UNIT 2

WATER CHEMISTRY AND CORROSION

PART-A

SHORT QUESTIONS WITH SOLUTIONS

Q1. Define hardness of water.

Answer :

Hardness of water is a characteristic that does not easily produce lather with soap but forms a white scum or precipitate.

Examples

$$\underset{\text{Sodium stearate}}{2C_{17}H_{35}COONa} + \underset{\substack{\text{(Hardness)}\\\text{(insoluble)}}}{CaCl_2} \longrightarrow \underset{\text{Calcium stearate}}{(C_{17}H_{35}COO)_2\,Ca\downarrow} + \underset{\text{(Sodium soap)}}{2NaCl}$$

$$2C_{17}H_{35}COONa + MgSO_4 \longrightarrow (C_{17}H_{35}COO)_2\,Mg\downarrow + Na_2SO_4$$

Magnesium stearate (insoluble)

Q2. List the names of the salts responsible for hardness of water.

Answer :

The names and formulae of the salts responsible for temporary and permanent hardness of water is shown in table below..

Hardness of Water	Salts Causing Hardness
1. Temporary hardness	❖ Calcium Bicarbonate - $Ca(HCO_3)_2$ ❖ Magnesium Bicarbonate - $Mg(HCO_3)_2$
2. Permanent hardness	❖ Magnesium Chloride - $MgCl_2$ ❖ Magnesium Sulphate - $MgSO_4$ ❖ Calcium Chloride - $CaCl_2$ ❖ Calcium Sulphate - $CaSO_4$

Q3. Why is rain water the purest form of natural water?

Answer :

Rain water is the main source of water for drinking and domestic purposes. Due to continuous evaporation of water from seas, ponds, rivers, and oceans, the clouds are formed. As a result of condensation of clouds, rain occurs. Rain water falling downwards is free from atmospheric pollutants and surface impurities. Rain water also has low hardness. It is directly collected in wells, springs, collecting tanks and can be utilized for domestic and other requirements. Hence, rain water is considered as the purest form of natural water.

Q4. Explain the principle of softening of water by ion-exchange method. **Jan.-13, Q6**

Answer :

Ion-exchange process is also called as demineralization process. In this process, all the ions present in water are eliminated by using ion-exchnage resins. Basically resins with acidic functional group are capable of exchanging H^+ ions with cations. Resins with basic functional groups are capable of exchanging OH^- ions with anions. Resins are classified as,

1. Cation exchange resins
2. Anion exchange resins.

Q5. Define the term "Reverse Osmosis" and what is its uses. Jan.-16, Q4

Answer :

Reverse Osmosis

Reverse osmosis is defined as the phenomenon by virtue of which flow of solvent takes place from a high concentration region to a low concentration region (when a semi-permeable membrane is placed between the two solutions of different concentrations). This flow takes place when hydrostatic pressure is greater than osmotic pressure.

Uses

Reverse Osmosis is used in

(i) Waste water treatment

(ii) Pure water production for industries

(iii) Desalination i.e., removal of salt from sea water.

Q6. Define the terms
(i) Scale and
(ii) Sludge.

Answer : June/July-17, Q6

Scales

Scales are hard, sticky deposits formed on the inner walls of the boiler

Sludges

Sludges are soft, loose and slimy deposits formed in the boiler

Q7. Define potable water.

Answer :

The water that is suitable for drinking and free from contaminants is referred as potable water or drinking water.

Q8. Define sedimentation.

Answer :

Sedimentation is the process of storing water in the huge tanks, in order to remove large suspended particles which settle down at the bottom (because of gravitational forces). This process is usually carried out in large tanks for 2 to 6 hours. The clean water is taken out by using the pumps.

Q9. Name three substances used for sterilization of water. June/July-15,Q4

Answer :

The substances used for sterilization of water are,

1. Bleaching powder
2. Chlorine and
3. Ozone gas.

Q10. Define chlorination.

Answer :

Chlorination is the process of purifying the drinking water by producing a powerful germicide such as Hypochlorous acid (HOCl).

When chloride is mixed with water, it produces hypochlorous acid which kills the germs present in water.

$$H_2O + Cl_2 \rightarrow \underset{\text{Hypochlorous acid}}{HOCl} + \underset{\text{Hydrochloric acid}}{HCl}$$

Q11. What is corrosion? Give two examples.

Answer :

The process of disintegration and degradation of surface of a solid material due to the chemical or electrochemical attack by surrounding environment is known as corrosion.

Example

(i) Rusting of iron

(ii) Formation of green film on copper when exposed to air containing CO_2 and other gases.

Q12. Explain the mechanism of electrochemical corrosion.

Answer :

April-16, Q3

Electrochemical corrosion involves separate anodic and cathodic parts between which current flows through the conducting medium. Since oxidation reaction takes place at anodic areas, corrosion occurs by destroying the metal either by dissolving it or assuming combined state. The resultant electrons float at the electrode.

At anodic area,

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

$$M^{n+} \rightarrow \text{Dissolves in solution}$$

Therefore, reduction reaction takes place at cathodic areas. This does not affect the cathode, as most of the metals cannot be reduced further.

At cathodic area,

$$M^{n+} + ne^{-} \rightarrow M\text{(reduction)}$$

The electrons released at the anode are consumed by cathode using either of the following two mechanisms.

(i) Evolution of hydrogen

or

(ii) Absorption of oxygen depending on the nature of corrosive environment.

(i) Evolution of Hydrogen

This cathodic reaction occurs in acidic environments.

Example: Corrosion of Fe in acid solution.

Anodic Reactions

$Fe \rightarrow Fe^{2+} + 2e^{-}$ (Oxidation)

The electrons liberated at anode are moved to cathode.

Cathodic Reactions

The liberated electrons from anode react with H^{+} ions at cathode and forms H_2 gas,

$2H^{+} + 2e^{-} \rightarrow H_2 \uparrow$ (Reduction)

Therefore, overall reaction of circuit is,

$Fe + 2H^{+} \rightarrow Fe^{2+} + H_2 \uparrow$

This mechanism is illustrated in figure below,

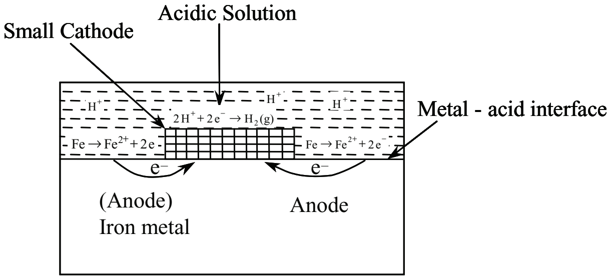


Figure: Mechanism of Wet Corrosion by Hydrogen Evolution

The corrosion causes displacement of hydrogen ions from acidic solution towards the cathodic area. Here, hydrogen ions consume electrons from anode area and liberates hydrogen.

(ii) Absorption of Oxygen

This cathodic reaction occurs usually in neutral medium.

Example: Rusting of iron in neutral aqueous solution of electrolytes in the presence of oxygen (atmosphere).

Q13. Write a note on Galvanic corrosion.

Answer : Jan.-12, Q5

Galvanic corrosion (Bimetallic) may occur when two different metals are in contact and are jointly exposed to corrosion atmosphere. Zinc and Copper, Zn and Ag, Fe and Cu constitutes galvanic couples.

In Zn and Cu galvanic cell, Zn behaves as anode where oxidation and corrosion occurs while Cu behaves as cathode which is protected. The difference in electrical potential between the two metals provides a driving force to pass through the corrodent and results in corrosion of the anodic metal close to the junction of the two metals. The larger the potential difference between the two metals, the greater may be the galvanic corrosion. Hence, this can be minimized by,

(i) Avoiding galvanic couple

(ii) Providing an insulating material between the two metals.

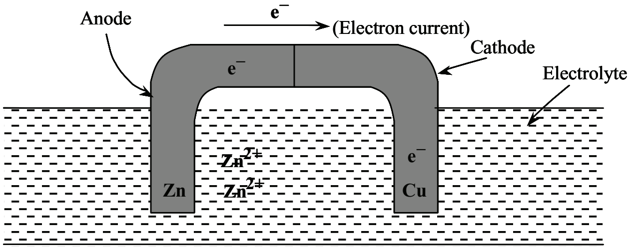


Figure: Galvanic Corrosion

Zn is less noble (anode), it gets attacked whereas Cu is more noble (cathode) and hence, it is protected. Electron current flows from anode to cathode.

Equation at anode is,

$Zn \rightarrow Zn^{2+} + 2e^-$ (oxidation)

Q14. What is waterline corrosion? Explain.

Answer : June/July-15, Q3

Waterline corrosion occurs due to the formation of oxygen concentration cells by differential aeration.

For instance, consider a steel tank containing water. It can be noticed that the maximum corrosion occurs at a point just below the level of the water. This is mainly due to the oxygen concentrated cell formed, as the dissolved oxygen is greater at the surface compared to surface below the water level. The metal at the water level acts as cathode and that on the below acts as anode. Due to poor conductivity of water, the ions just below the water level are readily available and leads to corrosion. If the water is free from acidity, then the corrosion takes place is very little. However, under practical conditions, the attack may be severe. This problem is also seen in ships, where the corrosion is accelerated by the marine plants attached to the side of the ship. It can be restricted by using antifouling paints.

The water line corrosion in a steel tank is illustrated in figure.

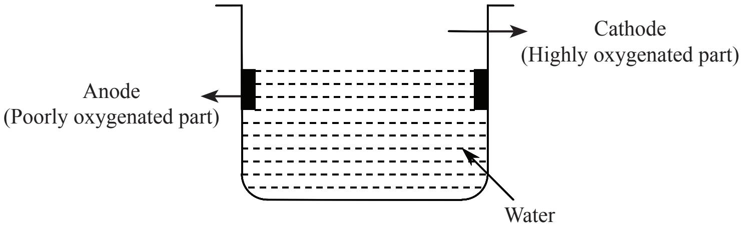


Figure: Water-line Corrosion

Reactions at anode,

$Fe \rightarrow Fe^{2+} + 2e^-$

$Fe^{2+} + 2(OH^-) \rightarrow Fe(OH)_2 \downarrow$

Reactions at cathode,

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

$4H^+ + O_2 + 4e^- \rightarrow 2H_2O$

Q15. Explain the formation of anodic areas on the surface of metallic materials through differential aeration and contact with different metals with reactions.

June-14, Q5

OR

Write a short note on differential aeration corrosion.

Answer :

June-11, Q6

Differential Aeration Corrosion (or) Concentration Cell Corrosion

Concentration cell corrosion is also known as differential aeration corrosion which occurs due to the formation of concentration cell by varying the concentration of oxygen or any electrolyte on the surface of the base metal.

This kind of electrochemical corrosion takes place in metal that is partly dipped in solutions, and partly covered with dust and sand etc. When a metal is partly immersed in a solution, the metal inside the solution has very poor aeration compared to the metal that is outside the solution. This difference in the air concentration of the base metal can produce the anode (with less aerated area) and cathode. Corrosion will take place at the anode area producing metal ion.

Example: Zinc metal partially dipped in a brackish solution (NaCl + H_2O) as shown in figure.

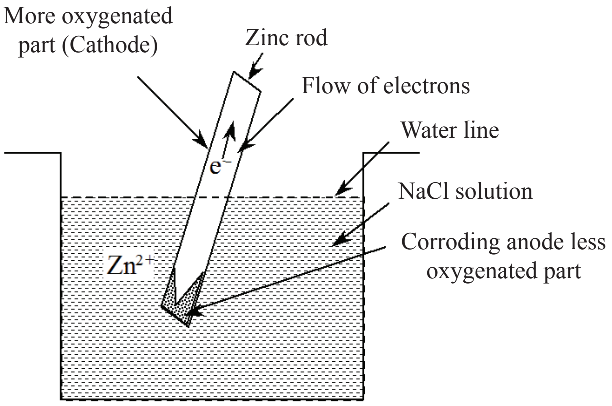


Figure: Concentration Cell Type Corrosion

The zinc rod above the solution is more strongly oxygenated and hence acts as cathode. On the other hand, the zinc rod dipped inside the solution has less access to oxygen and hence, a poorly oxygenated area acts as an anode. Therefore, a difference in potential is developed on the same metal and electrons start flowing from anode, producing metal ions or corrosion.

$$Zn \longrightarrow Zn^{2+} + 2e^- \text{ (Anode)}$$

$$\frac{1}{2}O_2 + H_2O + 2e^- \longrightarrow 2OH^- \text{ (Cathode)}$$

Q16. Why does corrosion of water filled steel tanks occur below the waterline?

Answer :

When water is stored in a steel tank, it is generally found that the maximum corrosion occurs just below the water line. This is due to high concentration of oxygen above the water line compared to the oxygen dissolved in water. The metal above waterline acts as cathode and the metal below waterline acts as anode. In the water tank all the requirements for a galvanic cell exist the anode and cathode, the electrolyte (water) and the metal conductor (steel tank). In this cell (steel tank) the corrosion is accentuated in the region of low oxygen concentration. Hence, corrosion occurs just below the water line in a water filled steel tank.

Q17. A copper equipment should not posses a small steel bolt. Why?

Answer :

June-17, Q6

Copper equipment should not possess a steel bolt because, the steel bolt may cause higher rates of corrosion. This means that when equipments are constructed with dissimilar metals containing a conductivity fluid in contact with both metals, an electric potential may generate between two metals, causes one of the metal higher in electrochemical series dissolve into conductivity fluid and gets deposited on other metals. This type of corrosion is called galvanic corrosion. Here iron (Steel bolt) is having higher electrochemical series than copper hence it can get dissolved.

Q18. Iron corrodes under drops of salt solution. Give reason.

Answer : Dec.-17, Q5

Iron corrodes under drops of water or salt solution. This is because, the portions of the metal covered by the droplets are deprived of oxygen and form anode with respect to the other areas which are freely exposed to air. Metal at less-aerated anodic areas dissolves and the corrosion product is deposited at the cathodic areas.

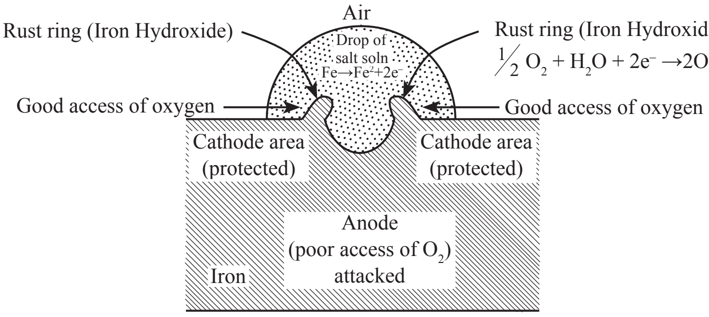


Figure: Mechanism of Differential Aeration Attack

Q19. In a structure two dissimilar metals should not be allowed to come in contact with each other. Why?

Answer : Jan.-13, Q5

In a structure, two dissimilar metals should not be allowed to come in contact with each other as this leads to galvanic corrosion.

Q20. What is anodic coating?

Answer :

Anodic coating is defined as metallic coating in which a more active metal is coated over a base metal.

Example

Coating of zinc over iron

In this, Zinc – More active metal
Iron – Base metal.

The coated metal undergoes corrosion in order to prevent the base metal from corrosion. This coated metal is known as sacrificial anode.

Q21. What happens when cathodic coating breaks?

Answer :

Cathodic coating is done to protect the base metal which is present beneath it. If cathodic coating breaks, the base metal gets corroded rapidly due to the exposure. The metal which is exposed acts as anode and the coating acts as cathode leading to corrosion.

Q22. Define surface coating.

Answer :

Surface coating is a non-metallic inorganic coating that is applied on the surface of a base metal to protect it from corrosion and reactive compounds. It is also referred as chemical conversion coating. It is considered as a base for oils, paints, lacquers etc.

Q23. What do you mean by Hot-dipping?

Answer :

Hot dipping is a process of coating a metal having low melting point over another metal having high melting point. In this method, base metal is dipped into a bath of molten coating metal.

Example:

Coating of tin over iron or steel.

PART-B

ESSAY QUESTIONS WITH SOLUTIONS

2.1 WATER CHEMISTRY

2.1.1 Hardness of Water – Types and Units of Hardness, Estimation of Temporary and Permanent Hardness of Water by EDTA Method. Alkalinity of Water and its Determination

Q24. What is hardness of water? Give the causes of hardness.

Answer :

Hardness of Water

For answer refer Unit-2, Q1.

Causes

(i) Hardness of water is caused due to the presence of dissolved salts such as calcium and magnesium.

(ii) It is also caused due to the presence of dissolved non-carbonate constituents like chlorides, sulphates of calcium, magnesium, heavy metals like iron.

Q25. Discuss the types of hardness of water. Also distinguish between them.

OR

Distinguish between temporary and permanent hardness of water. **June-11, Q16(c)**

(Refer Only Differences Between Temporary and Permanent Hardness of Water)

Answer :

Types of Hardness of Water

Hardness of water is of two types. They are,

(a) Temporary hardness or carbonate hardness.

(b) Permanent hardness or non-carbonate hardness.

(a) Temporary Hardness or Carbonate Hardness

Temporary hardness of water is due to the presence of dissolved bicarbonates of calcium, magnesium and other heavy metals.

This type of hardness can be easily removed by either boiling the water or adding lime to it. Boiling decomposes (breaks) the bicarbonates, due to which a crust is deposited at the bottom of vessel.

Example: Calcium bicarbonate $Ca(HCO_3)_2$ on heating gives,

$$Ca(HCO_3)_2 \xrightarrow{\text{Heat}} CaCO_3\downarrow + H_2O + CO_2\uparrow$$

(b) Permanent Hardness or Non-carbonate Hardness

Permanent hardness of water is due to the presence of chlorides and sulphates of calcium, magnesium and other heavy metals.

The permanent hardness of water cannot be removed by just boiling or adding lime to water. It is removed by using special methods and techniques like permutit process etc.

Differences Between Temporary and Permanent Hardness of Water

Parameter		Temporary Hardness	Permanent Hardness
1.	Causes	Calcium carbonate, magnesium carbonate	Calcium chloride, calcium sulphate, magnesium and carbonate of iron, chloride, magnesium sulphate and heavy metals.
2.	Removal of Hardness	It can be easily removed by boiling	It is difficult to remove water.
3.	Treatment	(i) Boiling water	(i) Soda (ii) Lime.
4.	Salts	When temporary hard water is boiled, the salts present in it break into insoluble carbonates or hydroxides	When permanent hard water is boiled, the salts present in it do not break into carbonates and insoluble carbonates hydroxides or hydroxides.
5.	Other names	Carbonate hardness (or) Alkaline hardness	Non-carbonate hardness (or) Non-alkaline hardness.

Q26. What are the different units in which the hardness of water is expressed? How are they related?

Answer :

The different units in which the hardness of water is expressed are,

(i) Parts Per Million (PPM)

1 PPM = 1 part of $CaCO_3$ equivalent hardness in 10^6 parts of water.

i.e., a PPM is the number of parts of mass of $CaCO_3$ equivalent hardness in one million (10^6) parts of water.

$CaCO_3$ equivalent is given by,

$$\frac{\text{Mass of salt}}{\text{Gram molecular weight of salt}} \times 100$$

(ii) Milligrams Per Litre (mg/L)

1 mg/L = 1 mg of $CaCO_3$ equivalent hardness per litre of water.

(iii) Clarke's Degree (°Cl)

1°Cl = 1 part of $CaCO_3$ equivalent hardness per 70,000 parts of water.

or

1°Cl = 1 grain of $CaCO_3$ equivalent hardness per gallon (10 lb) of water.

(iv) Degree French (°Fr)

1°Fr = 1 part of $CaCO_3$ equivalent hardness per 10^5 parts of water.

Relationship between Various Units of Hardness of Water

(i) 1 ppm = 1 mg/L
= 0.1°Fr
= 0.07° Cl

(ii) 1 mg/L = 1 ppm
= 0.1°Fr
= 0.07°Cl

(iii) 1 °Cl = 1.433°Fr
= 14.3 ppm
= 14.3 mg/L

(iv) 1°Fr = 10 ppm
= 10 mg/L
= 0.7° Cl

Q27. What are the different types of hardness of water? Explain their determination by using EDTA method.

Jan.-13, Q13(b)

OR

Explain the EDTA method for the determination of temporary and permanent hardness of water.

Dec.-16, Q13(a)

(Refer Only Determination of Hardness of Water)

OR

How do you determine the temporary and permanent hardness of water by EDTA method? Explain. **April-16, Q16(b)**

(Refer Only Determination of Hardness of Water)

OR

How do you determine the permanent hardness of water by EDTA method? Explain.

June/July-15, Q17(a)

(Refer Only Determination of Hardness of Water)

OR

Explain the determination of temporary and permanent hardness of water by EDTA method.

June-14, Q16(a)

(Refer Only Determination of Hardness of Water)

OR

Describe the determination of hardness of water by EDTA method.

(Refer Only Determination of Hardness of Water)

Answer : **(Jan.-12, Q17(a) | June-10, Q13(a))**

Types of Hardness of Water

For answer refer Unit - 1, Q25, Topic: Types of Hardness of water.

Determination of Hardness of Water

The Ethylene Diamine Tetra Acid (EDTA) or complexometric method is the best technique to estimate the hardness of water.

The aim of this method is to determine the weight of total, permanent and temporary hardness present in a sample of water.

Principle

In EDTA method, Eriochrome Black-T (EBT) acts as an indicator. When this indicator is added to the water sample, it reacts with M^{2+} (i.e., Ca^{2+} or Mg^{2+}) producing an unstable complex metal of wine red colour.

$$\text{EBT} + M^{2+} \longrightarrow \underset{\text{(Unstable complex-wine red colour)}}{\text{M-EBT} + 2H^+}$$

When the sodium salt of EDTA reacts with water containing Ca^{2+} and Mg^{2+} ions, a stable complex is formed.

$$\text{i.e., EDTA} + M^{2+} \longrightarrow \underset{\text{(Stable complex)}}{\text{M-EDTA} + 2H^+}$$

Finally, M^{2+} ions are removed from the unstable complex through EDTA. As a result wine red colour is turned into steel blue colour.

$$\text{i.e., EDTA} + \underset{\text{(Complex)}}{\text{M-EBT}} \longrightarrow \underset{\text{(Complex)}}{\text{M-EDTA}} + \underset{\text{(Steel Blue)}}{\text{EBT}}$$

The EDTA metal complex is stable at pH of 8 to 10.

Reagents Required

(i) EDTA (0.01 M)

It is prepared by dissolving 4 gms of disodium salt crystals in one litre of distilled water.

(ii) Standard Hard Water

It is formed by dissolving 1 gm of $CaCO_3$ in hydrochloric acid (few drops). Then the residue is diluted in distilled water to make 1 litre of solution.

(iii) Indicator

Only 0.5 gm of EBT is dissolved in 100 ml of water.

(iv) Buffer Solution

67.5 gms of ammonium chloride is added to 570 ml of concentrated ammonium hydroxide. Then the solution is diluted with distilled water to make it 1 litre of solution.

Procedure

(i) Standardization of EDTA Solution

The burette is filled with the EDTA solution 50 ml of standard hard water is pipette out into a clean conical flask. Then 10-15 ml of buffer solution is added to few drops of Erichrome black-*T* indicator. The wine red solution present in the conical flask is titrated against the burette EDTA solution till the wine red colour changes to steel blue colour.

Let the volume of EDTA consumed be V_1 ml.

(ii) Estimation of Total Hardness

Pipette out 50 ml of sample hard water into the conical flask. Add the ammonia buffer and indicator and titrate it against the same EDTA burette solution to get the endpoint.

Let V_2 be the volume of EDTA consumed.

(iii) Estimation of Permanent Hardness

The water sample of 250 ml is taken in a beaker and evaporated nearly to 50 ml. The temporary hard salts settle down. Filter and wash thoroughly and make up the solution again to 250 ml. Pipette out 50 ml of the made up solution into a clean conical flask and titrate it against the EDTA, burette solution to get the endpoint.

Let the volume of EDTA consumed be V_3 ml.

Calculation

V_1 ml of EDTA is consumed by 50 ml standard hard water.

V_1 ml of EDTA = 50 mg of $CaCO_3$

$\therefore$ 1 ml of EDTA = $\frac{50}{V_1}$ mg of $CaCO_3$ equivalent hardness

(V_2 ml of EDTA is consumed by 50 ml sample hard water)

1 ml of EDTA is consumed by mg of $CaCO_3$ equivalent hardness

$\therefore$ V_2 ml of EDTA = $\frac{50}{V_1} \times V_2$ mg of $CaCO_3$ equivalent hardness

50 ml sample hard water contains $\frac{50}{V_1} \times V_2$ mg of $CaCO_3$

$\therefore$ 1000 ml (1 litre) sample hard water,

$$= \frac{50}{V_1} \times \frac{V_2}{50} \times 1000 \text{ mg/lt.}$$

$\therefore$ Total hardness = $\frac{V_2}{V_1} \times 1000$ mg of $CaCO_3$ (ppm)

Permanent Hardness

50 ml of sample hard water after removing temporary hardness consumes V_3 ml EDTA.

1 ml of EDTA= $\frac{50}{V_1}$ mg of $CaCO_3$

$\therefore$ V_3 ml of EDTA= $\frac{50}{V_1} \times V_3$ mg $CaCO_3$

50 ml of sample hard water after boiling contains,

$$= \frac{50}{V_1} \times V_3 \text{ mg } CaCO_3$$

$\therefore$ 1000 ml of sample hard water,

$$= \frac{50}{V_1} \times \frac{V_3}{50} \times 1000 \text{ mg/lt of } CaCO_3 \text{ equivalent hardness}$$

$$= \frac{V_3}{V_1} \times 1000 \text{ mg/lt of } CaCO_3 \text{ (ppm)}$$

Temporary Hardness

Temporary hardness = Total hardness – Permanent hardness

$$= \left(\frac{V_2}{V_1} \times 1000\right) - \left(\frac{V_3}{V_1} \times 1000\right)$$

$$= 1000 \times \left(\frac{V_2}{V_1} - \frac{V_3}{V_1}\right) \text{ppm}$$

$$= 1000 \times \left(\frac{V_2 - V_3}{V_1}\right) \text{ppm of } CaCO_3 \text{ equivalent hardness.}$$

Q28. Explain the procedure for the determination of alkalinity of water. June/July-17, Q13(a)

OR

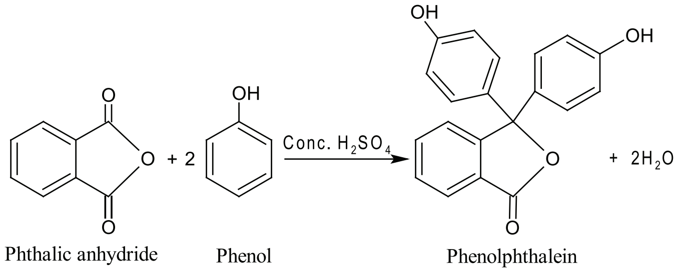
What is phenolphthalein and methyl orange alkalinity of water? Explain. Jan.-16, Q17(a)

Answer :

Phenolphthalein is a colourless compound having molecular formula of $C_{20}H_{14}O_4$. It is denoted as ‘Hln’ (or) ‘phph’. It is a component of universal indicator.

Preparation

Phenolphthalein is obtained by the condensation of Phthalic anhydride. i.e., Phthalic anhydride when treated with phenol, in presence of H_2SO_4,



Properties

1. Phenolphthalein is,
   (i) Partially soluble in water.
   (ii) Colourless in acidic conditions.
   (iii) Highly soluble in alcohols.
2. It exhibits pink color in basic/alkali conditions.

Applications

It is mainly used in acid - base titrations

Alkalinity of Water

The presence of alkalinity in water sample is caused due to,

(i) Caustic alkalinity i.e., OH^- and CO_3^{2-} ions

(ii) Temporary hardness i.e., HCO_3^- ions.

In order to determine the alkalinity, the water sample is titrated against a standard solution using suitable indicators i.e., phenolpthalein and methyl orange indicator.

The phenolpthalein indicator is used for the determination of alkalinity by hydroxides and carbonates, whereas methyl orange indicator is used for the determination of alkalinity by bicarbonates.

$$\text{i.e.,}\quad \begin{array}{ll} \text{(i)} & [OH^-]+[H^+]\rightarrow H_2O \\ \text{(ii)} & [CO_3^{2-}]+[H^+]\rightarrow [HCO_3^-] \\ \text{(iii)} & [HCO_3^-]+[H^+]\rightarrow H_2O + CO_2 \end{array} \quad \begin{array}{l} \rightarrow \text{Phenolptha lein (P)} \\ \\ \rightarrow \text{Methyl orange (M)} \end{array}$$

The following are the combinations that produce alkalinity in water,

(i) OH^- only

(ii) CO_3^{2-} only

(iii) HCO_3^- only

(iv) OH^- and CO_3^{2-}

(v) CO_3^{2-} and HCO_3^-

The combination of OH^- and HCO_3^- ions is not considered since they produce CO_3^{2-} ions.

i.e., $OH^- + HCO_3^- \rightarrow CO_3^{2-} + H_2O$

Procedure

Step 1

Take 100 ml of water sample in a titration flask.

Step 2

Put 2 or 3 drops of phenolpthalein indicator into the flask (a pink colour appears).

Step 3

Then add $\left(\frac{N}{50}\right)$ sulphuric acid till the pink colour disappears.

Step 4

Now add 2 or 3 drops of methyl orange to the above solution.

Step 5

Repeat the process until the pink colour reappears.

Calculations

Let the volume of water be V ml

Let the volume of standard acid used to phenolphthalein end point be V_1 ml

Let the volume of standard acid used to methyl orange end point be V_2 ml

Then the expression of phenolphthalein alkalinity = $\dfrac{\text{Normality}\left(\dfrac{N}{50}\right)\times\text{Volume of acid}(V_1)}{\text{Volume of water sample}}\times 50\times 1000 = a$ ppm

The expression of methyl orange alkalinity = $\dfrac{\text{Normality}\left(\dfrac{N}{50}\right)\times\text{Volume of acid}(V_1+V_2)}{\text{Volume of water sample}}\times 50\times 1000 = b$ ppm

For different values of 'P' and 'M', the alkalinity of water in ions is depicted in table.

Value of P and M	Hydroxide (OH^-)	Carbonate (CO_3^{2-})	Bicarbonate (HCO_3^-)
P = 0	0	0	M
P = M	P = M	0	0
$P = \frac{1}{2}M$	0	2P (or) 2M	0
$P < \frac{1}{2}M$	0	2P	M – 2P
$P > \frac{1}{2}M$	2P – M	2(M – P)	0

Table

2.1.2 Water Softening by Ion Exchange and Reverse Osmosis Methods

Q29. Discuss the ion-exchange method of softening hard water. **June/July-17, Q16(b)**

OR

Describe the ion - exchange method of softening of water. **Jan.-16, Q12(b)**

OR

Describe the softening of water by ion-exchange method. **June-13, Q13(b)**

Answer :

Ion-exchange process is also called as demineralization process. In this process, all the ions present in water are eliminated by using ion-exchange resins. Basically resins with acidic functional group are capable of exchanging H^+ ions with cations. Resins with basic functional groups are capable of exchanging OH^- ions with anions. Resins are classified as,

1. Cation exchange resins
2. Anion exchange resins.

1. Cation Exchange Resins

These are capable of exchanging their hydrogen ions with cations in water.

2. Anion Exchange Resins

These are capable of exchanging their OH^- ions with anions in water.

In ion-exchange process, hard water is allowed to pass through cation exchange resins, which remove Ca^{2+} and Mg^{2+} ions and exchange equivalent amount of H^+ ions. Anion exchange resins remove bicarbonates, chlorides and sulphates from water and exchange equivalent amount of OH^- ions. Thus, when hard water is allowed to pass through cation hardness is observed by the following reactions.

Cation Exchange Reactions

$$2RH^+ + Ca^{2+} \rightarrow R_2Ca^{2+}\ 2H^+$$

$$2RH^+ + Mg^{2+} \rightarrow R_2Mg^{2+} + 2H^+ \qquad (\because RH^+ = \text{Cation exchange resin})$$

Anion Exchange Reactions

$$R'OH^- + Cl^- \rightarrow R'Cl^- + OH^-$$

$$2R'OH^- + S_4^{2-} \rightarrow R_2'\ S_4^{2-} + 2OH^-$$

$$2R'OH^- + CO_3^{2-} \rightarrow R_2'\ CO_3^{2-} + 2OH^- \ (\because R'OH = \text{Anion exchange resin})$$

H^+ and OH^- ions, thus released in water from respective cation and anion exchange columns, get combined to produce water molecules.

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

The water coming out from the exchanger is ion free i.e., free from anions and cations. Thus, water of zero hardness is obtained.

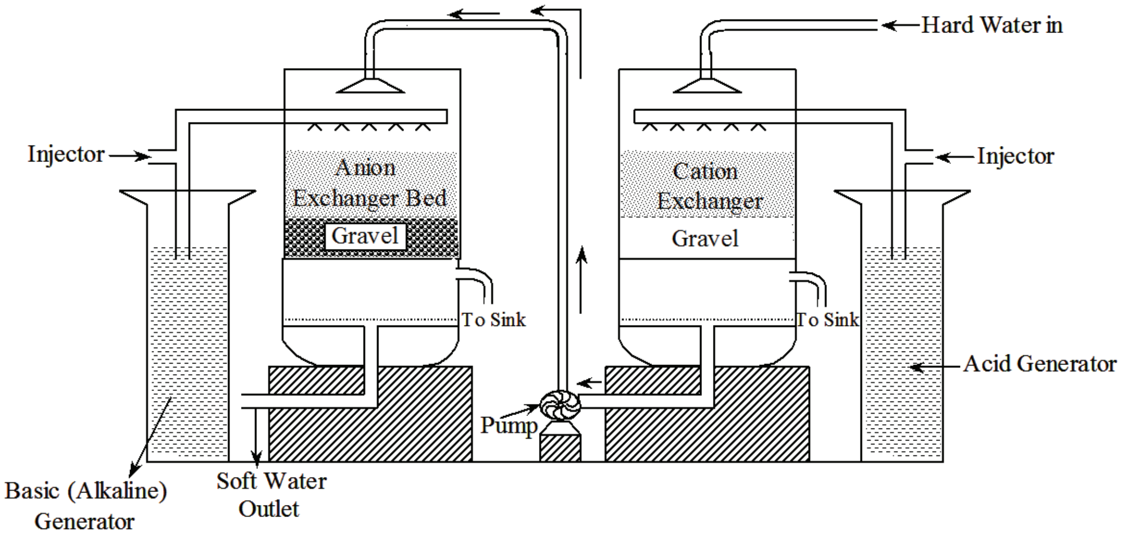


Figure: Ion-exchange Process

Regeneration

When cation exchanger looses capacity of producing H^+ ions and anions exchanger looses capacity of producing OH^- ions, they are said to be exhausted. The exhausted cation exchanger is regenerated by passing it through dilute sulphuric acid (H_2SO_4).

$$R^2Ca^{2+} + 2H^+ \rightarrow 2RH^+ + Ca^{2+}$$

The exhausted anion exchanger is regenerated by passing a dilute solution of NaOH.

$$R_2'\ SO_4^{2-} + 2OH^- \rightarrow 2R'OH^- + SO_4^{2-}$$

Merits

1. The process can be used to soften highly acidic or alkaline water.
2. It produces water of very low hardness (2 ppm). So, it is very good for treating water in high-pressure boilers.

Demerits

1. The equipment is costly and more expensive chemicals are needed.
2. If water contains turbidity, the output of the process is reduced. The turbidity must be below 10 ppm, else it has to be removed by coagulation and filtration methods.

Q30. What is reverse osmosis? How is sea water purified by using this technique? May/June-18, Q14(a)

OR

What is reverse osmosis? How is this process help in softening of water? May/June-12, Q6

Answer :

Reverse osmosis can be defined as the phenomenon by virtue of which flow of solvent takes place from a high concentration region to a low concentration region (when a semi-permeable membrane is placed between the two solutions of different concentrations).

This flow takes place when a hydrostatic pressure is greater than the osmotic pressure.

Figure below illustrates the cell used in the reverse osmosis process.

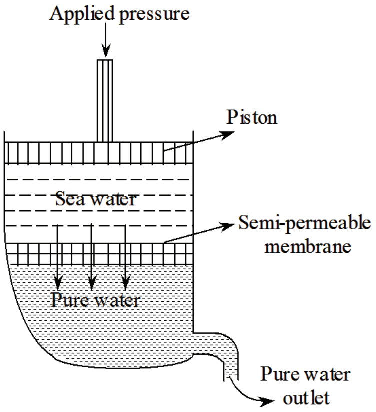


Figure : Reverse Osmosis Cell

Reverse Osmosis is also known as 'Super-filtration' 'hyper-filtration'.

In this method, impure water is first taken in a cell and a pressure of 15 to 49 kg/cm^2 is applied on it. Due to this pressure, pure water comes out through the semi-permeable membrane present on either sides of the tube. The membrane is a very thin film of cellulose acetate dissolves solute particles, such as molecules and ions to pass through it.

Thus, this way reverse osmosis removes both ionic and non-ionic salts present in water and gives pure drinking water at the outlet.

2.1.3 Numerical Problems

Q31. Calculate the carbonate and non-carbonate hardness of a sample of water in ppm containing: $Ca(HCO_3)_2$ = 8.1 mg.L^{-1}; $Mg(HCO_3)_2$ = 7.8 mg.L^{-1}; $MgCl_2$ = 9.5 mg.L^{-1}; $CaSO_4$ = 13.6 mg.L^{-1}.

Answer : June/July-17, Q5

Given that,

For a sample of water,

$Ca(HCO_3)_2$ = 8.1mg L^{-1}

$Mg(HCO_3)_2$ = 7.8mg L^{-1}

$MgCl_2$ = 9.5mg L^{-1}

$CaSO_4$ = 13.6mg L^{-1}

$CaCO_3$ Equivalent

$CaCO_3$ equivalent of all the impurities is shown below.

Constituent	Amount	Multiplication factor $\left[\frac{100}{\text{mol.wt}}\right]$	$CaCO_3$ equivalent (Amount × Multiplication factor)
$Ca(HCO_3)_2$	8.1 mg L^{-1}	$\frac{100}{162}$	$8.1 \times \frac{100}{162} = 5$ mgL^{-1}
$Mg(HCO_3)_2$	7.8 mg L^{-1}	$\frac{100}{146}$	$7.8 \times \frac{100}{146} = 5.34$ mgL^{-1}
$CaSO_4$	13.6 mg L^{-1}	$\frac{100}{136}$	$13.6 \times \frac{100}{136} = 10$ mgL^{-1}
$MgCl_2$	9.5 mg L^{-1}	$\frac{100}{95}$	$9.5 \times \frac{100}{95} = 10$ mgL^{-1}

Carbonate Hardness (Temporary Hardness)

Temporary hardness of water is due to the presence of $Ca(HCO_3)_2$ and $Mg(HCO_3)$.

Temporary Hardness = $CaCO_3$ equivalent of $[Ca(HCO_3)_2]$ + $CaCO_3$ equivalent of $[Mg(HCO_3)_2]$

= 5 + 5.34

∴ Temporary Hardness = 10.34 mgL^{-1}.

Non-corbonate Hardness (Permanent Hardness)

Permanent hardness of water is due to the presence of $CaSO_4$, $MgCl_2$.

Permanent Hardness = $CaCO_3$ equivalent of $[CaSO_4 + MgCl_2]$

= 10 + 10

∴ Permanent Hardness = 20 mgL^{-1}.

Q32. Calculate temporary hardness and permanent hardness of a sample of water containing,

$Mg(HCO_3)_2$ = 7.3 mg. L^{-1}; $Ca(HCO_3)_2$ = 16.2 mg.L^{-1}.

$MgCl_2$ = 9.5 mg. L^{-1}; $CaSO_4$ = 13.6 mg.L^{-1}.

Answer : **Dec.-16, Q6**

Given that,

For a sample of water,

$Mg(HCO_3)_2$ = 7.3 mg/lit

$Ca(HCO_3)_2$ = 16.2 mg/lit

$MgCl_2$ = 9.5 mg/lit

$CaSO_4$ = 13.6 mg/lit

$CaCO_3$ equivalent

$CaCO_3$ equivalent of all impurities is shown below,

Constituent	Amount mg/lit	Multiplication factor $\left[\frac{100}{\text{mol.wt.}}\right]$	$CaCO_3$ equivalent (Amount × Multiplication factor)
$Mg(HCO_3)_2$	7.3	$\frac{100}{146}$	$7.3 \times \frac{100}{146}$ = 5 mg/lit
$Ca(HCO_3)_2$	16.2	$\frac{100}{162}$	$16.2 \times \frac{100}{162}$ = 10 mg/lit
$MgCl_2$	9.5	$\frac{100}{95}$	$9.5 \times \frac{100}{95}$ = 10 mg/lit
$CaSO_4$	13.6	$\frac{100}{136}$	$13.6 \times \frac{100}{136}$ = 10 mg/lit

Temporary Hardness

Temporary Hardness of water is due to the presence of $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$.

Temporary Hardness = $CaCO_3$ equivalent of $[Mg(HCO_3)_2]$ + $CaCO_3$ equivalent of $[Ca(HCO_3)_2]$

= 5 + 10

= 15

∴ Temporary Hardness = 15 mg/lit.

Permanent Hardness

Permanent Hardness of water is due to the presence of $MgCl_2$ and $CaSO_4$.

Permanent Hardness = $CaSO_2$ equivalent of [$MgCl_2$ + $CaSO_4$]

= 10 + 10

= 20

$\therefore$ Permanent Hardness = 20 mg/lit.

Q33. 50 ml of standard hard water consumed 15 ml. of 0.01 M EDTA solution. 50 ml. of a water sample consumed 25 ml. of same EDTA solution. Calculate the total hardness of water sample.

Answer : **May/June-12, Q13(c)**

Given that,

50 ml of Standard Hard Water (SHW) consumed 15 ml of 0.01M EDTA solution.

50 ml of a water sample consumed 25 ml of 0.01M EDTA solution.

Since, 50 ml of SHW consumed 15 ml of EDTA, 1 ml of EDTA corresponds to $\frac{50}{15}$ ml of SHW and $\frac{50}{15} \times 1$ mg of $CaCO_3$

[$\because$ 1 ml of 0.01M EDTA solution = 1 mg of CaCO3].

And, 50 ml of water sample consumed 25 ml of EDTA,

i.e., $25 \times \frac{50}{15} \times 1$ mg of $CaCO_3$.

Hence, 1 litre (or 1000 ml) of water sample consumes,

$25 \times \frac{50}{15} \times \frac{1000}{50}$ mg of $CaCO_3$ equivalent

$= \frac{5}{3} \times 1000$ mg of $CaCO_3$ equivalent

$= 1.66 \times 1000$ mg of $CaCO_3$ equivalent

= 1660 mg of $CaCO_3$

$\therefore$ Total hardness of water = 1660 mg of $CaCO_3$

Q34. Calculate the temporary and permanent hardness of sample of water containing:

$Ca(HCO_3)_2$ = 32.4 mg/l, $Mg(HCO_3)_2$ = 29.2 mg/l

$CaSO_4$ = 27.2 mg/l, $MgCl_2$ = 9.5 mg/l and NaCl = 40 mg/l.

Answer : **June-12, Q13(C)**

Given that,

For a sample of water,

$Ca(HCO_3)_2$ = 32.4 mg/l

$Mg(HCO_3)_2$ = 29.2 mg/l

$CaSO_4$ = 27.2 mg/l

$MgCl_2$ = 9.5 mg/l

NaCl = 40 mg/l

$CaCO_3$ Equivalent

$CaCO_3$ equivalent of all the impurities is shown below,

Constituent	Amount	Multiplication factor $\left[\frac{100}{(\text{mol.wt.})}\right]$	$CaCO_3$ equivalent (Amount × multiplication factor)
$Ca(HCO_3)_2$	32.4 mg/l	$\frac{100}{162}$	$32.4 \times \frac{100}{162} = 20$ mg/l
$Mg(HCO_3)_2$	29.2 mg/l	$\frac{100}{146}$	$29.2 \times \frac{100}{146} = 20$ mg/l
$CaSO_4$	27.2 mg/l	$\frac{100}{136}$	$27.2 \times \frac{100}{136} = 20$ mg/l
$MgCl_2$	9.5 mg/l	$\frac{100}{95}$	$9.5 \times \frac{100}{95} = 10$ mg/l
NaCl	40 mg/l	$\frac{100}{117}$	$40 \times \frac{100}{117} = 34.18$ mg/l

Temporary Hardness

Temporary Hardness of water is due to the presence of $Ca(HCO_3)_2$ and $Mg(HCO_3)$

Temporary Hardness = $CaCO_3$ equivalent of $[Ca(HCO_3)_2]$ + $CaCO_3$ equivalent of $[Mg\ (HCO_3)_2]$ = 20 + 20

∴ Temporary hardness = 40 mg/l

Permanent Hardness

Permanent hardness of water is due to the presence of $CaSO_4$, $MgCl_2$ and NaCl

Permenent Hardness = $CaCo_3$ equivalent of $[CaSo_4 + Mgcl_2 + NaCl]$ = [20 + 10 + 34.18]

∴ Permanent hardness = 64.18 mg/l

Q35. A sample of hard water contains the following dissolved salts per liter. CO_2 =44 mg, $Ca(HCO_3)_2$ =16.4 mg, $Mg(HCO_3)_2$ = 14.6 mg, $CaCl_2$ = 111 mg, $MgSO_4$ = 12 mg and $CaSO_4$ = 13.6 mg. Calculate the temporary and permanent hardness of water in ºFr and ºClarke.

Answer :

Given that,

For a sample of hard water,

CO_2 = 44 mg/l

$Ca(HCO_3)_2$ = 16.4 mg/l

$Mg(HCO_3)_2$ = 14.6 mg/l

$CaCl_2$ = 111 mg/l

$MgSO_4$ = 12 mg/l

$CaSO_4$ = 13.6 mg/l

$CaCO_3$ Equivalent

Table below illustrates the $CaCO_3$ equivalents of all the dissolved salts,

Constituent -	Amount (100/mol.wt)	Multiplication -	$CaCO_3$ Equivalent (Amount × Multiplication factor)
$Ca(HCO_3)_2$	16.4 mg/l	100/162	16.4 × 100/162 = 10.123 mg/l
$Mg(HCO_3)_2$	14.6 mg/l	100/146	14.6 × 100/146 = 10 mg/l
$CaCl_2$	111 mg/l	100/111	111 × 100/111 = 100 mg/l
$MgSO_4$	12 mg/l	100/120	12 × 100/120 = 10 mg/l
CO_2	44 mg/l	–	Ignored as it does not contribute to hardness
$CaSO_4$	13.6 mg/l	100/136	13.6 × 100/136 = 10 mg/l

Table: $CaCO_3$ Equivalent

Temporary Hardness

Temporary hardness of water is due to the presence of $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$

$\therefore$ Temporary hardness = $CaCO_3$ equivalent of $[Ca(HCO_3)_2]$ + $CaCO_3$ equivalent of $Mg(HCO_3)_2$

Temporary hardness = $CaCO_3$ equivalent of $[Ca(HCO_3)_2 + Mg(HCO_3)_2]$

= 10.123 + 10

= 20.123 mg/l or ppm

= 20.123 × 0.07 °Cl ($\because$ 1 ppm = 0.07 °Cl)

= 1.408 °Cl.

(or)

= 20.123 × 0.1 °Fr ($\because$ 1 ppm = 0.1°Fr)

= 2.0123 °Fr

$\therefore$ Temporary hardness = 1.408ºCl or 2.0123ºF

Permanent Hardness

Permanent hardness of water is due to the presence of $CaCl_2$, $MgSO_4$ and $CaSO_4$.

$\therefore$ Permanent hardness = $CaCO_3$ equivalent of $[CaCl_2 + MgSO_4 + CaSO_4]$

= 100 + 10 + 10

= 120 mg/l or ppm

= 120 × 0.07 °Cl [$\because$ 1 ppm = 0.07°Cl]

= 8.4 ºCl

(or)

= 120 × 0.1 ºFr [$\because$ 1 ppm = 0.1°Fr]

= 12 ºFr

$\therefore$ Permanent hardness = 8.4ºCl or 12ºFr

Q36. 100 ml of raw water sample on titration with $\frac{N}{50}$ H_2SO_4 required 12.4 ml of acid to phenolphthalein end point, 15.2 ml of acid to methyl organge end point. Describe the type and extent of alkalinity present in the water sample.

Answer : May/June-18, Q14(b)

Given that,

For a raw water sample,

Volume of water, V_1 = 100 ml

Normality of acid, $N_2 = \frac{1}{50} = 0.02$ N

Phenolphthalein end point, P = 12.4 ml

Additional acid added = 15.2 ml

$M = P + 15.2$ ml

$= 12.4 + 15.2$ ml

$M = 27.6$ ml

Type of Alkalinity

P = 12.4 ml and

M = 27.6 ml

Here, $P < \frac{1}{2}M$ (i.e., $12.4 < \frac{27.6}{2} = 12.4 < 13.8$)

As $P < \frac{1}{2}M$, the alkalinity is due to the presence of CO_3^{2-} and HCO_3^- ions.

$\therefore$ Volume of acid in CO_3^{2-} type = $2P$

Volume of acid in HCO_3^- type = $M - 2P$

Total Alkalinity

(a) Alkalinity due to CO_3^{2-} Type

The expression for alkalinity in terms of $CaCO_3$ equivalent is,

$$\text{Alkalinity} = \frac{\text{Volume of acid}(V_2) \times \text{Normality of acid }(N_2) \times 50,000}{\text{Volume of water sample }(V_1)}$$

$$= \frac{2P \times 0.02 \times 50,000}{100}$$

$$= 2 \times 12.4 \times 0.02 \times 500$$

$$= 248 \text{ ppm}$$

$\therefore$ Alkalinity due to CO_3^{2-} type $(A_1) = 248$ ppm

(b) Alkalinity due to HCO_3^- Type

The expression for alkalinity in terms of $CaCO_3$ equivalent is,

$$\text{Alkalinity} = \frac{V_2 \times N_2 \times 50,000}{V_1}$$

$$= \frac{(M - 2P) \times 0.02 \times 50,000}{100}$$

$$= (27.6 - 24.8) \times 0.02 \times 500$$

$$= 2.8 \times 0.02 \times 500$$

$$= 28 \text{ ppm}$$

Alkalinity due to HCO_3^- type $(A_2) = 28$ ppm

$$\text{Total alkalinity} = A_1 + A_2$$

$$= 248 + 28$$

$$= 276 \text{ ppm}$$

$\therefore$ Total alkalinity $= 276$ ppm

Q37. 100 ml of a water sample required 20 ml of $\frac{N}{50}$ H_2SO_4 for neutralization to phenolphthalein end point. After, this methyl orange indicator was added to this and further acid required was 15 ml. Calculate the type and amount of alkalinity of water.

Answer : June-11, Q17(c)

Given that,

For a water sample,

Volume of water, $V_1 = 100$ ml

Phenolphthalein end point, $P = 20$ ml

Normality of acid, $N_2 = \frac{1}{50} = 0.02$ N

Additional acid added = 15 ml

$$M = P + 15 \text{ ml}$$

$$= 20 + 15 \text{ ml}$$

$$\therefore M = 35 \text{ ml}$$

Type of Alkalinity

$$P = 20 \text{ ml and}$$

$$M = 35 \text{ ml}$$

Here, $P > \frac{1}{2}M$ (i.e., $20 > \frac{35}{2} = 20 > 17.5$)

As $P > \frac{1}{2}M$, the alkalinity is due to the presence of OH^- and CO_3^{2-} ions.

$\therefore$ Volume of acid in OH^- type $= 2P - M$

Volume of acid in CO_3^{2-} type $= 2(M - P)$

Total Alkanity

(a) Alkanity due to OH^- Type

The expression for alkalinity in terms of $CaCO_3$ equivalent is,

$$\text{Alkalinity} = \frac{\text{Volume of acid }(V_2)\times\text{Normality of acid }(N_2)\times 50{,}000}{\text{Volume of water sample }(V_1)}$$

$$= \frac{(2P-M)\times 0.02\times 50{,}000}{100}$$

$$= (2 \times 20 - 35)\ 0.02 \times 500$$

$$= (40 - 35)\ 0.02 \times 500$$

$$= 5 \times 0.02 \times 500$$

$$= 50 \text{ ppm}$$

$\therefore$ Alkalinity due to OH^- type $(A_1) = 50$ ppm

(b) Alkalinity due to CO_3^{2-} Type

The expression for alkalinity in terms of $CaCO_3$ equivalent is,

$$\text{Alkalinity} = \frac{V_2\times N_2\times 50{,}000}{V_1}$$

$$= \frac{2(M-P)\times 0.02\times 50{,}000}{100}$$

$$= 2(35 - 20)\ 0.02 \times 500$$

$$= 2(15)\ (10) = 300 \text{ ppm}$$

Alkalinity due to CO_3^{2-} type $(A_2) = 300$ ppm

Total alkalinity $= A_1 + A_2$

$= 50 + 300 = 350$ ppm

$\therefore$ Total alkalinity $= 350$ ppm

2.1.4 Specifications of Potable Water. Sterilization by Chlorination. Break Point Chlorination

Q38. Write the specification of potable water. May/June-18, Q6

OR

Mention the specifications of potable water. Dec.-16, Q13(b)

Answer :

Specifications of potable water are classified into two types,

(i) Primary specifications

(ii) Secondary specifications.

(i) Primary Specifications

Depending on the effect on human health, primary specifications represent the maximum contaminant levels of different dissolved minerals.

(ii) Secondary Specifications

Based on the taste, colour, smell and hardness of the water, these specifications are different in different places.

The common specifications of potable water are mentioned below,

(a) It must be free from harmful minerals.

(b) Its pH value must lie between 6.5-8.5.

(c) It must be free from pathogenic bacteria.

(d) The permissible limits of iron and manganese must be 0.3 mg/l and 0.05 mg/l respectively.

(e) It must be non-corrosive in nature.

(f) It should not contain any dissolved gases such as H_2S.

Q39. What is meant by sterilization of water? Why is it necessary? Explain how sterilization of water is carried out by using chlorine.

Answer :

Sterilization of Water

Sterilization of water refers to process that kills effectively or eliminates transmissible agents such as fungi, bacteria, viruses etc., from water. It can be achieved through application of heat, chemicals, irradiation, high pressure or filtration. Stored water must be sterilized prior to use in holding disinfected water for use. This requires the addition of considerably more chlorine compound than mere disinfection i.e., 50 parts per million of available chlorine.

Necessity of Sterilization of Water

Treating water by sedimentation, filtration and storage removes all the suspended particles, but, will not completely eliminate the bacteria. Total elimination of bacteria is achieved only by sterilization. These microbes includes,

(a) The enteric bacteria belonging to Salmonella, Shigella and Vibrio groups.

(b) The intersinal protozoa such as Entamoeba histolytica.

(c) Worms such as Schistosomes.

(d) Viruses such as those of infectious hepatitis.

(e) Caliform organisms which indicate water pollution, though not pathogenic.

Caliform and enteric bacteria are easily destroyed but viruses and cysts of E.hystolytica are resistant to disinfection.

Sterilization of water can be done in the following ways.

Sterilization by Chlorination

Chlorine may be added in the form of bleaching powder or directly as a gas or in the form of concentrated solution in water. The treatment should give accurate dosage, good distribution and sufficient time of contact (approximately 30 minutes) so as to ensure effective sterilization.

Chlorine reacts with water and gives hypochlorous acid and this undergoes dissociation to liberate nascent oxygen. This nascent oxygen liberated destroys the germs and bacteria by oxidation. The OCl^- ions are capable of rupturing the cell membranes of the disease producing microbes.

$$\begin{aligned} CaOCl_2 + H_2O &\rightarrow Ca(OH)_2 + Cl_2 \\ Cl_2 + H_2O &\rightarrow HOCl + HCl \\ \underset{\text{(Hypochlorous acid)}}{HOCl} &\rightarrow \underset{\text{(Nascent oxygen)}}{[O]} + HCl \end{aligned}$$

Q40. Illustrate Break Point Chlorination.

May/June-18,Q16(b)

OR

Discuss the concept of break point chlorination.

June/July-17,Q13(b)

OR

Explain the concept of breakpoint chlorination.

Answer : **Dec.-16,Q16(b)**

Break-point Chlorination

Break point chlorination (or) Free residual chlorination is a controlled process in which sufficient amount of chlorine is added for oxidation of all organic matter, destroying bacteria and reacting with any ammonia present in water leaving slight amount of free chlorine. This excess of chlorine present in free form in water will produce unpleasant taste and odour and produces irritation on mucous membrane if consumed. The quantity of chlorine in water should not exceed 0.1 to 0.2 ppm.

Example

The existence of free chlorine i.e., break-through point, in treated water is determined experimentally as follows,

Consider a water sample taken from well or river, now the water rich in organic compounds or ammonia is mixed with chlorine gradually in steps.

Chlorine added to water sample (after sometime) is estimated. It is found that the residual chlorine in water is less than the amount of chlorine added initially. It is because some amount of chlorine added is consumed by oxidizing bacteria or organic matter or ammonia present in water.

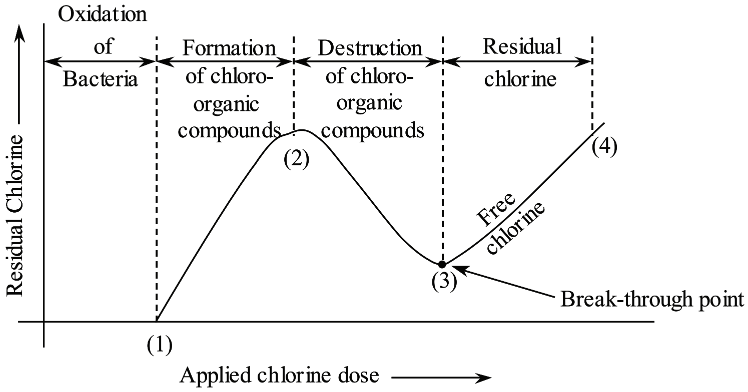


Figure: Break-point Chlorination

If chlorine addition is increased further, it is seen that a curve as shown in figure is obtained. A straight line of increase in quantity of residual chlorine is obtained, this line indicates formation of chloro-organic compounds. By further increasing chlorine dose, we will get a sudden decrease in residual chlorine, this is due to the destruction of chloro-organic compounds.

From figure, point (1) to (2) is due to the formation of chloro-organic compounds. And from point (2) to (3) is due to the destruction of chloro-organic compounds.

Point (3) in figure is "break-point" at which free residual chlorine begins to appear as per the pervious dose added. At this point, all tastes, odours (chlorinous and others) will disappear, resulting in water free from bad tastes and odours. Some of the organic compounds present in water gets defy-oxidation at lower concentration of chlorine which gets oxidized at break-point chlorine concentration. At break-point, chlorine present is highly persistent and powerful disinfectant, which will destroy pathogenic organisms present in water, thereby making it free from infections.

2.2 CORROSION

2.2.1 Causes and its Effects. Types of Corrosion – Dry or Chemical Corrosion and Wet or Electrochemical Corrosion and their Mechanism

Q41. What is corrosion? What are the units in which it is expressed?

Answer :

Corrosion

For answer refer Unit-2, Q11.

Units of Corrosion

Corrosion is the measure of thickness of the oxide layer that is formed over the surface of a metal, the rate of corrosion can be measured using the following units.

1. Milli-ampere per square centimeter (mA/cm^2) – It gives current flow rate through metal layer.
2. Mils/year or mpy or μm/year (milli-inch per year or 0.0254 mm per year) – It gives penetration rate.
3. g/m^2/day (grams per square metre per day) – It gives mass loss of metal per day.

Rate of corrosion (in mpy) is calculated using,

$$R = \frac{(\text{Weight loss in grams}) \times (22{,}300)}{\text{Area (cm}^2) \times \text{Density (g/m}^3) \times \text{Time of exposure (hr)}}$$

Q42. What are the causes and effects of corrosion?

Answer :

Causes of Corrosion

The various factors that cause corrosion of materials are,

1. Type of material
2. Designing of the material
3. Temperature
4. Chemicals present in environment.

Effects of Corrosion

The effects or consequences that occur due to corrosion are,

1. Corrosion causes damaging of buildings, historical monuments and boilers.
2. It decreases the efficiency of machine causing the failure of structure and its mechanical strength.
3. Corrosion decreases the thickness of metal and its appearance. Hence, the cost of the material gets reduced.
4. It also blocks pipes, thereby causing difficulty in the operation of pumps.

Q43. Explain different types of corrosion and write their mechanism.

Answer :

When a metal is exposed to environment, the disintegration of metal occurs due to the following types of corrosion,

1. Dry or direct chemical corrosion
2. Wet or electrochemical or immersed corrosion.

The corrosion process is slow, gradual and continuous process, which occurs on the surface of the metal.

1. Dry or Direct Chemical Corrosion

The direct contact of metal with environment leads to dry or direct chemical corrosion. In this, the direct chemical action occurs over the surface of metal in the dry state due to the existence of gases (such as O_2, H_2, halogens, H_2S, SO_2, N_2) and certain anhydrous inorganic liquids nearer to the metal surface.

This corrosion is divided into three types. They are,

(a) Oxidation corrosion

(b) Corrosion by gases like (Cl_2, H_2, SO_2, F_2, CO_2, H_2S) other than oxygen

(c) Liquid metal corrosion.

(a) Oxidation Corrosion

The direct attack of oxygen on the metal at low or high temperature in the absence of moisture results in oxidation corrosion and forms metal oxide. The general chemical reactions in oxidation corrosion are as follows,

$$\begin{array}{c} 2\,M \rightarrow 2\,M^{n+} + 2\,ne^{-}\,(\text{Loss of } e^{-}) \\ \frac{n}{2}O_2 + 2\,ne^{-} \rightarrow nO^{2-}\,(\text{Gain of } e^{-}) \\ \hline 2\,M + \frac{n}{2}O_2 \rightarrow 2\,M^{n+} + nO^{2-}\,(\text{Total reaction}) \\ (\text{Oxide formation}) \\ \hline \end{array}$$

Mechanism of Oxidation Corrosion

Initially, the surface of metal is coated with a thick film of oxide layer which may act as retardant for further corrosion of the surface.

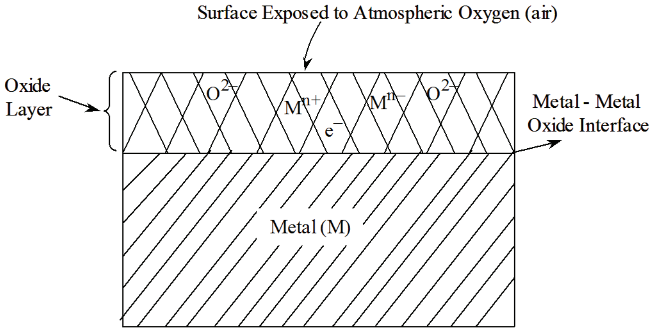


Figure: Oxidation Corrosion

The extent of oxidation corrosion depends on the type of oxide layer formed on the metal surface.

(i) Stable Oxide Layer

If the oxide layer formed is stable then, it acts as a strong protective coating to the metal surface. This will prevent further penetration of oxygen towards the metal i.e., further corrosion of metal is stopped.

Example

Al, Cr, Cu, Pb and Sn form stable oxide layer.

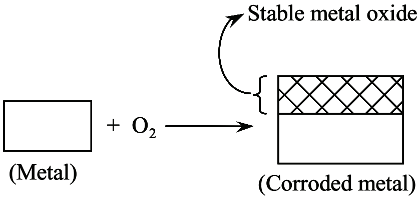


Figure: Stable Oxide Layer

(ii) **Unstable Oxide Layer**

If the oxide layer formed is unstable then, the oxidation corrosion is a reversible process and oxide layer formed decomposes back into metal and oxygen. So, oxidation corrosion is not possible.

Example

Pt, Ag and Au do not undergo oxidation corrosion.

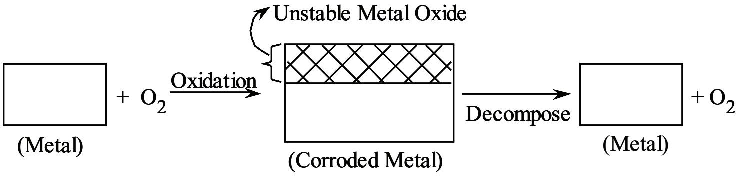


Figure: Unstable Oxide Layer

(iii) **Volatile Oxide Layer**

If the oxide layer formed is volatile, then the base metal is exposed to further corrosion, thereby causing severe loss of the metal.

Example

Molybdenum oxide formed on Molybdenum is volatile in nature.

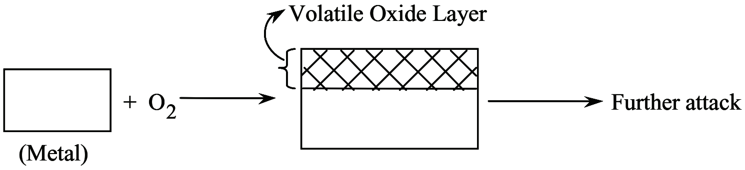


Figure: Volatile Oxide Layer

(iv) **Porous Oxide Layer**

If the oxide layer formed is porous i.e., it allows oxygen through it for further attack, then it will result in rapid and continuous corrosion.

Example

Alkali and Alkaline earth metals form porous oxide layer.

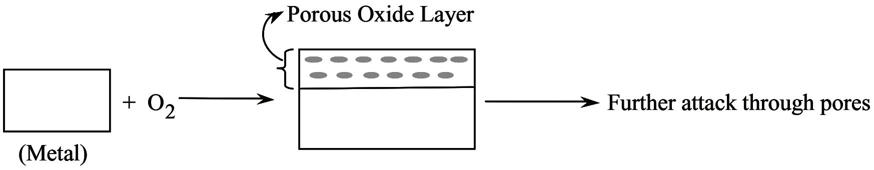


Figure: Porous Oxide Layer

(b) **Corrosion by Gases other than Oxygen**

Corrosion by other gases such as SO_2, CO_2, Cl_2, H_2S and F_2 depends mainly on the affinity of the metal towards the gas to form a corrosive layer on the metal surface.

Example

In case of silver metal and chlorine gas, AgCl layer is formed, which stops further corrosive attack of chlorine on silver.

(c) **Liquid Metal Corrosion**

Liquid metal corrosion takes place due to the chemical action of flowing liquid metal at high temperatures over a solid metal.

The two possible cases are,

(i) Penetration of liquid metal into the solid metal internally or

(ii) A solid metal gets dissolved in a hot liquid metal.

Example

Corrosion of cadmium rods by sodium metal acts as coolant in nuclear reactors.

2. Wet or Electrochemical or Immersed Corrosion

Electrochemical corrosion is a process in which a part or all of the metal is transformed from a metallic to an ionic state. This corrosion mostly occurs under wet or moist conditions due to the formation of short-circuited galvanic cells. It is a fast process which involves the setting up of a large number of galvanic cells.

Mechanism of Electrochemical Corrosion

For remaining answer refer, Unit-1, Q12.

Q44. Define metallic corrosion. Explain electrochemical theory of corrosion. June/July-15, Q12(a))

OR

Define corrosion of metals. Explain the mechanism of electrochemical theory of wet corrosion.

Answer : Jan.-12, Q13(a)

Corrosion of Metals

For answer refer Unit-2, Q11.

Mechanism of Electrochemical theory of Wet Corrosion

For answer refer Unit-2, Q12.

Q45. Differentiate between chemical and electrochemical corrosion. June-13, Q5

OR

Differentiate between dry corrosion and wet corrosion.

Answer : June-11, Q13(a)

	Dry Corrosion		Wet Corrosion
1.	Dry corrosion is also called as chemical corrosion.	1.	Wet corrosion is also called as electrochemical corrosion.
2.	It occurs in dry conditions.	2.	It occurs in the presence of moisture or electrolytes.
3.	Direct chemical attack on the metal by environment is involved.	3.	It involves the formation of large number of electrochemical cells.
4.	Absorption mechanism explains dry corrosion.	4.	It is explained by the mechanism of electrochemical reactions.
5.	It occurs on both homogeneous and heterogeneous surfaces.	5.	It occurs on heterogeneous metal surface only.
6.	Uniform corrosion takes place.	6.	Non-uniform corrosion takes place. If the anode area is small, pitting is more frequent.
7.	It is a slow process.	7.	It is a quick process.
8.	Corrosion products accumulate at the same place where corrosion occurs.	8.	Corrosion occurs at anode but products accumulate near the cathode.
9.	It takes place at low temperature.	9.	It takes place at high temperature.

2.2.2 Electrochemical Corrosion – Waterline and Pitting Corrosion. Factors Influencing Rate of Corrosion

Q46. Explain the different types of electrochemical corrosion.

Answer :

Electrochemical corrosion is primarily of two types. They are,

(a) Galvanic cell corrosion (Bimetallic)

(b) Differential aeration corrosion (or) concentration cell corrosion.

(a) Galvanic Cell Corrosion (Bimetallic)

For answer refer Unit-2, Q13.

(b) Differential Aeration Corrosion (or) Concentration Cell Corrosion

For answer refer, Unit-2, Q15.

Differential aeration corrosion is again classified into,

(i) Waterline corrosion
(ii) Pitting corrosion
(iii) Intergranular corrosion
(iv) Stress corrosion
(v) Crevice corrosion.

Few of the above corrosion is explain in detail below:

(i) Waterline Corrosion

For answer refer Unit-2, Q14.

(ii) Pitting Corrosion

Pitting corrosion is a localized attack which occurs due to the formation of holes around a relatively unattached metal, i.e., when the surface of the metal is rough with pits and holes over it. Pitting corrosion depends on the polishing surface of metal and cracks of protective surface film. Any metal with rough surface can easily be violated by pitting corrosion resulting in cracking of the protective film at specific points on the metal surface. The breakdown of protective film occurs due to scratches, non-uniform surface finish, alternating stresses, sliding under load, chemical attack and impingement attack (which is caused due to turbulent flow of a solution over a metal surface).

Example

When an iron piece is dipped in acidic water and stored for a long time, corrosion occurs along the iron piece. The highly oxygenated area acts as the cathode and is unaffected by corrosion, while the poorly oxygenated area acts as anode and is highly affected by corrosion under acidic conditions. Pitting of the metal occurs when there is a break in the protection layer.

Figure below illustrates the corrosion of iron piece at its surface.

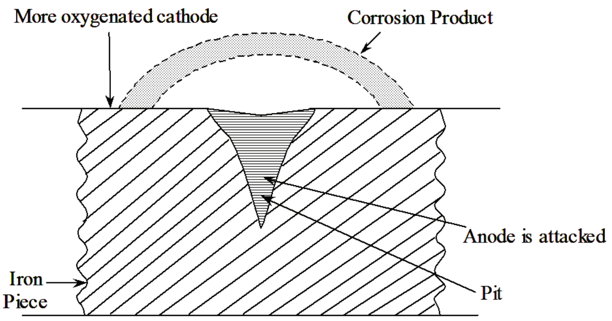


Figure: Pitting Corrosion at the Surface of Iron Piece

Due to the difference in the areas of Anode (small) and Cathode (large), a potential difference is established at the localised spots. This inturn form pits on the metal and thus generates corrosion current. The rate of corrosion increases with the formation of small pits.

Chemical Reactions

The chemical reactions that take place during the corrosion mechanism are,

At anode : $Fe \rightarrow Fe^{2+} + 2e^-$

At cathode : $\frac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH^-$

Net reaction : $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$.

Q47. What is corrosion of metals? Describe the mechanism of electrochemical corrosion by
(i) Hydrogen evolution and
(ii) Oxygen absorption.

Answer : June-17, Q13(b)

Corrosion of Metals

For answer refer Unit-2, Q11.

(i) Hydrogen Evolution

For answer refer Unit-2, Q12, Topic: Evolution of Hydrogen.

(ii) Oxygen Absorption

For answer refer Unit-2, Q12, Topic: Absorption of Oxygen.

Rusting of Iron based on Electrochemical Theory of Corrosion

Initially, the surface of iron is coated with a thin film of iron oxide. If some cracks appear on this film, anodic areas are developed on the surface and rest of the metal plates act as cathode as shown in the figure.

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

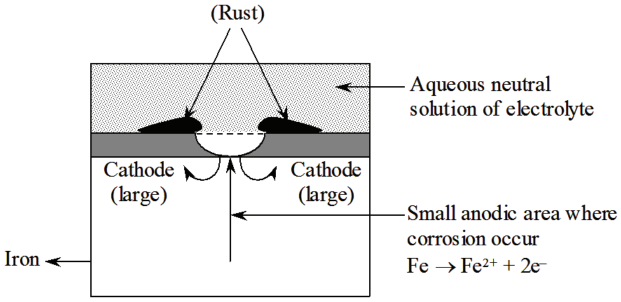


Figure: Rusting of Iron

Anodic Reactions

At small anodic area (caused by cracks in the oxide film where corrosion occurs) iron undergoes oxidation to produce ferrous ions with liberation of two electrons.

$$Fe \rightarrow Fe^{2+} + 2e^-$$

Cathodic Reactions

These liberated electrons flow through iron metal from anodic to cathodic areas, where electrons are consumed by the dissolved oxygen as,

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

The Fe^{2+} ions from anode and OH^- ions from cathode combine and form ferrous hydroxide which is precipitated out

i.e., $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2\downarrow$

In the presence of excess oxygen, ferrous hydroxide is easily oxidized to ferric hydroxide.

i.e., $4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$

This is called yellow rust which corresponds to $FeO_3\,H_2O$ or FeO(OH). An increase in oxygen content has two effects. They are,

(i) It forces the cathodic reaction to the right producing more OH^- ions and

(ii) It removes more electrons and therefore, accelerates the corrosion at the anode.

Each of these effects constitute more reactancts for the rust forming reaction. Presence of oxygen greatly accelerates both corrosion and rust formation (corrosion occurs at the anode, but rust forms at the cathode.

Q48. Explain the factors affecting corrosion with respect to nature of metal.

Answer :

The factors affecting corrosion with respect to the nature of a metal are,

(i) Overvoltage

(ii) Purity of metal

(iii) Nature of oxide film

(iv) Nature of corrosion product.

(i) Overvoltage

Overvoltage of a metal in corrosive atmosphere is inversely related to its corrosion rate.

For instance, a zinc metal dipped in 1M of sulphuric acid (H_2SO_4) has a normal hydrogen voltage of about 0.7 V. The sulphuric acid gradually corrodes the zinc i.e., the process of corrosion is very slow. The rate of corrosion of zinc can be increased by adding few drops of copper sulphate ($CuSo_4$). This reduces the hydrogen overvoltage of zinc to 0.33 V. Therefore, a decrease in overvoltage leads to an increase in the corrosion rate.

(ii) Purity of Metal

When there are impurities in a metal, it causes heterogeneity which results in the formation of small electrochemical cell and corrodes anodic parts. For example, Zinc metal which contains the impurities (like Pb or Fe) undergoes corrosion due to the formation of local electrochemical cells. As the impurities increase corrosion of the metal also increases. Therefore, corrosion resistance of a metal can be improved by reducing the impurities in it.

(iii) Nature of Oxide Film

In an aerated atmosphere, the metals are covered by a thin film of metal oxide. The ratio of volume of the metal oxide to the volume of metal is called as the specific volume ratio. As the ratio of specific volume increases, the oxidative corrosion rate decreases.

Metal	Specific Volume Ratio	Corrosion Rate
Ni	1.6	High
Cr	2.0	Low
W	3.6	Least

It can be observed from table that the tungsten has lowest corrosion, even at high temperatures. Apart from these, metals like Al have a firm oxide film when compared to Fe, therefore A1 is less corrosive.

(iv) Nature of Corrosion Product

Oxide layers formed on the surface of metals act as physical barriers between the metal and the environment. This offers resistance to corrosion. However, the extent of protection depends upon coherence of the protective layer formed and its critical humidity.

Some of the metals that are affected by corrosion are,

1. Metals like Ni, Cr, Al and alloys like stainless steel form thin and firm protective oxide film and thus exhibit good corrosion resistance.

2. Metals like Cu, Pb cannot form highly protective films, but develop corrosion resistance by forming secondary layers of corrosion products.
3. Copper forms a coherent and adherent layer of basic copper carbonate or basic copper sulphate so as to offer resistance to the atmospheric corrosion.
4. In iron, the primary corrosion product is ferrous hydroxide that oxidizes to basic ferric carbonate and then to hydrated ferric oxide (rust). This oxide is non-adherent and incoherent as the oxidation of $Fe(OH)_2$ to $Fe(OH)_3$ involves decrease in volume. The rate of atmospheric corrosion of iron depends upon the extent of humidity present in the atmosphere, the degree of pollution of atmospheric air and the frequency of exposure to rain.

Q49. Explain how heterogeneity of metal increases the rate of corrosion.

Answer :

The presence of impurities in a metal generally cause "heterogeneity". The impurities present in a metal form minute galvanic cells under appropriate environment and corrode the anodic part. For example, impurities such as Pb, Fe or C in zinc leads to the formation of local electrochemical cells. The increase in exposure and extent of impurities are responsible for increasing the rate and extent of corrosion. Therefore, the corrosion resistance of a metal can be improved by increasing its purity. The percentage of purity of zinc and the corresponding corrosion rate is illustrated in table.

Purity % of Zinc	Corrosion Rate
99.999%	1
99.99%	2650
99.95%	7200

Table: Corrosion Rate of Zinc

Q50. What is meant by corrosion? Explain the factors which influence corrosion.

Dec.-17, Q13(a)

OR

Discuss the factors that affecting the rate of corrosion.

April-16, Q12(a)

OR

Discuss the factors affecting the rate of corrosion.

June-14, Q13(a)

OR

What are the factor affecting the rate of corrosion?

May/June-12, Q17(a)

OR

Discuss various factors that influence the rate of corrosion.

Answer : June-11, Q13(b)

Corrosion

For answer refer Unit-2, Q11.

The various factors affecting the rate of corrosion of a metal are,

(a) Position of Metals in Galvanic Series

Position of metals or alloys in galvanic series largely affects the rate of corrosion. The larger the distance between the metals, faster is the corrosion of the active metals (or anode).

(b) Relative Areas of Anode and Cathode

If two dissimilar metals or alloys are in electrical contact, the anodic area gets corroded and the rate of corrosion is directly proportional to the ratio of cathodic and anodic areas. Small anodic area leads to high rate of corrosion as the current density at small anodic area is very high.

(c) Nature of Corrosion Product

For answer refer Unit-2, Q48, Topic: Nature of Corrosion Product.

(d) Temperature

The reaction (corrosion) rate increases as the temperature of the environment increases, the diffusion rate and the reaction is enhanced due to the increase of temperature.

(e) Humidity

The corrosion rate is directly related to humidity of air. Critical humidity is the relative humidity above which the atmospheric corrosion rate of metal increases sharply. The basic principle of enhancement of corrosion in humid conditions is that atmospheric gases like CO_2, O_2 etc., and vapours present in atmosphere. These gases in atmospheric air furnishes water to the electrolyte, which is essential for setting up of an electrochemical corrosion cell. Oxide films present on the metal surface absorbs the moisture present in air and ensures the occurrence of electrochemical type corrosion. Hence, corrosion rate is increased.

(f) Influence of PH

Acidic media having pH < 7 causes more corrosion then the basic and neutral media. Thus, the corrosion can be reduced by increasing the pH of the media.

A pourbaix diagram is used to establish the relationship between the possibility of corrosion with reference to pH value of the solution and oxidation potential of metal. It also provides the information about pH- potential conditions such as prediction of corrosion and the ways to minimize the corrosion. The pourbaix diagrams for iron in water are as shown in figure (i) and Figure (ii).

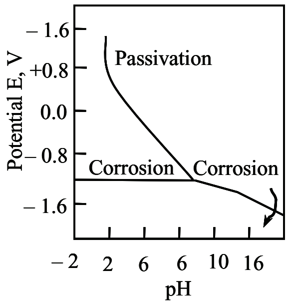


Figure (i)

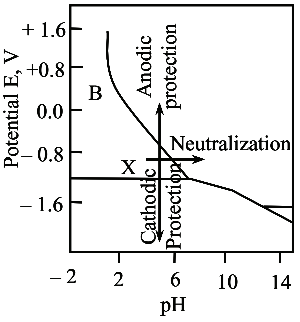


Figure (ii)

2.3 CORROSION CONTROL METHODS

2.3.1 Cathodic Protection Methods – Sacrificial anodic and Impressed Current Methods

Q51. What is cathodic protection? Explain sacrificial anode method.

(May/June-12, Q13(a)| June-10, Q3(b))

OR

What is cathodic protection? Explain sacrificial anodic protection method.

Answer : **Jan.-12, Q13(b)**

Cathodic Protection

The cathodic protection of metals is a method used to control the corrosion of metals where the nature of the corrosion medium cannot be changed. This method involves the protection of metals and alloys from corrosion, by making them completely cathodic. In other words, as there is no anode the metal is protected from corrosion.

Types

There are two types of cathodic protection. They are,

1. Sacrificial anodic protection
2. Impressed current cathodic protection.

Sacrificial Anodic Protection

In this method of cathodic protection, the structure of the metal is protected from corrosion by connecting it with a wire to a more active metal i.e., more anodic metal. This more anodic metal is known as sacrificial anode as it undergoes corrosion to protect the base metal (cathode). The metals which are commonly used as sacrificial anodes are Mg, Zn, Al and their alloys.

Example

Underground iron pipes are connected to more active metal i.e., magnesium (Mg) to avoid corrosion. Iron pipe acts as cathode whereas, Mg acts as anode and undergoes corrosion as shown in figure below,

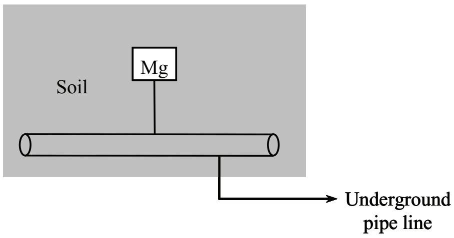


Figure: Sacrificial Anodic Protection

Applications of Sacrificial Anodic Protection Method

1. Sacrificial anodic protection is used to protect underground cables and pipelines from soil corrosion.
2. It is used to protect ships and boat from marine corrosion.
3. It is also used to prevent rusty water by inserting magnesium (Mg) sheets or rods into domestic water boilers or tanks.

Q52. What is impressed current cathodic protection? Dec.-17, Q6

Answer :

In this method of cathodic protection, an impressed current is applied to convert the corroding metal from anode to cathode. The applied current is in opposite direction which cancels (nullify) the corrosion current.

A required amount of direct current is applied (from battery or rectifier) to an insoluble anode (like graphite, high silica iron, stainless steel or platinum) present in soil or corrosion medium. This anode is connected to the corroding metal structure (buried pipe) which is to be protected as shown in figure.

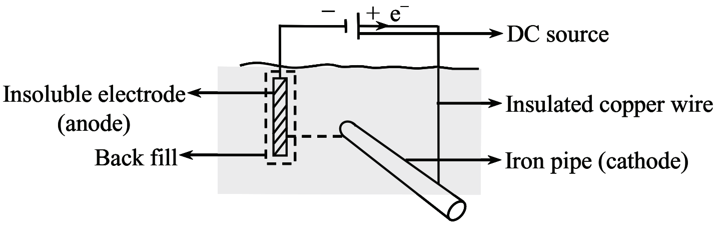


Figure: Impressed Current Cathodic Protection

Electrons are supplied from the externally connected cell (DC source). This enables the object (Iron pipe) to act itself as cathode and is not oxidized. Thus, the metal structure is protected from corrosion.

2.3.2 Surface Coating Methods: Hot Dipping – Galvanizing

Q53. Discuss in brief about the various types of surface coatings.

Answer :

The various types of surface coatings include,

1. Phosphate coating
2. Chromate coating
3. Chemical oxide coating
4. Anodized coating.

1. Phosphate Coating

Phosphate coating is obtained when the base metal chemically reacts with the aqueous solution of phosphoric acid and phosphate. It can be applied by spraying or immersion or brushing. It is generally grey in colour and can be converted to black by using a dye (bonderizing) followed by oiling (parkerizing).

2. Chromate Coating

Chromate coating is obtained when the article is initially placed in a bath of acidic potassium chromate and then in a bath of neutral chromate solution. It can be coated in various colours i.e., from olive drab to clear yellow.

Chromate films are non-porous, corrosion resistant and amorphous. They can be used as a base for enamels, points etc. They are especially used to protect aluminium, magnesium, cadmium-plated areas, zinc etc.

3. Chemical Oxide Coating

Chemical oxide coating is obtained when the base metal reacts with alkaline-oxidizing solution or gas. It is generally available in a variety of colours ranging from straw yellow to light blue. These coloured products can be produced by subjecting steel to 200 - 400°C of temperature in the presence of air. It is resistant to corrosion and acts as a base for oils, paints, waxes etc.

4. Anodized Coating

Anodized coating is obtained from anodic oxidation process by making base metal as anode. In anodic oxidation process, a moderate electric current is passed through a bath (containing chromic or sulphuric or oxalic acid) containing suspended alloy or metal from anode.

Due to its thickness, it is highly resistant to corrosion and mechanical injury.

Q54. Write in detail about galvanizing and tinning. Dec.-17, Q13(b)

OR

Explain about dipping methods.

Answer :

Dipping Methods

Hot dipping is a process of coating a metal having low melting point over another metal having high melting point.

In this method, base metal is dipped into a bath of molten coating metal.

Example: Coating of tin over iron or steel.

There are two types of hot dipping methods. They are,

1. Galvanizing
2. Tinning.

1. Galvanizing

Galvanizing is a process of coating a thin layer of zinc over an iron or steel article to protect it from corrosion.

The process of galvanizing of iron sheet is as shown in figure (1).

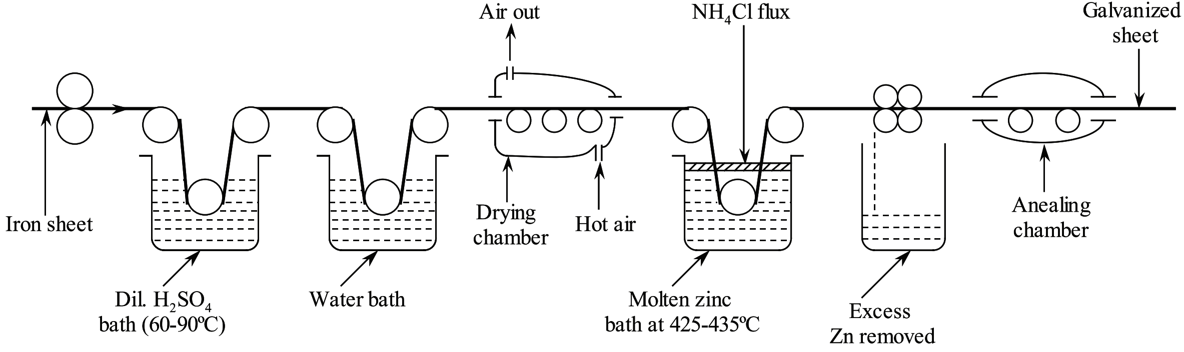


Figure (1): Galvanizing Method

In this process, initially iron or steel is immersed into a dilute sulphuric acid solution (H_2SO_4) at a temperature range of 60 to 90ºC for 15 to 20 minutes (pickling process). The scale, rust and other impurities present on the iron or steel are cleared up and then subjected to washing and drying. The dried iron or steel is dipped in the bath of molten zinc which is at 425 to 450ºC. The surface of the bath is covered with a flux of ammonium chloride to avoid oxide formation. When the iron piece is taken out from the bath, it is well coated with a thin layer of zinc. The excess zinc can be removed by passing it through a pair of hot rollers. It is then annealed at a temperature of 450ºC and then cooled slowly.

Galvanizing is most widely used to protect iron and steel products, such as wires, pipes, nails, bolts, screws, buckets, tubes and roofing sheets.

2. Tinning

Tinning is a process of coating tin over an iron or steel articles to protect it from corrosion. Since, tin is much inert than iron, it is more resistant to chemical attack.

The process of tinning an iron sheet is as shown in figure (2).

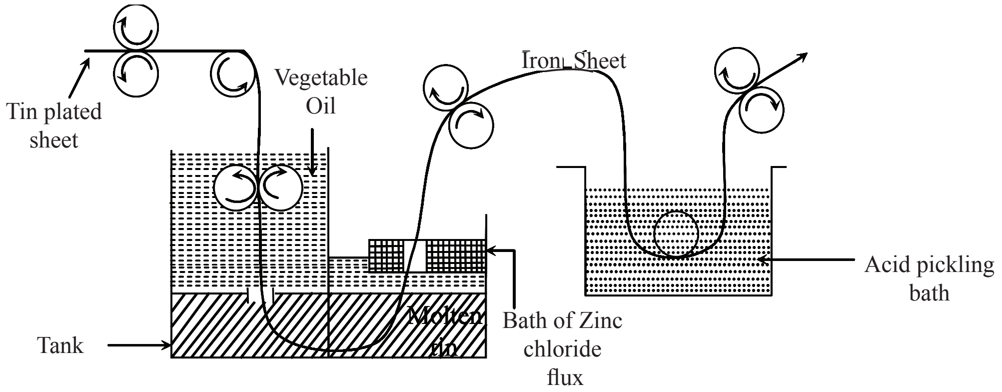


Figure (2): Tinning of Iron Sheet

In this process, initially iron sheet is dipped in dilute sulphuric acid (pickling process) in order to remove any oxide film (if any). A cleaned iron sheet is then passed through a bath of molten flux like zinc chloride, then through molten tin. Finally, it is then passed through a suitable vegetable oil to avoid oxidation on the hot surface. The excess tin is removed by passing it through a pair of rollers. Hence, a uniformly coated tin on iron sheet is obtained.

Tinning is most widely used for coating iron, steel, copper and brass sheets for storing food stuffs ghee, oils, kerosene and containers used for packing food materials.

Q55. Galvanization of iron articles is preferred to tinning. Give reason.

Answer : June-17, Q13(a)

Coating of iron with zinc (galvanization) is preferred to tinning because of the following reasons,

(i) Zinc protects the base metal iron if any pores or discontinuities occur. Because, zinc is more electro negative than iron. If coating of zinc is broken, then it acts as anode and the exposed iron portion acts as cathode. And zinc being more anodic undergoes corrosion and protects iron from rusting.

(ii) Sacrificially, zinc protects iron from rusting.

(iii) In tinning (coating iron with tin), tin is also a noble metal. It has higher reduction potential than iron.

(iv) Due to its higher corrosion resistance capability tin protects iron from corrosion. If at some place coating breaks, high rates of corrosion occurs, the exposed part of iron acts as anode and tin coating acts as cathode, establishing galvanic cell reaction.

(v) Therefore, tinning can cause intense corrosion at small broken coatings.