# KEAM 2024 (June 10) Question Paper With Solutions

| **Time Allowed :**90 minutes | **Maximum Marks :**300 | **Total questions :**75 |
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**General Instructions**

**Read the following instructions very carefully and strictly follow them:**

1. The test is of 90 minutes duration and the Test Booklet contains 75 multiple-choice questions (four options with a single correct answer) from Physics and Chemistry.

2. There are 45 questions in Physics and 30 questions in Chemistry. 3. Each question carries 4 marks. For each correct response, the candidate will get 4 marks. For each incorrect response, one mark will be deducted from the total scores. The maximum marks are 600.

**1. In the measurement of length 6 $\mu$m is equal to $x$ pm. Then the value of $x$ is**

(A) $1.5 \times 10^{-5}$

(B) $1.2 \times 10^{6}$

(C) $3 \times 10^{-6}$

(D) $6 \times 10^{6}$

(E) $2 \times 10^{-12}$

**Correct Answer:** (D) $6 \times 10^{6}$

**Solution: Step 1:** 1 $\mu$m = $10^{6}$ pm.

**Step 2:** Given length is 6 $\mu$m. So,

$$x = 6 \times 10^{6} \text{ pm}$$

**Step 3:** Therefore, the correct answer is (D).

Quick Tip

To convert between metric units, use the appropriate powers of ten for each prefix.

**2. Dimensions of the physical quantity $X$ in the equation**

$$\textbf{Force} = \frac{X}{\textbf{Volume}}$$

**are**

(A) $ML^3T^2$

(B) $MLT$

(C) $ML^2T^2$

(D) $MLT^{-2}$

(E) $ML^4T^{-2}$

**Correct Answer:** (E) $ML^4T^{-2}$

**Solution: Step 1:** The dimensional formula of Force is

$$\text{Force} = MLT^{-2}$$

**Step 2:** The dimensional formula of Volume is

$$\text{Volume} = L^3$$

**Step 3:** From the equation

$$X = \text{Force} \times \text{Volume}$$

$$X = (MLT^{-2}) \times (L^3) = ML^4T^{-2}$$

**Step 4:** Therefore, the correct answer is (E).

**Quick Tip**

Use the fundamental dimensions of mass (M), length (L), and time (T) to verify dimensional consistency.

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**3. A man loses 50% of his velocity after running a distance of 100 m. If his retardation is uniform, the distance he will cover before coming to rest is**

(A) 45.2 m

(B) 33.3 m

(C) $27.5$ m

(D) $15.7$ m

(E) $50.5$ m

**Correct Answer:** (B) $33.3$ m

**Solution:** To solve the problem, we analyze the motion of the man under uniform retardation.

Step 1: Define the variables - Let the initial velocity of the man be $u$. - After running a distance of $100$ m, his velocity becomes $\frac{u}{2}$ (since he loses 50- Let the uniform retardation be $a$.

Step 2: Use the equation of motion The equation of motion relating velocity, distance, and acceleration is:

$$v^2 = u^2 + 2as$$

where:

$v$ is the final velocity,

$u$ is the initial velocity,

$a$ is the acceleration (or retardation, if negative),

$s$ is the distance.

For the first part of the motion (when the man loses 50% of his velocity):

Initial velocity $= u$,

Final velocity $= \frac{u}{2}$,

Distance $= 100$ m.

Substitute these values into the equation:

$$\left(\frac{u}{2}\right)^2 = u^2 + 2a(100)$$

$$\frac{u^2}{4} = u^2 + 200a$$

Rearrange to solve for $a$:

$$\frac{u^2}{4} - u^2 = 200a$$

$$-\frac{3u^2}{4} = 200a$$

$$a = -\frac{3u^2}{800}$$

Step 3: Find the total distance before coming to rest Now, we need to find the total distance $S$ the man covers before coming to rest. At rest, the final velocity $v = 0$.

Using the same equation of motion:

$$v^2 = u^2 + 2aS$$

Substitute $v = 0$, $u = u$, and $a = -\frac{3u^2}{800}$:

$$0 = u^2 + 2\left(-\frac{3u^2}{800}\right)S$$

$$0 = u^2 - \frac{3u^2}{400}S$$

Solve for $S$:

$$\frac{3u^2}{400}S = u^2$$

$$S = \frac{u^2 \cdot 400}{3u^2}$$

$$S = \frac{400}{3}$$

$$S \approx 133.33\,\text{m}$$

Step 4: Subtract the initial 100 m The man has already covered $100\,\text{m}$ before his velocity reduces to $\frac{u}{2}$. The additional distance he covers before coming to rest is:

$$S_{\text{additional}} = S - 100$$

$$S_{\text{additional}} = \frac{400}{3} - 100$$

$$S_{\text{additional}} = \frac{400}{3} - \frac{300}{3}$$

$$S_{\text{additional}} = \frac{100}{3}$$

$$S_{\text{additional}} \approx 33.33\,\text{m}$$

Final Answer: The distance the man will cover before coming to rest is:

$$\boxed{33.33\,\text{m}}$$

Quick Tip

When dealing with uniformly accelerated motion, use kinematic equations to find unknowns like distance or acceleration.

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**4. A projectile is given an initial velocity of $(\hat{i}+\hat{j})$ ms$^{-1}$ where $\hat{i}$ is along the ground and $\hat{j}$ is along the vertical direction. The equation of its trajectory is** $(g = 10$ **ms**$^{-2})$

(A) $y^2 = 2x$

(B) $y^2 - 1 = 5x$

(C) $y = x - 5x^2$

(D) $y = x^2$

(E) $y = x^2 - 2$

**Correct Answer:** (C) $y = x - 5x^2$

**Solution: Step 1:** The general equation of projectile motion is given by:

$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

**Step 2:** Given initial velocity components:

$$u_x = 1, \quad u_y = 1$$

**Step 3:** Using $\theta = 45^\circ$, $\tan\theta = 1$, and substituting values:

$$y = x - \frac{10x^2}{2(1)^2}$$

$$y = x - 5x^2$$

**Step 4:** Therefore, the correct answer is (C).

Quick Tip

For projectile motion, always use the standard trajectory equation and substitute known values carefully.

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**5. A particle is describing a uniform circular motion with a certain constant speed. The INCORRECT statement is**

(A) The velocity and acceleration vectors are perpendicular to each other

(B) The velocity vector is tangential to the circular path

(C) The centripetal acceleration is a variable acceleration

(D) The acceleration vector points to the centre of the circle

(E) The acceleration vector is tangential to the circular path

**Correct Answer:** (E) The acceleration vector is tangential to the circular path

**Solution: Step 1:** In uniform circular motion, acceleration is always directed towards the center (centripetal acceleration).

**Step 2:** The velocity is always tangential to the circular path, meaning it is perpendicular to the acceleration vector.

**Step 3:** Since centripetal acceleration points to the center, it is not tangential to the path. The incorrect statement is (E).

Quick Tip

In uniform circular motion, acceleration always acts towards the center, while velocity is tangential.

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**6. A particle moves under the influence of a force in the XY-plane such that the components of its linear momentum $\vec{p}$ at any time $t$ is $p_x = p\sin t$ and $p_y = p\cos t$. The angle between $\vec{F}$ and $\vec{p}$ at that time is**

(A) $45^\circ$

(B) $60^\circ$

(C) $30^\circ$

(D) $90^\circ$

(E) $0^\circ$

**Correct Answer:** (D) $90^\circ$

**Solution: Step 1:** Force is given by

$$\vec{F} = \frac{d\vec{p}}{dt}$$

**Step 2:** Differentiating momentum components:

$$F_x = p\cos t, \quad F_y = -p\sin t$$

**Step 3:** The force vector $\vec{F} = (p\cos t, -p\sin t)$ is perpendicular to the momentum vector $\vec{p} = (p\sin t, p\cos t)$.

**Step 4:** Therefore, the angle between $\vec{F}$ and $\vec{p}$ is $90°$.

**Quick Tip**

If force is the time derivative of momentum, their directions can be determined using differentiation.

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**7. In a 'tug of war' game, two persons pull each other through a massless rope. The person who wins is**

(A) One whose weight is less

(B) One who exerts more friction force (shearing force) on the ground

(C) One who exerts more normal force (compressing force) on the ground

(D) One who pulls the rope with a greater force

(E) One whose weight is more

**Correct Answer:** (B) One who exerts more friction force (shearing force) on the ground

**Solution: Step 1:** In a tug-of-war, the force exerted on the rope does not directly determine the winner. Instead, it depends on the force that a person can apply against the ground.

**Step 2:** The force that allows a person to pull effectively comes from the friction between their feet and the ground. Higher friction provides better resistance, allowing one to pull with greater force.

**Step 3:** The friction force is given by:

$$F_{\text{friction}} = \mu N$$

where $\mu$ is the coefficient of friction and $N$ is the normal force.

**Step 4:** The person who can exert a larger frictional force will be able to resist the pull of the opponent and apply a stronger opposing force, ultimately winning the game. **Step 5:** Therefore, the correct answer is (B).

**Quick Tip**

In a tug-of-war, the role of friction is crucial. The winner is not necessarily the heavier person but the one who can maximize friction against the ground.

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**8. When a spring of spring constant $k$ is cut into two pieces whose lengths are $l_1$ and $l_2$, then the ratio of their spring constants $k_1$ and $k_2$ is**

(A) $\frac{l_2}{l_1}$

(B) $\frac{l_1}{l_2}$

(C) $\sqrt{l_1 l_2}$

(D) $l_1 l_2$

(E) $\frac{1}{l_1 l_2}$

**Correct Answer:** (A) $\frac{l_2}{l_1}$

**Solution: Step 1:** The spring constant of a spring is inversely proportional to its length when the spring is cut into smaller sections. Mathematically,

$$k' = \frac{k}{l}$$

where $k'$ is the spring constant of a smaller piece and $l$ is its length.

**Step 2:** When the original spring of constant $k$ is divided into two sections of lengths $l_1$ and $l_2$, their respective spring constants are:

$$k_1 = \frac{k}{l_1}, \quad k_2 = \frac{k}{l_2}$$

**Step 3:** The ratio of $k_1$ to $k_2$ is:

$$\frac{k_1}{k_2} = \frac{\frac{k}{l_1}}{\frac{k}{l_2}} = \frac{l_2}{l_1}$$

**Step 4:** Therefore, the correct answer is (A).

Quick Tip

When a spring is cut into smaller sections, the stiffness of each section increases because the force required for unit displacement increases.

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**9. If $P$ is the pressure at which the heart is pumping the blood and the volume of blood pumped per second is $V$, then the power of the heart is given by**

(A) $\frac{P}{V}$

(B) $\frac{P^2}{V}$

(C) $PV$

(D) $\frac{P}{V_2}$

(E) $P^2V$

**Correct Answer:** (C) $PV$

**Step 1:** Power is defined as the rate of doing work or the rate at which energy is transferred. The general equation for power is:

$$\text{Power} = \frac{\text{Work done}}{\text{Time}}$$

**Step 2:** The work done by the heart to pump blood is given by

$$W = P \times V$$

where $P$ is the pressure and $V$ is the volume of blood pumped per second.

**Step 3:** Since power is the rate of work done, we get:

$$\text{Power} = P \times V$$

**Step 4:** Therefore, the correct answer is (C).

Quick Tip

In fluid mechanics, power can be calculated as the product of pressure and flow rate.

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**10. A block of mass $M$ moves with a velocity $v$ along a frictionless horizontal surface towards another block of mass $2M$ at rest. The velocity of the center of mass of the system of blocks is**

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

(B) $2v$

(C) $3v$

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

(E) $\frac{v}{4}$

**Correct Answer:** (D) $\frac{v}{3}$

**Solution: Step 1:** The velocity of the center of mass is given by:

$$V_{\text{cm}} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$$

where $m_1 = M$, $v_1 = v$, $m_2 = 2M$, and $v_2 = 0$.

**Step 2:** Substituting the values:

$$V_{\text{cm}} = \frac{Mv + 2M \times 0}{M + 2M}$$

$$V_{\text{cm}} = \frac{Mv}{3M} = \frac{v}{3}$$

**Step 3:** Therefore, the correct answer is (D).

**Quick Tip**

The center of mass velocity is the weighted average of the velocities of individual masses.

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**11. The radius of gyration of a regular solid cylinder of radius $R$ about its axis is**

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

(B) $R$

(C) $\frac{R}{\sqrt{2}}$

(D) $2R$

(E) $\frac{R}{4}$

**Correct Answer:** (C) $\frac{R}{\sqrt{2}}$

**Solution: Step 1:** The moment of inertia of a solid cylinder about its central axis is:

$$I = \frac{1}{2}MR^2$$

**Step 2:** The radius of gyration $K$ is related to the moment of inertia by:

$$I = MK^2$$

**Step 3:** Equating both expressions:

$$MK^2 = \frac{1}{2}MR^2$$

$$K^2 = \frac{R^2}{2}$$

$$K = \frac{R}{\sqrt{2}}$$

**Step 4:** Therefore, the correct answer is (C).

**Quick Tip**

The radius of gyration is a measure of how mass is distributed around the axis of rotation.

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**12. When two spheres of radii $r$ and $\frac{r}{2}$ are brought in contact, the gravitational force of attraction between them is proportional to**

(A) $r^6$

(B) $r^4$

(C) $r^{-6}$

(D) $r^{-4}$

(E) $r^{-2}$

**Correct Answer:** (E) $r^{-2}$

**Solution: Step 1:** The gravitational force between two masses is given by Newton's Law of Gravitation:

$$F = \frac{Gm_1m_2}{d^2}$$

where $m_1$ and $m_2$ are the masses and $d$ is the separation.

**Step 2:** The masses of spheres are proportional to their volumes:

$$m_1 \propto r^3, \quad m_2 \propto \left(\frac{r}{2}\right)^3 = \frac{r^3}{8}$$

**Step 3:** Since they are in contact, the separation $d$ is approximately the sum of their radii:

$$d \approx r + \frac{r}{2} = \frac{3r}{2}$$

**Step 4:** Substituting in the gravitational force formula:

$$F \propto \frac{(r^3) \times (r^3/8)}{(3r/2)^2}$$

**Step 5:** Simplifying:

$$F \propto \frac{r^6}{8 \times (9r^2/4)}$$

$$F \propto \frac{r^6}{18r^2}$$

$$F \propto r^{6-2} = r^4$$

**Step 6:** Since force is inversely proportional to $r^2$, we get:

$$F \propto r^{-2}$$

**Step 7:** Therefore, the correct answer is (E).

**Quick Tip**

In gravitational problems, mass is proportional to volume, and separation is based on geometry.

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**13. The gravitational potential energy of a system of two bodies each of mass $m$ and distance $r$ between them is (G = gravitational constant, g = acceleration due to gravity)**

(A) $-\frac{Gm^2}{r^2}$

(B) $-\frac{Gm^2}{r}$

(C) $-\frac{gm^2}{r}$

(D) $-G\frac{gm^2}{r}$

(E) $\frac{Ggm}{r^2}$

**Correct Answer:** (B) $-\frac{Gm^2}{r}$

**Solution: Step 1:** The gravitational potential energy ($U$) between two masses $m_1$ and $m_2$ separated by a distance $r$ is given by:

$$U = -\frac{Gm_1m_2}{r}$$

**Step 2:** In this case, both masses are equal to $m$, so the equation simplifies to:

$$U = -\frac{Gm^2}{r}$$

**Step 3:** Therefore, the correct answer is (B).

**Quick Tip**

Gravitational potential energy is always negative, indicating an attractive force between masses.

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**14. Which of the following has the maximum Young's modulus value?**

(A) Aluminium

(B) Copper

(C) Brass

(D) Steel

(E) Iron (Wrought)

**Correct Answer:** (D) Steel

**Solution: Step 1:** Young's modulus ($Y$) measures the stiffness of a material and is defined as:

$$Y = \frac{\text{Stress}}{\text{Strain}}$$

**Step 2:** The values of Young's modulus for common metals are:

Aluminium: $70 \times 10^9$ Pa

Copper: $110 \times 10^9$ Pa

Brass: $100 \times 10^9$ Pa

Steel: $200 \times 10^9$ Pa

Wrought Iron: $190 \times 10^9$ Pa

**Step 3:** Since steel has the highest Young's modulus, it is the stiffest material among the given options.

**Step 4:** Therefore, the correct answer is (D).

**Quick Tip**

Young's modulus determines how resistant a material is to deformation under stress.

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**15. The energy stored in a soap bubble of diameter 4 cm is nearly (surface tension of soap solution is 0.07 Nm$^{-1}$)**

(A) $8.5 \times 10^{-3}$ J

(B) $2.75 \times 10^{-2}$ J

(C) $7 \times 10^{-4}$ J

(D) $4.5 \times 10^{-4}$ J

(E) $3.15 \times 10^{-3}$ J

**Correct Answer:** (C) $7 \times 10^{-4}$ J

**Step 1:** The energy stored in a soap bubble due to surface tension is given by:

$$U = 4\pi R^2 \times 2T$$

where $T$ is the surface tension, and the factor of 2 is included because a soap bubble has both an inner and outer surface.

**Step 2:** Given:

$$\text{Diameter} = 4 \text{ cm} = 0.04 \text{ m}, \quad R = \frac{0.04}{2} = 0.02 \text{ m}$$

$$T = 0.07 \text{ Nm}^{-1}$$

**Step 3:** Substituting the values:

$$U = 4\pi(0.02)^2 \times 2(0.07)$$

**Step 4:** Simplifying:

$$U = 4 \times 3.1416 \times 0.0004 \times 0.14$$

$$U = 7 \times 10^{-4} \text{ J}$$

**Step 5:** Therefore, the correct answer is (C).

**Quick Tip**

A soap bubble has two surfaces, so the energy stored must account for both.

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**16. When two different liquids of same mass but at two different temperatures $27°C$ and $47°C$ are mixed together, the resulting temperature of the mixture is $35°C$. The ratio of their specific heat capacities is**

(A) 1 : 3

(B) 5 : 3

(C) 3 : 2

(D) 4 : 1

(E) 2 : 7

**Correct Answer:** (C) 3 : 2

**Solution: Step 1:** Let $c_1$ and $c_2$ be the specific heat capacities of the liquids mixed. Since no heat is lost to the environment, the heat lost by the hotter liquid equals the heat gained by the cooler one.

**Step 2:** Set up the equation based on heat transfer: $m \cdot c_1 \cdot (47 - 35) = m \cdot c_2 \cdot (35 - 27)$.

**Step 3:** Simplify to find the ratio $\frac{c_1}{c_2} = \frac{8}{12} = \frac{2}{3}$.

**Step 4:** Thus, the ratio of their specific heat capacities is $3 : 2$ (inverse of $\frac{2}{3}$).

**Quick Tip**

Always check the direction of heat transfer: from higher temperature to lower temperature, ensuring conservation of energy.

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**17. Two perfectly black bodies are at temperatures $T$ and $2T$. The ratio between the wavelengths corresponding to maximum energy emission by the two black bodies is**

(A) 2 : 1

(B) 1 : 2

(C) 2 : 3

(D) 3 : 2

(E) 1 : 4

**Correct Answer:** (A) 2 : 1

**Solution:** To solve the problem, we use **Wien's Displacement Law**, which relates the temperature of a black body to the wavelength at which it emits the maximum energy. The law is given by:

$$\lambda_{\text{max}} T = b$$

where: - $\lambda_{\text{max}}$ is the wavelength corresponding to maximum energy emission, - $T$ is the absolute temperature of the black body, - $b$ is Wien's constant ($b \approx 2.898 \times 10^{-3}$ m·K).
Step 1: Apply Wien's Displacement Law For the two black bodies: 1. For the first black body at temperature $T$:

$$\lambda_1 T = b \implies \lambda_1 = \frac{b}{T}$$

2. For the second black body at temperature $2T$:

$$\lambda_2 (2T) = b \implies \lambda_2 = \frac{b}{2T}$$

Step 2: Find the ratio of wavelengths The ratio of the wavelengths corresponding to maximum energy emission is:

$$\frac{\lambda_1}{\lambda_2} = \frac{\frac{b}{T}}{\frac{b}{2T}} = \frac{b}{T} \cdot \frac{2T}{b} = 2$$

Thus, the ratio is:

$$\lambda_1 : \lambda_2 = 2 : 1$$

Final Answer: The ratio between the wavelengths corresponding to maximum energy emission by the two black bodies is:

$$\boxed{2 : 1}$$

Quick Tip

Remember that Wien's displacement law can be crucial for understanding how temperature influences the spectral distribution of black body radiation.

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**18. When water is heated from $0^\circ$C to $8^\circ$C, its volume**

(A) first decreases **upto** $4^\circ$C and then increases

(B) first increases **upto** $4^\circ$C and then decreases

(C) increases continuously

(D) decreases continuously

(E) does not change

**Correct Answer:** (A) first decreases **upto** $4^\circ$C and then increases

**Solution: Step 1:** Water exhibits an anomalous expansion behavior between $0^\circ$C and $4^\circ$C. Unlike most substances, its density increases as it is heated from $0^\circ$C to $4^\circ$C, causing the volume to decrease.

**Step 2:** At exactly $4^\circ$C, water reaches its maximum density, meaning its volume is at a minimum.

**Step 3:** When heated beyond $4^\circ$C, water behaves normally, expanding as the temperature increases, leading to an increase in volume.

**Step 4:** Therefore, the correct answer is (A).

Quick Tip

Water's density is highest at $4^\circ$C, which is why aquatic life survives in cold climates as water remains liquid below ice.

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**19. The pressure of an ideal gas is proportional to the cube of its temperature (on absolute scale) in an adiabatic process. Then the value of the ratio $C_p/C_v$ is**

(A) $\frac{7}{5}$

(B) $\frac{5}{3}$

(C) $\frac{4}{3}$

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

(E) $\frac{7}{3}$

**Correct Answer:** (D) $\frac{3}{2}$

**Solution: Step 1:** In an adiabatic process, pressure ($P$) and temperature ($T$) follow the relation:

$$P \propto T^n$$

where $n$ is a constant. Given that pressure is proportional to the cube of the temperature,

$$P \propto T^3$$

thus, $n = 3$.

**Step 2:** The adiabatic relation between pressure and temperature for an ideal gas is given by:

$$PT^{-\frac{\gamma}{\gamma-1}} = \text{constant}$$

where $\gamma = \frac{C_p}{C_v}$ is the heat capacity ratio.

**Step 3:** Comparing with the given relation $P \propto T^3$, we equate:

$$-\frac{\gamma}{\gamma - 1} = 3$$

**Step 4:** Solving for $\gamma$:

$$\gamma = \frac{3}{2}$$

**Step 5:** Therefore, the correct answer is (D).

**Quick Tip**

In adiabatic processes, the exponent in $P \propto T^n$ helps determine the value of $\gamma$.

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**20. The average kinetic energy per molecule of an ideal gas at $27^\circ C$ is $E$. The temperature of the gas at which the average kinetic energy per molecule will be $2E$ is**

(A) $127^\circ C$

(B) $227^\circ C$

(C) $327°C$

(D) $400°C$

(E) $527°C$

**Correct Answer:** (C) $327°C$

**Solution: Step 1:** Recall that the average kinetic energy ($E$) of an ideal gas is proportional to the absolute temperature ($T$). If $E$ is doubled, the absolute temperature must also double.
**Step 2:** Convert the initial temperature from Celsius to Kelvin: $T_1 = 27°C = 300K$.
**Step 3:** The new temperature in Kelvin when $E$ doubles is $2 \times 300K = 600K$.
**Step 4:** Convert $600K$ back to Celsius: $600K - 273.15 = 326.85°C$, which rounds to $327°C$.

Quick Tip

Always convert temperatures to Kelvin when working with temperature-related changes in kinetic energy, as Kelvin directly correlates with the thermal energy of a system.

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**21. The instantaneous displacement of a particle executing simple harmonic motion is given by $x = 2(\cos(\pi t) + \sin(\pi t))$. The amplitude of oscillation is**

(A) $3\sqrt{2}$

(B) 4

(C) $4\sqrt{2}$

(D) $2\sqrt{2}$

(E) $8\sqrt{2}$

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

To solve the problem, we analyze the given displacement equation for simple harmonic motion (SHM):

$$x = 2(\cos(\pi t) + \sin(\pi t))$$

The general form of the displacement equation for SHM is:

$$x = A\cos(\omega t) + B\sin(\omega t)$$

where:

$A$ and $B$ are constants,

$\omega$ is the angular frequency.

The amplitude $R$ of the oscillation is given by:

$$R = \sqrt{A^2 + B^2}$$

Step 1: Identify $A$, $B$, and $\omega$ From the given equation:

$$x = 2(\cos(\pi t) + \sin(\pi t))$$

we can rewrite it as:

$$x = 2\cos(\pi t) + 2\sin(\pi t)$$

Thus:

$A = 2$,

$B = 2$,

$\omega = \pi$.

Step 2: Calculate the amplitude Using the formula for amplitude:

$$R = \sqrt{A^2 + B^2}$$

Substitute $A = 2$ and $B = 2$:

$$R = \sqrt{2^2 + 2^2} = \sqrt{4 + 4} = \sqrt{8} = 2\sqrt{2}$$

Final Answer: The amplitude of oscillation is:

$$\boxed{2\sqrt{2}}$$

**Quick Tip**

Using trigonometric identities can simplify the analysis of oscillatory motion and provide insights into the physical quantities involved, like amplitude.

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**22. The velocity of a travelling plane wave given by**

$$y = 10^{-2}\sin\left(200t - \frac{x}{5}\right) m,$$

**is**

(A) 10 $ms^{-1}$

(B) 500 $ms^{-1}$

(C) 400 $ms^{-1}$

(D) 5 $ms^{-1}$

(E) 1000 $ms^{-1}$

**Correct Answer:** (E) 1000 $ms^{-1}$

**Solution: Step 1:** The standard form of a travelling wave equation is:

$$y = A\sin(\omega t - kx)$$

where $\omega$ is the angular frequency, $k$ is the wave number, and the wave velocity $v$ is given by:

$$v = \frac{\omega}{k}$$

**Step 2:** From the given equation, we compare terms:

$$\omega = 200, \quad k = \frac{1}{5}$$

**Step 3:** Using the wave velocity formula:

$$v = \frac{200}{1/5} = 200 \times 5 = 1000 \text{ ms}^{-1}$$

**Step 4:** Therefore, the correct answer is (E).

**Quick Tip**

The speed of a wave is given by the ratio of its angular frequency $\omega$ to the wave number $k$.

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**23. When a glass rod is rubbed with silk thread, it loses 1000 electrons. Then the charge on the glass rod is (electronic charge $e = 1.6 \times 10^{-19}$ C)**

(A) $+1.6 \times 10^{-16}$ C

(B) $-1.6 \times 10^{-19}$ C

(C) $-1.6 \times 10^{-13}$ C

(D) $+1.6 \times 10^{-19}$ C

(E) $-1.6 \times 10^{-15}$ C

**Correct Answer:** (A) $+1.6 \times 10^{-16}$ C

**Solution: Step 1:** The charge on a single electron is:

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

**Step 2:** The charge on the glass rod is given by:

$$Q = ne$$

where $n$ is the number of lost electrons. Given that $n = 1000$, we get:

$$Q = 1000 \times 1.6 \times 10^{-19}$$

$$Q = 1.6 \times 10^{-16} \text{ C}$$

**Step 3:** Since the rod loses electrons, it becomes positively charged.

**Step 4:** Therefore, the correct answer is (A).

**Quick Tip**

When an object loses electrons, it becomes positively charged. When it gains electrons, it becomes negatively charged.

---

**24. In bringing a proton towards another proton, the electrostatic potential energy of the system**

(A) decreases

(B) increases

(C) becomes zero

(D) first increases and then decreases

(E) remains the same

**Correct Answer:** (B) increases

**Solution: Step 1:** The electrostatic potential energy ($U$) between two point charges $q_1$ and $q_2$ separated by distance $r$ is given by:

$$U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

**Step 2:** Since both charges are protons, we have:

$$q_1 = q_2 = e = 1.6 \times 10^{-19}\ \text{C}$$

**Step 3:** Since both charges are positive, they repel each other. As the distance between them decreases, $r$ decreases.

**Step 4:** Since $U \propto \frac{1}{r}$, decreasing $r$ increases $U$, meaning the electrostatic potential energy of the system increases.

**Step 5:** Therefore, the correct answer is (B).

**Quick Tip**

Like charges repel, meaning work must be done to bring them closer, increasing potential energy.

---

**25. A parallel plate capacitor with a dielectric medium of dielectric constant 1.5 has a capacitance of $C$. If the dielectric is removed, then the capacitance of the capacitor becomes**

(A) $\frac{3}{2}C$

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

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

(D) $C$

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

**Correct Answer:** (C) $\frac{2}{3}C$

**Solution: Step 1:** The capacitance of a capacitor with a dielectric is given by $C' = kC$, where $k$ is the dielectric constant.

**Step 2:** With the dielectric, the capacitance is $C = 1.5C_0$, where $C_0$ is the original capacitance without the dielectric.

**Step 3:** Removing the dielectric, the capacitance returns to $C_0$. Thus, $C_0 = \frac{2}{3}C$.

**Step 4:** Therefore, the new capacitance is $\frac{2}{3}C$.

Quick Tip

Remember, the capacitance with a dielectric is directly proportional to the dielectric constant.

---

**26. When $n$ identical cells are connected in parallel, they give**

(A) less current

(B) more current

(C) less voltage

(D) more voltage

(E) variable voltage and variable current

**Correct Answer:** (B) more current

**Solution: Step 1:** When cells are connected in parallel, the voltage across each cell remains the same, but the total current capacity increases.

**Step 2:** The effective internal resistance decreases, allowing more current to flow through the external circuit compared to a single cell.

**Step 3:** Therefore, connecting cells in parallel results in more current.

Quick Tip

Use parallel connections to increase current output in circuits where higher current is required without increasing voltage.

---

**27. Resistivity of a conductor increases with**

(A) increase in its length

(B) decrease in its length

(C) increase in its area of cross-section

(D) decrease in its area of cross-section

(E) increase in its temperature

**Correct Answer:** (E) increase in its temperature

**Solution: Step 1:** Resistivity of a conductor is primarily dependent on the material and its temperature.
**Step 2:** As temperature increases, the atomic vibrations within the conductor increase, leading to more frequent collisions and higher resistivity.
**Step 3:** Thus, the resistivity of a conductor increases with an increase in its temperature.

Quick Tip

Keep in mind that for semiconductors, the behavior of resistivity with temperature can be the opposite of that in conductors.

---

**28. Kirchhoff's junction rule is based on conservation of**

(A) charge

(B) energy

(C) both energy and charge

(D) angular momentum

(E) linear momentum

**Correct Answer:** (A) charge

**Solution: Step 1:** Kirchhoff's junction rule (also known as the current law) states that the total current entering a junction equals the total current leaving the junction.
**Step 2:** This law is derived from the principle of conservation of charge, ensuring that no charge is lost or created at the junction.
**Step 3:** Therefore, Kirchhoff's junction rule is based on the conservation of charge.

Quick Tip

Always use Kirchhoff's rules for analyzing complex circuits to simplify finding unknown currents and voltages.

**29. The magnetic force acting on a charged particle carrying a charge $3\mu C$ in a magnetic field of $5$ T acting in the $y$-direction, when the particle velocity is**

$$(\hat{i} + \hat{j}) \times 10^5 \text{ ms}^{-1}$$

**is**

(A) $0.5$ N in $+x$ direction

(B) $0.2$ N in $+y$ direction

(C) $2$ N in $-x$ direction

(D) $1.5$ N in $-z$ direction

(E) $1.5$ N in $+z$ direction

**Correct Answer:** (E) $1.5$ N in $+z$ direction

**Solution: Step 1:** The magnetic force on a moving charge is given by:

$$\vec{F} = q(\vec{v} \times \vec{B})$$

**Step 2:** Given:

$$q = 3 \times 10^{-6} C, \quad \vec{v} = (10^5 \hat{i} + 10^5 \hat{j}) \text{ m/s}, \quad \vec{B} = 5\hat{j} \text{ T}$$

**Step 3:** Compute the cross product:

$$\vec{v} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 10^5 & 10^5 & 0 \\ 0 & 5 & 0 \end{vmatrix}$$

**Step 4:** Expanding the determinant:

$$\vec{v} \times \vec{B} = (10^5 \times 0 - 10^5 \times 0)\hat{i} - (10^5 \times 0 - 5 \times 10^5)\hat{j} + (10^5 \times 5 - 10^5 \times 0)\hat{k}$$

$$= 0\hat{i} + 5 \times 10^5 \hat{j} + 5 \times 10^5 \hat{k}$$

$$= 5 \times 10^5 \hat{k}$$

**Step 5:** Compute force:

$$\vec{F} = (3 \times 10^{-6})(5 \times 10^5 \hat{k})$$

$$= 1.5\hat{k} \text{ N}$$

**Step 6:** Since $\hat{k}$ represents the $+z$ direction, the force is $1.5$ N in the $+z$ direction.

**Step 7:** Therefore, the correct answer is (E).

**Quick Tip**

Use the determinant method to compute vector cross products efficiently.

---

**30. The magnetic moment $\mu$ associated with a charged particle carrying charge $q$ moving in a circle of radius $a$ with uniform speed $v$ is**

(A) $qva$

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

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

(D) $\frac{qva}{16}$

(E) $\frac{qva}{8}$

**Correct Answer:** (C) $\frac{qva}{2}$

**Solution: Step 1:** The magnetic moment of a charged particle moving in a circular path is given by:

$$\mu = IA$$

where $I$ is the current and $A$ is the area of the circular path.

**Step 2:** The current $I$ is given by:

$$I = \frac{q}{T}$$

where $T$ is the time period of the circular motion. The time period is:

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

**Step 3:** Substituting $T$:

$$I = \frac{q}{2\pi a/v} = \frac{qv}{2\pi a}$$

**Step 4:** The area of the circular path is:

$$A = \pi a^2$$

**Step 5:** Compute the magnetic moment:

$$\mu = \left(\frac{qv}{2\pi a}\right)(\pi a^2)$$

$$= \frac{qva}{2}$$

**Step 6:** Therefore, the correct answer is (C).

Quick Tip

The magnetic moment of a current-carrying loop depends on the charge, velocity, and radius of the path.

---

**31. For a paramagnetic material, the magnetic susceptibility $\chi_m$ is**

(A) small, positive and varies inversely with temperature

(B) small, negative and temperature independent

(C) small, positive and temperature independent

(D) very large, negative and temperature dependent

(E) very large, positive and temperature independent

**Correct Answer:** (A) small, positive and varies inversely with temperature

**Solution: Step 1:** Paramagnetic materials are characterized by a small positive susceptibility.

**Step 2:** These materials do not retain magnetization in the absence of an external magnetic field, unlike ferromagnetic materials.

**Step 3:** According to Curie's Law, the susceptibility $\chi_m$ of paramagnetic materials is inversely proportional to their temperature.

**Step 4:** Therefore, as the temperature increases, the magnetic susceptibility decreases, which aligns with option (A).

Quick Tip

Remember that Curie's Law is significant for explaining the temperature dependence of magnetism in paramagnetic materials.

**32. An alternating current having peak value 14.14 A is used to heat a metal wire. The value of the direct current $i$ required to produce the same heating effect in the same wire is**

(A) 0.707 A

(B) 28.28 A

(C) 7.07 A

(D) 10 A

(E) 14 A

**Correct Answer:** (D) 10 A

**Solution: Step 1:** The heating effect of a current is given by $I_{rms}^2 R$, where $I_{rms}$ is the root mean square current.

**Step 2:** For an AC current with a peak value $I_p = 14.14A$, $I_{rms} = \frac{I_p}{\sqrt{2}} = \frac{14.14}{\sqrt{2}} = 10A$.

**Step 3:** To achieve the same heating effect with DC, the DC current must equal the RMS value of the AC current.

**Step 4:** Therefore, the direct current required is 10 A.

Quick Tip

The RMS value of an AC is crucial for calculating equivalent heating effects, power ratings, and other practical aspects of electrical circuits.

---

**33. The number of windings in the primary and secondary of a transformer are 100 and 2000 respectively. If 50 V a.c is applied to the primary, the potential difference across the secondary is**

(A) 2000 V

(B) 1000 V

(C) 500 V

(D) 1500 V

(E) 2500 V

**Correct Answer:** (B) 1000 V

**Solution: Step 1:** Use the transformer equation $\frac{V_s}{V_p} = \frac{N_s}{N_p}$, where $V_s$ and $V_p$ are the secondary and primary voltages, and $N_s$ and $N_p$ are the number of turns in the secondary and primary coils, respectively.

**Step 2:** Substitute the known values: $\frac{2000}{100} = \frac{V_s}{50}$.

**Step 3:** Solving for $V_s$ gives $V_s = 20 \times 50 = 1000V$.

**Step 4:** Thus, the potential difference across the secondary is 1000 V.

Quick Tip

Understanding transformer ratios is essential for correctly designing and applying these devices in electrical systems.

---

**34. The correct order of arrangement of electromagnetic waves according to their wavelengths is**

(A) $Gammarays < AMradiowaves < FMradiowaves < Microwaves$

(B) $Microwaves < AMradiowaves < FMradiowaves < Gammarays$

(C) $Gammarays < Microwaves < AMradiowaves < FMradiowaves$

(D) $Gammarays < Microwaves < FMradiowaves < AMradiowaves$

(E) $AMradiowaves < FMradiowaves < Gammarays < Microwaves$

**Correct Answer:** (D) $Gammarays < Microwaves < FMradiowaves < AMradiowaves$

**Solution: Step 1:** Gamma rays have the shortest wavelengths in the electromagnetic spectrum.

**Step 2:** Microwaves have longer wavelengths than gamma rays but shorter than radio waves.

**Step 3:** Within radio waves, FM waves have shorter wavelengths compared to AM waves.

**Step 4:** Thus, the correct order from shortest to longest wavelength is gamma rays, microwaves, FM radio waves, and AM radio waves.

Quick Tip

Memorize the electromagnetic spectrum from gamma rays (shortest wavelength) to radio waves (longest wavelength) for easy reference.

---

**35. An ink mark is made on a piece of paper and a glass slab of thickness $t$ and refractive index $\mu$ is placed on it. If the image of the ink mark appears to be at a distance of $x$ from the top surface of the slab, then the value of $x$ is**

(A) $\mu t$

(B) $\frac{t}{\mu}$

(C) $\frac{\mu}{t}$

(D) $\frac{\mu-1}{t}$

(E) $\frac{t}{\mu-1}$

**Correct Answer:** (B) $\frac{t}{\mu}$

**Solution: Step 1:** The apparent depth $x$ when viewed through a transparent medium of refractive index $\mu$ and thickness $t$ is given by:

$$x = \frac{t}{\mu}$$

**Step 2:** This formula arises from the concept of refraction, where light appears to travel a shorter distance in a denser medium due to the bending of rays.

**Step 3:** Since the question asks for the apparent depth of the ink mark, we directly use the formula.

**Step 4:** Therefore, the correct answer is (B).

Quick Tip

Apparent depth is always less than actual depth when viewed through a denser medium.

---

**36. If the ratio of amplitudes of two light waves is 2 : 1, then the ratio between the intensities of the two waves is**

(A) $4:1$

(B) $1:1$

(C) $1:2$

(D) $1:4$

(E) $2:1$

**Correct Answer:** (A) $4:1$

**Solution: Step 1:** The intensity of a wave is proportional to the square of its amplitude:

$$I \propto A^2$$

**Step 2:** Given that the amplitude ratio is $2:1$, let $A_1 = 2A$ and $A_2 = A$.

**Step 3:** The intensity ratio is:

$$I_1 : I_2 = (2A)^2 : (A)^2$$

$$= 4A^2 : A^2 = 4:1$$

**Step 4:** Therefore, the correct answer is (A).

**Quick Tip**

Intensity is proportional to the square of amplitude: $I \propto A^2$.

---

**37. In Young's double slit experiment, to change the bandwidth from $\beta$ to $\frac{\beta}{4}$ without changing the experimental setup, the wavelength of light $\lambda$ used must be changed to**

(A) $4\lambda$

(B) $16\lambda$

(C) $\frac{\lambda}{4}$

(D) $\frac{\lambda}{16}$

(E) $8\lambda$

**Correct Answer:** (C) $\frac{\lambda}{4}$

**Solution: Step 1:** The fringe width (bandwidth) $\beta$ in Young's double slit experiment is given by:

$$\beta = \frac{\lambda D}{d}$$

where $\lambda$ is the wavelength of light, $D$ is the distance between the screen and the slits, and $d$ is the separation between the slits.

**Step 2:** Since $D$ and $d$ remain unchanged, the bandwidth is directly proportional to the wavelength:

$$\beta \propto \lambda$$

**Step 3:** To reduce the fringe width from $\beta$ to $\frac{\beta}{4}$, we must reduce the wavelength accordingly:

$$\lambda' = \frac{\lambda}{4}$$

**Step 4:** Therefore, the correct answer is (C).

**Quick Tip**

In Young's double slit experiment, fringe width is directly proportional to the wavelength of the light used.

---

**38. If the speed of a moving particle is decreased by 1%, the de Broglie wavelength of the wave associated with it**

(A) decreases by 1%

(B) increases by 1%

(C) decreases by 2%

(D) increases by 2%

(E) decreases by 5%

**Correct Answer:** (B) increases by 1%

**Solution: Step 1:** The de Broglie wavelength $\lambda$ of a particle is given by $\lambda = \frac{h}{mv}$, where $h$ is Planck's constant, $m$ is the mass, and $v$ is the velocity of the particle.

**Step 2:** A decrease in speed by 1% implies $v' = 0.99v$.

**Step 3:** The new wavelength $\lambda'$ becomes $\lambda' = \frac{h}{m \cdot 0.99v} = \frac{1}{0.99}\lambda \approx 1.01\lambda$.

**Step 4:** Thus, the de Broglie wavelength increases by approximately 1%.

**Quick Tip**

Remember that the de Broglie wavelength is inversely proportional to the velocity, so any decrease in speed results in an increase in wavelength.

---

**39. The photoelectric work function for a photosensitive material is 5.2 eV. The energy of the incident radiation for which the stopping potential is 6 V is**

(A) 1.2 eV

(B) 5.6 eV

(C) 6 eV

(D) 10 eV

(E) 11.2 eV

**Correct Answer:** (E) 11.2 eV

**Solution: Step 1:** Use the photoelectric equation: $K_{\text{max}} = E - \phi$, where $K_{\text{max}}$ is the maximum kinetic energy of the ejected electrons, $E$ is the energy of the incident photons, and $\phi$ is the work function.

**Step 2:** The maximum kinetic energy can also be expressed as $K_{\text{max}} = e \cdot V$, where $V$ is the stopping potential and $e$ is the elementary charge.

**Step 3:** Setting $e \cdot 6V = E - 5.2$ eV and solving for $E$ gives $E = 6 + 5.2 = 11.2$ eV.

**Step 4:** Therefore, the energy of the incident radiation is 11.2 eV.

**Quick Tip**

For photoelectric effect calculations, remember to convert the stopping potential to energy (in eV) by multiplying by the charge of an electron (approximately $1.6 \times 10^{-19}$ Coulombs).

---

**40. When the hydrogen atom is excited from the ground state,**

(A) potential energy increases but kinetic energy decreases

(B) both potential energy and kinetic energy decrease

(C) both potential energy and kinetic energy increase

(D) potential energy decreases but kinetic energy increases

(E) there is no change in the total energy

**Correct Answer:** (A) potential energy increases but kinetic energy decreases

**Solution: Step 1:** In quantum mechanics, the total energy of a hydrogen atom is given by the negative of its potential energy divided by two, $E = -\frac{PE}{2}$.

**Step 2:** When an atom is excited, the electron moves to a higher energy level, which means it is further from the nucleus.

**Step 3:** This increases the potential energy (less negative) because the electron is less tightly bound to the nucleus.

**Step 4:** Simultaneously, according to the virial theorem for the hydrogen atom, the kinetic energy $KE$ is $-\frac{PE}{2}$, thus decreasing in magnitude as the potential energy becomes less negative.

**Step 5:** Therefore, upon excitation, the potential energy increases (becomes less negative) and the kinetic energy decreases.

Quick Tip

Remember that in the context of quantum mechanics, increased potential energy for an electron means it is less bound to the nucleus, contrary to classical interpretations.

---

**41. In a nuclear decay, after the emission of one $\alpha$-particle and one $\beta$-particle**

(A) atomic number remains unchanged

(B) mass number is reduced by 4 units

(C) mass number is reduced by 8 units

(D) mass number increases by 4 units

(E) atomic number is increased by 2 units

**Correct Answer:** (B) mass number is reduced by 4 units

**Solution: Step 1:** An $\alpha$-particle consists of 2 protons and 2 neutrons, meaning its emission reduces the atomic number by 2 and the mass number by 4.

**Step 2:** A $\beta$-particle is an electron emitted when a neutron decays into a proton, meaning its emission increases the atomic number by 1 but does not change the mass number.

**Step 3:** Thus, the net effect of emitting one $\alpha$-particle and one $\beta$-particle is: - Mass number decreases by 4 (due to the $\alpha$-particle). - Atomic number decreases by 2 (from $\alpha$) but increases by 1 (from $\beta$), leading to a net decrease of 1.

**Step 4:** Since the question asks about the mass number, the correct answer is (B).

**Quick Tip**

Emission of an $\alpha$-particle reduces the mass number by 4, while a $\beta$-particle changes only the atomic number.

---

**42. If nuclear radius of $^{125}_{52}Te$ is 6 fermi, then the nuclear radius of $^{27}_{13}Al$ in fermi is**

(A) 3.6

(B) 5

(C) 2.5

(D) 1.7

(E) 4.2

**Correct Answer:** (A) 3.6

**Solution: Step 1:** The nuclear radius is given by the empirical formula:

$$R = R_0 A^{1/3}$$

where $A$ is the mass number and $R_0$ is a proportionality constant.

**Step 2:** Using the ratio of nuclear radii:

$$\frac{R_2}{R_1} = \left(\frac{A_2}{A_1}\right)^{1/3}$$

Given $R_1 = 6$ fermi for $A_1 = 125$ and $A_2 = 27$, we compute:

$$R_2 = 6 \times \left(\frac{27}{125}\right)^{1/3}$$

**Step 3:** Approximating the cube root:

$$\left(\frac{27}{125}\right)^{1/3} = \frac{3}{5} = 0.6$$

**Step 4:**

$$R_2 = 6 \times 0.6 = 3.6 \text{ fermi}$$

**Step 5:** Therefore, the correct answer is (A).

**Quick Tip**

The nuclear radius follows the $A^{1/3}$ proportionality, allowing estimation for different elements.

---

**43. Half-life of radon is 3.5 days. The amount of radon left out of 12 mg mass undecayed after 35 days is nearly**

(A) 0.006 mg

(B) 0.012 mg

(C) 0.024 mg

(D) 0.036 mg

(E) 0.048 mg

**Correct Answer:** (B) 0.012 mg

**Solution: Step 1:** The amount of a substance remaining after $n$ half-lives is given by:

$$N = N_0 \times \left(\frac{1}{2}\right)^n$$

where $N_0$ is the initial mass, and $n$ is the number of half-lives elapsed.

**Step 2:** Given:

$$N_0 = 12 \text{ mg}, \quad T_{1/2} = 3.5 \text{ days}, \quad t = 35 \text{ days}$$

$$n = \frac{t}{T_{1/2}} = \frac{35}{3.5} = 10$$

**Step 3:** Calculate remaining mass:

$$N = 12 \times \left(\frac{1}{2}\right)^{10}$$

**Step 4:**

$$\left(\frac{1}{2}\right)^{10} = \frac{1}{1024} \approx 0.00098$$

$$N = 12 \times 0.00098 = 0.0118 \approx 0.012 \text{ mg}$$

**Step 5:** Therefore, the correct answer is (B).

Quick Tip

The remaining mass in radioactive decay follows an exponential law based on the number of half-lives.

---

**44. In a p-n junction diode, reverse biasing**

(A) increases the number of majority charge carriers

(B) decreases the number of minority charge carriers

(C) increases the potential barrier

(D) decreases the potential barrier

(E) increases the number of both majority and minority charge carriers

**Correct Answer:** (C) increases the potential barrier

**Solution: Step 1:** Reverse biasing a p-n junction diode involves connecting the p-type material to the negative terminal and the n-type material to the positive terminal of an external voltage source.

**Step 2:** This external reverse bias increases the width of the depletion zone as it adds to the built-in potential across the junction.

**Step 3:** The increased depletion zone leads to a higher potential barrier, which impedes the flow of majority carriers across the junction, effectively increasing the resistance of the diode to current flow.

**Step 4:** Therefore, reverse biasing increases the potential barrier, aligning with option (C).

Quick Tip

Always remember that reverse biasing in diodes increases the depletion region and potential barrier, contrary to forward biasing which reduces both.

**45. Which one of the following is not a semiconductor?**

(A) Si

(B) Sb

(C) Ge

(D) CdS

(E) GaAs

**Correct Answer:** (B) Sb

**Solution: Step 1:** Silicon (Si) and Germanium (Ge) are well-known semiconductors commonly used in electronics.
**Step 2:** Cadmium Sulfide (CdS) and Gallium Arsenide (GaAs) are compound semiconductors used in various electronic and photonic devices.
**Step 3:** Antimony (Sb), however, is a metalloid and is typically not classified as a semiconductor; it does not exhibit the semiconductive properties like variable conductivity or bandgap manipulation typical of semiconductor materials.
**Step 4:** Therefore, Sb is not a semiconductor, correctly aligning with option (B).

Quick Tip

While some metalloids have semiconductive properties, not all metalloids (like Sb) are used as semiconductors in electronic devices.

---

**46. The number of significant figures in 0.0500L is**

(A) one

(B) two

(C) three

(D) four

(E) five

**Correct Answer:** (C) three

**Solution: Step 1:** In the value 0.0500L, the zeros following the decimal point but preceding non-zero digits are not counted as significant.

**Step 2:** The two zeros after the non-zero digits '5' are significant because they are trailing zeros in a decimal portion of the number.

**Step 3:** Therefore, there are three significant figures (5, 0, 0) in the measurement 0.0500L.

Quick Tip

Trailing zeros in a number containing a decimal point are significant. This rule helps in accurately conveying the precision of a measurement.

---

**47. Isobars are atoms with the same**

(A) atomic number

(B) mass number

(C) number of electrons

(D) number of protons

(E) number of neutrons

**Correct Answer:** (B) mass number

**Solution: Step 1:** Isobars are atoms (not necessarily of the same element) that have the same mass number but different atomic numbers.

**Step 2:** The mass number is defined as the total number of protons and neutrons in an atom's nucleus.

**Step 3:** Isobars have the same total number of nucleons (protons plus neutrons), which results in the same mass number.

**Step 4:** Therefore, the defining characteristic of isobars is that they share the same mass number, aligning with option (B).

Quick Tip

Isobars are particularly important in nuclear physics and radioactive decay processes, often having different stability and decay paths.

**48. The element with atomic number 111 was first named as Unununnium. What is its IUPAC name?**

(A) Nobelium

(B) Bohrium

(C) Lawrencium

(D) Roentgenium

(E) Rutherfordium

**Correct Answer:** (D) Roentgenium

**Solution: Step 1:** Elements with atomic numbers beyond 100 were initially assigned systematic names based on their digits.

**Step 2:** The element with atomic number 111 was initially called *Unununnium* (Uuu), following the IUPAC temporary naming convention.

**Step 3:** Later, IUPAC officially named element 111 as *Roentgenium* (Rg) in honor of Wilhelm Roentgen, the discoverer of X-rays.

**Step 4:** Therefore, the correct answer is (D).

Quick Tip

Elements with temporary names based on systematic nomenclature are later given permanent names by IUPAC.

---

**49. Octet rule is obeyed in**

(A) $SCl_2$

(B) $PF_5$

(C) $SF_6$

(D) $BCl_3$

(E) $H_2SO_4$

**Correct Answer:** (A) $SCl_2$

**Solution: Step 1:** The octet rule states that atoms tend to form bonds in such a way that they achieve a stable electron configuration with 8 valence electrons.

**Step 2:** In $SCl_2$ (Sulfur dichloride), sulfur forms two single bonds with chlorine, fulfilling its octet requirement (6 valence electrons + 2 shared electrons = 8).

**Step 3:** The other molecules: - $PF_5$ and $SF_6$ have expanded octets. - $BCl_3$ does not complete the octet (Boron has only 6 valence electrons). - $H_2SO_4$ involves delocalized bonding and resonance.

**Step 4:** Since only $SCl_2$ strictly follows the octet rule, the correct answer is (A).

**Quick Tip**

Elements in period 3 and beyond can have expanded octets due to available d-orbitals.

---

**50. A particular color of light has a wavelength of 663 nm. What is the energy possessed by the light?** (Planck's constant $h = 6.63 \times 10^{-34}$ J·s; Velocity of light $c = 3 \times 10^8$ m/s)

(A) $6.63 \times 10^{-19}$ J

(B) $6.63 \times 10^{-20}$ J

(C) $1.5 \times 10^{-19}$ J

(D) $3.0 \times 10^{-20}$ J

(E) $3.0 \times 10^{-19}$ J

**Correct Answer:** (E) $3.0 \times 10^{-19}$ J

**Solution: Step 1:** The energy of a photon is given by:

$$E = \frac{hc}{\lambda}$$

where: - $h = 6.63 \times 10^{-34}$ J·s - $c = 3 \times 10^8$ m/s - $\lambda = 663$ nm = $663 \times 10^{-9}$ m

**Step 2:** Substituting values:

$$E = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{663 \times 10^{-9}}$$

**Step 3:** Calculating the numerator:

$$(6.63 \times 10^{-34}) \times (3 \times 10^8) = 1.989 \times 10^{-25}$$

**Step 4:** Dividing by the denominator:

$$E = \frac{1.989 \times 10^{-25}}{663 \times 10^{-9}}$$

$$E = 3.0 \times 10^{-19} \text{ J}$$

**Step 5:** Therefore, the correct answer is (E).

**Quick Tip**

Photon energy is inversely proportional to wavelength: shorter wavelengths have higher energy.

---

**51. The molar enthalpy of vaporization of water at 1 bar and $100^\circ$C is 41 kJ mol$^{-1}$. What is the internal energy change, when 1 mol of water is vaporized at 1 bar pressure and $100^\circ$C? Assume water vapor as a perfect gas. (R = 8.3 J K$^{-1}$ mol$^{-1}$)**

(A) 37.9 kJ mol$^{-1}$

(B) 44.1 kJ mol$^{-1}$

(C) 34.7 kJ mol$^{-1}$

(D) 47.9 kJ mol$^{-1}$

(E) 34.9 kJ mol$^{-1}$

**Correct Answer:** (A) 37.9 kJ mol$^{-1}$

**Solution: Step 1:** The relationship between enthalpy change ($\Delta H$) and internal energy change ($\Delta U$) is given by:

$$\Delta H = \Delta U + P\Delta V$$

For 1 mole of an ideal gas, the volume change at constant pressure can be calculated as:

$$P\Delta V = RT$$

**Step 2:** Given:

$$\Delta H = 41 \text{ kJ mol}^{-1}, \quad R = 8.3 \text{ J K}^{-1} \text{ mol}^{-1}, \quad T = 373 \text{ K}$$

$$P\Delta V = (8.3 \times 373) \times 10^{-3} \text{ kJ}$$

**Step 3:** Computing the expansion work:

$$P\Delta V = 3.1 \text{ kJ}$$

**Step 4:** Substituting in the equation:

$$\Delta U = 41 - 3.1 = 37.9 \text{ kJ mol}^{-1}$$

**Step 5:** Therefore, the correct answer is (A).

**Quick Tip**

For an ideal gas, enthalpy change is always greater than internal energy change due to expansion work.

---

**52. 0.1 M HCl and 0.1 M $H_2SO_4$ each of volume 2 mL are mixed and the volume is made up to 6 mL by adding 2 mL of 0.01 N NaCl solution. The pH of the resulting mixture is**

(A) 1.17

(B) 1.0

(C) 0.3

(D) $\log 2 - \log 3$

(E) $\log 3 - \log 2$

**Correct Answer:** (B) 1.0

**Solution: Step 1:** The total concentration of $H^+$ ions is calculated as:

$$\text{HCl contribution} = 0.1M \times \frac{2}{6} = \frac{0.2}{6}$$

$$\text{H}_2\text{SO}_4 \text{ contribution} = 2 \times (0.1M \times \frac{2}{6}) = \frac{0.4}{6}$$

**Step 2:** Total $H^+$ concentration:

$$[\text{H}^+] = \frac{0.2}{6} + \frac{0.4}{6} = \frac{0.6}{6} = 0.1M$$

**Step 3:** pH calculation:

$$\text{pH} = -\log[H^+]$$

$$\text{pH} = -\log(0.1) = 1.0$$

**Step 4:** Therefore, the correct answer is (B).

**Quick Tip**

The total $H^+$ concentration determines pH; for strong acids, assume full dissociation.

---

**53. Which of the following molecules has two sigma ($\sigma$) and two pi ($\pi$) bonds?**

(A) $N_2$

(B) $C_2H_6$

(C) $N_2F_2$

(D) HCN

(E) $C_2H_2Cl_2$

**Correct Answer:** (D) HCN

**Solution: Step 1:** Sigma ($\sigma$) bonds are single bonds, while pi ($\pi$) bonds are additional bonds in double or triple bonds.

**Step 2:** Analyzing each molecule:

$N_2$ has 1 $\sigma$ and 2 $\pi$ bonds.

$C_2H_6$ has only $\sigma$ bonds.

$N_2F_2$ has only $\sigma$ bonds.

$HCN$ has a triple bond between C and N, meaning 1 $\sigma$ and 2 $\pi$ bonds between them.

Additionally, a $\sigma$ bond exists between H and C.

$C_2H_2Cl_2$ has different bonding but does not match the criteria.

**Step 3:** Since HCN has exactly 2 sigma bonds and 2 pi bonds, the correct answer is (D).

**Quick Tip**

Triple bonds consist of one sigma and two pi bonds.

**54. The following results were obtained in the gas phase reaction between nitric oxide and oxygen at a given temperature.**

| $[NO]_0$/ mol $L^{-1}$ | $[O_2]_0$/ mol $L^{-1}$ | Initial rate of formation of $NO_2$/mol $L^{-1}s^{-1}$ |
|---|---|---|
| 0.30 | 0.30 | 0.096 |
| 0.60 | 0.30 | 0.384 |
| 0.30 | 0.60 | 0.192 |

(A) 3 and 2

(B) 2 and 2

(C) 2 and 1

(D) 3 and 0

(E) 3 and 1

**Correct Answer:** (E) 3 and 1

**Solution: Step 1:** From the data, doubling the concentration of $[NO]$ from 0.30 to 0.60 (while keeping $[O_2]$ constant) results in quadrupling the rate, indicating a second-order dependence on $[NO]$.

**Step 2:** Increasing $[O_2]$ concentration from 0.30 to 0.60 (while keeping $[NO]$ constant) doubles the rate, indicating a first-order dependence on $[O_2]$.

**Step 3:** The total order of the reaction is $2(NO) + 1(O_2) = 3$.

**Step 4:** Thus, the total order is 3, and the order in $[O_2]$ is 1.

Quick Tip

To determine reaction order, vary the concentration of one reactant while keeping others constant and observe the change in rate.

**55. Which of the following is an example of pseudo first order reaction?**

(A) Thermal decomposition of $N_2O_5$ gas

(B) Decomposition of HI on gold surface

(C) Decomposition of $NH_3$ on platinum surface

(D) Inversion of sucrose

(E) Hydrogenation of ethene

**Correct Answer:** (D) Inversion of sucrose

**Solution: Step 1:** A pseudo first order reaction appears to be first order because one reactant is in such excess that its concentration does not noticeably change during the reaction.
**Step 2:** In the inversion of sucrose, sucrose is hydrolyzed to glucose and fructose in the presence of acid. The reaction is first order with respect to sucrose, with the acid effectively being in excess.
**Step 3:** This makes it a pseudo first order reaction as the concentration of water and acid do not limit the reaction rate.
**Step 4:** Therefore, the correct answer is the inversion of sucrose.

Quick Tip

Remember, in pseudo first order reactions, one or more reactants are present in such excess that they effectively remain constant throughout the reaction.

---

**56. Which of the following changes alone would cause increase in the value of the equilibrium constant of the reaction?** $PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g); \Delta H > 0$

(A) Increasing the volume of the reaction vessel

(B) Decreasing the volume of the reaction vessel

(C) Addition of catalyst to equilibrium mixture

(D) Addition of $PCl_5(g)$ to the equilibrium mixture

(E) Increasing the temperature

**Correct Answer:** (E) Increasing the temperature

**Solution: Step 1:** The reaction $PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$ is endothermic ($\Delta H > 0$).
**Step 2:** According to Le Chatelier's Principle, increasing the temperature of an endothermic reaction shifts the equilibrium to the right, favoring the formation of products.

**Step 3:** This shift increases the equilibrium constant $K$, as $K$ is a measure of product favorability at equilibrium.

**Step 4:** Therefore, increasing the temperature is the only option listed that will increase the equilibrium constant for this reaction.

**Quick Tip**

Always consider the sign of $\Delta H$ when predicting the effects of temperature changes on equilibrium.

---

**57. For the gas phase homogeneous equilibrium,**

$$2X(g) \rightleftharpoons 2Y(g) + Z(g),$$

**$K_C$ at 400K is $1 \times 10^{-3}$ mol L$^{-1}$. What is the value of $K_P$ for the equilibrium at 400K?**

$$R = 0.082 \text{ L atm K}^{-1}\text{mol}^{-1}$$

(A) $1 \times 10^{-3}$ atm

(B) $3.16 \times 10^{-4}$ atm

(C) $4.24 \times 10^{-4}$ atm

(D) $3.28 \times 10^{-2}$ atm

(E) $1.28 \times 10^{-2}$ atm

**Correct Answer:** (D) $3.28 \times 10^{-2}$ atm

**Solution: Step 1:** The relation between $K_P$ and $K_C$ is given by:

$$K_P = K_C(RT)^{\Delta n}$$

where $\Delta n$ is the change in the number of moles of gaseous products and reactants.

**Step 2:** From the reaction:

$$\Delta n = (2 + 1) - 2 = 1$$

**Step 3:** Given values:

$$K_C = 1 \times 10^{-3}, \quad R = 0.082, \quad T = 400 \text{ K}$$

**Step 4:** Calculating $K_P$:

$$K_P = (1 \times 10^{-3})(0.082 \times 400)^1$$

$$K_P = (1 \times 10^{-3})(32.8) = 3.28 \times 10^{-2} \text{ atm}$$

**Step 5:** Therefore, the correct answer is (D).

Quick Tip

Use the formula $K_P = K_C(RT)^{\Delta n}$ to convert between equilibrium constants.

---

**58. Which of the following pairs of aquated first transition metal ions have the same color?**

(A) $Cr^{3+}, Mn^{3+}$

(B) $Ti^{3+}, Cu^{2+}$

(C) $Fe^{2+}, Co^{2+}$

(D) $Fe^{2+}, Cu^{2+}$

(E) $Fe^{3+}, Co^{3+}$

**Correct Answer:** (A) $Cr^{3+}, Mn^{3+}$

**Solution: Step 1:** The color of transition metal ions depends on electronic configuration and ligand field effects.

**Step 2:** - $Cr^{3+}$ and $Mn^{3+}$ both exhibit purple/violet colors in aqueous solutions. - Other pairs exhibit different colors due to differences in d-orbital splitting.

**Step 3:** Therefore, the correct answer is (A).

Quick Tip

The colors of transition metal ions arise from d-d transitions in the presence of ligands.

---

**59. For the reaction**

$$3Fe_{(s)} + 2O_2(g) \rightarrow Fe_3O_4(s),$$

$\Delta H = -1650$ **kJ mol$^{-1}$,** $\Delta S = -600$ **J K$^{-1}$ mol$^{-1}$ at 300K. What is the value of free energy change for the reaction at 300K?**

(A) $-1470$ J mol$^{-1}$

(B) $-1830$ J mol$^{-1}$

(C) $-147.02$ kJ mol$^{-1}$

(D) $-1830$ kJ mol$^{-1}$

(E) $-1470$ kJ mol$^{-1}$

**Correct Answer:** (E) $-1470$ kJ mol$^{-1}$

**Solution: Step 1:** The Gibbs free energy change is calculated using:

$$\Delta G = \Delta H - T\Delta S$$

**Step 2:** Given:

$$\Delta H = -1650 \text{ kJ mol}^{-1}, \quad \Delta S = -600 \text{ J K}^{-1}\text{mol}^{-1} = -0.6 \text{ kJ K}^{-1}\text{mol}^{-1}, \quad T = 300 \text{ K}$$

**Step 3:** Compute $\Delta G$:

$$\Delta G = -1650 - (300 \times -0.6)$$

$$\Delta G = -1650 + 180$$

$$\Delta G = -1470 \text{ kJ mol}^{-1}$$

**Step 4:** Therefore, the correct answer is (E).

**Quick Tip**

The Gibbs free energy change determines spontaneity: $\Delta G < 0$ means a spontaneous reaction.

---

**60. In which of the following aqueous solutions of salt, is pH independent of the concentration of the salt?**

(A) Ammonium chloride

(B) Ferric chloride

(C) Ammonium acetate

(D) Sodium acetate

(E) Ammonium sulphate

**Correct Answer:** (C) Ammonium acetate

**Solution: Step 1:** Ammonium acetate ($CH_3COONH_4$) is a salt derived from a weak acid (acetic acid) and a weak base (ammonia).
**Step 2:** When dissolved in water, it completely dissociates into $CH_3COO^-$ and $NH_4^+$.
**Step 3:** Both the anion and the cation can react with water, but their effects on pH largely cancel each other out, resulting in a solution that acts as a buffer.
**Step 4:** Therefore, the pH of ammonium acetate solutions is relatively independent of its concentration compared to salts that yield ions from strong acids or bases.

Quick Tip

Buffer solutions resist changes in pH upon dilution or the addition of small amounts of acids or bases.

---

**61. The values of X, Y, and Z in the following chemical equation are respectively:**

$S_8 + XHNO_3$(**conc.**) $\rightarrow YH_2SO_4 + XNO_2 + ZH_2O$

(A) 24, 4, 8

(B) 36, 6, 18

(C) 48, 8, 24

(D) 48, 8, 16

(E) 24, 8, 12

**Correct Answer:** (D) 48, 8, 16

**Solution: Step 1:** Balance the reaction for sulfur $S_8$, ensuring that the atoms on both sides are equal for all elements.
**Step 2:** Given that $X = 48$, $Y = 8$, and $Z = 16$ implies each $S$ in $S_8$ reacts with 6 $HNO_3$ to produce 1 $H_2SO_4$ and 6 $NO_2$, while 2 $H_2O$ molecules are formed per $S_8$ molecule.

**Step 3:** This stoichiometry provides a complete balance of the equation, satisfying conservation of mass and charge.

**Step 4:** Thus, the values $X = 48$, $Y = 8$, and $Z = 16$ correctly balance the chemical equation.

Quick Tip

Always verify the balance of chemical equations by counting the number of atoms for each element on both sides of the equation.

---

**62. Which of the 3d block element has the minimum melting point?**

(A) Ti

(B) Fe

(C) Cr

(D) Mn

(E) Ag

**Correct Answer:** (E) Ag

**Solution: Step 1:** Silver (Ag) is often mistakenly included in questions about 3d transition metals due to its placement in group 11, similar to transition metals.

**Step 2:** Among the listed elements, Mn typically has the lowest melting point of the actual 3d transition metals.

**Step 3:** However, the inclusion of Ag, which is actually a 4d transition metal, not a 3d, and its low melting point compared to typical 3d metals, makes it the correct choice under the given options.

**Step 4:** Therefore, despite the potential error in categorization, Ag is the answer if included in the options for its lower melting point among the choices.

Quick Tip

Remember to clarify periodic table categories when presented with ambiguous elements or incorrect group listings in questions.

---

**63. Iron does not exhibit ——- oxidation state.**

(A) $+6$

(B) $+4$

(C) $+3$

(D) $+5$

(E) $+2$

**Correct Answer:** (D) $+5$

**Solution: Step 1:** Iron commonly exhibits oxidation states of $+2$ and $+3$, as seen in compounds such as FeO and $Fe_2O_3$.

**Step 2:** Iron can also exhibit oxidation states of $+4$ and $+6$ in compounds such as $FeO_2$ and ferrates ($FeO_4^{2-}$).

**Step 3:** However, iron does not commonly exhibit the $+5$ oxidation state, as no stable compounds with $Fe^{+5}$ are known.

**Step 4:** Therefore, the correct answer is (D).

Quick Tip

Iron most commonly exhibits oxidation states of $+2$ and $+3$, while higher oxidation states are rare.

---

**64. The correct electronic configuration of Uranium (Z=92) is**

(A) $[Rn]5f^3 6d^1 7s^2$

(B) $[Rn]5f^4 6d^0 7s^2$

(C) $[Rn]5f^6 6d^3 7s^0$

(D) $[Rn]5f^6 6d^1 7s^1$

(E) $[Rn]5f^6 6d^1 7s^0$

**Correct Answer:** (A) $[Rn]5f^3 6d^1 7s^2$

**Solution: Step 1:** Uranium (Z=92) belongs to the actinide series, and its electron configuration follows the Aufbau principle.

**Step 2:** The electron configuration of uranium is:

$$[\text{Rn}]5f^3 6d^1 7s^2$$

where: - Rn represents the radon core ($Z = 86$). - The remaining six electrons occupy the $5f$, $6d$, and $7s$ orbitals.

**Step 3:** The actinide elements tend to have electrons in both $f$ and $d$ orbitals due to energy level mixing.

**Step 4:** Therefore, the correct answer is (A).

**Quick Tip**

Actinides have partially filled $5f$ orbitals, which influence their chemical and physical properties.

---

**65. Which one of the following is an outer orbital complex?**

(A) $[Co(NH_3)_6]^{3+}$

(B) $[Fe(CN)_6]^{3-}$

(C) $[CoF_6]^{3-}$

(D) $[Co(C_2O_4)_3]^{3-}$

(E) $[Fe(NH_3)_6]^{3+}$

**Correct Answer:** (C) $[CoF_6]^{3-}$

**Solution: Step 1:** Inner orbital complexes use low-spin configurations with $d^2sp^3$ hybridization, whereas outer orbital complexes use high-spin configurations with $sp^3d^2$ hybridization.

**Step 2:** Fluoride ($F^-$) is a weak field ligand and does not cause strong crystal field splitting. As a result, cobalt in $[CoF_6]^{3-}$ adopts an outer orbital configuration with $sp^3d^2$ hybridization.

**Step 3:** The other complexes:

$[Co(NH_3)_6]^{3+}$ and $[Fe(CN)_6]^{3-}$ involve strong field ligands, leading to inner orbital configurations.

$[Co(C_2O_4)_3]^{3-}$ also forms an inner orbital complex.

**Step 4:** Since $[CoF_6]^{3-}$ is an outer orbital complex, the correct answer is (C).

Quick Tip

Weak field ligands like fluoride favor high-spin, outer orbital complexes, whereas strong field ligands induce low-spin, inner orbital configurations.

---

**66. Conformational isomerism is not possible in**

(A) ethane

(B) n-butane

(C) 2,3-dimethylbutane

(D) cyclohexane

(E) ethene

**Correct Answer:** (E) ethene

**Solution: Step 1:** Conformational isomerism occurs due to rotation around single bonds (sigma bonds), allowing the molecule to adopt different spatial orientations without breaking any bonds.

**Step 2:** Ethene ($C_2H_4$) contains a double bond between the two carbon atoms, which restricts rotation and thus prevents any conformational changes.

**Step 3:** In contrast, molecules like ethane, n-butane, 2,3-dimethylbutane, and cyclohexane all contain single sigma bonds that allow for such rotations.

**Step 4:** Therefore, ethene does not exhibit conformational isomerism due to the rigidity imposed by its double bond.

Quick Tip

Remember that double bonds are rigid and prevent rotation, which is necessary for conformational isomerism.

---

**67. When sodium nitroprusside is added to sodium fusion extract the presence of sulphur is indicated by the formation of a violet colored complex. Its formula is**

(A) $[Fe(CN)_5(NO)(SO_4)]^{4+}$

(B) $[Fe(CN)_5NOS]^{4-}$

(C) $[Fe(CN)_5(NO_2)(SO_4)]^{3-}$

(D) $[Fe(CN)_5(NO_3)(SO_4)]^{3-}$

(E) $[Fe(CN)_5(NO)(SO_4)]^{4-}$

**Correct Answer:** (B) $[Fe(CN)_5NOS]^{4-}$

**Solution: Step 1:** Sodium nitroprusside reacts with sulfur-containing compounds to form a violet complex due to the modification of the iron-cyanide complex.
**Step 2:** The correct formula of the violet complex formed in the presence of sulfur is $[Fe(CN)_5NOS]^{4-}$, where $NOS$ stands for the nitrosylsulphur ligand.
**Step 3:** This complex is particularly known for its diagnostic color change when interacting with sulfur.
**Step 4:** Hence, option (B) correctly represents the composition of the violet complex.

Quick Tip

Use the formation of specific colored complexes as a diagnostic tool in qualitative analysis to detect certain elements or groups.

---

**68. When n-hexane is heated to 773K at 10-20 atmosphere pressure in the presence of $Cr_2O_3$, benzene is formed. This reaction is called**

(A) pyrolysis

(B) refining

(C) reforming

(D) cracking

(E) isomerisation

**Correct Answer:** (C) reforming

**Solution: Step 1:** The process of converting alkanes into aromatics or cyclic hydrocarbons by dehydrogenation and isomerization under high temperature and pressure is known as catalytic reforming.

**Step 2:** $Cr_2O_3$ serves as a catalyst in this reaction, facilitating the rearrangement and dehydrogenation necessary to transform n-hexane into benzene.

**Step 3:** The conditions described (773K and 10-20 atmospheres) are typical for a reforming process, which aims to increase the octane number of gasoline.

**Step 4:** Therefore, the conversion of n-hexane to benzene under these conditions is best described as reforming.

**Quick Tip**

Catalytic reforming is crucial in modern refineries to improve the quality and efficiency of fuel production.

---

**69. The decreasing order of reactivity of butyl bromides in $S_N2$ reaction is**

(A) $(CH_3)_3CBr > CH_3CH_2CH_2CH_2Br > CH_3CH(CH_3)CH_2Br > CH_3CH_2CH(Br)CH_3$

(B) $CH_3CH_2CH_2CH_2Br > CH_3CH(CH_3)_2Br > (CH_3)_3CBr > CH_3CH_2CH(Br)CH_3$

(C) $(CH_3)_3CBr > CH_3CH(CH_3)CH_2Br > CH_3CH_2CH_2CH_2Br > CH_3CH_2CH(Br)CH_3$

(D) $CH_3CH_2CH_2CH_2Br > (CH_3)_3CBr > CH_3CH(CH_3)CHBr > CH_3CH(CH_3)CH_2Br$

(E) $CH_3CH_2CH_2CH_2Br > CH_3CH(CH_3)_2Br > CH_3CH_2CH(Br)CH_3 > (CH_3)_3CBr$

**Correct Answer:** (E)

$CH_3CH_2CH_2CH_2Br > CH_3CH(CH_3)_2Br > CH_3CH_2CH(Br)CH_3 > (CH_3)_3CBr$

**Solution: Step 1:** In $S_N2$ reactions, the reactivity of alkyl halides decreases with increasing steric hindrance around the carbon atom bearing the leaving group (bromine in this case).

**Step 2:** $CH_3CH_2CH_2CH_2Br$ (n-butyl bromide) is the least hindered and thus most reactive in $S_N2$ reactions due to having a primary carbon.

**Step 3:** $CH_3CH(CH_3)_2Br$ (isobutyl bromide) and $CH_3CH_2CH(Br)CH_3$ (sec-butyl bromide) are more hindered than n-butyl bromide. Isobutyl bromide, being less hindered than sec-butyl bromide, is more reactive.

**Step 4:** $(CH_3)_3CBr$ (tert-butyl bromide) is the most hindered with a tertiary carbon, making it the least reactive in $S_N2$ reactions.

**Step 5:** Thus, the correct order from most reactive to least reactive for $S_N2$ reactions is

$CH_3CH_2CH_2CH_2Br > CH_3CH(CH_3)_2Br > CH_3CH_2CH(Br)CH_3 > (CH_3)_3CBr.$

**Quick Tip**

Remember that $S_N2$ reactions are bimolecular nucleophilic substitutions where the rate of reaction is affected significantly by the steric environment around the reactive center.

---

**70. Which of the following is the most acidic compound?**

(A) p-Nitrophenol

(B) o-Nitrophenol

(C) o-Cresol

(D) p-Cresol

(E) Phenol

**Correct Answer:** (A) p-Nitrophenol

**Solution: Step 1:** The acidity of phenols is significantly influenced by substituents on the aromatic ring.

**Step 2:** Nitro groups are strong electron-withdrawing groups due to their -I (inductive) and -R (resonance) effects, which stabilize the phenoxide ion formed upon deprotonation.

**Step 3:** In para positions, the nitro group exerts a stronger electron-withdrawing effect compared to the ortho position due to better resonance stabilization of the negative charge on the oxygen atom of the phenoxide ion.

**Step 4:** Therefore, p-nitrophenol is more acidic than o-nitrophenol, cresols, and phenol, making it the most acidic compound among the given options.

**Quick Tip**

Remember that the presence of electron-withdrawing groups like nitro enhances the acidity of phenols by stabilizing the resulting anion.

---

**71. When propanoic acid is treated with bromine and red phosphorus in aqueous medium, 2-bromopropanoic acid is formed. This reaction is known as**

(A) Kolbe reaction

(B) Wurtz reaction

(C) Hell-Volhard-Zelinsky reaction

(D) Etard reaction

(E) Wurtz-Fittig reaction

**Correct Answer:** (C) Hell-Volhard-Zelinsky reaction

**Solution: Step 1:** The Hell-Volhard-Zelinsky reaction specifically involves the halogenation of the alpha-carbon of carboxylic acids.
**Step 2:** This reaction uses a halogen ($Br_2$) and red phosphorus, which generates phosphorus tribromide ($PBr_3$), acting as a catalyst.
**Step 3:** Phosphorus tribromide converts the carboxylic acid to an acyl bromide, which subsequently undergoes alpha-bromination.
**Step 4:** The product, 2-bromopropanoic acid, confirms the pathway and mechanism of the Hell-Volhard-Zelinsky reaction.

Quick Tip

The Hell-Volhard-Zelinsky reaction is useful for introducing bromine at the alpha position of carboxylic acids, often used in synthesis of more complex molecules.

---

**72. Which of the following groups is deactivating ortho-para directing in aromatic electrophilic substitution?**

(A) $-NO_2$

(B) $-OCH_3$

(C) $-CH_3$

(D) $-Cl$

(E) $-CHO$

**Correct Answer:** (D) $-Cl$

**Solution: Step 1:** Halogens, including chlorine, are generally deactivating because of their

strong electronegativity, which tends to withdraw electron density from the benzene ring through the inductive effect.

**Step 2:** Despite being deactivating, halogens are ortho-para directors because they can donate electron density back to the ring through resonance (mesomeric effect).

**Step 3:** Chlorine, therefore, is an ortho-para director but is overall deactivating due to its electron-withdrawing inductive effect being stronger than its electron-donating resonance effect.

Quick Tip

Remember, halogens are unique in that they are deactivating yet ortho-para directing due to their dual electronic effects.

---

**73. Gatterman reaction is used to convert benzene diazonium chloride to**

(A) benzene

(B) nitrobenzene

(C) phenetole

(D) phenol

(E) chlorobenzene

**Correct Answer:** (E) chlorobenzene

**Solution: Step 1:** The Gatterman reaction is a well-known method for introducing a chlorine atom into an aromatic ring.

**Step 2:** This reaction involves the use of benzene diazonium chloride, which, under the presence of copper(I) chloride (CuCl) and HCl, forms chlorobenzene.

**Step 3:** The reaction proceeds through the replacement of the diazonium group ($N_2^+$) by a chlorine atom.

**Step 4:** Therefore, benzene diazonium chloride is specifically converted to chlorobenzene in the Gatterman reaction.

Quick Tip

The Gatterman reaction is a key synthetic route for halogenating aromatic compounds, particularly useful for chlorination and bromination.

---

**74. The correct increasing order of basic strength is**

(A) $NH_3 < C_2H_5NH_2 < C_6H_5NH_2 < C_6H_5CH_2NH_2$

(B) $C_6H_5NH_2 < NH_3 < C_6H_5CH_2NH_2 < C_2H_5NH_2$

(C) $C_6H_5NH_2 < C_6H_5CH_2NH_2 < NH_3 < C_2H_5NH_2$

(D) $C_6H_5CH_2NH_2 < NH_3 < C_2H_5NH_2 < C_6H_5NH_2$

(E) $C_6H_5NH_2 < NH_3 < C_2H_5NH_2 < C_6H_5CH_2NH_2$

**Correct Answer:** (B) $C_6H_5NH_2 < NH_3 < C_6H_5CH_2NH_2 < C_2H_5NH_2$

**Solution: Step 1:** Aniline ($C_6H_5NH_2$) is less basic than ammonia ($NH_3$) due to the electron-withdrawing nature of the phenyl group via resonance.

**Step 2:** Benzylamine ($C_6H_5CH_2NH_2$) is more basic than aniline because the benzyl group is less electron-withdrawing compared to a direct phenyl attachment.

**Step 3:** Ethylamine ($C_2H_5NH_2$) is more basic than both benzylamine and ammonia due to the electron-donating effect of the ethyl group, enhancing the electron density on the nitrogen atom.

**Step 4:** The correct order of increasing basicity, considering the electronic effects, is therefore aniline, ammonia, benzylamine, and ethylamine.

Quick Tip

Basic strength in amines is influenced by the nature of substituents: electron-donating groups increase basicity while electron-withdrawing groups decrease it.

---

**75. Animal starch is**

(A) glycogen

(B) lactose

(C) cellulose

(D) amylase

(E) maltose

**Correct Answer:** (A) glycogen

**Solution: Step 1:** Animal starch is a common term used to refer to the primary form of stored carbohydrate in animals.
**Step 2:** Glycogen is a polysaccharide that serves as a form of energy storage in fungi and animals. It is highly branched and compact, making it ideal for quick energy release.
**Step 3:** Lactose, cellulose, amylase, and maltose have different roles: lactose is a sugar found in milk; cellulose is a structural component in plants; amylase is an enzyme that breaks down starch; and maltose, a disaccharide, is made from two glucose units.
**Step 4:** Therefore, the correct answer is glycogen, which matches the description of animal starch.

Quick Tip

Remember that glycogen is analogous to starch in plants but is more extensively branched and more compact, allowing for faster glucose release.

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