GATE Chemical Engineering

Sample Paper – 9

Duration: 128 Minutes **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Chemical Engineering** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Take $R = 8.314$ J/mol·K and $g = 9.81$ m/s^2 unless stated otherwise.

Process Calculations & Thermodynamics

Q1. A gas mixture contains 80 mol% nitrogen (molar mass 28) and 20 mol% oxygen (molar mass 32). The average (mean) molar mass of the mixture is: **[1 mark]**

(A) 30.0

(B) 28.0

(C) 28.8

(D) 32.0

Q2. Methane is burned with 25% excess air. For complete combustion the reaction is $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$. The number of moles of oxygen actually supplied per mole of methane is: **[1 mark]**

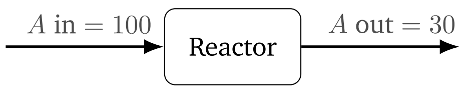
(A) 2.0

(B) 8.0

(C) 10.0

(D) 2.5

Q3. In the steady reactor shown, a fresh feed of species A enters at 100 mol/h and 30 mol/h of A leaves unconverted. The fractional conversion of A across the reactor is: **[1 mark]**



(A) 0.30

(B) 0.33

(C) 0.43

(D) 0.70

Q4. A closed system undergoes a process in which its internal energy decreases by 150 J while it performs 100 J of work on the surroundings. Using the first law $\Delta U = Q - W$, the heat transferred to the system is: **[1 mark]**

(A) -50 J

(B) $+50$ J

(C) -250 J

(D) $+250$ J

Q5. One mole of an ideal gas expands isothermally and reversibly from a volume V_1 to $2V_1$. Using $\Delta S = R\ln(V_2/V_1)$ with $R = 8.314$ J/mol·K, the entropy change of the gas is nearest to: **[1 mark]**

(A) 8.314 J/K

(B) 0.693 J/K

(C) 11.5 J/K

(D) 5.76 J/K

Q6. An ideal gas of molar mass 28 g/mol is held at 350 K and 1 bar (10^5 Pa). Taking $R = 8.314$ J/mol·K, the mass density of the gas, $\rho = PM/(RT)$, is nearest to: **[1 mark]**

(A) 1.20 kg/m^3

(B) 0.28 kg/m^3

(C) 0.962 kg/m^3

(D) 2.80 kg/m^3

Q7. For an exothermic reversible reaction at equilibrium, the temperature of the system is increased at constant pressure. According to Le Chatelier's principle and the van't Hoff relation, the thermodynamic equilibrium constant K will: **[1 mark]**

(A) decrease

(B) increase

(C) remain unchanged

(D) become zero

Q8. An ideal binary mixture of A and B obeys Raoult's law. At the system temperature $P_A^{sat} = 100$ kPa and $P_B^{sat} = 40$ kPa. If the total pressure over a boiling liquid is 60 kPa, the mole fraction x_A of A in the liquid, from $P = x_A P_A^{sat} + (1 - x_A) P_B^{sat}$, is: **[1 mark]**

(A) 0.50

(B) 0.60

(C) 0.33

(D) 0.20

Q9. A pure real gas at 10 bar has a fugacity coefficient of $\phi = 0.9$ at the system temperature. The fugacity of the gas, $f = \phi P$, is: **[1 mark]**

(A) 10 bar

(B) 9 bar

(C) 11.1 bar

(D) 0.9 bar

Q10. A reversible Carnot refrigerator operates between a cold space at 250 K and warm surroundings at 300 K. Its coefficient of performance, COP $= T_C/(T_H - T_C)$, is: **[1 mark]**

(A) 6.0

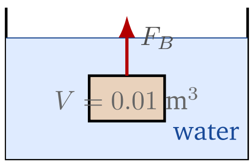
(B) 0.83

(C) 1.2

(D) 5.0

Fluid Mechanics & Mechanical Operations

Q11. A solid body of volume $0.01\ \text{m}^3$ is fully submerged in water, as shown. Taking $\rho_w = 1000\ \text{kg/m}^3$ and $g = 9.81\ \text{m/s}^2$, the buoyant force acting on the body, $F_B = \rho_w\, g\, V$, is: **[1 mark]**



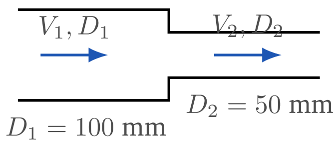
(A) 98.1 N

(B) 9.81 N

(C) 981 N

(D) 10.0 N

Q12. Water flows steadily through the pipe shown, which contracts from an inner diameter of 100 mm to 50 mm. If the mean velocity in the larger section is 1 m/s, then by continuity ($A_1V_1 = A_2V_2$) the mean velocity in the smaller section is: **[1 mark]**



(A) 0.25 m/s

(B) 2.0 m/s

(C) 4.0 m/s

(D) 1.0 m/s

Q13. Water of density 1000 kg/m^3 and dynamic viscosity 1×10^{-3} Pa·s flows through a pipe of internal diameter 20 mm at a mean velocity of 0.5 m/s. The Reynolds number of the flow, $Re = \rho V D/\mu$, is: **[1 mark]**

(A) $10\,000$

(B) 5000

(C) 1000

(D) $100\,000$

Q14. A centrifugal pump delivers a hydraulic (water) power of 1.5 kW to the fluid while operating at an overall efficiency of 75%. The shaft power that must be supplied to the pump, $P_{shaft} = P_{hyd}/\eta$, is: **[1 mark]**

(A) 1.125 kW

(B) 2.0 kW

(C) 1.5 kW

(D) 0.5 kW

Q15. A pressure of 196.2 kPa is to be expressed as an equivalent head of water. Taking $\rho_w = 1000$ kg/m^3 and $g = 9.81$ m/s^2, the head $h = p/(\rho_w g)$ is: **[1 mark]**

(A) 10 m

(B) 5 m

(C) 15 m

(D) 20 m

Q16. In the analysis of particulate solids, the sphericity of a particle is the ratio of the surface area of a sphere of the same volume to the actual surface area of the particle. For a cube, the sphericity is nearest to: **[1 mark]**

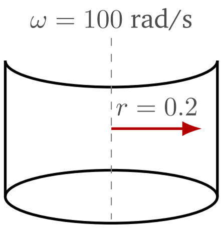
(A) 0.806

(B) 1.0

(C) 0.524

(D) 0.605

Q17. A tubular centrifuge bowl spins about its axis at an angular velocity of $\omega = 100$ rad/s, as shown. At a radius of $r = 0.2$ m the centrifugal acceleration is $a = \omega^2 r$. Expressed as a multiple of $g = 9.81$ m/s^2, this acceleration is nearest to: **[1 mark]**



(A) $100\,g$

(B) $204\,g$

(C) $2000\,g$

(D) $408\,g$

Q18. In size reduction, which law introduces a work index and states that the energy required per unit mass is proportional to $\left(1/\sqrt{L_2} - 1/\sqrt{L_1}\right)$, where L_1 and L_2 are the feed and product sizes? **[1 mark]**

(A) Bond's law

(B) Kick's law

(C) Rittinger's law

(D) Fick's law

Q19. A ball mill has a critical speed of 40 rpm. It is normally operated at 75% of its critical speed for effective grinding. The operating speed of the mill is: **[1 mark]**

(A) 40 rpm

(B) 30 rpm

(C) 53.3 rpm

(D) 20 rpm

Heat Transfer

Q20. Steady one-dimensional conduction occurs through a plane wall of thermal conductivity 2 W/m·K, face area 0.5 m^2 and thickness 0.2 m. The conduction thermal resistance of the wall, $R = L/(kA)$, is: **[1 mark]**

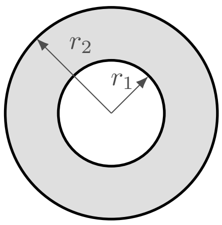
(A) 0.1 K/W

(B) 0.4 K/W

(C) 0.2 K/W

(D) 2.0 K/W

Q21. Heat conducts radially outward through the wall of a hollow pipe whose cross-section is shown, with inner radius $r_1 = 0.05$ m, outer radius $r_2 = 0.10$ m, length $L = 1$ m and thermal conductivity $k = 15$ W/m·K. The radial conduction resistance, $R = \dfrac{\ln(r_2/r_1)}{2\pi k L}$, is nearest to: **[2 marks]**



$k = 15$ W/m·K

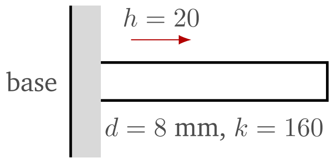
(A) 0.0147 K/W

(B) 0.00735 K/W

(C) 0.0736 K/W

(D) 0.00368 K/W

Q22. A circular pin fin of diameter 8 mm is made of a metal of thermal conductivity $k = 160$ W/m·K and is exposed to a convective coefficient $h = 20$ W/m^2·K. For a circular fin the fin parameter reduces to $m = \sqrt{4h/(kd)}$. Its value is nearest to: **[2 marks]**



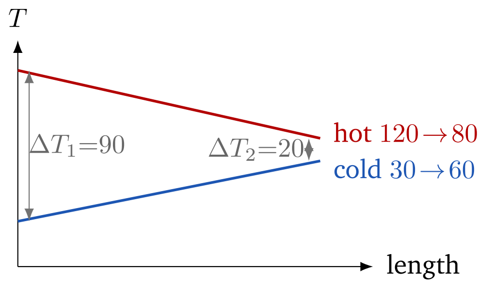
(A) 62.5 m^{-1}

(B) 15.8 m^{-1}

(C) 3.95 m^{-1}

(D) 7.91 m^{-1}

Q23. In the co-current double-pipe exchanger sketched, a hot fluid is cooled from 120 °C to 80 °C while a cold fluid is heated from 30 °C to 60 °C. The logarithmic mean temperature difference (LMTD) is nearest to: **[2 marks]**



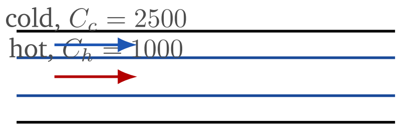
(A) 55.0 °C

(B) 90.0 °C

(C) 20.0 °C

(D) 46.5 °C

Q24. In the double-pipe exchanger shown, the two streams have heat-capacity rates $C_h = 1000$ W/K and $C_c = 2500$ W/K. In the effectiveness–NTU method the capacity ratio is $C_r = C_{\min}/C_{\max}$. Its value here is: **[2 marks]**



Double-pipe exchanger

(A) 2.5

(B) 0.4

(C) 1.0

(D) 0.25

Q25. A solid of thermal conductivity $k = 50$ W/m·K and characteristic length $L_c = 0.01$ m is cooled in a fluid with convective coefficient $h = 250$ W/m^2·K. The Biot number, $\text{Bi} = hL_c/k$, is: **[2 marks]**

(A) 0.5

(B) 0.005

(C) 0.05

(D) 5.0

Q26. A gray surface of emissivity $\varepsilon = 0.8$ and area 1 m^2 is at 400 K and radiates to large surroundings at 300 K. Taking $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, the net rate of radiant heat exchange, $q = \varepsilon\sigma A\,(T_1^4 - T_2^4)$, is nearest to: **[2 marks]**

(A) 1161 W

(B) 992 W

(C) 459 W

(D) 794 W

Q27. A single-effect evaporator concentrates a feed from 10% to 40% solids by mass. For a feed rate of 1000 kg/h, a solids balance ($0.10 \times 1000 = 0.40 \times P$) gives the thick-product rate P as: **[2 marks]**

(A) 400 kg/h

(B) 100 kg/h

(C) 250 kg/h

(D) 750 kg/h

Mass Transfer & Separation Processes

Q28. Steady equimolar counter-diffusion of A occurs across a stagnant gap of thickness 5 mm. The molecular diffusivity is $D = 2 \times 10^{-5}$ m^2/s and the concentration of A falls by $\Delta C = 4$ mol/m^3 across the gap. The molar flux, $N_A = D\,\Delta C/\delta$, is: **[2 marks]**

(A) 4×10^{-3} mol/m^2·s

(B) 8×10^{-3} mol/m^2·s

(C) 3.2×10^{-2} mol/m^2·s

(D) 1.6×10^{-2} mol/m^2·s

Q29. For convective mass transfer over a plate, the Sherwood number is Sh $= k_c L/D$. With $k_c = 0.01$ m/s, characteristic length $L = 0.1$ m and diffusivity $D = 2 \times 10^{-5}$ m^2/s, the Sherwood number is: **[2 marks]**

(A) 200

(B) 100

(C) 25

(D) 50

Q30. In two-film gas absorption the resistances (referred to the gas phase) are $1/k_g = 0.4$ and $m/k_l = 0.1$, in consistent units. The fraction of the total mass-transfer resistance that resides in the gas film, $(1/k_g)/(1/K_g)$, is: **[2 marks]**

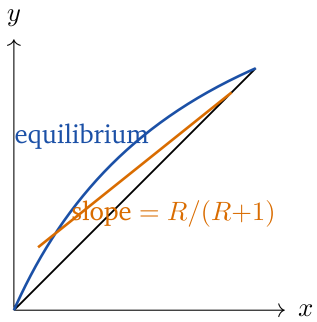
(A) 0.2

(B) 0.8

(C) 0.5

(D) 0.4

Q31. The McCabe–Thiele diagram for a distillation column is shown. The rectifying-section operating line has a slope of 0.8, and this slope equals $R/(R+1)$, where R is the reflux ratio. The value of R is: **[2 marks]**



(A) 4.0

(B) 0.8

(C) 1.25

(D) 5.0

Q32. A binary mixture with constant relative volatility $\alpha = 2.0$ is separated into a distillate $x_D = 0.98$ and a bottoms $x_W = 0.02$ (mole fractions of the light key). Fenske's equation gives $N_{\min} = \dfrac{\ln\left[(x_D/(1-x_D))((1-x_W)/x_W)\right]}{\ln \alpha}$. Its value is nearest to: **[2 marks]**

(A) 7.78

(B) 11.2

(C) 5.6

(D) 9.0

Q33. In a gas stripper the liquid flow rate is $L = 80$ mol/h, the gas flow rate is $G = 100$ mol/h and the equilibrium slope is $m = 1.6$. The stripping factor, defined as $S = mG/L$, is: **[2 marks]**

(A) 0.5

(B) 2.0

(C) 1.6

(D) 1.25

Q34. A packed absorption tower has a total packing height of $Z = 4$ m and a height of a transfer unit of HTU $= 0.5$ m. The number of transfer units it provides, NTU $= Z/\text{HTU}$, is: **[2 marks]**

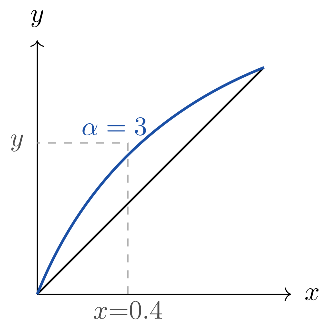
(A) 2

(B) 4

(C) 8

(D) 16

Q35. For an ideal binary system with constant relative volatility $\alpha = 3.0$, the equilibrium vapour mole fraction is $y = \dfrac{\alpha x}{1 + (\alpha - 1)x}$. For a liquid mole fraction $x = 0.4$, as read off the equilibrium curve shown, the vapour mole fraction y is nearest to: **[2 marks]**



(A) 0.667

(B) 0.400

(C) 0.545

(D) 0.750

Q36. A wet solid is dried in its constant-rate period at a constant drying flux of 1 kg/m^2·h over an exposed surface of 4 m^2. The time required to remove 8 kg of water, $t = \dfrac{\text{mass of water}}{\text{flux} \times \text{area}}$, is: **[2 marks]**

(A) 1 h

(B) 2 h

(C) 4 h

(D) 8 h

Reaction Engineering, Process Control & Plant Economics

Q37. A homogeneous liquid-phase reaction is first order with a rate constant $k = 0.05\ \text{min}^{-1}$. The time required to reach 90% conversion, $t = \dfrac{\ln[1/(1-X)]}{k}$, is nearest to: **[2 marks]**

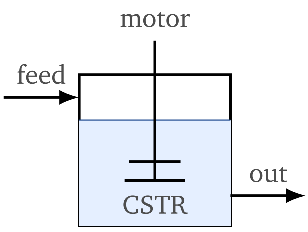
(A) 20.0 min

(B) 46.05 min

(C) 13.86 min

(D) 60.0 min

Q38. A first-order liquid-phase reaction ($k = 0.2\ \text{min}^{-1}$) is carried out in the ideal continuous stirred-tank reactor (CSTR) shown, operated at a space time of $\tau = 10$ min. Using $X = \dfrac{k\tau}{1+k\tau}$, the fractional conversion is nearest to: **[2 marks]**



(A) 0.500

(B) 0.800

(C) 0.667

(D) 0.333

Q39. A first-order liquid-phase reaction with rate constant $k = 0.4\ \text{min}^{-1}$ is carried out in an ideal plug-flow reactor (PFR). Using $k\tau = -\ln(1-X)$, the space time required for a conversion of $X = 0.8$ is nearest to: **[2 marks]**

(A) 2.0 min

(B) 5.0 min

(C) 1.61 min

(D) 4.02 min

Q40. The rate constant of a reaction is found to double when the temperature is raised from 300 K to 310 K. Taking $R = 8.314$ J/mol·K, the Arrhenius activation energy from $E_a = \dfrac{R\ln 2}{(1/300 - 1/310)}$ is nearest to: **[2 marks]**

(A) 25.0 kJ/mol

(B) 100 kJ/mol

(C) 53.6 kJ/mol

(D) 8.31 kJ/mol

Q41. An ideal reactor of working volume 50 L is fed by a liquid stream at a constant volumetric flow rate of 200 L/h. The space velocity of the reactor, defined as Q/V, is: **[2 marks]**

(A) 4.0 h^{-1}

(B) 0.25 h^{-1}

(C) 10 h^{-1}

(D) 250 h^{-1}

Q42. For a first-order reaction in a slab-shaped porous catalyst, the internal effectiveness factor is $\eta = \dfrac{\tanh\phi}{\phi}$, where ϕ is the Thiele modulus. For $\phi = 1.0$ (with $\tanh 1 = 0.7616$), the effectiveness factor is nearest to: **[2 marks]**

(A) 1.0

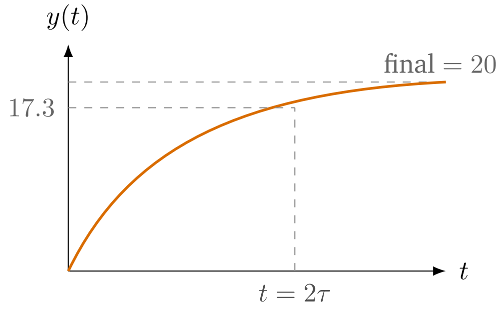
(B) 0.762

(C) 0.5

(D) 0.238

Q43. A first-order process with time constant $\tau = 4$ min and an ultimate output change of 20 units is subjected to a step input. Its response is $y(t) =$

$20\,(1-e^{-t/\tau})$, as sketched. The output change at $t = 2\tau$ (with $e^{-2} = 0.1353$) is nearest to: **[2 marks]**



(A) 17.29

(B) 12.64

(C) 20.0

(D) 8.65

Q44. A closed-loop control system behaves as an underdamped second-order system with a damping ratio $\zeta = 0.4$. For a step input the decay ratio is $\exp\left[-2\pi\zeta/\sqrt{1-\zeta^2}\right]$. Its value is nearest to: **[2 marks]**

(A) 0.254

(B) 0.163

(C) 0.0644

(D) 0.500

Q45. A purely proportional (P-only) controller is applied to a first-order process under a sustained load change. At the new steady state the controlled variable does not return exactly to its set point. This residual steady-state error is called the: **[2 marks]**

(A) offset

(B) overshoot

(C) decay ratio

(D) dead time

Q46. A process equipment is purchased for Rs. $5{,}00{,}000$ with an estimated salvage value of Rs. $50{,}000$ at the end of a service life of 9 years. Using straight-line depreciation, $D = (\text{cost} - \text{salvage})/\text{life}$, the book value of the equipment at the end of 3 years is: **[2 marks]**

(A) Rs. $3{,}50{,}000$

(B) Rs. $4{,}50{,}000$

(C) Rs. $2{,}00{,}000$

(D) Rs. $1{,}50{,}000$

Detailed Solutions

Q1.

Solution

Concept – the average molar mass of a mixture is the mole-fraction weighted sum of the component molar masses: $\bar{M} = \sum_i y_i M_i$.

Step 1 – list the mole fractions and molar masses: $y_{N_2} = 0.80$, $M_{N_2} = 28$; $y_{O_2} = 0.20$, $M_{O_2} = 32$.

Step 2 – weight the nitrogen term: $0.80 \times 28 = 22.4$

Step 3 – weight the oxygen term: $0.20 \times 32 = 6.4$

Step 4 – add the two contributions: $\bar{M} = 22.4 + 6.4$

$\bar{M} = 28.8$

Final Answer: $\bar{M} = 28.8 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept – excess air adds a fixed fraction of oxygen above the stoichiometric (theoretical) requirement: O_2 supplied $=$ (theoretical O_2) $\times(1 +$ fractional excess).

Step 1 – read the stoichiometric oxygen from the balanced reaction: $\mathrm{CH_4} + 2\,\mathrm{O_2} \rightarrow \mathrm{CO_2} + 2\,\mathrm{H_2O}$, so theoretical $O_2 = 2$ mol per mol CH_4.

Step 2 – write the excess fraction: 25% excess means a factor of $1 + 0.25 = 1.25$.

Step 3 – multiply the theoretical amount by this factor: O_2 supplied $= 2 \times 1.25$

Step 4 – evaluate: O_2 supplied $= 2.5$ mol per mol CH_4

Final Answer: 2.5 mol O_2 per mol $CH_4 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

Concept – fractional conversion is the amount reacted divided by the amount fed: $X = \dfrac{(A \text{ in}) - (A \text{ out})}{A \text{ in}}$.

Step 1 – read the two flows from the diagram: A in $= 100$ mol/h, A out $= 30$

mol/h.

Step 2 – find the amount of A reacted: $100 - 30 = 70$ mol/h

Step 3 – divide by the amount fed: $X = \frac{70}{100}$

Step 4 – evaluate: $X = 0.70$

Final Answer: $X = 0.70 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – first law for a closed system: $\Delta U = Q - W$, so the heat is $Q = \Delta U + W$.

Step 1 – assign signs to the data: Internal energy decreases, so $\Delta U = -150$ J; work done by the system on the surroundings is positive, $W = +100$ J.

Step 2 – rearrange the first law for Q: $Q = \Delta U + W$

Step 3 – substitute the values: $Q = (-150) + (100)$

Step 4 – evaluate: $Q = -50$ J

Interpretation of the sign: The negative sign shows that 50 J of heat is actually rejected by the system.

Final Answer: $Q = -50 \text{ J} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – entropy change of an ideal gas in isothermal reversible expansion: $\Delta S = R \ln \frac{V_2}{V_1}$.

Step 1 – list the data: $R = 8.314$ J/mol·K, $V_2/V_1 = 2$.

Step 2 – take the logarithm of the volume ratio: $\ln 2 = 0.6931$

Step 3 – multiply by the gas constant: $\Delta S = 8.314 \times 0.6931$

Step 4 – evaluate: $\Delta S = 5.763 \approx 5.76$ J/K

Final Answer: $\Delta S \approx 5.76 \text{ J/K} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – density of an ideal gas from the ideal-gas law: $\rho = \dfrac{PM}{RT}$.

Step 1 – list the data in SI units: $P = 10^5$ Pa, $M = 28$ g/mol $= 0.028$ kg/mol, $R = 8.314$ J/mol·K, $T = 350$ K.

Step 2 – form the numerator: $PM = 10^5 \times 0.028 = 2800$

Step 3 – form the denominator: $RT = 8.314 \times 350 = 2909.9$

Step 4 – divide: $\rho = \dfrac{2800}{2909.9}$

Step 5 – evaluate: $\rho = 0.962$ kg/m^3

Final Answer: $\rho \approx 0.962$ kg/m^3 $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – temperature dependence of the equilibrium constant (van't Hoff): $\dfrac{d\ln K}{dT} = \dfrac{\Delta H^\circ}{RT^2}$.

Step 1 – note the sign of the enthalpy for an exothermic reaction: For an exothermic reaction $\Delta H^\circ < 0$.

Step 2 – deduce the sign of the slope: With $\Delta H^\circ < 0$, the derivative $\dfrac{d\ln K}{dT}$ is negative.

Step 3 – interpret the negative slope: As temperature rises, $\ln K$ (and hence K) falls.

Step 4 – state the result: The equilibrium constant K decreases with increasing temperature (Le Chatelier: the equilibrium shifts to consume the added heat).

Final Answer: K decreases $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q7

Q8.

Solution

Concept – Raoult's law for an ideal binary liquid: $P = x_A P_A^{sat} + (1 - x_A) P_B^{sat}$.

Step 1 – list the data: $P = 60$ kPa, $P_A^{sat} = 100$ kPa, $P_B^{sat} = 40$ kPa.

Step 2 – substitute into Raoult's law: $60 = x_A(100) + (1 - x_A)(40)$

Step 3 – expand the right-hand side: $60 = 100x_A + 40 - 40x_A$

Step 4 – collect the x_A terms: $60 = 40 + 60x_A$

Step 5 – isolate x_A: $60 - 40 = 60x_A$

$20 = 60x_A$

Step 6 – solve: $x_A = \frac{20}{60} = 0.333$

Final Answer: $x_A = 0.33 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q8

Q9.

Solution

Concept – fugacity from the fugacity coefficient: $f = \phi P$, where ϕ is the fugacity coefficient.

Step 1 – list the data: $\phi = 0.9$, $P = 10$ bar.

Step 2 – substitute: $f = 0.9 \times 10$

Step 3 – evaluate: $f = 9$ bar

Why option A is wrong: $f = P = 10$ bar holds only for an ideal gas ($\phi = 1$); here $\phi = 0.9$, so the fugacity is below the pressure.

Final Answer: $f = 9 \text{ bar} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

Concept – coefficient of performance of a Carnot refrigerator: $\text{COP} = \frac{T_C}{T_H - T_C}$, with temperatures in kelvin.

Step 1 – list the temperatures: $T_C = 250$ K, $T_H = 300$ K.

Step 2 – find the temperature difference: $T_H - T_C = 300 - 250 = 50$ K

Step 3 – form the ratio: $\text{COP} = \frac{250}{50}$

Step 4 – evaluate: $\text{COP} = 5.0$

Final Answer: $\text{COP} = 5.0 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept – Archimedes' principle: The buoyant force equals the weight of the displaced fluid, $F_B = \rho_w \, g \, V$.

Step 1 – list the data: $\rho_w = 1000$ kg/m^3, $g = 9.81$ m/s^2, $V = 0.01$ m^3.

Step 2 – multiply the density and gravity: $\rho_w \, g = 1000 \times 9.81 = 9810$ N/m^3

Step 3 – multiply by the submerged volume: $F_B = 9810 \times 0.01$

Step 4 – evaluate: $F_B = 98.1$ N

Final Answer: $F_B = 98.1 \text{ N} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – conservation of mass (continuity) for an incompressible fluid: $A_1V_1 = A_2V_2$, and since $A \propto D^2$, $V_2 = V_1 \, (D_1/D_2)^2$.

Step 1 – list the data: $V_1 = 1$ m/s, $D_1 = 100$ mm, $D_2 = 50$ mm.

Step 2 – form the diameter ratio: $\dfrac{D_1}{D_2} = \dfrac{100}{50} = 2$

Step 3 – square the ratio (the area ratio): $\left(\dfrac{D_1}{D_2}\right)^2 = 2^2 = 4$

Step 4 – multiply by the upstream velocity: $V_2 = 1 \times 4$

Step 5 – evaluate: $V_2 = 4.0$ m/s

Final Answer: $V_2 = 4.0 \text{ m/s} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – the Reynolds number for pipe flow: $Re = \dfrac{\rho V D}{\mu}$.

Step 1 – list the data in SI units: $\rho = 1000$ kg/m^3, $V = 0.5$ m/s, $D = 20$ mm $= 0.02$ m, $\mu = 1 \times 10^{-3}$ Pa·s.

Step 2 – form the numerator: $\rho V D = 1000 \times 0.5 \times 0.02$

$= 10$

Step 3 – divide by the viscosity: $Re = \dfrac{10}{1 \times 10^{-3}}$

Step 4 – evaluate: $Re = 10\,000$

Final Answer: $Re = 10\,000 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – pump efficiency relates fluid power to shaft power: $\eta = \dfrac{P_{hyd}}{P_{shaft}}$, so $P_{shaft} = \dfrac{P_{hyd}}{\eta}$.

Step 1 – list the data: $P_{hyd} = 1.5$ kW, $\eta = 0.75$.

Step 2 – substitute into the formula: $P_{shaft} = \dfrac{1.5}{0.75}$

Step 3 – evaluate: $P_{shaft} = 2.0$ kW

Final Answer: $P_{shaft} = 2.0$ kW $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q14

Q15.

Solution

Concept – converting a pressure to an equivalent liquid head: $h = \dfrac{p}{\rho\, g}$.

Step 1 – list the data in SI units: $p = 196.2$ kPa $= 196{,}200$ Pa, $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2.

Step 2 – form the denominator: $\rho\, g = 1000 \times 9.81 = 9810$ N/m^3

Step 3 – divide the pressure by the specific weight: $h = \dfrac{196{,}200}{9810}$

Step 4 – evaluate: $h = 20$ m

Final Answer: $h = 20$ m $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q15

Q16.

Solution

Concept – sphericity is the surface area of the equal-volume sphere divided by the actual surface area of the particle: $\Psi = \dfrac{S_{\text{sphere of equal volume}}}{S_{\text{particle}}}$.

Step 1 – take a cube of side a: Volume $= a^3$, surface area of the cube $= 6a^2$.

Step 2 – find the radius of a sphere of the same volume: $\frac{4}{3}\pi r^3 = a^3 \Rightarrow r = a\left(\dfrac{3}{4\pi}\right)^{1/3} = 0.6204\,a$

Step 3 – find the surface area of that sphere: $S_{\text{sph}} = 4\pi r^2 = 4\pi(0.6204a)^2 = 4.836\,a^2$

Step 4 – form the sphericity: $\Psi = \dfrac{4.836\,a^2}{6\,a^2}$

Step 5 – evaluate: $\Psi = 0.806$

Final Answer: $\Psi \approx 0.806 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – centrifugal acceleration in a rotating bowl: $a = \omega^2 r$; its ratio to gravity is a/g.

Step 1 – list the data: $\omega = 100$ rad/s, $r = 0.2$ m, $g = 9.81$ m/s^2.

Step 2 – square the angular velocity: $\omega^2 = 100^2 = 10\,000$ s^{-2}

Step 3 – multiply by the radius: $a = 10\,000 \times 0.2 = 2000$ m/s^2

Step 4 – divide by g: $\dfrac{a}{g} = \dfrac{2000}{9.81}$

Step 5 – evaluate: $\dfrac{a}{g} = 203.9 \approx 204$

Final Answer: $a \approx 204\,g \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q17

Q18.

Solution

Concept – the three classical laws of comminution (size reduction): Rittinger (energy $\propto$ new surface), Kick (energy $\propto$ size-reduction ratio) and Bond (energy $\propto 1/\sqrt{L_2} - 1/\sqrt{L_1}$).

Step 1 – match the given expression to a law: The form $\left(1/\sqrt{L_2} - 1/\sqrt{L_1}\right)$ with a work index is the signature of Bond's law.

Step 2 – reject the other options: Kick's law uses $\ln(L_1/L_2)$; Rittinger's law uses $(1/L_2 - 1/L_1)$; Fick's law is a diffusion law and is unrelated.

Step 3 – state the answer: The described law is Bond's law.

Final Answer: Bond's law $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q18

Q19.

Solution

Concept – the operating speed is a fixed fraction of the critical speed: $n_{op} = (\text{fraction}) \times n_c$.

Step 1 – list the data: $n_c = 40$ rpm, fraction $= 0.75$.

Step 2 – multiply: $n_{op} = 0.75 \times 40$

Step 3 – evaluate: $n_{op} = 30$ rpm

Final Answer: $n_{op} = 30$ rpm $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q19

Q20.

Solution

Concept – conduction resistance of a plane wall: $R = \dfrac{L}{kA}$.

Step 1 – list the data: $L = 0.2$ m, $k = 2$ W/m·K, $A = 0.5$ m^2.

Step 2 – form the denominator: $kA = 2 \times 0.5 = 1.0$ W/K

Step 3 – divide the thickness by kA: $R = \dfrac{0.2}{1.0}$

Step 4 – evaluate: $R = 0.2$ K/W

Final Answer: $R = 0.2$ K/W $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q20

Q21.

Solution

Concept – radial conduction resistance of a hollow cylinder: $R = \dfrac{\ln(r_2/r_1)}{2\pi k L}$.

Step 1 – list the data: $r_1 = 0.05$ m, $r_2 = 0.10$ m, $k = 15$ W/m·K, $L = 1$ m.

Step 2 – form the radius ratio and its logarithm: $\dfrac{r_2}{r_1} = \dfrac{0.10}{0.05} = 2$

$\ln 2 = 0.6931$

Step 3 – form the denominator: $2\pi k L = 2 \times 3.1416 \times 15 \times 1 = 94.25$ W/K

Step 4 – divide: $R = \dfrac{0.6931}{94.25}$

Step 5 – evaluate: $R = 0.00735$ K/W

Final Answer: $R \approx 0.00735$ K/W $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q21

Q22.

Solution

Concept – the fin parameter for a circular pin fin: $m = \sqrt{\dfrac{hP}{kA_c}}$, and for a circle $P = \pi d$, $A_c = \pi d^2/4$, so $\dfrac{P}{A_c} = \dfrac{4}{d}$ and $m = \sqrt{\dfrac{4h}{kd}}$.

Step 1 – list the data in SI units: $h = 20$ W/m^2·K, $k = 160$ W/m·K, $d = 8$ mm $= 0.008$ m.

Step 2 – form the numerator inside the root: $4h = 4 \times 20 = 80$

Step 3 – form the denominator inside the root: $kd = 160 \times 0.008 = 1.28$

Step 4 – divide: $\dfrac{4h}{kd} = \dfrac{80}{1.28} = 62.5$

Step 5 – take the square root: $m = \sqrt{62.5} = 7.906 \approx 7.91$ m^{-1}

Why option A is wrong: 62.5 is the value of $4h/(kd)$ inside the root, not m; the square root must still be taken.

Final Answer: $m \approx 7.91$ m^{-1} $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q22

Q23.

Solution

Concept – log-mean temperature difference: $\text{LMTD} = \dfrac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$, using the end temperature differences.

Step 1 – find the two end differences (co-current, so both ends are hot minus cold at the same end): Inlet end: $\Delta T_1 = 120 - 30 = 90$ °C.

Outlet end: $\Delta T_2 = 80 - 60 = 20$ °C.

Step 2 – form the numerator: $\Delta T_1 - \Delta T_2 = 90 - 20 = 70$

Step 3 – form the log term: $\ln \dfrac{90}{20} = \ln 4.5 = 1.5041$

Step 4 – divide: $\text{LMTD} = \dfrac{70}{1.5041}$

Step 5 – evaluate: $\text{LMTD} = 46.54 \approx 46.5$ °C

Final Answer: $\text{LMTD} \approx 46.5\ °\text{C} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – capacity ratio in the effectiveness–NTU method: $C_r = \dfrac{C_{\min}}{C_{\max}}$.

Step 1 – identify the smaller and larger capacity rates: $C_h = 1000$ W/K and $C_c = 2500$ W/K, so $C_{\min} = 1000$ and $C_{\max} = 2500$.

Step 2 – form the ratio: $C_r = \dfrac{1000}{2500}$

Step 3 – evaluate: $C_r = 0.4$

Final Answer: $C_r = 0.4 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q24

Q25.

Solution

Concept – the Biot number compares internal conduction resistance to surface convection resistance: $\text{Bi} = \dfrac{hL_c}{k}$.

Step 1 – list the data: $h = 250$ W/m^2·K, $L_c = 0.01$ m, $k = 50$ W/m·K.

Step 2 – form the numerator: $hL_c = 250 \times 0.01 = 2.5$

Step 3 – divide by the conductivity: $\mathrm{Bi} = \dfrac{2.5}{50}$

Step 4 – evaluate: $\mathrm{Bi} = 0.05$

Remark: Since $\mathrm{Bi} < 0.1$, a lumped-capacitance analysis would be valid for this solid.

Final Answer: $\mathrm{Bi} = 0.05 \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q25

Q26.

Solution

Concept – net radiation exchange between a gray surface and large surroundings: $q = \varepsilon\sigma A\,(T_1^4 - T_2^4)$.

Step 1 – list the data: $\varepsilon = 0.8$, $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, $A = 1$ m^2, $T_1 = 400$ K, $T_2 = 300$ K.

Step 2 – raise each temperature to the fourth power: $T_1^4 = 400^4 = 2.560 \times 10^{10}$

$T_2^4 = 300^4 = 8.100 \times 10^9$

Step 3 – form the difference: $T_1^4 - T_2^4 = 2.560 \times 10^{10} - 0.810 \times 10^{10} = 1.750 \times 10^{10}$

Step 4 – multiply by σ: $5.67 \times 10^{-8} \times 1.750 \times 10^{10} = 992.3$

Step 5 – multiply by the emissivity (area is 1 m^2): $q = 0.8 \times 992.3 = 793.8$ W

Final Answer: $q \approx 794$ W $\Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q26

Q27.

Solution

Concept – an overall solids balance fixes the concentrated product rate: (solids in feed) $=$ (solids in product), i.e. $x_F F = x_P P$.

Step 1 – find the solids fed: $x_F F = 0.10 \times 1000 = 100$ kg/h of solids.

Step 2 – write the product-side solids: $x_P P = 0.40 \times P$

Step 3 – equate and solve for P: $0.40\,P = 100$

$P = \dfrac{100}{0.40}$

Step 4 – evaluate: $P = 250$ kg/h

Final Answer: $P = 250$ kg/h $\Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q27

Q28.

Solution

Concept – Fick's first law for steady diffusion across a gap: $N_A = \dfrac{D\,\Delta C}{\delta}$.

Step 1 – list the data in SI units: $D = 2 \times 10^{-5}$ m^2/s, $\Delta C = 4$ mol/m^3, $\delta = 5$ mm $= 5 \times 10^{-3}$ m.

Step 2 – form the numerator: $D\,\Delta C = 2 \times 10^{-5} \times 4 = 8 \times 10^{-5}$

Step 3 – divide by the gap thickness: $N_A = \dfrac{8 \times 10^{-5}}{5 \times 10^{-3}}$

Step 4 – evaluate: $N_A = 1.6 \times 10^{-2}$ mol/m^2·s

Final Answer: $N_A = 1.6 \times 10^{-2}$ mol/m^2·s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q28

Q29.

Solution

Concept – the Sherwood number is the dimensionless mass-transfer coefficient: $\text{Sh} = \dfrac{k_c L}{D}$.

Step 1 – list the data: $k_c = 0.01$ m/s, $L = 0.1$ m, $D = 2 \times 10^{-5}$ m^2/s.

Step 2 – form the numerator: $k_c L = 0.01 \times 0.1 = 1 \times 10^{-3}$

Step 3 – divide by the diffusivity: $\text{Sh} = \dfrac{1 \times 10^{-3}}{2 \times 10^{-5}}$

Step 4 – evaluate: $\text{Sh} = 50$

Final Answer: $\text{Sh} = 50 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q29

Q30.

Solution

Concept – the overall gas-phase resistance is the sum of the two film resistances: $\dfrac{1}{K_g} = \dfrac{1}{k_g} + \dfrac{m}{k_l}$; the gas-film fraction is $\dfrac{1/k_g}{1/K_g}$.

Step 1 – add the two resistances: $\dfrac{1}{K_g} = 0.4 + 0.1 = 0.5$

Step 2 – form the gas-film fraction: fraction $= \dfrac{1/k_g}{1/K_g} = \dfrac{0.4}{0.5}$

Step 3 – evaluate: fraction $= 0.8$

Interpretation: 80% of the total mass-transfer resistance lies in the gas film, so the process is gas-film controlled.

Final Answer: gas-film fraction $= 0.8 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – the rectifying operating-line slope in terms of the reflux ratio: slope $= \dfrac{R}{R+1}$.

Step 1 – set the given slope equal to the expression: $0.8 = \dfrac{R}{R+1}$

Step 2 – cross-multiply: $0.8\,(R+1) = R$

Step 3 – expand the left side: $0.8R + 0.8 = R$

Step 4 – collect the R terms: $0.8 = R - 0.8R = 0.2R$

Step 5 – solve for R: $R = \dfrac{0.8}{0.2} = 4.0$

Final Answer: $R = 4.0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q31

Q32.

Solution

Concept – Fenske's equation for the minimum number of stages at total reflux: $N_{\min} = \dfrac{\ln\left[(x_D/(1-x_D))((1-x_W)/x_W)\right]}{\ln\alpha}$.

Step 1 – list the data: $x_D = 0.98$, $x_W = 0.02$, $\alpha = 2.0$.

Step 2 – form the distillate ratio: $\dfrac{x_D}{1-x_D} = \dfrac{0.98}{0.02} = 49$

Step 3 – form the bottoms ratio: $\dfrac{1-x_W}{x_W} = \dfrac{0.98}{0.02} = 49$

Step 4 – multiply the two ratios: $49 \times 49 = 2401$

Step 5 – take the logarithm of the product: $\ln 2401 = 7.7836$

Step 6 – divide by $\ln\alpha$: $N_{\min} = \dfrac{7.7836}{\ln 2} = \dfrac{7.7836}{0.6931}$

Step 7 – evaluate: $N_{\min} = 11.23 \approx 11.2$

Final Answer: $N_{\min} \approx 11.2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – the stripping factor: $S = \dfrac{mG}{L}$ (the reciprocal of the absorption factor).

Step 1 – list the data: $m = 1.6$, $G = 100$ mol/h, $L = 80$ mol/h.

Step 2 – form the numerator: $mG = 1.6 \times 100 = 160$

Step 3 – divide by the liquid flow: $S = \dfrac{160}{80}$

Step 4 – evaluate: $S = 2.0$

Final Answer: $S = 2.0 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – packing height as the product of transfer-unit quantities: $Z = \text{HTU} \times \text{NTU}$, so $\text{NTU} = Z/\text{HTU}$.

Step 1 – list the data: $Z = 4$ m, $\text{HTU} = 0.5$ m.

Step 2 – form the ratio: $\text{NTU} = \dfrac{4}{0.5}$

Step 3 – evaluate: $\text{NTU} = 8$

Final Answer: $\text{NTU} = 8 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

Concept – equilibrium relation for constant relative volatility: $y = \dfrac{\alpha x}{1 + (\alpha - 1)x}$.

Step 1 – list the data: $\alpha = 3.0$, $x = 0.4$.

Step 2 – form the numerator: $\alpha x = 3.0 \times 0.4 = 1.2$

Step 3 – form the denominator: $1 + (\alpha - 1)x = 1 + (2.0)(0.4) = 1 + 0.8 = 1.8$

Step 4 – divide: $y = \dfrac{1.2}{1.8}$

Step 5 – evaluate: $y = 0.667$

Final Answer: $y \approx 0.667 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q35

Q36.

Solution

Concept – in the constant-rate drying period the removal rate is flux × area, so the time is mass divided by that rate: $t = \dfrac{m_{\text{water}}}{(\text{flux})\,A}$.

Step 1 – list the data: $m_{\text{water}} = 8$ kg, flux $= 1$ kg/m^2·h, $A = 4$ m^2.

Step 2 – form the removal rate: $(\text{flux})\,A = 1 \times 4 = 4$ kg/h

Step 3 – divide the mass by the rate: $t = \dfrac{8}{4}$

Step 4 – evaluate: $t = 2$ h

Final Answer: $t = 2\text{ h} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – time for a given conversion in a first-order reaction: $t = \dfrac{\ln[1/(1-X)]}{k}$.

Step 1 – list the data: $k = 0.05\ \text{min}^{-1}$, $X = 0.90$.

Step 2 – form the unreacted fraction: $1 - X = 1 - 0.90 = 0.10$

Step 3 – take the logarithm of its reciprocal: $\ln\dfrac{1}{0.10} = \ln 10 = 2.3026$

Step 4 – divide by the rate constant: $t = \dfrac{2.3026}{0.05}$

Step 5 – evaluate: $t = 46.05$ min

Final Answer: $t \approx 46.05\text{ min} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – conversion of a first-order reaction in a CSTR: $X = \dfrac{k\tau}{1+k\tau}$.

Step 1 – list the data: $k = 0.2$ min^{-1}, $\tau = 10$ min.

Step 2 – form the group $k\tau$**:** $k\tau = 0.2 \times 10 = 2$

Step 3 – substitute into the CSTR relation: $X = \dfrac{2}{1+2}$

Step 4 – simplify the denominator: $X = \dfrac{2}{3}$

Step 5 – evaluate: $X = 0.667$

Final Answer: $X \approx 0.667 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – design equation of a first-order PFR: $k\tau = -\ln(1-X)$, so $\tau = \dfrac{-\ln(1-X)}{k}$.

Step 1 – list the data: $k = 0.4$ min^{-1}, $X = 0.80$.

Step 2 – form the unreacted fraction: $1 - X = 1 - 0.80 = 0.20$

Step 3 – take the logarithm: $-\ln(0.20) = \ln 5 = 1.6094$

Step 4 – divide by the rate constant: $\tau = \dfrac{1.6094}{0.4}$

Step 5 – evaluate: $\tau = 4.024 \approx 4.02$ min

Final Answer: $\tau \approx 4.02$ min $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – Arrhenius equation applied at two temperatures: $\ln\dfrac{k_2}{k_1} = \dfrac{E_a}{R}\left(\dfrac{1}{T_1} - \dfrac{1}{T_2}\right)$, so $E_a = \dfrac{R\ln(k_2/k_1)}{(1/T_1 - 1/T_2)}$.

Step 1 – list the data: $k_2/k_1 = 2$, $T_1 = 300$ K, $T_2 = 310$ K, $R = 8.314$ J/mol·K.

Step 2 – take the logarithm of the rate-constant ratio: $\ln 2 = 0.6931$

Step 3 – form the reciprocal-temperature difference: $\dfrac{1}{300} - \dfrac{1}{310} = \dfrac{310-300}{300\times 310} = \dfrac{10}{93{,}000} = 1.0753\times 10^{-4}\ \text{K}^{-1}$

Step 4 – form the numerator: $R\ln 2 = 8.314\times 0.6931 = 5.763$

Step 5 – divide: $E_a = \dfrac{5.763}{1.0753\times 10^{-4}}$

Step 6 – evaluate: $E_a = 53{,}595$ J/mol ≈ 53.6 kJ/mol

Final Answer: $E_a \approx 53.6$ kJ/mol $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q40

Q41.

Solution

Concept – space velocity is the volumetric feed rate per unit reactor volume: $\text{SV} = \dfrac{Q}{V}$ (the reciprocal of the space time).

Step 1 – list the data: $Q = 200$ L/h, $V = 50$ L.

Step 2 – form the ratio: $\text{SV} = \dfrac{200}{50}$

Step 3 – evaluate: $\text{SV} = 4.0\ \text{h}^{-1}$

Final Answer: $\text{SV} = 4.0\ \text{h}^{-1} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – effectiveness factor for a first-order reaction in a slab: $\eta = \dfrac{\tanh\phi}{\phi}$.

Step 1 – list the data: $\phi = 1.0$, $\tanh 1 = 0.7616$.

Step 2 – substitute into the relation: $\eta = \dfrac{0.7616}{1.0}$

Step 3 – evaluate: $\eta = 0.762$

Remark: For $\phi = 1$ the pellet is only mildly diffusion-limited, so η is close to (but below) unity.

Final Answer: $\eta \approx 0.762 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – step response of a first-order process: $y(t) = K_p\,\Delta u\,(1 - e^{-t/\tau})$; here the ultimate change $K_p\,\Delta u = 20$.

Step 1 – list the data: Ultimate change $= 20$, evaluate at $t = 2\tau$, with $e^{-2} = 0.1353$.

Step 2 – form the bracket: $1 - e^{-2} = 1 - 0.1353 = 0.8647$

Step 3 – multiply by the ultimate change: $y(2\tau) = 20 \times 0.8647$

Step 4 – evaluate: $y(2\tau) = 17.29$

Check: At one time constant the response is 63.2%; at two time constants it has risen to 86.5% of the final value, consistent with $17.29/20$.

Final Answer: $y(2\tau) \approx 17.29 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q43

Q44.

Solution

Concept – decay ratio of an underdamped second-order system: decay ratio $= \exp\left[\dfrac{-2\pi\zeta}{\sqrt{1-\zeta^2}}\right]$ (it is the square of the overshoot).

Step 1 – list the data: $\zeta = 0.4$.

Step 2 – evaluate the denominator root: $\sqrt{1-\zeta^2} = \sqrt{1-0.16} = \sqrt{0.84} = 0.9165$

Step 3 – form the exponent: $\dfrac{-2\pi \times 0.4}{0.9165} = \dfrac{-2.5133}{0.9165} = -2.742$

Step 4 – take the exponential: $e^{-2.742} = 0.0644$

Final Answer: decay ratio $\approx 0.0644 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q44

Q45.

Solution

Concept – steady-state behaviour of a proportional-only controller: A P-only controller needs a non-zero error to generate the corrective action that balances a sustained load, so a residual error persists.

Step 1 – describe the residual error: After a load change the controlled variable settles at a value that differs from the set point.

Step 2 – name this residual error: This permanent steady-state deviation is called offset.

Step 3 – reject the distractors: Overshoot and decay ratio describe the transient (dynamic) response, and dead time is a transport delay, none of which is the steady-state error.

Final Answer: offset $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – straight-line depreciation and book value: Annual charge $D = \dfrac{\text{cost} - \text{salvage}}{\text{life}}$; book value after n years = cost $-nD$.

Step 1 – find the depreciable amount: cost $-$ salvage $= 5{,}00{,}000 - 50{,}000 = 4{,}50{,}000$

Step 2 – divide by the service life: $D = \dfrac{4{,}50{,}000}{9} = 50{,}000$ per year

Step 3 – find the depreciation accumulated in 3 years: $3D = 3 \times 50{,}000 = 1{,}50{,}000$

Step 4 – subtract from the original cost: book value $= 5{,}00{,}000 - 1{,}50{,}000$

Step 5 – evaluate: book value = Rs. $3{,}50{,}000$

Final Answer: book value = Rs. $3{,}50{,}000 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q46

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	D	3	D	4	A	5	D
6	C	7	A	8	C	9	B	10	D
11	A	12	C	13	A	14	B	15	D
16	A	17	B	18	A	19	B	20	C
21	B	22	D	23	D	24	B	25	C
26	D	27	C	28	D	29	D	30	B
31	A	32	B	33	B	34	C	35	A
36	B	37	B	38	C	39	D	40	C
41	A	42	B	43	A	44	C	45	A
46	A								