
Unit 3: Engineering Chemistry Notes

Unit 3 typically covers essential topics in electrochemistry, corrosion, and the chemistry of engineering materials like cement. Some syllabi also include lubricants in this unit.

I. Electrochemistry and Batteries

This section focuses on the fundamental principles of electrochemistry and various types of batteries.

- **Basic Concepts of Electrochemistry**
 - **Galvanic Cell:** A galvanic cell, also known as a voltaic cell, is an electrochemical cell that converts chemical energy into electrical energy through spontaneous redox reactions.
 - **Electrode Potential:** This refers to the potential difference that develops between an electrode and its surrounding electrolyte when they are in contact.
 - **Electrochemical Series:** This is a list of chemical elements arranged in order of their standard electrode potentials. For example, a question might involve calculating the potential of a half-cell like a zinc electrode in a 0.01M ZnSO₄ solution at 25°C, given its standard electrode potential ($E^\circ = 0.763\text{V}$).
 - **Nernst Equation and Applications:** The Nernst equation is crucial for calculating cell potentials under non-standard conditions. It also relates the electromotive force (e.m.f.) of a cell to thermodynamic functions such as change in enthalpy (ΔH), Gibbs free energy (ΔF or ΔG), and entropy (ΔS).
- **Batteries** Batteries are devices that store chemical energy and convert it into electrical energy. They are broadly classified into two main types:
 - **Primary Cells:** These are non-rechargeable batteries, meaning once the reactants are consumed, the battery cannot be easily restored to its original state by reversing the current. An example is the Dry Cell.
 - **Secondary Cells:** These are rechargeable batteries, which can be recharged by passing an electric current through them in the reverse direction. This restores the reactants to their original state. The **Lead Acid Battery** is a significant example of a secondary cell.
 - **Lead Acid Battery: Construction and Working (Charging/Discharging Chemistry):** The sources indicate that the construction and the chemistry involved in the charging and discharging processes of a lead-acid battery are important topics for discussion. *(Note: Specific diagrams or detailed*

chemical equations for the charging/discharging process were not provided in the given sources, only the prompt to discuss them.)

II. Corrosion

Corrosion is a critical topic in engineering chemistry due to its widespread impact on materials and infrastructure.

- **Introduction to Corrosion**

- **Definition:** Corrosion is defined as the **spontaneous destruction of metals and alloys** resulting from their chemical, electrochemical, or biochemical interactions with the environment. It is essentially the **reverse process of extracting metals from their ores**.
- **Examples:**
 - **Rusting of Iron:** When iron is exposed to the environment, a reddish-brown flaky layer primarily composed of iron oxide (Fe_3O_4) forms on its surface.
 - **Formation of Green Film on Copper:** Copper, upon exposure to moist air containing carbon dioxide, develops a green film, which is a basic copper carbonate [$\text{CuCO}_3 + \text{Cu}(\text{OH})_2$].
- **Consequences (Effects) of Corrosion:** Corrosion has significant economic and social implications:
 - **Decreased Machinery Efficiency:** Formation of corrosion products on machinery can reduce its efficiency, potentially leading to equipment failure and plant shutdowns.
 - **Product Contamination or Loss:** Corrosion can lead to the contamination or loss of manufactured products.
 - **Equipment Replacement:** Corroded equipment often necessitates costly replacement.
 - **Increased Maintenance:** Requires regular preventive maintenance, such as applying metallic or organic coatings.
 - **Release of Toxic Products:** Corroding materials can release toxic substances into the environment.
 - **Health Hazards:** Can cause health issues due to environmental pollution from corrosion by-products or the escape of chemicals from corroded equipment.
- **Types of Corrosion** Corrosion can manifest in various forms depending on the metal, environment, and specific conditions.
 - **Chemical Corrosion (Dry Corrosion):** This type of corrosion occurs directly between a metal and a non-aqueous environment. Its extent and protective nature often relate to the **Pilling-Bedworth Rule**. *(Note: The precise definition or*

derivation of the Pilling-Bedworth Rule itself is not provided in the sources, only its mention in relation to chemical corrosion.)

- **Electrochemical Corrosion (Wet Corrosion):** This is the most common type of corrosion, occurring when a metal is in contact with an electrolyte and involves electrochemical reactions. The **rusting of iron** is a prime example explained by this theory.
 - *(Note: While the mechanism of electrochemical corrosion of iron with hydrogen evolution is a prompted discussion point, detailed steps or a diagram for it were not provided in the sources.)*
- **Galvanic Corrosion:** This occurs when two dissimilar metals are in electrical contact within an electrolyte. The more active metal in the electrochemical series acts as the anode and corrodes preferentially.
- **Differential Aeration Corrosion:** This type of corrosion occurs when a metal surface is exposed to varying concentrations of oxygen or other oxidants. Areas with lower oxygen concentration become anodic and corrode.
- **Waterline Corrosion:** A specific instance of differential aeration corrosion where corrosion is concentrated at the interface between water and air.
- **Pitting Corrosion:** A localized form of corrosion that results in small holes or "pits" on the metal surface.
- **Crevice Corrosion:** This occurs in narrow gaps or confined spaces where stagnant solutions can accumulate, leading to localized corrosion.
- **Liquid Metal Corrosion.**
- **Pipeline Corrosion.**
- **Causes and Factors Influencing Corrosion** The rate and type of corrosion are influenced by various factors:
 - **Nature of the Environment:** The chemical composition, pH, temperature, and presence of impurities in the surrounding environment significantly affect corrosion rates.
 - **Temperature:** An increase in temperature generally **increases the rate of metallic corrosion.**
 - **Nature of the Metal:** This includes its purity, composition, and physical state.
- **Corrosion Prevention and Control** Preventing corrosion is crucial for extending the lifespan of materials and ensuring safety.
 - **Cathodic Protection:** A method where the metal to be protected is made the cathode of an electrochemical cell, thereby preventing its oxidation.
 - **Sacrificial Anodic Protection:** In this method, a more active metal (which acts as a sacrificial anode) is electrically connected to the metal requiring protection. The sacrificial anode corrodes preferentially, thereby protecting the main structure. For instance, coating iron with zinc (galvanization) makes zinc the sacrificial anode.

- **Impressed Current Cathodic Protection:** This technique involves applying an external direct current to the metal to be protected, forcing it to act as a cathode and thus preventing corrosion.
- **Corrosion Inhibitors:** These are chemical substances added in small concentrations to an environment to **reduce the rate of corrosion**.
- **Protective Coatings:** Applying a protective layer on the metal surface acts as a barrier against the corrosive environment.
 - **Paints:** Composed of various constituents, each serving a specific function in corrosion protection. Their drying mechanism involves processes where the oil forms a protective film. Pigments in paints also serve important functions.
 - **Metallic Coatings:**
 - **Anodic Metal Coating (Galvanization):** Coating a metal with a more electropositive metal, such as zinc on iron. This provides sacrificial protection.
 - **Cathodic Metal Coating (Tinning):** Coating a metal with a less electropositive metal, such as tin. This acts as a barrier, but if the coating is scratched, the underlying metal corrodes rapidly.
 - **Electroplating:** Involves depositing a thin layer of one metal onto another using an electric current. Gold (Au) electroplating is an example. It is critical to **strictly maintain the pH of the plating bath** during electroplating for effective deposition.
 - **Electroless Plating (Nickel - Ni):** This is a chemical deposition process that forms a uniform metallic coating without external electrical power.
 - **Principle/Pre-treatment:** Non-metallic surfaces, like plastics and glass, are first activated. This involves dipping them in a solution containing SnCl_2 and HCl , followed by immersion in a palladium chloride solution. A thin layer of palladium is formed on the surface upon drying.
 - **Plating Bath Composition:** A typical electroless nickel plating bath includes:
 - **Coating Solution:** Nickel chloride (NiCl_2) at 20 g/L.
 - **Reducing Agent:** Sodium hypophosphite (NaH_2PO_2) at 20 g/L.
 - **Complexing Agent:** Sodium succinate at 15 g/L.
 - **Buffer:** Sodium acetate at 10 g/L.
 - **Optimum pH:** 4.5.
 - **Optimum Temperature:** 93°C .
 - **Procedure:** The pretreated object is immersed in this specially prepared plating bath for a sufficient duration.
 - **Chemical Reactions:**
 - At the cathode (where deposition occurs): $\text{Ni}^{2+} + 2\text{e}^- \rightarrow \text{Ni}$

- At the anode (where oxidation occurs): $\text{H}_2\text{PO}_2^- + \text{H}_2\text{O} \rightarrow \text{H}_2\text{PO}_3^- + 2\text{H}^+ + 2\text{e}^-$
- **Net Reaction:** $\text{Ni}^{2+} + \text{H}_2\text{PO}_2^- + \text{H}_2\text{O} \rightarrow \text{Ni} + \text{H}_2\text{PO}_3^- + 2\text{H}^+$
- **Applications:** Electroless nickel plating is widely used in:
 - Electronic appliances.
 - Domestic and automotive sectors (e.g., jewelry, perfume bottle tops).
 - Creating decorative and functional works using polymers.
 - Manufacturing plastic cabinets for digital and electronic instruments.

III. Chemistry of Engineering Materials: Cement

This section covers the chemical aspects of cement, a crucial engineering material.

- **Cement:**
 - **Constituents:** The syllabus covers the chemical components that make up cement.
 - **Manufacturing:** The process by which cement is produced is a key topic.
 - **Hardening and Setting:** This refers to the chemical reactions that occur when cement mixes with water, leading to its solidification and strength development.
 - **Deterioration of Cement:** Understanding the factors and mechanisms that lead to the degradation of cement over time is also part of the curriculum.
- **Plaster of Paris (POP):** This material, derived from gypsum, is also covered within this unit.

IV. Lubricants

Some versions of the Unit 3 syllabus also introduce lubricants.

- **Lubricants:** These substances are used to reduce friction between surfaces in mutual contact, which in turn reduces the heat generated when the surfaces move.
 - **Classification:** Lubricants can be classified based on their physical state (e.g., solid, liquid, semi-solid, gaseous) and chemical composition.
 - **Mechanism:** This refers to how lubricants function to reduce friction, often by forming a thin film between moving surfaces.
 - **Applications:** Lubricants have diverse applications across various industries, from automotive engines to industrial machinery. *(Note: While these subtopics are listed in the syllabus, further in-depth explanations, specific examples, or derivations for lubricants were not detailed in the provided sources.)*