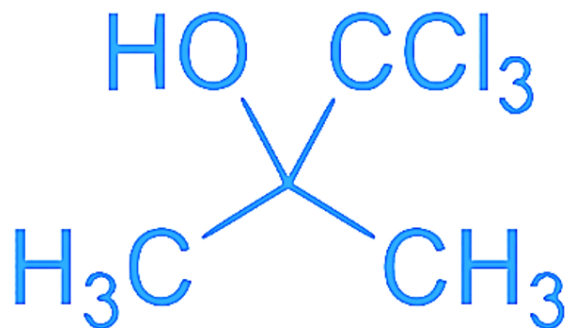


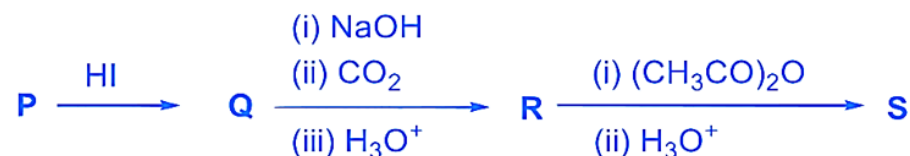
Chemistry

1. Reaction of iso-propylbenzene with O_2 followed by the treatment with H_3O^+ forms phenol and a by-product P . Reaction of P with 3 equivalents of Cl_2 gives compound Q . Treatment of Q with $Ca(OH)_2$ produces compound R and calcium salt S . The correct statement(s) regarding P , Q , R and S is(are) : A) Reaction of P with R in the presence of KOH followed by acidification gives $HO-C(CH_3)_2-CCl_3$



- B) Reaction of R with O_2 in the presence of light gives phosgene gas C) Q reacts with aqueous $NaOH$ to produce Cl_3CCH_2OH and $Cl_3CCOONa$ D) S on heating gives P
- A) A, B, D
 B) A, B, C
 C) A, C, D
 D) C, B, D

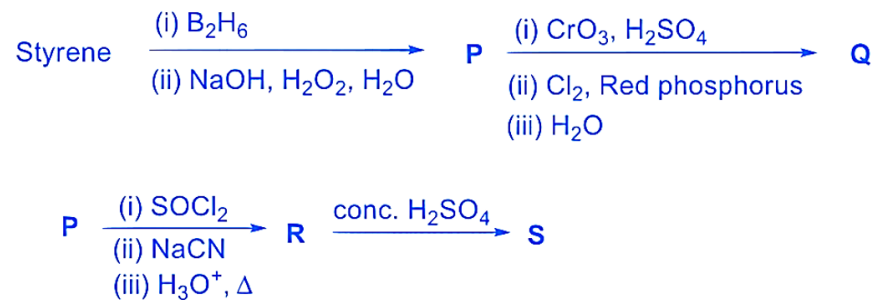
2. In the given reaction scheme, P is a phenyl alkyl ether, Q is an aromatic compound; R and S are the major products.



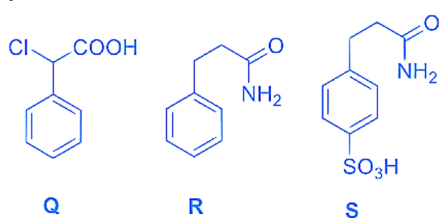
The correct statement about S is:

- A) It primarily inhibits noradrenaline degrading enzymes.
 B) It inhibits the synthesis of prostaglandin.
 C) It is a narcotic drug.
 D) It is ortho-acetylbenzoic acid.

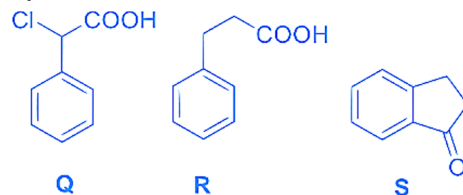
3. Consider the following reaction scheme and choose the correct option(s) for the major products Q,R and S.



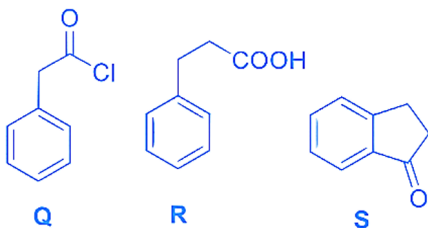
A)



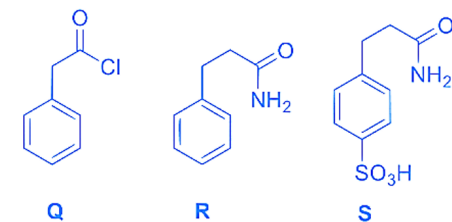
B)



C)



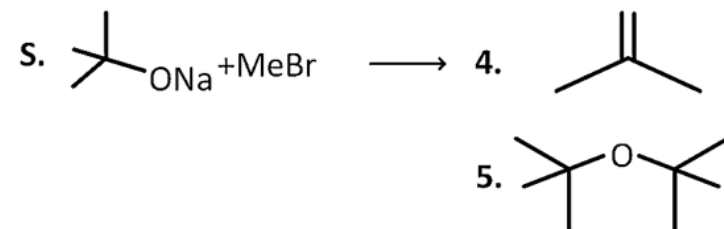
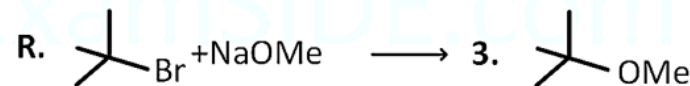
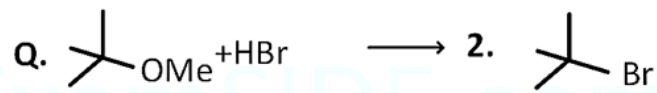
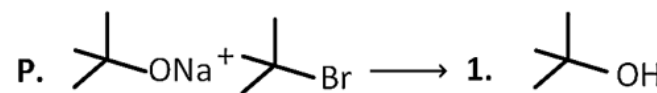
D)



4. Match the reactions in LIST-I with one or more products in LIST-II:

List - I

List - II



A) P – 1, 5; Q – 2; R – 3; S – 4

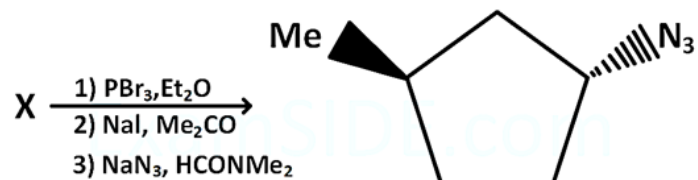
B) P – 1, 4; Q – 2; R – 4; S – 3

C)

D) P – 4, 5; Q – 4; R – 4; S – 3, 4

P – 1, 4; Q – 1, 2; R – 3, 4; S – 4

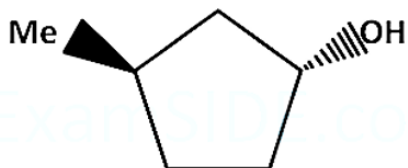
5. In the following reaction sequence, the correct structure(s) of X is



enantiomerically pure

(are):

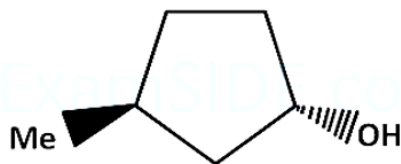
A)



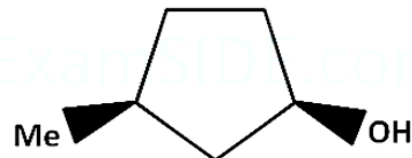
B)



C)



D)



6. For the identification of β -naphthol using dye test, it is necessary to use

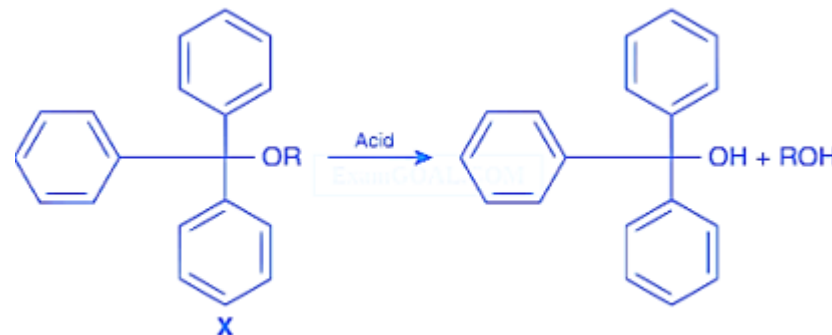
A) dichloromethane solution of β -naphthol.

B) acidic solution of β -naphthol.

C) neutral solution of β -naphthol.

D) alkaline solution of β -naphthol.

7. The acidic hydrolysis of ether (X) shown below is fastest when



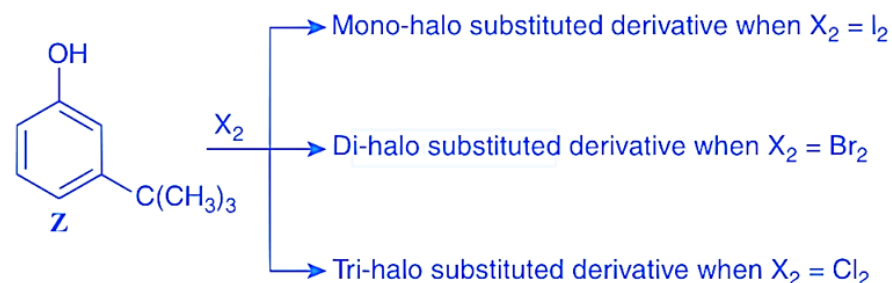
A) one phenyl group is replaced by a methyl group.

B) one phenyl group is replaced by a para-methoxyphenyl group.

C) two phenyl groups are replaced by two para-methoxyphenyl groups.

D) no structural change is made to X.

8. The reactivity of compound Z with different halogens under appropriate conditions is given below:



The observed pattern of electrophilic substitution can be explained by:

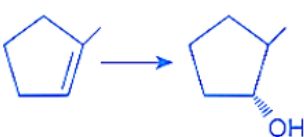
A) the steric effect on the halogen

B) the steric effect of the tert-butyl group

C) the electronic effect of the phenolic group

D) the electronic effect of the tert-butyl group

9. Match the chemical conversions in List I with the appropriate reagents in List II and select the correct answer using the code given below the lists:

List I	List II
P. 	1. (i) $\text{Hg}(\text{OAc})_2$; (ii) NaBH_4
Q. 	2. NaOEt
R. 	3. Et-Br
S. 	4. (i) BH_3 ; (ii) $\text{H}_2\text{O}_2/\text{NaOH}$

A) P-2, Q-3, R-1, S-4
C) P-2, Q-3, R-4, S-1

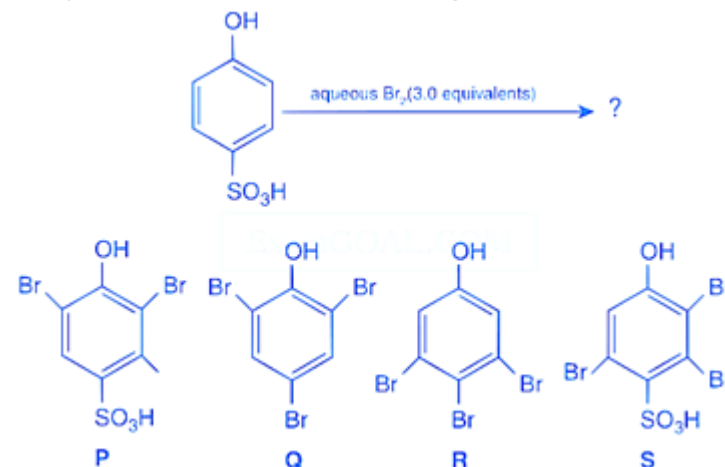
B) P-3, Q-2, R-1, S-4
D) P-3, Q-2, R-4, S-1

10. The compound that does NOT liberate CO_2 on treatment with aqueous sodium bicarbonate solution is:

A) Benzoic acid
C) Salicylic acid

B) Benzenesulphonic acid
D) Carboic acid (Phenol)

11. The major product(s) of the following reaction is(are)



A) P
C) R

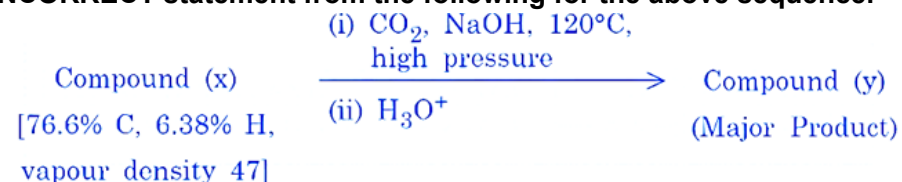
B) Q
D) S

12. (I) 1,2-Dihydroxybenzene (II) 1,3-Dihydroxybenzene (III) 1,4-Dihydroxybenzene (IV) Hydroxy benzene (Phenol) The increasing order of boiling points of the above mentioned alcohols is

A) $I < II < III < IV$
C) $IV < I < II < III$

B) $I < II < IV < III$
D) $IV < II < I < III$

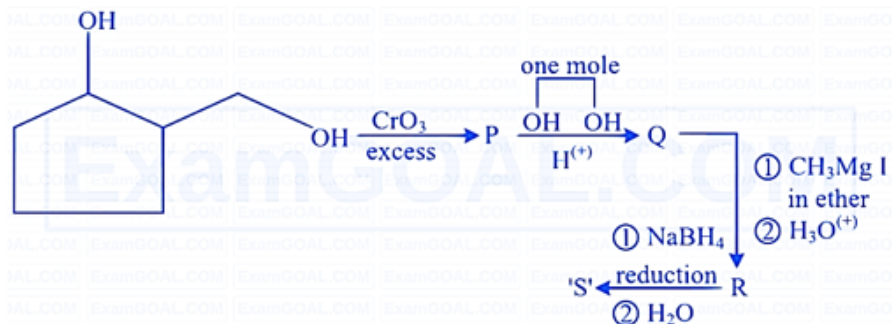
13. Consider the following reaction sequence: Compound (y) develops characteristic colour with neutral FeCl_3 solution. Identify the INCORRECT statement from the following for the above sequence.



A) Compound y will dissolve in NaHCO_3 and evolve a gas.
C) Both compounds x and y will dissolve in NaOH .

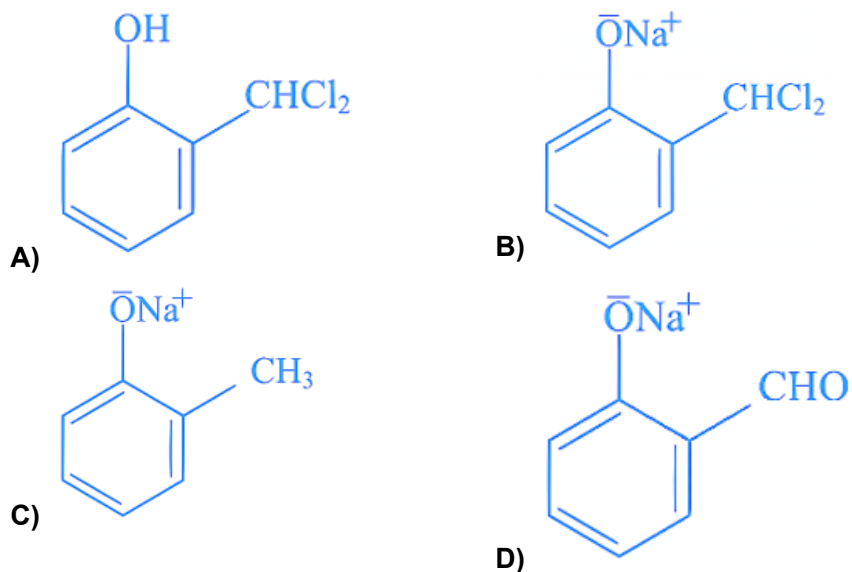
B) Compound x is more acidic than compound y.
D) Both compounds x and y will burn with sooty flame.

14. Given that 0.1 mole of compound S weighs ____g. Find the mass of 0.1 mole of compound S.

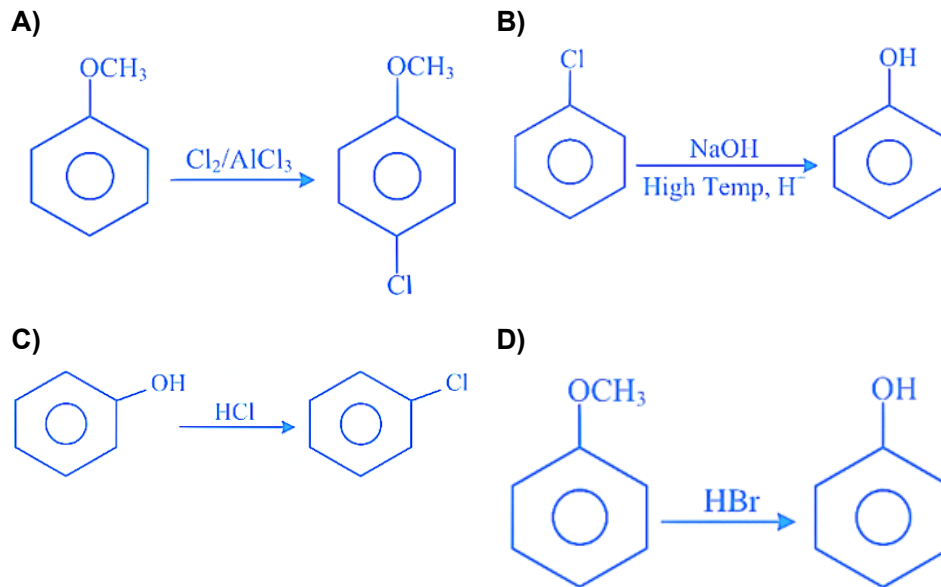


- A) 11 g
B) 13 g
C) 15 g
D) 17 g

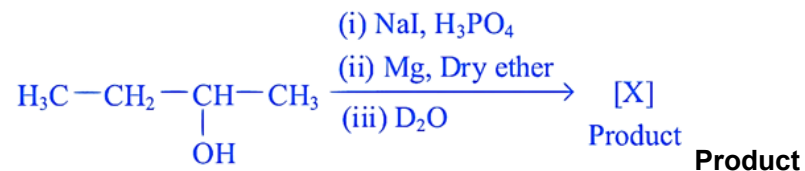
15. In Reimer-Tiemann reaction, phenol is converted into salicylaldehyde through an intermediate. The structure of intermediate is _____.



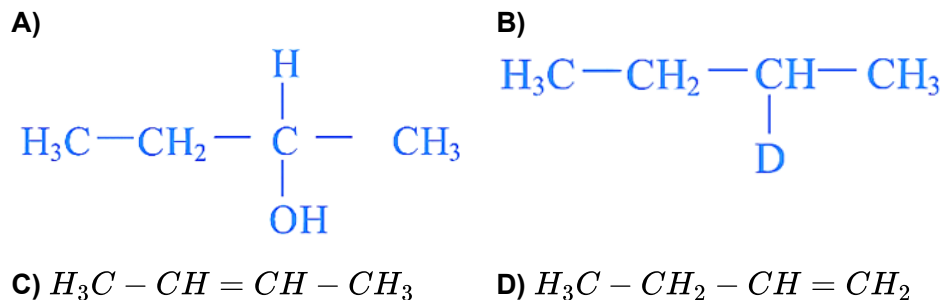
16. Which one of the following reactions is NOT possible?



17. Consider the following reaction sequence:



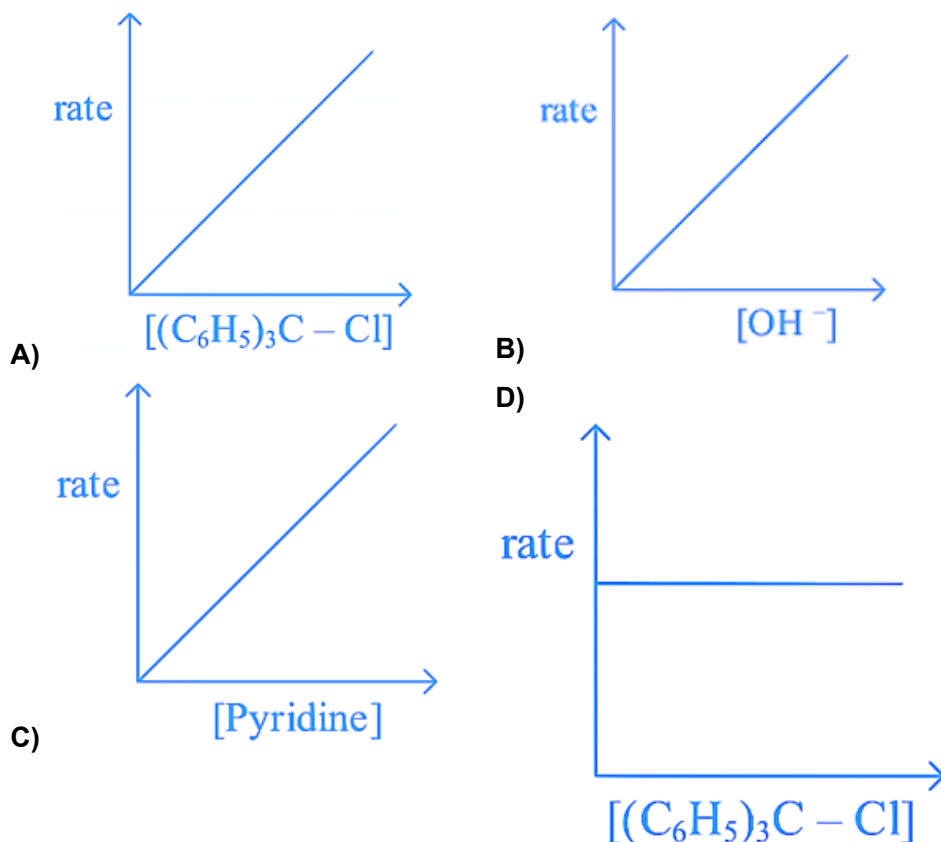
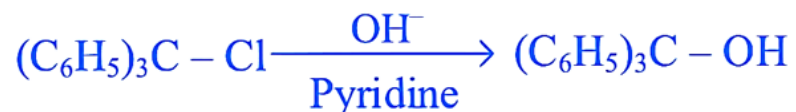
[X] formed in the above reaction is:



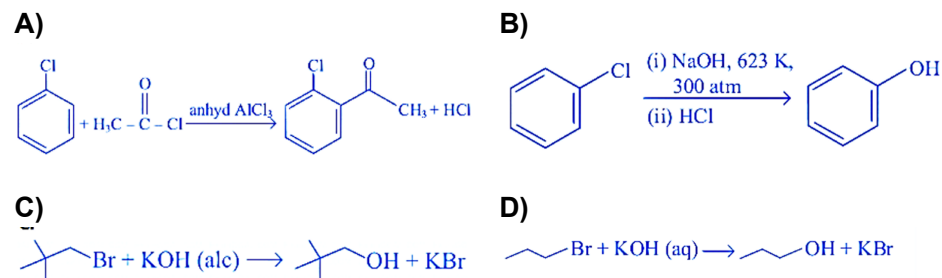
18. Given below are two statements: One is labelled as Assertion A and the other is labelled as Reason R. Assertion A: Butan-1-ol has higher boiling point than ethoxyethane. Reason R: Extensive hydrogen bonding leads to stronger association of molecules.

- A) A is false but R is true
 B) Both A and R are true but R is not the correct explanation of A
 C) Both A and R are true and R is the correct explanation of A
 D) A is true but R is false

19. The graph which represents the following reaction is:



20. Identify the incorrect option from the following:



21. An organic compound with molecular formula $\text{C}_8\text{H}_{10}\text{O}_2$ gives a violet coloration with neutral FeCl_3 solution and rotates plane-polarised light. Assuming it contains one phenolic $-\text{OH}$ group and one secondary alcohol group, what is the total number of possible isomers?
22. An organic compound has molecular formula $\text{C}_9\text{H}_{12}\text{O}_2$. It gives a violet colour with neutral FeCl_3 solution and rotates plane-polarised light. It contains one phenolic $-\text{OH}$ group, one secondary alcohol group in a $-\text{CH}(\text{OH})\text{CH}_3$ side chain, and one methyl group attached to the benzene ring. What is the total number of possible stereoisomers and positional isomers?
23. An organic compound ($\text{C}_8\text{H}_{10}\text{O}_2$) rotates plane-polarised light. It produces pink color with neutral FeCl_3 solution. What is the total number of all the possible isomers for this compound?
24. A hydroxy compound (X) with molar mass 122 g mol^{-1} is acetylated with acetic anhydride, using a large excess of the reagent ensuring complete acetylation of all hydroxyl groups. The product obtained has a molar mass of 290 g mol^{-1} . The number of hydroxyl groups present in compound (X) is:

25. One mole of phenol is treated with dilute HNO_3 at 298 K to give a mixture of products. The mixture is separated by steam distillation. The steam volatile compound (X) is separated. The increase in percentage of oxygen in (X) with respect to phenol is _____ $\times 10^{-1}\%$ (Given molar mass in g mol^{-1} : H : 1, C : 12, N : 14, O : 16)

Maths

26. Let $f(x) = \int \frac{2x}{(x^2+1)(x^2+3)} dx$. If $f(3) = \frac{1}{2}(\log_e 5 - \log_e 6)$, then $f(4)$ is equal to:

- A) $\log_e 19 - \log_e 20$ B) $\log_e 17 - \log_e 18$
C) $\frac{1}{2}(\log_e 19 - \log_e 17)$ D) $\frac{1}{2}(\log_e 17 - \log_e 19)$

27. Let $I(x) = \int \frac{x^2(x \sec^2 x + \tan x)}{(x \tan x + 1)^2} dx$. If $I(0) = 0$, then $I\left(\frac{\pi}{4}\right)$ is equal to:

- A) $\log_e \frac{(\pi+4)^2}{32} - \frac{\pi^2}{4(\pi+4)}$ B) $\log_e \frac{(\pi+4)^2}{16} - \frac{\pi^2}{4(\pi+4)}$
C) $\log_e \frac{(\pi+4)^2}{16} + \frac{\pi^2}{4(\pi+4)}$ D) $\log_e \frac{(\pi+4)^2}{32} + \frac{\pi^2}{4(\pi+4)}$

28. For $I(x) = \int \frac{\sec^2 x - 2022}{\sin^{2022} x} dx$, if $I\left(\frac{\pi}{4}\right) = 2^{1011}$, then:

- A) $3^{1010} I\left(\frac{\pi}{3}\right) - I\left(\frac{\pi}{6}\right) = 0$ B) $3^{1010} I\left(\frac{\pi}{6}\right) - I\left(\frac{\pi}{3}\right) = 0$
C) $3^{1011} I\left(\frac{\pi}{3}\right) - I\left(\frac{\pi}{6}\right) = 0$ D) $3^{1011} I\left(\frac{\pi}{6}\right) - I\left(\frac{\pi}{3}\right) = 0$

29. The integral $\int \left(\frac{x}{x \sin x + \cos x}\right)^2 dx$ is equal to (where C is a constant of integration):

- A) $\sec x - \frac{x \tan x}{x \sin x + \cos x} + C$ B) $\sec x + \frac{x \tan x}{x \sin x + \cos x} + C$
C) $\tan x - \frac{x \sec x}{x \sin x + \cos x} + C$ D) $\tan x + \frac{x \sec x}{x \sin x + \cos x} + C$

30. The integral $\int \cos(\log_e x) dx$ is equal to: (where C is a constant of integration)

- A) $\frac{x}{2}[\sin(\log_e x) - \cos(\log_e x)] + C$ B) $x[\cos(\log_e x) + \sin(\log_e x)] + C$
C) $\frac{x}{2}[\cos(\log_e x) + \sin(\log_e x)] + C$ D) $x[\cos(\log_e x) - \sin(\log_e x)] + C$

31. The value of the integral $\int_{\frac{\pi}{24}}^{\frac{5\pi}{24}} \frac{dx}{1 + \sqrt{\tan 2x}}$ is:

- A) $\frac{\pi}{3}$ B) $\frac{\pi}{18}$
C) $\frac{\pi}{6}$ D) $\frac{\pi}{12}$

32. The value of $\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{1}{1 + e^{\sin x}} dx$ is:

- A) π B) $\frac{3\pi}{2}$
C) $\frac{\pi}{2}$ D) $\frac{\pi}{4}$

33. The value of $\int_{-\pi/2}^{\pi/2} \frac{\cos^2 x}{1+3^x} dx$ is:

- A) 2π B) $\frac{\pi}{2}$
C) 4π D) $\frac{\pi}{4}$

34. The value $\int_0^1 \sqrt{2x^3 - 3x^2 + 3x - 1} dx$ is equal to:

- A) $5\sqrt{7}$ B) 1
C) 0 D) $2\sqrt{2}$

35. $\int_{-\pi}^{\pi} \frac{2x(1+\sin x)}{1+\cos^2 x} dx =$

- A) $\frac{\pi^2}{4}$ B) π^2
C) 0 D) $\frac{\pi}{2}$

36. $\int \frac{\cos x + x \sin x}{x(x + \cos x)} dx =$

- A) $\log \left| \frac{x}{x + \cos x} \right| + c$ B) $-\log \left| \frac{x}{x + \cos x} \right| + c$
C) $\log \left| \frac{x + \cos x}{2x} \right| + c$ D) $-\log \left| \frac{x + \cos x}{2x} \right| + c$

37. Integral of $\sqrt{1 + 2 \cot x (\cot x + \csc x)}$ with respect to x is:

- A) $2 \ln \cos \frac{x}{2} + c$ B) $2 \ln \sin \frac{x}{2} + c$
C) $\frac{1}{2} \ln \cos \frac{x}{2} + c$ D) $\ln \sin x \cdot \ln(\csc x - \cot x) + c$

38. $\int \frac{e^{\cot x}}{\sin^2 x} (2 \ln \csc x + \sin 2x) dx =$

- A) $-2e^{\cot x} \ln(\csc x) + c$ B) $e^{\cot x} \ln x + c$
 C) $e^{\cot x} \ln(\csc x) + c$ D) $e^{\cot x} \ln(\sin x) + c$

39. $\int \frac{1}{1+\cos x + \sin x} dx = \log_e |f(x)| + c$ then $f(x) =$

- A) $2 + \tan \frac{x}{2}$ B) $1 - \tan \frac{x}{2}$
 C) $2 - \tan \frac{x}{2}$ D) $1 + \tan \frac{x}{2}$

40. $\int_0^1 \frac{dx}{(5+2x-2x^2)(1+e^{2-4x})} =$

- A) $\frac{1}{2\sqrt{11}} \log_e \left(\frac{\sqrt{11}+1}{\sqrt{11}-1} \right)$ B) $\frac{1}{2\sqrt{11}} \log_e \left(\frac{\sqrt{11}+1}{\sqrt{11}} \right)$
 C) $\frac{1}{\sqrt{11}} \log_e \left(\frac{\sqrt{11}-1}{\sqrt{11}} \right)$ D) $\frac{1}{\sqrt{11}} \log_e \left(\frac{\sqrt{11}-1}{\sqrt{11}+1} \right)$

41. $\int_1^5 (x-1)(x-2)(x-3)(x-4)(x-5) dx =$

- A) 0 B) 2
 C) -2 D) 63

42. $\int_0^{1/\sqrt{2}} \frac{\sin^{-1} x}{(1-x^2)^{3/2}} dx =$

- A) $\frac{\pi}{4} + \frac{1}{2} \log 2$ B) $\frac{\pi}{4} - \frac{1}{2} \log 2$
 C) $\frac{\pi}{2} + \log 2$ D) $\frac{\pi}{2} - \log 2$

43. The value of $\int_{-1}^1 (\sqrt{1+x+x^2} - \sqrt{1-x+x^2}) dx$ is:

- A) 0 B) 1
 C) -1 D) None of these

44. $\int_0^{\pi/2} \frac{\sqrt{\cot x}}{\sqrt{\cot x} + \sqrt{\tan x}} dx =$

- A) π B) $\frac{\pi}{2}$
 C) $\frac{\pi}{4}$ D) $\frac{\pi}{3}$

45. $\int_0^{\pi/2} \frac{d\theta}{1+\tan \theta} =$

- A) π B) $\frac{\pi}{2}$
 C) $\frac{\pi}{3}$ D) $\frac{\pi}{4}$

46. Let $\int \frac{2-\tan x}{3+\tan x} dx = \frac{1}{2} (\alpha x + \log_e |\beta \sin x + \gamma \cos x|) + C$, where C is the constant of integration. Then $\alpha + \frac{\gamma}{\beta}$ is equal to:

47. The value of $\int_0^{20\pi} (\sin^4 x + \cos^4 x) dx$ is equal to $__\pi$:

48. If $\int_{-\pi/2}^{\pi/2} \frac{96x^2 \cos^2 x}{(1+e^x)} dx = \pi(\alpha\pi^2 + \beta)$, $\alpha, \beta \in \mathbb{Z}$, then $(\alpha + \beta)^2$ equals:

49. The integral $\int_{\pi/4}^{3\pi/4} \frac{dx}{1+\cos x}$ is equal to:

50. $\int_0^{\pi/2} \frac{\sin^{3/2} x dx}{\cos^{3/2} x + \sin^{3/2} x} = __\pi/x$, What is x value

Physics

51. When light of wavelength λ falls on a metallic surface, the stopping potential for the photoelectrons is 4.0, V. When a second light having wavelength twice that of the first light is used, the stopping potential becomes 1.5, V. The wavelength of the first light is _____ m. Given: $h = 6.63 \times 10^{-34}$, J.s, $e = 1.6 \times 10^{-19}$, C, $c = 3 \times 10^8$, m/s.

- A) 2.5×10^{-7} m B) 1.25×10^{-7} m
 C) 5.0×10^{-7} m D) 3.75×10^{-7} m

52. A light wave described by

$E = 50[\sin(4 \times 10^{15}t) + \sin(10 \times 10^{15}t)]$ (in SI units) falls on a metal surface of work function 2.0, eV. The maximum kinetic energy of the emitted photoelectrons is approximately _____ eV.

Given: $h = 6.6 \times 10^{-34}$, J.s and $e = 1.6 \times 10^{-19}$, C.

- A) 2.6 eV B) 4.6 eV
 C) 6.6 eV D) 8.6 eV

53. An electron of mass m is moving in an electric field $\vec{E} = -3E_0\hat{i}$, where E_0 is a positive constant, with an initial velocity $\vec{v} = v_0\hat{i}$, where $v_0 > 0$. If $\lambda_0 = \frac{h}{5mv_0}$ is its de Broglie wavelength at $t = 0$, its de Broglie wavelength at time t is

- A) $\frac{5\lambda_0}{1 - \frac{3eE_0}{mv_0}t}$ B) $\frac{5\lambda_0}{1 + \frac{3eE_0}{mv_0}t}$
 C) $\frac{5\lambda_0}{1 - \frac{6eE_0}{mv_0}t}$ D) $\frac{5\lambda_0}{1 + \frac{6eE_0}{mv_0}t}$

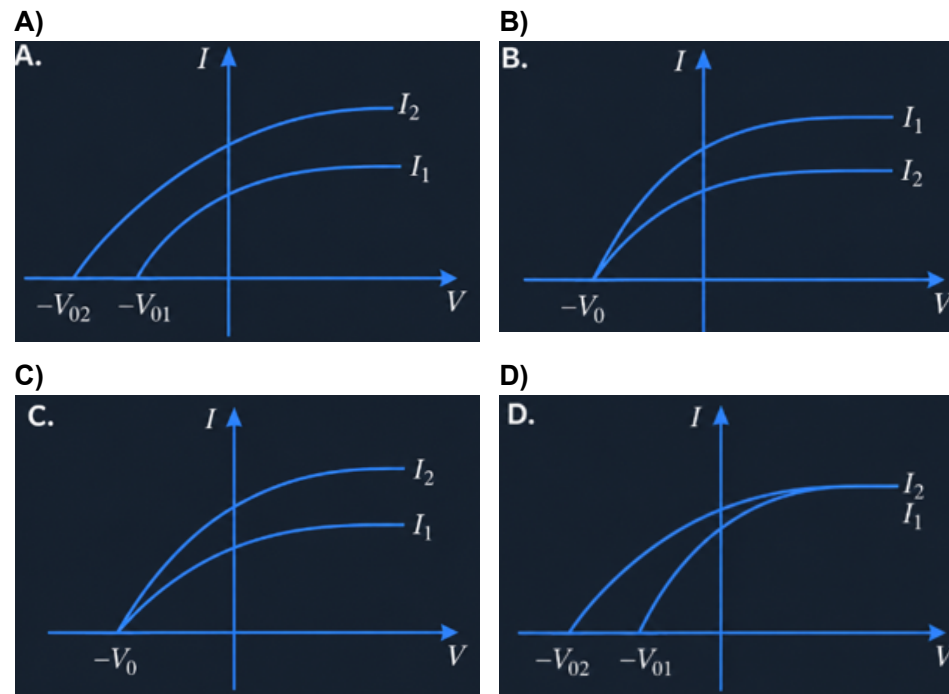
54. The work functions of potassium (K) and calcium (Ca) metals are 2.3, eV and 2.9, eV, respectively. If light of wavelength 500, nm is incident on these two metal surfaces, the photoelectric effect is possible for the case of

- A) Both K and Ca B) Neither K nor Ca
 C) Ca only D) K only

55. When UV light of wavelength 400, nm is incident on a metal surface having work function 2.0, eV, electron emission takes place. The stopping potential is: (Given $hc = 1240$, eV nm)

- A) 0.8V B) 1.1V
 C) 2.0V D) 3.1V

56. Which figure shows the correct variation of applied potential difference V with photoelectric current I for two different intensities of light ($I_1 < I_2$) having the same wavelength?

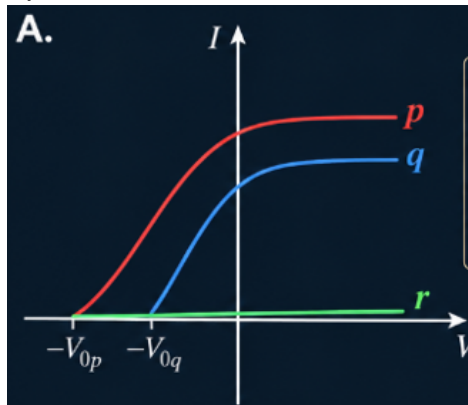


57. A metal surface is illuminated by light of two different wavelengths 250, nm and 400, nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are u_1 and u_2 , respectively. If the ratio $u_1 : u_2 = 2 : 1$ and $hc = 1240$, eV nm, the work function of the metal is nearly

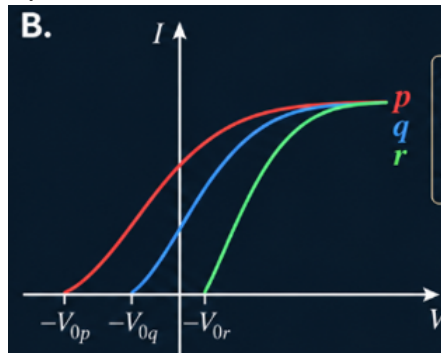
- A) 2.5, eV B) 3.1, eV
 C) 2.0, eV D) 3.7, eV

58. Photoelectric-effect experiments are performed using three different metal plates p , q and r , having work functions $\phi_p = 2.0$, eV, $\phi_q = 2.5$, eV and $\phi_r = 3.0$, eV, respectively. Monochromatic light of wavelength 450 , nm and equal intensity is incident on each plate. Assume 100 photoelectric emission efficiency and take $hc = 1240$, eV nm. The correct I - V graph is:

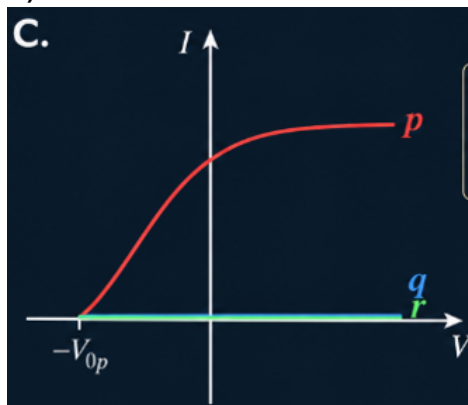
A)



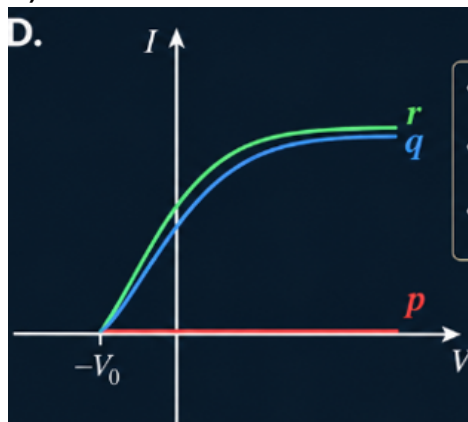
B)



C)



D)



59. The potential energy of a particle of mass m is given by

$$U(x) = \begin{cases} E_0, & 0 \leq x \leq 1 \\ 0, & x > 1 \end{cases} \quad \text{If } \lambda_1 \text{ and } \lambda_2 \text{ are the de Broglie}$$

wavelengths of the particle when $0 \leq x \leq 1$ and $x > 1$, respectively, and the total energy of the particle is $3E_0$, then the value of $\frac{\lambda_1}{\lambda_2}$ is:

A) $\sqrt{\frac{3}{2}}$

B) $\sqrt{2}$

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

D) 2

60. In the hydrogen atom spectrum, let R be the Rydberg constant.

Consider the following statements: A. The maximum wavelength of

the radiation in the Balmer series is $\frac{36}{5R}$. B. The Balmer series lies in the visible region of the electromagnetic spectrum. C. The

minimum wavelength of the radiation in the Paschen series is $\frac{9}{R}$.

D. The minimum wavelength of the radiation in the Lyman series is $\frac{1}{R}$. Choose the correct answer from the options given below.

A) A, B and C only

B) B, C and D only

C) A and D only

D) A, B, C and D

61. The energy of an electron in an orbit of the Bohr atom is $-0.04E_0$ eV, where E_0 is the ground-state energy. If L is the angular momentum of the electron in this orbit and h is Planck's constant, then $\frac{2\pi L}{h}$ is _____.

A) 6

B) 2

C) 5

D) 4

62. The ratio of the momentum of the photons corresponding to the 1st and 2nd lines of the Paschen series of hydrogen atoms is α/β . The possible values of α and β are:

- A) 128 and 189 B) 5 and 7
C) 189 and 128 D) 7 and 5

63. Considering the Bohr model of hydrogen-like atoms, the ratio of the radius of the 4th orbit of the electron in Be^{3+} and Li^{2+} is

- A) $\frac{3}{4}$ B) $\frac{4}{3}$
C) $\frac{9}{16}$ D) $\frac{16}{9}$

64. Assuming the validity of Bohr's atomic model for hydrogen-like ions, the radius of Li^{2+} ion in its ground state is given by $\frac{1}{X}a_0$, where a_0 is the first Bohr radius. The value of X is _____.

- A) 2 B) 9
C) 1 D) 3

65. Consider a hydrogen atom with v_k , r_k , and K_k denoting the velocity, orbital radius, and kinetic energy of the electron in the k^{th} orbit, respectively. The electron undergoes a transition from the n^{th} orbit to the 2nd orbit, emitting radiation corresponding to the Balmer series. Considering h to be Planck's constant and ε_0 the permittivity of free space, the correct statement(s) is/are:

- A) The magnitude of change in kinetic energy of the electron can be expressed as $\frac{he^2}{8\pi\varepsilon_0 h} \left(\frac{1}{r_2} - \frac{1}{r_n} \right)$.
B) The magnitude of change in de Broglie wavelength of the electron can be expressed as $\frac{4\pi\varepsilon_0 h^2}{e^2} \left| \frac{1}{n} - \frac{2}{n^2} \right|$.
C) The frequency of the radiation emitted can be expressed as $\frac{e^2}{8\pi\varepsilon_0 h} \left(\frac{1}{r_2} - \frac{1}{r_n} \right)$.
D) The magnitude of change in total energy of the electron can be expressed as $\frac{he^2}{4\pi\varepsilon_0} \left| \frac{v_n}{r_n} - \frac{v_2}{r_2} \right|$.

66. A particle of mass m is moving in a circular orbit under the influence of the central force $F(r) = -kr$, corresponding to the potential energy $V(r) = kr^2/2$, where k is a positive force constant and r is the radial distance from the origin. According to Bohr's quantization rule, the angular momentum of the particle is given by $L = n\hbar$, where $\hbar = h/(2\pi)$, h is Planck's constant, and n is a positive integer. If v and E are the speed and total energy of the particle, respectively, then which of the following expression(s) is(are) incorrect?

- A) $v^2 = n\hbar\sqrt{\frac{1}{mk}}$ B) $v^2 = n\hbar\sqrt{\frac{k}{m^3}}$
C) $\frac{L}{mr^2} = \sqrt{\frac{k}{m}}$ D) $E = \frac{n\hbar}{2}\sqrt{\frac{k}{m}}$

67. A free hydrogen atom after absorbing a photon of wavelength λ_a gets excited from the state $n = 1$ to the state $n = 4$. Immediately after that the electron jumps to $n = m$ state by emitting a photon of wavelength λ_e . Let the change in momentum of atom due to the absorption and the emission be Δp_a and Δp_e , respectively. If $\frac{\lambda_a}{\lambda_e} = 5$, which of the option(s) is/are correct? [Use $hc = 1242, \text{eVnm}$; $1, \text{nm} = 10^{-9}, \text{m}$, h and c are Planck's constant and speed of light in vacuum, respectively]

- A) The ratio of kinetic energy of the electron in the state $n = m$ to the state $n = 1$ is $\frac{1}{4}$ B) $m = 2$
C) $\frac{\Delta p_a}{\Delta p_e} = \frac{1}{4}$ D) $\lambda_e = 418, \text{nm}$

68. The wavelength of the first spectral line in the Balmer series of hydrogen atom is 6561. The wavelength of the second spectral line in the Balmer series of doubly-ionized lithium atom Li^{2+} is approximately:

- A) 540 B) 1215
C) 1640 D) 2430

69. A diatomic molecule has moment of inertia I . According to Bohr's quantization condition, its rotational energy in the n^{th} level ($n = 0$ is not allowed) is _____.

- A) $\frac{1}{n^2} \left(\frac{h^2}{8\pi^2 I} \right)$ B) $\frac{1}{n} \left(\frac{h^2}{8\pi^2 I} \right)$
 C) $n \left(\frac{h^2}{8\pi^2 I} \right)$ D) $n^2 \left(\frac{h^2}{8\pi^2 I} \right)$

70. The ratio of the kinetic energy of the $n = 2$ electron for the H atom to that of He^+ ion is

- A) $\frac{1}{4}$ B) $\frac{1}{2}$
 C) 1 D) 2

71. Consider an electron in the $n = 4$ orbit of a hydrogen-like atom with atomic number Z . At absolute temperature T , a neutron having thermal energy $k_B T$ has the same de Broglie wavelength as that of this electron. If this temperature is given by $T = \frac{Z^2 h^2}{\alpha \pi^2 a_0^2 m_N k_B}$, where h is Planck's constant, k_B is the Boltzmann constant, m_N is the mass of the neutron, and a_0 is the first Bohr radius of hydrogen, then the value of α is _____.

72. A hydrogen-like atom has atomic number Z . Photons emitted in the electronic transition from level $n = 5$ to level $n = 3$ in these atoms are used to perform a photoelectric-effect experiment on a target metal. The maximum kinetic energy of the photoelectrons generated is 4.704, eV. If the photoelectric threshold wavelength for the target metal is 310, nm, the value of Z is _____. Given: $hc = 1240, \text{eV} \cdot \text{nm}$ and $Rhc = 13.6, \text{eV}$, where R is the Rydberg constant.

73. In a photoelectric experiment, a parallel beam of monochromatic light with power of 160, W is incident on a perfectly absorbing cathode of work function 5.0, eV . The frequency of light is just above the threshold frequency, so that the photoelectrons are emitted with negligible kinetic energy. Assume that the photoelectron emission efficiency is 100. A potential difference of 500, V is applied between the cathode and the anode. All the emitted electrons are incident normally on the anode and are absorbed. The anode experiences a force $F = n \times 10^{-4}, N$ due to the impact of the electrons. The value of n is _____. Given: Mass of electron $m_e = 9 \times 10^{-31}, kg$ and $1.0, eV = 1.6 \times 10^{-19}, J$.

74. An electron in an excited state of Be^{3+} ion has angular momentum $\frac{5h}{2\pi}$. The de Broglie wavelength of the electron in this state is $p\pi a_0$ (where a_0 is the Bohr radius). The value of p is _____ $\frac{5}{x}$ is?.

75. The work functions of potassium and calcium are 2.3, eV and 2.9, eV, respectively. The ratio of the slope of the stopping potential versus frequency plot for potassium to that for calcium is _____.

ANSWER KEY

Chemistry

1.	1	8.	2	15.	2	22.	20
2.	2	9.	1	16.	3	23.	6
3.	2	10.	4	17.	2	24.	4
4.	2	11.	3	18.	3	25.	175
5.	2	12.	3	19.	1		
6.	4	13.	2	20.	3		
7.	3	14.	2	21.	6		

Maths

26.	4	33.	4	40.	1	47.	15
27.	1	34.	3	41.	1	48.	100
28.	1	35.	2	42.	2	49.	2
29.	3	36.	1	43.	1	50.	4
30.	3	37.	2	44.	3		
31.	4	38.	1	45.	4		
32.	3	39.	4	46.	4		

Physics

51.	1	58.	1	65.	3	72.	3
52.	2	59.	1	66.	4	73.	24
53.	2	60.	4	67.	1	74.	2
54.	4	61.	3	68.	1	75.	1
55.	2	62.	1	69.	4		
56.	3	63.	1	70.	1		
57.	1	64.	4	71.	128		

SOLUTIONS

Q1.

Answer: A

Explanation:

Identification of *P*: Cumene (isopropylbenzene) oxidation via the cumene hydroperoxide process yields phenol and acetone ($P = \text{CH}_3\text{COCH}_3$). Identification of Q, R, S: Acetone (*P*) reacts with 3 equivalents of Cl_2 to form 1,1,1-trichloroacetone ($Q = \text{Cl}_3\text{CCOCH}_3$). Treatment of *Q* with $\text{Ca}(\text{OH})_2$ causes haloform-like cleavage yielding chloroform ($R = \text{CHCl}_3$) and calcium acetate/salt ($S = \text{Ca}(\text{CH}_3\text{COO})_2$). Evaluating Options: A is correct: Reaction of acetone (*P*) with chloroform (*R*) in the presence of KOH (adapted Corey-Chaykovsky / base-catalyzed addition / chloretone synthesis) yields 1,1,1-trichloro-2-methylpropan-2-ol (chloretone). B is correct: Oxidation of chloroform ($R = \text{CHCl}_3$) with O_2 in the presence of light produces highly toxic phosgene (COCl_2) gas. D is correct: Thermal decomposition (dry distillation) of calcium acetate (*S*) gives acetone (*P*).

Q2.

Answer: B

Explanation:

The reaction sequence represents the classic synthesis of Aspirin (acetylsalicylic acid). Phenol or its derivative (*P*) undergoes Kolbe's reaction using NaOH followed by CO_2 and acidification to yield salicylic acid (*Q*). Salicylic acid (*Q*) upon acetylation with acetic anhydride $[(\text{CH}_3\text{CO})_2\text{O}]$ gives acetylsalicylic acid (*S*). Aspirin (*S*) acts as a non-steroidal anti-inflammatory drug (NSAID) and inhibits the synthesis of prostaglandins, which are chemicals mediating inflammation and pain.

Q3.

Answer: B

Explanation:

The reaction sequence starts with a specific functionalized substrate *P* subjected to chlorination using SOCl_2 , followed by nucleophilic substitution with NaCN and acid-catalyzed hydrolysis with heating (H_3O^+ , Δ) to form intermediate *Q* or *R*. Treatment with concentrated H_2SO_4 promotes intramolecular cyclization or sulfonation to form the major product *S*.

Q4.

Answer: B

Explanation:

Reaction P involves a sterically hindered tertiary alkyl halide and a strong base/nucleophile, leading predominantly to elimination ($\text{E}2$) to form an alkene along with some substitution. Reaction Q proceeds via an $\text{S}_{\text{N}}1$ mechanism due to the stability of the tertiary carbocation. Reaction R features a tertiary alkyl halide with a strong methoxide base, favoring elimination ($\text{E}2$). Reaction S involves a primary halide (MeBr) and a strong nucleophile, undergoing a clean $\text{S}_{\text{N}}2$ substitution to form an ether.

Q5.

Answer: B

Explanation:

The reaction sequence converts an optically active alcohol (X) into an azide with a net retention of configuration due to two successive $\text{S}_{\text{N}}2$ inversions. The first step involves PBr_3 with configuration inversion, the second step is a Finkelstein reaction with NaI causing a second inversion, and the third step is an $\text{S}_{\text{N}}2$ displacement with NaN_3 causing a third inversion. An odd number of inversions (3) results in the final stereochemical outcome relative to the starting alcohol. By tracing backward from the final product's configuration, we find that the starting alcohol X must possess the trans configuration between the methyl and hydroxyl groups.

Q6.

Answer: D

Explanation:

The dye test for phenols (β -naphthol) involves coupling with a diazonium salt (such as benzene diazonium chloride). This electrophilic aromatic substitution proceeds efficiently only when β -naphthol is converted into its corresponding naphthoxide ion in an alkaline medium, which greatly enhances the nucleophilicity of the aromatic ring.

Q7.

Answer: C

Explanation:

Acidic cleavage of ethers proceeds via an S_N1 mechanism involving the formation of a carbocation intermediate. Introducing electron-donating groups (such as a methoxy group at the para position of the phenyl rings) stabilizes the developing positive charge on the central carbon atom through resonance. Since ether X contains three phenyl groups attached to the central carbon, replacing two of these phenyl groups with electron-rich para-methoxyphenyl groups maximizes carbocation stabilization and significantly accelerates the rate of acidic hydrolysis.

Q8.

Answer: B

Explanation:

The nature of the incoming halogen (I_2 , Br_2 , Cl_2) varies in size and bulkiness. The bulky ortho/para directing groups and the bulky tert-butyl group create varying steric hindrance, influencing whether mono-, di-, or tri-substitution occurs depending on the steric bulk of the attacking halogen and the substituents on the ring.

Q9.

Answer: A

Explanation:

Each chemical conversion in List I corresponds to a standard organic reaction mechanism. For instance, converting a sodium phenoxide or alkoxide to an ethyl ether involves nucleophilic substitution using an alkyl halide ($Et - Br$), while alkene hydration methods depend on specific reagents such as oxymercuration-demercuration or hydroboration-oxidation.

Q10.

Answer: D

Explanation:

A compound can liberate carbon dioxide (CO_2) from an aqueous sodium bicarbonate ($NaHCO_3$) solution only if it is a stronger acid than carbonic acid (H_2CO_3). Carboic acid (phenol) is a weaker acid than carbonic acid and therefore does not react to liberate CO_2 .

Q11.

Answer: C

Explanation:

When 4-hydroxybenzenesulphonic acid is treated with 3.0 equivalents of aqueous Br_2 , the strongly activating phenolic group ($-OH$) directs electrophilic bromination to its ortho positions. Furthermore, the sulphonic acid group ($-SO_3H$) is a good leaving group and undergoes ipso-substitution (desulphonation) due to the strong activation by the $-OH$ group, yielding tribromophenol as the major product.

Q12.

Answer: C

Explanation:

Boiling points primarily depend on molecular mass, symmetry, and the extent of intermolecular hydrogen bonding. Hydroxy benzene (phenol) has only one $-OH$ group and forms relatively less extensive hydrogen bonding compared to dihydroxybenzenes which contain two $-OH$ groups. Among the dihydroxybenzenes, intramolecular hydrogen bonding in 1,2-dihydroxybenzene (catechol) lowers its boiling point, whereas intermolecular hydrogen bonding and symmetry are highest in 1,4-dihydroxybenzene (hydroquinone), giving it the highest boiling point.

Q13.

Answer: B

Explanation:

Compound (x) is phenol (C_6H_5OH), which undergoes Kolbe's reaction to yield salicylic acid as compound (y). Salicylic acid contains both phenolic $-OH$ and carboxylic $-COOH$ groups, making it more acidic than phenol due to intramolecular hydrogen bonding and stronger electron-withdrawing effects of the carboxylate group in its conjugate base. Thus, Statement B is incorrect.

Q14.

Answer: B

Explanation:

Based on the reaction sequence shown in the image (corresponding to JEE Main 2025 Q21), catechol undergoes oxidation with excess CrO_3 to form benzoquinone (P), which rearranges with H^+ to form a hydroxy-substituted quinone derivative (Q). Subsequent reduction of carbonyl groups with NaBH_4 yields compound R, and Grignard methylation followed by hydrolysis yields compound S ($\text{C}_7\text{H}_{10}\text{O}_2$, molar mass 130 g mol^{-1}). Thus, 0.1 mole of compound S weighs 13 g.

Q15.

Answer: B

Explanation:

In the Reimer-Tiemann reaction, phenol is treated with chloroform (CHCl_3) and aqueous sodium hydroxide (NaOH). Phenol first converts to sodium phenoxide. The reaction proceeds via the attack of dichlorocarbene ($:\text{CCl}_2$) on the ortho-position of the phenoxide ion, forming a substituted benzal chloride intermediate containing an $-\text{O}^-\text{Na}^+$ group and a $-\text{CHCl}_2$ group, which upon subsequent alkaline hydrolysis and acidification yields salicylaldehyde.

Q16.

Answer: C

Explanation:

The $-\text{OH}$ group in phenol is strongly bonded due to partial double bond character of the C-O bond arising from resonance with the benzene ring. Consequently, the cleavage of the C-O bond in phenol by HCl or other hydrohalic acids under normal conditions is not possible to yield chlorobenzene. Phenol is instead produced from chlorobenzene under drastic conditions (Dow's process, Option B), and ethers like methoxybenzene undergo cleavage with HBr (Option D).

Q17.

Answer: B

Explanation:

butan-2-ol reacts with NaI and H_3PO_4 to form 2-iodobutane. Reaction with magnesium in dry ether forms the Grignard reagent (sec-butylmagnesium iodide). Subsequent deuterolysis with D_2O replaces the magnesium-bearing carbon's metal with deuterium (D), yielding 2-deuteriobutane.

Q18.

Answer: C

Explanation:

Alcohols like butan-1-ol experience intermolecular hydrogen bonding due to the presence of the polar $-\text{OH}$ group, whereas ethers like ethoxyethane ($\text{C}_2\text{H}_5 - \text{O} - \text{C}_2\text{H}_5$) cannot form hydrogen bonds with themselves. This intermolecular hydrogen bonding in butan-1-ol leads to stronger association between molecules, requiring more energy (higher boiling point) to vaporize compared to ethoxyethane.

Q19.

Answer: A

Explanation:

The given reaction involves the substitution of triphenylmethyl chloride with a hydroxide ion in the presence of pyridine. Since triphenylmethyl carbocation is highly stable due to extensive resonance from three phenyl rings, the reaction proceeds via an S_N1 mechanism. In an S_N1 reaction, the rate depends only on the concentration of the substrate and is independent of the concentration of the nucleophile. Therefore, the rate is directly proportional to the concentration of $(\text{C}_6\text{H}_5)_3\text{C} - \text{Cl}$, making graph A the correct representation.

Q20.

Answer: C

Explanation:

Aromatic halides like chlorobenzene are unreactive toward nucleophilic substitution under mild conditions due to partial double-bond character of the $C \rightarrow Cl$ bond resulting from resonance. Therefore, the reaction of chlorobenzene with alcoholic KOH to form phenol (Option C) is incorrect; haloarenes require drastic conditions (such as high temperature and pressure, like in the Dow process) for nucleophilic substitution. In contrast, aliphatic halides like 1-bromopropane undergo nucleophilic substitution readily with aqueous KOH to yield alcohols (Option D), and chlorobenzene undergoes Friedel-Crafts acylation (Option A) and high-temperature nucleophilic substitution (Option B correctly describes the Dow process conditions).

Q21.

Answer: 6

Explanation:

The $FeCl_3$ test indicates a phenolic group. Optical rotation requires chirality. The structure can be represented by a hydroxyethyl group attached to a phenol ring, giving 3 positional isomers, and each has 2 enantiomers.

Q22.

Answer: 20

Explanation:

There are 10 distinct positional arrangements of the three different substituents on the benzene ring. The $CH(OH)$ carbon is chiral, giving 2 enantiomers for each arrangement.

Q23.

Answer: 6

Explanation:

The compound possesses a phenolic group ($-OH$) since it gives a positive test with neutral $FeCl_3$ solution. Because it rotates plane-polarised light, it must be optically active and contain a chiral carbon atom. Considering the molecular formula $C_8H_{10}O_2$, the possible structures that satisfy both conditions yield a total of 6 optically active isomers.

Q24.

Answer: 4

Explanation:

Each acetylation replaces a hydrogen atom of a hydroxyl group ($-OH$) with an acetyl group ($-COCH_3$), which results in a net mass increase of 42 g mol^{-1} per group. Dividing the total mass difference by 42 gives the number of hydroxyl groups.

Q25.

Answer: 175

Explanation:

The reaction of phenol with dilute HNO_3 yields a mixture of ortho- and para-nitrophenol, where o-nitrophenol is steam volatile. The percentage of oxygen in phenol is calculated using its molecular formula (C_6H_6O), and the percentage of oxygen in o-nitrophenol ($C_6H_5NO_3$) is calculated similarly. The difference between the two percentages gives the increase, which is then expressed in the required format.

Q26.

Answer: D

Explanation:

Substituting $t = x^2 \implies dt = 2x dx$ converts the integrand into partial fractions. Integrating yields $\frac{1}{2} \log_e \left| \frac{x^2+1}{x^2+3} \right| + C$. Using $f(3)$ to evaluate $C = 0$, substituting $x = 4$ gives $\frac{1}{2}(\log_e 17 - \log_e 19)$.

Q27.

Answer: A

Explanation:

Integration by parts with $u = x \sec x$ and $dv = \frac{x \sec^2 x + \tan x}{(x \tan x + 1)^2} dx$ yields

$I(x) = -\frac{x^2 \sec x}{x \tan x + 1} + 2 \log_e |x \sin x + \cos x| + C$. Evaluating at $x = \frac{\pi}{4}$ with $C = 0$ yields Option A.

Q28.

Answer: A

Explanation:

Integrating $\int \sec^2 x (\sin x)^{-2022} dx$ by parts gives $I(x) = \frac{\tan x}{\sin^{2022} x} + C$. Given

$I(\pi/4) = 2^{1011}$, $C = 0$. Evaluating $I(\pi/3)$ and $I(\pi/6)$ gives

$$3^{1010} I\left(\frac{\pi}{3}\right) - I\left(\frac{\pi}{6}\right) = 0.$$

Q29.

Answer: C

Explanation:

Rewriting the integrand as $(x \sec x) \cdot \frac{x \cos x}{(x \sin x + \cos x)^2}$ and using integration by parts

$$\text{yields } \tan x - \frac{x \sec x}{x \sin x + \cos x} + C.$$

Q30.

Answer: C

Explanation:

Substituting $t = \log_e x \implies x = e^t, dx = e^t dt$ transforms the integral into

$$\int e^t \cos t dt = \frac{e^t}{2} (\cos t + \sin t) + C = \frac{x}{2} [\cos(\log_e x) + \sin(\log_e x)] + C.$$

Q31.

Answer: D

Explanation:

Using King's property $\int_a^b f(x) dx = \int_a^b f(a+b-x) dx$ with $a+b = \frac{\pi}{4}$,

substituting $2x \rightarrow \frac{\pi}{2} - 2x$ gives $2I = b - a = \frac{5\pi}{24} - \frac{\pi}{24} = \frac{\pi}{6} \implies I = \frac{\pi}{12}$.

Q32.

Answer: C

Explanation:

Applying King's property $I = \int_{-\pi/2}^{\pi/2} \frac{1}{1+e^{-\sin x}} dx = \int_{-\pi/2}^{\pi/2} \frac{e^{\sin x}}{1+e^{\sin x}} dx$. Adding both

forms gives $2I = \int_{-\pi/2}^{\pi/2} 1 dx = \pi \implies I = \frac{\pi}{2}$.

Q33.

Answer: D

Explanation:

Using King's property,

$$2I = \int_{-\pi/2}^{\pi/2} \cos^2 x dx = 2 \int_0^{\pi/2} \cos^2 x dx = 2 \left(\frac{\pi}{4} \right) \implies I = \frac{\pi}{4}.$$

Q34.

Answer: C

Explanation:

Rewrite integrand as $\sqrt{x^3 + (x-1)^3}$. Using King's property $x \rightarrow 1-x$, the integrand changes sign ($f(1-x) = -f(x)$), evaluating the integral to 0.

Q35.

Answer: B

Explanation:

Split into two integrals: $\int_{-\pi}^{\pi} \frac{2x}{1+\cos^2 x} dx$ (odd function, equals 0) and $\int_{-\pi}^{\pi} \frac{2x \sin x}{1+\cos^2 x} dx$ (even function). Evaluating yields π^2 .

Q36.

Answer: A

Explanation:

Add and subtract x in the numerator: $\frac{(x+\cos x)-x(1-\sin x)}{x(x+\cos x)} = \frac{1}{x} - \frac{1-\sin x}{x+\cos x}$.

Integrating yields $\log|x| - \log|x+\cos x| + c = \log\left|\frac{x}{x+\cos x}\right| + c$.

Q37.

Answer: B

Explanation:

Inside square root:

$$1 + 2 \cot^2 x + 2 \cot x \csc x = \csc^2 x + \cot^2 x + 2 \csc x \cot x = (\csc x + \cot x)^2$$

. Square root gives $\csc x + \cot x = \cot(x/2)$. Integrating $\cot(x/2)$ yields

$$2 \ln \sin \frac{x}{2} + c.$$

Q38.

Answer: A

Explanation:

Substituting $t = \cot x \implies dt = -\csc^2 x dx$, using the standard form $\int e^t(f(t) + f'(t))dt = e^t f(t)$ with $f(t) = -2 \ln(\csc x)$ yields $-2e^{\cot x} \ln(\csc x) + c$.

Q39.

Answer: D

Explanation:

Using half-angle substitutions $t = \tan(x/2)$, the integral simplifies to $\int \frac{dt}{1+t} = \log_e |1 + \tan(x/2)| + c$, so $f(x) = 1 + \tan(x/2)$.

Q40.

Answer: A

Explanation:

Using King's property $x \rightarrow 1 - x$, the exponential term eliminates. The integral becomes $\frac{1}{2} \int_0^1 \frac{dx}{5+2x-2x^2} = \frac{1}{2\sqrt{11}} \log_e \left(\frac{\sqrt{11}+1}{\sqrt{11}-1} \right)$.

Q41.

Answer: A

Explanation:

Substitute $t = x - 3$. The integral becomes $\int_{-2}^2 t(t^2 - 1)(t^2 - 4)dt$. Since the integrand is an odd function over symmetric limits $[-2, 2]$, the integral evaluates to 0.

Q42.

Answer: B

Explanation:

Substituting $x = \sin \theta \implies dx = \cos \theta d\theta$ transforms integral into $\int_0^{\pi/4} \theta \sec^2 \theta d\theta$. Integration by parts gives $\frac{\pi}{4} - \frac{1}{2} \log 2$.

Q43.

Answer: A

Explanation:

Checking $f(-x) = \sqrt{1-x+x^2} - \sqrt{1+x+x^2} = -f(x)$, $f(x)$ is an odd function. Thus $\int_{-1}^1 f(x)dx = 0$.

Q44.

Answer: C

Explanation:

Using King's property $x \rightarrow \pi/2 - x$, $\cot x$ becomes $\tan x$. Adding both integrals yields $2I = \int_0^{\pi/2} 1 dx = \pi/2 \implies I = \pi/4$.

Q45.

Answer: D

Explanation:

Converting $\tan \theta = \frac{\sin \theta}{\cos \theta}$ gives $\int_0^{\pi/2} \frac{\cos \theta}{\cos \theta + \sin \theta} d\theta$. Using King's property, $2I = \int_0^{\pi/2} 1 d\theta = \pi/2 \implies I = \pi/4$.

Q46.

Answer: 4

Explanation:

Converting $\tan x$ to $\frac{\sin x}{\cos x}$ transforms the integrand into $\frac{2 \cos x - \sin x}{3 \cos x + \sin x}$. Expressing the numerator as $A(\text{denom}) + B(\text{denom}')$ gives $A = \frac{1}{2}$ and $B = -\frac{1}{2}$, leading to $\alpha = 1, \beta = 1, \gamma = 3$, so $\alpha + \frac{\gamma}{\beta} = 1 + 3 = 4$.

Q47.

Answer: 15

Explanation:

Since $\sin^4 x + \cos^4 x$ is periodic with period $\pi/2$, $\int_0^{20\pi} = 40 \int_0^{\pi/2} (\sin^4 x + \cos^4 x) dx$. Using Wallis' reduction formulas, $40 \times 2 \times \frac{3\pi}{16} = 15\pi$.

Q48.

Answer: 100

Explanation:

Using King's property (Tex translation failed), the $1 + e^x$ denominator term eliminates, leaving $96 \int_0^{\pi/2} x^2 \cos^2 x \, dx = \pi(2\pi^2 - 12)$. Thus $\alpha = 2, \beta = -12 \implies (\alpha + \beta)^2 = 100$.

Q49.

Answer: 2

Explanation:

Using $1 + \cos x = 2 \cos^2(x/2)$, the integral becomes

$$\frac{1}{2} \int_{\pi/4}^{3\pi/4} \sec^2(x/2) dx = [\tan(x/2)]_{\pi/4}^{3\pi/4} = \tan(3\pi/8) - \tan(\pi/8) = (\sqrt{2} + 1) - (\sqrt{2} - 1) = 2$$

Q50.

Answer: 4

Explanation:

Applying King's property $x \rightarrow \pi/2 - x$ transforms the numerator into $\cos^{3/2} x$.

Adding both integral expressions gives $2I = \int_0^{\pi/2} 1 \, dx = \pi/2 \implies I = \pi/4$.

Q51.

Answer: A

Explanation:

Using Einstein's photoelectric equation: $eV_s = \frac{hc}{\lambda} - \phi$ For the second wavelength, $\lambda_2 = 2\lambda$: $eV_2 = \frac{hc}{2\lambda} - \phi$ Subtracting: $e(V_1 - V_2) = \frac{hc}{2\lambda}$ Therefore, $\lambda = \frac{hc}{2e(V_1 - V_2)}$
 $= \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{2(1.6 \times 10^{-19})(4.0 - 1.5)} \approx 2.49 \times 10^{-7}, m \approx 2.5 \times 10^{-7}, m$.

Q52.

Answer: B

Explanation:

The higher angular frequency component produces the maximum-energy photons:

$$\omega_{\max} = 10 \times 10^{15}, \text{ rad/s} \text{ Photon energy: } E_\gamma = \hbar\omega = \frac{h\omega}{2\pi}$$

$$E_\gamma \approx \frac{(6.6 \times 10^{-34})(10 \times 10^{15})}{2\pi} \approx 1.05 \times 10^{-18}, \text{ J} \text{ Converting to eV:}$$

$$E_\gamma \approx \frac{1.05 \times 10^{-18}}{1.6 \times 10^{-19}} \approx 6.6, \text{ eV} \text{ Therefore, } K_{\max} = E_\gamma - \phi = 6.6 - 2.0 = 4.6, \text{ eV.}$$

Q53.

Answer: B

Explanation:

For an electron, charge $q = -e$. $\vec{F} = q\vec{E} = (-e)(-3E_0\hat{i}) = 3eE_0\hat{i}$ Hence,
 $a = \frac{3eE_0}{m}$ So, $v = v_0 + \frac{3eE_0}{m}t$ Using de Broglie relation, $\lambda = \frac{h}{mv}$ Since
 $\lambda_0 = \frac{h}{5mv_0}, \frac{h}{mv_0} = 5\lambda_0$ Therefore, $\lambda = \frac{5\lambda_0}{1 + \frac{3eE_0}{mv_0}t}$

Q54.

Answer: D

Explanation:

Energy of incident photon: $E = \frac{hc}{\lambda} = \frac{(6.6 \times 10^{-34})(3 \times 10^8)}{500 \times 10^{-9}} = 3.96 \times 10^{-19}, \text{ J}$
Converting into eV: $E = \frac{3.96 \times 10^{-19}}{1.6 \times 10^{-19}} \approx 2.48, \text{ eV}$ For photoelectric emission, $E \geq \phi$
. For K: $2.48 > 2.3 \text{ eV} \rightarrow$ photoelectric effect occurs. For Ca: $2.48 < 2.9 \text{ eV} \rightarrow$ photoelectric effect does not occur. Therefore, K only.

Q55.

Answer: B

Explanation:

Energy of incident photon: $E = \frac{hc}{\lambda} = \frac{1240}{400} = 3.1, \text{ eV}$ Using Einstein's photoelectric equation: $K_{\max} = E - \phi = 3.1 - 2.0 = 1.1, \text{ eV}$ Since $K_{\max} = eV_s, V_s = 1.1, \text{ V}$

Q56.

Answer: C

Explanation:

For photoelectric emission,

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

and

$$eV_0 = K_{\max}$$

Since both lights have the same wavelength,

$$\nu = \frac{c}{\lambda}$$

is the same for both.

Therefore, their maximum kinetic energies and stopping potentials are the same:

$$V_{01} = V_{02}$$

However, a higher intensity means more photons incident per second, producing more photoelectrons per second. Hence,

$$I_{s2} > I_{s1}$$

because $I_1 < I_2$.

Therefore, the correct graph has the same stopping potential but a higher saturation current for I_2 .

Q57.

Answer: A

Explanation:

Using Einstein's photoelectric equation, $K_{\max} = \frac{hc}{\lambda} - \phi$ Since $K_{\max} = \frac{1}{2}mu^2$,

and $u_1 : u_2 = 2 : 1$, $\frac{K_1}{K_2} = \frac{u_1^2}{u_2^2} = 4$. Photon energies: $E_1 = \frac{1240}{250} = 4.96$, eV

$E_2 = \frac{1240}{400} = 3.10$, eV Therefore, $\frac{4.96 - \phi}{3.10 - \phi} = 4$ Solving, $\phi = 2.48$, eV ≈ 2.5 , eV.

Q58.

Answer: A

Explanation:

Photon energy: $E_\gamma = \frac{hc}{\lambda} = \frac{1240}{450} \approx 2.76$, eV Compare with work functions: For p : $2.76 > 2.0 \rightarrow$ emission occurs. For q : $2.76 > 2.5 \rightarrow$ emission occurs. For r : $2.76 < 3.0 \rightarrow$ no emission. Stopping potentials: $V_{0p} = 2.76 - 2.0 = 0.76$, V $V_{0q} = 2.76 - 2.5 = 0.26$, V Since the light intensity and emission efficiency are the same for p and q , their saturation currents are equal. Hence, A.

Q59.

Answer: A

Explanation:

The kinetic energy is $K = E - U$. For $0 \leq x \leq 1$: $K_1 = 3E_0 - E_0 = 2E_0$ For $x > 1$: $K_2 = 3E_0 - 0 = 3E_0$ Since $\lambda = \frac{h}{\sqrt{2mK}}$, we have $\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{K_2}{K_1}} = \sqrt{\frac{3E_0}{2E_0}}$
 $\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{3}{2}}$

Q60.

Answer: D

Explanation:

Using the Rydberg formula, $\frac{1}{\lambda} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$. For the maximum wavelength, the energy difference is minimum, so $n_2 = n_1 + 1$. For the minimum wavelength, $n_2 \rightarrow \infty$. • Balmer maximum: $n_1 = 2$, $n_2 = 3$ $\frac{1}{\lambda_{\max}} = R \left(\frac{1}{4} - \frac{1}{9} \right) = \frac{5R}{36}$
 $\therefore \lambda_{\max} = \frac{36}{5R} \rightarrow$ A is correct. • Balmer series corresponds to transitions ending at $n = 2$ and lies in the visible region $\rightarrow$ B is correct. • Paschen minimum: $n_1 = 3$, $n_2 \rightarrow \infty$ $\frac{1}{\lambda_{\min}} = \frac{R}{9} \therefore \lambda_{\min} = \frac{9}{R} \rightarrow$ C is correct. • Lyman minimum: $n_1 = 1$, $n_2 \rightarrow \infty$ $\frac{1}{\lambda_{\min}} = R \therefore \lambda_{\min} = \frac{1}{R} \rightarrow$ D is correct. Hence, all four statements are correct.

Q61.

Answer: C

Explanation:

For the Bohr atom, $E_n = -\frac{E_0}{n^2}$ Given, $E_n = -0.04E_0$ Therefore, $\frac{1}{n^2} = 0.04 = \frac{1}{25}$ So, $n = 5$. Bohr's angular momentum is $L = \frac{nh}{2\pi}$. Hence, $\frac{2\pi L}{h} = n = 5$. Therefore, 5.

Q62.

Answer: A

Explanation:

Photon momentum is $p = \frac{h}{\lambda} = \frac{E}{c}$. For the Paschen series, transitions terminate at $n = 3$. 1st line: $4 \rightarrow 3$ $E_1 = hcR \left(\frac{1}{3^2} - \frac{1}{4^2} \right) = hcR \left(\frac{7}{144} \right)$ 2nd line: $5 \rightarrow 3$ $E_2 = hcR \left(\frac{1}{3^2} - \frac{1}{5^2} \right) = hcR \left(\frac{16}{225} \right)$ Since $p \propto E$, $\frac{p_1}{p_2} = \frac{7/144}{16/225} = \frac{175}{256}$. Thus, $\alpha = 175$ and $\beta = 256$.

Q63.

Answer: A

Explanation:

For a hydrogen-like atom, $r_n = \frac{n^2 a_0}{Z}$. For Be^{3+} , $Z = 4$: $r_{\text{Be}} = \frac{4^2 a_0}{4} = 4a_0$. For Li^{2+} , $Z = 3$: $r_{\text{Li}} = \frac{4^2 a_0}{3} = \frac{16a_0}{3}$. Therefore, $\frac{r_{\text{Be}}}{r_{\text{Li}}} = \frac{4}{16/3} = \frac{3}{4}$.

Q64.

Answer: D

Explanation:

For a hydrogen-like atom, the radius of the n^{th} orbit is $r_n = \frac{n^2 a_0}{Z}$. For Li^{2+} :

$Z = 3$, $n = 1$ Therefore, $r_1 = \frac{1^2 a_0}{3} = \frac{a_0}{3}$. Comparing with $r_1 = \frac{a_0}{X}$, we get $X = 3$.

Q65.

Answer: C

Explanation:

For a hydrogen atom, $E_k = -\frac{e^2}{8\pi\epsilon_0 r_k}$ for the total energy, while the kinetic energy is

$K_k = \frac{e^2}{8\pi\epsilon_0 r_k}$. For a transition $n \rightarrow 2$, $h\nu = E_n - E_2$ and therefore

$\nu = \frac{e^2}{8\pi\epsilon_0 h} \left(\frac{1}{r_2} - \frac{1}{r_n} \right)$. Hence, C is correct.

Q66.

Answer: D

Explanation:

For circular motion, $\frac{mv^2}{r} = kr$ so $v^2 = \frac{kr^2}{m}$. Using $L = mvr = n\hbar$, we obtain

$\frac{L}{mr^2} = \frac{v}{r} = \sqrt{\frac{k}{m}}$. Thus, option C is correct.

Q67.

Answer: A

Explanation:

For hydrogen, $E_n = -\frac{13.6}{n^2}$, eV. The energy required for the transition

$n = 1 \rightarrow 4$ is $\Delta E = 13.6 \left(1 - \frac{1}{16} \right) = 12.75$, eV. Since $\lambda_a/\lambda_e = 5$, the

emitted photon has one-fifth the energy of the absorbed photon:

$E_e = \frac{12.75}{5} = 2.55$, eV. Thus, $13.6 \left(\frac{1}{m^2} - \frac{1}{16} \right) = 2.55$ which gives $m = 2$.

Hence A and B are correct.

Q68.

Answer: A

Explanation:

For hydrogen, the first Balmer line corresponds to $3 \rightarrow 2$. For Li^{2+} , $Z = 3$, and the second Balmer line corresponds to $4 \rightarrow 2$. Using the Rydberg formula,

$\frac{1}{\lambda} = RZ^2 \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$. For hydrogen first line, $\frac{1}{\lambda_1} = R \left(\frac{1}{4} - \frac{1}{9} \right) = \frac{5R}{36}$.

For Li^{2+} second line, $\frac{1}{\lambda_2} = 9R \left(\frac{1}{4} - \frac{1}{16} \right) = \frac{27R}{16}$. Therefore,

$\frac{\lambda_2}{\lambda_1} = \frac{5/36}{27/16} = \frac{20}{243}$. Thus, $\lambda_2 = 6561 \times \frac{20}{243} = 540$.

Q69.

Answer: D

Explanation:

For rotational motion, $E = \frac{L^2}{2I}$. Using Bohr's quantization condition, $L = n\hbar = \frac{n\hbar}{2\pi}$

. Therefore, $E_n = \frac{1}{2I} \left(\frac{n\hbar}{2\pi} \right)^2 = n^2 \left(\frac{\hbar^2}{8\pi^2 I} \right)$. Hence, the correct answer is D.

Q70.

Answer: A

Explanation:

For a hydrogen-like atom, the kinetic energy of an electron in the n^{th} orbit is

$K_n \propto \frac{Z^2}{n^2}$. For H, $Z = 1$, and for He^+ , $Z = 2$. Since $n = 2$ is the same for both,

$\frac{K_H}{K_{\text{He}^+}} = \frac{1^2}{2^2} = \frac{1}{4}$.

Q71.

Answer: 128

Explanation:

For an electron in the n th Bohr orbit, $p_e = \frac{h}{\lambda_e} = \frac{Zh}{2\pi na_0}$ Since the neutron has the same de Broglie wavelength, $p_N = p_e$ Its thermal kinetic energy is $k_B T = \frac{p_N^2}{2m_N}$
Therefore, $T = \frac{Z^2 h^2}{8\pi^2 n^2 a_0^2 m_N k_B}$ Comparing with $T = \frac{Z^2 h^2}{\alpha \pi^2 a_0^2 m_N k_B}$, we get
 $\alpha = 8n^2 = 8(4)^2 = 128$.

Q72.

Answer: 3

Explanation:

Work function: $\phi = \frac{hc}{\lambda_0} = \frac{1240}{310} = 4, \text{eV}$ Hence photon energy: $E_\gamma = K_{\max} + \phi$
 $= 4.704 + 4 = 8.704, \text{eV}$ For the transition $n = 5 \rightarrow 3$:
 $E_\gamma = RhcZ^2 \left(\frac{1}{3^2} - \frac{1}{5^2} \right) 8.704 = 13.6Z^2 \left(\frac{1}{9} - \frac{1}{25} \right)$ This gives $Z^2 = 9$
Therefore, $Z = 3$.

Q73.

Answer: 24

Explanation:

Photon energy: $E_\gamma = 5(1.6 \times 10^{-19}) = 8 \times 10^{-19}, J$ Number of photons per second: $N = \frac{P}{E_\gamma} = \frac{160}{8 \times 10^{-19}} = 2 \times 10^{20}, s^{-1}$ Since emission efficiency is 100, electron arrival rate is also N . Electron momentum after acceleration through 500, V: $p = \sqrt{2m_e eV} = \sqrt{2(9 \times 10^{-31})(1.6 \times 10^{-19})(500)}$
 $\approx 1.2 \times 10^{-23}, kg, m/s$ Therefore, $F = Np = (2 \times 10^{20})(1.2 \times 10^{-23})$
 $= 2.4 \times 10^{-3}, N$ Thus, $F = 24 \times 10^{-4}, N$ $n = 24$

Q74.

Answer: 2

Explanation:

Bohr's angular momentum is $L = \frac{nh}{2\pi}$ Given, $L = \frac{5h}{2\pi}$ Therefore, $n = 5$. For a hydrogen-like ion, $r_n = \frac{n^2 a_0}{Z}$. For Be^{3+} , $Z = 4$: $r_5 = \frac{25a_0}{4}$. Using the standing-wave condition, $2\pi r_n = n\lambda$ Therefore, $\lambda = \frac{2\pi r_n}{n} = \frac{2\pi(25a_0/4)}{5} = \frac{5\pi a_0}{2}$. Thus, $p = \frac{5}{2}$.

Q75.

Answer: 1

Explanation:

Einstein's photoelectric equation is $eV_s = h\nu - \phi$ Rearranging, $V_s = \frac{h}{e}\nu - \frac{\phi}{e}$
Therefore, the slope of the V_s versus ν graph is slope $= \frac{h}{e}$ This slope is independent of the work function. Hence, $\frac{\text{slope } K}{\text{slope } Ca} = \frac{h/e}{h/e} = 1$.