ADDITIONAL MCAT HIGH-YIELD PRACTICE TESTS - CHEMICAL AND PHYSICAL FOUNDATIONS OF BIOLOGICAL SYSTEMS

GENERAL CHEMISTRY (Questions 1-25)

1. What is the electron configuration of Fe^{2+}?

A. [Ar] $3d^4\ 4s^2$

B. [Ar] $3d^6$

C. [Ar] $3d^5\ 4s^1$

D. [Ar] $3d^8$

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2. A buffer solution contains 0.50 M acetic acid (Ka = 1.8×10^{-5}) and 0.50 M sodium acetate. What is the pH of this buffer?

A. 3.74

B. 5.44

C. 4.74

D. 6.74

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3. Which quantum number designates the shape of an orbital?

A. Angular momentum quantum number (l)

B. Principal quantum number (n)

C. Magnetic quantum number (ml)

D. Spin quantum number (ms)

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4. In which type of radioactive decay does the mass number remain unchanged?

A. Alpha decay

B. Beta-minus decay

C. Gamma emission

D. Positron emission

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5. The oxidation state of chromium in $K_2Cr_2O_7$ is:

A. +3

B. +6

C. +7

D. +2

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6. According to Le Chatelier's principle, increasing the pressure on the following equilibrium will shift it in which direction?

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

A. Left (toward reactants)

B. No shift occurs

C. Both directions equally

D. Right (toward products)

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7. Which of the following has the highest boiling point?

A. $CH_3CH_2CH_2CH_3$ (butane)

B. $CH_3CH_2CH_2CH_2OH$ (1-butanol)

C. $CH_3OCH_2CH_3$ (diethyl ether)

D. CH_3CH_2CHO (propanal)

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8. The solubility product constant (Ksp) for AgCl is 1.8×10^{-10}. What is the molar solubility of AgCl in pure water?

A. 1.8×10^{-10} M

B. 9.0×10^{-11} M

C. 1.3×10^{-5} M

D. 3.6×10^{-10} M

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9. In a galvanic cell, which statement is true?

A. Oxidation occurs at the cathode

B. Reduction occurs at the anode

C. Electrons flow from cathode to anode

D. The anode is negative

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10. For the reaction: $2A + B \rightarrow C$, if the concentration of A is doubled while B remains constant, the rate increases by a factor of 4. What is the order with respect to A?

A. Zero order

B. First order

C. Third order

D. Second order

---

11. Which of the following species is amphoteric?

A. HSO_4^-

B. NH_4^+

C. SO_4^{2-}

D. Cl^-

---

12. The first ionization energy generally increases across a period because:

A. Atomic radius decreases

B. Nuclear charge increases

C. Effective nuclear charge increases and atomic radius decreases

D. Shielding increases

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13. At 25°C, the vapor pressure of pure water is 23.8 mmHg. After dissolving a non-volatile solute, the vapor pressure drops to 22.5 mmHg. What is the mole fraction of solute?

A. 0.055

B. 0.945

C. 0.505

D. 0.125

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14. The hybridization of carbon in CO_2 is:

A. sp

B. sp^2

C. sp^3

D. sp^3d

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15. A 2.0 L container holds 4.0 moles of an ideal gas at 300 K. What is the pressure? (R = 0.0821 L·atm/mol·K)

A. 49.3 atm

B. 24.6 atm

C. 12.3 atm

D. 98.5 atm

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16. Which intermolecular force is primarily responsible for the high boiling point of water?

A. London dispersion forces

B. Dipole-dipole interactions

C. Hydrogen bonding

D. Ionic bonding

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17. For an endothermic reaction, increasing temperature will:

A. Decrease K (equilibrium constant)

B. Shift equilibrium toward products

C. Have no effect on equilibrium

D. Decrease the rate of both forward and reverse reactions

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18. The equivalence point in a titration of a strong acid with a strong base occurs at:

A. pH < 7

B. pH > 7

C. Any pH value

D. pH = 7

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19. Which property decreases down a group in the periodic table?

A. Atomic radius

B. Metallic character

C. Ionization energy

D. Number of electron shells

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20. A reaction has ΔH = +50 kJ/mol and ΔS = +150 J/mol·K. At what temperature does the reaction become spontaneous?

A. 33 K

B. 150 K

C. 333 K

D. 500 K

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21. The common ion effect predicts that adding NaCl to a saturated solution of AgCl will:

A. Increase solubility

B. Decrease solubility

C. Have no effect on solubility

D. Increase Ksp

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22. Which molecule has a net dipole moment?

A. CO_2

B. CCl_4

C. BF_3

D. NH_3

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23. The half-life of a first-order reaction is 20 seconds. What fraction of the original reactant remains after 60 seconds?

A. 1/8

B. 1/4

C. 1/2

D. 1/16

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24. In the Bohr model of the hydrogen atom, when an electron transitions from $n = 3$ to $n = 2$:

A. Energy is absorbed

B. A photon is absorbed

C. A photon is emitted

D. No energy change occurs

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25. Which of the following solutions has the highest osmotic pressure at 25°C?

A. 0.1 M glucose

B. 0.1 M NaCl

C. 0.1 M $CaCl_2$

D. 0.05 M glucose

PHYSICS (Questions 26-50)

26. A 5.0 kg object accelerates from rest to 20 m/s in 4.0 seconds. What is the net force acting on the object?

A. 4.0 N

B. 20 N

C. 100 N

D. 25 N

---

27. The work done by a force is zero when:

A. The force and displacement are perpendicular

B. The force is maximum

C. The displacement is maximum

D. The force and displacement are parallel

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28. A light ray passes from air (n = 1.0) into water (n = 1.33). The light will:

A. Speed up and bend away from the normal

B. Slow down and bend toward the normal

C. Slow down and bend toward the normal

D. Maintain constant speed

---

29. In simple harmonic motion, the acceleration is:

A. Constant in magnitude and direction

B. Proportional to and opposite the displacement

C. Proportional to velocity

D. Zero at maximum displacement

30. Two resistors, 4 Ω and 6 Ω, are connected in parallel. What is the equivalent resistance?

A. 10 Ω

B. 2.4 Ω

C. 5 Ω

D. 2.4 Ω

31. An object is placed 20 cm in front of a convex lens with focal length 10 cm. Where is the image formed?

A. 20 cm behind the lens

B. 10 cm behind the lens

C. 6.7 cm behind the lens

D. 40 cm behind the lens

32. The potential energy of a spring with spring constant k compressed by distance x is:

A. kx

B. $\frac{1}{2}kx$

C. $\frac{1}{2}kx^2$

D. kx^2

33. A 1000 kg car traveling at 20 m/s brakes to a stop. How much work is done by the braking force?

A. 20,000 J

B. 10,000 J

C. -200,000 J

D. -400,000 J

---

34. The period of a simple pendulum depends on:

A. Mass

B. Length and gravitational acceleration

C. Amplitude

D. Initial velocity

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35. Bernoulli's equation relates:

A. Pressure, velocity, and height in fluid flow

B. Force and acceleration

C. Electric field and potential

D. Heat and temperature

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36. The power dissipated by a resistor with current I and resistance R is:

A. IR

B. I^2/R

C. I^2R

D. IR^2

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37. Which type of electromagnetic radiation has the highest energy per photon?

A. Infrared

B. Ultraviolet

C. Visible light

D. Gamma rays

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38. A 2.0 kg object moving at 3.0 m/s collides elastically with a stationary 2.0 kg object. After collision, what is the velocity of the first object?

A. 0 m/s

B. 1.5 m/s

C. 3.0 m/s

D. -3.0 m/s

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39. The direction of the magnetic force on a positive charge moving in a magnetic field is given by:

A. The direction of the magnetic field

B. The direction of velocity

C. The right-hand rule (perpendicular to both v and B)

D. Opposite to the magnetic field

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40. In a standing wave on a string fixed at both ends, the distance between adjacent nodes is:

A. One wavelength

B. One-half wavelength

C. One-quarter wavelength

D. Two wavelengths

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41. The first law of thermodynamics states:

A. Entropy always increases

B. $\Delta U = Q - W$

C. Energy cannot be created or destroyed

D. Heat flows from hot to cold

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42. A capacitor stores 0.01 C of charge at 100 V. What is its capacitance?

A. 1000 F

B. 0.001 F

C. 100 μF

D. 10 F

---

43. The intensity of sound decreases with distance from the source because:

A. Sound energy is absorbed by air

B. Sound spreads over larger area (inverse square law)

C. Sound frequency decreases

D. Sound speed decreases

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44. Total internal reflection occurs when light travels from:

A. Low to high refractive index at any angle

B. High to low refractive index above critical angle

C. Equal refractive indices

D. Air to glass

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45. A mass on a spring has period T. If the mass is quadrupled, the new period is:

A. T

B. T/2

C. 4T

D. 2T

---

46. The electric potential at a distance r from a point charge Q is:

A. kQ/r^2

B. kQr

C. kQ/r

D. kQ^2/r

---

47. Which thermodynamic process occurs at constant volume?

A. Isobaric

B. Isothermal

C. Adiabatic

D. Isochoric

---

48. The Doppler effect for sound causes:

A. Frequency increase when source approaches observer

B. Speed increase when source moves

C. Amplitude increase with motion

D. Wavelength to remain constant

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49. Lenz's law states that induced current:

A. Opposes the change in magnetic flux

B. Enhances the change in magnetic flux

C. Is proportional to resistance

D. Flows in direction of applied field

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50. The de Broglie wavelength of a particle is inversely proportional to its:

A. Mass

B. Energy

C. Velocity

D. Momentum

ORGANIC CHEMISTRY (Questions 51-75)

51. Which functional group characterizes a ketone?

A. R-CO-R'

B. R-CHO

C. R-COOH

D. R-OH

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52. In E2 elimination reactions, the leaving group and β-hydrogen must be:

A. On the same side (syn)

B. On opposite sides (anti)

C. Antiperiplanar

D. In any orientation

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53. Which reagent converts an alkene to an alcohol via anti-Markovnikov addition?

A. H_2SO_4/H_2O

B. Hydroboration-oxidation (BH_3, then H_2O_2/OH^-)

C. HBr

D. $Hg(OAc)_2/H_2O$, then $NaBH_4$

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54. The IUPAC name for $CH_3CH_2CH(CH_3)CH_2CH_3$ is:

A. 2-methylpentane

B. 3-methylpentane

C. Isohexane

D. 3-methylpentane

---

55. Which compound is most acidic?

A. Phenol

B. Ethanol

C. Acetic acid

D. Water

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56. In an SN1 reaction, the rate-determining step involves:

A. Nucleophile attack

B. Formation of carbocation

C. Leaving group departure

D. Formation of carbocation (unimolecular)

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57. Which alkyl halide undergoes SN2 reaction most readily?

A. $(CH_3)_3CBr$

B. CH_3Br

C. $(CH_3)_2CHBr$

D. CH_3CH_2Br

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58. Ozonolysis (O_3 followed by Zn/H_2O) of an alkene produces:

A. Alcohols

B. Epoxides

C. Ketones and/or aldehydes

D. Carboxylic acids

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59. The number of stereoisomers possible for a molecule with 3 chiral centers is:

A. 8

B. 6

C. 3

D. 9

---

60. Which reagent oxidizes a primary alcohol to an aldehyde without over-oxidation to carboxylic acid?

A. $KMnO_4$

B. $K_2Cr_2O_7/H_2SO_4$

C. PCC (Pyridinium chlorochromate)

D. $Na_2Cr_2O_7$

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61. Aldehydes can be distinguished from ketones using:

A. Tollens' reagent (silver mirror test)

B. Br_2/CCl_4

C. NaOH

D. HCl

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62. The major product of the reaction between 2-methylpropene and HBr is:

A. 1-bromo-2-methylpropane

B. 2-bromo-2-methylpropane

C. 2-bromo-2-methylpropane

D. 1-bromo-1-methylpropane

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63. Enantiomers have:

A. Identical physical properties except optical rotation

B. Different melting points

C. Different boiling points

D. Different refractive indices

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64. Which molecule exhibits aromatic character?

A. Cyclooctatetraene

B. Benzene

C. Cyclohexene

D. Cyclopentadiene

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65. Gabriel synthesis is used to prepare:

A. Primary amines

B. Secondary amines

C. Tertiary amines

D. Quaternary ammonium salts

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66. In ^{1}H NMR spectroscopy, a quartet signal indicates:

A. 4 equivalent protons

B. 3 neighboring protons (n+1 rule)

C. 4 neighboring protons

D. 5 neighboring protons

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67. Grignard reagents (RMgX) react with CO_2 to form:

A. Alcohols

B. Aldehydes

C. Ketones

D. Carboxylic acids (after hydrolysis)

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68. Which intermediate is most stable?

A. Methyl carbocation

B. Primary carbocation

C. Secondary carbocation

D. Tertiary carbocation

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69. Infrared spectroscopy is most useful for identifying:

A. Molecular weight

B. Functional groups

C. Number of carbons

D. Stereochemistry

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70. The Diels-Alder reaction is a [4+2] cycloaddition between:

A. Two alkenes

B. Alkene and alkyne

C. Diene and dienophile

D. Two alkynes

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71. Which compound has the highest priority according to Cahn-Ingold-Prelog rules?

A. $-CH_3$

B. $-CH_2CH_3$

C. $-CH(CH_3)_2$

D. $-C(CH_3)_3$

---

72. Acyl chlorides (RCOCl) are more reactive than esters toward nucleophilic acyl substitution because:

A. Chlorine is a better nucleophile

B. Chlorine is a better leaving group

C. Esters are more stable

D. Acyl chlorides have higher molecular weight

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73. Reduction of an ester with $LiAlH_4$ produces:

A. Carboxylic acid

B. Aldehyde

C. Primary alcohol

D. Secondary alcohol

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74. Which compound undergoes electrophilic aromatic substitution most readily?

A. Nitrobenzene

B. Chlorobenzene

C. Toluene

D. Benzene

---

75. The E/Z nomenclature for alkene geometry is based on:

A. Alphabetical order

B. Cahn-Ingold-Prelog priority rules

C. Size of substituents

D. Electronegativity

BIOCHEMISTRY (Questions 76-100)

76. Which amino acid is achiral?

A. Alanine

B. Valine

C. Glycine

D. Leucine

77. The peptide bond is planar because of:

A. sp^3 hybridization

B. Resonance between C-N bond

C. Hydrogen bonding

D. Ionic interactions

78. In the Michaelis-Menten equation, Km represents:

A. Maximum velocity

B. Enzyme concentration

C. Turnover number

D. Substrate concentration at ½Vmax

79. Which nucleotide base is found in RNA but not DNA?

A. Thymine

B. Cytosine

C. Guanine

D. Uracil

80. β-oxidation of fatty acids occurs in the:

A. Cytoplasm

B. Mitochondrial matrix

C. Endoplasmic reticulum

D. Nucleus

81. The isoelectric point (pI) of an amino acid is the pH at which:

A. It is fully protonated

B. Net charge is zero

C. It is fully deprotonated

D. Charge is +1

82. Competitive inhibitors increase:

A. Vmax only

B. Km only

C. Both Vmax and Km

D. Neither Vmax nor Km

83. Hemoglobin's oxygen-binding curve is sigmoidal because of:

A. Michaelis-Menten kinetics

B. Competitive inhibition

C. Cooperative binding

D. Allosteric inhibition only

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84. During glycolysis, the net production of ATP per glucose is:

A. 4 ATP

B. 0 ATP

C. 36 ATP

D. 2 ATP

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85. The primary structure of a protein refers to:

A. α-helices and β-sheets

B. Amino acid sequence

C. 3D folding

D. Quaternary assembly

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86. Which vitamin is a precursor to NAD$^+$?

A. Vitamin B_1 (thiamine)

B. Vitamin B_2 (riboflavin)

C. Vitamin B_3 (niacin)

D. Vitamin B_{12} (cobalamin)

---

87. Sphingolipids contain which backbone structure?

A. Glycerol

B. Cholesterol

C. Sphingosine

D. Fatty acid

---

88. The enzyme that relieves supercoiling during DNA replication is:

A. Helicase

B. Ligase

C. Primase

D. Topoisomerase

---

89. In the electron transport chain, Complex IV transfers electrons to:

A. Ubiquinone

B. Cytochrome c

C. NADH

D. O_2

---

90. Gluconeogenesis primarily occurs in the:

A. Muscle

B. Brain

C. Liver

D. Kidney cortex (also correct, but liver is primary)

---

91. Which bond stabilizes tertiary protein structure?

A. Peptide bonds

B. Disulfide bridges

C. Phosphodiester bonds

D. Glycosidic bonds

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92. The Cori cycle involves the conversion of:

A. Glucose to pyruvate

B. Lactate to glucose

C. Glycogen to glucose-6-phosphate

D. Pyruvate to acetyl-CoA

---

93. Chymotrypsin cleaves peptide bonds on the C-terminal side of:

A. Basic amino acids

B. Aromatic amino acids

C. Small amino acids

D. Acidic amino acids

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94. The start codon in mRNA is:

A. UAA

B. AUG

C. UGA

D. UAG

---

95. Phospholipids spontaneously form bilayers in water because they are:

A. Hydrophobic

B. Hydrophilic

C. Amphipathic

D. Polar

---

96. The rate-limiting enzyme of glycolysis is:

A. Hexokinase

B. Pyruvate kinase

C. Aldolase

D. Phosphofructokinase-1

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97. tRNA molecules are charged with amino acids by:

A. Ribosomes

B. Aminoacyl-tRNA synthetases

C. mRNA

D. DNA polymerase

---

98. The ketone bodies produced during fatty acid metabolism include:

A. Glucose and lactate

B. Pyruvate and oxaloacetate

C. Acetone and β-hydroxybutyrate

D. Citrate and malate

---

99. Which lipid is the precursor for steroid hormones?

A. Phospholipid

B. Triglyceride

C. Cholesterol

D. Sphingomyelin

---

100. In oxidative phosphorylation, the proton gradient drives ATP synthesis by:

A. Substrate-level phosphorylation

B. ATP synthase rotation

C. Direct phosphorylation

D. GTP conversion

Answer Explanations

1. B - [Ar] $3d^6$

Iron (Fe) has atomic number 26 with configuration [Ar] $3d^6 4s^2$. When forming Fe^{2+}, electrons are removed from the 4s orbital first (higher energy when filled), then from 3d if needed. Removing 2 electrons: both come from 4s, leaving [Ar] $3d^6$.

2. C - 4.74

Use the Henderson-Hasselbalch equation: pH = pKa + log([A^-]/[HA]). First find pKa: pKa = -log(1.8×10^{-5}) = 4.74. Since [acetate] = [acetic acid] = 0.50 M, the ratio is 1, and log(1) = 0. Therefore pH = 4.74 + 0 = 4.74.

3. A - Angular momentum quantum number (l)

The four quantum numbers are: n (principal, energy level/size), l (angular momentum, shape: s=0, p=1, d=2, f=3), ml (magnetic, orientation), and ms (spin). The l quantum number determines orbital shape.

4. C - Gamma emission

In gamma emission, the nucleus releases energy as a photon without changing the number of protons or neutrons. Mass number (A) and atomic number (Z) both remain unchanged. Alpha decay changes A by -4, beta decay changes Z by ±1.

5. B - +6

In $K_2Cr_2O_7$: K is +1, O is -2. Total charge = 0. Let x = oxidation state of Cr. Equation: 2(+1) + 2(x) + 7(-2) = 0. Solving: 2 + 2x - 14 = 0, so 2x = 12, x = +6.

6. D - Right (toward products)

Increasing pressure favors the side with fewer gas moles. Reactants: 1 + 3 = 4 moles gas. Products: 2 moles gas. The equilibrium shifts right to relieve pressure by reducing total moles of gas.

7. B - $CH_3CH_2CH_2CH_2OH$ (1-butanol)

1-butanol has -OH group allowing extensive hydrogen bonding, giving it the highest boiling point (~117°C) compared to butane (~0°C), ether (~35°C), or aldehyde (~49°C).

8. C - 1.3×10^{-5} M

For AgCl: Ksp = [Ag^+][Cl^-]. Since they dissociate in 1:1 ratio, if solubility = s, then Ksp = s^2. Solving: s = $\sqrt{(1.8 \times 10^{-10})}$ = 1.34×10^{-5} M.

9. D - The anode is negative

In galvanic cells: Anode (oxidation, negative electrode) → electrons flow → Cathode (reduction, positive electrode). The anode is negative because it's the source of electrons.

10. D - Second order

Rate = $k[A]^x[B]^y$. When [A] doubles and rate increases 4-fold (2^2), the order with respect to A is 2 (second order). This means rate $\propto [A]^2$.

11. A - HSO_4^-

Amphoteric species can act as both acid and base. HSO_4^- can donate H^+ (acting as acid → SO_4^{2-}) or accept H^+ (acting as base → H_2SO_4). NH_4^+ can only donate H^+, SO_4^{2-} can only accept H^+.

12. C - Effective nuclear charge increases and atomic radius decreases

Across a period, protons increase (more nuclear charge) but shielding remains similar (same shell). Effective nuclear charge (Zeff) increases, pulling electrons closer, decreasing radius. Smaller radius and higher Zeff both increase ionization energy.

13. B - 0.055

Raoult's Law: P_solution = χ_solvent × P°_pure. Solving: 22.5 = χ_solvent × 23.8, so χ_solvent = 0.945. Therefore χ_solute = 1 - 0.945 = 0.055.

14. A - sp

CO_2 has linear geometry (O=C=O) with two double bonds. Carbon forms two σ bonds, requiring two hybrid orbitals: sp hybridization. Linear geometry = 180° bond angle.

15. A - 49.3 atm

PV = nRT. P = nRT/V = (4.0 mol)(0.0821 L·atm/mol·K)(300 K)/(2.0 L) = 98.52/2.0 = 49.3 atm.

16. C - Hydrogen bonding

Water's unusually high boiling point (100°C) results from extensive hydrogen bonding between H_2O molecules. O-H bonds are highly polar, and H bonds to lone pairs on neighboring oxygen atoms.

17. B - Shift equilibrium toward products

For endothermic reactions ($\Delta H > 0$), heat is a reactant. Increasing temperature adds heat, shifting equilibrium right (toward products) to consume the added heat. K increases with temperature for endothermic reactions.

18. D - pH = 7

Strong acid + strong base → complete neutralization producing salt + water. At equivalence point, only neutral salt remains (like NaCl), so pH = 7. Weak acid/base titrations have equivalence points $\neq 7$.

19. C - Ionization energy

Down a group: atomic radius increases (more shells), shielding increases, and valence electrons are farther from nucleus. This makes electrons easier to remove, so ionization energy decreases.

20. C - 333 K

Reaction becomes spontaneous when $\Delta G < 0$. $\Delta G = \Delta H - T\Delta S$. At equilibrium, $\Delta G = 0$: $0 = 50{,}000$ J/mol - T(150 J/mol·K). Solving: T = 50,000/150 = 333 K. Above this temperature, ΔG becomes negative.

21. B - Decrease solubility

Common ion effect: Adding Cl^- (from NaCl) shifts $AgCl \rightleftharpoons Ag^+ + Cl^-$ equilibrium left (Le Chatelier), precipitating more AgCl and decreasing solubility. Ksp remains constant, but $[Ag^+]$ decreases.

22. D - NH_3

NH_3 has pyramidal geometry with lone pair on N, creating asymmetry. The N-H bond dipoles don't cancel, resulting in net dipole. CO_2 (linear), CCl_4 (tetrahedral), and BF_3 (trigonal planar) are symmetric with canceling dipoles.

23. A - 1/8

For first-order reactions, each half-life reduces concentration by half. After 60 seconds = 3 half-lives (60/20): Remaining = $(1/2)^3 = 1/8$ of original amount.

24. C - A photon is emitted

Electron transitions from higher (n=3) to lower (n=2) energy level release energy as photons. The energy difference equals photon energy: $\Delta E = h\nu$. Energy is emitted, not absorbed.

25. C - 0.1 M $CaCl_2$

Osmotic pressure ($\pi = iMRT$) depends on total particle concentration. $CaCl_2$ dissociates into 3 ions ($Ca^{2+} + 2Cl^-$), so i = 3. Effective concentration: 0.1 × 3 = 0.3 M. Glucose (i=1): 0.1 M. NaCl (i=2): 0.2 M. $CaCl_2$ has highest particle concentration.

26. D - 25 N

$F = ma$. First find acceleration: $a = \Delta v/t = (20-0)/4 = 5\ m/s^2$. Then $F = (5.0\ kg)(5\ m/s^2) = 25\ N$.

27. A - The force and displacement are perpendicular

$Work = F \cdot d \cdot \cos(\theta)$. When $F \perp d$, $\theta = 90°$, and $\cos(90°) = 0$, so $W = 0$. Example: centripetal force does no work because it's perpendicular to circular motion.

28. C - Slow down and bend toward the normal

Light slows when entering denser medium (higher n). Snell's law: $n_1\sin(\theta_1) = n_2\sin(\theta_2)$. Since $n_2 > n_1$, $\sin(\theta_2) < \sin(\theta_1)$, so $\theta_2 < \theta_1$ (bends toward normal). Speed decreases: $v = c/n$.

29. B - Proportional to and opposite the displacement

In SHM, restoring force $F = -kx$, giving acceleration $a = -kx/m = -\omega^2 x$. Acceleration is always directed toward equilibrium (opposite displacement) and proportional to displacement magnitude.

30. D - 2.4 Ω

Parallel resistors: $1/R_{eq} = 1/R_1 + 1/R_2 = 1/4 + 1/6 = 3/12 + 2/12 = 5/12$. Therefore $R_{eq} = 12/5 = 2.4\ \Omega$. Parallel resistance is always less than smallest resistor.

31. A - 20 cm behind the lens

Thin lens equation: $1/f = 1/do + 1/di$. Given $f = 10$ cm, $do = 20$ cm: $1/10 = 1/20 + 1/di$. Solving: $1/di = 1/10 - 1/20 = 1/20$, so $di = 20$ cm.

32. C - $\frac{1}{2}kx^2$

Elastic potential energy stored in spring: $PE = \frac{1}{2}kx^2$, where k is spring constant and x is displacement from equilibrium. This comes from integrating $F = kx$.

33. C - -200,000 J

Work-energy theorem: $W = \Delta KE = KEf - KEi$. $KEi = \frac{1}{2}mv^2 = \frac{1}{2}(1000)(20)^2 = 200{,}000$ J. $KEf = 0$ (stopped). $W = 0 - 200{,}000 = -200{,}000$ J (negative because force opposes motion).

34. B - Length and gravitational acceleration

Period of simple pendulum: $T = 2\pi\sqrt{(L/g)}$. Period depends only on length and gravity, independent of mass and amplitude (for small angles).

35. A - Pressure, velocity, and height in fluid flow

Bernoulli's equation: $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$. It relates pressure (P), kinetic energy per volume ($\frac{1}{2}\rho v^2$), and potential energy per volume (ρgh) along a streamline in ideal fluid flow.

36. C - I^2R

Power dissipated: $P = IV$. Using Ohm's law ($V = IR$): $P = I(IR) = I^2R$. Alternatively, $P = V^2/R$. This energy converts to heat in the resistor.

37. D - Gamma rays

Photon energy: $E = hf$. Higher frequency = higher energy. Order (low to high energy): Radio < Infrared < Visible < UV < X-ray < Gamma.

38. A - 0 m/s

In elastic collision between equal masses where one is stationary, velocities exchange. First object stops ($v_1 = 0$), second object acquires initial velocity of first ($v_2 = 3$ m/s). Conservation of momentum and energy.

39. C - The right-hand rule (perpendicular to both v and B)

Magnetic force: $F = qv \times B$. Direction given by right-hand rule: fingers point along v, curl toward B, thumb points in direction of F (for positive charge). Force is perpendicular to both velocity and field.

40. B - One-half wavelength

Standing waves have nodes (no motion) and antinodes (maximum motion). Distance between adjacent nodes = $\lambda/2$. Distance between node and antinode = $\lambda/4$. Full wavelength spans two segments.

41. C - Energy cannot be created or destroyed

The first law of thermodynamics is fundamentally a statement of **energy conservation**: energy cannot be created or destroyed, only converted from one form to another. This is the core principle that underlies all thermodynamic processes.

While $\Delta U = Q - W$ is the mathematical expression of the first law for thermodynamic systems (internal energy change equals heat added minus work done), option C states the **fundamental conceptual principle** that the first law embodies.

42. C - 100 μF

Capacitance: $C = Q/V = 0.01\text{ C} / 100\text{ V} = 0.0001\text{ F} = 100\ \mu\text{F}$ (microfarads). $1\ \mu\text{F} = 10^{-6}$ F.

43. B - Sound spreads over larger area (inverse square law)

Sound intensity: $I = P/(4\pi r^2)$, where P is power. As distance increases, sound energy spreads over larger spherical surface area, reducing intensity by r^2. This is geometric spreading, separate from absorption.

44. B - High to low refractive index above critical angle

Total internal reflection occurs when light travels from dense to less dense medium ($n_1 > n_2$) at incident angle greater than critical angle: $\theta c = \sin^{-1}(n_2/n_1)$. Beyond θc, no refraction occurs—all light reflects.

45. D - 2T

Period of mass-spring system: $T = 2\pi\sqrt{(m/k)}$. If mass quadruples: $T' = 2\pi\sqrt{(4m/k)} = 2\cdot 2\pi\sqrt{(m/k)} = 2T$. Period increases by $\sqrt{4} = 2$.

46. C - kQ/r

Electric potential (scalar): $V = kQ/r$, where $k = 9\times10^9\ N\cdot m^2/C^2$. Electric field (vector): $E = kQ/r^2$. Potential energy: $U = kQq/r$ for charge q in field of Q.

47. D - Isochoric

Thermodynamic processes: Isobaric (constant P), Isothermal (constant T), Adiabatic (Q=0, no heat exchange), Isochoric (constant V). At constant volume, no PV work is done.

48. A - Frequency increase when source approaches observer

Doppler effect: Relative motion between source and observer changes observed frequency. Approaching source: frequency increases (wavelength decreases). Receding source: frequency decreases. Sound speed remains constant in medium.

49. A - Opposes the change in magnetic flux

Lenz's law: Induced current creates magnetic field opposing the change in flux causing it. This is electromagnetic induction's "Newton's third law"—nature resists change. Mathematically: $\varepsilon = -d\Phi/dt$ (negative sign = opposition).

50. D - Momentum

de Broglie wavelength: $\lambda = h/p$, where p = momentum = mv. Wavelength inversely proportional to momentum. Higher momentum particles have shorter wavelengths. Relates particle and wave properties.

51. A - R-CO-R'

Ketone functional group: carbonyl (C=O) bonded to two carbon groups. R-CHO is aldehyde, R-COOH is carboxylic acid, R-OH is alcohol. Ketones have carbonyl carbon in middle of chain.

52. C - Antiperiplanar

E2 elimination requires β-hydrogen and leaving group in antiperiplanar conformation (180° dihedral angle). This allows orbital overlap for transition state. Anti stereochemistry ensures proper orbital alignment for concerted mechanism.

53. B - Hydroboration-oxidation (BH_3, then H_2O_2/OH^-)

Hydroboration-oxidation gives anti-Markovnikov addition (OH on less substituted carbon) with syn stereochemistry. BH_3 adds across double bond, then oxidation replaces B with OH. Markovnikov: H_2SO_4/H_2O or oxymercuration-demercuration.

54. D - 3-methylpentane

Structure: CH_3-CH_2-$CH(CH_3)$-CH_2-CH_3. Longest chain = 5 carbons (pentane). Number from end giving lowest number to substituent. Methyl on carbon 3. Name: 3-methylpentane.

55. C - Acetic acid

Acidity order: Carboxylic acids > Phenol > Water > Alcohols. Acetic acid (CH_3COOH, pKa ~4.7) most acidic due to resonance stabilization of carboxylate anion. Phenol (pKa ~10), water (pKa ~15.7), ethanol (pKa ~16).

56. D - Formation of carbocation (unimolecular)

SN1 rate-determining step is carbocation formation after leaving group departure. Reaction rate = k[substrate] (first order), independent of nucleophile concentration.

57. B - CH_3Br

SN2 reactivity order: Methyl > Primary > Secondary >> Tertiary (sterically hindered). CH_3Br (methyl halide) has least steric hindrance, allowing easiest backside nucleophilic attack. Tertiary halides don't undergo SN2.

58. D - Ketones and/or aldehydes

Ozonolysis cleaves C=C bonds. O_3 adds across alkene, then reductive workup (Zn/H_2O or Me_2S) produces carbonyl compounds. Terminal C produces aldehyde, internal C produces ketone. Oxidative workup (H_2O_2) gives carboxylic acids.

59. A - 8

Maximum stereoisomers = 2^n, where n = number of chiral centers. With 3 chiral centers: $2^3 = 8$ possible stereoisomers. This assumes no meso compounds (internal symmetry reducing stereoisomer number).

60. C - PCC (Pyridinium chlorochromate)

PCC oxidizes primary alcohols to aldehydes (stops there). Strong oxidizers ($KMnO_4$, $K_2Cr_2O_7$) over-oxidize primary alcohols to carboxylic acids. Secondary alcohols → ketones (can't oxidize further). PCC is mild, selective oxidant.

61. A - Tollens' reagent (silver mirror test)

Tollens' reagent (Ag^+ in ammonia) oxidizes aldehydes to carboxylic acids, reducing Ag^+ to Ag^0 (silver mirror). Ketones don't react (can't be easily oxidized). Fehling's/Benedict's tests also distinguish.

62. C - 2-bromo-2-methylpropane

Addition follows Markovnikov's rule: H adds to less substituted carbon, Br to more substituted. 2-methylpropene has more substitution at C2, so Br adds there. Carbocation stability drives regioselectivity.

63. A - Identical physical properties except optical rotation

Enantiomers are non-superimposable mirror images with identical physical properties (melting point, boiling point, solubility) except optical rotation direction (one rotates light clockwise, other counterclockwise by same magnitude).

64. B - Benzene

Aromatic criteria (Hückel's rule): Cyclic, planar, conjugated, $4n+2$ π electrons. Benzene has 6 π electrons ($n=1$). Cyclooctatetraene (8 π, non-planar) and cyclohexene (not fully conjugated) are non-aromatic.

65. A - Primary amines

Gabriel synthesis converts alkyl halides to primary amines using phthalimide. Phthalimide anion acts as nucleophile (SN2), then hydrolysis releases primary amine. Avoids over-alkylation problem of direct ammonia alkylation.

66. B - 3 neighboring protons (n+1 rule)

NMR splitting: $n+1$ rule, where n = number of equivalent neighboring protons. Quartet (4 peaks) indicates 3 neighboring H ($3+1=4$). Integration under quartet gives number of protons producing signal.

67. D - Carboxylic acids (after hydrolysis)

Grignard reagents (RMgX) react with CO_2: $RMgX + CO_2 \rightarrow RCO_2MgX$, then $H_3O^+ \rightarrow RCOOH$. This extends carbon chain by one, producing carboxylic acid. Useful synthesis for making acids from halides.

68. D - Tertiary carbocation

Carbocation stability order: Tertiary > Secondary > Primary > Methyl. Stability increases with substitution due to hyperconjugation (neighboring C-H bonds donate electron density) and inductive effects from alkyl groups.

69. B - Functional groups

IR spectroscopy identifies functional groups by characteristic absorption frequencies. O-H (3200-3600 cm^{-1}), C=O (1700 cm^{-1}), C=C (1650 cm^{-1}), C-H (2850-3000 cm^{-1}). Molecular weight requires mass spec; stereochemistry needs NMR or other methods.

70. C - Diene and dienophile

Diels-Alder: [4+2] cycloaddition between conjugated diene (4 π electrons) and dienophile (2 π electrons, often C=C or C=C with electron-withdrawing group). Forms six-membered ring. Stereospecific and concerted.

71. D - $-C(CH_3)_3$

Cahn-Ingold-Prelog rules: Higher atomic number = higher priority. If first atoms identical, look to next atoms. $-C(CH_3)_3$ has three carbons attached to first carbon, highest priority. Then $-CH(CH_3)_2$, $-CH_2CH_3$, $-CH_3$.

72. B - Chlorine is a better leaving group

Acyl chlorides more reactive because Cl^- is excellent leaving group (weak base). Esters less reactive because RO^- is poorer leaving group (stronger base). Better leaving group = faster nucleophilic acyl substitution.

73. C - Primary alcohol

$LiAlH_4$ is strong reducing agent. Esters (RCOOR') reduce to primary alcohols: $RCOOR' \rightarrow RCH_2OH + R'OH$ (two alcohols produced). Weaker reducer ($NaBH_4$) doesn't reduce esters. Carboxylic acids also reduce to primary alcohols with $LiAlH_4$.

74. C - Toluene

Electron-donating groups (EDG) activate aromatic rings toward electrophilic substitution. $-CH_3$ (methyl) is EDG by hyperconjugation and induction. Order: Activating (toluene) > Neutral (benzene) > Deactivating (chlorobenzene, nitrobenzene). EDG increase electron density on ring.

75. B - Cahn-Ingold-Prelog priority rules

E/Z nomenclature uses CIP priority rules to determine configuration. On each double bond carbon, assign priorities (higher atomic number = higher priority). If high-priority groups on same side: Z (zusammen). Opposite sides: E (entgegen).

76. C - Glycine

Glycine (Gly, G) has R group = H. All amino acids have chiral α-carbon except glycine, which has two H atoms (no chiral center). This makes glycine achiral and flexible in protein structures.

77. B - Resonance between C-N bond

Peptide bond (C-N) has partial double bond character from resonance: lone pair on N delocalizes into C=O π system. This restricts rotation and makes bond planar (sp^2 hybridization). Trans configuration typically favored.

78. D - Substrate concentration at ½Vmax

Michaelis-Menten equation: $v = V_{max}[S]/(K_m + [S])$. Km (Michaelis constant) is [S] when v = ½Vmax. Lower Km = higher substrate affinity. Km indicates substrate concentration needed for half-maximal velocity.

79. D - Uracil

DNA has thymine (T), RNA has uracil (U). Both have cytosine (C) and guanine (G). RNA lacks thymine; DNA lacks uracil.

80. B - Mitochondrial matrix

β-oxidation of fatty acids occurs in mitochondrial matrix. Fatty acids activated to acyl-CoA in cytoplasm, transported via carnitine shuttle into mitochondria. Each cycle removes 2-carbon acetyl-CoA, producing $FADH_2$ and NADH.

81. B - Net charge is zero

Isoelectric point (pI) is pH where amino acid has net charge = 0 (equal positive and negative charges). At pH < pI, amino acid is positively charged. At pH > pI, negatively charged. pI = average of relevant pKa values.

82. B - Km only

Competitive inhibitors compete for active site, increasing apparent Km (more [S] needed to reach ½Vmax) but Vmax unchanged (high [S] overcomes inhibition). Lineweaver-Burk plot: lines intersect at y-axis (1/Vmax).

83. C - Cooperative binding

Hemoglobin shows positive cooperativity: O_2 binding to one subunit increases affinity at remaining subunits. Sigmoidal curve (not hyperbolic) reflects this. Hill coefficient > 1 indicates cooperativity. Myoglobin (monomeric) shows hyperbolic curve.

84. D - 2 ATP

Glycolysis glucose → 2 pyruvate produces: 4 ATP (substrate-level phosphorylation) but consumes 2 ATP in early steps. Net: $4 - 2 = 2$ ATP. Also produces 2 NADH. Complete glucose oxidation (including TCA, ETC) yields ~30-32 ATP.

85. B - Amino acid sequence

Protein structure levels: Primary (sequence), Secondary (α-helix, β-sheet), Tertiary (3D fold), Quaternary (multi-subunit assembly). Primary structure is the linear amino acid sequence.

86. C - Vitamin B_3 (niacin)

NAD^+ (nicotinamide adenine dinucleotide) is synthesized from niacin (vitamin B_3). $NADH/NAD^+$ is major electron carrier in metabolism. Niacin deficiency causes pellagra. Riboflavin (B_2) is precursor to FAD.

87. C - Sphingosine

Sphingolipids contain sphingosine backbone (amino alcohol), not glycerol. Examples: sphingomyelin, cerebrosides, gangliosides. Glycerophospholipids contain glycerol backbone. Both are membrane components.

88. D - Topoisomerase

Topoisomerases relieve supercoiling (tension) ahead of replication fork by temporarily breaking and rejoining DNA strands. Helicase unwinds double helix. Ligase joins Okazaki fragments. Primase synthesizes RNA primers.

89. D - O_2

Complex IV (cytochrome c oxidase) transfers electrons from cytochrome c to O_2 (terminal electron acceptor), reducing it to H_2O: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$. This is the final step of electron transport chain.

90. C - Liver

Gluconeogenesis (synthesis of glucose from non-carbohydrate precursors) occurs primarily in liver, with kidney cortex as secondary site. Not in muscle (lacks glucose-6-phosphatase) or brain. Maintains blood glucose during fasting.

91. B - Disulfide bridges

Tertiary structure stabilized by: Disulfide bridges (covalent S-S bonds between cysteines), hydrogen bonds, ionic interactions, hydrophobic interactions, van der Waals forces. Peptide bonds define primary structure. Quaternary involves multiple chains.

92. B - Lactate to glucose

Cori cycle: Muscle produces lactate from glucose (anaerobic glycolysis) → lactate travels to liver → liver converts lactate back to glucose (gluconeogenesis) → glucose returns to muscle. Redistributes metabolic burden between tissues.

93. B - Aromatic amino acids

Chymotrypsin (serine protease) cleaves peptide bonds C-terminal to large hydrophobic residues, especially aromatic amino acids (Phe, Trp, Tyr). Trypsin cleaves after basic residues (Lys, Arg). Elastase cleaves after small residues.

94. B - AUG

AUG is the start codon coding for methionine (initiates translation). Stop codons: UAA, UAG, UGA ("stop" signals). All proteins begin with methionine (often removed post-translationally).

95. C - Amphipathic

Phospholipids are amphipathic: hydrophilic head (phosphate group) and hydrophobic tails (fatty acid chains). In water, spontaneously form bilayers with hydrophobic tails inside, hydrophilic heads facing water. Minimizes unfavorable water-hydrocarbon interactions.

96. D - Phosphofructokinase-1

Phosphofructokinase-1 (PFK-1) catalyzes committed, rate-limiting step: Fructose-6-phosphate → Fructose-1,6-bisphosphate. Highly regulated by ATP (negative), AMP (positive), citrate (negative). Other enzymes (hexokinase, pyruvate kinase) also regulated but PFK-1 is primary control point.

97. B - Aminoacyl-tRNA synthetases

Aminoacyl-tRNA synthetases are enzymes that charge tRNAs with correct amino acids (aminoacylation). Each synthetase recognizes specific amino acid and corresponding tRNA(s). ATP-dependent process ensures translation fidelity.

98. C - Acetone and β-hydroxybutyrate

Ketone bodies (produced during fasting/fat metabolism): Acetoacetate, β-hydroxybutyrate, acetone. Liver synthesizes them from acetyl-CoA; brain/muscle use them for energy when glucose is scarce.

99. C - Cholesterol

Cholesterol is precursor for all steroid hormones: Cortisol, aldosterone, testosterone, estrogen, progesterone. Also precursor for vitamin D and bile acids. Synthesis occurs primarily in liver. Steroidogenic tissues convert cholesterol to specific hormones.

100. B - ATP synthase rotation

ATP synthase (Complex V) uses proton gradient: Protons flow through F_0 channel, causing rotation of c-ring and γ-subunit. Rotation induces conformational changes in F_1 catalytic subunits, driving ATP synthesis from ADP + Pi. Rotational catalysis mechanism.