**CY3151- ENGINEERING CHEMISTRY**

**PART – C**

**UNIT I – WATER AND ITS TREATMENT**

**1) Explain Calgon Conditioning in Detail (Nov/Dec 2015, May 2016)**

**Calgon Conditioning:**

Calgon conditioning is a water treatment process used primarily to prevent scale formation in boilers and other water systems. It involves adding a compound known as **Calgon** (sodium hexametaphosphate) to the water. This process is aimed at preventing the precipitation of scale-forming salts like calcium and magnesium by dispersing them in the water.

**Principle:**

* **Calgon** acts as a dispersing agent. It prevents the formation of insoluble salts by keeping them in a soluble state. The process works by inhibiting the crystallization of salts (such as calcium carbonate, calcium sulfate, and magnesium salts), which are the primary contributors to scale buildup.
* When added to water, **Calgon** binds with calcium and magnesium ions, which would otherwise form solid scale deposits. The calcium and magnesium ions are kept in a dispersed, stable form, preventing them from precipitating and forming scale.

**Applications:**

1. **Boiler Water Treatment:** Calgon is used in boilers to prevent scale formation, which can damage the boiler’s internal components and reduce efficiency.
2. **Cooling Towers and Heat Exchangers:** In systems that involve heat exchange, Calgon helps keep scale-forming salts in solution, ensuring that heat transfer is efficient.
3. **Industrial Water Systems:** It’s also used in industrial water systems like cooling circuits, pipelines, and industrial boilers where scale formation is a concern.

**Mechanism of Action:**

* Calgon reacts with calcium (Ca²⁺) and magnesium (Mg²⁺) ions to form soluble complexes. These complexes do not precipitate, thus avoiding the formation of scale.
* The chemical formula for sodium hexametaphosphate is: (NaPO3)6(NaPO\_3)\_6(NaPO3​)6​
* It forms a stable complex with hardness-causing ions, keeping the water free from hard deposits.

**Advantages of Calgon Conditioning:**

* Prevents the formation of scale in boilers, pipes, and heat exchangers.
* Improves the efficiency of heat exchangers by keeping the surface free from deposits.
* Reduces maintenance costs by preventing scale buildup.
* Extends the lifespan of equipment by reducing corrosion and erosion caused by scale.

**Limitations:**

* **Cost**: Calgon conditioning can be an additional cost for water treatment processes.
* **Chemical Dependency**: It is a chemical-based solution, which may not be preferred in all industrial settings.

**2) Define and Explain the Significance of the Following:**

**i) Turbidity:**

* **Definition**: Turbidity is the cloudiness or haziness of a liquid caused by large numbers of individual particles (such as silt, clay, algae, or microorganisms) that are invisible to the naked eye.
* **Significance**:
  + **Water Quality Indicator**: Turbidity is used as an indicator of water quality. High turbidity in drinking water may indicate the presence of harmful microorganisms or pollutants.
  + **Impact on Treatment**: High turbidity can hinder water treatment processes, such as filtration and disinfection, by protecting pathogens from being removed.
  + **Health Risk**: High turbidity can increase the risk of waterborne diseases since microorganisms are often attached to particulate matter.

**ii) Hardness:**

* **Definition**: Hardness in water is the presence of dissolved minerals, primarily calcium (Ca²⁺) and magnesium (Mg²⁺) ions.
  + **Temporary Hardness**: Caused by bicarbonates of calcium and magnesium, which can be removed by boiling the water.
  + **Permanent Hardness**: Caused by sulfates or chlorides of calcium and magnesium, which cannot be removed by boiling.
* **Significance**:
  + **Scaling in Pipes and Boilers**: Hard water leads to the formation of scale in pipes, boilers, and heating elements, reducing their efficiency and lifespan.
  + **Detergent Effectiveness**: Hard water reduces the effectiveness of soaps and detergents, as they react with calcium and magnesium ions to form insoluble precipitates.
  + **Health Impacts**: While moderate hardness is not harmful to human health, extremely hard water may cause problems like kidney stones or digestive issues in some people.

**iii) pH:**

* **Definition**: pH is a measure of the acidity or alkalinity of a solution. It is expressed on a scale of 0 to 14, where 7 is neutral, values below 7 indicate acidity, and values above 7 indicate alkalinity.
* **Significance**:
  + **Water Treatment**: pH plays a critical role in the effectiveness of water treatment processes. For example, chlorine disinfection is more effective at lower pH levels.
  + **Corrosion Control**: The pH of water affects the rate of corrosion in pipes and equipment. Acidic water (low pH) can cause corrosion of metal surfaces, while alkaline water (high pH) can cause scale formation.
  + **Aquatic Life**: The pH of natural water bodies influences the health of aquatic ecosystems. Extreme pH levels can be harmful to fish and other aquatic organisms.
  + **Soil Quality**: pH affects the availability of nutrients in soil. Acidic soils may require lime to raise pH and make nutrients more available to plants.

**3) What is Meant by Disinfection? How is it Carried Out? Explain in Detail About Break Point Chlorination.**

**Disinfection:**

Disinfection is the process of eliminating or reducing harmful microorganisms in water, wastewater, or surfaces to safe levels. The goal is to kill or deactivate pathogens (such as bacteria, viruses, and protozoa) that can cause diseases.

**Methods of Disinfection:**

1. **Chlorination**: The most common method, where chlorine or its compounds (like chlorine dioxide, hypochlorites) are used to disinfect water.
2. **UV Radiation**: Ultraviolet light is used to destroy the DNA of microorganisms.
3. **Ozonation**: Ozone (O₃) is a powerful oxidizing agent that can disinfect water.
4. **Boiling**: Boiling water for a certain period can kill most pathogens.

**Break Point Chlorination:**

* **Definition**: Breakpoint chlorination is the process of adding chlorine to water in a stepwise manner until all the ammonia and organic matter (such as nitrogenous compounds) in the water are fully oxidized, after which free chlorine remains in the water as the disinfectant.
* **Steps of Break Point Chlorination**:
  1. **Initial Chlorine Addition**: When chlorine is first added to water, it reacts with ammonia and organic nitrogen compounds, forming chloramines (combined chlorine).
  2. **Chloramine Formation**: As chlorine continues to be added, the chloramines increase in concentration, but no free chlorine is available for disinfection.
  3. **Break Point**: The break point is reached when the amount of chlorine added is sufficient to break down the chloramines and oxidize the ammonia. At this point, a large amount of chlorine is consumed, and free chlorine (uncombined chlorine) is released into the water.
  4. **Post-Break Point**: After the breakpoint, the chlorine demand is met, and free chlorine is present. This free chlorine is the most effective form for disinfection.
* **Significance of Break Point Chlorination**:
  1. **Improved Disinfection**: Free chlorine is a powerful disinfectant, and its presence ensures effective elimination of pathogens.
  2. **Control of Chloramine Formation**: Chloramines, which are less effective disinfectants and cause taste and odor issues, are minimized.
  3. **Prevention of Waterborne Diseases**: Breakpoint chlorination ensures the water is free from harmful microorganisms, reducing the risk of waterborne diseases.

**Break Point Chlorination Curve:**

A typical breakpoint chlorination curve shows the relationship between chlorine dose and the residual chlorine concentration. Initially, combined chlorine is formed, but once the breakpoint is reached, the curve shows a sharp rise in free chlorine levels.

**UNIT-II NANOCHEMISTRY**

**1. Compare the Properties of Molecules, Nanoparticles, and Bulk Materials (AU May 2015)**

**Molecules:**

* **Size**: Molecules are composed of atoms bonded together, typically ranging from a few angstroms (Å) to a few nanometers (nm) in size.
* **Structure**: Molecules can be simple (such as water, H₂O) or complex (such as proteins, DNA). Their structure is defined by covalent or ionic bonds between atoms.
* **Properties**:
  + Molecules generally exhibit chemical properties, such as reactivity with other molecules, solubility, and polarity.
  + Molecular properties are largely determined by the type and arrangement of atoms and bonds.
* **Example**: Water (H₂O), Carbon dioxide (CO₂), DNA.

**Nanoparticles:**

* **Size**: Nanoparticles typically range in size from 1 to 100 nanometers. They often consist of several molecules or atoms arranged in a specific pattern or shape.
* **Structure**: Nanoparticles may have a variety of shapes (spherical, rod-like, cubic, etc.), and their properties depend heavily on their size, shape, and surface area.
* **Properties**:
  + Nanoparticles exhibit unique physical, chemical, and optical properties that differ significantly from those of bulk materials, including quantum effects.
  + They have a high surface area-to-volume ratio, which leads to enhanced reactivity.
  + The properties of nanoparticles can be tuned by altering their size and shape, making them useful in various applications, such as drug delivery and catalysis.
* **Example**: Gold nanoparticles, carbon nanotubes, quantum dots.

**Bulk Materials:**

* **Size**: Bulk materials are typically much larger than nanoparticles, ranging from micrometers (μm) to centimeters (cm) or more in size.
* **Structure**: Bulk materials have a well-defined macroscopic structure, and the arrangement of atoms or molecules forms a solid lattice or crystalline structure.
* **Properties**:
  + Bulk materials generally exhibit classical properties like conductivity, strength, and hardness, which are averaged over a large number of atoms.
  + The properties of bulk materials are more predictable and stable compared to nanoparticles, but they do not exhibit the unique properties associated with nanoscale dimensions, such as quantum effects.
  + The interaction of bulk materials with light, heat, and electricity is relatively less sensitive to size changes.
* **Example**: Metals (e.g., copper, aluminum), ceramics, wood.

**Comparison Summary:**

| **Property** | **Molecules** | **Nanoparticles** | **Bulk Materials** |
| --- | --- | --- | --- |
| **Size** | A few Å to a few nm | 1-100 nm | Micrometers to centimeters |
| **Structure** | Atomic or molecular bonds | Can vary (spherical, rod-like, etc.) | Crystalline or amorphous |
| **Surface Area** | Limited to molecular surface | High surface area-to-volume ratio | Low surface area-to-volume ratio |
| **Properties** | Chemical reactivity, solubility | Unique optical, electrical, chemical properties | Predictable macroscopic properties |
| **Example** | Water, CO₂ | Gold nanoparticles, Quantum dots | Copper, Aluminum, Wood |

**2. Write Short Notes on:**

**i) Carbon Nanotubes (AU Dec 2015)**

* **Definition**: Carbon nanotubes (CNTs) are cylindrical structures made of carbon atoms arranged in a hexagonal lattice. They can be single-walled (SWNTs) or multi-walled (MWNTs), with multiple concentric cylinders.
* **Properties**:
  + High mechanical strength (about 100 times stronger than steel).
  + Exceptional electrical and thermal conductivity.
  + Lightweight and flexible.
  + High surface area.
* **Applications**:
  + Electronics (transistors, sensors).
  + Nanocomposites (used in materials to enhance strength).
  + Energy storage (supercapacitors, batteries).
  + Drug delivery (due to their high surface area and biocompatibility).

**ii) Nanorods**

* **Definition**: Nanorods are nanoparticles that are elongated, typically with a length greater than their diameter. They are often made from metals, semiconductors, or polymers.
* **Properties**:
  + Can exhibit unique optical and electronic properties due to their anisotropic shape (e.g., plasmon resonance in metallic nanorods).
  + High surface area for chemical reactions.
  + They can be made from a variety of materials, allowing for tunable properties.
* **Applications**:
  + Drug delivery (due to their ability to easily interact with biomolecules).
  + Photovoltaics and other optoelectronic devices.
  + Catalysis and sensors.

**iii) Nanowires**

* **Definition**: Nanowires are one-dimensional nanostructures, typically with diameters on the order of 1-100 nm, and lengths that can be much larger.
* **Properties**:
  + They have excellent electrical, optical, and mechanical properties.
  + High aspect ratio and small size result in quantum mechanical effects that influence their conductivity.
  + Can exhibit high strength and flexibility.
* **Applications**:
  + Electronic devices (transistors, memory devices).
  + Sensors (for detecting gases or biomolecules).
  + Solar cells and light-emitting diodes (LEDs).

**3. Explain Briefly the Applications of Nanomaterials (A.U.T [TVN] Jan 2009)**

Nanomaterials have a wide range of applications due to their unique properties, such as high surface area, quantum effects, and size-dependent behavior. Here are some key areas where nanomaterials are used:

1. **Electronics**:
   * **Transistors and Circuits**: Nanoscale materials (such as carbon nanotubes and nanowires) are used to create smaller, faster, and more energy-efficient transistors.
   * **Quantum Dots**: These semiconductor nanocrystals are used in optoelectronic devices like LEDs and solar cells, providing enhanced light emission and tunable optical properties.
2. **Medicine**:
   * **Drug Delivery**: Nanomaterials like liposomes, nanoparticles, and carbon nanotubes are used for targeted drug delivery, allowing drugs to be released directly at the site of action.
   * **Biosensors**: Nanomaterials enable highly sensitive biosensors that can detect low concentrations of disease markers, pathogens, or toxins.
3. **Energy**:
   * **Solar Cells**: Nanomaterials, including quantum dots and nanowires, are used in next-generation solar cells to enhance light absorption and improve efficiency.
   * **Supercapacitors and Batteries**: Nanomaterials (e.g., graphene and carbon nanotubes) are used to improve energy storage devices, increasing their capacity and charge-discharge cycles.
4. **Environment**:
   * **Water Purification**: Nanomaterials like nanoparticles of titanium dioxide (TiO₂) are used in water purification systems to remove contaminants and pathogens.
   * **Pollution Control**: Nanomaterials can be used in catalytic converters to reduce air pollution or in environmental cleanup efforts (e.g., nanoremediation).
5. **Material Science**:
   * **Nanocomposites**: Nanomaterials are incorporated into materials (such as plastics, metals, or ceramics) to enhance mechanical strength, conductivity, and other properties.
   * **Coatings and Paints**: Nanomaterials are used to create more durable, corrosion-resistant, and self-cleaning surfaces in coatings and paints.
6. **Textiles**:
   * **Smart Fabrics**: Nanomaterials are used to create fabrics that are water-resistant, anti-microbial, or have other unique properties.
   * **Sensors**: Nanostructured fibers can be integrated into clothing for wearable sensors to monitor health parameters.

These applications demonstrate the versatility of nanomaterials in improving existing technologies and creating new possibilities across various industries.

**UNIT-III PHASE RULE AND COMPOSITES**

**1. What are Composites? Explain the Constituents of Composites.**

**Composites** are materials made by combining two or more distinct materials that have different physical and chemical properties. The resulting material has characteristics that are superior to those of the individual components. Composites are typically designed to achieve a combination of properties, such as strength, stiffness, toughness, or thermal and electrical conductivity, that are not found in any single material alone.

**Constituents of Composites:**

Composites generally consist of the following main components:

* **Matrix (Binder):**
  + The matrix is the continuous phase that surrounds and binds the reinforcing phase. It is typically made from materials like polymers, metals, or ceramics. The matrix holds the reinforcement in place and transmits the applied loads to it.
  + **Functions**: The matrix provides shape to the composite, transfers stresses to the reinforcement, protects the reinforcement from environmental damage, and can also provide resistance to heat, corrosion, or chemicals.
  + **Examples**: Polymer resins (in polymer composites), metal matrices (in metal matrix composites), and ceramic matrices (in ceramic matrix composites).
* **Reinforcement:**
  + Reinforcements are the phase that strengthens the composite material. They are generally harder, stronger, and stiffer than the matrix material. Reinforcements are often in the form of fibers, particles, or flakes.
  + **Functions**: The reinforcement provides strength and stiffness to the composite and improves its mechanical properties. The nature and volume fraction of the reinforcement significantly affect the overall performance of the composite.
  + **Examples**: Glass fibers, carbon fibers, aramid fibers, metal particles, and ceramic particles.
* **Interface (Bonding Agent):**
  + The interface is the region between the matrix and the reinforcement, where the bonding occurs. This bonding determines how well the stress is transferred between the matrix and the reinforcement. Good adhesion at the interface is crucial for the composite's mechanical performance.
  + **Function**: The interface helps in load transfer between the matrix and the reinforcement, improving the overall strength and durability of the composite.
  + **Examples**: Adhesive materials, chemical treatments, or coupling agents that enhance the bond between the matrix and the reinforcement.

**Types of Composites:**

* **Polymer Matrix Composites (PMC)**: The matrix is a polymer material, and the reinforcement is typically fibers (glass, carbon, or aramid). Example: FRP (Fiber-Reinforced Polymer).
* **Metal Matrix Composites (MMC)**: The matrix is a metal (e.g., aluminum), and the reinforcement can be ceramic or metallic fibers. Example: Aluminum matrix composites.
* **Ceramic Matrix Composites (CMC)**: The matrix is a ceramic, and the reinforcement is typically ceramic fibers. Example: Carbon fiber-reinforced ceramic composites.

**2. What are the Advantages of Polymer Composites? Explain Using FRP as an Example. (CBE A.U Jan 2009)**

**Polymer composites**, especially **Fiber-Reinforced Polymers (FRP)**, offer several advantages over traditional materials such as metals and ceramics. FRP composites are made by embedding reinforcing fibers (like glass, carbon, or aramid) into a polymer matrix, resulting in materials that are lightweight, strong, and versatile.

**Advantages of Polymer Composites (FRP):**

* **Lightweight**: One of the key advantages of polymer composites like FRP is their low density. The combination of strong fibers (such as carbon or glass) and a lightweight polymer matrix results in materials that are significantly lighter than metals. This makes them ideal for applications where weight reduction is critical, such as in aerospace and automotive industries.
* **High Strength-to-Weight Ratio**: Polymer composites possess an excellent strength-to-weight ratio, meaning they can withstand high stress without being heavy. This makes them ideal for structural applications that require strength but also demand low weight.
* **Corrosion Resistance**: FRPs are resistant to corrosion, which makes them suitable for use in harsh environments such as marine, chemical processing, and construction applications. Unlike metals, they do not rust or degrade when exposed to moisture, chemicals, or other environmental factors.
* **Design Flexibility**: FRP composites can be molded into complex shapes and structures with ease. This flexibility allows for the design of customized components with specific properties, which can be tailored to suit particular engineering requirements.
* **Fatigue Resistance**: Polymer composites, including FRPs, exhibit good fatigue resistance. This means they can withstand repeated stress and strain cycles without deteriorating or failing, making them suitable for applications that involve dynamic loading, such as in automotive or aerospace structures.
* **Thermal Insulation**: FRPs generally have low thermal conductivity, which provides good insulation against heat transfer. This property makes them useful in applications where temperature control is important, such as in insulation panels, pipes, or structural components exposed to heat.
* **Low Maintenance**: Due to their resistance to corrosion and wear, FRPs require less maintenance compared to metals. They are more durable in long-term use, which can result in cost savings over time.
* **Electrical Insulation**: FRP composites are also good electrical insulators, making them suitable for electrical and electronic applications where conduction must be avoided.

**Example – FRP (Fiber-Reinforced Polymer):**

* **Fiber**: The reinforcing fiber can be glass, carbon, or aramid.
  + **Glass fibers** provide good mechanical strength and are cost-effective.
  + **Carbon fibers** offer superior strength, stiffness, and resistance to fatigue, making them ideal for high-performance applications like aerospace.
  + **Aramid fibers** (such as Kevlar) offer high toughness and are used in applications requiring impact resistance, like ballistic armor and protective clothing.
* **Matrix**: The polymer matrix can be thermoset or thermoplastic polymers.
  + **Thermoset polymers** (such as epoxy, polyester, or vinyl ester) are commonly used due to their excellent mechanical properties and ability to cure into a rigid form.
  + **Thermoplastic polymers** are used when flexibility and reprocessing ability are needed.

**3. Write a Note on FRP. (Chen.A.U. Jan 2009, June 2009, TNV A.U Jan 2009, Coim A.U. Jan 2010)**

**Fiber-Reinforced Polymer (FRP)** is a composite material made by combining a polymer matrix (such as epoxy, polyester, or vinyl ester) with reinforcing fibers (typically glass, carbon, or aramid). The resulting material is lightweight, strong, and highly durable, making it suitable for a wide range of engineering and industrial applications.

**Constituents of FRP:**

* **Reinforcement**: The reinforcing fibers in FRP provide the material's strength and stiffness. The most commonly used fibers are:
  + **Glass fibers**: These fibers offer good strength and low cost, making them the most widely used type of fiber in FRPs.
  + **Carbon fibers**: These provide superior mechanical properties, including high strength and stiffness, making them suitable for high-performance applications like aerospace, automotive, and sports equipment.
  + **Aramid fibers**: Known for their toughness and impact resistance, aramid fibers (e.g., Kevlar) are used in protective gear and military applications.
* **Matrix**: The polymer matrix binds the fibers together and distributes the load across them. The matrix also protects the fibers from environmental damage. Common matrices include:
  + **Epoxy resins**: These are known for their excellent mechanical properties, corrosion resistance, and thermal stability.
  + **Polyester resins**: These are more cost-effective but offer slightly lower performance compared to epoxy.
  + **Vinyl ester resins**: These provide a balance between cost and performance, offering good corrosion resistance.

**Advantages of FRP:**

* **High Strength-to-Weight Ratio**: FRPs offer superior strength without the heavy weight associated with metals. This makes them ideal for applications where weight reduction is crucial.
* **Corrosion Resistance**: FRP composites do not rust or corrode like metals, making them suitable for applications in harsh environments.
* **Design Flexibility**: FRP composites can be molded into complex shapes, which gives engineers more freedom in designing components for specific applications.
* **Fatigue and Impact Resistance**: FRPs are resistant to fatigue and impact, making them ideal for applications that experience repetitive stress and strain.

**Applications of FRP:**

* **Aerospace**: FRPs are used in the manufacturing of lightweight, strong, and durable parts for aircraft and spacecraft.
* **Automotive**: Used in car bodies and components to reduce weight and improve fuel efficiency.
* **Construction**: FRPs are used in reinforcing concrete structures, bridges, and buildings due to their high strength and resistance to corrosion.
* **Marine**: FRPs are used in boat hulls and other marine structures due to their excellent resistance to water and corrosion.
* **Sports Equipment**: FRPs are used in sporting goods like bicycles, tennis rackets, and golf clubs due to their light weight and high strength.

**Disadvantages of FRP:**

* **High Cost**: The production of FRP materials, particularly carbon fiber-based composites, can be expensive.
* **Difficult to Repair**: When damaged, FRPs can be difficult and costly to repair, particularly in comparison to metals.
* **Environmental Impact**: The disposal of FRP materials can pose environmental challenges due to their non-biodegradable nature.

FRP continues to be a popular choice for applications where strength, lightweight properties, and corrosion resistance are crucial, and its use is expected to grow in various industries.

**UNIT-IV FUELS AND COMBUSTION**

**1. Estimate the Quantity of Minimum Air Required for the Complete Combustion of 3m³ of Coal Sample**

To estimate the quantity of air required for the complete combustion of the given coal sample, we need to use the stoichiometry of combustion reactions. Here's the step-by-step approach:

**Given data:**

* Coal composition:  
  C = 81%, H = 4%, O = 2%, N = 10%, S = 2%  
  The remaining is ash, which doesn't participate in combustion.
* Volume of coal sample = 3 m³

**Step 1: Write the Combustion Reactions**

1. For Carbon:

C+O2→CO2C + O\_2 \rightarrow CO\_2C+O2​→CO2​

Moles of oxygen required per mole of carbon = 1 mole.

1. For Hydrogen:

2H2+O2→2H2O2H\_2 + O\_2 \rightarrow 2H\_2O2H2​+O2​→2H2​O

Moles of oxygen required per mole of hydrogen = 0.5 moles.

1. For Sulfur:

S+O2→SO2S + O\_2 \rightarrow SO\_2S+O2​→SO2​

Moles of oxygen required per mole of sulfur = 1 mole.

1. For Nitrogen: Nitrogen does not participate in combustion directly, so no oxygen is required for nitrogen.

**Step 2: Calculate the Amount of Oxygen Needed** Let’s assume we have 1 m³ of coal. The percentage composition by mass translates into:

* Carbon (C) = 81% of 1 m³ = 0.81 m³
* Hydrogen (H) = 4% of 1 m³ = 0.04 m³
* Sulfur (S) = 2% of 1 m³ = 0.02 m³
* Nitrogen (N) = 10% of 1 m³ = 0.10 m³

The remaining volume is ash and does not participate in combustion.

**Step 3: Oxygen Requirement Calculation** Using stoichiometry, calculate the oxygen required for the combustion of each component.

* **For Carbon (C):** 1 mole of C requires 1 mole of O₂. The molar volume of gases is 22.4 L (or 0.0224 m³ at standard conditions). Hence, for 0.81 m³ of carbon:

O2 required for carbon=0.8122.4×1=0.0362 m³ of O2O\_2 \text{ required for carbon} = \frac{0.81}{22.4} \times 1 = 0.0362 \text{ m³ of O}\_2O2​ required for carbon=22.40.81​×1=0.0362 m³ of O2​

* **For Hydrogen (H):** 2 moles of H₂ require 1 mole of O₂. Hence, for 0.04 m³ of hydrogen:

O2 required for hydrogen=0.0422.4×0.5=0.0018 m³ of O2O\_2 \text{ required for hydrogen} = \frac{0.04}{22.4} \times 0.5 = 0.0018 \text{ m³ of O}\_2O2​ required for hydrogen=22.40.04​×0.5=0.0018 m³ of O2​

* **For Sulfur (S):** 1 mole of S requires 1 mole of O₂. Hence, for 0.02 m³ of sulfur:

O2 required for sulfur=0.0222.4×1=0.0009 m³ of O2O\_2 \text{ required for sulfur} = \frac{0.02}{22.4} \times 1 = 0.0009 \text{ m³ of O}\_2O2​ required for sulfur=22.40.02​×1=0.0009 m³ of O2​

**Step 4: Total Oxygen Requirement**

Total oxygen required=0.0362+0.0018+0.0009=0.0389 m³ of O2\text{Total oxygen required} = 0.0362 + 0.0018 + 0.0009 = 0.0389 \text{ m³ of O}\_2Total oxygen required=0.0362+0.0018+0.0009=0.0389 m³ of O2​

**Step 5: Air Required for Combustion** Air contains 21% oxygen by volume. Therefore, the volume of air required to provide the necessary oxygen is:

Volume of air required=0.03890.21=0.1857 m³ of air\text{Volume of air required} = \frac{0.0389}{0.21} = 0.1857 \text{ m³ of air}Volume of air required=0.210.0389​=0.1857 m³ of air

Now, for 3 m³ of coal, the total air required would be:

Air required for 3 m³ of coal=3×0.1857=0.5571 m³ of air\text{Air required for 3 m³ of coal} = 3 \times 0.1857 = 0.5571 \text{ m³ of air}Air required for 3 m³ of coal=3×0.1857=0.5571 m³ of air

Thus, the **minimum air required for the complete combustion** of 3 m³ of the coal sample is **0.5571 m³ of air**.

**2. Describe the Determination of Flue Gas Analysis and Discuss its Significance**

**Flue Gas Analysis** refers to the measurement of the gaseous emissions from the combustion of fuels, typically in a furnace, boiler, or any other combustion process. The main goal is to assess the efficiency of the combustion process and determine the levels of pollutants that are emitted, such as carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂), nitrogen (N₂), sulfur dioxide (SO₂), and particulate matter.

**Methods for Flue Gas Analysis:**

1. **Orsat Apparatus**: A laboratory method for analyzing gases like CO₂, O₂, and CO. It involves absorbing gases in specific solutions, and the changes in the volume of these gases are measured.
2. **Gas Analyzers**: Modern techniques include the use of infrared gas analyzers (IRGA), electrochemical sensors, and gas chromatography to determine concentrations of specific gases such as CO₂, CO, NOx, and SO₂.
3. **Draeger Tubes**: A simple field test method for detecting gases. The gases react with the chemical agents in the tubes, changing their color, which can be compared to a scale to estimate concentrations.

**Significance of Flue Gas Analysis:**

1. **Combustion Efficiency**: By analyzing the amount of oxygen and carbon dioxide in the flue gas, one can estimate the combustion efficiency. Ideally, a higher percentage of CO₂ and a lower percentage of O₂ in the flue gas suggest complete combustion.
2. **Pollution Control**: Monitoring emissions of CO, NOx, SO₂, and particulate matter helps ensure compliance with environmental regulations, minimizing the impact on air quality and health.
3. **Optimization of Fuel Usage**: Flue gas analysis helps identify if excess air is being used during combustion, which can lead to wasted fuel and reduced efficiency. Reducing excess air can optimize fuel consumption.
4. **Safety**: High levels of CO in flue gases indicate incomplete combustion, which is not only inefficient but also dangerous. Regular analysis ensures that dangerous conditions are avoided.

**3. What is Carbon Footprint? Mention Any 5 Important Sources? How to Lower Carbon Footprint?**

**Carbon Footprint:**

The **carbon footprint** refers to the total amount of greenhouse gases (GHGs) emitted into the atmosphere as a result of human activities, typically measured in equivalent tons of CO₂. It is an important metric for assessing the environmental impact of individual, organizational, or societal activities in terms of their contribution to climate change.

**Important Sources of Carbon Footprint:**

1. **Transportation**: The burning of fossil fuels in cars, trucks, planes, and ships releases significant amounts of CO₂ and other GHGs.
2. **Energy Consumption**: Electricity and heat generation from coal, oil, and natural gas produce large quantities of CO₂ emissions.
3. **Industry and Manufacturing**: Industrial processes, including cement production, chemical manufacturing, and steel production, contribute a substantial amount of CO₂.
4. **Agriculture**: Agricultural activities, including livestock farming, rice cultivation, and the use of synthetic fertilizers, release methane (CH₄), nitrous oxide (N₂O), and CO₂.
5. **Deforestation**: The clearing of forests for agriculture or urbanization reduces the Earth’s ability to absorb CO₂ from the atmosphere.

**How to Lower Carbon Footprint:**

1. **Energy Efficiency**: Use energy-efficient appliances, lighting, and heating/cooling systems. Additionally, opting for renewable energy sources like wind, solar, and hydro can significantly lower emissions.
2. **Sustainable Transportation**: Use public transportation, carpool, switch to electric vehicles, or consider walking or cycling instead of driving gas-powered cars.
3. **Reduce, Reuse, Recycle**: Reducing consumption, reusing items, and recycling materials such as paper, plastic, and metal helps reduce energy usage and waste, leading to lower emissions.
4. **Support Sustainable Agriculture**: Buy locally-produced and sustainably farmed foods. Reducing the demand for factory-farmed meat and processed food products can lower methane emissions.
5. **Carbon Offsetting**: Invest in projects that capture or prevent the release of CO₂, such as reforestation projects or renewable energy projects.

**UNIT – V- ENERGY SOURCES AND STORAGE DEVICES**

**1) What are Electric Vehicles? Explain their Working Principle, Advantages, and Disadvantages**

**Electric Vehicles (EVs)** are vehicles that are powered by one or more electric motors, which use electrical energy stored in rechargeable batteries or another energy storage device. Unlike traditional vehicles that rely on internal combustion engines (ICE) and fuel such as gasoline or diesel, EVs are powered solely by electricity.

**Working Principle of Electric Vehicles:**

1. **Battery**: The primary energy source in an EV is the battery, usually made of lithium-ion, which stores electrical energy.
2. **Electric Motor**: The electric motor uses the electrical energy from the battery to power the vehicle. It converts electrical energy into mechanical energy, which drives the vehicle's wheels.
3. **Power Electronics**: Power electronics, such as inverters, control the flow of electricity from the battery to the motor, regulating speed and torque.
4. **Regenerative Braking**: Many EVs use regenerative braking, which allows the motor to work in reverse during braking. This process converts the kinetic energy back into electrical energy, which is stored in the battery.
5. **Charging**: EVs are charged via electrical outlets (charging stations) that transfer electrical energy into the vehicle's battery.

**Advantages of Electric Vehicles:**

1. **Environmentally Friendly**: EVs produce zero tailpipe emissions, reducing air pollution and greenhouse gas emissions.
2. **Energy Efficiency**: EVs are more energy-efficient than conventional gasoline-powered vehicles due to the higher efficiency of electric motors compared to internal combustion engines.
3. **Lower Operating Costs**: EVs have fewer moving parts, reducing maintenance costs. Electricity is also typically cheaper than gasoline or diesel.
4. **Quieter Operation**: Electric vehicles produce little to no noise, contributing to lower noise pollution.
5. **Energy Independence**: EVs reduce reliance on fossil fuels, supporting energy independence and reducing oil imports.

**Disadvantages of Electric Vehicles:**

1. **Limited Range**: EVs typically have a shorter driving range compared to gasoline-powered vehicles, which can be a limitation for long trips.
2. **Charging Infrastructure**: The availability of charging stations is still limited in some areas, which may inconvenience users.
3. **Longer Refueling Time**: Charging an EV takes longer than refueling a conventional vehicle, especially with standard home chargers.
4. **Battery Lifespan and Cost**: EV batteries degrade over time and can be expensive to replace. Additionally, battery production has a significant environmental impact.
5. **High Initial Cost**: While the cost of EVs has been decreasing, they still tend to have a higher purchase price compared to traditional vehicles, primarily due to the cost of the battery.

**2) What is Microbial Fuel Cell? Explain Its Principle and Working with a Neat Diagram**

**Microbial Fuel Cell (MFC)** is a type of bio-electrochemical cell that uses bacteria to convert organic substrates (such as glucose or wastewater) directly into electricity through biochemical reactions. It operates by harnessing the electron flow from microbial metabolism.

**Principle of Microbial Fuel Cell:**

MFCs work based on the metabolic activities of microorganisms. The bacteria break down organic matter, releasing electrons, protons, and carbon dioxide. The electrons are captured and transferred to the anode, creating an electric current. The protons move to the cathode, where they combine with oxygen to form water.

**Working of Microbial Fuel Cell:**

1. **Anode Chamber**: Organic material (such as wastewater or glucose) is placed in the anode chamber. Microorganisms in the anode chamber metabolize the organic matter, producing electrons and protons.
2. **Electron Flow**: The electrons released by the microorganisms are transferred to the anode, where they travel through an external circuit (producing electricity) to the cathode.
3. **Cathode Chamber**: Oxygen is supplied to the cathode, where the protons move through a proton exchange membrane (PEM) from the anode to combine with the electrons and oxygen, forming water.
4. **Proton Exchange Membrane (PEM)**: The membrane separates the anode and cathode chambers, allowing only protons to pass through, which are essential for completing the electrical circuit.

**Diagram:**

Here’s a simple illustration of an MFC:

java

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Anode | | Proton Exchange Membrane (PEM) | | Cathode

| |

Organic matter + Microorganisms Oxygen + Electrons

→ Electrons → External Circuit → Water (H₂O)

**Applications of Microbial Fuel Cells:**

1. **Wastewater Treatment**: MFCs can treat wastewater while generating electricity, providing a dual benefit.
2. **Powering Remote Sensors**: MFCs can be used to power low-energy devices, especially in remote or off-grid areas.
3. **Bioremediation**: MFCs can be used to clean up pollutants in the environment by using microbes to degrade harmful substances while generating power.
4. **Renewable Energy Production**: MFCs offer a potential method of generating renewable energy from organic waste materials.

**3) Explain the Working Principle and Applications of Wind Energy and Geothermal Energy**

**Wind Energy:**

**Working Principle**:

1. **Wind Turbine**: Wind energy is harnessed by wind turbines, which convert the kinetic energy of wind into mechanical energy.
2. **Rotation of Blades**: As wind blows over the blades of the turbine, it causes them to rotate. The kinetic energy of the wind is transferred to the blades, which are connected to a rotor.
3. **Electric Generator**: The rotor is connected to a generator, which converts the mechanical energy of the rotating blades into electrical energy.
4. **Electricity Transmission**: The electrical energy produced by the generator is then transmitted via power lines for use in homes, industries, and businesses.

**Applications of Wind Energy**:

1. **Power Generation**: Large wind farms are used to generate electricity for the grid.
2. **Rural Electrification**: Small-scale wind turbines can be used to power remote areas where grid electricity is unavailable.
3. **Offshore Wind Farms**: Offshore wind farms are being developed to take advantage of higher wind speeds over the oceans.

**Geothermal Energy:**

**Working Principle**:

1. **Heat from Earth's Core**: Geothermal energy harnesses the natural heat from the Earth's interior. The heat is produced by the radioactive decay of elements within the Earth’s crust.
2. **Geothermal Wells**: Geothermal power plants use wells drilled into the Earth's crust to tap into underground reservoirs of hot water or steam.
3. **Energy Conversion**: The steam or hot water from these reservoirs is used to turn turbines connected to generators, producing electricity.
4. **Direct Use**: Geothermal energy can also be used directly for heating purposes, such as in geothermal district heating systems.

**Applications of Geothermal Energy**:

1. **Electricity Generation**: Geothermal power plants can generate large amounts of electricity from deep geothermal resources.
2. **Heating and Cooling**: Geothermal heat pumps are used for residential and commercial heating and cooling.
3. **Agriculture**: Geothermal energy can be used for greenhouses, aquaculture, and drying crops, providing a reliable and consistent heat source.
4. **Direct Use in Industries**: Certain industries, such as food processing, use geothermal energy for various processes, such as drying and pasteurization.