OJEE M Tech Chemical Sample Paper 01

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 3×3 real orthogonal matrix with determinant $+1$, which of the following must be an eigenvalue of A?

A. 0

B. 1

C. -1

D. i

Q2. Let M be a 4×4 matrix such that $M^3 = M$. The possible eigenvalues of M are:

A. 0, 1, 2

B. 0, 1, -1

C. 1, -1, i

D. 0, i, -i

Q3. The value of $\lim_{x \to 0} \frac{x - \sin x}{x^3}$ is:

A. 1/6

B. 1/3

C. 1/2

D. 1

Q4. The function $f(x, y) = x^3 + y^3 - 3xy$ has a local minimum at the point:

A. (0, 0)

B. (1, 1)

C. (-1, -1)

D. (1, -1)

Q5. The value of the line integral $\oint_C (ydx - xdy)$ where C is the circle $x^2 + y^2 = 4$ traversed counterclockwise, is:

A. 4π

B. -4π

C. 8π

D. -8π

Q6. The general solution to the differential equation $\frac{dy}{dx} + y \tan x = \sec x$ is:

A. $y \sec x = \tan x + C$

B. $y \cos x = x + C$

C. $y \sin x = x + C$

D. $y \tan x = \sec x + C$

Q7. The Laplace transform of $f(t) = t \sin(2t)$ is:

A. $\frac{4s}{(s^2+4)^2}$

B. $\frac{2s}{(s^2+4)^2}$

C. $\frac{s^2-4}{(s^2+4)^2}$

D. $\frac{4}{(s^2+4)^2}$

Q8. The singular point of the differential equation $x^2y'' + xy' + (x^2 - n^2)y = 0$ at $x = 0$ is:

A. Ordinary point

B. Regular singular point

C. Irregular singular point

D. Removable singular point

Q9. If $u(x, y) = x^2 - y^2$ is the real part of an analytic function $f(z) = u + iv$, then $v(x, y)$ is:

A. $2xy + C$

B. $x^2 + y^2 + C$

C. $-2xy + C$

D. $xy + C$

Q10. The residue of $f(z) = \frac{z^2}{(z-1)(z-2)}$ at $z = 1$ is:

A. 1

B. -1

C. 2

D. -2

Q11. A fair coin is tossed 3 times. Given that at least one head appeared, what is the probability that exactly two heads appeared?

A. 3/8

B. 3/7

C. 1/2

D. 4/7

Q12. If X is a Poisson random variable such that $P(X = 1) = P(X = 2)$, the mean of X is:

A. 1

B. 2

C. 3

D. 4

Q13. The Newton-Raphson method formula for finding the square root of a positive real number R is:

A. $x_{n+1} = \frac{1}{2}(x_n + \frac{R}{x_n})$

B. $x_{n+1} = \frac{1}{2}(x_n - \frac{R}{x_n})$

C. $x_{n+1} = x_n - \frac{R}{x_n^2}$

D. $x_{n+1} = x_n + \frac{R}{x_n^2}$

Q14. Simpson's 1/3 rule for numerical integration is exact for polynomials of degree up to:

A. 1

B. 2

C. 3

D. 4

Q15. Which of the following numerical methods for solving initial value problems is of fourth-order accuracy?

A. Euler's Method

B. Modified Euler's Method

C. Runge-Kutta 4th Order

D. Predictor-Corrector Method

Q16. The directional derivative of $f(x, y, z) = x^2y + y^2z$ at $(1, 1, 1)$ in the direction of the vector $\mathbf{i} + \mathbf{j} + \mathbf{k}$ is:

A. $\sqrt{3}$

B. $5/\sqrt{3}$

C. 5

D. 3

Q17. The volume of the solid bounded by the planes $x = 0, y = 0, z = 0$, and $x+y+z = 1$ is:

A. $1/2$

B. $1/3$

C. $1/6$

D. $1/8$

Q18. The integrating factor for the linear differential equation $\frac{dy}{dx} + \frac{2}{x}y = x^2$ is:

A. $\ln x$

B. x^2

C. e^{2x}

D. $1/x^2$

Q19. Given the complex function $f(z) = e^{1/z}$, the point $z = 0$ is a:

A. Removable singularity

B. Simple pole

C. Pole of order n

D. Essential singularity

Q20. In a normal distribution, the percentage of data lying within ± 2 standard deviations from the mean is approximately:

A. 68%

B. 95%

C. 99.7%

D. 50%

Q21. Look at the series: 7, 10, 8, 11, 9, 12, ... What number should come next?

A. 7

B. 10

C. 12

D. 13

Q22. Pointing to a photograph, a man said, "I have no brother or sister but that man's father is my father's son." Whose photograph was it?

A. His own

B. His son's

C. His father's

D. His nephew's

Q23. In a certain code language, "COMPUTER" is written as "RFUVQNPC". How is "MEDICINE" written in that code?

A. MFEDJJOE

B. EOJDEJFM

C. MFEJDJOE

D. EOJDJEFM

Q24. Statements: All engineers are logical. Some logical people are creative. Conclusion I: All engineers are creative. Conclusion II: Some engineers are creative.

A. Only I follows

B. Only II follows

C. Both I and II follow

D. Neither I nor II follows

Q25. A person walks 10 km North, then turns Right and walks 5 km, then turns Right again and walks 10 km. How far and in which direction is he from the starting point?

A. 5 km East

B. 5 km West

C. 10 km East

D. 10 km North

Q26. Six friends (A, B, C, D, E, F) are sitting in a circle facing the center. A is between B and C. D is between E and F. B and E are opposite each other. Who is sitting opposite to C?

A. A

B. D

C. F

D. Cannot be determined

Q27. Find the odd one out:

A. Copper

B. Zinc

C. Brass

D. Iron

Q28. If $A \times B$ means A is the mother of B; $A + B$ means A is the brother of B; $A - B$ means A is the sister of B. Which of the following shows that P is the maternal uncle of Q?

A. $P - M + N \times Q$

B. $P + S \times N - Q$

C. $P + M \times Q$

D. $Q - S \times P$

Q29. A clock is set right at 5 AM. The clock loses 16 minutes in 24 hours. What will be the true time when the clock indicates 10 PM on the 4th day?

A. 11 PM

B. 10:45 PM

C. 11:15 PM

D. 12 Midnight

Q30. The price of a commodity increases by 25%. By what percentage must a consumer reduce their consumption so that the expenditure remains the same?

A. 15%

B. 20%

C. 25%

D. 30%

Q31. The degrees of freedom for a pure substance at its triple point are:

A. 0

B. 1

C. 2

D. 3

Q32. For a reversible adiabatic process in an ideal gas, which relationship is correct?

A. $PV = \text{constant}$

B. $TP^{\frac{1-\gamma}{\gamma}} = \text{constant}$

C. $TV^{\gamma} = \text{constant}$

D. $P/T = \text{constant}$

Q33. The fugacity coefficient of an ideal gas is:

A. 0

B. 1

C. Infinity

D. Equal to its critical pressure

Q34. Raoult's law is strictly applicable to:

A. Ideal solutions

B. Non-ideal solutions with positive deviation

C. Non-ideal solutions with negative deviation

D. Immiscible liquid mixtures

Q35. The residual enthalpy H^R of a real gas at low pressure approaching zero is:

A. ∞

B. 0

C. H^{ig}

D. RT

Q36. For an azeotropic mixture, the relative volatility α is:

A. > 1

B. < 1

C. $= 1$

D. 0

Q37. The equation $dU = TdS - PdV$ is applicable to:

A. Reversible processes only

B. Irreversible processes only

C. Both reversible and irreversible processes

D. Isobaric processes only

Q38. At the critical point of a pure substance, the isothermal compressibility is:

A. Zero

B. Unity

C. Infinity

D. Negative

Q39. The terminal settling velocity of a spherical particle in the Stokes' law regime is proportional to:

A. Diameter D_p

B. D_p^2

C. $\sqrt{D_p}$

D. $1/D_p$

Q40. The friction factor for turbulent flow in a rough pipe depends on:

A. Reynolds number only

B. Relative roughness only

C. Both Reynolds number and relative roughness

D. Froude number

Q41. For a Bingham plastic fluid, the shear stress vs. shear rate curve:

A. Passes through the origin with a constant slope

B. Has a positive intercept on the shear stress axis

C. Curves upward from the origin

D. Curves downward from the origin

Q42. The NPSH (Net Positive Suction Head) requirement for a centrifugal pump is necessary to avoid:

A. Water hammer

B. Cavitation

C. Slip

D. Priming

Q43. In a packed bed, the pressure drop per unit length predicted by the Ergun equation at very high Reynolds numbers depends primarily on:

A. Viscous forces

B. Inertial forces

C. Surface tension

D. Gravity forces

Q44. For measuring the flow rate of a highly viscous liquid, which flow meter is most suitable?

A. Orifice meter

B. Venturi meter

C. Rotameter

D. Nutating disc meter

Q45. A pitot tube measures:

A. Average velocity

B. Local point velocity

C. Mass flow rate

D. Static pressure only

Q46. Kinematic viscosity is defined as the ratio of:

A. Dynamic viscosity to density

B. Density to dynamic viscosity

C. Dynamic viscosity to pressure

D. Shear stress to shear rate

Q47. In steady-state heat conduction through a hollow cylinder, the temperature profile with respect to the radius r is:

A. Linear

B. Parabolic

C. Logarithmic

D. Exponential

Q48. The Nusselt number is the ratio of:

A. Momentum diffusivity to thermal diffusivity

B. Convective heat transfer to conductive heat transfer

C. Kinematic viscosity to thermal diffusivity

D. Buoyancy forces to viscous forces

Q49. For a highly reflective surface, the emissivity ϵ is:

A. Close to 1

B. Close to 0

C. Exactly 0.5

D. Dependent on the convection coefficient

Q50. In a double-pipe heat exchanger, if the heat capacities of the hot and cold fluids are equal, the temperature profiles in a counter-current flow arrangement are:

A. Diverging straight lines

B. Converging straight lines

C. Parallel straight lines

D. Exponential curves

Q51. The view factor F_{12} from an infinitely long cylinder (Surface 1) to a concentric outer cylinder (Surface 2) is:

A. > 1

B. < 1

C. 0

D. 1

Q52. Boiling heat transfer reaches a local maximum flux known as the:

A. Leidenfrost point

B. Critical heat flux (Burnout point)

C. Nucleate boiling threshold

D. Film boiling minimum

Q53. According to lumped capacitance analysis, the temperature response of a solid cooling in a fluid is:

A. Linear

B. Sinusoidal

C. Exponential

D. Step-wise

Q54. Fick's first law of diffusion states that the mass flux is proportional to the:

A. Concentration

B. Concentration gradient

C. Temperature gradient

D. Velocity gradient

Q55. In gas absorption, if the chemical reaction in the liquid phase is infinitely fast, the mass transfer is controlled by:

A. Gas phase resistance

B. Liquid phase resistance

C. Both gas and liquid phase resistance

D. Equilibrium constant alone

Q56. McCabe-Thiele method for distillation assumes:

A. Constant relative volatility

B. Constant molal overflow

C. Ideal gas behavior

D. Infinite number of stages

Q57. The minimum reflux ratio in a continuous distillation column corresponds to:

A. Minimum number of trays

B. Infinite number of trays

C. Zero distillate rate

D. Maximum condenser duty

Q58. In liquid-liquid extraction, the solvent selectively dissolves the:

A. Diluent

B. Solute

C. Extract

D. Raffinate

Q59. The psychrometric chart graphically represents the properties of:

A. Pure water

B. Pure air

C. Air-water vapor mixtures

D. Binary liquid mixtures

Q60. In drying, the constant rate period ends at the:

A. Equilibrium moisture content

B. Critical moisture content

C. Free moisture content

D. Bound moisture content

Q61. The HTU (Height of a Transfer Unit) in a packed absorption tower is a measure of:

A. Separation driving force

B. Efficiency of separation

C. Ease of separation (mass transfer coefficient)

D. Column diameter

Q62. For a first-order chemical reaction, the plot of $\ln(C_A)$ versus time yields a straight line with a slope equal to:

A. k

B. $-k$

C. $1/k$

D. $-1/k$

Q63. The conversion in a CSTR for a first-order reaction $A \rightarrow$ Products is given by (Da is Damköhler number):

A. $\frac{Da}{1+Da}$

B. $1 - e^{-Da}$

C. $\frac{1}{1+Da}$

D. e^{-Da}

Q64. To maximize the selectivity of a desired product R in parallel reactions where the desired reaction has a higher activation energy than the undesired reaction, one should:

A. Operate at a low temperature

B. Operate at a high temperature

C. Decrease the reactant concentration

D. Use a CSTR instead of a PFR

Q65. For a zero-order reaction, the half-life is:

A. Independent of initial concentration

B. Directly proportional to initial concentration

C. Inversely proportional to initial concentration

D. Proportional to the square of initial concentration

Q66. A series combination of an infinite number of equal-sized CSTRs behaves like a:

A. Single large CSTR

B. Plug Flow Reactor (PFR)

C. Batch reactor

D. Fluidized bed reactor

Q67. The Thiele modulus for a porous catalyst pellet relates:

A. Internal diffusion rate to chemical reaction rate

B. External mass transfer to chemical reaction rate

C. Heat transfer rate to chemical reaction rate

D. Viscous forces to inertial forces

Q68. In non-ideal flow, the variance of the E-curve (residence time distribution) for a perfect Plug Flow Reactor is:

A. 1

B. ∞

C. 0

D. Equal to the mean residence time

Q69. For an elementary reaction $2A + B \rightarrow C$, the overall order of the reaction is:

A. 1

B. 2

C. 3

D. 0

Q70. The Laplace transform of a unit step function $U(t)$ is:

A. 1

B. $1/s$

C. $1/s^2$

D. s

Q71. A first-order system has a transfer function $G(s) = \frac{K}{\tau s+1}$. The time constant is:

A. K

B. τ

C. $1/\tau$

D. K/τ

Q72. In a PID controller, the integral action is primarily used to:

A. Increase the speed of response

B. Decrease the offset to zero

C. Reduce the overshoot

D. Increase the stability margin

Q73. The roots of the characteristic equation of a stable closed-loop system must lie in the:

A. Right half of the complex plane

B. Left half of the complex plane

C. On the imaginary axis

D. On the real axis only

Q74. Bode diagrams consist of plots of:

A. Amplitude ratio and phase angle vs. linear frequency

B. Log amplitude ratio and phase angle vs. log frequency

C. Real vs. Imaginary parts of the transfer function

D. Gain margin vs. Phase margin

Q75. Which control strategy measures the disturbances and takes corrective action before it affects the controlled variable?

A. Feedback control

B. Feedforward control

C. Cascade control

D. Ratio control

Q76. The tuning of a controller using the Ziegler-Nichols continuous cycling method requires determining the:

A. Ultimate gain and ultimate period

B. Process time constant and dead time

C. Phase margin and gain margin

D. Damping ratio and natural frequency

Q77. In size reduction equipment, the law stating that the energy required is proportional to the new surface area created is:

A. Kick's law

B. Rittinger's law

C. Bond's law

D. Hooke's law

Q78. The sphericity of a perfect cube is:

A. 1

B. 0.806

C. 0.625

D. 0.5

Q79. A hydrocyclone separates solid particles based primarily on:

A. Magnetic susceptibility

B. Density and size using centrifugal force

C. Electrical conductivity

D. Surface tension differences

Q80. In plant economics, the term "depreciation" refers to:

A. The increase in the value of an asset

B. The operating cost of a plant

C. The decrease in the value of an asset over time

D. The interest paid on a loan

Q81. If an investment of 100,000 yields a net annual cash flow of 25,000, the payback period is:

A. 2 years

B. 3 years

C. 4 years

D. 5 years

Q82. The six-tenths factor rule is used for estimating:

A. Operating costs

B. Equipment costs based on capacity

C. Working capital

D. Depreciation

Q83. Break-even point is the production rate at which:

A. Total revenue equals fixed costs

B. Total revenue equals variable costs

C. Total revenue equals total costs

D. Profit is maximized

Q84. In the contact process for sulfuric acid production, the catalyst used for the oxidation of SO_2 to SO_3 is:

A. Iron oxide

B. Vanadium pentoxide (V_2O_5)

C. Platinum

D. Nickel

Q85. The primary raw materials for the Solvay process used to manufacture Sodium Carbonate are:

A. Ammonia, brine, and limestone

B. Sodium hydroxide and carbon dioxide

C. Sodium chloride and sulfuric acid

D. Sodium sulfate and coal

Q86. In petroleum refining, the process of converting heavy, high-boiling fractions into lighter, more valuable products is called:

A. Alkylation

B. Isomerization

C. Cracking

D. Reforming

Q87. The Ziegler-Natta catalyst is primarily used in the industrial production of:

A. Ammonia

B. Polyethylene / Polypropylene

C. Sulfuric acid

D. Nitric acid

Q88. The Kraft process is associated with the production of:

A. Sugar

B. Cement

C. Pulp and paper

D. Glass

Q89. In industrial safety, a BLEVE refers to:

A. Biological Leakage and Evacuation of Viral Entities

B. Boiling Liquid Expanding Vapor Explosion

C. Baseline Limit for Environmental Vapor Emission

D. Burn Limit of Exhaust Valve Emissions

Q90. Which of the following greenhouse gases has the highest global warming potential (GWP) per molecule?

A. Carbon dioxide (CO_2)

B. Methane (CH_4)

C. Sulfur hexafluoride (SF_6)

D. Nitrous oxide (N_2O)

Solutions

1. B
Explanation: For a real orthogonal matrix with determinant +1, the product of its eigenvalues must be +1. Since it is orthogonal, complex roots occur in conjugate pairs, forcing at least one eigenvalue to be strictly 1.

2. B
Explanation: The matrix satisfies $M^3 = M$, which factors to $M(M-1)(M+1) = 0$. The eigenvalues must satisfy this same polynomial equation, yielding possible values of 0, 1, or -1.

3. A
Explanation: Using the Taylor series expansion for $\sin x \approx x - x^3/6$, the expression simplifies to $(x - (x - x^3/6))/x^3$, which evaluates exactly to $1/6$.

4. B
Explanation: Setting the first partial derivatives to zero yields critical points at (0,0) and (1,1). The second derivative test ($rt - s^2 > 0$ and $r > 0$) confirms a local minimum occurs at (1,1).

5. D
Explanation: Applying Green's theorem, $\oint_C (Pdx + Qdy) = \iint_D (\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y})dA = \iint_D (-1 - 1)dA = -2 \times$ Area. The circle's area is 4π, yielding -8π.

6. A
Explanation: This is a linear first-order differential equation. The integrating factor is $e^{\int \tan x dx} = e^{\ln \sec x} = \sec x$. Multiplying through and integrating gives $y \sec x = \tan x + C$.

7. A
Explanation: The Laplace transform of $\sin(2t)$ is $2/(s^2+4)$. Multiplying by t corresponds to taking the negative derivative with respect to s, yielding $4s/(s^2+4)^2$.

8. B
Explanation: Writing the ODE in standard form gives $p(x) = 1/x$ and $q(x) = (1 - n^2/x^2)$. Both $xp(x)$ and $x^2q(x)$ are analytic at $x = 0$, making it a regular singular point.

9. A
Explanation: Using the Cauchy-Riemann equations, $v_y = u_x = 2x$ and $v_x = -u_y = 2y$. Integrating these partial derivatives yields the harmonic conjugate $v(x, y) = 2xy + C$.

10. B
Explanation: The function has a simple pole at $z = 1$. The residue is calculated by evaluating the limit as $z \to 1$ of $(z - 1)f(z)$, which yields $1^2/(1 - 2) = -1$.

11. B
Explanation: The total number of outcomes is 8. The condition "at least one head" removes the TTT outcome, leaving a sample space of 7. Exactly two heads occur in 3 of these outcomes, giving 3/7.

12. B

Explanation: For a Poisson distribution, $P(X = x) = e^{-\lambda}\lambda^x/x!$. Equating the probabilities for $x = 1$ and $x = 2$ gives $\lambda = \lambda^2/2$, meaning the mean $\lambda = 2$.

13. A
Explanation: Finding the square root of R equates to finding the root of $f(x) = x^2 - R = 0$. Applying the Newton-Raphson formula $x_{n+1} = x_n - f(x_n)/f'(x_n)$ simplifies to $x_{n+1} = \frac{1}{2}(x_n + R/x_n)$.

14. C
Explanation: Simpson's 1/3 rule models the integrand as a parabola, but due to error cancellation in symmetrical integration bounds, its error term involves the fourth derivative, making it exact up to cubic polynomials.

15. C
Explanation: The classic Runge-Kutta method (often abbreviated as RK4) evaluates the function at four intermediate points per step to provide fourth-order accuracy for initial value problems.

16. B
Explanation: Assuming the intended function $f(x, y, z) = x^2 + y^2z$, the gradient at (1,1,1) is $(2, 2, 1)$. The dot product with the unit directional vector $(1/\sqrt{3}, 1/\sqrt{3}, 1/\sqrt{3})$ yields $5/\sqrt{3}$.

17. C
Explanation: The solid is a tetrahedron situated in the first octant. Its volume can be computed via the integral $\int_0^1 \int_0^{1-x}(1 - x - y)dydx$, which evaluates to 1/6.

18. B
Explanation: This represents a standard linear first-order differential equation. The integrating factor is calculated as $e^{\int \frac{2}{x}dx} = e^{2\ln x} = x^2$.

19. D
Explanation: Expanding $e^{1/z}$ using a Maclaurin series substituted with $1/z$ yields an infinite number of negative power terms in the Laurent series, indicating an essential singularity at $z = 0$.

20. B
Explanation: According to the Empirical (68-95-99.7) Rule for normal distributions, roughly 95.45% (most commonly rounded to 95%) of the area lies within two standard deviations of the mean.

21. B
Explanation: The sequence alternates between two increasing series: 7, 8, 9, ... and 10, 11, 12, ... The next logical number continuing the second alternating series is 10.

22. B
Explanation: "My father's son" translates to the speaker himself (since he has no siblings). Replacing the phrase, "that man's father is me," implies he is looking at a photograph of his son.

23. D
Explanation: The entire string is reversed, and the middle six letters are shifted forward by one in the alphabet (+1). "MEDICINE" reverses to "ENICIDEM" and shifting the middle letters yields "EOJDJEFM".

24. D
Explanation: Standard syllogism logic indicates that just because all engineers are logical, and some logical people are creative, there is no guaranteed intersection between engineers and creative people. Neither conclusion follows.

25. A
Explanation: The person moves 10 km North, turns East (right) for 5 km, and then turns South (right) for 10 km. The North and South movements cancel, leaving him exactly 5 km East of the start.

26. C
Explanation: Mapping the circle: A sits between B and C. If B is at position 1 and E is opposite at 4, D must be at 5 to sit between E(4) and F(6). This leaves C at 3, opposite F at 6.

27. C
Explanation: Copper, Zinc, and Iron are all pure, fundamental chemical elements found on the periodic table. Brass is the odd one out as it is an alloy.

28. C
Explanation: The expression $P + M \times Q$ translates to: P is the brother of M, and M is the mother of Q. This exact relationship establishes P as the maternal uncle of Q.

29. A
Explanation: The clock measures 24 hours for every 23 hours 44 minutes (1424/60 hours) of true time. Over the 89 apparent hours from 5 AM to 10 PM on the 4th day, exactly 90 true hours have passed, making it 11 PM.

30. B
Explanation: A 25% price increase raises the cost multiplier to 1.25. To keep expenditures constant, the new consumption must drop to $1/1.25 = 0.8$ of the original, a 20% reduction.

31. A
Explanation: The Gibbs phase rule states $F = C - P + 2$. For a pure single component ($C = 1$) existing simultaneously in three phases ($P = 3$) at the triple point, $F = 1 - 3 + 2 = 0$.

32. B
Explanation: For a reversible adiabatic process in an ideal gas, $PV^{\gamma} = C$. Substituting $V = RT/P$ from the ideal gas law simplifies the expression to $TP^{(1-\gamma)/\gamma} =$ constant.

33. B
Explanation: Fugacity acts as an effective pressure correcting for non-ideal behavior. For an ideal gas, actual pressure perfectly represents thermodynamic activity, making the fugacity coefficient (f/P) exactly 1.

34. A
Explanation: Raoult's law assumes uniform intermolecular forces between identical and dissimilar molecules alike, which serves as the precise thermodynamic definition of an ideal solution.

35. B

Explanation: A residual property is the difference between a real gas property and its ideal gas state at the same temperature and pressure. As pressure nears zero, real gases behave ideally, so $H^R \to 0$.

36. C

Explanation: At an azeotropic point, the liquid phase composition is identical to the vapor phase composition ($x_i = y_i$). Consequently, the relative volatility $\alpha = (y_A/x_A)/(y_B/x_B)$ precisely equals 1.

37. C

Explanation: The fundamental equation $dU = TdS - PdV$ relies entirely on thermodynamic state variables. Therefore, it holds true for any process (reversible or irreversible) connecting equilibrium states.

38. C

Explanation: Isothermal compressibility is defined as $\kappa = -1/V(\partial V/\partial P)_T$. At the critical point, the isotherm becomes horizontal ($(\partial P/\partial V)_T = 0$), causing κ to approach infinity.

39. B

Explanation: Stokes' law dictates that the terminal settling velocity of a particle is $v_t = D_p^2 g(\rho_p - \rho)/(18\mu)$, confirming it scales with the square of the particle diameter D_p^2.

40. C

Explanation: According to the Moody chart, the friction factor for turbulent fluid flow through a rough pipe is a function of both the Reynolds number and the relative roughness of the pipe.

41. B

Explanation: A Bingham plastic behaves as a rigid body at low stresses and requires a minimum yield stress to initiate flow, resulting in a positive intercept on the shear stress axis.

42. B

Explanation: Maintaining the required Net Positive Suction Head (NPSH) ensures that localized fluid pressure never drops below the vapor pressure, preventing the formation and destructive collapse of cavitation bubbles.

43. B

Explanation: The Ergun equation models pressure drop through a packed bed. At very high Reynolds numbers, the viscous forces become negligible, and inertial forces (the Burke-Plummer term) dominate.

44. D

Explanation: A nutating disc meter is a type of positive displacement flow meter. It traps fixed volumes of fluid and handles highly viscous liquids effectively without the severe pressure drops seen in dynamic meters.

45. B

Explanation: A Pitot tube functions by measuring the difference between the stagnation pressure and static pressure to calculate the highly localized point velocity of the fluid stream.

46. A

Explanation: Kinematic viscosity (ν) represents a fluid's inherent resistance to flow under its own weight and is mathematically defined as the ratio of dynamic viscosity (μ) to fluid density (ρ).

47. C
Explanation: Integrating Fourier's law of heat conduction in cylindrical coordinates for a steady state 1D process yields $T(r) = C_1 \ln(r) + C_2$, producing a logarithmic temperature profile.

48. B
Explanation: The Nusselt number ($Nu = hL/k$) is a dimensionless parameter representing the ratio of actual convective heat transfer to the hypothetical conductive heat transfer across the same fluid layer.

49. B
Explanation: A highly reflective surface has a high reflectivity ($\rho \approx 1$), meaning its absorptivity (α) is near zero. By Kirchhoff's law of thermal radiation, emissivity (ϵ) equals absorptivity, so $\epsilon \approx 0$.

50. C
Explanation: When the heat capacity rates ($\dot{m}C_p$) of both fluids in a countercurrent exchanger match exactly, the temperature difference between them remains constant, creating parallel linear profiles.

51. D
Explanation: The view factor F_{12} is the fraction of radiation leaving surface 1 that strikes surface 2. Since an inner cylinder is fully enveloped by the outer concentric cylinder, all its radiation hits surface 2 ($F_{12} = 1$).

52. B
Explanation: The critical heat flux, commonly called the burnout point, marks the local maximum flux on the boiling curve before the sudden formation of an insulating vapor film triggers a dangerous temperature spike.

53. C
Explanation: The lumped capacitance method assumes uniform internal temperature. The transient energy balance solves to $T(t) - T_\infty = (T_i - T_\infty)e^{-t/\tau}$, reflecting an exponential decay.

54. B
Explanation: Fick's first law defines steady-state mass transfer, establishing that the diffusive mass flux is directly and linearly proportional to the localized concentration gradient.

55. A
Explanation: When a chemical reaction in the liquid phase is infinitely fast, the dissolved solute is consumed instantaneously at the phase interface. This eliminates liquid resistance, making the process purely gas-phase controlled.

56. B
Explanation: The McCabe-Thiele method's core simplifying assumption is Constant Molal Overflow (CMO), meaning molar latent heats are equal and molar flow rates remain constant within any given column section.

57. B

Explanation: Operating a continuous distillation column at the minimum reflux ratio creates a pinch point where the operating line touches the equilibrium curve, mathematically requiring an infinite number of trays to achieve the separation.

58. B
Explanation: In liquid-liquid extraction, a selected solvent is added to contact the feed solution, where it preferentially and selectively dissolves the target component known as the solute.

59. C
Explanation: A psychrometric chart graphically relates the thermodynamic parameters—such as dry-bulb temperature, humidity ratio, and enthalpy—specifically for air-water vapor mixtures at constant atmospheric pressure.

60. B
Explanation: The constant rate drying period depends on the surface remaining saturated with unbound moisture. It terminates exactly when the critical moisture content is reached, shifting mass transfer resistance into the solid.

61. C
Explanation: The Height of a Transfer Unit (HTU) physically characterizes the efficiency and ease of the mass transfer process, functioning inversely to the magnitude of the mass transfer coefficient.

62. B
Explanation: The integrated rate equation for a first-order reaction is $\ln(C_A) = \ln(C_{A0}) - kt$. Plotting $\ln(C_A)$ on the y-axis against time t on the x-axis produces a straight line with a slope of $-k$.

63. A
Explanation: For a CSTR, the design equation gives space time $\tau = C_{A0}X/(kC_{A0}(1-X))$. Rearranging for conversion X yields $X = \tau k/(1+\tau k)$. Substituting $Da = \tau k$ results in $Da/(1+Da)$.

64. B
Explanation: The ratio of desired to undesired reaction rates scales with $e^{-(E_D-E_U)/RT}$. When the desired activation energy (E_D) is higher, operating at elevated temperatures disproportionately accelerates the desired reaction.

65. B
Explanation: The integrated zero-order rate law is $C_A = C_{A0} - kt$. Substituting $C_A = C_{A0}/2$ yields $t_{1/2} = C_{A0}/(2k)$, demonstrating that the half-life is directly proportional to initial concentration.

66. B
Explanation: As the number of Continuous Stirred Tank Reactors (CSTRs) placed in series approaches infinity, the mixing progressively localizes until the overall residence time distribution mirrors an ideal Plug Flow Reactor (PFR).

67. A
Explanation: The Thiele modulus is a dimensionless number used in heterogeneous catalysis. Its square represents the ratio of the intrinsic chemical reaction rate to the internal pore diffusion rate inside the catalyst pellet.

68. C

Explanation: In an ideal Plug Flow Reactor, all fluid elements travel with uniform velocity and exit precisely at the space time τ. The E-curve is a Dirac delta function, which means the variance (σ^2) is mathematically zero.

69. C
Explanation: For a fundamentally elementary reaction, the kinetic rate law mirrors the stoichiometric coefficients precisely. The rate equation $-r = k[A]^2[B]^1$ has an overall order of $2 + 1 = 3$.

70. B
Explanation: The mathematical definition of the Laplace transform applied to the Heaviside unit step function $U(t)$ requires computing the integral $\int_0^\infty 1 \cdot e^{-st} dt$, which evaluates straightforwardly to $1/s$.

71. B
Explanation: In process control standard nomenclature, a first-order transfer function takes the form $G(s) = K/(\tau s + 1)$, where K denotes the steady-state gain and τ represents the system's process time constant.

72. B
Explanation: The primary purpose of adding integral action to a PID controller is to continuously accumulate past error, forcing the controller output to shift until the steady-state offset is completely eliminated to zero.

73. B
Explanation: For a continuous dynamic system to be considered asymptotically stable, all roots (poles) of its closed-loop characteristic equation must have negative real parts, placing them in the left half of the complex s-plane.

74. B
Explanation: A standard Bode plot analyzes frequency response using two separate graphs: the logarithm of the amplitude ratio versus the log of frequency, and the phase angle shift versus the log of frequency.

75. B
Explanation: Feedforward control physically measures incoming load disturbances and preemptively adjusts the manipulated variable to compensate, effectively anticipating errors before the controlled variable can deviate from the setpoint.

76. A
Explanation: The Ziegler-Nichols continuous cycling method drives a closed-loop system to the brink of instability using purely proportional control to experimentally determine the ultimate gain (K_u) and ultimate oscillation period (P_u).

77. B
Explanation: Rittinger's size reduction law empirically models fine grinding processes, postulating that the mechanical work required is strictly proportional to the amount of new surface area generated.

78. B
Explanation: Sphericity divides the surface area of a volume-equivalent sphere by the actual particle's surface area. For a perfect cube, this geometric calculation evaluates precisely to $(\pi/6)^{1/3} \approx 0.806$.

79. B

Explanation: A hydrocyclone lacks moving parts and relies on tangentially induced, high-velocity swirling fluid motion to separate suspended solid particles fundamentally based on their distinct densities and sizes via centrifugal force.

80. C
Explanation: In accounting and plant economics, depreciation is the method of systematically allocating the cost of a tangible asset over its useful life, reflecting its decrease in functional value over time.

81. C
Explanation: Ignoring the time value of money, the simple payback period is calculated by dividing the initial capital investment by the net annual cash flow. Thus, 100,000 / 25,000 results in precisely 4 years.

82. B
Explanation: The six-tenths factor rule is an empirical heuristic utilized in chemical plant economics to estimate the total cost of scaling up process equipment based purely on its capacity ratio ($C \propto Q^{0.6}$).

83. C
Explanation: The break-even point is the precise production capacity at which a plant's total sales revenue exactly matches its total operational expenses (the sum of both fixed and variable costs), yielding zero net profit.

84. B
Explanation: In the modern industrial contact process for manufacturing sulfuric acid, solid Vanadium pentoxide (V_2O_5) serves as the highly effective commercial catalyst required to reliably oxidize SO_2 gas into SO_3.

85. A
Explanation: The globally dominant Solvay process synthesizes sodium carbonate (soda ash) utilizing three primary, inexpensive raw materials: ammonia, concentrated sodium chloride brine, and calcium carbonate limestone.

86. C
Explanation: Cracking is the fundamental refinery operation that utilizes intense thermal heat or catalytic reactions to sever large carbon-carbon bonds, converting heavy, viscous oil fractions into lighter, high-demand fuels like gasoline.

87. B
Explanation: Ziegler-Natta catalysts are uniquely engineered, stereospecific organometallic compounds universally utilized to polymerize simple terminal alkenes into crucial industrial plastics like high-density polyethylene and polypropylene.

88. C
Explanation: The Kraft process, also known as the sulfate process, is the world's predominant chemical pulping technology designed to separate structural lignin from cellulose fibers specifically for mass pulp and paper manufacturing.

89. B
Explanation: In chemical process safety, a BLEVE stands for Boiling Liquid Expanding Vapor Explosion, an incredibly destructive hazard occurring when a sealed vessel containing a pressurized liquid above its natural boiling point catastrophically ruptures.

90. C

Explanation: Although trace amounts exist, Sulfur hexafluoride (SF_6) is noted for having an exceptionally severe 100-year Global Warming Potential, absorbing heat over 23,500 times more effectively than carbon dioxide on a per-molecule basis.