MHT CET 2026 May 18 Shift 1

Question Paper (Memory-Based) with Solutions

Conducted by Maharashtra State CET Cell

General Instructions

(i) **Duration:** The total duration of the examination is 3 hours (180 minutes).

(ii) **Total Marks:** The complete paper carries a maximum of 200 marks.

(iii) **Structure:** The paper has 3 Sections:

- **Section A:** 50 Multiple Choice Questions (Physics)
- **Section B:** 50 Multiple Choice Questions (Chemistry)
- **Section C:** 50 Multiple Choice Questions (Mathematics)

(iv) **Compulsory Questions:** All 150 questions are compulsory.

(v) Each question has four options. Only **one** option is correct.

(vi) **Right Answer:** +1 marks for Physics and Chemistry Questions. +2 marks for Mathematics Questions

(vii) **Incorrect Answer:** (No Negative marking).

(viii) **Unanswered/Marked for Review:** 0 marks.

1. If a polygon has 54 diagonals, find the number of sides of the polygon.

(A) 10

(B) 11

(C) 12

(D) 15

Correct Answer: (C) 12

Solution:

Concept: A polygon is a closed geometric figure with three or more straight sides. In any polygon with n sides, diagonals are line segments joining non-adjacent vertices.
The formula for the number of diagonals in an n-sided polygon is:

$$D = \frac{n(n-3)}{2}$$

Derivation: From n vertices, total line segments formed are:

$$\binom{n}{2} = \frac{n(n-1)}{2}$$

Out of these, n are sides of the polygon. Therefore diagonals are:

$$D = \frac{n(n-1)}{2} - n = \frac{n(n-1-2)}{2} = \frac{n(n-3)}{2}$$

Step 1: Using the given information $D = 54$.

$$54 = \frac{n(n-3)}{2}$$

Step 2: Simplify the equation.
Multiply both sides by 2:

$$108 = n(n-3)$$

$$108 = n^2 - 3n$$

Step 3: Form quadratic equation.

$$n^2 - 3n - 108 = 0$$

Now factorize. We need two numbers whose product is -108 and sum is -3. The pair is -12 and 9.

$$n^2 - 12n + 9n - 108 = 0$$

Grouping:

$$n(n-12) + 9(n-12) = 0$$

$$(n-12)(n+9)=0$$

Step 4: Find valid value of n.

$$n-12=0 \Rightarrow n=12$$

$$n+9=0 \Rightarrow n=-9$$

Since number of sides cannot be negative, we reject $n=-9$.

Therefore,

$$n=12$$

Quick Tip: Use the formula $D=\frac{n(n-3)}{2}$ directly and quickly verify by substituting the value of n to avoid solving full quadratic in exam conditions.

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2. If $y=\cos^{-1}x$, find $\frac{d^2y}{dx^2}$ in terms of y.

(A) $-\csc^2 y \cot y$

(B) $\csc^2 y \cot y$

(C) $-\csc y \cot^2 y$

(D) $\csc y \cot^2 y$

Correct Answer: (A) $-\csc^2 y \cot y$

Solution:

Concept: The problem involves differentiating an inverse trigonometric function and expressing the second derivative entirely in terms of y. We use implicit differentiation and the chain rule. Key ideas:

- Implicit differentiation for inverse functions
- Chain rule: $\frac{d}{dx}[f(y)]=f'(y)\frac{dy}{dx}$
- Trigonometric derivatives: $\frac{d}{dy}(\csc y)=-\csc y \cot y$

Step 1: Converting inverse form to trigonometric form.

$$y = \cos^{-1} x \Rightarrow x = \cos y$$

Step 2: First derivative.

Differentiate $x = \cos y$ w.r.t. x:

$$\frac{d}{dx}(x) = \frac{d}{dx}(\cos y)$$

$$1 = -\sin y \cdot \frac{dy}{dx}$$

$$\frac{dy}{dx} = -\frac{1}{\sin y} = -\csc y$$

Step 3: Second derivative using chain rule.

$$\frac{d^2y}{dx^2} = \frac{d}{dx}(-\csc y)$$

Apply chain rule:

$$\frac{d^2y}{dx^2} = \frac{d}{dy}(-\csc y) \cdot \frac{dy}{dx}$$

Now,

$$\frac{d}{dy}(-\csc y) = \csc y \cot y$$

So,

$$\frac{d^2y}{dx^2} = (\csc y \cot y) \cdot \frac{dy}{dx}$$

Step 4: Substitute $\frac{dy}{dx} = -\csc y$.

$$\frac{d^2y}{dx^2} = (\csc y \cot y)(-\csc y)$$

$$\frac{d^2y}{dx^2} = -\csc^2 y \cot y$$

Quick Tip: For second derivatives in inverse trig functions, always convert to $x = f(y)$ first. It makes chain rule application much cleaner and avoids messy algebra.

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3. If $A = \begin{bmatrix} 4 & 5 \\ 2 & 1 \end{bmatrix}$, find A^{-1}.

(A) $\begin{bmatrix} 1/6 & -5/6 \\ -1/3 & 2/3 \end{bmatrix}$

(B) $\begin{bmatrix} -1/6 & 5/6 \\ 1/3 & -2/3 \end{bmatrix}$

(C) $\begin{bmatrix} -1 & 5 \\ 2 & -4 \end{bmatrix}$

(D) $\begin{bmatrix} 4 & -5 \\ -2 & 1 \end{bmatrix}$

Correct Answer: (B) $\begin{bmatrix} -1/6 & 5/6 \\ 1/3 & -2/3 \end{bmatrix}$

Solution:

Concept: For a 2×2 matrix

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix},$$

the inverse exists if $|A| \neq 0$, where

$$|A| = ad - bc$$

The inverse is given by:

$$A^{-1} = \frac{1}{|A|} \text{adj}(A)$$

For a 2×2 matrix:

$$\text{adj}(A) = \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

Step 1: Finding determinant.

Given:

$$A = \begin{bmatrix} 4 & 5 \\ 2 & 1 \end{bmatrix}$$

$$|A| = (4 \times 1) - (5 \times 2)$$

$$|A| = 4 - 10 = -6$$

Since $|A| \neq 0$, inverse exists.

Step 2: Finding adjoint of A.

Swap diagonal elements and change signs of off-diagonal elements:

$$\text{adj}(A) = \begin{bmatrix} 1 & -5 \\ -2 & 4 \end{bmatrix}$$

Step 3: Applying inverse formula.

$$A^{-1} = \frac{1}{-6}\begin{bmatrix} 1 & -5 \\ -2 & 4 \end{bmatrix}$$

Multiply each entry:

$$A^{-1} = \begin{bmatrix} -1/6 & 5/6 \\ 2/6 & -4/6 \end{bmatrix}$$

Simplify:

$$A^{-1} = \begin{bmatrix} -1/6 & 5/6 \\ 1/3 & -2/3 \end{bmatrix}$$

Quick Tip: For 2×2 matrices, always use the shortcut: Swap diagonal elements, change signs of off-diagonal elements, then divide by determinant.

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4. If $\int x^3 e^x \, dx = e^x(px^3 + qx^2 + rx + s) + C$, then find the value of $p + q + r + s$.

(A) -2

(B) 0

(C) 1

(D) 6

Correct Answer: (A) -2

Solution:

Concept: This type of integral, involving a polynomial multiplied by an exponential function, is solved using Integration by Parts repeatedly. The standard formula is:

$$\int u\,dv = uv - \int v\,du$$

We choose u as the algebraic function because repeated differentiation eventually reduces it to zero (LIATE rule).

Step 1: First integration by parts.

Let

$$I = \int x^3 e^x\,dx$$

Take:

$$u = x^3 \Rightarrow du = 3x^2 dx$$

$$dv = e^x dx \Rightarrow v = e^x$$

Then:

$$I = x^3 e^x - 3\int x^2 e^x dx \quad \cdots (1)$$

Step 2: Second integration by parts.

For $\int x^2 e^x dx$:

$$u = x^2, \quad du = 2x dx, \quad v = e^x$$

$$\int x^2 e^x dx = x^2 e^x - 2\int x e^x dx$$

Substitute into (1):

$$I = x^3 e^x - 3(x^2 e^x - 2\int x e^x dx)$$

$$I = x^3 e^x - 3x^2 e^x + 6\int x e^x dx \quad \cdots (2)$$

Step 3: Third integration by parts.

For $\int x e^x dx$:

$$u = x, \quad du = dx, \quad v = e^x$$

$$\int xe^x dx = xe^x - \int e^x dx = xe^x - e^x$$

Substitute into (2):

$$I = x^3e^x - 3x^2e^x + 6(xe^x - e^x) + C$$

$$I = x^3e^x - 3x^2e^x + 6xe^x - 6e^x + C$$

Step 4: Factorization and comparison.

$$I = e^x(x^3 - 3x^2 + 6x - 6) + C$$

Comparing with:

$$I = e^x(px^3 + qx^2 + rx + s) + C$$

We get:

$$p = 1, \quad q = -3, \quad r = 6, \quad s = -6$$

Step 5: Required sum.

$$p + q + r + s = 1 - 3 + 6 - 6 = -2$$

Quick Tip: For integrals of the form $\int x^n e^x dx$, use repeated differentiation of the polynomial (tabular or shortcut method) instead of full integration by parts each time.

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5. Find the distance between the point $2\hat{i} + \hat{j} - \hat{k}$ and the plane $\vec{r} \cdot (\hat{i} - 2\hat{j} + 4\hat{k}) = 9$.

(A) $\frac{13}{\sqrt{21}}$

(B) $\frac{9}{\sqrt{21}}$

(C) $\frac{13}{21}$

(D) $\frac{21}{\sqrt{13}}$

Correct Answer: (A) $\frac{13}{\sqrt{21}}$

Solution:

Concept: The shortest distance from a point to a plane is along the perpendicular (normal) to the plane. For a plane

$$\vec{r} \cdot \vec{n} = d$$

and a point with position vector $\vec{a}$, the distance is:

$$D = \frac{|\vec{a} \cdot \vec{n} - d|}{|\vec{n}|}$$

Step 1: Identifying given values.
Point:

$$\vec{a} = 2\hat{i} + \hat{j} - \hat{k}$$

Plane:

$$\vec{r} \cdot (\hat{i} - 2\hat{j} + 4\hat{k}) = 9$$

So,

$$\vec{n} = \hat{i} - 2\hat{j} + 4\hat{k}, \quad d = 9$$

Step 2: Compute dot product $\vec{a} \cdot \vec{n}$.

$$\vec{a} \cdot \vec{n} = (2)(1) + (1)(-2) + (-1)(4)$$

$$= 2 - 2 - 4 = -4$$

Step 3: Magnitude of normal vector.

$$|\vec{n}| = \sqrt{1^2 + (-2)^2 + 4^2}$$

$$|\vec{n}| = \sqrt{1 + 4 + 16} = \sqrt{21}$$

Step 4: Apply distance formula.

$$D = \frac{|\vec{a} \cdot \vec{n} - d|}{|\vec{n}|}$$

$$D = \frac{|-4-9|}{\sqrt{21}}$$

$$D = \frac{|-13|}{\sqrt{21}} = \frac{13}{\sqrt{21}}$$

Quick Tip: For point–plane distance problems, always treat the plane as $\vec{r} \cdot \vec{n} - d = 0$ to avoid sign mistakes in exams.

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6. If the scalar triple product of three vectors $\vec{a}, \vec{b}, \vec{c}$ is given as $[\vec{a}\ \vec{b}\ \vec{c}] = 3$, then find the value of the scalar triple product of their cross products, denoted as $[\vec{a} \times \vec{b} \quad \vec{b} \times \vec{c} \quad \vec{c} \times \vec{a}]$.

(A) 3

(B) 6

(C) 9

(D) 27

Correct Answer: (C) 9

Solution:

Concept: The scalar triple product (STP) of three vectors is defined as:

$$[\vec{u}\ \vec{v}\ \vec{w}] = \vec{u} \cdot (\vec{v} \times \vec{w})$$

Key properties:

- Cyclic property:
$$[\vec{a}\ \vec{b}\ \vec{c}] = [\vec{b}\ \vec{c}\ \vec{a}] = [\vec{c}\ \vec{a}\ \vec{b}]$$
- If two vectors are same/parallel, STP = 0.
- Important identity:
$$[\vec{a} \times \vec{b} \ \ \vec{b} \times \vec{c} \ \ \vec{c} \times \vec{a}] = [\vec{a}\ \vec{b}\ \vec{c}]^2$$

Step 1: Recognizing required identity.

We need to evaluate:

$$[\vec{a} \times \vec{b} \ \ \vec{b} \times \vec{c} \ \ \vec{c} \times \vec{a}]$$

Using the standard vector identity:

$$[\vec{a}\times\vec{b}\ \ \vec{b}\times\vec{c}\ \ \vec{c}\times\vec{a}] = [\vec{a}\ \vec{b}\ \vec{c}]^2$$

Step 2: Substituting given value.

Given:

$$[\vec{a}\ \vec{b}\ \vec{c}] = 3$$

So,

$$[\vec{a}\times\vec{b}\ \ \vec{b}\times\vec{c}\ \ \vec{c}\times\vec{a}] = 3^2$$

Step 3: Final calculation.

$$= 9$$

Quick Tip: Memorize the identity:

$$[\vec{a}\times\vec{b}\ \vec{b}\times\vec{c}\ \vec{c}\times\vec{a}] = [\vec{a}\ \vec{b}\ \vec{c}]^2$$

It saves a lot of time in competitive exams.

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7. Evaluate the indefinite integral:

$$\int \frac{x^3 \sin[\tan^{-1}(x^4)]}{1+x^8}\,dx$$

(A) $\frac{1}{4}\cos[\tan^{-1}(x^4)] + C$

(B) $-\frac{1}{4}\cos[\tan^{-1}(x^4)] + C$

(C) $\frac{1}{4}\sin[\tan^{-1}(x^4)] + C$

(D) $-\frac{1}{4}\sin[\tan^{-1}(x^4)] + C$

Correct Answer: (B) $-\frac{1}{4}\cos[\tan^{-1}(x^4)] + C$

Solution:

Concept: This integral is solved using the method of substitution. When a composite function appears along with its derivative structure in the integrand, substitution simplifies the expression.

Key formulas:

- Chain rule:
$$\frac{d}{dx}[f(g(x))] = f'(g(x)) \cdot g'(x)$$

- Derivative of inverse tangent:
$$\frac{d}{dx}(\tan^{-1} u) = \frac{1}{1+u^2}\frac{du}{dx}$$

- Integral:
$$\int \sin t \, dt = -\cos t + C$$

Step 1: Identifying substitution.

Observe:
$$\int \frac{x^3 \sin[\tan^{-1}(x^4)]}{1+x^8} dx$$

Let:
$$t = \tan^{-1}(x^4)$$

Step 2: Differentiating substitution.

$$\frac{dt}{dx} = \frac{1}{1+(x^4)^2} \cdot 4x^3$$

$$\frac{dt}{dx} = \frac{4x^3}{1+x^8}$$

So,
$$dt = \frac{4x^3}{1+x^8} dx$$

$$\frac{x^3}{1+x^8} dx = \frac{1}{4} dt$$

Step 3: Substituting into integral.

$$I = \int \sin(t) \cdot \frac{1}{4} dt$$

$$I = \frac{1}{4} \int \sin t \, dt$$

Step 4: Integration.

$$I = \frac{1}{4}(-\cos t) + C$$

$$I = -\frac{1}{4} \cos t + C$$

Substitute back $t = \tan^{-1}(x^4)$:

$$I = -\frac{1}{4} \cos[\tan^{-1}(x^4)] + C$$

Quick Tip: Whenever you see a composite function like $f(x^n)$, check if x^{n-1} appears in the numerator. It is a strong indicator that substitution will simplify the integral immediately.

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8. If $A = \begin{bmatrix} 1 & -2 & 2 \\ 0 & 2 & -3 \\ 3 & -2 & 4 \end{bmatrix}$, find the value of the matrix expression $A(I + \text{adj}\, A)$, where I is the identity matrix of the same order as A.

(A) $\begin{bmatrix} 8 & -2 & 2 \\ 0 & 8 & -3 \\ 3 & -2 & 8 \end{bmatrix}$

(B) $\begin{bmatrix} 9 & -2 & 2 \\ 0 & 10 & -3 \\ 3 & -2 & 12 \end{bmatrix}$

(C) $\begin{bmatrix} 1 & -16 & 16 \\ 0 & 16 & -24 \\ 24 & -16 & 32 \end{bmatrix}$

(D) $\begin{bmatrix} 9 & 0 & 0 \\ 0 & 10 & 0 \\ 0 & 0 & 12 \end{bmatrix}$

Correct Answer: (B) $\begin{bmatrix} 9 & -2 & 2 \\ 0 & 10 & -3 \\ 3 & -2 & 12 \end{bmatrix}$

Solution:

Concept: We use key matrix identities instead of directly computing the adjoint:

- Distributive law: $A(B+C) = AB + AC$
- Identity property: $AI = A$
- Adjoint identity: $A \cdot \text{adj}(A) = |A|I$

So,

$$A(I + \text{adj}A) = A + A \cdot \text{adj}A = A + |A|I$$

Step 1: Simplifying expression.

$$A(I + \text{adj}A) = AI + A \cdot \text{adj}A$$

$$= A + |A|I$$

So we only need determinant of A.

Step 2: Finding determinant of A.

$$A = \begin{bmatrix} 1 & -2 & 2 \\ 0 & 2 & -3 \\ 3 & -2 & 4 \end{bmatrix}$$

Expand along first column:

$$|A| = 1 \begin{vmatrix} 2 & -3 \\ -2 & 4 \end{vmatrix} + 3 \begin{vmatrix} -2 & 2 \\ 2 & -3 \end{vmatrix}$$

Compute minors:

$$\begin{vmatrix} 2 & -3 \\ -2 & 4 \end{vmatrix} = (2)(4) - (-3)(-2) = 8 - 6 = 2$$

$$\begin{vmatrix} -2 & 2 \\ 2 & -3 \end{vmatrix} = (-2)(-3) - (2)(2) = 6 - 4 = 2$$

So,

$$|A| = 1(2) + 3(2) = 2 + 6 = 8$$

Step 3: Compute final expression.

$$A + 8I$$

$$8I = \begin{bmatrix} 8 & 0 & 0 \\ 0 & 8 & 0 \\ 0 & 0 & 8 \end{bmatrix}$$

$$A + 8I = \begin{bmatrix} 1+8 & -2 & 2 \\ 0 & 2+8 & -3 \\ 3 & -2 & 4+8 \end{bmatrix}$$

$$= \begin{bmatrix} 9 & -2 & 2 \\ 0 & 10 & -3 \\ 3 & -2 & 12 \end{bmatrix}$$

Quick Tip: Always replace $A \cdot \text{adj}(A)$ with $|A|I$. It saves time and avoids the heavy computation of cofactors in higher-order matrices.

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9. Evaluate the indefinite integral:

$$\int e^x(\sin x + \cos x)\,dx$$

(A) $e^x \cos x + C$

(B) $e^x \sin x + C$

(C) $-e^x \sin x + C$

(D) $e^x(\sin x - \cos x) + C$

Correct Answer: (B) $e^x \sin x + C$

Solution:

Concept: This integral is based on recognizing a standard pattern:

$$\int e^x[f(x) + f'(x)]\,dx = e^x f(x) + C$$

This comes directly from the product rule:

$$\frac{d}{dx}(e^x f(x)) = e^x f(x) + e^x f'(x)$$

Step 1: Identify the pattern.

Given:

$$I = \int e^x(\sin x + \cos x)\,dx$$

Compare with $f(x) + f'(x)$:

Let

$$f(x) = \sin x \quad \Rightarrow \quad f'(x) = \cos x$$

So the integrand becomes:

$$e^x[f(x) + f'(x)]$$

Step 2: Apply the formula.

Using:

$$\int e^x[f(x) + f'(x)]\,dx = e^x f(x) + C$$

We get:

$$I = e^x \sin x + C$$

Step 3: Verification (optional idea).

Differentiate $e^x \sin x$:

$$\frac{d}{dx}(e^x \sin x) = e^x \sin x + e^x \cos x = e^x(\sin x + \cos x)$$

This matches the integrand, so the result is correct.

Quick Tip: Whenever you see e^x multiplied by a sum of two functions, check if one is the derivative of the other. It often indicates a direct $e^x[f(x)+f'(x)]$ pattern.

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10. In $\triangle ABC$, if $\angle C = \frac{2\pi}{3}$, then the value of $\cos^2 A + \cos^2 B - \cos A \cos B$ is:

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

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

(C) 1

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

Correct Answer: (B) $\frac{3}{4}$

Solution:

Concept: In any triangle,

$$A + B + C = \pi$$

We use trigonometric identities:

- $\cos^2 x = \frac{1+\cos 2x}{2}$
- $\cos A \cos B = \frac{1}{2}[\cos(A+B) + \cos(A-B)]$

Step 1: Using angle sum property.

$$A + B = \pi - C = \pi - \frac{2\pi}{3} = \frac{\pi}{3}$$

So,

$$\cos(A+B) = \cos\left(\frac{\pi}{3}\right) = \frac{1}{2}$$

Step 2: Simplify $\cos^2 A + \cos^2 B$.

$$\cos^2 A + \cos^2 B = \frac{1+\cos 2A}{2} + \frac{1+\cos 2B}{2}$$

$$= 1 + \frac{1}{2}(\cos 2A + \cos 2B)$$

Using sum-to-product:

$$\cos 2A + \cos 2B = 2\cos(A+B)\cos(A-B)$$

So,

$$\cos^2 A + \cos^2 B = 1 + \cos(A+B)\cos(A-B)$$

Substitute $\cos(A+B) = \frac{1}{2}$:

$$\cos^2 A + \cos^2 B = 1 + \frac{1}{2}\cos(A-B) \quad \cdots(1)$$

Step 3: Simplify $\cos A \cos B$.

$$\cos A \cos B = \frac{1}{2}[\cos(A+B) + \cos(A-B)]$$

$$= \frac{1}{2}\left[\frac{1}{2} + \cos(A-B)\right]$$

$$= \frac{1}{4} + \frac{1}{2}\cos(A-B) \quad \cdots(2)$$

Step 4: Compute required expression.

Let

$$E = \cos^2 A + \cos^2 B - \cos A \cos B$$

Substitute (1) and (2):

$$E = \left(1 + \frac{1}{2}\cos(A-B)\right) - \left(\frac{1}{4} + \frac{1}{2}\cos(A-B)\right)$$

$$E = 1 - \frac{1}{4} = \frac{3}{4}$$

Quick Tip: For triangle-based trig expressions, try using $A+B = \pi - C$ first. It often reduces everything to a single known angle and cancels complicated terms quickly.

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11. Which of the following compounds is NOT in the gaseous phase at 25°C?

(A) ClF

(B) BrF

(C) IF_3

(D) ClF_3

Correct Answer: (C) IF_3

Solution:

Concept: Interhalogen compounds are formed when two different halogen atoms react with each other. They are generally represented by the formula AX_n, where n can be 1, 3, 5, or 7. The physical state of these compounds at room temperature (25°C or 298 K) depends largely on molecular mass and intermolecular forces (Van der Waals forces). As atomic size increases, polarizability increases, leading to stronger dispersion forces and higher boiling points. Hence, lighter interhalogens tend to be gases, while heavier ones may be liquids or solids.

Step 1: Evaluating ClF (Chlorine monofluoride).

ClF is a small diatomic interhalogen compound with a very low boiling point (around −100°C). Since room temperature is much higher than its boiling point, ClF exists as a gas at 25°C.

Step 2: Evaluating BrF (Bromine monofluoride).

BrF is relatively less stable but, in general consideration, behaves as a low-boiling interhalogen species. Its boiling point is around room temperature, and it is treated as a gaseous species under standard conditions.

Step 3: Evaluating ClF_3 (Chlorine trifluoride).

ClF_3 has a boiling point of about 11.7°C. Since 25°C is higher than its boiling point, it exists as a gas at room temperature.

Step 4: Evaluating IF_3 (Iodine trifluoride).

IF_3 contains iodine, a large atom with high polarizability, leading to strong intermolecular forces. As a result, IF_3 is a yellow solid at room temperature (25°C) and is not gaseous.

Step 5: Conclusion.

Among the given options:

- ClF: gas at 25°C
- BrF: gas at 25°C
- ClF_3: gas at 25°C
- IF_3: solid at 25°C

Therefore, $IF_3 is NOT in the gaseous phase at 25°C$.

Quick Tip: In interhalogen compounds, lighter molecules (like ClF, BrF, ClF_3) are generally gases, while iodine-containing interhalogens (especially IF_3, ICl_3) tend to be solids due to stronger intermolecular forces..

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12. A solution is prepared by dissolving 2 g of a non-volatile solute in 500 mL of solution at 27°C. The osmotic pressure of the solution is 0.82 atm. The molar mass of the solute is:

(A) $100\,\text{g mol}^{-1}$

$(B) 120\,\text{g mol}^{-1}$

$(C) 150\,\text{g mol}^{-1}$

$(D) 180\,\text{g mol}^{-1}$

Correct Answer: (B) $120\,\text{g mol}^{-1}$

Solution:

Concept: Osmotic pressure (π) is a colligative property that depends on the number of solute particles in solution. For a dilute solution of a non-volatile, non-electrolyte solute, it is given by the van't Hoff equation:

$$\pi = CRT$$

where C is molar concentration, R is the gas constant, and T is absolute temperature.
Since $C = \frac{w}{MV}$, the formula becomes:

$$\pi = \frac{wRT}{MV}$$

where w is mass of solute and M is molar mass.

Step 1: Given data and unit conversion.

- Mass of solute, $w = 2\,\text{g}$
- Volume of solution, $V = 500\,\text{mL} = 0.5\,\text{L}$
- Temperature, $T = 27°\text{C} = 300\,\text{K}$
- Osmotic pressure, $\pi = 0.82\,\text{atm}$
- Gas constant, $R = 0.082\,\text{L atm K}^{-1}\,\text{mol}^{-1}$

Step 2: Rearranging formula for molar mass.

$$M = \frac{wRT}{\pi V}$$

Step 3: Substituting values.

$$M = \frac{2 \times 0.082 \times 300}{0.82 \times 0.5}$$

$$M = \frac{2 \times 24.6}{0.41}$$

Now simplify in a smarter way:

$$M = \left(\frac{0.082}{0.82}\right)\left(\frac{2 \times 300}{0.5}\right)$$

$$M = \left(\frac{1}{10}\right)(1200)$$

$$M = 120\,\text{g mol}^{-1}$$

Quick Tip: Always convert temperature to Kelvin and volume to liters before applying colligative property formulas. Also try cancelling constants like $R = 0.082$ with given values like 0.82 to simplify calculations quickly.

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13. What is the oxidation state of sulfur in Marshall's acid ($H_2S_2O_8$)?

(A) +4

(B) +5

(C) +6

(D) +7

Correct Answer: (C) +6

Solution:

Concept: The oxidation state of an atom is the hypothetical charge it would have if all bonds were treated as ionic. In compounds containing peroxide linkages (—O—O—), oxygen does not always have an oxidation state of −2; instead, each peroxide oxygen is assigned −1. This is crucial in compounds like peroxydisulfuric acid (Marshall's acid), $H_2S_2O_8$.

Sulfur belongs to Group 16 and has a maximum oxidation state of +6.

Step 1: Applying the naive oxidation state method.

Assuming H = +1 and all O = -2:

$$2(+1) + 2x + 8(-2) = 0$$

$$2 + 2x - 16 = 0$$

$$2x = 14 \Rightarrow x = +7$$

This result is impossible because sulfur cannot exceed +6, indicating incorrect treatment of oxygen atoms.

Step 2: Recognizing peroxide linkage in structure.

Marshall's acid ($H_2S_2O_8$) has the following structure:

$$HO - SO_2 - O - O - SO_2 - OH$$

Oxygen atoms are classified as:

- 6 oxygen atoms with oxidation state -2 (double bonded O and OH oxygens)
- 2 peroxide oxygen atoms with oxidation state -1 (-O-O- linkage)

Step 3: Correct oxidation state calculation.

$$2(+1) + 2x + 6(-2) + 2(-1) = 0$$

$$2 + 2x - 12 - 2 = 0$$

$$2x - 12 = 0$$

$$x = +6$$

Thus, oxidation state of sulfur is +6.

Step 4: Verification using valence rule.

Sulfur is in Group 16 and its maximum oxidation state is +6. The result matches this limit, confirming correctness.

Quick Tip: If oxidation state comes out greater than +6 for sulfur (or +7 for chlorine, etc.), always check for peroxide (-O-O-) or similar abnormal oxygen bonding situations.

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14. Oil of wintergreen is chemically known as:

(A) Methyl acetate

(B) Methyl salicylate

(C) Ethyl salicylate

(D) Salicylic acid

Correct Answer: (B) Methyl salicylate

Solution:

Concept: Oil of wintergreen is a naturally occurring aromatic ester obtained mainly from plants of the genus *Gaultheria*. In organic chemistry, it is identified as an ester formed from salicylic acid and methanol. Esters are typically responsible for characteristic pleasant odors and follow the naming pattern: alkyl group (from alcohol) + carboxylate (from acid).

Step 1: Identifying the main constituent of oil of wintergreen.

Oil of wintergreen is primarily composed of methyl salicylate (about 96–99

Step 2: Understanding its formation.

Methyl salicylate is formed by Fischer esterification:

$$\text{Salicylic acid} + \text{Methanol} \xrightarrow{H_2SO_4} \text{Methyl salicylate} + H_2O$$

This reaction produces a characteristic aromatic oily liquid with a strong mint-like odor.

Step 3: Evaluating the options.

- Methyl acetate: Simple ester of acetic acid, fruity smell, unrelated to wintergreen.
- Methyl salicylate: Correct compound known as oil of wintergreen.
- Ethyl salicylate: Ethanol-based ester, different compound.
- Salicylic acid: Parent acid, solid and non-aromatic in odor compared to ester.

Step 4: Applications.

Methyl salicylate is used as a flavoring agent and in medicinal pain-relief ointments due to its analgesic and warming properties.

Quick Tip: Oil of wintergreen = Methyl salicylate = ester of salicylic acid + methanol. It is commonly used in muscle pain relief balms and has a strong mint-like smell.

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15. Which of the following does not belong to Group 16 elements?

(A) Oxygen

(B) Sulfur

(C) Selenium

(D) Chlorine

Correct Answer: (D) Chlorine

Solution:

Concept: The periodic table is divided into groups where elements in the same group have similar properties due to the same number of valence electrons. Group 16 elements are known as the Chalcogens and have the general valence shell electronic configuration ns^2np^4, meaning they contain six valence electrons.

Step 1: Identifying Group 16 elements.

Group 16 consists of:

- Oxygen (O)
- Sulfur (S)
- Selenium (Se)
- Tellurium (Te)
- Polonium (Po)
- Livermorium (Lv)

From the given options, Oxygen, Sulfur, and Selenium belong to Group 16.

Step 2: Identifying Chlorine.

Chlorine (Cl), atomic number 17, has the electronic configuration $[Ne]3s^23p^5$, indicating seven valence electrons. Therefore, it belongs to Group 17 (Halogens), not Group 16.

Step 3: Conclusion.

Since Chlorine belongs to Group 17, it does not belong to Group 16.

Quick Tip: Group 16 elements have 6 valence electrons (ns^2np^4), while Group 17 elements have 7 valence electrons (ns^2np^5). Chlorine is a halogen, not a chalcogen.
