Chemistry and Physics

Topics

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I. Introduction, Percentages, and Percentiles

The Chemical and Physical Foundations of Biological Systems section asks you to solve problems by combining your knowledge of chemical and physical foundational concepts with your scientific inquiry and reasoning skills. This section tests your understanding of the mechanical, physical, and biochemical functions of human tissues, organs, and organ systems. It also tests your knowledge of the basic chemical and physical principles that underlie the mechanisms operating in the human body and your ability to reason about and apply your understanding of these basic chemical and physical principles to living systems.

This section is designed to:

1. Test introductory-level biology, organic and inorganic chemistry, and physics concepts.

2. Test biochemistry concepts at the level taught in many colleges and universities in first-semester biochemistry courses.

3. Test molecular biology topics at the level taught in many colleges and universities in introductory biology sequences and first-semester biochemistry courses.

4. Test basic research methods and statistics concepts described by many baccalaureate faculty as important to success in introductory science courses.

5. Require you to demonstrate your scientific inquiry and reasoning, research methods, and statistics skills as applied to the natural sciences.

59 Questions, 95 minutes:

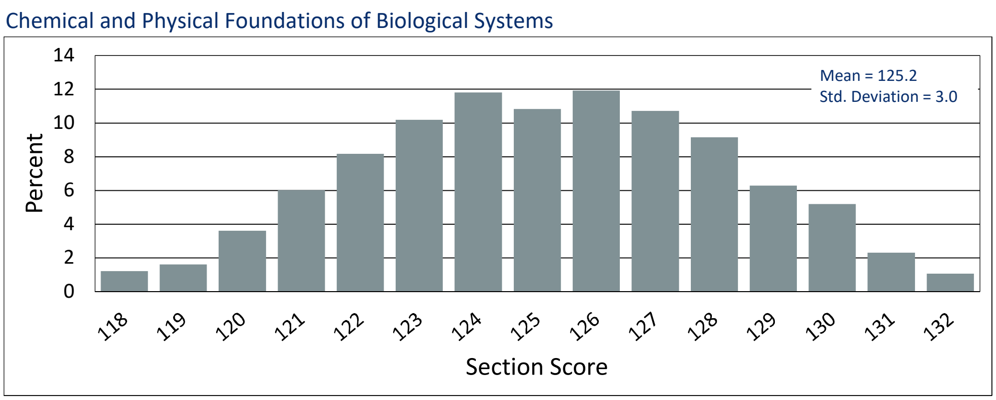
1. 10 Passage-based sets of questions with 4-6 questions per set
2. 15 Discrete questions

Subject	Bio-BCHM Section (%)	CP Section (%)	Average (%)
Biochemistry	25	25	25
Biology	65	5	35
General Chemistry	5	30	17.5
Physics	0	25	12.5
Organic Chemistry	5	15	10

Table 1 Subject percentage by section

Section	Foundational Concept	Percentage (%)
Bio-BCHM	1	55
	2	20
	3	25
CP	4	40
	5	60

Table 2 Foundational concept percentage by section



Section Score	Percentile Rank
118	1
119	3
120	6
121	12
122	21
123	31
124	43
125	53
126	65
127	76
128	85
129	91
130	97
131	99
132	100

Figure 1 and **Table 3** CP section score percent and percentile rank

II. General Math Concepts and Techniques

It's important for you to know that questions on the natural, behavioral, and social sciences sections will ask you to use certain mathematical concepts and techniques. As the descriptions of the scientific inquiry and reasoning skills suggest, some questions will ask you to analyze and manipulate scientific data to show that you can:

1. Recognize and interpret linear, semi-log, and log-log scales and calculate slopes from data found in figures, graphs, and tables

2. Demonstrate a general understanding of significant digits and the use of reasonable numerical estimates in performing measurements and calculations

3. Use metric units, including converting units within the metric system and between metric and English units (conversion factors will be provided when needed), and dimensional analysis (using units to balance equations)

4. Perform arithmetic calculations involving the following: probability, proportion, ratio, percentage, and square-root estimations

5. Demonstrate a general understanding (Algebra II-level) of exponentials and logarithms (natural and base 10), scientific notation, and solving simultaneous equations

6. Demonstrate a general understanding of the following trigonometric concepts: definitions of basic (sine, cosine, tangent) and inverse ($\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$) functions; sin and cos values of 0°, 90°, and 180°; relationships between the lengths of sides of right triangles containing angles of 30°, 45°, and 60°

7. Demonstrate a general understanding of vector addition and subtraction and the right-hand rule (knowledge of dot and cross products is not required)

Note also that an understanding of calculus is not required, and a periodic table will be provided during the exam.

III. Foundational Concept 4 - Physics

Complex living organisms transport materials, sense their environment, process signals, and respond to changes using processes that can be understood in terms of physical principles. The processes that take place within organisms follow the laws of physics. They can be quantified with equations that model the behavior at a fundamental level. For example, the principles of electromagnetic radiation, and its interactions with matter, can be exploited to generate structural information about molecules or to generate images of the human body. So, too, can atomic structure be used to predict the physical and chemical properties of atoms, including the amount of electromagnetic energy required to cause ionization.

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D. Light and Sound 10

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A. Motion, Forces, Energy, and Equilibrium

Translational motion, forces, work, energy, and equilibrium in living systems. Category 4A focuses on motion and its causes, and various forms of energy and their interconversions. The motion of any object can be described in terms of displacement, velocity, and acceleration. Objects accelerate when subjected to external forces and are at equilibrium when the net force and the net torque acting upon them are zero. Many aspects of motion can be calculated with the knowledge that energy is conserved, even though it may be converted into different forms. In a living system, the energy for motion comes from the metabolism of fuel molecules, but the energetic requirements remain subject to the same physical principles.

The content in this category covers several physics topics relevant to living systems including translational motion, forces, work, energy, and equilibrium. The topics and subtopics in this category are the following:

1. Translational Motion
    a. Units and dimensions
    b. Vectors, components, and vector addition
    c. Speed and velocity - average and instantaneous

2. Force, Torque, and Equilibrium
    a. Newton's laws of motion
    b. Friction - static and kinetic
    c. Center of mass
    d. Vector analysis of forces acting on a point object
    e. Torques and lever arms

3. Work and Energy
    a. Work done by a constant force: $W = Fd\cos\theta$
    b. Mechanical advantage
    c. Work-energy theorem
    d. Conservative forces
    e. Kinetic energy: $KE = \frac{1}{2}mv^2$
    f. Potential energy - gravitational (local), $PE = mgh$; spring, $PE = \frac{1}{2}kx^2$
    g. Conservation of energy
    h. Power

4. Periodic Motion
    a. Amplitude, frequency, phase
    b. Transverse and longitudinal waves - wavelength and propagation speed

B. Fluids

Importance of fluids for the circulation of blood, gas movement, and gas exchange. Category 4B focuses on the behavior of fluids, which is relevant to the functioning of the pulmonary and circulatory systems. Fluids are featured in several physiologically important processes, including the circulation of blood, gas movement into and out of the lungs, and gas exchange with the blood. The energetic requirements of fluid dynamics can be modeled using physical equations. A thorough understanding of fluids is necessary to understand the origins of numerous forms of disease.

The content in this category covers hydrostatic pressure, fluid flow rates, viscosity, the Kinetic Molecular Theory of Gases, and the Ideal Gas Law. The topics and subtopics in this category are the following:

1. Fluids
    a. Density and specific gravity
    b. Buoyancy and Archimedes' principle
    c. Hydrostatic pressure - hydrostatic pressure, $P = \rho gh$; Pascal's law
    d. Viscosity - Poiseuille flow
    e. Continuity equation, Av = constant
    f. Concept of turbulence at high velocities
    g. Surface tension
    h. Bernoulli's equation
    i. Venturi effect and pitot tube

2. Circulatory System - Arterial and venous systems, pressure and flow characteristics

3. Gas Phase
    a. Absolute temperature - Kelvin (K) scale
    b. Pressure and the simple mercury barometer
    c. Molar volume = 22.4 L/mol (at 0°C and 1 atm)
    d. Ideal gas - definition; ideal gas law, $PV = nRT$; Boyle's law, PV = constant; Charles' law, V/T = constant; Avogadro's law, V/n = constant
    e. Kinetic molecular theory of gases - heat capacity at constant volume and at constant pressure; Boltzmann's constant
    f. Deviation of real gas behavior from ideal gas law - qualitative and quantitative (van der Waals' equation)
    g. Partial pressure and mole fraction
    h. Dalton's law relating partial pressure to composition

C. Electrochemistry and Circuits

Electrochemistry and electrical circuits and their elements. Category 4C emphasizes the nature of electrical currents and voltages; how energy can be converted into electrical forms that can be used to perform chemical transformations or work; and how electrical impulses can be transmitted over long distances in the nervous system. Charged particles can be set in motion by the action of an applied electrical field, and can be used to transmit energy or information over long distances. The energy released during certain chemical reactions can be converted to electrical energy, which can be harnessed to perform other reactions or work.

Physiologically, a concentration gradient of charged particles is set up across the cell membrane of neurons at considerable energetic expense. This allows for the rapid transmission of signals using electrical impulses—changes in the electrical voltage across the membrane—under the action of some external stimulus.

The content in this category covers electrical circuit elements, electrical circuits, and electrochemistry. The topics and subtopics in this category are the following:

1. Electrostatics
    a. Charge, conductors, and charge conservation
    b. Insulators
    c. Coulomb's law
    d. Electric field **E** - field lines and field due to a charge distribution
    e. Electrostatic energy and electric potential at a point in space

2. Circuit Elements
    a. Current $I = \Delta Q/\Delta t$ and sign conventions
    b. Batteries - electromotive force and voltage
    c. Resistance - resistivity, $\rho = RA/L$; Ohm's law, $I = V/R$; resistors in series and parallel
    d. Capacitance - parallel plate capacitor and dielectrics; energy of charged capacitor; capacitors in series and parallel
    e. Conductivity - metallic and electrolytic
    f. Ammeters and voltmeters

3. Magnetism
    a. Definition of magnetic field ***B***
    b. Motion of charged particle in magnetic fields - Lorentz force

4. Electrochemistry
    a. Electrolytic cell - electrolysis; electron flow - oxidation and reduction at the electrodes; electrolyte; Faraday's law relating current and the amount of element deposited, or gas liberated, at an electrode
    b. Galvanic (Voltaic) cells - half-reactions; reduction potentials and cell potential; direction of electron flow
    c. Concentration cell - direction of electron flow and Nernst equation
    d. Batteries - lead-storage and nickel-cadmium batteries

D. Light and Sound

How light and sound interact with matter. Category 4D focuses on the properties of light and sound; how the interactions of light and sound with matter can be used by an organism to sense its environment; and how these interactions can also be used to generate structural information or images. Light is a form of electromagnetic radiation—waves of electric and magnetic fields that transmit energy. The behavior of light depends on its frequency (or wavelength). The properties of light are exploited in the optical elements of the eye to focus rays of light on sensory elements. When light interacts with matter, spectroscopic changes occur that can be used to identify the material on an atomic or molecular level. Differential absorption of electromagnetic radiation can be used to generate images useful in diagnostic medicine. Interference and diffraction of light waves are used in many analytical and diagnostic techniques. The photon model of light explains why electromagnetic radiation of different wavelengths interacts differently with matter.

When mechanical energy is transmitted through solids, liquids, and gases, oscillating pressure waves known as “sound” are generated. Sound waves are audible if the sensory elements of the ear vibrate in response to exposure to these vibrations. The detection of reflected sound waves is utilized in ultrasound imaging. This non-invasive technique readily locates dense subcutaneous structures, such as bone and cartilage, and is very useful in diagnostic medicine.

The content in this category covers the properties of both light and sound and how these energy waves interact with matter. The topics and subtopics in this category are the following:

1. Sound
    a. Production of sound
    b. Relative speed of sound in solids, liquids, and gases
    c. Intensity of sound, decibel units, and the log scale
    d. Attenuation (damping)
    e. Doppler effect - moving sound source or observer and the reflection of sound from a moving object
    f. Pitch
    g. Resonance in pipes and strings
    h. Ultrasound and shock waves

2. Light and Electromagnetic Radiation
    a. Concept of interference - Young double-slit experiment
    b. Thin films, diffraction grating, single-slit diffraction
    c. Other diffraction phenomena and X-ray diffraction
    d. Polarization of light - linear and circular
    e. Properties of EM radiation - velocity equals c (*in vacuo*); EM radiation consists of perpendicularly oscillating electric and magnetic fields and the direction of propagation is perpendicular to both
    f. Classification of the EM spectrum and photon energy, $E = hf$
    g. Visual spectrum and color

3. Molecular Structure and Absorption Spectra
    a. Infrared region - intramolecular vibration and rotations; recognizing common characteristic group absorptions and the fingerprint region
    b. Visible region - absorption in visible region gives complementary color, e.g., carotene; effect of structural changes on absorption, e.g., acid-base indicators
    c. UV region - π-electron transitions and non-bonding electron transitions; conjugated systems
    d. NMR spectroscopy - protons in a magnetic field and equivalent protons; spin-spin splitting

4. Geometrical Optics
    a. Reflection from plane surface - angle of incidence equals angle of reflection
    b. Refraction, refractive index n, and Snell's law ($n_1 \sin\theta_1 = n_2 \sin\theta_2$)
    c. Dispersion - dependance of index of refraction on wavelength
    d. Conditions for total internal reflection
    e. Spherical mirrors - center of curvature and focal length; real and virtual images
    f. Thin lenses - converging and diverging lenses; thin-lens equation, $1/p + 1/q = 1/f$; lens strength, power, and diopters
    g. Combination of lenses
    h. Lens aberration
    i. Optical instruments including the human eye

E. Atoms and Nuclear Chemistry

Atoms, nuclear decay, electronic structure, and atomic chemical behavior - Category 4E focuses on sub-atomic particles, the atomic nucleus, nuclear radiation, the structure of the atom, and how the configuration of any particular atom can be used to predict its physical and chemical properties. Atoms are classified by their atomic number: the number of protons in the atomic nucleus, which also includes neutrons. Chemical interactions between atoms are the result of electrostatic forces involving the electrons and the nuclei. Because neutrons are uncharged, they do not dramatically affect the chemistry of any particular type of atom, but do affect the stability of the nucleus itself.

When a nucleus is unstable, decay results from one of several different processes, which are random, but occur at well-characterized average rates. The products of nuclear decay (alpha, beta, and gamma rays) can interact with living tissue, breaking chemical bonds and ionizing atoms and molecules in the process. The electronic structure of an atom is responsible for its chemical and physical properties. Only discrete energy levels are allowed for electrons. These levels are described individually by quantum numbers. Since the outermost, or valence, electrons are responsible for the strongest chemical interactions, a description of these electrons alone is a good first approximation to describe the behavior of any particular type of atom. Mass spectrometry is an analytical tool that allows characterization of atoms or molecules, based on well recognized fragmentation patterns and the charge to mass ratio (m/z) of ions generated in the gas phase.

The content in this category covers atomic structure, nuclear decay, electronic structure, and the periodic nature of atomic chemical behavior. The topics and subtopics in this category are the following:

1. Atomic Nucleus
   a. Atomic number and atomic weight
   b. Neutrons, protons, and isotopes
   c. Nuclear forces and binding energy
   d. Radioactive decay - α, β, and γ decay; half-life, exponential decay, and semi-log plots
   e. Mass spectrometer

2. Electronic Structure
    a. Orbital structure of the hydrogen atom, principle quantum number *n*, number of electrons per orbital
    b. Ground state and excited states
    c. Absorption and emission line spectra
    d. Pauli Exclusion Principle
    e. Paramagnetism and diamagnetism
    f. Conventional notation for electronic structure
    g. Bohr atom
    h. Heisenberg Uncertainty Principle
    i. Effective nuclear charge
    j. Photoelectric effect

3. Periodic Table: Classification of Elements into Groups by Electronic Structure
    a. Representative elements
    b. Metals and nonmetals
    c. Alkali and alkaline earth metals
    d. Transition metals
    e. Oxygen group and the halogens
    f. Noble gases

4. Periodic Table: Variations of Chemical Properties with Group and Row
    a. Valence electrons
    b. First and second ionization energies - definition and trend
    c. Electron affinity - definition and trend
    d. Electronegativity - definition and trend
    e. Electron shells and the sizes of atoms and ions

5. Stoichiometry
    a. Molecular weight
    b. Empirical versus molecular formula
    c. Metric units commonly used in the context of chemistry
    d. Description of composition by percent mass
    e. Mole concept and Avogadro's number N_A
    f. Definition of density
    g. Oxidation number - common oxidizing and reducing agents; disproportionation reactions
    h. Description of reactions by chemical equations - conventions for writing chemical equations; balancing equations including redox equations; limiting reactants and theoretical yields

IV. Foundational Concept 5 - Chemistry

The principles that govern chemical interactions and reactions form the basis for a broader understanding of the molecular dynamics of living systems. The chemical processes that take place within organisms are readily understood within the framework of the behavior of solutions, thermodynamics, molecular structure, intermolecular interactions, molecular dynamics, and molecular reactivity.

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B. Molecules and Intermolecular Forces 16

C. Separation and Purification Methods 17

D. Structure and Reactivity of Molecules 18

E. Thermodynamics and Kinetics 20

A. Water and Solutions

Unique nature of water and its solutions. Category 5A emphasizes the nature of solution formation, factors that affect solubility, and the properties and behavior of aqueous solutions, with special emphasis on the acid-base behavior of dissolved solutes.

In order to fully understand the complex and dynamic nature of living systems, it is first necessary to understand the unique nature of water and its solutions. The unique properties of water allow it to strongly interact with and mobilize many types of solutes, including ions. Water is also unique in its ability to absorb energy and buffer living systems from the chemical changes necessary to sustain life. The content in this category covers the nature of solutions, solubility, acids, bases, and buffers. The topics and subtopics in this category are the following:

1. Acid-Base Equilibria
   a. Acid-base definitions - Arrhenius, Brønsted-Lowry, Lewis
   b. Ionization of water - water-dissociation constant K_w; definition of pH
   c. Conjugate acids and bases
   d. Strong acids and bases
   e. Weak acids and bases - dissociation of weak acids ad bases with or without added salt; hydrolysis of salts of weak acids or bases; calculating the pH of solutions of weak acids or bases
   f. Equilibrium constants - K_a, K_b, pK_a, pK_b
   g. Buffers - definition and concepts; influence on titration curves

2. Ions in Solutions
   a. Common anions and cations - names, formulas, and charges
   b. Ion hydration

3. Solubility
   a. Units of concentration - molarity and molality
   b. Solubility product constant K_{sp}
   c. Common-ion effect and its use in laboratory separations - complex ion formation and solubility; solubility and pH

4. Titration
   a. Neutralization and indicators
   b. Interpretation of titration curves
   c. Redox titration

B. Molecules and Intermolecular Forces

Nature of molecules and intermolecular interactions. Category 5B focuses on molecular structure and how it affects the strength of intermolecular interactions. Covalent bonding involves the sharing of electrons between atoms. If the result of such interactions is not a network solid, then the covalently bonded substance will be discrete and molecular.

The shape of molecules can be predicted based on electrostatic principles and quantum mechanics since only two electrons can occupy the same orbital. Bond polarity (both direction and magnitude) can be predicted based on knowledge of the valence electron structure of the constituent atoms. The strength of intermolecular interactions depends on molecular shape and the polarity of the covalent bonds present. The solubility and other physical properties of molecular substances depend on the strength of intermolecular interactions.

The content in this category covers the nature of molecules and includes covalent bonding, molecular structure, nomenclature, and intermolecular interactions. The topics and subtopics in this category are the following:

1. Covalent Bond
   a. Lewis electron dot structures and formal charge
   b. Delocalized electrons and resonance structures
   c. Partial ionic character - role of electronegativity in determining charge distribution; dipole moment
   d. σ and π bonds - hybrid orbitals: sp^3, sp^2, sp and their respective geometries; VSEPR and the prediction of molecular geometry
   e. Multiple bonding - effect on bond length and bond energies; rigidity in molecular structure
   f. Isomers - structural, conformational, *cis*-*trans* (*E*-*Z*), and stereoisomers
   g. Stereoisomers - enantiomers and diastereomers; polarization of light, optical activity, and specific rotation; absolute and relative configurations; *R* and *S* configurations

2. Liquid Phase - Intermolecular Forces
   a. Hydrogen bonding
   b. Dipole interactions
   c. Van der Waals forces (London dispersion forces)

C. Separation and Purification Methods

Category 5C emphasizes how differential intermolecular interactions can be used to effect chemical separations. Analysis of complex mixtures of substances—especially biologically relevant materials—typically requires separation of the components. Many methods have been developed to accomplish this task, and the method used is dependent on the types of substances which comprise the mixture. All of these methods rely on the magnification of potential differences in the strength of intermolecular interactions.

The content in this category covers separation and purification methods including: extraction, liquid and gas chromatography, and electrophoresis. The topics and subtopics in this category are the following:

1. Extraction - distribution of solute between two immiscible solvents

2. Distillation

3. Chromatography
   a. Basic principles involved in the separation process
   b. Paper and thin-layer chromatography
   c. Column chromatography
   d. Gas-liquid and HPLC chromatography

4. Separation and purification of peptides and proteins
   a. Electrophoresis
   b. Quantitative analysis
   c. Chromatography - size-exclusion, ion-exchange, and affinity

5. Racemic mixtures - separation of enantiomers

D. Structure and Reactivity of Molecules

Structure, function, and reactivity of biologically-relevant molecules. Category 5D emphasizes the varied nature of biologically-relevant molecules, and how patterns of covalent bonding can be used to predict the chemical reactivity of these molecules and their structure and function within a living system. The structure of biological molecules forms the basis of their chemical reactions including oligomerization and polymerization. Unique aspects of each type of biological molecule dictate their role in living systems, whether providing structure or information storage, or serving as fuel and catalysts.

The content in this category covers the structure, function, and reactivity of biologically-relevant molecules including the mechanistic considerations that dictate their modes of reactivity. The topics and subtopics in this category are the following:

1. Macromolecules
    a. Synthesis of α-amino acids - Strecker and Gabriel synthesis
    b. Lipids - storage (TAG and saponification); signals and cofactors (fat-soluble vitamins, steroids, prostaglandins)
    c. Carbohydrates - keto-enol tautomerism of monosaccharides

2. Aldehydes and Ketones
    a. Nomenclature and physical properties
    b. Nucleophilic addition reactions at the C=O group - steric and electronic effects of substituents on reactivity; acetal-hemiacetal formation; imine-enamine formation; cyanohydrin formation; hydride reagents
    c. Oxidation of aldehydes
    d. Reactions at the α-carbon - acidity of α-hydrogens, carbanions, and enolate chemistry; keto-enol tautomerism and α-racemization; Aldol condensation and retro-aldol; kinetic vs. thermodynamic enolates

3. Alcohols
    a. Nomenclature, acidity, and hydrogen bonding
    b. Important reactions - oxidation; substitution reactions (S_N1 and S_N2) protection of alcohols; preparation of mesylates and tosylates

4. Carboxylic Acids
    a. Nomenclature and physical properties
    b. Reactions at the C=O group - anhydride formation; esters and lactones, amides and lactams; reduction and decarboxylation; reactions at the α-carbon (substitution)

5. Acid Derivatives
    a. Anhydrides, esters, and amides
    b. Nomenclature and physical properties
    c. Important reactions - nucleophilic acyl substitution; transesterification; hydrolysis of amides
    d. General principles - relative reactivity of acid derivatives; steric and electronic effects; strain in lactones and lactams, e.g., in β-lactams

6. Aromatic Compounds
    a. Phenols - oxidation and reduction, e.g., hydroquinone, ubiquinones: biological two-electron redox centers
    b. Polycyclic and heterocyclic aromatic compounds
    c. Biological aromatic heterocycles

E. Thermodynamics and Kinetics

Principles of chemical thermodynamics and kinetics. Category 5E emphasizes how relative energy dictates the overall favorability of chemical processes and the rate at which these processes can occur. The processes that occur in living systems are dynamic, and they follow the principles of chemical thermodynamics and kinetics. The position of chemical equilibrium is dictated by the relative energies of products and reactants. The rate at which chemical equilibrium is attained is dictated by a variety of factors: concentration of reactants, temperature, and the amount of catalyst (if any).

Biological systems have evolved to harness energy, and utilize it in very efficient ways to support all processes of life, including homeostasis and anabolism. Biological catalysts, known as enzymes, have evolved to allow all of the relevant chemical reactions required to sustain life to occur both rapidly and efficiently, and under the narrow set of conditions required.

The content in this category covers all principles of chemical thermodynamics and kinetics including enzymatic catalysis. The topics and subtopics in this category are the following:

1. Energy Changes in Chemical Reactions - Thermochemistry and Thermodynamics
    a. Thermodynamic system - state function
    b. Zeroth law - concept of temperature
    c. First law - conservation of energy in thermodynamic processes
    d. *PV*-diagrams: work done = area under curve or enclosed in a curve
    e. Second law - entropy as a measure of “disorder”; relative entropy of gas, liquid, and crystal states
    f. Measurement of heat changes (calorimetry), heat capacity, and specific heat
    g. Heat transfer - conduction, convection, and radiation
    h. Coefficient of expansion
    i. Endothermic and exothermic reactions - enthalpy (*H*) and standard heats of reaction and formation; Hess’s Law of Heat Summation
    j. Bond dissociation energy as related to heats of formation
    k. Heat of fusion and vaporization
    l. Phase diagrams - pressure and temperature

2. Rate Processes in Chemical Reactions
   a. Reaction rate
   b. Dependance of reaction rate on concentration of reactants
      i. Rate law and rate constant
      ii. Reaction order
   c. Rate-determining (rate-limiting) step
   d. Dependance of reaction rate on temperature - activation energy and Arrhenius equation
   e. Reaction energy profiles
      i. Interpretation of profiles - reactants, products, activation energy, and ΔH
      ii. Transition state (activated complex) and intermediates
   f. Kinetic control vs. thermodynamic control of a reaction
   g. Catalysts
   h. Equilibrium in reversible reactions - Law of Mass Action; equilibrium constant K_{eq}; application of Le Châtelier's Principle; standard free energy $\Delta G°$ and the equilibrium constant K_{eq}