

BIO503 – BIOLOGICAL PHYSICS

MID TERM IMPORTANT QUESTIONS

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1. Differentiate between temperature and heat.

Temperature is the measure of how hot or cold a substance is and indicates the average kinetic energy of the particles within it. It is measured using a thermometer and expressed in units such as Celsius (°C), Fahrenheit (°F), or Kelvin (K). Temperature is an intensive property, meaning it does not depend on the amount of substance present. For example, a cup of boiling water and a large pot of boiling water may have the same temperature even though they contain different amounts of water.

Heat is a form of energy that transfers from one object to another because of a difference in temperature. Heat always moves from a hotter body to a colder body until thermal equilibrium is reached. It is measured in joules or calories and depends on the mass and nature of the substance. Unlike temperature, heat is an extensive property because the amount of heat changes with the quantity of matter. Heat can increase the temperature of a substance or change its physical state, such as turning ice into water or water into steam. In simple terms, temperature tells us how hot something is, while heat refers to the energy transferred due to that temperature difference.

2. What are different types of equilibrium?

Static Equilibrium: Static equilibrium occurs when a body remains completely at rest because all the forces acting on it are balanced. An example is a person standing still, where the downward gravitational force is balanced by the upward support force from the ground.

Dynamic Equilibrium: Dynamic equilibrium exists when movement or reactions continue, but the overall condition of the system remains constant because opposite processes occur at equal rates. In living systems, the movement of molecules across cell membranes is an example of dynamic equilibrium.

Stable Equilibrium: Stable equilibrium occurs when a body returns to its original position after being slightly disturbed. This type of equilibrium is important in maintaining body posture and balance in organisms.

Unstable Equilibrium: Unstable equilibrium occurs when a slight disturbance causes a body to move farther away from its original position. For example, a person standing on a narrow edge can easily lose balance after a small displacement.

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Neutral Equilibrium: Neutral equilibrium exists when a body remains in its new position after displacement without returning to its original state or moving farther away. A ball resting on a flat surface is a common example.

Mechanical Equilibrium: Mechanical equilibrium is the condition in which the sum of all forces and torques acting on a body is zero. This prevents acceleration or rotational motion in the system.

Thermal Equilibrium: Thermal equilibrium occurs when two systems in contact have the same temperature, so no net transfer of heat takes place between them.

Chemical Equilibrium: Chemical equilibrium is reached when the rate of the forward chemical reaction becomes equal to the rate of the reverse reaction, resulting in constant concentrations of reactants and products.

3. What are types of amino acids?

Essential Amino Acids

Essential amino acids are those that cannot be synthesized by the human body in sufficient amounts and must be obtained through diet. These amino acids are important for protein synthesis, tissue repair, enzyme activity, and metabolic regulation. Examples include leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.

Non-Essential Amino Acids

Non-essential amino acids are produced naturally within the body and therefore do not need to be obtained directly from food. They play important roles in maintaining cellular structure, metabolism, and physiological functions. Examples include alanine, asparagine, aspartic acid, and glutamic acid.

Conditionally Essential Amino Acids

Conditionally essential amino acids are usually synthesized by the body, but during periods of illness, stress, injury, or rapid growth, their production may become insufficient. In such conditions, they must be supplied through diet. Examples include arginine, cysteine, glutamine, glycine, proline, and tyrosine.

Polar Amino Acids

Polar amino acids contain side chains that can interact with water through hydrogen bonding. These amino acids are often found on the outer surfaces of proteins and contribute to solubility and molecular interactions. Examples include serine, threonine, and asparagine.

Non-Polar Amino Acids

Non-polar amino acids possess hydrophobic side chains that do not interact easily with water. They are commonly located in the inner core of proteins and help maintain protein structure and stability. Examples include valine, leucine, alanine, and phenylalanine.

Acidic Amino Acids

Acidic amino acids contain carboxyl groups in their side chains, giving them a negative charge at physiological pH. These amino acids participate in ionic interactions and enzyme functions. Examples are aspartic acid and glutamic acid.

Basic Amino Acids

Basic amino acids have side chains containing amino groups that carry a positive charge at physiological pH. They are important in maintaining protein structure and binding negatively charged molecules such as DNA. Examples include lysine, arginine, and histidine.

Aromatic Amino Acids

Aromatic amino acids contain ring-shaped structures that absorb ultraviolet light and contribute to protein interactions. Examples include phenylalanine, tyrosine, and tryptophan.

4. Explain fluid mosaic model of plasma membrane.

Introduction

The fluid mosaic model explains the structure of the plasma membrane. It was proposed by S. J. Singer and Garth L. Nicolson in 1972. According to this model, the membrane is a flexible and dynamic structure made of lipids, proteins, and carbohydrates.

Structure of Plasma Membrane

The membrane mainly consists of a phospholipid bilayer. Each phospholipid has a hydrophilic head and hydrophobic tails. The heads face the watery environment inside and outside the cell, while the tails remain inward. Proteins are embedded within the bilayer and help in transport, communication, and enzymatic activities. Carbohydrates attached to proteins and lipids are involved in cell recognition and signaling.

Fluid and Mosaic Nature

The membrane is called “fluid” because phospholipids and proteins can move within the layer, giving flexibility to the membrane. Cholesterol helps maintain membrane stability and fluidity. The term “mosaic” describes the irregular arrangement of proteins and other molecules within the membrane.

Functions

The plasma membrane controls the movement of substances into and out of the cell, maintains cell shape, and helps in communication and transport processes such as endocytosis and exocytosis.

5. Explain Brownian motion.

Brownian Motion

Brownian motion is the random and zigzag movement of tiny particles suspended in a liquid or gas. It occurs because the particles are continuously bombarded by fast-moving molecules of the surrounding medium. This phenomenon was first observed by Robert Brown in 1827 while studying pollen grains in water. Brownian motion increases with temperature and is more noticeable in smaller particles. It plays an important role in diffusion and transport of substances in biological systems.

6. Explain first law of thermodynamics.

First Law of Thermodynamics

The first law of thermodynamics states that energy can neither be created nor destroyed; it can only be transformed from one form to another. According to this law, the total energy of an isolated system always remains constant. Mathematically, it is expressed as:

$$\Delta Q = \Delta U + W$$

Where, ΔQ is the heat supplied to the system, ΔU is the change in internal energy, and (W) is the work done by the system.

In biological systems, this law explains how organisms convert chemical energy from food into mechanical work, heat, and other forms of energy required for life processes.

7. Explain third law of thermodynamics with water as an example.

Third Law of Thermodynamics

The third law of thermodynamics states that as the temperature of a substance approaches absolute zero (0 K), the motion of its molecules becomes minimum and the entropy approaches zero. At absolute zero, a perfectly pure crystal has maximum order and minimum molecular motion.

Water can be taken as an example. As the temperature of water decreases, the movement of water molecules slows down. When water freezes into ice, the molecules become more arranged and ordered. If the temperature could reach absolute zero, the molecular motion would nearly stop completely, and the ice crystal would attain minimum entropy.

8. Write history of biophysics.

History of Biophysics

Biophysics developed from the combination of biology and physics to explain biological processes using physical principles. The foundations of biophysics began in ancient times when scientists studied the structure and functions of living organisms. However, modern biophysics started to grow during the 17th and 18th centuries with advances in physics, chemistry, and microscopy.

Galileo Galilei and Isaac Newton contributed physical laws that later helped in understanding biological motion and mechanics. In the 19th century, scientists such as Hermann von Helmholtz applied principles of energy and thermodynamics to living systems and greatly advanced the field.

During the 20th century, biophysics expanded rapidly with the discovery of cellular and molecular structures. Erwin Schrödinger explained the physical basis of life in his famous work *What is Life?* Later, James Watson and Francis Crick described the double-helix structure of DNA with the help of X-ray diffraction studies.

Today, biophysics is an important branch of science used in molecular biology, medical imaging, biotechnology, genetics, and the study of cellular processes. It helps scientists understand life at molecular, cellular, and systemic levels.

9. Write applications of Biophysics in biology.

Applications of Biophysics in Biology

- ✓ **Study of Cell Membranes:** Biophysics helps in understanding the structure, permeability, and transport mechanisms of plasma membranes.
- ✓ **Molecular Biology:** It explains the structure and function of biological molecules such as DNA, RNA, and proteins.
- ✓ **Medical Imaging:** Principles of biophysics are used in X-rays, MRI, CT scans, and ultrasound for diagnosis of diseases.
- ✓ **Nerve and Muscle Function:** Biophysics explains the transmission of nerve impulses and muscle contraction through electrical and mechanical principles.
- ✓ **Enzyme Activity:** It helps in studying enzyme kinetics, energy changes, and biochemical reactions in living organisms.
- ✓ **Bioenergetics:** Biophysics explains how organisms produce, store, and use energy during metabolic processes.
- ✓ **Genetics and Biotechnology:** Techniques such as X-ray crystallography and electrophoresis are used to study genes and proteins.
- ✓ **Circulation and Respiration:** Physical laws are applied to understand blood flow, gas exchange, and respiratory mechanics.
- ✓ **Radiation Biology:** Biophysics studies the effects of radiation on living tissues and its use in cancer treatment.
- ✓ **Microscopy and Imaging Techniques:** Advanced microscopes and imaging methods help in observing cells, tissues, and molecular structures in detail.

10. What are enzymes?

Enzymes

Enzymes are biological catalysts that speed up chemical reactions in living organisms without being consumed during the process. Most enzymes are proteins and are essential for maintaining metabolic activities in cells. Enzymes work by lowering the activation energy required for a reaction, allowing biochemical reactions to occur rapidly under normal body conditions. Each enzyme is specific to a particular substrate, forming an enzyme-substrate complex during the reaction. Enzymes play important roles in digestion, respiration, DNA replication, muscle activity, and energy production. Their activity is affected by factors such as temperature, pH, and substrate concentration. Examples of enzymes include amylase, lipase, pepsin, and catalase.

11. Explain membrane biophysics and its role in biology.

Membrane Biophysics and Its Role in Biology

Membrane biophysics is the study of the physical properties and functions of biological membranes. It explains how cell membranes control the movement of substances, maintain cell structure, and support communication between cells. Biological membranes are mainly composed of phospholipids, proteins, and carbohydrates arranged in a fluid bilayer. The membrane acts as a selectively permeable barrier that allows specific molecules and ions to enter or leave the cell. Membrane biophysics helps in understanding processes such as diffusion, osmosis, active transport, and electrical signaling in nerve cells. It also explains membrane fluidity, ion channel activity, and energy transfer across membranes. In biology, membrane biophysics is important for maintaining homeostasis, cell signaling, nutrient transport, and cellular communication. It also plays a major role in medical research, drug delivery, and understanding diseases related to membrane dysfunction.

12. Write chemical structure of DNA.

Chemical Structure of DNA

DNA (Deoxyribonucleic Acid) is the genetic material present in living organisms. It is composed of two long polynucleotide chains arranged in a double-helix structure, discovered by James Watson and Francis Crick. Each nucleotide of DNA consists of three components:

1. A deoxyribose sugar
2. A phosphate group
3. A nitrogenous base

The nitrogenous bases are of four types:

- Adenine (A)
- Thymine (T)
- Guanine (G)
- Cytosine (C)

Adenine pairs with thymine through two hydrogen bonds, while guanine pairs with cytosine through three hydrogen bonds. The sugar and phosphate groups form the backbone of the DNA strand, while the nitrogenous bases project inward and form complementary base pairs. The two strands run in opposite directions, forming an antiparallel double helix structure. The chemical formula of DNA contains elements such as carbon, hydrogen, oxygen, nitrogen, and phosphorus, which together help store and transmit genetic information in cells.

13. Why iodine has high dispersion forces?

Iodine has high dispersion forces because its atoms are large and contain many electrons. The large electron cloud around iodine atoms is easily distorted, leading to the formation of temporary dipoles. These temporary dipoles produce strong London dispersion forces between iodine molecules. As the size and number of electrons increase, the strength of dispersion forces also increases. Since iodine is heavier and larger than other halogens like fluorine and chlorine, it experiences much stronger intermolecular attractions. This is why iodine exists as a solid at room temperature and has relatively high melting and boiling points.

14. Enlist 5 major discoveries in Biophysics.

Five Major Discoveries in Biophysics

- ✓ **Discovery of DNA Double Helix Structure:** James Watson and Francis Crick explained the double-helix structure of DNA, helping scientists understand genetic inheritance.
- ✓ **X-ray Crystallography of Biomolecules:** The use of X-ray crystallography made it possible to determine the structures of proteins and nucleic acids at the molecular level.
- ✓ **Discovery of Cell Membrane Structure:** The fluid mosaic model proposed by S. J. Singer and Garth L. Nicolson explained the dynamic structure of biological membranes.
- ✓ **Understanding Nerve Impulse Transmission:** Biophysical studies revealed how electrical signals travel through neurons by the movement of ions across membranes.
- ✓ **Development of Medical Imaging Techniques:** Technologies such as X-rays, MRI, CT scans, and ultrasound were developed using biophysical principles for disease diagnosis and medical research.

15. Define entropy and its unit.

Entropy is a thermodynamic property that measures the degree of disorder or randomness in a system. In biological and physical systems, it also represents the unavailability of energy to do useful work. As a system becomes more disordered, its entropy increases. In living systems, entropy is important for understanding energy transformations, diffusion, and the tendency of processes to move toward equilibrium. The SI unit of entropy is joule per kelvin (J/K).

16. Why hydrogen bonding does occurs?

Hydrogen bonding occurs because of the unequal sharing of electrons in a covalent bond between hydrogen and highly electronegative atoms such as oxygen, nitrogen, or fluorine. When hydrogen is bonded to one of these atoms, the electron density is pulled toward the electronegative atom, making hydrogen slightly positive (δ^+) and the other atom slightly negative (δ^-). This partial positive hydrogen is attracted to lone pairs of electrons on nearby electronegative atoms, forming a hydrogen bond. In biological systems, these weak interactions are very important because they help maintain the structure of water, proteins, and DNA. For example, hydrogen bonds stabilize the double helix structure of DNA and also influence the folding of proteins.

17. What is random walk?

A random walk is a type of movement in which a particle or object moves in a sequence of steps in random directions, with no fixed path or predictable pattern. Each step is independent of the previous one, meaning the direction and distance of movement are determined randomly. In biological and physical systems, random walk is important in explaining the movement of molecules such as gases in air or solutes in a liquid. For example, diffusion in cells occurs due to the random motion of molecules, where particles gradually spread from regions of higher concentration to lower concentration.

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18. Write a short note on London Forces or Dispersion forces of Halogen family.

London forces (also called dispersion forces) are weak intermolecular forces that arise due to temporary fluctuations in the electron cloud of atoms or molecules. These fluctuations create instant dipoles, which induce dipoles in nearby particles, leading to attraction between them.

In the halogen family (F_2 , Cl_2 , Br_2 , I_2), these forces are the only type of intermolecular attraction present because halogens are non-polar diatomic molecules. The strength of dispersion forces increases as we move down the group from fluorine to iodine. This is because atomic size and number of electrons increase, making the electron cloud more polarizable. As a result, fluorine and chlorine are gases at room temperature due to weak dispersion forces, bromine is a liquid, and iodine is a solid due to much stronger London dispersion forces. Thus, dispersion forces strongly influence the physical states and boiling points of halogens.

19. Write note on active site of enzymes.

Active Site of Enzymes

The active site of an enzyme is a specific region where substrate molecules bind and undergo a chemical reaction. It is usually a small, highly specific pocket or cleft formed by the three-dimensional folding of the enzyme's polypeptide chain.

The active site has a unique shape and chemical environment that is complementary to its substrate, allowing the formation of an enzyme–substrate complex. This specificity is often explained by the lock-and-key model or the induced fit model, where the enzyme slightly changes its shape to better accommodate the substrate.

Amino acid residues present in the active site play a direct role in catalysis by lowering the activation energy of the reaction. The active site is essential for enzyme efficiency, specificity, and regulation of biochemical reactions in living organisms.

20. What do you know about kinetic energy and potential energy?

Kinetic energy is the energy possessed by a body due to its motion. Any moving particle or object has kinetic energy, and it depends on both the mass of the object and the square of its velocity. In biological systems, kinetic energy is seen in the movement of molecules, diffusion of gases, blood flow, and muscle contraction.

Potential energy is the stored energy in a body due to its position, structure, or state. It has the ability to do work when released. In living systems, potential energy is present in chemical bonds of molecules such as glucose and ATP, as well as in concentration gradients across membranes.

21. Write a note on secondary structure of protein.

Secondary Structure of Protein

The secondary structure of a protein refers to the local folding or arrangement of the polypeptide chain into specific regular patterns. This structure is mainly stabilized by hydrogen bonding between the backbone atoms of the amino acids, particularly between the carbonyl oxygen ($C=O$) and the amide hydrogen ($N-H$).

The two most common types of secondary structures are the α -helix and the β -pleated sheet. In the α -helix, the polypeptide chain coils into a spiral shape, with hydrogen bonds forming between nearby turns of the helix. In the β -pleated sheet, the polypeptide chains are arranged side by side and are stabilized by hydrogen bonds between adjacent strands, forming a sheet-like structure.

Secondary structure is important because it provides stability and contributes to the overall shape of proteins, which is essential for their biological function.

22. Difference between alpha helix and beta sheets.

Alpha Helix

An alpha helix is a type of protein secondary structure in which the polypeptide chain coils into a right-handed spiral shape. This structure is stabilized by hydrogen bonds formed between the carbonyl oxygen of one amino acid and the amide hydrogen of another amino acid located four residues ahead in the same chain. The alpha helix is compact and cylindrical, which provides flexibility and strength to proteins such as keratin found in hair and nails.

Beta Sheet

A beta sheet is another type of protein secondary structure formed when polypeptide chains are stretched out and arranged side by side in a sheet-like structure. The strands may run in the same direction (parallel) or in opposite directions (antiparallel). Hydrogen bonds form between adjacent strands, stabilizing the structure. Beta sheets provide rigidity and strength and are commonly found in proteins like silk fibroin.

23. Write short note on MRS.

Magnetic Resonance Spectroscopy (MRS)

Magnetic Resonance Spectroscopy (MRS) is a non-invasive biophysical technique used to study the chemical composition and metabolic changes in tissues. It is based on the same principle as MRI, where nuclei such as hydrogen respond to a strong magnetic field and radiofrequency pulses. Unlike MRI, which produces structural images, MRS provides information about the biochemical environment of tissues by measuring the concentration of specific metabolites such as N-acetylaspartate, choline, creatine, and lactate. This helps in understanding cellular metabolism and biochemical changes in both normal and diseased conditions. MRS is widely used in medical research and clinical diagnosis, especially in brain disorders, tumors, epilepsy, and neurodegenerative diseases. It plays an important role in early disease detection and monitoring treatment response.

24. Explain the formation of Alpha Helix.

Formation of Alpha Helix

The alpha helix is formed when a polypeptide chain folds into a regular, spiral structure due to hydrogen bonding within the backbone of the protein. This folding occurs as the chain adopts a stable and energetically favorable conformation. In this structure, the carbonyl oxygen ($C=O$) of one amino acid forms a hydrogen bond with the amide hydrogen ($N-H$) of another amino acid located four residues ahead in the same chain. These repeated hydrogen bonds run parallel to the helical axis and stabilize the spiral shape.

The side chains (R-groups) of amino acids extend outward from the helix, preventing steric hindrance and allowing interactions with the surrounding environment. The helix typically forms in a right-handed direction because it is more stable for L-amino acids found in proteins.

This structure is important in biological systems as it provides strength, elasticity, and functional stability to proteins such as keratin and myosin.

25. Differentiate between macroscopic and microscopic approach of thermodynamics.

Macroscopic Approach of Thermodynamics

The macroscopic approach deals with the bulk properties of a system without considering the behavior of individual molecules. It describes matter in terms of measurable quantities such as temperature, pressure, volume, and internal energy. This approach is also called classical thermodynamics and is useful for studying large systems like gases, liquids, and biological organisms as a whole. In biophysical systems, it helps in understanding processes such as heat transfer in tissues and energy changes in metabolism.

Microscopic Approach of Thermodynamics

The microscopic approach explains thermodynamic behavior based on the motion and interaction of individual molecules or particles. It uses concepts from statistical mechanics to describe properties like molecular energy, velocity, and distribution. This approach provides a deeper understanding of how macroscopic properties arise from molecular behavior. In biological systems, it is used to study molecular diffusion, enzyme reactions, and protein dynamics at the molecular level.

26. Write uniqueness of biophysicist.

- ✓ A biophysicist is unique because they integrate principles of biology, physics, chemistry, and mathematics to study living systems in a more quantitative and analytical way.
- ✓ Instead of only describing biological phenomena, they explain how and why processes occur using physical laws such as thermodynamics, mechanics, electricity, and molecular interactions.
- ✓ They investigate life at different levels, including molecular (DNA, proteins), cellular (membrane transport, signaling), and system levels (blood flow, nerve conduction).
- ✓ They use advanced scientific instruments and techniques like spectroscopy, X-ray crystallography, MRI, CT scans, electron microscopy, and computational modeling to analyze biological structures and functions.
- ✓ A biophysicist builds mathematical and physical models to predict biological behavior, such as enzyme activity, diffusion, or energy transfer in cells.
- ✓ They contribute significantly to modern fields like medical imaging, biotechnology, pharmacology, genetic engineering, and drug design by applying physical concepts to biological problems.
- ✓ Their work bridges theory and experiment, helping to convert complex biological systems into measurable and explainable physical processes.

27. What are hormones?

- ✓ Hormones are chemical messengers produced by endocrine glands in living organisms.
- ✓ They are released directly into the bloodstream and travel to target organs or tissues to regulate specific physiological functions.
- ✓ Even in very small concentrations, hormones have strong effects on growth, metabolism, reproduction, and homeostasis.
- ✓ They bind to specific receptors on target cells, triggering biochemical and physiological responses.
- ✓ Examples include insulin (regulates blood glucose), adrenaline (fight-or-flight response), and thyroxine (controls metabolism).
- ✓ In biophysical terms, hormone action depends on molecular interactions, receptor binding, and signal transduction processes at the cellular level.

28. Define quasi equilibrium process.

A quasi-equilibrium process (or quasi-static process) is a thermodynamic process that occurs so slowly that the system remains almost in equilibrium throughout the entire change. At every stage of the process, the macroscopic variables such as pressure, temperature, and volume are nearly uniform and well-defined. Because the system passes through a continuous sequence of equilibrium states, standard thermodynamic equations can be applied at each step.

In reality, no process is perfectly quasi-static, but it is an idealization used to simplify analysis in physics and biophysics. It is especially useful for understanding slow biological and physical processes where changes happen gradually, such as controlled diffusion, osmotic balance, and regulated biochemical reactions.

29. Define anabolic pathways with example.

Anabolic pathways are metabolic pathways in which complex molecules are synthesized from simpler ones, requiring an input of energy. These processes are essential for growth, repair, and maintenance of cells because they build cellular components and store energy in chemical bonds. In biophysical and biological systems, anabolic reactions are usually endergonic, meaning they consume energy, often in the form of ATP. These pathways involve the formation of macromolecules such as proteins, nucleic acids, and polysaccharides from their basic building blocks like amino acids, nucleotides, and glucose.

A common example of an anabolic pathway is protein synthesis, where amino acids are joined together to form proteins. Another important example is photosynthesis, in which plants synthesize glucose from carbon dioxide and water using light energy.

30. Write applications of Mass Spectrometry.

- ✓ Mass spectrometry is an analytical technique used to determine the mass-to-charge ratio of ions, helping in the identification and quantification of biomolecules with high precision.
- ✓ In proteomics, it is widely used to identify proteins, determine amino acid sequences, and analyze post-translational modifications, which helps in understanding protein structure and function in biological systems.
- ✓ In metabolomics, it is used to study small metabolites in cells and biological fluids, allowing researchers to understand metabolic pathways and biochemical changes in health and disease.
- ✓ In genomics and nucleic acid research, mass spectrometry helps in analyzing DNA, RNA fragments, and identifying genetic variations and mutations.
- ✓ In medical diagnostics, it is used to detect disease biomarkers in blood, urine, and tissues, which supports early diagnosis of conditions such as cancer, diabetes, and metabolic disorders.
- ✓ In pharmacology and drug development, it is applied to study drug metabolism, drug distribution in the body, and interactions between drugs and proteins, improving drug safety and effectiveness.
- ✓ In structural biology, it helps determine molecular composition and conformational changes in biomolecules, supporting the study of protein folding and interactions.
- ✓ It is also used in environmental and forensic analysis to detect pollutants, toxins, drugs, and trace evidence with high sensitivity and accuracy.

31. What is thermodynamics? Write statement of four laws of thermodynamics.

Thermodynamics is the branch of physics that deals with energy, heat, work, and the relationships between them in physical systems. It explains how energy is transferred and transformed, and how it affects the state of matter.

Statements of the Four Laws of Thermodynamics

Zeroth Law of Thermodynamics:

If two systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other. (This law defines temperature.)

First Law of Thermodynamics:

Energy cannot be created or destroyed, only converted from one form to another. The total energy of an isolated system remains constant. (Mathematically: $\Delta U = Q - W$, where U is internal energy, Q is heat added, and W is work done by the system.)

Second Law of Thermodynamics:

The entropy of an isolated system always increases over time, and natural processes tend to move toward greater disorder or randomness. (Heat cannot spontaneously flow from a colder body to a hotter body.)

Third Law of Thermodynamics:

As the temperature of a system approaches absolute zero, the entropy of the system approaches a minimum constant value (often zero for a perfect crystal). (It is impossible to reach absolute zero temperature in a finite number of steps.)

32. Define free energy and write differences between endergonic and exergonic reaction.

Free Energy (Gibbs Free Energy)

Free energy, specifically Gibbs free energy (G), is the portion of a system's energy that is available to perform useful work at constant temperature and pressure. It helps predict whether a chemical reaction can occur spontaneously. It is expressed as $G = H - TS$, where H is enthalpy, T is temperature in Kelvin, and S is entropy. A change in free energy (ΔG) indicates whether a reaction releases energy or requires energy input.

Difference between Endergonic and Exergonic Reactions (Paragraph form)

Endergonic and exergonic reactions differ mainly in energy flow and spontaneity. Endergonic reactions absorb energy from their surroundings, meaning they require an input of energy to proceed and have a positive change in Gibbs free energy ($\Delta G > 0$), making them non-spontaneous; an example is photosynthesis where light energy is used to build glucose. In contrast, exergonic reactions release energy into the surroundings, have a negative Gibbs free energy change ($\Delta G < 0$), and occur spontaneously without continuous energy input; cellular respiration is a common example where glucose is broken down to release energy.

33. Write differences between physical and chemical properties.

Physical properties are those characteristics of a substance that can be observed or measured without changing its chemical composition. These properties describe the physical state or appearance of a substance. Examples include color, density, melting point, boiling point, solubility, and conductivity. In biophysical systems, physical properties help in understanding processes such as diffusion, membrane permeability, and heat transfer in biological tissues without altering the chemical nature of biomolecules.

Chemical properties, on the other hand, describe the ability of a substance to undergo a chemical change and form new substances. These properties become evident during chemical reactions where the molecular structure of the substance is altered. Examples include reactivity, flammability, acidity, and oxidation state. In biological systems, chemical properties are important for understanding metabolic reactions, enzyme activity, and biochemical transformations such as digestion and respiration.

34. State the learning outcomes of biological physics.

- ✓ Understanding how physical laws (mechanics, thermodynamics, electromagnetism) explain biological processes such as diffusion, osmosis, and membrane transport
- ✓ Explaining the structure and function of biomolecules like DNA, proteins, and enzymes using physical and chemical principles
- ✓ Analyzing physiological processes such as nerve impulse conduction, muscle contraction, and blood circulation through quantitative and physical approaches
- ✓ Developing the ability to use mathematical models to describe and predict biological system behavior
- ✓ Gaining knowledge of energy transfer and bioenergetics in living organisms
- ✓ Understanding the working principles of modern diagnostic and research tools such as MRI, CT scans, spectroscopy, and microscopy
- ✓ Building interdisciplinary thinking by linking physics with biology to solve biological and medical problems
- ✓ Enhancing experimental and analytical skills for studying complex biological systems

35. Explain the concept of heat transfer.

Heat transfer is the process by which thermal energy moves from a region of higher temperature to a region of lower temperature due to a temperature difference. This process continues until thermal equilibrium is reached, where both regions attain the same temperature. In biological systems, heat transfer is important for maintaining body temperature, enzyme activity, and metabolic stability.

There are three main modes of heat transfer: conduction, convection, and radiation. Conduction occurs when heat is transferred through direct contact between particles, such as heat moving through skin or tissues. Convection involves the movement of heat through fluids (liquids or gases) by the physical movement of the medium, such as blood circulation distributing heat in the body. Radiation is the transfer of heat through electromagnetic waves without the need for a medium, such as heat loss from the human body to the surrounding environment.

36. How do biophysicists help in structural analysis of DNA?

Biophysicists play a key role in understanding the structure of DNA by applying physical principles and advanced analytical techniques to study biomolecules at the atomic level. They use methods such as X-ray diffraction, nuclear magnetic resonance (NMR) spectroscopy, and cryo-electron microscopy to determine the three-dimensional arrangement of DNA.

One of the major contributions was the use of X-ray crystallography data, which helped reveal the double-helix structure of DNA, showing how two antiparallel strands are held together by hydrogen bonds between complementary base pairs. This structural insight explained how genetic information is stored and replicated.

Biophysicists also use computational modeling and simulation techniques to study DNA stability, flexibility, and interactions with proteins and drugs. These studies help in understanding genetic regulation, mutation mechanisms, and DNA-protein binding.

Overall, biophysicists bridge physics and biology to provide a detailed structural and functional understanding of DNA at the molecular level.

37. Which one has a high boiling point and why? N_2 and CO_2 .

Between nitrogen (N_2) and carbon dioxide (CO_2), carbon dioxide has a higher boiling point. This is because CO_2 molecules are larger and have more electrons compared to N_2 , which increases the strength of London dispersion forces (van der Waals forces) between CO_2 molecules. Stronger intermolecular forces require more energy to overcome, resulting in a higher boiling point. Although both N_2 and CO_2 are non-polar molecules overall, CO_2 has greater polarizability due to its larger molecular size and linear structure, which enhances temporary dipole formation. Therefore, CO_2 has stronger intermolecular attractions and a higher boiling point than N_2 .

38. Define diffusion, simple diffusion, and diffusion gradient and diffusion rate.

Diffusion is the passive movement of particles from a region of higher concentration to a region of lower concentration due to their random thermal motion until equilibrium is reached. It does not require any external energy input and is an important process in biological systems for the transport of gases, nutrients, and waste products.

Simple diffusion is a type of diffusion in which molecules move directly across a membrane without the help of transport proteins or channels. It usually occurs for small, non-polar molecules such as oxygen and carbon dioxide that can easily pass through the lipid bilayer.

Diffusion gradient refers to the difference in concentration of a substance between two regions. The greater the difference in concentration, the steeper the diffusion gradient, and the faster the rate of diffusion.

Diffusion rate is the speed at which a substance moves from a region of higher concentration to a region of lower concentration. It depends on factors such as temperature, concentration gradient, surface area, and the size of the diffusing particles.

39. Define intermolecular forces with examples.

Intermolecular forces are the attractive or repulsive forces that exist between neighboring molecules. These forces are weaker than chemical bonds but are very important in determining the physical properties of substances such as boiling point, melting point, solubility, and viscosity. In biological systems, intermolecular forces help maintain the structure of biomolecules and influence interactions between proteins, DNA, and water.

There are different types of intermolecular forces. London dispersion forces occur due to temporary fluctuations in electron distribution and are present in all molecules, especially in non-polar substances like oxygen (O_2) and nitrogen (N_2). Dipole-dipole interactions occur between polar molecules, such as hydrogen chloride (HCl), where opposite partial charges attract each other.

Hydrogen bonding is a stronger type of intermolecular force that occurs when hydrogen is bonded to highly electronegative atoms like oxygen, nitrogen, or fluorine. Examples include water (H_2O) and DNA base pairing, where hydrogen bonds help stabilize the double helix structure.

40. Define and show relationship between Celsius, Fahrenheit and Kelvin scale.

Celsius, Fahrenheit, and Kelvin Scales & Their Relationship

Temperature can be measured using three common scales: Celsius ($^{\circ}C$), Fahrenheit ($^{\circ}F$), and Kelvin (K). The Celsius scale is based on the freezing point of water at $0^{\circ}C$ and boiling point at $100^{\circ}C$ under standard atmospheric pressure. The Fahrenheit scale sets the freezing point of water at $32^{\circ}F$ and boiling point at $212^{\circ}F$. The Kelvin scale is an absolute temperature scale used in science, where 0 K represents absolute zero, the point at which molecular motion nearly stops. The relationship between these scales is given by the following conversions:

$$K = ^{\circ}C + 273.15$$

$$^{\circ}F = \frac{9}{5}(^{\circ}C) + 32$$

$$^{\circ}C = \frac{5}{9}(^{\circ}F - 32)$$

These relationships show how temperature values can be converted between different scales while describing the same thermal state of a system. In biophysical studies, Kelvin is preferred because it directly relates to molecular energy and thermodynamic calculations.

41. What is centrifugation and its principle?

Centrifugation is a laboratory technique used to separate components of a mixture based on differences in their density by spinning the sample at high speed in a centrifuge machine. It is widely used in biophysics and biology for separating cells, organelles, proteins, and other biological particles from fluids.

Principle

The principle of centrifugation is based on the application of centrifugal force. When a sample is rotated at high speed, particles experience an outward force away from the center of rotation. Heavier and denser particles sediment more quickly toward the bottom of the tube, while lighter particles remain in the upper layers. The rate of sedimentation depends on factors such as particle size, shape, density, and the speed of rotation (revolutions per minute, RPM).

42. Define Gauge pressure and Vapor pressure.

Gauge Pressure

Gauge pressure is the pressure of a fluid measured relative to the surrounding atmospheric pressure. It shows how much the pressure inside a system is above or below atmospheric pressure. If a pressure is measured using a gauge (like a tire pressure gauge), it usually indicates gauge pressure. In biological and physical systems, it helps in understanding blood pressure and respiratory pressures. Mathematically, it is given by:

$$\text{Gauge pressure} = \text{Absolute pressure} - \text{Atmospheric pressure.}$$

Vapor Pressure

Vapor pressure is the pressure exerted by the vapor of a liquid when it is in equilibrium with its liquid phase in a closed container. It represents the tendency of a liquid to evaporate. A liquid with high vapor pressure evaporates easily because its molecules escape into the vapor phase more readily. In biological systems, vapor pressure is important in processes like evaporation from skin and lungs, and it also affects boiling point of liquids.

43. What is protein classification?

Protein classification is the systematic grouping of proteins based on their structure, composition, shape, and function. It helps in understanding how different proteins behave in biological systems and how they perform specific roles in living organisms.

Based on shape

Based on shape, proteins are mainly classified into fibrous proteins and globular proteins. Fibrous proteins are long, thread-like, and insoluble in water, providing structural support in tissues, such as collagen in connective tissue and keratin in hair. Globular proteins are compact, spherical, and usually soluble in water, performing functional roles like enzymes, antibodies, and hemoglobin.

Based on Chemical Composition

Based on chemical composition, proteins are classified into simple, conjugated, and derived proteins. Simple proteins are made up only of amino acids, such as albumin. Conjugated proteins contain a non-protein group called a prosthetic group, such as glycoproteins or hemoproteins. Derived proteins are formed from partial hydrolysis or denaturation of proteins.

44. Describe denaturation and protein folding.

Protein Folding

Protein folding is the process by which a newly synthesized polypeptide chain attains its specific three-dimensional structure. This structure is essential for the protein to become biologically active. Folding is driven by interactions such as hydrogen bonding, hydrophobic interactions, ionic bonds, and van der Waals forces. The final folded form includes primary, secondary, tertiary, and sometimes quaternary structure, and determines the protein's function in biological systems.

Denaturation

Denaturation is the process in which a protein loses its native structure due to external factors such as high temperature, extreme pH, chemicals, or radiation. During denaturation, the weak bonds that maintain the protein's three-dimensional structure are disrupted, causing loss of biological activity. However, the primary structure (amino acid sequence) usually remains unchanged.

45. What are learning goals of biophysics?

- ✓ To understand biological systems using principles of physics and quantitative analysis
- ✓ To explain physical laws governing processes such as diffusion, osmosis, membrane transport, and energy transfer in living organisms
- ✓ To study the structure and function of biomolecules like DNA, proteins, and enzymes using physical and chemical concepts
- ✓ To develop analytical, mathematical, and problem-solving skills for biological problems
- ✓ To apply thermodynamics, mechanics, and electromagnetism in explaining life processes
- ✓ To gain knowledge of modern techniques like MRI, CT scans, spectroscopy, and microscopy
- ✓ To connect theoretical concepts with experimental methods in biological research
- ✓ To apply biophysical knowledge in medicine, biotechnology, and related life sciences fields

46. What is active site? How active site lowers the activation energy barriers?

Active site is a specific region on an enzyme where the substrate binds and the chemical reaction takes place. It is a small pocket or cleft formed by the folding of the enzyme's polypeptide chain. The active site has a unique shape and chemical environment that is highly specific to its substrate. The active site lowers the activation energy barrier by stabilizing the transition state of the reaction. When the substrate binds to the active site, an enzyme-substrate complex is formed, which brings reacting molecules closer together and in the correct orientation. This reduces the energy required for the reaction to proceed.

In addition, the active site may strain the substrate bonds, making them easier to break, and provide a suitable microenvironment (such as acidic or basic conditions) that favors the reaction. These combined effects speed up the reaction without the enzyme being consumed.

47. What are components of nucleotide?

A nucleotide is the basic structural unit of nucleic acids (DNA and RNA). It is composed of three main components.

The first component is a pentose sugar, which is either deoxyribose in DNA or ribose in RNA. This sugar forms the central part of the nucleotide structure.

The second component is a nitrogenous base, which carries genetic information. These bases are divided into two types: purines (adenine and guanine) and pyrimidines (cytosine, thymine in DNA, and uracil in RNA).

The third component is a phosphate group, which is attached to the sugar and helps in forming phosphodiester bonds between nucleotides, creating the backbone of DNA and RNA strands.

Together, these three components form a nucleotide, which is essential for genetic information storage and transfer in living systems.

48. Differentiate between renewable and non-renewable sources of energy.

Renewable sources of energy are those energy resources that are naturally replenished in a short period of time and can be used repeatedly without being exhausted. These include solar energy, wind energy, hydroelectric energy, geothermal energy, and biomass energy. In biological and environmental systems, renewable energy is considered sustainable because it has minimal environmental impact and supports long-term ecological balance.

Non-renewable sources of energy are those that exist in limited amounts and take millions of years to form. Once consumed, they cannot be replaced in a short time. Examples include fossil fuels such as coal, petroleum, and natural gas, as well as nuclear fuels like uranium. These energy sources are widely used due to their high energy output, but they contribute to pollution and environmental degradation.

49. Where is DNA present in prokaryotes?

In prokaryotes, DNA is present in the nucleoid region of the cell. Unlike eukaryotic cells, prokaryotes do not have a well-defined nucleus surrounded by a nuclear membrane. The nucleoid is an irregular, non-membrane-bound region in the cytoplasm where a single circular chromosome of DNA is located. This DNA is not associated with histone proteins as in eukaryotes, although some protein-like structures may help in its organization. In addition to the nucleoid, prokaryotes may also contain small extra-chromosomal DNA molecules called plasmids, which carry genes for special functions such as antibiotic resistance.

50. Write examples of all four laws of thermodynamics in living cells.

Examples of all four laws of thermodynamics in living cells

The zeroth law of thermodynamics in living systems is observed in temperature regulation. When two parts of the body, such as blood and tissues, reach the same temperature, they are in thermal equilibrium. This principle allows the body to maintain a constant internal temperature, essential for enzyme activity and metabolic stability.

The first law of thermodynamics is seen in cellular energy conversion. For example, during respiration, the chemical energy stored in glucose is converted into ATP, heat, and mechanical work. Energy is neither created nor destroyed but transformed from one form to another within the cell.

The second law of thermodynamics is reflected in metabolic processes where energy transformations increase entropy. For instance, during the breakdown of glucose, energy is released and some is lost as heat, increasing the disorder of the surroundings. Cells must continuously use energy to maintain order and organization.

The third law of thermodynamics is approached in biological systems when molecular motion decreases at very low temperatures. Although living cells cannot reach absolute zero, in conditions like cryopreservation, biochemical activity nearly stops, and molecular motion is minimized, reflecting the concept of minimum entropy at absolute zero.

51. Give five examples of entropy in daily life.

Entropy is a measure of disorder or randomness in a system, and it naturally tends to increase in everyday processes.

- ✓ One example is ice melting into water, where the ordered crystal structure of ice becomes a more disordered liquid state, increasing entropy.
- ✓ Another example is diffusion of perfume in air, where perfume molecules spread randomly throughout the room instead of remaining concentrated in one place.
- ✓ A third example is mixing of sugar in tea, where sugar molecules disperse uniformly in the liquid, increasing disorder.
- ✓ A fourth example is burning of wood, where solid wood converts into ash, smoke, and gases, resulting in a highly disordered system.
- ✓ A fifth example is mixing of gases, such as oxygen and nitrogen in air, where molecules spread and mix randomly over time rather than remaining separated.

52. Define system and surrounding.

A system is the part of the universe that is selected for study in thermodynamics or biophysics. It can be a cell, a chemical reaction, a living organism, or any specific region where energy and matter changes are being analyzed. The system has a definite boundary, which may be real or imaginary.

The surroundings are everything outside the system that can interact with it. This includes all other matter and space in the environment that may exchange energy or matter with the system.

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