Unit: Corrosion Science

Important Questions with Hints

1. What is corrosion of metals?

Hints: Corrosion is a process of gradual deterioration and degradation of a metal surface by chemical or electrochemical reaction of metal with environment.

2. What is Pilling-Wedworth rule?

Hints: This rule states that a metal is protective or non-porous if the volume of metal oxide layer is at least equal or greater than the volume of metal from which it is formed. The metal oxide layer is non protective and porous if the volume of oxide is less than the volume of the metal.

3. Iron corrodes faster than aluminium, even though iron is placed below aluminium in the electrochemical series. Why?

Hints: When aluminium is exposed to environment, it forms a non-porous protective oxide film of Al_2O_3. This oxide film of aluminium surface does not permit corrosion to occur. So, aluminium is not corroded easily.

4. Rusting of iron is quicker in saline water than in ordinary water. Why?

Hints: Saline water contains common salt, sodium chloride, which leads conductivity of water. When saline water comes in contact with iron, corrosion current increases and rusting of iron takes place rapidly.

5. How does rain effects on corrosion?

Hints: Rain may have following important effects on corrosion:

i. It may remove corrosion product as in the case on nickel.
ii. Its presence may develop a product having protective quantities as in the case of copper.
iii. The rate of attack may be increased as a result of break down or removal of an otherwise protective coating.

6. Why does corrosion occur in steel pipe connected to copper plumbing?

Hints: Steel is an alloy of iron, which is higher in the electrochemical series. So, it forms the anode. Hence, iron undergoes oxidation and gets corroded when steel pipe is connected to copper plumbing is exposed to a corroding environment.

7. What do you mean by galvanic corrosion?

Hints: When two dissimilar metals such as zinc and copper are electrically connected and exposed to an electrolyte, the metal higher in electrochemical series, i.e. zinc in the present case, undergoes corrosion and the type of corrosion is called galvanic corrosion. For example, corrosion in steel pipe connected to copper plumbing.

8. Why does corrosion of water filled steel tanks occur below the waterline? [2012]

Hints: The areas of steel tank above the water line is more oxygenated and acts as cathode, whereas the areas below water line is not exposed to air and act as anode. Thus, the anodic area below water line undergoes oxidation and gets corroded. This is called differential aeration corrosion.

9. What is meant by tem passivity? [2014]

Hints: Passivity is the phenomenon in which a metal or an alloy shows high corrosion resistance due to formation of highly protective and very thin surface film, which is about 0.0004 mm thick. This film is insoluble, non-porous, and self-healing in nature. The metal such as Ti, Cr, Al, etc. and a wide verity stainless steel alloys containing Cr show high corrosion resistance due to formation of protective oxide film of these metals easily. Any damage to this film is automatically repaired in oxidising environments. In reducing environment, the passive metals become chemically active and undergo corrosion.

10. Describe the significances of Pilling-Bedworth rule.

Hints: (i) If volume of metal is far greater than that of metal, the oxide film is non-porous. These metals are the least susceptible to oxidation corrosion.

(ii) If the volume of oxide layer is far less than that of metal, oxide layer are sufficiently stressed or stained, leading to the formation of pores or cracks. These metals are highly susceptible to corrosion.

(iii) Corrosion by other gases e.g. chlorine (Cl_2), hydrogen sulphide (H_2S), etc.:

(a) Silver (Ag) undergoes corrosion in presence of Cl_2 according to the following reaction:

$$2Ag + Cl_2 = 2AgCl$$

However, AgCl film is protective and prevents further attack of chlorine on silver.

(b) Tin (Sn) reacts with chlorine to form $SnCl_4$, which is volatile and hence accelerates the corrosion of tin metal.

$$Sn + 2Cl_2 = SnCl_4$$

11. Presence of acidic oxides like CO_2, SO_2 and NO_2 accelerates the rusting of iron. Why?

Hints: Iron in presence of acidic oxides readily forms the corresponding salts. The portion of iron surface, not in touch with the acidic oxides, forms the anode. The iron surface eroded by the acidic oxides forms the cathodes, accelerating the rusting of iron.

12. Why does impure metal corrode faster than pure metal?

Hints: The impurities in metal cause heterogeneity in metal surface and form tiny electrochemical cells. The anodic areas of these electrochemical cells get corroded readily.

13. Crevice corrosion is accelerated by deposition of dust or impurities in crevice area. Why?

Hints: These impurities restrict the supply of oxygen underneath the coved portion of metal. The coved crevice area act as anode and suffers further corrosion.

14. What is rusting of iron?

Hints: When a droplet of water containing dissolved oxygen comes in contact with iron metal, an electrochemical cell is set up. At the anodic areas, iron dissolves as Fe^{2+} ions with the liberation of electrons. The liberated electrons flow from anodic to cathodic areas through the iron metal, where the electrons are intercepted by the dissolved oxygen,

At cathode, $Fe \longrightarrow Fe^{2+} + 2e^-$

At anode, $O^{2+} + 4e^- + 2H_2O \longrightarrow 4OH^-$

$$2Fe + O_2 + 2H_2O \longrightarrow 2Fe^{2+} + 4OH^-$$

Fe^{2+} ions at anode and OH^- ions at cathode diffuse and combine to form $Fe(OH)_2$

In presence of excess oxygen, $Fe(OH)_2$ oxidised to $Fe(OH)_3$

$$4Fe(OH)_2 + 2H_2O + O_2 \longrightarrow 4Fe(OH)_3$$

The yellow product is called rust, $Fe(OH)_3$, which has the actual composition as $Fe_2O_3.H_2O$

15. How does waterline corrosion ships prevented?

Hints: Waterline corrosion is prevented by painting the sides of ships by special antifouling paints.

16. Pure copper is immune to stress corrosion than Brass. Why?

Hints: Brass is an alloy of copper and zinc. So, in corroding environment containing traces of ammonia or amines, copper and zinc present in brass form complexes $[Cu(NH_3)_4]^{2+}$ and $[Zn(NH_3)_4]^{2+}$. This results in dissolution of brass leading to formation of fissures, which propagate and lead to development of cracks.

17. What do you mean by the terms galvanization and tinning?

Hints: Coating of zinc on iron by hot dipping is called galvanization and coating of tin on iron is called tinning.

18. What is Sheradizing? Where it is used?

Hints: The cementation coating of iron articles with zinc power is termed as Sheradizing. It is preferred by treatment of iron in zinc powder for two to three hours at 350-370 ^{O}C.

Sheradizing is used for protecting screws, bolts, nuts, washers, etc.

19. Why does part of a nail inside the wood undergo corrosion easily?

Hints: The part of nail inside the wood is not exposed to atmospheric condition and becomes deoxygenated thereby behaves as anode. So, due to differential aeration, the part of nail inside the wood acting as anode, undergoes oxidation and gets corroded.

20. A copper equipment should not possess a small steel bolt. Why?

Hints: Steel contains iron, which is more anodic than copper. So, steel bolt acts as anode and gets corroded. The copper equipment acts as cathode and is protected. Since anodic area is very small, so it is completely corroded in the due course of time and action of bolt gets finished.

21. What do you mean by electrochemical corrosion? Explain anodic and cathodic electrochemical corrosion.

Hints: Corrosion which takes place when a conducting metal is in contact with the metal or when two different metals or alloys are partially or completely immersed in a solution.

Metals, which have non-uniform surface behaves like small electrochemical cell in presence of water containing carbon dioxide and dissolved oxygen (DO). This corrosion is an electrochemical phenomenon, which involves the flow of electron between the anodic and cathodic area.

Mechanism of Electrochemical corrosion:

Electrochemical corrosion may occur in two different processes

(a) Absorption of oxygen (b) Evaluation of hydrogen

Absorption of oxygen mechanism: Let M be the metal, which release electrons and are captured at cathodic area by oxygen.

Anode: $M \rightarrow M^{n+} + ne^-$ (oxidation)

Cathode: $O_2 + 4e^- + H_2O \rightarrow 4OH^-$ (reduction)

The hydroxide ions thus formed combine with metal ions to form corrosion products (figure 1)

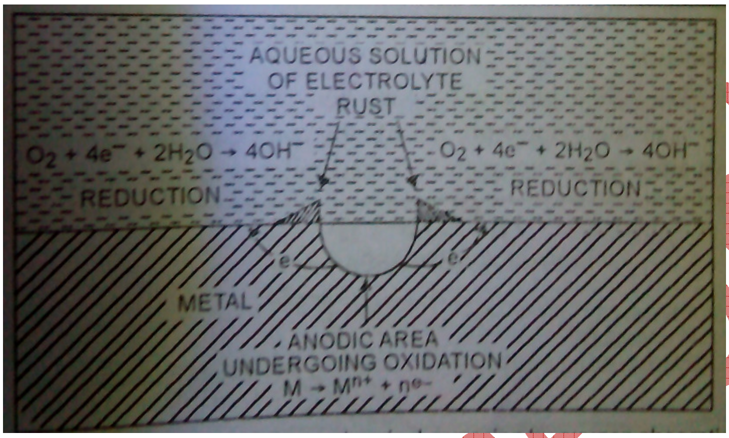

Figure 1

Evaluation of hydrogen mechanism: When the environment is acidic then oxidation occurs in anode where loss of electron takes place. There electrons are captured at cathode area by H^+ resulting in the formation of H_2

Anode: $M \rightarrow M^{n+} + ne^-$ (oxidation)

Cathode: $2H^+ + 2e^- \rightarrow H_2$ (reduction)

Overall: $2M + 2nH^+ \rightarrow 2M^{n+} + nH_2$

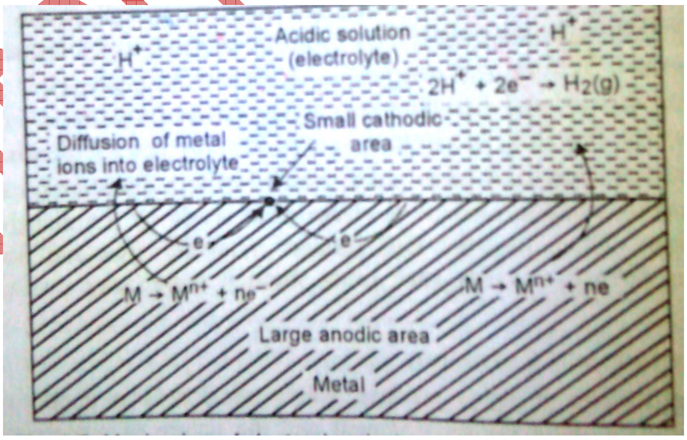

Figure 2

Thus, hydrogen ions once displace from the acidic solution by metal ions and metal gradually dissolves at the anode. Hydrogen are liberated at the cathode. This process is continuously takes place and hence metal surface leads to corrosion.

22. What do you mean by cathode protection? Define the terms sacrificial anode protection and impressed current cathode protection.

Hints: Cathode protection is a technique which is used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. Or it can be defined as the technique to prevent corrosion by converting all the anode sites on the metal surface to cathode sites by supplying electrical current from an alternating source.

Sacrificial anode is one type of cathodic protection system, where anode is made from a metal alloy with a more active voltage than the metal of the structure it is protecting. The difference in potential between the two metals means the sacrificial anode material corrodes in preference to the structure. This effectively stops the oxidation reactions on the metal of the structure being protected. Metals which are used as sacrificial anode include magnesium, zinc and aluminium. Typical uses are for the hulls of the ships and boats, offshore, pipelines and production platforms, in salt-water cool marine engines, on small boat propellers and rudders etc.

The advantage of sacrificial anode systems over others are they need no external power source, easy to install, the low voltage and current between the anode and the surface it is protecting frequently generates stray current.

Impressed current cathodic protection is a type of system applied where there are elevated current requirements for protection against corrosion. This system works by delivering controlled amount of DC current to the surfaces immersed in water with the lid of ultra-reliable zinc electrodes as well as combined anodes of metal oxide. This system helpful to protect against corrosion for a broad range of metallic materials in different settings such as pipelines, boat hulls, storage tanks etc.

23. What are inhibitors? Explain about anodic and cathodic inhibitors.[2012C, 2014, 2014C, 2015]

Hints: Inhibitors are substances which when added in small quantity to the aqueous medium, decreases the rate of corrosion of the metal. They may be organic or inorganic small molecules that dissolve in the corroding medium but don't form any protective film or scale either in cathodic or anodic area.

Anodic inhibitors are generally salts react with metal ions to form insoluble compounds. They form a thin film on the anodic surface and prevent further corrosion. Examples of anodic inhibitors include silicates, phosphates, chromates of alkali and transition metals.

Cathodic inhibitors: In acidic medium, corrosion takes place due to cathodic reaction, where hydrogen is liberated.

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

Thus, corrosion at anode can be controlled by (a) decreasing the evaluation of hydrogen at the cathode, (b) Increasing the over voltage of hydrogen at the anode

The evaluation of hydrogen can be controlled by addition of organic inhibitors such as amines, heavy metal soaps, substituted ureas and thioureas. Antimony and arsenic oxides or salts such as meta arsenate are also used as inhibitors.

In neutral solutions, the cathodic reactions is due to absorption ofoxygen and formed OH^- ions

$H_2O\ 1/2O_2 + 2e^- \rightarrow 2OH^-$

This can be eliminated by adding reducing agents such as sodium sulphite (Na2SO3) or deaeration. Diffusion to the cathodic areas can be retarded by adding inhibitors like Zn, Ni or Mg salts to the corroding medium.

24. What are the different factors which affect corrosion? [2011C, 2014]

Hints: The different factors which affect the corrosion are:

1. Nature of metal: purity, physical state of metal
2. Nature of oxide film: volume of oxide (pilling-Bedworth rule)
3. Nature of corrosion products
4. Passivity and passivation
5. Over voltage of hydrogen

(Details in standard books)

25. What is rust? How much rust will be formed when 100kg of iron have completely rusted away?

Hints: Chemically rust is hydrated iron oxide, $Fe_2O_3.3H_2O$

The molecular weight of rust = 214

214 g rust contains = 112 g Fe

112 g iron produces rust = 214 g

100 kg iron produces rust = (214 x 100)/112 = 191.07 kg

Practice yourself

1. **Explain about the following with suitable mechanism**
   - **(i) Pitting corrosion [2011, 2011C, 2013C, 2015]**
   - **(ii) Crevice corrosion**
   - **(iii) Stress corrosion**
   - **(iv) Water-line corrosion**
   - **(v) Intergranular corrosion**
   - **(vi) Concentration cell corrosion**
2. **What is electrochemical corrosion? Explain the electrochemical corrosion in terms of hydrogen evaluation and oxygen absorption mechanism. [2014, 2015]**
3. **Explain the various factors influencing the rate of corrosion**
4. **Discuss the role metal oxide formed in oxidation corrosion with the help of Pilling-Bedworth rule.**
5. **How corrosion is protected by catholic protection?**
6. **How corrosion can be protected by proper designing of metal articles?**
7. **Explain the mechanism of wet corrosion.**
8. **Write short notes on:**
   - **(a) Cathodic protection**
   - **(b) Galvanization and tinning**
   - **(c) Corrosion by differential aeration**
   - **(d) Corrosion inhibitors**

    - **(e) Anodic protection**
    - **(f) Metallic coating for corrosion prevention**
    - **(g) Metal cladding for corrosion prevention**
    - **(h) Pilling Bed-Worth rule** **[2014, 2015]**

9. How can galvanic corrosion be prevented?

10. Explain the difference in the use of anodic and cathodic coatings for corrosion protection.

11. Suggest the preventive measures to control corrosion **[2014]**

12. What is differential aeration corrosion **[2013C, 2014C]**

13. The rate of metallic corrosion increases with increase in temperature, Give reason. **[2014C]**

14. Explain why corrosion takes place at anode but corroded product forms at cathode or nearly cathode area. **[2013]**

15. How is cathode protection of iron different from its galvanization? **[2013]**

16. Discuss the influence of the following factors on the rate of metallic corrosion (any two) **[2012]**

    - **(i) Nature of corrosion product**
    - **(ii) pH**
    - **(iii) Nature of metal**

Materials collected and prepared from:
J. Borah *etal*, Chemistry for Polytechnic, Vol 2, Kalyani Publishers
P.C. Jain *etal*, Engineering Chemistry, Dhanpat Rai Publishing Company(P) Ltd.
M.G. Fontana, Corrosion Engineering, McGraw-Hill