HINTS & SOLUTIONS

EXERCISE - 1

Single Choice

1. (C)

2. Emission of photo electron is independent of external factor. It depends only on the nature of the material and wavelength of incident light

3. The number of photo electron depends on the number of photons

Number of photon $= \frac{I}{hc/\lambda} = \frac{\lambda \cdot I}{hc} \propto \lambda$

Ratio of no. of photo electrons $= \frac{\lambda_A}{\lambda_B}$

4. $\frac{hC}{\lambda} = \phi + eV$ ....(i)

$\frac{hC}{2\lambda} = \phi + \frac{eV}{3}$ ....(ii)

$3 \cdot II - I$

$\Rightarrow \left(\frac{3}{2} - 1\right)\frac{hc}{\lambda} = 2\phi \Rightarrow \phi = \frac{hc}{4\lambda} \quad \therefore \lambda_{th} = 4\lambda$

5. (A)

6. Frequency of light does not change with medium.

7. Stopping potential = maximum kinetic energy of e = 4V.

8. (B)

9. $C = \lambda \cdot \nu = \frac{h}{p} \cdot \frac{E}{h} = \frac{E}{p}$

10. (A)

11. (D)

12. $\lambda = \frac{h}{p}$

Since the momenta of the two particles are equal, λ are same.

13. $r = a_0 \frac{n^2}{Z} = a_0 \cdot \frac{2^2}{4} = a_0$

14. K.E. of neutron $E = \frac{3}{2}kT$

$\lambda_d = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m \times \frac{3}{2}kT}}$

$\Rightarrow \lambda_2 = \lambda.\sqrt{\frac{(927+273)}{27+273}} = 2\lambda.$

15. $E_n(Li^{2+}) = E_1(H) \Rightarrow -13.6\frac{3^2}{n^2} = -13.6 \times \frac{1}{1} \Rightarrow n = 3$

16. (B) 17. (C) 18. (A)

19. Since speed reduces to half, KE reduced to

$\frac{1}{4}$ th $\Rightarrow$ $n = 2 \Rightarrow mvr = \frac{nh}{2\pi}$

$mv_0 r = 1.\frac{h}{2\pi}$ I

$m\frac{v_0}{2} r` = 2 \cdot \frac{h}{2\pi}$ II

I and II

$r' = 4.r$

20. (D)

21. $12.1 = E(n=3) - E(n=1)$

$10.2 = E(n=2) - E(n=1)$

$1.9 = E(n=3) - E(n=2)$

At least two atoms must be enveloped as there connot be two transition from same level from same atom.

22. (C)

23. 12.1 eV radiation will excite a hydrogen atom in ground state to n = 3

state number of possible transition $= {}^nC_2 = {}^3C_2 = 3.$

24. $\frac{1}{\lambda_1} = R\left(\frac{1}{4} - \frac{1}{9}\right) \Rightarrow \lambda_1 = \frac{4 \times 9}{5R}$

similarly $\frac{1}{\lambda_2} = R\left(\frac{1}{4} - \frac{1}{4^2}\right)$

$\Rightarrow \lambda_2 = \frac{16}{3R} = \frac{16}{3} \times \frac{5\lambda}{4 \times 9} = \frac{20}{27}\lambda$

26. $E = 13.6\left(\frac{Z^2}{n^2}\right) \Delta E_H = \frac{13.6(1)^2}{(1)^2} - \frac{13.6(1)^2}{(2)^2} = 10.2\,eV = h\nu$

$$\Delta E_{Li} = \frac{13.6(3)^2}{(1)^2} - \frac{13.6(3)^2}{(2)^2} = 91.80\ eV = h\,(9\,\nu)$$

27. The contineous x-ray comes out because the striking electron loser its kinetic energy

28. 10 eV electron cannot excite a hydrogen atom Hence collision is elastic.

29. (B) **30.** (C)

31. 

32. The energy of x–ray is more that of U.V. light. Hence, the K.E. of emitted photoelectron is more and hence stopping potential required is also more.

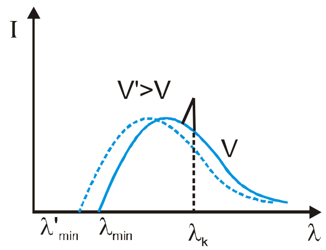
33. (D)

34. $\frac{K}{\lambda_1} = E_\infty - E_1 \Rightarrow \frac{K}{\lambda_2} = E_\infty - E_2$

$\frac{K}{\lambda_3} = E_2 - E_3 \Rightarrow \frac{1}{\lambda_1} - \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$

35. (B) **36.** (A)

37. By increasing the operating voltage, l_k does not change but l_{min} decreases



Hence, $\lambda_k - \lambda_{min}$

38. (D)

39. $hf = 13.6(Z-1)^2 . \left(1 - \frac{1}{4}\right) = 13.6 \times \frac{3}{4}(31-1)^2$

$$hf' = 13.6 \times \frac{3}{4}(51-1)^2 \Rightarrow \frac{f'}{f} = \frac{50^2}{30^2} \Rightarrow f' = \frac{25}{9}.f$$

40. (B)

41. $P = P_- + P_+$

$= 200 \times (6.25 \times 10^{18} + 3.125 \times 10^{18}) \times 1.6 \times 10^{-19}\,W = 300\,W.$

42. (D)

43. $\frac{1}{\lambda} = R\,(Z-1)^2 \times \left(1 - \frac{1}{4}\right)$

$\Rightarrow \frac{1875R}{4} = R\,(Z_1 - 1)^2\,\frac{3}{4}$

$\Rightarrow Z_1 = 26$

and $675\,R = R\,(Z_2 - 2)^2 . \frac{3}{4} \Rightarrow Z_2 = 31$

Hence number of elements = 4

44. (C)

45. Number of photons emitted per second.

$$N = \frac{\eta}{100} \times \frac{P\lambda}{hc}$$

Potential of the sphere after time t is

$$V' = V - \frac{(Ne)t}{4\pi\varepsilon_o R} = V - \frac{\eta P\lambda et}{400\pi\varepsilon_0 Rhc}$$

46. (B)

47. When the source is 3 times farther, number of photons falling on the surface becomes $\frac{1}{9}$th but the frequency remains same. Hence stopping potential will be same i.e. 0.6V and saturation current become $\frac{1}{9} \times 18$ mA = 2mA,

48. (B)

49. Some of the energy of photon will be absorbed by the electron. Hence, energy of the photon will reduce correspondingly wavelength will increase and frequency decreases.

50. (D)

51. As the distance of the source doubles, the photons falling on the photon cell becomes $\frac{1}{4}$th. Hence, number of photoelectrons will also become $\frac{1}{4}$th.

52. The threshold frequency for Al must be greater as it has higher work function.

53. (A) **54.** (D)

55. Stopping potential depends on the K.E. of emitted electron. The K.E. of emitted electron depends on the frequency of the photon, not on the intensity of the photon.

56. $E_n = 13.6\dfrac{Z^2}{n^2}$

$$\Delta E_H = \frac{13.6(1)^2}{(1)^2} - \frac{13.6(1)^2}{(2)^2} = 10.2\text{eV}$$

$$\Delta E_{He} = \frac{13.6(2)^2}{(1)^2} - \frac{13.6(2)^2}{(2)^2} = 40.8\text{ eV}$$

57. (D) **58.** (A)

59. In photoelectric experiment, speed of fastest emitted electron is given by –

$$\frac{1}{2}mv^2_{max} = \frac{hc}{\lambda} - w$$

Case- I : $\dfrac{1}{2}mv^2 = \dfrac{hc}{\lambda} - w$ ....**(i)**

Case- II : $\dfrac{1}{2}mv'^2 = \dfrac{hc}{3\lambda/4} - w$

$\dfrac{1}{2}mv'^2 = \dfrac{4hc}{3\lambda} - w$ ....**(ii)**

From eqn. **(i)** & **(ii)**

$v'^2 = \dfrac{4}{3}v^2 + \dfrac{w}{3}$ Hence, $v' > v\sqrt{\dfrac{4}{3}}$.

60. The maximum kinetic energy avaiable for transition to potential energy/excitation energy is :

$$\frac{1}{2}\cdot\frac{m_\alpha m_H}{m_\alpha + m_H}\cdot(v_{rel})^2$$

$$= \frac{4m_{,}m_H}{5m}.(v_\alpha + v_H)^2 = \frac{2m}{5}.(v_\alpha^2 + v_H^2 + 2v_\alpha v_H)$$

$$= \frac{2m}{5}\left[\frac{2.E_\alpha}{4m} + \frac{2E_4}{m} + 2.\sqrt{\frac{2E.\alpha}{4m}.\frac{2E_H}{m}}\right]$$

$$= \frac{2}{5}\left[\frac{2.1}{2} + 2\times 8.4 + 2\times\sqrt{2.1\times 8.4}\right] = 10.5\text{ eV} > 10.2\text{ eV}$$

Hence, inelastic collision is possible.

61. Have speeds varying from zero up to a certain maximum value

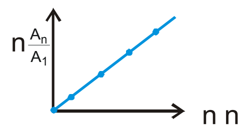
62. (D)

EXERCISE - 2

Part # I : Multiple Choice

1. $A_n = \pi r^2 = \pi(r_0 n^2)^2 = \pi r_0^2 n^4$

$\ell n\dfrac{A_n}{A_1} = \ell n(n^4) = 4\ \ell n\ n.$



2. (C, D)

3. K_α : transition from $2 \to 1$

Similarly for $K_\beta : 3 \to 1$, $K_\gamma : 4 \to 1$; $L_\alpha : 3 \to 2 : M_\alpha :$ $4 \to 3$

Now we can compare energy and λ.

4. Photon exerts force due to change in momentum photon transfers its energy to the material. Photon transfers its energy to the material.

Since, it exerts force, hence imparts impulse also.

5. (A,D)

6. The photo electric effect can be explained if photon is considered as particle i.e.quantum nature

7. (A,B,C)

8. $K_{max} = E - W$

Therefore,

$T_A = 4.25 - W_A$ ......**(i)**

$T_B = (T_A - 1.50) = 4.70 - W_B$ ......**(ii)**

Equation **(i)** and **(ii)** gives,

$W_B - W_A = 1.95$ eV ......**(iii)**

de-Broglie wavelength is given by

$\lambda = \dfrac{h}{\sqrt{2Km}}$ or $\lambda \propto \dfrac{1}{\sqrt{K}}$ K = KE of elecron

$$\therefore \frac{\lambda_B}{\lambda_A} = \sqrt{\frac{K_A}{K_B}}$$

or $2 = \sqrt{\dfrac{T_A}{T_A - 1.5}}$ or $T_A = 2eV$

From equation **(i)**

$W_A = 4.25 - T_A = 2.25$ eV

From equations **(iii)** ,

$W_B + 1.95\text{ eV} = (2.25 + 1.95)$ eV

or $W_B = 4.20$ eV.

$T_B = 4.70 - W_B = 4.70 - 4.20 = 0.50$ eV.

Part # II : Assertion & Reason

1. D

2. Striking two photons simultaneously the same electron is rare.

3. Any $2e^-$ may make same number of collision and may have same kinetic energy as they come out the metal.

4. As electron jumps from n = 2 to n = 1, angular momentum (nh/2π) does not remain conserved. Hence statement-1 is false.

EXERCISE - 3

Part # I : Matrix Match Type

1. $A \to R$; $B \to Q,S$; $C \to P$; $D \to Q,S$

2. Saturation photo current is directly proportional to intensity.

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

   Stopping voltage is independent of intensity.

3. **(A)** Frequency of orbiting electron $v_n \propto \dfrac{z^2}{n^3}$

   $f = \dfrac{v}{2\pi r}$.

   (B) angular momentum of orbiting electron $L = \dfrac{nh}{2\pi}$.

   (C) Magnetic moment of orbiting electron $\propto$ n.

   $M = i \times \pi R^2 = \dfrac{e}{T}\pi R^2$

   (D) Average current due to orbiting of electron

   $i \propto \dfrac{z^2}{n^3}$.

Part # II : Comprehension

Comprehension # 1

1. (D) 2. (C) 3. (D)

Comprehension # 2

1. $\Delta E = \dfrac{12400}{4500\text{Å}}$

   $\Delta E = 2.75$ eV ....**(1)**

   for photoelectric effect

   $\Delta E > W_0$ (work function).

2. $\Delta E = W_0 + E_k (E_k) = \Delta E - W_0$

   for maximum value of (E_k), W_0 should be minimum.

   W_0 for lithium = 2.3 eV

   $\therefore$ $(E_k) = 2.75 - 2.3 = 0.45$ eV.

3. The maximum magnitude of stopping potential will be for metal of least work function.

   $\therefore$ required stopping potential is

   $V_s = \dfrac{h\nu - \phi_0}{e} = 0.45$ volt.

EXERCISE - 4

Subjective Type

1. $(0.6 \times 10^{15} h - 2e)$ J $= 0.48$ eV

2. $KE_{max} = \dfrac{hc}{\lambda} - \phi$

   $\dfrac{P^2}{2m} = \left(\dfrac{1.24 \times 10^4}{4000} - 2.5\right) eV = 0.6 eV$;

   $P = \sqrt{2 \times 9.1 \times 10^{-31} \times 0.6 \times 1.6 \times 10^{-19}} = 4.2 \times 10^{-25}$ kg.m/s

3. $I = \eta \cdot \dfrac{P}{E_\lambda} \times \dfrac{e}{100} = 1.84 \times 10^{-6}$ amp

4. $B = 2 \times 10^{-6}$ Tesla $\sin[3.0 \times 10^{15} s^{-1})t] \sin[(6.0 \times 10^{15} s^{-1})t]$

   1×10^{-6} Tesla $[\cos\{3.0 \times 10^{15} s^{-1})t\} - \cos\{(9.0 \times 10^{15} s^{-1})t\}]$

   maximum frequency of the wave $\dfrac{9 \times 10^{15}}{2\pi} s^{-1}$

   maximum kinetic energy of the photoelectrons

   $= \left(\dfrac{9 \times 10^{15}}{2\pi e} h - 2\right)$ eV $= 3.93$ eV **Ans.**

5. $dV_s = \frac{hc}{e}.\frac{d\lambda}{\lambda^2} = -\frac{hc}{228e} \times 10^7 = -5.5 \times 10^{-2}$ volt

6. Power consumed = 10 W

Power emitted = 0.6 × 10W = 6W

Number of photons emitted per second

$= \frac{\text{Power emitted}}{\text{energy of each photon}}$

$= \frac{6}{(6.63\times10^{-34})\times\frac{(3\times10^8)}{590\times10^{-9}}} = 1.77 \times 10^{19}$

7. $\frac{1.3\times30}{3\times10^8} = 1.3\times10^{-7}$

8. $F = \frac{\Delta P}{\Delta t}$ = change of momentum of one photon x no. of photons per second

$= \left(\frac{h}{\lambda}\times2\times\cos60^o\right)\times\frac{dn}{dt}$

$= \frac{6.63\times10^{-34}}{663\times10^{-9}} \times 2 \times \frac{1}{2} \times (5 \times 10^{19}) = 5 \times 10^{-8}$ N

9. Maximum K.E. of the electron $e^- = E_\lambda - \phi$

$E = \frac{hc}{\lambda} - \frac{hc}{\lambda_{th}}$

λ_d = de–broglie wavelength,

$\frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m.hc.\frac{\lambda_{th}-\lambda}{\lambda.\lambda_{th}}}}$

$\Rightarrow \lambda_d = \sqrt{\frac{h.\lambda.\lambda_{th}}{2m.c.(\lambda_{th}-\lambda)}} = 12.08$ Å.

10. r = 0.529;

(a) $r(n=2) = 0.529 \times \frac{2^2}{2} = 1.058$ Å

$E(n=2) = -13.6 \times \frac{2^2}{2^2} = -13.6$ eV

(b) $r(n=3) = 0.529 \times \frac{3^2}{2} = 2.38$ Å

$E(n=3) = -13.6 \times \frac{2^2}{3^2} = -6.04$ eV.

11. $\lambda = \frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2+\lambda_2^2}}$

12. $\lambda = 2\pi r = 2\pi \times 0.529$ Å $= 1.058\,\pi$ Å

13 $T = \frac{2E_0}{3K}$ K $= 1.05 \times 10^5$ K

14. BE of last electron

$E = 13.6 \times Z^2 = \frac{hc}{\lambda}$

$\Rightarrow Z^2 = \frac{1.24\times10^4}{13.6\times228} \approx 4 \Rightarrow Z = 2$

15. The smallest wavelength corresponds to transition from n = 1 to n = ∞.

(a) $\Delta E = 13.6$ eV

$\Rightarrow \lambda = \frac{1.24\times10^4}{13.6}$ Å = 911 Å = 91 nm.

(b) $\Delta E = 13.6 \times 2^2$ ev

$\Rightarrow \lambda = \frac{124\times10^4}{13.6\times4}$ Å = 228 Å = 23 nm.

16. K_{1max} = maximum K.E. of ejected electron in first case = 13.6 eV

$\therefore E_\lambda = \phi + K_{1max}$

$\Rightarrow h\nu = \phi + 13.6$ eV ....**(i)**

$K_{2max} = E_\lambda - \phi = h.\frac{5}{6}.\upsilon - \phi$

$= \frac{5}{6}h\upsilon - (h\upsilon - 13.6\text{ eV})$ ....**(ii)**

The energy of radiation of λ = 1215 Å is

$= \frac{12400}{1215}$ eV = 10.2 eV

This is the energy of the e^-

$10.2\text{ eV} = -\frac{h\upsilon}{6} + 13.6\text{eV}$

$\Rightarrow \nu = \frac{(13.6-10.2)\times6\text{eV}}{h} = 5 \times 10^{15}$ Hz.

17. $\frac{v_0}{r_0}\cdot\frac{z^2}{n^3} = \frac{2.19\times10^6}{0.529\times10^{-10}}\times\frac{Z^2}{n^3} = 2.07\times10^{16}\ s^{-1}$

18. He^{+} 4

19. Total energy of radiation

$$E = \frac{hc}{\lambda_1}+\frac{hc}{\lambda_2}$$

$$13.6\times4\times\left(1-\frac{1}{n^2}\right) = \left(\frac{1240}{108.5}+\frac{1240}{30.4}\right)\ eV$$

$$1-\frac{1}{n^2} = \frac{1}{13.6\times4}\times52.22$$

n = 5.

20. $\frac{(E - E')}{E}\times100 = 0.55\ x\ 10^{-6}\ \%$

21. Energy of the first time in Lyman series

$$E = 13.6\times\left(1-\frac{1}{4}\right)\ eV = 10.2\ eV$$

$$\text{velocity of atoms} = \frac{p}{m} = \frac{E}{c}.\frac{1}{m}$$

$$= \frac{10.2\times1.6\times10^{-19}}{3\times10^8\times1.67\times10^{-24}}\ m/s = 3.25\ m/s.$$

22. The loss in kinetic energy should be 10.2 eV so that the hydrogen atom may be excited to first excited state. For minimum kinetic energy case, the two atoms will move together.

$mv_0 = (m+m)\ v \Rightarrow v = v_0/2$

$$\text{loss in kinetic energy} = \frac{1}{2}\ mv_0^2 - \frac{1}{2}\ (2m)\left(\frac{v_0}{2}\right)^2$$

$$10.2eV = \frac{1}{4}\ .\ mv_0^2 = \frac{1}{2}.T$$

$\therefore\ T = 2\times10.2\ eV = 20.4\ eV$

23. **(a)** $\Delta E = 13.6\times3^2\times\left(\frac{1}{1}-\frac{1}{3^2}\right)\ eV$

$= 13.6\times8\ eV$

$$\lambda = \frac{hc}{\Delta E} = \frac{12400}{13.6\times8}\ Å = 113.7\ Å$$

(b) no. of spectral lines $= {}^nC_2$

$= {}^3C_2 = 3.$

24. $\lambda_{cut\ off} = \frac{hc}{eV}$

$\Rightarrow\ \frac{\Delta\lambda}{\lambda} = -\frac{\Delta V}{V}$

$\Rightarrow$ % decrease in cut off wavelength = 0.1%.

25. $\lambda = \frac{hc}{40\times10^3 e}\ m = 31.05\ pm$

26. $KE = \frac{hc}{\lambda_{min}}\ \Rightarrow\ \lambda_{min} = \frac{hc}{KE}$

$$\lambda_1 - \lambda_2 = 1.24\times10^4\left(\frac{1}{v}-\frac{1}{1\cdot5v}\right)\ °A$$

$$26\times10^{-2} = 1.24\times10^4\times\frac{1}{3V}$$

$$\therefore\ V = \frac{1.24\times10^4}{3\times26\times10^{-2}} = 15.9\times10^3\ V$$

27. $\frac{1}{\lambda} = R(Z-b)^2\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$

apply this equation we get,

$$\lambda_1 = \left(\frac{26-1}{29-1}\right)^2\ 193\ pm = 154\ pm$$

28. $\lambda_1 = \frac{hc}{20\times10^3\times(0.7)e} = 88.6\ pm,$

$$\lambda_2 = \frac{hc}{20\times10^3\times(0.7\times0.3)e} = 295.6\ pm,$$

$$\lambda_3 = \frac{hc}{20\times10^3\times0.7\times(0.3)^2 e} = 985.6\ pm,$$

29. No. of Photons $= \frac{P}{E_\lambda} = \frac{P\lambda}{hc}\cdot s^{-1}$

$$\text{no of photo electron s/s} = \frac{P\lambda}{hc}.\frac{1}{10^6}$$

$$\therefore\ \text{Photo current} = \frac{P\lambda}{hc\times10^6}\cdot e$$

$$= \frac{5\times800\times10^{-9}\times(1.6\times10^{-19})}{6.63\times10^{-34}\times3\times10^8\times10^6}\ A = 3.2\ \mu A.$$

30. $\lambda = D\sin\phi$ and $\lambda = \frac{12.27}{\sqrt{V}}\,\text{Å}$ So $\frac{12.27}{\sqrt{V}} = D\sin\phi$

$$\therefore \quad \frac{12.27\times10^{-10}}{\sqrt{10\times10^{3}}} = 0.55\times10^{-10}\sin\phi$$

$$\sin\phi = \frac{12.27}{0.53\times100} = 0.2231$$

or $\quad \phi = \sin^{-1}(0.2231) \approx 12.89°$

31. $W = \left(\frac{hc}{200\times10^{-9}e} - \frac{hc}{100\times10^{-9}e} + 10\right)eV = 3.8\ eV$

32. $B_{min} = \frac{20}{e}\sqrt{2m_e\left(\frac{hc}{4\times10^{-7}} - 2.39\ e\right)} = 5.70\times10^{-5}\ T$

33. E_λ = Energy of the photon $= \frac{hc}{\lambda} = \frac{1.24\times10^{4}}{4000}\ eV$

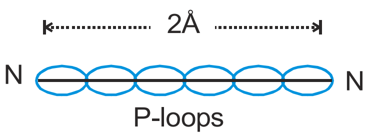
KE of e = 3.1 eV

(a) KE of emithed $e^- = (3.9\times(0.9)^2 - 2.2)\ eV = 0.31 eV$

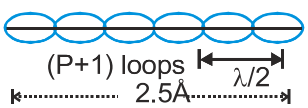
(b) For e^- not be come out, its energy should be less then 2.2 eV. i.e., $(3.1)\times(0.9)^n < 2.2 \qquad n > 4$

34. From the figure it is clear that

$p\,.\,(\lambda/2) \quad = 2\ \text{Å}$



$(p+1)\lambda/2 \quad = 2.5\ \text{Å}$



$\therefore \quad \lambda/2 = (2.5 - 2.0)\ \text{Å} = 0.5\ \text{Å}$

or $\quad \lambda = 1\ \text{Å} = 10^{-10}$m

(i) de Broglie wavelength is given by

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2Km}} \quad K = \text{kinetic energy of electron}$$

$$\therefore K = \frac{h}{2m\lambda^2} = \frac{(6.63\times10^{-34})^2}{2(9.1\times10^{-31})(10^{-10})^2} = 2.415\times10^{-17} J$$

$$= \left(\frac{2.415\times10^{-17}}{1.6\times10^{-19}}\right)eV \quad \therefore K = 150.8\ eV \quad \textbf{Ans.}$$

(ii) 

The least value of d will be when only one loop is formed

$d_{min} = \lambda/2$

$\therefore\ d_{min} = \lambda/2$ or $\qquad d_{min} = 0.5\ \text{Å}$ **Ans.**

35. (a) $n = \frac{P}{E_\lambda} = \frac{1.4\times10^{3}}{\frac{6.63\times10^{-34}\times3\times10^{8}}{5000\times10^{-10}}} = 3.5\times10^{21}$

(b) If N be the no. of photons then these photons will fall on the surface in time

$$\Delta t = \frac{1}{C}$$

$\therefore \quad n = \frac{N}{\Delta t} = N.\,C \qquad \therefore\ n = \frac{n}{C} = \frac{3.5\times10^{21}}{3\times10^{8}}$

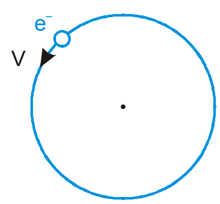
$= 1.2\times10^{13}$

(c) No of photon emithed per second by the sun

$= n\,.\,4\pi r^2 = 3.5\times10^{21}\times4\pi\,(1.5\times10^{11})^2$

$= 9.9\times10^{44}$

36. Effective current



$$I = \frac{e\omega}{2\pi}$$

$$B = \frac{\mu_0 I}{2R}$$

$$B = \frac{\mu_0 I}{2R} = \frac{\mu_0}{2}\cdot\frac{e\omega}{2\pi R} = \frac{\mu_0}{4\pi}\cdot\frac{eV}{R^2}$$

$$= 10^{-7}\times1.6\times10^{-19}\times\frac{(2.19\times10^{6})}{(0.529\times10^{-10})^2}\ T = 12.5\ T.$$

37. (a) $\sqrt{\frac{h}{2\pi eB}}$ **(b)** $\sqrt{\frac{nh}{2\pi eB}}$ **(c)** $\sqrt{\frac{heB}{2\pi m^2}}$

38. $fr\ell \quad f = \frac{1}{T} = \frac{\upsilon}{2\pi r} = \frac{\upsilon}{2\pi r}\times r\times\ell$

$$= \frac{\upsilon}{2\pi}\times\frac{nh}{2\pi} = \frac{v_0\times\frac{z}{n}}{2\pi}\times\frac{nh}{2\pi} = \text{independen of 'n'}$$

So, $fr\ell \propto n^o$.

39. $\frac{1}{2}ke\left[1+2\ln\left(\frac{nh}{2\pi\sqrt{kema^2}}\right)\right]$

40. **(a)** In energy units, 1 rydberg = 13.6 eV. The energy needed to detach the electron is 4 × 13.6 eV. The energy in the ground state is, therefore, $E_1 = -4 \times 13.6$ eV. The energy of the first excited state (n = 2) is $E_2 = \frac{E_1}{4} = 13.6$ eV = 40.8 eV. The wavelength of the radiation emitted is

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

(b) The energy of a hydrogen-like ion in ground state is $E = Z^2E_0$ where Z = atomic number and $E_0 = -13.6$ eV.

Thus, Z = 2. The radius of the first orbit is $\frac{a_0}{Z}$

where $a_0 = 5 \times 10^{-11}$ m.

Thus, $r = \frac{a_0}{Z} = 2.5 \times 10^{-11}$ m

41. $v_0 = \frac{hc}{\lambda e} - 2 = 0.55$ volts

42. **(i)** Maximum energy from one atom

$$= \frac{4800}{49}Rch \times \frac{1}{100} = \frac{48}{49}Rch.$$

(ii) $\Delta E = 13.6\left(1 - \frac{1}{(n+1)^2}\right)$ eV

$$= \frac{48}{49} \times 13.6 = 13.6 \times \left(1 - \frac{1}{(n+1)^2}\right) \Rightarrow n = 6.$$

(iii) Since n = 6 is the excited state. An atom can emit a maximum transition of 6.

∴ Total no. of photons = 6 × 100 = 600.

43. **(a)** 2000 Å, 1500 Å,

(b) Assume energy of level 1 to be zero

------------------$E_4 = 7.75$ eV

------------------$E_3 = 7.35$ eV

------------------$E_2 = 6.2$ eV

------------------$E_1 = 0$ eV

(c) 8.27 volt

44. In case of inelastic callision, the H-atom will be in excited state. The minimum energy will be when it is perfectly inelastic is, the two (n) and (H) both come to rest will move will same velocity i.e.

$$nV + vH \rightarrow \quad n + H$$

from energy conservation

$$2 \times \frac{1}{2}mv^2 = E \qquad v = \sqrt{\frac{E}{m}}$$

where E is the excitation energy

45. **(i)** $r_0 = \frac{2h^2}{\pi^2 m} \times \frac{4\pi\varepsilon_0}{e^2} = 4.23$ Å

(ii) $\frac{1}{2}m\left(\frac{e^2\pi}{4\pi\varepsilon_0 h}\right)^2 J = 3.4$ e

46. **(i)** $\lambda_{min} = \frac{hc}{\text{K.E. of } e^-} = \frac{12400}{20 \times 10^3}$ Å $= 0.62$ Å $= 62$ pm

(ii) Since $\lambda_{min} = 62$ pm, K_a from A will not be obtained

(iii) L–photons can be emitted if electron from L–shell can be removed the energy required to remove L–shell electrons.

$$= 55.5\text{ KeV} + \frac{12400}{124 \times 10^{-2}}\text{ eV} = 15.5\text{ KeV}$$

As the energy of encoming electron is 20 keV > 15.5 KeV, the L–shell electron can be removed. Hence, L photon can be obtained.

The minimum wavelength will correspond to the transimition from ∞ to L–shell.

$$\lambda = \frac{12400}{15.5 \times 10^3}\text{ A} = 0.8\text{ Å}.$$

47. **(a)** He^+, **(b)** $K_{min} = \frac{5}{4}\Delta E = \frac{5}{4} \times 51\text{ eV} = 63.75$ eV

48. Momentum of recoiling atom

$$= \text{momentum of the photon} = \frac{E}{c}$$

$$\text{K.E. of recoiling atom} = \frac{P^2}{2m} = \frac{E^2}{2mc^2}$$

$$= \left(\frac{6.4 \times 10^3 \times 1.6}{3 \times 10^8}\right)^2 \times \frac{1}{2 \times (9.3 \times 10^{-26})}J$$

$= 0.63 \times 10^{-22}$ J = 3.9×10^{-4} eV.

49. **(i)** k_α **(ii)** 102 keV.

50. From the given conditions :

$E_n - E_2 = (10.2 + 17)\text{eV} = 27.2$ eV.

and $E_n - E_3 = (4.25 + 5.95)$ eV $= 10.2$ eV

Equations **(i)** – **(ii)** gives.

$E_3 - E_2 = 17.0$ eV

or $Z^2(13.6)\left(\frac{1}{4}-\frac{1}{9}\right) = 17.0$

$\Rightarrow Z^2(13.6)(5/36) = 17.0$

$\Rightarrow Z^2 = 9.$ **or** $Z = 3.$

From equation **(i)** ,

$$Z^2(13.6)\left(\frac{1}{4}-\frac{1}{n^2}\right) = 27.2$$

or $(3)^2(13.6)\left(\frac{1}{4}-\frac{1}{n^2}\right) = 27.2.$

or $\left(\frac{1}{4}-\frac{1}{n^2}\right) = 0.222$

or $\frac{1}{n^2} = 0.0278.$ or $n^2 = 36.$ $\therefore$ $n = 6.$

51. $\left[\frac{hc}{0.36\times10^{-9}e}+16\right]\text{eV} = 3.47$ KeV

52. **(a)** $10^5\ s^{-1}$ **(b)** 286.18 **(d)** $\frac{1000}{9}$ sec $= 111$s

EXERCISE - 5

Part # I : AIEEE/JEE-MAIN

1. $hf = hf_0 + \frac{1}{2}mv^2$

Hence, $v_1^2 = \frac{2hf_1}{m} - \frac{2hf_0}{m}$

$\Rightarrow v_2^2 = \frac{2hf_2}{m} - \frac{2hf_0}{m}$

$\therefore v_1^2 - v_2^2 = \frac{2h}{m}[f_1 - f_2]$

2. Masses of two nuclei are different.

3. $E = -Z^2\frac{13.6}{n^2}$ eV

For first excited state

$E_2 = -3^2 \times \frac{13.6}{4} = 30.6$ eV

Ionization energy for first excited state of Li^{2+} is 30.6 eV.

4. The third line from the red end corresponds to yellow region i.e. $n^2 = 5$. Thus transition will be from n_2 (= 5) to n_1 (< 5).

5. $\lambda = \frac{h}{mv} = 1.105 \times 10^{-33}$ m

6. For s-electron, $\ell = 0$

7. Initial momentum of surface

$p_i = \frac{E}{C}$

where c = velocity of light (constant). Since, the surface is perfectly reflecting so, the same momentum will be reflected completely

Final momentum

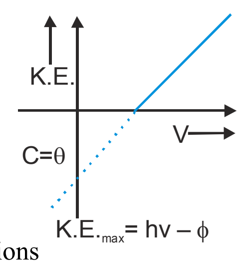
$p_f = \frac{E}{C}$ (negative value)

$\therefore$ Change in momentum $\Delta_p = p_f - p_i = -\frac{E}{C} - \frac{E}{C} = -\frac{2E}{C}$

Thus, momentum transferred to the surface is

$\Delta_{p'} = |\Delta_p| = \frac{2E}{C}$

8. Einstein's photoelectric equation is



The equation of line is

$y = mx + C$

Comparing above two equations

$m = h, c = -\phi$

Hence, slope of graph is equal to Planck's constant (non–variable) and does not depend on intensity of radiation.

9. $\frac{hc}{\lambda} = \phi$

$\Rightarrow \lambda_{max} = \frac{hc}{\phi} = \frac{6.6\times10^{-34}\times3\times10^8}{4\times1.6\times10^{-19}} = 310$nm

10. $I' = Ie^{-\mu x} \Rightarrow \; -\mu x = \log \frac{I'}{I}$

$-\mu .36 = \log \frac{I}{8I}$ .... **(i)**

$-\mu x' = \log \frac{I}{2I}$ .... **(ii)**

From Eq. **(i)** and **(ii)**,

$\frac{36}{x} = \frac{3\log\left(\frac{1}{2}\right)}{\log\frac{1}{2}} \qquad \therefore \qquad x' = 12\text{ mm}$

11. $\frac{I_2}{I_1} = \frac{(r_1)^2}{(r_2)^2} \Rightarrow I_2 = 4\,I_1$

Now, since number of electrons emitted per second is directly proportional to intensity so, number of electrons emitted by photocathode would increase by a factor of 4.

12. $E = Rhc\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$E_{(4\to3)} = Rhc\left[\frac{1}{3^2} - \frac{1}{4^2}\right] = Rhc\left[\frac{7}{9\times16}\right] = 0.05\text{ Rhc}$

$E_{(4\to2)} = \left[\frac{1}{2^2} - \frac{1}{4^2}\right] = Rhc\left[\frac{3}{16}\right] = 0.2\text{ Rhc}$

$E_{(2\to1)} = Rhc\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] = Rhc\left[\frac{3}{4}\right] = 0.75\text{ Rhc}$

$E_{(1\to3)} = Rhc\left[\frac{1}{(3)^2} - \frac{1}{(1)^2}\right] = \frac{8}{9}Rhc = -0.9\text{ Rhc}$

$\therefore$ Thus, III transition gives most energy.

13. We know $\lambda = \frac{h}{m\upsilon}$ and $K = \frac{1}{2}m\upsilon^2 = \frac{(m\upsilon)^2}{2m}$

$\Rightarrow m\upsilon = \sqrt{2mK}$ Thus $\lambda = \frac{h}{\sqrt{2mK}}$

$\Rightarrow \lambda \propto \frac{1}{\sqrt{K}} \;\therefore\; \frac{\lambda_2}{\lambda_1} = \frac{\sqrt{K_1}}{\sqrt{K_2}} = \frac{\sqrt{K_1}}{\sqrt{2K_1}} \;(\because K_2 = 2K_1)$

$\Rightarrow \frac{\lambda_2}{\lambda} = \frac{1}{\sqrt{2}} \qquad \therefore \qquad \lambda_2 = \frac{1}{\sqrt{2}}$

14. 10^{-10} sec.

15. $\frac{1}{m}$

16. $\lambda = \frac{1242\text{eVnm}}{11.2} \approx 1100\text{Å}$ Ultraviolet region

18. $E = pc, \quad h\nu = pc, \quad p = \frac{h\nu}{c}$.

19. For highest frequency in emission spectra the difference of energy between two states involved should be maximum

$\Delta eV_{2-4} = 10.2\text{ eV}, \quad \Delta E_{\infty-1} = 13.6\text{ eV}$

$\Delta E_{\infty-1} = 3.4\text{ eV}, \Delta E_{6-2} < \Delta E_{\infty-2}, \; \Delta E_{6-2} < \Delta E_{2-1}$

So photons of highest frequency will be emitted for $n = 2$ to $n = 1$.

20. $\frac{mv^2}{r} = \frac{K}{r}$ ...**(1)** , $mvr = \frac{nh}{2\pi}$ ....**(2)**

Solve these equation

21. $5 \to 4$ Transition energy from 5 to 4 will be lessthan from $4 \to 3$. All other transition energy are higher than that for $4 \to 3$.

22. $E_\lambda = \frac{1240}{400}\text{ eV} = 3.1\text{ eV}$

$E_\lambda - k = (3.10 - 1.68)\text{eV} = 1.42\text{ eV}$

$Q < 1.42\text{ eV}$

23. Energy of X-rays-photon is greater then ultraviolet photon.

So, V_0 and K_{max} increases.

Electrons have speed ranging from 0 to maximum, because before emitting a large number of collisions take place and energy is lost in collision.

24. Energy of each photon $= \frac{4000}{10^{20}} = 4\times10^{17}$

$\lambda = \frac{12400\times1.6\times10^{-19}}{4\times10^{-17}}\,A^0 = 49.6\text{ Å}$

It is in ultraviolet rays spectrum.

25. $E_1 = -\frac{13.6(3)^2}{(1)^2} \Rightarrow E_3 = -\frac{13.6(3)^2}{(3)^2} \quad \therefore \quad \Delta E = E_3 - E_1$

$= 13.6(3)^2\left[1 - \frac{1}{9}\right] = \frac{13.6\times9\times8}{9} \quad \Delta E = 108.8\text{ eV.}$ **Ans.**

26. $h\nu = h\nu_0 + k_{max} \Rightarrow k_{max} = h\nu - h\nu_0$

27. $P_i = 0 \Rightarrow P_f = P_1 + P_2$

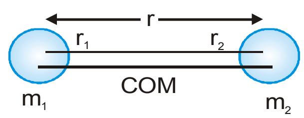
$P_i = P_f \Rightarrow 0 = P_1 + P_2$

$(P_1 = -P_2) \Rightarrow \lambda_1 = \dfrac{h}{P_1}$

$\lambda_2 = \dfrac{h}{P_2} \Rightarrow |\lambda_1| = |\lambda_2| \Rightarrow \lambda_1 = \lambda_2 = \lambda.$

28. If $n = 4 \Rightarrow$ lines $= \dfrac{n(n-1)}{2} = 6$

29. $m_1r_1 = m_2r_2 \Rightarrow r_1 + r_2 = r$



$\therefore\ r_1 = \dfrac{m_2 r}{m_1 + m_2} \Rightarrow r_2 = \dfrac{m_1 r}{m_1 + m_2} \quad \therefore\ \varepsilon = \dfrac{1}{2} I\omega^2$

$= \dfrac{1}{2}(m_1 r_1^2 + m_2 r_2^2).\omega^2$ ....**(i)**

$mvr = \dfrac{h}{2\pi} = I\omega \Rightarrow \omega = \dfrac{nh}{2\pi I}$

$\therefore\ \varepsilon = \dfrac{1}{2} I . \dfrac{n^2h^2}{4\pi^2 I^2} = \dfrac{n^2h^2}{8\pi^2} \dfrac{1}{(m_1 r_1^2 + m_2 r_2^2)}$

$= \dfrac{n^2h^2}{8\pi^2} \dfrac{1}{m_1 \dfrac{m_2^2 r_0^2}{(m_1+m_2)^2} + m_2 \dfrac{m_1^2 r^2}{(m_1+m_2)^2}}$

$= \dfrac{n^2h^2}{8\pi^2 r^2} \dfrac{(m_1+m_2)^2}{m_1 m_2 (m_1+m_2)} = \dfrac{(m_1+m_2)\, n^2h^2}{8\pi^2 r^2 m_1 m_2}$

30. As λ is increased, there will be a value of λ above which photoelectrons will be cease to come out so photocurrent will become zero. Hance (4) is correct answer.

31. $\Delta E = h\nu$

$\nu = \dfrac{\Delta E}{h} = k\left[\dfrac{1}{(n-1)^2} - \dfrac{1}{n^2}\right]$

$= \dfrac{k2n}{n^2(n-1)^2} \approx \dfrac{2k}{n^3} \propto \dfrac{1}{n^3}$

Part # II : IIT-JEE ADVANCED

1. $U = eV = eV_0 \ln\left(\dfrac{r}{r_0}\right) \quad \therefore\ |F| = \left|-\dfrac{dU}{dr}\right| = \dfrac{eV_0}{r}$

This force will provide the necessary centripetal force. Hence

$\dfrac{mv^2}{r} = \dfrac{eV_0}{r}$ **or** $\upsilon = \sqrt{\dfrac{eV_0}{m}}$ ...**(i)**

$m\upsilon r = \dfrac{nh}{2\pi}$ ...**(ii)**

Dividing equation **(ii)** by **(i)** we have

$mr = \left(\dfrac{nh}{2\pi}\right)\sqrt{\dfrac{m}{eV_0}}$ **or** $r_n \propto n$

2. $(r_m)\left(\dfrac{m^2}{z}\right)(0.53\ \text{Å}) = (n \times 0.53)\text{Å}$

$\therefore\ \dfrac{m^2}{z} = n$

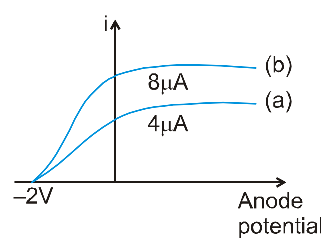
$m = 5$ for 100 Fm^{257} (the outermost shell) and $z = 100$

$\therefore\ n = \dfrac{(5)^2}{100} = \dfrac{1}{4}$

3. Maximum kinetic energy of the photoelectrons would be

$K_{max} = E - W = (5-3)\ eV = 2eV$

Therefore, the stopping potential is 2 Volt. Saturation current depends on the intensity of light incident. When the intensity is doubled the saturation current will also become two fold. The corresponding graphs are shown in figure.



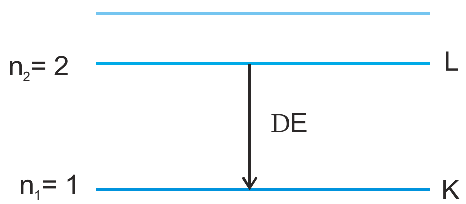
4. $DE = h\nu = Rhc\,(z-b)^2\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

For K-series $b = 1$

$\therefore\ \nu = Rc\,(z-1)^2\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

Substituting the values

$$4.2 \times 10^{18} = (1.1 \times 10^{7})(3 \times 10^{8})(z-1)^2 \left(\frac{1}{1} - \frac{1}{4}\right)$$



$\therefore \quad (z-1)^2 = 1697$

or $\quad z - 1 \approx 41$ or $z = 42$

5. Saturation current is proportional to intensity while stopping potential increases with increase in frequency. Hence A & B same intensity. B & C same frequency. Therefore, the correct option is (a)

6. $$\frac{\lambda_1}{\lambda_2} = \frac{\dfrac{h}{\sqrt{2mE}}}{\dfrac{hc}{E}} \Rightarrow \frac{\lambda_1}{\lambda_2} \alpha\, E^{1/2}$$

Therefore, the correct option is (B).

7. Wavelengths corresponding to minimum wavelength (λ_{min}) or maximum energy will emit photoelectrons having maximum kinetic energy.
(λ_{min}) belonging to Balmer series and lying in the given range (450 nm to 750 nm) corresponds to transition from (n = 4 to n = 2). Here,

$$E_4 = \frac{13.6}{(4)^2} = -0.85 \text{ eV} \text{ and } E_2 = -\frac{13.6}{(2)^2} = -3.4 \text{ eV}$$

$\therefore \quad \Delta E = E_4 - E_2 = 2.55$ eV

K_{max} = Energy of photon – work function
$= 2.55 - 2.0 = 0.55$ eV

8. For $K_\alpha \Rightarrow \sqrt{v} \propto (z-1) \Rightarrow \dfrac{1}{\sqrt{\lambda}} \propto (z-1)$

or $\quad \lambda \propto \dfrac{1}{(z-1)^2}$ ....(i)

$4\lambda \propto \dfrac{1}{(z'-1)^2}$ ....(ii)

$$\Rightarrow \frac{1}{4} = \frac{(z'-1)^2}{(z-1)^2} \quad \Rightarrow \frac{z'-1}{z-1} = \frac{1}{2}$$

$\Rightarrow 2z' - 2 = z - 1 \Rightarrow 2z' - 2 = 11 - 1 = 10 \quad \Rightarrow z' = 6$

9. First photon will excite the atom to I excited state, which when returning to ground state will emit a photon of energy 10.2 eV second photon will ionize the atom (13.6 eV will be used up in this process). The extra energy (=15 – 13.6 = 1.4 eV) will be carried by electron as its kinetic energy.
So a photon of energy 13.6 eV and an electron of energy 1.4 eV will be emitted.

10. For $0 \le x \le 1$, $KE = 2E_0 - E_0 = E_0$

$$\text{for } x > 1, KE = 2E_0 \quad \frac{\lambda_1}{\lambda_2} = \frac{h/P_1}{h/P_2} = \frac{P_2}{P_1} = \sqrt{\frac{KE_2}{KE_1}}$$

$$= \sqrt{\frac{2E_0}{E_0}} = \sqrt{2}$$

11. $\dfrac{hc}{\lambda} - \phi = eV \Rightarrow V = \dfrac{hc}{e\lambda} - \dfrac{\phi}{e}$

For plate 1 : Plate 2 Plate 3

$\dfrac{\phi_1}{e} = 0.001 \quad \dfrac{\phi_2}{e} = 0.002 \quad \dfrac{\phi_3}{e} = 0.004$

$\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$

For plate 2, threshold wavelength

$$\lambda = \frac{hc}{\phi_2} = \frac{hc}{0.002\ hc} = \frac{1000}{2} = 500 \text{ nm}$$

For plate 3, threshold wavelength

$$\lambda = \frac{hc}{\phi_3} = \frac{hc}{0.004\ hc} = \frac{1000}{4} = 250 \text{ nm}$$

Since violet colour light λ is 400 nm, so $\lambda_{violet} < \lambda_{threshold}$ for plate 2.
So, violet colour light will eject photo–electrons from plate 2 and not from plate 3.

12. $$\frac{1}{\lambda} = RZ^2\left(1 - \frac{1}{(n+1)^2}\right) = \frac{1}{(h/mv)} = \frac{mv}{h} = \frac{mvr}{hr}$$

$$= \frac{(n+1)h}{2\pi hr} = \frac{n+1}{2\pi r} \quad \text{Putting, } r = \frac{r_0 (n+1)^2}{Z}$$

$$\frac{1}{\lambda} = RZ^2\left(1 - \frac{1}{(n+1)^2}\right) = \frac{(n+1)Z}{2\pi r_0 (n+1)^2}$$

$$\Rightarrow (n+1) - \frac{1}{(n+1)} = \frac{1}{2\pi r_0 ZR}$$

$$= \frac{1}{2\pi \times 11 \times 0.53 \times 10^{-10} \times 1.1 \times 10^{7}}$$

$$= \frac{1000}{2\pi \times 12.1 \times 0.53} = 24.8 \Rightarrow (n+1) = 25 \Rightarrow n = 24$$

Ans. n = 24.

13. The series in uv region is Lyman series. Longest wavelength corresponds to minimum energy which occurs in transition from n = 2 to n = 1.

$$\therefore \quad 122 = \frac{1/R}{\frac{1}{1^2} - \frac{1}{2^2}} \qquad \text{....(1)}$$

The smallest wavelength in the infrared region corresponds to maximum energy of Paschen series

$$\lambda = \frac{1/R}{\frac{1}{3^2} - \frac{1}{\infty}} \qquad \text{....(2)}$$

from (1) and (2) $\lambda = 823.5$ nm.

14. Both statements are correct but statement (2) is not correct explaination of statement (1).

Energy of characteristic x-ray depends on the difference in energy levels.

15. $p = \frac{h}{\lambda} \Rightarrow \quad \text{K.E.} = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

If entire K.E. of electron is converted into photon then

$$\frac{h^2}{2m\lambda^2} = \frac{hc}{\lambda_0} \quad \Rightarrow \quad \lambda_0 = \frac{2mc\lambda^2}{h}$$

16. $\lambda_{min} = \frac{hc}{eV}$.

Cut off wavelength depends on the energy of the accelerated electrons and is independent of nature of target.

$$\lambda_{K\alpha} \propto \frac{1}{(z-b)^2}$$

characteristic wavelength depend on atomic no and cut off wavelength depend on energy of e^-.

17. $\Delta E_H = \frac{3}{4} \times 13.6 \text{ eV}$ = Energy released by H atom. Let He^+ go to nth state.

So energy required

$$\Delta E_{He} = 13.6 \times 4 \left(\frac{1}{4} - \frac{1}{n^2}\right) \text{eV} \Rightarrow \Delta E_{He} = \Delta E_H$$

$$\Rightarrow \frac{3}{4} \times 13.6 = 13.6 \times 4 \left(\frac{1}{4} - \frac{1}{n^2}\right) \Rightarrow n = 4$$

Ans. C

18. The wavelength corresponding to transition from n = 4 to n = 3 in He^+ corresponds to visible region. Its wavelength is :

$$\frac{hc}{\lambda} = 13.6 \times 4 \left[\frac{1}{9} - \frac{1}{16}\right]$$

$$\frac{4.1 \times 10^{-15} \times 3 \times 10^8}{\lambda(m)} = 13.6 \times 4 \times \frac{7}{9 \times 16}$$

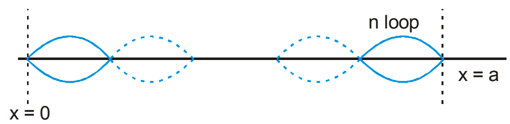
$$\Rightarrow \lambda = \frac{4.1 \times 10^{-15} \times 3 \times 10^8}{13.6 \times 4 \times \frac{7}{9 \times 16}} m$$

$\lambda = 4.68 \times 10^{-7}$ m. So, **Ans (C).**

19. $\text{K.E.} = -\text{T.E.} \Rightarrow \frac{K_H}{K_{He}} = \frac{TE_H}{TE_{He}}$

For same 'n' $\frac{TE_H}{TE_{H_e}} = \frac{(Z_H)^2}{(Z_{He})^2} = \frac{1}{4}$

20.



$n\frac{\lambda}{2} = a \qquad$ and $\qquad p = \frac{h}{\lambda} = \frac{nh}{2a}$

Energy $\qquad E = \frac{p^2}{2m} = \frac{n^2h^2}{8ma^2} \Rightarrow E \propto \frac{1}{a^2}$

21. $E = \frac{n^2h^2}{8ma^2}$

For ground state n = 1 $\Rightarrow E_1$

$$= \frac{(1)^2(6.6 \times 10^{-34})^2}{8 \times 10^{-30} \times (6.6 \times 10^{-9})^2 \times 1.6 \times 10^{-19}} = 8 \text{ meV}$$

22. $P = \frac{nh}{2a} = mv \Rightarrow \qquad v \propto n$

23. $E_{\lambda_1 = 550nm} = \frac{1240}{550} eV = 2.25 eV$

$$\Rightarrow E_{\lambda_2 = 450nm} = \frac{1240}{450} eV = 2.8 eV$$

$$E_{\lambda_3 = 350nm} = \frac{1240}{350} eV = 3.5 eV$$

For metal r, only λ_3 is able to generate photoelectron.

For metal q, only λ_2 and λ_3 are able to generate photoelectron.

For metal p, all wavelength are able to generate photoelectron.

Hence photoelectric current will be maximum for p and least for r.

24. $P_1 = \sqrt{2m(100\,eV)} \Rightarrow \lambda_P = \dfrac{h}{\sqrt{2m(100\,eV)}}$

$\Rightarrow \lambda_\alpha = \dfrac{h}{\sqrt{2(4m)2(100\,eV)}} \Rightarrow \dfrac{\lambda_P}{\lambda_\alpha} = \sqrt{8}$

$\Rightarrow$ The ratio $\dfrac{\lambda_P}{\lambda_\alpha}$, to the nearest integer, is equal to 3.

25. $I\omega = \dfrac{nh}{2\pi}$

Rotational kinetic energy $= \dfrac{1}{2}I\omega^2 = \dfrac{1}{2}\dfrac{n^2h^2}{4\pi^2 I} = \dfrac{n^2h^2}{8\pi^2 I}$

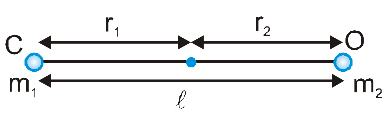
26. hf = change in rotational kinetic energy (f = frequency)

$hf = \dfrac{3h^2}{8\pi^2 I}$

$I = \dfrac{3h}{8\pi^2 f} = \dfrac{3\times 2\pi\times 10^{-34}}{8\pi^2\times\frac{4}{\pi}\times 10^{11}} = 0.1875\times 10^{-45}$

$I = 1.875\times 10^{-46}\ kg\,m^2$.

27. $m_1r_1 = m_2r_2 \Rightarrow 12r_1 = 16r_2$



$\dfrac{r_1}{r_2} = \dfrac{4}{3} \Rightarrow \dfrac{r_1}{\ell} = \dfrac{4}{7} \Rightarrow r_1 = \dfrac{4}{7}\ell$

Now, $I = m_1r_1^2 + m_2r_2^2$

$= m_1r_1(\ell)$

$= m_1\left(\dfrac{4}{7}\ell\right)\ell \Rightarrow I = \left(\dfrac{4m_1}{7}\right)\ell^2 \Rightarrow \ell = \sqrt{\dfrac{7I}{4m_1}}$

$\ell = \sqrt{\dfrac{7\times 1.87\times 10^{-46}}{4\times 12\times\frac{5}{3}\times 10^{-27}}} = 0.128\times 10^{-9}\,m = 1.28\times 10^{-10}\,m$

28. $\dfrac{1}{\lambda_{H_2}} = RZ_H^2\left[\dfrac{1}{4}-\dfrac{1}{9}\right] = R(1)^2\left[\dfrac{5}{36}\right]$

$\Rightarrow \dfrac{1}{\lambda_{He}} = RZ_{He}^2\left[\dfrac{1}{4}-\dfrac{1}{16}\right] = R(4)\left[\dfrac{3}{16}\right]$

$\dfrac{\lambda_{He}}{\lambda_{H_2}} = \dfrac{1}{4}\left[\dfrac{16}{3}\times\dfrac{5}{36}\right] = \dfrac{5}{27}$

$\Rightarrow \lambda_{He} = \dfrac{5}{27}\times 6561 = 1215\ \text{Å}$

29. $\left[\sqrt{\dfrac{Ne^2}{m\varepsilon_0}}\right] = \sqrt{\dfrac{\frac{1}{L^3}\times Q^2}{M\times\frac{Q^2}{L^2\times F}}} = \dfrac{1}{T}$

So only (C) is dimensionally correct

30. For resonance

$\omega = \omega_P = \sqrt{\dfrac{Ne^2}{m\varepsilon_0}} = \sqrt{\dfrac{4\times 10^{27}\times(1.6\times 10^{-19})^2}{10^{-30}\times 10^{-11}}}$

$\Rightarrow \omega = 3.2\times 10^{15}$

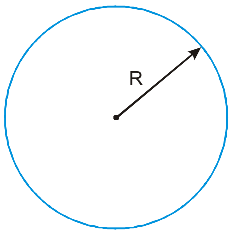
$f = \dfrac{\omega}{2\pi} = \dfrac{3.2\times 10^{15}}{2\times 3.14} \approx \dfrac{1}{2}\times 10^{15}$

$\lambda = \dfrac{c}{f} = \dfrac{3\times 10^8}{\frac{1}{2}\times 10^{15}} \Rightarrow \lambda \approx 600\ nm$

31. $R = 1\,cm \Rightarrow f = 4.7\,cm$

$\dfrac{hc}{\lambda} = \phi + eV \Rightarrow \dfrac{1240(ev)(nm)}{200(nm)} = 4.7\,(eV) + eV$

$\dfrac{1240}{200}e = 4.7\,e + eV$



$6.2 - 4.7 = V$

$\therefore\ V = 1.5$ volt

$\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{R} = 1.5$

$(9\times 10^9)\dfrac{Ne}{\frac{1}{100}} = 1.5 \Rightarrow 9\times 10^{11}\ Ne = 1.5;$

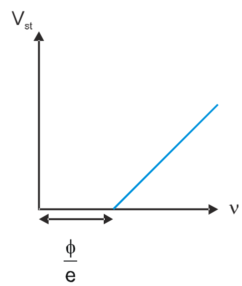
$N = \dfrac{1.5}{9\times 10^{11}\times 1.6\times 10^{-19}} = \dfrac{15}{16}\times\dfrac{1}{9}\times 10^8$

$= \dfrac{5}{3\times 16}\times 10^8 = \dfrac{50}{48}\times 10^7\ \therefore\ Z = 7$

32. Change in momentum $= \dfrac{\text{power} \times \text{total time}}{\text{speed of light}}$

$$= \frac{P \times t}{c} \quad 1.0 \times 10^{-17}\ \text{kg} \times \text{m/s}$$

33. $KE_{max} = h\nu - \phi$



$eV_{st} = h\nu - \phi$

$V_{st} = \left(\dfrac{h}{e}\right)\nu - \dfrac{\phi}{e}$

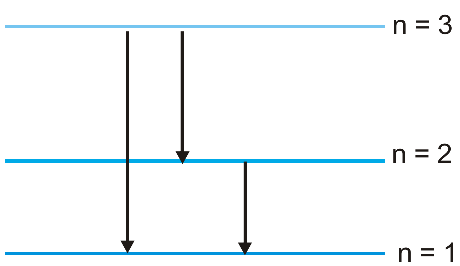
$y = mx + C$

So slope will be $\left(\dfrac{h}{e}\right)$, and it will be same for both the metals.

So ratio of the slopes = 1

34. $R_n = 4.5\ a_0$

$L = mvr = \dfrac{3h}{2\pi}$ [as n = 3, z = 2]



$$\frac{1}{\lambda} = Rz^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{1}{\lambda_{3\to1}} = R4\left[\frac{1}{1} - \frac{1}{9}\right] = 4R\frac{8}{9} \Rightarrow \lambda_{3\to1} = \frac{9}{32R}$$

$$\frac{1}{\lambda_{2\to1}} = R4\left[\frac{1}{1} - \frac{1}{4}\right] = \frac{3}{4}4R \Rightarrow \lambda_{2\to1} = \frac{1}{3R}$$

$$\frac{1}{\lambda_{3\to2}} = R4\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5}{36}4R \Rightarrow \lambda_{3\to2} = \frac{9}{5R}$$

MOCK TEST

1 We have $K_\alpha = \dfrac{m_y}{m_y + m_\alpha}.Q$

$\Rightarrow K_\alpha = \dfrac{A-4}{A}.Q$

$\Rightarrow 48 = \dfrac{A-4}{A}.50 \Rightarrow A = 100$

2. Angular momentum (mvr) = $n.\dfrac{h}{2\pi}$

$= \dfrac{h}{2\pi}\ (n = 1)$

3. First excitation energy $= RhC\left(\dfrac{1}{1^2} - \dfrac{1}{2^2}\right)$

$= RhC\ \dfrac{3}{4}$

$\therefore \dfrac{3}{4} RhC = V$ e.v.

$\therefore RhC = \dfrac{4V}{3}$ e.v.

4. The electron ejected with maximum speed v_{max} are stopped by electric field E = 4N/C after travelling a distance d = 1m

$\therefore \dfrac{1}{2} mV_{max}{}^2 = eE\,d = 4eV$

The energy of incident photon $= \dfrac{1240}{200} = 6.2$ eV

From equation of photo electric effect

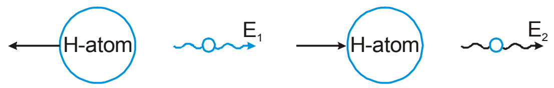
$\dfrac{1}{2} mv_{max}{}^2 = h\upsilon - \phi_0$

$\therefore \phi_0 = 6.2 - 4 = 2.2$ eV.

5. $\lambda = \dfrac{h}{\sqrt{2mK}}$

$\Rightarrow \dfrac{\lambda_e}{\lambda_p} = \sqrt{\dfrac{M}{m}}$

K = qV is same for both proton and electron.

6. 

Case - Case -

In the first case K.E. of H-atom increases due to recoil whereas in the second case K.E. decreases due to recoil but $E_1 + KE_1 = E_2 + KE_2$.

$\therefore \quad E_2 > E_1$

7. Linear momentum $\Rightarrow \quad mv \,\alpha\, \frac{1}{n}$

angular momentum $\Rightarrow mvr \,\alpha\, n$

$\therefore$ product of linear momentum and angular momentum $\alpha\, n$

8. Energy of photon is given by mc^2 now the maximum energy of photon is equal to the maximum energy of electron = eV

hence $mc^2 = ev$

$\Rightarrow m = \frac{eV}{c^2}$

$$= \frac{1.6\times10^{-19}\times18\times10^{3}}{(3\times10^{8})^2} = 3.2\times10^{-32}\text{ kg}$$

9. Using $\frac{1}{\lambda} = R(z-1)^2\left[\frac{1}{n_2^{\,2}} - \frac{1}{n_1^{\,2}}\right]$

For α particle ; $n_1 = 2, n_2 = 1$

For metal A ; $\frac{1875R}{4} = R(Z_1-1)^2\left(\frac{3}{4}\right)$

$\Rightarrow z_1 = 26$

For metal B; $675R = R(Z_2-1)^2\left(\frac{3}{4}\right)$

$\Rightarrow z_2 = 31$

Therefore, 4 elements lie between A and B, i.e. with Z= 27, 28 ,29 , 30

10. For 2nd line of Balmer seires in hydrogen specturm

$$\frac{1}{\lambda} = R(1)\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3}{16}R$$

For Li^{2+} $\frac{1}{\lambda} = R(3)^2\left(\frac{1}{6^2} - \frac{1}{12^2}\right) = \frac{3}{16}R$

which is satisfied by only (D).

11. We have : K.E. $= \frac{P^2}{2m_e} = \frac{hc}{\lambda_{min}}$.

$$\Rightarrow \quad P = \sqrt{\frac{2hcm_e}{\lambda_{min}}}$$

Also, $\lambda_{de\ broglie} = \frac{h}{p} = \sqrt{\frac{h\lambda_{min}}{2m_eC}}$

for $\lambda_{min} = 10Å : \lambda_{de\ broglie} \cong 0.3Å$

12. Energy of nth sate in Hydrogen is same as energy of 3nth state in Li^{++}.

$\therefore$ $3 \to 1$ transition in H would give same energy as the $3\times3 \to 1\times3$ transition in Li^{++}.

13. $\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi$

$$\frac{1}{2}mv'^2 = \frac{hc}{(3\lambda/4)} - \phi$$

$$= \frac{4hc}{3\lambda} - \phi$$

Clearly $\quad v' > \sqrt{\frac{4}{3}}\,v$

14. No. of photoelectron emitted per second,

$$n = \frac{\text{Power (watt)}\times\text{Emission \%}}{\text{Energy of 1 photon (inJ)}\times100}$$

$$= \frac{1.5\times10^{-3}\,W\times(10^{-3})\times0.1}{\frac{1240(nm)(eV)}{400(nm)}\times e\times100} = \frac{0.48}{e}\times10^{-6}.$$

(energy of 1 photon $= \frac{1240\,nm/eV}{400\,nm\times e}$ Joule)

$\therefore$ Photo current = ne = 0.48 μA

15. for K_α $\frac{1}{\lambda_\alpha} = \frac{3R}{4}(Z-1)^2$

transition is from n =2 to n =1

$$\Rightarrow \quad (Z-1) = \sqrt{\frac{4}{3R\lambda_\alpha}}$$

$$= \sqrt{\frac{4}{3\times1.1\times10^{7}\times1.8\times10^{-10}}}$$

$$= \frac{200}{3}\sqrt{\frac{5}{33}} = \frac{78}{3} = 26. \Rightarrow Z = 27$$

16. λ_m will increase to 3 λ_m due to decrease in the energy of bombarding electrons. Hence no characteristic x-rays will be visible, only continous X-ray will be produced.

17. $\because$ $B = \frac{\mu_0 I}{2r}$ and $I = \frac{e}{T}$

$$B = \frac{\mu_0 e}{2rT} \quad [r \propto n^2, T \propto n^3]$$

$$\Rightarrow B \propto \frac{1}{n^5}$$

18. $i = \frac{q}{T}$ Now $T^2 \propto r^3 \propto n^6$

$$\Rightarrow i \propto \frac{1}{n^3}$$

$$\Rightarrow T \propto n^3 \quad \frac{i_1}{i_2} = \frac{H_2^3}{H_1^3} = \frac{(1)^3}{(2)^3} = i_2 = 8i_1$$

19. Ground state n = 1

first excited state n = 2

$$KE = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r}(z=1)$$

$$\therefore \; KE = \frac{14.4\times10^{-10}}{2r}\,eV$$

Now $r = 0.53\,n^2\,A^o\,(z=1)$

$$(KE)_1 = \frac{14.4\times10^{-10}}{2\times0.53\times10^{-10}}\,eV = 13.58\,eV$$

$$\therefore \; (KE)_2 = \frac{14.4\times10^{-10}}{2\times0.53\times10^{-10}\times4}\,ev = 3.39\,ev$$

$\therefore$ KE decreases by = 10.2 ev

Now $PE = \frac{-1}{4\pi\varepsilon_0}\frac{e^2}{r} = \frac{-14.4\times10^{-10}}{r}\,ev$

$$\therefore \; (PE)_1 = \frac{-14.4\times10^{-10}}{0.53\times10^{-10}}\,ev = -27.1\,ev$$

$$(PE)_2 = \frac{-14.4\times10^{-10}}{0.53\times10^{-10}\times4} = -6.79ev$$

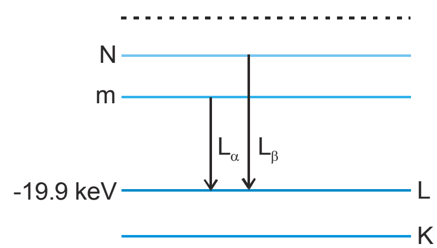
$\therefore$ PE increases by = 20.4 ev

Now Angular momentum

$$L = mvr = \frac{nh}{2\pi}$$

$$L_2 - L_1 = \frac{h}{2\pi} = \frac{6.6\times10^{-34}}{6.28} = 1.05\times10^{-34}\,J\text{–sec.}$$

20. $\lambda_{min.} = \frac{12400}{V_0}$ Å



$$\frac{12400}{20,000} = .62\text{ Å} \approx 62{\cdot}1\text{pm}$$

Any transition to L will have energy less than or equal to 19·9 kev $\Rightarrow$ so B.

21. $|F| = \frac{dU}{dr} = \frac{Ke^2}{r^4}$ ....(1)

$\frac{Ke^2}{r^4} = \frac{mv^2}{r}$ ....(2)

and $mvr = \frac{nh}{2\pi}$ ....(3)

By (2) and (3)

$r = \frac{Ke^2 4\pi^2}{h^2}\frac{m}{n^2} = K_1\frac{m}{n^2}$ ....(4)

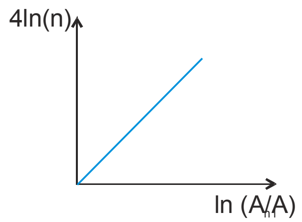
Total energy = $\frac{1}{2}$ (potential energy) = $\frac{Ke^2}{6r^3}$

$$= \frac{-Ke^2}{6\left(\frac{K_1 m}{n^2}\right)^3} = \frac{-Ke^2n^6}{6K_1^3m^3}$$

Total energy $\propto n^6$

Total energy $\propto m^{-3}$ $\therefore$ **(A)** and **(B)** are correct.

22. $\because r_n = n^2r_1$



$$\ell n\left(\frac{A_n}{A_1}\right) = \ell n\left(\frac{\pi r_n^2}{\pi r_1^2}\right)$$

$= \ell n\ n^4 = 4\ \ell n\ (n)$

23. Energy of photoelectron emitted is different because after absorbing the photon electrons within metals collide with other atom before being ejected out of metal.

Hence statement 2 is correct explanation of statement 1.

24. de-Broglie wavelength associated with gas molecules varies as $\lambda \propto \frac{1}{\sqrt{T}}$.

25. Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

26. For Balmer series,

$n_1 = 2$, (lower)

$n_2 = 3, 4, ...$ (higher)

$\therefore$ In transition (VI), Photon of Balmer series is absorbed.

27. In transition II

$E_2 = -3.4$ eV, $E_4 = -0.85$ eV

$\Delta E = 2.55$ eV

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

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

$\Rightarrow \lambda = 487$ nm.

28. Wavelength of radiation = 103 nm = 1030 Å

$\therefore \quad \Delta E = \frac{12400}{1030\text{Å}} \simeq 12.0$ eV

So difference of energy should be 12.0 eV (approx)

Hence $n_1 = 1$ and $n_2 = 3$

(–13.6)eV (–1.51)eV

$\therefore$ Transition is V.

29. Consider two equation

$eV_s = \frac{1}{2}mv^2_{max} = h\nu - \phi_0$ .... **(1)**

no of photoelectrons ejected/sec.

$\propto$ no. of photons/second .... **(2)**

(A) As frequency is increased keeping intensity constant.

$|V_s|$ will increase, $\frac{1}{2}m(v^2_{max})$ will increase and saturation current will remains same.

(B) As frequency is increased and intensity is decreased.

$|V_s|$ will increase, $\frac{1}{2}m(v^2_{max})$ will increase and saturation current will decrease.

(C) It work function is increased photo emission may stop.

(D) If intensity is increased and frequency is decreased. saturation current will increase.

30. $KE_{max} = (5 - \phi)$ eV

when these electrons are accelerated through 5V,

they will reach the anode with energy = $(5 - \phi + 5)$eV

$\therefore 10 - \phi = 8$

ϕ = 2eV Ans.

Current is less than saturation current Ans.

Because if slowest electron also reached the plate it would have 5eV energy at the anode, but there it is given that the minimum energy is 6eV.

31. (i) maximum energy of emitted photon

$$= \frac{\frac{4800}{49}\text{Rch}}{100} = \frac{48}{49}\text{Rch}$$

(ii) Energy released if electron jumps from level n′

to level 1 = $\text{Rch}\left(\frac{1}{1^2} - \frac{1}{n'^2}\right)$

$\therefore$ $\text{Rch}\left(\frac{1}{1^2} - \frac{1}{n'^2}\right) = \frac{48}{49}\text{Rch}$

$\therefore$ n′ = 7 then n excited state = n′ – 1

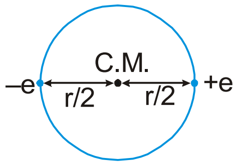
$\therefore$ n = 6

(iii) Each atom can emit a maximum of 6 photons

$\because$ there are 100 atoms, maximum number of photons that can be emitted = 600.

Ans. (i) $\frac{48}{49}$ **Rch, (ii) n = 6, (iii) 600.**

48. (i) $\frac{Ke^2}{r^2} = m\omega^2 \frac{r}{2}$ .....**(1)**



and $m\left(\omega\frac{r}{2}\right)\frac{r}{2} \times 2 = \frac{nh}{2\pi}$ ...**(2)**

By **(1)** and **(2)** $r = \frac{n^2h^2}{2\pi^2 mKe^2} = \left(\frac{n^2h^2}{4\pi^2 mKe^2}\right) \times 2$

$= (0.529\ \text{Å}) \times 2n^2$

For first excited state n = 2

$\therefore$ $r = 8 \times 0.529\ \text{Å}$

$r = 4.232\ \text{Å}$

(ii) $KE = \frac{1}{2}m\left(\omega\frac{r}{2}\right)^2 = \frac{1}{2} \cdot \frac{m.\omega^2 r^2}{4} = \frac{Ke^2}{4r}$

$$= \frac{Ke^2}{4\times(0.529\text{Å}\times 2)} = \frac{13.6\,\text{eV}}{4} = 3.4\ \text{eV}$$

Ans. (i) 423 (ii) 34