

Chemical Engineering

1. Which of the following is an intensive property of a thermodynamic system?

- A) Volume
- B) Mass
- C) Energy
- D) Temperature

Answer: D) Temperature

Explanation: An intensive property (e.g., temperature, pressure, density) is a property of matter that does not depend on the amount of the substance, whereas an extensive property (e.g., mass, volume) does.

2. For a Newtonian fluid, the shear stress is directly proportional to the:

- A) Velocity of the fluid.
- B) Shear rate or velocity gradient.
- C) Viscosity of the fluid.
- D) Density of the fluid.

Answer: B) Shear rate or velocity gradient.

Explanation: This is the definition of a Newtonian fluid, expressed by the equation $\tau = \mu(du/dy)$, where τ is shear stress, μ is viscosity, and du/dy is the shear rate.

3. The mode of heat transfer that does not require a medium for propagation is:

- A) Conduction.
- B) Convection.
- C) Radiation.
- D) Advection.

Answer: C) Radiation.

Explanation: Heat transfer by radiation occurs via electromagnetic waves and can travel through a vacuum, as exemplified by the heat we receive from the sun.

4. Which equipment is used for the fine grinding of soft to medium-hard materials, operating on the principle of impact and attrition?

- A) Jaw crusher.
- B) Gyratory crusher.
- C) Ball mill.
- D) Hammer mill.

Answer: D) Hammer mill.

Explanation: Hammer mills use high-speed rotating hammers to shatter and pulverize material, making them suitable for applications requiring fine particle sizes.

5. Fick's first law of diffusion relates the molar flux of a component to its:

- A) Temperature gradient.
- B) Pressure gradient.
- C) Concentration gradient.
- D) Velocity gradient.

Answer: C) Concentration gradient.

Explanation: Fick's first law states that the molar flux is directly proportional to the concentration gradient, describing the movement of a substance from a region of higher concentration to one of lower concentration.

6. The primary purpose of 'catalytic cracking' in a petroleum refinery is to:

- A) Remove sulfur from crude oil.
- B) Increase the octane number of gasoline.
- C) Convert heavy, high-boiling point hydrocarbons into lighter, more valuable products like gasoline.
- D) Separate crude oil into its various fractions.

Answer: C) Convert heavy, high-boiling point hydrocarbons into lighter, more valuable products like gasoline.

Explanation: Cracking breaks down large hydrocarbon molecules into smaller, more useful ones using a catalyst, heat, and pressure.

7. The Haber-Bosch process is the most common industrial method for producing:

- A) Sulfuric acid.
- B) Ammonia.
- C) Urea.

D) Nitric acid.

Answer: B) Ammonia.

Explanation: This process synthesizes ammonia (NH_3) by reacting nitrogen from the air with hydrogen, typically derived from natural gas, under high pressure and temperature in the presence of an iron catalyst. Ammonia is a key component of most nitrogen-based fertilizers.

8. The 'Solvay process' is an industrial method for the production of:

A) Sodium hydroxide (Caustic soda).

B) Sodium carbonate (Soda ash).

C) Chlorine.

D) Hydrochloric acid.

Answer: B) Sodium carbonate (Soda ash).

Explanation: The Solvay process uses brine (sodium chloride) and limestone (calcium carbonate) as raw materials to produce sodium carbonate, a vital chemical for the glass, detergent, and chemical industries.

9. In a chemical process, the 'limiting reactant' is the reactant that:

A) Is present in the largest stoichiometric amount.

B) Is the most expensive.

C) Is completely consumed first and determines the maximum amount of product that can be formed.

D) Has the lowest molar mass.

Answer: C) Is completely consumed first and determines the maximum amount of product that can be formed.

Explanation: The limiting reactant dictates the theoretical yield of the reaction. Once it is used up, the reaction stops.

10. A Proportional-Integral-Derivative (PID) controller is widely used in process control to:

A) Only measure the process variable.

B) Manipulate a final control element to maintain a process variable at a desired setpoint.

C) Act as a safety interlock.

D) Only display the process variable.

Answer: B) Manipulate a final control element to maintain a process variable at a desired setpoint.

Explanation: A PID controller calculates an output based on the present error (Proportional), past accumulated error (Integral), and future predicted error (Derivative) to provide precise and stable control.

11. The First Law of Thermodynamics is a statement of the principle of:

- A) Conservation of energy.
- B) Conservation of mass.
- C) The direction of spontaneous processes.
- D) The absolute zero of temperature.

Answer: A) Conservation of energy.

Explanation: The First Law states that energy cannot be created or destroyed, only converted from one form to another. In a thermodynamic cycle, the net heat supplied equals the net work done.

12. The Arrhenius equation in chemical reaction engineering describes the effect of which variable on the reaction rate constant?

- A) Pressure.
- B) Concentration.
- C) Temperature.
- D) Catalyst loading.

Answer: C) Temperature.

Explanation: The Arrhenius equation, $k = Ae^{(-E_a/RT)}$, shows that the rate constant (k) increases exponentially with temperature (T).

13. The 'calorific value' of a fuel is the amount of:

- A) Heat released during its complete combustion.
- B) Energy required to ignite it.
- C) Carbon present in the fuel.
- D) Light produced during combustion.

Answer: A) Heat released during its complete combustion.

Explanation: It is a measure of the energy content of a fuel, typically expressed in units like kJ/kg or kJ/m³. The higher calorific value (HCV) includes the latent heat of vaporization of water, while the lower calorific value (LCV) does not.

14. The most common material of construction for pipes and vessels in the chemical industry, known for its good strength and corrosion resistance at a reasonable cost, is:

- A) Glass.
- B) Copper.
- C) Carbon steel.
- D) Titanium.

Answer: C) Carbon steel.

Explanation: Carbon steel is a versatile and economical material used for a wide range of applications where severe corrosion is not an issue.

15. A 'distillation column' is a process equipment unit used to:

- A) Separate components of a liquid mixture based on differences in their boiling points.
- B) Mix two or more liquids.
- C) Increase the pressure of a fluid.
- D) Grind solid materials.

Answer: A) Separate components of a liquid mixture based on differences in their boiling points.

Explanation: Distillation is a fundamental separation process where more volatile components vaporize, rise up the column, and are then condensed and collected, while less volatile components remain as liquids.

16. In chemical engineering plant economics, 'working capital' refers to the:

- A) Total cost of the plant and equipment.
- B) Money required to operate the plant, covering raw materials, inventory, and accounts receivable.
- C) Annual profit of the plant.
- D) Cost of land and buildings.

Answer: B) Money required to operate the plant, covering raw materials, inventory, and accounts receivable.

Explanation: Working capital is the fund needed for the day-to-day operations of a business, representing the difference between current assets and current liabilities.

17. The primary function of a 'moderator' in a nuclear reactor is to:

- A) Absorb neutrons to control the chain reaction.

- B) Slow down fast neutrons to thermal energies to increase the probability of fission.
- C) Remove heat from the reactor core.
- D) Provide structural support for the fuel rods.

Answer: B) Slow down fast neutrons to thermal energies to increase the probability of fission.

Explanation: Materials like heavy water or graphite are used as moderators because they can reduce the kinetic energy of neutrons without absorbing them.

18. A 'muffle furnace' is a type of furnace where the:

- A) Material is in direct contact with the flames and combustion gases.
- B) Heat source is separated from the material being heated by a muffle (retort).
- C) Heat is generated by an electric arc.
- D) Material is heated in a vacuum.

Answer: B) The heat source is separated from the material being heated by a muffle (retort).

Explanation: This indirect heating prevents contamination of the workpiece by the products of combustion, making it suitable for applications like ashing, heat treating, and materials testing.

19. 'Refractoriness' is the ability of a material to:

- A) Conduct electricity at high temperatures.
- B) Withstand high temperatures without deforming or melting.
- C) Resist chemical attack.
- D) Absorb heat quickly.

Answer: B) Withstand high temperatures without deforming or melting.

Explanation: Refractory materials, like alumina and silica bricks, are essential for lining furnaces, kilns, and reactors, providing thermal insulation and containing high-temperature processes.

20. The 'Biochemical Oxygen Demand' (BOD) in environmental engineering is a measure of the:

- A) Amount of oxygen required by microorganisms to decompose organic matter in water.
- B) Total amount of dissolved oxygen in water.
- C) Amount of toxic chemicals in water.
- D) Acidity of the water.

Answer: A) The amount of oxygen required by microorganisms to decompose organic matter in water.

Explanation: BOD is a key indicator of water pollution. A high BOD value indicates a large amount of biodegradable organic material, which can deplete the dissolved oxygen in the water, harming aquatic life.

21. 'Polymerization' is a process in which:

- A) Large polymer molecules are broken down into smaller ones.
- B) Small monomer molecules link together to form large polymer chains or networks.
- C) A polymer is melted and molded into a shape.
- D) A polymer is dissolved in a solvent.

Answer: B) Small monomer molecules link together to form large polymer chains or networks.

Explanation: This is the fundamental process for creating all synthetic plastics, rubbers, and fibers.

22. The Reynolds number (Re) is a dimensionless group that represents the ratio of:

- A) Inertial forces to viscous forces.
- B) Gravitational forces to viscous forces.
- C) Pressure forces to inertial forces.
- D) Buoyant forces to viscous forces.

Answer: A) Inertial forces to viscous forces.

Explanation: The Reynolds number is crucial for determining the flow regime of a fluid, with low values (typically < 2100 in a pipe) indicating laminar flow and high values (> 4000) indicating turbulent flow.

23. A 'shell and tube heat exchanger' is designed so that:

- A) Two fluids mix directly to exchange heat.
- B) One fluid flows through a bundle of tubes while the other flows over the tubes within a sealed shell.
- C) Heat is transferred through a solid wall.
- D) Heat is transferred by radiation only.

Answer: B) One fluid flows through a bundle of tubes while the other flows over the tubes within a sealed shell.

Explanation: This is one of the most common types of heat exchangers in the industry due to its versatility and robust design.

24. 'Screening' in mechanical operations is a method for:

- A) Separating particles based on their size.
- B) Separating particles based on their density.
- C) Grinding particles to a smaller size.
- D) Mixing solid particles.

Answer: A) Separating particles based on their size.

Explanation: Screening involves passing a mixture of particles over a screen with specific aperture sizes. Particles smaller than the apertures pass through (undersize), while larger particles are retained (oversize).

25. The 'Lewis number' (Le) is a dimensionless number defined as the ratio of:

- A) Thermal diffusivity to mass diffusivity.
- B) Momentum diffusivity (kinematic viscosity) to thermal diffusivity.
- C) Mass diffusivity to momentum diffusivity.
- D) Thermal diffusivity to momentum diffusivity.

Answer: A) Thermal diffusivity to mass diffusivity.

Explanation: The Lewis number is used to characterize fluid flows where there is simultaneous heat and mass transfer, relating the thickness of the thermal boundary layer to the concentration boundary layer.

26. 'Reforming' in a petroleum refinery is a process used to:

- A) Break large hydrocarbon molecules into smaller ones.
- B) Convert low-octane linear hydrocarbons (paraffins) into high-octane branched-chain (isoparaffins) and aromatic hydrocarbons.
- C) Remove sulfur compounds from petroleum fractions.
- D) Combine small hydrocarbon molecules into larger ones.

Answer: B) Convert low-octane linear hydrocarbons (paraffins) into high-octane branched-chain (isoparaffins) and aromatic hydrocarbons.

Explanation: Catalytic reforming is a key process for producing high-octane gasoline blending components.

27. 'Urea' is a widely used nitrogen fertilizer that is produced commercially by reacting:

- A) Ammonia and nitric acid.

B) Ammonia and carbon dioxide.

C) Methane and nitrogen.

D) Calcium cyanamide and water.

Answer: B) Ammonia and carbon dioxide.

Explanation: The process involves reacting ammonia and CO₂ at high pressure and temperature to form ammonium carbamate, which is then dehydrated to produce urea.

28. The 'contact process' is the current industrial method for producing:

A) Nitric acid.

B) Ammonia.

C) Sulfuric acid.

D) Hydrochloric acid.

Answer: C) Sulfuric acid.

Explanation: The key step in this process is the catalytic oxidation of sulfur dioxide (SO₂) to sulfur trioxide (SO₃) using a vanadium pentoxide catalyst. The SO₃ is then absorbed in concentrated sulfuric acid.

29. The 'percent excess' of a reactant is defined as the amount of reactant supplied:

A) Above the amount required for complete reaction with the limiting reactant.

B) That remains unreacted at the end of the process.

C) That is lost due to leaks.

D) In the product stream.

Answer: A) Above the amount required for complete reaction with the limiting reactant.

Explanation: Supplying a reactant in excess is often done to ensure the complete conversion of the more valuable or limiting reactant.

30. A 'thermocouple' is a sensor used to measure temperature based on the:

A) Seebeck effect.

B) Peltier effect.

C) Thomson effect.

D) Joule effect.

Answer: A) Seebeck effect.

Explanation: The Seebeck effect is the phenomenon where a voltage is produced at the junction of two dissimilar metals, and this voltage is proportional to the temperature of the junction.

31. The 'Carnot cycle' is a theoretical thermodynamic cycle that:

- A) Represents the most efficient cycle possible for converting heat into work between two temperatures.
- B) Describes the operation of a typical internal combustion engine.
- C) Is used in refrigeration cycles.
- D) Involves four irreversible processes.

Answer: A) Represents the most efficient cycle possible for converting heat into work between two temperatures.

Explanation: The Carnot cycle consists of two isothermal and two adiabatic processes, all of which are reversible. It sets the theoretical upper limit on the efficiency of any heat engine.

32. A 'CSTR' (Continuous Stirred-Tank Reactor) is a type of chemical reactor characterized by:

- A) The uniform composition and temperature of the contents throughout the reactor.
- B) A concentration gradient along the length of the reactor.
- C) Batch operation.
- D) Very high pressure operation.

Answer: A) The uniform composition and temperature of the contents throughout the reactor.

Explanation: Due to vigorous mixing, the properties of the exit stream from a CSTR are the same as the properties of the material inside the reactor.

33. 'Incomplete combustion' of a hydrocarbon fuel occurs when there is insufficient oxygen, leading to the formation of:

- A) Only carbon dioxide and water.
- B) Carbon monoxide and soot (elemental carbon).
- C) Nitrogen oxides.
- D) Sulfur dioxide.

Answer: B) Carbon monoxide and soot (elemental carbon).

Explanation: Incomplete combustion is inefficient as it does not release all the available energy from the fuel, and it produces harmful pollutants like CO.

34. 'Stainless steel' is an alloy of iron that is resistant to corrosion primarily due to the presence of a significant amount of:

- A) Carbon.
- B) Manganese.
- C) Chromium.
- D) Nickel.

Answer: C) Chromium.

Explanation: Chromium forms a thin, passive, and self-healing layer of chromium oxide on the surface of the steel, which protects the underlying iron from rusting and corrosion.

35. A 'centrifugal pump' moves a fluid by:

- A) Trapping a fixed volume of fluid and forcing it out (positive displacement).
- B) Using a reciprocating piston.
- C) Transferring rotational kinetic energy from an impeller to the fluid.
- D) Using a jet of high-pressure steam.

Answer: C) Transferring rotational kinetic energy from an impeller to the fluid.

Explanation: The rapidly rotating impeller accelerates the fluid radially outward, increasing its velocity and pressure.

36. The 'payback period' in plant economics is the time required for:

- A) The plant to reach its design capacity.
- B) The total profit to equal the total operating cost.
- C) The cumulative net cash flow to equal the initial investment.
- D) The project to be completed.

Answer: C) The cumulative net cash flow to equal the initial investment.

Explanation: It is a simple measure of how quickly an investment will generate enough cash to recover its initial cost.

37. The 'control rods' in a nuclear reactor are made of a material that is a strong neutron absorber, such as:

- A) Uranium.
- B) Graphite.
- C) Heavy water.

D) Boron or cadmium.

Answer: D) Boron or cadmium.

Explanation: By inserting or withdrawing the control rods from the reactor core, the rate of the fission chain reaction can be controlled, and the reactor can be shut down.

38. 'Annealing' is a heat treatment process used in furnace technology to:

A) Harden a metal.

B) Increase the toughness of a metal.

C) Soften a metal, relieve internal stresses, and improve its ductility and machinability.

D) Create a corrosion-resistant surface.

Answer: C) Soften a metal, relieve internal stresses, and improve its ductility and machinability.

Explanation: Annealing involves heating the material to a specific temperature, holding it there, and then cooling it slowly.

39. 'Acidic refractories' are materials that are stable in the presence of acidic slags and atmospheres. A common example is:

A) Magnesite (MgO).

B) Dolomite.

C) Silica (SiO₂).

D) Chromite.

Answer: C) Silica (SiO₂).

Explanation: Basic refractories like magnesite would react with an acidic environment, while acidic refractories like silica are resistant to it.

40. An 'electrostatic precipitator' is an air pollution control device used to remove:

A) Gaseous pollutants like SO₂.

B) Particulate matter (dust, smoke, and ash) from a gas stream.

C) Volatile organic compounds (VOCs).

D) Odors.

Answer: B) Particulate matter (dust, smoke, and ash) from a gas stream.

Explanation: It works by charging the particles using a high-voltage corona and then collecting them on oppositely charged plates.

41. 'Vulcanization' is a chemical process for converting natural rubber into a more durable material by heating it with:

- A) Sulfur.
- B) Oxygen.
- C) Chlorine.
- D) Carbon black.

Answer: A) Sulfur.

Explanation: The sulfur forms cross-links between the individual polymer chains, which makes the rubber harder, more durable, and more resistant to chemical attack.

42. Bernoulli's principle for fluid flow is a statement derived from the:

- A) Conservation of mass.
- B) Conservation of momentum.
- C) Conservation of energy.
- D) First law of thermodynamics.

Answer: C) Conservation of energy.

Explanation: Bernoulli's equation relates the pressure, velocity, and elevation of a moving fluid, stating that an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy.

43. The 'effectiveness' of a heat exchanger is defined as the ratio of the:

- A) Actual heat transfer rate to the maximum possible heat transfer rate.
- B) Heat transfer coefficient on the tube side to that on the shell side.
- C) Log mean temperature difference to the arithmetic mean temperature difference.
- D) Inlet temperature of the hot fluid to the outlet temperature of the cold fluid.

Answer: A) Actual heat transfer rate to the maximum possible heat transfer rate.

Explanation: The effectiveness-NTU method is a way to analyze the performance of a heat exchanger when the outlet temperatures are unknown.

44. 'Elutriation' is a mechanical operation that separates particles based on their:

- A) Size and density by using a vertically upward-flowing fluid.
- B) Magnetic properties.
- C) Electrical conductivity.

D) Solubility.

Answer: A) Size and density by using a vertically upward-flowing fluid.

Explanation: In an elutriator, smaller and lighter particles are carried upward by the fluid stream, while larger and denser particles settle downward against the flow.

45. The 'penetration theory' of mass transfer assumes that the:

A) Mass transfer occurs by steady-state diffusion through a stagnant film.

B) Mass transfer occurs in a series of eddies and swirls.

C) Mass transfer into a fluid element occurs during its brief exposure to another phase.

D) Concentration is uniform throughout the fluid.

Answer: C) Mass transfer into a fluid element occurs during its brief exposure to another phase.

Explanation: This theory models the mass transfer at a gas-liquid interface by considering unsteady-state diffusion into packets of liquid that are brought to the surface for a short contact time.

46. The purpose of 'hydrotreating' in a refinery is to:

A) Increase the octane number of gasoline.

B) Remove impurities like sulfur, nitrogen, and metals from petroleum fractions by reacting them with hydrogen.

C) Break down heavy hydrocarbons.

D) Blend different gasoline components.

Answer: B) Remove impurities like sulfur, nitrogen, and metals from petroleum fractions by reacting them with hydrogen.

Explanation: Hydrotreating is crucial for meeting environmental regulations on fuel quality and for protecting downstream catalysts from being poisoned.

47. 'Triple superphosphate' (TSP) is a high-analysis phosphorus fertilizer made by reacting:

A) Phosphate rock with sulfuric acid.

B) Phosphate rock with phosphoric acid.

C) Ammonia with phosphoric acid.

D) Phosphate rock with nitric acid.

Answer: B) Phosphate rock with phosphoric acid.

Explanation: This process produces a fertilizer with a much higher phosphorus content (P_2O_5) compared to ordinary superphosphate, which is made using sulfuric acid.

48. A 'by-product' in a chemical process is a:

- A) Material that is recycled back to the reactor.
- B) The main desired product.
- C) A secondary product that is formed along with the main product.
- D) An impurity in the raw material.

Answer: C) A secondary product that is formed along with the main product.

Explanation: A by-product can have commercial value (a co-product) or it can be a waste stream that requires disposal.

49. A 'tie substance' or 'inert' in a stoichiometric calculation is a component that:

- A) Is the limiting reactant.
- B) Is produced in the reaction.
- C) Passes through the process unchanged.
- D) Is a catalyst for the reaction.

Answer: C) Passes through the process unchanged.

Explanation: Tie substances, like nitrogen from the air in a combustion process, are useful for material balances because their quantity remains constant, allowing for the calculation of other unknown stream flows.

50. An 'orifice meter' is an instrument used to measure:

- A) Temperature.
- B) Pressure.
- C) Liquid level.
- D) Fluid flow rate.

Answer: D) Fluid flow rate.

Explanation: It works by creating a pressure drop as the fluid passes through a restriction (the orifice plate). The flow rate is proportional to the square root of this pressure differential.

51. The 'Joule-Thomson effect' describes the change in:

- A) Temperature of a real gas when it is allowed to expand freely through a valve or porous plug.

- B) Volume of a gas with pressure at constant temperature.
- C) Enthalpy of a system during a phase change.
- D) Entropy of the universe during a spontaneous process.

Answer: A) Temperature of a real gas when it is allowed to expand freely through a valve or porous plug.

Explanation: This isenthalpic expansion can cause either cooling (as in liquefaction processes) or heating, depending on the gas and its initial temperature and pressure.

52. The 'space time' in a flow reactor is the:

- A) Time a fluid element spends inside the reactor.
- B) Time required to process one reactor volume of feed at specified conditions.
- C) Time required to start up the reactor.
- D) Time between catalyst regenerations.

Answer: B) The time required to process one reactor volume of feed at specified conditions.

Explanation: Space time (τ) is a key design parameter for continuous reactors, defined as the reactor volume divided by the volumetric flow rate of the feed ($\tau = V/v_0$).

53. A 'stoichiometric mixture' of a fuel and an oxidizer is one in which:

- A) There is an excess of fuel.
- B) There is an excess of oxidizer.
- C) There is exactly the right amount of oxidizer to completely burn the fuel.
- D) The fuel and oxidizer are in equal molar amounts.

Answer: C) There is exactly the right amount of oxidizer to completely burn the fuel.

Explanation: A stoichiometric combustion results in products containing only CO₂, H₂O, and N₂ (if the oxidizer is air), with no leftover fuel or oxygen.

54. 'Creep' is a mode of material failure characterized by the:

- A) Sudden fracture of a material under a cyclic load.
- B) Slow and continuous deformation of a material under a constant stress at high temperatures.
- C) Electrochemical degradation of a material.
- D) Brittle fracture of a material at low temperatures.

Answer: B) Slow and continuous deformation of a material under a constant stress at high temperatures.

Explanation: Creep is a major design consideration for equipment that operates at elevated temperatures, such as furnace tubes, turbine blades, and reactor vessels.

55. 'NPSH' (Net Positive Suction Head) is a critical parameter for a pump that relates to:

- A) The pressure required at the discharge of the pump.
- B) The efficiency of the pump.
- C) The pressure required at the suction of the pump to prevent cavitation.
- D) The power consumed by the pump.

Answer: C) The pressure required at the suction of the pump to prevent cavitation.

Explanation: Cavitation is the formation and collapse of vapor bubbles inside a pump, which can cause severe damage. The NPSH available from the system must be greater than the NPSH required by the pump to avoid this.

56. 'Depreciation' in plant economics is the:

- A) Decrease in the market value of a plant's products.
- B) Gradual loss in the value of an asset over time due to wear and tear, age, and obsolescence.
- C) Cost of raw materials.
- D) Daily operating cost of the plant.

Answer: B) The gradual loss in the value of an asset over time due to wear and tear, age, and obsolescence.

Explanation: Depreciation is an accounting concept that allows a company to allocate the cost of a tangible asset over its useful life for tax and accounting purposes.

57. The 'enrichment' of uranium for nuclear fuel involves increasing the concentration of which isotope?

- A) Uranium-238.
- B) Uranium-235.
- C) Uranium-234.
- D) Uranium-239.

Answer: B) Uranium-235.

Explanation: Natural uranium consists of over 99% U-238, which is not fissile. The concentration of the fissile isotope, U-235, must be increased from its natural abundance of about 0.7% to typically 3-5% for use in commercial light-water reactors.

58. The primary mechanism of heat transfer from the flames to the tubes in a furnace is:

- A) Conduction.
- B) Convection.
- C) Radiation.
- D) Conduction and convection equally.

Answer: C) Radiation.

Explanation: At the high temperatures found in industrial furnaces, radiation from the hot combustion gases and refractory walls is the dominant mode of heat transfer.

59. The 'pyrometric cone equivalent' (PCE) is used to determine the:

- A) Thermal conductivity of a refractory.
- B) Crushing strength of a refractory.
- C) Heat-softening point or refractoriness of a refractory material.
- D) Porosity of a refractory.

Answer: C) The heat-softening point or refractoriness of a refractory material.

Explanation: It is a method where a test cone made of the refractory material is heated alongside standard pyrometric cones. The PCE value corresponds to the standard cone that softens and bends at the same temperature as the test cone.

60. A 'scrubber' is an environmental engineering device used to:

- A) Remove particulate matter from a gas stream using a liquid.
- B) Remove gaseous pollutants from a gas stream by dissolving them in a liquid.
- C) Both A and B.
- D) Burn combustible waste gases.

Answer: C) Both A and B.

Explanation: Wet scrubbers are versatile pollution control devices that can remove both solid particles and gases (like SO_2 or HCl) from an exhaust stream by bringing it into contact with a scrubbing liquid.