OJEE LE Tech (BSc) Sample Paper 02

A) Mode and Time: The exam is a Computer Based Test (CBT) lasting 60 minutes.
B) Total Questions: The exam contains 60 questions.
C) Marking Scheme & Rules:

- +4 marks for each correct answer; -1 mark for each incorrect answer.

Q1. The value of the limit $\lim_{x\to 0} \frac{x-\sin x}{x^3}$ is:

A. 1

B. 1/3

C. 1/6

D. 0

Q2. By the Rank-Nullity Theorem, if $T : V \to W$ is a linear transformation, then the dimension of V is equal to the sum of:

A. Rank of T and dimension of W

B. Rank of T and Nullity of T

C. Nullity of T and dimension of W

D. Rank of T and determinant of T

Q3. The necessary and sufficient condition for the differential equation $M(x, y)dx + N(x, y)dy = 0$ to be exact is:

A. $\frac{\partial M}{\partial x} = \frac{\partial N}{\partial y}$

B. $\frac{\partial M}{\partial y} = -\frac{\partial N}{\partial x}$

C. $\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$

D. $\frac{\partial M}{\partial x} = -\frac{\partial N}{\partial y}$

Q4. According to Cauchy's Integral Formula, if $f(z)$ is analytic within and on a simple closed contour C, and a is a point inside C, then $\oint_C \frac{f(z)}{z-a}dz$ evaluates to:

A. 0

B. $2\pi i f(a)$

C. $\pi i f(a)$

D. $f(a)$

Q5. For any continuously differentiable vector field $\mathbf{A}$, the divergence of the curl of $\mathbf{A}$ $(\nabla \cdot (\nabla \times \mathbf{A}))$ is always equal to:

A. $\mathbf{A}$

B. $\nabla^2 \mathbf{A}$

C. 0

D. 1

Q6. The eigenvalues of an idempotent matrix $(A^2 = A)$ are always:

A. -1 or 1

B. 0 or 1

C. Complex numbers

D. Purely imaginary

Q7. In a Poisson probability distribution, if the mean is denoted by λ, then the variance of the distribution is:

A. λ^2

B. $\sqrt{\lambda}$

C. λ

D. $1/\lambda$

Q8. What is the order of convergence for the Newton-Raphson method?

A. Linear (1)

B. Super-linear (1.618)

C. Quadratic (2)

D. Cubic (3)

Q9. The order of the alternating group A_4 (the group of even permutations of 4 symbols) is:

A. 24

B. 12

C. 6

D. 4

Q10. Euler's formula mathematically connects complex exponentials with trigonometric functions. It is given by $e^{i\theta} =$:

A. $\cosh\theta + i\sinh\theta$

B. $\sin\theta + i\cos\theta$

C. $\cos\theta + i\sin\theta$

D. $\cos\theta - i\sin\theta$

Q11. The Laplace transform of the function $f(t) = t^n$ (where n is a positive integer) is given by:

A. $\frac{n!}{s^n}$

B. $\frac{(n-1)!}{s^n}$

C. $\frac{n!}{s^{n+1}}$

D. $\frac{1}{s^{n+1}}$

Q12. The one-dimensional heat conduction equation $\frac{\partial u}{\partial t} = \alpha^2 \frac{\partial^2 u}{\partial x^2}$ is classified as a:

A. Elliptic partial differential equation

B. Hyperbolic partial differential equation

C. Parabolic partial differential equation

D. Linear ordinary differential equation

Q13. The sequence defined by $a_n = \left(1 + \frac{1}{n}\right)^n$ converges to which fundamental mathematical constant?

A. π

B. 1

C. 0

D. e

Q14. The Wronskian $W(y_1, y_2)$ of the functions $y_1 = e^x$ and $y_2 = e^{-x}$ is:

A. 2

B. -2

C. 0

D. e^{2x}

Q15. The integrating factor for the linear first-order differential equation $\frac{dy}{dx} + \frac{1}{x}y = x^2$ is:

A. e^x

B. x

C. $\ln x$

D. x^2

Q16. If $(AB)^T$ represents the transpose of the product of two compatible matrices A and B, then $(AB)^T$ is identically equal to:

A. $A^T B^T$

B. $B^T A^T$

C. $A^{-1} B^{-1}$

D. BA

Q17. The curl of the standard position vector $\mathbf{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$ evaluates to:

A. 3

B. 1

C. $\mathbf{0}$

D. $x\mathbf{i} - y\mathbf{j}$

Q18. The direction of the maximum directional derivative of a scalar function $\phi(x, y, z)$ at a given point is along the vector:

A. $\nabla\phi$

B. $\nabla^2\phi$

C. $\nabla \times \phi$

D. Normal vector to the z-axis

Q19. In numerical integration, Simpson's 3/8 rule requires that the number of sub-intervals (n) must be a multiple of:

A. 2

B. 3

C. 4

D. 8

Q20. According to the Bolzano-Weierstrass theorem, every bounded sequence of real numbers must have at least one:

A. Zero limit

B. Divergent subsequence

C. Convergent subsequence

D. Constant term

Q21. The particular integral (P.I.) of the differential equation $(D^2 + 1)y = \sin x$ is:

A. $-\frac{x}{2}\cos x$

B. $\frac{x}{2}\sin x$

C. $-\frac{1}{2}\sin x$

D. $\cos x$

Q22. The Maclaurin series expansion of $\sin x$ contains:

A. Both odd and even powers of x

B. Only even powers of x

C. Only odd powers of x

D. No powers of x higher than 3

Q23. If the real part $u(x, y)$ of an analytic complex function $f(z) = u + iv$ satisfies Laplace's equation, then u is called a:

A. Harmonic function

B. Meromorphic function

C. Conjugate function

D. Holomorphic function

Q24. Which of the following numerical methods is considered a 'direct' method for solving a system of linear algebraic equations?

A. Gauss-Seidel method

B. Jacobi iteration method

C. Relaxation method

D. Gauss elimination method

Q25. For a complex function $f(z) = \frac{e^z}{z}$, what is the value of the residue at its simple pole $z = 0$?

A. 0

B. e

C. 1

D. $2\pi i$

Q26. The Fourier series expansion of an even periodic function on the interval $[-\pi, \pi]$ consists only of:

A. Sine terms

B. Cosine terms and a constant

C. Both Sine and Cosine terms

D. Odd harmonics

Q27. The volume of a solid generated by revolving the area bounded by the curve $y = f(x)$, the x-axis, and the ordinates $x = a$, $x = b$ about the x-axis is given by the integral:

A. $\int_a^b 2\pi y dx$

B. $\int_a^b \pi y^2 dx$

C. $\int_a^b \pi x^2 dy$

D. $\int_a^b y^2 dx$

Q28. If a vector field $\mathbf{F}$ is irrotational, then which of the following vector identities holds true?

A. $\nabla \cdot \mathbf{F} = 0$

B. $\nabla \times \mathbf{F} = \mathbf{0}$

C. $\nabla(\nabla \cdot \mathbf{F}) = \mathbf{0}$

D. $\nabla^2 \mathbf{F} = \mathbf{0}$

Q29. The mathematical root of the equation $x^3 - x - 1 = 0$ naturally lies between which two consecutive integers?

A. 0 and 1

B. 1 and 2

C. -1 and 0

D. 2 and 3

Q30. What is the rank of a non-singular (invertible) $n \times n$ square matrix?

A. 0

B. 1

C. $n/2$

D. n

Q31. Maxwell's addition of the "displacement current" to Ampere's law was necessitated by the existence of:

A. Static electric fields

B. Time-varying electric fields

C. Constant magnetic fields

D. Magnetic monopoles

Q32. The Compton wavelength of an electron ($\lambda_c = h/m_e c$) has an approximate value of:

A. 0.024 Å

B. 1.024 Å

C. 2.4 Å

D. 0.0024 Å

Q33. The zero-point energy of a one-dimensional quantum harmonic oscillator is mathematically given by:

A. 0

B. $\hbar\omega$

C. $\frac{1}{2}\hbar\omega$

D. $\frac{3}{2}\hbar\omega$

Q34. In Special Relativity, the Lorentz factor (γ) that determines time dilation and length contraction is defined as:

A. $\sqrt{1 - v^2/c^2}$

B. $\frac{1}{\sqrt{1-v^2/c^2}}$

C. $1 - v^2/c^2$

D. $\frac{1}{1-v^2/c^2}$

Q35. In a perfectly reversible adiabatic process, which thermodynamic property of the system remains strictly constant?

A. Temperature

B. Pressure

C. Volume

D. Entropy

Q36. The Poynting vector **S**, which describes the directional energy flux of an electromagnetic field, is calculated by the cross product:

A. $\mathbf{E} \times \mathbf{B}$

B. $\mathbf{H} \times \mathbf{E}$

C. $\mathbf{E} \times \mathbf{H}$

D. $\mathbf{B} \times \mathbf{E}$

Q37. In an N-type extrinsic semiconductor, the donor energy level sits immediately:

A. Below the valence band

B. Above the conduction band

C. Below the conduction band

D. In the exact middle of the band gap

Q38. The de Broglie wavelength (λ) of an electron accelerated through a potential difference of V volts is approximately equal to:

A. $\frac{1.227}{\sqrt{V}}$ nm

B. $\frac{12.27}{V}$ Å

C. $\frac{12.27}{\sqrt{V}}$ Å

D. $\frac{1.227}{V}$ nm

Q39. The Hall coefficient (R_H) of a material is inversely proportional to:

A. The applied magnetic field

B. The temperature of the material

C. The charge carrier density (n)

D. The electric field intensity

Q40. According to the Stefan-Boltzmann law, if the absolute temperature of a black body is doubled, the total energy radiated per second increases by a factor of:

A. 2

B. 4

C. 8

D. 16

Q41. The ground state energy of an electron in a standard Hydrogen atom is theoretically calculated to be:

A. -1.51 eV

B. -3.4 eV

C. -13.6 eV

D. 0 eV

Q42. Which of Maxwell's equations is a direct mathematical formulation of Faraday's Law of electromagnetic induction?

A. $\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$

B. $\nabla \cdot \mathbf{B} = 0$

C. $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$

D. $\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$

Q43. The ratio of specific heats ($\gamma = C_p/C_v$) for an ideal monatomic gas is:

A. 1.33

B. 1.40

C. 1.67

D. 1.28

Q44. The critical temperature (T_c) of a superconductor marks the precise point where its:

A. Magnetic permeability becomes infinite

B. Electrical resistance drops abruptly to zero

C. Thermal conductivity drops to zero

D. Volume expands infinitely

Q45. The Pauli Exclusion Principle dictates that no two identical fermions in a quantum system can simultaneously possess the same:

A. Principal quantum number

B. Orbital angular momentum

C. Spin state

D. Set of all four quantum numbers

Q46. In organic chemistry, an S_N1 (Substitution Nucleophilic Unimolecular) reaction mechanism proceeds via the formation of which intermediate?

A. Carbanion

B. Free radical

C. Carbocation

D. Transition state only

Q47. What is the proper SI unit of the rate constant (k) for a zero-order chemical reaction?

A. s^{-1}

B. $mol \cdot L^{-1} \cdot s^{-1}$

C. $L \cdot mol^{-1} \cdot s^{-1}$

D. $L^2 \cdot mol^{-2} \cdot s^{-1}$

Q48. The relationship between the standard Gibbs free energy change (ΔG°) and the standard electromotive force (EMF) of a cell (E°) is given by:

A. $\Delta G^\circ = nFE^\circ$

B. $\Delta G^\circ = -nFE^\circ$

C. $\Delta G^\circ = -RT \ln E^\circ$

D. $\Delta G^\circ = E^\circ / nF$

Q49. What is the highest formal oxidation state exhibited by Manganese (Mn) in the compound Potassium permanganate ($KMnO_4$)?

A. +3

B. +5

C. +6

D. +7

Q50. The versatile chelating ligand EDTA (Ethylenediaminetetraacetic acid) bonds to a central metal ion at how many sites, making it a:

A. Bidentate ligand

B. Tridentate ligand

C. Tetradentate ligand

D. Hexadentate ligand

Q51. The Cannizzaro reaction is a chemical disproportionation reaction predominantly given by:

A. Aldehydes containing an alpha-hydrogen

B. Ketones with alpha-hydrogens

C. Aldehydes lacking an alpha-hydrogen

D. Carboxylic acids

Q52. The fundamental thermodynamic condition for a chemical process to occur spontaneously at constant temperature and pressure is:

A. $\Delta H > 0$

B. $\Delta S < 0$

C. $\Delta G = 0$

D. $\Delta G < 0$

Q53. In solid-state crystallography, the total number of distinct three-dimensional Bravais lattices mathematically possible is:

A. 7

B. 14

C. 21

D. 32

Q54. At its specific Isoelectric point (pI), an amino acid in an aqueous solution exists predominantly as a:

A. Positively charged cation

B. Negatively charged anion

C. Neutral molecule with no charged groups

D. Zwitterion with a net charge of zero

Q55. The Friedel-Crafts alkylation of an aromatic ring requires a specific catalyst. Which of the following is most commonly used?

A. Anhydrous $AlCl_3$

B. Dilute H_2SO_4

C. Aqueous $NaOH$

D. Metallic Nickel

Q56. In a molecule of benzene (C_6H_6), the carbon atoms undergo which type of molecular hybridization?

A. sp

B. sp^2

C. sp^3

D. sp^3d

Q57. Among the following oxyacids of chlorine, which one is experimentally proven to be the strongest acid?

A. Hypochlorous acid ($HClO$)

B. Chlorous acid ($HClO_2$)

C. Chloric acid ($HClO_3$)

D. Perchloric acid ($HClO_4$)

Q58. According to the Pauling scale, which element possesses the highest electronegativity in the entire periodic table?

A. Oxygen (O)

B. Chlorine (Cl)

C. Nitrogen (N)

D. Fluorine (F)

Q59. By international IUPAC convention, the standard electrode potential (E°) of the Standard Hydrogen Electrode (SHE) at all temperatures is assigned a value of:

A. -1.00 V

B. 0.00 V

C. 1.00 V

D. 1.23 V

Q60. The Arrhenius equation mathematically defines the dependence of the chemical reaction rate constant (k) on the absolute temperature and the:

A. Activation energy (E_a)

B. Gibbs free energy (ΔG)

C. Enthalpy of reaction (ΔH)

D. Entropy of activation ($\Delta S^{\ddagger}$)

Solutions

1. C
Explanation: Applying L'Hopital's rule repeatedly or substituting the Maclaurin series for $\sin x = x - x^3/3! + x^5/5! - \dots$ gives $\frac{x-(x-x^3/6+\dots)}{x^3}$, which simplifies to $1/6$ as $x \to 0$.

2. B
Explanation: The Rank-Nullity Theorem is a fundamental theorem in linear algebra stating that for a linear transformation T defined on a vector space V, $\text{Rank}(T) + \text{Nullity}(T) = \text{Dimension of } V$.

3. C
Explanation: For a first-order differential equation $Mdx + Ndy = 0$ to be exact, it must satisfy the integrability condition that the partial derivative of M with respect to y equals the partial derivative of N with respect to x.

4. B
Explanation: Cauchy's Integral Formula states that the contour integral $\oint \frac{f(z)}{z-a}dz$ along a simple closed curve C evaluated counterclockwise is equal to $2\pi i \cdot f(a)$.

5. C
Explanation: In vector calculus, a standard identity proves that the divergence of the curl of any twice-differentiable vector field is identically zero ($\nabla \cdot (\nabla \times \mathbf{A}) = 0$).

6. B
Explanation: Let λ be an eigenvalue of A, associated with eigenvector v. Then $Av = \lambda v$. Since $A^2 = A$, $A(Av) = Av \implies A(\lambda v) = \lambda v \implies \lambda(Av) = \lambda v \implies \lambda^2 v = \lambda v$. Since $v \neq 0$, $\lambda^2 - \lambda = 0$, giving $\lambda = 0$ or 1.

7. C
Explanation: A unique property of the Poisson probability distribution is that both its expected value (mean) and its variance are mathematically equal to the rate parameter, λ.

8. C
Explanation: The Newton-Raphson numerical method for finding roots converges quadratically, meaning the number of correct decimal places approximately doubles with each successive iteration near the root.

9. B
Explanation: The symmetric group S_4 has $4! = 24$ elements. The alternating group A_4 consists of exactly half of those (only the even permutations), making its order $24/2 = 12$.

10. C
Explanation: Euler's formula establishes the fundamental relationship between trigonometric functions and complex exponential functions as $e^{i\theta} = \cos\theta + i\sin\theta$.

11. C
Explanation: By definition, the Laplace transform of t^n integrates to exactly $\frac{n!}{s^{n+1}}$ for any positive integer n assuming $s > 0$.

12. C

Explanation: The heat equation $u_t - \alpha^2 u_{xx} = 0$ has discriminant $B^2 - 4AC = 0^2 - 4(0)(-\alpha^2) = 0$. Since the discriminant is zero, it is classified as a parabolic PDE.

13. D
Explanation: The limit definition of the natural exponential base e is widely defined in calculus as the limit of the sequence $(1 + 1/n)^n$ as n approaches infinity.

14. B
Explanation: The Wronskian determinant is $W = (y_1 \cdot y_2') - (y_1' \cdot y_2) = (e^x \cdot -e^{-x}) - (e^x \cdot e^{-x}) = -1 - 1 = -2$.

15. B
Explanation: The integrating factor (I.F.) is calculated as $e^{\int P(x)dx}$. Here $P(x) = 1/x$, so I.F. $= e^{\int (1/x)dx} = e^{\ln x} = x$.

16. B
Explanation: The "socks-and-shoes" property of matrix multiplication states that the transpose of a product of matrices equals the product of their transposes in reverse order: $(AB)^T = B^T A^T$.

17. C
Explanation: The curl of the position vector $\mathbf{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$ is $\nabla \times \mathbf{r} = (\frac{\partial z}{\partial y} - \frac{\partial y}{\partial z})\mathbf{i} - \cdots = 0\mathbf{i} - 0\mathbf{j} + 0\mathbf{k} = \mathbf{0}$.

18. A
Explanation: The directional derivative of a scalar field ϕ is given by the dot product of the gradient $\nabla\phi$ and a unit vector. It achieves its maximum magnitude exactly in the direction of the gradient vector $\nabla\phi$.

19. B
Explanation: Simpson's 3/8 rule evaluates the definite integral by fitting cubic polynomials through sets of 4 points (3 intervals). Therefore, the total number of sub-intervals must be a multiple of 3.

20. C
Explanation: The Bolzano-Weierstrass theorem is a fundamental result in real analysis which states that every infinite, bounded sequence of real numbers possesses at least one convergent subsequence.

21. A
Explanation: The P.I. for $(D^2 + a^2)y = \sin ax$ is given by $-x\frac{\cos ax}{2a}$. Here $a = 1$, so the P.I. evaluates to $-\frac{x}{2}\cos x$.

22. C
Explanation: The sine function is an odd function ($\sin(-x) = -\sin x$). Accordingly, its Maclaurin series expansion $(x - x^3/3! + x^5/5! - \dots)$ contains strictly odd powers of x.

23. A
Explanation: Any real-valued function with continuous second partial derivatives that satisfies Laplace's equation ($\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$) is mathematically defined as a harmonic function.

24. D

Explanation: Gauss elimination operates in a finite, fixed number of steps to find the exact solution (ignoring rounding errors), making it a direct method, whereas Gauss-Seidel and Jacobi are iterative methods.

25. C

Explanation: For a simple pole at $z = 0$, the residue is found by $\lim_{z\to 0} z \cdot f(z) = \lim_{z\to 0} z \cdot \frac{e^z}{z} = e^0 = 1$.

26. B

Explanation: For an even function $f(-x) = f(x)$, the product $f(x)\sin(nx)$ is odd, making the integrals for all sine coefficients (b_n) equal to zero. The series contains only cosine terms and the constant a_0.

27. B

Explanation: By the disk method in calculus, the volume of a solid of revolution around the x-axis is given by integrating the area of circular cross-sections (πr^2) along the axis: $V = \int_a^b \pi y^2 dx$.

28. B

Explanation: A vector field is defined as irrotational (conservative) if its curl is zero everywhere in the field, mathematically denoted as $\nabla \times \mathbf{F} = \mathbf{0}$.

29. B

Explanation: Let $f(x) = x^3 - x - 1$. Testing integers: $f(1) = 1 - 1 - 1 = -1$ (negative). $f(2) = 8 - 2 - 1 = 5$ (positive). By the Intermediate Value Theorem, a root lies between 1 and 2.

30. D

Explanation: A non-singular (invertible) matrix has a non-zero determinant, meaning all its rows and columns are linearly independent. Therefore, an $n \times n$ non-singular matrix has full rank, which is n.

31. B

Explanation: Maxwell added the displacement current term ($\varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$) to Ampere's Law to resolve mathematical inconsistencies regarding charge conservation, proving that a changing electric field induces a magnetic field.

32. A

Explanation: The Compton wavelength of an electron is computed as $h/(m_e c)$. Substituting Planck's constant, electron mass, and the speed of light yields approximately 2.426×10^{-12} meters, or 0.024 Å.

33. C

Explanation: Solving the Schrödinger equation for a 1D harmonic oscillator yields energy levels $E_n = (n + 1/2)\hbar\omega$. For the lowest ground state ($n = 0$), the zero-point energy is non-zero at $\frac{1}{2}\hbar\omega$.

34. B

Explanation: The Lorentz factor (γ), essential in relativistic transformation equations, describes how much time, length, and relativistic mass change for an object while moving, defined as $\gamma = 1/\sqrt{1 - v^2/c^2}$.

35. D

Explanation: In a reversible adiabatic process, no heat is exchanged with the environment ($dQ = 0$). By definition, the change in entropy is $dS = dQ_{rev}/T = 0$,

meaning the entropy remains constant (isentropic).

36. C
Explanation: The Poynting vector mathematically represents the magnitude and direction of the flow of electromagnetic power, calculated as the cross product of the electric field (**E**) and the magnetizing field (**H**).

37. C
Explanation: In an N-type semiconductor, donor impurities (like Phosphorus) introduce extra electrons. The energy level for these loosely bound electrons sits discretely just below the bottom of the conduction band.

38. C
Explanation: The de Broglie wavelength for an accelerated electron is $\lambda = h/\sqrt{2m_e eV}$. Inputting the constants gives a simplified empirical formula of approximately $12.27/\sqrt{V}$ Angstroms.

39. C
Explanation: The Hall coefficient (R_H) is fundamentally equal to $1/(nq)$, where n is the charge carrier density and q is the elementary charge. Thus, it is inversely proportional to the carrier density.

40. D
Explanation: The Stefan-Boltzmann law states that emitted energy $E \propto T^4$. If temperature T is doubled to $2T$, the new energy emitted becomes $(2T)^4 = 16T^4$, meaning it increases by a factor of 16.

41. C
Explanation: Using the Bohr model or quantum mechanics, the energy levels of a hydrogen atom are given by $E_n = -13.6/n^2$ eV. For the ground state ($n = 1$), the energy is precisely -13.6 eV.

42. C
Explanation: Faraday's Law of induction states that a time-varying magnetic field produces a circulating electric field. Maxwell formulated this mathematically as the curl equation $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$.

43. C
Explanation: For an ideal monatomic gas (like Helium or Argon), it has 3 translational degrees of freedom. $C_v = \frac{3}{2}R$ and $C_p = \frac{5}{2}R$. Their ratio $\gamma = (\frac{5}{2}R)/(\frac{3}{2}R) = 5/3 \approx 1.67$.

44. B
Explanation: Superconductivity is defined as the phenomenon where a material's electrical resistance drops exactly to zero when it is cooled below its characteristic critical temperature (T_c).

45. D
Explanation: The Pauli Exclusion Principle is a quantum mechanical principle asserting that no two identical fermions (such as electrons in an atom) can simultaneously occupy the exact same quantum state, meaning all four quantum numbers (n, l, m_l, m_s) cannot match.

46. C
Explanation: The S_N1 mechanism is a two-step process. The first, rate-determining

step involves the departure of the leaving group to form a positively charged intermediate known as a carbocation.

47. B

Explanation: For a zero-order reaction, the rate is independent of concentration: Rate $= k[A]^0 = k$. Therefore, the units of k are identical to the units of reaction rate, which is concentration over time ($mol \cdot L^{-1} \cdot s^{-1}$).

48. B

Explanation: The maximum electrical work a cell can do is related to the decrease in Gibbs free energy. The mathematical equation linking them is $\Delta G^\circ = -nFE^\circ$.

49. D

Explanation: In $KMnO_4$, Potassium (K) is $+1$ and Oxygen (O) is -2. Let Mn be x. The equation is $1 + x + 4(-2) = 0 \implies x - 7 = 0 \implies x = +7$.

50. D

Explanation: EDTA is a classic hexadentate ligand. It utilizes two nitrogen atoms and four oxygen atoms (from carboxylate groups) to form six separate coordinate covalent bonds with a single central metal ion.

51. C

Explanation: The Cannizzaro reaction is a base-catalyzed disproportionation reaction (simultaneous oxidation and reduction) specifically restricted to aldehydes that do not possess any alpha-hydrogens (e.g., formaldehyde, benzaldehyde).

52. D

Explanation: According to thermodynamics, a process at constant temperature and pressure is spontaneous in the forward direction if and only if the change in its Gibbs free energy (ΔG) is negative ($\Delta G < 0$).

53. B

Explanation: Auguste Bravais mathematically proved in 1848 that there are exactly 14 distinct lattice arrangements in three-dimensional space that can describe the crystal structure of all geometric minerals.

54. D

Explanation: At the specific pH known as the isoelectric point (pI), the amino acid's carboxyl group is deprotonated ($-$) and the amine group is protonated ($+$), creating a neutral bipolar ion called a zwitterion.

55. A

Explanation: The Friedel-Crafts alkylation reaction utilizes a strong Lewis acid catalyst, most commonly anhydrous Aluminum chloride ($AlCl_3$), to generate the highly reactive carbocation electrophile from an alkyl halide.

56. B

Explanation: In the benzene ring, each carbon atom is bonded to three other atoms (two carbons and one hydrogen) via sigma bonds, leaving one unhybridized p-orbital to form the delocalized pi ring. This requires sp^2 hybridization.

57. D

Explanation: Acidic strength of oxyacids increases with the oxidation number of the central atom. In Perchloric acid ($HClO_4$), Chlorine has the highest oxidation state ($+7$), making it the strongest acid.

58. D

Explanation: Fluorine is located at the top right of the halogens in the periodic table and possesses the highest tendency to attract shared electrons in a chemical bond, giving it an electronegativity of 3.98 on the Pauling scale.

59. B

Explanation: The Standard Hydrogen Electrode (SHE) is the universal reference electrode for electrochemistry. By strict international agreement, its standard electrode potential is arbitrarily set exactly to 0.00 Volts.

60. A

Explanation: The Arrhenius equation is expressed as $k = Ae^{-E_a/RT}$. It clearly demonstrates how the rate constant (k) relies exponentially on the absolute temperature (T) and the Activation energy (E_a).