CUET PG 2024 Nanoscience/Integrative Biosciences Question Paper with Solutions

Time Allowed :1 Hour 45 Mins	**Maximum Marks :**300	**Total Questions :**75

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The examination duration is 105 minutes. Manage your time effectively to attempt all questions within this period.
2. The total marks for this examination are 300. Aim to maximize your score by strategically answering each question.
3. There are 75 mandatory questions to be attempted in the Agro forestry paper. Ensure that all questions are answered.
4. Questions may appear in a shuffled order. Do not assume a fixed sequence and focus on each question as you proceed.
5. The marking of answers will be displayed as you answer. Use this feature to monitor your performance and adjust your strategy as needed.
6. You may mark questions for review and edit your answers later. Make sure to allocate time for reviewing marked questions before final submission.
7. Be aware of the detailed section and sub-section guidelines provided in the exam. Understanding these will aid in effectively navigating the exam.

1. The First Law of Thermodynamics represents:

(A) Law of conservation of mass
(B) Law of conservation of energy
(C) Law of conservation of entropy
(D) Law of conservation of momentum

Correct Answer: (B) Law of conservation of energy.

Solution:
The First Law of Thermodynamics is a statement of the principle of energy conservation. It essentially states that energy cannot be created or destroyed, only transformed from one form to another. For a closed system, the change in internal energy (ΔU) is equal to the heat added to the system (Q) minus the work done by the system (W). This is mathematically represented as:

$$\Delta U = Q - W$$

Here's a breakdown:

- ΔU: Represents the change in the internal energy of the system.
- Q: Represents the heat exchanged between the system and its surroundings.
- W: Represents the work done by or on the system.

The First Law is a fundamental principle that applies to all thermodynamic processes. It means that if you put energy into a system (as heat or work), it will either increase the system's internal energy, or the system will do work, or both.

> Quick Tip
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> Always think of the First Law as an "energy balance sheet" for a system. It doesn't describe how energy is used or exchanged (that's where other concepts like enthalpy and entropy come in), just that the total amount remains constant. Remember, internal energy (U) is a state function, dependent only on initial and final states, not the path taken to get there.

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2. Carnot engine is a reversible engine. It can be proved from the:

(A) Zeroth Law of Thermodynamics
(B) First Law of Thermodynamics
(C) Second Law of Thermodynamics
(D) Third Law of Thermodynamics

Correct Answer: (C) Second Law of Thermodynamics.

Solution:
The Carnot engine is a theoretical thermodynamic cycle that is reversible and operates with the maximum possible efficiency. The proof that the Carnot engine is reversible is deeply rooted in the Second Law of Thermodynamics, particularly its implications for entropy changes and the direction of thermodynamic processes. The Second Law states that in a reversible process, the total entropy of an isolated system remains constant ($\Delta S = 0$), while irreversible processes lead to an increase in entropy ($\Delta S > 0$).
The Carnot cycle is a series of reversible steps. Because each step is reversible, the process can run in reverse and the total change in entropy for the entire cycle is zero. The proof involves showing that no other engine operating between the same two temperatures could be more efficient than the Carnot engine without violating the Second Law. This analysis uses the fact that reversible processes can be reversed without leaving a trace and that if another engine was more efficient the process would violate the Second Law.

Quick Tip

The Carnot engine's reversibility (where changes can be reversed back to the starting point), combined with its operation between two constant-temperature heat reservoirs, leads to maximum possible efficiency, meaning it's the ideal, theoretical scenario, and real-world engines always perform worse. The engine operates in four fully reversible steps: isothermal expansion, adiabatic expansion, isothermal compression, and adiabatic compression.

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3. From the Hall Effect experiment, one can measure:

(A) Carrier concentration
(B) Nature of charge carriers
(C) Carrier concentration and Mobility of charge carriers
(D) Nature of charge carriers, concentration of charge carriers as well as their mobility

Correct Answer: (C) Carrier concentration and Mobility of charge carriers.

Solution:
The Hall Effect experiment involves applying a magnetic field perpendicular to a current flowing through a conductor (or semiconductor). This results in a voltage, known as the Hall voltage, being generated perpendicular to both the current and the magnetic field. The Hall voltage (V_H) is related to the magnetic field (B), the current (I), the charge carrier density (n), and the thickness of the material (t) by the equation:

$$V_H = \frac{IB}{net}$$

Where e is the charge of an electron.
From this experiment, two crucial parameters can be deduced:

- Charge Carrier Concentration (n): By measuring the Hall voltage and knowing other parameters, the density of charge carriers (whether they are electrons or holes) can be determined.
- Mobility (μ): By measuring both the Hall voltage and the conductivity, the charge carrier mobility can be calculated. Mobility is related to how fast the charge carriers move in an electric field and is related to their scattering rate in the material.

The Hall effect can also tell you the sign of the charge carriers since the Hall voltage has opposite polarities for electrons and holes. Thus, the Hall experiment allows us to measure carrier concentration, mobility and the type of the charge carriers present (electrons or holes)

Quick Tip

Remember that in a Hall Effect setup, the magnetic field must be perpendicular to the current flow. The voltage that develops across the material (the Hall voltage) is directly proportional to the product of current and magnetic field, so by measuring the Hall voltage and knowing the other parameters, you can extract a lot of useful information about carrier properties.

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4. With the reduction in particle size, optical absorption spectrum shows:

(A) Blue Shift
(B) Red Shift
(C) Green Shift
(D) Yellow Shift

Correct Answer: (A) Blue Shift.

Solution:
When the particle size of a material is reduced to the nanoscale, a phenomenon known as quantum confinement occurs. This means that the energy levels available for electrons within the material become discrete and move further apart from one another. As a result the band gap increases. As particle sizes decrease, the quantum confinement effect becomes more pronounced, leading to an increase in the energy required for electronic transitions. This, in turn, causes a shift in the absorption spectrum towards higher energies, corresponding to shorter wavelengths. This shift toward shorter wavelengths is referred to as a blue shift.

Quick Tip

In Quantum Dots the energy gap in these materials becomes inversely proportional to its size. The higher the energy gap, the shorter the wavelength of the emitted light.

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5. Bragg's law of diffraction is used to determine the:

(A) Crystallite size
(B) Crystal structure
(C) Particle size
(D) Crystal structure as well as particle size

Correct Answer: (B) Crystal structure.

Solution:
Bragg's law describes the conditions for constructive interference when X-rays are scattered by

a crystal lattice. The law is expressed mathematically as:

$$n\lambda = 2d \sin\theta$$

where:

- n is an integer representing the order of diffraction.
- λ is the wavelength of the X-rays.
- d is the spacing between atomic planes in the crystal.
- θ is the angle of incidence (and reflection) of the X-rays with respect to the atomic planes.

Bragg's law helps us understand how X-rays interact with crystals, which allows scientists to determine crystal structure. This is because the diffraction pattern created depends on the arrangement of atoms in the crystal lattice. The measured angles of diffraction (θ) in X-ray diffraction experiments allow us to calculate the interplanar spacing (d), and then deduce the crystal structure using the arrangement of different crystal planes. While broadening of the peak relates to the crystallite size, but Bragg's law in itself does not give the particle size.

Quick Tip

By applying Bragg's law to x-ray diffraction patterns, we can map out the precise arrangement of atoms in a crystal. It's a crucial tool for understanding materials in both the natural and biological worlds.

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6. A bipolar junction transistor is said to be in active mode if:

(A) Base-emitter junction is forward biased and collector-emitter junction is reverse biased
(B) Base-emitter junction is reversed-biased and collector-emitter junction is forward biased
(C) Both the junctions are forward biased
(D) Both the junctions are reverse biased

Correct Answer: (A) Base-emitter junction is forward biased and collector-emitter junction is reverse biased.

Solution:
A bipolar junction transistor (BJT) has three regions: the emitter, the base, and the collector. It also has two junctions: the base-emitter junction and the collector-base junction. The active mode of a BJT is when the base-emitter junction is forward biased (meaning that the voltage at the base is higher than the emitter for an NPN transistor, and the opposite for a PNP transistor) and the collector-base junction is reverse biased (the voltage at the collector is higher than the base for an NPN transistor, and vice-versa for a PNP). In an NPN transistor, for example, the active mode is achieved when:

- The base-emitter junction is forward biased meaning that the base voltage (Vb) ¿ emitter voltage (Ve), and the

- The collector-base junction is reverse biased meaning the collector voltage (Vc) ¿ base voltage (Vb).

In active mode, the BJT acts as an amplifier, where a small change in the base current can cause a large change in the collector current. This region is most useful for amplification in BJT circuits.

Quick Tip

Remember the difference between the three regions of operation of BJT which are the cut off region (both junctions reversed biased), the active region (EB junction forward biased and CB junction reversed biased) and the saturation region (both junctions forward biased). The base current acts as the control signal, allowing you to increase the current flow between the collector and emitter.

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7. In a Quantum dot, degree of confinement is:

(A) Zero
(B) One
(C) Two
(D) Three

Correct Answer: (D) Three.

Solution:
A quantum dot is a semiconductor material where electrons are confined in all three spatial dimensions. The degree of confinement refers to how many dimensions are constrained for electron movement. Let's consider other confinement types:

- Quantum Well: Electrons are confined in one dimension, allowing them to move freely in two dimensions (so its degree of confinement is 1).
- Quantum Wire: Electrons are confined in two dimensions, but can freely move along one dimension (so its degree of confinement is 2).

In quantum dots, the electrons are confined in all three dimensions (x, y, z). This three-dimensional confinement leads to discrete energy levels for the electrons, similar to those in atoms. These discrete energy levels are responsible for many of their unique properties, like fluorescence, different colors depending on the size, etc.

Quick Tip

Confined dimensions influence how electrons behave within quantum dots, leading to quantized energy levels. This size-dependent tunability of properties makes them incredibly useful for a wide array of applications, such as biomedicine and materials science.

8. The failure of Michelson-Morley experiment indicated:

(A) Existence of ether medium
(B) Speed of light is directional
(C) Speed of light is invariant
(D) Light has dual nature

Correct Answer: (C) Speed of light is invariant.

Solution:
The Michelson-Morley experiment was designed to detect the presence of a hypothetical medium called "ether" through which it was believed that light propagated. The experiment, conducted using an interferometer, aimed to measure the variation in the speed of light due to the Earth's motion through the ether. The expectation was that the speed of light would be different depending on the direction relative to Earth's movement, i.e., have different values when measured along and perpendicular to Earth's velocity.
However, the experiment produced a null result. This means that no variation in the speed of light could be measured regardless of the orientation of the equipment with respect to the earth's orbit around the sun. This result was inconsistent with the expectation that an ether medium existed and that the speed of light depends on the motion of the light source. It led to the conclusion that the speed of light is constant for all observers, regardless of their motion or that of the light source. This key finding was later incorporated into Einstein's theory of special relativity, which states that the speed of light in a vacuum (c) is a universal constant. The Michelson-Morley experiment therefore did not prove any of the other options mentioned, and was instead very important in the establishment of the Special Theory of Relativity.

Quick Tip

Think of the null result of the Michelson-Morley experiment as a major turning point for modern physics. Because the result was not what they expected, it paved the way for the special theory of relativity, highlighting the importance of questioning existing dogma in scientific research.

9. A rigid body is dropped from the top of a tower. Midway it splits in two unequal parts. The Centre of mass of the system:

(A) shifts horizontally towards the heavier part
(B) shifts horizontally towards the lighter part
(C) doesnot shift horizontally
(D) shifts depending on the velocity at the time of split

Correct Answer: (C) does not shift horizontally.

Solution:
The center of mass of a system is the average location of all its mass. The motion of the center of mass of a system is not affected by internal forces (like the force of the rigid body breaking apart); it only changes due to external forces (in this case, gravity). Since gravity acts vertically downward, there is no external horizontal force acting on the system. When the rigid body is falling, it's accelerating in the vertical direction only because of gravity. When the rigid body splits into two parts, no new horizontal forces are introduced, so there is no reason for the center of mass to move horizontally. Although the individual fragments may move horizontally due to the split, their center of mass will remain in the vertical line of motion and will continue to accelerate downwards due to gravity.

Quick Tip

Think of the center of mass as representing the entire system. When internal forces occur within a system, they have no impact on the center of mass' trajectory because each internal force has an equal and opposite reaction force, canceling any net force on the center of mass.

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10. A system in thermodynamic equilibrium satisfies the following requirements:

(A) A system is in mechanical equilibrium
(B) A system is in mechanical equilibrium and chemical equilibrium
(C) A system is in mechanical equilibrium and thermal equilibrium
(D) A system is in mechanical equilibrium, chemical equilibrium and thermal equilibrium

Correct Answer: (D) A system is in mechanical equilibrium, chemical equilibrium and thermal equilibrium.

Solution:
Thermodynamic equilibrium refers to a state where a system's macroscopic properties do not change over time. This state is achieved when a system has reached a balance in several different aspects of its energy and matter exchange with its surroundings, and its components. These aspects are captured by three primary types of equilibrium:

- Mechanical Equilibrium: This means that there are no net forces acting on the system or its parts. There are no pressure gradients. In a closed system, it implies that the pressure is uniform throughout.
- Chemical Equilibrium: This means that there are no changes in the chemical composition of the system. The net rate of all chemical reactions is zero. This means there is no further net conversion of reactants to products or vice-versa
- Thermal Equilibrium: This means that the temperature of the system is uniform throughout and the system is at the same temperature as its surroundings. There is no further net heat exchange between the system and its surroundings or different components within it.

For a system to be in full thermodynamic equilibrium, it must satisfy all three of these conditions simultaneously.

> Quick Tip
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> Note that a system must be in mechanical, thermal and chemical equilibrium simultaneously to reach the thermodynamic equilibrium. If any of the equilibriums is not met, the system cannot be in the thermodynamic equilibrium.

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11. Which of the following orbitals will have a radial node?

(A) 1s orbital
(B) 2s orbital
(C) 2p orbital
(D) 3d orbital

Correct Answer: (B) 2s orbital.

Solution:
A radial node is a region in an atomic orbital where the radial probability density function (the probability of finding an electron at a certain distance from the nucleus) is zero. The number of radial nodes for an atomic orbital can be calculated using the formula:
[Radial Nodes = n - l - 1]
where:

- (n) is the principal quantum number
- (l) is the azimuthal quantum number

Let's analyze each given orbital:

- 1s orbital: (n = 1), (l = 0). Radial nodes = 1 - 0 - 1 = 0.
- 2s orbital: (n = 2), (l = 0). Radial nodes = 2 - 0 - 1 = 1.
- 2p orbital: (n = 2), (l = 1). Radial nodes = 2 - 1 - 1 = 0.
- 3d orbital: (n = 3), (l = 2). Radial nodes = 3 - 2 - 1 = 0.

Only the 2s orbital has a radial node based on this calculation, while the 1s, 2p, and 3d orbitals do not have radial nodes.

> Quick Tip
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> The formula for calculating the number of nodes is n - l - 1 where n represents the principal quantum number and l represents the azimuthal quantum number. The 's' orbital has an azimuthal quantum number of 0, and the radial nodes are spherical in shape, while angular nodes are planar and occur only in non-s orbitals.

12. Primitive cell has ..... lattice point per unit cell

(A) one
(B) two
(C) three
(D) four

Correct Answer: (A) one.

Solution: A primitive cell (also known as a simple cell) is a unit cell that contains only one lattice point. This lattice point is considered to be at the corners of a 3D unit cell. In other words, each corner of the primitive unit cell is shared by 8 adjacent unit cells. Since the corners are shared, the total number of lattice points contributed by each of the 8 corners is:

$$8 \times \frac{1}{8} = 1$$

Therefore, a primitive cell contains only one lattice point per unit cell. Simple cubic structures are examples of primitive cells. In contrast, body-centered and face centered unit cells have more than one lattice point per unit cell since there are lattice points at the cell centers or faces as well as the corners.

Quick Tip

A unit cell is the smallest repeating structure of a crystal lattice, and when this unit cell has its lattice points at the corners, it is called a primitive cell and the structure can be reproduced in three dimensions to get a 3D lattice of the crystal, by translation.

13. Filling of electrons in degenerate orbitals are governed by:

(A) Hunds rule
(B) Planck's Law
(C) de-Broglie's wave particle duality
(D) Photoelectric effect

Correct Answer: (A) Hunds rule.

Solution: Degenerate orbitals are atomic orbitals that have the same energy level. These are usually p, d, and f subshells. Hund's rule describes the way electrons are filled into these orbitals. This rule states that:

- Electrons will individually occupy each orbital within a subshell before doubling up in any one orbital.
- Electrons in singly occupied orbitals will all have the same spin (either all spin-up or all spin-down).

This rule is a direct consequence of the repulsive forces between electrons, as electrons will try to maximize the distance between them, and occupy different orbitals before pairing in the same orbital. This results in the maximum possible number of unpaired electrons with parallel spins for a system.
The other options are not relevant to electron filling in atomic orbitals:

- Planck's Law relates the energy of a photon to its frequency.
- de-Broglie's wave-particle duality describes the dual nature of matter, that it has both wavelike and particle like properties.
- Photoelectric effect describes the ejection of electrons when light is incident on a material.

Quick Tip

When applying Hund's rule, remember that the electrons will try to occupy different sub-orbitals within a particular orbital, before pairing, as that minimizes repulsive forces. The spins will also remain parallel until pairing, as this configuration increases the overall stability of the atom.

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14. Arrange the following radiations in terms of the increasing order of their ionizing power:
(A). X-rays
(B). Beta-particles
(C). Alpha-particles
(D). Gamma-rays
Choose the correct answer from the options given below:
(1) (A), (B), (C), (D)
(2) (A), (B), (D), (C)
(3) (B), (A), (D), (C)
(4) (C), (B), (A), (D)

Correct Answer: (2) (A), (B), (D), (C)

Solution: Ionizing power refers to the ability of radiation to remove electrons from atoms or molecules, creating ions. The ionizing power depends on the energy and the charge of the radiation.

- **Alpha particles (α):** These are the most massive (consisting of two protons and two neutrons) and are doubly charged (+2e). However, their ionizing power is high, but their penetration is low because of their high charge and large mass.
- **Beta particles (β):** These are high-energy electrons (or positrons) and have a charge of $-1e$ or $+1e$. They are much smaller than alpha particles and more penetrating, with moderate ionizing power.

- **X-rays:** These are high-energy electromagnetic radiation with no charge. Their ionizing power is less than charged particles because of their lower interaction probability with matter than charged particles. Their penetration is higher than beta particles.
- **Gamma rays (γ):** These are the highest energy electromagnetic radiation, with no charge. Their penetration power is much higher than X-rays, and they are highly ionizing.

Based on the charge, mass and energy of these radiations, we can order their ionizing power as follows: X-rays ¡ Beta particles ¡ Gamma rays ¡ Alpha particles. Therefore in terms of increasing order of ionizing power: X-rays, Beta particles, Gamma rays and Alpha particles. In terms of options the correct order is: (A) X-rays, (B) Beta particles, (D) Gamma rays, (C) Alpha particles

Quick Tip

Remember that the more massive and charged the particle is, the greater is its ionizing power and the lower its penetration power, which is why alpha particles are the strongest ionizers, however, they are stopped by a sheet of paper.

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15. No two particles can occupy the same state is the consequence of:

(A) Maxwell-Boltzmann distribution
(B) Bose-Einstein Distribution
(C) Fermi-Dirac Distribution
(D) Classical Distribution

Correct Answer: (C) Fermi-Dirac Distribution.

Solution: The principle that no two fermions can occupy the same quantum state is the Pauli Exclusion Principle. The Fermi-Dirac distribution is used to describe the statistical behavior of fermions. These are particles that obey the Pauli exclusion principle and have half-integer spin (e.g. electrons, protons, neutrons).

- Fermi-Dirac distribution: This describes how fermions are distributed among different energy levels, where each level can be occupied by at most one particle. This distribution incorporates the Pauli Exclusion Principle.
- Maxwell-Boltzmann distribution: This describes the statistical behavior of classical (distinguishable) particles and is used for ideal gases at high temperatures. It does not incorporate the Pauli Exclusion principle and assumes that the particles can occupy any state in any number.
- Bose-Einstein distribution: Describes how bosons are distributed. Bosons have integer spin (e.g. photons, gluons, and phonons) and can occupy the same quantum state with no limit to the number of particles per state.

The Pauli Exclusion Principle, is a direct consequence of the Fermi-Dirac statistics and explains the structure of atoms, molecules, nuclei etc.

Quick Tip

The Fermi-Dirac distribution explains why metals are good conductors (many electrons are easily excited), and why insulators are poor conductors (few electrons are easily excited).

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16. Which of the following metals possesses the highest melting point?

(A) Sodium (Na)
(B) Lithium (Li)
(C) Potassium (K)
(D) Cesium (Cs)

Correct Answer: (B) Lithium (Li)

Solution: Among the alkali metals, lithium has the highest melting point due to its small atomic size and strong metallic bonding. The melting point trend in Group 1 elements decreases as atomic size increases, weakening the metallic bonds. Therefore, the order of melting points is:

- Lithium (Li): Highest melting point
- Sodium (Na)
- Potassium (K)
- Cesium (Cs): Lowest melting point

This trend highlights the relationship between atomic size and bond strength in metallic structures.

Quick Tip

Melting points generally decrease down a group for alkali metals, because there is greater electron shielding, and weaker metallic bonding. There are no strong or weak covalent bonds between metals, instead, the metal atoms share a "sea of electrons", so metals with strong metallic bonds have high melting points.

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17. The factors that influence the ionization energy are:

(A) Size of the atom
(B) Charge of the atom
(C) Size and charge of the atom
(D) Size, charge, and type of electron involved (s, p, d, or f)

Correct Answer: (D) Size, charge, and type of electron involved (s, p, d, or f)

Solution: Ionization energy, the energy required to remove an electron from a gaseous atom, depends on the following factors:

- **Atomic Size:** Smaller atoms have higher ionization energy due to stronger nuclear attraction.
- **Nuclear Charge:** Higher nuclear charge increases the attraction between the nucleus and electrons, raising ionization energy.
- **Type of Electron:** Electrons in the s-orbital experience less shielding than those in p, d, or f orbitals, making them harder to remove.

For example, elements in the same period show increasing ionization energy as nuclear charge increases.

Quick Tip

The factors affecting ionization energy include the nuclear charge, atomic size and the electron type. The ionization energy increases left to right due to nuclear charge, and decreases as you go down a group, because there are more shells that shield the outermost electrons. s-electrons are harder to remove than p-electrons.

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18. The number of gram molecules of a substance present in unit volume is termed as:

(A) Activity
(B) Normal solution
(C) Molar concentration
(D) Active mass

Correct Answer: (C) Molar concentration

Solution: Molar concentration, also known as molarity, is defined as the number of moles of a solute present in 1 liter of solution. It is expressed as:

$$M = \frac{\text{moles of solute}}{\text{volume of solution (L)}}$$

This concept is critical in stoichiometric calculations and solution preparation. Other related terms include:

- **Activity:** Effective concentration of a species in a solution.
- **Normal solution:** Concentration expressed in equivalents per liter.
- **Active mass:** An older term used in reaction rate expressions.

Quick Tip

Molarity (M) is defined as the number of moles of solute per liter of solution and is very useful in reactions, where we're using moles to balance the reactions. However, molarity changes with temperature due to changes in volume, and molality is preferred in that case.

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19. Among the following molecules, the one with the highest dipole moment is:

(A) CH_3Cl
(B) CH_2Cl_2
(C) $CHCl_3$
(D) CCl_4

Correct Answer: (A) CH_3Cl

Solution: Dipole moment measures the separation of positive and negative charges in a molecule. It depends on bond polarity and molecular geometry:

- **CH_3Cl:** Significant dipole moment due to one polar C-Cl bond and asymmetric geometry.
- **CH_2Cl_2:** Lower dipole moment as the two C-Cl bonds partially cancel each other.
- **$CHCl_3$:** Further reduced dipole moment due to three C-Cl bonds.
- **CCl_4:** No dipole moment due to perfect symmetry.

Thus, CH_3Cl has the highest dipole moment due to its single polar bond and lack of significant cancellation.

Quick Tip

Dipole moments depend on electronegativity differences and the spatial orientation of the bonds. Symmetrical molecules cancel out the effects of all dipole moments of individual bonds, and as such, the molecule has no net dipole moment.

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20. Toluene reacts with a halogen in the presence of iron (III) chloride giving ortho and para compounds. The reaction is:

(A) Electrophilic addition reaction
(B) Electrophilic substitution reaction
(C) Free radical addition reaction
(D) Nucleophilic substitution reaction

Correct Answer: (B) Electrophilic substitution reaction

Solution: Toluene undergoes electrophilic substitution when treated with halogens in the presence of $FeCl_3$, a Lewis acid catalyst. The methyl group on toluene activates the ortho and para positions for substitution due to its electron-donating effect. The reaction mechanism involves:

- Generation of an electrophile (e.g., Cl^+) by $FeCl_3$.
- Electrophile attack at the activated positions.
- Stabilization of the intermediate carbocation and subsequent restoration of aromaticity.

This reaction is characteristic of aromatic compounds.

Quick Tip

Always look at the substituent that is already attached to the benzene ring to figure out whether the incoming electrophile will attach itself at the ortho/para position, or the meta position, and this depends on the group's ability to donate or withdraw electron density via resonance or induction.

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21. Scanning tunneling microscope works on the principle of:

(A) Quantum mechanical tunneling
(B) Photoelectric effect
(C) Stefan's Law
(D) Meissner effect

Correct Answer: (A) Quantum mechanical tunneling

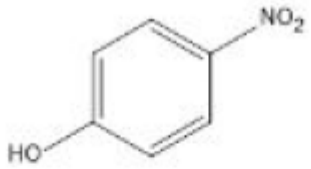
Solution: The scanning tunneling microscope (STM) operates on the principle of quantum mechanical tunneling. When a sharp conducting tip is brought very close to a conductive or semiconductive surface, electrons tunnel through the vacuum gap between the tip and the surface. The tunneling current depends on the tip-sample distance, allowing atomic-scale resolution imaging.

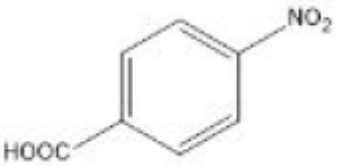
- **Key Feature:** The STM provides real-time visualization of atomic arrangements on surfaces.
- **Application:** STM is widely used to study surface structures, defects, and electronic properties at the nanoscale.

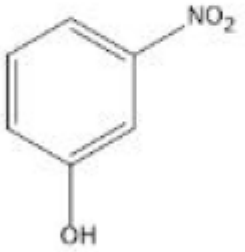
Quick Tip

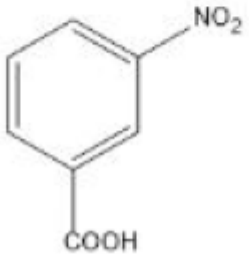
The scanning tunneling microscope has a metallic tip with a small vacuum gap and it works by detecting changes in a tunneling current of electrons, which is exponentially dependent on the gap distance, and so, by controlling this, it can get highly accurate imaging at the atomic scale.

22. Strongest acid among the following is:

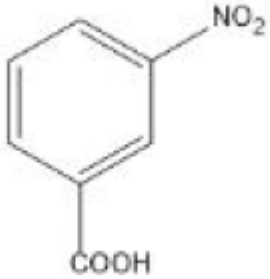
1. 

2. 

3. 

4. 

Correct Answer: (4)

4. 

Solution: Meta-nitrobenzoic acid (option 4) is the strongest acid among the given options a nitro group is a strong electron-withdrawing substituent which increases the acidity. When substituted at the meta position, the nitro group stabilizes the negative charge of the conjugate base through inductive effect, making it more stable compared to the options. The decreasing order of acidity is:

- Trichloroacetic acid: phenolic hydroxyl groups (option 1 and 3) weaker
- Formic acid: Strong due to the absence of electron-donating groups.

- Acetic acid: Weaker as the methyl group has an electron-donating effect.
- Benzoic acid: Weakest due to resonance stabilization of the benzene ring.

This shows the relationship between molecular structure and acidity.

Quick Tip

The strength of an acid depends on how stable its conjugate base is, because the stronger the acid, the weaker its conjugate base, and the stability of that conjugate base is determined by the electron donating or withdrawing properties of nearby substituents.

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23. The number of isomers for the compound with molecular formula $C_2BrClFI$ is:

(A) 3
(B) 4
(C) 5
(D) 6

Correct Answer: (D) 6

Solution: The compound $C_2BrClFI$ can form 6 isomers based on the arrangements of substituents around the carbon atoms. These include:

- Structural isomers: Different connectivity of atoms.
- Geometrical isomers: Cis-trans configurations around the double bond.
- Optical isomers: Non-superimposable mirror images due to chiral centers.

Systematically considering all possible configurations gives 6 unique isomers.

Quick Tip

Keep in mind that isomers are compounds with the same molecular formula, but different structural or spatial arrangements. When finding isomers, include all possible structural and stereoisomers (geometrical and optical).

---

24. Which of the following statements is incorrect about sucrose?

(A) Ordinary table sugar is called sucrose
(B) Sucrose is a disaccharide
(C) Sucrose has a molecular formula of $C_{12}H_{22}O_{11}$
(D) Sucrose gives a positive test with Benedict's and Tollens' solutions

Correct Answer: (D) Sucrose gives a positive test with Benedict's and Tollens' solutions

Solution: Sucrose is a non-reducing sugar because it does not have a free aldehyde or ketone group. In sucrose, the glucose and fructose units are linked by their anomeric carbons, preventing the molecule from reacting with Benedict's or Tollens' solutions. Other points:

- Sucrose is commonly referred to as table sugar.
- It is a disaccharide with the formula $C_{12}H_{22}O_{11}$.
- Non-reducing sugars do not participate in redox reactions typical of reducing sugars.

Quick Tip

Reducing sugars have a hemiacetal or hemiketal end group, while non-reducing sugars do not. If there is a free aldehyde or ketone group, it'll react with Benedicts and Tollens reagents and reduce them. The glucose and fructose residues of sucrose are linked through their anomeric carbons, resulting in a non-reducing sugar.

---

25. Which of the following are called artificial atoms?

(A) Electrons
(B) Molecules
(C) Quantum dots
(D) H-atoms

Correct Answer: (C) Quantum dots

Solution: Quantum dots are nanoscale semiconductor particles that exhibit discrete energy levels due to quantum confinement. These properties mimic the behavior of individual atoms, earning them the nickname "artificial atoms". Features include:

- Size-dependent electronic and optical properties.
- Applications in imaging, quantum computing, and photovoltaics.
- Ability to emit tunable fluorescence based on particle size.

This distinct behavior is why they are likened to atoms in functionality and versatility.

Quick Tip

Quantum dots are extremely versatile nanomaterials because of quantum confinement and the discrete energy levels that occur as a result of quantum confinement. They can also be manufactured in different sizes, which allows for precise control of their electronic and optical properties, which is a boon for scientists.

26. Which scientist is often referred to as the Father of Nanotechnology?

(A) Albert Einstein
(B) Max Planck
(C) Niels Bohr
(D) Richard Feynman

Correct Answer: (D) Richard Feynman

Solution: Richard Feynman is considered the "Father of Nanotechnology" due to his visionary 1959 lecture titled "There's Plenty of Room at the Bottom." In this talk, he outlined the potential of manipulating matter at the atomic and molecular levels. Key contributions include:

- Envisioning nanoscale machines and molecular assemblers.
- Proposing the idea of atomic-scale manufacturing.
- Inspiring decades of research in nanotechnology and material science.

This foundational vision has shaped the modern field of nanotechnology.

Quick Tip

Richard Feynman envisioned the manipulation of individual atoms and molecules to build devices at an atomic scale, and he introduced the idea of nanoscale machines. This lecture laid the foundation for the field of nanotechnology.

27. X-rays are used for the determination of crystal structure because:

(A) They can travel in vacuum
(B) They are mechanical waves
(C) Their wavelength is of the same order as interplanar spacing in crystals
(D) Their speed changes with the change of medium

Correct Answer: (C) Their wavelength is of the same order as interplanar spacing in crystals

Solution: X-rays are ideal for determining crystal structures because their wavelengths (approximately 0.1–10 nm) match the interplanar spacing of crystal lattices. This enables constructive interference when X-rays interact with atoms in the crystal, following Bragg's law:

$$n\lambda = 2d \sin\theta$$

where:

- n: Order of diffraction.

- λ: Wavelength of X-rays.
- d: Interplanar spacing.
- θ: Angle of incidence.

The diffraction pattern generated by this interaction is analyzed to determine the atomic arrangement and symmetry in the crystal.

Quick Tip

X-rays used for structural analysis have wavelengths that are of the same order as atomic distances in the crystalline solids. This makes them suitable to study the interatomic distances. XRD patterns can also tell us about the different crystalline phases and the defects present in the crystalline lattice.

---

28. Carbon nanotubes are nanostructures:

(A) Zero-dimensional
(B) One-dimensional
(C) Two-dimensional
(D) Three-dimensional

Correct Answer: (B) One-dimensional

Solution: Carbon nanotubes (CNTs) are classified as one-dimensional nanostructures because their length is significantly greater than their diameter, which is typically in the nanometer range. Properties include:

- **Types:** Single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs).
- **Exceptional properties:** High tensile strength, excellent electrical conductivity, and thermal stability.
- **Applications:** Used in nanotechnology, electronics, and material science, including energy storage devices and drug delivery systems.

The 1D structure results in unique physical and electronic properties, making CNTs highly valuable in advanced applications.

Quick Tip

Carbon nanotubes have unique electronic, mechanical, and thermal properties, due to their unique 1D structure, allowing for various applications like high strength composites and efficient transistors.

---

29. Tendency of an atom to attract electrons to itself when combined in a group is called:

(A) Workfunction
(B) Electronegativity
(C) Polarization
(D) Catenation

Correct Answer: (B) Electronegativity

Solution: Electronegativity is the measure of an atom's ability to attract shared electrons in a chemical bond. Factors influencing electronegativity include:

- **Atomic size:** Smaller atoms have higher electronegativity as the nucleus is closer to the bonding electrons.
- **Nuclear charge:** Higher positive charge in the nucleus increases the attraction for bonding electrons.

For example, fluorine is the most electronegative element due to its small size and high nuclear charge.

Quick Tip

Electronegativity increases with the increase in effective nuclear charge and decreases with the increasing atomic size. The atoms that have high electronegativity include fluorine and oxygen, while those with low electronegativity are cesium and francium.

---

30. Which of the following diodes is used in voltage-regulation circuits?

(A) Photodiode
(B) Light Emitting Diode (LED)
(C) Tunnel diode
(D) Zener diode

Correct Answer: (D) Zener diode

Solution: Zener diodes are designed to operate in the reverse breakdown region, maintaining a constant output voltage across a load. Features include:

- **Reverse breakdown voltage:** The voltage at which the diode allows significant reverse current without damage.
- **Voltage regulation:** Zener diodes are widely used in power supplies to stabilize output voltage.
- **Protection:** They safeguard sensitive components from voltage surges.

This makes Zener diodes indispensable in voltage-regulation circuits.

> Quick Tip
>
> Zener diodes are designed to maintain a constant voltage when reverse biased, which allows them to protect electronic devices from overvoltage and provide stable voltage outputs.

---

31. In a bipolar junction transistor:

1. Collector Current I_C = Emitter Current I_E + Base Current I_B
2. Emitter Current I_E = Collector Current I_C + Base Current I_B
3. Base Current I_B = Emitter Current I_E + Collector Current I_C
4. Base, emitter, and collector currents are equal.

Correct Answer: 2. Emitter Current I_E = Collector Current I_C + Base Current I_B

Solution: In a bipolar junction transistor (BJT):

- I_E (emitter current) is the total current leaving the emitter.
- I_C (collector current) and I_B (base current) are components of I_E.
- According to Kirchhoff's Current Law (KCL): $I_E = I_C + I_B$.

Typically, I_B is much smaller than I_C, making I_E approximately equal to I_C.

> Quick Tip
>
> The relationship between the currents is IE = IB + IC. Note that base current is a control current in the BJT that is used to amplify the output signals.

---

32. Photons are classified as:

(A) Fermions
(B) Bosons
(C) Classical Particles
(D) Nucleons

Correct Answer: (B) Bosons

Solution: Photons are classified as bosons because they have integer spin ($s = 1$) and follow Bose-Einstein statistics. Characteristics include:

- **Force carriers:** Photons mediate electromagnetic interactions.
- **No Pauli exclusion:** Unlike fermions, multiple photons can occupy the same quantum state.
- **Examples:** Other bosons include gluons, W/Z bosons, and the Higgs boson.

Quick Tip

Fermions (particles with half-integer spin) and bosons have different statistical behaviors and different quantum properties. Photons being bosons do not obey Pauli's exclusion principle, unlike fermions.

---

33. Which of the following statements is incorrect about Silicon?

(A) Its atomic number is 14
(B) It has semiconducting nature
(C) It is a direct band gap semiconductor
(D) Silicon is the backbone of the semiconductor industry

Correct Answer: (C) It is a direct band gap semiconductor

Solution: Silicon is an indirect band gap semiconductor, meaning its conduction band minimum and valence band maximum occur at different momentum values. Other points:

- Atomic number: 14.
- Silicon dominates the semiconductor industry due to its abundance and favorable electronic properties.
- Applications: Used in transistors, diodes, and integrated circuits.

Quick Tip

In indirect band gap materials such as silicon, the minimum of the conduction band does not directly correspond to the maximum of the valence band, so the radiative recombination is difficult, and requires phonons for the transfer of momentum. In direct band gap materials, the radiative recombination is very efficient as there is no need for momentum transfer.

---

34. Meissner effect is a phenomenon of:

(A) Perfect diamagnetism
(B) Perfect paramagnetism

(C) Perfect ferromagnetism
(D) Perfect antiferromagnetism

Correct Answer: (A) Perfect diamagnetism

Solution: The Meissner effect describes the expulsion of magnetic fields from a superconductor when it is cooled below its critical temperature. Key features:

- **Perfect diamagnetism:** Magnetic susceptibility becomes -1.
- **Superconducting state:** The material transitions to zero electrical resistance.
- **Applications:** Used in magnetic levitation and superconducting magnets.

> Quick Tip
>
> When a superconductor is cooled below its critical temperature, it expels all magnetic fields, thus demonstrating perfect diamagnetism, which is fundamental to magnetic levitation and many applications in the field of advanced materials.

---

35. Which of the following processes is carried out at constant pressure?

(A) Isothermal Process
(B) Isobaric Process
(C) Adiabatic Process
(D) Isochoric Process

Correct Answer: (B) Isobaric Process

Solution: An isobaric process occurs when the pressure of a system remains constant, even as volume and temperature change. Examples include:

- Heating or cooling of a gas in a piston-cylinder setup.
- Phase changes at constant atmospheric pressure.

Other processes:

- Isothermal: Constant temperature.
- Adiabatic: No heat exchange.
- Isochoric: Constant volume.

Quick Tip

Keep in mind that in an isobaric process the pressure remains constant, whereas in an isothermal process the temperature remains constant. Isochoric processes involve constant volume, and no heat exchange occurs in adiabatic processes.

---

36. Which among the following would be a linear species?

(A) ICl_2^-
(B) IF_c^-
(C) I_3^-
(D) H_2O

Correct Answer: (C) I_3^-

Solution: The I_3^- ion exhibits a linear geometry due to its electronic arrangement. According to the Valence Shell Electron Pair Repulsion (VSEPR) theory:

- The central iodine atom in I_3^- has three lone pairs of electrons and forms bonds with two outer iodine atoms.
- The lone pairs arrange symmetrically to minimize electron repulsion, resulting in a bond angle of 180°.

This linear geometry is a characteristic of triatomic species with symmetric electron distribution.

Quick Tip

Using the Valence Shell Electron Pair Repulsion theory (VSEPR), the linear shape occurs when there are two bonding regions (two atoms bonded to the central atom) and zero or three symmetrically arranged lone pairs (like in I_3^-).

---

37. In gram staining, cell walls of Gram-positive bacteria become dehydrated during treatment with alcohol due to:

(A) Lower Lipid Content
(B) Higher Lipid Content
(C) Lower Protein Content
(D) Higher Protein Content

Correct Answer: (A) Lower Lipid Content

Solution: Gram-positive bacteria retain the purple stain in Gram staining due to their thick peptidoglycan layer, which has low lipid content. When treated with alcohol:

- The alcohol dehydrates the peptidoglycan layer, causing it to shrink and trap the crystal violet-iodine complex.
- Gram-negative bacteria, with higher lipid content, lose the outer membrane and the stain during alcohol treatment.

This property differentiates Gram-positive and Gram-negative bacteria in microbiological analysis.

Quick Tip

Gram positive bacteria have thick peptidoglycan layers, and lower lipid content in their cell walls, while gram-negative bacteria have thin peptidoglycan layers and higher lipid content. This difference in the cell wall leads to a differential staining as the alcohol washes away the lipid and the crystal violet stain.

---

38. Which is the polymer of Fructose?

(A) Starch
(B) Glycogen
(C) Inulin
(D) Cellulose

Correct Answer: (C) Inulin

Solution: Inulin is a polysaccharide composed of fructose units linked by $\beta(2 \rightarrow 1)$ glycosidic bonds. It is a storage carbohydrate found in plants like chicory and Jerusalem artichokes.

- Unlike starch (a glucose polymer), inulin is not digested by human enzymes and functions as dietary fiber.
- It acts as a prebiotic, promoting the growth of beneficial gut bacteria.

Inulin's unique structure makes it valuable in health and nutrition research.

Quick Tip

Inulin is a polymer of fructose that is commonly used in the food industry to aid in dietary fibre uptake.

---

39. Which of the following is a thiol-containing amino acid?

(A) Cysteine
(B) Glycine

(C) Serine
(D) Tryptophan

Correct Answer: (A) Cysteine

Solution: Cysteine is a sulfur-containing amino acid featuring a thiol (-SH) group in its side chain. This group plays critical roles in protein chemistry:

- Forms disulfide bonds (-S-S-) during oxidation, stabilizing protein structures.
- Participates in catalytic activity in enzyme active sites.

Cysteine's unique properties make it indispensable in maintaining protein structure and function.

Quick Tip

Cysteine forms disulfide bonds, which are strong covalent bonds that can stabilize the tertiary and quaternary structure of proteins by linking two cysteine residues together.

---

40. The antigen specificity of a particular B cell:

(A) Is induced by interaction with antigen
(B) Is due to light chain of antibody
(C) Is due to heavy chain of antibody
(D) Is determined by heavy and light chain variable region sequence

Correct Answer: (D) Is determined by heavy and light chain variable region sequence.

Solution: Antigen specificity, the ability of a B cell to recognize and bind to a specific antigen, is primarily determined by the variable regions of its antibodies. These regions:

- Form the antigen-binding site, which is highly variable to bind to a wide range of antigens.
- Undergo somatic recombination, a process that generates a diverse repertoire of antibody binding sites.
- Involve both the heavy and light chain variable regions, which together form the antigen-binding pocket.

Options A, B and C are incorrect because they do not fully explain how specificity arises. While interaction with antigen is important for activation, it does not determine specificity. The heavy and light chain contribute to specificity and is due to both not just individual chain.

Quick Tip

Variable regions are located at the tips of the arms of the antibody molecule, and they are the antigen-binding sites. These regions contain sequences that are unique and are generated by somatic recombination in the B cells.

---

41. Which of the following properties is NOT exhibited by TH cells?

(A) Stimulate division of B cells
(B) Are cytotoxic for other cells
(C) Stimulate division of cytotoxic T cells
(D) Stimulate migration of macrophages

Correct Answer: (B) Are cytotoxic for other cells

Solution: Helper T cells (TH cells) are a type of white blood cells that plays a crucial role in adaptive immune response. Their main functions involve:

- **Stimulating B cell division and antibody production**: TH cells help B cells proliferate and differentiate into plasma cells, which produce antibodies.
- **Activating Cytotoxic T cells**: TH cells stimulate the activation and expansion of cytotoxic T cells (Tc) cells using cytokines. Cytotoxic T cells are the cells responsible for direct killing of infected cells or tumor cells.
- **Stimulating macrophage activity**: TH cells enhance the phagocytic and microbicidal activity of macrophages through cytokines.

TH cells themselves are *not* cytotoxic. Cytotoxicity is a primary function of cytotoxic T cells, not helper T cells. Cytotoxic T cells have CD8+ receptors. TH cells has CD4+ receptors.

Quick Tip

Helper T cells are key for activating and coordinating other cells. Cytokines are secreted by helper T cells, which act as messengers for various cells of the immune system. Cytotoxic T cells directly destroy infected or cancerous cells, by using mechanisms such as perforin and granzyme.

---

42. In germ line gene therapy, healthy gene is inserted into:

(A) Hepatic cells
(B) Fibroblast cells
(C) Endothelium
(D) Sperms or Eggs

Correct Answer: (D) Sperms or Eggs.

Solution: Germline gene therapy involves inserting a functional gene into germ cells (sperms or eggs) or very early-stage embryos. This ensures that the genetic modification is heritable, meaning the change will be passed down to future generations. This method aims to correct genetic defects not just in an individual but also in their future progeny. Options A, B and C (Hepatic, fibroblast and endothelium cells) are somatic cells, which are not passed down to future generations.

Quick Tip

Somatic gene therapy targets non-reproductive cells and the changes are not inherited. Germline therapy is complex and raises many ethical considerations because it has implications for future generations.

---

43. Restriction Endonuclease type I is involved in:

(A) Endonuclease and Methylase
(B) Cleaving and Methylation
(C) Cut DNA within palindromic sequences
(D) Cut DNA within non-palindromic sequences

Correct Answer: (A) Endonuclease and Methylase.

Solution: Type I restriction enzymes have both endonuclease (cleaving DNA) and methyltransferase (modifying DNA by adding a methyl group) activities. They:

- Recognize specific DNA sequences but cleave DNA at random locations far away from the recognition site.
- Methylate specific bases within the recognition sequence to protect the host DNA from cleavage.

This dual functionality is characteristic of Type I restriction enzymes, differentiating them from other types of restriction enzymes that mainly perform cleavage. Type II enzymes cleave DNA at specific site. Type III enzymes cleave DNA at a specific sequence but not at the recognition site.

Quick Tip

Type II restriction enzymes are very precise, cut at or near the recognition site, and are useful for various applications in molecular biology, while type I enzymes cleave DNA at random sites and are not suitable for targeted applications.

---

44. The Ti plasmid of Agrobacterium tumefaciens contains a transposon called:

(A) T DNA
(B) R DNA
(C) cDNA
(D) A DNA

Correct Answer: (A) T DNA.

Solution: The Ti (tumor-inducing) plasmid of Agrobacterium tumefaciens contains a segment of DNA called T DNA (Transfer DNA), which is transferred from the bacteria to the plant genome during infection. The T-DNA is a specific DNA that contains the genes required for tumor growth in plants. Options R, cDNA and A DNA are not related to the Ti plasmid.

Quick Tip

The Ti plasmid is engineered such that the T-DNA region can be replaced with any desired foreign gene, which can then be inserted into the host plant's genome. The T-DNA is transferred to plant cells, where the introduced gene is expressed, thus allowing for genetic modification.

---

45. Nitrogenase enzyme involved in nitrogen fixation works best in:

(A) Aerobic conditions
(B) Anaerobic conditions
(C) Insensitive to oxygen
(D) Both aerobic and anaerobic conditions

Correct Answer: (B) Anaerobic conditions.

Solution: Nitrogenase is the enzyme responsible for biological nitrogen fixation, that is converting atmospheric nitrogen (N2) into ammonia (NH3). It is extremely sensitive to oxygen, meaning it is irreversibly inactivated by it. The nitrogenase requires anaerobic conditions to function effectively. Many nitrogen fixing organisms have special adaptations to create an environment of low oxygen partial pressure for the functioning of nitrogenase. For example, in legumes, leghemoglobin in the root nodules creates an oxygen-free environment. This is because oxygen is an oxidizing agent that interferes with the redox reactions of the nitrogenase enzyme. Therefore, nitrogen fixation is favored in oxygen free conditions.

Quick Tip

Nitrogen fixation is the chemical process in which the atmospheric nitrogen is converted into ammonia. Nitrogenase enzymes are extremely sensitive to oxygen, that is why it works in anaerobic conditions and bacteria such as Rhizobium have specialized structures called leghemoglobin which is used to remove oxygen from the environment.

---

46. Arrange the following electromagnetic radiations in the order of decreasing wavelength:
(A). Microwaves
(B). Gamma rays
(C). X-rays
(D). Visible rays
Choose the correct answer from the options given below:
(1) (A), (D), (C), (B)
(2) (B), (C), (D), (A)
(3) (B), (A), (D), (C)
(4) (C), (B), (D), (A)

Correct Answer: (1) (A), (D), (C), (B)

Solution: Electromagnetic radiation is organized in the electromagnetic spectrum, ordered based on wavelength. The order of electromagnetic radiation according to wavelength, from longest to shortest is: Radio waves, Microwaves, Infrared, Visible light, Ultraviolet, X-rays and Gamma rays. Therefore:

- **Microwaves:** These have the longest wavelength of the given options and the lowest energy
- **Visible rays:** Visible light has an intermediate wavelength, ranging between about 400-700 nm
- **X-rays:** X-rays have a shorter wavelength than visible light, and are associated with higher energy.
- **Gamma rays:** Gamma rays have the shortest wavelength and the highest energy amongst the given radiations.

The correct order of decreasing wavelength is therefore, Microwaves ¿ Visible rays ¿ X-rays ¿ Gamma rays

Quick Tip

Remember the relationship between wavelength and energy: Longer wavelengths have less energy, and shorter wavelengths have more energy.

47. Which of the following is correct about electromagnetic waves?
(A). Sound waves are electromagnetic in nature
(B). They travel in vacuum
(C). Electromagnetic waves are longitudinal (formation of compression and rarefaction) in nature
(D). X-rays are electromagnetic in nature
Choose the correct answer from the options given below:
(1) (A), (D), and (D) only
(2) (A), (B), and (C) only
(3) (B) only
(4) (B) and (D) only

Correct Answer: (4) (B) and (D) only

Solution: Electromagnetic waves have the following characteristics:

- **Travel in vacuum**: They do not require a medium for propagation, unlike mechanical waves, such as sound.
- **Transverse waves**: Electromagnetic waves are characterized by oscillating electric and magnetic fields which are perpendicular to each other and also to the direction of wave propagation.
- **Include X-rays and gamma rays:** X-rays are a high-energy form of electromagnetic radiation, along with gamma rays, visible light, UV and radio waves
- **Not sound waves**: sound waves are mechanical waves and require medium for propagation. They are also longitudinal waves.

Therefore, statements B and D are correct, while statements A and C are incorrect.

Quick Tip

Mechanical waves such as sound require a medium to travel. The EM waves are transverse and can travel through a vacuum, and these waves consist of electric and magnetic fields perpendicular to the direction of propagation.

---

48. Which of the following statement is correct?
(A). The stronger the acid, the weaker will be its conjugate base
(B). The stronger the acid, the stronger will be its conjugate base
(C). The larger the pKa of the conjugate acid, the weaker is its base
(D). The larger the pKa of the conjugate acid, the stronger is its base
Choose the correct answer from the options given below:
(1) D only
(2) B and C only
(3) A and D only

(4) B only

Correct Answer: (3) A and D only

Solution: The strength of an acid is inversely related to the strength of its conjugate base.

- **Strong acids** dissociate completely, producing stable conjugate bases with little tendency to accept a proton. Therefore statement (A) is correct, that is, the stronger the acid, the weaker is the conjugate base.
- **pKa value:** is the indicator of acid strength; the larger the pKa value, the weaker the acid.

Therefore a higher pKa indicates a weaker acid, which leads to a stronger conjugate base and statement (D) is correct, that is, the larger the pKa value of the conjugate acid, the stronger its base. Statements B and C are incorrect.

Quick Tip

A strong acid dissociates completely to form its conjugate base, which is very weak and has low affinity for a proton. A weak acid dissociates only partly and thus, its conjugate base is stronger and has higher affinity for a proton.

---

49. All the metal halides have negative enthalpies of formation. Thermodynamically feasible from them. Arrange the following halides from most to least negative enthalpies of formation for any given metal:
(A). Iodide
(B). Chloride
(C). Bromide
(D). Fluoride
Choose the correct answer from the options given below:
(1) (A), (C), (B), (D)
(2) (A), (B), (C), (D)
(3) (D), (B), (C), (A)
(4) (D), (C), (B), (A)

Correct Answer: (3) (D), (B), (C), (A)

Solution: The enthalpy of formation of a metal halide is mainly related to its lattice energy, which is the energy released when the ions form the solid lattice.

- **Fluoride (F-):** Fluoride ions are the smallest halide ions, which results in a high lattice energy and therefore, most negative enthalpy of formation when they combine with metals.
- **Chloride (Cl-):** Chloride ions are larger than fluoride, which leads to a smaller lattice energy than fluorides but still greater than the other halides, with correspondingly less negative enthalpy of formation.

- **Bromide (Br-):** Bromide ions are larger than chloride ions, resulting in even smaller lattice energy and correspondingly lower negative enthalpy of formation.
- **Iodide (I-):** Iodide ions are the largest among halides, leading to the smallest lattice energy and thus the least negative enthalpy of formation.

Thus, the order of enthalpy of formation from most negative to least negative is Fluoride ¿ Chloride ¿ Bromide ¿ Iodide.

Quick Tip

Enthalpy of formation is the energy released when one mole of a compound is formed from its elements in their standard states. The smaller ions have stronger electrostatic forces of attraction, which leads to greater lattice energy and higher negative enthalpy of formation.

---

50. Arrange the following oxoacids in the order of their increasing acidic strength:
(A). HOCl
(B). $HOCl_2$
(C). $HOCl_3$
(D). $HOCl_4$
Choose the correct answer from the options given below:
(1) (D), (C), (A), (B)
(2) (B), (A), (C), (D)
(3) (A), (B), (C), (D)
(4) (C), (A), (B), (D)

Correct Answer: (3) (A), (B), (C), (D)

Solution: The acidic strength of oxoacids increases with the number of oxygen atoms attached to the central atom. This is because more oxygen atoms stabilize the conjugate base through resonance.

- HOCl has one oxygen atom
- HOClO has two oxygen atoms
- HOClO2 has three oxygen atoms
- HOClO3 has four oxygen atoms.

The order of increasing acid strength is HOCl ¡ HOClO ¡ HOClO2 ¡ HOClO3. The higher the number of oxygen atoms, the greater the resonance and stabilization of the conjugate base, and thus a stronger acid.

Quick Tip

The more electronegative oxygen atoms that are attached to the central atom, the more the electron density of the conjugate base will be delocalized, which increases its stability, thus strengthening the acid.

---

51. Arrange the following in the order of increasing basic strength:
(A). NH_3
(B). PH_3
(C). AsH_3
(D). BiH_3
Choose the correct answer from the options given below:
(1) (A), (C), (B), (D)
(2) (A), (B), (C), (D)
(3) (B), (D), (C), (A)
(4) (D), (C), (B), (A)

Correct Answer: (4) (D), (C), (B), (A)

Solution: The basic strength of group 15 hydrides decreases down the group. The basic strength of these compounds is related to the availability of the lone pair of electrons on the central atom for donation, for the formation of a new bond.

- **NH3:** It is the smallest among the group 15 hydrides and the lone pair is highly available and accessible. Therefore it is the strongest base.
- **PH3, AsH3, and BiH3:** As you move down the group the atoms get larger (P, As and Bi). Due to the increased size of the central atom, the lone pair becomes more diffuse and is held more weakly, making them less effective at forming a bond with a proton. Therefore basicity decreases with increasing size of the atom.

Thus, the order of increasing basic strength is BiH3 ¡ AsH3 ¡ PH3 ¡ NH3.

Quick Tip

As you go down a group, the atomic size increases, which makes the lone pair less readily available for bonding, and the basic strength decreases down the group in group 15 elements.

---

52. Arrange the following in decreasing order of nucleophilicity:
(A). H_2O
(B). NH_3
(C). OH^-
(D). NH_2^-

Choose the correct answer from the options given below:
(1) (A), (B), (C), (D)
(2) (D), (C), (B), (A)
(3) (C), (D), (B), (A)
(4) (D), (B), (C), (A)

Correct Answer: (2) (D), (C), (B), (A)

Solution: Nucleophilicity is the ability of a species to donate a lone pair to form a new bond. Factors like charge, electronegativity, and solvent affect nucleophilicity.

- **Charge:** Anionic species (OH-, NH2-) are stronger nucleophiles than neutral species (H2O, NH3), because of the high electron density resulting from the negative charge.
- **Electronegativity:** Within the same period, less electronegative atoms are better nucleophiles, for example N is less electronegative than O. NH2- is therefore a better nucleophile than OH-.

Therefore, the order of decreasing nucleophilicity is NH2- ¿ OH- ¿ NH3 ¿ H2O

Quick Tip

Nucleophilicity is the measure of the rate at which a species (nucleophile) will attack an electrophile, whereas basicity measures the thermodynamic stability of an atom. Generally, anions are stronger nucleophiles, and the higher the electronegativity, the lower the nucleophilicity.

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53. The correct order of steps in PCR is:
(A). Annealing
(B). Denaturation
(C). Extension
Choose the correct answer from the options given below:
(1) (A), (B), (C)
(2) (B), (A), (C)
(3) (B), (C), (A)
(4) (C), (B), (A)

Correct Answer: (2) (B), (A), (C)

Solution: PCR (Polymerase Chain Reaction) is a technique used to amplify DNA by three main steps:

- **Denaturation:** The DNA is heated to 95°C, causing the double stranded DNA molecule to separate into two single strands.
- **Annealing:** The temperature is lowered to 50-65°C to allow the primers to bind to the complementary sequences of the DNA strands.

- **Extension:** The temperature is raised to 72°C (optimum temperature for Taq DNA Polymerase) to allow DNA polymerase to synthesize new DNA strands by adding nucleotides to the primers.

These steps are repeated in cycles to amplify specific regions of the DNA. The correct order is therefore Denaturation -¿ Annealing -¿ Extension.

Quick Tip

Denaturation helps separate the two strands of DNA by breaking the hydrogen bonds, annealing helps the primer bind to its complementary sequence and extension helps in adding of nucleotides by DNA polymerase.

---

54. Which of the following enzymes of Krebs' cycle is also involved in the mitochondrial electron transport system?
(A). Citrate synthase
(B). Succinate dehydrogenase
(C). Malate dehydrogenase
(D). Isocitrate dehydrogenase

Correct Answer: (B) Succinate dehydrogenase

Solution: Succinate dehydrogenase is an enzyme that is involved both in the Krebs cycle (citric acid cycle) and the electron transport chain (ETC). In Krebs cycle, succinate dehydrogenase catalyzes the oxidation of succinate to fumarate and at the same time in the ETC, it transfers the electrons to FADH2 to ubiquinone (coenzyme Q). This is the only enzyme that is embedded in the inner mitochondrial membrane, linking two major energy producing metabolic processes.

Quick Tip

Succinate dehydrogenase is a membrane-bound enzyme that oxidizes succinate to fumarate in the Krebs cycle and also transfers electrons from FADH2 to ubiquinone (coenzyme Q) in the electron transport chain.

---

55. Sequential steps of Prophase of Meiosis I:
(A). Zygotene
(B). Pachytene
(C). Leptotene
(D). Diakinesis
(E). Diplotene
Choose the correct answer from the options given below:
(1) (A), (B), (C), (E), (D)
(2) (C), (A), (B), (E), (D)

(3) (B), (E), (D), (C), (A)
(4) (C), (B), (D), (E), (A)

Correct Answer: (2) (C), (A), (B), (E), (D)

Solution: Prophase I of meiosis is divided into 5 stages that are characterized by specific events:

- **Leptotene:** Chromosomes condense and become visible under microscope.
- **Zygotene:** Homologous chromosomes pair up forming synaptonemal complex.
- **Pachytene:** Crossing over occurs between homologous chromosomes.
- **Diplotene:** Synaptonemal complex disassembles, and chiasmata (cross over points) becomes visible.
- **Diakinesis:** Chromosomes condense further and chiasmata move to terminal positions, preparing for separation.

The correct sequence is therefore Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

Quick Tip

Prophase 1 is the longest phase of meiosis. Leptotene is when the chromosomes condense; zygotene when chromosomes pair up; pachytene for crossing over; diplotene when they start to separate, and diakinesis when they are ready for metaphase.

---

56. The conditions for a reversible isothermal process are:
(A). Infinitesimally slow process
(B). Infinitely fast process
(C). Constant Pressure
(D). Constant Temperature
Choose the correct answer from the options given below:
(1) (A) and (D) only
(2) (A), (C), and (D) only
(3) (B), (C), and (D) only
(4) (D) only

Correct Answer: (1) (A) and (D) only

Solution: A reversible isothermal process is a thermodynamic process where the temperature remains constant throughout and the process is carried out infinitely slowly.

- **Isothermal:** means that the temperature remains constant.
- **Reversible:** It occurs when the system is in equilibrium at all times, requiring an infinitesimally slow change and therefore infinitesimally slow process.

Pressure may change during an isothermal reversible process. Therefore, correct conditions are Infinitesimally slow process and constant temperature.

> Quick Tip
>
> Isothermal processes occur at constant temperature and reversible processes are carried out extremely slowly with no change in equilibrium, which is why they are difficult to achieve in real life.

---

57. Crystalline materials possess:
(A). Sharp melting point and boiling point
(B). Anisotropic properties
(C). Periodic arrangement of atoms
(D). Isotropic properties
Choose the correct answer from the options given below:
(1) (A), (C), and (D) only
(2) (A) and (C) only
(3) (A), (B), and (D) only
(4) (C) and (D) only

Correct Answer: (2) (A) and (C) only

Solution: Crystalline materials are characterized by a highly ordered and repeating arrangement of atoms in a lattice. This gives rise to:

- **Sharp melting point and boiling point:** Due to the uniform arrangement and bonding, crystalline materials have a defined melting and boiling point.
- **Periodic arrangement of atoms:** This defines the crystalline nature, with atoms arranged in a repeating pattern.

Isotropic properties, meaning properties are the same in all directions, are characteristic of amorphous materials.

> Quick Tip
>
> Crystalline solids have a repeating arrangement of atoms that create a lattice structure, and because of this they have well defined melting points, and properties such as refractive index are different in different dimensions (anisotropy).

---

58. Which of the following are the correct postulates of the quantum theory of light?
(A). Each photon of frequency v has the energy hv, the same as Planck's energy.
(B). The higher v, the greater the photon energy hv.

(C). Blue color has lower energy than green color.
(D). Changing the intensity of the incident light beam will change the frequency v of the photon.
Choose the correct answer from the options given below:
(1) (A), (B), and (C) only
(2) (A), (B), and (D) only
(3) (A) and (B) only
(4) (A) and (D) only

Correct Answer: (3) (A) and (B) only

Solution: Quantum theory of light proposes that light is comprised of individual packets of energy called photons.

- **Photon energy**: Each photon of frequency v has energy E=hv (where h is Planck's constant), it is the same as Planck's energy.
- **Frequency and energy relationship:** Photon energy is directly proportional to the frequency (v); the higher the frequency, the greater the photon energy.
- **Color and frequency:** Blue light has a higher frequency than green light, meaning blue has higher energy than green light.
- **Intensity and Frequency**: Changing the intensity of light means changing the number of photons, and has no effect on the frequency of each photon.

Therefore, options A and B are correct.

Quick Tip

The energy of the photon is given by E=hv where h is planck's constant and v is the frequency. The frequency is not dependent on the intensity of light, which is why higher frequency light such as blue light has more energy than red light.

---

59. The following species have an equal number of electrons. Arrange them in increasing order of their size:
(A). Ne
(B). Na^+
(C). O^{2-}
(D). F^-
Choose the correct answer from the options given below:
(1) (A), (B), (C), (D)
(2) (B), (C), (A), (D)
(3) (B), (A), (D), (C)
(4) (D), (C), (A), (B)

Correct Answer: (3) (B), (A), (D), (C)

Solution: The species listed are isoelectronic, meaning they have the same number of electrons (10 electrons). The size of isoelectronic species is determined by the nuclear charge (number of protons). With a higher nuclear charge (number of protons), the electrons are pulled more tightly towards the nucleus resulting in a smaller size.

- **Na^+**: Sodium has 11 protons, 10 electrons. It has the highest nuclear charge among these species and therefore the smallest size.
- **Ne:** Neon has 10 protons and 10 electrons, and is neutral.
- **F^-**: Fluorine has 9 protons and 10 electrons, resulting in a larger size than Na^+ or Ne because of less nuclear charge and also because it is an anion, with added electron repulsions.
- **O^{2-}**: Oxygen has 8 protons and 10 electrons. It has the smallest nuclear charge among the isoelectronic species and is also a doubly charged anion which causes strong electron repulsions leading to the largest size.

Thus, the order of increasing size is Na^+ ¡ Ne ¡ F^- ¡ O^{2-}

Quick Tip

Cations are smaller than their corresponding neutral atoms, due to the increase in the effective nuclear charge, whereas anions are bigger due to an increase in electron repulsion.

---

60. Identify the correct statements with reference to VSEPR theory:
(A). Lone pairs cause more repulsion than double bonds.
(B). Double bonds cause more repulsion than a single bond.
(C). Triple bonds cause more repulsion than a double bond.
(D). Single bonds cause more repulsion than a lone pair.
Choose the correct answer from the options given below:
(1) (A), (B), and (C) only
(2) (B) and (C) only
(3) (A) and (B) only
(4) (B), (C), and (D) only

Correct Answer: (2) (B) and (C) only

Solution: VSEPR (Valence Shell Electron Pair Repulsion) theory explains molecular shapes by stating that electron pairs in the valence shell of a central atom repel each other, therefore arranging themselves to minimize repulsions.

- **Lone pairs, triple bonds, double bonds and single bonds** create a hierarchy of repulsive forces between electron pairs.
- **Lone pairs:** Experience the strongest repulsive forces because they are only held by one nucleus and occupy a large space around the central atom.

- **Multiple bonds** (triple and double bonds): They create more repulsion than single bonds because they have a higher electron density.
- Therefore, the order of repulsion is: Lone pair ¿ Triple Bond ¿ Double Bond ¿ Single bond.

Therefore, statements B and C are correct, and A and D are incorrect.

Quick Tip

Lone pair repulsion is higher than bond pair repulsion. Triple bonds being electron dense regions have higher repulsion than double and single bonds. Thus, lone pairs are the most effective at disrupting the regular geometric shape of the molecule, by increasing the bond angles.

---

61. Which of the following arrangements does not represent the correct order of properties stated against it?
(A). $V^{2+} < Cr^{2+} < Mn^{2+} < Fe^{2+}$: Paramagnetic behavior
(B). $Zn^{2+} < Ni^{2+} < Cr^{2+} < Fe^{2+}$: Number of unpaired electrons
(C). $Sc^{3+} < Ti^{3+} < V^{3+} < Cr^{3+} < Mn^{3+}$: Number of oxidation states
(D). $Co^{2+} < Cr^{2+} < Mn^{2+} < Ni^{2+}$: Stability in aqueous solution
Choose the correct answer from the options given below:
(1) (A), (B) and (C) only
(2) (A) and (C) only
(3) (A), (B) and (D)
(4) (B), (C) and (D) only

Correct Answer: (3) (A), (B) and (D)

Solution: Here's an analysis of the given properties for the arrangements:

(A) **Paramagnetic Behavior**: Paramagnetism is due to unpaired electrons. The expected order would follow the number of unpaired electrons. Fe^{2+} with four unpaired electrons should be more paramagnetic than Mn^{2+} and less paramagnetic than Cr^{2+}. The given order is incorrect.

(B) **Number of Unpaired Electrons**: The number of unpaired electrons for the transition metal cations in the given list does not follow a regular increasing pattern. For example, Cr^{2+} will have 4 unpaired electrons whereas Ni^{2+} will have 2 unpaired electrons. Zn^{2+} is diamagnetic. Thus this order is incorrect.

(C) **Number of Oxidation States**: Transition metals exhibit a variety of oxidation states, where the lower the number of d electrons the lesser the oxidation states will be. Sc^{3+} can exist as Sc^{3+}. The stability increases from Ti^{3+} to Mn^{3+}. Therefore, the given order is correct.

(D) **Stability in Aqueous Solution**: The stability of transition metal ions in aqueous solution is influenced by several factors like the charge density, hydration energy and crystal

field stabilization energy. Stability order is not consistent and is based on these factors and is highly complex and does not follow a general trend. The given order is not correct.

Quick Tip

The number of unpaired electrons dictates the paramagnetic behavior, but it should not be interpreted without taking into account the experimental conditions as well as ligand field effects.

---

62. The process of vulcanization makes rubber:
(A). Soluble in water
(B). Elastic
(C). Hard
(D). Soft
Choose the correct answer from the options given below:
(1) (A), (B) and (D) only
(2) (B) and (C) only
(3) (B) and (D)
(4) (B) only

Correct Answer: (2) (B) and (C) only

Solution: Vulcanization is a chemical process where rubber is heated with sulfur. This process:

- **Forms cross-links** between polymer chains of rubber molecules through disulfide bridges between the double bonds present in natural rubber.
- **Increases elasticity**: These cross-links make the rubber more elastic by reducing the movement of polymer chains.
- **Increases hardness**: It also makes it harder and more durable as it also increases the tensile strength.
- **Reduced solubility** It makes it less soluble in solvents.

Therefore, vulcanization makes the rubber more elastic and hard.

Quick Tip

Vulcanization enhances rubber by introducing sulfur cross-links which create a stable three dimensional network in the polymer chains, thus improving its properties like elasticity, tensile strength, and durability.

---

63. Which of the following will give benzoic acid on acidic hydrolysis?
(A). Phenyl cyanide
(B). Benzimidazole
(C). Benzoic anhydride
(D). Methyl benzoate
Choose the correct answer from the options given below:
(1) (A) and (D) only
(2) (A), (C) and (D) only
(3) (A), (B), (C) and (D)
(4) (C) and (D) only

Correct Answer: (2) (A), (C) and (D) only

Solution: Hydrolysis in the presence of an acid breaks specific bonds in molecules to produce different products.

- **Phenyl cyanide** (benzonitrile) undergoes hydrolysis to form benzoic acid.
- **Benzoic anhydride** forms two molecules of benzoic acid on acidic hydrolysis.
- **Methyl benzoate** is an ester that undergoes hydrolysis to form benzoic acid and methanol.
- **Benzimidazole** will not undergo this type of hydrolysis and will not form benzoic acid.

Thus, the compounds in options A, C and D will form benzoic acid upon acidic hydrolysis.

Quick Tip

Hydrolysis reactions involve the addition of water, and they break down chemical bonds. Compounds like nitriles, esters and anhydrides can react with water in the presence of acids or bases to yield carboxylic acids.

---

64. Match List-I with List-II:

List-I	**List-II**
(A) CCl_4	(i) Insecticide
(B) CF_2Cl_2	(ii) Refrigerant
(C) CHI_3	(iii) Antiseptic for wounds
(D) CH_2Cl_2	(iv) Propellant for aerosols

Correct Answer: (2) (A) - (i), (B) - (ii), (C) - (iii), (D) - (iv)

Solution:
Each compound is matched to its application based on its chemical properties and uses:

- CCl_4 (Carbon tetrachloride) was historically used as an insecticide due to its toxic properties, though its use is now restricted.

- CF_2Cl_2 (Dichlorodifluoromethane) is widely used as a refrigerant because of its stable and non-reactive nature.
- CHI_3 (Iodoform) is used as an antiseptic for wounds, known for its distinctive odor.
- CH_2Cl_2 (Dichloromethane) is a volatile compound commonly used as a propellant in aerosols.

Quick Tip

Remember:

- CCl_4 is an insecticide but is now restricted due to toxicity.
- CF_2Cl_2 is a stable refrigerant, commonly found in older air conditioning systems.
- CHI_3 is an antiseptic known for wound treatment and its smell.
- CH_2Cl_2 is preferred as a propellant due to its high volatility and low flammability.

---

65. Two metals are completely miscible with each other to form a continuous range of solid solutions only if:
(A). Two metals must be similar in size—their metallic radii must not differ by more than 15%.
(B). Both metals must have the same crystal structure.
(C). The chemical properties must be similar particularly the same electronegativity.
(D). Both metals must have the same electrical conductivity.
Choose the correct answer from the options given below:
(1) (A) and (D) only
(2) (A), (B) and (C) only
(3) (A), (B), (C) and (D)
(4) (B) and (C) only

Correct Answer: (4) (B) and (C) only

Solution: The Hume-Rothery rules describe the necessary conditions for forming a substitutional solid solution.

- **Atomic size**: The two metals should have similar atomic sizes, with metallic radii differing by not more than 15%.
- **Crystal structure**: They should have the same crystal structure for atoms to replace each other in the lattice.
- **Electronegativity**: The chemical properties should be similar, particularly their electronegativity, so that they bond with similar strengths to their neighbors in the crystal lattice.
- **Electrical conductivity**: Electrical conductivity is not a requirement for forming solid solution.

Therefore, B and C are correct conditions.

Quick Tip

The atomic size needs to be similar and the crystal structures should be same or similar to form a solid solution, the electronegativity needs to be similar for a uniform distribution in the solid solution.

---

66. Arrange the following structures in terms of increasing order of confinement:
(A). Quantum Well
(B). Bulk Material
(C). Quantum Dot
(D). Carbon Nanotube
Choose the correct answer from the options given below:
(1) (A), (B), (C), (D)
(2) (B), (A), (D), (C)
(3) (C), (B), (A), (D)
(4) (D), (B), (C), (A)

Correct Answer: (2) (B), (A), (D), (C)

Solution: Confinement in nanomaterials refers to the restriction of particle movement in one or more dimensions.

- **Bulk Material**: There is no confinement and particles have freedom of movement in all the dimensions.
- **Quantum Well**: The particles are confined in one dimension only.
- **Carbon Nanotube**: Particles are confined to two dimensions (moving along the tube).
- **Quantum Dot**: Particles are confined in all three dimensions leading to quantum confinement.

Therefore, the order of increasing confinement is Bulk material ¡ Quantum well ¡ Carbon nanotube ¡ Quantum dot.

Quick Tip

Bulk materials have no confinement as the electron is free to move in all 3 dimensions, whereas quantum wells confine motion in 1 dimension, quantum wires confine motion in 2 dimensions and quantum dots confine motion in all 3 dimensions.

---

67. Match List-I with List-II:

List-I (System)	List-II (Axial lengths and angles)
(A) Cubic	(I) a = b ≠ c, $\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$
(B) Tetragonal	(II) a ≠ b ≠ c, $\alpha = \beta = \gamma = 90^\circ$
(C) Orthorhombic	(III) a = b ≠ c, $\alpha = \beta = \gamma = 90^\circ$
(D) Hexagonal	(IV) a = b = c, $\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$

Choose the correct answer from the options given below:
1. (A) - (IV), (B) - (II), (C) - (III), (D) - (I)
2. (A) - (I), (B) - (III), (C) - (II), (D) - (IV)
3. (A) - (IV), (B) - (II), (C) - (I), (D) - (III)
4. (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

Correct Answer: (2) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)

Solution:
Crystal systems are classified based on their axial lengths and angles:

- Cubic: All sides are equal, and all angles are 90°
- Tetragonal: Two sides are equal, one different, all angles 90°
- Orthorhombic: All sides unequal, all angles 90°
- Hexagonal: Two sides equal, one different, two angles 90° and one 120°

Therefore, the correct matching is: (A) - (I), (B) - (III), (C) - (II), (D) - (IV).

Quick Tip

There are 7 crystal systems and these systems can be distinguished by analyzing the length of the axes and the angle between them. The axial relationship will determine the shape and symmetry of the crystal.

---

68. Match List-I with List-II:

List-I (Type of Crystalline Solid)	List-II (Example)
(A) Ionic	(I) Methane, CH_4
(B) Covalent	(II) Copper, Cu
(C) Molecular	(III) Sodium Chloride, NaCl
(D) Metallic	(IV) Diamond, C

Choose the correct answer from the options given below:
1. (A) - (III), (B) - (II), (C) - (I), (D) - (IV).
2. (A) - (III), (B) - (I), (C) - (II), (D) - (IV).
3. (A) - (II), (B) - (I), (C) - (IV), (D) - (III).
4. (A) - (III), (B) - (IV), (C) - (I), (D) - (II).

Correct Answer: (4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Solution:
Crystalline solids are categorized by their bonding:

- Ionic solids: are held by electrostatic forces (NaCl).
- Covalent solids: have covalent network bonds (Diamond, C).
- Molecular solids: held by weak forces (Methane, CH_4).
- Metallic solids: have delocalized electrons(Copper, Cu).

The correct answer is: (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Quick Tip

Ionic solids are held together with strong electrostatic attractions, covalent solids have a network of covalent bonds, molecular solids are held together by weak intermolecular forces, while metallic solids have metallic bonds through a sea of delocalized electrons.

---

69. Match List-I with List-II:

List-I	**List-II**
(A) Principal Quantum Number (n)	(i) -1/2, +1/2
(B) Azimuthal Quantum Number (l)	(ii) 1, 2, 3,...
(C) Magnetic Quantum Number (m_l)	(iii) 0, ± 1, ± 2, ± 3, ..., ± l
(D) Spin Quantum Number (s)	(iv) 0, 1, 2,... n - 1

Choose the correct answer from the options given below:
1. (A) - (ii), (B) - (iv), (C) - (iii), (D) - (i).
2. (A) - (ii), (B) - (iii), (C) - (iv), (D) - (i).
3. (A) - (iv), (B) - (ii), (C) - (iii), (D) - (i).
4. (A) - (iv), (B) - (ii), (C) - (i), (D) - (iii).

Correct Answer: (1) (A) - (ii), (B) - (iv), (C) - (iii), (D) - (i)

Solution:
Quantum numbers describe properties of atomic orbitals:

- Principal quantum number (n) = main energy level (1, 2, 3...)
- Azimuthal quantum number (l) = orbital shape (0 to n-1)
- Magnetic quantum number (m_l) = orbital orientation (-l to +l)
- Spin quantum number (s) = electron spin (+1/2 or -1/2)

Therefore the correct matching is: (A) - (ii), (B) - (iv), (C) - (iii), (D) - (i)

Quick Tip

To remember the quantum numbers, just think about how each of them is defined and which value it takes. Principle quantum numbers range from 1 to infinity, azimuthal quantum numbers range from 0 to n-1, magnetic quantum numbers range from -l to +l, and spin quantum numbers are always either +1/2 or -1/2.

---

70. Match List-I with List-II:

List-I	**List-II**
(A) XeF_2	(i) Trigonal Planar
(B) BF_3	(ii) Distorted Octahedral
(C) XeF_4	(iii) Linear
(D) SF_6	(iv) Regular Octahedral

Choose the correct answer from the options given below:
1. (A) - (i), (B) - (iii), (C) - (ii), (D) - (iv).
2. (A) - (iii), (B) - (i), (C) - (ii), (D) - (iv).
3. (A) - (iv), (B) - (iii), (C) - (ii), (D) - (i).
4. (A) - (iii), (B) - (iv), (C) - (i), (D) - (ii).

Correct Answer: (2) (A) - (iii), (B) - (i), (C) - (ii), (D) - (iv)

Solution:
The molecular geometries are from VSEPR:

- XeF_2: Linear due to three lone pairs and two bond pairs.
- BF_3: Trigonal planar due to three bond pairs and no lone pairs.
- XeF_4: Distorted octahedral with four bond pairs and two lone pairs.
- SF_6: Regular octahedral with six bond pairs and no lone pairs.

The correct matching is: (A) - (iii), (B) - (i), (C) - (ii), (D) - (iv).

Quick Tip

VSEPR theory is used to determine molecular geometries by minimizing electron pair repulsions. Lone pairs are more repulsive than bonding pairs and therefore tend to compress bond angles, distorting the geometry from its ideal shape.

---

71. Match List-I with List-II:

List-I	List-II
(A) Linus Pauling	(i) Alpha particle scattering experiment
(B) Albert Einstein	(ii) Photoelectric effect
(C) Ernest Rutherford	(iii) Electronegativity
(D) Max Planck	(iv) Black body radiations

Choose the correct answer from the options given below:
(1) (A) - (III), (B) - (II), (C) - (I), (D) - (IV)
(2) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)
(3) (A) - (IV), (B) - (III), (C) - (I), (D) - (II)
(4) (A) - (III), (B) - (II), (C) - (IV), (D) - (I)

Correct Answer: (1) (A) - (iii), (B) - (ii), (C) - (i), (D) - (iv)

Solution:
Scientists with their major scientific contributions:

- Linus Pauling = concept of electronegativity
- Albert Einstein = photoelectric effect
- Ernest Rutherford = alpha particle scattering experiment
- Max Planck = quantum theory of black body radiation

The correct answer is: (A) - (iii), (B) - (ii), (C) - (i), (D) - (iv).

Quick Tip

Linus Pauling defined electronegativity which is the ability to attract electrons in a covalent bond; Albert Einstein explained the photoelectric effect, which demonstrates the particle nature of light; Ernest Rutherford discovered the atomic nucleus by alpha scattering; Max Planck proposed quantized energy of black body radiation.

---

72. Match List-I with List-II:

List-I	List-II
(A) Alkaline phosphatase	(i) Cleaves DNA
(B) DNA Polymerase	(ii) Cleaves ssDNA
(C) SI Nuclease	(iii) Nick translation
(D) DNase I	(iv) Removes phosphate group at 5' end of DNA

Choose the correct answer from the options given below:
(1) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)
(2) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)
(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (1) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

Solution:
Enzymes with their functions:

- Alkaline phosphatase removes 5' phosphate groups from DNA and RNA
- DNA polymerase is involved in nick translation.
- S1 Nuclease cleaves single stranded DNA
- DNase I cleaves DNA randomly.

Therefore, the correct matching is: (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

Quick Tip

Alkaline phosphatase removes phosphate groups, DNA polymerase is involved in nick translation, S1 nuclease is involved in single stranded DNA cleavage, and DNase I degrades DNA randomly.

---

73. Match List-I with List-II:

List-I	**List-II**
(A) IgA	(i) Basophils
(B) IgE	(ii) Secretory components
(C) IgG	(iii) Pentamer
(D) IgM	(iv) Crosses Placenta

Choose the correct answer from the options given below:
(1) (A) - (II), (B) - (I), (C) - (IV), (D) - (III)
(2) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)
(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)
(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (3) (A) - (II), (B) - (I), (C) - (IV), (D) - (III)

Solution:
Immunoglobulins with their specific roles:

- IgA is in mucosal secretions and is associated with secretory components.
- IgE activate basophils and mast cells in allergic reactions.
- IgG crosses the placenta, providing immunity to fetus.
- IgM is the first antibody in an immune response and exists as a pentamer.

Therefore, the correct answer is: (A) - (II), (B) - (I), (C) - (IV), (D) - (III)

Quick Tip

IgA is found in secretions, IgE is involved in allergy, IgG is the most abundant antibody in the blood, and IgM is produced first during an immune response. Understanding the function of each will help to distinguish them based on their properties.

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74. Match List-I with List-II:

List-I	**List-II**
(A) Thiamine (B1)	(i) Riboflavin adenine nucleotide
(B) Riboflavin (B2)	(ii) Tetrahydrofolic acid
(C) Niacin	(iii) Nicotinamide adenine dinucleotide
(D) Folic acid	(iv) Co-carboxylase

Choose the correct answer from the options given below:
(1) (A) - (IV), (B) - (I), (C) - (III), (D) - (II)
(2) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)
(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)
(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (1) (A) - (IV), (B) - (I), (C) - (III), (D) - (II)

Solution:
Vitamins and their metabolic coenzyme roles:

- Thiamine (Vitamin B1) is essential for carbohydrate metabolism, as it's a precursor for co-carboxylase.
- Riboflavin forms important coenzymes, like flavin adenine dinucleotide (FAD) and riboflavin adenine nucleotide, which are vital for redox reactions.
- Niacin is converted into nicotinamide adenine dinucleotide (NAD) and NADP, both crucial for many metabolic processes, especially in redox reactions.
- Folic acid plays a role in nucleotide synthesis, and it is metabolized to tetrahydrofolic acid.

The correct matching is: (A) - (iv), (B) - (i), (C) - (iii), (D) - (ii).

Quick Tip

To remember vitamin functions, link each vitamin to its specific coenzyme role: Thiamine (B1) to co-carboxylase, Riboflavin (B2) to FAD/FMN, Niacin to NAD/NADP, and Folic acid to tetrahydrofolic acid.

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75. Match List-I with List-II:

List-I	List-II
(A) Lyman	(i) n = 2, 3, 4, ...
(B) Balmer	(ii) n = 3, 4, 5, ...
(C) Paschen	(iii) n = 4, 5, 6, ...
(D) Bracket	(iv) n = 5, 6, 7, ...

Choose the correct answer from the options given below:
(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)
(2) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)
(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)
(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (1) (A) - (i), (B) - (ii), (C) - (iii), (D) - (iv)

Solution:
Hydrogen spectral series and their transitions:

- Lyman series ends at n=1 and involves levels of n=2,3,4 etc.
- Balmer series ends at n=2 and involves energy levels of n=3,4,5 etc
- Paschen series ends at n=3 and involves energy levels of n =4,5,6 etc
- Bracket series ends at n=4 and involves energy levels of n=5,6,7 etc

The correct matching is: (A) - (i), (B) - (ii), (C) - (iii), (D) - (iv).

Quick Tip

Lyman transitions end in n=1, emitting UV radiation; Balmer transitions end in n=2 and emit visible light; Paschen ends in n=3 with IR radiation, and Bracket series is in far IR with n=4.