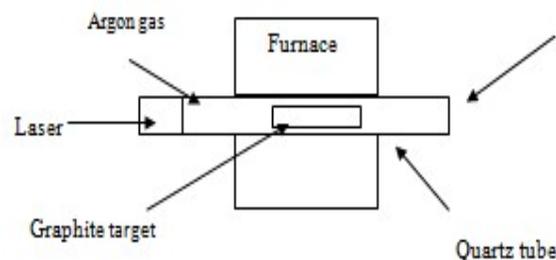
#### i) Top down

- Top down approach involves the breaking down **bulk material into nano sized particles**.
- This method is carried out by the following process.
  1. Laser ablation
  2. Chemical vapour deposition
  3. Electro deposition



#### 1. Laser Ablation Method

The following figure illustrates the apparatus for making carbon nanotubes by laser evaporation. Nanotubes of 10 to 20 nm in diameter and 100µm long can be made by this method.



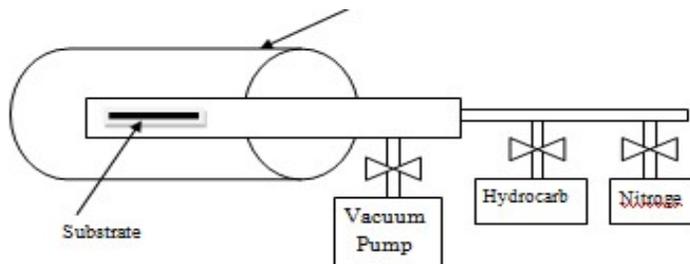
A quartz tube containing argon gas and a graphite target are heated to 1200<sup>0</sup>C. The tube contained, but somewhat outside the furnace, a water cooled copper collector. The graphite target contains small amounts of Cobalt and Nickel that acts as catalytic nucleation sites for the formation of the tubes.

## 2. Chemical Vapour Deposition Method

It is process of chemically reacting a volatile compound of a material with other gases to produce a non-volatile solid that deposit automatically on a place of substrate. CVD reaction requires activation energy to proceed by many methods.

- Plasma enhanced CVD (reaction proceed by plasma)
- Thermal CVD (reaction proceed by Heat energy)
- Laser CVD (reaction proceed by Laser)

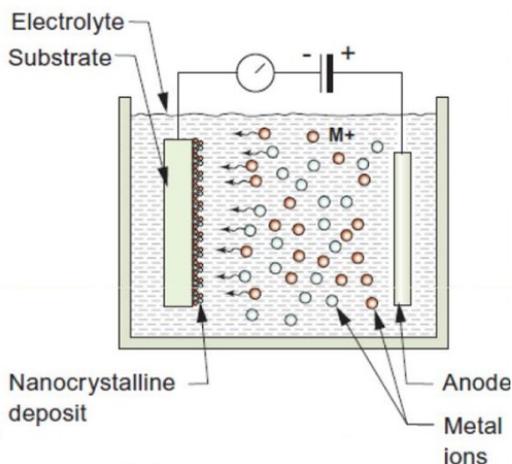
The chemical vapour deposition method involves decomposing a hydrocarbon gas such as methane (CH<sub>4</sub>) at 1100<sup>0</sup>C. As the gas decomposes, carbon atoms are produced that then condense on a cooler substrate that may contain catalyst, iron. This method produce tubes with open ends. This procedure allows continuous fabrication.



**Fig: Chemical vapour deposition methods**

## 3. Electrodeposition Method

- Nano structural materials can be prepared by this method.
- A sheet of nano structured copper can be fabricated by putting two electrodes in an electrolyte of copper sulphate and applying a voltage between two electrodes. A layer of nanostructured copper will be deposited on the negative titanium electrode. A sheet of copper with 2mm thick can be made by this process.



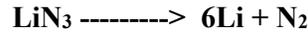
## 5.2.6. Explain the synthesis of nano particles by Bottom Up method.

### 1. Thermolysis

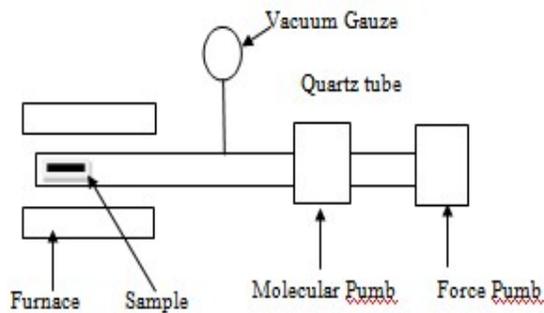
- Nanoparticles can be made by decomposing solids or liquids at high temperatures having metal cations, or molecular anions or metal organic compounds. This is called thermolysis.

#### Examples

- Li particles can be made by decomposing lithium azide,  $\text{LiN}_3$ . The material is placed in a quartz tube in vacuum and heated to  $400^\circ\text{C}$  as shown below



- At about  $370^\circ\text{C}$  the  $\text{LiN}_3$  decomposes and releases  $\text{N}_2$  gas. The remaining Li atoms to form a colloidal metal nanoparticles with sizes  $< 5 \text{ nm}$ .
- A more complex example is formation of gold nanoparticles from a thiolate complex,  $[\text{C}_{14}\text{H}_{29}(\text{CH}_3)_3\text{N}][\text{Au}(\text{SC}_{12}\text{H}_{25})_2]$  at  $180^\circ\text{C}$  for 5 hours under  $\text{N}_2$  atmosphere. This produces gold nanoparticles of average size  $26 \text{ nm}$  which are directly passivated by alkyl groups derived from gold nanoparticles.



#### a). Solvothermal Synthesis

- In solvothermal synthesis, solvents are used for heating at higher temperature than their respective boiling points in a sealed vessel or autoclave with the autogeneous pressure for higher atmospheric pressure raising the boiling point of solvent.
- For example Cadmium stearate and Sellenium powder mixed in the solvent like toluene and a reducing agent tetralin are used to prepare the nanocrystals of CdSe.

#### b). Hydrothermal Synthesis

- In this method to synthesis the nanoparticle by chemical reaction in aqueous solution heated in a sealed vessel. Alkaline solution is used to increase the solubility. For example  $\text{BaTiO}_3$  nanoparticles are produced at below  $400^\circ\text{C}$ .



#### 4. Precipitation Methods

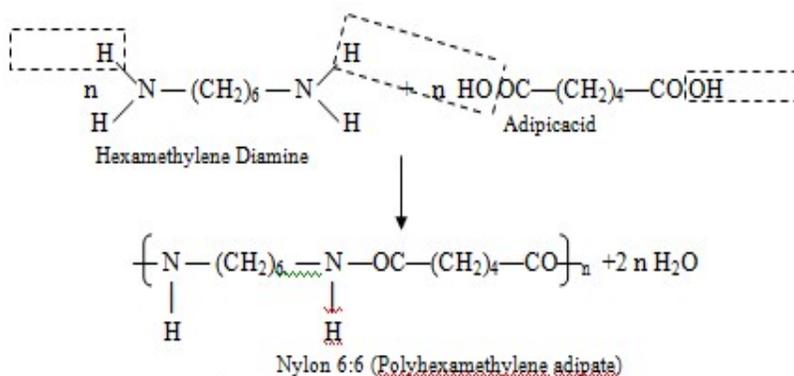
- 10 gm of sodium hexa metaphosphate was dissolved in 80 ml of distilled water in 250 ml beaker with constant stirring. Then 10ml of 1M sodium sulphate solution was added followed by 10ml of 1M barium nitrate solution. The resulting g solution was stirred for 1 hour, Precipitation occurs slowly.
- The resulting precipitate was then centrifuged, washed with distilled water and vacuum dried. But in the absence of stabilizing agent bulk barium sulphate precipitate is obtained.



#### 5.2.7. How is Nylon 6,6 and PVC(Poly Vinyl Chloride) prepared? State its properties and uses.

##### Nylon 6, 6

Hexamethylene Diamine and adipic acid condense to form a polymer Nylon6,6.



##### Properties:

- Nylons are insoluble in common organic solvents but soluble in phenol and formic acid.
- They possess high thermal stability and good abrasion resistance.
- They are translucent, whitest, horny and high melting polymers.
- They possess low coefficient of friction.

##### Uses:

- Nylons are used for making filaments for ropes, bristles for tooth-brushes and films, etc.
- Nylon-6 and Nylon -11 are mainly used for moulding purpose for gears, bearings, etc.
- Nylon 6, 6 is used for fibers, which is used making socks, dresses, carpets, etc.

##### Polyvinyl Chloride

Polyvinyl chloride is obtained by heating water emulsion of vinyl chloride in presence of benzoyl peroxide (or) hydrogen peroxide under pressure.



**Uses:** It is used to make a wide range of things including pipes, plastic windows, electrical cable insulation, sheet materials for flooring and other uses, footwear, clothing, table cover and rain coat.

### 5.2.8. Explain the polymerization process.

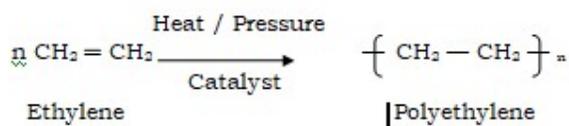
Polymerization can be classified into following three types.

1. Addition polymerization
2. Condensation polymerization (or) Stepwise polymerization
3. Co-polymerization

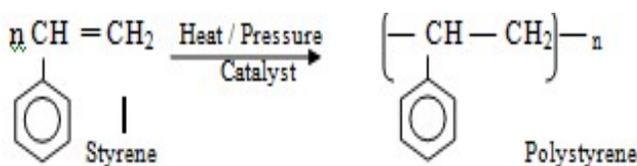
#### 1. Addition Polymerization.

- Addition polymerization is a reaction that yields a polymer, which is an exact multiple of the original monomeric molecule. Such a monomeric molecule usually contains one or more double bonds.
- During the addition polymerization reaction the double bonds break and become a single bond unit with functional sites on either side of the monomer unit.
- Many such units attach to form a polymer molecule. In this addition polymerization, there is no elimination of any molecule. Some of the examples of addition polymerization are the formation of polyethene, poly styrene, PVC etc...

#### Example: 1



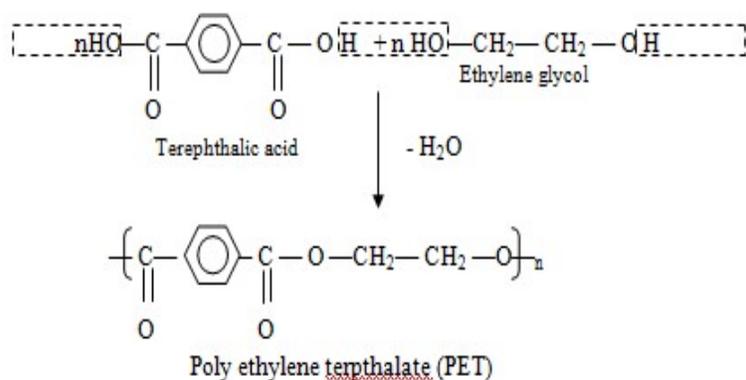
#### Example: 2 Polystyrene is obtained by the polymerization of styrene.



#### 2. Condensation polymerization (or) Stepwise polymerization:

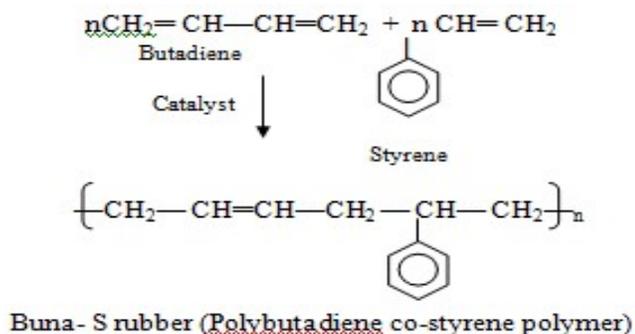
- Condensation polymerization is a reaction between the simple polar groups containing monomers, which yield a polymer with the elimination of a small molecule like H<sub>2</sub>O, HCl etc. Some of the examples of condensation polymerization are the formation of Polyester, Nylon, Nylon6/6, Novolac etc,

- **Example:1** It is prepared by the condensation of terephthalic acid and ethylene glycol.



### 3. Copolymerization:

- It is the joint polymerization in which two or more different monomers combine to give a polymer. High molecular weight polymers obtained by copolymerization. Copolymerization is mainly carried out to vary the properties of polymers such as hardness, strength, rigidity etc...
- Some of the examples of Copolymerization are the formation of polybutadiene co-styrene polymer (Buna -S- Rubber), polyacrylonitrile-co-vinyl chloride polymer etc.



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