UNIT 5

SENSORS, WATER TREATMENT AND E-WASTE MANAGEMENT

SENSORS

Introduction to Sensors

- **A sensor is a device that receives and responds to a signal. This signal must be some type of energy, heat, light, motion, electrical, or chemical reaction.**
- Once a sensor detects one or more of these signals (an input), it converts it into an analog or digital output signal.
- A few examples of sensors are: Conductometric sensors, optical sensor, electrochemical sensors, gas sensors etc.
- **Advantages of sensors**:
  - ➢ improved sensitivity during data capture
  - ➢ Continuous, real-time analysis.
- **Application of sensors**
  - ➢ Sensors are pervasive. They are embedded in our bodies, automobiles, airplanes, cellular telephones, radios, chemical plants, industrial plants and countless other applications.
  - ➢ Without the use of sensors, there would be no automation

Conductometric sensors

A conductometric sensor is a type of electrochemical sensor that measures changes in the electrical conductivity of a solution, typically an electrolyte, in response to the presence of a specific analyte.

The basic principle behind conductometric sensors is the alteration of ion mobility or the concentration of ions in the solution due to a chemical or physical change induced by the target analyte.

Conductivity cell acts as the sensor in conductometric titrations. Conductivity cell is a cell consisting of two platinum foil electrodes which is used to measure the conductivity of solution.

Construction working and application of Conductometric sensors in estimation of Acid mixtures using standard NaOH solution

Principle:

- Titration in which conductivity measurements are made use of in determining the end point of a reaction is called conductometric titration.

- Here a sharp change in the conductivity is noticed at the end point.
- Conductance of any solution depends on number of ions and mobility of ions. The underlying principle in such a titration is the substitution of an ion of one mobility by an ion of another mobility which results in change in conductivity.
- Consider the titration of mixture of Hydrochloric acid and Acetic acid with sodium hydroxide. In a conductometric titration, the titrant is added from the burette to a known volume of the solution 9 acid mixture) to be titrated and the conductivities are measured during the course of the titration.
- A graph of conductivity against the volume of titrant is plotted when two or more straight line curves are obtained. The point of intersection of two straight lines gives the equivalencepoint.
- At the start of the titration, the acid solution has a high conductivity due to highly mobile H^+. When NaOH is added to acid mixture, the highly mobile H^+ are replaced by less mobile Na^+. This will result in a rapid decrease in conductivity. Hence the conductivity decreases. Further addition of alkali will cause a gradual increase in conductivity till neutralisation of acetic acid is complete. This slow increase in conductivity is due to sodium acetate. Finally there is conductivity rises sharply due to highly mobile OH^-.

Application of conductometric sensor

Gas Sensing: Conductometric gas sensors are used to detect gases based on the changes in conductivity caused by the gas interacting with the sensor's surface.

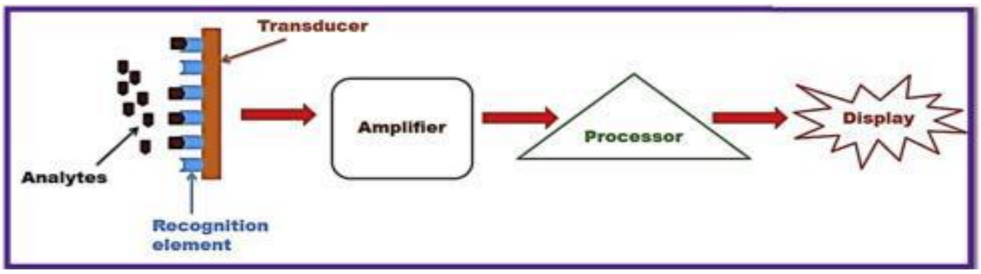
Ion Detection: Conductometric sensors can be employed for detecting specific ions in a solution by using ion-selective membranes or materials that selectively interact with certain ions.

Chemical and Biological Sensing: These sensors can be designed to detect changes in conductivity resulting from chemical reactions or interactions with biological molecules, making them useful for various applications, such as environmental monitoring and medical diagnostics.

Process Monitoring: Conductometric sensors are utilized in industrial processes to monitor changes in conductivity that may indicate the presence of specific substances or the progression of chemical reactions.

Electrochemical Sensors

- An electrochemical sensor is a type of sensor that utilizes the principles of electrochemistry to detect and measure the concentration of specific chemical or biological species in a sample. These sensors are widely used in various fields such as environmental monitoring, medical diagnostics, industrial process control, and consumer electronics.
- Electrochemical sensors are made up of three essential components: a sample, a receptor and Transducer. Receptor that binds the sample, the sample or analyte, and a transducer to convert the reaction into a measurable electrical signal. In the case of electrochemical sensors, the electrode acts as the transducer.
- Electrochemical sensors are electrodes. An electrode surface is used as the site of the reaction. The electrode will either oxidize or reduce the analyte of interest. Electrochemical sensing always requires a closed circuit. The current that is produced from the reaction is monitored and used to calculate important data such as concentrations from the sample.
- The fundamental concept in the detection of analytes by electrochemical sensors involves the measurement of electric current generated by chemical reactions in the electrochemical system. Electrochemical sensor's working mechanism involves the interaction of the target analyte material with the electrode surface and bringing the desired change as a consequence to a redox reaction, which generates an electrical signal that can be transformed to explore the nature of the analyte species.



There are different types of electrochemical sensors, and they can be classified based on the type of electrochemical reaction they utilize. The main types include:

- **Potentiometric Sensors:** Measure the potential difference between the working and reference electrodes without any current flow. pH sensors are common examples.
- **Amperometric Sensors:** Measure the current resulting from the electrochemical reaction at the working electrode. These sensors are commonly used for detecting gases and certain ions.

- **Conductometric Sensors:** Measure changes in the electrical conductivity of the electrolyte due to the presence of the analyte.
- **Impedimetric Sensors:** Measure the impedance (opposition to the flow of alternating current) of the system, which changes with the presence and concentration of the target analyte.

Electrochemical sensors in Potentiometric analysis of FAS using Standard K2Cr2O7

Principle:

- A titration in which the equivalence point of a reaction is determined with the help of the measurement of potential of the reaction mixture is known as a potentiometeric titration.
- A bright platinum electrode is used in oxidation - reduction titration and the potential of this electrode is determined by the activity ratio of the substance being oxidized or reduced (Ex: FAS against $K_2Cr_2O_7$). The determining factor in oxidation - reduction reaction is the ratio of the concentration of the oxidized and reduced forms of certain ion species.

Procedure, Observation and Calculation and graph follow lab manual

Application Electrochemical sensors in real time analysis

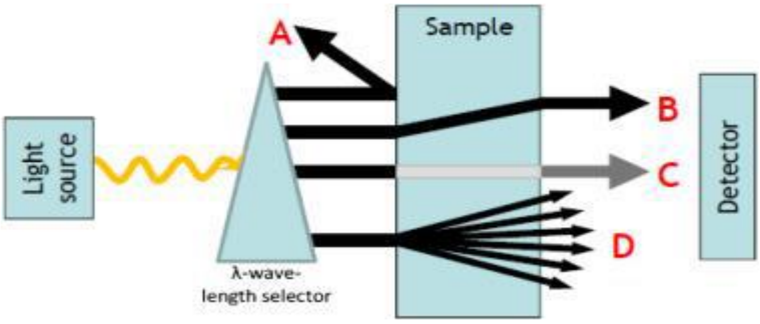
- Electrochemical sensors offer advantages such as high sensitivity, selectivity, and the ability to operate in real-time. They are commonly used in applications where rapid and specific detection of analytes is essential. Examples include glucose monitoring in diabetes management, environmental monitoring of pollutants, and detection of various biomolecules in healthcare and biotechnology.

Optical sensors

- Optical sensors are devices that use light to detect and measure physical or chemical properties of a material. They are based on the interaction between light and the substance being analyzed. Optical sensors find applications in various fields, including environmental monitoring, medical diagnostics, industrial processes, and telecommunications.
- Colorimetric sensor is one of the type of optical sensors where by measuring the intensity of light concentration of the analyte is measured.
- **Optical sensors are electronic components designed to detect and convert incident light rays into electrical signals**. These components are useful for measuring the

intensity of incident light and converting it into a form readable by an integrated measuring device.

- When light falls on the sample following changes takes place to the incident light, some part of light get absorbed, some part of light gets transmitted and some part of light gets reflected.
- Optical sensors use visible or ultraviolet light to for analysis. The detector monitors varies by technique (e.g., refractive index, scattering, diffraction, absorbance, reflectance, photoluminescence, chemiluminescence, etc.), can cover different regions of the electromagnetic spectrum, and can allow measurement of multiple properties.



Colorimetric estimation of Copper using CuSO4 solution

Principle:

- The relation between the light absorption capacity of a medium and the concentration of the coloured constituents in solution is given by Beer's law. The law states that "The intensity of a beam of monochromatic light decreases exponentially as the concentration of the absorbing substance increases".
- Absorbance of the solutions are measured at a particular wave length using a photoelectric colorimeter. A plot of absorbance or optical density against concentration of the solution gives a straight line which serves as a standard curve .
- The test solution whose concentration is to be determined is also treated in a similar manner to develop the colour and its absorbance is measured. From the standard curve the concentration of the metal ion in the test solution can be determined.

Procedure, Observation and Calculation and graph follow lab manual

Applications of Optical Sensors in Real time analysis

- Optical sensors are integral parts of many common devices, including computers, copy machines (xerox) and light fixtures that turn on automatically in the dark.
- And some of the common applications include alarm systems, synchros for photographic flashes and systems that can detect the presence of objects.

WATER CHEMISTRY

Impurities in water

The impurities in water are broadly classified into 4 types.

1. Dissolved solids: It mainly consists of chlorides, bicarbonates and sulphates of Ca and Mg ; along with small amounts of nitrates, nitrites and silicates.

2. Dissolved gases: The dissolved gases prevented in water are O_2, CO_2, SO_2, NH_3, oxides of Nitrogen (all from atmosphere)

3. Suspended matter: The organic suspensions includes decomposed vegetables and animal matter. The inorganic matter includes fine particles of sand, clay, silica, hydroxides of Fe and Al.

4. Biological impurities: Microorganisms and pathogenic bacteria are present in water. Ex. Algae, fungi, protozoa etc.

HARDENESS:

Determination of Temporary and Permanent Hardness:

Temporary hardness of water is due to the presence of bicarbonates of Ca and Mg and permanent hardness is caused by chlorides and sulphates of Ca and Mg salts. The unit of hardness is parts per million (ppm) of $caco_3$ equivalent.

Ethylene Diamine Tetra Acetic acid (EDTA) forms complexes with Ca^{2+} and M_g^{2+} ions in water. The total hardness of water is determined by titrating a known volume of hard water against EDTA at pH 10 using Erichrome black- T (EBT) indicator. Same volume of another portion of water is boiled then bicarbonates are converted in to insoluble carbonates. The precipitate is flittered and the filtrate is titrated against EDTA, which gives permanent hardness and the difference between total and permanent hardness gives temporary hardness.

Procedure and calculations:

a. Estimation of total hardness

Pipette out 50 ml of water into a conical flask and add 1 ml of NH_3-NH_4Cl buffer followed by 2 drops of Eriochrome Black-T indicator. Titrate the solution against 0.01 M EDTA till colour changes from wine red to blue, let the volume of EDTA required be V_1 ml.

1000 ml of 1M EDTA = 100 g of $CaCO_3$

V_1 ml of 0.01 M EDTA = $\frac{V1 \times 0.01 \times 100}{1000}$ g of $CaCO_3$ = $\frac{V1}{1000}$ g of $CaCO_3$

$$50 \text{ ml of water contains} = \frac{V1}{1000 \times 50} \text{ g of } CaCO_3$$

$$10^6 \text{ ml of water contains} = \frac{V1}{1000 \times 50} \times 10^6 \text{ ppm of } CaCO_3$$

ie., $20 \times V_1$ ppm of $CaCO_3$

b. Estimation of permanent hardness:

Pipette out 50ml of water into a beaker and boil for 30 minutes. Cool and filter into a conical flask, add 1 ml of buffer followed by 2 drops of Eriochrome Black-T indicator and titrate against 0.01 M EDTA till the colour changes from wine red to blue. Let the volume of EDTA required be V_2 ml .

Permanent hardness of water is $20 \times V_2$ ppm of $CaCO_3$

Temporary hardness of water is $20 \times (V_1 - V_2)$ ppm of $CaCO_3$

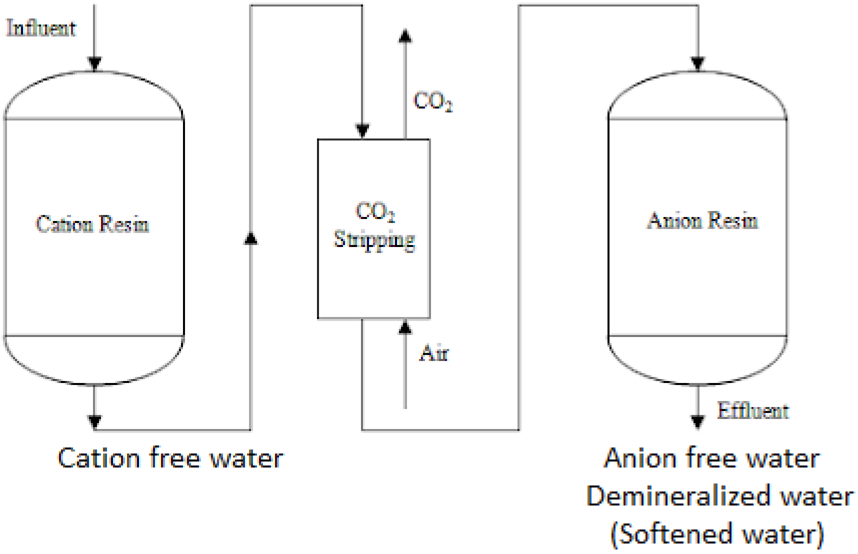
Disadvantages of Hard water :

- When hard water is heated, lime scale forms and is deposited in water pipes and appliances.
- The buildup of deposits in pipes and appliances can result in blockages, and in appliances, it can reduce energy efficiency and shorten life of appliances. Washing garments in such appliances make garments appear dull and grey, losing all of their colors.
- With soap or detergents, lathering is challenging. Additionally, using hard water increases the likelihood of scum buildup, which wastes soap.
- Hard water can cause dry skin and hair loss in people, among other effects.

Removal of Hardness (Softening of water) by ion exchange process

The presence of certain metal ions like calcium and magnesium as bicarbonates, chlorides, and sulphates in water causes hardness in water. The process of removing these ions from hard water is called softening of water. The most common method for removing water hardness is by using ion-exchange resin. Ion exchange resin contains cation and anion exchange resins which are made up of cross linked polymers with porous structure with desirable functional group. Example: Styrene-divinyl benzene copolymer with strong acidic sulphonate functional group is used as cation exchange resin and Styrene-divinyl benzene copolymer with strong basic quaternary ammonium functional group is used as anion exchange resin

Cationic resin is able to exchange H^+ ions with cation such as Ca^{2+} and Mg^{2+}ions present in hard water. Similarly anionic resin is able to exchange its OH^- ion with anions such as Cl^- SO_4^{2-} ions present in hard water.



$2RH + Ca^{2+} \longrightarrow R_2Ca + 2H^+$ $\qquad$ $R\,OH + Cl^- \longrightarrow R\,Cl^- + OH^-$

Process: Cation and anion exchange resin is packed in separate columns. Hard water is first passed into cation resin where Ca^{2+} and Mg^{2+}ions present in hard water are exchanged with H^+ ion of cation resin. The water is then passed into anion exchange resin where Cl^- SO_4^{2-} ions in hard water are exchanged with OH^- ion of anion resin. The H^+ and OH^- ions in resin combines to form water molecule. Water coming out from ion exchange process is called deionized water or potable water.

$$H^+ + OH^- \longrightarrow H_2O$$

Advantages :

- Easy to operate and both acidic and alkaline water can be softened.
- Very low hardness (0 – 2 ppm) water is obtained.
- Demineralized water can be used for industrial as well as domestic purposes.
- The exchanger can be regenerated & used again and again.

Disadvantage :

- Equipment is expensive

Potable water:

Water that is suitable for human consumption and free from hazardous chemicals and pathogenic microorganisms is called potable water.

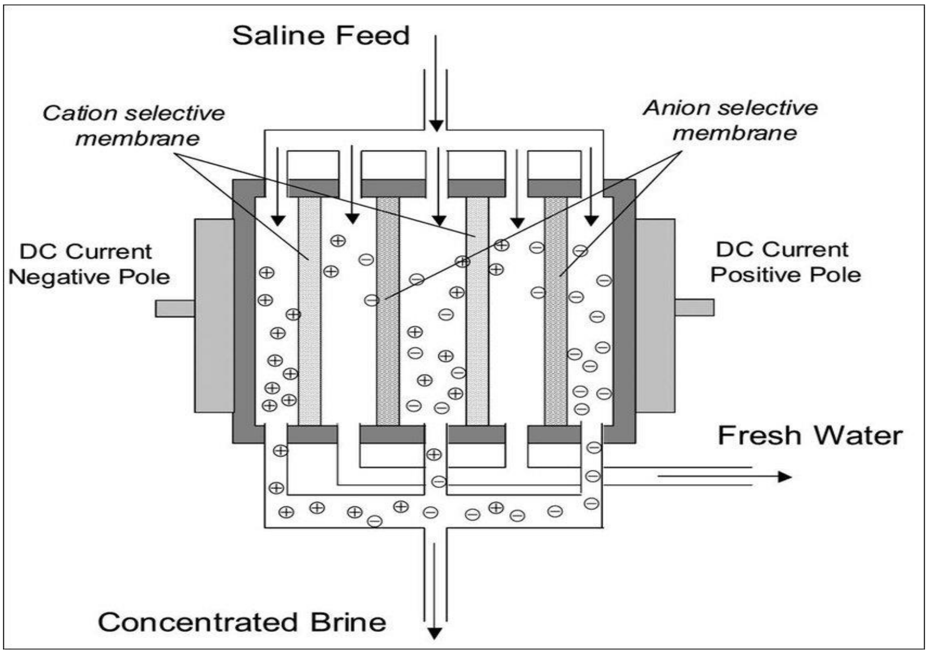
Desalination of sea water :

Desalination is the process of removing dissolved salts present in sea water. There are generally two methods available for desalination.

1. Reverse osmosis 2. Electrodialysis

Electrodialysis

It is the process of decreasing the concentration of salts in brackish water using ion selective membrane under the influence of applied e m f. Ion selective permeable membranes are used for this process. The cation membranes are permeable to only cation while onion membranes are permeable to only anions. This process gives pure water by decreasing salt concentration.



The process of migration of ions present in the solution towards the oppositely charged electrodes when an e m f is applied is known as Electro dialysis. An Electro dialysis cell consists of a series of alternative cation and anion permeable membranes [C & A] The anode is placed near the anion permeable membrane while the cathode is placed near the cation permeable membrane. A suitable e m f is applied across the two electrodes immersed in salt solution. Under the influence of the applied emf, the cation selective membrane repels -ve charged ions, but allows +ve ions i.e., Sodium ions (Na^+) move through the cation permeable membrane (C) while anion selective membrane allows anions to enter through it i.e., chlorine ions (Cl^-) move through the anion permeable membrane (A) . The impurities are filtered through the membrane from water. Therefore, water in one chamber of the cell is desalinated water, while the salt water concentration increased in the next chamber . Thus we get stream of pure water & is pumped off and concentrated brine solution is discharged through the outlet. Hence this method enhances the efficient separation.

Advantages:

- High water recovery rates even for raw water with high sulphate content.
- Ion exchange membranes tolerate higher level of chlorine & extreme pH values.

Disadvantages :

- Neutral toxic components such as viruses or bacteria are not removed by electrodialysis. Hence, a post-treatment may be required prior to the use as potable water.

Uses: Treatment of metal finishing wastes, battery manufacture, glass etching and desalination of effluents.

Dissolved Oxygen:

DO is a measure of the ability of water to oxidize organic impurities into it. DO is necessary for aerobic biological activities. In the absence of sufficient amount of DO in water, aquatic organisms die. DO content predicts the purity of water bodies.

BOD :

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed (i. e., demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample. Lower is the BOD, better is the quality of water. BOD of drinking water should be less than **ONE**. Both organic (dead plant and animal matter) and inorganic matter (nitrates and phosphates) contribute to high BOD levels.

BOD is defined as the amount of oxygen required in milligrams by the microorganisms to bring about oxidation of biologically oxidisable compounds present in 1 litre of waste water sample over a period of 5 days at 20^o C.

It is expressed in mg dm^{-3} or ppm. BOD estimation is very important in sewage treatment as it indicates the amount of decomposable organic matter in sewage.

Determination of BOD of waste water:

Principle:

In Winkler's method of BOD determination, the given sample of water is treated with manganous sulphate and alkaline KI. In alkaline medium dissolved oxygen oxidises Mn^{2+} to Mn^{4+}. On acidification Mn^{4+} oxidises iodide to free iodine. The liberated iodine is titrated against standard sodium thiosulphate solution using starch as an indicator.

$$MnSO_4 + 2\,KOH \longrightarrow Mn(OH)_2 + K_2SO_4$$

$$2\,Mn(OH)_2 + O_2 \longrightarrow \underset{\text{Basic manganese oxyhydroxide}}{2\,MnO(OH)_2}$$

$$MnO(OH)_2 + H_2SO_4 \longrightarrow MnSO_4 + 2\,H_2O + (O)$$

$$2\,KI + H_2SO_4 + (O) \longrightarrow K_2SO_4 + I_2 + H_2O$$

$$2\,Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6 + 2\,NaI$$

$$I_2 + \text{Starch} \longrightarrow \text{Blue complex}$$

Procedure:

A known volume of sewage water is diluted with known volume of water which contains nutrients for bacterial growth. Equal volumes of diluted samples are filled in two BOD bottles. DO content in one of the bottles is determined immediately by using Winkler's method as follows. To a known volume of diluted water, 5 ml of $MnSO_4$ solution & 5 ml of alkaline KI are added and shaken for about 15 minutes till $MnO(OH)_2$ gets precipitated as $MnSO_4$. Then precipitate is dissolved in 2 ml of 1:1 H_2SO_4 and the liberated I_2 is titrated against standard sodium thiosulphate. The titre value is DO_1 which indicates the total dissolved oxygen available at the start of the experiment.

The DO content of second bottle is determined after 5 days of incubation by same method to obtain DO_2.

Calculation:

$$\textbf{BOD} = \frac{DO_1 - DO_2}{A} \times B \quad \text{mg dm}^{-3}$$

Where DO_1 = DO of diluted sample immediately after preparation

DO_2 = DO of diluted sample after 5 days of incubation at 20^{o} c

A = Volume of sample before dilution

B = Volume of sample after dilution

COD:

Chemical oxygen demand (COD) is defined as the amount of oxygen required in milligrams by the microorganisms to bring about oxidation of biologically oxidizable and biologically inert compounds present in 1 litre of waste water sample.

COD is always greater than BOD since COD represents the total amount of oxygen required to oxidise all oxidisable impurities i.e., biologically oxidisable & biologically inert matter in a sample of sewage wastes whereas BOD oxidises only biologically oxidisable impurities in a sample.

Determination of COD of waste water:

Principle:

Determination of COD involves the addition of excess of standard potassium dichromate ($K_2Cr_2O_7$) solution and H_2SO_4 to waste water sample. The $K_2Cr_2O_7$ oxidizes impurities. The amount of unreacted dichromate is determined by back titration against ferrous ammonium sulphate (FAS). The amount of $K_2Cr_2O_7$ initially added to the waste water is determined by blank titration.

Therefore the difference between blank and back titre values correspond to the amount of FAS which is equivalent to the amount of $K_2Cr_2O_7$ actually used up for the oxidizing the impurities. The amount of $K_2Cr_2O_7$ consumed is used to calculate COD.

Procedure:

Back Titration : Pipette out 25 cm^3 of waste water sample and add 10 cm^3 of $K_2Cr_2O_7$ into a conical flask. Add 1 tt of H_2SO_4 containing silver sulphate followed by 2-3 drops of ferroin indicator and titrate against the standard FAS solution until the colour changes from bluish green to reddish brown. Let the volume of FAS consumed be 'Y' cm^3.

Blank Titration : Perform the same procedure and titration again by using 25cm^3 of distilled water instead of waste water. Let the volume of FAS consumed be 'X' cm^3.

Calculation:

1cm^3 of 1N FAS solution = 8 mg of oxygen

(X - Y) cm^3 of Z N FAS solution = $8 \times (X-Y) \times Z$ = 'a' mg of oxygen

25 cm^3 of water sample contains 'a'mg of oxygen

1000 cm^3 of water sample contains $\frac{1000 \times a}{25}$ mg of oxygen

Therefore, COD of the given water sample = -------------- mg/litre

E-waste management

Introduction to E-waste management

- E-waste or electronic waste is created when an electronic product is discarded after the end of its useful life.
- The rapid expansion of technology means that avery large amount of e-waste is created every minute.
- Electronic Waste or E-Waste describes rejected electrical or electronic devices such as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets, and refrigerators.
- All items of electrical and electronic equipment and its parts that have been discarded by the user as waste without the purpose of re-use or re-cycle is called Electronic Waste.
- Any item which is considered as Electronic Waste has a Lifetime Profile.
- Lifetime Profile includes the information about hazardous quantity present in discarded items, economic value and the effects on environment and health of people if they are not recycled appropriately.
- Electronic Waste is dismantled and sorted manually in developing countries unlike developed nations.

The main causes of Electronic Waste

- Advancement in Technology.
- Changes in style fashion and status.
- End of their helpful life.
- Not taking precautions while handling them.

Composition of E-Waste includes materials like:

E-waste can be classified on the basis of its composition and components. Ferrous and nonferrous metals, glass, plastics, pollutants, and other are the six categories of materials reported for e-waste composition.

- Valuable metals like gold, platinum, silver and palladium.

- Useful metals like copper, aluminium, iron etc.
- Hazardous substances like radioactive isotopes and mercury.
- Toxic substances like PCB's and Dioxins.
- Plastic like High Impact Polystyrene (HIPS), Acrylonitrile Butadiene Styrene (ABS), Polycarbonate (PC), Polyphenylene oxide (PPO) etc.

Sources of E-waste

Any appliance that runs on electricity has the potential to cause damage to the environment if it is not disposed properly. Common things of electrical and electronic waste are:

- Large household appliances like refrigerators/freezers, washing machines, dishwashers, televisions.
- Small household appliances which include toasters, coffee makers, irons, hairdryers.
- Information Technology (IT) and Telecommunications equipment namely personal computers, telephones, mobile phones, laptops, printers, scanners, photocopiers etc.
- Lighting equipment such as fluorescent lamps. Electronic or Electrical tools i.e. handheld drills, saws, screwdrivers etc.
- Toys, leisure and sports equipment.
- Monitoring and control instruments.
- Automatic dispensers.

Characteristics of E-waste

They composed of various plastic elements and metallic elements which may be harmful for the environment. Disposal of e-waste: e-waste are hard to dispose. The plastic components are collected and sent to recycling unit. The non-harmful metallic units like the steel also sent for recycling.

4 characteristics of E-waste are ignitability, corrosivity, reactivity, or toxicity

Need of E-waste management

- Reducing waste will not only protect the environment but will also save on costs or reduce expenses for disposal. In the same way, recycling and/or reusing the waste that is produced benefits the environment by lessening the need to extract resources and lowers the potential for contamination.
- E-Waste is a rich source of rare earth metals like gold, silver, copper etc. efficient recovery of these precious metals can bring a significant economic growth and reduction in carbon footprint too

- The major objective of e-waste management is to reduce, reuse, and recycle. Some of the e-waste consists of valuable covering or materials inside which can be reused or recycled. Whereas some of the e-waste may contain hazardous chemical materials which should be disposed of carefully without causing harm to nature

Toxic materials used in manufacturing of E-waste electronic and electrical products

- Electronic waste contains toxic components that are dangerous to human health, such as mercury, lead, cadmium, poly brominated flame retardants, barium and lithium.
- E-waste contains numerous toxic chemicals including metals such as lead, cadmium, mercury, and nickel, and organic compounds such as flame retardants, chlorofluorocarbons, polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), and polychlorinated dibenzo-p-dioxins and furans (PCDD/Fs).
- E-waste also contain radioactive materials which cannot be easily destroyed. If such materials enters the food chain or mix up with the environment the it leads to lot of human health problems and also on ecological problems.

Recycling and Recovery

- The recycling of e-waste serves a lot of useful purposes. For instance, include protecting human and environmental health by keeping those devices out of landfills.
- Recovering the parts within the devices that still have value, and providing manufacturers with recycled metals that can be used to make new products.
- E-waste recycling is the disassembly and separation of components and raw materials of waste electronics; when referring to specific types of e-waste, the terms like computer recycling or mobile phone recycling may be used. Like other waste streams, re-use, donation and repair are common sustainable ways to dispose of IT waste.
- Recycling is considered environmentally friendly because it prevents hazardous waste, including heavy metals and carcinogens, from entering the atmosphere, landfill or waterways. While electronics consist a small fraction of total waste generated, they are far more dangerous.

Different approaches of recycling of E-waste

- **Separation -** This is the first stage of recycling e-waste. In this step e-waste are separated and transport the e-wastes to recycling facilities and plants. Further e-waste are separated into smaller pieces for proper sorting. With the use of hands, these tiny prices get sorted and then manually dismantled. After this, the materials get categorized into core materials and components.

- **Thermal treatment** - Open Burning is the primary method of thermal waste treatment but is considered as an environmentally invasive process. No pollution controlling devices are engaged in open burning, allowing pollutants to escape into the environment. Examples of thermal treatment processes are incineration, molten salt, pyrolysis, calcination, wet air oxidation, and microwave discharge.
- **Hydrometallurgical treatment** - The hydrometallurgical process primarily involves the use of chemical reagents, where strong acids are used to leach base metals while chemical reagents such as cyanide, halide, thiourea, and thiosulfate are used to leach out precious metals from e-waste.

  The main methods include adsorption, chelation, ion exchange, leaching, precipitation, and solvent extraction. The disadvantage of precipitation lies in the difficulty in recovering pure products. Acid leaching is generally preferred to basic leaching in the industry owing to high dissolution of valuable metals.

  Hydrometallurgy is environmentally benign compared to other recycling techniques such as pyrometallurgy and reduces the need for mining virgin materials. It can contribute to creating a circular economy for high-value minerals such as Lithium, Manganese, Nickel, and Cobalt.
- **Pyrometurlurgical methods -** Pyrometallurgy is the predominantly used technology for industrial e-waste treatment. Pyrometallurgical treatment of e-waste commonly involves smelting in furnaces at high temperatures, incineration, combustion, and pyrolysis, and in these unit processes the metals are separated based on their chemical and metallurgical properties. Examples include decomposition of hydrates such as ferric hydroxide to ferric oxide and water vapor, the decomposition of calcium carbonate to calcium oxide and carbon dioxide as well as iron carbonate to iron oxide
- **Direct recycling** – involves direct recycling as the recovery, regeneration, and reuse of battery components directly without breaking down the chemical structure.

Direct recycling allows for the recovery of a larger proportion of valuable materials from the battery compared to other recycling methods. This is because direct recycling avoids the need for intermediate processing steps, which can result in the loss of valuable metals and chemicals.

Advantages of Recycling

- E-waste recycling and management E-waste recycling is the developing, assembly, buying or promoting new electronic products which are prepared from waste materials.
- E-waste recycling has multiple benefits a. Retrieving valuable materials from electronics.
- Provides a shot in the arm to employment generation E-waste recycling is quintessential because it helps in ameliorating a big threat dangling over vital natural resources.
- Present research activities for recovering precious and base metals from waste printed circuit boards are eyeing on Hydrometallurgical techniques
- The main part of the recycling process is dismantling, that is, elimination of different parts of e-waste that are the source of hazardous pollutants such as PCB, Hg, separation of plastic that contains PVC, removal of CRT and separation of valuable metals like copper, lead, silver and gold from the waste.

Recycling of Li-ion batteries

From their initial discovery in the 1970s through the awarding of the Nobel Prize in 2019, the use of lithium-ion batteries has increased exponentially.

As the world has grown and depend on the power which has brought by lithium-ion batteries, their manufacturing and disposal have increasingly become subjects of political and environmental concerns.

World reserves of lithium, cobalt, and other metals are limited and unevenly distributed, while their mining is energy and labour intensive and creates considerable pollution. As a result, natural disasters, war, or resource allocation decisions may also change the availability of these materials.

- Recycling of Li-ion batteries is essential for conserving resources, protecting the environment, and providing economic benefits.
- The recycling process involves collection, sorting, mechanical shredding, material separation, purification, and reuse.
- Challenges include technical complexity, safety concerns, and economic factors.
- Future improvements will come from technological advances, regulatory support, and increased public awareness.

Following steps are carried out in recycling process of Li ion battery

1. **Collection**: Batteries are collected from various sources such as households, industries, and EVs. Collection points can include retail stores, recycling centers, and dedicated drop-off points.

2. **Sorting and Discharging**: Batteries are sorted by type and chemical composition. They are safely discharged to prevent any risk of fire or explosion during processing.
3. **Mechanical Shredding**: Batteries are mechanically shredded into small pieces to separate different components. This step helps in exposing the metals and other materials inside the battery.
4. **Material Separation**: there are 3 important method of Li ion recycling
    - **Pyrometallurgical Process**: Involves high-temperature processing to melt and separate metals.
    - **Hydrometallurgical Process**: Uses chemical solutions to dissolve and extract metals.
    - **Direct Recycling**: Attempts to refurbish and reuse battery components with minimal chemical alteration.
5. **Purification and Refining**: Extracted metals undergo purification to remove impurities. Achieves high-grade materials that can be reused in new batteries or other products.
6. **Reuse in Manufacturing**: Purified materials are reintroduced into the supply chain. Used in manufacturing new batteries or other electronic components.

Extraction of Gold from E-waste

Importance of Extracting Gold from E-waste

1. **Resource Recovery**: Gold and other precious metals are limited resources. Recovering them from e-waste reduces the need for mining. Thereby, helps in conserving natural resources and minimizing environmental damage from mining activities.
2. **Environmental Protection**: Prevents hazardous substances in e-waste from leaching into the environment. Reduces the overall carbon footprint associated with mining and processing new materials.
3. **Economic Benefits**: Recovering gold from e-waste can be economically profitable. Provides a sustainable source of valuable metals for various industries.

Sources of Gold in E-waste

Printed Circuit Boards (PCBs): Gold is used in connectors, contacts, and IC chips due to its excellent conductivity and resistance to corrosion.

Connectors and Contacts: Found in various electronic components, gold plating is commonly used for its reliability and durability.

Memory Chips: Gold is used in the bonding wires and connectors in memory chips and other semiconductor devices.

Extraction Processes of Gold from e-waste

1. **Mechanical Separation**:

Disassembly: Manual or automated disassembly of e-waste to separate components containing gold.

Shredding: E-waste is shredded into smaller pieces to facilitate further processing.

2. **Physical Separation**:

Magnetic Separation: Uses magnets to remove ferrous metals.

Eddy Current Separation: Separates non-ferrous metals based on their electrical conductivity.

Density Separation: Separates materials based on their density using techniques like air classification and water separation.

3. **Chemical Processes**:

i. Hydrometallurgical Process:

Leaching: E-waste is treated with chemicals (e.g., cyanide, aqua regia) to dissolve gold. In this process First, anode sludge without copper is leached into a roughly 4-9 molar nitric acid at 40-115 degrees Celsius. Silver, selenium, and tellurium are dissolved in this situation; the waste leached into nitric acid is processed at a high temperature between 40 to 110 degrees centigrade with aqua regia to dissolve gold.

Precipitation: Gold is precipitated out of the solution using reducing agents like zinc or activated carbon.

ii. Pyrometallurgical Process:

Smelting: E-waste is heated to high temperatures to melt and separate metals.

Refining: Impurities are removed to obtain pure gold.

4. **Biotechnological Methods**:

Bioleaching: Microbiological processes have been proposed over the last decade as possible alternatives to extracting precious metals such as copper, gold, palladium and silver from e-waste.

Aspergillus niger and Chromobacterium biolaceum are two microorganisms that have been found as suitable and sustainable methods of extracting gold from gold plated electronic devices

Advantages of Gold Extraction from E-Waste

1. The potential for the recovery of gold and other useful metals from e-waste to benefit both the global economy and society at large is unimaginable.
2. A significant reduction in both carbon emissions and other harsh environmental consequences that result from gold mining