

MUMBAI UNIVERSITY CBCGS SEM 2
ENGINEERING CHEMISTRY – II Dec 2023 SOLUTIONS

Q.1. a Explain why gold, silver, platinum do not undergo corrosion. [5]

Ans:- Gold, silver, and platinum are known as noble metals because they are highly resistant to corrosion or oxidation under normal environmental conditions. This resistance is primarily due to their unique electronic configurations and chemical properties:

- **Low Reactivity:** These metals have relatively low reactivity with oxygen, moisture, and other common environmental elements. Their outer electron shells are either completely filled or contain a stable configuration of electrons, making them less likely to undergo chemical reactions.
- **Electronegativity:** Gold, silver, and platinum have low electronegativity, which means they have a weak tendency to attract additional electrons. As a result, they are less likely to participate in reactions that involve electron transfer, such as oxidation.
- **Chemical Stability:** The atomic structures of these metals make them stable in various chemical environments. They form strong metallic bonds, which are resistant to breaking apart in the presence of substances that typically cause corrosion in other metals.
- **Passivation:** Gold, silver, and platinum can form protective oxide layers on their surfaces, which act as barriers against further corrosion. These oxide layers are stable and adhere tightly to the metal surface, preventing deeper penetration of corrosive agents.
- **Inertness:** Noble metals are generally inert, meaning they do not readily react with acids, bases, or other chemicals. This inertness further contributes to their resistance to corrosion.

While gold, silver, and platinum are highly resistant to corrosion under most conditions, they can still be affected by certain harsh environments or specific chemical reactions. However, compared to many other metals, their corrosion resistance is exceptionally high, making them valuable materials for various applications, including jewelry, electronics, and industrial processes.

b. b A coal sample was subjected to ultimate analysis. 1.5 g of coal sample on combustion in bomb calorimeter produced 0.24g of BaSO₄. Calculate the % of sulphur. [5]

Ans:- To calculate the percentage of sulfur in the coal sample, we can use the information provided about the amount of BaSO₄ produced during combustion. BaSO₄ is formed when all the sulfur in the coal sample is converted to BaSO₄.

Given:

Mass of coal sample = 1.5 g

Mass of BaSO₄ produced = 0.24 g
The molar mass of BaSO₄ (barium sulfate) is:

Molar mass of Ba = 137.33 g/mol

Molar mass of S = 32.06 g/mol

Molar mass of O = 16.00 g/mol

Total molar mass of BaSO₄ = 137.33 + 32.06 + (4 × 16.00) = 233.33 g/mol

Now, let's find the number of moles of BaSO₄ produced:

Number of moles of BaSO₄ = Mass of BaSO₄ produced / Molar mass of BaSO₄

= 0.24 g / 233.33 g/mol

≈ 0.00103 moles

Since 1 mole of BaSO₄ contains 1 mole of sulfur (S), the number of moles of sulfur in the coal sample is also 0.00103 moles.

Now, let's calculate the percentage of sulfur in the coal sample:

Percentage of sulfur = (Mass of sulfur / Mass of coal sample) × 100%

= (0.00103 moles × 32.06 g/mol) / 1.5 g × 100%

≈ (0.033 g / 1.5 g) × 100%

≈ 2.20%

Therefore, the percentage of sulfur in the coal sample is approximately 2.20%.

c. Explain the principle “prevention of wastes” of green chemistry. [5]

Ans:- The principle of "prevention of waste" is a fundamental aspect of green chemistry, which aims to design chemical processes and products in a way that minimizes or eliminates the generation of hazardous substances and waste materials. This principle is often referred to as "waste minimization" or "source reduction."

Thereby reducing the need for costly and environmentally damaging waste management practices such as treatment, disposal, and remediation. Several key strategies underlie the principle of waste prevention in green chemistry:

1. **Atom Economy:** This concept refers to the efficiency of chemical reactions in utilizing all the atoms present in the starting materials to form desired products, thereby minimizing the generation of by-products or waste.
2. **Catalysis:** The use of catalysts can enhance reaction rates and selectivity, leading to higher yields of desired products and minimizing the formation of unwanted by-products.
3. **Sustainable Synthesis:** Green chemistry emphasizes the development of synthetic routes that use renewable feedstocks, non-toxic reagents, and environmentally benign solvents. By choosing greener alternatives to traditional reactants and solvents, chemists can minimize the generation of hazardous wastes.
4. **Design for Degradation:** Green chemistry advocates for the design of products that degrade into harmless or benign substances after use, reducing their persistence and potential for environmental accumulation.
5. **Process Intensification:** Intensification techniques such as continuous processing, solvent-free reactions, and microreactor technology can enhance process efficiency.

and reduce waste generation by minimizing the use of energy, materials, and resources.

Overall, the principle of waste prevention in green chemistry emphasizes the importance of proactive design strategies to minimize the generation of hazardous substances and waste materials throughout the entire lifecycle of chemical products and processes. By integrating waste prevention principles into chemical design.

d. Define spectroscopy and give any two differences between absorption and emission spectra. [5]

Ans:- Spectroscopy is a branch of science concerned with the study of the interaction between matter and electromagnetic radiation. It involves analyzing how materials absorb, emit, or scatter electromagnetic radiation across a range of wavelengths or frequencies. Spectroscopic techniques are widely used in various scientific disciplines, including chemistry, physics, astronomy, and biology, to obtain information about the composition, structure, and properties of materials.

Differences between absorption and emission spectra:

1. Nature of Measurement:

- **Absorption Spectrum:** In absorption spectroscopy, the spectrum is obtained by measuring the absorption of electromagnetic radiation as it passes through a sample. The spectrum shows the wavelengths or frequencies at which the sample absorbs light.
- **Emission Spectrum:** In emission spectroscopy, the spectrum is obtained by measuring the intensity of the light emitted by a sample after it has been excited by external energy sources such as heat, electricity, or light. The spectrum shows the wavelengths or frequencies of the emitted light.

2. Information Revealed:

- **Absorption Spectrum:** The absorption spectrum provides information about the energies required for transitions between different energy levels within the sample. It indicates which wavelengths or frequencies of light are absorbed by the sample, corresponding to transitions from lower to higher energy levels.
- **Emission Spectrum:** The emission spectrum provides information about the energies released when excited electrons return to lower energy levels within the sample. It indicates which wavelengths or frequencies of light are emitted by the sample as a result of electronic transitions from higher to lower energy levels.

These differences highlight the complementary nature of absorption and emission spectroscopy, with absorption spectra revealing the energies needed for electronic transitions and emission spectra revealing the energies released during electronic transition.

e. What is knocking? What are the effects of knocking of gasoline. [5]

Ans:-

Knocking, also known as engine knocking or detonation, is an undesirable phenomenon that occurs in internal combustion engines. It is characterized by the sudden, uncontrolled combustion of the air-fuel mixture in the combustion chamber, often resulting in a sharp

metallic knocking or pinging sound. Knocking typically occurs when the air-fuel mixture ignites prematurely or spontaneously before the optimal timing set by the engine's ignition system.

The effects of knocking on gasoline engines include:

1. **Reduced Engine Efficiency:** Knocking disrupts the normal combustion process, leading to inefficient utilization of fuel. The uncontrolled combustion causes pressure waves within the combustion chamber that can interfere with the piston's movement, reducing the engine's power output and overall efficiency.
2. **Engine Damage:** Persistent knocking can cause significant damage to the engine components over time. The sudden pressure spikes generated by knocking can subject the piston, cylinder walls, valves, and other internal components to excessive stress and heat, leading to wear, deformation, and even mechanical failure.
3. **Increased Fuel Consumption:** Knocking forces the engine to operate at suboptimal conditions, resulting in increased fuel consumption to maintain performance levels. The engine compensates for the loss of power by consuming more fuel, reducing fuel efficiency and increasing operating costs.
4. **Emission of Harmful Pollutants:** Knocking can lead to incomplete combustion of the air-fuel mixture, resulting in higher emissions of pollutants such as carbon monoxide (CO), unburned hydrocarbons (HC), and nitrogen oxides (NOx). These pollutants contribute to air pollution and have adverse effects on human health and the environment.
5. **Engine Overheating:** The intense heat generated by knocking can cause localized overheating in the combustion chamber and surrounding engine components. Over time, this heat buildup can lead to thermal stress, heat fatigue, and ultimately, engine overheating, which can further exacerbate knocking and lead to catastrophic engine failure if not addressed.

To prevent knocking and its adverse effects, modern engines are equipped with various control systems and technologies, including knock sensors, electronic engine management systems, variable valve timing, and direct fuel injection.

f. Calculate the standard emf of a cell reaction at 250C ,

Cr(s)|Cr³⁺(1M)||Co²⁺(1M)|Co(s) E_{oCo} = - 0.280V, E_{oCr} = -0.74 [5]

Ans:- To calculate the standard electromotive force (emf) of the cell reaction at 25°C (298 K), we can use the Nernst equation:

$$E = E^{\circ} - \frac{RT}{nF} \ln(Q)$$

Where:

- E is the cell potential.
- E° is the standard cell potential.
- R is the gas constant (8.314 J/(mol·K)).
- T is the temperature in Kelvin (25°C = 298 K).
- n is the number of moles of electrons transferred in the balanced cell reaction.
- F is the Faraday constant (96485 C/mol).
- Q is the reaction quotient.

Given the cell reaction: $Cr(s) \rightarrow Cr^{3+}(1M) || Co^{2+}(1M) \rightarrow Co(s)$

The balanced cell reaction is: $Cr(s) + Co^{2+}(aq) \rightarrow Cr^{3+}(aq) + Co(s)$

The number of moles of electrons transferred (n) in this reaction is 1.

The reaction quotient (Q) for this cell reaction is given by: $Q = \frac{[Cr^{2+}]}{[Cr^{3+}]}$

Given that both concentrations are 1 M, $Q = 1$.

Now, let's calculate the standard cell potential (E°) using the standard reduction potentials (E_{Co° and E_{Cr°):

$$E^\circ = E_{\text{cathode}^\circ} - E_{\text{anode}^\circ}$$

$$E^\circ = (-0.280V) - (-0.74V)$$

$$E^\circ = 0.46V$$

Now, let's substitute the values into the Nernst equation:

$$E = 0.46V - (1 \text{ mol} \times 96485 \text{ C/mol}) (8.314 \text{ J/(mol} \cdot \text{K)}) \times (298 \text{ K}) \ln(1)$$

Solving this equation:

$$E = 0.46V - (96485 \text{ C/mol}) (2472.572 \text{ J/mol}) \times \ln(1)$$

$$E = 0.46V - 0.0256V$$

$$E \approx 0.4344V$$

Therefore, the standard emf of the cell reaction at 25°C is approximately 0.4344 V.

g. Distinguish between galvanizing and tinning

[5]

Ans:- Certainly, let's present the comparison between galvanizing and tinning in a tabular format for clarity:

Aspect	Galvanizing	Tinning
Purpose	Protect iron or steel surfaces from corrosion	Prevent oxidation and enhance solderability
Metal Coating	Zinc layer applied through hot-dip galvanizing or electroplating	Tin layer applied through hot-dipping, electroplating, or soldering
Base Metals	Primarily used on iron or steel surfaces, can be applied to other metals	Commonly applied to copper surfaces, can be used on other metals
Appearance	Shiny, metallic appearance, may develop matte gray patina over time	Bright, silvery appearance, provides smooth, uniform surface
Common Examples	Steel structures, automotive parts	Copper cookware, electrical components

This table outlines the key differences between galvanizing and tinning, including their purposes, methods of application, base metals, appearance, and common examples.

Q.2.A. Define corrosion? Explain the mechanism of corrosion by absorption of oxygen with diagram and reactions.

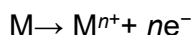
[6]

Ans:- Corrosion is a natural process that occurs when metals react with their environment, leading to the deterioration of their properties, such as strength and appearance. It typically involves the gradual degradation of metals due to chemical or electrochemical reactions with substances in

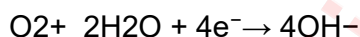
their surroundings, such as oxygen, water, acids, or salts. Corrosion can occur in various forms, including rusting (for iron and steel), tarnishing (for silver), and patina formation (for copper).

The mechanism of corrosion by absorption of oxygen, also known as atmospheric corrosion or oxidation corrosion, primarily affects metals such as iron (steel), aluminum, and copper. It involves the reaction of metal atoms with oxygen molecules in the presence of moisture or water vapor. The overall process can be summarized as follows:

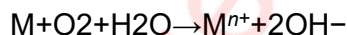
1. **Formation of Oxide Layer:** When a metal surface is exposed to oxygen and moisture, metal atoms react with oxygen to form metal oxides. This initial reaction often occurs at microscopic imperfections or defects on the metal surface.
2. **Formation of Corrosion Cell:** The formation of metal oxides creates localized differences in electrical potential on the metal surface, leading to the formation of electrochemical cells known as corrosion cells. These cells consist of anodic and cathodic regions, where oxidation and reduction reactions occur, respectively.
3. **Anodic Reaction:** At the anodic regions of the metal surface, metal atoms lose electrons and are oxidized to form metal ions, releasing electrons into the metal. The anodic reaction typically involves the dissolution of metal atoms into solution as positively charged ions, releasing electrons according to the following equation:



4. **Cathodic Reaction:** At the cathodic regions of the metal surface, oxygen molecules from the surrounding environment gain electrons and are reduced to form hydroxide ions (OH⁻) or water molecules, depending on the presence of water. The cathodic reaction can be represented as:

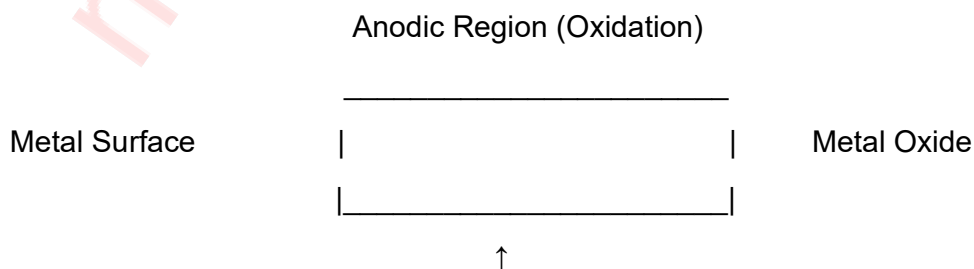


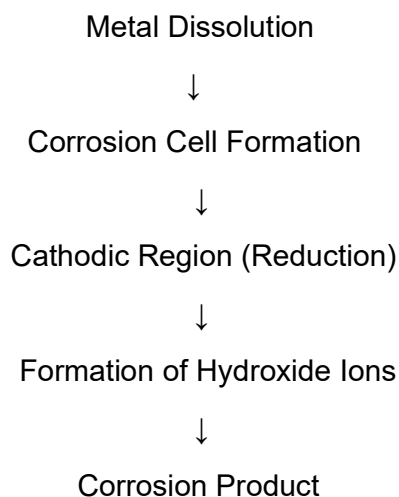
5. **Overall Corrosion Reaction:** The combination of the anodic and cathodic reactions results in the overall corrosion process, where metal atoms are oxidized, and oxygen is reduced. This overall reaction can be represented as:



The formation of metal oxides and hydroxides leads to the development of corrosion products, such as rust (iron oxide) or patina (copper oxide), which can further accelerate the corrosion process by providing pathways for moisture and oxygen to reach the underlying metal surface.

Below is a simplified diagram illustrating the mechanism of corrosion by absorption of oxygen:





In this diagram:

- The metal surface undergoes oxidation (anodic reaction) at localized regions.
- Metal ions are released into solution, contributing to the corrosion process.
- Oxygen reduction (cathodic reaction) occurs at cathodic regions, leading to the formation of hydroxide ions.

b What is green fuel? Give the preparation method of bio-diesel and also mention its advantages. [5]

Ans:- Green fuel generally refers to any type of fuel that is produced from renewable resources, is environmentally friendly, and has lower carbon emissions compared to traditional fossil fuels. One common type of green fuel is biodiesel. Biodiesel is a renewable fuel derived from natural oils such as soybean oil, rapeseed oil, or used cooking oil through a process called transesterification. Here's a simplified preparation method for biodiesel:

1. **Feedstock Selection:** Choose a suitable vegetable oil or animal fat as the feedstock. Common sources include soybean oil, canola oil, palm oil, and used cooking oil.
2. **Pre-treatment:** If the feedstock is not already in a suitable form, it may need pre-treatment to remove impurities such as water, free fatty acids, and particulates.
3. **Transesterification:** This is the main chemical reaction where the triglycerides in the feedstock (oils and fats) react with an alcohol (typically methanol or ethanol) in the presence of a catalyst (such as sodium hydroxide or potassium hydroxide). This reaction produces biodiesel (methyl or ethyl esters) and glycerin as a byproduct.
4. **Separation:** After the transesterification reaction, the mixture is allowed to settle, separating the biodiesel from the glycerin and any other impurities.
5. **Washing and Drying:** The biodiesel is washed to remove any remaining impurities and then dried to remove any water content.
6. **Quality Testing:** Finally, the biodiesel is tested for quality and compliance

C. Write a note on oxygenates and role of catalytic converter. [4]

Ans:- Oxygenates are a class of organic compounds that contain oxygen atoms within their molecular structure. Common examples include alcohols such as ethanol and methanol, as well as ethers like methyl tert-butyl ether (MTBE) and ethyl tert-butyl ether (ETBE). These compounds are often added to gasoline to enhance its performance and reduce harmful emissions.

The addition of oxygenates to gasoline serves several purposes:

Oxygenation: Oxygenates increase the oxygen content of gasoline, which promotes more complete combustion in engines.

Octane Boosting: Many oxygenates have high octane ratings, which helps to improve the octane quality of gasoline.

Emission Reduction: Oxygenates facilitate cleaner combustion by promoting more efficient burning of fuel. This leads to lower emissions of pollutants such as nitrogen oxides (NO_x) and particulate matter (PM)

Catalytic converters play a crucial role in mitigating the environmental impact of vehicle emissions, including those resulting from the use of oxygenated gasoline. These devices are located in the exhaust system of automobiles and contain catalysts, typically platinum, palladium, and rhodium, which facilitate chemical reactions that convert harmful pollutants into less harmful substances.

The catalytic converter functions through two main processes:

Oxidation: In the first stage, the catalyst promotes the oxidation of carbon monoxide (CO) and unburned hydrocarbons (HC) to carbon dioxide (CO₂) and water (H₂O), respectively. This process reduces the emission of these harmful pollutants.

Reduction: In the second stage, the catalyst facilitates the reduction of nitrogen oxides (NO_x) into nitrogen (N₂) and oxygen (O₂) through a process called selective catalytic reduction (SCR). This further reduces harmful emissions, particularly nitrogen oxides which are a major contributor to air pollution.

Q.3 a How do the following factors affect the rate of corrosion: (i) Relative areas of anodic to cathodic part. (ii) Position of metal in galvanic series. (iii) Purity of metal. [6]

Ans:- Effect of Various Factors on the Rate of Corrosion

(i) Relative areas of anodic to cathodic part:

In a galvanic corrosion process, the rate of corrosion is influenced by the relative areas of the anodic and cathodic parts. Galvanic corrosion occurs when two dissimilar metals are in electrical contact in the presence of an electrolyte. In this process, one metal (the anode) undergoes corrosion, while the other metal (the cathode) remains protected.

If the anodic area is larger than the cathodic area, the rate of corrosion will be higher because there is more surface area available for the corrosion process to occur.

(ii) Position of metal in galvanic series:

The position of a metal in the galvanic series directly affects its susceptibility to corrosion. The galvanic series ranks metals and alloys according to their relative nobility or tendency to corrode in a given environment. Metals higher in the galvanic series (such as gold and platinum) are more noble and resist corrosion, while those lower in the series (such as zinc and magnesium) are more active and corrode more readily.

(iii) Purity of metal:

The purity of a metal can significantly influence its susceptibility to corrosion. Impurities in metals can act as sites for localized corrosion, such as pitting corrosion or crevice corrosion. Additionally, impurities can alter the structure of the metal, making it more prone to certain types of corrosion.

For example, in stainless steel, the presence of sulfur can lead to the formation of sulfide inclusions, which can initiate pitting corrosion. Similarly, phosphorus impurities in copper can lead to the formation of copper phosphides, which are more susceptible to corrosion than pure copper.

b. Calculate higher and lower calorific value of coal sample containing C-80%, O-3%, H-7%, S-3.5%, N=2.1% and the remaining is ash. [5]

Ans:- To calculate the higher and lower calorific values of the coal sample, we'll use the Dulong formula, which is an approximation commonly used for solid fuels like coal. The formula for calculating the higher calorific value (HCV) and lower calorific value (LCV) is as follows:

$$\text{HCV} = 8080C + 34500 \left(\frac{H-O}{8} \right) + 2240 S$$

$$\text{LCV} = 8080C + 2440 \left(\frac{H-O}{8} \right) + 2240 S + 137 N$$

Where:

C , H , O , S , and N are the percentages of carbon, hydrogen, oxygen, sulfur, and nitrogen in the coal sample, respectively.

Given the composition of the coal sample:

Carbon (C) = 80%

Hydrogen (H) = 7%

Oxygen (O) = 3%

Sulfur (S) = 3.5%

Nitrogen (N) = 2.1%

Remaining is ash

Let's calculate the higher and lower calorific values:

Higher Calorific Value (HCV):

$$\text{HCV} = 8080(80) + 34500(7 - 3/8) + 2240(3.5)$$

$$\text{HCV} = 646400 + 120225 + 7840$$

$$\text{HCV} = 774465 \text{ cal/g}$$

Lower Calorific Value (LCV):

$$\text{LCV} = 8080(80) + 2440(7 - 3/8) + 2240(3.5) + 137(2.1)$$

$$\text{LCV} = 646400 + 21180 + 7840 + 282.7$$

$$\text{LCV} = 676702.7 \text{ cal/g}$$

Therefore, the higher calorific value (HCV) of the coal sample is approximately 774,465 cal/g and the lower calorific value (LCV) is approximately 676,702.7 cal/g.

c. Differentiate between Electrolytic and Galvanic cell.**[4]****Ans:-**

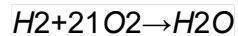
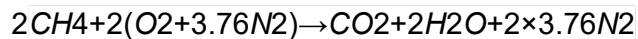
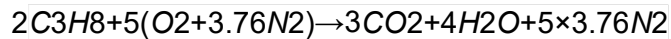
Feature	Electrolytic Cell	Galvanic Cell
Nature of Reaction	Non-spontaneous reaction, driven by an external electrical source (electricity is applied to force a chemical reaction).	Spontaneous reaction, occurs without the need for an external power source (chemical reaction generates electricity).
Direction of Electron Flow	Electron flow is from the external power source to the electrode where reduction occurs (cathode) and from the electrode where oxidation occurs (anode) back to the power source.	Electron flow is from the anode (where oxidation occurs) to the cathode (where reduction occurs) through an external circuit.
Purpose	Used for electrolysis, which involves processes like electroplating, electrorefining, and decomposition of compounds.	Used as batteries or cells to generate electrical energy.
Electrolyte	Usually contains an ionic compound (electrolyte) dissolved in a solvent (electrolyte solution) or in a molten state.	Typically utilizes two different metal electrodes immersed in an electrolyte solution, facilitating a redox reaction.
Anode and Cathode	Anode is the positive electrode where oxidation occurs, and the cathode is the negative electrode where reduction occurs.	Anode is the negative electrode where oxidation occurs, and the cathode is the positive electrode where reduction occurs.
Electrodes	Electrodes are typically inert and do not participate in the reaction.	Electrodes may be inert or active, depending on the specific type of galvanic cell. In active electrodes, one electrode oxidizes and the other reduces.
Voltage	Voltage applied is usually higher than the cell potential to drive the non-spontaneous reaction.	Voltage produced is determined by the difference in the reduction potentials of the two metals involved.
Examples	Electrolysis of water, electroplating of metals, extraction of metals from ores.	Lead-acid battery, Daniell cell, and fuel cells are examples of galvanic cells.

Q.4 a Calculate the volume and weight of air required for complete combustion of 1m³ of gaseous fuel having the following composition: CO = 10%, C₃H₈ = 12%, CH₄ = 30%, N₂ = 3 %, H₂ = 40%, CO₂ = 3%, O₂ = 2.0% (Molecular weight of air =28.949). [6]

Ans:- To calculate the volume and weight of air required for complete combustion of the given gaseous fuel composition, we first need to determine the stoichiometric air-fuel ratio for each component and then use that information to find the overall air-fuel ratio. From there, we can calculate the volume and weight of air required.

Determine the Stoichiometric Air-Fuel Ratio for Each Component:

The stoichiometric air-fuel ratio for complete combustion of each component can be determined using their respective stoichiometric chemical equations. Here are the equations for the given components:



Now we can calculate the stoichiometric air-fuel ratio (AFR) for each component using these equations.

Calculate the Stoichiometric Air-Fuel Ratio (AFR) for Each Component:

- For C₃H₈: $AFR = \frac{5(2 + 3.76)}{2} = 5 \times 5.76 = 28.8$
- For CH₄: $AFR = \frac{2(2 + 3.76)}{2} = 2 \times 5.76 = 11.52$
- For H₂: $AFR = \frac{1(2 + 3.76)}{2} = 1 \times 5.76 = 5.76$
- For CO: $AFR = \frac{1(2 + 3.76)}{1} = 1 \times 5.76 = 5.76$

Calculate the Overall Stoichiometric Air-Fuel Ratio (AFR):

The overall stoichiometric air-fuel ratio (AFR) is the weighted average of the individual AFRs based on the fuel composition. We'll use the percentages provided.

$$AFR = (0.10 \times 5.76) + (0.12 \times 28.8) + (0.30 \times 11.52) + (0.40 \times 5.76)$$

$$AFR = 0.576 + 3.456 + 3.456 + 2.304$$

$$AFR = 9.792$$

Calculate the Volume of Air Required:

The volume of air required can be calculated using the ideal gas law:

$$PV = nRT$$

Where:

- P = pressure (assume standard pressure)
- V = volume of air
- n = number of moles of air
- R = universal gas constant
- T = temperature (assume standard temperature)

Since the volume of fuel is 1 m^3 , and the air-fuel ratio is 2.3616, the volume of air required is 1×2.3616

Calculate the Weight of Air Required:

- To find the weight of air required, we'll use the molecular weight of air provided:
- Molecular weight of air = 28.949 g/mol
- Using the volume of air and the molecular weight, we can find the weight of air required:
- Weight of air = Volume of air \times Molecular weight of air

Weight of air = $(1 \times 2.3616) \times 28.949$

Weight of air = 67.9578

So, the volume of air required for complete combustion of 1 m^3 of the given gaseous fuel composition is approximately 2.3616 m^3 , and the weight of air required is approximately 67.96 kg

b Write a traditional and greener pathway for the synthesis of carbaryl. Write the name of the principle associated with this synthesis. [5]

Ans:- Carbaryl, a widely used insecticide, can be synthesized through traditional and greener pathways. The traditional pathway typically involves multiple steps with various chemical reactions and often requires the use of hazardous chemicals and solvents. On the other hand, greener pathways aim to minimize environmental impact by utilizing safer reagents, minimizing waste generation, and employing more sustainable reaction conditions.

1. Traditional Synthesis of Carbaryl:

The traditional synthesis of carbaryl involves multiple steps, including the reaction of methylamine with nitrous acid to produce N-methyl-N-nitrosomethylamine. This intermediate then reacts with 1-naphthol to form the desired product, carbaryl. This process often requires the use of hazardous reagents and generates significant waste.

2. Greener Synthesis of Carbaryl:

A greener pathway for the synthesis of carbaryl involves utilizing more environmentally friendly reagents and reaction conditions. One such approach could be the direct condensation of 1-naphthol with methylamine under mild and sustainable reaction conditions, possibly using a catalyst to enhance the reaction rate and selectivity. This approach reduces the number of synthetic steps, minimizes waste generation, and eliminates the need for hazardous intermediates.

3. Principle Associated with Greener Synthesis:

The principle associated with greener synthesis pathways, including the greener synthesis of carbaryl, is the concept of Green Chemistry. Green Chemistry aims to design chemical processes and products that minimize the use and generation of hazardous substances, reduce energy consumption, and promote sustainability throughout the entire lifecycle of a chemical product. By following the principles of Green Chemistry, chemists strive to develop safer, more environmentally benign synthesis routes that contribute to a more sustainable future.

c What is the selection rule? Explain any two Selection rules. [4]

Ans:- Selection rules play a crucial role in understanding various phenomena such as atomic and molecular spectroscopy.

Here are explanations of two important selection rules:

- Selection Rule for Atomic Transitions in Hydrogenic Atoms:

In hydrogenic atoms, such as hydrogen (H), singly ionized helium (He⁺), and other one-electron ions, the selection rule governs the transitions between different energy levels. The primary selection rule for these transitions is known as the $\Delta n = \pm 1$ rule. It states that an electron can transition between energy levels only if the change in the principal quantum number (n) is ± 1 . This rule arises from the quantization of angular momentum and the wave nature of electrons in the atom.

For example, when an electron transitions from a higher energy level (e.g., $\Delta n = 3$) to a lower energy level (e.g., $n = 2$), $\Delta n = 3 - 2 = 1$, making this transition allowed.

Conversely, transitions such as $\Delta n = 3$ to $\Delta n = 1$ (where $\Delta n = 3 - 1 = 2$) are forbidden according to this selection rule.

- Selection Rule for Vibrational Transitions in Molecules:

In molecules, vibrational transitions occur when molecules absorb or emit energy, leading to changes in their vibrational energy levels. The selection rule for vibrational transitions in molecules is governed by the $\Delta v = \pm 1$ rule. This rule dictates that a molecule can undergo a vibrational transition only if the change in vibrational quantum number (Δv) is ± 1 .

For example, in a diatomic molecule, a transition from the ground vibrational state ($v = 0$) to the first excited vibrational state ($v = 1$) is allowed because $\Delta v = 1 - 0 = 1$. Similarly, transitions from $v = 1$ to $v = 2$, or vice versa, are also allowed. However, transitions like $v = 0$ to $v = 2$ (where $\Delta v = 2$) are forbidden according to this selection rule.

These selection rules are essential for interpreting experimental observations in spectroscopy and understanding the behavior of atoms and molecules under the influence of electromagnetic radiation. They provide valuable insights into the allowed transitions and the properties of quantum systems.

Q.5 a Define spectroscopy and electromagnetic spectrum show the various regions of electromagnetic spectrum with the help of diagram.[6]

Ans:-

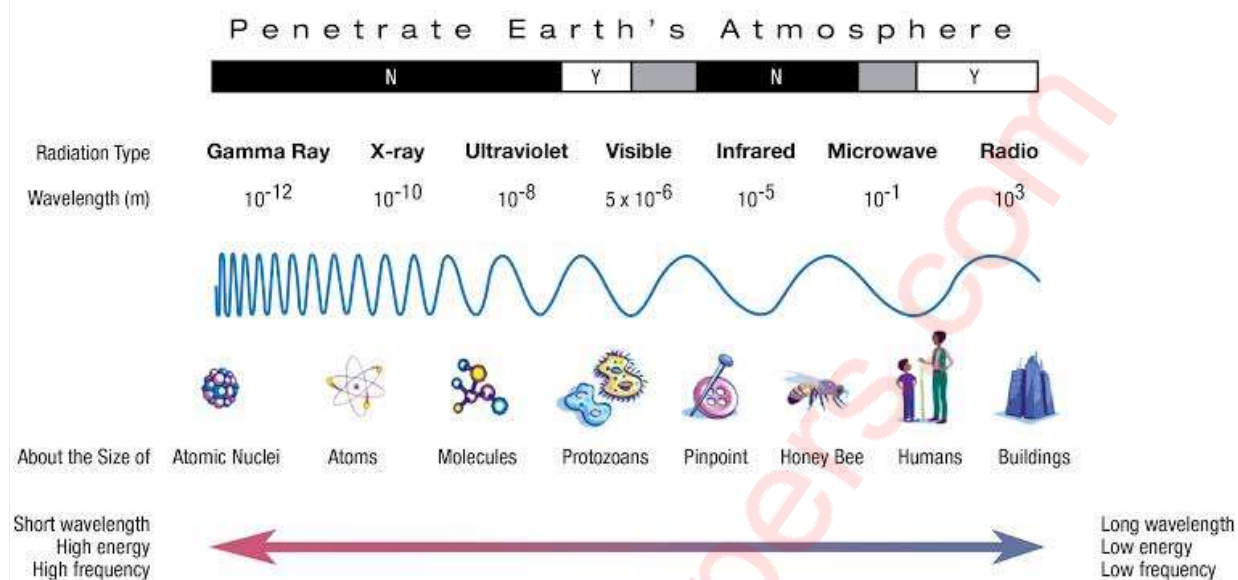
Definition of Spectroscopy: Spectroscopy is the study of the interaction between matter and electromagnetic radiation. It involves analyzing how light interacts with molecules and atoms, providing valuable information about their structure, composition, and properties. By measuring the absorption, emission, or scattering of electromagnetic radiation, spectroscopy can reveal details about the energy levels, electronic transitions, and molecular vibrations of a substance

Definition of Electromagnetic Spectrum: The electromagnetic spectrum encompasses the entire range of electromagnetic radiation, extending from the longest wavelengths (radio waves) to the shortest wavelengths (gamma rays). It includes a diverse range of electromagnetic waves, each characterized by its frequency, wavelength, and energy.

Regions of the Electromagnetic Spectrum: Here are the various regions of the electromagnetic spectrum, along with their typical wavelengths and common applications:

1. Radio Waves:
 - Wavelengths: Greater than 1 millimeter
 - Applications: Radio broadcasting, telecommunications, radar, Wi-Fi
2. Microwaves:
 - Wavelengths: 1 millimeter to 1 meter
 - Applications: Microwave ovens, satellite communication, radar, wireless networking
3. Infrared Radiation:
 - Wavelengths: 0.7 micrometers to 1 millimeter
 - Applications: Thermal imaging, remote sensing, infrared spectroscopy
4. Visible Light:
 - Wavelengths: 400 to 700 nanometers
 - Applications: Vision, photography, colorimetry, optical microscopy
5. Ultraviolet (UV) Radiation:
 - Wavelengths: 10 to 400 nanometers
 - Applications: Sterilization, fluorescence, UV spectroscopy
6. X-Rays:
 - Wavelengths: 0.01 to 10 nanometers
 - Applications: Medical imaging, airport security screening, X-ray crystallography
7. Gamma Rays:
 - Wavelengths: Less than 0.01 nanometers
 - Applications: Nuclear medicine, radiation therapy, gamma-ray spectroscopy

THE ELECTROMAGNETIC SPECTRUM



b Calculate the percentage atom economy for the following reaction with respect to acetanilide. $C_6H_5NH_2 + (CH_3CO)_2O \rightarrow C_6H_5NHCOCH_3 + CH_3COOH$ Given Atomic Weights: C = 12, H = 1, O = 16, N = 14. [5]

Ans:- To calculate the percentage atom economy for a reaction, we need to compare the total mass of desired products to the total mass of all reactants, expressed as a percentage.

First, let's determine the molar masses of all the compounds involved in the reaction:

- Acetanilide ($C_6H_5NHCOCH_3$):
- Carbon (C): $6 \times 12 = 72$ g/mol
- Hydrogen (H): $7 \times 1 = 7$ g/mol
- Nitrogen (N): $1 \times 14 = 14$ g/mol
- Oxygen (O): $1 \times 16 = 16$ g/mol

Total molar mass: $72+7+14+16=109$ g/mol

- Acetic anhydride ($(CH_3CO)_2O$):
- Carbon (C): $4 \times 12 = 48$ g/mol
- Hydrogen (H): $2 \times 1 = 2$ g/mol
- Oxygen (O): $3 \times 16 = 48$ g/mol

Total molar mass: $48+2+48=98$ g/mol

Now, let's calculate the percentage atom economy:

Determine the total mass of all reactants:

Total mass of reactants = mass of C₆H₅NH₂ + mass of (CH₃CO)₂O

- Total mass of C₆H₅NH₂ = (mass of C) + (mass of H) + (mass of N) =
 $6 \times 12 + 5 \times 1 + 1 \times 14 = 78 \text{ g/mol}$
- Total mass of (CH₃CO)₂O = (mass of C) + (mass of H) + (mass of O) =
 $4 \times 12 + 2 \times 1 + 3 \times 16 = 98 \text{ g/mol}$

Total mass of reactants = $78 + 98 = 176 \text{ g/mol}$

Determine the total mass of desired products:

Total mass of desired products = mass of C₆H₅NHCOCH₃ + mass of CH₃COOH

Total mass of C₆H₅NHCOCH₃ = 109 g/mol (as calculated above)

Total mass of CH₃COOH = (mass of C) + (mass of H) + (mass of O) = $2 \times 12 + 4 \times 1 + 2 \times 16 = 60 \text{ g/mol}$

Total mass of desired products = $109 + 60 = 169 \text{ g/mol}$

Calculate the percentage atom economy:

Percentage atom economy

= $\frac{\text{Total mass of desired products}}{\text{Total mass of all reactants}} \times 100$

Percentage atom economy = $\frac{169}{176} \times 100$

Percentage atom economy $\approx 96.02\%$

So, the percentage atom economy for the given reaction with respect to acetanilide is approximately 96.02%.

c Explain impressed current cathodic protection of corrosion control. [4]

Ans:- Impressed current cathodic protection (ICCP) is a widely used technique for corrosion control in various structures, particularly in buried or submerged metal structures such as pipelines, storage tanks, offshore platforms, and reinforced concrete structures. This method involves the application of an external electric current to the structure, which polarizes the metal surface and shifts its potential to a more negative value, thus reducing the rate of corrosion.

Here's how impressed current cathodic protection works and its key components:

Anode System: In ICCP systems, one or more anodes are installed around the structure to be protected. These anodes are made of materials such as graphite, mixed metal oxides, or platinum-coated titanium, which have a higher tendency to corrode compared to the structure they are protecting. When the ICCP system is active, the anodes serve as the source of electrons, releasing them into the surrounding environment.

Power Supply: A power supply unit, typically a rectifier, is connected to the anode system. The rectifier converts alternating current (AC) from the power grid into direct current (DC),

which is then applied to the anodes. The power supply delivers a controlled amount of current to the anodes, ensuring that the structure remains polarized within the desired protective potential range.

Reference Electrode: A reference electrode is placed near the structure to monitor its potential. This electrode provides feedback to the ICCP system, allowing it to adjust the output current to maintain the desired protective potential. Common reference electrodes used in ICCP systems include silver/silver chloride (Ag/AgCl) electrodes.

Electrical Connection: Electrical cables connect the anodes, power supply, and reference electrode to form a closed circuit. Proper installation of these connections is essential to ensure the efficient delivery of current and accurate potential monitoring.

Electrolyte: The structure to be protected and the anodes are immersed in an electrolyte, which could be soil, water, or concrete. The electrolyte provides the medium through which the electrical current flows between the anodes and the structure. The electrolyte also facilitates ion transport, allowing ions to migrate from the anodes to the structure, where they neutralize corrosive reactions.

6 . a What is an electrochemical cell? Give construction and working of any one reference electrode with the help of diagram and reactions [6]

Ans:- An electrochemical cell is a device that converts chemical energy into electrical energy through redox reactions. It consists of two electrodes, an electrolyte solution, and an external circuit through which electrons can flow. The two electrodes are immersed in separate compartments containing electrolytes, and the redox reactions occurring at the electrodes generate an electric current that flows through the external circuit, performing useful work.

Construction and Working of the Standard Hydrogen Electrode (SHE):

The Standard Hydrogen Electrode (SHE) is a reference electrode commonly used in electrochemical measurements to establish a standard hydrogen electrode potential of 0 volts at standard conditions (1 atm pressure and 25°C temperature). The SHE consists of a platinum electrode immersed in a solution of hydrogen ions with a hydrogen gas bubble maintained at constant pressure.

Construction:

Platinum Electrode: A platinum wire or foil is typically used as the electrode material due to its inertness and stability.

Electrolyte: The electrolyte solution typically consists of an acidic solution containing hydrogen ions (H^+). The concentration of hydrogen ions is maintained at 1 molar (1 M) to ensure standard conditions.

Hydrogen Gas: A stream of pure hydrogen gas at 1 atm pressure is bubbled through the electrolyte solution. The hydrogen gas provides a source of electrons for the reduction reaction at the electrode.

Working:

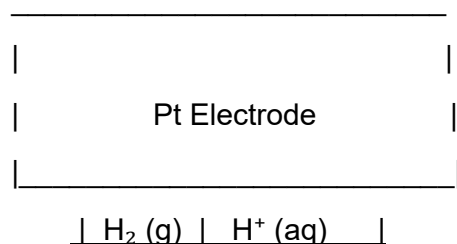
Establishment of Equilibrium: The hydrogen gas bubble establishes equilibrium with the hydrogen ions in the electrolyte solution. At standard conditions, the partial pressure of hydrogen gas (P_{H_2}) above the solution is 1 atm.

Reduction Reaction: The platinum electrode catalyzes the reduction of hydrogen ions from the solution to form hydrogen gas: $2H^+(aq) + 2e^- \rightarrow H_2(g)$

Generation of Reference Potential: The SHE is designed to have a standard electrode potential of 0 volts under standard conditions. The potential of the SHE serves as the reference against which the electrode potentials of other half-cells are measured.

Equilibrium Potential: At equilibrium, the rate of the forward reaction (reduction of H^+ ions) is equal to the rate of the reverse reaction (evolution of H_2 gas). The electrode potential at this equilibrium is defined as the standard hydrogen electrode potential (E°) and is assigned a value of 0 volts.

Diagram:



Reactions:

Reduction Reaction (Cathodic Half-Reaction): $2H^+(aq) + 2e^- \rightarrow H_2(g)$

Oxidation Reaction (Anodic Half-Reaction) - Not explicitly shown, but it involves the generation of protons and electrons: $H_2(g) \rightarrow 2H^+(aq) + 2e^-$

b Define Octane and Cetane number. 2.4999 g of coal sample was taken in a silica crucible and heated in an oven maintained at 1100C for one hour. The weight after heating was 2.368g. Calculate the percentage moisture content in the coal. [5]

Ans:- Definition of Octane Number: Octane number is a measure of the anti-knock properties of gasoline (petrol) or other hydrocarbon fuels used in spark-ignition internal combustion engines. It represents the fuel's resistance to premature detonation (knocking) when subjected to high compression ratios in an engine cylinder.

Definition of Cetane Number: Cetane number is a measure of the ignition quality of diesel fuel. It represents the fuel's ability to ignite and burn smoothly in a compression-ignition (diesel) engine without causing knocking or excessive delay in combustion. Higher cetane numbers indicate shorter ignition delays and better combustion efficiency.

1. Calculation of Percentage Moisture Content in Coal:

Given:

- Initial weight of coal sample before heating = 2.4999 g
- Final weight of coal sample after heating = 2.368 g
- The percentage moisture content in the coal can be calculated using the formula:
- Percentage Moisture Content = $\frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100\%$

2. Substituting the given values:

- Percentage Moisture Content = $\frac{2.4999 \text{ g} - 2.368 \text{ g}}{2.4999 \text{ g}} \times 100\%$
- Percentage Moisture Content = $\frac{0.1319 \text{ g}}{2.4999 \text{ g}} \times 100\%$
- Percentage Moisture Content = $0.0528 \times 100\%$
- Percentage Moisture Content = 5.28%

Therefore, the percentage moisture content in the coal sample is approximately 5.28%.

c. Explain mechanism of electrochemical corrosion by the evolution of hydrogen with the help of a diagram. [4]

Ans:- Electrochemical corrosion, also known as electrochemical dissolution or simply corrosion, is a process in which metal ions dissolve from a metallic surface due to electrochemical reactions occurring at the interface between the metal and its surrounding environment. One common mechanism of electrochemical corrosion involves the evolution of hydrogen gas, known as hydrogen evolution corrosion. This process typically occurs when metals such as iron or steel are exposed to aqueous environments containing dissolved hydrogen ions (H^+) or water molecules (H_2O).

Mechanism of Electrochemical Corrosion by the Evolution of Hydrogen:

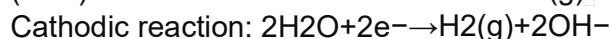
Formation of Anodic and Cathodic Sites:

At localized areas on the metal surface, imperfections or irregularities can create sites with different electrochemical properties. These sites can serve as either anodic or cathodic regions.

Anodic sites are where metal atoms lose electrons (oxidation) and dissolve into the electrolyte solution as metal ions (e.g., Fe^{2+}). At these sites, the following reaction occurs:



Cathodic sites are where reduction reactions take place, typically involving the reduction of hydrogen ions (H^+) or water molecules (H_2O) to form hydrogen gas (H_2) and hydroxide ions (OH^-):



Formation of Electrochemical Cell:

The anodic and cathodic sites, along with the surrounding electrolyte solution, form an electrochemical cell.

At the anodic site, metal atoms lose electrons and dissolve into the solution as metal ions.

At the cathodic site, hydrogen ions (H^+) or water molecules (H_2O) are reduced to form hydrogen gas (H_2).

Electron Transfer and Ion Migration:

Electrons released during the oxidation process (at the anodic site) flow through the metal and reach the cathodic site, where reduction reactions occur.

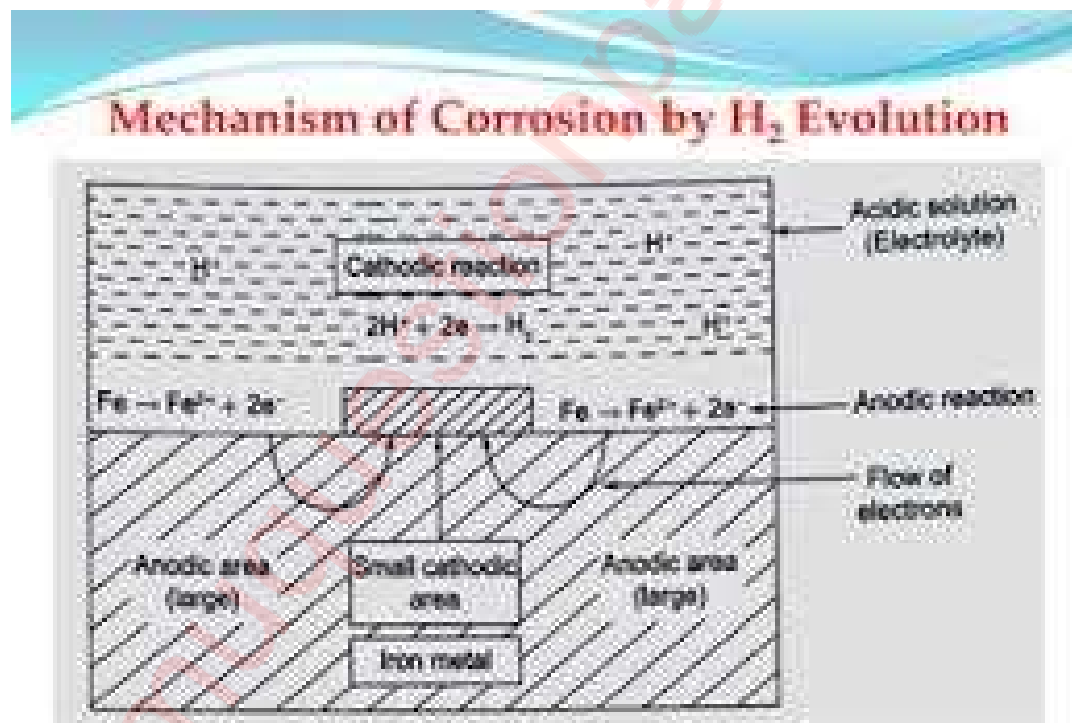
Metal ions generated at the anodic site migrate into the electrolyte solution, while hydrogen gas bubbles evolve at the cathodic site.

Overall Process:

The overall corrosion process involves the continuous oxidation of metal atoms at the anodic sites, accompanied by the reduction of hydrogen ions or water molecules at the cathodic sites to form hydrogen gas.

The accumulation of hydrogen gas bubbles on the metal surface may lead to the formation of blisters, pits, or other surface irregularities, further promoting corrosion.

Diagram:



This process can result in the degradation of metal structures and the loss of material integrity over time.