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02-04-2025_SHIFT-1 JEE MAINS SESSION-II QUESTION PAPER WITH KEY AND SOLUTIONS

MATHEMATICS

SECTION-I

1. Let one focus of the hyperbola $H:\frac{x^2}{a^2}-\frac{y^2}{b^2}=1$ be at $\left(\sqrt{10},0\right)$ and the corresponding directrix be $x=\frac{9}{\sqrt{10}}$. If e and ℓ respectively are the eccentricity and the length of the latus rectum of H, then $9\left(e^2+l\right)$ is equal to:

1) 15 2) 16 3) 14 4) 12

Key: 2

Sol: $ae=\sqrt{10}\rightarrow(1)$

$\frac{a}{e}=\frac{9}{\sqrt{10}}\rightarrow(2)$

$(1)\times(2)$

$a=3, e=\frac{\sqrt{10}}{3}$

$b=1$

$9\left(e^2+l\right)=16$

2. If S and S' are the foci of the ellipse $\frac{x^2}{18}+\frac{y^2}{9}=1$ and P be a point on the ellipse, then min (SP.S'P)+ max (SP.S'P) is equal to :

1) $3\left(1+\sqrt{2}\right)$ 2) 9 3) 27 4) $3\left(6+\sqrt{2}\right)$

Key: 3

Sol: $SP=a+ex_1$

$=a+ea\cos\theta$

$S'P=a-ea\cos\theta$

$SP.S'P=a^2-a^2e^2\cos^2\theta$

$=a^2\left(1-e^2\cos^2\theta\right)$

$=18-9\cos^2\theta$

$\max=18,\ \min=9$

$\min\left(SP.SP'\right)+\max\left(SP.SP'\right)=18+9\Rightarrow 27$

3. Let $P_n=\alpha^n+\beta^n, n\in N$. If $P_{10}=123, P_9=76, P_B=47$ *and* $P_1=1$, then the quadratic equation having roots $\frac{1}{\alpha}$ *and* $\frac{1}{\beta}$ is :

1) $x^2-x+1=0$ 2) $x^2-x-1=0$ 3) $x^2+x+1=0$ 4) $x^2+x-1=0$

Key: 4

Sol: $P_{10}=P_9+P_8 \Rightarrow P_{10}-P_9-P_8=0$

By Newtons method

$x^2-x-1=0$

As $P_1=1 \Rightarrow \alpha+\beta=1, \alpha\beta=1$

The quadratic equation whose roots are $\frac{1}{\alpha},\frac{1}{\beta}$ is

$$x^2-x\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)+\frac{1}{\alpha\beta}=0$$

$$x^2-x\left(\frac{\beta+\alpha}{\alpha\beta}\right)+\frac{1}{\alpha\beta}=0$$

$$x^2+x-1=0$$

4. Let $a \in R$ and A be a matrix of order 3×3 such that $\det(A)=-4 \; and \; A+I=\begin{bmatrix}1 & a & 1\\ 2 & 1 & 0\\ a & 1 & 2\end{bmatrix}$ where I is the identity matrix of order 3×3. If $\det\left((a+1)adj\left((a-1)A\right)\right)$ is $2^m3^n, m,n \in \{0,1,2,...,20\}$, then $m+n$ is equal to :

1) 14 2) 16 3) 15 4) 17

Key: 2

Sol: $$A=\begin{bmatrix}1 & a & 1\\ 2 & 1 & 0\\ a & 1 & 2\end{bmatrix}-\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$$

$$=\begin{bmatrix}0 & a & 1\\ 2 & 0 & 0\\ a & 1 & 1\end{bmatrix}$$

$|A|=-4 \Rightarrow a=3$

$|4\,adj\,2A|=2^{16}$

5. Let z be a complex number such that $|z|=1$. If $\frac{2+k^2z}{k+\bar{z}}=kz,\ k \in R$, then the maximum distance of $k+ik^2$ from the circle $|z-(1+2i)|=1$ is :

1) 3 2) $\sqrt{5}+1$ 3) $\sqrt{3}+1$ 4) 2

Key: 2

Sol: $|Z|=1 \qquad \frac{Z+K^2Z}{K+\bar{Z}}=kZ \qquad\qquad Z\bar{Z}=1$

$$Z\frac{\left(2+k^2z\right)}{\left(kz+1\right)}=kZ$$

$k=2$

Max distance from $(2,4)$ to circle $(x-1)^2+(y-2)^2=1$

$Cp+r=\sqrt{5}+1$

6. Let $A=\begin{bmatrix}\alpha & -1\\ 6 & \beta\end{bmatrix}$, $\alpha>0$, such that $\det(A)=0$ *and* $\alpha+\beta=1$. If I denotes 2×2 identity matrix, then the matrix $(1+A)^8$ is:

1) $\begin{bmatrix}257 & -64\\ 514 & -127\end{bmatrix}$ 2) $\begin{bmatrix}766 & -255\\ 1530 & -509\end{bmatrix}$

3) $\begin{bmatrix}1025 & -511\\ 2024 & -1024\end{bmatrix}$ 4) $\begin{bmatrix}4 & -1\\ 6 & -1\end{bmatrix}$

Key: 2

Sol: $A=\begin{bmatrix}\alpha & -1\\ 6 & \beta\end{bmatrix}$

$|A|=0$

$\Rightarrow \alpha\beta=-6$

$\alpha+\beta=1$

$\alpha=3,\beta=-2$

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

$(I+A)^8=8C_0I+(8C_1+8C_2+.....+8C_8)A$

$=\begin{bmatrix}766 & -255\\ 1530 & -509\end{bmatrix}$

7. If $\theta\in[-2\pi,2\pi]$, then the number of solutions of $2\sqrt{2}\cos^2\theta+\left(2-\sqrt{6}\right)\cos\theta-\sqrt{3}=0$, is equal to :

1) 6 2) 10 3) 8 4) 12

Key: 3

Sol: $2\sqrt{2}Cos^2\theta+\left(2-\sqrt{6}\right)\cos\theta-\sqrt{3}=0$

$Cos\theta=-\dfrac{1}{\sqrt{2}}$

$\cos\theta=\dfrac{\sqrt{3}}{2}$

Number of solutions $[-2\pi,2\pi]$ *is* 8

8. If the system of linear equations

$3x+y+\beta z=3$

$2x+\alpha y-z=-3$

$x+2y+z=4$

Has infinitely many solutions, then the value of $22\beta-9\alpha$ is :

1) 37 2) 49 3) 31 4) 43

Key: 3

Sol: $\begin{vmatrix}3 & 1 & 3\\ 2 & \alpha & -3\\ 1 & 2 & 4\end{vmatrix}=0$ $\qquad \alpha=-\dfrac{19}{9}$

$\begin{vmatrix}3 & 3 & \beta\\ 2 & -3 & -1\\ 1 & 4 & 1\end{vmatrix}=0$ $\qquad \beta=\dfrac{6}{11}$

9. The number of sequences of ten terms, whose terms are either 0 or 1 or 2, that contain exactly five 1s and exactly three 2s, is equal to:

1) 360 2) 1820 3) 45 4) 2520

Key: 4

Sol: $\frac{10!}{5!3!2!}=2520$

10. If $\vec{a}$ is a nonzero vector such that its projections on the vectors $2\hat{i}-\hat{j}+2\hat{k}, \hat{i}+2\hat{j}-2\hat{k}$ *and* $\hat{k}$ are equal, then a unit vector along $\vec{a}$ is:

1) $\frac{1}{\sqrt{155}}\left(7\hat{i}+9\hat{j}+5\hat{k}\right)$ 2) $\frac{1}{\sqrt{155}}\left(-7\hat{i}+9\hat{j}+5\hat{k}\right)$

3) $\frac{1}{\sqrt{155}}\left(7\hat{i}+9\hat{j}-5\hat{k}\right)$ 4) $\frac{1}{\sqrt{155}}\left(-7\hat{i}+9\hat{j}-5\hat{k}\right)$

Key: 1

Sol: Projection of $\bar{a}$ on $2i-j+2k, i+2j-2k$ and k are equal

Verify $\bar{a}=\frac{7i+9j+5k}{\sqrt{155}}$

11. The term independent of x in the expansion of $\left[\frac{(x+1)}{\left(x^{2/3}+1-x^{1/3}\right)}-\frac{(x-1)}{\left(x-x^{1/2}\right)}\right]^{10}, x>1$, is :

1) 210 2) 150 3) 240 4) 120

Key: 1

Sol: $\left(x^{1/3}-\frac{1}{x^{1/2}}\right)^{10}$

$T_{r+1}={}^{10}C_r\left(x^{1/3}\right)^{10-r}\left(\frac{-1}{x^{1/2}}\right)^r$

$\frac{10-r}{3}-\frac{r}{2}=0\Rightarrow r=4$

The term independent of $x={}^{10}C_4=210$

12. For $\alpha,\beta,\gamma\in R$, if $\lim\limits_{x\to 0}\frac{x^2\sin\alpha x+(\gamma-1)e^{x^2}}{\sin 2x-\beta x}=3,$ then $\beta+\gamma-\alpha$ is equal to :

1) 7 2) 6 3) -1 4) 4

Key: 1

Sol: $\underset{x\to 0}{lt}\, x^2\frac{\left[\frac{\alpha x}{1!}+\frac{(\alpha x)^3}{3!}+.....\right]+(r-1)\left[1+\frac{x^2}{1!}+\frac{x^4}{2!}+....\right]}{\left[\frac{2x}{1!}-\frac{(2x)^3}{3!}+.....\right]-\beta x}$

$\underset{x\to 0}{lt}\frac{(r-1)+(r-1)x^2+\alpha x^3}{x(\beta-2)-\frac{4}{3}x^3}$

$r=1,\quad \beta=2,\ \alpha=-4$

$\beta+\gamma-\alpha=7$

13. Let $f:R\to R$ be a twice differentiable function such that $(\sin x\cos y)\left(f(2x+2y)-f(2x-2y)\right)=(\cos x\sin y)\left(f(2x+2y)\right)+f(2x-2y))$, for all $x,y\in R$. If $f'(0)=\frac{1}{2}$, then the value of $24f''\left(\frac{5\pi}{3}\right)$ is :

1) 2 2) -2 3) -3 4) 3

Key:3

Sol: $f(2x+2y)=\sin(x+y)$

$f(x)=k\sin\frac{x}{2}$

$f'(0)=\frac{1}{2}\Rightarrow k=1$

$f(x)=\sin\frac{x}{2},\qquad f''\left(\frac{5\pi}{3}\right)=-\frac{1}{8}$

$24f''\left(\frac{5\pi}{3}\right)=-3$

14. The largest $n\in N$ such that 3^n divides 50! is :

1) 22 2) 20 3) 23 4) 21

Key:1

Sol: $n=\left[\frac{50}{3}\right]+\left[\frac{50}{3^2}\right]+\left[\frac{50}{3^3}\right]$

$=16+5+1=22$

15. Let $a_1,a_2,a_3,.....$ be in an A.P. such that $\sum_{k=1}^{12}a_{2k-1}=-\frac{72}{5}a_1,\ a_1\neq 0$. If $\sum_{k=1}^{n}a_k=0$, then n is :

1) 18 2) 17 3) 11 4) 10

Key: 3

Sol: $a_1+a_3+.....+a_{23}=-\frac{72}{5}$

$\frac{12}{2}\left[2a_1+11\times 2d\right]=-\frac{72}{5}$

$a+5d=0\ \Rightarrow 2a+10d=0$

$a_1+a_2+.....+a_n=0$

$\frac{n}{2}\left[2a+(n-1)d\right]=0$

$2a+(n-1)d=0$

n = 11

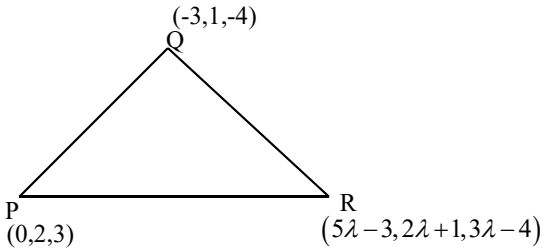
16. Let the vertices Q and R of the triangle PQR lie on the line $\frac{x+3}{5}=\frac{y-1}{2}=\frac{z+4}{3},QR=5$ and the coordinates of the point P be $(0,2,3)$. If the area of the triangle PQR is $\frac{m}{n}$ then :

1) $5m-21\sqrt{2}n=0$ 2) $5m-2\sqrt{21}n=0$

3) $2m-5\sqrt{21}n=0$ 4) $m-5\sqrt{21}n=0$

Key: 3

Sol:



Area of $\Delta PQR = \frac{m}{n}$

$$\frac{1}{2}\begin{vmatrix} i & j & k \\ 3 & 1 & 7 \\ 5\lambda & 2\lambda & 3\lambda \end{vmatrix} = \frac{m}{n} \Rightarrow \frac{\lambda}{2}\sqrt{798} = \frac{m}{n}$$

$$\Rightarrow \frac{5}{2\sqrt{38}} \times \sqrt{38 \times 21} = \frac{m}{n}$$

$$\Rightarrow 2m - 5\sqrt{21}n = 0$$

17. Let the focal chord PQ of the parabola $y^2 = 4x$ make an angle of 60° with the positive x-axis where P lies in the first quadrant. If the circle, whose one diameter is PS, S being the focus of the parabola, touches the y-axis at the point $(0,\alpha)$, then $5\alpha^2$ is equal to

1) 30 2) 15 3) 20 4) 25

Key: 2

Sol: $y^2 = 4x \rightarrow (1)$

$m = \tan 60^\circ = 3$

Equation of focal chord is

$y = \sqrt{3}(x-1) \rightarrow 2$

From $(1)\&(2)$ $P = \left(3, 2\sqrt{3}\right)$

Now circle $S : (x-1)(x-3) + (y-0)\left(y - 2\sqrt{3}\right) = 0$

touches y-axis at $(0,a) \Rightarrow a = \sqrt{3}$

$\therefore 5a^2 = 15$

18. If the function $f(x) = 2x^3 - 9ax^2 + 12a^2x + 1$, where a>0 , attains its local maximum and local minimum values at p and q, respectively , such that $p^2 = q$, then $f(3)$ is equal to :

1) 10 2) 23 3) 55 4) 37

Key:4

Sol: $f(x) = 2x^3 - 9ax^2 + 12a^2x + 1$

$f'(x) = 6x^2 - 18ax + 12a^2$

For max. or min. $f'(x) = 0 \Rightarrow x = a, 2a$

f is maximum at $x = a$ & minimum $x = 2a$

$\therefore p = a;\ q = 2a$

$\because p^2 = q \Rightarrow a = 2$

$\Rightarrow f(3) = 37$

19. Let A be the set of all functions $f : z \rightarrow z$ *and* R be a relation on A such that $R = \{(f,g) : f(0) = g(1) \text{ and } f(1) = g(0)\}$. Then R is :

1) Symmetric but neither reflective nor transitive

2) Reflexive but neither symmetric nor transitive
3) Symmetric and transitive but nor reflective
4) Transitive but neither reflexive nor symmetric

Key: 1

Sol: Let A be set of all functions

$f: Z \to Z$ and R be a relation on A

$f(0) = g(1),\ f(1) = g(0)$

$R = \{(f,g): f(0) = g(1)\ and\ f(1) = g(0)\}$

$\Rightarrow$ R is symmetric but neither reflective nor transitive

20. Let ABCD be a tetrahedron such that the edges AB, AC and AD are mutually perpendicular. Let the areas of the triangles ABC, ACD and ADB be 5,6 and 7 square units respectively. Then the area (in square units of the ΔBCD is equal to :

1) 12 2) $\sqrt{110}$ 3) $7\sqrt{3}$ 4) $\sqrt{340}$

Key: 2

Sol: Area of $BCD = \sqrt{5^2 + 6^2 + 7^2} = \sqrt{110}$

SECTION-II

21. The absolute difference between the squares of the radii of the two circles passing through the point (-9, 4) and touching the lines $x + y = 3\ and\ x - y = 3$, is equal to

_____

Key: 768

Sol: $r_1^2 = (-5+9)^2 + 16 = 32$

$r_2^2 = (-37+9)^2 + 16 = 800$

$\left|r_1^2 - r_2^2\right| = 768$

22. Let [.] denote the greatest integer function. If $\int_0^{e^3} \left[\frac{1}{e^{x-1}}\right] dx = \alpha - \log_e 2$, then α^3 is equal to

_____

Key: 8

Sol: $\int_0^{e^3} \left[e^{1-x}\right] dx$

$= \int_0^{1-\ln 2} \left[e^{1-x}\right] dx + \int_{1-\ln 2}^{1} \left[1 - e^{1-x}\right] dx + \int_1^{e^3} \left[e^{1-x}\right] dx$

$= 2\int_0^{1-\ln 2} dx + 1\int_{1-\ln 2}^{1} dx + 0$

$= 2[1 - \ln 2] + 1 - (1 - \ln 2)$

$= 2 - 2\ln 2 + \ln 2$

$= 2 - \ln 2 \Rightarrow \alpha = 2$

$\alpha^3 = 8$

23. Three distinct numbers are selected randomly from the set $\{1,2,3,.....40\}$. If the probability that the selected numbers are in an increasing G.P, is $\frac{m}{n}$, gcd (m, n) = 1, then m + n is equal to _____

Key: 4954

Sol: $n(s) = {}^{40}C_3 = 9880$

$n(E) = 28$

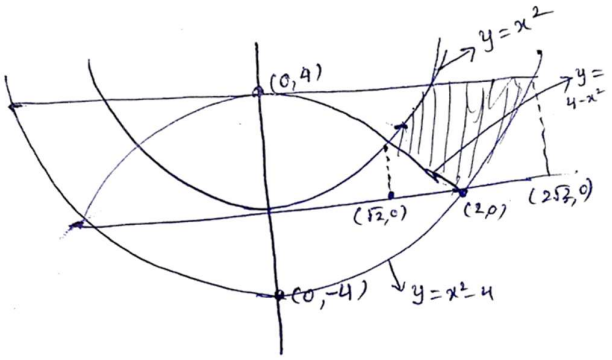
$p(E) = \frac{28}{9880} = \frac{14}{4940} = \frac{m}{n}$

$m + n = 4954$

24. If the area of the region $\left\{(x,y) : |4-x^2| \le y \le x^2, y \le 4, x \ge 0\right\}$ is $\left(\frac{80\sqrt{2}}{\alpha} - \beta\right), \alpha, \beta \in N$, then $\alpha + \beta$ is equal to _____

Key: 22

Sol:



$Area = \int_{\sqrt{2}}^{2} \left(x^2 - \left(4 - x^2\right)\right) dx + \int_{2}^{2\sqrt{2}} \left(4 - \left(x^2 - 4\right)\right) dx$

$= \left[\frac{2x^3}{3} - 4x\right]_{\sqrt{2}}^{2} + \left[8 - x^2\right]_{2}^{2\sqrt{2}}$

$= -\frac{8}{3} + \frac{8\sqrt{2}}{3} + \frac{32\sqrt{2}}{3} - \frac{40}{3}$

$= \frac{40\sqrt{2}}{3} - \frac{48}{3}$

$= \frac{80\sqrt{2}}{6} - 16$

$\alpha = 6,\ \beta = 16$

$\alpha + \beta = 22$

25. Let $f : R \to R$ be a thrice differentiable odd function satisfying $f'(x) \ge 0, f''(x) = f(x), f(0) = 0, f'(0) = 3$. Then $9f(\log_e 3)$ is equal to _____

Key: 36

Sol: $f''(x) = f(x)$

$f'(x) f''(x) = f'(x) f(x)$

$\frac{\left[f'(x)\right]^2}{2} = \frac{\left[f(x)\right]^2}{2} + \frac{c}{2}$

$\left[f'(x)\right]^2 = \left[f(x)\right]^2 + c$

$f'(0) = 3,\ f(0) = 0$

$c = 9$

$$f'(x)=\sqrt{f^2(x)+9}$$

$$\int\frac{f'(x)}{\sqrt{f^2(x)+9}}=1$$

$$\sinh^{-1}\left(\frac{f(x)}{3}\right)=x$$

$$f(x)=3\sinh x$$

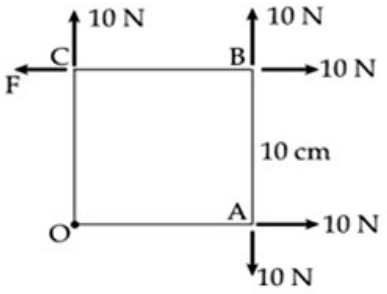
$$=3\frac{\left[e^x-e^{-x}\right]}{2}$$

$$f(\log_e 3)=4$$

PHYSICS

SECTION-I

26. A Square Lamina OABC of length 10 cm is pivoted at 'O'. Forces act at Lamina as shown in figure. If Lamina remains stationary. Then the magnitude of F is :



1) $10\sqrt{2}$ 2) 20 N 3) 10 N 4) 0 (zero)

Key: 3

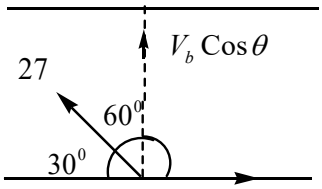
Sol: In mechanical equilibrium Net torque is zero
In equilibrium net force is zero So F = 10 N

27. A river is flowing from west to east direction with speed of 9 kmh^{-1}. If a boat capable of moving at a maximum speed of 27 kmh^{-1} in still water crosses the river in half a minute, while moving with maximum speed at an angle of 150^0 to direction of river flow, then the width of the river is :

1) 300 m 2) 112.5 m 3) 75 m 4) 1125 $\times\sqrt{3}\,m$

Key: 2

Sol:



$d = V_b \cos\theta \times t$

= 112.5m

28. Considering the Bohr's atomic model for hydrogen atom:

A) the energy of H atom in ground state is same as energy of He^+ ion in its first excited state.

B) the energy of H atom in ground state is same as that for Li^{++} ion in its second excited state.

C) the energy of H atom in ground state is same as that of He^+ ion for its ground State

D) the energy of He^+ ion in its first excited state is same as that for Li^{++} ion in its ground State

Choose the correct answer from the options given below:

1) (A), (C) only 2) (A), (D) only

3) (A), (B) only 4) (B), (D) only

Key: 3

Sol: $E_n = -\frac{13.6}{n^2} \times z^2$ *So A & B*

29. Moment of inertia of rod of mass 'M' and length 'L' about an axis passing through its Center and normal to its length is 'α'. Now the rod is cut into two equal parts and these parts are joined symmetrically to form a cross shape. Moment of inertia of cross about an axis passing through the center and normal to plane containing cross is:

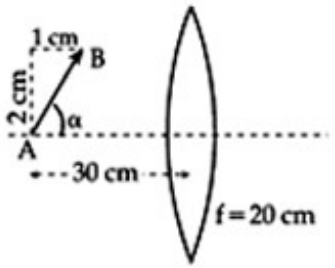
1) $\frac{\alpha}{2}$ 2) $\frac{\alpha}{4}$ 3) $\frac{\alpha}{8}$ 4) α

Key: 2

Sol: $I_1 = \frac{ml^2}{12} = \alpha$

$$I_2 = 2\frac{\frac{m}{2}\left(\frac{l}{2}\right)^2}{12} = \frac{ml^2}{48} = \frac{\alpha}{4}$$

30. A slanted object AB is placed on one side of convex lens as shown in the diagram. The image is formed on the opposite side. Angle made by the image with principal axis is:



1) $+45^0$ 2) -45^0 3) $-\frac{\alpha}{2}$ 4) $-\alpha$

Key: 4

Sol: $m = \frac{v}{u} = 2$, $du = 1$

$\frac{hi}{hv} = m$

$hi = 4$

$\frac{dv}{du} = m^2 = 4$

$dv = 4$

$\text{Tan}\,\beta = \frac{dhi}{dv} = \frac{4}{4} = 1 \therefore \beta = -45^0$

31. Let B_1 be the magnitude of magnetic field at center of a circular coil of radius R carrying current I. Let B_2 be the magnitude of magnetic field at an axial distance 'x' from the center. For $x : R = 3 : 4, \frac{B_2}{B_1}$ is :

1) $25:16$ 2) $4:5$ 3) $64:125$ 4) $16:25$

Key: 3

Sol: $B_1 = \frac{\mu_0 ni}{2R}$ $B_2 = \frac{\mu_0 ni R^2}{2\left(R^2 + x^2\right)^{3/2}}$

$\frac{B_2}{B_1} = \frac{64}{125}$

32. The relationship between the magnetic susceptibility (x) and the magnetic permeability (μ) is given by :

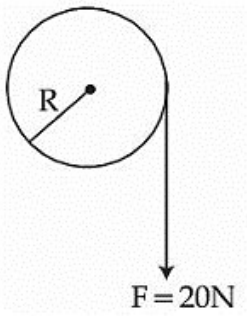
(μ_0 is permeability of free space and μ_r is relative permeability)

1) $X = \mu_r + 1$ 2) $X = \frac{\mu}{\mu_0} - 1$ 3) $X = \frac{\mu_r}{\mu_0} + 1$ 4) $X = 1 - \frac{\mu}{\mu_0}$

Key: 2

Sol: $\mu_r = \frac{\mu}{\mu_0} \Rightarrow \mu_r = 1 + x$

33. A cord of negligible mass is wound around the rim of a wheel supported by spokes with negligible mass. The mass of wheel is 10 kg and radius is 10cm and it can freely rotate without any friction. Initially the wheel is at rest. If a steady pull of 20N is applied on the cord. The angular velocity of the wheel, after the cord is unwound by 1 m. would be:



1) 20 rad/ s 2) 10 rad/ s 3) 30 rad/s 4) 0 rad/s

Key: 1

Sol: $\tau = I\alpha \quad RF = I\alpha \; But \; I = MR^2$

$\therefore \alpha = 20 rad/s^2$

$\theta = \frac{s}{r} = 10$

$\omega^2 - \omega_0^2 = 2\alpha\theta \;\; \omega = \sqrt{2 \times 20 \times 10} = 20 rad/s$

34. A particle is subjected to two simple harmonic motions as:

$x_1 = \sqrt{7}\sin 5t \, cm$ and $x_2 = 2\sqrt{7}\sin\left(5t + \frac{\pi}{3}\right) cm$

Where x is displacement and t is time in seconds.

The maximum acceleration of the particle is $x \times 10^{-2} \, ms^{-2}$ .The value of x is :

1) $5\sqrt{7}$ 2) 175 3) $25\sqrt{7}$ 4) 125

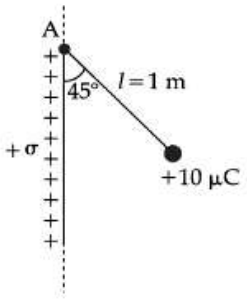
Key: 2

Sol: $a_R = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi}$, $\phi = \pi/3$

$a_R = 7 cm/s^2$, $a_{max} = -\omega^2 a_R = 175 \times 10^{-2} \, m/s$

35. A small bob of mass 100 mg and charge +10 μc is connected to an insulating string of length l m. It is brought near to an infinitely long non- conducting sheet of charge density 'σ' as shown in figure. If string subtends an angle of 45^0 with the sheet at equilibrium the charge density of sheet will be.

(Given $\in_0 = 8.85 \times 10^{-12} \frac{F}{m}$ and acceleration due to gravity , $g = 10 \frac{m}{s^2}$)



1) $0.885\,nC/m^2$ 2) $1.77\,nC/m^2$ 3) $17.7\,nC/m^2$ 4) $885\,nC/m^2$

Key: 2

Sol: $f = mg\tan\theta$

$Eq = mg\tan\theta$

$\frac{\sigma}{2\in_0}q = mg\tan\theta \qquad \sigma = 1.77\,nc/m^2$

36. A point charge + q is placed at the origin. A second point charge +9q is placed at $(d,0,0)$ In Cartesian coordinate system. The point in between them where the electric field vanishes is

1) $(4d/3,0,0)$ 2) $(d/3,0,0)$ 3) $(3d/4,0,0)$ 4) $(d/4,0,0)$

Key: 4

Sol: $x = \dfrac{d}{\sqrt{\frac{q_2}{q_1}}+1}$

$x = d/4$

$\therefore\left(\frac{d}{4},0,0\right)$

37. In an adiabatic process, which of the following statements is true?

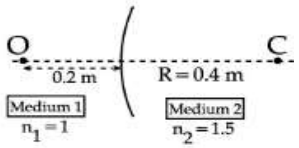
1) The molar heat capacity is infinite
2) Work done by the gas equals the increase in internal energy
3) The molar heat capacity is zero
4) The internal energy of the gas decreases as the temperature increases.

Key: 3

Sol: $ms = \frac{dQ}{dT}$

$dQ = 0 \Rightarrow ms = 0\ dQ = 0$

38.



A spherical surface separates two media of refractive indices 1 and 1.5 as shown in figure Distance of the image of an object 'O' is :
(C is the center of the curvature of the spherical surface and R is the radius of the curvature)

1) 0.24 m right to the spherical surface
2) 0.4 m left to the spherical surface
3) 0.4 m right to the spherical surface
4) 0.24 m left to the spherical surface.

Key: 2

Sol: $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\left(\frac{\mu_2-\mu_1}{R}\right)$

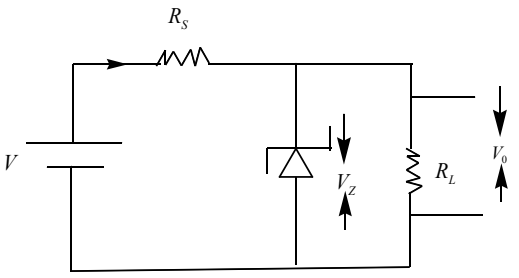
$\therefore v=-0.4\,m$

39. A zener diode with 5 V zener voltage is used to regulate an unregulated dc voltage input Of 25 V. For a 400 Ω resistor connected in series, the zener current is found to be 4 Times Load current. The load current (I_L) and load resistance (R_L) are:

1) $I_L=10\,A; R_L=0.5\,\Omega$ 2) $I_L=10\,mA; R_L=500\,\Omega$

3) $I_L=20\,mA; R_L=250\,\Omega$ 4) $I_L=0.02\,mA; R_L=250\,\Omega$

Key: 2



Sol: $I=\frac{v}{R}=\frac{20}{400}$

$I_z=4I_L$

$I-I_L=4I_L$

$\therefore I_L=10mA$

$V=I\,R_L \Rightarrow R_L=500\,\Omega$

40. A monochromatic light is incident on a metallic plate having work function ϕ An electron, emitted normally to the plate from a point A with maximum kinetic energy, enters a constant magnetic field perpendicular to the initial velocity of electron. The electron passes through a curve and hits back the plate at Point B. The distance between A and B is

(**Given:** The magnitude of charge of an electron is e and mass m , h is Planck's constant and c is the velocity of the light. Take the magnetic field exists through out the path of electron)

1) $\sqrt{2m\left(\frac{hc}{\lambda}-\phi\right)}/eB$ 2) $\sqrt{m\left(\frac{hc}{\lambda}-\phi\right)}/eB$

3) $\sqrt{8m\left(\frac{hc}{\lambda}-\phi\right)}/eB$ 4) $2\sqrt{m\left(\frac{hc}{\lambda}-\phi\right)}/eB$

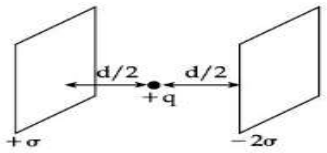
Key : 3

Sol: $\frac{1}{2}mv^2=\left(\frac{hc}{\lambda}-\phi\right)$

$R=\frac{mv}{Bq}$

$\therefore R=\frac{1}{eB}\sqrt{8m\left(\frac{hc}{\lambda}-\phi\right)}$

41. Consider two infinitely large plane parallel conducting plates as shown below. The plates are uniformly charged with a surface density $+\sigma$ and -2σ. The force experienced by a point charge + q placed at the mid-point between the two plates will be:



1) $\frac{3\sigma}{4\in_0}$ 2) $\frac{\sigma q}{2\in_0}$ 3) $\frac{3\sigma q}{2\in_0}$ 4) $\frac{\sigma q}{4\in_0}$

Key: 3

Sol: $E=\frac{\sigma}{2\in_0}+\frac{2\sigma}{2\in_0}$

$E=\frac{3\sigma}{2\in_0}$

$F=Eq$

$\therefore F=\frac{3\sigma q}{2\in_0}$

42. The battery of a mobile phone is rated as 4.2 V , 5800 mAh. How much energy is stored in it when fully charged ?

1) 48.7 kJ 2) 43.8 kJ 3) 87.7 kJ 4) 24.4 kJ

Key: 3

Sol: Work done W= qv

$=5800\times10^{-3}\times3600\times4.2$

= 87.7 KJ

43. A light wave is propagating with plane wave fronts of the type $x+y+z=cons\tan t$. The angle made by the direction of wave propagation with x- axis is :

1) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$ 2) $\cos^{-1}\left(\sqrt{\frac{2}{3}}\right)$ 3) $\cos^{-1}\left(\frac{1}{3}\right)$ 4) $\cos^{-1}\left(\frac{2}{3}\right)$

Key:1

Sol: $\text{Cos}\alpha=\frac{Ax}{|A|}$

$\alpha=\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$

44. The equation for a real gas is given by $\left(P+\frac{a}{V^2}\right)(V-b)=RT,$ where P, V, T and R are the pressure, volume, temperature and gas constant, respectively, The dimension of ab^{-2} is equivalent to that of:

1) Strain 2) Compressibility 3) Planck's constant 4) Energy density

Key: 4

Sol: Acc to principle of homogeneity $a=ML^5T^{-2}, b=L^3$

$ab^{-2}=ML^{-1}T^{-2}=$ Energy density

45. Match **List- I** with **List- II.**

List- I	**List- II**
(A) Coefficient of viscosity	(I) $\left[ML^0T^{-3}\right]$
(B) Intensity of wave	(II) $\left[ML^{-2}T^{-2}\right]$
(C) Pressure gradient	(III) $\left[M^{-1}LT^2\right]$
(D) Compressibility	(IV) $\left[ML^{-1}T^{-1}\right]$

Choose the correct Answer from the options given below

1) $(A)-(IV),B-(I),C-(II),D-(III)$ 2) $(A)-(I),B-(IV),C-(III),D-(II)$

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

Key: 1

Sol: Coefficient of viscosity- $ML^{-1}T^{-1}$

Intensity of wave - $ML^{0}T^{-3}$

Pressure gradient - $ML^{-2}T^{-2}$

Compressibility - $M^{-1}LT^{-2}$

SECTION-II

46. A person travelling on a straight line moves with a uniform velocity v_1 for a distance x and with a uniform velocity v_2 for the next $\frac{3x}{2}$ distance. The average velocity in this motion is $\frac{50}{7}\ m/s$. If v_1 is 5 m/s then v_2 = _____m/s

Key: 10

Sol: $V_{Avg} = \frac{Total\ dis\tan ce}{Total\ time}$

$$V_{Avg} = \frac{x+\frac{3x}{2}}{\frac{x}{v_1}+\frac{3x}{2v_2}} \therefore v_2 = 10m/s$$

47. A vessel with square cross section and height of 6 m is vertically partitioned. A small window of 100 cm^2 with hinged door is fitted at a depth of 3 m in the partitioned wall. One part of the vessel is filled completely with water and the other side is filled with liquid having density $1.5\times10^3\ kg/m^3$. What force one needs to apply on the hinged door so that it does not get opened?
(Acceleration due to gravity =10 m/s^2)

Key: 150

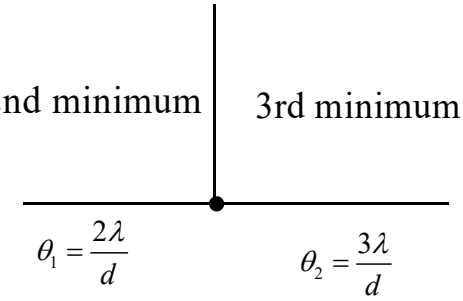
Sol: Force needed so that window may not be opened $f = \Delta pA \quad = (p_1 - p_2)\,g\,h\,A$

$f = 150N$

48. If the measured angular separation between the second minimum to the left of the central maximum and the third minimum to the right of the central maximum is 30^0 in a single slit diffraction pattern recorded using 628 nm light, then the width of the slit is _____ μm

Key: 6

Sol:



$\theta = \theta_1 + \theta_2 \Rightarrow \pi/6 = (2+3)\lambda/d = \frac{5\lambda}{d}$

$d = \frac{30\lambda}{\pi}$

d= $6\mu m$

49. γ_A is the specific heat ratio of monatomic gas A having 3 transitional degrees of freedom γ_B is the specific heat ratio of polyatomic gas B having 3 translational , 3 rotational degrees of freedom and 1 vibrational mode. If $\frac{\gamma_A}{\gamma_B} = \left(1+\frac{1}{n}\right)$ then the value of n is

_____

Key: 3

Sol: $\gamma_A = \frac{5}{3}, \gamma_B = \frac{9}{7}$

$\frac{\gamma_A}{\gamma_B} = \frac{35}{27}$

$1+\frac{1}{n} = \frac{35}{27} = n = \frac{27}{8}$

n= 3

50. A steel wire of length 2 m and Young's modulus $2.0\times10^{11} Nm^{-2}$ is stretched by a force, If Poisson ration and transverse strain for the wire are 0.2 and 10^{-3} respectively. Then the elastic potential energy density of the wire is _____$\times10^5$ $(in \quad SI\ Units)$

Key: 25

Sol: $\sigma = \frac{\Delta r/r}{\Delta l/l} \Rightarrow \frac{\Delta l}{l} = 5\times10^{-3}$

Elastic plastic Energy density

$U = \frac{1}{2}\times Y \times \left(\frac{\Delta l}{l}\right)^2$

$U = \frac{1}{2}\times 2\times10^{11}\times25\times10^{-6} = 25\times10^5$

CHEMISTRY
SECTION-I

51. An optically active alkyl halide $C_4H_9B_r[A]$ reacts with hot KOH dissolved in ethanol and forms alkene $[B]$ as major product which reacts with bromine to give dibromide $[C]$. The compound $[C]$ is converted into a gas $[D]$ upon reacting with alcoholic $NaNH_2$. During hydration 18 gram of water is added to 1 mole of gas $[D]$ on warming with mercuric sulphate and dilute acid and at 333K to from compound [E]. The IUPAC name of compound [E] is :

1) Butan-2-one 2) Butan-1-al 3) But-2-yne 4) Butan-2-ol

Key : 1

Sol :

$$\underset{(A)}{CH_3-\overset{*}{C}H(Br)-CH_2-CH_3} \rightarrow \underset{(B)}{CH_3-CH=CH-CH_3} \xrightarrow{Br_2}$$

$$CH_3-CH(Br)-CH(Br)-CH_3 \xrightarrow[-2NH_3\ -2NaCl]{NaNH_2} CH_3-C\equiv C-CH_3 \xrightarrow[H_2O]{Hg^{+2}/H^+} CH_3-CO-CH_2CH_3$$

(C) (D) $333k$

52. If equal volumes of AB_2 and XY (both are salts) aqueous solutions are mixed, which of the following Combination will give a precipitate of AY_2 at 300K?
(Given $K_{sp}\,(at\ 300K)$ for $AY_2 = 5.2\times10^{-7}$)

1) $2.0\times10^{-2}M\ AB_2, 2.0\times10^{-2}M\ XY$ 2) $3.6\times10^{-3}M\ AB_2, 5.0\times10^{-4}M\ XY$

3) $1.5\times10^{-4}M\ AB_2, 1.5\times10^{-3}M\ XY$ 4) $2.0\times10^{-4}M\ AB_2, 0.8\times10^{-3}M\ XY$

Key : 1

Sol : After mixing the two solutions in equal volumes the conc of the salts ion reduced to half.

Opt-1 : $\left[1\times10^{-2}\right]\times\left[1\times10^{-2}\right]=10^{-4}M$

$10^{-4} > 5.2\times10^{-7}$

Ionic product $> Ksp$

Hence ppt is formed.

Opt-2 $\left[\frac{3.6\times10^{-3}}{2}\right]\left[\frac{5\times10^{-4}}{2}\right]$

$1.8\times10^{-3}\times2.5\times10^{-4}$

$=1.8\times2.5\times10^{-7}$

$=4.5\times10^{-7} < Ksp$

Hence ppt is not formed.

Opt-3 $\left[\frac{1.5\times10^{-4}}{2}\right]\left[\frac{1.5\times10^{-3}}{2}\right]$

$=0.75\times0.75\times10^{-8}$

$=0.5625\times10^{-8} < Ksp$ hence ppt is not formed.

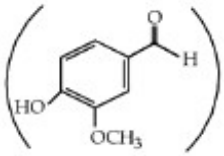
Opt-4 $\left[\frac{2.0\times10^{-4}}{2}\right]\left[\frac{0.8\times10^{-3}}{2}\right]$

$=1\times10^{-4}\times0.4\times10^{-3}$

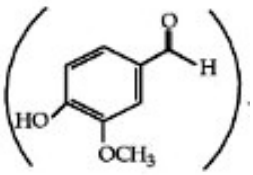
$0.4\times10^{-7} < Ksp$

$\therefore$ ppt is not formed.

53. Given below are two statements :



Statement (I) : Vanillin will react with $NaOH$ and also with Tollen's reagent



Statement (II) : Vanillin will undergo self aldol condensation very easily.

In the light of above statements, choose the most appropriate answer from the options given below :

1. Statement I is correct but Statement II is incorrect
2. Statement I is incorrect but Statement II is correct
3. Both Statement I and Statement II are correct
4. Both Statement I and Statement II are incorrect

Key : 1

Sol : Vanillin reacts with $NaOH$ and undergoes acid base reaction with phenolic hydroxyl group.

Present in it forming vanillin phenoxide which is more soluble in water. Vanillin also reacts with Tollens reagent due the presence of aldehydic group.

Vanillin does not undergoes self aldol condensation due to absence of a $\alpha-$ hydrogen.

54. Among $SO_2, NF_3, NH_3, XeF_2, CIF_3$ and SF_4, the hybridization of the molecule with non-zero dipole moment and highest number of lone-pairs of electrons on the central atom is

1) sp^3d^2 2) sp^3d 3) dsp^2 4) sp^3

Key : 2

Sol : NF_3 : No. of lone pairs =1

SO_2 : No. of lone pairs =1

NH_3 : No. of lone pairs=1

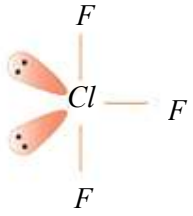
SF_4 : No. of lone pairs =1

XeF_2 : No. of lone pairs =3

ClF_3 : No. of lone pairs =2

XeF_2 is planar molecule & net dipole moment is zero.

ClF_3



it has T shape molecule no. of σ bonds =3

No. of lone pairs =2

Hybridization = sp^3d

55. Choose the correct tests with respectively observations:

A) $CuSO_4$(acidified with acetic acid)+ $K_4\left[Fe(CN)_6\right] \rightarrow$ Chocolate brown precipitate

B) $FeCl_3 + K_4\left[Fe(CN)_6\right] \rightarrow$ Prussian blue precipitate

C) $ZnCl_2 + K_4\left(Fe(CN)_6\right)$ neutralised with $NH_4OH \rightarrow$ white or bluish white precipitate

D) $MgCl_2 + K_4\left[Fe(CN)_6\right] \rightarrow$ Blue precipitate

E) $BaCl_2 + K_4\left[Fe(CN)_6\right]$ neutralised with $NaOH \rightarrow$ White precipitate.

Choose the correct answer from the options given below:

1) C, D and E only 2) A, B and C only

3) A, D and E only 4) B, D and E only

Key : 2

Sol : A) $2Cu^{+2} + \left[Fe(CN)_6\right]^{-4} \rightarrow Cu_2\left[Fe(CN)\right]$ Copper ferro cyanide

(Chocolate brown colour ppt)

B) $4Fe^{+3}+3\left[Fe(CN)_6\right]^{-4}\rightarrow Fe_4\left[Fe(CN)_6\right]_3$ Ferric Ferro cyanide

(Prussian blue ppt)

C) $2Zn^{+2}+\left[Fe(CN)_6\right]^{4-}\rightarrow Zn_2\left[Fe(CN)_6\right]$ Zinc ferro cyanide

(white ppt)

D) $MgCl_2$ does not react with $K_4\left[Fe(CN)_6\right]$ to form a blue ppt. magnesium ferrocyanide is usually white ppt

E) $Ba^{+2}+\left[Fe(CN)_6\right]^{-4}\rightarrow Ba_2\left[Fe(CN)_6\right]$ barium ferrocyanide

(white ppt).

56. Given below are two statements :

Statement –I : The metallic radius of Al is less than that of Ga.

Statement –II : The ionic radius of Al^{3+} is less than that of Ga^{3+}

In the light of the above statements, choose the most appropriate answer from the options given below.

1. Both Statement I and Statement II are incorrect
2. Statement I is correct but Statement II is incorrect
3. Both Statement I and Statement II are correct
4. Statement I is incorrect but Statement II is correct

Key : 4

Sol : Metallic radius of $Ga < Al$

Ionic radius of $Ga^{+3} > Al^{+3}$

57. A solution made by mixing one mole of volatile liquid A with 3 moles of volatile liquid B. The vapour pressure of pure A is 200 mm Hg and that of the solution in 500 mm Hg. The vapour pressure of pure B and the least volatile component of the solution, respectively are :

1) 600 mm Hg, B 2) 1400 mm Hg, A

3) 1400 mm Hg, B D) 600 mm Hg, A

Key : 4

Sol : For an ideal gas solution

$P_T=P_A^0\times+P_B^0\times B$

$A=\frac{1}{4},\times B=\frac{3}{4}$

$500=200\times\frac{1}{4}+P_B^0\times\frac{3}{4}$

$P_B^0=600mm$ of Hg

and least volatile compound is A

58. On complete combustion 1.0g of an organic compound (X) gave 1.46 g of CO_2 and 0.567 g of H_2O. The empirical formula mass of compound (X) is _____g.

(Given molecular mas in g $mol^{-1}C$: 12,H:1,O:16)

1) 30 2) 15 3) 60 4) 45

Key : 1

Sol : % of $=\frac{12}{44}\times\frac{1.46}{1}\times100$

= % of $c=39.81$

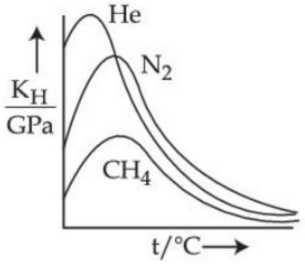
% of $H = \frac{2}{18} \times \frac{0.567}{1} \times 100 = 6.3$

Remaining percentage is oxygen = 53.9

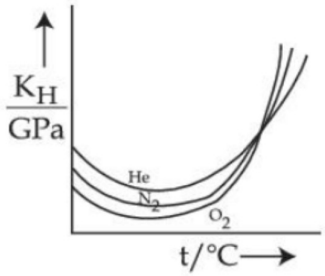
C	H	O
$\frac{39.81}{12}$	$\frac{6.3}{1}$	$\frac{53.9}{16}$
3.3	6.3	3.3
1	2	1

The empirical formula is CH_2O molecular weight is =12+2+16=30

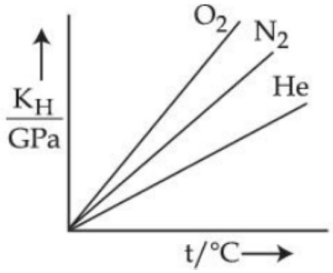
59. Which of the following graph correctly represents the plots of K_H at 1 bar for gases in water versus temperature?



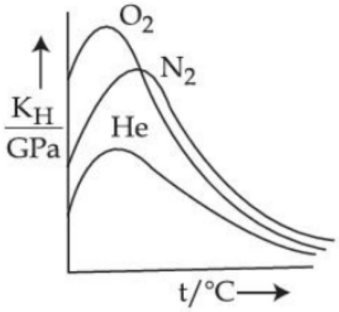
1)



2)



3)



4)

Key : 1

Sol : $K_H = \frac{P}{X_A}$ at constant of temperature

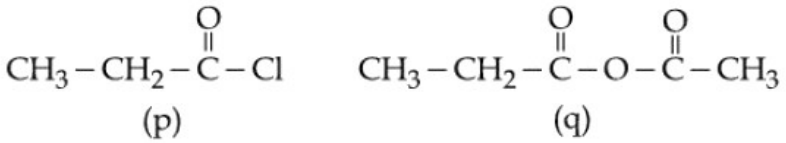
But $K_H \alpha T$

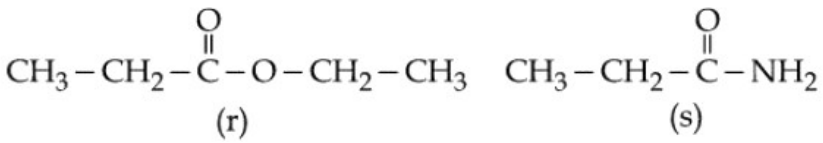
$\frac{K_H}{P} = \frac{1}{X_A}.T$

$\frac{K_H}{P} = \frac{1}{X_A}.T^0C$

$y = mx$

60. Consider the following molecules :





The correct order of rate of hydrolysis is :

1) $r > q > p > s$ 2) $q > p > r > s$ 3) $p > r > q > s$ 4) $p > q > r > s$

Key : 4

Sol : The rate of hydrolysis of carboxylic acid derivative is in the order acid chlorides > acid anhydride > Ester > amide.

The order is based on electrophilic nature of carbonyl group and leaving ability of the groups.

61. Identify the correct statement among the following :

1) All naturally occurring amino acids except glycine contains one chiral centre

2) All naturally occurring amino acids are optically active.

3) Glutamic acid the only amino acid that contains a –COOH group at the side chain.

4) Amino acid, cysteine can easily undergoes dimerization due to the presence of free SH group.

Key : 4

Sol : All naturally occurring alpha amino acids except glycine are optically active because the contains chiral carbon atoms. Where as in glycine chiral carbon is absent.

Glutamic acid and aspartic acid as both possess a carboxylic group on their side chain making them acidic amino acids.

Amino acid, cysteine can undergoes dimerization due to presence of free SH group to form disulphide bond.

During dimerization of cysteine oxidation of two SH groups results in the formation of disulphide bonds.

62. The property/properties that show irregularity in first elements of group-17 is/are :

1) Covalent radius 2) Electron affinity

3) Ionic radius 4) First ionization energy

Choose the correct answer from the options given below :

1) B only 2) A and C only 3) A,B,C and D 4) B and D only

Key : 1

Sol : Fluorine has a relatively low electron affinity compared to other halogens due to its small size and high electron density (greater $e^- - e^-$ repulsions)

63. Given below are two statements :

Statement –I : In octahedral complexes, when $\Delta_0 < P$ high spin complexes are formed. When $\Delta_0 > P$ low spin complexes are formed.

Statement – II : In tetrahedral complexes because of $\Delta_t < P$, low spin complexes are rarely formed. In the light of the above statements, choose the most appropriate answer from the options given below :

1) Statement I is correct but Statement II is incorrect

2) Statement I is incorrect but Statement II is correct

3) Both Statement I and Statement II are correct

4) Both Statement I and Statement II are incorrect.

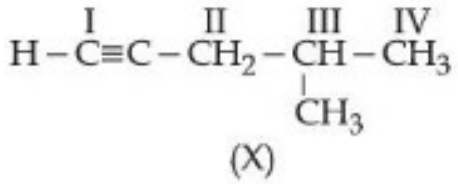
Key : 3

Sol : In octahedral complexes, when $\Delta_0 < P$ high spin complexes are formed.

When $\Delta_0 > P$ low spin complexes are formed.

In tetrahedral complexes because of $\Delta_t < P$, low spin complexes are rarely formed. Mostly high spin complexes are formed.

64. Consider the following compound (X)



(X)

The most stable and least stable carbon radicals, respectively, produced by homolytic cleavage of corresponding C-H bond are :

1) I,IV 2) III,II 3) II,IV 4) II,I

Key : 4

Sol : II Carbon is more stable due to resonance

I Carbon is least stable due to free radical present on sp carbon

65. The correct order of basic nature in aqueous solution for the bases :

NH_3, H_2N-NH_2, $CH_3CH_2NH_2$, $(CH_3CH_2)_2NH$ and $(CH_3CH_2)_3N$

1. $NH_2-NH_2 < NH_3 < CH_3CH_2NH_2 < (CH_3CH_2)_3N < (CH_3CH_2)_2NH$
2. $H_2N-NH_2 < NH_3 < (CH_3CH_2)_3N < CH_3CH_2NH_2 < (CH_3CH_2)_2NH$
3. $NH_3 < H_2N-NH_2 < CH_3CH_2NH_2 < (CH_3CH_2)_2NH < (CH_3CH_2)_3N$
4. $NH_3 < H_2N-NH_2 < (CH_3CH_2)_3N < CH_3CH_2NH_2 < (CH_3CH_2)_2NH$

Key : 1

Sol : Order of basicity of ethyl amines in aqueous solution $2^0 > 3^0 > 1^0$ which is based on inductive effect steric hindrance and solvation effect.

Between ammonia and hydrazine, NH_3 is more basic than N_2H_4 because availability of lone pairs in ammonia is more than N_2H_4 . In N_2H_4 $-I$ effect NH_2 group decreasing availability of lone pair on other nitrogen.

66. A molecule with the formula AX_4Y has all its elements from p-block. Element A is rarest monoatomic, non-radioactive from its group and has lowest ionization enthalpy value among A,X and Y. Elements X and Y have first and second highest electronegativity values respectively among all the known elements. The shape of the molecule is :

1) Trigonal bipyramidal 2) Square pyramidal

3) Pentagonal planar 4) Octahedral

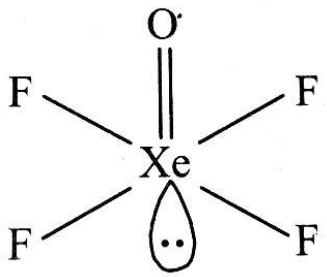
Key : 2

Sol : Rarest monoatomic & non-radio active element in xenon.

X: 1st electro negative =F

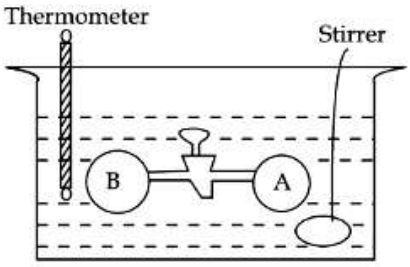
Y : 2nd electro negative =O

Formula : $XeOF_4$



$XeOF_4$ molecule has a square pyramidal shape.

67.



The vessels A and B are connected via stopcock. The vessel A is filled with a gas at a certain pressure. The entire assembly is immersed in water and is allowed to come to thermal equilibrium with water. After opening the stopcock the gas from vessel A expands into vessel B and no change in temperature is observed in the thermometer. Which of the following statement is true.

1) $dq \neq 0$
2) $dU \neq 0$
3) $dw \neq 0$
4) The pressure in the vessel B before opening the stopcock is zero.

Key : 3 (Note : NTA Key-4. If vacuum is considered option 4 is correct)

Sol : Since gas is expanding from bulb 'A' to 'B' work is done by the gas

$\therefore\ dw \neq 0$

68.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

Consider the above reaction, what mass of $CaCl_2$ will be formed if 250 ml, of 0.76 M HCl reacts with 1000g of $CaCO_3$?

(Given : Molar mass of Ca, C, O, H and Cl are 40,12,16,1 and 35.5 g mol^{-1} respectively)

1) 10.545 g 2) 3.908 g 3) 5.272 g 4) 2.636 g

Key : 1

Sol : $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

No. of moles of $HCl = \dfrac{M \times w}{1000}$

$= \frac{0.76 \times 250}{1000}$

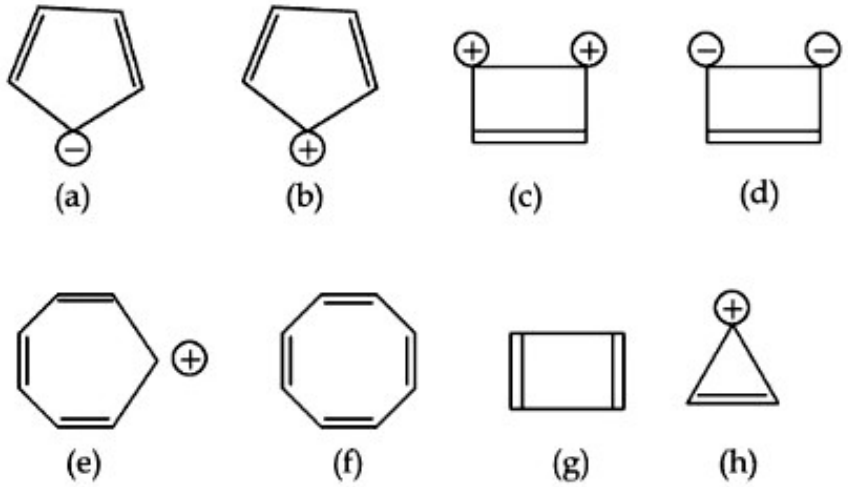
No. of HCl moles = 0.19 mole of HCl.

$2 \times 36.5g$ of HCl $\rightarrow 111g$ of $CaCl_2$

$0.19 \times 36.5g$ _____?

$\frac{0.19 \times 111 \times 36.5}{2 \times 36.5} = 10.545g$

69. Designate whether each of the following compounds is aromatic or not aromatic.



1) a,c,d,e,h aromatic and b,f,g not aromatic
2) e,g aromatic and a,b,c,d,f,h not aromatic
3) b,e,f,g aromatic and a,c,d,h not aromatic
4) a,b,c,d aromatic and e,f,g,h not aromatic

Key : 1

Sol : a,c,d,e,h are aromatic because they are satisfied Huckel's rule of aromaticity
Where as b & g are anti aromatic
f is non aromatic due to non-planarity.

70. According to Bohr's model of hydrogen atom, which of the following statement is incorrect?
A) Radius of 4th orbit is four times larger than that of 2nd orbit
B) Radius of 8th orbit is four times larger than that of 4th orbit
C) Radius of 3rd orbit is nine times larger than that of 1st orbit
D) Radius of 6th orbit is three times larger than that of 4th orbit.

Key : 4

Sol : 1) Radius of 4th orbit is four times larger tan that of 2nd orbit

$\therefore$ radius ratio $= \frac{n_4^2}{n_2^2} = \frac{(4)^2}{(2)^2} = \frac{16}{4} = 4$

this statement is correct

2) Radius of 8th orbit is four times larger than that of 4th orbit

$\therefore$ radius ratio $= \frac{(n8)^2}{n_4^2} = \frac{8^2}{4^2} = \frac{64}{16} = 4$

This statement is correct

3) Radius of third orbit is nine time larger than that of 1st orbit

Radius ratio $= = \frac{(n3)^2}{n_1^2} = \frac{(3)^2}{1^2} = \frac{9}{1} = 9$

This statement is correct

4) Radius of 6th orbit is three times larger than that of 4th orbit

Radius ratio $= = \frac{(n6)^2}{n_4^2} = \frac{6^2}{4^2} = \frac{36}{16} = 2.25$

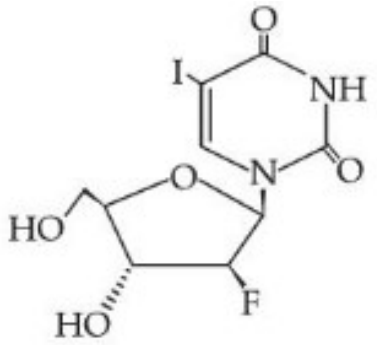
Not 3

This statement is incorrect.

$\therefore$ final answer is 4.

SECTION-II

71. 0.1 mol of the following given antiviral compound (P) will weigh _____ $\times 10^{-1} g$



(P)

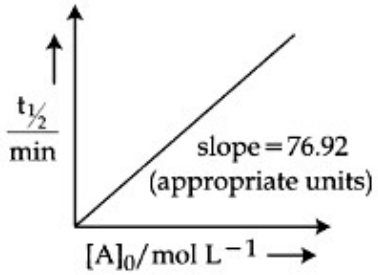
(Given : molar mass in g $mol^{-1} H:1, C:12, N;14, O:16, F:19, I:127$)

Key : 372

Sol : 1 mole of antiviral compound (P) weighs -372gm.

so, 0.1 mol of given antiviral compound weighs $372 \times 10^{-1} g$

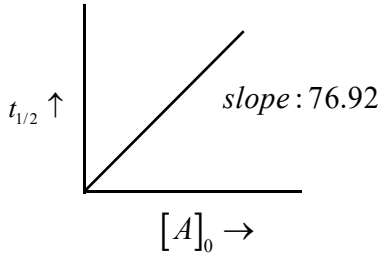
72. For the reaction $A \rightarrow$ products



The concentration of A at 10 minutes is _____ $\times 10^{-3} mol\ L^{-1}$ (nearest integer). The reaction was started with 2.5 mol L^{-1} of A.

Key : 2435

Sol :



For zero order

$t_{1/2} \alpha [A]_0$

$t_{1/2} = \frac{[A_0]}{2k_0}$

Slope (m) $= \frac{1}{2k_0}$

$\frac{1}{2k_0} = 76.92$

$k_0 = \frac{1}{76.92 \times 2}$

$k_0 = 0.0065 = 65 \times 10^{-4}$

$k_0 = \frac{[A]_0 - [A]_t}{t}$

$t = 10\,\text{min}$

$65 \times 10^{-4} = 2.5 - [A]_t$

$[A]_t = 2.5 - \left(65 \times 10^{-4} \times 10\right)$

$[A]_t = 2.5 - 65 \times 10^{-3}$

$= 2.5 - 6.5 \times 10^{-2}$

$= 2.435 = 2435 \times 10^{-3}$

73. Consider the following equilibrium $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

0.1 mol of CO along with a catalyst is present in a 2 dm^3 flask maintained at 500K. Hydrogen is introduced into the flask until the pressure is 5 bar and 0.04 mol of CH_3OH is formed. The K_p^0 is _____$\times 10^{-3}$ (nearest integer).

Given: $R = 0.08$ dm^3 bar K^{-1} mol^{-1}

Assume only methanol is formed as the product and the system follows ideal gas behaviour.

Key : 74

Sol : Ideal gas is Pv=nRT

Equilibrium constant Kp is defined in terms of partial pressures.

Change in moles of $CH_3OH = +0.04mol$

Change in moles of $CO = -0.04$ moles

Change in the moles of H_2 is $-2 \times 0.04 = -00.08mol$

$\therefore$ moles of CO at equilibrium $= 0.1 - 0.04 = 0.06mol$

Moles of H_2 at equilibrium initial $n_{H_2\text{initial}} - 0.08$

Moles of CH_3OH at equilibrium =0.04

$n_{total} = n_{CO} + n_{H_2} + n_{CH_3OH}$

$= 0.06 + n_{H_2\text{initial}} - 0.08 + 0.04$

$n_{total} = n_{H_2initial} + 0.02$

$\therefore\ P_{total}v = n_{total}RT$

$5 \times 2 = \left(n_{H_2\text{intial}} + 0.02\right) \times 0.08 \times 500$

$10 = \left(n_{H_2\,\text{intial}} + 0.02\right) \times 40$

$n_{H_2\,\text{int}ial} + 0.02 = \frac{10}{40} = 0.25$

$n_{H_2\,\text{int}ial} = 0.25 - 0.02 = 0.23mol$

$n_{H_2\,equilibrium} = 0.23 - 0.08 = 0.15mol$

$n_{total} = 0.06 + 0.15 + 0.04 = 0.25 mol$

$P_i = \frac{n_i}{n_{total}} \times P_{total}$

$P_{Co} = \frac{0.06}{0.25} \times 5 = 1.2 bar$

$P_{H_2} = \frac{0.15}{0.25} \times 5 = 3 bar$

$P_{CH_3OH} = \frac{0.04}{0.25} \times 5 = 0.8 bar$

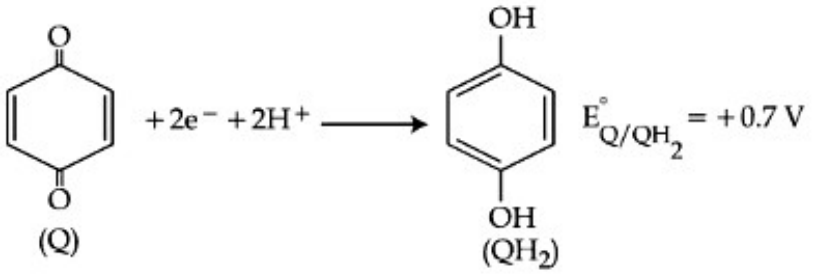
$K_p = \frac{P_{CH_3OH}}{P_{Co} \times P_{H_2}^2} = \frac{0.8}{1.2 \times 3^2} = \frac{0.8}{1.2 \times 9}$

$= 0.07407 = 74.07 \times 10^{-3}$

74. Consider the following electrochemical cell at standard condition

$Au(s)|QH_2,Q|NH_4X(0.01\ M)||Ag^+(1\ M)|Ag(s)\ \ E_{cell} = +0.4\ V$

The couple QH_2 / Q represents quinhydrone electrode, the half cell reaction is given below



[Given : $E^0_{Ag^+/Ag} = +0.8V$ and $\frac{2.303RT}{F} = 0.06V$]

The pK_b value of the ammonium halide salt (NH_4X) used here is _____(nearest integer)

Key : 6

Sol : $2Ag^+ + 2e^- \rightarrow 2Ag$

$QH_2 \rightarrow Q + 2H^+ + 2e^-$

$2Ag^+ + QH_2 \rightarrow Q + 2Ag + 2H^+$

$K = \frac{\left[H^+\right]^2}{\left[Ag^{+2}\right]^2}$

$E_{Cell} = E^0_{Cell} - \frac{0.06}{2} \log \frac{\left[H^+\right]^2}{1^2}$

$\Rightarrow 0.4 = 0.1 - \frac{0.06}{2} \log \left[H^+\right]^2$

$\Rightarrow 0.3 = \frac{0.06}{2} \times 2 \log \left[H^+\right]$

$\Rightarrow 5 = -\log \left[H^+\right]$

$-\log \left[H^+\right] = \frac{1}{2} \log kw + \frac{1}{2} \log \left(-\frac{1}{2} \log kb\right)$

$pH = 5 = \frac{1}{2} \times 14 + \frac{1}{2} \times \log\left(10^{-2}\right) - \frac{1}{2} \log kb$

$\Rightarrow 5 = 7 + 1 - \frac{1}{2}\log kb$

$= 3 = \frac{1}{2}(-\log kb)$

$6 = pkb$

75. A transition metal (M) among Mn,Cr,Co and Fe has the highest standard electrode potential $\left(M^{3+}/M^{2+}\right)$. If forms a metal complex of the type $\left[M(CN)_6\right]^{4-}$. The number of electrons present in the e_g orbital of the complex is _____

Key : 1

Sol : Cobalt has highest value of $E^0_{Co^{+3}/Co^{+2}}$

The complex may be $\left[Co(CN)_6\right]^{-4}$

CN is a strong field ligand.

The configuration $t^6_{2g}e^1_g$

No. of electrons in e_g is 1