RGIT FE-SAHYOG

APPLIED CHEMISTRY 1 Question Bank

📢 Important Note Regarding Applied Chemistry Question Bank

Dear First-Year Engineering Students,

We are pleased to provide you with a carefully prepared Applied Chemistry Question Bank based on the analysis of past year question papers (PYQs) adhering to the NEP 2020 syllabus.

Please read this **caution** carefully:

1. **Reference Material Only:** This Question Bank is solely for reference and practice purposes. It is designed to highlight the most frequently tested concepts and question structures from the past.
2. **No Guarantee:** There is absolutely no guarantee that the questions in the upcoming examination will be drawn *exclusively* from this set.
3. **Comprehensive Preparation is Key:** High scores are achieved by mastering the entire syllabus (Modules I through VI), understanding the underlying concepts, and practising both derivations and numerical problems.
4. **Do check PYQs for questions that are not given here**

Our recommendation is to **use this Question Bank as a guide to:**

- **Identify High-Priority Topics**.
- **Master the Standard Derivations** (5-mark questions) and practice solving
- **Numericals** (3-mark and 5-mark questions).

Do not limit your study to these questions alone. Ensure you cover all the concepts listed in the Applied Chemistry syllabus for complete and thorough preparation.

Read the question bank till the **Last Page** for maximum benefit.

Best of luck with your studies!

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Team FE SAHYOG

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List of IMP/Frequent Questions Module Wise:

Module I. Fuels and Combustion

1. A sample of coal has the following composition:
   C = 80%, O = 8%, H = 6%, S = 1.5%, N = 1%.
   Calculate the Higher Calorific Value (HCV) and Lower Calorific Value (LCV) of the coal.
2. Describe the determination of Sulphur OR Carbon & Hydrogen in a coal sample, including the chemical equations and procedures involved.
3. What are the characteristics of a good fuel?
4. What are the advantages of gaseous fuels over solid and liquid fuels?

Module II: Corrosion

5. Explain the effect of the following factors on the rate of corrosion: pH, Purity of metal, and Relative Anodic/Cathodic Area.
6. Explain the mechanism of Sacrificial Anode protection in Cathodic Protection, including diagrams and applications.
7. Distinguish between Galvanizing and Tinning (Explain the difference in protection mechanism: Anodic vs. Cathodic).
8. Explain the methods used for corrosion control via material selection and proper design of equipment.
9. Define corrosion. How would you join two dissimilar metals to prevent corrosion?

Module III: Alloys

10. State the Condensed Phase Rule equation. Explain its application with the help of a phase diagram to the two-component Lead-Silver (Pb-Ag) system.
11. An alloy of tin and lead contains 73% Sn. Find the mass of eutectic present in 1 kg of the alloy.
12. What are the purposes of making an alloy? Why are alloys preferred over pure metals?

Module IV: Introduction to Polymers

13. In a polymer sample 30% molecules have a molecular mass 20,000, 40% have molecular mass 30,000 and the 30% have 60,000. Calculate the weight average (Mw), number average (Mn) molecular weight and polydispersity index (PDI) of polymer sample ?
14. Explain the definition and significance of Glass Transition Temperature (Tg) and Viscoelasticity properties of polymers.

15. Explain the definition and significance of Electrical (Insulation Resistance/Dielectric Strength) and Optical (Refractive Index/Transmittance) properties of polymers.

Module V: Introduction to Composites

16. Define and differentiate between the Matrix Phase and the Dispersed Phase (Reinforcement) of a composite.
17. Explain the structure, applications, and advantages of Sandwich Panels of structural composite.
18. Explain the structure and characteristics of Carbon Fiber Reinforced Composites (CFRC) or Glass Fiber Reinforced Composites (GFRC).

Module VI: Green Chemistry for Sustainable Development

19. Explain the synthesis of Adipic Acid by traditional and green pathways, highlighting the Green Chemistry principle involved.
20. Explain the synthesis of Indigo Dye by traditional and green pathways.
21. Explain the synthesis of Carbaryl by traditional and green pathways.
22. Write a short note on Supercritical CO_2 (Green Solvent) OR Biodiesel (Green Fuel).

Solutions of these 22 IMP Quesitons

Q1. A sample of coal has the following composition:

C = 80%, O = 8%, H = 6%, S = 1.5%, N = 1%.
Calculate the Higher Calorific Value (HCV) and **Lower Calorific Value (LCV) of the coal.**

Sol:
Step 1 – Dulong's Formula:
HCV = (1/100)[8080C + 34500(H – O/8) + 2240S]
Step 2 – Substitute values:
C = 80, H = 6, O = 8, S = 1.5
Compute (H – O/8):
O/8 = 8/8 = 1
H – O/8 = 6 – 1 = 5
Step 3 – Apply formula:
HCV = (1/100)[8080(80) + 34500(5) + 2240(1.5)]
Term 1: 8080 × 80 = 646400
Term 2: 34500 × 5 = 172500
Term 3: 2240 × 1.5 = 3360
Sum = 646400 + 172500 + 3360 = 822260
HCV = 822260 / 100 = 8222.6 kcal/kg
Step 4 – LCV Calculation:
LCV = HCV – 0.09H × 587
0.09 × 6 = 0.54
0.54 × 587 = 316.98
LCV = 8222.6 – 316.98 = 7905.62 kcal/kg
Final Answers:
HCV = 8222.6 kcal/kg
LCV = 7905.6 kcal/kg

Q2 .Describe the determination of Sulphur OR Carbon & Hydrogen in a coal sample, including the chemical equations and procedures involved.

Ans:

Step 1

Carbon and Hydrogen Determination: The coal sample is burned in a stream of oxygen. The carbon in the coal is converted to carbon dioxide (CO2) and the hydrogen is converted to water (H2O). The CO2 and H2O are absorbed in suitable absorbents and weighed. The percentage of carbon and hydrogen is calculated from the increase in weight of the absorbents.

Step 2

Sulphur Determination: The coal sample is burned in a bomb calorimeter or in a stream of oxygen. The sulphur in the coal is converted to sulphur dioxide (SO2). The SO2 is absorbed in a suitable absorbent and converted to sulphuric acid (H2SO4). The amount of sulphur is determined by titrating the sulphuric acid with a standard solution of a base.

Step 3

Calculation: The percentages of carbon, hydrogen, and sulphur are calculated based on the weights of the absorbents and the coal sample. The formulas used are:

$$\%\mathrm{C} = \frac{\text{Weight of CO2} \times 12}{\text{Weight of coal sample} \times 44} \times 100$$

$$\%\mathrm{H} = \frac{\text{Weight of H2O} \times 2}{\text{Weight of coal sample} \times 18} \times 100$$

$$\%\mathrm{S} = \frac{\text{Weight of SO2} \times 32}{\text{Weight of coal sample} \times 64} \times 100$$

Q3. What are the characteristics of a good fuel?

Ans:

A good fuel efficiently provides energy with characteristics like high calorific value, a moderate ignition temperature, and clean burning (little smoke/ash). It should be easily available, inexpensive, and simple to transport/store, while also being safe to handle and non-toxic, ensuring controlled combustion and minimal harmful emissions like CO, SOx, or H2S.

Key Characteristics:

- **High Calorific Value:** Releases a large amount of heat energy per unit mass or volume.
- **Moderate Ignition Temperature:** Ignites easily at a reasonable temperature but doesn't combust spontaneously (not too high, not too low).
- **Clean Burning**: Burns completely with little smoke, ash, or harmful/toxic gases (like carbon monoxide, sulfur oxides).
- **Easy Availability & Cost:** Readily available in large quantities and affordable.
- **Safe Handling & Storage:** Easy to transport, store, and handle without fire hazards.
- **Moderate Combustion Rate**: Burns at a steady, controllable, and moderate speed.
- **Low Moisture & Ash:** Contains low levels of non-combustible matter and moisture to maximize energy output.

Q4. What are the advantages of gaseous fuels over solid and liquid fuels?

Ans:

Gaseous fuels offer numerous advantages over solid fuels (like coal) and liquid fuels (like petrol or diesel) due to their physical state and chemical composition.[1]

Here are the key advantages of gaseous fuels:

1. **High Calorific Value (CV):** Gaseous fuels generally possess a high CV, meaning they produce a large amount of heat energy per unit mass or volume, leading to higher efficiency.
2. **Clean Combustion:** They burn cleanly with little to no smoke, soot, or ash residue. This eliminates the cost and environmental impact associated with ash disposal (a major issue with solid fuels).
3. **Easy Ignition and Control:**
    - They are easily ignited.
    - The rate of fuel supply and, consequently, the heat output can be precisely controlled by simple valve adjustments.
4. **Uniformity of Heat:** Gaseous fuels mix readily with air, ensuring complete combustion and providing a uniform heat distribution over the entire space or furnace.
5. **Handling and Storage:**
    - **Requires Less Space:** Storage is simple, requiring only gas cylinders or underground pipelines, which saves valuable storage space compared to solid piles or large liquid tanks.
    - **Easy Transport:** They can be easily and economically transported through pipelines (e.g., CNG, PNG), eliminating the need for extensive road/rail logistics.
6. **Minimal Pollution:** Their combustion products are primarily CO2 and H2O, with significantly lower emissions of $SO2 (Sulfur Dioxide) and particulate matter, making them more environmentally friendly.
7. **No Wastage:** The entire volume of gas is utilized in combustion; there is no loss due to storage handling or incomplete burning, unlike solid fuels.

Q5. Explain the effect of the following factors on the rate of corrosion: pH, Purity of metal, and Relative Anodic/Cathodic Area.

Ans:

1. Effect of pH (Acidity/Alkalinity of the Medium)
The rate of corrosion is strongly influenced by the pH of the surrounding environment, primarily because the cathodic reaction often involves H+ ions.

pH Range	Condition	Effect on Corrosion Rate	Explanation
Highly Acidic ($\mathrm{pH} < 4$)	Highly corrosive	**Rapid/High Rate**	The high concentration of H^+ ions causes the rapid evolution of hydrogen gas at the cathode ($2\mathrm{H}^+ + 2\mathrm{e}^- \rightarrow \mathrm{H}_2$). This prevents polarization and maintains a high corrosion rate.
Neutral or Mildly Alkaline ($\mathrm{pH} 5 - 9$)	Moderately corrosive	**Slow/Moderate Rate**	In this range, the rate is controlled by the rate of oxygen diffusion to the cathodic surface, and the corrosion product often forms a protective oxide layer.
Highly Alkaline ($\mathrm{pH} > 10$)	Non-corrosive	**Very Low Rate**	Most metals form stable, insoluble hydroxide or oxide films in alkaline conditions (passivation), which protect the underlying metal from further attack.

2. Effect of Purity of the Metal
The purity of a metal is inversely proportional to the corrosion rate.

- **Purity:** Corrosion rate is **low** for pure metals.
    - **Reason:** Perfectly pure metals corrode slowly because the entire surface is chemically uniform, and local electrochemical cells cannot be easily set up.
- **Impurities:** Corrosion rate is **high** for impure metals.
    - **Reason:** Impurities within the metal act as **local cathodes** when they come into contact with the main metal (anode) in the presence of an electrolyte. This sets up numerous small galvanic cells that drive the corrosion process rapidly.
    - **Example:** Zinc metal containing small traces of iron impurities corrodes much faster than highly pure zinc when placed in a dilute acid solution.

3. Effect of Relative Anodic and Cathodic Area

The relative sizes of the anodic and cathodic areas are critical in determining the *intensity* (or speed) of corrosion.

- **Small Anode, Large Cathode:** Corrosion is **very rapid** and localized.
    - **Explanation:** The anodic reaction (metal dissolution) is concentrated over a very small area, while the cathodic reaction (reduction) is spread over a large area. The large cathode efficiently consumes electrons, forcing the small anode to dissolve at a very fast rate to supply those electrons.
    - **Example:** A scratch or pinhole in a tin-plated iron sheet (where tin is cathodic to iron) exposes a small anodic iron area to a large cathodic tin area, leading to rapid, deep pitting corrosion of the iron.
- **Large Anode, Small Cathode:** Corrosion is **slow** and widespread (uniform).
    - **Explanation:** The small cathodic area quickly becomes polarized (electron accumulation), slowing down the entire corrosion process. The small anode dissolves slowly over a large surface.
    - **Example:** A scratch in a galvanized iron sheet (where zinc is anodic to iron) exposes a small cathodic iron area to a large anodic zinc area. The zinc corrodes slowly over a large area, protecting the iron.

Q6. Explain the mechanism of Sacrificial Anode protection in Cathodic Protection, including diagrams and applications.

Ams:

Mechanism of Sacrificial Anode Protection (Cathodic Protection)

Sacrificial Anode Protection is a type of **Cathodic Protection** where the metal structure being protected (e.g., iron pipe) is converted into a cathode by connecting it to a more **active** (more anodic) metal. The more active metal then corrodes (sacrifices itself) while protecting the main **I. Principle**

The principle is based on the **Galvanic Series**. A metal higher (more anodic) in the series sacrifices itself by acting as the anode, thereby forcing the metal lower (more cathodic) in the series, which is the structure to be protected, to act as the cathode. Corrosion only occurs at the anode; hence, the protected structure remains safe.

- **Sacrificial Metal (Anode):** Must be highly anodic (e.g., Zinc, Magnesium, Aluminum).
- **Protected Structure (Cathode):** The structure being saved (e.g., Iron or Steel).

II. Mechanism

1. **Connection:** The sacrificial metal block (anode) is electrically connected to the metal structure (cathode) to be protected.
2. **Redox Reaction:** When the system is immersed in an electrolyte (e.g., soil, seawater), an electrochemical cell is established.
3. **Anodic Reaction (Corrosion):** The sacrificial metal (Anode) undergoes oxidation and dissolves into the electrolyte, releasing electrons.

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

4. **Cathodic Reaction (Protection):** The electrons flow through the electrical connection to the protected structure (Cathode). The structure receives these electrons, preventing its own metal atoms from undergoing oxidation. The electron surplus facilitates the normal cathodic reactions (like oxygen reduction or hydrogen evolution) on the surface of the structure.

$$\frac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH^- \quad \text{(in neutral/alkaline water)}$$

or

$$2H^+ + 2e^- \rightarrow H_2 \quad \text{(in acidic medium)}$$

5. **Protection:** Since the protected structure acts entirely as a cathode, it becomes immune to corrosion.
6. **Replenishment:** The sacrificial anode must be replaced periodically once it is completely consumed.

III. Key Advantages and Applications

Feature	Advantage	Applications
Simplicity	Requires no external power supply; relies only on the potential difference between the two metals.	**Underground Pipelines** (gas, oil, water), protected using Magnesium or Zinc anodes buried nearby.
Reliability	Few moving parts; easy to install and maintain in remote locations.	**Ship Hulls** and **Rudders**, where Zinc blocks are bolted onto the steel hull.
Marine Use	Highly effective in seawater (an excellent electrolyte).	**Storage Tanks** (especially domestic water heaters), where Magnesium rods are inserted.
Safety	Does not generate hazardous high voltages.	**Jetties and Piers** (steel structures in marine environments).

Q7. Distinguish between Galvanizing and Tinning (Explain the difference in protection mechanism: Anodic vs. Cathodic).

Ans:

Feature	Galvanizing	Tinning
Coating Metal	**Zinc (Zn)**	**Tin (Sn)**
Base Metal	Iron or Steel	Iron or Steel
Position in Galvanic Series	Zinc is **more anodic** (more active) than Iron.	Tin is **more cathodic** (more noble) than Iron.
Protection Mechanism	**Anodic / Sacrificial Protection**	**Cathodic / Noble Protection**
Action when Coating is Broken (Key Difference)	The exposed Iron/Steel is protected. Zinc, being more active, corrodes preferentially (sacrifices itself) to protect the Iron, even if the coating is scratched.	The exposed Iron/Steel is **not protected** and corrodes rapidly. Since Iron is more anodic than Tin, it corrodes faster due to the formation of a small anode (Iron) and a large cathode (Tin).
Main Advantage	Provides **long-lasting protection** even if damaged.	Coating is non-toxic and non-reactive, making it safe for food.
Common Application	Roofing sheets, pipes, buckets, utility fittings.	Food containers (tiffin boxes, cans), coating on copper utensils.

Q8. Explain the methods used for corrosion control via material selection and proper design of equipment.

Ans:

1. Corrosion Control by Material Selection

The most straightforward way to avoid corrosion is to select materials that are inherently resistant to the operating environment.

Method	Description	Example/Principle
Using Pure Metals	Highly pure metals generally have a lower rate of corrosion than impure metals because they lack the necessary impurities to form local galvanic cells.	Using highly pure aluminium in specialized chemical processes.
Using Alloys	Alloys can be selected based on their tendency to form stable, protective oxide films (passivation).	**Stainless Steel** (containing chromium) is highly resistant because it forms an inert, self-healing oxide layer on its surface.
Using Non-Metals	Where temperature and mechanical strength allow, non-metallic materials should be used to eliminate electrochemical corrosion altogether.	Using **Plastics**, **Glass**, or **Ceramics** for lining tanks and pipes handling corrosive liquids (e.g., HCl storage).
Selecting Noble Metals	Choosing metals that are far apart from the common metal components in the galvanic series to reduce potential differences.	Using **Copper** piping instead of steel if the connecting fittings are primarily copper-based.

2. Corrosion Control by Proper Equipment Design

Poor design can create environments that accelerate corrosion, even if the materials selected are suitable. Good engineering design eliminates features that promote localized corrosion.

1. **Avoid Sharp Bends and Corners:**
    - **Issue:** Sharp bends cause turbulence and high velocity flow on one side of the pipe, leading to **erosion corrosion**. They also serve as stress concentration points.

- **Solution:** Use **smooth, gradual curves** or rounded corners wherever possible to ensure streamlined fluid flow.

2. **Eliminate Crevices and Stagnant Areas:**
    - **Issue:** Gaps, lap joints, rivets, and dead-end sections trap moisture, dirt, and trapped air, leading to **crevice corrosion** and **concentration cell corrosion** (differential aeration).
    - **Solution:** Design structures to **avoid crevices** (e.g., use butt welds instead of lap joints). Ensure proper drainage and avoid dead-end pipes where fluid can stagnate.
3. **Minimize Stress Concentration:**
    - **Issue:** Areas under high localized stress (e.g., cold-worked areas, heavily bolted sections) are anodic relative to the unstressed bulk metal, leading to **stress corrosion cracking (SCC)**.
    - **Solution:** Use proper heat treatment (annealing) to relieve internal stresses after fabrication. Avoid excessive pressures or loads during operation.
4. **Avoid Heterogeneous Assemblies:**
    - **Issue:** Joining two dissimilar metals (e.g., copper and iron) creates a large galvanic potential difference, causing the more anodic metal to corrode rapidly (galvanic corrosion).
    - **Solution:** If dissimilar metals must be used, **insulate them** electrically using non-conducting gaskets or spacers, or ensure the anodic part (which will corrode) has a much larger surface area than the cathodic part.
5. **Accessibility for Maintenance:**
    - **Issue:** Design should allow easy access for cleaning, inspection, and the application/repair of protective coatings.
    - **Solution:** Ensure parts prone to corrosion (like bolts or filters) are easily replaceable.

Q9. Define corrosion. How would you join two dissimilar metals to prevent corrosion?

Ans:

Definition of Corrosion

Corrosion is defined as the spontaneous, irreversible destruction, deterioration, or gradual eating away of a metal (or its alloys) due to its chemical or electrochemical reaction with its surrounding environment.

- Key Outcome: The metal converts from its desired metallic state (low energy, refined state) back into a more stable compound form (usually oxides, hydroxides, or sulphides, which are its original ores), resulting in the loss of useful properties of the metal.
- Most Common Type: Electrochemical (Wet) Corrosion, which requires both moisture (electrolyte) and oxygen to occur.

How to Join Two Dissimilar Metals to Prevent Corrosion

Joining two dissimilar metals creates a high risk of Galvanic Corrosion because an electrochemical cell is immediately established. The metal that is more anodic (more active/higher in the Galvanic Series) will corrode rapidly to protect the metal that is more cathodic (more noble/lower in the series).

To join them while preventing corrosion, you must follow these two strategies:

1. Electrical Insulation (Avoid Cell Formation)
The most effective method is to break the electrical connection between the two metals, which prevents the galvanic cell from functioning.

- Method: Separate the two metals physically using insulating materials.
- Practical Application: Use a gasket (made of rubber, plastic, or Teflon) or non-conducting spacers between the dissimilar metal components (e.g., between an aluminum pipe and a steel valve) to prevent electron flow.

2. Design and Area Control (Minimize Damage)
If electrical contact is unavoidable, the structure must be designed to minimize the intensity of corrosion damage.

- Avoid Small Anode/Large Cathode: The most dangerous situation is having a small anodic area connected to a large cathodic area (this leads to rapid, localized pitting of the anode).
- Best Practice: Ensure the anodic metal (the one that will corrode) has a much larger surface area than the cathodic metal (the one being protected). This

spreads the corrosion of the anode over a wide area, reducing the corrosion rate per unit area and making the damage less severe.

- Example: If connecting Steel (Cathode) and Zinc (Anode), the Zinc component should be significantly larger.

3. Using a Third, Sacrificial Metal

Introducing a third, highly anodic metal that is more active than both of the metals being joined.

- Method: Connect a sacrificial anode (like magnesium or zinc) to the junction of the two dissimilar metals.
- Effect: The sacrificial metal will preferentially corrode, providing electrons to both metals being joined, thus protecting them both.

Q10. State the Condensed Phase Rule equation. Explain its application with the help of a phase diagram to the two-component Lead-Silver (Pb-Ag) system.

Ans:

1. The Condensed Phase Rule Equation

The general Phase Rule (Gibbs Phase Rule) relates the number of degrees of freedom (F) to the number of components (C) and the number of phases (P) in a system:

$$F = C - P + 2$$

Where the factor '2' accounts for the two independent variables: Temperature (T) and Pressure (P).

Condensed Phase Rule

For solid-liquid equilibrium systems (like the Pb-Ag alloy), the effect of pressure variations on the system is negligible because solids and liquids are virtually incompressible.Therefore, pressure is considered constant (usually atmospheric pressure), and the degree of freedom associated with it is ignored.

By fixing the pressure, the Phase Rule reduces by one degree of freedom, resulting in the Condensed Phase Rule Equation:

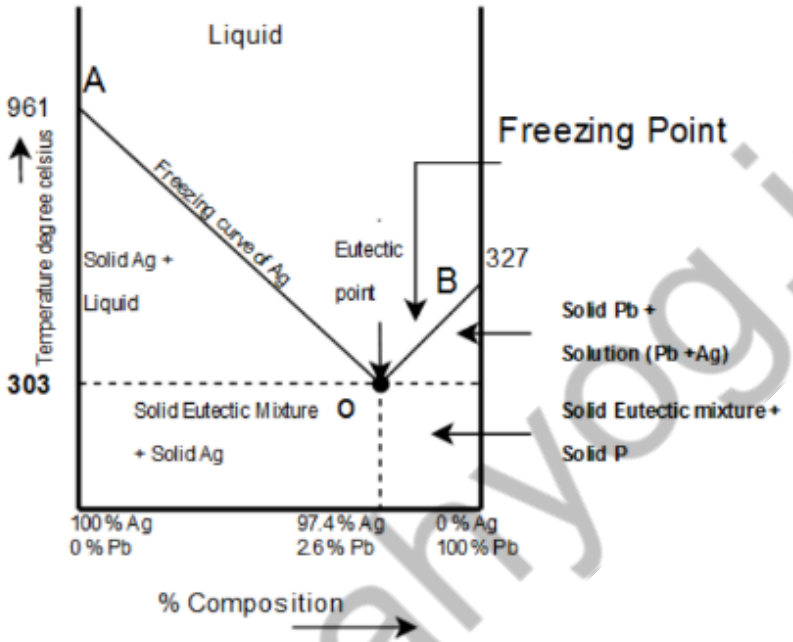
$$F = C - P + 1$$

Where the factor '1' accounts only for the Temperature (T) as the independent variable.

2. Application to the Lead-Silver (Pb-Ag) System

The Pb-Ag system is a two-component system (C=2) that exhibits a simple eutectic mixture. The phase diagram is a graphical representation used to study the solubility and crystallization points of Pb and Ag mixtures.

The Phase Diagram



Q11. An alloy of tin and lead contains 73% Sn. Find the mass of eutectic present in 1 kg of the alloy.

Sol:

Use the Pb–Sn phase diagram and the lever rule (MU standard).
Given (from standard Pb–Sn phase diagram):
Eutectic composition (Ce) = 61.9% Sn
Composition of β–solid (Cβ) at eutectic temperature ≈97.5% Sn
Overall alloy composition (C0) = 73% Sn
Step 1: Identify phases on cooling at eutectic temperature.
Because 73% Sn > 61.9% Sn, the alloy lies on the Sn-rich side.
Primary phase = β-solid (Sn-rich solid)
Remaining liquid transforms into eutectic.
Step 2: Apply Lever Rule for fraction of eutectic:
Fraction of eutectic = (Cβ– C0) / (Cβ– Ce)
Substitute:
Cβ= 97.5

C0 = 73
Ce = 61.9
Fraction = (97.5 – 73) / (97.5 – 61.9)
= 24.5 / 35.6
= 0.688 (approx.)
Step 3: Convert fraction to mass of eutectic in 1 kg alloy:
Mass eutectic = 0.688 × 1 kg = 0.688 kg
Final Answer:
Mass of eutectic in 1 kg alloy = 0.688 kg (≈688 g)

Q12. What are the purposes of making an alloy? Why are alloys preferred over pure metals?

Ans: Alloys are physical mixtures of two or more elements (at least one of which must be a metal) made primarily to enhance or modify the parent metal's properties.

The primary purposes are:

1. To Increase Hardness and Strength: Pure metals are often soft and malleable. Introducing foreign atoms into the crystal lattice of the parent metal disrupts the orderly arrangement and impedes the movement of dislocations (defects), making the alloy much harder and stronger.
    - Example: Pure iron is soft; alloying it with carbon creates strong, hard Steel.
2. To Lower the Melting Point: Alloying can significantly lower the melting point compared to the constituent metals, making the alloy easier to cast or solder.
    - Example: Solder (an alloy of tin and lead) has a lower melting point than either pure tin or pure lead, making it suitable for electrical joints.
3. To Improve Corrosion Resistance: Many metals are highly susceptible to chemical attack. Alloying can force the metal to form a protective layer (passivation) or stabilize existing protective layers.
    - Example: Adding Chromium to Iron makes Stainless Steel, which forms a highly stable, inert chromium oxide layer, preventing rust.
4. To Change Color and Appearance: Alloys are often produced for aesthetic purposes.
    - Example: Gold is alloyed with copper or silver to change its color and increase its strength for jewelry.
5. To Modify Electrical and Magnetic Properties: Alloying can be used to either increase or decrease the electrical resistance of a metal based on the application.

- Example: Alloys like Nichrome (Nickel and Chromium) are used in heating elements because they have high electrical resistance and do not oxidize at high temperatures.

Why Alloys are Preferred over Pure Metals

Alloys are preferred over pure metals in most engineering applications because they offer a superior combination of desired properties that a single pure metal cannot provide:

- Tailored Performance: Alloys allow engineers to tailor mechanical, thermal, and chemical properties to meet specific structural and environmental demands (e.g., high strength at high temperature, or good conductivity with high wear resistance).
- Cost-Effectiveness: Often, using a small amount of an expensive alloying agent (like nickel) combined with a cheaper base metal (like iron) results in a cost-effective material (like steel) with properties rivaling that of the pure expensive metal.
- Wider Application Range: Pure metals are too soft or reactive for most structural and industrial uses, while alloys provide the necessary ruggedness, strength, and durability for demanding applications.

Q13. In a polymer sample 30% molecules have a molecular mass 20,000, 40% have molecular mass 30,000 and the 30% have 60,000. Calculate the weight average (Mw), number average (Mn) molecular weight and polydispersity index (PDI) of polymer sample.

Ans:

Fraction (i)	Number of Molecules (Ni)	Molecular Weight (Mi)	NiMi	NiMi2
1	30	20,000	6,00,000	1200 x 10^7
2	40	30,000	12,00,000	3600 x 10^7
3	30	60,000	18,00,000	10800 x 10^7
Sum (Σ)	ΣNi = 100		ΣNi Mi = 36,00,000	$\Sigma NiMi^2$

Fraction (i)	Number of Molecules (Ni)	Molecular Weight (Mi)	NiMi	NiMi2
				= 15600 x 10^7

Step 1: Calculate the Number Average Molecular Weight ($\overline{M}_n$)

The formula for $\overline{M}_n$ is the ratio of the total weight of the polymer to the total number of molecules.

$$\overline{M}_n = \frac{\sum N_i M_i}{\sum N_i}$$

$$\overline{M}_n = \frac{36,00,000}{100}$$

$$\overline{M}_n = 36,000$$

Step 2: Calculate the Weight Average Molecular Weight ($\overline{M}_w$)

The formula for $\overline{M}_w$ emphasizes the contribution of heavier molecules.

$$\overline{M}_w = \frac{\sum N_i M_i^2}{\sum N_i M_i}$$

$$\overline{M}_w = \frac{15600 \times 10^7}{36,00,000}$$

$$\overline{M}_w = \frac{156 \times 10^9}{3.6 \times 10^6} \quad \text{or} \quad \frac{15,600,000,000}{3,600,000}$$

$$\overline{M}_w \approx 43,333.33$$

Step 3: Calculate the Polydispersity Index (PDI)

The PDI indicates the breadth of the molecular weight distribution.

$$PDI = \frac{\overline{M}_w}{\overline{M}_n}$$

$$PDI = \frac{43,333.33}{36,000}$$

$$PDI \approx 1.204$$

Final Answer:

- **Number Average Molecular Weight ($\overline{M}_n$): 36,000**
- **Weight Average Molecular Weight ($\overline{M}_w$): 43,333.33**
- **Polydispersity Index (PDI): 1.204**

(Since PDI > 1, the polymer is polydisperse.)

Q14. Explain the definition and significance of Glass Transition Temperature (Tg) and Viscoelasticity properties of polymers.

Ans:

1. Glass Transition Temperature (T_g)

Definition

The Glass Transition Temperature (T_g) is a critical second-order transition temperature (below the melting point, T_m) at which an **amorphous** or **semi-crystalline polymer** transitions from a hard, brittle, glassy, and rigid state to a softer, more flexible, and rubbery state.

- Below T_g: The polymer chains are frozen in position. The polymer exhibits glassy, rigid, and brittle behavior.
- Above T_g: Local movement of small chain segments (like rotation of side groups) begins, allowing the material to exhibit rubbery or highly viscous behavior.

Significance of T_g

The T_g value is the most important factor in determining the practical application of a polymer:

1. **Service Temperature:** For a polymer to be used as a plastic or rigid material (like housing or casings), its T_g must be **above** the operating temperature.
2. **Elastomers/Rubbers:** For a polymer to act as a rubber (an elastomer), its T_g must be **below** the operating temperature (e.g., room temperature or service temperature) so that the material remains flexible.
3. **Processing:** T_g determines the temperature required for processing techniques like molding and extrusion.

Polymer Type	Tg vs. Room Temperature (TRoom)	Behavior
Plastics (e.g., PVC)	Tg > TRoom	Rigid, brittle, and glassy
Elastomers (e.g., Rubber)	Tg < TRoom	Soft, flexible, and elastic

2. Viscoelasticity

Definition

Viscoelasticity is the property of materials that exhibit both viscous (liquid-like) and elastic (solid-like) characteristics when undergoing deformation. It refers to the time-dependent mechanical response of a polymer.

- Viscous Component: Represents energy dissipation (like honey flowing). The material permanently deforms under stress.
- Elastic Component: Represents energy storage (like a spring). The material recovers its original shape after the stress is removed.

A viscoelastic material will show:

1. Creep: If a constant stress is applied, the strain (deformation) increases gradually over time (viscous flow).
2. Stress Relaxation: If a constant strain is maintained, the stress required to hold it at that strain decreases over time (viscous flow).

Significance of Viscoelasticity

Understanding viscoelasticity is vital for engineering applications of polymers:

1. Long-Term Performance: It predicts how a polymer structure (like a plastic seat or a rubber tire) will behave under sustained load (creep) or intermittent loads (fatigue) over its lifetime.
2. High-Speed/Impact Behavior: At very high strain rates (like impact), a viscoelastic polymer behaves more like a stiff, brittle solid (elastic response). At low strain rates, it behaves more like a liquid (viscous response).
3. Damping: Viscoelastic materials are excellent at absorbing mechanical energy and converting it into heat, making them ideal for use in shock absorbers and vibration dampeners.

Q15. Explain the definition and significance of Electrical (Insulation Resistance/Dielectric Strength) and Optical (Refractive Index/Transmittance) properties of polymers.

Ans:

1. Electrical Properties of Polymers

Polymers are generally covalent materials and lack free electrons, making them excellent electrical insulators. Key properties include insulation resistance and dielectric strength.

A. Insulation Resistance

- Definition: Insulation resistance is the property of a polymer that determines its ability to resist the flow of electric current. It is measured in Ohms (Ω) and can be classified as:
    1. Volume Resistivity: Resistance to current flow through the bulk (volume) of the material.
    2. Surface Resistivity: Resistance to current flow across the surface of the material.
- Significance:
    - High Resistivity is Good: Polymers used in cables, wires, and electronic casings (like PVC, Polyethylene) must have very high insulation resistance to prevent leakage of current and ensure safety.
    - Environmental Impact: Moisture, contamination, and high temperatures can decrease insulation resistance, leading to electrical breakdown.

B. Dielectric Strength

- Definition: Dielectric strength is the maximum voltage (electrical stress) a polymer insulator can withstand before electrical breakdown (failure) occurs. It is usually expressed in Volts per unit thickness (e.g.,kV/mm).
- Significance:
    - Preventing Failure: Materials used as capacitors, insulators, and circuit board substrates (e.g., Bakelite, PTFE) must have high dielectric strength to ensure they do not short-circuit or break down under high operating voltages.
    - Design Factor: This property guides the minimum thickness required for an insulator in a high-voltage application.

2. Optical Properties of Polymers

Optical properties govern how a polymer interacts with light (visible, UV, IR) and are essential for applications ranging from lenses to packaging. Key properties include refractive index and transmittance.

A. Refractive Index (n)

- Definition: The refractive index (n) is a dimensionless number that describes how light, or any other radiation, propagates through a medium. It is calculated as the ratio of the speed of light in a vacuum (c) to the speed of light in the polymer material (v).

$$n = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in polymer}} = \frac{c}{v}$$

- Significance:
    - Lens/Prism Design: It is the fundamental property used in designing optical components like lenses (e.g., Polycarbonate, Acrylic) and optical fibers, determining their light-bending ability.
    - Clarity: A uniform refractive index across the material ensures clarity and prevents light scattering.

B. Transmittance

- Definition: Transmittance is the measure of the fraction of incident light (or electromagnetic radiation) that passes through a polymer sample without being absorbed or scattered. It is usually expressed as a percentage.
- Significance:
    - Transparency: High transmittance is required for applications where clarity is essential, such as protective coatings, windows (e.g., Acrylic sheets), and clear packaging (e.g., PET bottles).

- Absorbers/Filters: Conversely, low transmittance (high absorbance) is desirable for polymers used as UV-filters or dark lenses.

Q16. Define and differentiate between the Matrix Phase and the Dispersed Phase (Reinforcement) of a composite.

Ans:

1. Definition of Composite Components

A Composite Material is defined as a material consisting of two or more distinct constituents (phases) that are chemically dissimilar, insoluble in each other, and when combined, exhibit properties superior to those of the individual components.

The two main phases are:

A. Matrix Phase (Continuous Phase)

- Definition: The matrix phase is the continuous phase within the composite. It is the bulk material that surrounds, holds, and binds the reinforcing dispersed phase together.
- Primary Function: To transfer the load (stress) to the dispersed phase, protect the reinforcement from the environment, and provide physical shape and cohesion to the composite structure.
- Examples: Polymers (Epoxy, Polyester), Metals (Aluminum, Magnesium), or Ceramics.

B. Dispersed Phase (Discontinuous/Reinforcement Phase)

- Definition: The dispersed phase consists of discrete, non-continuous units (fibers, particles, flakes) embedded within the matrix. It is also known as the reinforcement.
- Primary Function: To bear the majority of the applied load and provide the material with superior stiffness, strength, and other mechanical properties (like wear resistance).
- Examples: Carbon fibers, Glass fibers, Kevlar fibers, Silicon Carbide particles.

Feature	**Matrix Phase**	**Dispersed Phase (Reinforcement)**
Role	Binder, load transfer medium, and protector.	Load bearer, strength provider.
Continuity	Continuous (forms the bulk structure).	Discontinuous (discrete particles or fibers).

Feature	Matrix Phase	Dispersed Phase (Reinforcement)
Typical Properties	Lower strength and modulus (soft, ductile).	Higher strength, higher modulus (hard, brittle).
Failure Mode	Fails first; often dictates the environmental stability (e.g., thermal resistance).	Resists fracture; determines the ultimate strength of the composite.
Common Materials	Resins, epoxy, aluminum, concrete.	Glass fibers, carbon fibers, silicon carbide.

Q17. Explain the structure, applications, and advantages of Sandwich Panels of structural composite.

Ans:

Structure of Sandwich Panels

A Sandwich Panel is a type of structural composite characterized by a layered construction, functioning like an I-beam.

1. Structure: It consists of three main layers permanently bonded together:
    - Two Outer Face Sheets (Skins): These are thin, dense, and strong layers made of materials like Fiber-Reinforced Polymers (FRP), Aluminum, Steel, or Plywood. They carry the tensile and compressive loads (in-plane loads) and resist bending moments.
    - One Inner Core: This is a thick, lightweight layer made of materials like polymeric foam (e.g., polyurethane foam, polystyrene foam), honeycomb structures (made of paper, aluminum, or polymer), or balsa wood.
2. Functionality: The thin face sheets bear most of the stress, while the thick, lightweight core separates the faces to increase the panel's moment of inertia. This separation dramatically increases the bending stiffness and strength of the panel without significantly increasing its weight.

Advantages of Sandwich Panels

Sandwich construction is preferred in many industries due to its exceptional properties:

1. **High Stiffness-to-Weight Ratio**: This is the primary advantage. They offer extremely high rigidity and bending stiffness for their mass, making them highly efficient structures.

2. **Excellent Insulation:** The thick, often foamed, core provides superior thermal and acoustic (sound) insulation properties.
3. **Damping Properties:** The composite structure, especially the core material, is excellent at absorbing vibrations and shock.
4. **Corrosion Resistance:** If polymer or FRP face sheets are used, the panels offer inherent resistance to chemical attack and environmental degradation.

Applications of Sandwich Panels

Due to their unique combination of low weight, high strength, and insulation properties, sandwich panels are widely used:

1. **Aerospace and Automotive**: Used extensively in aircraft fuselage sections, interior panels, flooring, and rotor blades, as well as high-speed trains, where weight reduction is critical.
2. **Construction:** Used as lightweight, high-strength walls, roofs, and façade panels in buildings, particularly in prefabricated structures and cold storage facilities (due to insulation).
3. **Marine:** Used in the decks, hulls, and bulkheads of high-performance boats and yachts to save weight and improve buoyancy.
4. **Containers**: Used in manufacturing refrigerated (reefer) containers and large truck bodies that require structural integrity and excellent thermal insulation.

Q18. Explain the structure and characteristics of Carbon Fiber Reinforced Composites (CFRC) or Glass Fiber Reinforced Composites (GFRC).

Ans:

1. Glass Fiber Reinforced Composites (GFRC) / Fiberglass

GFRC, commonly known as Fiberglass, is the most common and lowest-cost type of fiber-reinforced polymer (FRP).

Structure

- **Matrix**: Typically a polymer resin, such as Polyester, Vinyl Ester, or Epoxy.
- **Reinforcement**: Glass fibers (most commonly E-glass or S-glass), which are inexpensive, high-strength glass filaments. These fibers are strong in tension and are embedded within the polymer matrix.
- **Functionality**: The glass fibers provide the tensile strength and stiffness, while the resin matrix transfers the load between the fibers and protects them from the environment.

Characteristics

1. **High Strength-to-Weight Ratio**: Offers good strength and stiffness, though generally lower than CFRC.
2. **Excellent Electrical Insulator**: Glass is a non-conductor, making GFRC ideal for electrical applications.
3. **Low Cost**: Glass fibers are significantly cheaper to produce than carbon fibers.
4. **Corrosion Resistant**: Resistant to water, chemicals, and environmental degradation (as long as the matrix is intact).
5. **Relatively Poor Fatigue Resistance**: Mechanical properties degrade over time under repeated stress cycles.

Applications

- Boat hulls and marine structures.
- Automotive body panels, bumpers, and interiors.
- Pipes, storage tanks, and industrial containers.
- Printed Circuit Boards (PCBs) and electrical insulation.

2. Carbon Fiber Reinforced Composites (CFRC)

CFRC is a high-performance material known for its extreme strength and stiffness, often replacing metals in critical applications.

Structure

- **Matrix:** Usually a high-performance polymer resin, most commonly Epoxy.
- **Reinforcement**: Carbon Fibers, which are thin filaments derived from carbonizing materials like Polyacrylonitrile (PAN). These fibers have exceptionally high tensile strength, high modulus (stiffness), and very low density.
- **Functionality**: The carbon fibers bear the extreme mechanical load, while the epoxy matrix ensures the fibers remain aligned and facilitates load distribution.

Characteristics

1. **Exceptional Strength and Stiffness**: CFRC has a higher specific strength (strength/density) and specific modulus (stiffness/density) than nearly all conventional engineering materials, including steel and aluminum.
2. **Extremely Lightweight**: Due to the low density of carbon, CFRC leads to significant weight savings.
3. **High Fatigue and Creep Resistance:** Maintains structural integrity under repeated loads and sustained stress better than GFRC.
4. **High Thermal and Chemical Resistance**: Resists high temperatures and many corrosive chemicals.

5. Electrically Conductive: Unlike glass, carbon is conductive, which is a key difference and can be an advantage (for EMI shielding) or a disadvantage (in electrical insulation).

Applications

- **Aerospace:** Primary structures, wings, and fuselage parts in aircraft.
- **Sports Equipment:** High-end bicycles, racing car components (Formula 1), golf club shafts, and tennis rackets.
- **Medical:** X-ray tables and prosthetics due to its strength and radiolucency.
- **High-End Consumer Goods:** Drones and high-performance electronics casings.

Q19. Explain the synthesis of Adipic Acid by traditional and green pathways, highlighting the Green Chemistry principle involved.

Ans:

Synthesis of Adipic Acid

Adipic acid is a dicarboxylic acid primarily used in the production of Nylon-6,6.

1. Traditional (Conventional) Pathway

The traditional method is energy-intensive, hazardous, and uses non-renewable feedstock.

Feature	Description
Raw Material	**Benzene** (derived from crude oil).
Process	Benzene is hydrogenated to Cyclohexane, followed by oxidation using a mixture of **Nitric Acid (HNO_3)** and air.
Steps	1. Benzene is converted to Cyclohexane. 2. Cyclohexane is oxidized to a mixture of Cyclohexanone and Cyclohexanol (known as KA oil). 3. The KA oil is oxidized to Adipic Acid using concentrated HNO_3.
Reaction	$\text{Benzene} \xrightarrow{H_2} \text{Cyclohexane} \xrightarrow{O_2, HNO_3} \text{Adipic Acid} + N_2O \uparrow$

2. Green Pathway (Draths and Frost Method)
This process, developed by Draths and Frost, completely eliminates the use of hazardous chemicals and non-renewable feedstocks.

Feature	Description
Raw Material	**D-Glucose** (a renewable carbohydrate derived from biomass).
Process	It is a biocatalytic (fermentation) process involving genetically modified organisms, followed by a simple hydrogenation step.
Steps	1. Glucose is converted to **Muconic Acid** using a genetically engineered strain of $E.Coli.$ 2. Muconic Acid is then reduced (hydrogenated) to Adipic Acid.
Reaction	$\text{Glucose} \xrightarrow{\text{E. Coli enzyme}} \text{Muconic Acid} \xrightarrow{H_2\ (\text{Reduction})} \text{Adipic Acid}$
Major Advantages	* Uses a renewable, non-toxic, and inexpensive feedstock. * Avoids the generation of N_2O gas. * The reaction uses water as a solvent (a green solvent).

Q20. Explain the synthesis of Indigo Dye by traditional and green pathways.

Ans:

Traditional indigo synthesis involves harsh chemicals like aniline, formaldehyde, and hydrogen cyanide, generating toxic waste, while green pathways use genetically engineered microbes (like E. coli) to ferment glucose or enzymes to convert indole into indigo, offering reduced pollution, lower energy, and sustainable feedstock. Traditional methods are chemically intensive; green methods are biocatalytic, leveraging synthetic biology for a more environmentally friendly, bio-based production.

Traditional (Chemical) Pathway:

This industrial method starts from petroleum-derived aniline and uses several toxic steps:

- Aniline to Phenylglycine: Aniline reacts with formaldehyde and hydrogen cyanide (HCN) to form phenylglycinonitrile, which is then hydrolyzed to phenylglycine.
- Cyclization: Phenylglycine is heated under alkaline conditions (using sodium amide, $NaNH_2$) to cyclize and form indigo (indigotin).

- Drawbacks: This process involves highly hazardous substances, generates significant waste, requires harsh conditions (high heat, strong bases), and is energy-intensive.

Green Pathways:

Green chemistry focuses on sustainable, biological methods for indigo production.

Biotechnological Production (Microbial Fermentation):

- Process: Genetically modified bacteria, often E. coli, are engineered with metabolic pathways to convert renewable sugar sources (like glucose) directly into indigo.
- Mechanism: The microbes perform enzymatic conversions, essentially acting as tiny factories under mild fermentation conditions (neutral pH, ~30°C).
- Advantages: Eliminates toxic chemicals, uses renewable feedstocks, lowers energy use, and produces a cleaner product with fewer byproducts.

Enzymatic Synthesis (Biocatalysis):

- Process: Specific enzymes, like engineered heme-domain cytochrome P450 (CYPBM3F87A) or unspecific peroxygenases (UPOs), are used to catalyze the conversion of indole (or its derivatives) into indigo.
- Mechanism: These enzymes facilitate the oxidative coupling of indole molecules, creating the indigo chromophore.
- Advantages: High specificity, mild reaction conditions, potential for enzyme immobilization, and reduced environmental impact compared to chemical routes.

In essence, green pathways replace hazardous chemical steps with biological processes, making indigo production cleaner, safer, and more sustainable.

Q21. Explain the synthesis of Carbaryl by traditional and green pathways.

Ans:Carbaryl synthesis traditionally involves highly toxic methyl isocyanate (MIC) reacting with 1-naphthol, while green pathways aim to avoid MIC by changing the reaction sequence, using safer solvents (water, ethanol), or employing phosgene differently to form an intermediate like 1-naphthyl chloroformate, followed by reaction with methylamine, aligning with green chemistry principles of reducing hazardous substances and improving safety.

Traditional Pathway

1. **React 1-Naphthol with Methyl Isocyanate (MIC):** The primary method involves directly reacting 1-naphthol with methyl isocyanate (CH_3NCO).

2. **Hazard:** This route is inherently dangerous due to the extreme toxicity and volatility of methyl isocyanate, famously linked to the Bhopal disaster.

Green Pathways

Green approaches focus on avoiding MIC and hazardous solvents, often by altering the sequence or reagents:

1. **Phosgene-based Route (Safer Sequence):**
    - React 1-naphthol with phosgene ($COCl_2$) in an alkaline medium to form 1-naphthyl chloroformate (less hazardous intermediate).
    - React this intermediate with methylamine (CH_3NH_2) to yield carbaryl.
    - **Green Principle:** This avoids handling bulk MIC, making the process safer by generating the reactive intermediate in situ.
2. **Safer Solvents:**
    - Using water or ethanol instead of hazardous organic solvents for the reaction.
3. **Bio-based/Catalytic Methods (Emerging):**
    - Though less established for Carbaryl itself, green chemistry also explores biosynthesis (using engineered microbes) or catalytic routes with renewable resources, aiming for better atom economy and waste reduction, as seen in related chemical syntheses.

Key Green Chemistry Principles Applied

- **Prevention:** Minimizing waste and hazardous substances.
- **Safer Chemicals:** Designing less toxic products and intermediates (e.g., using chloroformate instead of MIC).
- **Safer Solvents & Auxiliaries:** Replacing harmful solvents with water or ethanol.
- **Inherently Safer Chemistry for Accident Prevention:** Changing reaction pathways to avoid dangerous materials like MIC.

Q22. Write a short note on Supercritical CO2 (Green Solvent) OR Biodiesel (Green Fuel)

Option A: Supercritical CO_2 (Green Solvent)

Supercritical Carbon Dioxide ($scCO_2$) is a substance that is at a temperature and pressure above its critical point, where it exists as a single fluid state with properties intermediate between a gas and a liquid. It is one of the most important green solvents.

Definition

- **Critical Point:** For CO_2, the critical temperature (T_c) is $31.1^\circ C$ and the critical pressure (P_c) is $73.8\ bar$. When CO_2 is maintained above these conditions, it becomes a supercritical fluid.

Properties of $scCO_2$

1. **High Diffusivity (Gas-like):** $scCO_2$ has high gas-like diffusivity, allowing it to penetrate materials easily and rapidly.
2. **Tunable Solvent Power (Liquid-like):** Its density, and thus its solvent power, can be precisely adjusted by changing the pressure and temperature. It is an excellent solvent for non-polar and slightly polar compounds.
3. **Low Viscosity (Gas-like):** Low viscosity allows for fast mass transfer and extraction.
4. **Green Attributes:** It is non-toxic, non-flammable, non-polluting, and readily available as a byproduct from industrial processes. It is easily removed from the product simply by reducing the pressure, leaving zero residual solvent.

Applications

- **Decaffeination:** Used to extract caffeine from coffee beans.
- **Dry Cleaning:** Used as a non-toxic alternative to conventional, toxic chemical solvents.
- **Extraction:** Used for extracting natural products, flavors, and fragrances (e.g., extracting essential oils).

Option B: Biodiesel (Green Fuel)

Biodiesel is a green, renewable liquid fuel derived from natural fats and oils. It is used as a complete replacement for, or additive to, petroleum-based diesel fuel.

Definition and Synthesis

- **Chemical Nature:** Biodiesel consists of a mixture of **fatty acid methyl esters (FAME)**.
- **Raw Materials:** Vegetable oils (e.g., soybean, palm, rapeseed), animal fats, or waste cooking oil.
- **Synthesis (Transesterification):** The process involves reacting the triglyceride (oil/fat) with a short-chain alcohol (usually methanol) in the presence of a catalyst (like NaOH or KOH).

$$\text{Triglyceride} + 3 \times \text{Methanol} \xrightarrow{\text{Catalyst}} 3 \times \text{Fatty Acid Methyl Ester (Biodiesel)} + \text{Gl}$$

Advantages (Green Attributes)

1. **Renewable Feedstock:** It is made from biological sources that can be continuously grown, making it a sustainable alternative to non-renewable petroleum diesel.
2. **Lower Emissions:** Biodiesel combustion produces significantly lower levels of unburnt hydrocarbons, carbon monoxide (CO), and particulate matter compared to petroleum diesel.
3. **Zero Net $\mathrm{CO_2}$:** While it produces $\mathrm{CO_2}$ upon burning, the plants used to make the oil (raw material) absorb an equivalent amount of $\mathrm{CO_2}$ during their growth, making the cycle **carbon neutral**.
4. **Biodegradable:** Biodiesel is readily biodegradable, reducing the environmental impact of spills.
5. **High Cetane Number:** It has a higher cetane number than petroleum diesel, leading to better ignition quality and engine performance.

Applications

- Transportation (blended with petroleum diesel or used purely in standard diesel engines).
- Heating oil for homes and commercial boilers.

Trans-esterification of BIODIESEL