

OJEE M Tech Chemical Sample Paper 02

A) Mode and Time: The exam is a Computer Based Test (CBT) lasting 120 minutes.

B) Total Questions: The exam contains 90 questions.

C) Marking Scheme & Rules:

- +4 for correct answers and -1 for incorrect responses.

Q1. If A is a real symmetric matrix, then its eigenvalues are always:

- A. Zero
- B. Purely imaginary
- C. Real
- D. Complex conjugates

Q2. The divergence of the curl of any sufficiently smooth vector field $\mathbf{F}$ is:

- A. 0
- B. 1
- C. $\nabla^2 \mathbf{F}$
- D. $|\mathbf{F}|$

Q3. The value of the contour integral $\oint_C \frac{dz}{z-3}$ where C is the circle $|z| = 2$ traversed counterclockwise is:

- A. 0
- B. $2\pi i$
- C. $-2\pi i$
- D. $3\pi i$

Q4. The differential equation $\frac{d^2 y}{dx^2} - 4y = 0$ has the general solution:

- A. $y = c_1 e^{2x} + c_2 e^{-2x}$
- B. $y = c_1 \cos(2x) + c_2 \sin(2x)$
- C. $y = c_1 x e^{2x}$
- D. $y = c_1 e^{4x} + c_2 e^{-4x}$

Q5. The Laplace transform of $f(t) = e^{at}$ is:

- A. $\frac{1}{s+a}$
- B. $\frac{1}{s-a}$
- C. $\frac{a}{s^2+a^2}$
- D. $\frac{s}{s^2+a^2}$

Q6. Which of the following is an integrating factor for the differential equation $x \frac{dy}{dx} - y = x^2$?

- A. $1/x^2$
- B. $1/x$
- C. x
- D. x^2

Q7. A square matrix A is called nilpotent of index k if:

- A. $A^k = I$
- B. $A^k = A$
- C. $A^k = 0$
- D. $A^T = A$

Q8. The value of $\lim_{x \rightarrow 0} \frac{1 - \cos(2x)}{x^2}$ is:

- A. 0
- B. 1
- C. 2
- D. 4

Q9. If $P(A) = 0.4$, $P(B) = 0.5$, and A and B are independent events, then $P(A \cup B)$ is:

- A. 0.2
- B. 0.7
- C. 0.9
- D. 0.5

Q10. In a binomial distribution, if the mean is 4 and the variance is 3, what is the probability of success p ?

- A. $1/4$

B. $3/4$

C. $1/3$

D. $1/2$

Q11. The order of convergence of the Newton-Raphson method for a simple root is:

A. Linear

B. Quadratic

C. Cubic

D. Fractional

Q12. The Taylor series expansion of $f(x) = e^x$ around $x = 0$ is:

A. $1 - x + \frac{x^2}{2!} - \dots$

B. $1 + x + \frac{x^2}{2!} + \dots$

C. $x - \frac{x^3}{3!} + \dots$

D. $1 - \frac{x^2}{2!} + \dots$

Q13. Using the Trapezoidal rule with one interval to evaluate $\int_0^1 x^2 dx$ yields:

A. 0

B. 0.5

C. 1

D. 0.333

Q14. A bag contains 3 red and 4 black balls. Two balls are drawn at random. The probability that both are red is:

A. $1/7$

B. $3/7$

C. $2/7$

D. $1/21$

Q15. The function $f(z) = \bar{z}$ (complex conjugate of z) is analytic:

A. Nowhere

B. Everywhere

- C. Only at origin
- D. On the real axis

Q16. The solution of the partial differential equation $\frac{\partial u}{\partial x} = c \frac{\partial u}{\partial y}$ can be found using the method of:

- A. Separation of variables
- B. Euler's method
- C. Simplex method
- D. Newton-Raphson

Q17. The maximum value of the function $f(x) = -x^2 + 4x + 1$ is:

- A. 3
- B. 4
- C. 5
- D. 6

Q18. The determinant of a 3×3 matrix with rows $[1, 2, 3]$, $[2, 4, 6]$, $[7, 8, 9]$ is:

- A. 0
- B. 1
- C. -1
- D. 10

Q19. If $\mathbf{u} \cdot \mathbf{v} = 0$ for non-zero vectors $\mathbf{u}$ and $\mathbf{v}$, the vectors are:

- A. Parallel
- B. Orthogonal
- C. Collinear
- D. Linearly dependent

Q20. For a standard normal distribution, the mean and variance are respectively:

- A. 1 and 0
- B. 0 and 1
- C. 0 and 0
- D. 1 and 1

Q21. Find the missing number in the sequence: 2, 6, 12, 20, 30, ...

- A. 40
- B. 42
- C. 44
- D. 46

Q22. If "TABLE" is coded as "UBCMF", then "CHAIR" will be coded as:

- A. DIBJS
- B. DIZJQ
- C. DIBKS
- D. DHCJS

Q23. Pointing to a woman, a man says, "She is the only daughter of my mother's husband." How is the woman related to the man?

- A. Aunt
- B. Sister
- C. Wife
- D. Daughter

Q24. If A is taller than B, but shorter than C. D is taller than C. Who is the tallest?

- A. A
- B. B
- C. C
- D. D

Q25. A man walks 5 km East, turns right and walks 4 km, then turns left and walks 5 km. In which direction is he from the starting point?

- A. North-East
- B. South-East
- C. North-West
- D. South-West

Q26. Statements: All cats are dogs. All dogs are animals. Conclusion: All cats are animals.

- A. True
- B. False
- C. Cannot be determined
- D. Invalid reasoning

Q27. Find the odd one out:

- A. Square
- B. Circle
- C. Rectangle
- D. Triangle

Q28. In a row of 30 students, Rohan is 15th from the left. What is his position from the right?

- A. 15th
- B. 16th
- C. 14th
- D. 17th

Q29. A train 100 meters long is running at a speed of 36 km/hr. How long will it take to pass a stationary pole?

- A. 10 seconds
- B. 12 seconds
- C. 15 seconds
- D. 20 seconds

Q30. If the day before yesterday was Thursday, what day will it be tomorrow?

- A. Sunday
- B. Monday
- C. Saturday
- D. Friday

Q31. The Maxwell relation corresponding to the fundamental equation $dH = TdS + VdP$ is:

A. $(\frac{\partial T}{\partial P})_S = (\frac{\partial V}{\partial S})_P$

B. $-(\frac{\partial T}{\partial V})_S = (\frac{\partial P}{\partial S})_V$

C. $(\frac{\partial S}{\partial P})_T = -(\frac{\partial V}{\partial T})_P$

D. $(\frac{\partial S}{\partial V})_T = (\frac{\partial P}{\partial T})_V$

Q32. The efficiency of a Carnot engine working between T_{hot} and T_{cold} is:

A. $1 - T_{hot}/T_{cold}$

B. $1 - T_{cold}/T_{hot}$

C. T_{cold}/T_{hot}

D. $T_{hot}/(T_{hot} - T_{cold})$

Q33. For a binary ideal solution, the activity coefficient of each component is:

A. 0

B. 1

C. Infinity

D. Equal to its mole fraction

Q34. The Joule-Thomson coefficient for an ideal gas is:

A. Positive

B. Negative

C. Zero

D. Infinity

Q35. In the van der Waals equation $(P + a/V^2)(V - b) = RT$, the term ' a ' accounts for:

A. Molecular volume

B. Intermolecular attraction

C. Kinetic energy

D. Compressibility

Q36. According to boundary layer theory, the boundary layer thickness δ for laminar flow over a flat plate varies with distance x as:

A. x

B. x^2

- C. $x^{1/2}$
- D. $x^{-1/2}$

Q37. A U-tube manometer measures:

- A. Absolute pressure
- B. Velocity
- C. Pressure difference
- D. Mass flow rate

Q38. In fluid flow, the Froude number is the ratio of inertial forces to:

- A. Viscous forces
- B. Gravity forces
- C. Surface tension
- D. Elastic forces

Q39. Cavitation in a centrifugal pump occurs when the local pressure drops below the:

- A. Atmospheric pressure
- B. Vapor pressure
- C. Critical pressure
- D. Stagnation pressure

Q40. For fully developed laminar flow in a circular pipe, the friction factor f (Darcy) is equal to:

- A. $16/Re$
- B. $64/Re$
- C. $0.079Re^{-0.25}$
- D. $0.316Re^{-0.25}$

Q41. The critical radius of insulation for a cylinder with thermal conductivity k and external convection coefficient h is:

- A. h/k
- B. k/h
- C. $2k/h$

D. $k/(2h)$

Q42. For heat transfer in fully developed turbulent flow in pipes, the Dittus-Boelter equation indicates that the Nusselt number is proportional to Reynolds number raised to the power of:

- A. 0.5
- B. 0.8
- C. 1.0
- D. 0.33

Q43. The view factor of a completely enclosed surface 1 with respect to itself, if it is strictly convex, is:

- A. 1
- B. 0.5
- C. 0
- D. Depends on surface area

Q44. In a 1-2 shell and tube heat exchanger, the LMTD correction factor F is introduced to account for:

- A. Fouling
- B. Non-countercurrent flow
- C. Phase change
- D. Heat losses

Q45. The Biot number represents the ratio of:

- A. Internal conduction resistance to external convection resistance
- B. External convection resistance to internal conduction resistance
- C. Momentum diffusivity to thermal diffusivity
- D. Buoyancy to viscous forces

Q46. In mass transfer, the surface renewal theory proposed by Danckwerts assumes the mass transfer coefficient is proportional to:

- A. D_{AB}
- B. $D_{AB}^{0.5}$

C. D_{AB}^2

D. $1/D_{AB}$

Q47. At the flooding point in a packed absorption column, the pressure drop:

- A. Decreases rapidly
- B. Remains constant
- C. Increases sharply
- D. Becomes zero

Q48. In a McCabe-Thiele diagram, the q -line for a saturated vapor feed is:

- A. Vertical
- B. Horizontal
- C. Has a slope of 1
- D. Has a slope of -1

Q49. Relative volatility α_{AB} can be expressed in terms of vapor pressures (P_A^{sat} , P_B^{sat}) for ideal mixtures as:

- A. P_A^{sat} / P_B^{sat}
- B. P_B^{sat} / P_A^{sat}
- C. $P_A^{sat} \times P_B^{sat}$
- D. $P_A^{sat} - P_B^{sat}$

Q50. In a triangular phase diagram for liquid-liquid extraction, the plait point represents the state where:

- A. The extract phase vanishes
- B. The raffinate phase vanishes
- C. Extract and raffinate phases become identical
- D. Maximum solvent is present

Q51. For an elementary reaction $A \rightarrow B$ taking place in a CSTR, the Damköhler number (Da) represents the ratio of:

- A. Space time to reaction time
- B. Reaction time to space time

- C. Residence time to mixing time
- D. Reaction rate to mass transfer rate

Q52. To maximize the yield of the intermediate product R in series reactions $A \rightarrow R \rightarrow S$, one should use a:

- A. Batch reactor or PFR
- B. CSTR
- C. Fluidized bed
- D. Series of CSTRs

Q53. The unit of the rate constant k for a second-order reaction is:

- A. s^{-1}
- B. $m^3/(kmol \cdot s)$
- C. $kmol/(m^3 \cdot s)$
- D. Dimensionless

Q54. For an exothermic reversible reaction, the equilibrium conversion:

- A. Increases with temperature
- B. Decreases with temperature
- C. Is independent of temperature
- D. Reaches a maximum then decreases

Q55. The internal effectiveness factor for a porous catalyst particle approaches 1 when the Thiele modulus is:

- A. Very large
- B. Equal to 1
- C. Very small (near zero)
- D. Negative

Q56. The transfer function of a pure dead time (transport delay) system with delay t_d is:

- A. $e^{t_d s}$
- B. $e^{-t_d s}$

C. $1/(t_d s + 1)$

D. $t_d s + 1$

Q57. A second-order system is critically damped when the damping ratio ζ is:

A. < 1

B. $= 1$

C. > 1

D. $= 0$

Q58. In the Routh array, if there is one sign change in the first column, the system has:

A. One root in the right-half plane

B. Two roots in the right-half plane

C. One root on the imaginary axis

D. No roots in the right-half plane

Q59. For a stable control system, the gain margin must be:

A. < 1

B. $= 1$

C. > 1

D. < 0

Q60. Cascade control is primarily used to:

A. Eliminate offset completely

B. Reject secondary disturbances before they affect the primary variable

C. Increase the ultimate gain

D. Decrease the overall order of the system

Q61. Tyler standard screen series is based on a screen scale ratio of:

A. $\sqrt{2}$

B. $\sqrt{3}$

C. 2

D. 1.5

Q62. In constant pressure filtration, the plot of dt/dV versus V (where V is filtrate volume) yields a:

- A. Parabola
- B. Straight line
- C. Logarithmic curve
- D. Horizontal line

Q63. During hindered settling, the settling velocity of particles compared to their terminal settling velocity is:

- A. Higher
- B. Lower
- C. Equal
- D. Zero

Q64. The power number for an agitator in the fully turbulent regime is:

- A. Inversely proportional to Reynolds number
- B. Directly proportional to Reynolds number
- C. Independent of Reynolds number
- D. Proportional to the square of the Reynolds number

Q65. A cyclone separator operates essentially on the principle of:

- A. Gravity settling
- B. Centrifugal force
- C. Magnetic separation
- D. Electrostatic precipitation

Q66. Lang factor is used to estimate:

- A. Operating cost
- B. Total fixed capital investment from delivered equipment cost
- C. Depreciation rate
- D. Working capital

Q67. The straight-line depreciation method assumes that the value of an asset decreases:

- A. Exponentially
- B. Logarithmically
- C. By a constant percentage each year
- D. By a constant amount each year

Q68. At the optimum reflux ratio, the total annual cost of a distillation column is:

- A. Maximum
- B. Minimum
- C. Zero
- D. Equal to operating cost

Q69. In a manufacturing plant, the cost of raw materials is classified as a:

- A. Fixed cost
- B. Variable cost
- C. Overhead cost
- D. Capital cost

Q70. The Net Present Value (NPV) of a strictly profitable project must be:

- A. Zero
- B. Negative
- C. Positive
- D. Equal to the discount rate

Q71. In the Haber process for ammonia synthesis, the operating pressure is typically around:

- A. 1 atm
- B. 10 atm
- C. 150-250 atm
- D. 1000 atm

Q72. The main raw materials for the production of urea are:

- A. Ammonia and carbon monoxide
- B. Ammonia and carbon dioxide

- C. Nitric acid and carbon dioxide
- D. Ammonium nitrate and water

Q73. Fluid Catalytic Cracking (FCC) predominantly uses which type of catalyst?

- A. Iron oxide
- B. Platinum on alumina
- C. Zeolites
- D. Vanadium pentoxide

Q74. The monomers used in the production of Nylon 6,6 are:

- A. Caprolactam
- B. Adipic acid and hexamethylenediamine
- C. Ethylene glycol and terephthalic acid
- D. Styrene and butadiene

Q75. The primary active constituent in Portland cement that provides early strength is:

- A. Tricalcium silicate
- B. Dicalcium silicate
- C. Tricalcium aluminate
- D. Tetracalcium aluminoferrite

Q76. Synthesis gas (Syngas) is a mixture primarily consisting of:

- A. CO and H_2
- B. CO_2 and H_2
- C. CH_4 and O_2
- D. N_2 and H_2

Q77. In polymer engineering, the polydispersity index (PDI) is the ratio of:

- A. M_n/M_w
- B. M_w/M_n
- C. M_z/M_w
- D. M_v/M_n

Q78. Vulcanization of rubber involves adding which element to create cross-links?

- A. Carbon
- B. Silicon
- C. Sulfur
- D. Phosphorus

Q79. Sweetening of petroleum products refers to the removal of:

- A. Water
- B. Waxes
- C. Sulfur compounds (mercaptans)
- D. Aromatics

Q80. Prilling is a standard industrial process used to produce:

- A. Liquid fertilizers
- B. Granular/spherical urea or ammonium nitrate
- C. Powdered cement
- D. Flaked polymers

Q81. According to Le Chatelier's principle, increasing the pressure of a gaseous reaction at equilibrium shifts the reaction towards:

- A. The side with more moles of gas
- B. The side with fewer moles of gas
- C. The endothermic direction
- D. The exothermic direction

Q82. For a pseudoplastic fluid, the apparent viscosity:

- A. Increases with increasing shear rate
- B. Decreases with increasing shear rate
- C. Remains constant
- D. Is independent of time

Q83. The Grashof number in natural convection plays a role analogous to which dimensionless number in forced convection?

- A. Prandtl number
- B. Nusselt number
- C. Reynolds number
- D. Schmidt number

Q84. Absorption with chemical reaction in a packed column is typically intended to:

- A. Decrease the mass transfer coefficient
- B. Increase the solubility and mass transfer rate
- C. Reduce the flooding velocity
- D. Increase the gas phase resistance

Q85. If a chemical reaction has an activation energy of zero, its rate constant:

- A. Increases exponentially with temperature
- B. Decreases with temperature
- C. Is independent of temperature
- D. Is exactly zero

Q86. A PI controller produces an output that is proportional to:

- A. The error
- B. The integral of the error
- C. The error and the integral of the error
- D. The rate of change of the error

Q87. Bond's crushing law states that the work required to form particles of size D_p from a very large feed is proportional to:

- A. $1/D_p$
- B. $1/D_p^2$
- C. $1/\sqrt{D_p}$
- D. $\sqrt{D_p}$

Q88. Working capital for a chemical plant typically includes funds for:

- A. Major equipment purchases

- B. Land acquisition
- C. Raw materials and product inventories
- D. Process design engineering

Q89. In the production of sulfuric acid, sulfur dioxide is converted to sulfur trioxide in a:

- A. Rotary kiln
- B. Multiple-hearth roaster
- C. Fixed bed catalytic converter
- D. Fluidized bed reactor

Q90. Which instrument measures the humidity of a gas stream by using two identical thermometers, one with a wetted wick?

- A. Anemometer
- B. Hygrometer (Psychrometer)
- C. Barometer
- D. Manometer

Solutions

1. C

Explanation: A fundamental theorem in linear algebra states that all eigenvalues of a real symmetric matrix are entirely real numbers.

2. A

Explanation: The divergence of the curl of any vector field $\mathbf{F}$ ($\nabla \cdot (\nabla \times \mathbf{F})$) is identically zero by vector calculus identities.

3. A

Explanation: The singularity is at $z = 3$, which lies completely outside the contour $|z| = 2$. By Cauchy's Integral Theorem, the integral over the closed path is 0.

4. A

Explanation: The characteristic equation is $r^2 - 4 = 0$, giving roots $r = \pm 2$. Thus, the general solution is $y = c_1 e^{2x} + c_2 e^{-2x}$.

5. B

Explanation: By definition, the Laplace transform of e^{at} is evaluated via $\int_0^\infty e^{-st} e^{at} dt$, which converges to $1/(s - a)$ for $s > a$.

6. B

Explanation: Rewriting in standard form: $y' - (1/x)y = x$. The integrating factor is $e^{\int -(1/x)dx} = e^{-\ln x} = 1/x$.

7. C

Explanation: A matrix A is nilpotent of index k if $A^k = 0$ while $A^{k-1} \neq 0$, meaning it eventually becomes the zero matrix when raised to a power.

8. C

Explanation: Applying L'Hôpital's rule twice or using the expansion $\cos(2x) \approx 1 - (2x)^2/2 = 1 - 2x^2$, the limit evaluates to $2x^2/x^2 = 2$.

9. B

Explanation: For independent events, $P(A \cap B) = P(A)P(B) = 0.2$. Then $P(A \cup B) = P(A) + P(B) - P(A \cap B) = 0.4 + 0.5 - 0.2 = 0.7$.

10. A

Explanation: For a binomial distribution, mean $= np = 4$ and variance $= np(1 - p) = 3$. Dividing variance by mean gives $1 - p = 3/4$, so $p = 1/4$.

11. B

Explanation: The Newton-Raphson method generally exhibits quadratic convergence, meaning the error at each step is proportional to the square of the error from the previous step.

12. B

Explanation: The standard Maclaurin series (Taylor series at $x = 0$) for e^x is the sum of $x^n/n!$ from $n = 0$ to ∞ , giving $1 + x + x^2/2! + \dots$

13. B

Explanation: The Trapezoidal rule with one interval from 0 to 1 estimates the integral as $\frac{1-0}{2}[f(0) + f(1)] = 0.5[0 + 1] = 0.5$.

14. A

Explanation: Total ways to draw 2 balls from 7 is $\binom{7}{2} = 21$. Ways to draw 2 red balls from 3 is $\binom{3}{2} = 3$. Probability = $3/21 = 1/7$.

15. A

Explanation: The function $f(z) = \bar{z} = x - iy$ has $u_x = 1$ and $v_y = -1$. It fails the Cauchy-Riemann equations ($u_x = v_y$) everywhere, so it is nowhere analytic.

16. A

Explanation: The classical analytical method for solving linear partial differential equations is the separation of variables, assuming $u(x, y) = X(x)Y(y)$.

17. C

Explanation: The derivative $f'(x) = -2x + 4 = 0 \implies x = 2$. Substituting back, $f(2) = -4 + 8 + 1 = 5$. Since $f''(x) = -2 < 0$, it is a maximum.

18. A

Explanation: The second row $[2, 4, 6]$ is exactly twice the first row $[1, 2, 3]$. Because two rows are linearly dependent (proportional), the determinant is 0.

19. B

Explanation: The dot product of two non-zero vectors is zero if and only if the cosine of the angle between them is zero, meaning they are orthogonal (perpendicular).

20. B

Explanation: A standard normal distribution curve, denoted usually as $Z \sim N(0, 1)$, is precisely scaled to have a mean (μ) of 0 and a variance (σ^2) of 1.

21. B

Explanation: The differences between consecutive terms are 4, 6, 8, 10. The next difference should be 12. Therefore, $30 + 12 = 42$.

22. A

Explanation: Each letter is shifted by +1 in the alphabet. T $\rightarrow$ U, A $\rightarrow$ B, etc. Applying this to CHAIR gives D, I, B, J, S.

23. B

Explanation: "My mother's husband" is the man's father. The "only daughter" of his father is his sister.

24. D

Explanation: From the prompt: $B < A < C$, and $C < D$. Chaining these inequalities gives $B < A < C < D$, clearly making D the tallest.

25. B

Explanation: He goes 5km East, turns South (right) for 4km, then turns East (left) for 5km. He ends up South and East from his starting point.

26. A

Explanation: This is a standard valid syllogism. If the set of cats is fully contained within dogs, and dogs within animals, then cats are absolutely within animals.

27. B

Explanation: A square, rectangle, and triangle are all polygons formed by straight line segments. A circle is formed by a continuous curve, making it the odd one out.

28. B

Explanation: Total students = (Position from left) + (Position from right) - 1. Thus, $30 = 15 + R - 1$, meaning $R = 16$.

29. A

Explanation: First, convert 36 km/hr to m/s: $36 \times (5/18) = 10$ m/s. The time to pass a point is Distance / Speed = $100/10 = 10$ seconds.

30. A

Explanation: If the day before yesterday was Thursday, today is Saturday. Therefore, tomorrow will logically be Sunday.

31. A

Explanation: From the fundamental equation $dH = TdS + VdP$, taking crossed partial derivatives yields the Maxwell relation $(\partial T/\partial P)_S = (\partial V/\partial S)_P$.

32. B

Explanation: The thermal efficiency of an ideal Carnot cycle is defined strictly by the absolute temperatures of the heat reservoirs: $\eta = 1 - T_{cold}/T_{hot}$.

33. B

Explanation: For an ideal solution, the interactions between different molecules equal the interactions between identical ones, rendering the activity coefficient exactly 1.

34. C

Explanation: An ideal gas implies no intermolecular forces. Thus, an isenthalpic expansion results in no temperature change, yielding a Joule-Thomson coefficient of exactly zero.

35. B

Explanation: In the van der Waals model, the ' a/V^2 ' term corrects for the pressure reduction caused by attractive intermolecular forces between gas particles.

36. C

Explanation: According to Blasius' exact solution for laminar boundary layer flow over a flat plate, $\delta \propto \sqrt{\nu x/U_\infty}$, meaning it grows with $x^{1/2}$.

37. C

Explanation: A simple U-tube manometer inherently measures the differential pressure between its two legs by equating the hydrostatic fluid column height differences.

38. B

Explanation: The Froude number ($Fr = V/\sqrt{gL}$) is a dimensionless parameter formally defining the ratio of a fluid's inertial forces to its gravitational forces.

39. B

Explanation: Cavitation bubbles form when the highly localized fluid pressure inside a pump drops below the fluid's vapor pressure, causing it to spontaneously boil.

40. B

Explanation: For laminar pipe flow, the Hagen-Poiseuille equation dictates that the Darcy friction factor is $64/Re$, while the Fanning friction factor is $16/Re$.

41. B

Explanation: The critical radius for cylindrical insulation, where total thermal resistance is minimized and heat transfer is maximized, is calculated exactly as $r_c = k/h$.

42. B

Explanation: The Dittus-Boelter correlation takes the form $Nu = 0.023Re^{0.8}Pr^n$, explicitly showing that the Nusselt number is proportional to $Re^{0.8}$.

43. C

Explanation: A strictly convex surface cannot "see" any part of itself. Therefore, all radiation leaving it strikes other surfaces, making its self-view factor $F_{11} = 0$.

44. B

Explanation: Shell and tube heat exchangers with multiple passes experience a mix of co-current and counter-current flows, requiring the correction factor F to adjust the ideal LMTD.

45. A

Explanation: The Biot number ($Bi = hL/k_{solid}$) scales the internal conductive resistance of a solid body against the external convective thermal resistance of the fluid.

46. B

Explanation: Danckwerts' surface renewal theory models mass transfer as continuous replacements of surface fluid elements, predicting the coefficient $k_L \propto \sqrt{D_{AB}}$.

47. C

Explanation: At the flooding point, liquid completely fills the void spaces in the packing, severely restricting gas flow and causing the pressure drop to increase sharply.

48. B

Explanation: For a saturated vapor feed, the feed quality $q = 0$. The slope of the q -line is $q/(q - 1) = 0/(-1) = 0$, producing a perfectly horizontal line on the diagram.

49. A

Explanation: By combining Raoult's and Dalton's laws for an ideal binary system, the relative volatility α_{AB} simplifies exactly to the ratio of the pure component vapor pressures.

50. C

Explanation: On a ternary phase diagram, the plait point marks the exact boundary of the two-phase region where the extract and raffinate phases merge and become identical in composition.

51. A

Explanation: The Damköhler number ($Da = \tau k$ for first-order) fundamentally contrasts the reactor's space time (residence time) against the characteristic time required for the chemical reaction.

52. A

Explanation: For series reactions, high back-mixing (as in a CSTR) accelerates the secondary breakdown of the intermediate product R . A PFR or batch reactor

maximizes R 's yield.

53. B

Explanation: The rate law is $-r_A = kC_A^2$. Given $-r_A$ is in $\text{kmol}/(\text{m}^3 \cdot \text{s})$ and C_A is in kmol/m^3 , k must have units of $\text{m}^3/(\text{kmol} \cdot \text{s})$.

54. B

Explanation: According to Le Chatelier's principle and van 't Hoff's equation, raising the temperature of an exothermic reaction shifts the equilibrium backward, decreasing conversion.

55. C

Explanation: A small Thiele modulus indicates that surface reaction kinetics are the rate-limiting step, allowing reactant concentration to remain uniform throughout the pore, making effectiveness ≈ 1 .

56. B

Explanation: Applying the time-shifting property of Laplace transforms, a strict time delay of t_d mathematically translates to multiplying the signal in the s -domain by $e^{-t_d s}$.

57. B

Explanation: A damping ratio $\zeta = 1$ defines a critically damped system, which represents the fastest return to steady state without experiencing any oscillatory overshoot.

58. A

Explanation: The Routh-Hurwitz stability criterion dictates that the number of roots located in the unstable right-half plane exactly equals the number of sign changes in the array's first column.

59. C

Explanation: For Bode stability, the amplitude ratio must be less than 1 when the phase lag hits -180° . Consequently, the gain margin (defined as $1/AR_{\text{crossover}}$) must be strictly > 1 .

60. B

Explanation: Cascade control employs an inner secondary loop to swiftly detect and reject localized disturbances before they can noticeably affect the primary, slow-responding controlled variable.

61. A

Explanation: The standard Tyler screen scale is geometrically progressed. The ratio of the aperture width of any screen to the one immediately below it is $\sqrt{2}$ (approx 1.414).

62. B

Explanation: The general filtration equation for constant pressure rearranges to $dt/dV = K_p V + B$. Plotting dt/dV against V naturally yields a straight line with slope K_p .

63. B

Explanation: In hindered settling, the high concentration of particles creates upward fluid displacement currents and significant particle interactions, resulting in a lower settling velocity than terminal free settling.

64. C

Explanation: In unbaffled or fully baffled turbulent mixing (Reynolds $> 10,000$), inertial forces entirely dominate viscous forces, rendering the power number constant and independent of Reynolds number.

65. B

Explanation: A cyclone separator directs particle-laden gas in a tight vortex, utilizing strong centrifugal forces—which greatly exceed gravity—to drive dense solid particles radially to the wall.

66. B

Explanation: The Lang factor is a classic empirical multiplier used in preliminary plant design to swiftly estimate the total fixed capital investment based strictly on the delivered cost of major equipment.

67. D

Explanation: Straight-line depreciation evenly distributes the loss of an asset's value, subtracting a constant, fixed monetary amount every single year over its estimated useful life.

68. B

Explanation: The optimum reflux ratio defines the specific operating point where the sum of the annualized fixed capital cost (trays/columns) and operating cost (reboiler/condenser duties) hits its absolute minimum.

69. B

Explanation: Raw material costs directly and proportionally scale with the volume of product manufactured, fundamentally categorizing them as variable operating costs.

70. C

Explanation: A positive Net Present Value explicitly indicates that the projected earnings generated by a project or investment exceed the anticipated costs, both discounted back to present value.

71. C

Explanation: The Haber process converts nitrogen and hydrogen into ammonia. To favor the forward exothermic reaction via Le Chatelier's principle, typical modern industrial operations utilize pressures of 150-250 atm.

72. B

Explanation: Urea ($CO(NH_2)_2$) is synthesized commercially on a massive scale by reacting liquid ammonia with carbon dioxide at high pressures to form ammonium carbamate, which then dehydrates.

73. C

Explanation: Modern FCC units employ highly active, acid-site-rich synthetic Zeolite catalysts to selectively crack large, heavy hydrocarbon feedstocks into valuable gasoline and olefinic streams.

74. B

Explanation: Nylon 6,6 is a step-growth condensation polymer formed by the precise stoichiometric reaction of a 6-carbon diacid (adipic acid) and a 6-carbon diamine (hexamethylenediamine).

75. A

Explanation: In Portland cement hydration, Tricalcium silicate (C_3S) reacts rapidly with water to form calcium silicate hydrate gel, heavily dictating the concrete's crucial early strength development.

76. A

Explanation: Syngas (Synthesis gas) is a versatile industrial fuel gas and chemical precursor mixture composed primarily of carbon monoxide (CO) and hydrogen (H_2).

77. B

Explanation: The Polydispersity Index (PDI) measures the broadness of a molecular weight distribution, calculated as the weight-average molecular weight (M_w) divided by the number-average molecular weight (M_n).

78. C

Explanation: Vulcanization is a chemical process that drastically improves the durability and elasticity of natural rubber by introducing Sulfur to form stable cross-bridges between polymer chains.

79. C

Explanation: Sweetening is a refinery treating process primarily aimed at removing or safely converting foul-smelling, corrosive sulfur compounds (mercaptans) from petroleum products.

80. B

Explanation: Prilling involves dripping molten material down a tall cooling tower to solidify into small, free-flowing spherical pellets, commonly used for urea and ammonium nitrate fertilizers.

81. B

Explanation: By Le Chatelier's principle, applying higher pressure to a gaseous system forces the equilibrium to shift toward the side with fewer gas molecules to counteract the applied stress.

82. B

Explanation: Pseudoplastic (shear-thinning) fluids structurally align under stress, causing their apparent viscosity to progressively decrease as the applied shear rate increases.

83. C

Explanation: The Grashof number characterizes the ratio of buoyancy to viscous forces in natural convection, serving the exact fluid-dynamic scaling role that the Reynolds number serves in forced convection.

84. B

Explanation: Introducing a rapid chemical reaction in the liquid phase drastically steepens the concentration gradient near the interface, enhancing both the capacity (solubility) and the overall mass transfer rate.

85. C

Explanation: According to the Arrhenius equation ($k = Ae^{-E_a/RT}$), if the activation energy $E_a = 0$, the exponential term becomes $e^0 = 1$, rendering the rate constant k equal to A , entirely independent of temperature.

86. C

Explanation: A Proportional-Integral (PI) controller generates an output linearly combining a proportional response to the current error and an integral response to the accumulated historical error.

87. C

Explanation: Bond's empirically derived crushing law states that the work input required for intermediate size reduction scales inversely with the square root of the final product particle diameter ($1/\sqrt{D_p}$).

88. C

Explanation: Working capital represents the liquid funds absolutely necessary to sustain day-to-day operations, including covering raw material purchases, maintaining inventories, and managing accounts receivable.

89. C

Explanation: In the Contact Process, the highly exothermic, temperature-sensitive oxidation of SO_2 to SO_3 is conducted over Vanadium pentoxide catalyst beds arranged within a large multi-stage fixed bed converter.

90. B

Explanation: A sling psychrometer (or hygrometer) utilizes simultaneous readings from a dry-bulb thermometer and a wet-bulb thermometer to thermodynamically determine the relative humidity of an air stream.