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Solution of Internal Assessment Test 2 – December 2023

Sub:	Chemistry	Sub Code:	BCHEE102	Branch:	ECE
Date:	04-12-2023	Duration:	90 min's	Max Marks:	50
		Sem / Sec:	I / M, N, O & P		

Question no. 1 is COMPULSORY and answer any THREE FULL Questions from the rest.

	MARKS	CO	RBT
1 (a) What are conducting polymers? Explain the conduction mechanism in polyacetylene. Mention its commercial applications.	[7]	CO1	L3
(b) Explain the principle, instrumentation and applications of potentiometric sensor by taking estimation of iron as an example.	[7]	CO4	L2
2 (a) What are electrochemical sensors? Explain their working principle and mention any 2 applications.	[6]	CO4	L2
(b) What are reference electrodes? Describe the construction and working of calomel electrode.	[6]	CO3	L2
3 (a) Explain the principle and instrumentation of colorimetric sensors and its application in the estimation of copper.	[6]	CO4	L2
(b) What are concentration cell? Explain the construction and working of electrolyte concentration cell with suitable example.	[6]	CO3	L2
4 (a) What are ion selective electrodes? Explain determination of pH of a solution using glass electrode.	[6]	CO3	L2

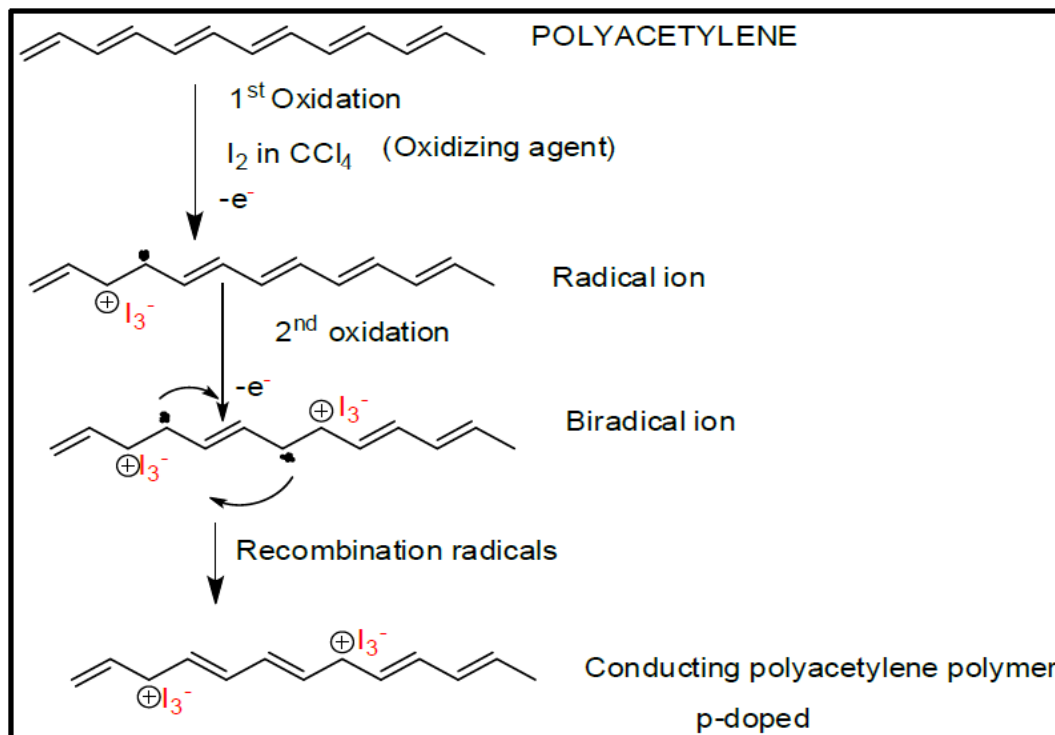
(b) In a sample of polymer 100 molecules have molecular mass 10^3 g/mol, 200 molecules have molecular mass 10^4 g/mol and 250 molecules have molecular mass 10^5 g/mol. Calculate number average molecular mass, weight average molecular mass and PDI.	[6]	CO1	L2
5(a) The EMF of concentration cell, constructed by combining two lithium rods immersed in lithium sulphate solution is, 0.180 V at 25 °C. If concentration of anodic compartment is 0.004 M. Calculate the concentration of cathodic compartment. Represent the cell and write the cell reaction.	[6]	CO3	L3
(b) Explain construction, working and applications of glass electrode.	[6]	CO3	L3
6 (a) Describe the extraction of Cu and Au from e-waste.	[6]	CO3	L2
(b) Explain the principle and instrumentation of conductometric sensors and its applications in the estimation of weak acid.	[6]	CO4	L2
7 (a) Discuss the preparation, properties and commercial applications of graphene oxide.	[6]	CO1	L2
(b) What are thermometric sensors? Describe their working principle and mention any 4 applications.	[6]	CO4	L2

(Chief Course Instructor)

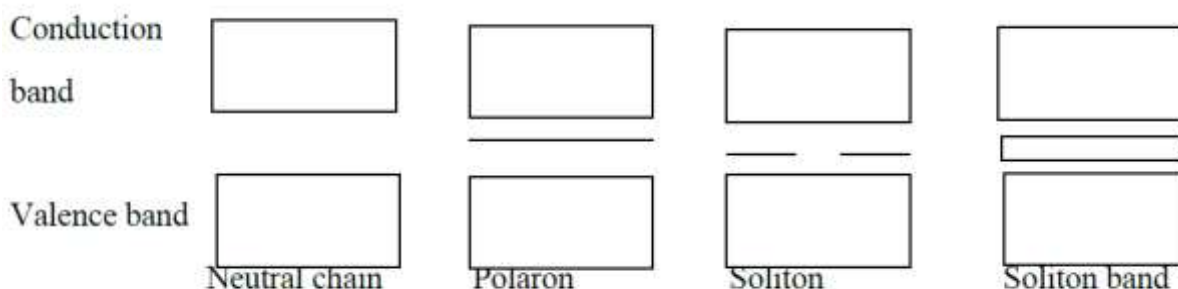
Answer 1(a) Polymers which can conduct electricity are called conducting polymers.

Mechanism of conduction in polyacetylene:

(i) By Oxidative doping (p-doping): In this process, π -back bone of polymer is partially oxidized using a suitable oxidizing agent such as I_2 in CCl_4 . The removal of an electron from the polymer π -back bone leads to the formation of delocalized radical ion called polaron. A second oxidation of chain containing polaron produces bipolaron which on radical recombination yields two charge carries on each chain. The positive charge sites on the polymer chain are compensated by anion I_3^- formed by the oxidizing agent during doping. The delocalized positive charges on the polymer chain are mobile, not the dopant anions. Thus these delocalized positive charges are current carriers for conduction. These charges must move from chain to chain as well as along the chain for bulk conduction.



If polyacetylene is heavily doped, polarons form pairs called solitons. In polyacetylenes the solitons are delocalized over 12 carbon atoms. Due to the formation of soliton, a new localized electronic state appears in the middle of the energy gap. When the doping is high, several charged solitons form soliton band. This band can later merge with edges of valence and conduction bands thus exhibiting conductivity.



Application of polyacetylene: .

The most extensively studied and is widely investigated computationally and experimentally for use in electronic devices such as light-emitting diodes, water purification devices, hydrogen storage, and biosensors.

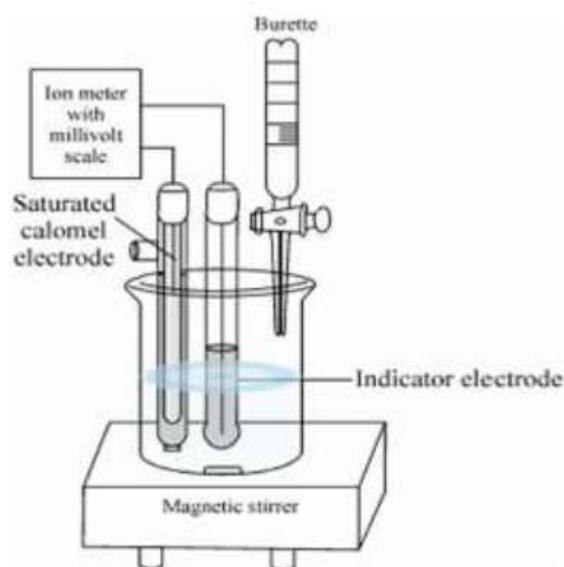
Answer 1(b) Principle: The procedure of using measurement of emf to determine the concentration of ionic species in solution is called as potentiometry also known as potentiometric titration. When a metal M is immersed in a solution containing its own ions M^{n+} , the electrode potential is

given by Nernst equation.

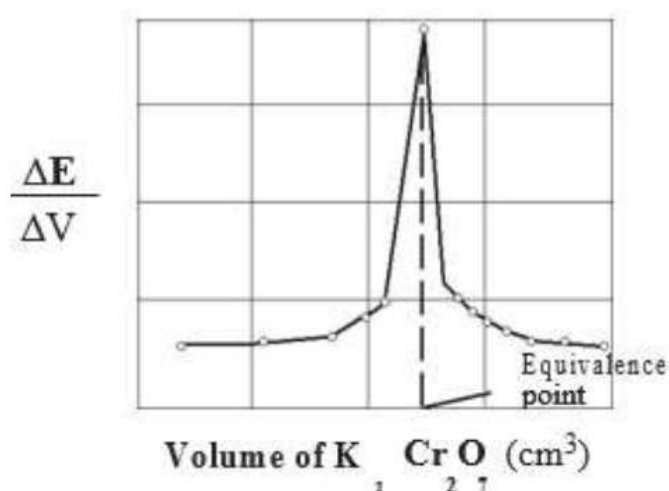
$$E = E^\circ + \frac{0.0591}{n} \log [M^{n+}]$$

Thus, the concentration can be calculated, provided E° of the electrode is known. The principle involved in potentiometric titration is the measurement of emf between two electrodes, an indicator electrode, (the potential of which is function of the concentration of the ion to be determined) and a reference electrode of constant potential. In this method, the measurement of emf is made while the titration is in progress. The equivalence point of the reaction is revealed by a sudden change in potential in the plot of emf readings against the volume of titrant.

Instrumentation: A potentiometer consists of: (i) Calomel electrode as a reference electrode, (ii) Platinum electrode as an indicator electrode, (iii) a device for measuring the potential and (iv) Magnetic stirrer.

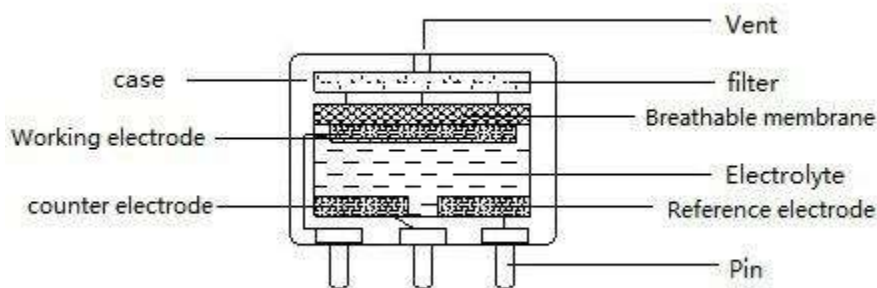


Application: Potentiometric estimation of FAS using standard $K_2Cr_2O_7$ solution: Pipette out 25ml of FAS into a beaker. Add 1 t.t dil H_2SO_4 , immerse calomel electrode + platinum electrode into it. Connect the assembly to a potentiometer and measure the potential by adding $K_2Cr_2O_7$ in the increments of 0.5ml. Plot graph $\Delta E / \Delta V$ against volume of $K_2Cr_2O_7$, and determine the equivalence point. From the normality and volume $K_2Cr_2O_7$, solutions calculate the normality and the weight of FAS in the given solution.



Answer 2(a) Electrochemical sensors are devices that give information about the composition of a system in real time by coupling a chemically selective layer (the recognition element) to an electrochemical transducer. **Electrochemical sensors** are made on the basis of ion conduction. According to the formation of their electrical characteristics, electrochemical sensors can be divided into potential sensors, conductivity sensors, electricity sensors, polarographic sensors, and electrolytic sensors. Electrochemical sensors are mainly used to analyze gas, liquid, or solid components dissolved in liquids, the measurement of liquid pH, conductivity, and oxidation-reduction potential.

Working Principle: The electrochemical sensor works by reacting with the measured gas and generating an electric signal proportional to the gas concentration. A typical electrochemical sensor consists of a sensing electrode and a counter electrode and is separated by a thin electrolytic layer.



The gas first reacts with the sensor through the tiny capillary-shaped opening, then the hydrophobic barrier layer, and finally reaches the electrode surface. Using this method can allow an appropriate amount of gas to react with the sensing electrode to form a sufficient electrical signal while preventing electrolytes from leaking out of the sensor. The electrochemical sensor contains the following main components:

- a) **Breathable membrane** (also called hydrophobic membrane): The breathable membrane is used to cover the sensing (catalytic) electrode, and in some cases, it is used to control the molecular weight of the gas reaching the electrode surface.
- b) **Electrode:** The electrode material should be a catalytic material that can perform semi-electrolytic reactions over a long period of time. Generally, electrodes are made of precious metals, such as platinum or gold, which react effectively with gas molecules after catalysis.
- c) **Electrolyte:** The electrolyte must be able to carry out the electrolysis reaction and effectively transfer the ionic charge to the electrode.
- d) **Filter:** Sometimes a scrubber filter is installed in front of the sensor to filter out unwanted gas. The most commonly used filter material is activated carbon.

Application of electrochemical sensors

- i. **Humidity sensor** - The sensor used to measure relative humidity is coated with piezoelectric quartz crystal, which is made of small quartz crystal by photolithography and chemical etching technology.

(ii) Detection of toxic gases like nitrogen oxide, hydrogen sulfide and sulfur dioxide with high selectivity and sensitivity

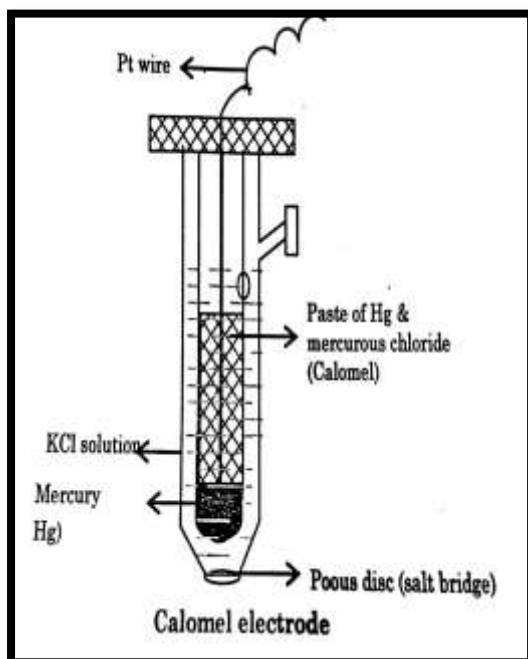
Answer 2(b) Reference Electrodes

Reference electrodes are the electrodes whose potentials are known and they are used for the determination of potentials of other electrodes.

Calomel electrode: It is a metal – metal salt ion electrodes and also a secondary reference electrode.

Construction: It consists of mercury, mercurous chloride and a solution of KCl. It is made up of glass tube, Hg is placed at the bottom of the glass tube. It is covered with a paste of calomel (HgCl_2) and KCl solution. A solution of KCl is introduced above the paste through the side tube. Electrical contact is made through Pt wire (dipped in Hg). This glass tube is taken into another glass tube, which has a side tube and a porous plug

at the bottom. This porous plug act as salt bridge. The conc of KCl solution used is either decinormal, normal or saturated. Correspondingly, the electrode is known as decinormal, normal or saturated calomel electrode. This constitutes one half cell. Calomel electrode can act as either anode or cathode. It is connected to the other half cell through salt bridge.

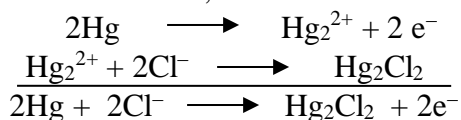


Half cell representation

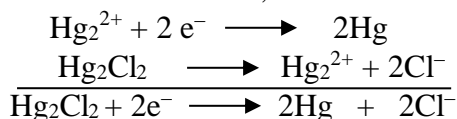
The calomel electrode is represented as, $\text{Hg} / \text{Hg}_2\text{Cl}_2 (\text{s}) / \text{Cl}^-$ (anode)
Or $\text{Cl}^- / \text{Hg}_2\text{Cl}_2 (\text{s}) / \text{Hg}$ (Cathode)

Working: Depending on the potential of electrode with which the calomel electrode is connected, calomel electrode acts as anode or cathode.

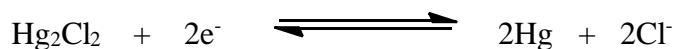
(a). When it acts as anode, electrode reaction is



(b) When it acts as cathode, electrode reaction is



Thus, Net reversible electrode reaction is



Electrode potential is calculated using Nernst equation,

$$E_{\text{cal}} = E^\circ - \frac{2.303RT}{2F} \log [\text{Cl}^-]^2$$

Applications:

1. It is used as secondary reference electrode in all potentiometric determinations.
2. Used in glass or combined electrode to determine the pH of the unknown solution.

Answer 3(a) Principle: Colorimetry is a scientific technique that is used to determine the concentration of colored compounds in solutions.

When a beam of incident light of intensity I_0 passes through a solution, a part of the incident light is reflected (I_r), a part is absorbed (I_a) and rest of the light is transmitted (I_t)

Thus, $I_0 = I_r + I_a + I_t$

In colorimeter, I_r is eliminated. For this purpose, the amount of light relected (I_r) is kept constant by using cells that have identical properties. (I_o) & (I_t) is then measured. Colorimetry measurements are based on Beer-Lambert's law which states that when a monochromatic light passes through a transparent medium, the amount of light absorbed is directly proportional to the concentration and path length of the solution.

$$A = \epsilon ct$$

Where A is absorbance, ϵ is the molar extinction coefficient, c is the concentration, t is the path length. If t, the path length is kept constant, then, $A \propto c$. Hence a plot of absorbance against concentration gives a straight line.

Instrumentation: Photoelectric colorimeter consists of

- (i) Tungsten lamp as the light source.
- (ii) A filter which provides the desired wavelength range wherein the solution gives the maximum absorbance.
- (iii) A sample cell
- (iv) A photocell detector: Detector are photosensitive elements which converts light energy into electrical energy

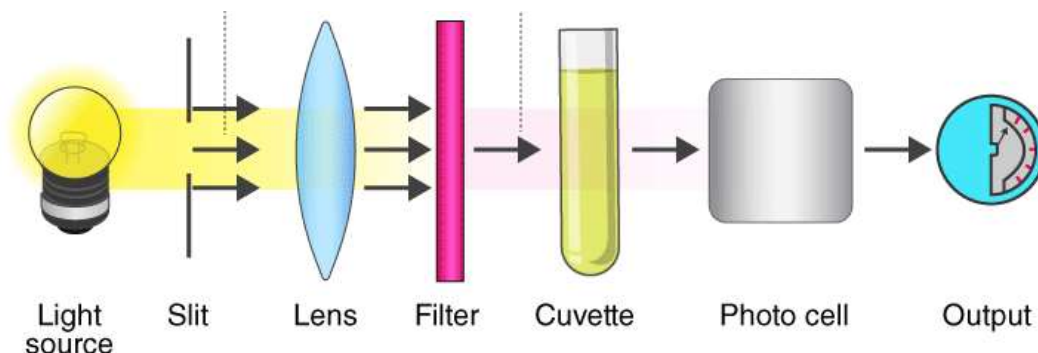
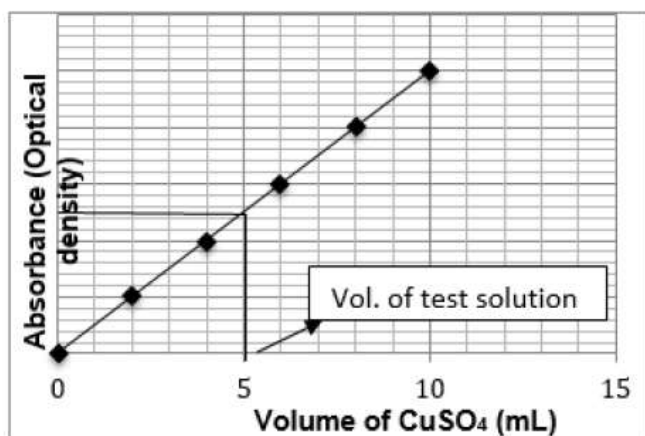


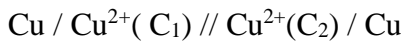
Fig: Schematic layout of colorimeter

Application: Colorimetric estimation of Cu in $CuSO_4$. Draw out 2, 4, 6, 8, and 10 ml cm^3 of the Copper sulphate solution into 50 cm^3 volumetric flask. Add 5 cm^3 of ammonia solution to each of them and dilute upto the mark with distilled water and mix well. Prepare a blank solution by diluting 5 cm^3 of ammonia solution in 50 cm^3 volumetric flasks. For test solution add 5ml of NH_3 and make up to the mark. Measure the absorbance of each of these against blank solution at 620 nm. Plot a graph of absorbance (OD) against volume of copper sulphate solution and determine the volume of copper sulphate solution in the test sample as shown in the figure and find the amount of copper present in it.

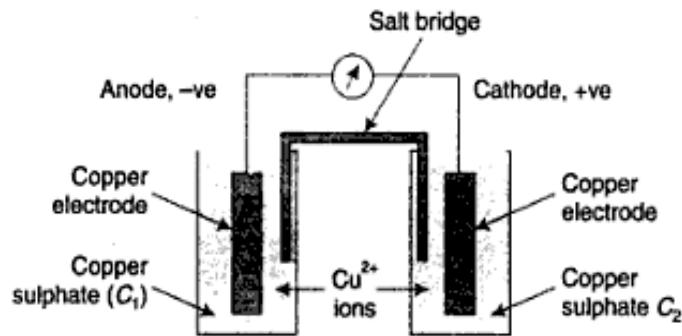


Answer 3(b) Concentration cell: In these cells, the two electrodes of same element is in contact with solution of same metal ion (electrolyte) but of different concentration.

Eg. Two copper electrodes immersed in copper sulphate solutions of different concentrations C_1 and C_2 . Cell is represented as

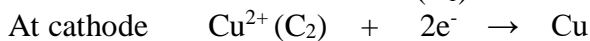
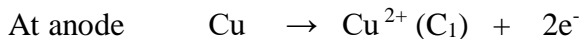


Construction:



Electrolyte Concentration cell

The Electrode reactions are as follows:



EMF of cell is given by

$$E_{cell} = E_{cathode} - E_{anode}$$

$$= \left[E^\circ + \frac{2.303RT}{nF} \log C_2 \right] - \left[E^\circ + \frac{2.303RT}{nF} \log C_1 \right]$$

$$E_{cell} = \frac{2.303RT}{nF} \log \frac{C_2}{C_1}$$

Where C_2 is the concentration at cathode while C_1 is the concentration at anode.

The following conclusions are drawn from the above eq.

1. When two solutions are of the same concentration i.e. $C_2 = C_1$, no current flows. The cell reaction is a change in concentration as a result of which current flows. Therefore cell can operate only as long as concentration terms are different.
2. For above cell to be operative, E_{cell} should be positive which is possible only if $C_2 > C_1$. Thus the direction of spontaneous reaction is from the more concentrated one to the less concentrated one.
3. In a concentration cell, electrode with lower electrolyte concentration acts as anode and the one with

higher electrolyte concentration acts as cathode. Higher the ratio $\left[\frac{C_2}{C_1} \right]$, higher is the emf.

Answer 4(a) Ion selective electrodes selectively respond to a specific ion in a mixture and potential developed is a function of concentration of that ion in the solution. These electrodes consist of a membrane which is capable of exchanging specific ions with solution with which it is in contact. These are also called as membrane electrodes. Eg. Glass electrode.

Determination of pH using glass electrode

To determine the pH of given solution, glass electrode is dipped in a solution whose pH is to be determined. It is combined with a saturated calomel electrode (ref electrode) through a salt bridge. The cell assembly is represented as



EMF of the So formed cell is determined by using electronic voltmeter.

$$E_{\text{cell}} = E_{\text{Cathode}} - E_{\text{anode}} \quad (\text{Conventionally glass electrode is cathode})$$

$$E_{\text{cell}} = E_G - E_{\text{cal}}$$

Substituting value of E_G from Eq. 5 into above equation

$$E_{\text{cell}} = E_G^\circ - 0.0591\text{pH} - E_{\text{cal}}$$

$$\text{pH} = \frac{E_G^\circ - E_{\text{cal}} - E_{\text{cell}}}{0.0591}$$

$$\text{pH} = \frac{K - E_{\text{cell}}}{0.0591} \quad \text{where, K is known as glass electrode assembly constant.}$$

E_G° value or K is evaluated by dipping the glass electrode in a solution of known pH and measuring emf of the cell formed when coupled with a calomel electrode. Next the same assembly is dipped into test solution and the pH of test solution can be determined.

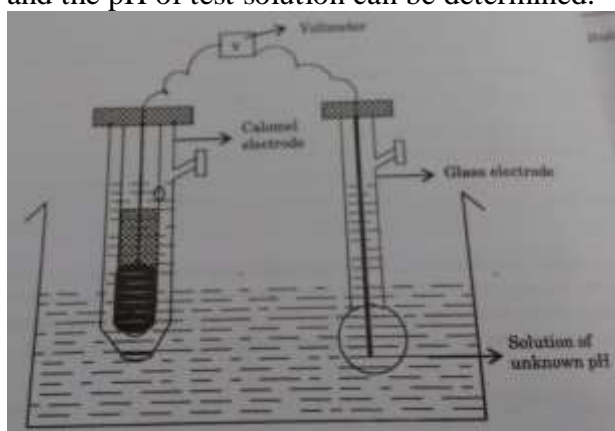


Fig : determination of pH using Glass electrode

Answer 4(b) Solution:

$$\text{Number average molecular weight} = \frac{N_1M_1 + N_2M_2 + N_3M_3}{N_1 + N_2 + N_3}$$

$$= \frac{(100 \times 1000) + (200 \times 10000) + (250 \times 100000)}{100 + 200 + 250}$$

$$= 49,272.72 \text{ g/mol}$$

$$\text{Weight average molecular weight} = \frac{N_1M_1^2 + N_2M_2^2 + N_3M_3^2}{N_1M_1 + N_2M_2 + N_3M_3}$$

$$= \frac{(100 \times 1000 \times 1000) + (200 \times 10000 \times 10000) + (250 \times 100000 \times 100000)}{(100 \times 1000) + (200 \times 10000) + (250 \times 100000)}$$

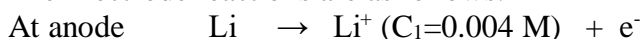
$$= 92992.61 \text{ g/mol}$$

$$\text{PDI} = \text{Mw/Mn} = 49272.72/92992.61 = 1.88$$

Answer 5(a) Concentration Cells:

Cell representation: $\text{Li(s)} / \text{Li}^+ (\text{C}_1 = 0.004 \text{ M}) // \text{Li}^+ (\text{C}_2 = x \text{ M}) / \text{Li(s)}$

The Electrode reactions are as follows:



At cathode $\text{Li}^+ (\text{C}_2 = x \text{ M}) + e^- \rightarrow \text{Li}$
 EMF of cell is given by

$$E_{\text{cell}} = \frac{2.303RT}{nF} \log \frac{C_2}{C_1}$$

$$0.180 = \frac{2.303 \times 8.314 \times 298}{2 \times 96500} \log \frac{X}{0.004}$$

$$X = 4.43 \text{ M}$$

Answer 5(b) Ion Selective electrodes These electrodes selectively respond to a specific ion in a mixture and potential developed is a function of concentration of that ion in the solution. These electrodes consist of a membrane which is capable of exchanging specific ions with solution with which it is in contact. These are also called as membrane electrodes. Eg. Glass electrode.

Glass Electrode

Construction: The glass electrode consist of glass tube, the bottom of the glass tube is glass bulb made up of very thin glass membrane. The thickness of glass membrane varies from 0.03 mm to 0.1 mm. The membrane is made up of special glass of low melting point and high electrical conductivity. Its composition is $\text{SiO}_2 - 72\%$, $\text{Na}_2\text{O} - 22\%$, $\text{CaO} - 6\%$. It can sense H^+ ions up to a pH of about 9. Glass bulb contains 0.1 N HCl (Assume concentration is C_2). An Ag/AgCl electrode (internal reference electrode) is placed in the solution and connected by a pt wire for electrical contact.

Fig: Glass Electrode

The electrode is represented as, $\text{Ag/AgCl (s) / 0.1N HCl / Glass}$

Working of glass electrode: When the glass electrode is dipped into any solution containing H^+ ions, the Na^+ ions of the glass membrane are exchanged for H^+ ions of the test solution.

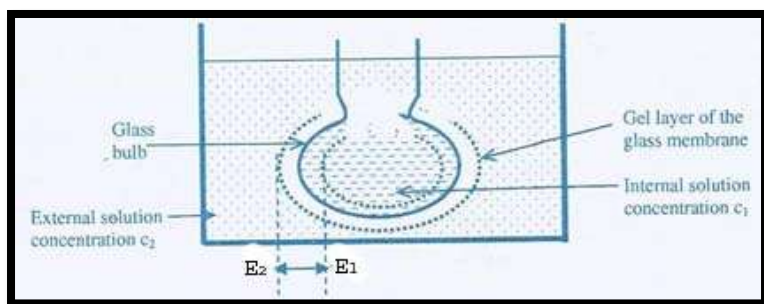
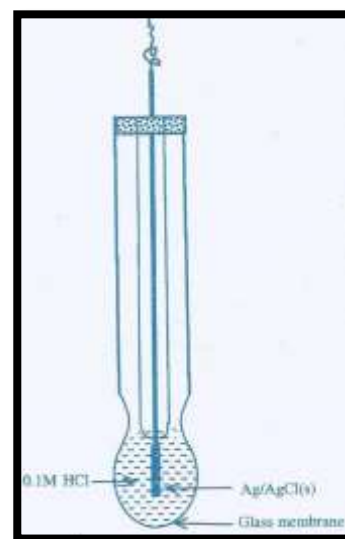


Fig : Boundary Potential ($E_b = E_2 - E_1$)

If a thin walled bulb containing an acid is immersed in another solution containing H^+ ions (fig), a potential is developed across the glass membrane. This is called the boundary potential E_b . It is a potential developed across the glass membrane when concentration of the solution inside and outside the glass membrane are different. The E_b is due to the difference in potential ($E_2 - E_1$) developed across the gel layer of the glass membrane between the two liquid.

Mathematically it is represented as,

$$E_b = E_2 - E_1$$

Where, $E_2 =$ Potential due to H^+ present in outside solution (Unknown solution)
 $E_1 =$ Potential due to H^+ present in inside solution (known solution)

According to Nernst equation

$$E_b = \frac{2.303RT}{nF} \log \frac{C_2}{C_1}$$

$$E_b = \frac{0.0591}{n} \log C_2 - \frac{0.0591}{n} \log C_1 \dots \dots \dots (1)$$

Where, C_2 is the concentration of H^+ ions of the solution into which glass membrane is dipped. The concentration of H^+ ion inside the bulb (C_1) is constant i.e. $C_1 = 0.1$ M.

Thus, $E_b = \frac{0.0591}{n} \log C_2 + K$ or

$= K + 0.0591 \log C_2$

Glass electrode selects only H^+ ions ignoring other ions.

Hence $C_2 = H^+$

$E_b = K + 0.0591 \log [H^+]$

Where, $\log [H^+] = -pH$

Thus, $E_b = K - 0.0591pH \dots \dots \dots (2)$

The combined glass electrode is dipped into acidic solution, then the potential of the glass electrode is given by....

$E_G = E_b + E_{Ag-AgCl} \dots \dots \dots (3)$

From equation 1, theoretically if $C_1 = C_2$, E_b should be 0, however it has been observed practically that even when $C_1 = C_2$, a small potential is developed which is called as asymmetric potential (E_{asym}). Hence equation 3 can be rewritten as

$E_G = E_b + E_{Ag-AgCl} + E_{asym} \dots \dots \dots (4)$

Substituting the value of E_b from equation (2) in equation (4)

$E_G = K - 0.0591pH + E_{Ag/AgCl} + E_{assy}$

$E_G = E^{\circ}_G - 0.0591pH \dots \dots \dots (5)$ Where ($E^{\circ}_G = K + E_{Ag/AgCl} + E_{assy}$)

The above expression (eq 5) indicate that the potential of glass electrode, E_G varies with the pH of the acidic solution.

Advantages of Glass electrode:

1. It can be used in presence of strong oxidizing /reducing substances and metal ions.
2. It does not get poisoned easily.
3. Equilibrium is easily attained.
4. Portable and compact.

Limitation of glass electrode:

1. It can be used up to pH 13 but becomes sensitive to Na^+ ions above pH 9 resulting in an alkaline error.
2. It does not function satisfactorily in pure alcohol.
3. It has to be handled with care because of glass electrode, and is very fragile.

Answer 6(a) Extraction of copper and gold from e-waste: The electronic waste also contains fair percentage of precious metals like Cu, Ag, Au, Pd, Rh etc. These metals can be recovered from E-waste at cheaper cost than from the usual ores. The recycling of metals such as gold and copper from discarded e-waste is an important aspect to develop the environmental friendly manufacturing processes. Techniques such as Pyrometallurgy, Hydrometallurgy and Biohydrometallurgy are used to recover precious metals like copper, silver and gold.

The extraction of copper and gold from e-waste using hydrometallurgical route comprises the liberation of the metallic fractions from downsized PCBs, a two-stage acid leaching process to provide a bulk separation of copper and gold from the other metals present, and subsequent purification of the copper and gold-containing solutions by solvent extraction using highly selective phenolic oxime and amide extractants, respectively.

Following steps are involved in the process.

1. Pre-processing: After collection of e-waste, it is segregated, delaminated, cleaned with water and acetone and treated with N,N-dimethylacetamide (DMA) to remove the organic components (epoxy resins) present in the e-waste. This pretreated e-waste is shredded into small pieces and powdered, further it is subjected to recovery of precious metals. The metals were dissolved in acid and non-metallic component such as plastic and ceramic is separated by filtration.

2. Leaching: The liberated metallic fraction collected from the pre-processing step was leached in two stages to provide a bulk separation of copper and gold from the other metals present.

(i) First stage leaching process involves the selective dissolution of copper over gold. The samples were dissolved in dilute nitric acid, which almost exclusively leached the copper.

(ii) The filtered residue was then subjected to a second stage leaching process using sulfuric acid and halide salts (NaCl, NaBr) to selectively dissolve, silver and tin.

3. Solvent extraction:

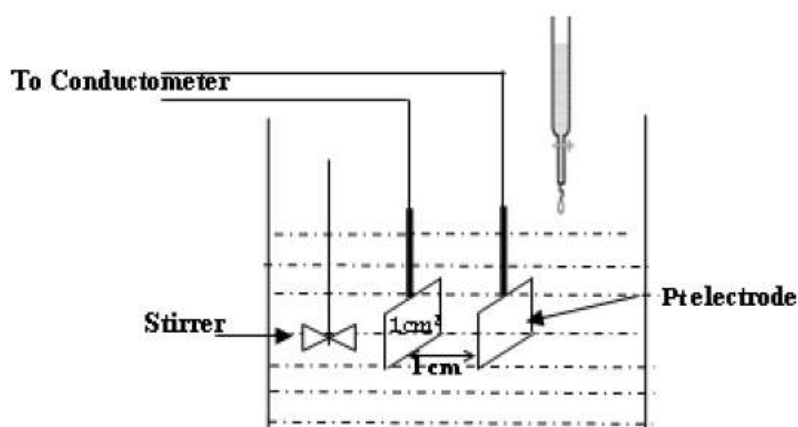
(i) Recovery of Cu: Distilled water and ammonia solution was added to the leach solutions obtained after stage-one leaching process. To selectively recover the copper, the phenolic oxime dissolved in kerosene was used as the extractant. The Cu metal loaded organic phase was separated from the acidic aqueous leach liquor and washed with either sulfuric acid or nitric acid.

(ii) Recovery of Au: In the second-stage solvent extraction, an organic amide diluted in toluene was used as the extractant. The gold-loaded organic phase was then separated from the aqueous phase and stripped of the metal using either water or sodium hydroxide.

Answer 6(b) Principle: Conductometry is based on Ohm's law which states that the current i (amperes) flowing in a conductor is directly proportional to the applied electromotive force, E (volts), and inversely proportional to the resistance R (ohms) of the conductor. The reciprocal of the resistance is called the conductance (Ease with which electric current flows

through a conductor). Specific conductance of a solution is defined as the conductance of a solution present between two parallel electrodes which have 1cm^2 area of cross section and which have kept 1cm apart. The conductance of solution depends on the number and mobility of ions. The substitution of ions with different ionic mobility affects the electrolytic conductivity. Therefore, the equivalence point can be determined by means of conductivity measurement for a neutralization reaction between an acid and a base. Equivalence point is determined graphically by plotting conductance against titer values.

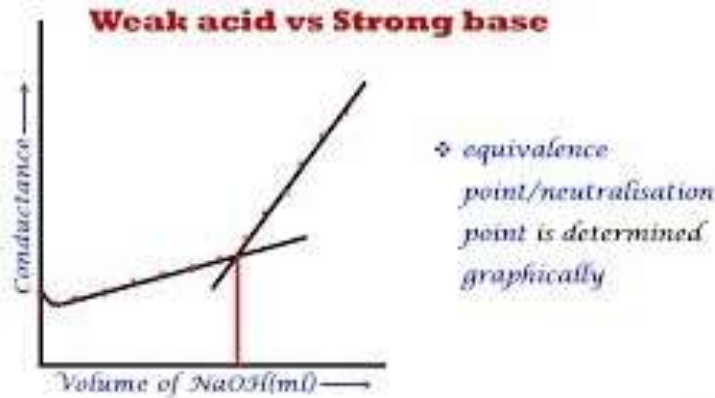
Instrumentation: Conductometer consists of: (1) conductivity cell having two platinum electrodes; and a (ii) conductometer. A simple arrangement of conductometric titration is depicted in figure. The solution to be titrated is taken in the beaker.



Application in the

estimation of weak: Pipette out 50ml of sample into a beaker. Immerse the conductivity cell into it. Connect the conductivity cell to a conductivity meter and measure the conductance by adding NaOH from the burette by increment of 1 ml. Plot a graph of conductance against volume of NaOH. Determine the neutralization point from the graph as shown below.

Weak acid with a strong base: (CH₃COOH Vs NaOH): In the conductometric titration of a weak acid with a strong base, the conductance of the acid will be initially low due to poor dissociation of acetic acid. On complete neutralization of the acid, further addition of base leads to an increase in the number of more mobile OH⁻ ions. Hence conductance increases sharply.



Answer 7(a) Graphene Oxide

- Graphene oxide (GO) is a layered carbon structure with oxygen-containing functional groups (=O, -OH, -O-, -COOH) attached to both sides of the layer as well as the edges of the plane.
- As with any 2D carbon material, GO can also have either single layer or multilayer structure.
- A structure with one layer is graphene oxide; two layers of graphene oxide are referred to as a two-layered GO, GO with five to ten layers is called multi layered GO, and material with eleven or more layers is called graphite oxide.
- In contrary to graphene, GO is hydrophilic, and it is hence relatively simple to prepare a water- or organic solvent-based suspensions.
- Highly oxidized forms of GO are electric insulators with a bandgap of approximately 2.2 eV.
- Simplistically, GO is a monolayer sheet of graphite containing hydroxyl, carboxyl, and epoxy oxygen groups on its basal plane and edges, resulting in a mixture of sp² and sp³ hybridized carbon atoms.

Properties of Graphene Oxide:

- The properties of graphene can be changed by the functionalization of graphene oxide. The chemically-altered graphene's could possibly be used in several applications.
- Graphene Oxide has a high surface area, and so it can be fit for use as electrode material for batteries, capacitors and solar cells.
- Graphene Oxide is cheaper and easier to manufacture than graphene, and so may enter mass production and use sooner.
- GO can easily be mixed with different polymers and other materials, and enhance properties of composite materials like tensile strength, elasticity, conductivity and more.

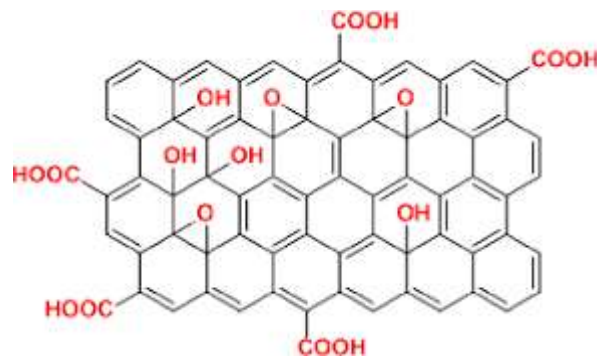
Synthesis of Graphene Oxide:

- There are several ways to prepare graphite oxide/graphene oxide. The most common way is to use an oxidizing agent in an acidic environment.
- In this procedure, phosphoric acid is mixed with sulphuric acid in the ratio 1:9 and potassium permanganate and graphite added in the ratio 6:1 in an ice bath.
- The mixture is then heated at 50°C and stirred for 12 h
- After cooling down, the mixture is poured onto ice
- Finally, 30% H₂O₂ is added in order to remove the excess of potassium permanganate.

- Phosphoric acid works as a dispersive and etching agent, as well as a stabilizer of the oxidation process, which makes the synthesis of GO safe.
- This route produces a higher yield of GO with a higher level of oxidation and a more regular structure.

Applications of Graphene Oxide:

- Air pollution caused by the industrial release of harmful gases such as CO₂, CO, NO₂, and NH₃.
- GO can be employed in catalysis for converting polluting gases during industrial processing.
- The approach of GO application in this area can be divided into two paths: pollutant adsorption and conversion.
- The functional groups of few-layered GO composites exhibit unique adsorption behaviour towards different gases like acetone, formaldehyde, H₂S, SO₂, and NO_x can be adsorbed by GO-based composites.
- GO exhibits high adsorption ability towards Cd(II), Co(II), Au(III), Pd(II), Ga(III), and Pt(IV).
- Adsorption ability mainly depends on the synthesizing method. Multilayered graphene oxide nanosheets show a very high affinity towards Pb(II) ions, with a sorption capacity of about 842 mg g⁻¹ at 293 K.
- Small-molecule drug delivery seems to be another promising medical application of GO. Small molecules of drugs can be attached to a GO surface using pH-sensitive linkers.



Answer 7(b) Thermometric sensor quantify the quantity of heat energy or even coldness produced by an item or system, allowing us to “sense” or detect any physical change in that temperature, generating an analog or digital output.

Classification:

The temperature sensor is one of the most frequently used sensors, which is widely used in computers, automobiles, kitchen appliances, air conditioners, and household thermostats. The five common types of temperature sensors include,

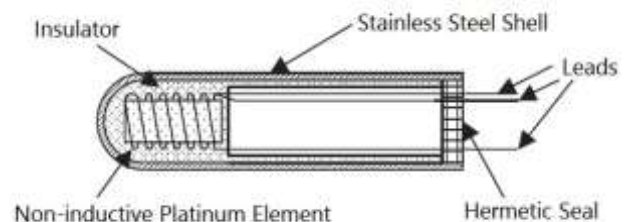
- Thermocouples,
- Thermistors,
- RTDs (Resistance Temperature Detectors),
- Analog thermometer IC, and
- Digital thermometer IC.

Working principle:

Different types of temperature sensors have different working principles:

Resistance temperature detectors (RTD) measures the temperature according to the rule that the resistance of the conductor changes with temperature. The temperature-sensing element of resistance thermometers are commonly made of metal wires as platinum and copper, and at low temperatures, carbon, germanium, and rhodium iron are often used for the element. Because they are almost made of platinum, we often call them platinum resistance thermometers.

As the temperature changes, the resistance value of the metal also changes. And for different metals, the resistance value changes differently with the temperature, which can be directly used as the output signal.



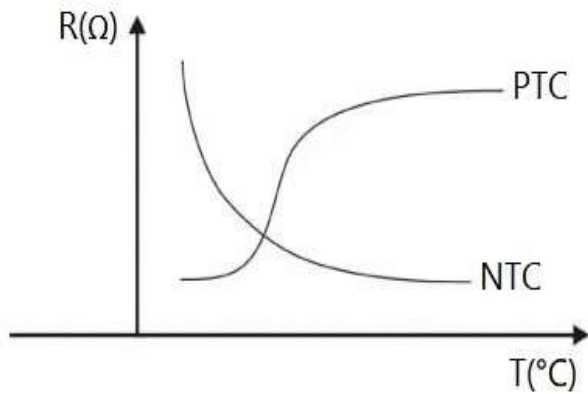
Resistance changes in 2 different ways:

Positive temperature coefficient

- temperature increases & resistance increases
- Temperature decreases & resistance decreases

Negative temperature coefficient

- temperature increases & resistance decreases
- Temperature decreases & resistance increases



Application:

1. Sensing Application - The thermal conversion method of temperature sensors is often used to measure physical quantities, such as flow rate, radiation, gas pressure and type, humidity, thermochemical reaction, etc.
2. Biomedical Domain - Special temperature sensors are often applied for biomedical applications. These temperature sensors have low power consumption, long-term stability, and high reliability, with an accuracy of less than 0.1°C between 32°C and 44°C
3. Industrial Application - Integrated temperature sensors can be applied in automation and microbe thermal detection.
4. Consumer Products - Many low-cost integrated temperature sensors and transmitters have been used in consumer products such as washing machines, refrigerators, and air conditioners.