

# SCO INTERNATIONAL CHEMISTRY OLYMPIAD

## CLASS 8 OFFICIAL QUESTION PAPER

Official question paper with answer key and explanations

Designed for schools, teachers, parents, and students; aligned with globally used middle-school science learning expectations, chemistry safety awareness, sustainability, and evidence-based scientific reasoning.

Synthetic Fibres	Metals & Non-metals	Fossil Fuels	Combustion	Sustainability
Objective Paper	Answer Key	Explanations	PDF-ready	Global Standard

## SCO International Chemistry Olympiad - Class 8 Official Question Paper

### Official Exam Snapshot

<b>Exam Name</b>	SCO International Chemistry Olympiad	<b>Class</b>	8
<b>Question Paper</b>	Set H	<b>Academic Year</b>	
<b>Duration</b>	60 minutes	<b>Type</b>	Objective / MCQ
<b>Total Questions</b>	50	<b>Negative Marking</b>	No
<b>Core Chapters</b>	Synthetic fibres, materials, fossil fuels, combustion	<b>Format</b>	One correct option

*Instructions: Read each question carefully. Choose one correct option only. All question passages, data, and reasoning details are placed inside the main question block for clean PDF readability.*

### Guidelines for Candidates

- Total Questions: 50 | Time: 60 minutes.
- Before the exam begins, candidates may receive additional time to complete required personal details on the OMR sheet or online exam profile.
- The question paper includes General Chemistry, Applied/Case Study, Reason-Assertion, and Achievers-level reasoning questions.
- Every question has exactly one correct answer. Select one response only.
- There is no negative marking unless a school-specific circular states otherwise.
- Calculators are not allowed unless explicitly approved by the exam authority.
- Use careful reading, scientific reasoning, and evidence from the question before choosing the answer.

## Question Paper

### Section 1: General Chemistry and Core Concepts

**Q1. Which type of polymerization is primarily used in the industrial production of polyethylene, a widely used plastic?**

- A) Condensation polymerization
- B) Addition polymerization
- C) Ring-opening polymerization
- D) Ionic polymerization

**Answer: B. Addition polymerization**

**Explanation:** Polyethylene is produced by addition polymerization, where monomers (ethylene) add to each other without the loss of small molecules. This process typically involves a free radical mechanism under high pressure or with catalysts. Condensation polymerization, by contrast, involves the elimination of a small molecule (like water) and is not used for making polyethylene.

**Q2. Synthetic fibers such as nylon are known for their high strength and durability. Which characteristic of condensation polymerization contributes to these properties in synthetic fibers?**

- A) The formation of long chains with strong covalent bonds and minimal side groups
- B) The production of cross-linked networks that limit flexibility
- C) The incorporation of small molecules during polymer growth that act as plasticizers
- D) The reversible nature of the polymerization reaction

**Answer: A. The formation of long chains with strong covalent bonds and minimal side groups**

**Explanation:** Nylon is produced by condensation polymerization, which forms long, linear polymer chains with strong covalent bonds. The absence of bulky side groups allows for close packing and strong intermolecular forces (like hydrogen bonding), contributing to high strength and durability. Cross-linking (option B) is more common in thermosetting plastics, not in flexible fibers like nylon.

**Q3. Metals are generally malleable, ductile, and conduct electricity, while non-metals tend to be brittle and poor conductors. Which of the following best explains these contrasting physical properties?**

- A) The presence of free electrons in metals that allow for delocalized bonding
- B) The covalent bonding in metals and ionic bonding in non-metals
- C) The crystalline structure of metals versus the amorphous structure of non-metals
- D) The higher atomic weight of metals compared to non-metals

**Answer: A. The presence of free electrons in metals that allow for delocalized bonding**

**Explanation:** Metals have a structure where valence electrons are not attached to any specific atom (delocalized), which allows them to move freely. This "sea of electrons" gives metals their malleability, ductility, and excellent electrical conductivity. Non-metals typically form covalent bonds that do not support such electron mobility.

**Q4. Alloys are mixtures of two or more metals (or a metal and a non-metal) that are designed to improve material properties. Which of the following statements best describes why alloys often exhibit enhanced strength compared to their constituent metals?**

- A) Alloys contain impurities that weaken the metal structure.
- B) The intermingling of different atoms disrupts the regular lattice, hindering dislocation movement.

- C) Alloys have larger atomic radii, which increases bond length and flexibility.  
D) The presence of multiple phases in alloys reduces their melting point.

**Answer: B. The intermingling of different atoms disrupts the regular lattice, hindering dislocation movement.**

**Explanation:** Alloys are stronger because the different sizes and types of atoms disrupt the uniform lattice structure of pure metals. This disruption hinders the movement of dislocations (defects), which in turn increases the material's strength and hardness

**Q5. Coal and petroleum are fossil fuels formed from ancient organic matter. Which formation factor strongly influences the differences in their chemical composition and maturity?**

- A) The type of organisms that contributed to the original organic material  
B) The temperature and pressure conditions during their formation  
C) The amount of water present during fossilization  
D) The presence of radioactive elements in the formation environment

**Answer: B. The temperature and pressure conditions during their formation**

**Explanation:** The differences in chemical composition between coal (a carbon-rich solid) and petroleum (a liquid mixture of hydrocarbons) are mainly due to the varying temperature and pressure conditions during their formation. Different heat and pressure histories during burial and maturation strongly affect how ancient organic matter becomes solid carbon-rich coal or liquid hydrocarbon-rich petroleum.

**Q6. Petroleum consists of various hydrocarbon fractions, each with different boiling points. Which physical property is used to separate these fractions in a process known as fractional distillation?**

- A) Density differences  
B) Boiling point differences  
C) Solubility in water  
D) Viscosity differences

**Answer: B. Boiling point differences**

**Explanation:** Fractional distillation separates petroleum into different fractions based on their boiling points. Components with lower boiling points vaporize at lower temperatures and are separated from those with higher boiling points, enabling the production of gasoline, diesel, kerosene, etc.

**Q7. During the combustion of hydrocarbons, the color of the flame can indicate the efficiency of the combustion process. Which of the following flame colors typically indicates a complete combustion of hydrocarbons?**

- A) Blue flame  
B) Yellow flame  
C) Orange flame  
D) Red flame

**Answer: A. Blue flame**

**Explanation:** A blue flame typically indicates complete combustion, where hydrocarbons are efficiently oxidized to produce carbon dioxide and water with minimal soot. Incomplete combustion usually results in yellow or orange flames due to the presence of unburnt carbon particles.

**Q8. The presence of certain chemical elements in a flame can be detected by their characteristic emission spectra. Which of the following elements produces a bright yellow emission when introduced into a flame test?**

- A) Sodium
- B) Potassium
- C) Calcium
- D) Copper

**Answer: A. Sodium**

**Explanation:** Sodium produces a bright yellow color in a flame test due to the specific wavelength of light emitted by excited sodium atoms. This characteristic emission is commonly used as a qualitative test for sodium ions.

**Q9. During the incineration of plastic waste, incomplete combustion may lead to the formation of toxic compounds. Which of the following toxic substances is most commonly associated with the incomplete combustion of chlorinated plastics?**

- A) Carbon monoxide
- B) Dioxins
- C) Nitrogen oxides
- D) Sulfur dioxide

**Answer: B. Dioxins**

**Explanation:** Incomplete combustion of chlorinated plastics (such as PVC) can lead to the formation of dioxins, which are highly toxic environmental pollutants. Dioxins are known for their persistence in the environment and potential to cause serious health issues.

**Q10. In a modern power plant, coal is used as a primary fuel source. Combustion efficiency and emissions are monitored using various analytical techniques. Which of the following instruments is most likely used to measure the concentration of gaseous emissions (such as CO<sub>2</sub> and NO<sub>x</sub>) from coal combustion?**

- A) Mass spectrometer
- B) Infrared gas analyzer
- C) Ultraviolet-visible spectrophotometer
- D) Chromatography

**Answer: B. Infrared gas analyzer**

**Explanation:** An infrared gas analyzer is commonly used to measure concentrations of gaseous emissions like CO<sub>2</sub> and NO<sub>x</sub> from combustion processes. It works by detecting the absorption of infrared radiation at specific wavelengths characteristic of these gases, allowing for real-time monitoring of combustion efficiency and environmental impact.

## Section 2: Advanced Application and Conceptual Chemistry

**Q11. Synthetic polymers can be classified based on their stereochemistry, which affects their physical properties. In the polymerization of propylene to form polypropylene, the tacticity (arrangement of the methyl groups) influences crystallinity and melting point.**

Which type of polypropylene typically exhibits the highest degree of crystallinity and, consequently, a higher melting point?

- A) Atactic polypropylene
- B) Syndiotactic polypropylene
- C) Isotactic polypropylene
- D) Heterotactic polypropylene

**Answer: C. Isotactic polypropylene**

**Explanation:** Isotactic polypropylene has all the methyl groups oriented on the same side of the polymer chain, allowing the chains to pack closely and form a highly crystalline structure, which results in a higher melting point and improved mechanical properties.

**Q12. Cross-linking in polymers significantly alters the physical properties of plastics by forming a three-dimensional network.**

How does cross-linking affect the mechanical and thermal properties of a plastic material?

- A) Increases flexibility and decreases thermal stability
- B) Enhances rigidity and increases thermal stability
- C) Decreases both rigidity and thermal stability
- D) Has no significant effect on mechanical or thermal properties

**Answer: B. Enhances rigidity and increases thermal stability**

**Explanation:** Cross-linking creates a network structure that restricts the movement of polymer chains, resulting in increased rigidity and improved resistance to heat. Cross-linked polymers often cannot be melted and reshaped, which is typical of thermosetting plastics.

**Q13. The physical properties of metals, such as electrical conductivity and malleability, are explained by the nature of metallic bonding.**

Which characteristic of metallic bonding is most responsible for the high electrical conductivity of metals?

- A) The strong covalent bonds between metal atoms
- B) The presence of a delocalized "sea" of electrons
- C) The ionic interactions between metal cations and anions
- D) The directional bonds that hold metal atoms in fixed positions

**Answer: B. The presence of a delocalized "sea" of electrons**

**Explanation:** In metallic bonding, electrons are not bound to any specific atom; instead, they move freely throughout the lattice. This electron mobility enables metals to conduct electricity efficiently and also contributes to their malleability and ductility.

**Q14. Non-metals can exist in different allotropic forms that exhibit unique physical and chemical properties. For example, carbon exists as diamond and graphite.**

Why is diamond an excellent electrical insulator while graphite is a good conductor of electricity?

- A) Diamond has a layered structure while graphite has a three-dimensional network.

- B) Graphite's delocalized electrons in its planar layers allow for electron mobility, unlike the strong covalent network in diamond.
- C) Diamond has more free electrons compared to graphite.
- D) Graphite is denser than diamond, enhancing its conductivity.

**Answer: B. Graphite's delocalized electrons in its planar layers allow for electron mobility, unlike the strong covalent network in diamond.**

**Explanation:** Graphite consists of layers of carbon atoms arranged in a hexagonal lattice, where one electron per atom is free to move within the layers, allowing electrical conduction. In contrast, diamond has a three-dimensional network of strong covalent bonds with no free electrons, making it an insulator.

**Q15. Coal is classified into different types based on the degree of carbonization and the environmental conditions during its formation.**

Which type of coal, characterized by the highest carbon content and energy density, is typically formed under the greatest pressure and temperature conditions?

- A) Lignite
- B) Sub-bituminous coal
- C) Bituminous coal
- D) Anthracite

**Answer: D. Anthracite**

**Explanation:** Anthracite coal has the highest carbon content and energy density among the coal types. It forms under the highest pressure and temperature conditions over long geological periods, resulting in a more mature, less volatile fuel.

**Q16. Petroleum is a complex mixture of hydrocarbons, and fractional distillation separates it into useful fractions based on boiling point differences.**

Which of the following statements best explains how fractional distillation separates the components of crude oil?

- A) Components are separated based solely on differences in their molecular weight.
- B) Components with lower boiling points vaporize first, while those with higher boiling points vaporize later, allowing sequential condensation.
- C) All components vaporize simultaneously, and condensation is controlled by pressure changes only.
- D) The process relies on differences in solubility in water.

**Answer: B. Components with lower boiling points vaporize first, while those with higher boiling points vaporize later, allowing sequential condensation.**

**Explanation:** Fractional distillation utilizes differences in boiling points: lighter fractions (with lower boiling points) vaporize at lower temperatures and are condensed separately, while heavier fractions vaporize at higher temperatures. This allows for efficient separation of the complex mixture.

**Q17. The color and temperature of a flame in the combustion of hydrocarbons provide insights into the efficiency of the reaction.**

Which combination of flame color and associated combustion characteristics indicates complete combustion of a hydrocarbon fuel?

- A) Yellow flame with low temperature, indicating incomplete combustion
- B) Blue flame with high temperature, indicating complete combustion
- C) Red flame with moderate temperature, indicating partial combustion

D) White flame with variable temperature, indicating turbulent combustion

**Answer: B. Blue flame with high temperature, indicating complete combustion**

**Explanation:** A blue flame is typically indicative of complete combustion, where the fuel is efficiently oxidized, producing carbon dioxide and water. This process releases maximum energy, resulting in a high flame temperature and minimal soot production.

**Q18. During qualitative analysis, flame tests are used to identify metal ions based on their characteristic emission spectra.**

Which metal ion is identified by a bright crimson (red) flame in a flame test?

- A) Sodium
- B) Calcium
- C) Strontium
- D) Copper

**Answer: C. Strontium**

**Explanation:** Strontium ions typically produce a bright crimson or red flame. Sodium ions yield a bright yellow flame, calcium gives an orange-red flame, and copper usually produces a green or blue-green flame.

**Q19. Incomplete combustion of plastics can lead to the formation of harmful compounds that pose environmental and health risks.**

Which of the following toxic compounds is most likely to be produced during the incomplete combustion of plastics containing chlorine (e.g., PVC)?

- A) Carbon dioxide
- B) Dioxins
- C) Methane
- D) Ammonia

**Answer: B. Dioxins**

**Explanation:** When chlorinated plastics like PVC are incompletely combusted, they can form dioxins-highly toxic compounds known for their persistence in the environment and serious health hazards, including carcinogenicity.

**Q20. The efficiency of combustion reactions in power plants is influenced by thermodynamic principles that determine energy release and conversion.**

Which thermodynamic parameter is most directly associated with the efficiency of a combustion reaction in converting chemical energy into useful work?

- A) Enthalpy change ( $\Delta H$ )
- B) Entropy change ( $\Delta S$ )
- C) Gibbs free energy change ( $\Delta G$ )
- D) Specific heat capacity

**Answer: C. Gibbs free energy change ( $\Delta G$ )**

**Explanation:** The Gibbs free energy change ( $\Delta G$ ) determines whether a reaction is spontaneous and how much useful work can be extracted from it. In combustion, a highly negative  $\Delta G$  indicates that the reaction can release substantial energy, contributing to higher efficiency in converting chemical energy into work, as seen in power plant applications.

### Section 3: Case Study

**Q21. A municipal recycling plant is evaluating new methods to recycle polyethylene terephthalate (PET) plastic bottles. Recent research indicates that advanced catalytic depolymerization can break PET into its monomers at lower temperatures, reducing energy consumption and harmful emissions. However, the process efficiency depends on the purity of the waste stream and the type of catalyst used. Engineers are comparing two catalysts: Catalyst X, which works well at 150°C but requires high purity PET, and Catalyst Y, which operates at 200°C but tolerates impurities better.**

Which factor should be prioritized to achieve an eco-friendly recycling process that balances energy efficiency and waste tolerance?

- A) Use Catalyst X exclusively, as lower temperatures always guarantee lower emissions.
- B) Use Catalyst Y exclusively, since high impurity tolerance is more critical than energy consumption.
- C) Implement a pre-sorting stage to achieve high-purity PET and then use Catalyst X for its lower operating temperature.
- D) Blend both catalysts to operate at an intermediate temperature without any additional processing.

**Answer: C. Implement a pre-sorting stage to achieve high-purity PET and then use Catalyst X for its lower operating temperature.**

**Explanation:** Lower operating temperatures reduce energy consumption and emissions. By introducing a pre-sorting stage to ensure high-purity PET, the process can then utilize Catalyst X effectively. This integrated approach balances environmental sustainability with process efficiency.

**Q22. An aerospace manufacturer is developing a new composite material for aircraft exteriors. The material combines a non-metal polymer matrix with metallic fibers to enhance strength and conductivity. However, the metallic fibers are prone to corrosion when exposed to atmospheric moisture. Researchers are testing various surface treatments to protect the fibers, including anodization and polymer coating. They find that a specific polymer coating significantly reduces corrosion rates while maintaining the composite's electrical conductivity.**

What is the primary reason the polymer-coated metallic fibers exhibit improved corrosion resistance?

- A) The coating acts as a physical barrier, preventing exposure to moisture and oxygen.
- B) The coating chemically reacts with the metal to form a more stable alloy.
- C) The coating increases the metal's intrinsic conductivity, reducing corrosion.
- D) The coating removes impurities from the metal surface, eliminating corrosion initiators.

**Answer: A. The coating acts as a physical barrier, preventing exposure to moisture and oxygen.**

**Explanation:** A polymer coating provides a protective barrier that prevents environmental agents (moisture and oxygen) from reaching the metal surface, thereby reducing corrosion. The coating does not chemically alter the metal, but its barrier properties are key to enhancing durability.

**Q23. An oil refinery is optimizing its fractional distillation process to improve yield and quality of various petroleum fractions. Engineers note that adjusting the temperature gradient in the distillation column can enhance separation efficiency. Recent trials indicate that even a slight modification in operating pressure significantly affects the boiling point of lighter fractions, such as gasoline and naphtha, as well as heavier fractions like diesel.**

Which principle explains the effect of pressure on the boiling points of petroleum components during fractional distillation?

- A) Le Chatelier's principle

- B) Raoult's law
- C) Dalton's law of partial pressures
- D) The Clausius-Clapeyron equation

**Answer: D. The Clausius-Clapeyron equation**

**Explanation:** The Clausius-Clapeyron equation relates the change in vapor pressure to the temperature change, thereby explaining how altering the pressure in a distillation column affects boiling points. This principle is critical in refining processes to optimize the separation of different petroleum fractions.

**Q24. A power plant burning coal is being upgraded to reduce its environmental impact. Engineers are evaluating methods to increase combustion efficiency and reduce emissions. One approach involves optimizing the fuel-to-air ratio, while another employs catalytic converters to reduce pollutants like nitrogen oxides ( $\text{NO}_x$ ) and sulfur dioxide ( $\text{SO}_2$ ). Recent data indicate that even small improvements in the fuel-to-air ratio can significantly lower incomplete combustion by-products, while catalytic converters further mitigate toxic emissions.**

Which combination of strategies most effectively improves the overall environmental performance of the power plant?

- A) Solely optimizing the fuel-to-air ratio
- B) Solely installing catalytic converters
- C) Combining optimized fuel-to-air ratios with catalytic converter technology
- D) Increasing coal feed to boost combustion temperature

**Answer: C. Combining optimized fuel-to-air ratios with catalytic converter technology**

**Explanation:** Optimizing the fuel-to-air ratio improves combustion efficiency and minimizes the production of unburned hydrocarbons and soot, while catalytic converters chemically convert harmful emissions into less toxic substances. Together, these strategies provide a comprehensive approach to reducing the plant's environmental impact.

**Q25. A research team is developing a new synthetic fibre for use in high-performance sportswear. The fibre is produced via addition polymerization, and its properties are influenced by the polymer's tacticity and molecular weight. Advanced characterization techniques reveal that increased molecular weight enhances tensile strength, while the arrangement of side groups (tacticity) significantly affects elasticity and water absorption.**

Which combination of polymer properties would be most desirable for sportswear that requires both high strength and low water absorption?

- A) Low molecular weight and atactic arrangement
- B) High molecular weight and isotactic arrangement
- C) High molecular weight and atactic arrangement
- D) Low molecular weight and syndiotactic arrangement

**Answer: B. High molecular weight and isotactic arrangement**

**Explanation:** A high molecular weight provides enhanced tensile strength, while an isotactic arrangement (where all side groups are aligned on one side) allows for tight packing and lower water absorption, making it ideal for high-performance sportswear.

**Q26. A city faces an environmental challenge due to the incineration of plastic waste. Incomplete combustion of plastics leads to the formation of toxic compounds, including dioxins and furans. Researchers are investigating how variations in combustion temperature and oxygen supply affect**

**the formation of these pollutants. They observe that maintaining a controlled high-temperature environment with excess oxygen minimizes the formation of toxic by-products.**

Which combustion condition is most effective in minimizing the formation of dioxins during plastic incineration?

- A) Low temperature with limited oxygen supply
- B) High temperature with a rich fuel mixture
- C) High temperature with excess oxygen
- D) Low temperature with excess oxygen

**Answer: C. High temperature with excess oxygen**

**Explanation:** Complete combustion, achieved at high temperatures with excess oxygen, minimizes the formation of dioxins by ensuring that chlorinated compounds are fully oxidized to  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and  $\text{HCl}$  rather than forming complex toxic by-products. Insufficient oxygen or lower temperatures favor incomplete combustion, leading to dioxin formation.

**Q27. A new research project is investigating the conversion of coal into synthetic liquid fuels using catalytic liquefaction. The process involves breaking down complex organic molecules in coal under high pressure and temperature in the presence of catalysts. The research team focuses on optimizing catalyst composition to improve yield and reduce energy consumption. They are also studying the thermodynamic efficiency of the process, aiming to lower the Gibbs free energy required for the reaction.**

Which thermodynamic concept is most directly relevant to optimizing the coal liquefaction process?

- A) Boyle's law
- B) Gibbs free energy ( $\Delta G$ )
- C) Newton's law of cooling
- D) Faraday's laws of electrolysis

**Answer: B. Gibbs free energy ( $\Delta G$ )**

**Explanation:** Gibbs free energy ( $\Delta G$ ) determines the spontaneity of a chemical reaction. Optimizing the liquefaction process involves lowering the  $\Delta G$  of the reaction, thereby making the process more energetically favorable and efficient. This concept is central to evaluating and improving chemical processes.

**Q28. An industrial research group is developing a biodiesel production process that utilizes waste cooking oil. The process involves transesterification of triglycerides using a base catalyst to produce fatty acid methyl esters (FAME) and glycerol. Simultaneously, the researchers monitor the reaction using spectroscopy to ensure complete conversion and to minimize side reactions. The process parameters, including temperature, catalyst concentration, and reaction time, are optimized for maximum yield.**

Which physical-chemical principle is crucial in ensuring complete conversion during the transesterification process for biodiesel production?

- A) Le Chatelier's principle, by shifting the equilibrium toward product formation
- B) Dalton's law of partial pressures
- C) Snell's law of refraction
- D) The principle of conservation of energy

**Answer: A. Le Chatelier's principle, by shifting the equilibrium toward product formation**

**Explanation:** Le Chatelier's principle states that a system at equilibrium will adjust to counteract changes. In transesterification, using an excess of methanol can shift the equilibrium toward the formation of FAME (biodiesel) and glycerol, ensuring a higher conversion rate of triglycerides and better process efficiency.

**Q29. A manufacturer is developing a new fire-resistant plastic material for use in construction and transportation. The research focuses on incorporating flame retardant additives and modifying the polymer backbone through copolymerization. Advanced thermal analysis shows that the modified plastic decomposes at higher temperatures and produces fewer flammable gases during combustion.**

Which mechanism is primarily responsible for the improved fire resistance of the modified plastic?

- A) Enhanced cross-linking that increases the melting point
- B) The presence of halogenated flame retardants that release free radicals
- C) Copolymerization that introduces bulky side groups, hindering polymer chain mobility
- D) The catalytic formation of a char layer that acts as a thermal barrier during combustion

**Answer: D. The catalytic formation of a char layer that acts as a thermal barrier during combustion**

**Explanation:** Many flame retardants work by promoting the formation of a char layer on the surface of the burning material. This char layer insulates the underlying material, slows down heat transfer, and reduces the release of flammable gases, thereby enhancing fire resistance. Options A, B, and C do not adequately explain the observed improvement in thermal stability.

**Q30. A city is implementing an advanced waste-to-energy plant to reduce landfill use and generate electricity. The process involves the combustion of municipal waste in a controlled environment. Engineers utilize sophisticated sensors and infrared spectroscopy to monitor the combustion process in real time, ensuring that the reaction operates at optimal temperatures and that pollutants such as  $\text{NO}_x$  and  $\text{SO}_2$  are minimized. Additionally, the plant employs catalytic converters to further reduce emissions.**

Which integrated approach best explains the plant's strategy for maximizing energy output while minimizing environmental impact?

- A) Operating at lower temperatures to reduce energy consumption
- B) Utilizing real-time monitoring with infrared spectroscopy and catalytic converters to ensure complete combustion and minimize pollutant formation
- C) Increasing the feed rate of waste to boost production regardless of combustion efficiency
- D) Relying solely on mechanical filtration to remove pollutants after combustion

**Answer: B. Utilizing real-time monitoring with infrared spectroscopy and catalytic converters to ensure complete combustion and minimize pollutant formation**

**Explanation:** By employing real-time monitoring techniques (such as infrared spectroscopy), the plant can precisely control combustion conditions to ensure complete oxidation of waste. Catalytic converters then further reduce harmful emissions. This integrated strategy maximizes energy output while mitigating the environmental impact, making it a sustainable waste-to-energy solution.

## Section 4: Reason and Assertion

**Q31. Assertion: Polyethylene, one of the most common plastics, is synthesized via addition polymerization.**

Reason: Addition polymerization involves the successive addition of monomer units without the elimination of any small molecules.

**Answer: A**

**Explanation:** Both the assertion and the reason are true, and the fact that addition polymerization does not produce by-products (such as water) explains why polyethylene is synthesized through this method.

**Q32. Assertion: Nylon, a widely used synthetic fibre, exhibits high tensile strength and durability.**

Reason: Nylon is produced by condensation polymerization, where the elimination of small molecules (like water) allows the formation of long, linear polymer chains with extensive hydrogen bonding.

**Answer: A**

**Explanation:** Both statements are true, and the production process (condensation polymerization) creates strong intermolecular forces that enhance nylon's strength and durability.

**Q33. Assertion: Metals are excellent electrical conductors.**

Reason: The presence of a delocalized "sea of electrons" in metals allows for free electron movement, which facilitates electrical conduction.

**Answer: A**

**Explanation:** Both the assertion and the reason are true, and the free electron model directly explains the high electrical conductivity observed in metals.

**Q34. Assertion: Alloying improves the mechanical strength of metals compared to their pure forms.**

Reason: The intermingling of different atoms in an alloy disrupts the regular crystal lattice, thereby hindering the movement of dislocations and increasing strength.

**Answer: A**

**Explanation:** Both statements are true, and the disruption of the crystal lattice by alloying elements is the primary mechanism that increases a metal's strength.

**Q35. Assertion: Anthracite coal has a higher carbon content and energy density than bituminous coal.**

Reason: Anthracite is formed under higher pressure and temperature conditions, resulting in more complete carbonization of the original organic material.

**Answer: A**

**Explanation:** Both the assertion and the reason are true, and the formation conditions of anthracite explain its higher carbon content and superior energy density compared to less mature coals.

**Q36. Assertion: A blue flame during hydrocarbon combustion indicates complete combustion.**

Reason: A blue flame signifies that the fuel is being efficiently oxidized to carbon dioxide and water, with minimal production of unburnt carbon (soot).

**Answer: A**

**Explanation:** Both statements are true; the blue flame is a hallmark of complete combustion where there is optimal oxygen supply and minimal soot production, confirming the efficient oxidation of the fuel.

**Q37. Assertion: Incomplete combustion of hydrocarbons often leads to the production of carbon monoxide (CO).**

Reason: Insufficient oxygen supply during combustion results in the partial oxidation of carbon, forming CO instead of carbon dioxide.

**Answer: A**

**Explanation:** Both statements are true. When oxygen is limited, carbon does not fully oxidize, and carbon monoxide is produced. This explains the occurrence of CO during incomplete combustion.

**Q38. Assertion: Graphite is an effective electrical conductor, whereas diamond is an electrical insulator.**

Reason: Graphite's layered structure contains delocalized electrons that can move freely, while diamond's tetrahedral network has electrons tightly bound in strong covalent bonds.

**Answer: A**

**Explanation:** Both the assertion and the reason are true, and the contrasting structures of graphite and diamond explain their different electrical properties.

**Q39. Assertion: Cross-linked polymers generally exhibit enhanced thermal stability compared to non-cross-linked polymers.**

Reason : Cross-linking restricts the mobility of polymer chains, reducing their ability to flow or deform at elevated temperatures.

**Answer: A**

**Explanation:** Both statements are true. The formation of a cross-linked network increases resistance to heat-induced softening, thereby improving thermal stability.

**Q40. Assertion : Fractional distillation is an essential process in petroleum refining.**

Reason: The process separates petroleum components based on their different boiling points, which arise from variations in molecular weight and structure.

**Answer: A**

**Explanation:** Both the assertion and the reason are true, and the differences in boiling points of petroleum fractions directly explain how fractional distillation is used to separate them.

## Section 5: Achievers Section

**Q41. A recent study has focused on enhancing the sustainability of bio-based plastics by modifying polylactic acid (PLA). Researchers found that incorporating controlled amounts of cross-linking agents improved mechanical strength without severely compromising biodegradability. They determined that the degree of cross-linking was critical in balancing the material's durability and its ability to decompose in the environment.**

Which factor is most crucial for optimizing the performance of bio-based PLA plastics?

- A) Maximizing the cross-linking density for ultimate strength
- B) Minimizing cross-linking to maintain rapid biodegradation
- C) Controlling the degree of cross-linking to achieve a balance between mechanical strength and biodegradability
- D) Eliminating cross-linking entirely to enhance processability

**Answer: C. Controlling the degree of cross-linking to achieve a balance between mechanical strength and biodegradability**

**Explanation:** An optimal, controlled level of cross-linking enhances tensile strength and durability while still permitting biodegradation. Excessive cross-linking would hinder decomposition, whereas too little might not provide sufficient strength.

**Q42. A team of researchers developed a composite material by dispersing silver nanoparticles in a polymer matrix. Their goal was to achieve both enhanced electrical conductivity and antimicrobial properties. The study revealed that the uniform dispersion and the size distribution of the silver nanoparticles were crucial for achieving the desired properties.**

Which factor is most critical for the effectiveness of these nanocomposite materials?

- A) The overall volume fraction of nanoparticles regardless of their dispersion
- B) Uniform dispersion and controlled nanoparticle size to maximize conductivity and antimicrobial action
- C) The use of the largest possible nanoparticles to increase conductivity
- D) Agglomeration of nanoparticles to form conductive clusters

**Answer: B. Uniform dispersion and controlled nanoparticle size to maximize conductivity and antimicrobial action**

**Explanation:** Uniform dispersion ensures that the silver nanoparticles are evenly distributed throughout the polymer, enhancing electrical pathways and antimicrobial surface area. Controlled particle size optimizes these effects; agglomeration or size extremes reduce overall performance.

**Q43. Researchers using gas chromatography-mass spectrometry (GC-MS) analyzed different fractions of petroleum. They observed that the ratio of branched-chain to straight-chain alkanes significantly affects fuel quality, with branched-chain alkanes typically having lower boiling points and more efficient combustion properties.**

Which statement best explains the impact of branched-chain alkanes on fuel quality?

- A) They decrease the volatility of the fuel, making it less efficient for combustion
- B) They have higher boiling points, leading to incomplete combustion
- C) Their lower boiling points enhance fuel vaporization and efficient combustion
- D) They increase the density of the fuel, improving energy content per liter

**Answer: C. Their lower boiling points enhance fuel vaporization and efficient combustion**

**Explanation:** Branched-chain alkanes tend to have lower boiling points compared to straight-chain alkanes, leading to better vaporization and more complete combustion, which improves the overall efficiency and quality of the fuel.

**Q44. A power plant using biodiesel has been retrofitted with a system to optimize the fuel-to-air ratio in its combustion chamber. Research shows that achieving a blue flame indicates complete combustion, which minimizes the formation of soot and harmful by-products. Engineers noted that operating under precise conditions yields a significantly cleaner and more energy-efficient process.**

Which outcome is most directly associated with observing a blue flame during biodiesel combustion?

- A) Incomplete combustion leading to increased soot
- B) Complete combustion with optimal oxidation of fuel
- C) Excess oxygen causing reduced fuel efficiency

D) Overheating of the combustion chamber

**Answer: B. Complete combustion with optimal oxidation of fuel**

**Explanation:** A blue flame is characteristic of complete combustion, where the fuel is entirely oxidized to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ , with minimal production of soot or other incomplete combustion by-products. This indicates efficient energy conversion and lower emissions.

**Q45. An environmental study on the incineration of plastic waste revealed that plastics with higher degrees of cross-linking produce less volatile organic compounds (VOCs) during combustion. Researchers observed that a well-cross-linked polymer network tends to form more char, which acts as a barrier to further combustion.**

What is the primary effect of a higher degree of cross-linking on the combustion behavior of plastics?

- A) It increases the release of VOCs and toxic emissions
- B) It promotes the formation of a protective char layer, reducing the release of volatile compounds
- C) It lowers the melting point, leading to incomplete combustion
- D) It accelerates the degradation process, resulting in higher soot production

**Answer: B. It promotes the formation of a protective char layer, reducing the release of volatile compounds**

**Explanation:** A highly cross-linked polymer network restricts chain mobility and promotes the formation of a stable char layer during combustion. This char acts as a physical barrier, reducing the emission of VOCs and other toxic substances.

**Q46. A research group used X-ray diffraction (XRD) to study phase transitions in an iron-carbon alloy. Their findings indicate that as carbon content increases, the formation of cementite ( $\text{Fe}_3\text{C}$ ) occurs, which significantly alters the alloy's mechanical properties. The study correlates the presence of cementite with an increase in hardness and brittleness.**

Which of the following best describes the impact of cementite formation in steel?

- A) It decreases the hardness while increasing ductility
- B) It increases hardness but reduces ductility, making the material more brittle
- C) It has no significant impact on the alloy's properties
- D) It enhances both hardness and ductility simultaneously

**Answer: B. It increases hardness but reduces ductility, making the material more brittle**

**Explanation:** The formation of cementite in steel increases the hardness of the material due to the rigid structure of  $\text{Fe}_3\text{C}$ . However, this also results in decreased ductility, making the steel more brittle—a common trade-off in alloy design.

**Q47. A novel pyrolysis process is being developed to convert coal into synthetic liquid fuels. Researchers found that increasing the pyrolysis temperature shifts the product distribution toward lighter hydrocarbons, thereby enhancing fuel quality. The process efficiency is analyzed using thermodynamic models that predict changes in Gibbs free energy ( $\Delta G$ ).**

Which thermodynamic concept best explains the shift in product distribution with increased temperature during pyrolysis?

- A) Le Chatelier's principle, shifting equilibrium in exothermic reactions
- B) The Clausius-Clapeyron equation describing phase transitions
- C) Gibbs free energy minimization driving the formation of more stable, lighter hydrocarbons
- D) The ideal gas law governing molecular diffusion

**Answer: C. Gibbs free energy minimization driving the formation of more stable, lighter hydrocarbons**

**Explanation:** Increasing the pyrolysis temperature affects the Gibbs free energy ( $\Delta G$ ) of the reactions, favoring the formation of lighter, more stable hydrocarbons. This thermodynamic drive helps explain why higher temperatures result in a shift toward lighter fractions.

**Q48. An urban environmental monitoring project employs portable infrared spectroscopy to analyze gaseous emissions from incomplete combustion processes. The spectrometer detects specific absorption peaks corresponding to  $\text{CO}_2$ ,  $\text{NO}_x$ , and volatile organic compounds (VOCs). Researchers use this data to assess air quality in real time.**

Which fundamental principle of infrared spectroscopy is primarily utilized to detect these gaseous pollutants?

- A) The inelastic scattering of photons by gas molecules
- B) The unique vibrational modes of molecular bonds absorbing specific wavelengths of infrared light
- C) The reflection of infrared light by gas molecules
- D) The ionization of gas molecules by infrared radiation

**Answer: B. The unique vibrational modes of molecular bonds absorbing specific wavelengths of infrared light**

**Explanation:** Infrared spectroscopy relies on the fact that different molecular bonds absorb infrared light at characteristic wavelengths due to their vibrational modes. This property allows the detection and quantification of specific gases based on their unique absorption spectra.

**Q49. A research team is investigating chemical recycling techniques to depolymerize synthetic fibres into their monomer components. In one study, they employ an acid-catalyzed depolymerization reaction to break down polyester-based fibres. Kinetic analysis indicates that the reaction rate is highly dependent on both acid concentration and temperature.**

Which reaction parameter is most critical in optimizing the depolymerization process for efficient monomer recovery?

- A) Maintaining low acid concentration to prevent side reactions
- B) Increasing temperature to accelerate the reaction without compromising monomer integrity
- C) Carefully controlling acid concentration and temperature to achieve a high reaction rate while minimizing degradation of the recovered monomers
- D) Using a neutral catalyst instead of an acid to avoid harsh reaction conditions

**Answer: C. Carefully controlling acid concentration and temperature to achieve a high reaction rate while minimizing degradation of the recovered monomers**

**Explanation:** Optimizing depolymerization requires balancing reaction conditions: sufficient acid concentration and temperature are necessary to drive the reaction, but overly harsh conditions can degrade the monomers. Thus, precise control is essential for efficient and clean recovery.

**Q50. An industrial research facility employs laser-based spectroscopy to monitor the combustion of petroleum products in real time. By analyzing the spectral emissions from the flame, scientists can detect variations in combustion efficiency and pollutant formation. The technique measures both the intensity and wavelength of emitted light, which vary with the chemical composition and temperature of the flame.**

Which interdisciplinary principle best explains how laser-based spectroscopy provides insights into combustion efficiency?

- A) The absorption of ultraviolet light by combustion by-products

- B) The inelastic scattering of laser light by high-energy electrons in the flame
- C) The emission spectra resulting from molecular transitions that are sensitive to temperature and chemical composition
- D) The reflection of laser light off particulate matter in the flame

**Answer: C. The emission spectra resulting from molecular transitions that are sensitive to temperature and chemical composition**

**Explanation:** Laser-based spectroscopy captures the emission spectra of molecules in the flame, which arise from electronic and vibrational transitions. These spectra are sensitive to the flame's temperature and chemical composition, allowing for real-time analysis of combustion efficiency and the detection of pollutants.

## Answer Key

Q.No.	Ans.	Q.No.	Ans.	Q.No.	Ans.	Q.No.	Ans.	Q.No.	Ans.
1	<b>B</b>	2	<b>A</b>	3	<b>A</b>	4	<b>B</b>	5	<b>B</b>
6	<b>B</b>	7	<b>A</b>	8	<b>A</b>	9	<b>B</b>	10	<b>B</b>
11	<b>C</b>	12	<b>B</b>	13	<b>B</b>	14	<b>B</b>	15	<b>D</b>
16	<b>B</b>	17	<b>B</b>	18	<b>C</b>	19	<b>B</b>	20	<b>C</b>
21	<b>C</b>	22	<b>A</b>	23	<b>D</b>	24	<b>C</b>	25	<b>B</b>
26	<b>C</b>	27	<b>B</b>	28	<b>A</b>	29	<b>D</b>	30	<b>B</b>
31	<b>A</b>	32	<b>A</b>	33	<b>A</b>	34	<b>A</b>	35	<b>A</b>
36	<b>A</b>	37	<b>A</b>	38	<b>A</b>	39	<b>A</b>	40	<b>A</b>
41	<b>C</b>	42	<b>B</b>	43	<b>C</b>	44	<b>B</b>	45	<b>B</b>
46	<b>B</b>	47	<b>C</b>	48	<b>B</b>	49	<b>C</b>	50	<b>C</b>

Note: Each question block in this Word file also includes the answer and explanation for teacher/student review.

**End of Paper**