

PRACTICE EXAM 14: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. What is the general solution of the first-order equation $y' + 2y = 0$?
 - A. $y = Ce^{(2x)}$
 - B. $y = C \cdot \cos(2x)$
 - C. $y = Cx^{-2}$
 - D. $y = Ce^{(-2x)}$

2. Evaluate the definite integral of $2x$ from $x = 0$ to $x = 3$.
 - A. 3
 - B. 6
 - C. 9
 - D. 18

3. Two matrices can be multiplied when the number of columns of the first equals the number of:
 - A. Columns of the second
 - B. Rows of the first
 - C. Rows of the second
 - D. Total elements

4. What is the derivative of $\tan(x)$ with respect to x ?

- A. $\sec^2(x)$
- B. $-\csc^2(x)$
- C. $\cot(x)$
- D. $\sec(x)\tan(x)$

5. Evaluate the limit of $(e^x - 1)/x$ as x approaches 0.

- A. 1
- B. 0
- C. e
- D. Infinity

6. The cross product of two vectors produces a vector that is:

- A. Parallel to both
- B. Of zero length
- C. In the plane of both
- D. Perpendicular to both

Probability and Statistics

7. Two fair dice are rolled. What is the probability that the sum equals 7?

- A. 0.50
- B. 0.028
- C. 0.083
- D. 0.167

8. What is the mode of the data set 3, 5, 5, 7, and 9?

- A. 7
- B. 5
- C. 5.8
- D. 9

9. In how many distinct orders can 5 different items be arranged?

- A. 25
- B. 20
- C. 60
- D. 120

10. A normal distribution is fully specified by its:

- A. Mean and standard deviation
- B. Median alone
- C. Range only
- D. Mode and range

11. Given $P(A \cap B) = 0.2$ and $P(B) = 0.5$, what is the conditional probability $P(A|B)$?

- A. 0.4
- B. 0.1
- C. 0.7
- D. 2.5

Engineering Sciences

12. What is the momentum of a 5 kg mass moving at 8 m/s?

- A. 0.625 kg·m/s
- B. 13 kg·m/s
- C. 40 kg·m/s
- D. 1.6 kg·m/s

13. What power is dissipated in a 6 Ω resistor across a 12 V supply, using $P = V^2/R$?

- A. 2 W
- B. 72 W
- C. 144 W
- D. 24 W

14. What is the potential energy of a 10 kg mass raised 5 m ($g = 9.81 \text{ m/s}^2$)?

- A. 50 J
- B. 490.5 J
- C. 98.1 J
- D. 5000 J

15. What charge passes a point when a current of 3 A flows for 4 seconds?

- A. 12 C
- B. 0.75 C
- C. 7 C

D. 1.33 C

Materials Science

16. The resistance of a material to localised plastic deformation such as indentation is its:

- A. Toughness
- B. Hardness
- C. Ductility
- D. Density

17. Annealing a metal generally:

- A. Increases its hardness sharply
- B. Softens it and relieves internal stress
- C. Makes it brittle
- D. Raises its melting point

18. The rate of atomic diffusion in a solid increases:

- A. Exponentially with temperature
- B. Linearly with pressure
- C. Only at the melting point
- D. Inversely with temperature

19. In a galvanic couple, the more active metal becomes the:

- A. Cathode and is protected

- B. Anode and corrodes preferentially
- C. Inert electrode
- D. Insulator

20. Compared with metals, ceramics are generally:

- A. Soft and ductile
- B. Good electrical conductors
- C. Low-melting and elastic
- D. Hard and brittle with high melting points

Chemistry and Biology

21. An aqueous solution has a hydroxide concentration of 1×10^{-3} mol/L. What is its pH?

- A. 11
- B. 3
- C. 7
- D. 1×10^{-3}

22. What is the molar mass of sodium chloride, NaCl?

- A. 58.5 g/mol
- B. 23 g/mol
- C. 35.5 g/mol
- D. 40 g/mol

23. How many moles of ideal gas occupy 0.02 m^3 at 200 kPa and 300 K ($R = 8.314 \text{ J/mol}\cdot\text{K}$)?

- A. 0.8 mol
- B. 3.2 mol
- C. 1.6 mol
- D. 8 mol

24. Increasing the pressure on the equilibrium $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$ shifts it toward:

- A. The reactant side
- B. No net change
- C. The side with more moles
- D. The side with fewer moles of gas

25. For $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ with excess hydrogen, how many moles of water form from 5 mol of oxygen?

- A. 5 mol
- B. 10 mol
- C. 2.5 mol
- D. 20 mol

26. In most of its compounds, the oxidation state of hydrogen is:

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

27. As a rough rule, a 10 °C rise in temperature:

- A. Halves the reaction rate
- B. Has no effect on the rate
- C. Doubles the reaction rate
- D. Always quadruples the rate

28. Enzymes function biologically as:

- A. Energy sources
- B. Catalysts that lower activation energy
- C. Structural fibres
- D. Genetic codes

Fluid Mechanics

29. A fluid (density 800 kg/m^3 , viscosity $0.04 \text{ Pa}\cdot\text{s}$) flows at 2 m/s through a 0.05 m pipe. What is the Reynolds number?

- A. 200
- B. 2000
- C. 20000
- D. 400

30. Flow at 3 m/s in a 0.09 m^2 duct enters a 0.03 m^2 section. What is the velocity in the smaller section?

- A. 1 m/s
- B. 3 m/s
- C. 9 m/s
- D. 6 m/s

31. Bernoulli's equation applies strictly only to flow that is:

- A. Turbulent and compressible
- B. Unsteady with friction
- C. Any real pipe flow
- D. Steady, incompressible, and frictionless

32. What is the hydrostatic pressure at a depth of 2.5 m in water (density 1000 kg/m^3)?

- A. 2.5 kPa
- B. 24.5 kPa
- C. 245 kPa
- D. 2.45 kPa

33. For laminar pipe flow at a Reynolds number of 200, what is the Darcy friction factor?

- A. 64
- B. 3.2
- C. 0.032
- D. 0.32

34. A pump delivers $0.1 \text{ m}^3/\text{s}$ of water against a head of 10 m. What is the ideal hydraulic power?

- A. 9.81 kW
- B. 0.98 kW
- C. 98 kW
- D. 981 W

35. A flow of $1.2 \text{ m}^3/\text{s}$ passes through a duct of cross-sectional area 0.3 m^2 . What is the velocity?

- A. 4 m/s
- B. 0.25 m/s
- C. 0.36 m/s
- D. 40 m/s

36. Using the Darcy equation with $f = 0.02$, $L = 50 \text{ m}$, $D = 0.1 \text{ m}$, and $v = 3 \text{ m/s}$, what is the head loss?

- A. 2.29 m
- B. 4.59 m
- C. 9.18 m
- D. 1.15 m

37. Flow in which fluid particles move in smooth, parallel layers is described as:

- A. Turbulent
- B. Transitional
- C. Supersonic
- D. Laminar

Thermodynamics

38. A Carnot engine operates between 600 K and 300 K. What is its maximum efficiency?

- A. 25%
- B. 75%
- C. 40%

D. 50%

39. Three moles of an ideal gas ($C_p = 30 \text{ J/mol}\cdot\text{K}$) are heated by 20 K at constant pressure. What is the enthalpy change?

A. 900 J

B. 1800 J

C. 600 J

D. 3600 J

40. A closed system has its internal energy raised by 400 J while doing 150 J of work. How much heat was added?

A. 250 J

B. 400 J

C. 550 J

D. 150 J

41. Steam enters an adiabatic turbine at 3200 kJ/kg and leaves at 2800 kJ/kg, flowing at 4 kg/s. What is the shaft power?

A. 1600 kW

B. 800 kW

C. 400 kW

D. 3200 kW

42. A heat pump delivers 800 W of heat while consuming 200 W of work. What is its heating coefficient of performance?

A. 4

- B. 3
- C. 0.25
- D. 5

43. An equimolar liquid mixture of A (pure vapour pressure 120 kPa) and B (80 kPa) follows Raoult's law. What is the bubble-point pressure?

- A. 80 kPa
- B. 120 kPa
- C. 200 kPa
- D. 100 kPa

44. The entropy of a perfect crystal at absolute zero is:

- A. Infinite
- B. Zero
- C. Maximum
- D. Equal to its enthalpy

45. A process with no heat transfer to or from the surroundings is described as:

- A. Adiabatic
- B. Isothermal
- C. Isobaric
- D. Isochoric

46. A reaction is spontaneous when its Gibbs free energy change is:

- A. Positive

- B. Zero
- C. Negative
- D. Equal to the enthalpy

Material and Energy Balances

47. A 1000 kg/h feed is separated into a 350 kg/h vapour stream and a liquid stream. What is the liquid flow rate?

- A. 1350 kg/h
- B. 650 kg/h
- C. 350 kg/h
- D. 1000 kg/h

48. An evaporator concentrates 800 kg/h of a 10% solids feed to a 40% solids product. What is the product flow rate?

- A. 600 kg/h
- B. 80 kg/h
- C. 200 kg/h
- D. 320 kg/h

49. Complete combustion of methane follows $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$. How many moles of oxygen are needed for 6 mol of methane?

- A. 6 mol
- B. 3 mol
- C. 18 mol
- D. 12 mol

50. A 150 kg stream of 20% salt is mixed with a 50 kg stream of 60% salt. What is the salt content of the mixture?

- A. 20%
- B. 40%
- C. 30%
- D. 60%

51. A reactor is fed 400 mol of A, of which 100 mol leaves unreacted. What is the conversion?

- A. 25%
- B. 100%
- C. 75%
- D. 100 mol

52. A process recycles 300 mol/h and receives a fresh feed of 150 mol/h. What is the recycle ratio?

- A. 0.5
- B. 2
- C. 450
- D. 1

53. How much heat is required to raise 50 kg of oil by 30 °C, with a specific heat of 2.0 kJ/kg·K?

- A. 750 kJ
- B. 1500 kJ
- C. 3000 kJ
- D. 6000 kJ

54. A solid has a moisture content of 20% on a wet basis. What is the equivalent moisture content on a dry basis?

- A. 20%
- B. 16.7%
- C. 25%
- D. 80%

55. In the reaction $A \rightarrow 2B$, 7 mol of A reacts completely. How many moles of B are formed?

- A. 7 mol
- B. 3.5 mol
- C. 21 mol
- D. 14 mol

56. A burner needs 8 mol of oxygen stoichiometrically but is supplied with 10 mol. What is the percentage excess oxygen?

- A. 20%
- B. 80%
- C. 25%
- D. 125%

57. In a material balance, a tie component is one that:

- A. Reacts completely
- B. Passes unchanged from one stream to another
- C. Is always water
- D. Is the limiting reactant

Heat Transfer

58. A 0.2 m thick wall ($k = 2 \text{ W/m}\cdot\text{K}$, area 5 m^2) has a $40 \text{ }^\circ\text{C}$ temperature difference across it. What is the conductive heat rate?

- A. 200 W
- B. 400 W
- C. 800 W
- D. 2000 W

59. A 4 m^2 surface transfers 2400 W by convection with a temperature difference of $30 \text{ }^\circ\text{C}$. What is the convective heat-transfer coefficient?

- A. $80 \text{ W/m}^2\cdot\text{K}$
- B. $200 \text{ W/m}^2\cdot\text{K}$
- C. $5 \text{ W/m}^2\cdot\text{K}$
- D. $20 \text{ W/m}^2\cdot\text{K}$

60. If the absolute temperature of a radiating surface is doubled, by what factor does its emissive power increase?

- A. $4\times$
- B. $16\times$
- C. $8\times$
- D. $2\times$

61. In a counter-current exchanger, the hot stream cools from $100 \text{ }^\circ\text{C}$ to $60 \text{ }^\circ\text{C}$ while the cold stream warms from $30 \text{ }^\circ\text{C}$ to $50 \text{ }^\circ\text{C}$. What is the log-mean temperature difference?

- A. $40 \text{ }^\circ\text{C}$

- B. 35 °C
- C. 39.2 °C
- D. 45 °C

62. Two wall layers have thermal resistances of 0.2 K/W and 0.3 K/W in series. What is the total resistance?

- A. 0.06 K/W
- B. 0.5 K/W
- C. 1.0 K/W
- D. 0.1 K/W

63. Two convective films, each 400 W/m²·K, act in series with negligible wall resistance. What is the overall coefficient U?

- A. 200 W/m²·K
- B. 400 W/m²·K
- C. 800 W/m²·K
- D. 100 W/m²·K

64. An exchanger has $U = 150 \text{ W/m}^2\cdot\text{K}$, area 8 m², and a log-mean temperature difference of 30 °C. What is the heat duty?

- A. 36 kW
- B. 18 kW
- C. 72 kW
- D. 12 kW

65. A fin is attached to a surface in order to:

- A. Reduce the surface area
- B. Insulate the surface
- C. Lower the temperature gradient
- D. Increase the area for heat transfer

66. A perfect black body is defined as one that:

- A. Reflects all incident radiation
- B. Absorbs all incident radiation
- C. Transmits all incident radiation
- D. Emits no radiation

Mass Transfer and Separation

67. A species diffuses through a 2 mm film with $D = 4 \times 10^{-9} \text{ m}^2/\text{s}$ and a concentration difference of 15 mol/m^3 . What is the molar flux?

- A. $6 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- B. $1.5 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- C. $3 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- D. $3 \times 10^{-3} \text{ mol/m}^2 \cdot \text{s}$

68. For a relative volatility of 4, what vapour composition is in equilibrium with a liquid of mole fraction 0.3?

- A. 0.30
- B. 0.40
- C. 0.50
- D. 0.63

69. At minimum reflux, a distillation column requires:

- A. An infinite number of stages
- B. The fewest stages
- C. Zero stages
- D. No condenser

70. A solute with a distribution coefficient of 3 is contacted once with an equal volume of solvent. What fraction transfers to the extract?

- A. 0.50
- B. 0.67
- C. 0.75
- D. 0.25

71. A dilute absorber removes 95% of a solute, so $C_{in}/C_{out} = 20$. What is the number of transfer units, $NTU = \ln(C_{in}/C_{out})$?

- A. 0.95
- B. 20
- C. 3.0
- D. 1.0

72. A stripping operation transfers a solute from the:

- A. Solid to the liquid phase
- B. Gas to the solid phase
- C. Gas to the liquid phase
- D. Liquid phase to the gas phase

73. The driving force for mass transfer between two contacting phases is the departure from:

- A. Equilibrium
- B. Atmospheric pressure
- C. The boiling point
- D. The critical point

74. Reverse osmosis separates by forcing solvent through a membrane against:

- A. The osmotic pressure gradient
- B. Gravity alone
- C. A temperature gradient
- D. An applied electric field

75. Activated carbon removes dissolved contaminants chiefly by:

- A. Chemical neutralisation
- B. Evaporation
- C. Adsorption onto its porous surface
- D. Magnetic attraction

Solids Handling

76. A 100 μm particle ($\Delta\rho = 1500 \text{ kg/m}^3$) settles in a fluid of viscosity $1 \times 10^{-3} \text{ Pa}\cdot\text{s}$. What is its Stokes' law terminal velocity?

- A. $1.6 \times 10^{-2} \text{ m/s}$
- B. $4.1 \times 10^{-3} \text{ m/s}$
- C. $8.17 \times 10^{-3} \text{ m/s}$

D. 2.5×10^{-2} m/s

77. A free-flowing powder is characterised by a:

- A. High angle of repose
- B. Zero density
- C. High cohesion
- D. Low angle of repose

78. A cyclone separates particles from a gas stream using:

- A. An applied electric field
- B. A fine filter cloth
- C. Gravity settling alone
- D. Centrifugal force in a swirling flow

79. Bridging, or arching, in a storage hopper occurs when:

- A. The powder liquefies
- B. Particles interlock and block the outlet
- C. The hopper is overfilled
- D. The moisture evaporates

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.2 \text{ min}^{-1}$) starts at 4 mol/L. What is the concentration after 5 minutes, using $C = C_0 e^{-kt}$?

- A. 2.0 mol/L
- B. 0.74 mol/L

- C. 1.47 mol/L
- D. 0.37 mol/L

81. A first-order reaction ($k = 0.6 \text{ min}^{-1}$) runs in a PFR with a space time of 5 minutes. What conversion is achieved, using $X = 1 - e^{(-k\tau)}$?

- A. 0.63
- B. 0.78
- C. 0.86
- D. 0.95

82. A first-order reaction ($k = 0.5 \text{ min}^{-1}$) reaches 75% conversion in a CSTR. What space time is required?

- A. 3 min
- B. 6 min
- C. 12 min
- D. 1.5 min

83. For a second-order reaction, doubling the reactant concentration multiplies the rate by:

- A. 4
- B. 2
- C. 8
- D. 1

84. For the reversible reaction $A \rightleftharpoons B$, the forward rate constant is 20 and the reverse is 5. What is the equilibrium constant?

- A. 4

- B. 25
- C. 0.25
- D. 15

85. A catalyst increases a reaction rate chiefly by:

- A. Raising the temperature
- B. Increasing the reactant concentration
- C. Lowering the activation energy
- D. Removing the products

86. The mean residence time in a continuous reactor equals the:

- A. Flow rate divided by the volume
- B. Conversion multiplied by the volume
- C. Reactor volume divided by the volumetric flow rate
- D. Rate constant multiplied by the volume

Engineering Economics

87. What is the future worth of \$5,000 invested for 4 years at 8% interest ($1.08^4 = 1.3605$)?

- A. \$6,803
- B. \$5,400
- C. \$7,200
- D. \$8,100

88. What is the present worth of \$20,000 to be received in 4 years at 6% interest ($1.06^4 = 1.2625$)?

- A. \$15,842
- B. \$18,800
- C. \$20,000
- D. \$25,250

89. A \$60,000 asset with a \$6,000 salvage value is depreciated straight-line over 6 years. What is the annual depreciation?

- A. \$10,000
- B. \$9,000
- C. \$11,000
- D. \$54,000

90. A \$200,000 investment yields an annual profit of \$40,000. What is the simple return on investment?

- A. 20%
- B. 5%
- C. 50%
- D. 2%

Process Design

91. Which diagram shows the major equipment, process streams, and key operating conditions but not every individual instrument?

- A. The block flow diagram
- B. The plot plan
- C. The P&ID
- D. The process flow diagram

92. Increasing the reflux ratio in a distillation column:

- A. Reduces the number of stages required but raises energy cost
- B. Lowers both the number of stages and the energy cost
- C. Has no effect on the number of stages
- D. Eliminates the reboiler duty

93. Equipment that cost \$80,000 at a cost index of 600 is re-estimated at a current index of 900. What is the updated cost?

- A. \$120,000
- B. \$53,333
- C. \$80,000
- D. \$96,000

94. A design safety factor is applied in order to:

- A. Minimise the capital cost
- B. Reduce the operating temperature
- C. Simplify the drawings
- D. Allow for uncertainties and prevent undersizing

95. For the same conversion of a positive-order reaction, a plug-flow reactor generally requires:

- A. A larger volume than a single CSTR
- B. The same volume as a CSTR
- C. No reactor at all
- D. A smaller volume than a single CSTR

96. Warm cooling water is returned to a cooling tower in order to:

- A. Reject its absorbed heat to the atmosphere
- B. Be chemically purified only
- C. Raise its pressure
- D. Be converted into steam

97. A heat exchanger that recovers heat from a hot product stream to preheat the cold feed is called a:

- A. Trim cooler
- B. Fired heater
- C. Flash drum
- D. Feed-effluent (recuperative) exchanger

Process Control

98. Which controller mode acts to eliminate steady-state offset?

- A. Proportional action
- B. Integral action
- C. Derivative action
- D. On-off action

99. A thermocouple produces a small voltage that depends on:

- A. The line pressure
- B. The temperature difference between its junctions
- C. The flow rate

D. The pH

100. A feedforward controller works by:

- A. Responding only after an error appears
- B. Ignoring all disturbances
- C. Measuring a disturbance and correcting before it affects the output
- D. Switching fully on or fully off

101. The final control element in most process control loops is the:

- A. Control valve
- B. Transmitter
- C. Set point
- D. Sensor

Safety, Health, and Environment

102. The flash point of a liquid is the lowest temperature at which:

- A. It gives off enough vapour to form an ignitable mixture
- B. It boils completely
- C. It freezes
- D. It decomposes

103. A HAZOP study systematically applies:

- A. Cost rankings to each unit
- B. Guide words to process deviations

- C. Random sampling of streams
- D. Financial audits

104. The LD50 of a substance is the dose that is:

- A. Safe for everyone
- B. Detectable by smell
- C. Lethal to 50% of a test population
- D. The maximum legal exposure limit

105. A pressure relief valve must be sized for the:

- A. Normal operating flow only
- B. Minimum expected flow
- C. Average daily flow
- D. Worst-case relieving scenario

106. A scrubber is installed in a gas stream in order to:

- A. Raise the gas temperature
- B. Compress the gas
- C. Remove pollutants before discharge to the atmosphere
- D. Measure the flow rate

Ethics and Professional Practice

107. An engineer must keep a client's proprietary information confidential unless:

- A. A competitor requests it
- B. Disclosure is required to protect public safety
- C. It would increase profit
- D. The project is finished

108. Accepting an assignment outside one's area of competence is acceptable only when:

- A. The deadline is tight
- B. The engineer gains the needed qualification or associates with a qualified expert
- C. The fee is high
- D. No one else is available

109. When building on another engineer's work, one must:

- A. Claim it as original
- B. Ignore the source entirely
- C. Give proper credit and obtain permission where required
- D. Alter it to disguise the source

110. Sustainable design seeks to meet present needs while:

- A. Maximising short-term output
- B. Not compromising the ability of future generations to meet theirs
- C. Ignoring resource limits
- D. Minimising only the initial cost

Practice Exam 14 – Answer Key and Explanations

- 1. D** — Separating $dy/dx = -2y$ gives $y = Ce^{(-2x)}$, exponential decay proportional to the current value. The negative exponent reflects a quantity falling at a rate set by the constant 2.
- 2. C** — The antiderivative of $2x$ is x^2 , evaluated from 0 to 3 as $3^2 - 0 = 9$. Definite integration accumulates the area under the line.
- 3. C** — Matrix multiplication is defined only when the columns of the first matrix equal the rows of the second, so the inner dimensions match. The product then takes the outer dimensions.
- 4. A** — The derivative of $\tan(x)$ is $\sec^2(x)$. This standard result appears throughout the analysis of rates and trigonometric integrals.
- 5. A** — The limit of $(e^x - 1)/x$ as $x \rightarrow 0$ is 1, since the exponential's slope at the origin is 1. This underlies the linearisation of exponentials near zero.
- 6. D** — The cross product yields a vector perpendicular to the plane of the two original vectors, with direction given by the right-hand rule. This orthogonality defines torque and angular-momentum directions.
- 7. D** — Six of the 36 equally likely outcomes sum to 7, giving $6/36 = 0.167$. Seven is the most probable total for two dice.
- 8. B** — The mode is the most frequently occurring value, which is 5 (appearing twice). The mode identifies the data's most common observation.
- 9. D** — The number of arrangements of 5 distinct items is $5! = 120$. The factorial counts the orderings of all elements.
- 10. A** — A normal distribution is completely defined by its mean and standard deviation, which fix its centre and spread. All other properties follow from these two parameters.
- 11. A** — Conditional probability is $P(A \cap B)/P(B) = 0.2/0.5 = 0.4$. It rescales the joint probability to the reduced sample space of B.
- 12. C** — Momentum is mass times velocity, $5 \times 8 = 40$ kg·m/s. This quantity is conserved in collisions absent external forces.
- 13. D** — Power is $V^2/R = 12^2/6 = 144/6 = 24$ W. This form is convenient when the voltage across a resistor is known.
- 14. B** — Potential energy is $mgh = 10 \times 9.81 \times 5 = 490.5$ J. Raising a mass stores energy equal to the work done against gravity.

- 15. A** — Charge is current times time, $Q = It = 3 \times 4 = 12$ C. The coulomb measures the accumulated flow of charge.
- 16. B** — Hardness is the resistance of a material to localised plastic deformation such as indentation or scratching. It is measured by tests like Brinell and Rockwell and correlates with wear resistance.
- 17. B** — Annealing heats a metal and cools it slowly, softening it and relieving internal residual stresses. This restores ductility and improves workability after cold working.
- 18. A** — Atomic diffusion in solids follows an Arrhenius dependence, rising exponentially with temperature. Higher temperature gives atoms the energy to jump between lattice sites far more often.
- 19. B** — In a galvanic couple, the more active (less noble) metal becomes the anode and corrodes preferentially, protecting the more noble metal. This principle underlies sacrificial-anode protection.
- 20. D** — Ceramics are typically hard and brittle with high melting points, owing to their strong ionic and covalent bonds. They resist heat and wear but fracture without the plastic yielding seen in metals.
- 21. A** — With $[\text{OH}^-] = 10^{-3}$, the pOH is 3 and $\text{pH} = 14 - 3 = 11$. The pH and pOH always sum to 14 at 25 °C.
- 22. A** — Summing atomic masses, Na (23) + Cl (35.5) = 58.5 g/mol. Molar mass converts between mass and moles in stoichiometry.
- 23. C** — Rearranging the ideal gas law, $n = PV/RT = (200,000 \times 0.02)/(8.314 \times 300) = 4000/2494 = 1.6$ mol. The relation fixes the amount of gas from its state.
- 24. D** — By Le Chatelier's principle, raising the pressure shifts the equilibrium toward the side with fewer moles of gas, here the two moles of ammonia. The system relieves the pressure by reducing the total gas quantity.
- 25. B** — The one-to-two stoichiometry gives two moles of water per mole of oxygen, so 5 mol of oxygen yields 10 mol of water. Oxygen is the limiting reactant with hydrogen in excess.
- 26. D** — Hydrogen carries an oxidation state of +1 in most of its compounds, the exception being metal hydrides where it is -1. This consistent value aids in balancing redox reactions.
- 27. C** — As a useful rule of thumb, a 10 °C rise roughly doubles the reaction rate, reflecting the strong temperature dependence of the rate constant. This guides the choice of operating temperature.
- 28. B** — Enzymes are biological catalysts that lower the activation energy of cellular reactions, speeding them without being consumed. Their specificity lets cells control which reactions proceed.
- 29. B** — Reynolds number is $\rho vD/\mu = (800 \times 2 \times 0.05)/0.04 = 2000$. This value lies at the laminar-turbulent transition.

- 30. C** — Continuity gives $v_2 = v_1 A_1 / A_2 = 3 \times (0.09 / 0.03) = 9$ m/s. The threefold area reduction triples the velocity.
- 31. D** — Bernoulli's equation holds strictly only for steady, incompressible, frictionless flow along a streamline. Real flows require correction terms for friction and other losses.
- 32. B** — Hydrostatic pressure is $\rho g h = 1000 \times 9.81 \times 2.5 = 24,525$ Pa ≈ 24.5 kPa. Pressure rises linearly with depth.
- 33. D** — For laminar flow, the friction factor is $64 / \text{Re} = 64 / 200 = 0.32$. The inverse dependence on Reynolds number gives high friction at low flow.
- 34. A** — Ideal hydraulic power is $\rho g Q H = 1000 \times 9.81 \times 0.1 \times 10 = 9810$ W = 9.81 kW. Dividing by efficiency would give the shaft power.
- 35. A** — Velocity is flow over area, $1.2 / 0.3 = 4$ m/s. This follows directly from the continuity equation.
- 36. B** — The Darcy equation gives $h_f = f(L/D)(v^2/2g) = 0.02 \times (50/0.1) \times (9/19.62) = 4.59$ m. Friction head loss scales with the square of velocity.
- 37. D** — Flow in smooth, parallel layers without mixing between them is laminar, occurring at low Reynolds numbers. Above the transition it becomes turbulent with chaotic mixing.
- 38. D** — Carnot efficiency is $1 - T_c / T_h = 1 - 300 / 600 = 0.50$, or 50%. The temperature ratio alone fixes this ceiling.
- 39. B** — Enthalpy change at constant pressure is $n C_p \Delta T = 3 \times 30 \times 20 = 1800$ J. The constant-pressure heat capacity accounts for the expansion work as well.
- 40. C** — The first law gives $Q = \Delta U + W = 400 + 150 = 550$ J. Heat supplied both raises internal energy and does work.
- 41. A** — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 4 \times (3200 - 2800) = 1600$ kW. The enthalpy drop converts directly into shaft work.
- 42. A** — The heating coefficient of performance is $Q_h / W = 800 / 200 = 4$. The heat pump delivers more heat than the work it consumes.
- 43. D** — Raoult's law gives the bubble pressure as $0.5 \times 120 + 0.5 \times 80 = 100$ kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.
- 44. B** — By the third law of thermodynamics, the entropy of a perfect crystal at absolute zero is zero. With a single accessible microstate, there is no configurational disorder.
- 45. A** — A process with no heat exchange with the surroundings is adiabatic. Rapid compressions and well-insulated processes approximate this condition.

- 46. C** — A reaction is spontaneous when its Gibbs free energy change is negative, indicating a net release of usable energy. The sign of ΔG sets the direction of spontaneous change.
- 47. B** — A steady-state mass balance gives the liquid as $1000 - 350 = 650$ kg/h. Conservation of mass closes the separation.
- 48. C** — A solids balance gives $0.10 \times 800 = 0.40 \times L$, so the product is $L = 200$ kg/h. The non-volatile solids fix the product rate.
- 49. D** — At 2 mol of oxygen per mole of methane, 6 mol of methane needs $6 \times 2 = 12$ mol. Combustion stoichiometry sets the oxygen demand.
- 50. C** — The combined salt is $0.20 \times 150 + 0.60 \times 50 = 30 + 30 = 60$ kg in 200 kg, giving 30%. A component balance yields the blended composition.
- 51. C** — Conversion is $(400 - 100)/400 = 75\%$. This fraction measures how completely the feed is consumed.
- 52. B** — The recycle ratio is recycle over fresh feed, $300/150 = 2$. It characterises the process's reliance on recycling.
- 53. C** — Sensible heat is $mC_p\Delta T = 50 \times 2.0 \times 30 = 3000$ kJ. This relation sizes the heating duty for a temperature change.
- 54. C** — Converting 20% wet basis gives dry basis $= 20/(100 - 20) = 25\%$. The dry basis exceeds the wet basis because its denominator excludes the water.
- 55. D** — The stoichiometry produces two moles of B per mole of A, so 7 mol of A yields 14 mol of B. Reaction stoichiometry converts reactant consumed into product formed.
- 56. C** — Percentage excess is $(10 - 8)/8 = 25\%$. The surplus oxygen ensures complete combustion.
- 57. B** — A tie component passes unchanged from one stream into another, providing a fixed link between them. It greatly simplifies material-balance calculations by anchoring the stream relationships.
- 58. D** — Fourier's law gives $Q = kA\Delta T/L = (2 \times 5 \times 40)/0.2 = 2000$ W. Conductive heat rate scales with conductivity, area, and driving temperature.
- 59. D** — Rearranging $Q = hA\Delta T$ gives $h = 2400/(4 \times 30) = 20$ W/m²·K. The coefficient measures how effectively the fluid removes heat.
- 60. B** — Emissive power scales with the fourth power of absolute temperature, so doubling T raises it by $2^4 = 16$ times. This steep dependence makes radiation dominant at high temperatures.
- 61. C** — With $\Delta T_1 = 100 - 50 = 50$ °C and $\Delta T_2 = 60 - 30 = 30$ °C, the log-mean is $(50 - 30)/\ln(50/30) = 39.2$ °C. The LMTD is the correct mean driving force, below the arithmetic mean of 40 °C.

- 62. B** — Series thermal resistances add directly, $0.2 + 0.3 = 0.5$ K/W. The thermal-circuit analogy makes composite-wall analysis straightforward.
- 63. A** — With negligible wall resistance, $1/U = 1/400 + 1/400 = 0.005$, so $U = 200$ W/m²·K. Two equal series films halve the overall coefficient.
- 64. A** — Exchanger duty is $UA\Delta T = 150 \times 8 \times 30 = 36,000$ W = 36 kW. This product of coefficient, area, and driving force sizes the exchanger.
- 65. D** — A fin extends the heat-transfer surface area, allowing more heat to flow from a surface to the surrounding fluid. Fins are used where the convective coefficient is low, as on air-cooled surfaces.
- 66. B** — A perfect black body absorbs all incident radiation at every wavelength, reflecting and transmitting none. It is also the ideal emitter, serving as the reference for radiative properties.
- 67. C** — Fick's law gives flux = $D \cdot \Delta C / \delta = (4 \times 10^{-9} \times 15) / (2 \times 10^{-3}) = 3 \times 10^{-5}$ mol/m²·s. Flux rises with diffusivity and concentration difference and falls with film thickness.
- 68. D** — Using $y = \alpha x / [1 + (\alpha - 1)x] = (4 \times 0.3) / (1 + 3 \times 0.3) = 1.2 / 1.9 = 0.63$. The vapour is enriched in the volatile component relative to the liquid.
- 69. A** — At minimum reflux a distillation column would require an infinite number of stages, since the operating and equilibrium lines just touch. Real columns operate above this limiting reflux.
- 70. C** — For equal volumes with $K = 3$, the fraction extracted is $K / (K + 1) = 3 / 4 = 0.75$. A higher distribution coefficient sends more solute to the extract.
- 71. C** — The number of transfer units is $\ln(C_{in} / C_{out}) = \ln(20) \approx 3.0$. NTU rises with the fractional removal demanded.
- 72. D** — Stripping transfers a solute from the liquid phase into a gas phase, the reverse of absorption. It is used to remove dissolved volatiles from a liquid stream.
- 73. A** — The driving force for interphase mass transfer is the system's departure from equilibrium between the phases. Transfer continues until the phases reach equilibrium and the driving force vanishes.
- 74. A** — Reverse osmosis forces solvent through a semipermeable membrane against the natural osmotic pressure gradient, leaving solute behind. The applied pressure must exceed the osmotic pressure to produce flow.
- 75. C** — Activated carbon removes contaminants by adsorption onto its very large internal porous surface area. Its high surface area per unit mass makes it an effective adsorbent for trace organics.
- 76. C** — Stokes' law gives $v = gd^2\Delta\rho / (18\mu) = (9.81 \times (1 \times 10^{-4})^2 \times 1500) / (18 \times 10^{-3}) = 8.17 \times 10^{-3}$ m/s. The square dependence on diameter makes settling highly size-sensitive.

- 77. D** — A free-flowing powder has a low angle of repose, forming a shallow pile because the particles slide easily over one another. Cohesive, poorly flowing powders form steeper piles.
- 78. D** — A cyclone uses centrifugal force in a swirling gas flow to fling heavier particles outward to the wall, where they fall out. It needs no moving parts or filter media.
- 79. B** — Bridging or arching occurs when particles interlock above a hopper outlet to form a stable arch that blocks flow. It is a common cause of erratic or stopped discharge from storage bins.
- 80. C** — First-order decay gives $C = C_0 e^{(-kt)} = 4 \times e^{(-0.2 \times 5)} = 4 \times e^{(-1)} = 4 \times 0.368 = 1.47$ mol/L. The concentration falls exponentially at a rate fixed by k .
- 81. D** — For a first-order PFR, conversion is $X = 1 - e^{(-k\tau)} = 1 - e^{(-0.6 \times 5)} = 1 - e^{(-3)} = 0.95$. The plug-flow reactor reaches high conversion efficiently.
- 82. B** — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.75/(0.5 \times 0.25) = 6$ min. High conversion in a CSTR demands a long residence time because it operates at the low exit concentration.
- 83. A** — For a second-order reaction, the rate depends on concentration squared, so doubling the concentration multiplies the rate by $2^2 = 4$. The order is found from how rate responds to concentration.
- 84. A** — At equilibrium the forward and reverse rates balance, so $K = k_{\text{forward}}/k_{\text{reverse}} = 20/5 = 4$. This links the kinetic constants to the equilibrium position.
- 85. C** — A catalyst speeds a reaction chiefly by lowering its activation energy, providing an easier pathway. With a smaller barrier, a larger fraction of molecules can react at a given temperature.
- 86. C** — Mean residence time is the reactor volume divided by the volumetric flow rate, V/Q . It measures the average time a fluid element spends inside the reactor.
- 87. A** — Future worth is $P(1 + i)^n = 5000 \times 1.08^4 = 5000 \times 1.3605 = \$6,803$. Compounding grows the sum forward at the stated rate.
- 88. A** — Present worth is $F/(1 + i)^n = 20,000/1.06^4 = 20,000/1.2625 = \$15,842$. Discounting reflects that a future sum is worth less today.
- 89. B** — Straight-line depreciation is $(60,000 - 6,000)/6 = \$9,000$ per year. This even allocation spreads the depreciable basis across the service life.
- 90. A** — Return on investment is annual profit over investment, $40,000/200,000 = 20\%$. It expresses the yearly earnings as a fraction of the capital committed.
- 91. D** — The process flow diagram shows the major equipment, process streams, and key operating conditions, but stops short of the full instrumentation detail of a P&ID. It is the primary working diagram for process engineers.

92. A — Raising the reflux ratio reduces the number of theoretical stages a column needs but increases the reboiler and condenser energy load. This trade-off between equipment size and energy cost defines the economic optimum.

93. A — Updating with the cost index gives $80,000 \times (900/600) = \$120,000$. The index ratio corrects the historical cost for inflation.

94. D — A design safety factor oversizes equipment to allow for uncertainties in loads, properties, and analysis, ensuring it is not undersized in service. It provides a deliberate margin against unexpected conditions.

95. D — For a positive-order reaction at the same conversion, a PFR requires a smaller volume than a single CSTR, because it operates at higher average concentration. The CSTR runs entirely at the low exit concentration, slowing the reaction.

96. A — Warm cooling water is returned to a cooling tower to reject its absorbed heat to the atmosphere, mainly through evaporation. The cooled water is then recirculated, conserving water and energy.

97. D — A feed-effluent, or recuperative, exchanger recovers heat from a hot product stream to preheat the cold feed entering the process. This heat integration reduces the external heating and cooling utilities required.

98. B — Integral action eliminates steady-state offset by continuing to adjust the output until the accumulated error is driven to zero. It complements proportional action, which alone leaves a residual offset.

99. B — A thermocouple generates a voltage that depends on the temperature difference between its measuring and reference junctions, by the Seebeck effect. This makes it a simple, rugged temperature sensor over a wide range.

100. C — A feedforward controller measures a disturbance and acts to correct for it before it affects the controlled output. This anticipatory action contrasts with feedback, which responds only after an error appears.

101. A — The final control element in most process loops is the control valve, which adjusts the manipulated flow on the controller's command. It is the actuator that physically implements the control action.

102. A — The flash point is the lowest temperature at which a liquid gives off enough vapour to form an ignitable mixture with air. It is a key measure of a liquid's fire hazard during storage and handling.

103. B — A HAZOP study systematically applies guide words such as "more," "less," and "no" to process parameters to uncover deviations and their causes. This structured approach identifies hazards that might otherwise be missed.

104. C — The LD50 is the dose that is lethal to 50% of a test population, a standard measure of acute toxicity. A lower LD50 indicates a more acutely toxic substance.

105. D — A pressure relief valve must be sized for the worst-case relieving scenario, such as a blocked outlet or fire exposure, to ensure adequate venting capacity. Undersizing for a milder case could allow dangerous overpressure.

106. C — A scrubber removes pollutants such as acid gases or particulates from a gas stream before it is discharged to the atmosphere. It is a common end-of-pipe control for meeting emission limits.

107. B — An engineer must keep a client's proprietary information confidential, except where disclosure is required to protect public health and safety. The paramount duty to the public can override the obligation of confidentiality.

108. B — Accepting work outside one's competence is acceptable only when the engineer obtains the necessary qualification or collaborates with a qualified expert. This protects the public from work performed without adequate expertise.

109. C — When building on another engineer's work, one must give proper credit and obtain permission where required, respecting their intellectual contribution. Claiming or disguising others' work is a serious breach of professional ethics.

110. B — Sustainable design meets present needs without compromising the ability of future generations to meet their own. This balances current benefit against long-term resource and environmental stewardship.