Solution for IAT 1 (BCHEE102) October 2023

Internal Assessment Test 1 – Oct-2023

Sub:	Chemistry					Sub Code:	BCHEE102	Branch:	ECE
Date:	31-10-2023	Duration:	90 min’s	Max Marks:	50	Sem / Sec:	I / M, N, O & P		OBE

		Question no. 1 is COMPULSORY and answer any THREE FULL Questions from the rest.	MARKS	CO	RBT
1	(a)	Define corrosion. Explain the electrochemical theory of corrosion taking rusting of iron as example.	[7]	CO3	L3
	(b)	What are photovoltaic cells? Explain construction and working of PV cells and mention its advantages	[7]	CO2	L3
2	(a)	Describe construction, working and applications of Li polymer battery.	[6]	CO2	L2
	(b)	What are fuel cells? Explain construction and working of methanol-oxygen fuel cell.	[6]	CO2	L2
3	(a)	Discuss classification of batteries with suitable examples.	[6]	CO2	L1
	(b)	Discuss the construction and working of polymer electrolyte fuel cell and mention its applications.	[6]	CO2	L2

4	(a)	Define battery. Explain construction and working of Na-ion battery with charge and discharge reactions.	[6]	CO2	L2
	(b)	Discuss in detail the type of corrosion taking place in the following cases: (i) A steel screw in tin sheet for a long time (ii) Uneven deposition of dust over the metal surface	[6]	CO2	L3
5	(a)	Discuss the methods of disposal of e-waste.	[6]	CO3	L3
	(b)	What is cathodic protection for controlling corrosion? Explain sacrificial method of corrosion control.	[6]	CO3	L1
6	(a)	What is anodizing? Discuss the anodizing of aluminium.	[6]	CO3	L3
	(b)	What is e-waste ? Discuss effects of e-waste on environment and human health.	[6]	CO3	L2
7	(a)	What is e-waste ? Discuss effects of e-waste on environment and human health.	[6]	CO3	L1
	(b)	Define corrosion penetration rate (CPR). A thick steel sheet of area 450 cm^2 is exposed to air near the ocean. After 2 years it was found to experience a weight loss of 365 gm due to corrosion. Calculate CPR in mpy and mmy. [Density of the metal is 7.9 gm/cm^3, K(mpy) = 534 and K (mm/y) = 87.6].	[6]	CO3	L3

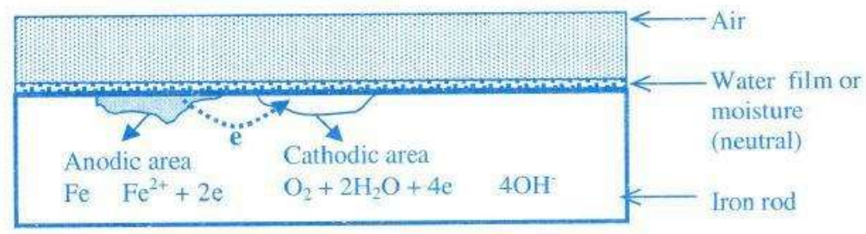
(Chief Course Instructor)

Answer 1(a) :

Definition: Corrosion is defined as the **destruction of metal or alloys from its surface by the surrounding environment through chemical or electrochemical changes**.

Eg. 1. Rusting of Fe- A reddish brown scale formation on iron. It is due to the formation of hydrated ferric oxide.

Electrochemical theory of corrosion: Most of the corrosion problems are best explained on the basis of electrochemical theory.



(i) According to electrochemical theory, corrosion of metals takes place due to the formation of minute galvanic cells over the surface of metal. Thus anodic and cathodic regions are formed on the same metal surface or when two metals are in contact with each other in the presence of a conducting medium.

(ii) At the anodic region oxidation reaction takes place and the **metal gets converted into its ions by liberating electrons**. Consequently, **metal undergoes corrosion at the anodic region**.

$$M \longrightarrow M^+ + ne^-$$

Ex: $Fe \longrightarrow Fe^{2+} + 2e^-$

(iii) The electrons flow from the anodic to cathodic area and at the cathodic region, reduction takes place. Since metal cannot be reduced further**, metal atoms at the cathodic region are unaffected by the cathodic reaction**. Some constitutions of the corrosion medium take part in the cathodic reaction. There are three possible ways in which the reduction can take place.

(i) If the solution is aerated and almost neutral, oxygen is reduced in presence of water to OH- ions according to the equation.

$$\frac{1}{2}O_2 + H_2O + 2e^- \longrightarrow 2OH^-$$

(ii) If the solution is deaerated and almost neutral the cathodic reaction involves formation of hydroxyl ions with evolution of hydrogen gas.

$$2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$$

(iii) If the solution is deaerated and acidic, the H^+ ions are reduced to H_2

$$2H^+ + 2e^- \longrightarrow H_2 \uparrow$$

(iv) The electrons liberated at the anodic region migrates to the cathodic region constituting corrosion current, the metal ions liberated at the anode and some anions liberated at the cathode diffuse towards each other through the conducting medium-range and form a corrosion products.

Corrosion of iron produced Fe^{2+} ions and OH^- ions at the anode and cathode sites respectively. These ions diffuse towards each other and produce insoluble $Fe(OH)_2$.

$$Fe^{2+} + 2OH^- \longrightarrow \underset{\text{(Ferrous hydroxide)}}{Fe(OH)_2}$$

In an oxidizing environment, it is oxidized to ferric oxide and the rust is hydrated ferric oxide.

$$2Fe(OH)_2 + \frac{1}{2}O_2 + (n-2)H_2O \longrightarrow [Fe_2O_3.nH_2O]\ [\text{Rust}]$$

Corrosion of metal continues as long as both anodic and cathodic reactions take place simultaneously.

Answer 1(b) :

Photovoltaic Cells:

Photovoltaic cells or solar cells are semiconductor device that converts sunlight into direct current (DC) electricity. As long as light is shining on the solar cell, it generates electrical power. When light stops, electricity stops.

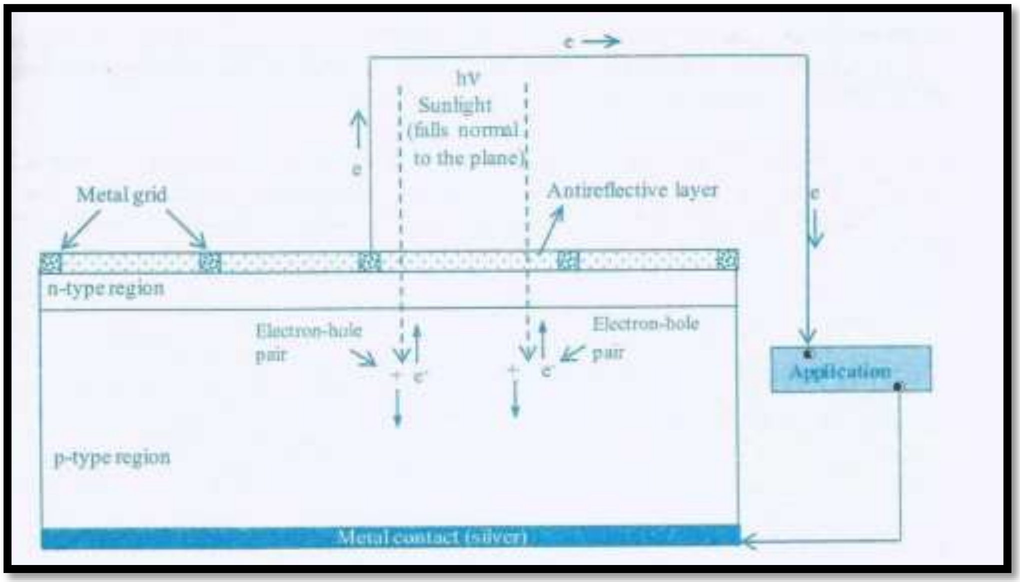


Figure Photovoltaic cells

Construction & Working of Photovoltaic Cells

Construction:

- Photovoltaic Cells consist of a semiconductor diode (p-n junction) made of a silicon.
- Silicon wafer or very thin silicon slices are made by silicon blocks and they are doped by p-type and n-type dopents to make p-n junction.
- It has two electrical contact, on one of its sides, a metallic grid is used and on the other side a layer of noble metal (such as Ag) is used.
- The metal grid permits the light to fall on the diode between the grid lines.
- The part between the metallic grid is coated with antireflective compound. eg TiO_2

Working:

- Electromagnetic radiation consists of particle called photon (hv). They carry a certain amount of energy given by the Plank quantum equation.

$$E = hc/\lambda$$

Where, h = Planck's constant, c = velocity of light, λ = wavelength of the radiation

- The electromagnetic radiation (sunlight) falls normal to the plane of the solar cell, the photons which possess energy sufficient to overcome the barrier potential are absorbed, electrons are ejected and electron-hole pairs are formed.
- The electrons move towards the n-region (as it is positively charged). The electrons are driven into the external circuit and used for various applications or appliances.

Advantage of Photovoltaic cells -

1. It is unlimited, inexhaustible and renewable source of energy.
2. The solar cell operates reliably for a long period of time with no maintenance.
3. A photovoltaic system can be constructed to any size based on energy requirement.
4. Easy to operate
5. Quick installation.
6. Can be integrated into new or existing building structure.
7. Completely pollution free during its use.

Disadvantage of Photovoltaic cells –

1. High installation cost.
2. Energy can be produced only during the day-time.
3. The efficiency of solar cells depends on the seasonal variations, latitude and climate.
4. Space required to generate unit power output is relatively more.
5. Solar cell generates DC current. It needs to be converted to AC for use.

Answer 2a:

Lithium polymer (LiPo) Batteries

LiPo batteries are composed of a lithium-based cathode and anode separated by a polymer electrolyte. LiPo batteries differ from other lithium-ion (Li-ion) batteries in that they have a solid polymer electrolyte component rather than a liquid electrolyte. Common polymer electrolytes may be dry, porous or a gel, and include poly(methyl methacrylate) (PMMA), poly(acrylonitrile) (PAN), poly(vinylidene fluoride) (PVdF), and poly(ethylene oxide) (PEO).

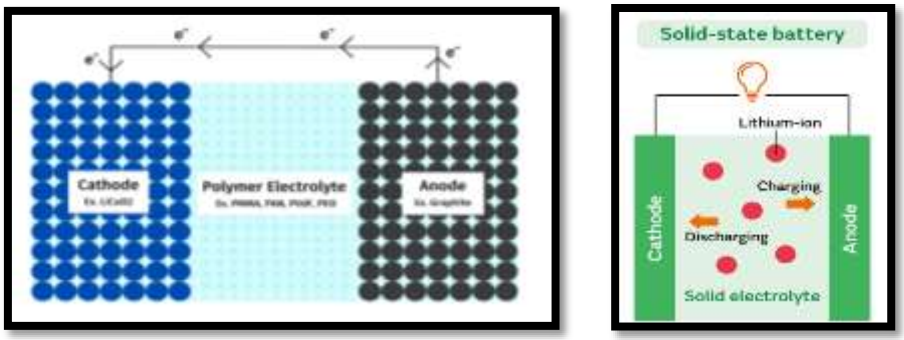


Figure: LiPo Battery

Construction:

Anode: Lithium intercalated Carbon or graphite

Cathode: lithium transition metal oxides (such as lithium-cobalt oxide ($LiCoO_2$)),

Electrolyte & Separator: High conductivity semisolid (gel) polymers electrolyte polymer electrolytes and include poly(methyl methacrylate) (PMMA), poly(acrylonitrile) (PAN)

Working:

At anode: $$Li_xC_6 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} xLi^+ + xe^- + C_6$$

At cathode: $$LiCoO_2 + xLi^+ + xe^- \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} Li_{1+x}\,CoO_2$$

Overall cell reaction: $$xLiC_6 + Li\,CoO_2 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} Li_{1+x}\,CoO_2 + xC_6$$

Applications: These batteries provide higher specific energy than other lithium battery types and are used in applications where weight is a critical feature, such as mobile devices, radio-controlled aircraft and some electric vehicles.

Answer 2b.

Definition: A fuel cell is a device that converts the chemical energy of a fuel (hydrogen, natural gas, methanol, gasoline, etc.) and an oxidant (air or oxygen) into electricity.

Construction, working and applications of methanol–oxygen fuel cell.

It is good example for liquid fuel cell. They use either acidic or alkaline medium. The preferred electrolyte is the acidic. Methanol is an efficient active organic fuel at low temperature.

Construction: Methanol – oxygen fuel cell consist of

1. Anode – It is a porous Nickel (Ni) electrode impregnated with Pt/Pd catalyst.
2. Cathode - It is a porous Nickel (Ni) electrode coated with silver (Ag) catalyst.
3. Electrolyte – Aqueous sulphuric acid (H_2SO_4), 3.7 M.
4. Active components: (a) Fuel – Methanol mixed with sulphuric acid supplied at anode. (b) Oxidant – Pure oxygen is supplied at cathode.

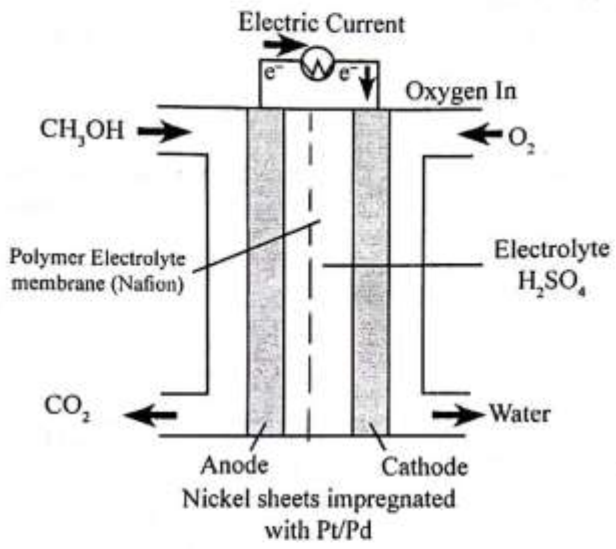


Figure: Methanol – oxygen fuel cell

Working:

Cell reaction;

Anode Reaction: $CH_3OH + H_2O \longrightarrow CO_2 + 6H^+ + 6e^-$

Cathode Reaction**:** $3/2\ O_2 + 6\ H^+ + 6e^- \longrightarrow 3\ H_2O$

Overall Cell Reaction: $CH_3OH + 3/2\ O_2 \longrightarrow CO_2 + 2\ H_2O$

H_2O and CO_2 are formed as by-products but they do not harm the cell functioning because they are removed as and when they are formed.

Cell Potential : 1.2 V

Applications:

1. used in automobiles, military applications.
2. Power backup and portable instruments.
3. In large scale power production.

Answer 3a.

Classification of Batteries

Batteries are classified under the following categories:

● **Primary battery:** In primary batteries, chemical energy stored in the battery is converted to electrical energy spontaneously as long as active materials are present. This battery cannot be recharged, because cell reaction is irreversible. *Example:* Zn-MnO_2 battery, Li-MnO_2 battery.

● **Secondary battery:** This battery can be recharged by passing electric current, because cell reactions are reversible. The redox reaction is reversed during recharing. Electrical energy is stored in the form of chemical energy in these batteries and used when needed. *Example:* Lead acid battery, Ni-MH battery, Li-ion battery. Primary cells act only as galvanic cell, whereas, a secondary cell can act both as galvanic cell and electrolytic cell. During discharging it acts as galvanic cell converting chemical energy to electrical energy and during charging process it acts as electrolytic cell converting electrical energy to chemical energy

● **Reserve battery:** In this battery, one of the key component is stored separately, and is incorporated into battery when required. When long storage is required, reserve batteries are often used, since the active component of the cell is separated until needed, thus reducing self-discharge. *Example:* Mg-AgCl battery. They are activated by adding sea water. These batteries have high reliability and long shelf life, hence they find applications in missiles and submarines. Another example is zinc-air batteries where the cell is sealed until use, the seal is removed to admit air and activate the cell when needed.

Answer 3b.

Construction, working and applications of polymer electrolyte fuel cell.

Polymer electrolyte fuel cells (PEFC) are electrochemical devices, converting the chemical energy of fuel directly into electrical energy. They are also known as Polymer electrolyte membrane (PEM) fuel cells or proton exchange membrane fuel cells. They deliver high power density and offer the advantages of low weight and volume compared with other fuel cells.

Construction: A PEFC comprising a proton-conductive solid polymer electrolyte membrane of thickness 50–180 μm and porous carbon electrodes containing a platinum or platinum alloy catalyst (Figure). The most typical polymer electrolyte membrane is the perfluorosulfonic-acid-type ion exchange membrane such as Nafion, which has a molecular structure based on a main polytetrafluoroethylene chain with side chains containing sulfonic acid. Pure hydrogen or hydrogen reformed from methanol or natural gas is used as fuel.

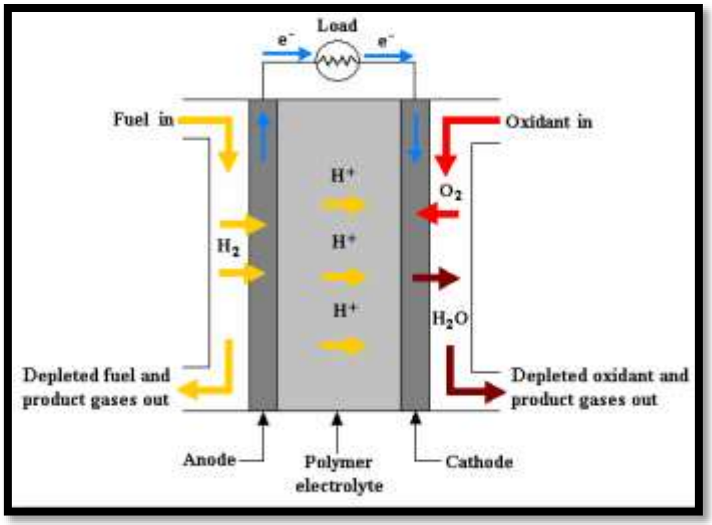


Figure: Polymer electrolyte fuel cell

Working:

Hydrogen supplied to the anode side is oxidized, and produced H^+ moves through the membrane to the cathode side. This H^+ is used in the reaction in which water is formed by the reduction of oxygen supplied to the cathode side. As the electrons generated at the anode flow through the external circuit to arrive at the cathode, an electric current can be retrieved. The reactions at the anode and cathode, and the overall reaction, are given as follows.

Anode: $H_2 \rightarrow 2H^+ + 2e^-$

Cathode: $\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$

Overall reaction: $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$

Applications: Polymer electrolyte fuel cells (PEFCs) are of interest as power sources in vehicles and portable applications because of their high energy efficiency and environmentally friendly qualities.

<u>**Answer 4a.**</u> Battery is a device which convert chemical energy into electrical energy on demand through redox titrations. OR

Battery is a device consisting of two or more galvanic cells arranged in series or parallel or both, that can generate electrical energy.

Construction:

Anode: Non-graphitic anodes, which consist largely of various carbonaceous materials (such as carbon black, pitch-based carbon-fibers, hard carbons etc)

Cathode: layer and tunnel type transition metal oxides, transition metal sulfides and fluorides etc

Electrolyte: The most common electrolyte formulations for SIBs are $NaClO_4$ or $NaPF_6$ salts in carbonate ester solvents (particularly propylene carbonate).

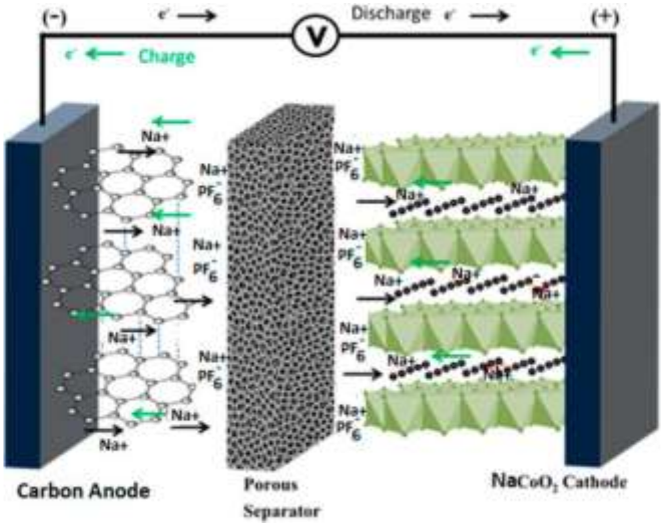


Figure. Na-ion Battery (SIB)

Working principles of SIBs

When the battery is being charged, Na atoms in the cathode release electrons to the external circuit and become ions which migrate through the electrolyte toward the anode, where they combine with electrons from the external circuit while reacting with the layered anode material. This process is reversed during discharge.

At anode:

$$Na_xC_6 \xrightleftharpoons[\text{Charge}]{\text{Discharge}} xNa^+ + xe^- + C_6$$

At cathode:

$$NaMO_2 + xNa^+ + xe^- \xrightleftharpoons[\text{Charge}]{\text{Discharge}} Na_{1+x}MO_2 + C_6$$

Overall cell reaction:

$$Na_xC_6 + NaMO_2 \xrightleftharpoons[\text{Charge}]{\text{Discharge}} Na_{1+x}MO_2 + C_6$$

Answer: 4b.

Vanadium redox flow battery: The vanadium redox battery (VRB), also known as the vanadium flow battery (VFB) or vanadium redox flow battery (VRFB), is a type of rechargeable flow battery. It employs vanadium ions as charge carriers.

Construction: A vanadium redox battery consists of an assembly of power cells in which two electrolytes are separated by a proton exchange membrane.

Electrodes: The electrodes in a VRB cell are carbon based. The most common types are carbon felt, carbon paper, carbon cloth, and graphite felt. Recently, carbon nanotube-based electrodes have attracted interest from the scientific community.

Electrolytes: Both electrolytes are vanadium-based. The electrolyte in the positive half-cells contains VO_2^+ and VO^{2+} ions, while the electrolyte in the negative half-cells consists of V^{3+} and V^{2+} ions. The electrolytes can be prepared by several processes, including electrolytically dissolving vanadium pentoxide (V_2O_5) in sulfuric acid (H_2SO_4). The solution remains strongly acidic in use.

Membrane: The most common membrane material is perfluorinated sulfonic acid (PFSA) (Nafion). polytetrafluoroethylene (Teflon).

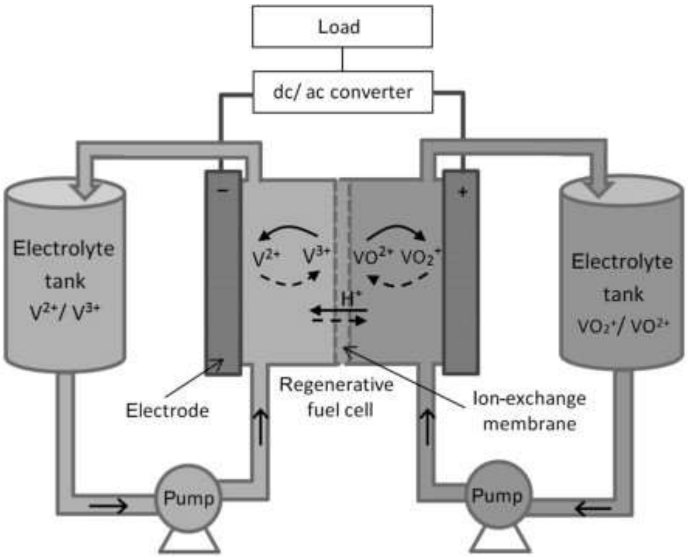


Figure. A diagram of a vanadium redox flow battery

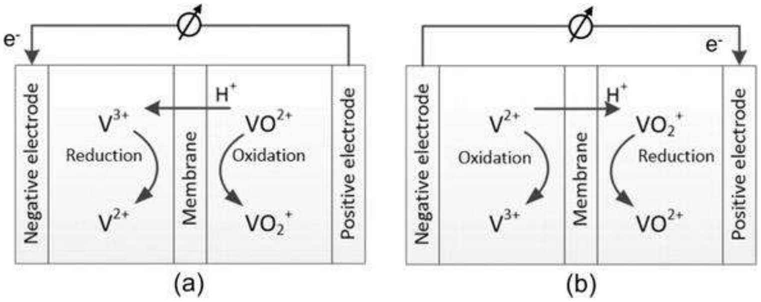


Figure. Vanadium redox flow battery: (a) charge reaction and (b) discharge reaction.

Working:

At Anode: $V^{2+} \overset{\text{Discharge}}{\underset{\text{Charge}}{\longleftrightarrow}} V^{3+} + e^-$

Positive electrode: $VO_2^{+} + e^{-} + 2H^{+} \xleftrightarrow[\text{Charge}]{\text{Discharge}} VO^{2+} + H_2O$

Overall reaction: $VO_2^{+} + V^{2+} + 2H^{+} \xleftrightarrow[\text{Charge}]{\text{Discharge}} VO^{2+} + V^{3+} + H_2O$ $(E^0 = 1.26\text{ V})$

Application: Vanadium batteries are typically used for grid energy storage, i.e., attached to power plants/electrical grids.

Answer 5a

(i) The type of corrosion which takes place when steel screw is in contact with Sn sheet is Differential metal corrosion (Galvanic corrosion)

- Differential metal corrosion arises when two dissimilar metals are in contact with each other. Under this condition a potential difference is set up resulting in a galvanic current.
- A metal placed high in the electrochemical series is said to be anodic to the one placed below it.
- In this case steel screw (Fe) acts as anode and tin acts as cathode.
- A galvanic cell forms in this cell, and electrons flow from steel screw (Fe) to Sn, indicating that Fe is the anode and Sn is the cathode. The reaction that take place as follows-

$$Fe \longrightarrow Fe^{2+} + 2e^{-} \quad \text{(anode)}$$

$$\tfrac{1}{2} O_2 + 2H_2O + 2e^{-} \longrightarrow 2OH^{-}$$

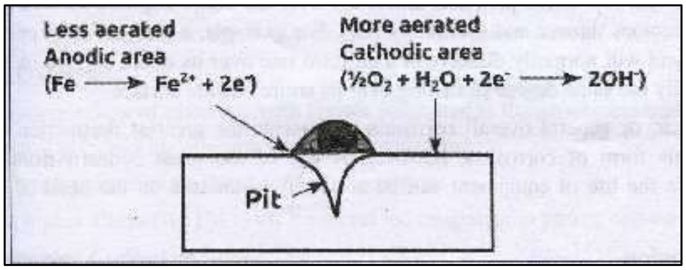
$$Fe^{2+} + 2\,OH^{-} \longrightarrow Fe(OH)_2$$

(Ferrous hydroxide)

$$2\,Fe(OH)_2 + (n-2)\,H_2O + \tfrac{1}{2} O_2 \longrightarrow [Fe_2O_3.nH_2O]\ [\text{Rust}]$$

Fig. Corrosion in Bimetallic couple

(ii) The type of corrosion which takes place when dust is deposited unevenly is known as pitting corrosion. It is an example of differential aeration corrosion.



Pitting corrosion results when small particles of dust get deposited on a steel surface. The portion covered by the dust will not be well aerated compared to the exposed surface. The covered portion acts as anode with respect to the surface exposed. Once a pit is formed the rate of corrosion increases. This is because of the formation of small anodic area. The cathode induces the small anodic area to corrode faster by accepting electrons from the anodic are resulting in the enlargement of the pit.

A galvanic cell forms and reaction that take place are as follows-

$$Fe \longrightarrow Fe^{2+} + 2e^- \quad \text{(anode)}$$

$$\frac{1}{2} O_2 + 2H_2O + 2e^- \longrightarrow 2OH^-$$

$$Fe^{2+} + 2\,OH^- \longrightarrow Fe(OH)_2$$

(Ferrous hydroxide)

$$2\,Fe(OH)_2 + (n-2)\,H_2O + O_2 \longrightarrow [Fe_2O_3.nH_2O]\ \text{[Rust]}$$

<u>Answer 5b</u> Methods of disposal of E-waste:

To avoid the toxic effects of e-waste, it is crucial to dispose them in proper manner, so that items can be recycled, refurbished, resold, or reused.

Following methods are used to dispose e-waste:

Landfills: This is the most commonly used method of disposing e-waste. In this method, large trenches are made in the soil to bury e-waste. But this is not a good method to dispose e-waste because e-waste contains toxic substances like lead, mercury, etc., that leak into the earth and harm the underground water and soil. Incineration: It is also the most commonly used method to dispose of e-waste. In this method, the e-waste is burned at high temperatures in specially designed incinerators. Due to which the volume of e-waste is reduced and the energy produced by this method is also utilized separately. But this is also not a good method because when the e-waste burns, it releases harmful gases which harm our environment.

Acid Bath: In this method, the e-waste is soaked in powerful sulphuric, hydrochloric, nitric acid solutions that remove the metal from the e-waste. The recovered metal is further reused to create other products. This method also has drawbacks, like the acid solutions sometimes dumped into the water resources which is harmful for living things.

Recycling: This is the most efficient method and also environmentally friendly. Recycling involves dismantling, processing and end processing. In this method, separation is done to recover used circuit boards, ICs, motherboard, etc from the e-waste and recycle them. Precious metals like copper, lead, etc., are separated from the e-waste using a PCB recycling machine without harming the environment.

Re-use: It includes direct second hand use or use after slight modifications to the original functioning equipment like Inkjet cartridge is used after refilling. Old working computers can be donated to schools or organization working in the field of education. Computers beyond repairs can be returned back to the manufacturers. This can considerably reduce the volume of E-Waste generation converted into less hazardous compounds.

Answer 6a

CATHODIC PROTECTION: Cathodic protection is a method of protecting a metal or alloy from corrosion by converting it completely into cathodic and no part of it is allowed to act as anode. This can be achieved by providing electrons from an external source.

Principle: Metals normally undergo corrosion by electrochemical process with the formation of anodic and cathodic regions in contact with each other. The corrosion of metal takes place at the anodic region whereas at the cathodic region the metal is unaffected. Therefore, corrosion can be prevented by eliminating the anode sites and converting the entire metal into cathodic area.

There are two methods of cathodic protection.

(i) Sacrificial anodic method.

(i) Sacrificial anodic method:

In this method, the base metal structure is converted into a cathode by connected it to a more active [higher up in galvanic series or less noble] metal. This active metal actually acts as an auxiliary anode. Mostly Zn, Mg, Al are the common auxiliary anodes used in this method. These metals being more active, acts as anode and undergo destruction and protect the metal structure. Since the anode material sacrifice to protect the metal structure, the method is known as sacrificial anode method. After continuous use exhausted sacrificial anodes are replaced by new ones as and when required. Eg: A Mg/ Zn block connected to buried oil storage tank, Mg/Zn base areas fixed to the side of ocean going ships, Mg/ Zn blocks area connected to the buried pipe lines.

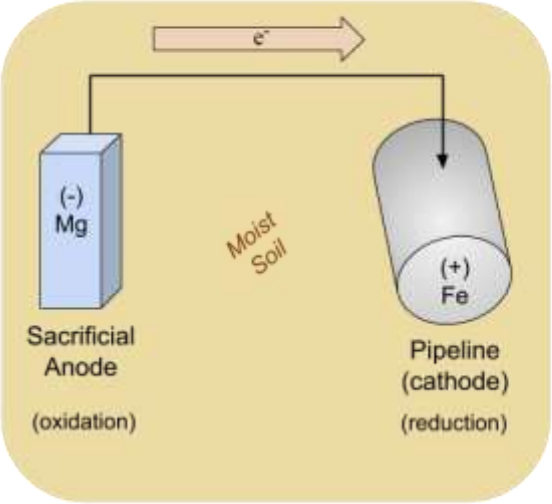


Fig: Cathodic Protection by sacrificial anode

Advantage:
(i)The method is simple.
(ii) low installation cost.
(iii) minimum maintenance cost.
(iv) Doesn’t require power supply.

Disadvantages: Involves recurring expenditure for Replacement of consumed anodes.

Answer 6b

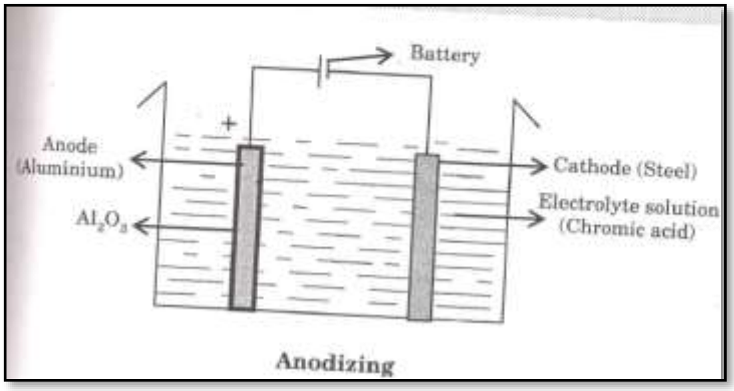
Anodizing : It is a process in which a protective passive oxide film is artificially (chemically or electrochemically) produced on certain metals. It is also called as anodic oxidation process.

Anodized coating is generally produced on non ferrous metals like Al, Zn, Mg and their alloys by anodic oxidation process.

In anodizing of aluminium, clean, polished aluminium is taken as anode and immersed in an electrolytic cell containing chromic acid or sulphuric acid. Inert electrodes like lead is generally used as cathode. The anodic oxide film formed on Al as aluminium oxide, which is porous. The pores are finally sealed by dipping in hot water to produce $Al_2O_3 \cdot H_2O$, which acts as a non-porous protective layer preventing corrosion.

Anode reaction: $2Al + 3H_2O \rightarrow Al_2O_3 + 6H^+ + 6e^-$

Cathode reaction: $6H^+ + 6e^- \rightarrow 3H_2$



Anodizing

Answer 7a:

Definition: E-waste or electronic waste means discarded electrical or electronic devices or components.

Effects of e-waste on environment and human health: E-waste is a serious issue for our environment because it releases harmful toxic chemicals from the metals due to chemical reactions and these toxic chemicals harm our environment, therefore they must be handled with care when no longer wanted or needed.

Electronic scrap components, such as CPUs, contain potentially harmful materials such as lead, cadmium, beryllium, or brominated flame retardants. Improper disposal of e-waste is highly dangerous to the global environment involving significant risk to the health of workers and their communities

Effects on Air quality: Contamination in the air occurs when e-waste is informally disposed of by dismantling, shredding, or melting the materials, releasing dust particles or toxins, such as dioxins, into the environment that cause air pollution and damage respiratory health. Chronic diseases and cancers are at a higher risk to occur when burning e-waste because it also releases fine particles, which can travel thousands of miles, creating numerous negative health risks to humans and animals. The air pollution caused by e-waste impacts some animal species more than others, which may be endangering these species and the biodiversity of certain regions that are chronically polluted. Over time, air pollution can hurt water quality, soil, and plant species, creating irreversible damage to ecosystems.

Effects on Soil: When the improper disposal of e-waste in regular landfills or in places where it is dumped illegally, both heavy metals and flame retardants can seep directly from the e-waste into the soil, causing contamination of underlying groundwater or contamination of crops that may be planted nearby or in the area in the future. When the soil is contaminated by heavy metals, the crops become vulnerable to absorbing these toxins, which can cause many illnesses and doesn’t allow the farmland to be as productive as possible.

Effects on Water: After soil contamination, heavy metals from e-waste, such as mercury, lithium, lead, and barium, then leak through the earth even further to reach groundwater. When these heavy metals reach groundwater, they eventually make their way into ponds, streams, rivers, and lakes. Through these pathways, acidification and toxicity are created in the water, which is unsafe for animals, plants, and communities even if they are miles away from a recycling site. Clean drinking water becomes problematic to find.

Effects on Humans: Electronic waste contains toxic components that are dangerous to human health, such as mercury, lead, cadmium, polybrominated flame retardants, barium, and lithium. The negative health effects of these toxins on humans include brain, heart, liver, kidney, and skeletal system damage. It can also considerably affect the nervous and reproductive systems of the human body, leading to disease and birth defects.

Answer 7b: Corrosion Penetration Rate (CPR) is defined in three ways: (1) the speed at which any metal in a specific environment deteriorates due to a chemical reaction in the metal when it is exposed to a corrosive environment, (2) the amount of corrosion lost per year in thickness, (3) the speed at which corrosion spreads to the inner portions of a material.

The CPR is calculated as follows:

CPR = (k x W) / (D x A x T)

where k = a constant depends on unit used.

when K = 534 the mpy will be used. when K = 87.6, mm/yr will be used.

W = total weight lost (m_o – m) m = weight after corroded m_o = weight before corroded

T = time taken for the loss of metal

A = the surface area of the exposed metal

D = the metal density in g/cm^3

Corrosion penetrating rate in mpy

CPR = KW/DAT

Weight loss, W= 455×10^3 mg

Density, D = $7.9 g/cm^3$; Time, T = 2×24×365 hours

Area A = 60 in^2

$$CPR = \frac{534 \times 365 \times 10^3 \times 6.45}{7.9 \times 450 \times 2 \times 24 \times 365}$$

CPR = 20.18 mpy

Corrosion penetrating rate mm/y

CPR = KW/DAT

Weight loss, W= 455×10^3 mg

Density, D = $7.9 g/cm_3$; Time, T = 6×24×365

Area A = 60 in^2 = 60×6.45 cm^2 = 387 cm^2

$$CPR = \frac{87.6 \times 365 \times 10^3}{7.9 \times 450 \times 2 \times 24 \times 365}$$

CPR = 0.513 mm/y