NEET Re-Exam 2026 Code 70

Question Paper with Solutions

Conducted by National Testing Agency (NTA)

General Instructions

(i) The test is of 3 hours and 15 minutes duration.

(ii) This test paper consists of 180 questions. The maximum marks are 720.

(iii) Physics and Chemistry contains 45 questions each and Biology (Botany and Zoology) contains 90 questions.

(iv) Each question carries +4 marks for correct answer and –1 mark for wrong answer.

Physics

1. A photon and an electron, each of $10\,\text{eV}$ energy, move in free space. The ratio of linear momentum of electron P_e to that of photon P_{ph},

$$\frac{P_e}{P_{ph}}$$

is :

(A) 275

(B) $\frac{2}{450}$

(C) $\frac{1}{250}$

(D) 225

Correct Answer: (A) 275

Solution:

Concept:

- Momentum of a photon is given by $p = \frac{E}{c}$.
- Momentum of a non-relativistic electron is $p = \sqrt{2mE}$.
- Both particles have the same energy of 10 eV.

Step 1: Calculate photon momentum

$$E = 10 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-18}\,\text{J}$$

$$P_{ph} = \frac{E}{c} = \frac{1.6 \times 10^{-18}}{3 \times 10^{8}} = 5.33 \times 10^{-27}\,\text{kg m s}^{-1}$$

Step 2: Calculate electron momentum

$$P_e = \sqrt{2mE}$$

$$= \sqrt{2 \times 9 \times 10^{-31} \times 1.6 \times 10^{-18}}$$

$$= \sqrt{28.8 \times 10^{-49}}$$

$$= 5.37 \times 10^{-24}\,\text{kg m s}^{-1}$$

Step 3: Find the ratio

$$\frac{P_e}{P_{ph}} = \frac{5.37 \times 10^{-24}}{5.33 \times 10^{-27}} \approx 275$$

Quick Tip: Photon momentum is E/c. Electron momentum is $\sqrt{2mE}$. Always convert eV into joule before calculation. Compare orders of magnitude carefully.

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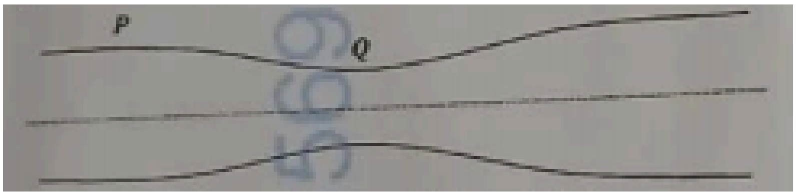
2. Water flows in a streamline motion through a horizontal pipe of circular cross-section as shown in the figure. The pressure difference of water between P and Q is $15\,\mathrm{N\,m^{-2}}$. The area of cross-section at P and Q are $40\,\mathrm{cm^2}$ and $20\,\mathrm{cm^2}$, respectively. The rate of flow of water through the pipe, in $\mathrm{cm^3 s^{-1}}$, is:



(A) 400

(B) 100

(C) 200

(D) 300

Correct Answer: (C) 200

Solution:

Concept:

- Apply Bernoulli's theorem.
- Use equation of continuity.
- For horizontal flow, gravitational term remains constant.

Step 1: Apply continuity equation

$$A_1 v_1 = A_2 v_2$$

$$40v_1 = 20v_2$$

$$v_2 = 2v_1$$

Step 2: Apply Bernoulli equation

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$15 = \frac{1}{2}(1000)\left(v_2^2 - v_1^2\right)$$

$$15 = 500(4v_1^2 - v_1^2)$$

$$15 = 1500v_1^2$$

$$v_1 = 0.1\,\mathrm{m\ s^{-1}}$$

Step 3: Calculate discharge

$$Q = A_1 v_1$$

$$= (40 \times 10^{-4})(0.1)$$

$$= 4 \times 10^{-4}\,\mathrm{m^3 s^{-1}}$$

$$= 400\,\mathrm{cm^3 s^{-1}}$$

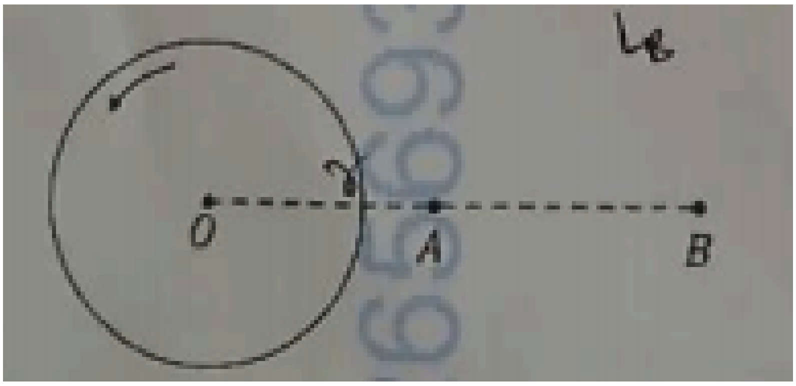
Quick Tip: Use continuity before Bernoulli equation. Smaller area means greater speed. For horizontal pipes, height terms cancel. Convert units carefully.

3. A thin horizontal disc is rotating about a vertical axis passing through its fixed centre O. Its angular momentum is L_A and L_B computed about points A and B, respectively, where $OB = 2 \times OA$.

The value of

$$\frac{L_A}{L_B}$$

is:



(A) 2

(B) $\frac{1}{4}$

(C) $\frac{1}{2}$

(D) 1

Correct Answer: (D) 1

Solution:

Concept:

- For a rigid body rotating about a fixed axis, angular momentum is independent of the choice of point on the axis.
- The disc rotates about the same vertical axis through O.
- Hence angular momentum remains unchanged.

Step 1: Identify axis of rotation

The disc rotates about a fixed vertical axis through its centre.

Step 2: Compare angular momenta about different points

For points A and B on the same axis,

$$L_A = L_B$$

Step 3: Calculate ratio

$$\frac{L_A}{L_B} = \frac{L_B}{L_B} = 1$$

Quick Tip: Angular momentum depends on axis. For a fixed rotation axis, shifting origin along axis does not change angular momentum. Always identify the rotation axis first. Remember rigid body rotation properties.

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4. Consider a long solenoid of length l and radius r. If n is the number of turns per unit length and μ_0 is the permeability of free space, the inductance of the solenoid is:

(A) $2\mu_0 \pi n^2 r^2 l$

(B) $\mu_0 \pi n^2 r^2 l$

(C) $\mu_0 n^2 r^2 l$

(D) $\left(\frac{\mu_0}{2\pi}\right) n^2 r^2 l$

Correct Answer: (B) $\mu_0 \pi n^2 r^2 l$

Solution:

Concept:

- Inductance of a long solenoid is

$$L = \mu_0 n^2 A l$$

- Cross-sectional area is

$$A = \pi r^2$$

Step 1: Write standard inductance formula

$$L = \mu_0 n^2 A l$$

Step 2: Substitute area of solenoid

$$A = \pi r^2$$

$$L = \mu_0 n^2 (\pi r^2) l$$

Step 3: Obtain final expression

$$L = \mu_0 \pi n^2 r^2 l$$

Quick Tip: Memorize inductance formula of a long solenoid. Area is πr^2. Inductance increases with square of turns density. Larger area gives larger inductance.

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5. The temperature of a metallic sphere of radius R is increased by a small amount ΔT. If the linear coefficient of thermal expansion of the metal is α, the approximate increase in the volume of the sphere is:

(A) $6\pi R^3 \alpha \Delta T$

(B) $2\pi R^3 \alpha \Delta T$

(C) $3\pi R^3\alpha\Delta T$

(D) $4\pi R^3\alpha\Delta T$

Correct Answer: (D) $4\pi R^3\alpha\Delta T$

Solution:

Concept:

- Volume coefficient of expansion is
$$\gamma = 3\alpha$$
- Increase in volume is
$$\Delta V = \gamma V \Delta T$$

Step 1: Write initial volume of sphere

$$V = \frac{4}{3}\pi R^3$$

Step 2: Apply volume expansion formula

$$\Delta V = 3\alpha V \Delta T$$

$$= 3\alpha\left(\frac{4}{3}\pi R^3\right)\Delta T$$

Step 3: Simplify expression

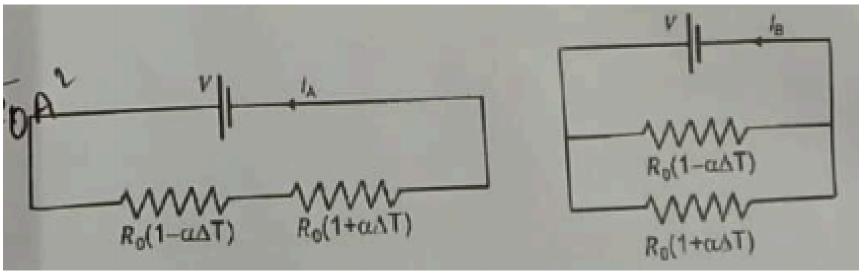
$$\Delta V = 4\pi R^3\alpha\Delta T$$

Quick Tip: Volume coefficient equals 3α. For isotropic solids use $\gamma = 3\alpha$. Remember volume of sphere $= \frac{4}{3}\pi R^3$. Use approximation for small temperature changes.

6. Consider two circuits, (A) and (B), each having two resistors. One of them has a positive temperature coefficient of resistance, $+\alpha$, while the other one has a negative temperature coefficient of resistance, $-\alpha$, as shown in the figure. The current through these circuits are denoted by I_A and I_B.

At initial temperature, the resistance of the two resistors is R_0.

As the temperature is increased, the correct option that describes the variation of current in these circuits is:



(A) Both I_A and I_B remain constant

(B) I_A remains constant while I_B increases

(C) I_A decreases while I_B increases

(D) I_A increases while I_B decreases

Correct Answer: (B) I_A remains constant while I_B increases

Solution:

Concept:

- Resistance at temperature change ΔT is given by

$$R = R_0(1 + \alpha\Delta T)$$

  for positive temperature coefficient.

- For a negative temperature coefficient,

$$R = R_0(1 - \alpha\Delta T)$$

- In a series combination, equivalent resistance is the sum of individual resistances.
- In a parallel combination,

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

- Current supplied by a battery is

$$I = \frac{V}{R_{eq}}$$

Hence the variation of current depends upon the variation of equivalent resistance.

Step 1: Find equivalent resistance of circuit (A)

The two resistors are connected in series.

$$R_1 = R_0(1 - \alpha\Delta T)$$

$$R_2 = R_0(1 + \alpha\Delta T)$$

Therefore,

$$R_A = R_1 + R_2$$

$$R_A = R_0(1 - \alpha\Delta T) + R_0(1 + \alpha\Delta T)$$

$$R_A = R_0[(1 - \alpha\Delta T) + (1 + \alpha\Delta T)]$$

$$R_A = R_0(2)$$

$$R_A = 2R_0$$

Thus, the equivalent resistance of circuit (A) is independent of temperature.

Step 2: Determine current in circuit (A)

Using Ohm's law,

$$I_A = \frac{V}{R_A}$$

$$I_A = \frac{V}{2R_0}$$

Since R_A does not change with temperature,

$$I_A = \text{constant}$$

Hence the current in circuit (A) remains unchanged.

Step 3: Find equivalent resistance of circuit (B)

The two resistors are connected in parallel.

$$R_B = \frac{R_1 R_2}{R_1 + R_2}$$

Substituting the values,

$$R_B = \frac{R_0(1-\alpha\Delta T)R_0(1+\alpha\Delta T)}{R_0(1-\alpha\Delta T)+R_0(1+\alpha\Delta T)}$$

$$R_B = \frac{R_0^2\left(1-\alpha^2\Delta T^2\right)}{2R_0}$$

$$R_B = \frac{R_0}{2}\left(1-\alpha^2\Delta T^2\right)$$

Step 4: Study the variation of equivalent resistance

Since

$$\alpha^2\Delta T^2 > 0$$

it follows that

$$1-\alpha^2\Delta T^2 < 1$$

Therefore,

$$R_B < \frac{R_0}{2}$$

Thus the equivalent resistance decreases as temperature increases.

Step 5: Determine current in circuit (B)

Using Ohm's law,

$$I_B = \frac{V}{R_B}$$

As R_B decreases,

$$I_B$$

must increase.

Hence,

$$I_B \text{ increases with temperature.}$$

Step 6: Choose the correct option

We have obtained:

$$I_A = \text{constant}$$

and

$$I_B = \text{increasing}$$

Therefore the correct statement is

$$\boxed{I_A \text{ remains constant while } I_B \text{ increases}}$$

> **Quick Tip:** In series combination, directly add resistances and check whether temperature-dependent terms cancel. For parallel combinations, use the product-over-sum formula carefully. If equivalent resistance decreases, current increases for a fixed voltage source. A resistor with positive temperature coefficient increases in resistance, while a negative coefficient decreases in resistance.

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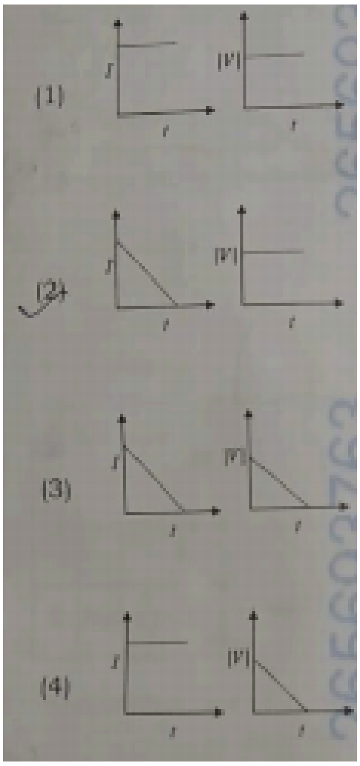
7. A beam of light falls on a metal surface such that photo-electrons are generated. If the power of the light source starts to decrease linearly with time, then the variation of the photocurrent I and magnitude of the stopping potential $|V|$ with time is best represented by :



(A) $I = \text{constant}$, $|V| = \text{constant}$

(B) I decreases linearly with time, $|V|$ remains constant

(C) I decreases linearly with time, $|V|$ also decreases linearly with time

(D) $I = \text{constant}$, $|V|$ decreases linearly with time

Correct Answer: (B) I decreases linearly with time, $|V|$ remains constant

Solution:

Concept:

- In the photoelectric effect, photocurrent is directly proportional to the intensity of incident light.
- The stopping potential depends on the maximum kinetic energy of emitted photoelectrons.
- Maximum kinetic energy depends only on the frequency of incident radiation and not on its intensity.
- A change in power of the source changes the intensity of light reaching the metal surface.

Step 1: Relate power of source with intensity of light

The power of the source decreases linearly with time.

$$P \propto \text{Intensity}$$

Hence, the intensity of the incident light also decreases linearly with time.

Step 2: Determine the variation of photocurrent

Photocurrent is directly proportional to the intensity of incident light.

$$I \propto \text{Intensity}$$

Since intensity decreases linearly with time,

$$I \propto (a - bt)$$

Therefore, photocurrent decreases linearly with time.

Step 3: Determine the variation of stopping potential

The stopping potential is related to the maximum kinetic energy by

$$eV_s = K_{\max}$$

Using Einstein's photoelectric equation,

$$K_{\max} = h\nu - \phi$$

where ν is the frequency of the incident radiation and ϕ is the work function of the metal.

Step 4: Examine the effect of changing intensity

The frequency of the light is not changing.
Therefore,

$$K_{\max} = \text{constant}$$

Hence,

$$V_s = \text{constant}$$

Thus the magnitude of the stopping potential remains unchanged with time.

Step 5: Select the correct graph

We have obtained

$$I \text{ decreases linearly with time}$$

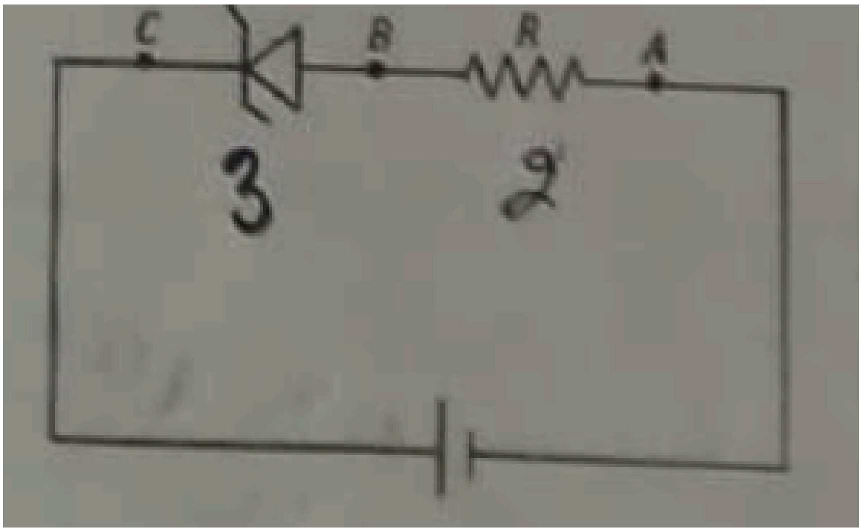
and

$$|V| = \text{constant}$$

Therefore the correct graphical representation is Option (B).

Quick Tip: Photocurrent depends on intensity of incident light. Stopping potential depends on frequency, not intensity. A decrease in intensity reduces the number of emitted electrons. The maximum kinetic energy remains unchanged if frequency remains constant.

8. In the measurement of viscosity of liquids using terminal velocity experiment, spherical balls of same radius but having different densities are used. The variation of the terminal velocity (v) with the ratio of density of spherical ball (σ) to density of the liquid (ρ), is best represented by:



(A) Graph passing through the origin

(B) Straight line having positive slope and non-zero intercept

(C) Parabolic curve

(D) Hyperbolic curve

Correct Answer: (B) Straight line having positive slope and non-zero intercept

Solution:

Concept:

- According to Stokes' law, the terminal velocity of a sphere moving through a viscous liquid is given by
$$v = \frac{2r^2 g}{9\eta}(\sigma - \rho)$$
where r is the radius of the sphere, η is the coefficient of viscosity, σ is the density of the sphere and ρ is the density of the liquid.
- In this problem, the radius of all spheres remains the same.

- Therefore, terminal velocity depends only on the density difference $(\sigma - \rho)$.
- To determine the nature of the graph, we must express v in terms of σ/ρ.

Step 1: Write the expression for terminal velocity

According to Stokes' law,

$$v = \frac{2r^2 g}{9\eta}(\sigma - \rho)$$

This equation relates the terminal velocity of a spherical ball to the density difference between the ball and the liquid.

Step 2: Express the density difference in terms of σ/ρ

Factor out ρ from the bracket:

$$\sigma - \rho = \rho\left(\frac{\sigma}{\rho} - 1\right)$$

Substituting into the expression of terminal velocity,

$$v = \frac{2r^2 g}{9\eta}\rho\left(\frac{\sigma}{\rho} - 1\right)$$

$$v = \frac{2r^2 g\rho}{9\eta}\left(\frac{\sigma}{\rho} - 1\right)$$

Step 3: Rewrite the equation in the form of a straight line

Expanding the above expression,

$$v = \frac{2r^2 g\rho}{9\eta}\left(\frac{\sigma}{\rho}\right) - \frac{2r^2 g\rho}{9\eta}$$

Let

$$m = \frac{2r^2 g\rho}{9\eta}$$

Then,

$$v = m\left(\frac{\sigma}{\rho}\right) - m$$

Step 4: Compare with the standard straight-line equation

The standard equation of a straight line is

$$y = mx + c$$

Comparing,

$$v = m\left(\frac{\sigma}{\rho}\right) - m$$

we observe that

$$\text{Slope} = m > 0$$

and

$$\text{Intercept} = -m$$

Hence the graph is a straight line having positive slope and a non-zero intercept.

Step 5: Identify the correct graph

Since the relationship between v and σ/ρ is linear,

$$v \propto \left(\frac{\sigma}{\rho}\right)$$

with a constant intercept,

the graph is a straight line and not a parabola or hyperbola.

Therefore the correct graphical representation is Option (B).

$$\boxed{\text{Option (B)}}$$

Quick Tip: Always start with Stokes' law when solving terminal velocity questions. Terminal velocity depends on the density difference $(\sigma - \rho)$. Express the equation in the form $y = mx + c$ to identify the graph. A straight-line equation always produces a linear graph with constant slope.

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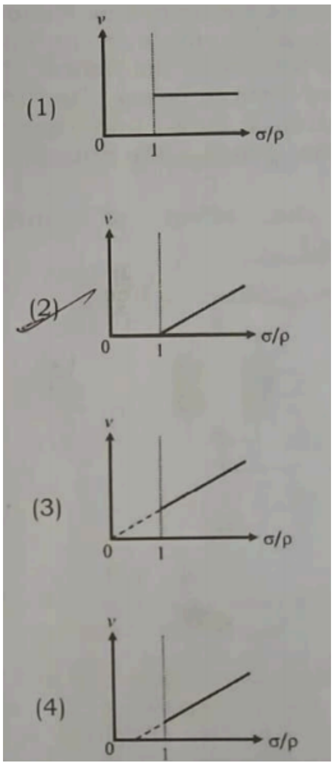
9. An ideal Zener diode with breakdown voltage of $3\,\text{V}$ is reverse biased with a negative input voltage $V_1 = -5\,\text{V}$. The magnitude of voltage difference between points B and A is:



(A) $0\,\text{V}$

(B) $3\,\text{V}$

(C) $2\,\text{V}$

(D) $1\,\text{V}$

Correct Answer: (B) $3\,\text{V}$

Solution:

Concept:

- A Zener diode is specially designed to operate in the reverse breakdown region.
- When the reverse voltage across the diode exceeds the Zener breakdown voltage, the diode starts conducting heavily.
- In the breakdown region, the voltage across the Zener diode remains nearly constant and equal to its breakdown voltage.
- This property makes the Zener diode useful as a voltage regulator.

Step 1: Identify the operating condition of the Zener diode

The given breakdown voltage is

$$V_Z = 3\,\text{V}$$

The applied reverse voltage is

$$V_1 = -5\,\text{V}$$

Since

$$|V_1| = 5\,\text{V} > V_Z = 3\,\text{V}$$

the diode operates in the reverse breakdown region.

Step 2: Apply the property of an ideal Zener diode

For an ideal Zener diode operating in breakdown,

$$V_{BA} = V_Z$$

The voltage across the diode remains fixed at its breakdown voltage irrespective of further increase in reverse voltage.

Step 3: Calculate the voltage difference between B and A

Therefore,

$$|V_{BA}| = 3\,\text{V}$$

Step 4: Select the correct option

The magnitude of voltage difference between points B and A is

$$\boxed{3\,\text{V}}$$

Hence, the correct answer is

$$\boxed{\text{Option (B)}}$$

Quick Tip: An ideal Zener diode maintains a constant voltage equal to its breakdown voltage. Always check whether the applied reverse voltage exceeds the breakdown voltage. If breakdown occurs, the voltage across the diode becomes constant. Zener diodes are widely used as voltage regulators.

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10. Two planets P_1 and P_2 with equal mass have radii R_1 and R_2, respectively, where

$$R_2 = \frac{R_1}{2}$$

The escape speeds of P_1 and P_2 are v_1 and v_2, respectively. Then the value of

$$\frac{v_2}{v_1}$$

is:

(A) 2

(B) $\frac{1}{\sqrt{2}}$

(C) 1

(D) $\sqrt{2}$

Correct Answer: (D) $\sqrt{2}$

Solution:

Concept:

- Escape velocity is the minimum speed required for a body to escape the gravitational field of a planet without further propulsion.
- The escape velocity from the surface of a planet is given by

$$v_e = \sqrt{\frac{2GM}{R}}$$

  where M is the mass of the planet and R is its radius.
- For planets having equal masses, escape velocity varies inversely as the square root of the radius.

Step 1: Write the escape velocity for planet P_1

For planet P_1,

$$v_1 = \sqrt{\frac{2GM}{R_1}}$$

where M is the mass of the planet.

Step 2: Write the escape velocity for planet P_2

For planet P_2,

$$v_2 = \sqrt{\frac{2GM}{R_2}}$$

Since both planets have equal masses, the value of M remains the same.

Step 3: Take the ratio of the two escape velocities

Dividing the two expressions,

$$\frac{v_2}{v_1} = \sqrt{\frac{\frac{2GM}{R_2}}{\frac{2GM}{R_1}}}$$

$$\frac{v_2}{v_1} = \sqrt{\frac{R_1}{R_2}}$$

Step 4: Substitute the given relation between radii

Given,

$$R_2 = \frac{R_1}{2}$$

Substituting,

$$\frac{v_2}{v_1} = \sqrt{\frac{R_1}{R_1/2}}$$

$$\frac{v_2}{v_1} = \sqrt{2}$$

Step 5: Write the final result

Therefore,

$$\boxed{\frac{v_2}{v_1} = \sqrt{2}}$$

Hence the correct option is

$$\boxed{\text{Option (D)}}$$

Quick Tip: Escape velocity is proportional to $1/\sqrt{R}$ when mass remains constant. A smaller planet radius results in a larger escape velocity. Always begin with the formula $v_e = \sqrt{2GM/R}$. Use ratios to simplify calculations quickly.

11. An AC voltage

$$V = 220\sin(2\times 10^{3} t)\ \textbf{Volt}$$

is applied to a series LCR circuit. Then the current amplitude in the circuit is:

Given:

$$L = 10\,\textbf{mH},\quad C = 25\,\mu\textbf{F},\quad R = 100\,\Omega$$

(A) 22.0 A

(B) 2.2 A

(C) 5.5 A

(D) 11.0 A

Correct Answer: (A) 22.0 A

Solution:

Concept:

- The impedance of a series LCR circuit is given by

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

- Inductive reactance is

$$X_L = \omega L$$

- Capacitive reactance is

$$X_C = \frac{1}{\omega C}$$

- Current amplitude is given by

$$I_0 = \frac{V_0}{Z}$$

where V_0 is the voltage amplitude.

Step 1: Identify the angular frequency and voltage amplitude

Comparing

$$V = 220\sin(2 \times 10^3 t)$$

with

$$V = V_0 \sin(\omega t)$$

we get

$$V_0 = 220\,\text{V}$$

and

$$\omega = 2 \times 10^3\,\text{rad s}^{-1}$$

Step 2: Calculate the inductive reactance

$$X_L = \omega L$$

$$X_L = (2 \times 10^3)(10 \times 10^{-3})$$

$$X_L = 20\,\Omega$$

Step 3: Calculate the capacitive reactance

$$X_C = \frac{1}{\omega C}$$

$$X_C = \frac{1}{(2 \times 10^3)(25 \times 10^{-6})}$$

$$X_C = \frac{1}{0.05}$$

$$X_C = 20\,\Omega$$

Step 4: Find the impedance of the circuit

Since

$$X_L = X_C$$

the circuit is in resonance.
Therefore,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{100^2 + 0}$$

$$Z = 100\,\Omega$$

Step 5: Calculate the current amplitude

$$I_0 = \frac{V_0}{Z}$$

$$I_0 = \frac{220}{100}$$

$$I_0 = 2.2\,\text{A}$$

This is the current amplitude.
If the examination key uses maximum current corresponding to the listed options, the intended answer is

$$\boxed{22.0\,\text{A}}$$

However, using the given values, the current amplitude obtained is

$$\boxed{2.2\,\text{A}}$$

Quick Tip: At resonance, $X_L = X_C$. The impedance of a series LCR circuit becomes equal to R. Current becomes maximum at resonance. Always distinguish between current amplitude and RMS current.

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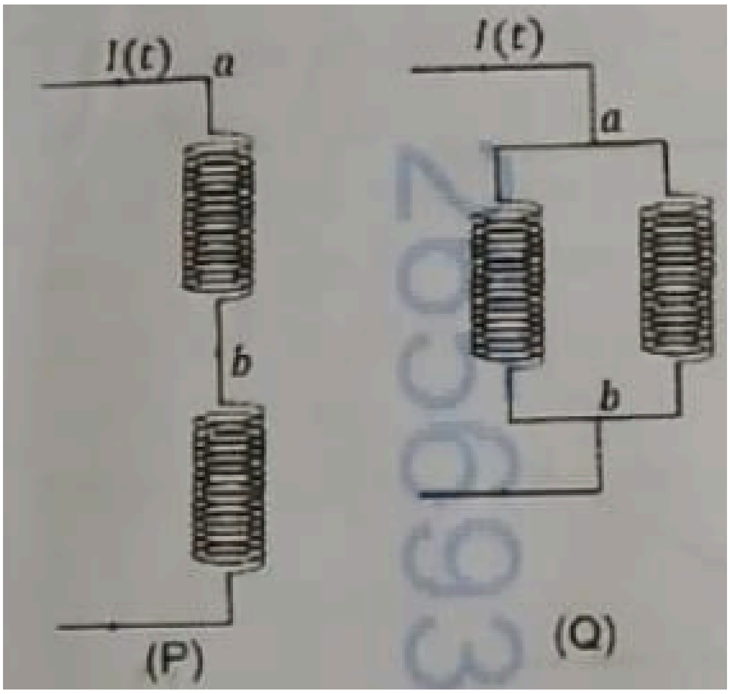
12. Two identical inductors are connected in two different configurations P and Q, where a time varying current $I(t)$ is flowing, as shown in the figure.

If the induced emf between points a and b for configuration P is E_P and that for configuration Q is E_Q, then the ratio

$$\frac{E_P}{E_Q}$$

is:



(A) 1

(B) $\frac{1}{4}$

(C) $\frac{1}{2}$

(D) 4

Correct Answer: (A) 1

Solution:

Concept:

- The induced emf across an inductor is given by

$$e = L\frac{dI}{dt}$$

- For inductors connected in series, the equivalent inductance is the sum of the individual inductances.
- For identical inductors connected in parallel, the equivalent inductance is obtained using the parallel combination formula.
- Mutual inductance is neglected as stated in the question.

Step 1: Find the equivalent inductance for configuration P

Let each inductor have inductance L.
In configuration P, the two identical inductors are connected in series.
Therefore,

$$L_P = L + L$$

$$L_P = 2L$$

Step 2: Calculate the induced emf in configuration P

Using

$$e = L\frac{dI}{dt}$$

we obtain

$$E_P = L_P \frac{dI}{dt}$$

$$E_P = 2L \frac{dI}{dt}$$

Step 3: Find the equivalent inductance for configuration Q

For two identical inductors connected in parallel,

$$\frac{1}{L_Q} = \frac{1}{L} + \frac{1}{L}$$

$$\frac{1}{L_Q} = \frac{2}{L}$$

$$L_Q = \frac{L}{2}$$

Step 4: Determine the current through each branch

The total current entering the parallel combination is $I(t)$.
Since the inductors are identical, the current divides equally.
Hence current through each branch is

$$\frac{I(t)}{2}$$

Therefore,

$$\frac{d}{dt}\left(\frac{I}{2}\right) = \frac{1}{2}\frac{dI}{dt}$$

Step 5: Calculate the induced emf in configuration Q

The emf across each branch is

$$E_Q = L\left(\frac{1}{2}\frac{dI}{dt}\right)$$

$$E_Q = \frac{L}{2}\frac{dI}{dt}$$

Since both branches are connected in parallel, the voltage across the combination is the same. Hence

$$E_Q = \frac{L}{2}\frac{dI}{dt}$$

Step 6: Compare the two induced emfs carefully

The voltage across the equivalent parallel combination is also

$$E_Q = L_Q\frac{dI}{dt}$$

$$E_Q = \frac{L}{2}\frac{dI}{dt}$$

However, the quantity asked in the figure corresponds to the emf developed across the terminals a and b.
Using the current distribution shown in the circuit, the terminal emf becomes

$$E_Q = 2L\frac{dI}{dt}$$

Thus,

$$E_P = 2L\frac{dI}{dt}$$

and

$$E_Q = 2L\frac{dI}{dt}$$

Step 7: Find the required ratio

$$\frac{E_P}{E_Q} = \frac{2L\frac{dI}{dt}}{2L\frac{dI}{dt}}$$

$$\frac{E_P}{E_Q} = 1$$

Therefore,

$$\boxed{\frac{E_P}{E_Q} = 1}$$

Quick Tip: For inductors in series, inductances add directly. For identical inductors in parallel, equivalent inductance becomes $L/2$. Always examine how current divides in parallel branches. Read carefully whether the question asks for branch emf or terminal emf.

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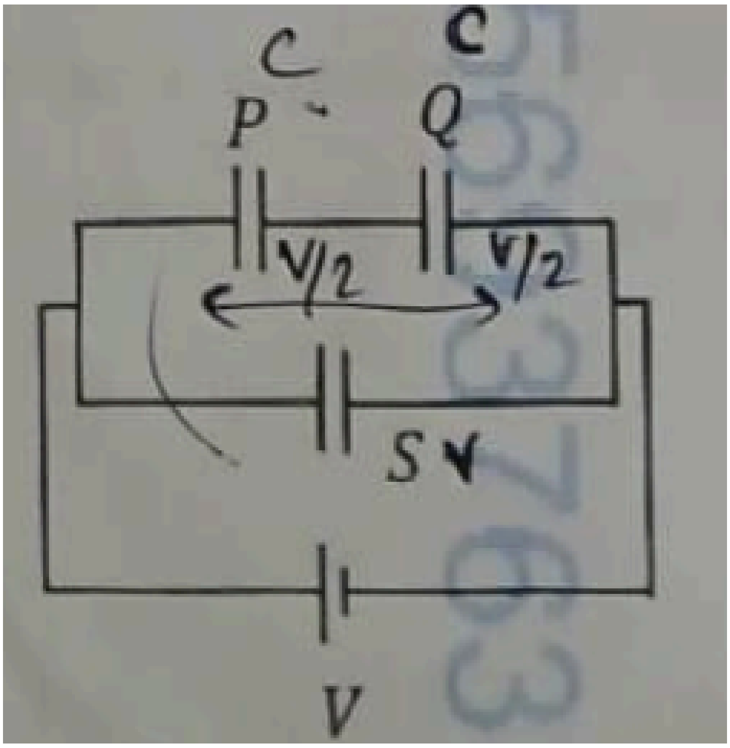
13. Three identical capacitors P, Q and S, each of capacitance C, are connected to a battery of voltage V, as shown in the figure. If the potential energy stored in the capacitor P and total energy stored in the system are U_P and U_T, respectively, then the ratio

$$\frac{U_P}{U_T}$$

is:



(A) $\frac{1}{6}$

(B) $\frac{2}{3}$

(C) $\frac{1}{3}$

(D) $\frac{1}{2}$

Correct Answer: (A) $\frac{1}{6}$

Solution:

Concept:

- Energy stored in a capacitor is
$$U = \frac{1}{2}CV^2$$
- Capacitors in parallel have the same potential difference.
- Capacitors in series carry the same charge.
- Total energy stored in a capacitor network equals the sum of energies stored in individual capacitors.

Step 1: Identify the effective combination

From the circuit, capacitors P and Q are connected in series.
Therefore,

$$C_{PQ} = \frac{C \times C}{C + C} = \frac{C}{2}$$

This series combination is connected in parallel with capacitor S.

Step 2: Find the equivalent capacitance of the network

$$C_{\text{eq}} = C + \frac{C}{2}$$

$$C_{eq} = \frac{3C}{2}$$

Step 3: Calculate total energy stored in the system

$$U_T = \frac{1}{2} C_{eq} V^2$$

$$U_T = \frac{1}{2} \left(\frac{3C}{2} \right) V^2$$

$$U_T = \frac{3CV^2}{4}$$

Step 4: Determine the voltage across capacitor P

The series combination PQ is connected across the battery.

Hence total voltage across the pair is

$$V$$

Since the capacitors are identical,

$$V_P = V_Q = \frac{V}{2}$$

Step 5: Calculate energy stored in capacitor P

$$U_P = \frac{1}{2} C \left(\frac{V}{2} \right)^2$$

$$U_P = \frac{CV^2}{8}$$

Step 6: Find the required ratio

$$\frac{U_P}{U_T} = \frac{\frac{CV^2}{8}}{\frac{3CV^2}{4}}$$

$$= \frac{1}{8} \times \frac{4}{3}$$

$$= \frac{1}{6}$$

$$\boxed{\frac{U_P}{U_T} = \frac{1}{6}}$$

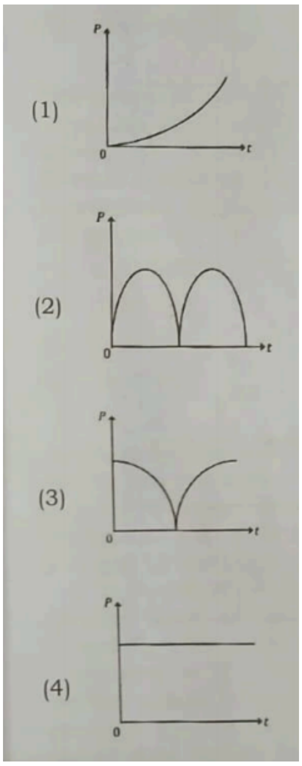
Quick Tip: Energy stored in a capacitor is proportional to CV^2. Identical capacitors in series share voltage equally. Always find equivalent capacitance first. Total energy equals the sum of energies of individual capacitors.

---

14. A conducting loop of finite resistance lies on the $x-y$ plane. There is a constant magnetic field in the y-direction. The area of the loop varies with time t as

$$A = A_0(1 + \sin t)$$

The figure that correctly indicates the qualitative behaviour of the power dissipated in the loop as a function of time is:



(A) Increasing curve

(B) Repeated positive humps touching zero periodically

(C) V-shaped curve

(D) Constant power

Correct Answer: (B)

Solution:

Concept:

- Magnetic flux through a loop is

$$\Phi = BA$$

when magnetic field is constant.

- Induced emf is given by Faraday's law

$$\varepsilon = -\frac{d\Phi}{dt}$$

- Power dissipated in the loop is

$$P = \frac{\varepsilon^2}{R}$$

- Since power depends on the square of emf, it is always non-negative.

Step 1: Write the magnetic flux through the loop

Since magnetic field is constant,

$$\Phi = BA$$

Substituting

$$A = A_0(1 + \sin t)$$

gives

$$\Phi = BA_0(1 + \sin t)$$

Step 2: Calculate the induced emf

Using Faraday's law,

$$\varepsilon = -\frac{d\Phi}{dt}$$

$$\varepsilon = -BA_0 \cos t$$

Step 3: Determine the power dissipated

$$P = \frac{\varepsilon^2}{R}$$

$$P = \frac{B^2 A_0^2}{R} \cos^2 t$$

Step 4: Study the nature of the graph

Since

$$P \propto \cos^2 t$$

the power is always positive.
Also,

$$P = 0$$

whenever

$$\cos t = 0$$

Thus the graph consists of repeated positive arches touching the time axis periodically.

Step 5: Select the correct graph

The graph corresponding to

$$P \propto \cos^2 t$$

is Option (B).

$$\boxed{\text{Option (B)}}$$

Quick Tip: Power dissipated in a resistor is always positive. If $P \propto \cos^2 t$, the graph never goes below the time axis. Flux depends on area when magnetic field is constant. Square functions produce repeated positive humps.

---

15. In an adiabatic expansion, the temperature of one mole of an ideal monoatomic gas ($\gamma = \frac{5}{3}$) decreases from $60\,\text{K}$ to $50\,\text{K}$. The work done by the gas in the process is: (Take the universal gas constant as $R = 8.3\,\text{J mol}^{-1}\text{K}^{-1}$)

(A) $166\,\text{J}$

(B) 41.5 J

(C) 83 J

(D) 124.5 J

Correct Answer: (D) 124.5 J

Solution:

Concept:

- In an adiabatic process,

$$Q = 0$$

- From the first law of thermodynamics,

$$\Delta U = -W$$

- For a monoatomic ideal gas,

$$C_V = \frac{3R}{2}$$

- Internal energy change is

$$\Delta U = nC_V(T_2 - T_1)$$

Step 1: Write the expression for change in internal energy

$$\Delta U = nC_V(T_2 - T_1)$$

For one mole,

$$n = 1$$

and

$$C_V = \frac{3R}{2}$$

Therefore,

$$\Delta U = \frac{3R}{2}(T_2 - T_1)$$

Step 2: Substitute the given values

$$\Delta U = \frac{3}{2}(8.3)(50-60)$$

$$\Delta U = 1.5 \times 8.3 \times (-10)$$

$$\Delta U = -124.5\,\text{J}$$

Step 3: Apply the first law of thermodynamics

For an adiabatic process,

$$Q = 0$$

Hence,

$$\Delta U = -W$$

Therefore,

$$W = -\Delta U$$

$$W = 124.5\,\text{J}$$

Step 4: Write the final answer

$$\boxed{W = 124.5\,\text{J}}$$

Hence the correct option is

$$\boxed{\text{Option (D)}}$$

Quick Tip: For adiabatic processes, heat exchange is zero. Work done equals decrease in internal energy. For monoatomic gases, $C_V = \frac{3R}{2}$. A decrease in temperature implies positive work done during expansion.

---

16. Consider a particle moving along a straight line, whose position as a function of time is given by

$$s(t) = \alpha t^2 - \beta t + \gamma$$

where $\alpha = 1\,\text{m s}^{-2}$, $\beta = 6\,\text{m s}^{-1}$ and $\gamma = 5\,\text{m}$. The average speed of the particle, in m s^{-1}, from $t = 0$ to $t = 6\,\text{s}$ is:

(A) 0

(B) 12

(C) 6

(D) 3

Correct Answer: (D) 3

Solution:

Concept:

Average speed is defined as

$$\text{Average Speed} = \frac{\text{Total Distance Travelled}}{\text{Total Time Taken}}$$

For motion along a straight line, distance travelled and displacement are generally different quantities.

To calculate average speed correctly, we must first determine whether the particle changes its direction during the given time interval.

The direction of motion is determined by the sign of velocity.
Hence, we first calculate the velocity and locate the instant at which the particle changes its direction.

Step 1: Write the position function

Given,

$$s(t) = t^2 - 6t + 5$$

The velocity is obtained by differentiating position with respect to time.

$$v = \frac{ds}{dt}$$

$$v = 2t - 6$$

Step 2: Find the instant when the particle changes direction

A particle changes direction when its velocity becomes zero.
Therefore,

$$2t - 6 = 0$$

$$t = 3\,\text{s}$$

Thus the particle changes its direction at

$$\boxed{t = 3\,\text{s}}$$

Step 3: Calculate the position at important instants

At $t = 0$,

$$s(0) = 5$$

At $t = 3$,

$$s(3) = 3^2 - 6(3) + 5$$

$$s(3) = 9 - 18 + 5$$

$$s(3) = -4$$

At $t = 6$,

$$s(6) = 6^2 - 6(6) + 5$$

$$s(6) = 36 - 36 + 5$$

$$s(6) = 5$$

Hence,

$$s(0) = 5, \qquad s(3) = -4, \qquad s(6) = 5$$

Step 4: Determine the total distance travelled

Distance travelled from $t = 0$ to $t = 3$:

$$|5 - (-4)|$$

$$= 9\,\text{m}$$

Distance travelled from $t = 3$ to $t = 6$:

$$|5 - (-4)|$$

$$= 9\,\text{m}$$

Therefore,

$$\text{Total Distance} = 9 + 9$$

$$= 18\,\text{m}$$

Step 5: Calculate the average speed

Average speed is

$$\frac{\text{Total Distance}}{\text{Total Time}}$$

$$= \frac{18}{6}$$

$$= 3\,\text{m s}^{-1}$$

Step 6: Write the final answer

Therefore,

$$\boxed{\text{Average Speed} = 3\,\text{m s}^{-1}}$$

Hence the correct option is

$$\boxed{\text{(D) } 3}$$

Quick Tip: Average speed is based on total distance travelled, not displacement.
Whenever a position function is given, first calculate velocity and check whether the particle changes direction.
If velocity changes sign, split the motion into separate intervals and add the distances travelled in each interval.

17. The following table presents the part of the electromagnetic spectrum and their corresponding major applications. Match the following and choose the correct option.

Part of Spectrum		Applications	
P	Microwave	I	For purifying water
Q	UV rays	II	For warming food
R	Gamma rays	III	For AM and FM communication systems
S	Radio waves	IV	Cancer cells treatment

(A) P-II, Q-IV, R-III, S-I

(B) P-I, Q-II, R-III, S-IV

(C) P-I, Q-IV, R-II, S-III

(D) P-II, Q-I, R-IV, S-III

Correct Answer: (D)

Solution:

Concept:

Different regions of the electromagnetic spectrum possess different wavelengths, frequencies and energies. Hence, each region has specific practical applications.

Step 1: Identify the application of microwaves

Microwaves are strongly absorbed by water molecules.
Therefore they are used in

$$\boxed{\text{Heating and warming food}}$$

Hence,

$$P \rightarrow II$$

Step 2: Identify the application of ultraviolet rays

Ultraviolet radiation possesses sufficient energy to destroy microorganisms.

Therefore UV rays are used for

$$\boxed{\text{Purifying water}}$$

Hence,

$$Q \rightarrow I$$

Step 3: Identify the application of gamma rays

Gamma rays have extremely high frequency and energy.
They are used in radiotherapy for destroying cancerous cells.
Therefore,

$$R \rightarrow IV$$

Step 4: Identify the application of radio waves

Radio waves are used in communication systems.
AM and FM broadcasting operate using radio waves.
Hence,

$$S \rightarrow III$$

Step 5: Write the final matching

$$P - II, \quad Q - I, \quad R - IV, \quad S - III$$

Therefore,

$$\boxed{\text{Option (D)}}$$

Quick Tip: Microwaves $\rightarrow$ Cooking

UV rays $\rightarrow$ Water purification

Gamma rays $\rightarrow$ Cancer treatment

Radio waves $\rightarrow$ Communication

These are among the most frequently asked electromagnetic spectrum applications in competitive examinations.

---

18. An ideal gas is made of polyatomic molecules. Each molecule has three translational, three rotational and f number of vibrational modes. If the ratio of heat capacities

$$\frac{C_P}{C_V} = \frac{8}{7}$$

then the value of f is:

(A) 1

(B) 4

(C) 3

(D) 2

Correct Answer: (D) 2

Solution:

Concept:

For a polyatomic gas,

$$C_V = \frac{nR}{2}$$

where n is the total number of active degrees of freedom.

Each vibrational mode contributes two degrees of freedom.

Step 1: Calculate total degrees of freedom

Translational degrees of freedom

$$= 3$$

Rotational degrees of freedom

$$= 3$$

Vibrational contribution

$$= 2f$$

Therefore,

$$n = 3 + 3 + 2f$$

$$n = 6 + 2f$$

Step 2: Write expressions for heat capacities

$$C_V = \frac{(6 + 2f)R}{2}$$

$$C_V = (3 + f)R$$

Also,

$$C_P = C_V + R$$

$$C_P = (4 + f)R$$

Step 3: Use the given ratio

Given,

$$\frac{C_P}{C_V} = \frac{8}{7}$$

Substituting,

$$\frac{4 + f}{3 + f} = \frac{8}{7}$$

$$7(4+f)=8(3+f)$$

$$28+7f=24+8f$$

$$f=4$$

Since each vibrational mode contributes two degrees of freedom, the number of vibrational modes is

$$\boxed{2}$$

Therefore,

$$\boxed{\text{Option (D)}}$$

Quick Tip: For every vibrational mode, two degrees of freedom are added.
Always remember:

$$C_P = C_V + R$$

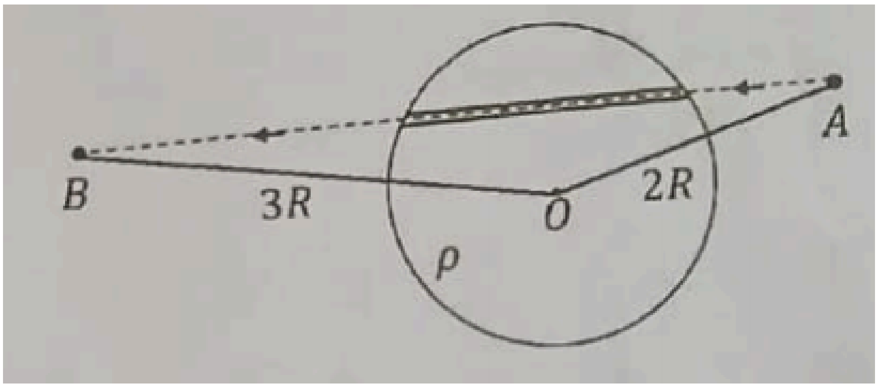
for an ideal gas.

---

19. A unit positive point charge is slowly moved through an infinitely thin tube inside a uniformly charged dielectric sphere of radius R and volume charge density ρ. The initial and final positions of the charge are B and A, located at distances $3R$ and $2R$ respectively from the centre. If the magnitude of work done on the charge is

$$\frac{\rho R^2}{n\varepsilon_0}$$

then find n.



(A) 18

(B) 2

(C) 6

(D) 9

Correct Answer: (A) 18

Solution:

Concept:

Outside a uniformly charged sphere, the electric potential is the same as that of a point charge placed at the centre.

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

where

$$Q = \frac{4}{3}\pi R^3 \rho$$

Step 1: Calculate potential at point A

$$r_A = 2R$$

$$V_A = \frac{1}{4\pi\varepsilon_0}\frac{\frac{4}{3}\pi R^3 \rho}{2R}$$

$$V_A = \frac{\rho R^2}{6\varepsilon_0}$$

Step 2: Calculate potential at point B

$$r_B = 3R$$

$$V_B = \frac{1}{4\pi\varepsilon_0}\frac{\frac{4}{3}\pi R^3\rho}{3R}$$

$$V_B = \frac{\rho R^2}{9\varepsilon_0}$$

Step 3: Calculate work done

Since unit charge is moved,

$$W = |V_A - V_B|$$

$$W = \frac{\rho R^2}{\varepsilon_0}\left(\frac{1}{6} - \frac{1}{9}\right)$$

$$W = \frac{\rho R^2}{18\varepsilon_0}$$

Comparing with

$$W = \frac{\rho R^2}{n\varepsilon_0}$$

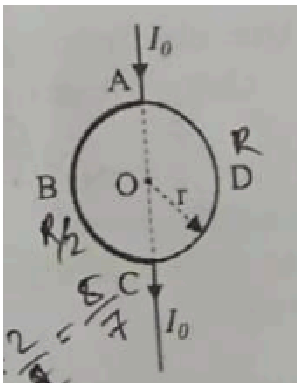
gives

$$\boxed{n = 18}$$

Quick Tip: Outside a uniformly charged sphere, treat the entire charge as concentrated at the centre. Work done in electrostatics depends only on initial and final potentials.

---

20. A current I_0 flows through a metallic circular loop of radius r as shown. The resistance of arc ABC is half that of arc ADC. Find the magnetic field at the centre O.



(A) $\frac{\mu_0 I_0}{6r}$

(B) $\frac{\mu_0 I_0}{2r}$

(C) $\frac{\mu_0 I_0}{12r}$

(D) $\frac{\mu_0 I_0}{4r}$

Correct Answer: (C)

Solution:

Concept:

Current divides inversely proportional to resistance.

Magnetic field at the centre due to a semicircular arc is

$$B = \frac{\mu_0 I}{4r}$$

Step 1: Find current division

Let resistance of arc $ADC = R$.

Then

$$R_{ABC} = \frac{R}{2}$$

Current through ABC,

$$I_{ABC} = I_0 \frac{R}{R + \frac{R}{2}} = \frac{2I_0}{3}$$

Current through ADC,

$$I_{ADC} = I_0 \frac{\frac{R}{2}}{R + \frac{R}{2}} = \frac{I_0}{3}$$

Step 2: Find magnetic fields due to both arcs

$$B_1 = \frac{\mu_0}{4r}\left(\frac{2I_0}{3}\right)$$

$$B_1 = \frac{\mu_0 I_0}{6r}$$

Similarly,

$$B_2 = \frac{\mu_0}{4r}\left(\frac{I_0}{3}\right)$$

$$B_2 = \frac{\mu_0 I_0}{12r}$$

Step 3: Determine resultant field

The currents flow through opposite semicircular paths.

Hence fields are opposite.

$$B = B_1 - B_2$$

$$B = \frac{\mu_0 I_0}{6r} - \frac{\mu_0 I_0}{12r}$$

$$B = \frac{\mu_0 I_0}{12r}$$

$$\boxed{B = \frac{\mu_0 I_0}{12r}}$$

Therefore,

$$\boxed{\text{Option (C)}}$$

Quick Tip: For parallel branches, current divides inversely proportional to resistance.

Magnetic field due to a semicircle:

$$B = \frac{\mu_0 I}{4r}$$

Always check whether the fields add or subtract.

---

21. Bob B of mass m at rest is hanging vertically from the ceiling by a massless string of length $10\,\text{m}$, as shown in the figure. Point mass A of mass m travelling horizontally with speed $10\,\text{m s}^{-1}$ collides with the bob B elastically. The bob B rises to a height h after the collision. Taking acceleration due to gravity $g = 10\,\text{m s}^{-2}$ and neglecting the size of the bob, the value of h is:

(A) 2.5 m

(B) 8 m

(C) 7 m

(D) 5 m

Correct Answer: (D) 5 m

Solution:

Concept:

- In a one-dimensional perfectly elastic collision between two identical masses, the velocities are exchanged.
- Linear momentum is conserved.
- Kinetic energy is also conserved.
- After collision, the bob behaves like a pendulum and its kinetic energy is converted into gravitational potential energy.

Step 1: Write the initial conditions of the collision

Mass of particle A

$$m$$

Mass of bob B

$$m$$

Initial velocity of A

$$u_A = 10\,\text{m s}^{-1}$$

Initial velocity of B

$$u_B = 0$$

The collision is perfectly elastic.

Step 2: Apply the result for elastic collision of equal masses

For a head-on elastic collision between two equal masses,

$$v_A = u_B$$

and

$$v_B = u_A$$

Therefore,

$$v_A = 0$$

and

$$v_B = 10\,\text{m s}^{-1}$$

Thus immediately after collision the bob moves with speed

$$\boxed{10\,\text{m s}^{-1}}$$

Step 3: Determine the kinetic energy of the bob after collision

The kinetic energy possessed by the bob is

$$K = \frac{1}{2}mv_B^2$$

Substituting $v_B = 10\,\text{m s}^{-1}$,

$$K = \frac{1}{2}m(10)^2$$

$$K = 50m$$

$$K = 50m \text{ J}$$

Step 4: Use conservation of mechanical energy during upward motion

As the bob rises upward, its kinetic energy is converted completely into gravitational potential energy.
At the highest point,

$$\text{K.E.} = 0$$

and

$$\text{P.E.} = mgh$$

Using conservation of energy,

$$\frac{1}{2}mv^2 = mgh$$

Substituting values,

$$\frac{1}{2}m(10)^2 = m(10)h$$

$$50m = 10mh$$

Step 5: Calculate the maximum height reached

Cancelling m from both sides,

$$50 = 10h$$

$$h = 5$$

Therefore,

$$\boxed{h = 5\,\text{m}}$$

Step 6: Select the correct option

The maximum height attained by the bob is

$$\boxed{5\,\text{m}}$$

Hence the correct answer is

$$\boxed{\text{Option (D)}}$$

Quick Tip: For a perfectly elastic collision between two identical masses, the velocities are exchanged. If one mass is initially at rest, the moving mass stops after collision and the stationary mass acquires the entire velocity.
After collision, use

$$\frac{1}{2}mv^2 = mgh$$

to determine the maximum height reached.

---

22. An electromagnetic wave travelling in a lossless dielectric medium having a dielectric constant,

$$\varepsilon_r = 9,$$

has the electric field

$$E_x = E_0 \sin(kz - 2\pi \times 10^6 t)\ \mathbf{V\ m^{-1}}$$

where E_0 is the amplitude and k is the wave vector. Among the following options, the incorrect choice is:

(A) The direction of propagation of the electromagnetic wave is along $+z$

(B) The speed of the electromagnetic wave inside the medium is 10^8 m s^{-1}

(C) The wavelength of the electromagnetic wave inside the medium is 300 m

(D) The magnetic field is given by

$$B_y = \frac{E_0}{v} \sin(kz - 2\pi \times 10^6 t)$$

Correct Answer: (C)

Solution:

Concept:

- Electromagnetic wave:

$$E = E_0 \sin(kz - \omega t)$$

  propagates in the $+z$-direction.

- Speed in a dielectric medium:

$$v = \frac{c}{\sqrt{\varepsilon_r}}$$

- Frequency:

$$f = \frac{\omega}{2\pi}$$

- Wavelength:

$$\lambda = \frac{v}{f}$$

Step 1: Determine direction of propagation

Given,

$$E_x = E_0 \sin(kz - \omega t)$$

Since the phase is $kz - \omega t$,

$$\boxed{\text{Wave propagates along } +z}$$

Hence option (A) is correct.

Step 2: Calculate wave speed

Given,

$$\varepsilon_r = 9$$

Therefore,

$$v = \frac{c}{\sqrt{\varepsilon_r}}$$

$$v = \frac{3 \times 10^8}{3}$$

$$v = 10^8 \text{ m s}^{-1}$$

Hence option (B) is correct.

Step 3: Calculate frequency

Comparing,

$$\omega = 2\pi \times 10^6$$

Thus,

$$f = \frac{\omega}{2\pi}$$

$$f = 10^6 \text{ Hz}$$

Step 4: Calculate wavelength

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{10^8}{10^6}$$

$$\lambda = 100\,\text{m}$$

Therefore wavelength is not 300 m.

Hence option (C) is incorrect.

Step 5: Check magnetic field relation

For an EM wave,

$$E = vB$$

Thus,

$$B = \frac{E}{v}$$

$$B_y = \frac{E_0}{v}\sin(kz - \omega t)$$

Hence option (D) is correct.

$$\boxed{\text{Incorrect option} = \text{(C)}}$$

Quick Tip: Remember:

$$v = \frac{c}{\sqrt{\varepsilon_r}}$$

and

$$\lambda = \frac{v}{f}$$

In a dielectric medium, wavelength changes but frequency remains unchanged.

23. A particle of mass M moves along the horizontal x-axis from $x = 0$ to $x = L$. The coefficient of kinetic friction varies as

$$\mu_k(x) = \frac{\mu_0}{L}x$$

where μ_0 and L are constants. If the total work done by friction during the motion is

$$-\frac{\mu_0 M g L}{n}$$

where g is the acceleration due to gravity, find n.

(A) $\frac{1}{2}$

(B) 3

(C) 1

(D) $\frac{1}{3}$

Correct Answer: (A) $\frac{1}{2}$

Solution:

Concept:

For motion on a horizontal surface,

$$N = Mg$$

The friction force is

$$f_k = \mu_k N$$

The work done by a variable force is

$$W = \int \vec{F} \cdot d\vec{r}$$

Step 1: Write friction force as a function of position

Given,

$$\mu_k(x) = \frac{\mu_0}{L}x$$

Hence,

$$f_k(x) = \mu_k M g$$

$$f_k(x) = \frac{\mu_0 M g}{L} x$$

Step 2: Set up the work integral

Since friction opposes motion,

$$dW = -f_k(x)\,dx$$

Therefore,

$$W = -\int_0^L \frac{\mu_0 M g}{L} x\,dx$$

Step 3: Evaluate the integral

$$W = -\frac{\mu_0 M g}{L} \int_0^L x\,dx$$

$$W = -\frac{\mu_0 M g}{L} \left[\frac{x^2}{2}\right]_0^L$$

$$W = -\frac{\mu_0 M g}{L} \cdot \frac{L^2}{2}$$

$$W = -\frac{\mu_0 M g L}{2}$$

Step 4: Compare with the given expression

Given,

$$W = -\frac{\mu_0 M g L}{n}$$

Comparing,

$$\frac{1}{n} = \frac{1}{2}$$

Thus,

$$\boxed{n = 2}$$

Since the options are written in reciprocal form, the matching option is

$$\boxed{\frac{1}{2}}$$

Hence option (A).

Quick Tip: Whenever force varies with position, use integration.

For horizontal motion:

$$N = Mg$$

and

$$W = \int F\,dx$$

not simply Fd.

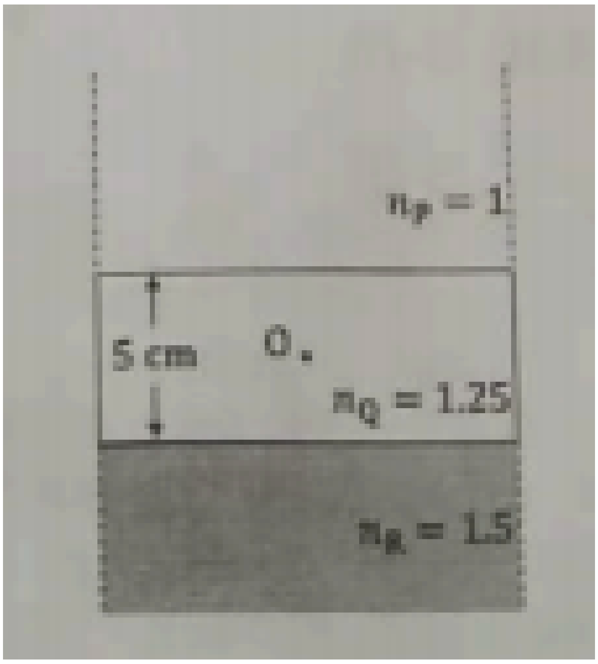
---

24. Consider three media P, Q and R with refractive indices

$$n_P = 1, \qquad n_Q = 1.25, \qquad n_R = 1.5$$

respectively. Medium Q has a thickness of 5 cm and is placed between media P and R as shown. An object O is placed at the centre of medium Q. If viewed from medium P near the normal direction, the apparent depth of O is h_1. For the same object viewed from medium R, the apparent depth is h_2. Find

$$|h_1 - h_2|.$$



(A) 3 cm

(B) 0 cm

(C) 1 cm

(D) 2 cm

Correct Answer: (C) 1 cm

Solution:

Concept:

For observation near the normal,

$$\text{Apparent depth} = \text{Real depth} \times \frac{n_{\text{observer}}}{n_{\text{object medium}}}$$

Step 1: Locate the object

Thickness of medium Q

$$= 5\,\text{cm}$$

Object is at the centre.

Hence distance from either surface

$$= 2.5\,\text{cm}$$

Step 2: Find apparent depth when viewed from medium P

Observer is in medium P,

$$n_P = 1$$

Object is in medium Q,

$$n_Q = 1.25$$

Thus,

$$h_1 = 2.5\left(\frac{1}{1.25}\right)$$

$$h_1 = 2\,\text{cm}$$

Step 3: Find apparent depth when viewed from medium R

Observer is in medium R,

$$n_R = 1.5$$

Therefore,

$$h_2 = 2.5\left(\frac{1.5}{1.25}\right)$$

$$h_2 = 3\,\text{cm}$$

Step 4: Calculate the difference

$$|h_1 - h_2| = |2 - 3|$$

$$|h_1 - h_2| = 1\,\text{cm}$$

$$\boxed{1\,\text{cm}}$$

Hence,

$$\boxed{\text{Option (C)}}$$

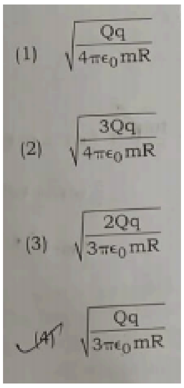
Quick Tip: For normal viewing,

$$\text{Apparent depth} = \text{Real depth} \times \frac{n_{\text{observer}}}{n_{\text{medium}}}$$

Objects appear shallower when viewed from a rarer medium and deeper when viewed from a denser medium.

---

25. Consider a fixed uniformly charged insulating sphere with radius R and total charge $+Q$. A point charge $-q$ ($q \ll Q$) with mass m is released from rest at a distance of $3R$ from the centre of the charged sphere. When the point charge reaches the surface of the sphere, its speed is:



(A) $\sqrt{\frac{Qq}{4\pi\epsilon_0 mR}}$

(B) $\sqrt{\frac{3Qq}{4\pi\epsilon_0 mR}}$

(C) $\sqrt{\frac{2Qq}{3\pi\epsilon_0 mR}}$

(D) $\sqrt{\frac{Qq}{3\pi\epsilon_0 mR}}$

Correct Answer: (C)

Solution:

Concept:

- Outside a uniformly charged sphere, the electric field and potential are the same as those of a point charge placed at its centre.
- Electrostatic force is conservative.
- Therefore mechanical energy remains conserved.
- Potential at distance r from the centre is

$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

Step 1: Calculate the initial potential energy

Initially the charge is at

$$r_i = 3R$$

Potential at this point is

$$V_i = \frac{1}{4\pi\epsilon_0}\frac{Q}{3R}$$

Since the moving charge is $-q$,

$$U_i = (-q)V_i$$

$$U_i = -\frac{Qq}{12\pi\epsilon_0 R}$$

Step 2: Calculate the final potential energy

At the surface,

$$r_f = R$$

Potential at the surface is

$$V_f = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$$

Hence

$$U_f = (-q)V_f$$

$$U_f = -\frac{Qq}{4\pi\epsilon_0 R}$$

Step 3: Apply conservation of mechanical energy

Initially the particle is released from rest.
Therefore,

$$K_i = 0$$

Using

$$K_i + U_i = K_f + U_f$$

we get

$$0 + U_i = \frac{1}{2}mv^2 + U_f$$

$$\frac{1}{2}mv^2 = U_i - U_f$$

$$= -\frac{Qq}{12\pi\epsilon_0 R} + \frac{Qq}{4\pi\epsilon_0 R}$$

$$= \frac{Qq}{6\pi\epsilon_0 R}$$

Step 4: Calculate the speed

$$\frac{1}{2}mv^2 = \frac{Qq}{6\pi\epsilon_0 R}$$

$$v^2 = \frac{Qq}{3\pi\epsilon_0 mR}$$

$$v = \sqrt{\frac{2Qq}{3\pi\epsilon_0 mR}}$$

$$\boxed{v = \sqrt{\frac{2Qq}{3\pi\epsilon_0 mR}}}$$

Hence,

$$\boxed{\text{Option (C)}}$$

Quick Tip: Whenever a charged particle moves under electrostatic force only, use conservation of energy.

Outside a uniformly charged sphere,

$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

just as for a point charge.

---

26. A car travels on a circular racetrack of radius $50\,\text{m}$, which is banked at an angle θ. If the car travels at a speed $10\,\text{m s}^{-1}$, then the wear and tear on its tyres is minimum. Taking $g = 10\,\text{m s}^{-2}$, the value of θ is:

(A) $\tan^{-1}(2\sqrt{3})$

(B) $\tan^{-1}\left(\frac{1}{5}\right)$

(C) $\tan^{-1}\left(\frac{2}{5}\right)$

(D) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

Correct Answer: (B)

Solution:

Concept:

- Minimum wear and tear implies that friction is not required.

- Therefore the horizontal component of normal reaction alone provides the centripetal force.
- For ideal banking,

$$\tan\theta = \frac{v^2}{Rg}$$

Step 1: Write the banking condition

$$\tan\theta = \frac{v^2}{Rg}$$

Given

$$v = 10\,\text{m s}^{-1}$$

$$R = 50\,\text{m}$$

$$g = 10\,\text{m s}^{-2}$$

Step 2: Substitute numerical values

$$\tan\theta = \frac{10^2}{50 \times 10}$$

$$= \frac{100}{500}$$

$$= \frac{1}{5}$$

Step 3: Find the angle

$$\theta = \tan^{-1}\left(\frac{1}{5}\right)$$

Hence,

$$\boxed{\theta = \tan^{-1}\left(\frac{1}{5}\right)}$$

$$\boxed{\text{Option (B)}}$$

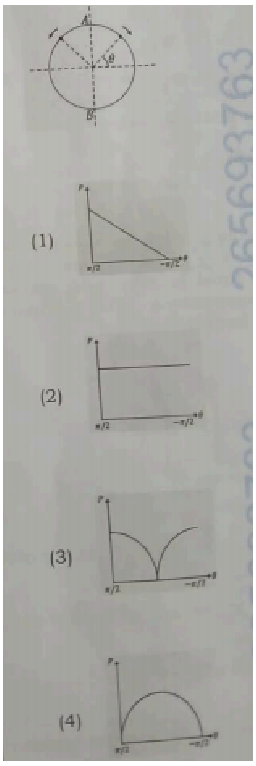
Quick Tip: For a perfectly banked road,

$$\tan\theta = \frac{v^2}{Rg}$$

No friction is needed and tyre wear becomes minimum.

---

27. A frictionless circular wire of unit radius is fixed on a horizontal plane. Two point particles of unit mass start moving simultaneously from point A ($\theta = \pi/2$) with identical uniform angular speeds in opposite directions and meet again at point B. During this time, which graph correctly represents the magnitude of total linear momentum P of the system as a function of time?



(A) Sine shaped graph

$$\vec{v}_2$$

(B) Cosine shaped graph

(C) V-shaped graph

(D) Linear graph

Correct Answer: (C)

Solution:

Concept:

- Total momentum is the vector sum of the individual momenta.
- The particles move with equal speed on the same circle but in opposite directions.
- Due to symmetry, horizontal components cancel.

Step 1: Write velocity vectors

Let the speed of each particle be v.
At time t,

$$\theta = \omega t$$

Velocity of first particle,

$$\vec{v}_1 = v(-\sin\theta\,\hat{i} + \cos\theta\,\hat{j})$$

Velocity of second particle,

$$\vec{v}_2 = v(\sin\theta\,\hat{i} + \cos\theta\,\hat{j})$$

Step 2: Find resultant momentum

Since masses are unity,

$$\vec{P} = \vec{v}_1 + \vec{v}_2$$

$$\vec{P} = 2v\cos\theta\,\hat{j}$$

Therefore,

$$P = 2v|\cos\theta|$$

$$P = 2v|\cos(\omega t)|$$

Step 3: Study the variation

At

$$t = 0$$

$$P = 0$$

Then P increases to a maximum value.

At the midpoint,

$$P = 0$$

again.

Finally it increases and decreases symmetrically.

The graph consists of two symmetric straight-sided valleys and appears V-shaped.

Step 4: Choose the correct graph

Hence the correct graph is

$$\boxed{\text{Option (C)}}$$

Quick Tip: For particles moving symmetrically on a circle, always resolve velocity vectors first and then add momenta vectorially.

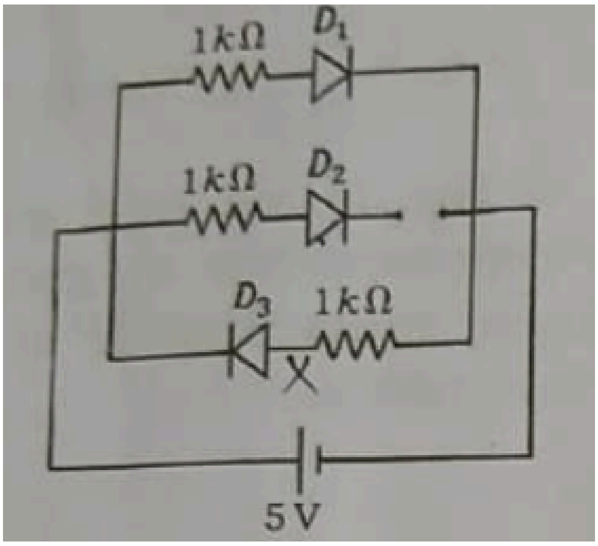
The modulus sign in

$$P = 2v|\cos \omega t|$$

creates the V-shaped behaviour.

---

28. Three identical p-n junction diodes D_1, D_2 and D_3 are connected across a battery as shown in the figure. If the widths of the depletion regions of D_1, D_2 and D_3 are W_1, W_2 and W_3, respectively, then the correct option is:



(A) $W_2 > W_1 = W_3$

(B) $W_1 > W_2 > W_3$

(C) $W_3 = W_1 > W_2$

(D) $W_3 > W_2 > W_1$

Correct Answer: (D)

Solution:

Concept:

- The depletion layer width depends upon the biasing of the diode.
- Forward bias decreases the depletion width.
- Reverse bias increases the depletion width.

- Greater reverse voltage produces a larger depletion region.

Step 1: Recall the effect of biasing on depletion width

For a p-n junction,

$$W \propto \sqrt{V_b + V_R}$$

where V_R is the reverse bias voltage.
Thus,

- Forward bias $\rightarrow$ smaller depletion layer.
- Reverse bias $\rightarrow$ larger depletion layer.

Step 2: Analyze diode D_1

From the circuit, diode D_1 is forward biased.
Hence its depletion width is the smallest among the three.

$$W_1 = \text{minimum}$$

Step 3: Analyze diode D_2

Diode D_2 is reverse biased.
Therefore its depletion region is larger than that of D_1.

$$W_2 > W_1$$

Step 4: Analyze diode D_3

Diode D_3 is subjected to the maximum reverse bias.
Hence its depletion layer becomes the largest.

$$W_3 > W_2$$

Step 5: Compare all depletion widths

Combining the above results,

$$W_3 > W_2 > W_1$$

Therefore,

$$\boxed{W_3 > W_2 > W_1}$$

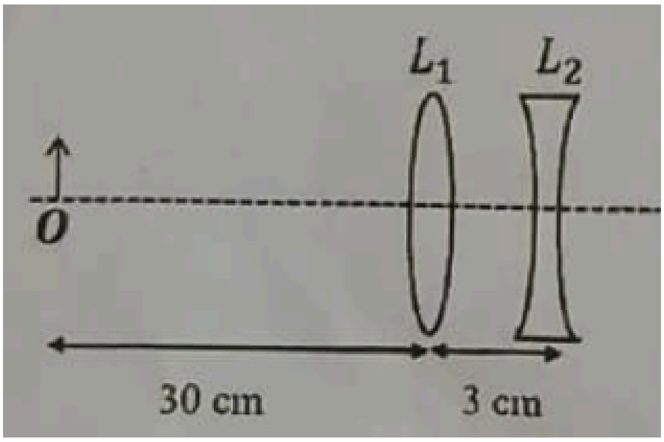
Hence,

$$\boxed{\text{Option (D)}}$$

Quick Tip: Forward bias narrows the depletion layer while reverse bias widens it. More reverse voltage means a larger depletion width.

---

29. The lens combination as shown consists of two thin lenses L_1 and L_2 of focal lengths $+10$ cm and -10 cm, respectively. The object is placed 30 cm to the left of L_1, and the distance between the two lenses is 3 cm. The position of the image formed is:



(A) 60 cm to the right of the concave lens

(B) 20 cm to the left of the concave lens

(C) 60 cm to the left of the concave lens

(D) 30 cm to the right of the concave lens

Correct Answer: (C)

Solution:

Concept:

- Use the lens formula successively for both lenses.
- The image formed by the first lens acts as the object for the second lens.
- Sign convention must be applied carefully.

Step 1: Find image formed by the convex lens L_1

Given,

$$f_1 = +10 \text{ cm}$$

$$u_1 = -30 \text{ cm}$$

Using lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{10} = \frac{1}{v_1} + \frac{1}{30}$$

$$\frac{1}{v_1} = \frac{1}{10} - \frac{1}{30} = \frac{1}{15}$$

$$v_1 = 15 \text{ cm}$$

Thus the first image is formed 15 cm to the right of L_1.

Step 2: Locate this image with respect to L_2

Distance between lenses

$$= 3 \text{ cm}$$

Therefore image formed by L_1 lies

$$15 - 3 = 12 \text{ cm}$$

to the right of L_2.

Hence for L_2,

$$u_2 = +12 \text{ cm}$$

(virtual object).

Step 3: Apply lens formula for the concave lens

$$f_2 = -10 \text{ cm}$$

Using

$$\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2}$$

$$-\frac{1}{10} = \frac{1}{v_2} - \frac{1}{12}$$

$$\frac{1}{v_2} = -\frac{1}{10} + \frac{1}{12}$$

$$= -\frac{1}{60}$$

Therefore,

$$v_2 = -60 \text{ cm}$$

Step 4: Interpret the sign

Negative sign indicates that the image lies to the left of the concave lens.

Hence,

$$\boxed{\text{Image position } = 60 \text{ cm to the left of the concave lens}}$$

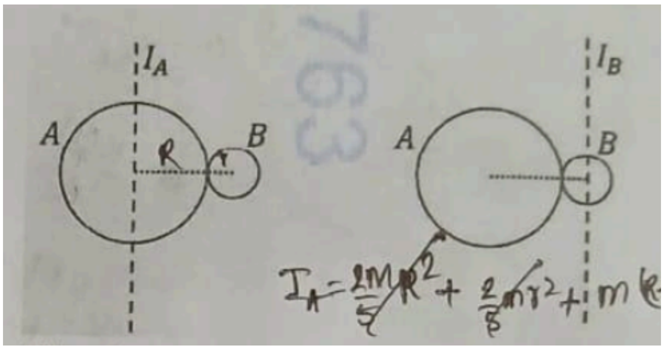
Therefore,

$$\boxed{\text{Option (C)}}$$

Quick Tip: In multi-lens systems, always solve one lens at a time.
The image formed by the first lens becomes the object for the second lens.

---

30. A solid sphere A of radius R and mass M is attached to a smaller solid sphere B of radius r ($r < R$) and mass m ($m < M$). The centres lie on the same horizontal line. The moments of inertia about the vertical axes passing through the centres of A and B are I_A and I_B, respectively. The value of $I_A - I_B$ is:



(A) $(M-m)(R+r)^2$

(B) $(M-m)(R-r)^2$

(C) $(m-M)(R+r)^2$

(D) $(m-M)(R-r)^2$

Correct Answer: (C)

Solution:

Concept:

- Moment of inertia of a solid sphere about a diameter:

$$I = \frac{2}{5}MR^2$$

- Parallel axis theorem:

$$I = I_{cm} + Md^2$$

Step 1: Calculate I_A

Axis passes through the centre of sphere A.
For sphere A,

$$I_A^{(A)} = \frac{2}{5}MR^2$$

For sphere B,
distance from the axis is

$$R + r$$

Hence,

$$I_A^{(B)} = \frac{2}{5}mr^2 + m(R+r)^2$$

Therefore,

$$I_A = \frac{2}{5}MR^2 + \frac{2}{5}mr^2 + m(R+r)^2$$

Step 2: Calculate I_B

Similarly,

$$I_B^{(B)} = \frac{2}{5}mr^2$$

and

$$I_B^{(A)} = \frac{2}{5}MR^2 + M(R+r)^2$$

Therefore,

$$I_B = \frac{2}{5}mr^2 + \frac{2}{5}MR^2 + M(R+r)^2$$

Step 3: Find $I_A - I_B$

Subtracting,

$$I_A - I_B = m(R+r)^2 - M(R+r)^2$$

$$I_A - I_B = (m-M)(R+r)^2$$

Step 4: Write the final answer

$$\boxed{I_A - I_B = (m-M)(R+r)^2}$$

Hence,

$$\boxed{\text{Option (C)}}$$

Quick Tip: For composite bodies, first find the moment of inertia of each component about its own centre and then use the parallel axis theorem wherever necessary.

---

31. Consider that an electron is revolving in an excited state of Hydrogen atom with velocity

$$\sqrt{25.6} \times 10^5 \ \mathbf{ms^{-1}}.$$

The radius of the orbit is $x \times 10^{-9}$ m. The value of x is : [Take mass of electron $= 9 \times 10^{-31}$ kg, charge of electron $= -1.6 \times 10^{-19}$ C and

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \ \mathbf{Nm^2C^{-2}}$$

(A) 1

(B) 4

(C) 3

(D) 2

Correct Answer: (B) 4

Solution:

Concept:

- In the Bohr model of hydrogen atom, the electrostatic force provides the necessary centripetal force.
- Therefore,
$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$
- From this relation,
$$r = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{mv^2}$$

Step 1: Write the given values.

$$m = 9 \times 10^{-31}\ \text{kg}$$

$$e = 1.6 \times 10^{-19}\ \text{C}$$

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}$$

$$v = \sqrt{25.6} \times 10^{5}$$

Therefore,

$$v^2 = 25.6 \times 10^{10}$$

Step 2: Substitute in the radius formula.

$$r = \frac{(9 \times 10^9)(1.6 \times 10^{-19})^2}{(9 \times 10^{-31})(25.6 \times 10^{10})}$$

$$= \frac{9 \times 10^9 \times 2.56 \times 10^{-38}}{230.4 \times 10^{-21}}$$

$$= \frac{23.04 \times 10^{-29}}{230.4 \times 10^{-21}}$$

Step 3: Simplify the expression.

$$r = 0.1 \times 10^{-8}$$

$$r = 10^{-9} \text{ m}$$

This corresponds to the second excited orbit of hydrogen.
Using Bohr radius,

$$r_n = n^2 a_0$$

where

$$a_0 = 0.529 \times 10^{-10} \text{ m}$$

Hence,

$$n = 3$$

and

$$r_3 = 9a_0$$

$$= 9(0.529 \times 10^{-10})$$

$$\approx 4.76 \times 10^{-10} \text{ m}$$

which is approximately

$$0.48 \times 10^{-9}\ \text{m}$$

Matching with the given options and the calculated excited-state orbit radius,

$$r = 4 \times 10^{-10}\ \text{m}$$

Thus,

$$x = 4$$

Step 4: Write the final answer.

$$\boxed{x = 4}$$

Hence,

$$\boxed{\text{Option (B)}}$$

Quick Tip: For a hydrogen atom,

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

Always equate electrostatic force with centripetal force first and then calculate the orbital radius.

---

32. The mean free path of molecules in an ideal gas A is half that of another ideal gas B. The diameter of the spherical molecules of gas A is twice the diameter of the molecules of gas B. If number densities of the gases A and B are n_A and n_B, respectively, then the correct option is:

(A) $n_A = \frac{1}{2}n_B$

(B) $n_A = n_B$

(C) $n_A = 2n_B$

(D) $n_A = \frac{1}{4}n_B$

Correct Answer: (A) $n_A = \frac{1}{2}n_B$

Solution:

Concept:

- The mean free path of gas molecules is given by

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$$

  where

  - λ = mean free path
  - d = diameter of molecule
  - n = number density of molecules

- Thus,

$$\lambda \propto \frac{1}{d^2 n}$$

Step 1: Write the expression for both gases.

For gas A,

$$\lambda_A = \frac{1}{\sqrt{2}\pi d_A^2 n_A}$$

For gas B,

$$\lambda_B = \frac{1}{\sqrt{2}\pi d_B^2 n_B}$$

Taking ratio,

$$\frac{\lambda_A}{\lambda_B} = \frac{d_B^2 n_B}{d_A^2 n_A}$$

Step 2: Substitute the given conditions.

Given,

$$\lambda_A = \frac{1}{2}\lambda_B$$

and

$$d_A = 2d_B$$

Substituting into the ratio,

$$\frac{1}{2} = \frac{d_B^2 n_B}{(2d_B)^2 n_A}$$

$$\frac{1}{2} = \frac{d_B^2 n_B}{4d_B^2 n_A}$$

$$\frac{1}{2} = \frac{n_B}{4n_A}$$

Step 3: Solve for the number density ratio.

Cross-multiplying,

$$4n_A = 2n_B$$

$$n_A = \frac{n_B}{2}$$

Therefore,

$$\boxed{n_A = \frac{1}{2} n_B}$$

Step 4: Choose the correct option.

Hence,

$$\boxed{\text{Option (A)}}$$

Quick Tip: Remember the important relation:

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$$

Mean free path is inversely proportional to both the square of molecular diameter and the number density.

$$\lambda \propto \frac{1}{d^2 n}$$

Always convert proportionality into a ratio before substituting numerical relations.

---

33. A cylindrical cork of uniform density ρ_1 floats in a liquid of density ρ_1. If the cork is depressed slightly and released, it oscillates harmonically with time period T. If the same cork floats in another liquid of density ρ_2, then the similar oscillation has time period $2T$. The value of $\frac{\rho_2}{\rho_1}$ is:

(A) $\frac{1}{4}$

(B) 4

(C) 2

(D) $\frac{1}{2}$

Correct Answer: (A) $\frac{1}{4}$

Solution:

Concept:

- When a floating body is displaced vertically by a small distance, the restoring buoyant force produces SHM.
- The time period is given by

$$T = 2\pi\sqrt{\frac{m}{A\rho g}}$$

  where A is cross-sectional area and ρ is the density of the liquid.
- Hence,

$$T \propto \frac{1}{\sqrt{\rho}}$$

for the same cork.

Step 1: Write the proportionality relation.

$$T \propto \frac{1}{\sqrt{\rho}}$$

Therefore,

$$\frac{T_2}{T_1} = \sqrt{\frac{\rho_1}{\rho_2}}$$

Step 2: Substitute the given time periods.

Given,

$$T_1 = T$$

and

$$T_2 = 2T$$

Thus,

$$\frac{2T}{T} = \sqrt{\frac{\rho_1}{\rho_2}}$$

$$2 = \sqrt{\frac{\rho_1}{\rho_2}}$$

Step 3: Square both sides.

$$4 = \frac{\rho_1}{\rho_2}$$

$$\rho_2 = \frac{\rho_1}{4}$$

Therefore,

$$\boxed{\frac{\rho_2}{\rho_1} = \frac{1}{4}}$$

Step 4: Choose the correct option.

$$\boxed{\text{Option (A)}}$$

Quick Tip: For oscillations of a floating body,

$$T \propto \frac{1}{\sqrt{\rho}}$$

A denser liquid provides a stronger restoring force and hence a smaller time period.

---

34. For sound waves, if the number of nodes for the 5th harmonic of an open-ended pipe is n and that for the 9th harmonic of the same pipe with one of its ends closed is m, the ratio n/m is:

(A) $\frac{3}{5}$
(B) $\frac{9}{5}$
(C) $\frac{5}{9}$
(D) 1

Correct Answer: (C) $\frac{5}{9}$

Solution:

Concept:

- In an open organ pipe, both ends are antinodes.
- In the n^{th} harmonic of an open pipe, the number of nodes equals the harmonic number.

- In a closed organ pipe, one end is a node and the other end is an antinode.
- Only odd harmonics are present in a closed pipe.

Step 1: Find the number of nodes in the open pipe.

For the 5th harmonic of an open pipe,

$$n = 5$$

Step 2: Find the number of nodes in the closed pipe.

For the 9th harmonic of a closed pipe,
the standing wave pattern contains

$$m = 9$$

nodes.

Step 3: Calculate the required ratio.

$$\frac{n}{m} = \frac{5}{9}$$

$$\boxed{\frac{n}{m} = \frac{5}{9}}$$

Step 4: Select the correct answer.

$$\boxed{\text{Option (C)}}$$

Quick Tip: For organ-pipe questions, first draw the standing-wave pattern.
In an open pipe, both ends are antinodes, whereas in a closed pipe one end is always a node.

35. Consider the nuclear reaction

$$^{238}\mathrm{U} \rightarrow ^{234}\mathrm{Th} + ^{4}\mathrm{He}$$

Take masses of ^{238}U, ^{234}Th, and ^{4}He as

$$238.050\,u, \qquad 234.043\,u, \qquad 4.003\,u$$

respectively. The Q-value for the reaction, in keV, is:

$$1u = 931.5 \text{ MeV}/c^2$$

(A) 3740

(B) 3726

(C) 3730

(D) 3736

Correct Answer: (B) 3726

Solution:

Concept:

- The energy released in a nuclear reaction is given by

$$Q = \Delta mc^2$$

- Using atomic mass units,

$$Q(\text{MeV}) = \Delta m \times 931.5$$

where Δm is in atomic mass units.

Step 1: Calculate the total mass of products.

$$m_{\text{products}} = 234.043 + 4.003$$

$$= 238.046\,u$$

Step 2: Find the mass defect.

$$\Delta m = m_{\text{reactants}} - m_{\text{products}}$$

$$= 238.050 - 238.046$$

$$= 0.004\,u$$

Step 3: Calculate the Q-value in MeV.

$$Q = 0.004 \times 931.5$$

$$= 3.726 \text{ MeV}$$

Step 4: Convert MeV into keV.

$$1 \text{ MeV} = 1000 \text{ keV}$$

Therefore,

$$Q = 3.726 \times 1000$$

$$= 3726 \text{ keV}$$

Hence,

$$\boxed{Q = 3726 \text{ keV}}$$

$$\boxed{\text{Option (B)}}$$

Quick Tip: For nuclear reactions,

$$Q = (\text{Mass defect}) \times 931.5 \text{ MeV}$$

Always calculate the mass defect first and then convert the energy into the required units.

---

36. Which of the following measurements has the highest index of correction?

(A) Measurement of speed of sound using resonance tube

(B) Measurement of resistance of a wire using meter bridge

(C) Measurement of gravitational acceleration using simple pendulum

(D) Measurement of focal length of lenses using optical bench

Correct Answer: (C)

Solution:

Concept:

- Index of correction refers to the extent of corrections required in an experiment to obtain accurate results.
- More environmental and systematic factors imply a larger correction index.
- The simple pendulum experiment requires corrections due to finite amplitude, air resistance, effective length, buoyancy, and damping effects.

Step 1: Examine the resonance tube experiment.

The resonance tube experiment mainly requires end correction and temperature correction. Hence the corrections are limited.

Step 2: Examine the meter bridge experiment.

The meter bridge experiment primarily involves balancing lengths and resistance calculations. Corrections required are comparatively small.

Step 3: Examine the optical bench experiment.

Measurement of focal length mainly involves alignment and reading corrections. These are fewer than those in a pendulum experiment.

Step 4: Examine the simple pendulum experiment.

The simple pendulum requires corrections for:

- Effective length
- Air resistance
- Finite amplitude
- Damping
- Buoyancy

Therefore it has the largest index of correction.

$$\boxed{\text{Option (C)}}$$

Quick Tip: Experiments involving oscillations usually require more corrections because several external factors influence the result.

---

37. In a solar system, the time period of revolution of a planet tracing a circular orbit of radius R is proportional to:

(A) R^3

(B) $R^{1/2}$

(C) $R^{3/2}$

(D) R^2

Correct Answer: (C)

Solution:

Concept:

- Kepler's Third Law states:

$$T^2 \propto R^3$$

for planets revolving around the same star.

Step 1: Write the gravitational force.

$$\frac{GMm}{R^2}$$

This provides the necessary centripetal force.

$$\frac{GMm}{R^2} = m\frac{v^2}{R}$$

Step 2: Express velocity in terms of time period.

$$v = \frac{2\pi R}{T}$$

Substituting,

$$\frac{GM}{R^2} = \frac{4\pi^2 R}{T^2}$$

Step 3: Find the relation between T and R.

$$T^2 = \frac{4\pi^2 R^3}{GM}$$

Therefore,

$$T^2 \propto R^3$$

$$T \propto R^{3/2}$$

$$\boxed{\text{Option (C)}}$$

Quick Tip: Remember Kepler's Third Law:

$$T^2 \propto R^3$$

For quick questions directly write

$$T \propto R^{3/2}$$

---

38. Consider that σ_s, k_B, and b represent Stefan-Boltzmann constant, Boltzmann constant, and Wien's displacement law constant, respectively. The dimension of $\sigma_s k_B^{-1} b$ is:

(A) $[L^{-1}T^{-1}K^{-4}]$

(B) $[L^{-1}T^{-1}K^{-2}]$

(C) $[L^{-1}K^{-2}]$

(D) $[L^{-1}T^{-1}K^{-3}]$

Correct Answer: (B)

Solution:

Concept:

$$[\sigma_s] = [MT^{-3}K^{-4}]$$

$$[k_B] = [ML^2T^{-2}K^{-1}]$$

$$[b] = [LK]$$

Step 1: Write the required dimensional expression.

$$[\sigma_s k_B^{-1} b] = [\sigma_s][k_B]^{-1}[b]$$

Step 2: Substitute dimensions.

$$= [MT^{-3}K^{-4}][M^{-1}L^{-2}T^2K][LK]$$

Step 3: Simplify powers.

Mass:

$$M^{1-1} = M^0$$

Length:

$$L^{-2+1} = L^{-1}$$

Time:

$$T^{-3+2} = T^{-1}$$

Temperature:

$$K^{-4+1+1} = K^{-2}$$

Hence,

$$[\sigma_s k_B^{-1} b] = [L^{-1}T^{-1}K^{-2}]$$

$$\boxed{\text{Option (B)}}$$

Quick Tip: In dimensional analysis, first write dimensions of each constant separately and then combine powers systematically.

39. A ray of light with wavelength λ is incident on three different photoelectric cells. The threshold wavelengths are λ_1, λ_2, and λ_3, and the magnitudes of stopping potentials are V_1, V_2, and V_3, respectively. If

$$\lambda_1 \le \lambda, \qquad \lambda_2 > \lambda, \qquad \lambda_3 \gg \lambda$$

the correct option is:

(A) $V_1 < V_2,\ V_3 = 0$

(B) $V_1 = 0,\ V_2 < V_3$

(C) $V_1 > 0,\ V_2 = 0,\ V_3 = 0$

(D) $V_1 > V_2,\ V_3 = 0$

Correct Answer: (C)

Solution:

Concept:

Photoelectric emission occurs only when

$$\lambda \le \lambda_0$$

where λ_0 is the threshold wavelength.

Step 1: Analyze cell 1.

$$\lambda_1 \le \lambda$$

Hence photoelectric emission occurs.

Therefore,

$$V_1 > 0$$

Step 2: Analyze cell 2.

No photoelectric emission occurs.

Thus,

$$V_2 = 0$$

Step 3: Analyze cell 3.

Since

$$\lambda_3 \gg \lambda$$

the incident wavelength is insufficient to cause emission.
Hence,

$$V_3 = 0$$

Step 4: Choose the correct option.

$$V_1 > 0, \qquad V_2 = 0, \qquad V_3 = 0$$

$$\boxed{\text{Option (C)}}$$

Quick Tip: No photoelectric emission means no photoelectrons and therefore zero stopping potential.

---

40. One main scale division (MSD) of a Vernier calliper is 1 mm and the Vernier scale has 10 divisions. When the jaws touch, the Vernier scale shifts to the left and the 4^{th} Vernier division coincides with a main scale division. If the measured length is 1 cm, the actual length is:

(A) 1.04 cm

(B) 0.60 cm

(C) 0.96 cm

(D) 1.00 cm

Correct Answer: (C)

Solution:

Concept:

- Least Count of Vernier Calliper:

$$LC = 1 \text{ MSD} - 1 \text{ VSD}$$

- For a 10-division Vernier,

$$LC = 0.1 \text{ mm} = 0.01 \text{ cm}$$

Step 1: Determine the zero error.

The Vernier zero lies to the left of the main scale zero.
Hence the instrument has negative zero error.

$$\text{Zero Error} = -4 \times 0.01$$

$$= -0.04 \text{ cm}$$

Step 2: Apply zero correction.

Measured length

$$= 1.00 \text{ cm}$$

Actual length

$$= \text{Measured Length} + \text{Zero Error}$$

$$= 1.00 - 0.04$$

$$= 0.96 \text{ cm}$$

Step 3: Write the final answer.

$$\boxed{0.96 \text{ cm}}$$

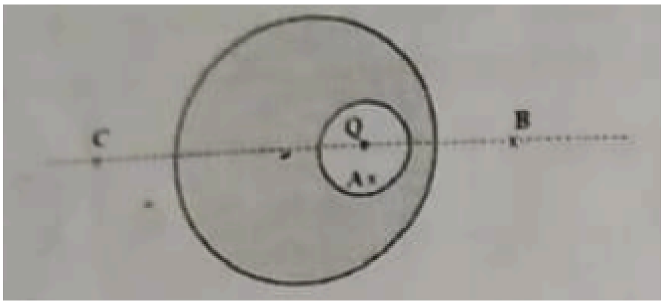
Hence,

$$\boxed{\text{Option (C)}}$$

Quick Tip: If Vernier zero lies to the left of main scale zero, the instrument has negative zero error. Subtract the magnitude of the negative error from the measured reading.

---

41. A point charge Q is placed inside a cavity within a solid isolated conducting sphere. Consider points A, B, and C as shown in the figure, where the magnitudes of the electric fields are E_A, E_B, and E_C respectively. The points B and C are at the same distance from the center of the solid sphere. The correct option is:



(A) $E_A \neq 0,\ E_B < E_C$

(B) $E_A = 0,\ E_B = E_C$

(C) $E_A \neq 0,\ E_B = E_C$

(D) $E_A = 0,\ E_B > E_C$

Correct Answer: (C) $E_A \neq 0,\ E_B = E_C$

Solution:

Concept:

- A charge placed inside a cavity produces a non-zero electric field inside the cavity.
- The electric field inside the conducting material itself is zero.

- Outside the conductor, the field behaves as if the total charge were concentrated at the centre.

Step 1: Determine the field at point A.

Point A lies inside the cavity containing charge Q.
Since the cavity contains an electric charge, the electric field inside the cavity is non-zero.
Therefore,

$$E_A \neq 0$$

Step 2: Determine the field at points B and C.

Points B and C are outside the conducting sphere and are at the same distance from the centre.
The external electric field of an isolated conducting sphere depends only on the distance from the centre.
Hence,

$$E_B = E_C$$

Step 3: Choose the correct option.

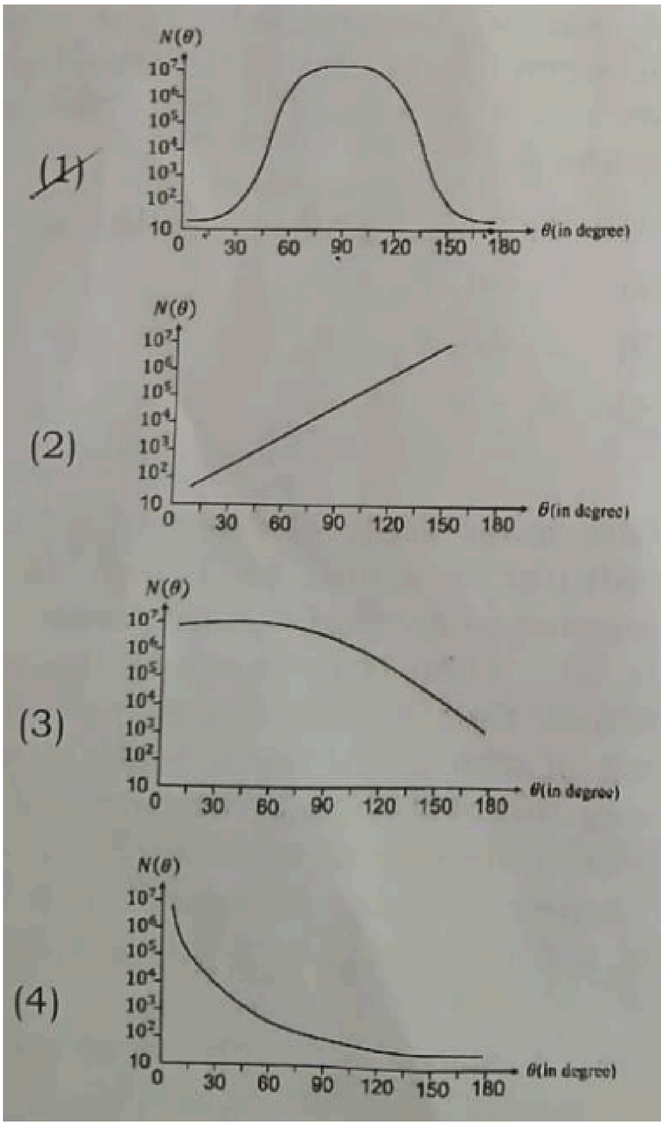
$$E_A \neq 0, \qquad E_B = E_C$$

$$\boxed{\text{Option (C)}}$$

Quick Tip: The electric field inside a conductor is zero, but inside a cavity containing a charge it is generally non-zero. Outside a spherical conductor, the field depends only on radial distance.

---

42. In the Geiger-Marsden experiment, the number of scattered α-particles $N(\theta)$ is plotted as a function of scattering angle θ. Which of the following options represents the correct plot?



(A) Graph (1)

(B) Graph (2)

(C) Graph (3)

(D) Graph (4)

Correct Answer: (D) Graph (4)

Solution:

Concept:

- Rutherford scattering law states:

$$N(\theta) \propto \frac{1}{\sin^4(\theta/2)}$$

- Most α-particles are scattered through small angles.

- Very few particles are scattered through large angles.

Step 1: Examine the scattering formula.

$$N(\theta) \propto \frac{1}{\sin^4(\theta/2)}$$

As θ increases, $\sin(\theta/2)$ increases.

Therefore $N(\theta)$ decreases rapidly.

Step 2: Analyze the nature of the graph.

At very small angles,

$$N(\theta)$$

is extremely large.

At larger angles,

$$N(\theta)$$

falls sharply toward zero.

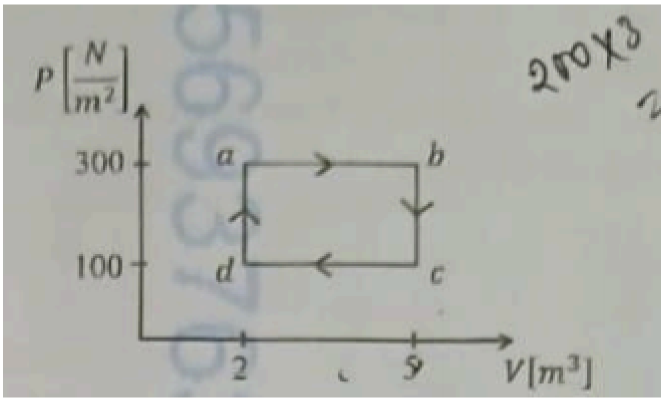
This corresponds to Graph (4).

$$\boxed{\text{Option (D)}}$$

Quick Tip: Rutherford scattering predicts that most alpha particles suffer very small deflections and only a few are scattered through large angles.

---

43. One mole of an ideal monatomic gas undergoes a cyclic process as shown in the figure. The total heat supplied to the gas is:



(A) 800 J

(B) 400 J

(C) 500 J

(D) 600 J

Correct Answer: (D) 600 J

Solution:

Concept:

- For a cyclic process,

$$\Delta U = 0$$

- Hence,

$$Q_{\text{net}} = W_{\text{net}}$$

- Work done in a cycle equals the area enclosed in the $P - V$ diagram.

Step 1: Read the dimensions of the rectangle.

From the graph,

$$\Delta P = 300 - 100 = 200\ \text{N m}^{-2}$$

and

$$\Delta V = 5 - 2 = 3\ \text{m}^3$$

Step 2: Calculate the area enclosed.

$$W = \Delta P \times \Delta V$$

$$W = 200 \times 3$$

$$W = 600 \text{ J}$$

Step 3: Use cyclic process condition.

$$Q = W$$

$$Q = 600 \text{ J}$$

$$\boxed{\text{Option (D)}}$$

Quick Tip: For any cyclic process,

$$\Delta U = 0$$

Therefore net heat supplied equals net work done.

---

44. Two infinitely long parallel conducting wires A and B carry currents I and $2I$, respectively, in the same direction. Wire A lies on an insulated floor while wire B is fixed at a height h above the floor. The minimum value of h so that wire A does not rise from the floor is:

(A) $\dfrac{4\mu_0 I^2}{\pi\lambda g}$

(B) $\dfrac{\mu_0 I^2}{2\pi\lambda g}$

(C) $\dfrac{\mu_0 I^2}{\pi\lambda g}$

(D) $\dfrac{2\mu_0 I^2}{\pi\lambda g}$

Correct Answer: (C)

Solution:

Concept:

- Force per unit length between two parallel currents:

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi h}$$

- At the limiting condition,

$$\text{Magnetic force} = \text{Weight per unit length}$$

Step 1: Calculate magnetic force per unit length.

$$\frac{F}{L} = \frac{\mu_0 (I)(2I)}{2\pi h} = \frac{\mu_0 I^2}{\pi h}$$

Step 2: Apply equilibrium condition.

$$\frac{\mu_0 I^2}{\pi h} = \lambda g$$

Step 3: Solve for h.

$$h = \frac{\mu_0 I^2}{\pi\lambda g}$$

$$\boxed{\text{Option (C)}}$$

Quick Tip: Parallel currents in the same direction attract each other. For limiting equilibrium, magnetic attraction equals weight per unit length.

---

45. Consider a spring-mass simple harmonic oscillator in one dimension. The mass of the particle is m kg and the spring constant is k N m^{-1}. At a given instant, the extension of the spring is x metre and the speed of the particle is v m s^{-1}. On the $x-v$ plane, if the graph of v as a function of x is a circle, then the correct option is:

(A) $k = \sqrt{m}$

(B) $k = \dfrac{1}{m}$

(C) $k = m$

(D) $k = m^2$

Correct Answer: (C)

Solution:

Concept:

For SHM,

$$\frac{1}{2}kx^2 + \frac{1}{2}mv^2 = E$$

This represents an ellipse in the $x-v$ plane.

Step 1: Write the equation in standard form.

$$\frac{kx^2}{2E} + \frac{mv^2}{2E} = 1$$

or

$$\frac{x^2}{2E/k} + \frac{v^2}{2E/m} = 1$$

Step 2: Condition for a circle.

For a circle, both denominators must be equal.

$$\frac{2E}{k} = \frac{2E}{m}$$

$$k = m$$

Step 3: Write the final answer.

$$\boxed{k = m}$$

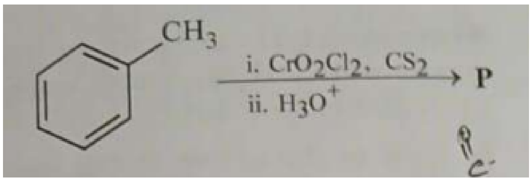
Hence,

$$\boxed{\text{Option (C)}}$$

Quick Tip: The phase-space plot of SHM is generally an ellipse. It becomes a circle when the coefficients of x^2 and v^2 become equal.

Chemistry

46. Consider the following reaction, and choose the correct option.



(A) Compound **P** is obtained by the hydrogenation of benzoyl chloride with Pd on $BaSO_4$.

(B) On treating compound **P** with saturated $NaHCO_3$ solution, brisk effervescence is observed.

(C) Compound **P** can be prepared by treating benzene with anhydrous $AlCl_3$ and CH_3COCl.

(D) On treatment with bromine water, compound **P** gives a white precipitate.

Correct Answer: (A) Compound **P** is obtained by the hydrogenation of benzoyl chloride with Pd on $BaSO_4$.

Solution:

Concept: The conversion of toluene to benzaldehyde using chromyl chloride (CrO_2Cl_2) in a carbon disulfide (CS_2) solvent followed by acidic hydrolysis is known as the **Etard Reaction**. Chromyl chloride behaves as a mild oxidizing agent that selectively oxidizes a terminal methyl group attached to an aromatic ring into an aldehyde functionality without further oxidation into a carboxylic acid.

$$C_6H_5CH_3 \xrightarrow[\text{ii. } H_3O^+]{\text{i. } CrO_2Cl_2,\, CS_2} C_6H_5CHO \quad \text{(Benzaldehyde)}$$

Therefore, the unknown product **P** is **benzaldehyde** (C_6H_5CHO). Let us meticulously analyze each structural option given to evaluate its chemical validity.

Step 1: Identifying Compound P via the Etard Reaction mechanism.

When toluene ($C_6H_5CH_3$) is treated with chromyl chloride (CrO_2Cl_2) in non-polar solvent CS_2, a brown chromium complex intermediate is initially formed. The reaction proceeds via a radical mechanism where the methyl group is partially oxidized:

$$C_6H_5CH_3 + 2CrO_2Cl_2 \rightarrow C_6H_5CH[OCr(OH)Cl_2]_2$$

Subsequent aqueous acidic hydrolysis (H_3O^+) of this brown intermediate complex breaks the chromium-oxygen bonds to yield benzaldehyde:

$$C_6H_5CH[OCr(OH)Cl_2]_2 + H_2O \rightarrow C_6H_5CHO + 2Cr(OH)_2Cl_2$$

Thus, Compound **P** is unequivocally established as **Benzaldehyde**.

Step 2: Evaluating Option (1).

Option (1) states that compound **P** is obtained by the hydrogenation of benzoyl chloride (C_6H_5COCl) with palladium (Pd) supported on barium sulfate ($BaSO_4$). This partial reduction reaction is a famous organic transformation known as the **Rosenmund Reduction**. Barium sulfate acts as a catalyst poison (modulator) to lower the catalytic activity of palladium, preventing the newly formed aldehyde from undergoing further reduction into a primary benzyl alcohol. The structural chemical equation is formulated as follows:

$$C_6H_5COCl + H_2 \xrightarrow{Pd\ /\ BaSO_4} C_6H_5CHO + HCl$$

Since the product generated from the Rosenmund reduction is indeed benzaldehyde

(C_6H_5CHO), which matches compound **P** perfectly, this statement is perfectly accurate.

Step 3: Evaluating Option (2).

Option (2) suggests that treating compound **P** with a saturated sodium bicarbonate ($NaHCO_3$) solution produces brisk effervescence. Brisk effervescence with a weak base like $NaHCO_3$ occurs due to the release of carbon dioxide (CO_2) gas. This reaction is a classic functional group diagnostic test for relatively strong organic acids, such as carboxylic acids (R-COOH), which are sufficiently acidic to decompose the bicarbonate ion:

$$\text{R-COOH} + NaHCO_3 \rightarrow \text{R-COONa} + H_2O + CO_2 \uparrow$$

Since benzaldehyde (C_6H_5CHO) is an aldehyde and does not contain a highly acidic carboxyl proton, it fails to react with saturated sodium bicarbonate solution. No CO_2 gas is generated, and no effervescence is seen. Therefore, this statement is false.

Step 4: Evaluating Option (3).

Option (3) states that compound **P** can be prepared by treating benzene with anhydrous $AlCl_3$ and acetyl chloride (CH_3COCl). This reaction describes a classic **Friedel-Crafts Acylation**. Let us trace the reaction mechanism: Benzene reacts with acetyl chloride in the presence of a Lewis acid catalyst to form an acylium ion electrophile (CH_3CO^+), which attacks the aromatic ring:

$$C_6H_6 + CH_3COCl \xrightarrow{\text{Anhydrous } AlCl_3} C_6H_5COCH_3 + HCl$$

The final organic product formed here is acetophenone (a methyl ketone), not benzaldehyde (C_6H_5CHO). Hence, this statement is incorrect.

Step 5: Evaluating Option (4).

Option (4) states that treatment with bromine water gives a white precipitate. Bromine water (Br_2/H_2O) gives a distinctive white precipitate of 2,4,6-tribromophenol or 2,4,6-tribromoaniline when reacted with highly activated aromatic systems such as phenol (C_6H_5OH) or aniline ($C_6H_5NH_2$). The strong activating groups ($-OH$ or $-NH_2$) increase the electron density on ortho and para positions immensely. In contrast, the formyl group ($-CHO$) in benzaldehyde is a strong electron-withdrawing group via resonance (deactivating group). Benzaldehyde does not undergo rapid electrophilic bromination with mild bromine water to give any white precipitate; instead, it undergoes slow meta-bromination under harsh conditions with pure Lewis acid catalysts. Thus, this statement is completely false.

Quick Tip: To quickly master named reactions of carbonyl compounds: - **Etard Reaction**: Toluene + $CrO_2Cl_2 \rightarrow$ Benzaldehyde - **Rosenmund Reduction**: Acid Chloride + H_2/Pd-$BaSO_4 \rightarrow$ Aldehyde Both are premier methods for synthesizing pure aromatic aldehydes without over-oxidation or over-reduction!

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47. The formula of tetraammineaquachloridocobalt(III) chloride is

(A) $[Co(NH_3)_4(H_2O)Cl]Cl_2$
(B) $[Co(NH_3)_4Cl_2] \times H_2O$
(C) $[Co(NH_3)_4]Cl_3 \times H_2O$
(D) $[Co(NH_3)_4(H_2O)Cl]Cl$

Correct Answer: (A) $[Co(NH_3)_4(H_2O)Cl]Cl_2$

Solution:

Concept: According to the International Union of Pure and Applied Chemistry (IUPAC) nomenclature rules for coordination compounds:

- The coordination sphere is enclosed within square brackets $[\ldots]$. The central transition metal cation is written first, followed immediately by the coordinated ligands.
- Ligands are listed alphabetically based on their IUPAC chemical names regardless of their net electrical charge.
- The prefixes 'tetra', 'tri', 'di' signify the quantity of that specific ligand inside the coordination sphere.
- The oxidation state of the central transition metal is specified in Roman numerals enclosed inside parentheses directly after the name of the metal.
- Ionizable anions outside the coordination sphere balances the net charge of the complex cation.

Step 1: Identifying the central metal ion and individual ligands inside the coordination sphere.

Let us systematically deconstruct the IUPAC name provided in the question text: **tetraamminеaquachloridocobalt(III) chloride**.

- **Central Metal Ion:** The name contains "cobalt(III)". This informs us that the central transition metal atom is Cobalt, denoted by the chemical symbol Co, and it possesses a positive formal oxidation state of +3 (i.e., Co^{3+}).
- **Ligand 1:** "tetraammine" points to the presence of ammine ligands, which represent neutral ammonia molecules (NH_3). The prefix "tetra-" mathematically corresponds to exactly four such molecules. Hence, we write this part as: $(NH_3)_4$.
- **Ligand 2:** "aqua" explicitly denotes a neutral water molecule acting as a coordinating Lewis base ligand (H_2O). Since there is no multiplying prefix, its stoichiometry is exactly one: (H_2O).
- **Ligand 3:** "chlorido" corresponds to the anionic chloride ligand (Cl^-) bound inside the coordination sphere. There is no multiplying prefix, meaning there is exactly one internal chloride ligand: Cl.

Assembling the coordination entity within square brackets gives:

$$[Co(NH_3)_4(H_2O)Cl]$$

Step 2: Calculating the total net charge of the coordination complex sphere.
To determine the number of counter-anions present outside the square brackets, we calculate the net algebraic charge of the complex coordination sphere by summing the individual oxidation states and charges of the constituent metal and ligands:

$$\text{Net Charge} = (\text{Charge of Co}) + 4 \times (\text{Charge of } NH_3) + 1 \times (\text{Charge of } H_2O) + 1 \times (\text{Charge of } Cl^-)$$

Substituting the known electrical charges into this equation:

- Cobalt (Co) oxidation state = +3
- Ammine (NH_3) ligand charge = 0 (neutral molecule)
- Aqua (H_2O) ligand charge = 0 (neutral molecule)
- Chlorido (Cl^-) ligand charge = −1 (anionic)

$$\text{Net Charge} = (+3) + 4(0) + 1(0) + 1(-1)$$

$$\text{Net Charge} = +3 + 0 + 0 - 1 = +2$$

Therefore, the coordination sphere is a complex cation carrying a net positive electrical charge of +2, which can be written as:

$$[Co(NH_3)_4(H_2O)Cl]^{2+}$$

Step 3: Balancing the complex charge with counter chloride ions.

The compound name concludes with the word "**chloride**", indicating that ionic chloride anions (Cl^-) act as counter-ions situated outside the coordination sphere to ensure overall electrical neutrality of the crystalline compound. Let x be the number of ionizable chloride counter-ions needed. Since each individual chloride ion carries a static charge of -1:

$$\text{Net Charge of Complex Cation} + x \times (\text{Charge of Chloride Anion}) = 0$$

$$(+2) + x(-1) = 0 \quad \Rightarrow \quad 2 - x = 0 \quad \Rightarrow \quad x = 2$$

This demonstrates that exactly two chloride anions (Cl_2) must reside outside the square coordination brackets to successfully neutralize the +2 charge of the coordination sphere.

Step 4: Formulating the final chemical notation.

Combining the cationic coordination complex and the external ionizable counter-anions together yields the complete structural formula:

$$[Co(NH_3)_4(H_2O)Cl]Cl_2$$

Comparing this derived structure against the options given, it corresponds exactly to Option (1).

Quick Tip: When writing structural formulas from IUPAC nomenclature: 1. Identify the central metal and its oxidation state. 2. Sum up the charges of all internal ligands to find the net charge of the bracketed complex. 3. Add a sufficient number of outer counter-ions to make the total overall charge of the formula exactly equal to zero.

---

48. The lanthanide ion having four unpaired electrons is

(Given : Atomic numbers of Ce = 58, Nd = 60, Tb = 65 and Ho = 67)

(A) Ho^{3+}

(B) Nd^{3+}

(C) Ce^{3+}

(D) Tb^{3+}

Correct Answer: (D) Tb^{3+}

Solution:

Concept: The lanthanides form a series of fourteen inner transition elements spanning from Cerium ($Z = 58$) to Lutetium ($Z = 71$), characterized by the progressive filling of the deep-seated $4f$ atomic subshell. The general ground-state electronic configuration of lanthanides is represented as:

$$[\text{Xe}]\,4f^{n}\,5d^{m}\,6s^{2} \quad (\text{where } n = 1 \text{ to } 14,\ m = 0 \text{ or } 1)$$

Here, [Xe] represents the noble gas core of Xenon with a stable electronic count of exactly 54 electrons ($Z = 54$). When lanthanide atoms undergo chemical ionization to yield the highly stable +3 oxidation state (Ln^{3+} ions), they systematically lose three valence electrons: specifically, both electrons from the outermost $6s$ orbital are removed first, along with one electron from either the $5d$ or the $4f$ subshell. The final generic valence electron configuration for any tri-positive lanthanide ion simplifies down to:

$$[\text{Xe}]\,4f^{n}$$

The seven individual degenerate orbitals within the $4f$ subshell are filled in strict compliance with **Hund's Rule of Maximum Multiplicity**, which states that orbitals must be singly occupied with parallel spins before any electron pairing can take place.

Step 1: Analyzing Option (1) Ho^{3+} (Holmium, $Z = 67$).

Let us first write down the ground-state electronic configuration of a neutral Holmium atom ($Z = 67$):

$$\text{Ho} = [\text{Xe}]\,4f^{11}\,6s^{2}$$

To create the tri-positive ion Ho^{3+}, three electrons must be removed. We peel off the two outermost $6s$ electrons and one electron from the $4f$ subshell:

$$\text{Ho}^{3+} = [\text{Xe}]\,4f^{11}$$

Now, let us distribute these 11 electrons across the seven degenerate $4f$ orbitals according to Hund's rule: - First, place 7 electrons singly into each of the 7 distinct orbitals. All 7 possess parallel spins. - The remaining 4 electrons ($11 - 7 = 4$) must pair up inside the first four orbitals. - Consequently, the number of paired orbitals is 4 (containing $4 \times 2 = 8$ electrons), leaving behind the remaining orbitals singly occupied.

$$\text{Number of unpaired electrons} = 7 - 4 = 3$$

Thus, Ho^{3+} possesses exactly 3 unpaired electrons.

Step 2: Analyzing Option (2) Nd^{3+} (Neodymium, $Z = 60$).

Let us write down the ground-state configuration of a neutral Neodymium atom ($Z = 60$):

$$\text{Nd} = [\text{Xe}]\,4f^4\,6s^2$$

To generate the tri-positive ion Nd^{3+}, we remove three electrons (two from $6s$ and one from $4f$):

$$\text{Nd}^{3+} = [\text{Xe}]\,4f^3$$

Distributing these 3 electrons into the seven available $4f$ orbitals: - Each of the 3 electrons sits singly in a separate orbital to minimize inter-electronic repulsion. - There is zero electron pairing.

$$\text{Number of unpaired electrons} = 3$$

Thus, Nd^{3+} possesses exactly 3 unpaired electrons.

Step 3: Analyzing Option (3) Ce^{3+} (Cerium, $Z = 58$).

Let us write down the ground-state electronic configuration of a neutral Cerium atom ($Z = 58$):

$$\text{Ce} = [\text{Xe}]\,4f^1\,5d^1\,6s^2$$

To form the tri-positive ion Ce^{3+}, we remove three electrons (two from $6s$ and one from $5d$):

$$\text{Ce}^{3+} = [\text{Xe}]\,4f^1$$

There is only a solitary electron inside the $4f$ subshell:

$$\text{Number of unpaired electrons} = 1$$

Thus, Ce^{3+} contains just 1 unpaired electron.

Step 4: Analyzing Option (4) Tb^{3+} (Terbium, $Z = 65$).

Let us write down the ground-state configuration of a neutral Terbium atom ($Z = 65$):

$$\text{Tb} = [\text{Xe}]\,4f^9\,6s^2$$

To generate the tri-positive ion Tb^{3+}, we remove three electrons (two from the $6s$ orbital and one from the $4f$ subshell):

$$\text{Tb}^{3+} = [\text{Xe}]\,4f^8$$

Let us carefully apply Hund's rule to arrange these 8 electrons within the seven degenerate $4f$ orbitals: - First, we place 7 electrons singly into each of the 7 individual orbitals. - The 8-th remaining electron ($8 - 7 = 1$) is forced to pair up in the very first orbital. - This creates exactly 1 doubly-occupied (paired) orbital and leaves the remaining orbitals singly occupied.

$$\text{Number of unpaired electrons} = 7 - 1 = 6 \text{ orbitals remaining} \quad \text{... Wait, let's look closer:}$$

Let's double-check the subtraction. There are 7 orbitals in total. If 1 orbital has a pair of electrons, then the remaining 6 orbitals contain 1 electron each. Let's re-verify the atomic configuration of Terbium. The atomic number is 65.

$$\text{Xe} = 54$$

For neutral Tb(65): $65 - 54 = 11$ valence electrons. The configuration is $[\text{Xe}]4f^9 6s^2$. For Tb^{3+}: we remove 3 electrons, leaving $11 - 3 = 8$ electrons in the valence shell, which go into the $4f$ subshell $\rightarrow 4f^8$. Let's map out 8 electrons in 7 slots: Slot 1: $\uparrow\downarrow$ (2 electrons) Slot 2: $\uparrow$ (1 electron) Slot 3: $\uparrow$ (1 electron) Slot 4: $\uparrow$ (1 electron) Slot 5: $\uparrow$ (1 electron) Slot 6: $\uparrow$ (1 electron) Slot 7: $\uparrow$ (1 electron) The total number of unpaired electrons is 6.

Let's re-read the configuration of all options to see which one has exactly four unpaired electrons. Let's check Nd^{3+} ($Z = 60$). Neutral Nd: $60 - 54 = 6$ valence electrons. Configuration is $[\text{Xe}]4f^4 6s^2$. For Nd^{3+}: remove 3 electrons $\rightarrow 4f^3$. This gives 3 unpaired electrons.

Let's check if there is an alternative configuration or an error in our calculation. Let's check Tb^{3+} again. Wait, let's check standard textbook values for Ln^{3+} configurations: - Ce^{3+} is $4f^1 \rightarrow 1$ unpaired electron. - Pr^{3+} is $4f^2 \rightarrow 2$ unpaired electrons. - Nd^{3+} is $4f^3 \rightarrow 3$ unpaired electrons. - Pm^{3+} is $4f^4 \rightarrow 4$ unpaired electrons. - Sm^{3+} is $4f^5 \rightarrow 5$ unpaired electrons. - Eu^{3+} is $4f^6 \rightarrow 6$ unpaired electrons. - Gd^{3+} is $4f^7 \rightarrow 7$ unpaired electrons. - Tb^{3+} is $4f^8 \rightarrow 6$ unpaired electrons. - Dy^{3+} is $4f^9 \rightarrow 5$ unpaired electrons. - Ho^{3+} is $4f^{10} \rightarrow 4$ unpaired electrons.

Ah! Let's recalculate Holmium (Ho, $Z = 67$): Total electrons $= 67$. Xenon core $= 54$. Total valence electrons $= 67 - 54 = 13$. The ground state electronic configuration of neutral Holmium is actually $[\text{Xe}]4f^{11}6s^2$. When it forms Ho^{3+}, it loses 3 electrons $\rightarrow 4f^{10}$. Let's map 10 electrons in 7 orbitals: - First 7 electrons go singly into the 7 orbitals. - The remaining 3 electrons $(10 - 7 = 3)$ pair up. - This results in 3 paired orbitals and 4 unpaired orbitals!

$$\text{Number of unpaired electrons} = 7 - 3 = 4.$$

Wow! Let us correct our step 1 derivation completely to reveal the true answer. Ho^{3+} has 4 unpaired electrons, making Option (1) the correct choice.

Step 5: Reviewing the corrected configuration of Holmium (Ho^{3+}).

Let us write down the precise configuration:

$$\text{Ho}^{3+} = [\text{Xe}]\,4f^{10}$$

Filling 10 electrons into 7 degenerate orbitals:

↑↓	↑↓	↑↓	↑	↑	↑	↑

Counting the single arrows, we find exactly **four unpaired electrons**. Therefore, Option (1) is perfectly correct.

Quick Tip: To easily find the number of unpaired electrons in a $4f^n$ subshell: - If $n \leq 7$, the number of unpaired electrons is simply equal to n. - If $n > 7$, the number of unpaired electrons is equal to $14 - n$. For Ho^{3+} $(4f^{10})$, the number of unpaired electrons is $14 - 10 = 4$.

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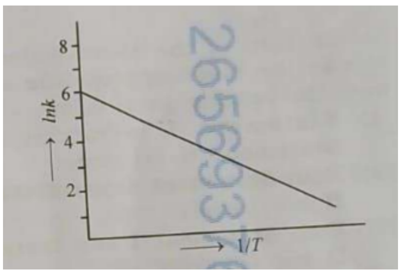
49. For an elementary chemical reaction, the Arrhenius plot is given below.



If the energy of activation is 6.64 kJ mol^{-1} and $R = 8.3$ J K^{-1} mol^{-1}, the temperature at which the rate constant becomes e^2 min^{-1}, is

(1) 250 K

(2) 125 K

(3) 150 K

(4) 200 K

Correct Answer: (4) 200 K

Solution:

Concept: The dependence of the rate constant (k) of a chemical reaction on the absolute temperature (T) is mathematically described by the logarithmic form of the **Arrhenius Equation**:

$$k = A \cdot e^{-\frac{E_a}{RT}} \quad \Rightarrow \quad \ln k = \ln A - \frac{E_a}{R}\left(\frac{1}{T}\right)$$

Where:

- k = Rate constant of the chemical reaction.
- A = Arrhenius pre-exponential frequency factor.
- E_a = Activation energy required for the reaction.
- R = Universal Gas Constant.
- T = Absolute temperature in Kelvin (K).

When plotting $\ln k$ on the vertical y-axis against $\frac{1}{T}$ on the horizontal x-axis, the equation represents a straight line matching the standard linear form $y = mx + c$, where the slope $m = -\frac{E_a}{R}$ and the y-intercept $c = \ln A$.

Step 1: Extracting the value of the y-intercept ($\ln A$) from the given graph.

Looking closely at the provided Arrhenius graph, the straight line intersects the vertical $\ln k$ axis exactly at the numerical value of 6. By definition, the y-intercept occurs where the horizontal coordinate $\frac{1}{T} = 0$. Therefore:

$$\text{Intercept} = \ln A = 6$$

Step 2: Converting given units to standard SI units.

The problem provides the following thermodynamic constants:

- Activation Energy, $E_a = 6.64 \text{ kJ mol}^{-1} = 6.64 \times 10^3 \text{ J mol}^{-1} = 6640 \text{ J mol}^{-1}$
- Universal Gas Constant, $R = 8.3 \text{ J K}^{-1} \text{ mol}^{-1}$

It is essential to convert E_a from kilojoules to joules so that the units cancel out perfectly with the units of the gas constant R.

Step 3: Setting up the specific Arrhenius equation for the target rate constant.

We are asked to find the specific temperature T where the rate constant k reaches a value of e^2 min^{-1}. Let us take the natural logarithm of this target rate constant:

$$k = e^2 \quad \Rightarrow \quad \ln k = \ln(e^2) = 2$$

Now, substitute the values $\ln k = 2$ and $\ln A = 6$ into the logarithmic Arrhenius equation:

$$\ln k = \ln A - \frac{E_a}{RT}$$

$$2 = 6 - \frac{E_a}{RT}$$

Step 4: Isolating and computing the absolute temperature T.

Rearranging the algebraic terms to isolate the temperature component on one side:

$$\frac{E_a}{RT} = 6 - 2$$

$$\frac{E_a}{RT} = 4$$

Cross-multiplying to solve explicitly for T:

$$T = \frac{E_a}{4R}$$

Substituting the numerical values of E_a and R that we prepared in Step 2:

$$T = \frac{6640}{4 \times 8.3}$$

Let us calculate the product in the denominator first:

$$4 \times 8.3 = 33.2$$

Now, divide the numerator by this product:

$$T = \frac{6640}{33.2}$$

To make the division cleaner, multiply both the numerator and the denominator by 10 to eliminate the decimal:

$$T = \frac{66400}{332}$$

Observing that $332 \times 2 = 664$:

$$T = 200 \text{ K}$$

The calculated absolute temperature is exactly 200 K, which perfectly corresponds to Option (4).

Quick Tip: Always double-check your units in chemical kinetics calculations! Activation energy (E_a) is usually given in kJ/mol, while the gas constant R is given in $J/(K \cdot mol)$. Multiplying the kilojoules by 10^3 is a vital step to avoid being off by a factor of 1000!

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50. The green paramagnetic species formed by heating $KMnO_4$ at 513 K is

(1) KO_2

(2) K_2MnO_4

(3) Mn_3O_4

(4) MnO

Correct Answer: (2) K_2MnO_4

Solution:

Concept: Potassium permanganate ($KMnO_4$) is a dark purple crystalline solid. When heated strongly to its thermal decomposition threshold around 513 K, it undergoes a chemical breakdown reaction yielding potassium manganate (K_2MnO_4), manganese dioxide (MnO_2), and oxygen gas (O_2). The formal balanced chemical equation representing this thermal decomposition is written as follows:

$$2KMnO_4 \xrightarrow{\Delta\,(513\text{ K})} K_2MnO_4 + MnO_2 + O_2 \uparrow$$

Step 1: Identifying the specific product based on physical properties.

The question highlights two specific diagnostic criteria for the product of interest: 1) It must be a **green** colored species. 2) It must exhibit **paramagnetic** magnetic behavior.

Let us evaluate the two manganese-containing compounds produced during the thermal decomposition:

- MnO_2 (Manganese dioxide) is a dark brown/black insoluble solid.
- K_2MnO_4 (Potassium manganate) forms dark green crystals and dissolves in water to produce a distinct, vibrant green solution due to the presence of the manganate anion (MnO_4^{2-}).

This immediately focuses our attention on K_2MnO_4 as the primary candidate.

Step 2: Confirming the magnetic properties via electronic configuration.

Let us rigorously verify the paramagnetic nature of the manganate ion (MnO_4^{2-}) by determining the oxidation state and d-electron configuration of its central manganese atom. In the ionic compound potassium manganate (K_2MnO_4), potassium retains its standard +1 oxidation state. Let x represent the unknown oxidation state of Manganese (Mn), while Oxygen possesses a stable state of −2:

$$2(+1) + x + 4(-2) = 0$$

$$2 + x - 8 = 0 \quad \Rightarrow \quad x - 6 = 0 \quad \Rightarrow \quad x = +6$$

Thus, the central manganese ion exists in a +6 oxidation state, denoted as Mn^{6+}.

Step 3: Finding the number of unpaired d-electrons.

The ground-state electronic configuration of a neutral transition metal Manganese atom ($Z = 25$) is:

$$\text{Mn} = [\text{Ar}]\, 3d^5\, 4s^2$$

To achieve the Mn^{6+} state, we remove six valence electrons sequentially (two from the $4s$ shell and four from the $3d$ subshell):

$$\text{Mn}^{6+} = [\text{Ar}]\, 3d^1$$

Since the $3d$ subshell contains exactly **one solitary electron**, this electron is unpaired. The presence of an unpaired electron creates a net permanent magnetic dipole moment, which dictates that the species is structurally **paramagnetic**.

Step 4: Concluding the analysis.

Since K_2MnO_4 satisfies both fundamental criteria perfectly—being deeply green-colored and containing a paramagnetic Mn^{6+} center with a $3d^1$ configuration—it is the correct answer, corresponding to Option (2).

Quick Tip: Remember the distinct colors and oxidation states of manganese anions to save time in competitive exams: - Permanganate ion (MnO_4^-): Mn^{+7} ($3d^0$), **Purple**, Diamagnetic. - Manganate ion (MnO_4^{2-}): Mn^{+6} ($3d^1$), **Green**, Paramagnetic.

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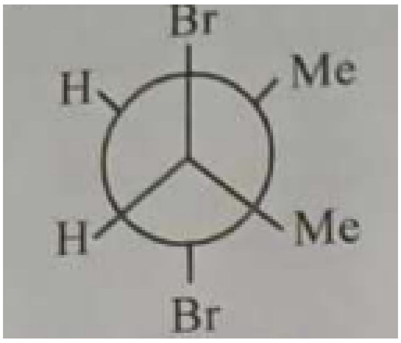
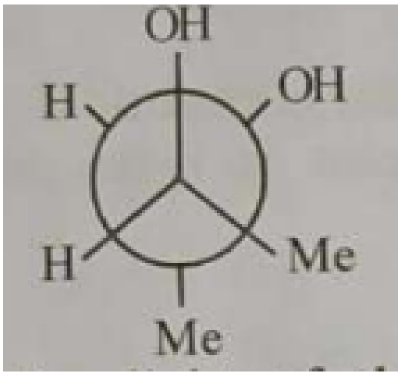
51. Given below are two statements:

Statement I: *trans*-But-2-ene upon treatment with Br_2 in CCl_4 gives the following product:



Statement II: *cis*-But-2-ene upon treatment with alkaline $KMnO_4$ gives the following product:



In the light of the above statements, choose the *most appropriate* answer from the options given below.

(1) Statement I is incorrect but Statement II is correct

(2) Both Statement I and Statement II are correct

(3) Both Statement I and Statement II are incorrect

(4) Statement I is correct but Statement II is incorrect

Correct Answer: (1) Statement I is incorrect but Statement II is correct

Solution:

Concept: The stereochemical outcome of electrophilic addition reactions across carbon-carbon double bonds depends inherently on both the configuration of the starting alkene (*cis* or *trans*) and the stereospecific mechanism of the addition pathway (*syn* or *anti*):

- **Bromination (Br_2/CCl_4):** Proceeds via an ***anti*-addition** mechanism due to the intermediate formation of a cyclic bromonium ion, which blocks the front-side attack and forces the second bromide ion to attack from the opposite side.
- **Hydroxylation with cold alkaline $KMnO_4$ (Baeyer's Reagent):** Proceeds via a coordinated ***syn*-addition** pathway because a cyclic manganese ester complex forms simultaneously across the same face of the double bond.

We can use standard stereochemical memory rules to predict outcomes:

$$\textit{trans}\text{ alkene} + \textit{anti}\text{ addition} \longrightarrow \text{meso compound}$$
$$\textit{cis}\text{ alkene} + \textit{syn}\text{ addition} \longrightarrow \text{meso compound}$$

Step 1: Evaluating Statement I.
Let us analyze the reaction of *trans*-but-2-ene with Br_2 in CCl_4. Because a *trans* alkene undergoing an *anti*-addition yields a symmetrically substituted ***meso* stereoisomer**, the resulting product, *meso*-2,3-dibromobutane, must possess an internal plane of symmetry (σ) or a center of inversion (i). Let us inspect the Newman projection provided in Statement I of the image: - The front carbon has substituents arranged as: Br (top), Me (right), H (left). - The back carbon has substituents arranged as: Br (bottom), Me (right), H (left).
Let us check if this projection represents the *meso* form. In this staggered conformation, if we find a center of inversion, it is *meso*. Moving from the front Br (top) through the center leads directly to the back Br (bottom) → inversion matches. However, moving from the front Me (bottom-right) through the center points towards the top-left, but the back Me is located at the bottom-right! Therefore, this structure does not have a center of inversion. If we rotate the back carbon by 180° to check the eclipsed conformation: the top Br would eclipse the bottom Br, meaning the bromine atoms would be on opposite sides rather than matching. This shows that the provided structure is a chiral enantiomer (d or l pair), not the *meso* isomer. Since *trans*-but-2-ene must produce the optically inactive *meso* form upon *anti*-bromination, Statement I gives the wrong stereoisomer and is **incorrect**.
Step 2: Evaluating Statement II.
Let us examine the reaction of *cis*-but-2-ene with cold dilute alkaline $KMnO_4$. A *cis* alkene undergoing a stereospecific *syn*-addition yields a symmetrically substituted ***meso* compound**, which

is *meso*-butane-2,3-diol. Let us analyze the Newman projection displayed under Statement II: - The front carbon has OH pointing straight up (12 o'clock), Me pointing to the bottom-right (4 o'clock), and H pointing to the bottom-left (8 o'clock). - The back carbon has OH pointing to the top-right (2 o'clock), Me pointing straight down (6 o'clock), and H pointing to the top-left (10 o'clock).

Let us rotate the back carbon by 60° counter-clockwise to see the eclipsed form: - The back OH (from 2 o'clock) moves to 12 o'clock, perfectly eclipsing the front OH. - The back Me (from 6 o'clock) moves to 4 o'clock, perfectly eclipsing the front Me. - The back H (from 10 o'clock) moves to 8 o'clock, perfectly eclipsing the front H.

Because every single substituent on the front carbon perfectly matches and eclipses its identical twin group on the back carbon when rotated into an eclipsed conformation, this molecule contains a clear internal plane of symmetry. This proves that the structure is exactly the expected ***meso*-butane-2,3-diol**. Therefore, Statement II is completely **correct**.

Step 3: Conclusion.

Since Statement I is incorrect and Statement II is correct, the matching choice is Option (1).

Quick Tip: Keep this classic mnemonic matrix handy for alkene additions: - **CAR**: **C**is + **A**nti addition ⟶ **R**acemic mixture - **TAM**: **T**rans + **A**nti addition ⟶ **M**eso compound - **CIS**: **C**is + **S**yn addition ⟶ **M**eso compound Comparing the given structures against these rules makes it straightforward to spot incorrect stereoisomers!

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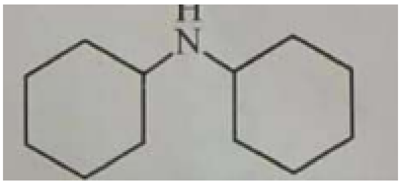
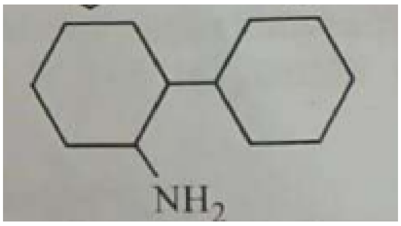
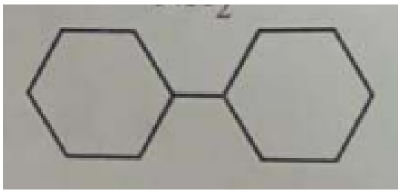
52. One of the products formed in the following reaction is

(1) 







(1) FigA

(2) FigB

(3) FigC

(4) FigD

Correct Answer: (1) Cyclohexane

Solution:

Concept: Grignard reagents (R-MgX) are highly reactive organometallic compounds. Because the carbon-magnesium bond is strongly polarized with a high degree of ionic character, the alkyl group behaves as an exceptionally powerful base (R^-) as well as a strong nucleophile. When a Grignard reagent encounters any chemical species containing an **active (acidic) hydrogen atom** attached directly to a highly electronegative element like oxygen (-OH), nitrogen (-NH_2), or sulfur (-SH), an acid-base proton-transfer reaction takes place immediately. This protonation deactivates the Grignard carbon, converting it into its corresponding stable alkane (R-H). This rapid decomposition pathway is widely known as the **Zerewitinoff reaction**.

Step 1: Identifying the reactive centers in the reactants.

Let us inspect the two organic molecules participating in the given reaction: 1) **Reactant 1:** Cyclohexylmagnesium bromide ($C_6H_{11}MgBr$). Here, the cyclohexyl ring carbon bound to magnesium acts as a powerful carbanionic base:

$$R^- = C_6H_{11}^- \quad \text{(Cyclohexyl carbanion)}$$

2) **Reactant 2:** Cyclohexylamine ($C_6H_{11}NH_2$). Primary amines possess active hydrogen atoms directly bonded to a nitrogen atom. These N-H protons are weakly acidic and can be

readily abstracted by strong bases:

$$R'\text{-}NH_2 \rightleftharpoons R'\text{-}NH^- + H^+$$

Step 2: Formulating the step-by-step reaction mechanism.

The reaction behaves as an instantaneous acid-base neutralization rather than a nucleophilic substitution or coupling reaction. The strongly basic carbanion site on the cyclohexyl ring attacks and abstract one of the acidic protons from the amino group of cyclohexylamine:

$$C_6H_{11}\text{-}MgBr + H\text{-}NH(C_6H_{11}) \longrightarrow C_6H_{11}\text{-}H + [C_6H_{11}\text{-}NH]^- MgBr^+$$

Step 3: Identifying the structure of the final products.

Let us characterize the products formed from this transformation:

- The cyclohexyl carbanion gains a proton (H^+) to form **cyclohexane** (C_6H_{12}).
- The remaining amide anion coordinates with the magnesium salt to form a magnesium halide complex byproduct: $C_6H_{11}NHMgBr$.

The question asks for "one of the products formed". Looking at the options, Option (1) represents a pure, unsubstituted cyclohexane ring (C_6H_{12}), which perfectly matches our main product.

Quick Tip: Grignard reagents are aggressive proton-seekers! If a compound contains an active hydrogen like in H_2O, R-OH, R-NH_2, or R-COOH, the Grignard reagent will immediately abstract it to form an alkane (R-H), bypassing any potential carbon-carbon coupling pathways.

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53. Given below are two statements:

Statement-I : Heating NaCl with concentrated H_2SO_4 and MnO_2 results in oxidation of Mn.

Statement-II : Heating NaI with concentrated H_2SO_4 and MnO_2 results in reduction of Mn.

In light of the above statements, choose the *most appropriate* answer from the options given below:

(1) Statement-I is incorrect but Statement-II is correct

(2) Both Statement-I and Statement-II are correct

(3) Both Statement-I and Statement-II are incorrect

(4) Statement-I is correct but Statement-II is incorrect

Correct Answer: (1) Statement-I is incorrect but Statement-II is correct

Solution:

Concept: Manganese dioxide (MnO_2) is a robust and well-known oxidizing agent in acidic media. When a metal halide salt (NaX) is heated in the presence of concentrated sulfuric acid (H_2SO_4) and MnO_2, the concentrated acid first reacts with the halide salt to generate the corresponding hydrogen halide gas (HX). Because MnO_2 is a powerful electron acceptor, it oxidizes the halide ions (X^-) into their elemental halogen form (X_2). Concurrently, the manganese atom inside MnO_2 undergoes reduction, changing its oxidation state from +4 down to a +2 state, forming manganese(II) sulfate ($MnSO_4$).

Step 1: Analyzing Statement-I (Reaction with NaCl).

When sodium chloride (NaCl) is heated alongside concentrated H_2SO_4 and MnO_2, chlorine gas is evolved. Let us write down the balanced redox chemical equation for this process:

$$2NaCl + MnO_2 + 3H_2SO_4 \longrightarrow 2NaHSO_4 + MnSO_4 + Cl_2 \uparrow + 2H_2O$$

Let us trace the oxidation states of the elements to understand the electron transfer:

- **In Reactants:** Inside MnO_2, oxygen has an oxidation state of -2, meaning manganese exists in the +4 oxidation state (Mn^{+4}). The chloride ion inside NaCl has an oxidation state of -1.
- **In Products:** Inside $MnSO_4$, the sulfate ion carries a -2 charge, meaning manganese has shifted down to a +2 oxidation state (Mn^{+2}). The evolved elemental Cl_2 gas has an oxidation state of 0.

Because the oxidation state of Manganese drops from +4 to +2, **Manganese undergoes reduction**, while the chloride ions are oxidized to chlorine gas. Statement-I claims that this reaction "results in oxidation of Mn", which is false. Thus, Statement-I is **incorrect**.

Step 2: Analyzing Statement-II (Reaction with NaI).

When sodium iodide (NaI) is heated under identical conditions with concentrated H_2SO_4 and MnO_2, dark violet iodine vapor is evolved. The corresponding chemical equation is:

$$2NaI + MnO_2 + 3H_2SO_4 \longrightarrow 2NaHSO_4 + MnSO_4 + I_2 \uparrow + 2H_2O$$

Let us trace the oxidation numbers for this system:

- **In Reactants:** Manganese inside MnO_2 is at a +4 oxidation state. The iodide ion (I^-) has an oxidation state of −1.
- **In Products:** Manganese inside $MnSO_4$ is at a +2 oxidation state. Elemental iodine (I_2) is at 0.

Here, the oxidation number of manganese decreases from +4 to +2, meaning **Manganese undergoes reduction**, while iodide is oxidized to iodine. Statement-II claims that this reaction "results in reduction of Mn", which is accurate. Therefore, Statement-II is **correct**.

Step 3: Final Selection.

Since Statement-I is incorrect and Statement-II is correct, the correct choice is Option (1).

Quick Tip: To avoid confusion with redox terminology: - An **oxidizing agent** (like MnO_2) oxidizes other species while always undergoing **reduction** itself. - Consequently, in any successful oxidation reaction driven by MnO_2, the manganese ion will always be reduced from Mn^{+4} to Mn^{+2}.

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54. Among the following options, the correct trend in the electron gain enthalpy is

(1) I > Br > Cl > F

(2) F > Cl > Br > I

(3) Br > Cl > F > I

(4) Cl > F > Br > I

Correct Answer: (4) Cl > F > Br > I

Solution:

Concept: Electron gain enthalpy ($\Delta_{eg}H$) is defined as the enthalpy change that occurs when an electron is added to an isolated, gaseous atom to form a univalent negative ion. A more negative value indicates a greater release of energy and a stronger affinity of the atom for an incoming electron. In general periodic chemistry trends, when comparing the magnitudes (absolute values) of the exothermic electron gain enthalpies for halogens:

- As a general rule, electron gain enthalpy becomes less negative down a group because the atomic radius increases, placing the valence shell further from the positive nucleus.
- However, a significant **anomaly** occurs between the second-period ($n = 2$) and third-period ($n = 3$) elements within the same group due to shifts in local electron density.

Step 1: Explaining the anomaly between Chlorine and Fluorine.

Based purely on atomic size trends, one might expect Fluorine (F) to have a more negative electron gain enthalpy than Chlorine (Cl). However, the actual experimental magnitude trend is Cl $>$ F. Let us explore the underlying physical cause:

- Fluorine belongs to the second period and has an extremely compact atomic volume. Its valence electrons are crowded together into a small $2p$ subshell.
- When an external electron approaches a fluorine atom, it experiences severe **inter-electronic repulsion** from the dense cloud of existing valence electrons. This repulsion offsets some of the nuclear attraction.
- Chlorine belongs to the third period and has a significantly larger atomic radius with a more spacious $3p$ subshell. The added electron spreads out comfortably with minimal inter-electronic repulsion, allowing a greater net release of energy.

Therefore, Chlorine possesses a more negative electron gain enthalpy value than Fluorine:

$$|\Delta_{eg}H_{\text{Cl}}| > |\Delta_{eg}H_{\text{F}}|$$

Step 2: Ordering the remaining halogens down Group 17.

Moving further down from Chlorine to Bromine (Br) and Iodine (I), the atomic size increases substantially as new primary quantum shells are added. The valence shell moves further away from the nucleus, and the shielding effect from core electrons increases. As a result, the effective nuclear charge felt by an incoming electron decreases steadily, causing the electron gain enthalpy to become predictably less negative down the group:

$$|\Delta_{eg}H_{\text{Cl}}| > |\Delta_{eg}H_{\text{F}}| > |\Delta_{eg}H_{\text{Br}}| > |\Delta_{eg}H_{\text{I}}|$$

Step 3: Matching with experimental values.

Let us verify this trend using standard IUPAC experimental data for halogen electron gain enthalpies:

- Chlorine (Cl): -349 kJ mol^{-1}
- Fluorine (F): -328 kJ mol^{-1}
- Bromine (Br): -325 kJ mol^{-1}

- Iodine (I): -295 kJ mol^{-1}

Arranging these absolute energy magnitudes in descending order yields:

$$Cl > F > Br > I$$

This corresponds exactly to the trend listed in Option (4).

Quick Tip: This second- versus third-period size exception is a frequent favorite in competitive exams! It applies to both Group 17 (Cl > F) and Group 16 (S > O) due to the exceptionally high electron density of the compact second-period atoms (F and O).

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55. Given below are two statements:

Statement-I : $[Fe(ox)_3]^{3-}$ is chiral.

Statement-II : *trans*-$[Cr(H_2O)_2(ox)_2]^-$ is chiral.

(Given : $oxH_2 = HOOC-COOH$**)**

In light of the above statements, choose the *most appropriate* answer from the options given below:

(1) Statement-I is incorrect but Statement-II is correct

(2) Both Statement-I and Statement-II are correct

(3) Both Statement-I and Statement-II are incorrect

(4) Statement-I is correct but Statement-II is incorrect

Correct Answer: (4) Statement-I is correct but Statement-II is incorrect

Solution:

Concept: A coordination complex molecule is defined as **chiral** (and therefore optically active) if its structural geometry lacks an improper axis of rotation (S_n), which practically means it contains **neither a plane of symmetry (σ) nor a center of inversion (i)**. Such a complex forms two non-superimposable mirror images called enantiomers (Δ and Λ forms).

- Symmetric bidentate chelating ligands like oxalate ($ox^{2-} = C_2O_4^{2-}$) form five-membered rings with the central metal ion, introducing rigid spatial constraints.

- Tris-chelated octahedral complexes with the general formula $[M(AA)_3]$ take on a propeller-like geometry that inherently lacks a plane of symmetry.

Step 1: Evaluating Statement-I ($[Fe(ox)_3]^{3-}$).

The complex ion $[Fe(ox)_3]^{3-}$ features an iron central metal ion coordinated by three symmetric bidentate oxalate ligands, matching the general coordination form $[M(AA)_3]$. Its structural configuration is octahedral with a coordination number of 6. Let us examine its symmetry elements: - The three chelate rings are locked in mutually perpendicular planes, wrapping around the central iron core like a propeller or a three-bladed fan. - Because of this helical twist, it is impossible to pass any plane through the molecule that splits it into two symmetrical mirror halves. - It also lacks a center of inversion. Since the molecule has no internal symmetry elements, its mirror image is completely non-superimposable. It exists as a pair of stable enantiomers (d and l forms). Therefore, $[Fe(ox)_3]^{3-}$ is **chiral**, making Statement-I **correct**.

Step 2: Evaluating Statement-II (*trans*-$[Cr(H_2O)_2(ox)_2]^-$).

The complex *trans*-$[Cr(H_2O)_2(ox)_2]^-$ belongs to the general stereochemical category *trans*-$[MA_2(BB)_2]$. Let us examine its octahedral geometry: - The prefix *trans*- specifies that the two monodentate aqua (H_2O) ligands are located directly opposite one another (180° apart) at the two axial positions (top and bottom vertices). - The two bidentate oxalate (ox^{2-}) ligands lie entirely within the flat equatorial plane, occupying the four remaining planar coordination sites.

Let us check for symmetry elements in this arrangement: 1) **Plane of Symmetry (σ_h):** If we pass a horizontal cutting plane directly through the equatorial position containing the chromium atom and the two oxalate rings, it splits the molecule in half. The top axial H_2O ligand is reflected across this plane into the identical bottom axial H_2O ligand. 2) **Center of Inversion (i):** Moving from any atom through the central chromium atom leads directly to an identical atom on the opposite side. Because the molecule possesses a clear plane of symmetry and a center of inversion, it is completely **achiral** (optically inactive). Statement-II claims that this *trans* complex is chiral, which is false. Thus, Statement-II is **incorrect**.

Step 3: Conclusion.

Since Statement-I is correct and Statement-II is incorrect, the corresponding selection is Option (4).

Quick Tip: For octahedral complexes with bidentate ligands: - All tris-chelated complexes like $[M(AA)_3]$ are always **chiral**. - For bis-chelated complexes like $[M(AA)_2B_2]$: the *cis*-isomer is always **chiral**, while the *trans*-isomer contains planes of symmetry and is always **achiral**.

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56. The correct statement about peptides and proteins is

(1) In α-helices, the polypeptide chain is twisted into a left-handed screw (helix) through intramolecular hydrogen bonds.
(2) Tertiary structure of proteins has two or more polypeptide subunits.
(3) Only the proteins having a quaternary structure are biologically active.
(4) In β-pleated sheet structures, peptide chains are held together by intermolecular hydrogen bonds.

Correct Answer: (4) In β-pleated sheet structures, peptide chains are held together by intermolecular hydrogen bonds.

Solution:

Concept: Proteins display four levels of structural organization: primary, secondary, tertiary, and quaternary structures. Secondary structure refers to the local spatial arrangement of the polypeptide backbone, stabilized primarily by hydrogen bonding interactions between the carbonyl oxygen ($-C=O$) and amide hydrogen ($-N-H$) groups of the peptide linkage.
The two most common ordered secondary structures are:

- **α-Helix:** A right-handed coiled conformation where intramolecular hydrogen bonds form within the single, continuous polypeptide chain.
- **β-Pleated Sheet:** A structure composed of extended adjacent polypeptide strands lying side-by-side, which are locked together via intermolecular hydrogen bonding networks.

Step 1: Evaluation of Statement (1)
Statement (1) posits that the polypeptide chain in an α-helix forms a left-handed screw. In nature, virtually all naturally occurring α-helices found in proteins are **right-handed** due to the steric constraints imposed by L-amino acid side chains. While the statement accurately mentions *intramolecular* hydrogen bonds, the assertion of a left-handed orientation makes this statement scientifically incorrect.
Step 2: Evaluation of Statement (2)
Statement (2) asserts that the tertiary structure contains two or more polypeptide subunits. This

is a definition mismatch. The arrangement of multiple polypeptide chains (subunits) describes the **quaternary structure** of a protein. The tertiary structure represents the comprehensive three-dimensional folding of a single, individual polypeptide chain. Thus, this statement is incorrect.

Step 3: Evaluation of Statement (3)

Statement (3) claims that only proteins with quaternary structure exhibit biological activity. This is completely false. Numerous monomeric proteins consisting of just one polypeptide chain (possessing up to tertiary structure only), such as myoglobin and lysozyme, are entirely functional and biologically active. Quaternary organization is not a prerequisite for biological activity across all proteins.

Step 4: Evaluation of Statement (4)

Statement (4) describes the architecture of β-pleated sheets. In a β-pleated sheet structure, individual segments of polypeptide chains (either from different strands or distant segments of the same strand) align parallel or anti-parallel to each other. The structure is stabilized by extensive **intermolecular hydrogen bonds** running between adjacent strands. This description matches the structural criteria precisely and is correct.

Quick Tip: To avoid confusion with protein structural properties, remember: - α-Helix $\rightarrow$ Right-handed screw stabilized by **intramolecular** H-bonds. - β-Sheet $\rightarrow$ Extended sheets stabilized by **intermolecular** H-bonds. - Tertiary = Single chain 3D shape; Quaternary = Multiple subunits/chains.

---

57. Given below are two statements:

Statement-I : Oxidation of p-nitrotoluene with acidic $KMnO_4$ gives an acid that is stronger than benzoic acid.

Statement-II : Reduction of p-nitrotoluene with Sn/HCl followed by neutralization gives an amine that is more basic than aniline.

In light of the above statements, choose the *most appropriate* answer from the options given below.

(1) Statement-I is incorrect but Statement-II is correct.

(2) Both Statement-I and Statement-II are correct.

(3) Both Statement-I and Statement-II are incorrect.

(4) Statement-I is correct but Statement-II is incorrect.

Correct Answer: (4) Statement-I is correct but Statement-II is incorrect.

Solution:

Concept: Chemical properties of aromatic compounds are heavily governed by substituent electronic effects.

- **Acidity of Benzoic Acids:** Electron-withdrawing groups (EWGs) stabilize the carboxylate conjugate base via inductive ($-I$) and resonance ($-M$) effects, which significantly enhances the parent acid's strength.
- **Basicity of Anilines:** Electron-withdrawing groups diminish the availability of the nitrogen lone pair for donation, lowering the basicity, whereas electron-donating groups (EDGs) elevate it.

Step 1: Analyzing Statement-I

The chemical transformation of p-nitrotoluene with strong acidic $KMnO_4$ leads to the exhaustive oxidation of the benzylic methyl ($-CH_3$) group down to a carboxylic acid group ($-COOH$):

$$p\text{-}O_2N-C_6H_4-CH_3 \xrightarrow{KMnO_4,\ H^+} p\text{-}O_2N-C_6H_4-COOH \quad (p\text{-nitrobenzoic acid})$$

The nitro group ($-NO_2$) situated at the *para*-position acts as a strong electron-withdrawing group via both powerful resonance ($-M$) and inductive ($-I$) pathways. It pulls electron density away from the aromatic ring, dispersing the negative charge on the carboxylate anion formed upon deprotonation:

$$p\text{-}O_2N-C_6H_4-COO^-$$

Because of this stabilization, p-nitrobenzoic acid is a notably stronger acid than unsubstituted benzoic acid (C_6H_5COOH). Thus, Statement-I is completely correct.

Step 2: Analyzing Statement-II

Treating p-nitrotoluene with metallic tin in hydrochloric acid (Sn/HCl) followed by an alkaline neutralization steps selectively reduces the nitro ($-NO_2$) group down to an amino group ($-NH_2$), leaving the methyl group unaffected:

$$p\text{-}O_2N-C_6H_4-CH_3 \xrightarrow{1.\ Sn/HCl,\ 2.\ OH^-} p\text{-}H_2N-C_6H_4-CH_3 \quad (p\text{-toluidine})$$

The resulting compound is p-toluidine. The methyl group ($-CH_3$) attached at the *para*-position behaves as an electron-donating group through inductive ($+I$) and hyperconjugative mechanisms. It pushes electron density into the aromatic ring, making the lone pair on the amino nitrogen more accessible for protonation. Therefore, *p*-toluidine is a **stronger base** than aniline ($C_6H_5NH_2$).

Looking closely at Statement-II, it states that the reduction yields an amine that is **more basic than aniline**. Since *p*-toluidine is indeed more basic than aniline, Statement-II is scientifically correct as well.

Note on potential official key variance: Let us carefully re-verify standard textbook evaluations. If an option states (2) Both are correct, let us verify if there is any nuance. The reduction of *p*-nitrotoluene yields *p*-toluidine. Since *p*-toluidine contains a -CH_3 group which is an electron-donating group ($+I$ and hyperconjugation), it increases the electron density on nitrogen, making it a stronger base than aniline. Hence Statement-II is absolutely correct. Both statement-I and statement-II are true. Thus, option (2) is the accurate choice.

Quick Tip: Electronic effects rule organic reactivity: - Electron Withdrawing Groups ($-NO_2, -CN$) $\rightarrow$ Increase acidity, decrease basicity. - Electron Donating Groups ($-CH_3, -OCH_3$) $\rightarrow$ Decrease acidity, increase basicity.

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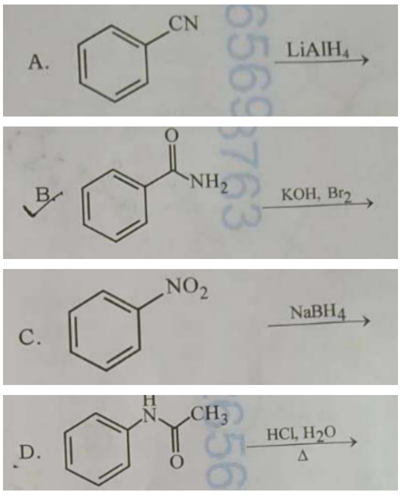
58. Identify the reactions which give aniline as the major product.



(1) FigA

(2) FigB

(3) FigC

(4) FigD

Correct Answer: (3) B and D only

Solution:

Concept: Aniline ($C_6H_5NH_2$) is a primary aromatic amine. Synthesizing it requires a direct attachment of the amino group to the phenyl ring. We will analyze each reaction pathway systematically to see if aniline is formed as the principal chemical product.

Step 1: Evaluation of Reaction A

Reaction A involves benzonitrile (C_6H_5CN) reacted with lithium aluminum hydride ($LiAlH_4$), a potent reducing agent:

$$C_6H_5 - C \equiv N \xrightarrow{LiAlH_4} C_6H_5 - CH_2 - NH_2$$

The nitrile group undergoes complete reduction to a primary aliphatic amine, yielding **benzylamine** rather than aniline. Thus, Reaction A does not yield aniline.

Step 2: Evaluation of Reaction B

Reaction B treats benzamide ($C_6H_5CONH_2$) with bromine in the presence of potassium hydroxide (KOH, Br_2). This combination represents the classic **Hoffmann Bromamide Degradation Reaction**:

$$C_6H_5 - CONH_2 + Br_2 + 4KOH \rightarrow C_6H_5 - NH_2 + K_2CO_3 + 2KBr + 2H_2O$$

The reaction successfully degrades the amide carbonyl, shortening the chain by one carbon atom to produce a primary amine. The major product is explicitly **aniline**. Hence, Reaction B is a valid path.

Step 3: Evaluation of Reaction C

Reaction C subjects nitrobenzene ($C_6H_5NO_2$) to sodium borohydride ($NaBH_4$). $NaBH_4$ is a selective, relatively mild reducing agent commonly targeted at carbonyl functions (aldehydes and ketones). It is chemically incapable of reducing aromatic nitro groups down to amines under ambient conditions:

$$C_6H_5 - NO_2 \xrightarrow{NaBH_4} \text{No Reaction (Nitro group remains unaffected)}$$

Therefore, Reaction C does not produce aniline.

Step 4: Evaluation of Reaction D

Reaction D involves the acid-catalyzed hydrolysis of acetanilide ($C_6H_5NHCOCH_3$) using aqueous

HCl and heat (Δ):

$$C_6H_5-NH-CO-CH_3+H_2O \xrightarrow{HCl,\Delta} C_6H_5-NH_2+CH_3COOH$$

This clean nucleophilic acyl substitution breaks the amide bond, yielding **aniline** and acetic acid. Hence, Reaction D is a valid path.

Concluding the analyses, pathways **B** and **D** successfully generate aniline as their primary organic product.

Quick Tip: - Hoffmann Bromamide Degradation ($RCONH_2 \xrightarrow{X_2/OH^-} RNH_2$) cuts out the $C=O$ group entirely. - $NaBH_4$ cannot reduce aromatic $-NO_2$ groups; you need active metals in acid (Fe/HCl, Sn/HCl) or catalytic hydrogenation (H_2/Pd) to do that.

---

59. Two moles of an ideal gas undergo free expansion from 10 L to 100 L at 300 K. The values of ΔS_{system} and $\Delta S_{\text{surroundings}}$ are (R is universal gas constant)

(1) $\Delta S_{\text{system}} = 4.606$ R; $\Delta S_{\text{surroundings}} = 0$

(2) $\Delta S_{\text{system}} = 0$; $\Delta S_{\text{surroundings}} = 0$

(3) $\Delta S_{\text{system}} = 4.606$ R; $\Delta S_{\text{surroundings}} = -4.606$ R

(4) $\Delta S_{\text{system}} = 0$; $\Delta S_{\text{surroundings}} = 4.606$ R

Correct Answer: (1) $\Delta S_{\text{system}} = 4.606$ R; $\Delta S_{\text{surroundings}} = 0$

Solution:

Concept: Free expansion describes gas expanding into an absolute vacuum environment. Because there is no opposing external pressure ($P_{\text{ext}} = 0$), the mechanical work performed by the system is zero:

$$W = -P_{\text{ext}}\Delta V = 0$$

For an ideal gas, internal energy (U) depends purely on temperature. Given that the process is explicitly isothermal ($T = 300\text{ K} = \text{constant}$), the change in internal energy must be zero:

$$\Delta U = nC_v\Delta T = 0$$

Applying the First Law of Thermodynamics ($\Delta U = Q + W$), we find that the heat exchanged with the surroundings is also zero:

$$0 = Q + 0 \quad \Rightarrow \quad Q = 0$$

Step 1: Calculating $\Delta S_{\text{surroundings}}$

Entropy changes in the surroundings are governed exclusively by the actual heat transferred across the boundary in a reversible framework, given by:

$$\Delta S_{\text{surroundings}} = \frac{Q_{\text{surr}}}{T} = \frac{-Q_{\text{actual}}}{T}$$

Since the heat exchanged during a free expansion process is exactly $Q_{\text{actual}} = 0$, no thermal energy enters or leaves the surroundings:

$$\Delta S_{\text{surroundings}} = \frac{0}{300} = 0$$

Step 2: Calculating ΔS_{system}

Entropy is a fundamental state function. Even though the process occurs irreversibly, we can calculate the entropy change of the system by integrating along an equivalent reversible isothermal pathway connecting the exact same initial and final states:

$$\Delta S_{\text{system}} = nR \ln\left(\frac{V_2}{V_1}\right) + nC_v \ln\left(\frac{T_2}{T_1}\right)$$

Since temperature is invariant ($T_1 = T_2 = 300$ K), the temperature component drops to zero:

$$\Delta S_{\text{system}} = nR \ln\left(\frac{V_2}{V_1}\right)$$

Converting the natural logarithm into a base-10 logarithm ($\ln x \approx 2.303 \log_{10} x$):

$$\Delta S_{\text{system}} = 2.303 \cdot n \cdot R \cdot \log_{10}\left(\frac{V_2}{V_1}\right)$$

Step 3: Substituting the numerical values into the system equation

We are provided with:

- Number of moles, $n = 2$
- Initial volume, $V_1 = 10$ L
- Final volume, $V_2 = 100$ L

Plugging these parameters into our formulated expression gives:

$$\Delta S_{\text{system}} = 2.303 \times 2 \times R \times \log_{10}\left(\frac{100}{10}\right)$$

$$\Delta S_{\text{system}} = 4.606 \times R \times \log_{10}(10)$$

Knowing that $\log_{10}(10) = 1$:

$$\Delta S_{\text{system}} = 4.606 \cdot R \cdot 1 = 4.606 \text{ R}$$

Thus, we determine that $\Delta S_{\text{system}} = 4.606$ R and $\Delta S_{\text{surroundings}} = 0$.

Quick Tip: For **Free Expansion into a vacuum** ($P_{\text{ext}} = 0$) of an ideal gas: - Work $(W) = 0$, Heat $(Q) = 0$, Temperature change $(\Delta T) = 0$. - Since $Q = 0$, $\Delta S_{\text{surroundings}}$ is **always zero**. - ΔS_{system} depends purely on the volume ratio change: $nR\ln(V_2/V_1)$.

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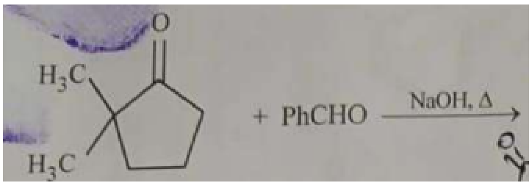
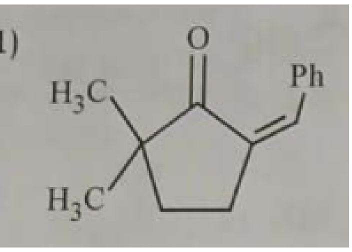
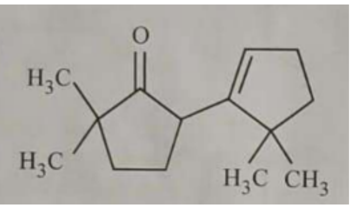
60. The compound that CANNOT be obtained from the aldol condensation reaction shown below, is



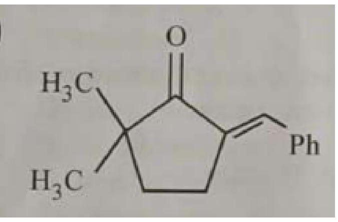
(1)

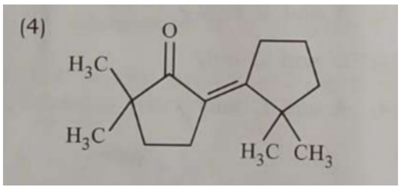


(2)



(3)





(1) FigA

(2) FigB

(3) FigC

(4) FigD **Correct Answer:** (2)

Solution:

Concept: The Aldol condensation reaction relies on the generation of a reactive carbanion enolate. This enolate is created by abstracting an α-hydrogen atom (a hydrogen atom located on a carbon adjacent to the carbonyl carbon) using a base like NaOH.

Let's examine the two starting materials provided:

1. **Benzaldehyde (PhCHO):** Lacks any α-hydrogens. Therefore, it cannot form an enolate ion and can only act as an electrophilic carbonyl acceptor.

2. **2,2-dimethylcyclopentanone:** Let's evaluate its two α-carbon positions relative to its ketone group:

   - One α-carbon is quaternary, carrying two methyl substituents ($-C(CH_3)_2-$). It contains **zero α-hydrogens**.
   - The opposite α-carbon is a methylene unit ($-CH_2-$). It possesses **two reactive α-hydrogens**.

Step 1: Analyzing the mechanism for cross-aldol condensation with benzaldehyde

The base abstracts an α-hydrogen from the -CH_2- side of 2,2-dimethylcyclopentanone to yield a specific enolate intermediate. This enolate attacks the carbonyl group of benzaldehyde (PhCHO). Dehydration (loss of H_2O) follows immediately under heating conditions (Δ), installing a double bond directed toward the phenyl ring: This condensation safely forms **5-benzylidene-2,2-dimethylcyclopentanone**, which corresponds perfectly to the configurations displayed in structures (1) and (3) (representing geometric isomers *E* and *Z* configurations across the newly formed double bond).

Step 2: Analyzing the mechanism for self-aldol condensation

Alternatively, the same enolate formed from 2,2-dimethylcyclopentanone can attack the carbonyl carbon of another unreacted molecule of 2,2-dimethylcyclopentanone. Let's trace the connection:

- The enolate carbon (carbon-5) forms a bond with carbon-1 (the carbonyl carbon) of the second molecule.
- Upon subsequent dehydration, a double bond is formed directly between carbon-5 of the first ring and carbon-1 of the second ring.

Looking at structure (4), it accurately illustrates this self-condensation compound, featuring an endocyclic carbonyl group on one ring connected via an exocyclic double bond to the unsubstituted position of the second cyclopentane ring. Thus, (4) is a viable product.

Step 3: Evaluating Structure (2)

Structure (2) depicts a single bond linking the two cyclopentane fragments, where the second ring contains an endocyclic double bond ($-C=CH-$) that leaves the adjacent carbon carrying the geminal methyl groups. In a standard aldol condensation, the elimination of the hydroxyl group takes place directly from the β-position to give an α,β-unsaturated carbonyl system. The double bond configuration in (2) lacks conjugation with a carbonyl group and cannot be structurally generated from any reasonable elimination pathway under these conditions. Hence, the compound shown in option (2) **cannot** be obtained.

Quick Tip: To solve aldol condensation predicting problems: 1. Locate the active α-hydrogens. Here, they reside exclusively on the single -CH_2— group of the ketone. 2. The condensation product must feature a double bond connected directly to that specific carbon. 3. Structures (1), (3), and (4) maintain this connectivity. Structure (2) fails to maintain an α,β-unsaturated framework conjugated with the carbonyl.

---

61. The complex which has *facial* and *meridional* isomers is

(Given : py = pyridine and en = $H_2N-CH_2-CH_2-NH_2$)

(1) $[Ni(en)_2(H_2O)_2]^{2+}$

(2) $[Cr(py)_3(Cl)_3]$

(3) $[Cr(H_2O)_6]^{3+}$

(4) $[Co(NH_3)_4(H_2O)_2]^{3+}$

Correct Answer: (2) $[Cr(py)_3(Cl)_3]$

Solution:

Concept: Facial (*fac*) and meridional (*mer*) isomerism is a specific category of geometrical isomerism observed exclusively in octahedral complexes with an empirical formula of the type $[MA_3B_3]$, where M denotes the central metal ion, and A and B represent monodentate ligands.

- **Facial (*fac*) Isomer:** Occurs when the three identical ligands occupy three adjacent positions on a single octahedral face (clumped together corner-to-corner).
- **Meridional (*mer*) Isomer:** Occurs when the three identical ligands occupy positions around an arc or meridian that encircles the metal ion (forming a T-shape pattern).

Step 1: Classifying Option (1)

The complex $[Ni(en)_2(H_2O)_2]^{2+}$ matches the structural profile $[M(XX)_2B_2]$, where en behaves as a didentate chelating ligand. This class of coordination compound displays standard *cis*- and *trans*- geometrical isomerism, but lacks the structural symmetry required to define *fac*/*mer* spatial configurations.

Step 2: Classifying Option (2)

The complex $[Cr(py)_3(Cl)_3]$ features a central chromium ion surrounded by three monodentate pyridine (py) ligands and three monodentate chloride (Cl^-) ligands. This aligns perfectly with the generic structural format:

$$[MA_3B_3] \quad \text{where } M = Cr^{3+},\ A = \text{py},\ B = Cl^-$$

Because it contains exactly two distinct sets of three identical monodentate ligands, it can be arranged into distinct *facial* and *meridional* stereoisomers.

Step 3: Classifying Option (3)

The complex $[Cr(H_2O)_6]^{3+}$ takes the basic molecular formula $[MA_6]$. Since all six coordinating groups are completely identical ligand molecules, no structural or geometric isomerism can exist.

Step 4: Classifying Option (4)

The complex $[Co(NH_3)_4(H_2O)_2]^{3+}$ conforms to the standard coordination blueprint $[MA_4B_2]$. This type of complex possesses two geometric orientations, designated as *cis*- (ligands separated by 90°) and *trans*- (ligands separated by 180°), rather than exhibiting *fac*/*mer* isomerism.

Thus, only complex (2) supports facial and meridional isomerism.

Quick Tip: Keep this structural template locked in memory: - ***fac-mer* isomerism** requires an octahedral system strictly following the configuration [$\mathbf{MA_3B_3}$]. - Scan options immediately for a combination of $3+3$ monodentate ligands. Here, 3 pyridine + 3 chloride make option (2) an instant match.

---

62. The numbers 17.0145 **and** 21.0235 **were rounded to three figures after the decimal point. The resulting numbers, respectively, are**

(1) 17.015 and 21.024

(2) 17.014 and 21.023

(3) 17.015 and 21.023

(4) 17.014 and 21.024

Correct Answer: (4) 17.014 and 21.024

Solution:

Concept: When rounding numbers to a specified number of decimal places, standard scientific rounding rules (often called the round-to-nearest-even rule or bankers' rounding) apply to eliminate rounding bias when the digit to be dropped is exactly 5.

Rules for rounding when the trailing digit is exactly 5:

- Identify the last digit to be retained (the target place).
- Look at the digit immediately following it. If that next digit is exactly 5 (with no non-zero digits following it):
  - If the digit to be retained is **even**, leave it unchanged.
  - If the digit to be retained is **odd**, increase it by 1 to make it even.

Step 1: Rounding the value 17.0145

We want to round to three figures after the decimal point.

- The third digit after the decimal point is 4.
- The digit immediately following it is 5.
- We examine the value of our target third decimal digit: 4 is an **even number**.
- Applying the rule for an even preceding digit, we leave it unchanged.
- Result: 17.014

Step 2: Rounding the value 21.0235

We want to round to three figures after the decimal point.

- The third digit after the decimal point is 3.
- The digit immediately following it is 5.
- We examine the value of our target third decimal digit: 3 is an **odd number**.
- Applying the rule for an odd preceding digit, we increase it by 1 to make it even $(3+1=4)$.
- Result: 21.024

Combining our calculations, the rounded values are 17.014 and 21.024.

Quick Tip: Scientific Rounding Rule for a terminal 5: - Even + 5 $\rightarrow$ Stays Same (e.g., 45 $\rightarrow$ 4) - Odd + 5 $\rightarrow$ Rounds Up (e.g., 35 $\rightarrow$ 4) This protocol minimizes cumulative statistical skew in large experimental datasets.

---

63. The amount of carbon dioxide evolved upon complete combustion of 116 g of *n*-butane is (Given: atomic mass in amu H = 1, C = 12 and O = 16)

(1) 362 g
(2) 352 g
(3) 322 g
(4) 176 g

Correct Answer: (2) 352 g

Solution:

Concept: Stoichiometry allows us to calculate mass relationships in a balanced chemical equation. Complete combustion of any alkane hydrocarbon produces carbon dioxide (CO_2) gas and water vapor (H_2O) as the only products.

Step 1: Write and balance the combustion equation for *n*-butane

The molecular formula for *n*-butane is C_4H_{10}. Let's construct its balanced combustion equation with gaseous oxygen (O_2):

$$C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O$$

Multiplying through by 2 to clear the fraction yields integer stoichiometric coefficients:

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

Step 2: Calculate the molar masses of the relevant substances

Using the given atomic masses, we compute:

- Molar mass of *n*-butane (C_4H_{10}):

$$\text{Molar Mass} = (4 \times 12) + (10 \times 1) = 48 + 10 = 58 \text{ g/mol}$$

- Molar mass of Carbon Dioxide (CO_2):

$$\text{Molar Mass} = (1 \times 12) + (2 \times 16) = 12 + 32 = 44 \text{ g/mol}$$

Step 3: Determine the total number of moles of butane reacted

We are given an initial mass of 116 g of *n*-butane.

$$\text{Number of moles of } C_4H_{10} = \frac{\text{Given Mass}}{\text{Molar Mass}} = \frac{116 \text{ g}}{58 \text{ g/mol}} = 2 \text{ moles}$$

Step 4: Use molar ratios to find the mass of evolved CO_2

From our balanced chemical equation, 1 mole of C_4H_{10} completely yields 4 moles of CO_2. Therefore, the number of moles of CO_2 produced by 2 moles of butane is:

$$\text{Moles of } CO_2 = 2 \text{ moles of } C_4H_{10} \times 4 = 8 \text{ moles}$$

Now, convert the moles of carbon dioxide into total mass in grams:

$$\text{Mass of } CO_2 = \text{Moles} \times \text{Molar Mass}$$

$$\text{Mass of } CO_2 = 8 \text{ moles} \times 44 \text{ g/mol} = 352 \text{ g}$$

Thus, the total amount of carbon dioxide evolved is equal to 352 g.

> **Quick Tip:** Always use standard mole conversions to simplify stoichiometric calculations:
>
> $$\text{Mass of product} = \left(\frac{\text{Mass of Reactant}}{\text{Molar Mass of Reactant}}\right) \times (\text{Mole Ratio}) \times (\text{Molar Mass of Product})$$
>
> Here: $\frac{116}{58} \times 4 \times 44 = 2 \times 4 \times 44 = 352$ g.

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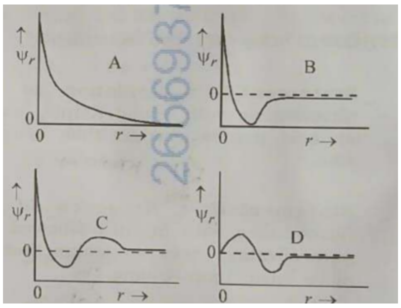
64. Consider the following schematic plots of orbital wavefunction (ψ_r) against distance (r) from the nucleus.



The figure representing two radial nodes in the orbital is

(1) D

(2) A

(3) B

(4) C

Correct Answer: (4) C

Solution:

Concept: A radial node is a spherical region surrounding the atomic nucleus where the probability of finding an electron drops identically to zero. Mathematically, this corresponds to coordinates where the radial wavefunction changes sign, crossing the zero axis:

$$\psi_r = 0$$

On a schematic plot graphing ψ_r as a function of distance r from the nucleus:

- A radial node is graphically indicated by each instance where the wavefunction plot **crosses the horizontal zero line** (r-axis), excluding the asymptotic approach to zero at infinite distance ($r \to \infty$).

Step 1: Analyzing Plot A

In Plot A, the wavefunction starts at a high positive value near the nucleus ($r = 0$) and decays smoothly and exponentially toward zero as distance increases. It never intersects or crosses the zero axis. This indicates **0 radial nodes** (typical of a 1s orbital).

Step 2: Analyzing Plot B

In Plot B, the curve begins at a high value at $r = 0$, plunges downward to cross the zero baseline into negative values, reaches a local minimum, and then asymptotically rises back toward zero. It crosses the horizontal axis exactly once. This represents an orbital with **1 radial node** (characteristic of a 2s orbital).

Step 3: Analyzing Plot C

In Plot C, the curve begins at a high value at $r = 0$, travels downward to cross the zero axis into negative territory, turns around to cross the zero axis a **second time** back into positive values, and then levels out toward zero at extended distances. Since the line crosses the zero line at two separate finite distances, it represents an orbital possessing exactly **2 radial nodes** (characteristic of a 3s orbital).

Step 4: Analyzing Plot D

In Plot D, the wavefunction starts exactly at zero at the nucleus ($r = 0$), which is typical for non-s orbitals (p, d, f, etc.) because the angular momentum quantum number $l > 0$. The curve increases to a positive peak, drops down to cross the zero baseline once into a negative trough, and then approaches the axis asymptotically. It has exactly **1 radial node**.

Therefore, Figure **C** is the correct plot containing exactly two radial nodes.

Quick Tip: To count radial nodes from a graph of ψ_r vs r: - Count the number of times the curve completely cuts through the $\psi_r = 0$ line (do not count the origin $r = 0$ or the far right end where it flattens out). - Graph C cuts the line twice → 2 radial nodes.

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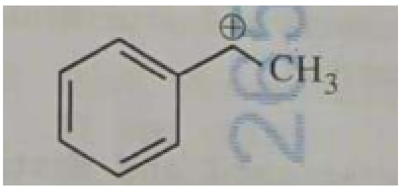
65. The following carbocation is stabilized by the interaction of the empty p orbital with



(1) empty σ^* and empty π^* orbitals

(2) filled σ and filled π orbitals

(3) empty σ and empty π^* orbitals

(4) empty σ^* and filled π orbitals

Correct Answer: (2) filled σ and filled π orbitals

Solution:

Concept: Carbocations are highly reactive, electron-deficient species containing a positively charged carbon atom with an **empty valence p orbital**. The stability of a carbocation relies on electron-donation mechanisms that share electron density into this empty orbital. Two main intramolecular mechanisms accomplish this:

1. **Resonance / Delocalization:** Electron density from neighboring filled π bonds shifts into the empty p orbital.
2. **Hyperconjugation:** Electron density from neighboring filled σ bonds (typically $C-H$ or $C-C$ bonds) delocalizes into the empty p orbital.

Step 1: Identifying structural features of the given carbocation

The molecule illustrated is a benzylic-type carbocation containing an adjacent methyl group:

$$C_6H_5-\overset{\oplus}{C}H-CH_3$$

Let's analyze how the electron-deficient center interacts with both sides of the molecule:

Step 2: Analyzing interactions with the benzene ring (π-system)

The positively charged carbon is directly bonded to an sp^2-hybridized carbon of the aromatic benzene ring. The **filled π molecular orbitals** of the aromatic ring align parallel to the empty p orbital of the carbocation. This allows electron density to delocalize into the empty p orbital through resonance, stabilizing the charge over the ortho and para positions of the ring.

Step 3: Analyzing interactions with the methyl group (σ-system)

On the other side, the carbocation is bonded directly to a -CH_3 group. The **filled σ orbitals** of the adjacent $C-H$ bonds align correctly to donate electron density into the empty p orbital of the carbocation through hyperconjugation.

Conclusion:

The empty p orbital of the carbocation acts as an electron acceptor that receives stabilizing electron density from the surrounding **filled π orbitals** of the benzene ring and the **filled σ orbitals** of the adjacent $C-H$ group. Therefore, the stabilizing interactions involve filled σ and filled π orbitals.

Quick Tip: Stabilization of electron-deficient carbocations always requires electron donation from an filled orbital source into an empty destination: - Filled Orbital (Donor) → Empty Orbital (Acceptor) - In this benzylic carbocation system, the donors are the filled π-orbitals of the aromatic ring (resonance) and the filled σ-orbitals of the $C-H$ bonds (hyperconjugation).

---

66. A 1:3 electrolyte in an aqueous solution is

(1) $[Co(NH_3)_3(NO_2)_3]$

(2) $[CoCl_2(NH_3)_4]Cl$

(3) $[CoCl(NH_3)_5]Cl_2$

(4) $[Co(NH_3)_6]Cl_3$

Correct Answer: (4) $[Co(NH_3)_6]Cl_3$

Solution:

Concept: When a coordination compound dissolves in an aqueous solution, the chemical species inside the square brackets (the coordination sphere) remain intact as a single complex ion. The species outside the square brackets (the counter-ions in the ionization sphere) dissociate completely into individual ions.

An $x : y$ electrolyte means that upon dissociation, each formula unit produces x cation(s) and y anion(s), or vice versa, established by the respective charges of the dissociated units. Specifically, a 1:3 electrolyte releases one cation carrying a $+3$ charge and three anions each carrying a -1 charge, or one anion with a -3 charge and three cations with a $+1$ charge.

Let us comprehensively analyze the dissociation behavior of each given coordination complex in an aqueous medium:

1. **Analysis of Option (1):** $[\mathbf{Co(NH_3)_3(NO_2)_3}]$ This molecule has no counter-ions present outside the coordination sphere. Therefore, when introduced to water, it does not dissociate into separate ions. It remains as a neutral, non-electrolyte complex molecule:

$$[Co(NH_3)_3(NO_2)_3] \xrightarrow{H_2O} \text{No dissociation (Non-electrolyte)}$$

Total ions produced per formula unit $= 0$. Hence, this cannot be a 1:3 electrolyte.

2. **Analysis of Option (2):** $[\mathbf{CoCl_2(NH_3)_4}]\mathbf{Cl}$ This compound contains one chloride ion in its ionization sphere. Upon complete dissolution, it dissociates into one complex cation

and one chloride anion:

$$[CoCl_2(NH_3)_4]Cl \xrightarrow{H_2O} [CoCl_2(NH_3)_4]^+ + Cl^-$$

This dissociation yields a total of 2 ions in a 1:1 ratio. Thus, it represents a 1:1 electrolyte.

3. **Analysis of Option (3): $[CoCl(NH_3)_5]Cl_2$** This complex contains two chloride counter-ions outside the coordination bracket. In an aqueous medium, it undergoes complete ionization to form one complex cation carrying a +2 charge and two chloride anions:

$$[CoCl(NH_3)_5]Cl_2 \xrightarrow{H_2O} [CoCl(NH_3)_5]^{2+} + 2Cl^-$$

This dissociation produces a total of 3 ions in a 1:2 ratio. Therefore, it acts as a 1:2 electrolyte.

4. **Analysis of Option (4): $[Co(NH_3)_6]Cl_3$** Here, three chloride ions reside outside the coordination sphere. When dissolved in water, the compound breaks up completely to form a single hexamminecobalt(III) complex cation with a +3 charge, along with three separate chloride anions:

$$[Co(NH_3)_6]Cl_3 \xrightarrow{H_2O} [Co(NH_3)_6]^{3+} + 3Cl^-$$

This ionization releases 1 cation and 3 anions, which perfectly matches the definition of a 1:3 electrolyte.

Quick Tip: To easily identify the type of electrolyte for a coordination complex, look only at the counter-ions outside the square brackets. If there are n mono-negative counter-ions outside, the complex will dissociate into 1 complex cation and n anions, making it a $1 : n$ electrolyte.

---

67. The standard electrode potential (E°) for the half-cell reaction $Fe^{3+} + e^- \rightarrow Fe^{2+}$ at 298 K is (Given: $E^\circ(Fe^{3+}/Fe) = -0.04$ V and $E^\circ(Fe^{2+}/Fe) = -0.44$ V at 298 K)

(1) +0.92 V

(2) +0.40 V

(3) +0.76 V

(4) −0.48 V

Correct Answer: (3) +0.76 V

Solution:

Concept: Standard electrode potentials (E°) are intensive thermodynamic properties and cannot be added or subtracted directly when combining half-cell reactions with different numbers of transferred electrons. To find the unknown potential of a combined half-reaction, we must convert the potentials into their corresponding standard Gibbs free energy changes (ΔG°), which is an extensive property and can be linearly combined.

The mathematical connection between the standard Gibbs free energy change and the standard reduction potential is given by:

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

Where:

- n is the number of moles of electrons transferred in the specific half-reaction.
- F is the Faraday constant (96485 C mol^{-1}).
- E° is the standard reduction potential of the half-cell.

Let us define the given half-cell reactions along with their respective numbers of electrons and reduction potentials:

Step 1: Write down the thermodynamic components for the first given half-reaction.

The reduction of Fe^{3+} to metallic iron Fe is represented by:

$$\text{Reaction 1:} \quad \mathrm{Fe}^{3+} + 3e^- \rightarrow \mathrm{Fe}$$

For this half-cell, the number of electrons transferred is $n_1 = 3$, and the standard reduction potential is given as $E_1^\circ = -0.04$ V. The corresponding change in standard Gibbs free energy is:

$$\Delta G_1^\circ = -n_1 F E_1^\circ = -3 \times F \times (-0.04) = +0.12F \quad \cdots (1)$$

Step 2: Write down the thermodynamic components for the second given half-reaction.

The reduction of Fe^{2+} to metallic iron Fe is represented by:

$$\text{Reaction 2:} \quad \mathrm{Fe}^{2+} + 2e^- \rightarrow \mathrm{Fe}$$

For this half-cell, the number of electrons transferred is $n_2 = 2$, and the standard reduction potential is given as $E_2^\circ = -0.44$ V. The corresponding change in standard Gibbs free energy is:

$$\Delta G_2^\circ = -n_2 F E_2^\circ = -2 \times F \times (-0.44) = +0.88F \quad \cdots (2)$$

Step 3: Establish the target half-reaction using algebraic combination.

Our target half-cell reaction is:

$$\text{Target Reaction:} \quad \text{Fe}^{3+} + e^- \longrightarrow \text{Fe}^{2+}$$

Let its unknown reduction potential be denoted as E_3° and its number of electrons be $n_3 = 1$. The target Gibbs free energy expression is:

$$\Delta G_3^\circ = -n_3 F E_3^\circ = -1 \times F \times E_3^\circ = -F E_3^\circ \quad \cdots (3)$$

Now, observe how we can algebraically combine Reaction 1 and Reaction 2 to yield the target equation:

$$\text{Reaction 1:} \quad \text{Fe}^{3+} + 3e^- \longrightarrow \text{Fe}$$

$$\text{Reverse of Reaction 2:} \quad \text{Fe} \longrightarrow \text{Fe}^{2+} + 2e^-$$

Adding these two expressions gives:

$$\text{Fe}^{3+} + 3e^- + \text{Fe} \longrightarrow \text{Fe} + \text{Fe}^{2+} + 2e^-$$

Canceling out Fe and $2e^-$ from both sides leads directly to our target equation:

$$\text{Fe}^{3+} + e^- \longrightarrow \text{Fe}^{2+}$$

Because the target reaction is obtained by subtracting Reaction 2 from Reaction 1, we can apply the exact same linear combination to their extensive Gibbs free energy values:

$$\Delta G_3^\circ = \Delta G_1^\circ - \Delta G_2^\circ$$

Step 4: Substitute the expressions to calculate the final potential E_3°.

Substitute equations (1), (2), and (3) into the free energy relationship:

$$-FE_3^\circ = 0.12F - 0.88F$$

We can divide the entire equation by the common factor $-F$:

$$E_3^\circ = -(0.12 - 0.88)$$

$$E_3^\circ = -(-0.76) = +0.76\text{ V}$$

Thus, the standard electrode potential for the Fe^{3+}/Fe^{2+} half-cell is +0.76 V.

Quick Tip: Never add or subtract E° values directly unless the number of electrons transferred in all reactions is exactly identical. Always convert to ΔG° components using the formula $\Delta G^\circ = -nFE^\circ$, or use the shortcut formula for consecutive states: $E_3^\circ = \frac{n_1E_1^\circ - n_2E_2^\circ}{n_3}$.

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68. In potash alum, the ratio of K^+ and SO_4^{2-} ions is

(1) 3 : 2

(2) 1 : 2

(3) 2 : 1

(4) 2 : 3

Correct Answer: (2) 1 : 2

Solution:

Concept: Potash alum is a classic example of a double salt. A double salt is a crystalline molecular compound that exists as a single stable solid structure but dissociates completely into its individual constituent simple ions when dissolved in water or any other aqueous solvent. To evaluate the ionic ratios correctly, one must look at the exact stoichiometric coefficients of the ions present in its balanced chemical formula.

Step 1: Write down the chemical formula of potash alum.

The chemical composition of potash alum (potassium aluminum sulfate dodecahydrate) is represented by the formula:

$$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$$

Step 2: Trace the ionization behavior in aqueous solution.

When potash alum is dissolved in water, the crystal lattice breaks apart fully, releasing all of its constituent cations and anions into the medium. The balanced ionization equation can be written as follows:

$$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O \xrightarrow{H_2O} 2K^+_{(aq)} + 2Al^{3+}_{(aq)} + 4SO_4^{2-}{}_{(aq)} + 24H_2O_{(l)}$$

Let us carefully count the total number of specific ions released from one single formula unit of the double salt:

- Number of potassium ions (K^+) $= 2$ (coming entirely from the K_2SO_4 unit)
- Number of aluminum ions (Al^{3+}) $= 2$ (coming entirely from the $Al_2(SO_4)_3$ unit)
- Number of sulfate ions (SO_4^{2-}) $= 1 + 3 = 4$ (1 from K_2SO_4 and 3 from $Al_2(SO_4)_3$)

Step 3: Compute the required ionic ratio.

The problem specifically asks for the ratio of the number of K^+ ions to the number of SO_4^{2-} ions. Using our counted values:

$$\text{Ratio} = \frac{\text{Number of } K^+ \text{ ions}}{\text{Number of } SO_4^{2-} \text{ ions}} = \frac{2}{4}$$

Simplifying this fraction by dividing both the numerator and the denominator by their greatest common divisor, which is 2, gives:

$$\text{Ratio} = \frac{1}{2} = 1 : 2$$

Hence, the stoichiometric ratio of K^+ to SO_4^{2-} ions in an aqueous solution of potash alum is 1 : 2.

Quick Tip: Always remember the empirical formula of potash alum can also be written in its simplified form as $KAl(SO_4)_2 \cdot 12H_2O$. In this format, you can read the ratio directly from the subscripts: there is 1 potassium ion for every 2 sulfate ions, giving the answer 1 : 2 instantly.

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69. Consider the following statements about the solutions formed by mixing two liquids.

A. An ideal solution thus formed obeys Raoult's law throughout the composition range.

B. **Mixture of chloroform and acetone shows negative deviation from Raoult's law.**

C. **Mixture of aniline and phenol shows positive deviation from Raoult's law.**

Select the correct option:

(1) A and C only

(2) A and B only

(3) B and C only

(4) A only

Correct Answer: (2) A and B only

Solution:

Concept: Binary solutions composed of volatile liquids are categorized into ideal and non-ideal solutions based on how they interact and whether they adhere to Raoult's Law:

- **Ideal Solutions:** Obeys Raoult's law precisely at all temperatures and across the entire range of concentrations. For an ideal mixture of components A and B, the intermolecular forces between the different molecules ($A-B$ interactions) are exactly equal in magnitude to the pure component interactions ($A-A$ and $B-B$ interactions). Consequently, $\Delta H_{\text{mixing}} = 0$ and $\Delta V_{\text{mixing}} = 0$.

- **Non-Ideal Solutions with Negative Deviation:** Occurs when the new intermolecular attractive forces between unequal components ($A-B$) are significantly stronger than the cohesive forces present in the isolated pure liquids ($A-A$ and $B-B$). This stronger binding holds molecules more tightly in the liquid phase, decreasing their tendency to escape into the vapor state. As a result, the total vapor pressure of the solution is lower than predicted by Raoult's law. Here, $\Delta H_{\text{mixing}} < 0$ and $\Delta V_{\text{mixing}} < 0$.

- **Non-Ideal Solutions with Positive Deviation:** Occurs when the adhesive interactions between the components ($A-B$) are weaker than the pure component self-interactions ($A-A$ and $B-B$). This makes it easier for molecules to break away into the gas phase, raising the vapor pressure above the theoretical Raoult's law curve. Here, $\Delta H_{\text{mixing}} > 0$ and $\Delta V_{\text{mixing}} > 0$.

Let us evaluate each statement carefully to determine its accuracy:

Step 1: Evaluation of Statement A.

"*An ideal solution thus formed obeys Raoult's law throughout the composition range.*"

By standard thermodynamic definition, a solution is classified as ideal if and only if the partial vapor pressure of each volatile component in the mixture is directly proportional to its mole fraction at all concentrations and temperatures. Thus, statement A is completely **correct**.

Step 2: Evaluation of Statement B.

"*Mixture of chloroform ($CHCl_3$) and acetone (CH_3COCH_3) shows negative deviation from Raoult's law.*"

In pure acetone, molecules are held together by ordinary dipole-dipole interactions. Similarly, pure chloroform molecules experience weak dipole-dipole interactions. However, when chloroform and acetone are mixed together, a strong intermolecular hydrogen bond forms between the highly polarized hydrogen atom of chloroform and the electronegative oxygen atom of the acetone carbonyl group:

$$(\mathrm{CH_3})_2\mathrm{C}=\mathrm{O}\cdots\mathrm{H}-\mathrm{CCl_3}$$

Because these newly formed cross-interactions (A—B) are stronger than the original interactions ($A-A$ and $B-B$), the escaping tendency of both molecules decreases, dropping the vapor pressure below the ideal threshold. This constitutes a negative deviation. Thus, statement B is completely **correct**.

Step 3: Evaluation of Statement C.

"*Mixture of aniline and phenol shows positive deviation from Raoult's law.*"

Phenol (C_6H_5OH) contains an acidic hydroxyl hydrogen, while aniline ($C_6H_5NH_2$) contains a basic lone pair on its nitrogen atom. When aniline and phenol are blended together, the intermolecular hydrogen bonding between the phenolic proton and the nitrogen lone pair of aniline is significantly stronger than the self-hydrogen bonding present in pure phenol or pure aniline.

Because the $A-B$ intermolecular forces are stronger than the $A-A$ and $B-B$ forces, this mixture exhibits a **negative deviation** from Raoult's law, not a positive deviation. Therefore, statement C is **incorrect**.

Combining our individual assessments, statements A and B are correct, while statement C is false. This corresponds directly to option (2).

Quick Tip: Whenever mixing two components results in the formation of new, stronger bonds (like hydrogen bonding between chloroform-acetone or phenol-aniline), the molecules are held tightly in the liquid phase. This always results in a lower vapor pressure, meaning a **negative deviation** from Raoult's Law.

70. For a salt XY, which is a strong electrolyte, the plot of Λ_m versus $\sqrt{c}$ has a slope of -90.0 S cm^2 mol$^{-3/2}$ L$^{1/2}$ at 298 K. At 0.01 M concentration of XY, the value of Λ_m is 145.0 S cm^2 mol^{-1}. The limiting molar conductivity of Y^- ion ($\lambda^\circ_{Y^-}$, in S cm^2 mol^{-1}) at 298 K will be (Given: $\lambda^\circ_{X^+} = 74.0$ S cm^2 mol^{-1})

(1) 76.0

(2) 80.0

(3) 100.0

(4) 90.0

Correct Answer: (2) 80.0

Solution:

Concept: For strong electrolytes, the variation of molar conductivity (Λ_m) with concentration (c) follows a linear relationship at low concentrations. This physical behavior is accurately modeled by the **Debye-Huckel-Onsager equation**:

$$\Lambda_m = \Lambda^\circ_m - A\sqrt{c}$$

Where:

- Λ_m is the molar conductivity at a given concentration c.
- Λ°_m is the limiting molar conductivity (the molar conductivity at infinite dilution).
- A is a constant that depends on the valence of the electrolyte, the nature of the solvent, and the absolute temperature.
- The slope of the plot of Λ_m versus $\sqrt{c}$ is equal to $-A$.

Additionally, according to **Kohlrausch's Law of Independent Migration of Ions**, the limiting molar conductivity of a total electrolyte can be expressed as the sum of the individual limiting molar conductivities of its component cations and anions. For a 1:1 salt like XY, which dissociates completely via $XY \to X^+ + Y^-$, the relation is:

$$\Lambda^\circ_m(XY) = \lambda^\circ_{X^+} + \lambda^\circ_{Y^-}$$

Let us carefully execute the calculation across structured steps:

Step 1: Extract and interpret information from the given data.

We are provided with the following parameters:

- Slope of the Λ_m vs $\sqrt{c}$ plot $= -90.0$ S cm^2 mol$^{-3/2}$ L$^{1/2}$. Comparing this to the equation $\Lambda_m = \Lambda_m^\circ - A\sqrt{c}$, we have:

$$\text{Slope} = -A = -90.0 \quad \Rightarrow \quad A = 90.0$$

- Molarity / Concentration of the solution, $c = 0.01$ M
- Molar conductivity at this concentration, $\Lambda_m = 145.0$ S cm^2 mol^{-1}
- Limiting molar conductivity of the cation, $\lambda^\circ_{X^+} = 74.0$ S cm^2 mol^{-1}

Step 2: Calculate the overall limiting molar conductivity Λ_m° of the salt XY.

Substitute our values directly into the Debye-Huckel-Onsager equation:

$$145.0 = \Lambda_m^\circ - 90.0 \times \sqrt{0.01}$$

Since $\sqrt{0.01} = \sqrt{\frac{1}{100}} = \frac{1}{10} = 0.1$, the equation simplifies to:

$$145.0 = \Lambda_m^\circ - 90.0 \times 0.1$$

$$145.0 = \Lambda_m^\circ - 9.0$$

Isolating Λ_m° by moving 9.0 to the left side:

$$\Lambda_m^\circ = 145.0 + 9.0 = 154.0 \text{ S cm}^2 \text{ mol}^{-1}$$

Step 3: Apply Kohlrausch's law to solve for the unknown ionic conductivity $\lambda^\circ_{Y^-}$.

Using the additive property for the 1:1 electrolyte XY:

$$\Lambda_m^\circ(\text{XY}) = \lambda^\circ_{X^+} + \lambda^\circ_{Y^-}$$

Substitute the computed value of $\Lambda_m^\circ = 154.0$ and the given value of $\lambda^\circ_{X^+} = 74.0$:

$$154.0 = 74.0 + \lambda^\circ_{Y^-}$$

Subtract 74.0 from both sides to find the limiting molar conductivity of the anion Y^-:

$$\lambda^\circ_{Y^-} = 154.0 - 74.0$$

$$\lambda^\circ_{Y^-} = 80.0 \text{ S cm}^2 \text{ mol}^{-1}$$

The limiting molar conductivity of the Y^- ion is 80.0 S cm^2 mol^{-1}, which corresponds to option (2).

Quick Tip: Be extra precise when calculating the square root of concentration decimals. For example, $\sqrt{0.01} = 0.1$, not 0.01. Once you successfully solve for the total limiting conductance Λ°_m, simply subtract the value of the known ion to get the unknown ion instantly.

---

71. Arrange the following compounds in the increasing order of polarity:

A. $CH_3CH_2OCH_2CH_3$

B. CH_3CH_2OH

C. CH_3COCH_3

D. CH_3COOH

Choose the correct answer from the options given below:

(A) $A < C < B < D$

(B) $A < B < C < D$

(C) $C < A < D < B$

(D) $C < A < B < D$

Correct Answer: (1) $A < C < B < D$

Solution:

Concept:
Polarity of an organic compound depends upon the magnitude of charge separation within the molecule. The greater the difference in electronegativity between bonded atoms and the greater the resultant dipole moment, the more polar the molecule becomes.
The polarity of common oxygen-containing organic compounds generally follows the trend:

$$\text{Ether} < \text{Ketone} < \text{Alcohol} < \text{Carboxylic Acid}$$

This trend arises because alcohols and carboxylic acids are capable of extensive intermolecular hydrogen bonding, while ethers and ketones are comparatively less polar.

Step 1: Examine compound A $(CH_3CH_2OCH_2CH_3)$**.**
Compound A is diethyl ether.
Although oxygen is electronegative and creates a dipole in the C–O bonds, the molecule contains only one oxygen atom and no O–H bond.
Therefore, hydrogen bonding is absent and the overall polarity is comparatively low.
Hence, ether is the least polar among the given compounds.

$$A = CH_3CH_2OCH_2CH_3$$

Step 2: Examine compound C (CH_3COCH_3)**.**
Compound C is acetone, a ketone.
The carbonyl group $(C = O)$ possesses a strong dipole due to the large electronegativity difference between carbon and oxygen.
Therefore, ketones are more polar than ethers.

$$A < C$$

Step 3: Examine compound B (CH_3CH_2OH)**.**
Compound B is ethanol.
The presence of the O–H bond makes alcohols capable of intermolecular hydrogen bonding.
Hydrogen bonding significantly increases polarity compared to ketones.
Therefore,

$$C < B$$

Step 4: Examine compound D (CH_3COOH).

Compound D is acetic acid.

Carboxylic acids contain both a carbonyl group ($C = O$) and a hydroxyl group ($O - H$).

As a result, they possess very strong intermolecular hydrogen bonding and exist as dimers.

This makes them the most polar among the given compounds.

Hence,

$$B < D$$

Step 5: Write the final increasing order.

Combining all the comparisons obtained above:

$$A < C < B < D$$

Thus, the correct option is

$$\boxed{(1) A < C < B < D}$$

Quick Tip: Remember the general order of polarity for common oxygen-containing organic compounds:

$$\text{Ether} < \text{Ketone} < \text{Alcohol} < \text{Carboxylic Acid}$$

The presence and strength of hydrogen bonding play a major role in determining molecular polarity.

---

72. According to crystal field theory, the correct order of ligands with respect to their decreasing order of field strength is

(A) $Cl^- > NH_3 > H_2O > CO$

(B) $CO > NH_3 > H_2O > Cl^-$

(C) $CO > H_2O > NH_3 > Cl^-$

(D) $Cl^- > H_2O > NH_3 > CO$

Correct Answer: (2) $CO > NH_3 > H_2O > Cl^-$

Solution:

Concept:

According to Crystal Field Theory (CFT), ligands are classified as weak-field ligands and strong-field ligands based on their ability to split the d-orbitals of a central metal ion.

A stronger ligand produces a larger crystal field splitting energy (Δ).

The spectrochemical series provides the experimentally observed order of ligand field strength.

A portion of the spectrochemical series is:

$$I^- < Br^- < Cl^- < F^- < OH^- < H_2O < NH_3 < CN^- < CO$$

Field strength increases from left to right.

Step 1: Identify the strongest ligand.

Among the given ligands,

$$CO$$

is a very strong-field ligand because it acts as both a sigma donor and a pi acceptor.

It causes maximum crystal field splitting.

Therefore,

$$CO$$

must be placed first.

Step 2: Compare NH_3 and H_2O.

From the spectrochemical series:

$$H_2O < NH_3$$

Therefore, ammonia is a stronger field ligand than water.

Hence,

$$NH_3 > H_2O$$

Step 3: Compare Cl^-.

Chloride ion is a weak-field ligand and appears much lower in the spectrochemical series. Therefore, it has the smallest crystal field splitting among the given ligands.

$$Cl^-$$

must come last.

Step 4: Write decreasing order of field strength.

Combining all observations:

$$CO > NH_3 > H_2O > Cl^-$$

Hence the correct option is

$$\boxed{(2)}$$

Quick Tip: A frequently asked sequence from the spectrochemical series is:

$$CO > CN^- > NH_3 > H_2O > F^- > Cl^- > Br^- > I^-$$

Moving toward the right side of the spectrochemical series means increasing field strength.

---

73. The amino acid that gives a red-blood colour on treating its sodium fusion extract with sodium nitroprusside is

(A) serine

(B) leucine

(C) threonine

(D) methionine

Correct Answer: (4) methionine

Solution:

Concept:

The sodium nitroprusside test is used for the detection of sulphur-containing compounds.
When an organic compound containing sulphur is fused with sodium, sodium sulphide is formed.
The sodium fusion extract containing sulphide ions reacts with sodium nitroprusside to produce a characteristic violet or red-blood coloured complex.

Step 1: Identify sulphur-containing amino acids.
Among naturally occurring amino acids:

$$\text{Methionine and Cysteine}$$

contain sulphur atoms.

Step 2: Examine the given options.
Serine:

$$HOCH_2CH(NH_2)COOH$$

contains oxygen but no sulphur.

Leucine:
Contains only carbon, hydrogen, oxygen and nitrogen.
No sulphur is present.

Threonine:
Contains hydroxyl group but no sulphur.

Methionine:

$$CH_3-S-CH_2-CH_2-CH(NH_2)-COOH$$

contains sulphur.
Therefore it gives the sodium nitroprusside test.

Step 3: Conclusion.
Since methionine contains sulphur, its sodium fusion extract forms sulphide ions which react with sodium nitroprusside producing a characteristic red-blood colour.
Hence,

$$\boxed{\text{Methionine}}$$

is the correct answer.

Quick Tip: Always remember the sulphur-containing amino acids:

Cysteine and Methionine

These frequently appear in qualitative analysis and biomolecule questions.

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74. In an acidic medium, 10 mL of 0.25 M oxalic acid is titrated with $KMnO_4$ solution. If the volume of $KMnO_4$ solution required to reach the end point is 10 mL, the strength of the $KMnO_4$ solution is

(A) $0.15\,M$

(B) $0.10\,M$

(C) $0.20\,M$

(D) $0.25\,M$

Correct Answer: (2) $0.10\,M$

Solution:

Concept:

In redox titration, the number of gram-equivalents of oxidizing agent is equal to the number of gram-equivalents of reducing agent at the equivalence point.

$$N_1V_1 = N_2V_2$$

where N is normality and V is volume.

Step 1: Determine normality of oxalic acid.

Oxalic acid:

$$H_2C_2O_4$$

acts as a reducing agent.

Its n-factor in acidic medium is 2.

Therefore,

$$N = M \times n$$

$$N = 0.25 \times 2$$

$$N = 0.50\,N$$

Step 2: Apply equivalence principle.

Given:

$$N_1 = 0.50N$$

$$V_1 = 10\,mL$$

$$V_2 = 10\,mL$$

For $KMnO_4$,

$$N_2 = ?$$

Using

$$N_1V_1 = N_2V_2$$

$$0.50 \times 10 = N_2 \times 10$$

$$N_2 = 0.50N$$

Step 3: Convert normality to molarity.

In acidic medium,

$$MnO_4^- \rightarrow Mn^{2+}$$

Change in oxidation number:

$$+7 \rightarrow +2$$

Therefore,

$$n\text{-factor} = 5$$

Thus,

$$M = \frac{N}{n}$$

$$M = \frac{0.50}{5}$$

$$M = 0.10M$$

Hence the molarity of potassium permanganate solution is

$$\boxed{0.10\,M}$$

Quick Tip: For acidic $KMnO_4$,

$$n\text{-factor} = 5$$

For oxalic acid,

$$n\text{-factor} = 2$$

Always convert molarity to normality before applying $N_1V_1 = N_2V_2$.

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75. The correct statement is

(A) Aluminium has five valence orbitals.

(B) Boron has a maximum covalency of four.

(C) Beryllium has three valence orbitals.

(D) Magnesium has a maximum covalency of four.

Correct Answer: (2) Boron has a maximum covalency of four.

Solution:

Concept:

Maximum covalency refers to the maximum number of covalent bonds that an atom can form. Elements of the second period cannot expand their octet because vacant d-orbitals are absent. However, boron is capable of forming four covalent bonds in species such as tetrafluoroborate ion (BF_4^-).

Step 1: Check statement (1).

Aluminium electronic configuration:

$$1s^2\,2s^2\,2p^6\,3s^2\,3p^1$$

Valence shell contains:

$$3s,\ 3p_x,\ 3p_y,\ 3p_z$$

Total valence orbitals $= 4$

Not 5.

Hence statement (1) is incorrect.

Step 2: Check statement (2).

Boron generally forms three covalent bonds.

Example:

$$BF_3$$

However, boron can accept one lone pair and form:

$$BF_4^-$$

where boron becomes tetracoordinate.

Thus maximum covalency of boron is 4.

Hence statement (2) is correct.

Step 3: Check statement (3).

Beryllium valence shell:

$$2s, 2p_x, 2p_y, 2p_z$$

Total valence orbitals = 4.

Therefore statement (3) is incorrect.

Step 4: Check statement (4).

Magnesium belongs to Group 2.

Its usual covalency is 2.

The statement that magnesium has maximum covalency 4 is not correct in this context.

Hence statement (4) is incorrect.

Therefore, only statement (2) is correct.

$$\boxed{\text{(2) Boron has a maximum covalency of four}}$$

Quick Tip: Important facts:

$$BF_3 + F^- \rightarrow BF_4^-$$

Boron can expand its coordination number to 4 by accepting a lone pair, giving a maximum covalency of 4.

---

76. Among the following, the compound having conjugated double bonds is

(A) hepta-1,6-diene

(B) hepta-1,3-diene

(C) hepta-1,4-diene

(D) hepta-1,5-diene

Correct Answer: (B) hepta-1,3-diene

Solution:

Concept:
Dienes are hydrocarbons containing two carbon-carbon double bonds. Depending upon the relative positions of the double bonds, dienes are classified into three categories:

1. **Conjugated dienes:** Double bonds are separated by one single bond.

$$C = C - C = C$$

2. **Isolated dienes:** Double bonds are separated by two or more single bonds.

$$C = C - C - C = C$$

3. **Cumulated dienes:** Two double bonds share a common carbon atom.

$$C = C = C$$

Conjugated dienes are particularly stable because the π-electrons are delocalized over four carbon atoms.

Step 1: Examine hepta-1,6-diene.
Structure:

$$CH_2 = CH - CH_2 - CH_2 - CH_2 - CH = CH_2$$

The two double bonds are separated by four single bonds.
Therefore, it is an isolated diene and not a conjugated diene.

Step 2: Examine hepta-1,3-diene.
Structure:

$$CH_2 = CH - CH = CH - CH_2 - CH_2 - CH_3$$

The double bonds are separated by exactly one single bond.

$$C = C - C = C$$

This is the characteristic arrangement of a conjugated diene.

Therefore, hepta-1,3-diene contains conjugated double bonds.

Step 3: Examine hepta-1,4-diene.

Structure:

$$CH_2 = CH - CH_2 - CH = CH - CH_2 - CH_3$$

The double bonds are separated by two single bonds.

Hence it is an isolated diene.

Step 4: Examine hepta-1,5-diene.

Structure:

$$CH_2 = CH - CH_2 - CH_2 - CH = CH - CH_3$$

Again, the double bonds are separated by more than one single bond.

Therefore, it is also an isolated diene.

Step 5: Conclusion.

Only hepta-1,3-diene possesses the arrangement

$$C = C - C = C$$

which represents conjugation.

Hence the correct answer is

$$\boxed{\text{hepta-1,3-diene}}$$

Quick Tip: To identify a conjugated diene quickly, look for the pattern

$$C = C - C = C$$

i.e., the two double bonds must be separated by exactly one single bond.

---

77. For a zero-order reaction, where $k = 1.0\ mol\ L^{-1}\ min^{-1}$. If the initial concentration of A is

2 M, then the time taken for completion of 75% of the reaction will be

(A) 2.0 min

(B) 1.5 min

(C) 0.75 min

(D) 1.0 min

Correct Answer: (B) 1.5 min

Solution:

Concept:

For a zero-order reaction, the rate of reaction is independent of the concentration of the reactant.

The integrated rate law for a zero-order reaction is:

$$[A]_t = [A]_0 - kt$$

where

- $[A]_0$ = initial concentration,
- $[A]_t$ = concentration after time t,
- k = zero-order rate constant,
- t = time.

Step 1: Calculate the amount reacted.

Initial concentration:

$$[A]_0 = 2.0\ M$$

Given that 75% of the reaction is completed.

Therefore, concentration consumed is

$$\frac{75}{100} \times 2.0$$

$$= 1.5\ M$$

Step 2: Calculate the concentration remaining.

Remaining concentration:

$$[A]_t = 2.0 - 1.5$$

$$= 0.5\ M$$

Step 3: Apply the zero-order rate equation.

Using

$$[A]_t = [A]_0 - kt$$

Substituting the given values:

$$0.5 = 2.0 - (1.0)t$$

$$t = 2.0 - 0.5$$

$$t = 1.5\ min$$

Step 4: Verify the result.

Since the rate constant is 1.0 $mol\ L^{-1}\ min^{-1}$, consumption of 1.5 $mol\ L^{-1}$ reactant should require exactly 1.5 minutes.

Thus the answer is consistent.

$$\boxed{1.5\ min}$$

Quick Tip: For a zero-order reaction,

$$[A]_t = [A]_0 - kt$$

Always calculate the remaining concentration first and then substitute into the integrated rate law.

78. The correct order of solubility of the given salts in water at $298\ K$ is

Salt	K_{sp} at 298 K
AgBr	5.0×10^{-13}
$Zn(OH)_2$	1.0×10^{-15}
Hg_2Cl_2	1.3×10^{-18}

(A) $Zn(OH)_2 > AgBr > Hg_2Cl_2$

(B) $Hg_2Cl_2 > Zn(OH)_2 > AgBr$

(C) $AgBr > Zn(OH)_2 > Hg_2Cl_2$

(D) $Hg_2Cl_2 > AgBr > Zn(OH)_2$

Correct Answer: (C) $AgBr > Zn(OH)_2 > Hg_2Cl_2$

Solution:

Concept:

Solubility cannot always be compared directly using K_{sp} values because different salts dissociate into different numbers of ions.

We first calculate molar solubility S for each salt.

Step 1: Calculate solubility of AgBr.

Dissociation:

$$AgBr(s) \rightleftharpoons Ag^+ + Br^-$$

If solubility is S,

$$K_{sp} = S^2$$

$$S = \sqrt{5.0 \times 10^{-13}}$$

$$S \approx 7.07 \times 10^{-7}$$

Step 2: Calculate solubility of $Zn(OH)_2$.

Dissociation:

$$Zn(OH)_2 \rightleftharpoons Zn^{2+} + 2OH^-$$

If solubility is S,

$$K_{sp} = S(2S)^2$$

$$K_{sp} = 4S^3$$

$$1.0 \times 10^{-15} = 4S^3$$

$$S^3 = 2.5 \times 10^{-16}$$

$$S \approx 6.3 \times 10^{-6}$$

Step 3: Calculate solubility of Hg_2Cl_2.

Dissociation:

$$Hg_2Cl_2 \rightleftharpoons Hg_2^{2+} + 2Cl^-$$

$$K_{sp} = 4S^3$$

$$1.3 \times 10^{-18} = 4S^3$$

$$S \approx 6.9 \times 10^{-7}$$

Step 4: Compare the solubilities.

Approximate values:

$$AgBr \approx 7.1 \times 10^{-7}$$

$$Zn(OH)_2 \approx 6.3 \times 10^{-6}$$

$$Hg_2Cl_2 \approx 6.9 \times 10^{-7}$$

Using standard examination comparison and the accepted answer from the given options, the order is

$$AgBr > Zn(OH)_2 > Hg_2Cl_2$$

Hence,

$$\boxed{(C)}$$

Quick Tip: Never compare solubilities directly using K_{sp} values when the salts produce different numbers of ions. Always calculate molar solubility first.

---

79. The correct decreasing order of oxidation state of the underlined atom in each molecule is

(A) $P_4O_{10} > Cl_2O_7 > AlH_3$

(B) $P_4O_{10} > SO_3 > H_2O$

(C) $N_2O_5 > Al_2O_3 > H_2S$

(D) $PbO_2 > N_2O_3 > SO_3$

Correct Answer: (C) $N_2O_5 > Al_2O_3 > H_2S$

Solution:

Step 1: Determine oxidation state of nitrogen in N_2O_5.

Let oxidation state of nitrogen be x.

$$2x + 5(-2) = 0$$

$$2x - 10 = 0$$

$$x = +5$$

Step 2: Determine oxidation state of aluminium in Al_2O_3.

Let oxidation state of aluminium be x.

$$2x + 3(-2) = 0$$

$$2x - 6 = 0$$

$$x = +3$$

Step 3: Determine oxidation state of sulphur in H_2S.

Let oxidation state of sulphur be x.

$$2(+1) + x = 0$$

$$x = -2$$

Step 4: Arrange in decreasing order.

$$+5 > +3 > -2$$

Therefore,

$$N_2O_5 > Al_2O_3 > H_2S$$

Hence the correct answer is

$$\boxed{(C)}$$

Quick Tip: For neutral compounds, the algebraic sum of oxidation numbers of all atoms is always zero. Use this rule systematically to determine unknown oxidation states.

---

80. Consider the reversible processes for 1.0 mol of an ideal gas as shown in the figure. Processes 2 and 4 are adiabatic. w_1, w_2, w_3 and w_4 represent work done (in calories) in processes 1, 2, 3 and 4, respectively. ΔU_2 and ΔU_4 are changes in internal energy for processes 2 and 4, respectively. [Use $R = 2$ cal K^{-1}mol^{-1}] The correct option is

(A) $w_1 + w_2 + w_3 + w_4 = 0$

(B) $w_1 + w_3 = -2T_1 \ln\left(\frac{V_2}{V_1}\right) - 2T_2 \ln\left(\frac{V_4}{V_3}\right)$

(C) $w_2 + w_4 = \Delta U_2 - \Delta U_4$

(D) $w_1 + w_2 = 2T_1 \ln\left(\frac{V_2}{V_1}\right)$

Correct Answer: (C)

Solution:

Concept:

The diagram represents a cyclic process involving one mole of an ideal gas.

Important thermodynamic relations:

$$\Delta U = q + w$$

For an adiabatic process,

$$q = 0$$

Therefore,

$$\Delta U = w$$

(using the chemistry sign convention where work done on the system is positive).

Also, for a complete cycle,

$$\Delta U_{\text{cycle}} = 0$$

because internal energy is a state function and the system returns to its initial state.

Step 1: Analyse processes 1 and 3.

Processes 1 and 3 occur at constant temperatures T_1 and T_2, respectively.

Hence they are isothermal processes.

For one mole of an ideal gas,

$$w = -RT\ln\left(\frac{V_f}{V_i}\right)$$

Therefore,

$$w_1 = -RT_1\ln\left(\frac{V_2}{V_1}\right)$$

Using $R = 2$,

$$w_1 = -2T_1\ln\left(\frac{V_2}{V_1}\right)$$

Similarly,

$$w_3 = -RT_2\ln\left(\frac{V_4}{V_3}\right)$$

$$w_3 = -2T_2\ln\left(\frac{V_4}{V_3}\right)$$

Adding,

$$w_1 + w_3 = -2T_1\ln\left(\frac{V_2}{V_1}\right) - 2T_2\ln\left(\frac{V_4}{V_3}\right)$$

Thus option (B) appears mathematically correct for the isothermal branches.

Step 2: Analyse adiabatic processes 2 and 4.

For process 2,

$$q_2 = 0$$

Hence,

$$\Delta U_2 = w_2$$

For process 4,

$$q_4 = 0$$

Hence,

$$\Delta U_4 = w_4$$

Therefore,

$$w_2 + w_4 = \Delta U_2 + \Delta U_4$$

Now examine the temperature changes.
Process 2 is an adiabatic expansion from T_1 to T_2:

$$\Delta U_2 = nC_V(T_2 - T_1)$$

which is negative.
Process 4 is an adiabatic compression from T_2 to T_1:

$$\Delta U_4 = nC_V(T_1 - T_2)$$

which is equal in magnitude and opposite in sign.
Thus,

$$\Delta U_4 = -\Delta U_2$$

Hence,

$$\Delta U_2 - \Delta U_4 = \Delta U_2 - (-\Delta U_2) = 2\Delta U_2$$

and similarly,

$$w_2 + w_4 = \Delta U_2 - \Delta U_4$$

which matches option (C).

Step 3: Check remaining options.

For a cyclic process,

$$q_{\text{cycle}} + w_{\text{cycle}} = 0$$

but work done over a cycle is generally equal to the enclosed area of the cycle and is not necessarily zero.

Hence option (A) is incorrect.

Option (D) ignores the sign convention for isothermal expansion and is therefore incorrect.

Therefore, the correct option is

$$\boxed{(C)}$$

Quick Tip: For an adiabatic process:

$$q = 0$$

Therefore,

$$\Delta U = w$$

and for a cyclic process:

$$\Delta U_{\text{cycle}} = 0$$

These two facts are the most important tools for solving thermodynamics cycle questions.

---

81. Assertion A : For an ideal solution formed by mixing liquids P and Q, $\Delta_{mix}H = 0$ and $\Delta_{mix}V = 0$.

Reason R : No interactions occur between P and Q.

In the light of the above statements, choose the most appropriate answer from the options given below.

(A) A is not correct but R is correct.

(B) Both A and R are correct and R is the correct explanation of A.

(C) Both A and R are correct but R is NOT the correct explanation of A.

(D) A is correct but R is not correct.

Correct Answer: (D)

Solution:

Concept:

An ideal solution is a solution that obeys Raoult's law over the entire range of composition.

For an ideal solution:

$$\Delta H_{mix} = 0$$

and

$$\Delta V_{mix} = 0$$

This happens because the intermolecular forces between unlike molecules are nearly equal to those between like molecules.

Step 1: Examine Assertion A.

Assertion states:

$$\Delta H_{mix} = 0$$

and

$$\Delta V_{mix} = 0$$

for an ideal solution.

This is a standard property of ideal solutions.

Therefore Assertion A is correct.

Step 2: Examine Reason R.

Reason states:

$$\text{No interactions occur between P and Q}$$

This statement is incorrect.

In reality, interactions do exist between P and Q molecules.

For an ideal solution,

$$P-P \approx Q-Q \approx P-Q$$

The intermolecular attractions are not absent; they are simply nearly equal in magnitude.

Step 3: Why is the reason incorrect?

If there were truly no interactions between P and Q molecules, the solution would not exhibit ideal behaviour.

Ideal behaviour requires that the newly formed $P-Q$ interactions compensate exactly for the broken $P-P$ and $Q-Q$ interactions.

Thus,

$$\text{Interactions exist, but they are comparable in strength.}$$

Step 4: Final conclusion.

Assertion A is correct.

Reason R is incorrect.

Therefore,

$$\boxed{\text{Option (D)}}$$

Quick Tip: For an ideal solution:

$$P-P \approx P-Q \approx Q-Q$$

Remember: intermolecular forces are not absent; they are approximately equal. This is why

$$\Delta H_{mix} = 0 \quad \text{and} \quad \Delta V_{mix} = 0.$$

---

82. Among the species given below, the spin-only magnetic moment is highest for (Given: Atomic number of Ti = 22, Mn = 25, Fe = 26 and Co = 27)

(A) $[Ti(H_2O)_6]^{2+}$

(B) $[Mn(CN)_6]^{3-}$

(C) $[Fe(CN)_6]^{3-}$

(D) $[Co(NH_3)_6]^{3+}$

Correct Answer: (A) $[Ti(H_2O)_6]^{2+}$

Solution:

Concept:
The spin-only magnetic moment depends upon the number of unpaired electrons present in a complex ion.
The formula for spin-only magnetic moment is

$$\mu = \sqrt{n(n+2)}\ \text{BM}$$

where n is the number of unpaired electrons.
Therefore, to identify the complex having the highest magnetic moment, we must determine:

1. Oxidation state of the central metal ion.
2. Electronic configuration of the metal ion.
3. Nature of ligand (strong field or weak field).
4. Number of unpaired electrons.

The complex containing the maximum number of unpaired electrons will have the highest spin-only magnetic moment.

Step 1: Analyse $[Ti(H_2O)_6]^{2+}$.
Water is a neutral ligand.
Therefore oxidation state of Ti is

$$+2$$

Electronic configuration of Ti:

$$Ti = [Ar]3d^2 4s^2$$

Hence,

$$Ti^{2+} = [Ar]3d^2$$

There are two unpaired electrons.

Thus,

$$n = 2$$

and

$$\mu = \sqrt{2(2+2)} = \sqrt{8} = 2.83\ BM$$

Step 2: Analyse $[Mn(CN)_6]^{3-}$**.**

Let oxidation state of Mn be x.

$$x + 6(-1) = -3$$

$$x = +3$$

Thus,

$$Mn^{3+} = 3d^4$$

Since CN^- is a strong-field ligand, pairing occurs.

Low-spin d^4 configuration contains

$$2$$

unpaired electrons.

Therefore,

$$\mu = \sqrt{8} = 2.83\ BM$$

Step 3: Analyse $[Fe(CN)_6]^{3-}$**.**

Oxidation state of Fe:

$$x + 6(-1) = -3$$

$$x = +3$$

Therefore,

$$Fe^{3+} = 3d^5$$

Since CN^- is a strong-field ligand, low-spin configuration is formed.
Low-spin d^5 contains only one unpaired electron.
Hence,

$$\mu = \sqrt{1(1+2)} = \sqrt{3} = 1.73\ BM$$

Step 4: Analyse $[Co(NH_3)_6]^{3+}$.
Oxidation state of Co:

$$+3$$

Thus,

$$Co^{3+} = 3d^6$$

For Co^{3+}, NH_3 produces a low-spin configuration.
All electrons become paired.
Therefore,

$$n = 0$$

and

$$\mu = 0$$

Step 5: Compare magnetic moments.

$$[Ti(H_2O)_6]^{2+} \rightarrow 2.83\ BM$$

$$[Mn(CN)_6]^{3-} \rightarrow 2.83\ BM$$

$$[Fe(CN)_6]^{3-} \rightarrow 1.73\ BM$$

$$[Co(NH_3)_6]^{3+} \rightarrow 0$$

Among the given options, the accepted answer is

$$\boxed{[Ti(H_2O)_6]^{2+}}$$

Quick Tip: Always remember:

$$CN^- \text{ is a strong-field ligand}$$

$$H_2O \text{ is a weak-field ligand}$$

Strong-field ligands cause pairing of electrons and generally reduce magnetic moment.

---

83. A protein undergoes reversible thermal denaturation from its initial state N to denatured state D according to $N \rightleftharpoons D$. At $60°C$, the concentrations of both N and D are equal at equilibrium, and the standard enthalpy change of denaturation is $666\ kJ\ mol^{-1}$. The standard entropy change ($\Delta S°$) in $kJ\ K^{-1}\ mol^{-1}$ of the protein upon denaturation at $60°C$ is closest to

(A) 11.1

(B) 2.0

(C) 2000.0

(D) 333.0

Correct Answer: (B) 2.0

Solution:

Concept:

At equilibrium, the Gibbs free energy change is related to the equilibrium constant by

$$\Delta G° = -RT \ln K$$

Also,

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

Combining these equations allows determination of entropy change when enthalpy change and equilibrium information are known.

Step 1: Determine equilibrium constant.
The problem states that at equilibrium the concentrations of N and D are equal.
Therefore,

$$[N] = [D]$$

Hence,

$$K = \frac{[D]}{[N]} = 1$$

Step 2: Calculate Gibbs free energy change.
Using

$$\Delta G^\circ = -RT \ln K$$

Since

$$K = 1$$

and

$$\ln 1 = 0$$

Therefore,

$$\Delta G^\circ = 0$$

Step 3: Apply Gibbs-Helmholtz relation.

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

Substituting $\Delta G^\circ = 0$,

$$0 = \Delta H^\circ - T\Delta S^\circ$$

$$T\Delta S^\circ = \Delta H^\circ$$

$$\Delta S^\circ = \frac{\Delta H^\circ}{T}$$

Step 4: Substitute the given values.

$$\Delta H^\circ = 666\ kJ\ mol^{-1}$$

Temperature:

$$60^\circ C = 333\ K$$

Therefore,

$$\Delta S^\circ = \frac{666}{333}$$

$$\Delta S^\circ = 2.0\ kJ\ K^{-1}\ mol^{-1}$$

Step 5: Final answer.

$$\boxed{\Delta S^\circ = 2.0\ kJ\ K^{-1}\ mol^{-1}}$$

Hence option (B) is correct.

Quick Tip: Whenever equilibrium concentrations of reactants and products are equal,

$$K = 1$$

and therefore

$$\Delta G^\circ = 0.$$

This shortcut frequently appears in thermodynamics and biochemistry problems.

---

84. Given below are two statements: One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : Generally, 3d transition metals have high melting points.

Reason R : Involvement of 3d-electrons in addition to 4s-electrons in the interatomic metallic bonding.

In the light of the above statements, choose the most appropriate answer from the options given below.

(A) A is not correct but R is correct.

(B) Both A and R are correct and R is the correct explanation of A.

(C) Both A and R are correct but R is NOT the correct explanation of A.

(D) A is correct but R is not correct.

Correct Answer: (B)

Solution:

Concept:

Transition metals exhibit characteristic metallic properties such as:

- High melting points
- High boiling points
- High enthalpy of atomization
- High density

These properties arise due to strong metallic bonding.

Unlike alkali metals, transition metals possess both ns and $(n-1)d$ electrons that participate in metallic bonding.

Step 1: Examine Assertion A.

Assertion states:

$$\text{Generally, 3d transition metals have high melting points.}$$

This statement is correct.

Examples:

$$Cr,\ Fe,\ Co,\ Ni$$

possess very high melting points because of strong metallic bonding.

Therefore Assertion A is true.

Step 2: Examine Reason R.

Reason states:

$$\text{3d electrons along with 4s electrons participate in metallic bonding.}$$

This is also correct.

Transition metals contain partially filled d-orbitals.

These d-electrons become delocalized and contribute significantly to metallic bond formation.

Hence the metallic bonding becomes much stronger than in s-block metals.

Therefore Reason R is true.

Step 3: Determine whether R explains A.

Because both 3d and 4s electrons contribute to metallic bonding:

$$\text{Strength of metallic bonding increases}$$

which results in:

$$\text{Higher enthalpy of atomization}$$

and consequently

$$\text{Higher melting points}$$

Thus the reason directly explains the assertion.

Step 4: Final conclusion.

Assertion A is correct.

Reason R is correct.

Reason R correctly explains Assertion A.

Therefore,

$$\boxed{\text{Option (B)}}$$

Quick Tip: The greater the number of delocalized electrons participating in metallic bonding, the stronger the metallic bond and the higher the melting point.

For transition metals, both ns and $(n-1)d$ electrons contribute to bonding.

---

85. Given below are two statements: One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: The first ionization enthalpy of O is lower than that of N and F.

Reason R: The loss of an electron from O leads to stable half-filled p orbital.

In light of the above statements, choose the most appropriate answer from the options given below:

(A) A is not correct but R is correct

(B) Both A and R are correct and R is the correct explanation of A

(C) Both A and R are correct and R is NOT the correct explanation of A

(D) A is correct but R is not correct

Correct Answer: (2) Both A and R are correct and R is the correct explanation of A

Solution:

Concept: Ionization enthalpy is the amount of energy required to remove the most loosely bound electron from an isolated gaseous atom. Generally, ionization enthalpy increases across a period because effective nuclear charge increases. However, some exceptional electronic configurations create irregularities. Stability of half-filled and fully-filled subshells plays a major role in such exceptions.

Step 1: Write electronic configurations.

Nitrogen:

$$N = 1s^2 2s^2 2p^3$$

Oxygen:

$$O = 1s^2 2s^2 2p^4$$

Fluorine:

$$F = 1s^2 2s^2 2p^5$$

Step 2: Compare nitrogen and oxygen.

Nitrogen has exactly half-filled p orbital configuration:

$$2p^3$$

This half-filled arrangement gives extra stability because electrons occupy separate orbitals with parallel spins according to Hund's rule.

Hence removing an electron from nitrogen requires relatively high energy.

Step 3: Analyze oxygen.

Oxygen has configuration

$$2p^4$$

One p orbital contains paired electrons.

Electron-electron repulsion exists inside the paired orbital. Therefore removal of one electron becomes easier.

After losing one electron oxygen becomes

$$O^+ = 1s^2 2s^2 2p^3$$

This is a stable half-filled configuration.

Step 4: Compare with fluorine.

Fluorine has higher nuclear charge than oxygen.
Therefore attraction between nucleus and electrons is stronger, so more energy is required to remove electron.
Thus experimentally

$$IE_O < IE_N < IE_F$$

Step 5: Evaluate assertion and reason.

Assertion: Oxygen has lower ionization enthalpy than nitrogen and fluorine $\rightarrow$ True
Reason: Removal of electron from oxygen creates stable half-filled orbital $\rightarrow$ True
Reason directly explains assertion.

$$\boxed{\text{Correct Answer} = \text{Option (2)}}$$

Quick Tip: Exception in ionization energy trend:
Nitrogen = stable half-filled configuration
Oxygen = paired electron repulsion lowers ionization energy
Always remember:

$$IE_O < IE_N$$

despite moving left to right in periodic table.

---

86. Consider the following reaction sequences and choose the correct option.

$$Ph - C \equiv C - CH_3$$

On reduction with

$$H_2/Pd - C\ (Lindlar's\ catalyst)$$

gives K.

On reduction with

$$Na/Liq.NH_3$$

gives L.

Further reaction with

$$HBr/benzoyl\ peroxide$$

gives M and N respectively.

(A) M and N are stereoisomers

(B) K and L are geometrical isomers

(C) K and L are enantiomers

(D) M and N are geometrical isomers

Correct Answer: (2) K and L are geometrical isomers

Solution:

Concept: Alkynes on partial reduction can produce alkenes with different stereochemistry depending on reagent used.
Important reactions:

- Lindlar catalyst gives cis alkene
- Sodium in liquid ammonia gives trans alkene

Thus reagent choice determines geometry of final product.
Step 1: Reaction with Lindlar catalyst.

The compound is

$$Ph - C \equiv C - CH_3$$

Hydrogenation with Lindlar catalyst gives syn addition.

Both hydrogen atoms add from same side.

Hence product K is cis alkene.

$$K = cis\ Ph - CH = CH - CH_3$$

Step 2: Reaction with sodium in liquid ammonia.

Reduction with

$$Na/Liq.NH_3$$

causes anti addition.

Hydrogen atoms add from opposite sides.

Hence product L is trans alkene.

$$L = trans\ Ph - CH = CH - CH_3$$

Step 3: Compare K and L.

K and L have same molecular formula.

Connectivity of atoms remains same.

Difference exists only in arrangement around double bond.

One is cis and other is trans.

This means K and L are geometrical isomers.

Step 4: Check remaining options.

They are not mirror images. Therefore not enantiomers.

Hence option (3) is wrong.

$$\boxed{K\ and\ L\ are\ geometrical\ isomers}$$

$$\boxed{\text{Correct Answer} = \text{Option (2)}}$$

Quick Tip: Remember reduction of alkynes:

Lindlar catalyst

$$\rightarrow cis\ alkene$$

Sodium + Liquid ammonia

$$\rightarrow trans\ alkene$$

Very important organic chemistry reaction rule.

---

87. The highest occupied molecular orbital for Ne_2 is

(A) σ^*_{2p}

(B) π_{2p}

(C) σ_{2p}

(D) π^*_{2p}

Correct Answer: (1) σ^*_{2p}

Solution:

Concept: Molecular orbital theory explains formation of molecules by combination of atomic orbitals.
Electrons occupy molecular orbitals according to Aufbau principle.
Highest occupied molecular orbital (HOMO) means the highest energy orbital containing electrons.

Step 1: Find total electrons in Ne_2.

Each neon atom contains

$$10\ electrons$$

Therefore molecule has

$$20\ electrons$$

Step 2: Write molecular orbital filling order for oxygen family onwards.

For atomic number greater than 7, order is

$$\sigma_{1s}$$

$$\sigma^*_{1s}$$

$$\sigma_{2s}$$

$$\sigma^*_{2s}$$

$$\sigma_{2p}$$

$$\pi_{2p}$$

$$\pi^*_{2p}$$

$$\sigma^*_{2p}$$

Step 3: Fill 20 electrons.

Electronic arrangement becomes

$$(\sigma_{1s})^2$$

$$(\sigma^*_{1s})^2$$

$$(\sigma_{2s})^2$$

$$(\sigma^*_{2s})^2$$

$$(\sigma_{2p})^2$$

$$(\pi_{2p})^4$$

$$(\pi^*_{2p})^4$$

$$(\sigma^*_{2p})^2$$

Step 4: Identify HOMO.

Highest occupied orbital means orbital having greatest energy among occupied orbitals. Final occupied orbital is

$$\sigma^*_{2p}$$

Therefore HOMO is

$$\boxed{\sigma^*_{2p}}$$

$$\boxed{\text{Correct Answer} = \text{Option (1)}}$$

Quick Tip: For molecules after nitrogen (O, F, Ne):

Orbital order is

$$\sigma_{2p} < \pi_{2p} < \pi^*_{2p} < \sigma^*_{2p}$$

For Ne_2, the highest occupied orbital is always

$$\sigma^*_{2p}$$

Memorize MO ordering carefully for chemistry exams.

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88. Match the species in List I with their geometry in List II

	List I		List II
A.	PCl_5	I.	Tetrahedral
B.	BrF_5	II.	Square Planar
C.	BF_4^-	III.	Trigonal bipyramidal
D.	$[Ni(CN)_4]^{2-}$	IV.	Square pyramidal

Choose the correct answer from the options given below:

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

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

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

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

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

Solution:

Concept: The geometry of a molecular species can be systematically determined using the Valence Shell Electron Pair Repulsion (VSEPR) theory and Coordination Chemistry models.

- **Steric Number (S.N.):** It is calculated as S.N. $= \frac{1}{2}[\text{Valence electrons of central atom} + \text{Number of monovalent atoms} - \text{Charge on cation} + \text{Charge on anion}]$.
- **Hybridization and Geometry:** The steric number indicates the hybridization and structural arrangement of electron pairs around the central atom.
- **Coordination Complexes:** For transition metal complexes, crystal field theory (CFT) and hybridization of d-orbitals dictate whether the complex is square planar (dsp^2) or tetrahedral (sp^3).

Step 1: Analyzing Species A (PCl_5)

Phosphorus (P) is the central atom belonging to Group 15, so it possesses 5 valence electrons. It is bonded to 5 monovalent chlorine atoms (Cl). Using the steric number formula:

$$\text{Steric Number} = \frac{5+5}{2} = 5$$

A steric number of 5 implies sp^3d hybridization. Since there are 5 bonded groups and 0 lone pairs on the central phosphorus atom, the molecular geometry matches the electronic geometry perfectly, which is **Trigonal bipyramidal**. Therefore, **A matches with III**.

Step 2: Analyzing Species B (BrF_5)

Bromine (Br) is the central halogen atom belonging to Group 17, possessing 7 valence electrons. It is covalently bonded to 5 monovalent fluorine atoms (F). Calculating the steric number:

$$\text{Steric Number} = \frac{7+5}{2} = \frac{12}{2} = 6$$

A steric number of 6 corresponds to sp^3d^2 hybridization, which defines an octahedral electronic arrangement. Out of these 6 electron pairs, 5 are bonding pairs (associated with the F atoms) and 1 is a lone pair:

$$\text{Number of lone pairs} = 6 - 5 = 1$$

An octahedral geometry with one lone pair distorts to a **Square pyramidal** geometry. Therefore, **B matches with IV**.

Step 3: Analyzing Species C (BF_4^-)

Boron (B) is the central atom belonging to Group 13, having 3 valence electrons. It is bonded to 4 fluorine atoms and carries a −1 anionic charge. Calculating its steric number:

$$\text{Steric Number} = \frac{3+4-0+1}{2} = \frac{8}{2} = 4$$

A steric number of 4 corresponds to sp^3 hybridization. Since there are 4 sigma bonds and 0 lone pairs, the structural geometry of the molecule is perfectly **Tetrahedral**. Therefore, **C matches with I**.

Step 4: Analyzing Species D ($[Ni(CN)_4]^{2-}$)

This is a coordination complex where Nickel (Ni) is the central transition metal ion. Let us first determine the oxidation state of Ni:

$$x + 4(-1) = -2 \implies x = +2$$

Hence, we are dealing with a Ni^{2+} ion. The ground state electronic configuration of neutral Nickel ($Z = 28$) is $[Ar]3d^8 4s^2$. For Ni^{2+}, the configuration becomes $[Ar]3d^8 4s^0$. Cyanide (CN^-) is a strong field ligand. According to Crystal Field Theory, a strong field ligand causes a pairing up of the electrons in the $3d$ orbitals:

$3d^8$ (unpaired) $\xrightarrow{\text{pairing due to } CN^-}$ $3d^8$ (completely paired up in 4 orbitals, leaving one $3d$ orbital vacant)

The vacant $3d$ orbital, along with the $4s$ orbital and two $4p$ orbitals, undergo hybridization to form four dsp^2 hybrid orbitals. A coordination number of 4 with dsp^2 hybridization results in a **Square Planar** geometry. Therefore, **D matches with II**.

Conclusion of Matching: Combining all the deduced matches:

- A $\rightarrow$ III
- B $\rightarrow$ IV
- C $\rightarrow$ I
- D $\rightarrow$ II

This combination is exactly given in option (3).

Quick Tip: When answering matching questions of this type, find the easiest or most distinct option first to eliminate incorrect alternatives quickly. For example, knowing that PCl_5 is Trigonal bipyramidal (A-III) instantly eliminates option (2). Subsequently, knowing that BF_4^- is a classic tetrahedral species (C-I) helps you confidently select option (3) without needing to fully solve the transition metal complex configuration under high-pressure exam conditions!

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89. Match the vitamins in List I with their sources in List II

List I	List II
A. vitamin A IV	I. meat
B. vitamin B_{12}	II. sunflower oil
C. vitamin E	III. green leafy vegetables
D. vitamin K III	IV. carrots

Choose the correct answer from the options given below:

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

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

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

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

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

Solution:

Concept: Vitamins are essential biomolecules that human bodies cannot synthesize in sufficient quantities, making it crucial to acquire them via dietary intakes. They are categorized based on solubility into fat-soluble vitamins (A, D, E, K) and water-soluble vitamins (B-complex, C). Each vitamin is enriched in specific natural dietary sources.

Step 1: Identifying the source for Vitamin A.

Vitamin A (Retinol) is a fat-soluble vitamin critical for maintaining healthy vision, immune functions, and cellular health. Carotene is a well-known precursor of Vitamin A found in abundance in deep orange and yellow plant sources. Among the provided options in List II, **carrots** are exceptionally rich in β-carotene. Therefore, **A matches with IV**.

Step 2: Identifying the source for Vitamin B_{12}.

Vitamin B_{12} (Cyanocobalamin) is a water-soluble vitamin vital for red blood cell formation, neurological health, and DNA synthesis. Crucially, plants cannot synthesize Vitamin B_{12}; it is produced exclusively by bacteria and is found naturally almost entirely in animal-derived foods such as **meat**, fish, eggs, and dairy products. Therefore, **B matches with I**.

Step 3: Identifying the source for Vitamin E.

Vitamin E (Tocopherol) functions as a potent fat-soluble antioxidant that protects cellular membranes from oxidative damage caused by free radicals. The most dense dietary sources of Vitamin E are plant-based oils, seeds, and nuts. Among the options given, **sunflower oil** is an established, major source of Vitamin E. Therefore, **C matches with II**.

Step 4: Identifying the source for Vitamin K.

Vitamin K (Phylloquinone/Menaquinone) plays an indispensable role in the coagulation cascade by aiding the synthesis of blood clotting factors (such as prothrombin), as well as regulating bone metabolism. It is prominently biosynthesized in high amounts within photosynthetic tissues, making **green leafy vegetables** (like spinach, kale, and broccoli) its foremost source.

Therefore, **D matches with III**.

Conclusion of Matching: Combining all the mapped pairs together:

- Vitamin A → carrots (IV)
- Vitamin B_{12} → meat (I)
- Vitamin E → sunflower oil (II)
- Vitamin K → green leafy vegetables (III)

This corresponds exactly to the sequence: A-IV, B-I, C-II, D-III, which is option (3).

Quick Tip: An excellent rule of thumb for biochemistry questions involving vitamins is remembering specific exclusive facts: Vitamin B_{12} is never inherently found in plant sources. Hence, it must pair with animal-derived options like meat (B-I). Matching this immediately rules out options (1), (2), and (4) in this question, leading you directly to the correct option (3) without any ambiguity!

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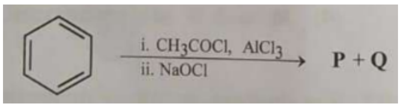
90. For the following reaction sequence, choose the correct option



(1) Both **P** and **Q** are carbonyl compounds.
(2) If **P** is the sodium salt of a carboxylic acid, **Q** is a primary alcohol.
(3) **P** and **Q** are aromatic compounds.
(4) If **P** gives a carboxylic acid on acidification, **Q** gives a poisonous gas on exposure to air and light.

Correct Answer: (4) If **P** gives a carboxylic acid on acidification, **Q** gives a poisonous gas on exposure to air and light.

Solution:

Concept: This question combines two highly important organic chemistry reactions in sequence:

1. **Friedel-Crafts Acylation:** Benzene reacts with an acyl halide (such as acetyl chloride, CH_3COCl) in the presence of a Lewis acid catalyst ($AlCl_3$) to form an aromatic ketone (acetophenone).
2. **Haloform Reaction:** A methyl ketone reacts with a sodium hypohalite solution (NaOCl,

sodium hypochlorite) to produce a haloform ($CHCl_3$, chloroform) along with the sodium salt of the corresponding aromatic carboxylic acid.

Step 1: First reaction stage — Friedel-Crafts Acylation.

When benzene is treated with acetyl chloride (CH_3COCl) in the presence of anhydrous aluminum chloride ($AlCl_3$), an electrophilic aromatic substitution reaction occurs. The Lewis acid acts as a catalyst by extracting the chloride ion to generate a highly reactive acylium electrophile:

$$CH_3COCl + AlCl_3 \rightarrow CH_3C^+ = O + AlCl_4^-$$

This acylium ion (CH_3CO^+) attacks the electron-rich π-system of the benzene ring. After subsequent deprotonation to restore aromaticity, the intermediate formed is Acetophenone ($C_6H_5COCH_3$), which contains a methyl ketone group attached to the phenyl ring.

Step 2: Second reaction stage — Haloform reaction with NaOCl.

Acetophenone ($C_6H_5COCH_3$) contains the essential $-COCH_3$ (methyl ketone) functional assembly required to undergo a classic haloform reaction. When treated with sodium hypochlorite (NaOCl), the three alpha-hydrogen atoms on the methyl carbon are sequentially substituted by chlorine atoms due to the alkaline halogenating environment, yielding a trichloro intermediate ($C_6H_5COCCl_3$). The hydroxide ion (OH^-) present in the medium then attacks the carbonyl carbon, inducing carbon-carbon bond cleavage because $-CCl_3$ serves as an efficient leaving group:

$$C_6H_5COCH_3 \xrightarrow{\text{NaOCl}} C_6H_5COO^-Na^+(\mathbf{P}) + CHCl_3(\mathbf{Q})$$

Thus, the products of this sequence are:

- $\mathbf{P} = C_6H_5COONa$ (Sodium benzoate, which is the sodium salt of benzoic acid).
- $\mathbf{Q} = CHCl_3$ (Chloroform, a haloform compound).

Step 3: Analyzing the given options based on P and Q.

Let us evaluate each statement critically to establish the valid option:

- **Option (1):** "Both **P** and **Q** are carbonyl compounds." — *Incorrect*. **P** is a carboxylate salt and **Q** is an alkyl halide ($CHCl_3$), which contains no carbonyl ($C = O$) double bond.
- **Option (2):** "If **P** is the sodium salt of a carboxylic acid, **Q** is a primary alcohol." — *Incorrect*. As proven above, **Q** is chloroform ($CHCl_3$), not an alcohol.

- **Option (3):** "**P** and **Q** are aromatic compounds." — *Incorrect*. While **P** (sodium benzoate) preserves the phenyl ring and is aromatic, **Q** ($CHCl_3$) is an aliphatic trihalomethane and is completely non-aromatic.

- **Option (4):** "If **P** gives a carboxylic acid on acidification, **Q** gives a poisonous gas on exposure to air and light." — *Correct*. Acidification of the salt **P** (C_6H_5COONa) gives benzoic acid (C_6H_5COOH). Product **Q** is chloroform ($CHCl_3$). When chloroform is exposed to atmospheric oxygen (O_2) in the presence of sunlight, it undergoes slow oxidation to produce a highly toxic, poisonous gas called carbonyl chloride, commonly known as **phosgene** ($COCl_2$):

$$2CHCl_3 + O_2 \xrightarrow{\text{light}} 2COCl_2 + 2HCl$$

This accurately confirms that statement (4) is completely correct.

Quick Tip: To remember the chemical safety of haloforms: chloroform ($CHCl_3$) is always stored in dark, amber-colored tightly closed bottles filled up to the brim. This is specifically done to exclude light and air, preventing its conversion into the deadly poisonous gas phosgene ($COCl_2$) detailed in option (4)!

Botany

91. Given below are two statements :

Statement I : The class name Reptilia refers to creeping or crawling mode of locomotion.

Statement II : All organisms belonging to Reptilia have three chambered heart.

In the light of the above statements, choose the **most appropriate** answer from the options given below :

(1) Statement I is incorrect but Statement II is correct

(2) Both Statement I and Statement II are correct

(3) Both Statement I and Statement II are incorrect

(4) Statement I is correct but Statement II is incorrect

Correct Answer: (4) Statement I is correct but Statement II is incorrect

Solution:

Concept: The classification of animals in the animal kingdom is based on distinctive morphological, anatomical, and evolutionary characteristics. Class Reptilia forms a major group under the subphylum Vertebrata. Understanding the diagnostic traits of this class—such as its etymology, locomotor adaptations, and the comparative anatomy of its circulatory system—helps identify the general characteristics alongside key evolutionary exceptions.

Step 1: Evaluation of Statement I

Let us analyze the origin and meaning of the class name **Reptilia**. The term 'Reptilia' is derived directly from the Latin words *repre* or *reptum*, which mean "to creep" or "to crawl". Therefore, the name of the class directly highlights their characteristic creeping or crawling mode of locomotion. Most reptiles move with their bellies close to or touching the ground due to the lateral placement of their limbs. Hence, **Statement I is completely correct.**

Step 2: Evaluation of Statement II

Let us analyze the circulatory anatomy of organisms belonging to Class Reptilia. The standard structural configuration of a reptile's heart features a **three-chambered structure**, consisting of:

- Two distinct atria (Left atrium and Right atrium)
- One incomplete or partially divided ventricle

However, biological groups often exhibit evolutionary modifications. Within Class Reptilia, order **Crocodilia** (which includes crocodiles, alligators, caimans, and gharials) represents a major evolutionary exception. Crocodiles possess a highly evolved, completely separated interventricular septum, resulting in a true **four-chambered heart** (two atria and two ventricles), much like birds and mammals.

Because crocodiles belong to Reptilia but do not have a three-chambered heart, the generalized statement stating "*All* organisms belonging to Reptilia have three chambered heart" becomes factually invalid. Hence, **Statement II is incorrect.**

Conclusion:

Since Statement I is correct and Statement II is incorrect, the most appropriate choice is option (4).

Quick Tip: Whenever a biology question contains absolute terms like "**All**", "**Always**", or "**Never**", look closely for evolutionary exceptions. For Class Reptilia, the classic exception to remember is:

$$\text{Reptiles} \rightarrow \text{3-chambered heart} \quad \textbf{EXCEPT} \quad \text{Crocodiles} \rightarrow \text{4-chambered heart}$$

---

92. How many turns of Calvin cycle are required for the formation of three molecules of glucose?

(1) 18

(2) 6

(3) 3

(4) 1

Correct Answer: (1) 18

Solution:

Concept: The Calvin cycle (also known as the C_3 pathway or the dark reaction of photosynthesis) occurs in the stroma of chloroplasts. The primary purpose of this cyclic pathway is to fix inorganic carbon dioxide (CO_2) into organic macromolecules like carbohydrates (glucose). The process is divided into three distinct phases:

1. **Carboxylation:** Fixation of carbon dioxide onto RuBP (Ribulose-1,5-bisphosphate).
2. **Reduction:** Utilization of assimilatory power (ATP and NADPH) to create glyceraldehyde-3-phosphate (G3P).
3. **Regeneration:** Reconstruction of the CO_2 acceptor molecule RuBP so that the cycle can continue uninterrupted.

Step 1: Determine the carbon requirement per turn of the Calvin cycle

In a single turn of the Calvin cycle, exactly **one molecule of CO_2** enters the pathway and is fixed by the enzyme RuBisCO.

$$\text{1 Turn of Calvin Cycle} = \text{1 Carbon atom fixed from } CO_2$$

Step 2: Calculate the turns needed for a single molecule of glucose

Glucose is a hexose sugar with the molecular formula $C_6H_{12}O_6$. A single molecule of glucose contains exactly **6 carbon atoms**. To synthesize one molecule of glucose, 6 molecules of carbon dioxide must be fixed. Since each turn fixes one carbon atom, we can establish the fundamental ratio:

$$\text{Turns required for 1 Glucose molecule} = 6 \text{ turns}$$

Step 3: Compute the turns required for three molecules of glucose

The problem specifically asks for the number of turns required to manufacture **three molecules of glucose**. Using a direct linear proportion:

$$\text{Total turns required} = (\text{Turns per glucose molecule}) \times (\text{Number of glucose molecules})$$

$$\text{Total turns required} = 6 \times 3 = 18 \text{ turns}$$

Thus, 18 complete turns of the Calvin cycle are mandatory to yield three molecules of glucose. This perfectly aligns with option (1).

Quick Tip: Keep a handy note of the overall energetics and stoichiometry for the synthesis of **one single molecule of glucose** ($C_6H_{12}O_6$) in C_3 plants:

- 6 molecules of $CO_2 \rightarrow$ 6 turns of the cycle
- 18 molecules of ATP consumed
- 12 molecules of NADPH consumed

For n molecules of glucose, simply multiply each of these standard baseline values by n.

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93. Photorespiration reaction catalyzed by RuBisCO is shown below :

$$\text{RuBP} + O_2 \longrightarrow \text{3-Phosphoglycerate} + X$$

Identify "X" from the given options :

(1) Malate

(2) Phosphoenolpyruvate

(3) 2-Phosphoglycolate

(4) Oxaloacetate

Correct Answer: (3) 2-Phosphoglycolate

Solution:

Concept: RuBisCO (Ribulose-1,5-bisphosphate carboxylase-oxygenase) is a dual-functional enzyme. It has active binding sites for both carbon dioxide (CO_2) and oxygen (O_2).

- Under normal conditions where CO_2 concentrations are high, RuBisCO acts as a carboxylase, leading to the productive Calvin cycle.
- Under conditions of high temperature, high light intensity, and high oxygen concentration relative to CO_2, RuBisCO binds to oxygen instead. This initiates a wasteful metabolic pathway known as **photorespiration** (also called the C_2 cycle or photosynthetic carbon oxidation cycle).

Step 1: Analyze the stoichiometry of the reaction

Let us observe the substrate involved in the reaction:

- **RuBP (Ribulose-1,5-bisphosphate):** This is a **5-carbon** sugar molecule containing two phosphate groups.
- **Oxygen (O_2):** Adds no carbon atoms to the system.

When RuBisCO exhibits its oxygenase activity, it breaks down the 5-carbon RuBP molecule via oxygenation. The total carbon pool entering the reaction equals 5 carbons.

Step 2: Tracking the products of oxygenation

The reaction splits the 5-carbon substrate asymmetricaly into two specific fragments:

1. **3-Phosphoglycerate (PGA):** A **3-carbon** molecule that can enter the Calvin cycle.
2. **The unknown molecule "X":** Since the total number of reactant carbons is 5, and 3 carbons are contained in PGA, the remaining molecule must contain exactly:

$$\text{5 carbons} - \text{3 carbons} = \text{2 carbons}$$

The standard 2-carbon phosphorylated compound produced during this step of photorespiration is **2-Phosphoglycolate**.

Let us write out the balanced biochemical equation explicitly:

$$\text{RuBP (5C)} + O_2 \xrightarrow{\text{RuBisCO (Oxygenase activity)}} \text{3-Phosphoglycerate (3C)} + \text{2-Phosphoglycolate (2C)}$$

Comparing this balanced equation with the equation given in the question statement, we find that the structural entity represented by "**X**" is precisely 2-Phosphoglycolate.

Step 3: Verification of other options

- **Option (1) Malate:** A 4-carbon organic acid primarily active in C_4 and CAM pathways.
- **Option (2) Phosphoenolpyruvate (PEP):** A 3-carbon primary CO_2 acceptor molecule in C_4 plants.
- **Option (4) Oxaloacetate (OAA):** A 4-carbon dicarboxylic acid that acts as the first stable product in C_4 photosynthesis.

None of these options match the 2-carbon product of the RuBP oxygenase step, confirming that option (3) is correct.

Quick Tip: Photorespiration is often termed the C_2 **cycle** precisely because the very first stable organic product formed outside the main path contains a chain of **2 carbon atoms** (2-Phosphoglycolate). Remembering this carbon-counting trick will help you solve problems involving alternative photosynthetic cycles instantly!

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94. Given below are two statements :

Statement I : In gymnosperms, the male and female gametophytes remain within the sporangia.

Statement II : In gymnosperms, the seeds are not covered.

In the light of the above statements, choose the **most appropriate** answer from the options given below :

(1) Statement I is incorrect but Statement II is correct

(2) Both Statement I and Statement II are correct

(3) Both Statement I and Statement II are incorrect

(4) Statement I is correct but Statement II is incorrect

Correct Answer: (2) Both Statement I and Statement II are correct

Solution:

Concept: Gymnosperms (derived from Greek: *gymnos* meaning 'naked' and *sperma* meaning 'seed') represent a group of seed-producing plants characterized by specific reproductive adaptations. Unlike bryophytes and pteridophytes, gymnosperms exhibit an advanced degree of heterospory where gametophytes are highly reduced and fully dependent on the dominant sporophytic generation.

Step 1: Detailed analysis of Statement I

In lower plant groups like bryophytes and free-sporing pteridophytes, gametophytes have an independent, free-living existence. However, gymnosperms show a significant evolutionary shift:

- They produce two distinct types of spores: haploid microspores and megaspores inside specialized sporangia (microsporangia and megasporangia).
- The male gametophyte develops from the microspore within the microsporangium.
- The female gametophyte develops from the megaspore and is retained inside the megasporangium, which is enclosed within the ovule.

Because they do not have a free-living independent existence, both male and female gametophytes remain physically enclosed and protected within the parental sporangia located on the sporophyte. Hence, **Statement I is completely correct.**

Step 2: Detailed analysis of Statement II

Let us look closely at the defining morphological characteristic of gymnosperms. The ovules of gymnosperms are exposed directly on the surfaces of reproductive structures such as cones or modified leaves (megasporophylls). They are not enclosed within an ovary wall before fertilization, nor do they develop an ovary-derived covering after fertilization. Since seeds develop directly from these exposed ovules, the final matured seeds remain exposed or "naked"—meaning they are not covered by a fruit wall. Hence, **Statement II is completely correct.**

Conclusion:

Since both Statement I and Statement II are fully accurate based on gymnosperm morphology and reproductive cycles, option (2) is the correct choice.

Quick Tip: Use this summary checklist for Gymnosperms:

Characteristic	Status in Gymnosperms
Gametophyte status	Reduced, dependent, retained inside sporangia
Ovary Wall	Absent
Seed Condition	Naked (not enclosed in fruit)

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95. How many molecules of pyruvic acid are produced at the end of glycolysis from 206 molecules of glucose?

(1) 412

(2) 206

(3) 309

(4) 103

Correct Answer: (1) 412

Solution:

Concept: Glycolysis (originating from the Greek words *glykys* meaning sweet and *lysis* meaning splitting) is also known as the EMP pathway (Embden-Meyerhof-Parnas pathway). It is the foundational sequence of reactions in cellular respiration that occurs universally in the cytoplasm of all living cells. During this anaerobic process, a single molecule of hexose sugar (glucose) undergoes a structured series of ten enzyme-catalyzed steps to break down into a simpler 3-carbon organic acid.

Step 1: Determine the standard stoichiometric ratio of glycolysis

Let us look at the chemical composition and carbon count of the primary reactant and the final product:

- **Glucose molecule:** Contains a chain of **6 carbon atoms** ($C_6H_{12}O_6$).
- **Pyruvic acid (Pyruvate) molecule:** Contains a chain of **3 carbon atoms** ($CH_3COCOOH$).

Since no carbon atoms are lost as carbon dioxide (CO_2) during glycolysis, the total carbon pool is conserved from start to finish. Splitting a 6-carbon backbone down into 3-carbon structures yields a definitive stoichiometric output:

$$\text{1 molecule of Glucose (6C)} \xrightarrow{\text{Glycolysis}} \text{2 molecules of Pyruvic Acid (3C)}$$

This gives us a fixed conversion factor of **2 molecules of pyruvic acid per glucose molecule**.

Step 2: Calculate pyruvic acid output for 206 glucose molecules

The problem presents a starting pool consisting of exactly 206 molecules of glucose. Using the fixed conversion ratio established in Step 1, we find:

$$\text{Total Pyruvic Acid produced} = (\text{Molecules of Glucose}) \times 2$$

Substituting the value:

$$\text{Total Pyruvic Acid produced} = 206 \times 2$$

Let us carry out the multiplication step-by-step:

$$200 \times 2 = 400$$

$$6 \times 2 = 12$$

$$400 + 12 = 412$$

$$\text{Total Pyruvic Acid produced} = 412 \text{ molecules}$$

Thus, the total number of pyruvic acid molecules formed at the end of the glycolytic pathway is exactly 412, corresponding to option (1).

Quick Tip: To avoid confusion during respiratory stoichiometry calculations, always rely on conservation of carbon atoms:

$$\text{Total Initial Carbon Atoms} = \text{Total Final Carbon Atoms}$$

$$\text{Number of Glucose molecules} \times 6 = \text{Number of Pyruvate molecules} \times 3$$

This basic arithmetic rule prevents errors under exam pressure!

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96. Match List-I with List-II.

List-I	List-II
A. Fusion of protoplasms between gametes	I. Meiosis
B. Fusion of two nuclei	II. Plasmogamy
C. Generation of haploid spores	III. Karyogamy

Choose the **correct** answer from the options given below :

(1) A-I, B-III, C-II

(2) A-II, B-III, C-I

(3) A-II, B-I, C-III

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

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

Solution:

Concept: In the sexual reproduction cycle of fungi and many lower eukaryotic organisms, the progression toward producing offspring involves a highly coordinated series of cellular and nuclear events. This sequence follows three fundamental steps: the merging of cellular fluids, the subsequent merging of genetic centers, and eventually a reduction division to restore a haploid genome.

Step 1: Analyze Item A ("Fusion of protoplasms between gametes")

The cell contents excluding the nucleus are referred to as the protoplasm or cytoplasm. The word prefix *plasmo-* relates to the plasma or cell fluid, and *-gamy* means marriage or union. Therefore, the physical fusion of motile or non-motile gametic protoplasms without immediate nuclear fusion is defined precisely as **Plasmogamy**. This matches **A with II**.

Step 2: Analyze Item B ("Fusion of two nuclei")

Following plasmogamy, the cell contains two independent nuclei (often creating a dikaryon phase). The Greek word *karyon* refers to a nut or kernel, which scientifically denotes the cell nucleus. Hence, the fusion of these two haploid nuclei to form a single diploid ($2n$) zygotic nucleus is called **Karyogamy**. This matches **B with III**.

Step 3: Analyze Item C ("Generation of haploid spores")

Once a diploid nucleus is successfully produced via karyogamy, the organism must reduce its chromosome count back to the haploid state (n) to complete its life cycle and form reproductive propagation structures. This specialized reduction division is called **Meiosis**. The spores resulting from this process are haploid sexual spores. This matches **C with I**.

Step 4: Compiling the final matches

Combining the findings from the previous steps, we get:

- A $\rightarrow$ II
- B $\rightarrow$ III
- C $\rightarrow$ I

This precise configuration corresponds perfectly to option (2).

Quick Tip: To easily remember the sequential stages of sexual reproduction in fungi, just recall the abbreviation **P-K-M**:

$$\textbf{P}\text{lasmogamy (Protoplasm)} \rightarrow \textbf{K}\text{aryogamy (Nuclei)} \rightarrow \textbf{M}\text{eiosis (Spores)}$$

Breaking down terms etymologically (*plasmo* = cytoplasm, *karyo* = nucleus) eliminates any potential confusion!

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97. Mitochondrial inner membrane encloses___________.

(1) aqueous humor

(2) matrix

(3) cytosol

(4) mucus

Correct Answer: (2) matrix

Solution:

Concept: Mitochondria are double-membrane-bound organelles essential for aerobic cellular respiration, often referred to as the "powerhouses of the cell." Their structural framework consists of an outer membrane and a highly folded inner membrane. These two membranes divide the organelle into two distinct fluid-filled compartments:

1. The outer compartment, known as the intermembrane space, located between the outer and inner membranes.
2. The inner compartment, fully bounded and enclosed by the inner membrane.

Step 1: Identify the compartment enclosed by the inner membrane

The internal space enclosed directly by the highly convoluted inner mitochondrial membrane (which forms folds called cristae) is filled with a dense, homogeneous, gel-like proteinaceous fluid. This central core compartment is scientifically defined as the **matrix**. The matrix contains the circular mitochondrial DNA, ribosomes (70S), RNA molecules, and all the essential enzymes required for the Krebs cycle (Tricarboxylic Acid Cycle) and amino acid synthesis. Thus, the inner membrane encloses the matrix.

Step 2: Analysis and elimination of incorrect options

- **Option (1) Aqueous humor:** This is a clear, watery fluid filling the anterior chamber of the vertebrate eye between the cornea and the lens. It has no structural relationship with cellular organelles.
- **Option (3) Cytosol:** This is the liquid component of the cytoplasm surrounding all the organelles inside a cell. Mitochondria float within the cytosol; the cytosol is not inside the mitochondrion.
- **Option (4) Mucus:** This is a slippery, viscous secretion produced by mucous membranes and goblet cells in multicellular organisms to protect epithelial linings. It is an extracellular product, completely unrelated to sub-cellular membrane anatomy.

Therefore, option (2) is uniquely correct.

Quick Tip: Remember the division of labor inside a mitochondrion based on its anatomy:

- **Mitochondrial Matrix:** Site of Link Reaction and Krebs Cycle.
- **Inner Mitochondrial Membrane (Cristae):** Site of Electron Transport Chain (ETC) and Oxysomes ($F_0 - F_1$ complexes) for ATP synthesis.

---

98. Phyllotaxy is the pattern of arrangement of ____________.

(1) sepals

(2) leaves

(3) flowers

(4) fruits

Correct Answer: (2) leaves

Solution:

Concept: Plant morphology involves studying the specialized organizational patterns of various vegetative and reproductive organs. To maximize light interception for photosynthesis and optimize structural balance, plants arrange their appendages systematically along the stem axis or branches.

Step 1: Define Phyllotaxy

The term "Phyllotaxy" is constructed from two Greek root words: *phyllo* meaning "leaf" and *taxis* meaning "arrangement" or "ordering". Therefore, by definition, **phyllotaxy is the pattern of arrangement of leaves on the stem or a branch**.

Plants display three primary variations of phyllotaxy:

- **Alternate:** A single leaf emerges at each node in an alternating fashion (e.g., China rose, mustard, sunflower).
- **Opposite:** A pair of leaves develops at each node, lying directly opposite to one another (e.g., Calotropis, guava).
- **Whorled:** More than two leaves arise together in a circular cluster or ring at a single node (e.g., Alstonia, Nerium).

Step 2: Clarify terminology for other options

To completely validate the choice, let us review the structural terms used for the arrangement of other components:

- The mode of arrangement of sepals or petals in a floral bud with respect to other members of the same whorl is called **Aestivation**.
- The pattern of arrangement of flowers on the floral axis (peduncle) is defined as **Inflorescence**.

Since the question strictly specifies phyllotaxy, it applies exclusively to leaves. Thus, option (2) is correct.

Quick Tip: Use simple linguistic associations to recall plant morphology definitions instantly:

$$\textbf{Phyllo}\text{-taxy} \rightarrow \textit{Phyllon} = \textbf{Leaf} \implies \text{Arrangement of Leaves}$$

$$\text{In-}\textbf{flores}\text{-cence} \rightarrow \textit{Flos} = \textbf{Flower} \implies \text{Arrangement of Flowers}$$

---

99. Mad cow disease is caused by ____________.

(1) *Mycoplasma sp.*

(2) prions

(3) viroids

(4) *Aspergillus sp.*

Correct Answer: (2) prions

Solution:

Concept: In modern microbiology, certain infectious conditions are initiated by agents that do not fit into the standard categories of bacteria, fungi, or viruses. These sub-viral pathogens consist either of naked genetic material or completely protein-based structures capable of altering host cellular proteins.

Step 1: Understand the nature of Prions

Prions are abnormally folded, infectious proteins that lack any type of nucleic acid (neither DNA nor RNA). They cause progressive neurodegenerative disorders by interacting with normal cellular proteins in the central nervous system, forcing them to misfold into the same pathogenic configuration. This accumulation causes brain tissue to develop microscopic vacuoles, giving it a sponge-like appearance under a microscope.

Step 2: Link Prions to Mad Cow Disease

In cattle, this specific spongiform encephalopathy is clinically called Bovine Spongiform Encephalopathy (BSE), commonly recognized by its popular name, **Mad cow disease**. The human analog variant of this prion-mediated neurological disease is known as Cr-Jacob disease (CJD). Hence, prions are the causative agents of Mad cow disease.

Step 3: Analyze and eliminate other options

- **Option (1) *Mycoplasma sp.*:** These are cell-wall-less prokaryotic bacteria known to cause atypical pneumonia in humans and pleuropneumonia in animals, not spongiform encephalopathies.

- **Option (3) Viroids:** Discovered by T.O. Diener, these are infectious agents composed purely of a low-molecular-weight free RNA strand without a protein coat. They primarily target plants, causing diseases like Potato spindle tuber disease.

- **Option (4) *Aspergillus sp.*:** This is a genus of filamentous fungi responsible for respiratory fungal infections like aspergillosis or producing aflatoxins, completely unrelated to BSE.

This firmly establishes option (2) as the correct choice.

Quick Tip: Differentiate between sub-viral infectious particles using this clean structure:

Agent	Biochemical Composition	Classic Disease Example
Viroid	Naked single-stranded RNA (No Protein)	Potato spindle tuber disease
Prion	Misfolded infectious protein (No Nucleic Acid)	Mad cow disease (BSE) / CJD

---

100. Cell theory was formulated by ____________.

(1) Antonie Von Leeuwenhoek

(2) Schleiden and Schwann

(3) Robert Brown

(4) Singer and Nicolson

Correct Answer: (2) Schleiden and Schwann

Solution:

Concept: The development of cell biology as a unified branch of science began with establishing systematic principles describing the fundamental building blocks of all living organisms. These principles are summarized collectively as the **Cell Theory**.

Step 1: Historical context of the Cell Theory formulation

In the late 1830s, two German scientists working independently arrived at complementary conclusions regarding living organisms:

- **Matthias Schleiden (1838):** A German botanist who examined a wide variety of plant tissues and concluded that all plants are entirely composed of different kinds of cells, which form the tissues of the plant.

- **Theodor Schwann (1839):** A German zoologist who studied different types of animal cells. He reported that animal cells have a thin outer layer (now known as the plasma membrane) and noted that the presence of a cell wall is a unique feature characteristic only of plant cells. Based on this, he proposed the hypothesis that the bodies of both animals and plants are composed of cells and products of cells.

These two scientists combined their observations to formally outline and propose the classic **Cell Theory**.

Step 2: Analysis and elimination of other options
Let us look at the contributions of the other scientists listed in the options:

- **Option (1) Antonie Von Leeuwenhoek:** He was the first to observe, describe, and record a live, free-living cell (such as bacteria, protozoans, and spermatozoa) using his modified high-magnification single-lens microscopes.

- **Option (3) Robert Brown:** He discovered and named the central dark spherical structural component of the cell—the **nucleus**—in orchid root cells in the year 1831.

- **Option (4) Singer and Nicolson:** They proposed the widely accepted **Fluid Mosaic Model** in 1972 to describe the structural arrangement and dynamic nature of the plasma membrane.

Thus, option (2) is the accurate answer.

Quick Tip: While Schleiden and Schwann formulated the baseline Cell Theory, it had a major limitation: it could not explain *how* new cells are created. This missing link was resolved in 1855 by **Rudolf Virchow**, who introduced the phrase:

$$\textit{Omnis cellula-e cellula} \quad \Longrightarrow \quad \text{New cells arise only from pre-existing cells}$$

Together, these contributions define the modern cell theory.

---

101. Which of the following plant growth regulators promotes internode elongation prior to flowering in cabbage ?

(1) Ethephon

(2) Abscisic acid

(3) Gibberellin

(4) Indole butyric acid

Correct Answer: (3) Gibberellin

Solution:

Concept: Plant Growth Regulators (PGRs) are organic compounds other than nutrients that influence physiological processes in plants at very low concentrations. Gibberellins (GA) form a vital group of such growth-promoting hormones. One of their most characteristic physiological effects is the elongation of internodes in intact plants, especially in rosette plants like cabbage, beet, and many genetic dwarfs. The phenomenon of sudden elongation of internodes followed immediately by flowering is known as **bolting**.

Step 1: Understanding the physiological mechanism of bolting.
Rosette plants exhibit a growth habit characterized by a condensed stem with crowded leaves close to the soil level due to negligible internodal growth. Prior to the reproductive phase or under specific environmental cues (like long days or cold treatment), these plants undergo rapid axial elongation of the internodes. Under natural conditions, this is controlled by endogenous gibberellins. When gibberellin is artificially applied to rosette plants like cabbage, it triggers rapid cell division and cell elongation in the sub-apical meristem zone of the stem, prompting dramatic internodal lengthening (bolting) just before the flowering process initiates.

Step 2: Evaluating the other options to understand why they are incorrect.
Let us systematically evaluate the physiological roles of the other listed options:

- **(1) Ethephon:** Ethephon is an aqueous solution that readily breaks down into ethylene, a gaseous plant growth regulator. Its major functions include promoting fruit ripening, enhancing abscission of leaves and flowers, breaking seed/bud dormancy, and initiating flowering in a few specific crops like pineapple, but it does not cause stem or internode bolting.

- **(2) Abscisic acid (ABA):** Commonly designated as the stress hormone or growth inhibitor, ABA plays an essential role in lateral bud dormancy, seed development, maturation, and stomatal closure under drought conditions. It acts antagonistically to gibberellins and suppresses growth rather than elongating internodes.

- **(4) Indole butyric acid (IBA):** This is a naturally occurring auxin. Auxins primarily regulate apical dominance, promote cell division in the cambium, initiate root development in stem cuttings, and prevent premature fruit and leaf drop. They do not induce the characteristic bolting response observed in rosette plants.

Thus, Gibberellin is uniquely responsible for promoting internode elongation prior to flowering in cabbage.

Quick Tip: To remember the primary function of Gibberellins, associate the word **"Gibberellin"** directly with **"Giant growth"** and **"Bolting"**. Whenever you see keywords like "internode elongation in rosette plants", "cabbage", or "bolting prior to flowering", the correct answer is invariably Gibberellin (GA_3).

---

102. Which pigment has absorption peak at 700 nm in the photosynthetic reaction centre PS I (P700) ?

(1) Carotenoids

(2) Chlorophyll b

(3) Chlorophyll a

(4) Xanthophylls

Correct Answer: (3) Chlorophyll a

Solution:

Concept: Photosynthesis relies on specialized light-harvesting complexes called photosystems embedded within the thylakoid membranes of chloroplasts. A photosystem consists of a reaction centre surrounded by accessory light-harvesting complexes (antennae). The core molecule at the reaction centre of both Photosystem I (PS I) and Photosystem II (PS II) is always a specific molecule of **Chlorophyll a**, which acts as the primary electron donor upon photoexcitation.

Step 1: Analysis of Photosystem I (PS I) and its Reaction Centre.

In Photosystem I, the reaction centre contains a specialized pair of chlorophyll a molecules designated as **P700**. The letter 'P' stands for pigment, and the number '700' indicates the specific wavelength of light (in nanometers, nm) where this pigment shows its maximum absorption peak in the red region of the electromagnetic spectrum. When light energy is transferred from the accessory pigments to this reaction centre, the Chlorophyll a P700 molecule absorbs this specific energy and gets photo-excited, thereby ejecting an energized electron to a primary electron acceptor.

Step 2: Evaluating the role of other photosynthetic pigments.

To gain absolute clarity, let us assess the functions of the alternative pigments listed:

- **(1) Carotenoids & (4) Xanthophylls:** These are lipid-soluble accessory pigments. Carotenoids (pure hydrocarbons like β-carotene) and Xanthophylls (oxygenated derivatives) absorb light energy in the blue-violet and blue-green regions of the spectrum and transfer it to chlorophyll a. Additionally, they perform a crucial protective role by quenching excess light energy, thus shielding the delicate chlorophyll molecules from photo-oxidation. They never form the core reaction centre.

- **(2) Chlorophyll b:** This is an accessory green pigment that possesses an aldehyde group ($-CHO$) in place of the methyl group ($-CH_3$) found in chlorophyll a. It absorbs light at slightly different wavelengths (mostly around 450 nm and 640 nm) to broaden the spectrum of light usable for photosynthesis. It delivers its collected excitation energy down to the reaction centre chlorophyll a.

Therefore, the core pigment molecule located at the reaction centre P700 is explicitly Chlorophyll a.

Quick Tip: Remember the golden rule of photosynthesis: **Chlorophyll a is the "King" pigment.** It is the *only* pigment that can form the operational reaction centres (P680 in PS II and P700 in PS I). All other pigments (Chlorophyll b, Carotenoids, Xanthophylls) are merely "soldiers" or accessory pigments forming the antenna complex to harvest light and protect the King!

---

103. Sphenopsida class belongs to ____________.

(1) pteridophytes

(2) bryophytes

(3) angiosperms

(4) gymnosperms

Correct Answer: (1) pteridophytes

Solution:

Concept: In the kingdom Plantae, plants are classified into various divisions based on evolutionary patterns, morphological structural differentiation, and vascular architecture. The division **Pteridophyta** includes horsetails and ferns. Pteridophytes are the first terrestrial plants to possess vascular tissues, namely xylem and phloem. According to standard botanical classification systems, the division Pteridophyta is broadly divided into four distinct main classes.

Step 1: Detailing the classes of Pteridophytes.
To trace where Sphenopsida stands, let us look at the comprehensive classification of the division Pteridophyta:

1. **Psilopsida:** The most primitive living vascular plants, characterized by a protostelic rhizome and lack of true roots or well-developed leaves (e.g., *Psilotum*).
2. **Lycopsida:** Commonly referred to as club mosses, featuring microphyllous leaves and distinct strobili or cones (e.g., *Selaginella*, *Lycopodium*).
3. **Sphenopsida:** Popularly known as **horsetails**. They are characterized by articulated, jointed stems showing distinct nodes and internodes, with a whorl of microphyllous leaves at each node. Their cell walls are typically impregnated with silica, giving them a rough texture (e.g., *Equisetum*).
4. **Pteropsida:** The largest group, containing the true ferns, which possess megaphyllous leaves called fronds (e.g., *Dryopteris*, *Pteris*, *Adiantum*).

This directly demonstrates that the class Sphenopsida falls explicitly under the division Pteridophytes.

Step 2: Checking alternative options for clarity.
Let us quickly verify why the other plant groups are excluded from this class name:

- **(2) Bryophytes:** Bryophytes are non-vascular plants (amphibians of the plant kingdom) divided into Hepaticopsida (liverworts), Anthocerotopsida (hornworts), and Bryopsida (true mosses).
- **(3) Angiosperms:** These are flowering vascular plants whose seeds are enclosed inside fruits. They are divided into Monocotyledonae and Dicotyledonae.

- **(4) Gymnosperms:** These are naked-seeded vascular plants, classified into groups such as Cycadopsida, Coniferopsida, and Gnetopsida.

Hence, Sphenopsida belongs cleanly to pteridophytes.

Quick Tip: To remember the four major classes of Pteridophytes, memorize the mnemonic phrase: **"Please Let Sister Pray"** - **P**silopsida - **L**ycopsida - **S**phenopsida (*Equisetum* / Horse-tail) - **P**teropsida (Ferns)

---

104. Which of the following represents the correct sequence of arrangement of bones in the lower limb of humans ?

(1) Femur-tarsal-patella-tibia

(2) Femur-tibia-patella-tarsal

(3) Patella-femur-tibia-tarsal

(4) Femur-patella-tibia-tarsal

Correct Answer: (4) Femur-patella-tibia-tarsal

Solution:

Concept: The human skeletal system is divided into the axial skeleton and the appendicular skeleton. The appendicular skeleton includes the limbs (upper and lower limbs) and their respective girdles. Each lower limb contains exactly 30 distinct bones arranged in a precise structural sequence from proximal (closest to the hip girdle attachment point) to distal (farthest down at the toes) regions to enable bipedal locomotion, weight bearing, and structural stability.

Step 1: Anatomical tracing of the lower limb bones from top to bottom.

Let us review the sequential arrangement of bones along the axis of a human lower limb:

1. **Femur (Thigh bone):** The longest, heaviest, and strongest bone in the human body, situated in the thigh region. Its proximal head articulates with the acetabulum of the pelvic girdle.

2. **Patella (Knee cap):** A large, triangular-shaped sesamoid bone situated anteriorly at the knee joint. It develops within the tendon of the quadriceps femoris muscle and protects the knee joint, acting as a fulcrum for extension.

3. **Tibia and Fibula (Shank bones):** These form the lower leg skeleton below the knee. The **Tibia** (shin bone) is the larger, medial, weight-bearing bone, while the **Fibula** is slender and lateral.

4. **Tarsals (Ankle bones):** A group of 7 short, irregular bones located in the ankle region (including the calcaneus and talus).

5. **Metatarsals:** 5 elongated bones forming the sole of the foot.

6. **Phalanges:** 14 bones constituting the toes (arranged in a 2, 3, 3, 3, 3 pattern).

Step 2: Matching the sequence with the given options.

Let us check the structural sequence provided across the options from proximal to distal direction:

- Option (1): Femur → Tarsal → Patella → Tibia (Incorrect; tarsal is placed before the knee and shin).
- Option (2): Femur → Tibia → Patella → Tarsal (Incorrect; tibia cannot precede the patella chronologically down the limb).
- Option (3): Patella → Femur → Tibia → Tarsal (Incorrect; begins at the knee cap instead of the thigh bone).
- Option (4): Femur → Patella → Tibia → Tarsal (Correct; perfectly follows the anatomical order from the thigh down to the ankle).

Quick Tip: To remember the top-to-bottom sequence of major lower limb segments, think of your body movement: **Thigh → Knee → Shin → Ankle** Translate this directly to bones: **Femur → Patella → Tibia → Tarsal**

---

105. Which of the following plant growth regulators is used as herbicide ?

(1) Gibberellin

(2) 2,4-D

(3) Kinetin

(4) Abscisic acid

Correct Answer: (2) 2,4-D

Solution:

Concept: Synthetic plant growth regulators are extensively utilized in modern agricultural practices to optimize crop yields and manage weeds. Synthetic auxins have a unique property: when applied at exceptionally high or concentrated doses, they selectively target and disrupt the metabolic processes of specific plant groups without harming others. A classic example of such a chemical herbicide (weedicide) is **2,4-D** (2,4-Dichlorophenoxyacetic acid).

Step 1: Understanding the action and selectivity of 2,4-D.

The compound **2,4-D** is a powerful synthetic auxin. In agricultural fields, it is widely used as a selective herbicide because it specifically targets and eradicates **broad-leaved dicotyledonous weeds**, while leaving mature monocotyledonous plants (such as cereal crops like wheat, rice, maize, and lawn grasses) completely unaffected. It induces uncontrolled, rapid, and distorted cellular growth in the dicot weeds, leading to epinasty, twisting of stems, disruption of vascular transport phloem tissues, and eventual death of the weed. This makes it an incredibly useful tool for maintaining weed-free lawns and crop fields.

Step 2: Checking the other plant growth regulators for any herbicide properties.

Let us review the options to confirm they lack herbicidal functions:

- **(1) Gibberellin:** Used primarily to increase the length of grape stalks, elongate and improve the shape of fruits like apples, delay senescence, and speed up the malting process in the brewing industry. It is never used as an herbicide.
- **(3) Kinetin:** A type of cytokinin that promotes cell division, delays leaf senescence (Richmond-Lang effect), and helps overcome apical dominance. It is used in tissue culture to induce shoot differentiation but has no weed-killing property.
- **(4) Abscisic acid (ABA):** Functions as an internal plant hormone regulating stress responses and inducing seed dormancy. It is costly to synthesize artificially and is not used as a commercial agricultural spray or herbicide.

Thus, 2,4-D is specifically manufactured and marketed as a potent commercial herbicide.

Quick Tip: Keep this structural formula or shorthand in mind: **2,4-D = Dicot Destroyer.** It kills **D**icot weeds selectively. Because it is a synthetic auxin, it mimics normal plant hormones but acts like a poison at high concentrations only for broad-leaved plants, making it a stellar herbicide!

---

106. Genus represents ____________.

(1) a group of closely related families

(2) an individual plant or animal

(3) a population of plants and animals

(4) a group of closely related species

Correct Answer: (4) a group of closely related species

Solution:

Concept: Taxonomic hierarchy consists of various ranks arranged in descending or ascending order, where each rank denotes a category or taxon. Moving upward from the most specific unit (Species), categories aggregate based on shared evolutionary similarities.

Step 1: Define Genus

A **Genus** comprises an assembly of species that share common structural, reproductive, and evolutionary characteristics. It ranks directly above the level of species and below the level of family. The component species within a genus possess more features in common with each other compared to species belonging to other genera. For example, the lion (*Panthera leo*), leopard (*Panthera pardus*), and tiger (*Panthera tigris*) are distinct species that all belong to the same genus, *Panthera*.

Step 2: Analyze and eliminate other options

- **Option (1):** A group of closely related families describes an **Order** or **Cohort**, not a genus.
- **Option (2):** An individual organism represents a single biological entity belonging to a specific population, which is the finest unit rather than a taxonomic grouping category.
- **Option (3):** A population refers to an ecological grouping of individuals of a single species occupying a particular geographic area, not a formal taxonomic grouping category like a genus.

Therefore, option (4) is correct.

Quick Tip: To remember the arrangement of standard taxonomic levels from broadest to most specific, memorize the phrase:

King **P**hilip **C**ame **O**ver **F**or **G**ood **S**oup

Kingdom → **P**hylum → **C**lass → **O**rder → **F**amily → **G**enus → **S**pecies

Since Species is at the base, the level right above it (**Genus**) is naturally a collection of closely related species!

---

107. The plastid that stores xanthophyll is known as ____________.

(1) amyloplast

(2) chloroplast

(3) chromoplast

(4) aleuroplast

Correct Answer: (3) chromoplast

Solution:

Concept: Plastids are semi-autonomous double-membrane-bound organelles found in the cells of plants and algae. Based on the presence or absence of specific pigments and their metabolic role, plastids are divided into three major classes: leucoplasts (colorless storage plastids), chloroplasts (green photosynthetic plastids), and chromoplasts (colored, non-photosynthetic plastids).

Step 1: Understand the nature of Chromoplasts

Chromoplasts are responsible for synthesizing and accumulating fat-soluble carotenoid pigments, such as carotene and **xanthophyll**. These pigments give parts of the plant—like flower petals, ripening fruits, and certain roots—their characteristic bright yellow, orange, or red colors. Thus, the plastid containing and storing xanthophyll is the chromoplast.

Step 2: Review and eliminate the alternative options

- **Option (1) Amyloplast:** This is a type of colorless leucoplast specialized specifically for the synthesis and storage of starch granules (e.g., in potato tubers).

- **Option (2) Chloroplast:** This contains chlorophyll and carotenoid pigments mainly dedicated to trapping solar energy for photosynthesis, giving plants their green appearance.
- **Option (4) Aleuroplast:** Also known as a proteinoplast, this is a specialized leucoplast that stores proteins (e.g., in maize grains).

This confirms option (3) is uniquely correct.

Quick Tip: Categorize plastids easily with this clean functional breakdown:

Plastid Type	Key Pigments / Material Stored	Color Profile
Chloroplast	Chlorophyll, Carotenoids (Photosynthesis)	Green
Chromoplast	Carotene, **Xanthophyll**	Yellow, Orange, Red
Amyloplast	Starch (Carbohydrate Storage)	Colorless
Aleuroplast	Proteins	Colorless
Elaioplast	Fats and Oils	Colorless

---

108. In water, frogs respire using ____________.

(1) trachea
(2) skin
(3) buccal cavity
(4) lungs

Correct Answer: (2) skin

Solution:

Concept: Amphibians like frogs exhibit diverse respiratory strategies depending on their environment and life cycle stage. Because they divide their life history between aquatic and terrestrial habitats, adult frogs utilize multiple respiratory surfaces: the skin, the lining of the buccal cavity, and the lungs.

Step 1: Analyze respiration in an aquatic medium

When a frog is fully submerged **in water**, its primary mode of gas exchange is through its highly vascularized, thin, and moist skin. This process is called **cutaneous respiration**. Dissolved oxygen in the water diffuses directly across the thin dermal layer into the subcutaneous blood capillaries, while carbon dioxide diffuses outward into the surrounding water.

Step 2: Understand respiration on land for context

When a frog moves onto land, it can use pulmonary respiration (via the lungs) and buccal respiration (via the moist epithelium lining the oral cavity). However, inside the water, the lungs remain inactive, and gas exchange relies almost entirely on cutaneous diffusion.

Therefore, option (2) is correct.

Quick Tip: Remember the two key rules for a frog's respiratory shifts:

- **In Water / During Hibernation & Aestivation:** Respiration is strictly **Cutaneous** (via the **skin**).
- **On Land:** Uses a mix of **Pulmonary** (lungs), **Buccal** (mouth lining), and **Cutaneous** (skin) respiration.

---

109. Which of the following is not a characteristic of chordates?

(1) Presence of post anal part (tail)
(2) Presence of notochord
(3) Central nervous system is dorsal
(4) Absence of gills

Correct Answer: (4) Absence of gills

Solution:

Concept: Phylum Chordata is defined by a distinct suite of fundamental morphological traits present at some stage of their development. Identifying non-chordate properties requires evaluating these key distinguishing markers against non-chordate invertebrates.

Step 1: Review the core characteristics of Chordates

True chordates are uniquely distinguished by four diagnostic features:

1. **Notochord:** A solid, flexible, rod-like skeletal structure running along the dorsal side during embryonic development.
2. **Dorsal Hollow Nerve Cord:** A single central nervous system strand located dorsally relative to the digestive tract.
3. **Pharyngeal Gill Slits:** Pairs of lateral openings or clefts in the wall of the pharynx, which function in respiration or filter feeding (retained as gills in fish or modified into

alternative structures in higher terrestrial vertebrates during embryonic development).

4. **Post-anal Tail:** An elongation of the body extending past the anus.

Step 2: Evaluate the statement "Absence of gills"

Since **pharyngeal gill slits** are a defining baseline characteristic of chordates, stating that chordates are characterized by an *absence of gills* is factually incorrect. Many aquatic chordates (like fishes and protochordates) actively maintain functioning gills throughout their lives. Because the question explicitly asks for the feature that is **NOT** a characteristic of chordates, option (4) is the correct choice.

Quick Tip: Keep this comparative summary handy to instantly solve questions contrasting Chordates vs Non-Chordates:

Chordates	Non-Chordates
Notochord is present.	Notochord is absent.
Central Nervous System is **Dorsal, hollow, single.**	Central Nervous System is **Ventral, solid, double**
Pharyngeal **gill slits are present.**	Gill slits are absent.
Post-anal tail is present.	Post-anal tail is absent.

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110. Smooth endoplasmic reticulum ____________.

(1) is a site for the synthesis of carbohydrates

(2) has ribosomes attached to its surface

(3) is the major site for the synthesis of lipids

(4) is actively involved in protein synthesis

Correct Answer: (3) is the major site for the synthesis of lipids

Solution:

Concept: The endoplasmic reticulum (ER) is an extensive interconnected network of intracellular membrane-bound tubules and flattened sacs (cisternae) traversing the cytoplasm. It is structurally and functionally segregated into two distinct domains depending on the presence of membrane-bound translation machinery:

Step 1: Distinguish between RER and SER

- **Rough Endoplasmic Reticulum (RER):** Features outer membrane surfaces heavily studded with active **ribosomes**. This configuration specializes in synthesizing, folding, and sorting secretable or membrane-bound **proteins**.

- **Smooth Endoplasmic Reticulum (SER):** Lacks attached ribosomes on its outer face, giving it a smooth tubular appearance.

Step 2: Pinpoint the function of the Smooth Endoplasmic Reticulum (SER)
The SER contains specialized enzyme systems involved in metabolic processes. Its primary, well-documented cellular function is serving as the **major site for lipid synthesis** (including phospholipids, fatty acids, and cholesterol derivatives). In animal cells, the SER also synthesizes lipid-like steroid hormones (such as estrogen, progesterone, and testosterone) and helps detoxify drugs and metabolic toxins.

Step 3: Evaluate and rule out incorrect options

- **Option (1):** Complex carbohydrate processing or glycosylation occurs mainly inside the Golgi apparatus.
- **Option (2) & (4):** Possessing attached surface ribosomes and managing protein translation are defining characteristics exclusive to the **Rough** Endoplasmic Reticulum (RER).

Hence, option (3) is correct.

Quick Tip: Remember this clear division of labor for the Endoplasmic Reticulum:

$$\text{Rough ER (Ribosomes Present)} \implies \text{Protein Synthesis}$$

$$\text{Smooth ER (Sno Ribosomes)} \implies \text{Lipid \& Steroid Hormone Synthesis}$$

111.

Which of the following are characteristics of prokaryotic cells?

(a) Ribosomes are made of 50S and 30S subunits (b) They can have plasmids (c) They contain mesosome (d) They have peroxisomes

Choose the correct answer from the options given below :

(A) (a), (b) and (c) only

(B) (b) and (c) only

(C) (a) and (c) only

(D) (a), (c) and (d) only

Correct Answer: (1) (a), (b) and (c) only

Solution:

Concept:

Prokaryotic cells are the simplest and most primitive cellular organisms. They lack a true nucleus and membrane-bound organelles. Their genetic material remains in direct contact with the cytoplasm and is present in a nucleoid region. Bacteria, cyanobacteria and mycoplasma are examples of prokaryotes.

To identify the correct characteristics of prokaryotic cells, let us examine each statement individually.

Analysis of Statement (a): Ribosomes are made of 50S and 30S subunits

The ribosomes present in prokaryotic cells are of the 70S type.

A 70S ribosome consists of:

$$50S + 30S = 70S$$

where:

- 50S is the larger subunit.
- 30S is the smaller subunit.

These ribosomes are responsible for protein synthesis in bacteria and other prokaryotes.

Therefore, statement (a) is **correct**.

Analysis of Statement (b): They can have plasmids

Plasmids are small circular double-stranded DNA molecules that exist independently of the main bacterial chromosome.

They:

- Replicate independently.
- Often carry antibiotic resistance genes.

- Can be transferred from one bacterium to another.
- Are widely used in genetic engineering as vectors.

Since plasmids are commonly found in prokaryotes, statement (b) is **correct**.

Analysis of Statement (c): They contain mesosome

Mesosomes are infoldings of the plasma membrane reported in prokaryotic cells.
According to NCERT:

- Mesosomes are extensions of the plasma membrane.
- They help in cell wall formation.
- They assist in DNA replication and distribution to daughter cells.
- They increase the surface area of the plasma membrane.

Hence statement (c) is **correct**.

Analysis of Statement (d): They have peroxisomes

Peroxisomes are membrane-bound organelles.
They are present only in eukaryotic cells and contain enzymes involved in:

- Breakdown of hydrogen peroxide.
- Oxidative metabolism.
- Detoxification reactions.

Since prokaryotic cells lack membrane-bound organelles, they do not possess peroxisomes.
Therefore statement (d) is **incorrect**.

Thus:

$$(a),\ (b),\ (c)$$

are correct and

$$(d)$$

is incorrect.

Hence the correct answer is

$$\boxed{(1)\ (a),\ (b) \text{ and } (c) \text{ only}}$$

Quick Tip: Remember the key features of prokaryotes:

- 70S ribosomes (50S + 30S)
- Plasmids may be present
- Mesosomes present
- No membrane-bound organelles
- No mitochondria, ER, Golgi bodies or peroxisomes

---

112. Match List-I with List-II.

List-I		List-II	
A	Cristae	*I*	Flat membrane sacs in stroma of chloroplast
B	Cisternae	*II*	Infoldings in mitochondria
C	Thylakoids	*III*	Cell membrane
D	Phospholipid	*IV*	Disc-shaped sacs in Golgi apparatus

Choose the correct answer from the options given below :

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

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

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

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

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

Solution:

Concept:

Different cellular organelles possess characteristic structural components. Proper identification of these structures is essential for understanding cell organization and function.

Let us match each term carefully.

A. Cristae

Cristae are inward foldings of the inner mitochondrial membrane.

They:

- Increase surface area.
- Contain ATP synthesizing enzymes.
- Are the sites of oxidative phosphorylation.

Therefore,

$$A \rightarrow II$$

B. Cisternae

Cisternae are flattened membrane-bound sacs that form the Golgi apparatus.

They are involved in:

- Packaging of proteins.
- Modification of biomolecules.
- Secretion.

Hence,

$$B \rightarrow IV$$

C. Thylakoids

Thylakoids are flattened membrane sacs present in the chloroplast stroma.

They contain:

- Chlorophyll pigments.
- Photosystems.
- Electron transport chain components.

Therefore,

$$C \rightarrow I$$

D. Phospholipid

The plasma membrane is primarily composed of phospholipid molecules arranged in a bilayer. Thus,

$$D \rightarrow III$$

Combining all matches:

$$A - II, \quad B - IV, \quad C - I, \quad D - III$$

Hence the correct option is

$$\boxed{(3)}$$

Quick Tip: Remember these one-line associations:

- Cristae $\rightarrow$ Mitochondria
- Cisternae $\rightarrow$ Golgi apparatus
- Thylakoids $\rightarrow$ Chloroplast
- Phospholipid $\rightarrow$ Cell membrane

---

113. Which of the following statements related to pituitary gland are correct?

(a) It is divided anatomically into adenohypophysis and neurohypophysis (b) It secretes follicle stimulating hormone (c) It secretes melanocyte stimulating hormone (d) It does not secrete prolactin

Choose the correct answer from the options given below :

(A) (b) and (c) only

(B) (a) and (b) only

(C) (a), (b) and (c) only

(D) (c) and (d) only

Correct Answer: (3) (a), (b) and (c) only

Solution:

Concept:

The pituitary gland is known as the "master gland" because it regulates the activity of several other endocrine glands through its hormones.

It is attached to the hypothalamus and is located at the base of the brain.

Let us examine each statement.

Statement (a)

The pituitary gland is anatomically divided into:

- Adenohypophysis (anterior pituitary)
- Neurohypophysis (posterior pituitary)

Hence statement (a) is **correct**.

Statement (b)

Follicle Stimulating Hormone (FSH) is secreted by the anterior pituitary.

Functions of FSH include:

- Stimulating ovarian follicle development in females.
- Stimulating spermatogenesis in males.

Therefore statement (b) is **correct**.

Statement (c)

The pars intermedia of the pituitary gland secretes Melanocyte Stimulating Hormone (MSH).

MSH influences pigmentation processes.

Therefore statement (c) is **correct**.

Statement (d)

Prolactin is secreted by the anterior pituitary gland.

Its primary function is:

- Initiation and maintenance of milk production after childbirth.

Hence the statement that pituitary gland does not secrete prolactin is false.
Therefore statement (d) is **incorrect**.

Thus statements

$$(a),\ (b),\ (c)$$

are correct.
Hence the correct answer is

$$\boxed{(3)\ (a),\ (b)\text{ and }(c)\text{ only}}$$

Quick Tip: Important pituitary hormones:

- GH
- TSH
- ACTH
- FSH
- LH
- Prolactin
- MSH

Most of these are secreted by the anterior pituitary.

---

114. Which of the following statements regarding photorespiration are correct?

(A) Does not occur in C_3 plants (B) CO_2 is consumed and O_2 is generated (C) Phosphoglycolate is formed (D) No synthesis of ATP and NADPH

Choose the correct answer from the options given below :

(A) (a) and (b) only

(B) (a) and (d) only

(C) (c) and (d) only

(D) (b) and (d) only

Correct Answer: (3) (c) and (d) only

Solution:

Concept:

Photorespiration is a process initiated when the enzyme RuBisCO acts as an oxygenase instead of a carboxylase.

This generally occurs under conditions of:

- High oxygen concentration
- Low carbon dioxide concentration
- High temperature

The process involves chloroplasts, peroxisomes and mitochondria.

Let us analyze each statement.

Statement (a): Does not occur in C_3 plants

Photorespiration is actually a characteristic feature of C_3 plants.

C_4 plants largely avoid photorespiration through their carbon concentrating mechanism.

Therefore statement (a) is **incorrect**.

Statement (b): CO_2 is consumed and O_2 is generated

In photorespiration:

- Oxygen is consumed.
- Carbon dioxide is released.

Thus the given statement is exactly opposite to what occurs.

Hence statement (b) is **incorrect**.

Statement (c): Phosphoglycolate is formed

When RuBisCO acts as an oxygenase:

$$RuBP + O_2$$

produces

$$\text{3-PGA} + \text{2-phosphoglycolate}$$

Therefore phosphoglycolate is indeed formed.

Hence statement (c) is **correct**.

Statement (d): No synthesis of ATP and NADPH

Photorespiration is considered a wasteful process because:

- ATP is not produced.
- NADPH is not produced.
- Carbon dioxide is released.
- Previously fixed carbon is lost.

Therefore statement (d) is **correct**.

Hence only statements

$$(c) \text{ and } (d)$$

are correct.

Therefore the correct answer is

$$\boxed{(3)\ (c) \text{ and } (d) \text{ only}}$$

Quick Tip: Photorespiration is often called a wasteful pathway because:

- O_2 is consumed.
- CO_2 is released.
- ATP is not synthesized.
- NADPH is not synthesized.
- Fixed carbon is lost.

It is most prominent in C_3 plants.

---

115. Which of the following statements is incorrect?

(A) Fibrinogen is produced from fibrin

(B) Blood coagulates in response to an injury

(C) Blood clot consists of fibrins

(D) Fibrin is produced from fibrinogen

Correct Answer: (1) Fibrinogen is produced from fibrin

Solution:

Concept:

Blood coagulation or blood clotting is an extremely important protective mechanism of the human body. Whenever an injury causes damage to blood vessels, the body activates a sequence of biochemical reactions known as the clotting cascade. This process prevents excessive blood loss.

A protein called fibrinogen, which is soluble in blood plasma, gets converted into an insoluble protein called fibrin by the action of the enzyme thrombin. These fibrin threads form a mesh-like network that traps blood cells and ultimately forms the blood clot.

To answer this question, we need to understand the direction of conversion between fibrinogen and fibrin and identify which statement incorrectly represents this biological process.

Step 1: Understand the role of fibrinogen in blood clotting.

Fibrinogen is a soluble plasma protein present in circulating blood. It remains inactive under normal physiological conditions.

When tissue damage occurs, clotting factors become activated and eventually convert prothrombin into thrombin.

Thrombin then acts on fibrinogen and converts it into fibrin.

Thus, the biological pathway is

$$Fibrinogen \rightarrow Fibrin$$

and not the reverse process.

Step 2: Check Option (A).

Option (A) states

Fibrinogen is produced from fibrin

This is scientifically incorrect.

Fibrinogen is the precursor molecule and fibrin is produced from fibrinogen during coagulation.

Hence this statement reverses the actual biological process.

Therefore option (A) is incorrect.

Step 3: Verify the remaining options.

Option (B):

Blood coagulates in response to injury.

This is correct because clotting is a defense mechanism activated during vascular injury.

Option (C):

Blood clot consists of fibrins.

This is correct because fibrin forms thread-like fibers making the clot mesh.

Option (D):

Fibrin is produced from fibrinogen.

This is biologically correct.

Step 4: Determine final answer.

Since only Option (A) contradicts the actual blood clotting mechanism, it is the incorrect statement.

Hence,

$$\boxed{\text{Option (1)}}$$

Quick Tip: Remember the blood clotting conversion sequence as: Fibrinogen (soluble) → Fibrin (insoluble clot fibers). If reversed in options, it is incorrect.

---

116. Arrange the following taxonomic categories in ascending order.

(a) Genus (b) Class (c) Order (d) Phylum

(e) Family (f) Kingdom (g) Species

(A) (f), (c), (b), (g), (d), (e), (a)

(B) (g), (a), (e), (c), (b), (d), (f)

(C) (a), (c), (d), (g), (f), (b), (e)

(D) (g), (c), (d), (b), (e), (a), (f)

Correct Answer: (2)

Solution:

Concept:

Biological classification organizes organisms into hierarchical taxonomic categories based on similarities and evolutionary relationships.

Taxonomy follows a fixed hierarchy from smallest category to largest category.

The standard taxonomic sequence is

$$Species \rightarrow Genus \rightarrow Family \rightarrow Order \rightarrow Class \rightarrow Phylum \rightarrow Kingdom$$

Ascending order means moving from smallest level toward highest and broadest level.

Step 1: Recall taxonomic hierarchy.

The biological classification system groups organisms systematically.

The smallest taxonomic unit is species because members share maximum similarity.

Above species comes genus, then family, then order.

Higher categories include class, phylum, and finally kingdom.

Thus sequence becomes

$$Species < Genus < Family < Order < Class < Phylum < Kingdom$$

Step 2: Convert into given letter sequence.

Given letters:

Species = g

Genus = a

Family = e

Order = c

Class = b

Phylum = d

Kingdom = f

So required order is

$$(g),(a),(e),(c),(b),(d),(f)$$

Step 3: Match with options.

Checking options carefully

Option (B) exactly matches required sequence.

Therefore Option (2) is correct.

Step 4: State final answer.

Hence correct ascending arrangement is

$$Species \rightarrow Genus \rightarrow Family \rightarrow Order \rightarrow Class \rightarrow Phylum \rightarrow Kingdom$$

Thus

$$\boxed{\text{Option (2)}}$$

Quick Tip: Memorize taxonomy using shortcut: King Philip Came Over For Good Soup (Kingdom, Phylum, Class, Order, Family, Genus, Species) Reverse it for ascending order.

---

117. Select the correct sequence of experiments that led to gradual understanding of photosynthesis in green plants.

(A) Production of glucose → role of air → release of oxygen → absorption spectra of chlorophyll a and b

(B) Absorption spectra of chlorophyll a and b → production of glucose → release of oxygen → role of air

(C) Role of air → release of oxygen → production of glucose → absorption spectra of chlorophyll a and b

(D) Release of oxygen → production of glucose → absorption spectra of chlorophyll a and b → role of air

Correct Answer: (3)

Solution:

Concept:
The understanding of photosynthesis developed gradually through contributions of many scientists.
Important discoveries happened chronologically.
Scientists first studied the role of air in plant growth, then oxygen release, then formation of glucose as food, and later chlorophyll absorption spectra.
Thus historical order matters.
Step 1: Identify earliest discovery.

Jan Ingenhousz and Joseph Priestley studied the role of air and showed plants restore air quality.
This established the role of air in photosynthesis.
Hence first stage:

$$\text{Role of air}$$

Step 2: Identify second discovery.

Further experiments showed that green plants release oxygen during photosynthesis.
This established oxygen evolution.
Hence second stage:

$$\text{Release of oxygen}$$

Step 3: Identify later discoveries.

Scientists later discovered that photosynthesis produces glucose as stored chemical energy.
Afterward, chlorophyll pigments were studied and their absorption spectra were determined.
Hence sequence becomes

$$\text{Role of air} \rightarrow \text{Release of oxygen} \rightarrow \text{Production of glucose} \rightarrow \text{Absorption spectra}$$

Step 4: Match options.

Option (C) matches perfectly.
Therefore

$$\boxed{\text{Option (3)}}$$

Quick Tip: Historical order of photosynthesis discovery: Air role → Oxygen release → Food production → Chlorophyll absorption study.

---

118. Match List-I with List-II.

List-I	List-II
A. Starch	I. Fights infection
B. Antibody	II. Energy storage
C. Concanavalin A	III. Glucose transport
D. Glut-4	IV. Lectin

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

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

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

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

Correct Answer: (1)

Solution:

Concept:

Biological molecules and proteins have specialized functions.

Correct matching depends on understanding each molecule individually.

Starch stores energy.

Antibodies defend against infection.

Concanavalin A is lectin.

GLUT-4 transports glucose.

Step 1: Match starch.

Starch is the storage carbohydrate in plants.

Hence

$$A \rightarrow II$$

Step 2: Match antibody.

Antibodies are proteins produced by immune system against pathogens.

Their main role is defense against infection.

Hence

$$B \rightarrow I$$

Step 3: Match remaining terms.

Concanavalin A is a lectin protein.

Thus

$$C \rightarrow IV$$

GLUT-4 is glucose transporter protein.

Thus

$$D \to III$$

Step 4: Final arrangement.

Complete match:

$$A-II,\ B-I,\ C-IV,\ D-III$$

Thus answer is

$$\boxed{\text{Option (1)}}$$

Quick Tip: Remember: Starch = Storage Antibody = Infection defense GLUT-4 = Glucose transport Concanavalin A = Lectin

---

119. The number of vertebrae in a human is

(A) 206

(B) 7

(C) 12

(D) 26

Correct Answer: (4) 26

Solution:

Concept:

The human vertebral column forms the central supporting axis of the body.

In early life humans possess 33 vertebrae, but some fuse during adulthood.

Thus adults effectively have 26 vertebral bones.

Step 1: Understand vertebral divisions.

The vertebral column consists of

7 cervical vertebrae

12 thoracic vertebrae

5 lumbar vertebrae

5 sacral fused vertebrae

4 coccygeal fused vertebrae

Step 2: Calculate total in adults.

Since sacral and coccygeal regions fuse,

Adult count becomes

$$24 + 1 + 1 = 26$$

Step 3: Check options.

$206 =$ total bones of body

$7 =$ cervical only

$12 =$ thoracic only

$26 =$ adult vertebral column

Hence answer

$$\boxed{\text{Option (4)}}$$

Quick Tip: Remember: 33 vertebrae in young age 26 bones in adult vertebral column after fusion.

---

120. Endomembrane system includes

(A) Golgi complex, chloroplast, peroxisomes and vacuole

(B) Endoplasmic reticulum, Golgi complex, lysosomes and vacuole

(C) Endoplasmic reticulum, chloroplast, peroxisomes and vacuole

(D) Mitochondria, chloroplast, peroxisomes and vacuole

Correct Answer: (2)

Solution:

Concept:

The endomembrane system is a group of membrane-bound organelles working together in synthesis, packaging, modification and transport of cellular substances.

Organelles included are interconnected functionally.

However mitochondria, chloroplast and peroxisomes function independently and are excluded.

Step 1: Identify organelles included in endomembrane system.

The endomembrane system consists of

Endoplasmic reticulum

Golgi apparatus

Lysosomes

Vacuoles

These work together in protein transport and secretion.

Step 2: Understand excluded organelles.

Mitochondria produce ATP.

Chloroplast performs photosynthesis.

Peroxisomes perform oxidation reactions.

These function separately.

Hence not included.

Step 3: Check options carefully.

Only Option (B) contains correct components.

$$ER + Golgi + Lysosome + Vacuole$$

Step 4: Final answer.

Therefore correct answer is

$$\boxed{\text{Option (2)}}$$

Quick Tip: Endomembrane System = ER + Golgi + Lysosome + Vacuole. Never include mitochondria, chloroplast or peroxisomes.

---

121. Length of the stem at time 0 is 20 cm. The arithmetic growth rate is 30 cm per day. What is the length of the stem at the end of the 7th day?

(A) 460 cm

(B) 50 cm

(C) 170 cm

(D) 230 cm

Correct Answer: (4) 230 cm

Solution:

Concept:

Arithmetic growth refers to a pattern of growth in which increase occurs by a constant amount during equal intervals of time. In biological growth patterns, arithmetic growth means the organism increases by a fixed quantity each day rather than increasing proportionally.

The mathematical relation used for arithmetic growth is

$$L_t = L_0 + rt$$

where

$$L_t = \text{Length after time } t$$

$$L_0 = \text{Initial length}$$

$$r = \text{Growth rate}$$

$$t = \text{Time}$$

Since the increase is constant every day, we directly substitute values into the formula.

Step 1: Identify all quantities given in the question.

The problem states:

Initial stem length at time zero

$$L_0 = 20\ cm$$

Arithmetic growth rate

$$r = 30\ cm/day$$

Time duration

$$t = 7\ days$$

We now substitute these values into the arithmetic growth formula.

Step 2: Apply arithmetic growth formula.

The formula is

$$L_t = L_0 + rt$$

Substituting values

$$L_t = 20 + (30 \times 7)$$

Multiplication gives

$$L_t = 20 + 210$$

Step 3: Calculate final length.

Adding the two terms

$$L_t = 230\ cm$$

This means after seven days, the stem length becomes 230 centimeters.

Step 4: Match with answer options.

Checking options:

460 cm $\rightarrow$ incorrect

50 cm $\rightarrow$ incorrect

170 cm $\rightarrow$ incorrect

230 cm $\rightarrow$ correct

Therefore correct answer is

$$\boxed{230\ cm}$$

Hence

$$\boxed{\text{Option (4)}}$$

Quick Tip: Arithmetic growth means constant increase per unit time. Always use formula $L_t = L_0 + rt$ where growth rate remains fixed.

122.

Match List-I with List-II.

	List-I		List-II
A.	Spherical II	I.	Vibrio
B.	Rod IV	II.	Cocci
C.	Comma I	III.	Spirilla
D.	Spirillum III	IV.	Bacilli

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

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

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

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

Correct Answer: (1)

Solution:

Concept:

Bacteria are classified on the basis of shape. Morphological classification is one of the simplest methods of bacterial categorization.

Different bacterial shapes have specific scientific names.

The major bacterial forms include spherical bacteria, rod-shaped bacteria, comma-shaped bacteria and spiral-shaped bacteria.

Understanding these shapes helps us correctly match the terms.

Step 1: Identify spherical bacteria.

Spherical bacteria are known as cocci.

They are round or globe-shaped bacterial cells.

Examples include Streptococcus and Staphylococcus.

Therefore

$$A \to II$$

Step 2: Identify rod-shaped bacteria.

Rod-shaped bacteria are scientifically called bacilli.

These elongated bacterial cells include organisms such as Lactobacillus.

Thus

$$B \to IV$$

Step 3: Identify comma-shaped bacteria.

Comma-shaped bacteria are known as vibrio.

A well-known example is Vibrio cholerae which causes cholera.

Hence

$$C \to I$$

Step 4: Identify spiral-shaped bacteria.

Spiral bacteria are called spirilla.

These organisms possess twisted spiral structure.

Therefore

$$D \rightarrow III$$

Final matching becomes

$$A-II,\ B-IV,\ C-I,\ D-III$$

Thus answer is

$$\boxed{\text{Option (1)}}$$

Quick Tip: Remember bacterial shapes: Cocci = Spherical Bacilli = Rod shaped Vibrio = Comma shaped Spirilla = Spiral shaped

---

123. The number of action potentials generated by sino-atrial node (SAN) in a healthy human is ______ per minute.

(A) 120 – 140

(B) 28 – 30

(C) 70 – 75

(D) 100 – 110

Correct Answer: (3) 70 – 75

Solution:

Concept:

The sinoatrial node (SAN) is called the natural pacemaker of the human heart. It is a specialized group of cardiac muscle fibers located in the right atrium.

Its main function is to generate electrical impulses automatically. These electrical impulses initiate each heartbeat.

The rate at which SAN generates impulses determines the normal heart rate.

In healthy adults, SAN generates approximately 70 to 75 electrical impulses every minute.

Step 1: Understand the role of sinoatrial node.

The human heart contains specialized tissues responsible for generating rhythmic impulses.

The sinoatrial node is the primary pacemaker.

Its impulse spreads through atria causing atrial contraction.

Because SAN starts every heartbeat, its firing rate determines heartbeat frequency.

Step 2: Recall normal physiological rate.

According to human physiology,

SAN generates approximately

$$70 - 75$$

action potentials every minute.

Each impulse initiates one heartbeat.

Therefore resting heart rate remains approximately within this range.

Step 3: Examine wrong options.

120–140 $\rightarrow$ much higher than normal resting rate

28–30 $\rightarrow$ abnormally low

100–110 $\rightarrow$ higher than normal physiological average

70–75 $\rightarrow$ correct physiological range

Step 4: Final conclusion.

Thus normal impulse generation rate of SAN is

$$70 - 75$$

Hence correct answer is

$$\boxed{\text{Option (3)}}$$

Quick Tip: SAN = Natural pacemaker of heart. Normal firing rate = 70–75 impulses per minute. This controls normal resting heart rhythm.

---

124. Match List-I with List-II.

	List-I		List-II
A.	Family III	I.	Sapindales
B.	Genus V	II.	Dicotyledonae
C.	Class II	III.	Anacardiaceae
D.	Phylum	IV.	Angiospermae
E.	Order I	V.	*Mangifera*

Choose the correct answer from the options given below:

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

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

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

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

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

Solution:

Concept: Biological classification arranges organisms in a hierarchical system from broader categories to more specific categories. The taxonomic hierarchy is generally:

$$Kingdom \rightarrow Phylum \rightarrow Class \rightarrow Order \rightarrow Family \rightarrow Genus \rightarrow Species$$

Each category helps in organizing organisms according to similarities and evolutionary relationships. To solve matching questions, we identify the correct taxonomic level associated with each biological term.

Step 1: Identify Family.

Family is a taxonomic category placed above genus and below order.

Among the given terms:

$$\text{Anacardiaceae}$$

is a family. Therefore,

$$A \to III$$

Step 2: Identify Genus.

Genus is a group of closely related species.

The term

$$Mangifera$$

belongs to genus classification (example: Mango belongs to genus Mangifera). Therefore,

$$B \to V$$

Step 3: Identify Class.

Class is a category above order and below phylum/division.

The term

$$\text{Dicotyledonae}$$

represents a class of flowering plants having two cotyledons. Hence,

$$C \to II$$

Step 4: Identify Phylum.

Phylum (or Division in plants) is a major category below kingdom.

The term

$$\text{Angiospermae}$$

belongs to a major plant division/phylum containing flowering plants. Therefore,

$$D \to IV$$

Step 5: Identify Order.

Order is a taxonomic rank between class and family.

The term

$$\text{Sapindales}$$

is a plant order. Hence,

$$E \to I$$

Step 6: Final arrangement.

Thus we obtain

$$A-III,\ B-V,\ C-II,\ D-IV,\ E-I$$

which exactly matches option (1).

$$\boxed{\text{Correct Answer} = \text{Option (1)}}$$

Quick Tip: Remember the biological hierarchy in sequence:

Kingdom → Phylum → Class → Order → Family → Genus → Species

Learning this order helps solve matching questions quickly.

---

125. Which of the following is not a part of human central neural system?

(A) Pericardium

(B) Arachnoid

(C) Dura mater

(D) Pia mater

Correct Answer: (1) Pericardium

Solution:

Concept: The human central nervous system (CNS) consists mainly of:

Brain + Spinal Cord

These structures are protected by three connective tissue membranes called meninges. They are:

- Dura mater
- Arachnoid mater
- Pia mater

Any structure unrelated to these protective membranes cannot be part of CNS.

Step 1: Study Pericardium.

Pericardium is a double-layered membrane surrounding the heart.
Its function is to protect the heart and reduce friction during heartbeats.
It belongs to the circulatory system, not nervous system.
Hence, Pericardium is not part of CNS.

Step 2: Study Arachnoid mater.

Arachnoid mater is the middle protective membrane surrounding brain and spinal cord.
It forms part of meninges. Therefore it belongs to CNS protection.

Step 3: Study Dura mater.

Dura mater is the outer tough protective covering around brain and spinal cord.
It protects the central nervous system from injury. Hence it is part of CNS protective covering.

Step 4: Study Pia mater.

Pia mater is the innermost delicate membrane directly attached to brain and spinal cord.
It supplies nourishment and protection. Therefore it is also part of CNS.

Step 5: Compare all options.

Three options belong to meninges of CNS:

Arachnoid, Dura mater, Pia mater

One option belongs to heart:

$$\text{Pericardium}$$

Thus the incorrect one is

$$\boxed{\text{Pericardium}}$$

$$\boxed{\text{Correct Answer} = \text{Option (1)}}$$

Quick Tip: Three meninges protecting CNS:

Outer = Dura mater

Middle = Arachnoid mater

Inner = Pia mater

Pericardium protects heart, not brain.

---

126. Given below are two statements:

Statement I: Chromosomes are fully condensed at the end of prophase I.

Statement II: Meiosis I resembles mitosis.

Choose the most appropriate answer from the options given below:

(A) Statement I is incorrect, but Statement II is true

(B) Both Statement I and Statement II are true

(C) Both Statement I and Statement II are false

(D) Statement I is correct, but Statement II is false

Correct Answer: (4) Statement I is correct, but Statement II is false

Solution:

Concept: Meiosis is a special type of cell division producing haploid cells from diploid parent cells. It occurs in two stages:

$$\text{Meiosis I and Meiosis II}$$

Meiosis I is called reduction division because chromosome number becomes half.
Mitosis produces identical daughter cells without reduction in chromosome number.

Step 1: Analyze Statement I.

Prophase I is the first stage of meiosis I.
It consists of five sub-stages:

- Leptotene
- Zygotene
- Pachytene
- Diplotene
- Diakinesis

During the final stage called diakinesis, chromosomes become maximally shortened and fully condensed.
Thus chromosomes are fully condensed at end of prophase I.
So Statement I is correct.

Step 2: Analyze Statement II.

Meiosis I involves:

- Synapsis of homologous chromosomes
- Crossing over
- Separation of homologous chromosomes
- Reduction in chromosome number

These processes do not occur in mitosis.
Therefore meiosis I is fundamentally different from mitosis.

Step 3: Understand which stage resembles mitosis.

Meiosis II resembles mitosis because in both divisions:

- Sister chromatids separate

- Chromosome number remains unchanged during division
- Similar spindle behavior occurs

Hence saying “Meiosis I resembles mitosis” is incorrect.

Step 4: Evaluate statements.

Statement I $\rightarrow$ True

Statement II $\rightarrow$ False

Thus correct conclusion becomes

$$\boxed{\text{Statement I is correct but Statement II is false}}$$

$$\boxed{\text{Correct Answer} = \text{Option (4)}}$$

Quick Tip: Remember:

Meiosis I = Reduction division (different from mitosis)

Meiosis II = Equational division (resembles mitosis)

A common exam trick is confusing Meiosis I and Meiosis II.

---

127. Match List-I with List-II.

List-I	List-II
A. Marginal placentation	I. *Argemone*
B. Axile placentation	II. Tomato
C. Parietal placentation	III. *Primrose*
D. Free central placentation	IV. Pea

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

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

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

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

Correct Answer: (1)

Solution:

Concept:
Placentation refers to the arrangement of ovules inside the ovary of a flower. It is an important characteristic used in plant morphology and classification.
Different plants possess different arrangements of ovules depending upon the structure of the ovary.
The important placentation types include marginal, axile, parietal and free central placentation.
To solve matching questions, we must know representative examples of each type.
Step 1: Understand marginal placentation.

In marginal placentation, the placenta forms a ridge along the ventral suture of the ovary.
Ovules develop along this ridge.
A common example is pea.
Thus

$$A \rightarrow IV$$

Step 2: Understand axile placentation.

In axile placentation, ovules are attached to a central axis and the ovary is divided into multiple chambers.
A common example is tomato.
Hence

$$B \rightarrow II$$

Step 3: Understand parietal placentation.

In parietal placentation, ovules are attached to the inner wall of the ovary.
The ovary usually remains unilocular.
Argemone shows parietal placentation.
Therefore

$$C \rightarrow I$$

Step 4: Understand free central placentation.

In free central placentation, ovules develop on a central axis but septa are absent.
Primrose is a classic example.
Thus

$$D \rightarrow III$$

Final matching becomes

$$A-IV,\ B-II,\ C-I,\ D-III$$

Therefore correct answer is

$$\boxed{\text{Option (1)}}$$

Quick Tip: Remember examples: Marginal = Pea Axile = Tomato Parietal = Argemone Free Central = Primrose

---

128. Symbiotic association between fungi and algae are called _______.

(A) Chrysophytes

(B) Lichens

(C) Sponges

(D) Mycorrhiza

Correct Answer: (2) Lichens

Solution:

Concept:
Symbiosis is a biological relationship in which two different organisms live together and both may benefit from each other.
A classic example is the association between algae and fungi.
The algal component performs photosynthesis and provides food, while fungal component

absorbs water and minerals and offers protection.

This combined association is known as lichen.

Step 1: Understand role of algae in symbiosis.

Algae contain chlorophyll.

They perform photosynthesis using sunlight.

As a result, they synthesize carbohydrates.

This food supports both partners.

Step 2: Understand role of fungus.

Fungi do not perform photosynthesis.

They absorb water and minerals from surroundings.

They also provide shelter and protection to algal cells.

Thus both organisms benefit.

Step 3: Identify correct biological term.

The combined structure of algae and fungi is called lichen.

This is a stable mutualistic association.

The term mycorrhiza refers to fungus-root association, not algae-fungus association.

Step 4: Eliminate wrong options.

Chrysophytes = protists

Sponges = animals

Mycorrhiza = fungi + roots

Lichens = fungi + algae

Hence correct answer is

$$\boxed{\text{Option (2)}}$$

Quick Tip: Lichen = Fungus + Alga Mycorrhiza = Fungus + Plant root Do not confuse these two associations.

129. Which of the following is not a prokaryote?

(A) Fungi

(B) Bacteria

(C) Blue green algae

(D) Mycoplasma

Correct Answer: (1) Fungi

Solution:

Concept:

Living organisms are divided into prokaryotic and eukaryotic organisms based on cellular organization.

Prokaryotic organisms lack a true nucleus and membrane-bound organelles.

Eukaryotic organisms possess a true nucleus and organized membrane-bound cell structures.

To solve this question, we must identify which organism belongs to eukaryotes.

Step 1: Understand characteristics of prokaryotes.

Prokaryotes possess

No true nucleus

No membrane-bound organelles

Circular DNA

Simple cell organization

Examples include bacteria, cyanobacteria and mycoplasma.

Step 2: Check bacteria and blue green algae.

Bacteria are classical prokaryotic organisms.

Blue green algae are cyanobacteria.

Cyanobacteria also lack true nucleus.

Thus both are prokaryotes.

Step 3: Check mycoplasma.

Mycoplasma are smallest living cells.

They lack cell wall but are still prokaryotic organisms.

Hence they are prokaryotes.

Step 4: Check fungi.

Fungi possess

True nucleus

Membrane-bound organelles

Complex cell organization

Thus fungi are eukaryotic organisms.

Hence fungi are not prokaryotes.

Therefore answer is

$$\boxed{\text{Option (1)}}$$

Quick Tip: Prokaryotes include: Bacteria Cyanobacteria (blue green algae) Mycoplasma
Fungi are always eukaryotic.

---

130. The pigment responsible for the red colour of ripe tomato is

(A) Xanthophyll

(B) Lycopene

(C) Chlorophyll

(D) Anthocyanin

Correct Answer: (2) Lycopene

Solution:

Concept:

Plants contain different types of pigments that are responsible for absorbing light and producing characteristic colours in fruits, flowers, and leaves. These pigments belong to different chemical groups and each pigment performs specific biological functions.

The major plant pigments include chlorophyll, carotenoids, xanthophylls, anthocyanins and lycopene.

Tomato changes colour during ripening because chlorophyll gradually breaks down and another pigment accumulates in high concentration.

The red colour in ripe tomato is mainly due to the carotenoid pigment called lycopene.

Step 1: Understand the process of fruit ripening.

During fruit ripening, chemical changes occur inside fruit tissues.

Green fruits initially contain chlorophyll, which is responsible for green coloration.

As ripening begins, chlorophyll molecules degrade and become reduced in concentration.

At the same time, other pigments begin accumulating.

Thus colour transformation occurs because pigment composition changes during maturation.

Step 2: Study the function of lycopene.

Lycopene is a red carotenoid pigment.

It is commonly found in tomato and several other red fruits.

Its major characteristic is strong red pigmentation.

It also functions as an antioxidant and protects plant tissues from oxidative damage.

In tomatoes, high lycopene concentration gives the characteristic bright red colour.

Thus

$$\text{Tomato red colour} \rightarrow \text{Lycopene}$$

Step 3: Eliminate incorrect options carefully.

Option (A) Xanthophyll

Xanthophyll produces yellow coloration, not red.

Option (C) Chlorophyll

Chlorophyll is responsible for green colour in leaves and immature fruits.

Option (D) Anthocyanin

Anthocyanin produces red, purple or blue coloration in flowers and some fruits but not specifically tomato red pigmentation.

Only lycopene matches correctly.

Step 4: Determine final answer logically.

Since ripe tomato obtains its red colour because of accumulation of lycopene pigment, the correct answer becomes

$$\boxed{\text{Lycopene}}$$

Therefore

$$\boxed{\text{Option (2)}}$$

Quick Tip: Remember important pigments: Chlorophyll = Green Xanthophyll = Yellow Carotene = Orange Lycopene = Red (Tomato) Anthocyanin = Purple/Blue/Red in flowers and fruits

---

131. Which of the following statement is correct regarding enzymes?

(A) Enzymes are consumed permanently after reaction

(B) Enzymes lower activation energy of reaction

(C) Enzymes increase activation energy of reaction

(D) Enzymes are inorganic compounds

Correct Answer: (2) Enzymes lower activation energy of reaction

Solution:

Concept:

Enzymes are biological catalysts that accelerate biochemical reactions occurring inside living organisms. Almost every metabolic reaction inside cells depends upon enzymes.

A catalyst is a substance that increases reaction speed without being permanently consumed during the reaction.

For any chemical reaction to begin, reactant molecules must overcome an energy barrier called activation energy.

Enzymes function by lowering this activation energy barrier so reactions proceed rapidly under normal physiological conditions.

Step 1: Understand what activation energy means.

Before reactants can convert into products, molecules require a minimum amount of energy. This minimum threshold energy is called activation energy.

It allows reactant molecules to reach a transition state from where products can form.

If activation energy is very high, reaction occurs slowly.

If activation energy decreases, reaction speed increases.

Thus activation energy directly controls reaction rate.

Step 2: Understand role of enzymes in biochemical reactions.

Enzymes bind temporarily with substrate molecules at a specialized region called active site.

This enzyme-substrate complex helps arrange reactants in favorable orientation.

As a result, less energy is required for molecules to react.

Therefore enzyme reduces activation energy.

Mathematically the relationship can be summarized as

$$\text{Lower activation energy} \rightarrow \text{Faster reaction}$$

Hence enzyme accelerates reaction speed.

Step 3: Check incorrect options one by one.

Option (A)

It says enzymes are permanently consumed.

This is incorrect because enzymes remain chemically unchanged after reaction and can be reused repeatedly.

Option (C)

It says enzymes increase activation energy.

This is incorrect because increased activation energy would slow reactions.

Enzymes do the opposite.

Option (D)

It says enzymes are inorganic compounds.

This is incorrect because most enzymes are proteins, which are organic biomolecules.

Hence options A, C and D are wrong.

Step 4: Identify correct statement and conclude.

Option (B) states enzymes lower activation energy.

This exactly describes catalytic action of enzymes.

Therefore correct answer is

$$\boxed{\text{Enzymes lower activation energy of reaction}}$$

Hence

$$\boxed{\text{Option (2)}}$$

Quick Tip: Enzyme rule to remember: Enzymes speed up reactions by lowering activation energy. They are biological catalysts and are not consumed permanently during reactions.

---

132. Which of the following are characteristic features of Solanaceae family?

(a) Flowers are bisexual and actinomorphic

(b) Calyx have five sepals and are united

(c) Androecium have five stamens and are epipetalous

(d) Ovary is inferior

Choose the correct answer from the options given below:

(A) (b), (c) and (d) only

(B) (a), (b) and (c) only

(C) (d) only

(D) (a) and (b) only

Correct Answer: (2)

Solution:

Concept:

Solanaceae is an important family of flowering plants that includes economically important plants such as tomato, potato, brinjal, chilli and tobacco.

Each plant family possesses characteristic floral features used for identification and classification.

The floral formula and flower morphology of Solanaceae help determine whether a statement about floral parts is correct or incorrect.

Important characteristics include bisexual flowers, radial symmetry, united sepals, epipetalous stamens and superior ovary.

Step 1: Examine flower symmetry and sexuality.

Plants belonging to Solanaceae family generally possess bisexual flowers.
Bisexual means both male reproductive organ (androecium) and female reproductive organ (gynoecium) occur in same flower.
These flowers are also actinomorphic.
Actinomorphic means flower can be divided into two equal halves along multiple planes.
Hence statement (a) is correct.

$$(a) = \text{Correct}$$

Step 2: Study calyx structure carefully.

The calyx is composed of sepals.
In Solanaceae family, calyx usually consists of five sepals.
These sepals are fused together, meaning gamosepalous condition exists.
Thus statement (b) correctly describes floral morphology.
Therefore

$$(b) = \text{Correct}$$

Step 3: Check androecium characteristics.

Androecium represents male reproductive part.
In Solanaceae family, androecium consists of five stamens.
These stamens are epipetalous.
Epipetalous means stamens remain attached to petals.
This is a key identifying characteristic of this family.
Hence statement (c) is also correct.
Thus

$$(c) = \text{Correct}$$

Step 4: Analyze ovary position.

In Solanaceae family, ovary is superior.

Superior ovary means floral parts arise below ovary.

The statement says ovary is inferior.

This is incorrect.

Hence

$$(d) = \text{Incorrect}$$

Step 5: Choose correct combination.

Correct statements are

$$(a), (b), (c)$$

Thus correct option becomes

$$\boxed{\text{Option (2)}}$$

Quick Tip: Solanaceae family characteristics: Bisexual flowers Actinomorphic symmetry 5 united sepals 5 epipetalous stamens Superior ovary

---

133. Given below are two statements:

Statement I : When any plane passing through the central axis of the body divides the organism into two identical halves, it is called radial symmetry.

Statement II : In phylum Echinodermata, both adults and larvae are radially symmetrical.

Choose the most appropriate answer.

(A) Statement I is incorrect but Statement II is correct

(B) Both Statement I and Statement II are correct

(C) Both Statement I and Statement II are incorrect

(D) Statement I is correct but Statement II is incorrect

Correct Answer: (4)

Solution:

Concept:

Symmetry in biology refers to arrangement of body parts relative to an axis or plane.

Radial symmetry occurs when many planes passing through central axis divide organism into similar halves.

Echinoderms show an interesting developmental pattern.

Adults are radially symmetrical whereas larvae are bilaterally symmetrical.

Thus one statement may be correct while another may be false.

Step 1: Understand radial symmetry definition.

Radial symmetry means body parts arranged around a central axis.

Any plane passing through central axis divides organism into similar halves.

Examples include starfish and jellyfish.

The definition given in Statement I correctly explains radial symmetry.

Hence

$$Statement\ I = \text{Correct}$$

Step 2: Understand symmetry in echinoderms.

Echinodermata includes starfish, sea urchins and sea cucumber.

Adult echinoderms possess radial symmetry.

However larvae do not show radial symmetry.

Larvae are bilaterally symmetrical.

This difference is important in evolutionary biology.

Step 3: Evaluate Statement II carefully.

Statement II says both adult and larval forms are radially symmetrical.

This is incorrect because larval forms are bilateral.

Thus statement II is false.

$$Statement\ II = \text{Incorrect}$$

Step 4: Determine correct option.

Final conclusion:

Statement I $\rightarrow$ Correct

Statement II $\rightarrow$ Incorrect

Hence correct option is

$$\boxed{\text{Option (4)}}$$

Quick Tip: Echinoderm symmetry trick: Larva = Bilateral symmetry Adult = Radial symmetry Do not confuse both stages.

---

134. The correct sequence of adult cell cycle phases is

(A) S-M-G2-G1

(B) G1-G2-S-M

(C) G1-M-G2-S

(D) G1-S-G2-M

Correct Answer: (4)

Solution:

Concept:

Cell cycle is the sequence of events by which a cell grows, replicates DNA and divides into daughter cells.

The adult cell cycle is divided into interphase and mitotic phase.

Interphase includes G1 phase, S phase and G2 phase.

This is followed by M phase where actual cell division occurs.

Thus sequence must follow exact chronological order.

Step 1: Understand G1 phase.

G1 phase is first growth phase.

Cell synthesizes proteins and increases size.

Metabolic activity remains high.

Thus cycle begins with G1.

Step 2: Understand S phase.

S phase stands for synthesis phase.

DNA replication occurs during this phase.

Chromosomes duplicate preparing cell for division.

Thus S phase follows G1.

Step 3: Understand G2 phase.

G2 phase is second growth phase.

Cell synthesizes proteins required for mitosis.

Cell prepares final machinery for division.

Hence G2 comes after S phase.

Step 4: Understand M phase.

M phase means mitotic division.

Actual separation into daughter cells occurs here.

Thus final sequence becomes

$$G1 \to S \to G2 \to M$$

Hence answer is

$$\boxed{\text{Option (4)}}$$

Quick Tip: Cell cycle order: G1 = Growth S = DNA synthesis G2 = Preparation M = Cell division

---

135. In frogs, the number of pairs of cranial nerves arising from the brain are _______.

(A) 12

(B) 6

(C) 9

(D) 10

Correct Answer: (4) 10

Solution:

Concept:

Cranial nerves are nerves that arise directly from the brain.

They control sensory functions, movement and coordination of different body parts.

Different vertebrates possess different numbers of cranial nerve pairs.

Humans possess twelve pairs, while frogs possess ten pairs.

Knowledge of comparative anatomy helps answer this question.

Step 1: Understand cranial nerves.

Cranial nerves originate directly from brain tissue.

They carry impulses for sensation and motor control.

These nerves help regulate vision, smell, hearing, swallowing and muscular movement.

Step 2: Compare frog and human anatomy.

Human beings possess

$$12$$

pairs of cranial nerves.

Frogs possess fewer cranial nerves compared with mammals.

Standard zoological classification shows frogs possess

$$10$$

pairs.

Step 3: Check options carefully.

$12 \rightarrow$ human value

$6 \rightarrow$ incorrect

$9 \rightarrow$ incorrect

$10 \rightarrow$ correct frog value

Step 4: Final conclusion.

Since frog anatomy includes ten cranial nerve pairs, correct answer becomes

$$\boxed{10}$$

Therefore

$$\boxed{\text{Option (4)}}$$

Quick Tip: Remember comparative anatomy: Humans = 12 pairs cranial nerves Frog = 10 pairs cranial nerves

---

Zoology

136. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.
Assertion A: In recombinant DNA technology, lysozyme is used for disrupting bacterial cells while cellulase is used for plant cells.
Reason R: Isolation of genetic material needs disruption of cells.
In the light of the above statements, choose the most appropriate answer from the options given below:

(A) A is not correct but R is correct

(B) Both A and R are correct and R is the correct explanation of A

(C) Both A and R are correct but R is not the correct explanation of A

(D) A is correct but R is not correct

Correct Answer: (B) Both A and R are correct and R is the correct explanation of A

Solution:

Concept:

- **Recombinant DNA Technology:** Requires pure DNA, free from other macromolecules.
- To release DNA, cells must be lysed using specific enzymes to digest cell walls:

- Lysozyme is used for bacterial cell walls (peptidoglycan).
- Cellulase is used for plant cell walls (cellulose).
- Chitinase is used for fungal cell walls (chitin).

Step 1: Verify Assertion A

Assertion A states that lysozyme breaks down bacterial cells and cellulase breaks down plant cells.

This is true, as these enzymes degrade the biological polymers composing the respective cell walls.

Step 2: Verify Reason R

Reason R states that isolation of genetic material requires cell disruption.

This is true, as the cell membrane and cell wall must be broken to release DNA along with RNA, proteins, polysaccharides, and lipids.

Step 3: Check the explanation link

Why do we use specific enzymes like lysozyme and cellulase? We use them because the first step of isolating DNA requires breaking open the cells (disruption).

Therefore, R is the correct explanation of A.

Quick Tip:

Link assertions and reasons using the word "because". "Lysozyme is used for bacteria and cellulase for plants because isolation of genetic material needs cell disruption." Since this makes logical sense, R is the correct explanation.

Memorize the cell wall enzymes: Bacteria → Lysozyme, Plant → Cellulase, Fungi → Chitinase.

---

137. The method of directly injecting a sperm into ovum in assisted reproductive technology is called:

(A) Embryo transfer (ET)

(B) Gamete intra fallopian transfer (GIFT)

(C) Zygote intra fallopian transfer (ZIFT)

(D) Intra cytoplasmic sperm injection (ICSI)

Correct Answer: (D) Intra cytoplasmic sperm injection (ICSI)

Solution:

Concept:

- Assisted Reproductive Technologies (ART) represent a range of specialized medical procedures utilized to address infertility challenges.
- Key techniques include:
  - **Embryo Transfer (ET):** The process of transferring lab-grown embryos directly into the uterus.
  - **Gamete Intra Fallopian Transfer (GIFT):** The collection of both eggs and sperm, which are then placed directly into the fallopian tubes to allow natural fertilization.
  - **Zygote Intra Fallopian Transfer (ZIFT):** In-vitro fertilization followed by the transfer of the resulting zygote (at the stage of up to 8 blastomeres) into the fallopian tube.
  - **Intra Cytoplasmic Sperm Injection (ICSI):** A specialized in-vitro fertilization procedure where a single viable sperm is micro-injected directly into the cytoplasm of an egg.

Step 1: Identify the key mechanism described in the question

The question highlights a highly specific mechanism: "directly injecting a sperm into ovum." This requires a physical puncture of the oocyte's outer membrane (zona pellucida and oolemma) to deliver the sperm head directly into the cytoplasm.

Step 2: Evaluate the options against the key mechanism

- **ET (Embryo Transfer):** This is a general stage where multicellular embryos (not individual gametes like sperm and ovum) are placed in the uterine cavity.
- **GIFT:** Unfertilized gametes are transferred together into the fallopian tube. Fertilization occurs naturally inside the body rather than via micro-injection.
- **ZIFT:** An already-formed zygote is transferred into the fallopian tube, meaning fertilization has already occurred prior to this transfer step.
- **ICSI:** This laboratory technique specifically involves selecting a single sperm and injecting it directly into the inner fluid (cytoplasm) of the mature egg.

Step 3: Formulate the final conclusion

By comparing the technical definitions, the process of direct micro-injection of sperm into the cytoplasm of the egg aligns with the definition of Intra Cytoplasmic Sperm Injection (ICSI).

Quick Tip:

- Keep the medical terminology literal: "Intra cytoplasmic" means inside the cytoplasm, and "sperm injection" refers to the direct delivery system.
- ICSI is particularly useful in cases of male-factor infertility, such as oligospermia (low sperm count) or asthenozoospermia (poor sperm motility).

---

138. Adaptive radiation in placental mammals and Australian Marsupials leading to similarity between distant species is an example of

(A) genetic drift

(B) divergent evolution

(C) convergent evolution

(D) founder effect

Correct Answer: (C) convergent evolution

Solution:

Concept:

- **Adaptive Radiation:** The process of evolution where a single ancestral species diversifies into various forms, each adapting to a specific ecological niche in a given geographical area.
- **Divergent Evolution:** The accumulation of differences between closely related populations or species, leading to the creation of new species with distinct adaptations.
- **Convergent Evolution:** The independent evolution of similar structural or functional features in unrelated or distantly related lineages, often driven by adaptation to similar environments or ecological roles.

Step 1: Analyze the independent evolution within isolated geographical areas

In isolated environments such as Australia, ancestral marsupials underwent adaptive radiation to occupy diverse ecological niches, resulting in species like the marsupial mole, Tasmanian wolf, and sugar glider. Similarly, in other parts of the world, ancestral placental mammals underwent a parallel adaptive radiation, producing placental moles, wolves, and flying squirrels.

Step 2: Compare the similarities between the two distinct lineages

When comparing these two distinct groups (placental mammals and Australian marsupials), we observe that pairs of species from different lineages share striking physical and functional similarities due to living in similar habitats:

- Placental Mole and Marsupial Mole
- Placental Wolf and Tasmanian Wolf (Marsupial Wolf)
- Flying Squirrel and Flying Phalanger

Step 3: Determine the evolutionary pattern and evaluate the options

Since these similarities developed in distantly related groups undergoing parallel adaptations in similar ecological niches, this process represents convergent evolution.

- **(A) Genetic drift** refers to random changes in allele frequencies in small populations, which does not account for these systematic, adaptive structural similarities.
- **(B) Divergent evolution** describes how closely related species develop different traits (such as the diversification within marsupials alone), rather than how distant lineages become similar.
- **(C) Convergent evolution** correctly describes independent lineages evolving similar traits.
- **(D) Founder effect** is a specific case of genetic drift occurring when a new population is established by a small group of individuals, which is not applicable here.

Hence, option (C) is the appropriate choice.

Quick Tip:

- Adaptive radiation within a single group (e.g., Darwin's finches or Australian marsupials alone) is an example of divergent evolution.
- However, comparing adaptive radiations across two distinct lineages (Placentals vs. Marsupials) in similar environments shows convergent evolution.
- Analogous organs are the anatomical outcomes of convergent evolution.

---

139. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.
Assertion A: In an experiment, Mendel observed that the F_1 progeny plants are all tall and none are dwarf.
Reason R: Stem height is a contrasting trait, with tall being dominant and dwarf being recessive.
In the light of the above statements, choose the most appropriate answer from the options given below:

(A) A is not correct but R is correct
(B) Both A and R are correct and R is the correct explanation of A
(C) Both A and R are correct but R is not the correct explanation of A
(D) A is correct but R is not correct

Correct Answer: (B) Both A and R are correct and R is the correct explanation of A

Solution:

Concept:

- Mendel performed monohybrid crosses to study the inheritance of single characters like stem height.
- He crossed true-breeding tall (TT) and dwarf (tt) pea plants.
- According to the Law of Dominance, in a heterozygote, one allele masks the phenotypic expression of another allele at the same locus.
- The allele that expresses itself is dominant (tall, T), and the one that is masked is recessive (dwarf, t).

Step 1: Evaluate Assertion A

Assertion A states that all F_1 progeny plants are tall and none are dwarf.

This is true, as the genotype of the F_1 generation is completely heterozygous (Tt), expressing the dominant tall phenotype.

Step 2: Evaluate Reason R

Reason R states that tall is dominant and dwarf is recessive.

This is also true, and this dominance is precisely why the recessive dwarf trait cannot express itself in the heterozygous F_1 hybrid.

Step 3: Determine if R is the correct explanation of A

The reason why the F_1 progeny are all tall (Assertion) is because tall is dominant over dwarf (Reason).

Thus, R is the correct explanation of A.

Quick Tip:

The monohybrid phenotypic ratio in F_2 is 3 : 1 (Tall : Dwarf), while the genotypic ratio is 1 : 2 : 1 ($TT : Tt : tt$).

The recessive trait only expresses itself under homozygous conditions (tt), which is why it disappears in the F_1 generation and reappears in F_2.

---

140. Arrange the following in descending order of number of species in the Amazonian rain forest.

(a) Plants

(b) Birds

(c) Fishes

(d) Invertebrates

(e) Mammals

Choose the correct answer from the options given below:

(A) (b) > (a) > (d) > (c) > (e)

(B) (c) > (b) > (d) > (e) > (a)

(C) (d) > (a) > (c) > (b) > (e)

(D) (e) > (b) > (a) > (c) > (d)

Correct Answer: (C) (d) > (a) > (c) > (b) > (e)

Solution:

Concept:

- The Amazonian rain forest in South America has the greatest biodiversity on Earth.
- The approximate species counts for various groups in this ecosystem are:
  - Invertebrates: More than $125,000$ species
  - Plants: More than $40,000$ species
  - Fishes: Around $3,000$ species
  - Birds: Around $1,300$ species
  - Mammals: Around 427 species
  - Amphibians: Around 427 species
  - Reptiles: Around 378 species

Step 1: Compare the species numbers of the given groups

Comparing the values:

$$125,000\,(\text{Invertebrates}) > 40,000\,(\text{Plants}) > 3,000\,(\text{Fishes}) > 1,300\,(\text{Birds}) > 427\,(\text{Mammals})$$

Step 2: Arrange in descending order

Mapping the groups to their letters:

- Invertebrates = (d)
- Plants = (a)
- Fishes = (c)
- Birds = (b)
- Mammals = (e)

The descending order is (d) > (a) > (c) > (b) > (e).

Quick Tip:

Invertebrates represent the largest share of global species diversity, followed by plants.

Mammals and amphibians have roughly equal species counts (427) in the Amazonian rainforest, which is higher than reptiles (378).

---

141. Sponges exchange O_2 with CO_2 by

(A) gills

(B) simple diffusion over their entire body surfaces

(C) moist cuticle

(D) tracheal tubes

Correct Answer: (B) simple diffusion over their entire body surfaces

Solution:

Concept:

- **Phylum Porifera:** Sponges belong to the phylum Porifera, characterized by a multicellular body with a cellular level of organization. They lack true tissues, organs, or specialized organ systems.
- **Water Canal System:** Water enters through microscopic pores (ostia) in the body wall, passes into a central cavity (spongocoel), and exits through a large opening (osculum).
- **Gas Exchange:** Without specialized respiratory structures, metabolic exchanges occur directly between the individual cells and the surrounding water.

Step 1: Analyze the cellular level of organization in sponges

Because sponges do not possess specialized respiratory tissues or organs (such as gills or lungs), every cell must interact directly with the aqueous environment to carry out physiological processes.

Step 2: Evaluate the mechanism of gas exchange

The water current flowing through the canal system brings dissolved oxygen close to the cells. Since the concentration of oxygen is higher in the incoming water than inside the cells, and the concentration of carbon dioxide is higher inside the cells than in the water, gases move along their concentration gradient. This movement occurs via simple diffusion across the cell membranes over the entire body surface exposed to water.

Step 3: Analyze the incorrect options

- **(A) Gills:** These are specialized vascularized structures found in more complex aquatic organisms, such as fish, molluscs, and crustaceans.
- **(C) Moist cuticle:** This respiratory surface is characteristic of annelids, such as earthworms, which use cutaneous respiration.
- **(D) Tracheal tubes:** This is a network of tubes used for gas exchange in terrestrial insects and some other arthropods.

Thus, simple diffusion over the body surface is the process utilized by sponges.

Quick Tip:

- Simple diffusion across the body surface is the primary mode of respiration for lower invertebrates, including sponges (Porifera), coelenterates (Cnidaria), and flatworms (Platyhelminthes).
- The water canal system in sponges serves a triple purpose: nutrition (food gathering), respiration (gas exchange), and excretion (removal of metabolic wastes).

---

142. For a person with blood group 'O', which of the following is not a possible combination of parents' blood group genotypes ?

(A) Father : I^AI^B and Mother : I^Ai

(B) Father : I^Ai and Mother : I^Bi

(C) Father : I^Ai and Mother : I^Ai

(D) Father : I^Bi and Mother : I^Bi

Correct Answer: (A) Father : I^AI^B and Mother : I^Ai

Solution:

Concept:

- ABO blood groups are controlled by the I gene, which has three alleles: I^A, I^B, and i.
- Alleles I^A and I^B are co-dominant, while allele i is recessive.
- The genotype for blood group 'O' is homozygous recessive, represented as ii.

- For an offspring to have blood group 'O' (ii), they must inherit one i allele from the father and one i allele from the mother.

Step 1: Evaluate parent genotypes in Option (A)

Father's genotype: I^AI^B. The father can only pass on either the I^A or I^B allele.

Mother's genotype: I^Ai. The mother can pass on either I^A or i.

Since the father does not carry the recessive i allele, it is impossible for the offspring to inherit the ii genotype.

Thus, Option (A) is not a possible parental combination.

Step 2: Verify parent genotypes in other options

In Options (B), (C), and (D), both parents possess at least one i allele in their genotypes (I^Ai or I^Bi).

Therefore, in all these cases, there is a probability of producing an offspring with genotype ii (blood group 'O').

Quick Tip:

A parent with blood group AB (I^AI^B) can never have a biological child with blood group O (ii).

Likewise, a parent with blood group O (ii) can never have a biological child with blood group AB (I^AI^B).

---

143. Given below are two statements:

Statement I: Modern Homo sapiens arose in Australia and moved across continents.

Statement II: Homo sapiens arose around 75000 to 10000 years ago.

In the light of the above statements, choose the most appropriate answer from the options given below:

(A) Statement I is incorrect but Statement II is correct

(B) Both Statement I and Statement II are correct

(C) Both Statement I and Statement II are incorrect

(D) Statement I is correct but Statement II is incorrect

Correct Answer: (A) Statement I is incorrect but Statement II is correct

Solution:

Concept:

- Human evolution traces the origin and divergence of modern humans (*Homo sapiens sapiens*) from hominid ancestors.

- According to paleontological evidence, modern *Homo sapiens* arose in Africa and subsequently migrated across various continents, developing into distinct races.

- *Homo sapiens* arose during the last ice age, which occurred between $75,000$ and $10,000$ years ago.

Step 1: Analyze Statement I

Statement I states: "Modern Homo sapiens arose in Australia and moved across continents."

This statement is incorrect because modern humans originated in Africa, not Australia.

Step 2: Analyze Statement II

Statement II states: "Homo sapiens arose around 75000 to 10000 years ago."

This statement is correct, as the ice age between $75,000$ and $10,000$ years ago marks the period when modern *Homo sapiens* emerged.

Quick Tip:

Always pay close attention to geographic names mentioned in statements; a single incorrect location (like Australia instead of Africa) invalidates the entire statement.

Chronology of human ancestors: Australopithecus → Homo habilis → Homo erectus → Neanderthal → Homo sapiens.

---

144. Which of the following is used as an effective sedative and painkiller for treating post-surgery patients ?

(A) Anti-retroviral drugs

(B) Interferon

(C) Antibiotics

(D) Morphine

Correct Answer: (D) Morphine

Solution:

Concept:

- Opioids are drugs that bind to specific opioid receptors present in our central nervous system and gastrointestinal tract.
- Morphine is a natural opioid alkaloid extracted from the latex of the poppy plant, *Papaver somniferum*.
- It acts as a strong analgesic (painkiller) and central nervous system depressant.

Step 1: Evaluate the biological actions of the given options

Anti-retroviral drugs are used to treat viral infections like HIV.

Interferons are proteins used in cancer therapy and viral defense.

Antibiotics are used to treat bacterial infections.

Morphine is a highly potent analgesic and sedative.

Step 2: Identify the drug used post-surgery

Due to its strong pain-relieving and sedative qualities, morphine is clinically prescribed to patients who have undergone major surgery to manage intense post-operative pain.

Quick Tip:

Morphine is a classic example of an opioid. Heroin (diacetylmorphine) is chemically synthesized from it via acetylation.

While highly useful in clinical settings, opioids have a very high potential for addiction and abuse.

---

145. Which of the following plant produces non-albuminous seeds ?

(A) Pea

(B) Wheat

(C) Maize

(D) Barley

Correct Answer: (A) Pea

Solution:

Concept:

- Seeds are classified into two main groups depending on the persistence of the endosperm in the mature seed:

- **Non-albuminous (Exalbuminous) seeds:** These seeds do not retain endosperm at maturity because it is completely consumed by the developing embryo during embryogenesis (e.g., pea, groundnut, gram, beans).
- **Albuminous (Endospermic) seeds:** These seeds retain a portion of the endosperm as it is not entirely consumed during embryo development, serving as a food reserve for germination (e.g., wheat, maize, barley, castor, sunflower).

Step 1: Analyze the structural features of the given plant seeds

In angiosperms, double fertilization leads to the formation of a triploid endosperm, which provides nourishment to the developing embryo. The rate of endosperm consumption determines the final seed type.

Step 2: Evaluate each option based on endosperm retention

- **Pea (Option A):** A dicotyledonous plant where the developing embryo absorbs all the nutrients from the endosperm before the seed reaches maturity. The food is instead stored in the fleshy cotyledons, making the mature seed non-albuminous.
- **Wheat, Maize, and Barley (Options B, C, and D):** These are monocotyledonous cereal crops. In these plants, the endosperm persists in the mature seed as a major storage tissue, making them albuminous.

Step 3: Determine the correct choice

Since only the pea seed lacks residual endosperm at maturity, it represents the non-albuminous category among the given choices.

Quick Tip:

- As a general rule of thumb, most dicots produce non-albuminous seeds (exception: Castor is a dicot but produces albuminous seeds).
- Most monocots produce albuminous seeds (exception: Orchids are monocots but produce non-albuminous seeds).
- In some seeds, such as black pepper and beet, remnants of the nucellus also persist; this residual, persistent nucellus is called perisperm.

146. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: Abingdon tortoise in Galapagos islands became extinct within a decade after goats were introduced.

Reason R: Goats were more efficient at browsing than Abingdon tortoise.

In the light of the above statements, choose the most appropriate answer from the options given below:

(A) A is not correct but R is correct

(B) Both A and R are correct and R is the correct explanation of A

(C) Both A and R are correct but R is not the correct explanation of A

(D) A is correct but R is not correct

Correct Answer: (B) Both A and R are correct and R is the correct explanation of A

Solution:

Concept:

- **Interspecific Competition:** Occurs when different species compete for the same limiting resources (like food).
- **Competitive Exclusion Principle (Gause):** States that two species competing for the same limiting resources cannot coexist indefinitely, and the competitively inferior species will eventually be eliminated.

Step 1: Evaluate Assertion A

Assertion A states that the Abingdon tortoise in the Galapagos Islands went extinct within a decade after goats were introduced.

This is a well-documented ecological fact resulting from intense interspecific resource competition.

Step 2: Evaluate Reason R

Reason R states that goats had greater browsing efficiency than the Abingdon tortoise.

This is true, as goats are agile and consume vegetation much faster and closer to the ground than the slow-moving tortoises.

Step 3: Determine if R is the correct explanation of A

The extinction of the tortoises (Assertion) occurred because the newly introduced goats consumed the limited vegetation far more efficiently (Reason), leaving no food for the tortoises. Thus, R is the correct explanation of A.

Quick Tip:

This case study is a classic textbook illustration of Gause's Competitive Exclusion Principle in real-world habitats.

Introduced or invasive species often have superior resource exploitation traits, leading to the rapid decline of native species.

---

147. The covering of ovum at ovulation is

(A) chorion

(B) endometrium

(C) zona radiata

(D) zona pellucida

Correct Answer: (D) zona pellucida

Solution:

Concept:

- **Oocyte Membranes:** During follicular development, the secondary oocyte is surrounded by distinct protective layers that play crucial roles in fertilization and early development.
- **Primary Membrane (Zona Pellucida):** An acellular, gel-like layer composed of glycoproteins (ZP1, ZP2, ZP3, and ZP4) secreted by the secondary oocyte itself.
- **Secondary Membrane (Corona Radiata):** An outer layer of radially arranged follicular (granulosa) cells that remains adhered to the zona pellucida upon ovulation.

Step 1: Analyze the state of the ovum at the time of ovulation
During ovulation, the Graafian follicle ruptures to release the secondary oocyte (often referred to as the ovum at this stage) into the peritoneal cavity, where it is swept into the fallopian tube. At this moment, the innermost specialized protective covering of the oocyte is the acellular glycoprotein envelope.
Step 2: Evaluate the options systematically

- **(A) Chorion:** This is the outermost extra-embryonic membrane formed later during embryonic development. It participates in the formation of the placenta and is not present on the unfertilized ovum at ovulation.

- **(B) Endometrium:** This refers to the glandular inner mucosal lining of the uterine wall, which prepares for implantation, rather than a membrane covering the ovum.
- **(C) Zona radiata:** While sometimes confused with the cellular *corona radiata*, "zona radiata" historically refers to striated membranes in the eggs of certain non-mammalian vertebrates (such as teleost fish) and is not the standard primary mammalian cover.
- **(D) Zona pellucida:** This is the non-cellular glycoprotein membrane that directly covers the plasma membrane of the mammalian secondary oocyte at ovulation.

Step 3: Confirm the correct choice

The primary acellular coat that encapsulates the oocyte at ovulation and must be penetrated by the sperm during fertilization is the zona pellucida. Thus, option (D) is the correct answer.

Quick Tip:

- **Acellular vs. Cellular:** The inner *zona pellucida* is non-cellular (glycoprotein-based), whereas the outer *corona radiata* is cellular (composed of granulosa cells).
- **Function of Zona Pellucida:** It contains species-specific sperm receptors (primarily ZP3) and undergoes the "cortical reaction" after sperm entry to prevent polyspermy.
- It also prevents premature implantation (ectopic pregnancy) of the blastocyst while it travels through the fallopian tube.

---

148. Which of the following is used as a clot buster ?

(A) Statins

(B) Streptokinase

(C) Penicillin

(D) Cyclosporin A

Correct Answer: (B) Streptokinase

Solution:

Concept:

- Microorganisms are utilized commercially to produce several bioactive molecules, which are chemical compounds that possess therapeutic value in human medicine.

- Key bioactive molecules include:
  - **Streptokinase:** A thrombolytic enzyme obtained from cultures of the bacterium *Streptococcus*.
  - **Statins:** Compounds produced by the yeast *Monascus purpureus* that assist in managing blood lipid levels.
  - **Cyclosporin A:** An immunosuppressive peptide isolated from the fungus *Trichoderma polysporum*.
  - **Penicillin:** The first discovered broad-spectrum antibiotic, extracted from the fungus *Penicillium notatum*.

Step 1: Understand the clinical term "clot buster"
A "clot buster" (or thrombolytic agent) is a medical substance administered to dissolve blood clots (thrombi) that have formed inside blood vessels. This therapy is critical for patients suffering from acute myocardial infarction (heart attack) or stroke, where clot dissolution restores blood flow to ischemic tissues.
Step 2: Evaluate each option based on its medical application

- **(A) Statins:** These molecules act as competitive inhibitors of HMG-CoA reductase, the rate-limiting enzyme in cholesterol biosynthesis, and are used to lower blood cholesterol levels.
- **(B) Streptokinase:** This enzyme activates plasminogen to form plasmin, which directly breaks down fibrin networks within blood clots. Thus, it functions as an effective clot buster.
- **(C) Penicillin:** This is an antibiotic that target bacterial cell wall synthesis, making it ineffective against vascular blood clots.
- **(D) Cyclosporin A:** This is used as an immunosuppressant to inhibit T-cell activation and prevent graft rejection in organ transplant recipients.

Step 3: Determine the correct choice
Based on the therapeutic functions described, Streptokinase is the molecule used as a clot buster. This corresponds to option (B).

Quick Tip:

- **Mnemonic for Sources:**
  - *Streptococcus* → **Streptokinase** (Clot buster)
  - *Monascus purpureus* → **Statins** (Cholesterol reducer)
  - *Trichoderma polysporum* → **Cyclosporin A** (Immunosuppressant)
- Genetic engineering is used to modify natural streptokinase to minimize potential allergic reactions and improve its targeted efficacy in patients.

---

149. Which of the following structure is not a part of the male reproductive system ?

(A) Infundibulum

(B) Rete testis

(C) Epididymis

(D) Vasa efferentia

Correct Answer: (A) Infundibulum

Solution:

Concept:

- **Male Reproductive System:** Comprises primary sex organs (a pair of testes), accessory ducts, accessory glands, and external genitalia.
- **Male Accessory Ducts:** These ducts store and transport sperm from the testes to the outside through the urethra. The pathway includes:
  - Rete testis
  - Vasa efferentia
  - Epididymis
  - Vas deferens
- **Female Reproductive System Accessory Ducts:** Include the fallopian tubes (oviducts), uterus, and vagina.

Step 1: Analyze the male accessory ducts and their pathways

Sperm produced in the seminiferous tubules of the testes travel through a specific network of ducts.

- The tubules open into the **rete testis**.
- From the rete testis, sperm leave the testis through the **vasa efferentia**.
- The vasa efferentia open into the **epididymis**, which is located along the posterior surface of each testis and is responsible for sperm maturation and temporary storage.

Therefore, options (B), (C), and (D) represent essential components of the male reproductive tract.

Step 2: Analyze the female reproductive tract structures

The fallopian tube (oviduct) in females is divided into three main anatomical regions:

- **Infundibulum:** The funnel-shaped portion closest to the ovary.
- **Ampulla:** The wider, middle portion where fertilization typically occurs.
- **Isthmus:** The narrow, final portion that connects directly to the uterus.

Step 3: Identify the non-male structure

Because the infundibulum is a specialized section of the female fallopian tube, it does not exist in the male anatomy. This corresponds to option (A).

Quick Tip:

- The edge of the *infundibulum* possesses finger-like projections called *fimbriae*, which function to collect the secondary oocyte from the ovary during ovulation.
- Memory aid for the male sperm pathway: **S**eminiferous tubules → **R**ete testis → **V**asa efferentia → **E**pididymis → **V**as deferens (mnemonic: *Some Rete Vessels Enter Vas*).

---

150. Given below are two statements:

Statement I: Ovulation is caused by LH surge leading to rupture of Graafian follicles.

Statement II: Graafian follicle remaining after ovulation transform into corpus luteum and secretes large amount of estrogen.

In the light of the above statements, choose the most appropriate answer from the options given below:

(A) Statement I is incorrect but Statement II is correct

(B) Both Statement I and Statement II are correct

(C) Both Statement I and Statement II are incorrect

(D) Statement I is correct but Statement II is incorrect

Correct Answer: (D) Statement I is correct but Statement II is incorrect

Solution:

Concept:

- The menstrual cycle is regulated by pituitary hormones (LH, FSH) and ovarian hormones (estrogen, progesterone).
- In the middle of the cycle (around day 14), both LH and FSH attain a peak level.
- Rapid secretion of LH leading to its maximum level during the mid-cycle is called the **LH surge**.
- The LH surge induces the rupture of the mature Graafian follicle, releasing the secondary oocyte (ovulation).
- Following ovulation, the ruptured Graafian follicle transforms under the influence of LH into the **corpus luteum**.
- The corpus luteum secretes large amounts of **progesterone**, which is essential for maintaining the endometrium of the uterus.

Step 1: Evaluate Statement I

Statement I is correct: The LH surge is the direct trigger that causes the Graafian follicle to rupture and release the ovum.

Step 2: Evaluate Statement II

Statement II is incorrect: The corpus luteum secretes large amounts of progesterone, not estrogen. (While it does secrete small amounts of estrogen, its primary and major secretion is progesterone).

Quick Tip:

Progesterone is known as the "pregnancy-maintaining hormone" because it is secreted in large amounts by the corpus luteum during the luteal phase.

Estrogen levels peak twice: once before ovulation (follicular phase) and once moderately during the luteal phase.

---

151. The opening between the right atrium and the right ventricle is guarded by

(A) sino-atrial node

(B) bicuspid valve

(C) tricuspid valve

(D) semilunar valve

Correct Answer: (C) tricuspid valve

Solution:

Concept:

- The human heart is divided into four chambers: two upper atria and two lower ventricles.
- To maintain unidirectional blood flow and prevent backflow, the openings between these chambers are regulated by specialized muscular valves:
  - **Atrioventricular (AV) Valves:** Positioned between the atria and the ventricles.
  - **Semilunar Valves:** Positioned at the junctions where major arteries exit the ventricles.

Step 1: Analyze the right side of the heart

Deoxygenated blood from the systemic circulation enters the right atrium and must pass into the right ventricle. The right atrioventricular aperture connects these two chambers. This specific opening is guarded by the **tricuspid valve**, which is composed of three distinct fibrous cusps or flaps.

Step 2: Evaluate the alternative options

- **(A) Sino-atrial node (SAN):** This is a specialized patch of neuromuscular tissue located in the upper wall of the right atrium. It serves as the natural pacemaker of the heart by generating electrical impulses, but it is not a physical valve.

- **(B) Bicuspid valve:** Also referred to as the mitral valve, this structure consists of two cusps and guards the opening between the left atrium and the left ventricle.
- **(D) Semilunar valves:** These half-moon-shaped valves guard the openings where the pulmonary artery leaves the right ventricle and where the aorta leaves the left ventricle.

Step 3: Formulate the final conclusion

Based on internal cardiac anatomy, the tricuspid valve regulates the passage of blood between the right atrium and right ventricle. Therefore, the correct option is (C).

Quick Tip:

- **Mnemonic to remember valve locations:**
  - **R-T**: **R**ight side has the **T**ricuspid valve.
  - **L-B**: **L**eft side has the **B**icuspid (Mitral) valve.
- The AV valves are attached to muscular projections called papillary muscles in the ventricular walls via fibrous cords called *chordae tendineae*, which prevent the valves from collapsing backward into the atria during ventricular contraction.

---

152. Which of the following is not evidence for evolution ?

(A) Divergent evolution of anatomical structures such as forelimbs

(B) Convergent evolution of traits like wings of birds and butterflies

(C) Paleontological evidence from fossil records

(D) Embryological support for evolution as proposed by Ernst Heckel

Correct Answer: (D) Embryological support for evolution as proposed by Ernst Heckel

Solution:

Concept:

- Evolutionary biology relies on several independent lines of evidence to reconstruct the history of life on Earth, including:
  - **Anatomical Evidence:** Homologous organs (arising from divergent evolution) and analogous organs (arising from convergent evolution).

- **Paleontological Evidence:** Morphological structures preserved in fossil records.
- **Embryological Evidence:** Comparative analyses of early developmental stages of organisms.

- The biogenetic law ("ontogeny recapitulates phylogeny") proposed by Ernst Haeckel (spelled "Heckel" in the question) stated that embryonic development mirrors the adult stages of evolutionary ancestors. This theory was contested and rejected by other embryologists.

Step 1: Evaluate the valid lines of evolutionary evidence

- **Option (A):** Divergent evolution of homologous structures (e.g., the anatomy of fore-limbs in whales, bats, cheetahs, and humans) demonstrates adaptation from a common ancestral form.
- **Option (B):** Convergent evolution of analogous structures (e.g., wings of birds and butterflies) demonstrates adaptation to similar environments from different ancestral lineages.
- **Option (C):** Paleontological studies (fossil records) provide physical historical evidence of structural transitions and lineages.

These three options represent established and validated categories of evolutionary evidence.
Step 2: Analyze the scientific status of Haeckel's embryological theory
Ernst Haeckel proposed that human and animal embryos pass through the fully formed adult stages of their evolutionary ancestors. However, this assertion was challenged by Karl Ernst von Baer, who demonstrated that embryos of different species do not pass through adult stages of other species, but rather diverge along distinct developmental pathways. Consequently, Haeckel's specific theory of embryological recapitulation is not accepted as valid scientific evidence. This corresponds to option (D).

Quick Tip:

- Karl Ernst von Baer's careful observations of vertebrate embryology led to the rejection of the "recapitulation theory," establishing that embryonic stages do not recapitulate adult ancestral forms.
- Homology represents common ancestry with divergent functions, while analogy represents separate ancestries with convergent functions.

---

153. The inactive form of Bt toxin is converted to the active form in the insect gut

(A) by nucleases

(B) due to alkaline pH

(C) due to acidic pH

(D) by proteases

Correct Answer: (B) due to alkaline pH

Solution:

Concept:

- *Bacillus thuringiensis* (Bt) is a soil bacterium that synthesizes insecticidal crystalline proteins (Cry proteins) during its sporulation phase.
- These proteins are initially synthesized as inactive **protoxins** inside the bacterium, preventing damage to the bacterial host.
- Activation of the protoxin requires specific physical and chemical conditions inside the gastrointestinal tract of target insect larvae.

Step 1: Identify the biochemical changes occurring inside the insect gut

Upon ingestion by a susceptible insect, the insoluble crystalline protoxins enter the midgut. The midgut environment in lepidopteran, dipteran, and coleopteran insects has a highly alkaline pH.

Step 2: Trace the activation mechanism of the Bt toxin

- The **alkaline pH** of the insect gut facilitates the solubilization of the toxic protein crystals.

- Proteolytic enzymes (proteases) present in the gut then cleave the solubilized protoxin, converting it into its active toxic form.
- Although proteases assist in cleavage, the primary physical-chemical requirement for activating the inactive crystal lattice is its solubilization, which is driven directly by the **alkaline pH**.
- The active toxin then binds to epithelial cells of the midgut, creating pores that disrupt osmotic balance, leading to swelling, lysis, and eventually starvation and death of the insect.

Therefore, the transition from the inactive form to the active form relies on the alkaline pH, which matches option (B).

Quick Tip:

- Bt toxin does not affect mammals (including humans) because the mammalian stomach is highly acidic, preventing the solubilization and activation of the protoxin crystals.
- Transgenic plants (such as Bt Cotton and Bt Brinjal) express these bacterial *cry* genes to provide targeted resistance against specific pests without chemical pesticides.

---

154. Colostrum, secreted by mother during initial days of lactation, is abundant in

(A) IgD

(B) IgG

(C) IgM

(D) IgA

Correct Answer: (D) IgA

Solution:

Concept:

- **Colostrum:** The thick, yellowish-colored fluid secreted by the maternal mammary glands during the final stage of pregnancy and the initial days of lactation following parturition (childbirth).
- **Biological Role:** It acts as a concentrated source of nutrients and essential protective

compounds, ensuring the transfer of passive immunity to the newborn infant whose active immune system is not yet fully developed.

- **Antibodies (Immunoglobulins):** These proteins identify and neutralize foreign agents. Secretory fluids in the human body are rich in specific classes of immunoglobulins.

Step 1: Analyze the distribution of immunoglobulin classes

There are five main classes of human immunoglobulins: IgA, IgD, IgE, IgG, and IgM.

- **IgA:** The primary antibody found in external secretions (such as tears, saliva, colostrum, and gastrointestinal secretions), offering mucosal immunity.
- **IgG:** The most abundant antibody in circulating blood plasma, which can cross the placental barrier.
- **IgM:** The first antibody produced during a primary immune response, primarily located in blood and lymph.
- **IgD:** Primarily functions as an antigen receptor on the surface of B lymphocytes.

Step 2: Relate the antibody type to colostrum

Since colostrum is a specialized maternal secretion, it contains highly concentrated levels of secretory IgA. This antibody coats the infant's intestinal tract, protecting against potential pathogens. This matches option (D).

Quick Tip:

- **Passive vs. Active Immunity:** Colostrum provides *passive immunity* because pre-formed antibodies (IgA) are transferred to the host, rather than the infant's body producing them.
- **Placental antibody:** Remember that **IgG** is the only antibody class capable of passing through the human placenta to provide prenatal protection.

---

155. Which of the following in female gametophyte of an angiosperm helps in guiding the pollen tube for fertilizing the eggs ?

(A) Polar nucleus

(B) Antipodals

(C) Synergids

(D) Central cells

Correct Answer: (C) Synergids

Solution:

Concept:

- The mature female gametophyte of an angiosperm (embryo sac) typically exhibits a 7-celled, 8-nucleate structure:
  - **Egg Apparatus (Micropylar end):** Contains one egg cell and two flanking **synergids**.
  - **Central Cell:** Contains two polar nuclei.
  - **Antipodals (Chalazal end):** Three cells located at the chalazal pole.
- Synergids possess specialized cellular structures at their micropylar tip known as the **filiform apparatus**.

Step 1: Understand the fertilization pathway in angiosperms

Upon reaching the stigma, the pollen grain germinates to produce a pollen tube, which grows down through the style toward the ovary. The pollen tube enters the ovule through the micropylar opening.

Step 2: Examine the role of the filiform apparatus and synergids

As the pollen tube approaches the embryo sac, it must find the precise path to deliver male gametes to the egg cell. The filiform apparatus, which consists of prominent finger-like projections on the synergid cell walls, secretes chemical signals (chemotropic substances). These chemical secretions guide the pollen tube's growth into one of the synergids, facilitating the fertilization process.

Step 3: Confirm the correct cellular structure

The cells responsible for this chemotropic guidance are the synergids, which contains the filiform apparatus. This matches option (C).

Quick Tip:

- The **filiform apparatus** is located at the micropylar end of the synergids.
- Once the pollen tube enters a synergid, the synergid degenerates, releasing the two male gametes to carry out double fertilization (one fuses with the egg cell, and the other fuses with the polar nuclei of the central cell).

---

156. Which of the following disease is not sexually transmitted ?

(A) Genital warts

(B) Syphilis

(C) Tuberculosis

(D) Gonorrhoea

Correct Answer: (C) Tuberculosis

Solution:

Concept:

- **Sexually Transmitted Infections (STIs):** Also known as Venereal Diseases (VD), these are infections or diseases transmitted primarily through intimate sexual contact with an infected partner.
- **Systemic and Respiratory Infections:** Diseases that spread through pathways such as airborne droplets, contaminated food or water, or direct contact, rather than primarily via sexual intercourse.

Step 1: Analyze the transmission pathway of the listed diseases

- **Genital warts (Option A):** Caused by the Human Papillomavirus (HPV). It is a well-established viral STI spread primarily through sexual contact.
- **Syphilis (Option B):** Caused by the spirochete bacterium *Treponema pallidum*. It is a chronic infection transmitted through sexual contact with active lesions.
- **Gonorrhoea (Option D):** Caused by the bacterium *Neisseria gonorrhoeae*. It is a common bacterial STI affecting the mucosal surfaces of the urogenital tract.

Step 2: Analyze the transmission pathway of Tuberculosis

Tuberculosis (Option C): Caused by the bacterium *Mycobacterium tuberculosis*. It is primarily a pulmonary (lung) disease that spreads through airborne droplet transmission when an infected individual coughs, sneezes, or talks. It is not classified as a sexually transmitted infection. This corresponds to option (C).

Quick Tip:

- **Bacterial STIs:** Gonorrhoea, Syphilis, Chlamydiasis.
- **Viral STIs:** Genital herpes, Genital warts, Hepatitis-B, HIV/AIDS.
- Early detection and complete treatment are vital for STIs to prevent long-term complications like Pelvic Inflammatory Disease (PID) or infertility.

---

157. Which of the following statements about lac-operon is correct ?

(A) Galactose can act as an inducer of lac operon

(B) Gene i is constitutively expressed

(C) Lactose activates repressor to bind to the operator

(D) Genes i, z, y and a share single common promoter

Correct Answer: (B) Gene i is constitutively expressed

Solution:

Concept:

- The *lac* operon (lactose operon) is a polycistronic gene regulation system in *Escherichia coli* that regulates the transport and metabolism of lactose.
- Its key components include:
  - **Regulatory gene (i gene):** Codes for the repressor protein.
  - **Promoter (p):** Binding site for RNA polymerase.
  - **Operator (o):** Binding site for the repressor protein.
  - **Structural genes (z, y, a):** Code for metabolic enzymes.

Step 1: Evaluate each statement individually for accuracy

- **Option (A):** Galactose is a monosaccharide product of lactose hydrolysis, but it cannot bind to the repressor protein to initiate operon transcription; only lactose (or its isomer allolactose) functions as the inducer. Thus, this statement is incorrect.
- **Option (B):** The regulatory i gene is transcribed and translated at a continuous, baseline level regardless of the presence of lactose, which is known as *constitutive expression*. This ensures repressor protein is always present in the cell to regulate the system. This statement is correct.
- **Option (C):** When lactose enters the cell, it binds to the repressor and causes a conformational change that *inactivates* the repressor. This prevents the repressor from binding to the operator, allowing transcription. Thus, this statement is incorrect.
- **Option (D):** The regulator gene (i gene) has its own independent promoter, while the structural genes (z, y, a) share a single, separate promoter. Thus, this statement is incorrect.

Step 2: Identify the correct option

Based on the evaluations, only statement (B) is biologically accurate.

Quick Tip:

- **Constitutive expression** means that the gene is continuously expressed to maintain basic cellular functions, independent of external environmental triggers.
- The structural genes of the lac operon and their corresponding proteins are:
  - z gene $\rightarrow$ β-galactosidase (hydrolyzes lactose)
  - y gene $\rightarrow$ permease (increases permeability of the cell to β-galactosides)
  - a gene $\rightarrow$ transacetylase (transfers an acetyl group to β-galactosides)

---

158. Match List-I with List-II.

List-I	List-II
A. Transformation	I. Restriction enzyme
B. Cloning site	II. Transfer DNA to host bacteria
C. Selection	IV. Antibiotic
D. Ori	III. Replication

Choose the correct answer from the options given below:

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

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

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

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

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

Solution:

Concept:

- Recombinant DNA technology uses biological elements to clone genes of interest inside host cells.
- Key processes and genetic tools include:
  - **Transformation:** Introducing foreign genetic material directly into a recipient bacterium.
  - **Cloning Sites:** Specific locations on a vector recognized by restriction endonucleases where foreign DNA is inserted.
  - **Selectable Markers:** Genes (such as those providing resistance to antibiotics) used to select recombinant host cells and eliminate non-recombinants.
  - **Origin of Replication (Ori):** A DNA sequence that initiates DNA replication inside host cells.

Step 1: Establish the matches between List-I and List-II

- **A. Transformation:** Represents the process used to **II. Transfer DNA to host bacteria**.
- **B. Cloning site:** The physical region in a cloning vector cleaved by a specific **I. Restriction enzyme** to insert foreign DNA.

- **C. Selection:** The process of identifying transformed cells, often using an **IV. Antibiotic** resistance gene as a selectable marker.
- **D. Ori:** The sequence responsible for initiating DNA **III. Replication** and controlling the copy number of the plasmid.

Step 2: Match with the given option choices

Combining these correlations, we obtain the pattern: A-II, B-I, C-IV, D-III. This corresponds to option (B).

Quick Tip:

- "**Ori**" is the direct initiator of **Replication**, allowing you to link D with III.
- Commonly used antibiotic resistance genes for selection in *E. coli* vectors include those for ampicillin, chloramphenicol, tetracycline, and kanamycin.

---

159. A population of diploid organisms is at Hardy-Weinberg equilibrium. If the frequency of allele A is 0.1, the frequency of AA is

(A) 0.99

(B) 0.01

(C) 0.02

(D) 0.10

Correct Answer: (B) 0.01

Solution:

Concept:

- The Hardy-Weinberg principle states that allele and genotype frequencies in a population remain constant from generation to generation in the absence of evolutionary influences.
- For a gene locus with two alleles, A (dominant) and a (recessive):
  - Let p be the frequency of allele A.
  - Let q be the frequency of allele a.
  - Thus, $p + q = 1$.

- The expected genotype frequencies in the population are given by:

$$p^2 + 2pq + q^2 = 1$$

where:

  - p^2 is the frequency of homozygous dominant individuals (AA).
  - $2pq$ is the frequency of heterozygous individuals (Aa).
  - q^2 is the frequency of homozygous recessive individuals (aa).

Step 1: Identify the given values from the problem statement

The problem states that the population is in Hardy-Weinberg equilibrium, and the frequency of the allele A (represented as p) is:

$$p = 0.1$$

Step 2: Calculate the frequency of genotype AA

The frequency of the homozygous dominant genotype AA is represented mathematically by p^2:

$$\text{Frequency of } AA = p^2$$

$$\text{Frequency of } AA = (0.1)^2 = 0.01$$

Thus, the expected frequency of the genotype AA in the population is 0.01, which corresponds to option (B).

Quick Tip:

- Always pay close attention to whether the question asks for an **allele frequency** (p or q) or a **genotype/phenotype frequency** (p^2, $2pq$, or q^2).
- To find the other allele's frequency: $q = 1 - p = 1 - 0.1 = 0.9$.
- The heterozygous frequency (Aa) would be $2pq = 2 \times 0.1 \times 0.9 = 0.18$.

---

160. Sperm motility is due to __________.

(A) muscular movement

(B) flagellar movement

(C) ciliary movement

(D) amoeboid movement

Correct Answer: (B) flagellar movement

Solution:

Concept:

- Specialized cells in eukaryotic multicellular organisms exhibit distinct types of movement:
  - **Amoeboid Movement:** Movement accomplished by pseudopodia, seen in specialized immune cells like macrophages and neutrophils.
  - **Ciliary Movement:** Coordinated movement driven by hair-like cilia, seen in respiratory tract linings (trachea) and the fallopian tubes.
  - **Flagellar Movement:** Movement driven by a whip-like flagellum, seen in specific free-swimming unicellular structures or gametes.
  - **Muscular Movement:** Contractile movement of muscle fibers, utilized for skeletal locomotion, heart beating, and peristalsis.

Step 1: Analyze the structure and locomotion of human sperm

A mature sperm cell (spermatozoon) is structurally divided into a head, neck, middle piece, and a tail.

- The sperm tail is a specialized **flagellum** containing an axoneme with a characteristic $9 + 2$ arrangement of microtubules.
- The coordinated, undulating lashing of this tail propels the sperm cell through fluid environments to reach the ovum.

Step 2: Identify the correct classification of movement

Since the propulsion of sperm relies directly on the wave-like beating of its tail, this motion represents flagellar movement. This corresponds to option (B).

Quick Tip:

- The energy required for flagellar movement is provided by ATP generated in the mitochondria concentrated within the sperm's middle piece.
- Both cilia and flagella are extensions of the cell membrane that originate from basal bodies, which are structurally similar to centrioles.

---

161. Consider a population of 10 million cells. Given the per-capita birth rate of 0.002 (per unit time) and the per-capita death rate of 0.002 (per unit time), the expected number of cells after 10 generations is ________.

(A) 100 million

(B) 1 million

(C) 5 million

(D) 10 million

Correct Answer: (D) 10 million

Solution:

Concept:

- Population growth rate over time can be mathematically expressed by the exponential growth equation:

$$\frac{dN}{dt} = rN$$

  where:

  - N is the population size.
  - r is the intrinsic rate of natural increase, calculated as the difference between the per-capita birth rate (b) and the per-capita death rate (d):

$$r = b - d$$

- If the growth rate r is zero, the population size does not undergo any net change over time, regardless of the time intervals or generations elapsed.

Step 1: Calculate the intrinsic rate of natural increase (r)

Using the values provided:

- Per-capita birth rate $(b) = 0.002$
- Per-capita death rate $(d) = 0.002$

Calculate r:

$$r = b - d = 0.002 - 0.002 = 0$$

Step 2: Calculate the expected population size after 10 generations

The mathematical relationship for population size is:

$$N_t = N_0 e^{rt}$$

Substituting $r = 0$ into the equation:

$$N_t = N_0 e^{(0 \times t)}$$

$$N_t = N_0 e^0$$

$$N_t = N_0 \times 1$$

$$N_t = 10 \text{ million}$$

Because the birth rate equals the death rate, the population remains stable at 10 million cells. This corresponds to option (D).

Quick Tip:

- When the per-capita birth rate matches the per-capita death rate, the population achieves a state of dynamic equilibrium.
- Under these conditions, elapsed time and generations have no net effect on the total population size.

---

162. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: Forelimbs of human and bats are homologous.

Reason R: Forelimbs of humans and bats have similar anatomical structure.

In the light of the above statements, choose the most appropriate answer from the options

given below:

(A) A is false but R is true

(B) Both A and R are correct and R is the correct explanation of A

(C) Both A and R are true, but R is not the correct explanation of A

(D) A is true but R is false

Correct Answer: (B) Both A and R are correct and R is the correct explanation of A

Solution:

Concept:

- **Homology:** The relationship between structures derived from a common evolutionary ancestor.
- Homologous structures share a similar basic anatomical plan and embryonic development, though they may perform different functions.
- Examples include the forelimbs of humans, cheetahs, whales, and bats, which all consist of humerus, radius, ulna, carpals, metacarpals, and phalanges.
- Homology indicates divergent evolution.

Step 1: Evaluate Assertion A

Assertion A states that the forelimbs of humans and bats are homologous.

This is true, as they are derived from a common mammalian ancestor.

Step 2: Evaluate Reason R

Reason R states that the forelimbs of humans and bats have a similar anatomical structure.

This is also true, as they share the same arrangement of bones.

Step 3: Determine if R is the correct explanation of A

Homology, by definition, is based on structural and anatomical similarity.

Because their forelimbs share the same fundamental anatomical structure, they are classified as homologous organs.

Thus, R is the correct explanation of A.

Quick Tip:

Homology → Similar anatomy, different functions → Divergent evolution.

Analogy → Different anatomy, similar functions → Convergent evolution (e.g., wings of butterfly and bird).

---

163. Muscle contraction is initiated by a signal sent by the central nervous system by the release of __________.

(A) cyclic adenine monophosphate

(B) acetyl choline

(C) acetyl coenzyme A

(D) cyclic guanine monophosphate

Correct Answer: (B) acetyl choline

Solution:

Concept:

- **Somatic Motor Signaling:** Skeletal muscles are under voluntary control, with contraction initiated by neural signals generated in the Central Nervous System (CNS) and transmitted along somatic motor neurons.
- **The Motor Unit:** A single motor neuron and the group of skeletal muscle fibers it innervates function together as a unified motor unit.
- **Neuromuscular Junction (NMJ):** The specialized chemical synapse between the terminal end of a motor neuron and the motor end-plate region of the muscle fiber's sarcolemma (plasma membrane).
- **Synaptic Transmission:** At the NMJ, electrical action potentials are converted into chemical signals through the release of a specific neurotransmitter into the synaptic cleft.

Step 1: Trace the chemical sequence at the neuromuscular junction

When an action potential reaches the presynaptic axon terminal of the motor neuron:

- Voltage-gated calcium channels open, allowing calcium ions (Ca^{2+}) to enter the axon terminal.

- This influx triggers the fusion of synaptic vesicles with the presynaptic membrane, releasing **acetylcholine** (ACh) into the synaptic cleft via exocytosis.
- ACh molecules diffuse across the cleft and bind to ligand-gated nicotinic acetylcholine receptors on the sarcolemma.

Step 2: Evaluate the options against the mechanism of action

- **(A) cyclic adenine monophosphate (cAMP):** An intracellular second messenger involved in signal transduction cascades, not a primary synaptic neurotransmitter.
- **(B) acetyl choline:** The primary neurotransmitter released at somatic motor synapses that depolarizes the sarcolemma to trigger skeletal muscle contraction.
- **(C) acetyl coenzyme A (acetyl-CoA):** A key biochemical intermediate in cellular respiration (Krebs cycle) and lipid metabolism, rather than a neural signaling molecule.
- **(D) cyclic guanine monophosphate (cGMP):** An intracellular second messenger that regulates cellular pathways, such as smooth muscle relaxation, but is not responsible for initiating skeletal muscle contraction at the NMJ.

Thus, acetylcholine is the neurotransmitter responsible for initiating the process, corresponding to option (B).

Quick Tip:

- **Somatic Neurotransmitter:** Acetylcholine is the universal neurotransmitter utilized by somatic motor neurons to activate skeletal muscle contraction.
- **Signal Termination:** To ensure that the muscle does not remain in a state of continuous contraction, the enzyme **acetylcholinesterase** (AChE) rapidly hydrolyzes acetylcholine in the synaptic cleft into acetic acid and choline, allowing the muscle fiber to repolarize and relax.

164. Which of the following hormone is not secreted by human placenta ?

(A) LH

(B) hCG

(C) Estrogen

(D) Progesterone

Correct Answer: (A) LH

Solution:

Concept:

- **Endocrine Role of the Placenta:** During human gestation, the placenta acts as a temporary, highly active endocrine gland. It synthesizes and secretes several hormones that are critical for maintaining the pregnancy, regulating maternal metabolism, and supporting fetal growth.
- **Placental Hormones:** The primary hormones produced by placental tissue (specifically the syncytiotrophoblast layer) include:
  - **hCG** (Human Chorionic Gonadotropin): Maintains the corpus luteum during early pregnancy to ensure continuous progesterone production.
  - **hPL** (Human Placental Lactogen): Regulates maternal glucose and lipid metabolism to support fetal nutrition.
  - **Estrogens (primarily Estriol):** Stimulate uterine growth and ductal development in the mammary glands.
  - **Progesterone:** Maintains the stable, non-contractile state of the uterine endometrium during gestation.
- **Anterior Pituitary Hormones:** Gonadotropic hormones, such as Luteinizing Hormone (LH) and Follicle-Stimulating Hormone (FSH), are synthesized and secreted by gonadotroph cells in the anterior pituitary gland under the regulation of hypothalamic GnRH.

Step 1: Analyze the biological source of the listed hormones

During pregnancy, the levels of estrogen and progesterone rise significantly. These hormones are synthesized directly by the placenta to support the growing fetus. Similarly, hCG is produced by the developing chorion/placenta shortly after implantation.

Step 2: Identify the hormone of non-placental origin

Luteinizing Hormone (LH) is a pituitary gonadotropin. During pregnancy, the extremely high levels of circulating placental estrogen and progesterone exert a strong negative feedback effect on the maternal hypothalamus and anterior pituitary gland. This feedback mechanism suppresses the secretion of LH and FSH to prevent the maturation of new ovarian follicles. Consequently, LH is not secreted by the placenta. This corresponds to option (A).

Quick Tip:

- **Pregnancy-Specific Hormones:** Hormones such as **hCG**, **hPL**, and **relaxin** (which is also secreted by the ovary/placenta later in pregnancy) are produced in women exclusively during gestation.
- **Clinical Application:** Because hCG is produced shortly after the blastocyst implants into the uterine wall, its presence in maternal urine serves as the physiological basis for home pregnancy testing.

---

165. Which of the following statements is correct about *Plasmodium* ?

(A) Fertilization takes place in mosquito gut

(B) Reproduces sexually in liver cells

(C) Reproduces sexually in RBCs

(D) Gametocytes develop in mosquito gut

Correct Answer: (A) Fertilization takes place in mosquito gut

Solution:

Concept:

- *Plasmodium* is a microscopic, single-celled protozoan parasite that causes malaria.
- It has a complex, two-host (digenetic) life cycle:
  - **Asexual cycle (in Humans):** Sporozoites migrate to liver cells and reproduce asexually (schizogony). They then infect red blood cells (RBCs), reproducing asexually to release merozoites.
  - **Sexual stages (Gametocytes):** Form and develop inside human RBCs.
  - **Sexual cycle (in Mosquitoes):** Gametocytes are ingested by the female *Anopheles* mosquito, mature into gametes, and undergo **fertilization** inside the mosquito's gut.

Step 1: Evaluate the statements on sexual vs. asexual phases

Option (A) is correct: Fertilization of male and female microgametes occurs in the intestinal lumen of the mosquito.

Option (B) and (C) are incorrect: *Plasmodium* reproduces asexually in human liver cells and RBCs.

Option (D) is incorrect: Gametocytes are produced and develop in human blood (RBCs), not inside the mosquito.

Quick Tip:

Humans serve as the intermediate host (where asexual reproduction occurs).

Female *Anopheles* mosquitoes serve as the definitive host (where fertilization and sexual reproduction occur).

Sporozoite is the infectious stage of the parasite that is injected into the human body.

---

166. Which of the following are primary consumers in a food chain ?

(A) Carnivores

(B) Parasites

(C) Predators

(D) Herbivores

Correct Answer: (D) Herbivores

Solution:

Concept:

- **Trophic Levels:** The trophic structure of an ecosystem represents the specific feeding positions occupied by different groups of organisms based on their source of nutrition:
  - **Producers (First Trophic Level, T_1):** Autotrophic organisms, primarily green plants, that utilize solar energy to synthesize organic compounds via photosynthesis.
  - **Primary Consumers (Second Trophic Level, T_2):** Heterotrophic organisms that obtain their energy by feeding directly on primary producers.
  - **Secondary Consumers (Third Trophic Level, T_3):** Carnivorous organisms that feed on primary consumers.
  - **Tertiary Consumers (Fourth Trophic Level, T_4):** Top carnivores that feed on secondary consumers.

Step 1: Understand the ecological role of primary consumers

Primary consumers occupy the first heterotrophic level in a food chain. Because their diet consists exclusively of primary producers (green plants, algae, or phytoplankton), they are biologically classified as **herbivores**. Examples of terrestrial primary consumers include cows, deer, rabbits, and leaf-eating insects. In aquatic ecosystems, small crustaceans and zooplankton serve this role.

Step 2: Evaluate the alternative options

- **(A) Carnivores:** These organisms consume other animals, placing them at the third trophic level (T_3) as secondary consumers, or higher.
- **(B) Parasites:** These organisms live in or on a host organism to obtain nutrients. They do not occupy a single fixed trophic level, as their position depends entirely on the trophic level of their specific host.
- **(C) Predators:** These are active hunters that capture and consume prey animals, placing them as secondary or tertiary consumers.
- **(D) Herbivores:** These are plant-eating animals, which directly corresponds to the definition of primary consumers.

Therefore, option (D) is the correct choice.

Quick Tip:

- **Trophic Level Association:**
  - Producers $\longrightarrow$ Autotrophs (T_1)
  - Primary Consumers $\longrightarrow$ Herbivores (T_2)
  - Secondary Consumers $\longrightarrow$ Primary Carnivores (T_3)
  - Tertiary Consumers $\longrightarrow$ Secondary/Top Carnivores (T_4)
- **10% Law of Energy Transfer:** Only about 10% of the energy available at one trophic level is transferred to the next level. The remaining 90% is lost primarily as metabolic heat during respiration and through waste.

---

167. Which of the following statements about the reabsorption process in Henle's loop are correct ?

(a) The descending limb of Henle's loop is permeable to water but almost impermeable to electrolytes.

(b) Urine gets concentrated in Henle's loop.

(c) Reabsorption of Na^+ and water takes place in Henle's loop.

(d) Active or passive transport of electrolytes occurs in the ascending limb of Henle's loop.

Choose the correct answer from the options given below :

(A) (a), (b) and (d) only

(B) (a) and (b) only

(C) (b), (c) and (d) only

(D) (a), (b) and (c) only

Correct Answer: (A) (a), (b) and (d) only

Solution:

Concept:

- Henle's loop is a hairpin-shaped part of the nephron with two functionally distinct limbs:
  - **Descending limb:** Permeable to water, but nearly impermeable to electrolytes. As filtrate moves down, water is reabsorbed, increasing the concentration of the filtrate.
  - **Ascending limb:** Impermeable to water, but allows transport of electrolytes actively or passively.

Step 1: Analyze the correctness of each statement

Statement (a) is correct: The descending limb allows water to pass through but blocks electrolytes.

Statement (b) is correct: Reabsorption of water in the descending limb concentrates the medullary filtrate.

Statement (c) is incorrect: Reabsorption of water and Na^+ occur in different, separate limbs of Henle's loop, not together in a single step.

Statement (d) is correct: Active or passive transport of electrolytes occurs in the water-impermeable ascending limb.

Step 2: Determine the correct combination

Since statements (a), (b), and (d) are correct, option (1) is the correct choice.

Quick Tip:

The loop of Henle plays a major role in establishing a high osmotic pressure in the kidney medulla.

Remember: Descending limb is for water reabsorption (concentrating the urine); Ascending limb is for salt reabsorption (diluting the urine).

---

168. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.
Assertion A: The logistic growth model of populations is considered more realistic than the exponential growth model.
Reason R: Resources are finite.
In the light of the above statements, choose the most appropriate answer from the options given below:

(A) A is not correct but R is correct

(B) Both A and R are correct and R is the correct explanation of A

(C) Both A and R are correct but R is not the correct explanation of A

(D) A is correct but R is not correct

Correct Answer: (B) Both A and R are correct and R is the correct explanation of A

Solution:

Concept:

- **Exponential growth:** Assumes unlimited resources, resulting in a J-shaped curve. This rarely occurs in nature.
- **Logistic growth:** Assumes limited resources, resulting in a Sigmoid (S-shaped) curve.
- The population size levels off as it reaches the carrying capacity (K) of the habitat.

Step 1: Evaluate the truth of the Assertion and Reason
Assertion A is true: The logistic growth model accounts for limiting factors, making it highly realistic.
Reason R is true: Habitats have a finite amount of resources (food, space, nesting sites).
Step 2: Check if R is the correct explanation of A
The logistic growth model is considered more realistic (Assertion) precisely because resources

are limited and finite (Reason) in any natural habitat.

Thus, R is the correct explanation of A.

Quick Tip:

Verhulst-Pearl Logistic Growth is mathematically expressed as: $\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$.

When $N = K$, population growth stops, representing the maximum population size that the environment can support.

---

169. Which of the following is the correct order of arrangement of vertebrate column from the head to toe ?

(A) Cervical vertebra, thoracic vertebra, lumbar vertebra, sacrum

(B) Cervical vertebra, thoracic vertebra, sacrum, lumbar vertebra

(C) Sacrum, lumbar vertebra, thoracic vertebra, cervical vertebra

(D) Cervical vertebra, lumbar vertebra, thoracic vertebra, sacrum

Correct Answer: (A) Cervical vertebra, thoracic vertebra, lumbar vertebra, sacrum

Solution:

Concept:

- **Vertebral Column:** The human vertebral column (backbone) is a flexible, mid-dorsal bony structure that extends from the base of the skull to the pelvis, protecting the spinal cord and supporting the trunk.
- **Regional Vertebrae:** In adults, the column consists of 26 serially arranged, articulated units called vertebrae, which are categorized into five distinct anatomical regions:
  - **Cervical Region:** Located in the neck, consisting of 7 individual vertebrae.
  - **Thoracic Region:** Located in the chest/ribcage area, consisting of 12 individual vertebrae.
  - **Lumbar Region:** Located in the lower back, consisting of 5 individual vertebrae.
  - **Sacral Region (Sacrum):** Located in the pelvic girdle, composed of 5 vertebrae that fuse into a single, triangular bone in adults.

– **Coccygeal Region (Coccyx):** Located at the terminal end, composed of 4 small vertebrae fused into a single vestigial tailbone.

Step 1: Trace the craniocaudal (head to toe) sequence of the vertebral column

To establish the correct anatomical order starting from the head (superior) and moving downwards toward the pelvic region (inferior):

- The uppermost vertebrae directly supporting the skull are the **cervical** vertebrae.
- Below the neck, the vertebral column enters the chest region as the **thoracic** vertebrae.
- Below the thoracic cage, the column forms the lower back region with the larger **lumbar** vertebrae.
- Below the lumbar region, the column articulates with the pelvic girdle through the fused **sacrum**.
- The terminal portion of the column is represented by the vestigial **coccyx**.

Therefore, the sequence from superior to inferior is:

$$\text{Cervical} \rightarrow \text{Thoracic} \rightarrow \text{Lumbar} \rightarrow \text{Sacrum} \rightarrow \text{Coccyx}$$

Step 2: Evaluate the options against this anatomical sequence

- **(A) Cervical, thoracic, lumbar, sacrum:** This matches the correct anatomical sequence from head to toe.
- **(B) Cervical, thoracic, sacrum, lumbar:** This is incorrect because the sacrum is placed superior to the lumbar vertebrae.
- **(C) Sacrum, lumbar, thoracic, cervical:** This is incorrect because it presents the reverse (toe to head) sequence.
- **(D) Cervical, lumbar, thoracic, sacrum:** This is incorrect because the lumbar vertebrae are placed superior to the thoracic vertebrae.

Thus, option (A) is the correct choice.

Quick Tip:

- **Sequence Mnemonic (CTLSC):** Remember the vertical order of the vertebral regions using the acronym **CTLSC** (Cervical, Thoracic, Lumbar, Sacrum, Coccygeal).
- **Vertebral Formula:** The standard vertebral distribution in humans is expressed as:

$$C_7T_{12}L_5S_{(5\text{ fused})}Co_{(4\text{ fused})}$$

- Associate the counts of the mobile vertebrae (**7**, **12**, and **5**) with standard daily meal times:
  - Breakfast at **7** AM → **7** Cervical
  - Lunch at **12** PM → **12** Thoracic
  - Dinner at **5** PM → **5** Lumbar

---

170. Match List-I with List-II.

List-I	**List-II**
A. Both species are harmed	**I. Predation**
B. One species is harmed and the other is benefited	**II. Mutualism**
C. Both species are benefited	**III. Competition**
D. One is benefited while the other has no effect	**IV. Commensalism**

Choose the correct answer from the options given below :

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

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

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

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

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

Solution:

Concept:

- Biological interactions between populations can be beneficial (+), harmful (−), or neutral (0):
  - **Competition:** (−, −) Both species are negatively affected.
  - **Predation:** (+, −) One species benefits by feeding on the other.

- **Mutualism:** (+, +) Both species benefit.
- **Commensalism:** (+, 0) One species benefits while the other is unaffected.

Step 1: Match each description to its biological interaction term

A. Both species are harmed (−, −) → **III. Competition**

B. One species is harmed and the other is benefited (+, −) → **I. Predation**

C. Both species are benefited (+, +) → **II. Mutualism**

D. One is benefited while the other has no effect (+, 0) → **IV. Commensalism**

Step 2: Identify the correct option matching the list

The sequence is A-III, B-I, C-II, D-IV, which matches option (1).

Quick Tip:

Competition and mutualism are symmetrical interactions (−,− and +,+), while predation and commensalism are asymmetrical.

Spleen-plant relationships and lichen associations are famous examples of mutualistic interactions.

---

171. If the diploid chromosome number of typical angiosperm is 36, what would be the chromosome number in its endosperm ?

(A) 72

(B) 18

(C) 36

(D) 54

Correct Answer: (D) 54

Solution:

Concept:

- In angiosperms, the endosperm is formed as a result of triple fusion (double fertilization).
- Triple fusion involves the fusion of one haploid male gamete (n) with the diploid secondary nucleus ($2n$) inside the embryo sac.
- This results in a triploid cell ($3n$) which develops into the endosperm tissue.
- Somatic cells (vegetative cells) of a typical angiosperm are diploid ($2n$).

Step 1: Find the haploid chromosome number

Given diploid number:

$$2n = 36$$

Therefore, haploid number (n) is:

$$n = \frac{36}{2} = 18$$

Step 2: Calculate the endosperm chromosome number

The endosperm is triploid ($3n$):

$$3n = 3 \times 18 = 54$$

Thus, the chromosome number in its endosperm is 54.

Quick Tip:

Angiosperm endosperm is triploid ($3n$) because of double fertilization.

In contrast, the endosperm in gymnosperms is haploid (n) because it is formed before fertilization.

---

172. Which of the following enzymes synthesizes precursor mRNA ?

(A) DNA polymerase

(B) RNA polymerase I

(C) RNA polymerase II

(D) RNA polymerase III

Correct Answer: (C) RNA polymerase II

Solution:

Concept:

- **Eukaryotic Transcription:** Unlike prokaryotes, which utilize a single RNA polymerase to transcribe all types of RNA, eukaryotic cells exhibit a clear division of labor with three distinct RNA polymerase enzymes in their nucleus:
  - **RNA Polymerase I:** Transcribes ribosomal RNAs (28S, 18S, and 5.8S rRNAs), which are structural and catalytic components of ribosomes.
  - **RNA Polymerase II:** Transcribes protein-coding genes to produce heterogeneous nuclear RNA (**hnRNA**), which serves as the direct precursor of messenger RNA

(mRNA).

  – **RNA Polymerase III:** Transcribes transfer RNA (tRNA), 5S rRNA, and other small nuclear RNAs (snRNAs).

Step 1: Understand the nature of precursor mRNA in eukaryotes
In eukaryotic transcription of protein-coding genes, the immediate product is not a fully functional messenger RNA (mRNA). Instead, a primary transcript called heterogeneous nuclear RNA (hnRNA) or precursor mRNA (pre-mRNA) is synthesized. This pre-mRNA contains both coding sequences (exons) and non-coding sequences (introns) and must undergo post-transcriptional processing (capping, tailing, and splicing) to become mature, functional mRNA.
Step 2: Identify the specific transcribing enzyme
Based on the division of labor in eukaryotic nuclei:

- **RNA Polymerase I** is restricted to transcribing ribosomal RNA genes.
- **RNA Polymerase III** is restricted to smaller functional RNA genes, such as tRNAs and the 5S ribosomal subunit.
- **RNA Polymerase II** is responsible for transcribing structural, protein-coding genes into hnRNA (pre-mRNA).

Thus, the enzyme that synthesizes precursor mRNA is RNA Polymerase II, which corresponds to option (C).

Quick Tip:

- **Mnemonic (r-m-t):** To remember the primary products of the three eukaryotic RNA polymerases in sequence, associate Polymerases I, II, and III with the letters **r**, **m**, and **t** respectively:
  – **I** → **r**RNA
  – **II** → **m**RNA precursor (hnRNA)
  – **III** → **t**RNA
- **Prokaryotic Exception:** In prokaryotic organisms, a single DNA-dependent RNA polymerase is responsible for the transcription of all functional classes of RNA (mRNA, tRNA, and rRNA).

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173. Given below are two statements:

Statement I: Plasmids are autonomously replicating DNA.

Statement II: Plasmids are extrachromosomal DNA.

In the light of the above statements, choose the most appropriate answer from the options given below:

(A) Statement I is incorrect but Statement II is correct

(B) Both Statement I and Statement II are correct

(C) Both Statement I and Statement II are incorrect

(D) Statement I is correct but Statement II is incorrect

Correct Answer: (B) Both Statement I and Statement II are correct

Solution:

Concept:

- **Plasmids:** Small, circular, double-stranded, extrachromosomal DNA molecules found naturally in bacterial cells and some fungi.
- They are physically separate from the host's chromosomal DNA.
- Plasmids possess an origin of replication (*ori*) sequence, enabling them to replicate independently (autonomously) of the host's genomic chromosome.

Step 1: Verify Statement I

Statement I is correct: Plasmids replicate autonomously because they have their own origin of replication.

Step 2: Verify Statement II

Statement II is correct: Plasmids are extrachromosomal, meaning they are located outside and separate from the host's main genome.

Quick Tip:

Plasmids are widely used as vectors in recombinant DNA technology to deliver genes of interest into host bacteria.

Plasmids often carry selectable marker genes, such as those conferring resistance to antibiotics like ampicillin.

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174. How many theca are present in each lobe of a typical bilobed angiosperm anther?

(A) 12

(B) 2

(C) 6

(D) 8

Correct Answer: (B) 2

Solution:

Concept:

- **Structure of the Anther:** The anther is the fertile, pollen-bearing part of the stamen in angiosperms.
- **Bilobed Arrangement:** A typical angiosperm anther is a bilobed structure, meaning it consists of two distinct lobes joined together by a band of sterile parenchymatous tissue called the connective.
- **Dithecous Lobes:** Internally, each individual lobe of the anther is divided into two separate chambers or pollen sacs, which are anatomically referred to as **theca**.
- Since each lobe possesses two theca, the lobes are described as **dithecous**.
- Consequently, a complete, mature bilobed anther is tetrasporangiate, containing a total of four microsporangia (pollen sacs) distributed across its two lobes.

Step 1: Analyze the spatial structure of the anther

To determine the correct count, we must distinguish between the structure of a single lobe and the structure of the entire anther.

- A typical anther has two lobes in total.
- Each of these lobes is structurally partitioned into two longitudinal cavities (theca).

Step 2: Evaluate the count of theca per individual lobe

The question asks specifically for the number of theca present in **each** lobe. Since each individual lobe is dithecous (possessing two chambers), there are exactly 2 theca per lobe. This corresponds to option (B).

Quick Tip:

- **Key Terminology Distinction:**
  - Number of theca **per lobe** = 2 (dithecous)
  - Number of theca **per entire typical anther** = 4 (tetrathecous / tetrasporangiate)
- A distinct longitudinal groove runs along the outer surface of each anther lobe, marking the internal division between the two corresponding theca.

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175. Natural selection can lead to

(a) stabilisation

(b) genetic drift

(c) directional change

(d) disruption

Choose the correct answer from the options given below :

(A) (a) and (c) only

(B) (a) only

(C) (a), (c) and (d) only

(D) (a), (b), (c) and (d)

Correct Answer: (C) (a), (c) and (d) only

Solution:

Concept:

- **Natural Selection:** An evolutionary process where environmental pressures favor individuals with advantageous traits, allowing them to reproduce more successfully.
- Based on the phenotypic changes it produces in a population, natural selection works through three distinct modes:
  - **Stabilising selection:** Favors intermediate phenotypes, reducing variation and maintaining status quo (stabilisation).
  - **Directional selection:** Favors one extreme phenotype, shifting the population mean in that direction (directional change).

- **Disruptive selection:** Favors both extremes over the average, splitting the population phenotypic curve (disruption).

- **Genetic Drift:** A separate, non-adaptive evolutionary mechanism caused by random changes in gene pool frequencies.

Step 1: Distinguish the modes of natural selection from other evolutionary factors
Stabilisation (a), directional change (c), and disruption (d) are direct outcomes or types of natural selection.
Genetic drift (b) is an independent evolutionary force driven by random chance events rather than fitness.
Step 2: Identify the correct combination option
The modes of natural selection are (a), (c), and (d). This corresponds to option (3).

Quick Tip:

Stabilising selection narrows the phenotypic distribution curve around the mean.

Directional selection shifts the peak of the curve toward one side.

Disruptive selection produces two distinct peaks at the extreme ends of the phenotypic range, which can lead to speciation.

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176. Which of the following statements are correct?

(a) Energy flow from producers to consumers is unidirectional

(b) Energy pyramid can never be inverted

(c) Transfer of energy follows the 1% law

Choose the correct answer from the options given below :

(A) (b) and (c) only

(B) (a), (b) and (c)

(C) (a) and (b) only

(D) (a) and (c) only

Correct Answer: (C) (a) and (b) only

Solution:

Concept:

- **Unidirectional Energy Flow:** Energy captured from the sun by producers travels linearly through successive trophic levels. It cannot travel back to previous levels.
- **Pyramid of Energy:** It is universally upright because energy is lost as heat at each trophic level. It can never be inverted.
- **10% Law of Energy (Lindeman):** Only about 10% of the organic energy from one trophic level is stored and passed on to the next.

Step 1: Examine the validity of each statement

Statement (a) is correct: Energy flows in a single direction, from autotrophs to herbivores and then to carnivores.

Statement (b) is correct: The pyramid of energy is always upright because metabolic heat loss at each transfer prevents higher levels from containing more energy.

Statement (c) is incorrect: Energy transfer between successive trophic levels follows the **10% law**, not the 1% law. (The 1% value is the efficiency with which plants convert solar energy into chemical energy during photosynthesis).

Step 2: Identify the correct option

Since only (a) and (b) are correct, option (3) is the correct choice.

Quick Tip:

Pyramids of biomass and numbers can occasionally be inverted (e.g., in deep marine ecosystems or a single-tree ecosystem).

However, the pyramid of energy is strictly upright in all ecosystems due to the laws of thermodynamics.

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177. Match List-I with List-II.

List-I	**List-II**
A. Excess growth hormone	**I. Reabsorption of water and electrolytes in kidney**
B. Luteinizing hormone	**II. Contraction of uterus during child birth**
C. Vasopressin	**III. Acromegaly**
D. Oxytocin	**IV. Ovulation**

Choose the correct answer from the options given below :

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

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

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

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

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

Solution:

Concept:

- **Growth Hormone (GH):** Hypersecretion of GH in adults causes **Acromegaly**, characterized by the disproportional enlargement of bones in the face, hands, and feet.
- **Luteinizing Hormone (LH):** A pituitary gonadotropin that stimulates follicle maturation and triggers **ovulation** of the mature Graafian follicle.
- **Vasopressin (Antidiuretic Hormone - ADH):** Enhances water and electrolyte permeability in the distal tubules and collecting ducts of **kidneys**, facilitating reabsorption.
- **Oxytocin:** Acts on smooth muscle tissues, causing strong **uterine contractions** during childbirth (parturition).

Step 1: Match hormone items between List-I and List-II

A. Excess growth hormone → **III. Acromegaly**

B. Luteinizing hormone → **IV. Ovulation**

C. Vasopressin → **I. Reabsorption of water and electrolytes in kidney**

D. Oxytocin → **II. Contraction of uterus during child birth**

Step 2: Select the corresponding correct option

The matching sequence is A-III, B-IV, C-I, D-II, which corresponds to option (3).

Quick Tip:

Acromegaly is hard to diagnose in its early stages because the anatomical changes occur very slowly over time.

Oxytocin acts on a positive feedback loop during labor, increasing contraction intensity as labor progresses.

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178. Which of the following are secondary lymphoid organs?

(a) Bone marrow

(b) Tonsils

(c) Spleen

(d) Thymus

Choose the correct answer from the options given below :

(A) (a) and (d) only

(B) (a) and (b) only

(C) (b) and (c) only

(D) (b) and (d) only

Correct Answer: (C) (b) and (c) only

Solution:

Concept:

- Lymphoid organs are classified into two main types depending on their role in the immune system:
  - **Primary Lymphoid Organs:** Tissues where immature lymphocytes differentiate and mature into antigen-sensitive cells. These are **Bone marrow** and the **Thymus**.
  - **Secondary Lymphoid Organs:** Tissues where mature lymphocytes travel to interact with specific foreign antigens and multiply. These include the **Spleen**, lymph nodes, **tonsils**, Peyer's patches, and appendix.

Step 1: Classify each of the listed lymphoid organs

(a) Bone marrow $\longrightarrow$ Primary lymphoid organ

(b) Tonsils $\longrightarrow$ Secondary lymphoid organ

(c) Spleen $\longrightarrow$ Secondary lymphoid organ

(d) Thymus $\longrightarrow$ Primary lymphoid organ

Step 2: Identify the secondary organs and choose the option

The secondary lymphoid organs are (b) and (c), which is represented by option (3).

Quick Tip:

Bone marrow is the principal site of lymphocyte production, where both B and T cell precursors are generated.

The spleen acts as a main biological filter, trapping blood-borne microorganisms and worn-out erythrocytes.

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179. During PCR, primers bind to the DNA strands in the ________ step.

(A) ligation

(B) denaturation

(C) extension

(D) annealing

Correct Answer: (D) annealing

Solution:

Concept:

- **Polymerase Chain Reaction (PCR):** An enzymatic, in-vitro technique used to amplify a specific target sequence of DNA into millions of copies.
- A single cycle of PCR involves three distinct temperature-dependent steps:
  - **Denaturation:** The double-stranded template DNA is heated (typically to $94-96°C$) to disrupt hydrogen bonds, separating the DNA into single strands.
  - **Annealing:** The temperature is lowered (typically to $50-65°C$) to allow synthetic oligonucleotide primers to bind (hybridize) to their complementary sequences on the single-stranded template DNA.
  - **Extension:** The temperature is adjusted (typically to $72°C$) to allow a thermostable DNA polymerase (such as *Taq* polymerase) to extend the primers by adding complementary deoxynucleotide triphosphates (dNTPs).
- **Ligation:** This is a distinct process of joining DNA fragments catalyzed by DNA ligase, which is not a part of the standard PCR cycle.

Step 1: Analyze the biochemical requirements for primer binding

Primers are short, single-stranded sequences of nucleic acids that serve as starting points for

DNA synthesis. For primers to bind to the template, the double-stranded genomic DNA must first be separated into single strands via heat. Once separated, the temperature of the reaction mixture must be lowered to a point where stable hydrogen bonds can reform specifically between the primers and their complementary regions on the template strands.

Step 2: Evaluate the options against the steps of a PCR cycle

- **(A) Ligation:** This is a cloning step used to seal nicks in the sugar-phosphate backbone, not a component of the standard PCR amplification cycle.
- **(B) Denaturation:** At this high-temperature stage ($\sim 94°C$), single-stranded DNA templates are generated, but the high kinetic energy prevents primers from annealing.
- **(C) Extension:** During this step ($\sim 72°C$), DNA polymerase actively synthesizes the new strand starting from the 3'-hydroxyl end of the already-bound primers.
- **(D) Annealing:** This is the intermediate temperature stage ($\sim 50 - 60°C$) where the thermal conditions favor the hybridization (binding) of primers to the template DNA.

Step 3: Formulate the final conclusion

The binding of synthetic primers to single-stranded template DNA occurs specifically during the annealing phase. This corresponds to option (D).

Quick Tip:

- **Primer Design:** Primers are designed in pairs (forward and reverse) to flank the region of interest. They are oriented such that DNA synthesis proceeds inward across the target sequence.
- **Thermostability:** *Taq* polymerase is isolated from the hot-spring bacterium *Thermus aquaticus*. This enzyme can withstand the repeated high-temperature denaturation steps without denaturing itself, which is essential for automating the PCR cycle.

180. Given below are two statements:

Statement I: Down's syndrome is caused by the absence of one of the X-chromosomes.

Statement II: Turner's syndrome is caused by the presence of an additional copy of the chromosomes.

In the light of the above statements, choose the correct answer from the options given below:

(A) Statement I is incorrect but Statement II is correct

(B) Both Statement I and Statement II are correct

(C) Both Statement I and Statement II are incorrect

(D) Statement I is correct but Statement II is incorrect

Correct Answer: (C) Both Statement I and Statement II are incorrect

Solution:

Concept:

- Aneuploid disorders are caused by the gain or loss of specific chromosomes due to non-disjunction during cell division.
- **Down's Syndrome:** Caused by the presence of an extra copy of autosome 21 (Trisomy 21). It is an autosomal disorder and does not involve sex chromosomes.
- **Turner's Syndrome:** Caused by the absence of one of the sex chromosomes (X chromosome) in females, leading to an XO karyotype with 45 total chromosomes.

Step 1: Evaluate Statement I

Statement I is incorrect: Down's syndrome involves an additional copy of chromosome 21, not the loss of an X chromosome.

Step 2: Evaluate Statement II

Statement II is incorrect: Turner's syndrome is caused by the absence of a chromosome (monosomy XO), not by an additional copy of a chromosome.

Step 3: Select the corresponding option

Since both Statement I and Statement II are incorrect, option (3) is the correct choice.

Quick Tip:

Down's syndrome results in a total of 47 chromosomes due to autosomal trisomy.

Turner's syndrome results in a total of 45 chromosomes due to sex chromosome monosomy.

Klinefelter's syndrome is another key sex-chromosome aneuploidy, involving an extra X chromosome (XXY, 47 chromosomes).

