Date :

Name : ATOM, MOLECULES & NUCLEI.

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1. Given :

$\lambda = 5.986 \times 10^{-7} m$

$P = 10 W.$

To Find : $n = ?$

Solution :

$$P = \frac{nhc}{\lambda}$$

$$\therefore n = \frac{P\lambda}{hc}$$

$$= \frac{10 \times 5.986 \times 10^{-7}}{6.63 \times 10^{-34} \times 3 \times 10^{8}}$$

$$= \frac{59.86 \times 10^{-7}}{19.89 \times 10^{-26}}$$

$$n = 3 \times 10^{19}.$$

2. Solution :

$h\nu$ (difference in energy) = 2.3 eV

i.e, $h\nu = 2.3 \times 1.6 \times 10^{-19}$ J.

$$\therefore \nu = \frac{2.3 \times 1.6 \times 10^{-19}}{h}$$

$$\nu = \frac{2.3 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$\nu = \frac{3.08}{6.63} \times 10^{15}$$

$$\nu = 5.5 \times 10^{14} \text{ Hz.}$$

3. Solution:

$$h\nu = \frac{E_1}{n_2^2} - \frac{E_1}{n_1^2}$$

$$= \frac{-13.6}{(3)^2} + \frac{13.6}{(1)^2}$$

$$= -13.6\left[1 - \frac{1}{9}\right]$$

$$h\nu = 12.104$$

$$\therefore \nu = \frac{12.104\ eV}{h}$$

$$= \frac{12.104 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$\nu = 2.924 \times 10^{15}\ Hz$$

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

$$= \frac{3 \times 10^{8}}{2.924 \times 10^{15}}$$

$$= 1.025 \times 10^{-7}\ m$$

hence, $\frac{1}{\lambda} = \frac{1}{1.025 \times 10^{-7}}$

$$= 0.975 \times 10^{7}$$

$$\frac{1}{\lambda} = 9.75 \times 10^{6}\ m^{-1}$$

4. Solution:

$r_n = n^2 r_0$ (Where $r_0 = 0.53\ \text{Å}$)

$\therefore r_1 = 1^2 \cdot r_0$

$r_1 = r_0 = 0.53\ \text{Å}$

$= 0.53 \times 10^{-10} m$

$r_2 = (2)^2 \cdot r_0$

$= 4 \times 0.53 \times 10^{-10} m$

$= 2.12 \times 10^{-10} m$

5. Solution:

$L_n = \frac{nh}{2\pi}$

$\therefore L_1 = \frac{1 \times h}{2\pi} = \frac{h}{2\pi}$

$L_1 = \frac{6.63 \times 10^{-34}}{2 \times 3.14}$

$L_1 = 1.056 \times 10^{-34}\ kg\ m^2/s$

Similarly,

$L_5 = \frac{5h}{2\pi}$

$= 5L_1$

$= 5 \times 1.056 \times 10^{-34}$

$= 5.28 \times 10^{-34}\ kg\ m^2/s$

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6. Given :

$n = 1$ (For Ground state)

To Find : r_0, P_1, L

Solution :

1) Radius of electron in ground state

$$r_0 = \frac{\varepsilon_0 h^2}{\pi . m e^2}$$

$$= \frac{8.85 \times 10^{-12} \times (6.63 \times 10^{-34})^2}{3.14 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}$$

2) Linear Momentum

$$P_n = m V_n$$

$$= m \cdot \frac{e^2}{2 \varepsilon_0 n h} \qquad \left(\because V_n = \frac{e^2}{2\varepsilon_0 n h}\right)$$

Putting $n = 1$ (Ground State)

$$P_1 = \frac{9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}{2 \times 8.85 \times 10^{-12} \times 1 \times 6.63 \times 10^{-34}}$$

$$= \frac{23.296 \times 10^{-31} \times 10^{-38}}{117.351 \times 10^{-12} \times 10^{-34}}$$

$$= 2 \times 10^{-24} \ kg\,m^2/s$$

3) Angular Momentum

$$L_n = \frac{nh}{2\pi}$$

Putting, $n = 1$

$\therefore L_1 = \frac{1 \times h}{2\pi} = \frac{h}{2\pi}$

$= \frac{6.63 \times 10^{-34}}{2 \times 3.14}$

$= 1.056 \times 10^{-34}$ Kg m^2/s

4) Kinetic Energy:

$K.E. = \frac{me^4}{8 \varepsilon_0^2 n^2 h^2}$

Putting $n = 1$,

$K.E. = \frac{me^4}{8 \varepsilon_0^2 h^2}$

$= \frac{9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^4}{8 \times (8.85 \times 10^{-12})^2 \times (6.63 \times 10^{-34})^2}$

$= 13.56$ eV.

5) Potential Energy:

$P.E. = \frac{-me^4}{4 \varepsilon_0^2 n^2 h^2}$

$= \frac{-2 me^4}{2 \times 4 \varepsilon_0^2 n^2 h^2}$

$= -2 \times \frac{me^4}{8 \varepsilon_0^2 n^2 h^2}$

$= -2 \times K.E.$

$= -2 \times 13.56$

$P.E. = -27.12$ eV

6) Total Energy:

$TE = K.E. + P.E$

$= K.E + (-2 P.E)$

$= -KE$

$= -13.56$ eV.

7. Solution :

For Lyman series of H_2,

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad n_1 = 1 \;\; \& \;\; n_2 = 2, 3, 4 \ldots \infty$$

For first member,

$n_1 = 1 \;\; \& \;\; n_2 = 2.$

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

$$\therefore \frac{1}{\lambda} = R\left(1 - \frac{1}{4}\right)$$

$$\frac{1}{\lambda} = R \cdot \frac{3}{4}$$

$$\therefore R = \frac{4}{3\lambda} = \frac{4}{3 \times 1.215 \times 10^{-7}}$$

$$= \frac{4}{3.645 \times 10^{-7}}$$

$$\therefore R = 1.097 \times 10^{7} \, m^{-1}$$

For Balmer series,

$$\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{n^2}\right) \qquad [n = 3, 4, 5 \ldots \infty]$$

$\therefore$ For 3rd member, $n = 5$.

$$\therefore \frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{5^2}\right]$$

$$\therefore \frac{1}{\lambda} = 1.097 \times 10^{7} \, [0.25 - 0.04]$$

$$\frac{1}{\lambda} = 1.097 \times 0.21 \times 10^{7}$$

$$\frac{1}{\lambda} = 0.2303 \times 10^{7}$$

$$\therefore \lambda = 4.342 \times 10^{-7}$$

8. Solution :

Series limit is $\lambda_s = 3646 \, \mathring{A}$

for series limit $n_2 = \infty$

$\therefore \frac{1}{\lambda_s} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ becomes,

$$\frac{1}{3.646 \times 10^{-7}} = R\left[\frac{1}{n_1^2} - \frac{1}{\infty^2}\right] = \frac{R}{n_1^2}$$

$\therefore n_1^2 = R \times 3.646 \times 10^{-7}$

$= 1.097 \times 3.646 \times 10^{7} \times 10^{-7}$

$n_1^2 = 3.999$

$\therefore n_1 = 1.999$

n_1 must be an integer.

$\therefore n_1 \approx 2$, Hence given series is Balmer series.

For longest wavelength of Balmer series,

$n_1 = 2$ & $n_2 = 3$

$\therefore \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ becomes,

$$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$$

$$\therefore \lambda = \frac{36}{5R} = \frac{36}{5 \times 1.097 \times 10^{7}}$$

$$\boxed{\lambda = 6.563 \times 10^{-7} \, m}$$

Wave number $= \frac{1}{\lambda} = \frac{1}{6.563 \times 10^{-7}}$

$= 1.524 \times 10^{6} \, m^{-1}$

Now, $\lambda = 6.563 \times 10^{-7}$

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

$= \frac{3 \times 10^{8}}{6.563 \times 10^{-7}}$

$= 0.457 \times 10^{15}$

$$\boxed{= 4.57 \times 10^{14} \, Hz}$$

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For Balmer Series,

$n_1 = 2$ & $n_2 = 3$ for largest wavelength

$$\therefore \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$\therefore \frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\therefore \frac{1}{\lambda} = R\left[\frac{5}{36}\right]$$

$$\therefore R = \frac{36}{5\lambda}$$

$$= \frac{36}{5 \times 6.563 \times 10^{-7}}$$

$$R = 1.097 \times 10^{7}\ m^{-1}$$

9. Solution :

a) $V = 10^2 V$

$\therefore eV = 1.6 \times 10^{-19} \times 10^2 J$

$E = 1.6 \times 10^{-17} J$

$\therefore \lambda = \frac{h}{\sqrt{2mE}}$

$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-17}}}$

$= \frac{6.63 \times 10^{-34}}{\sqrt{29.152 \times 10^{-48}}}$

$= \frac{6.63 \times 10^{-34}}{5.399 \times 10^{-34}}$

$= 1.22 \times 10^{-10}$

$\boxed{\lambda = 1.22 \mathring{A}}$

b) $V = 10^5 V$

$\therefore eV = 1.6 \times 10^{-19} \times 10^5 J$

$E = 1.6 \times 10^{-14} J$

$\lambda = \frac{h}{\sqrt{2mE}}$

$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-14}}}$

$= \frac{6.63 \times 10^{-34}}{\sqrt{29.152 \times 10^{-45}}}$

$= \frac{6.63 \times 10^{-34}}{1.707 \times 10^{-22}}$

$\boxed{\lambda = 3.88 \times 10^{-12} m}$

10. Given :

$V = 10^3 V$

$\therefore E = eV = 1.6 \times 10^{-19} \times 10^3 J$

$= 1.6 \times 10^{-16} J$

To Find : λ.

Solution :

$$\lambda = \frac{h}{\sqrt{2ME}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-16}}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{29.12 \times 10^{-47}}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2.912 \times 10^{-46}}}$$

$$= \frac{6.63 \times 10^{-34}}{1.706 \times 10^{-23}}$$

$$= 3.88 \times 10^{-11}$$

$\therefore \lambda = 0.388 \times 10^{-10} m.$

11. Given :

$m_\alpha = 6.62 \times 10^{-24} \times 10^{-3}$

$m_\alpha = 6.62 \times 10^{-27}$ kg

$v = 8 \times 10^{8}$ cm/s

$= 8 \times 10^{8} \times 10^{-2}$ m/s

$v = 8 \times 10^{6}$ m/s

To Find : $\lambda = ?$

Solution :

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\lambda = \frac{6.63 \times 10^{-34}}{6.62 \times 10^{-27} \times 8 \times 10^{6}}$$

$$= 0.125 \times 10^{-13}$$

$\therefore \lambda = 1.25 \times 10^{-14}$ m

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12. Given :

$\lambda = 0.5 A^\circ$

To Find : V = ?

Solution :

$$\lambda = \frac{h}{\sqrt{2meV}}$$

$$0.5 \times 10^{-10} = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times V}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{29.12 \times 10^{-50} V}}$$

$$0.5 \times 10^{-10} = \frac{6.63 \times 10^{-34}}{5.393 \times 10^{-25} \times \sqrt{V}}$$

$$\therefore \sqrt{V} = \frac{6.63 \times 10^{-34}}{2.698 \times 10^{-35}}$$

$$\sqrt{V} = 2.457 \times 10^{-1}$$

~~$\therefore V = 6.038 \times 10^{2} V$~~ 603.8

$$\therefore V = 6.038 \times 10^{2} V$$

$$= 603.8 V$$

13. Solution :

Radius of orbit in ground state

$r_0 = 0.5 Å$

Now,

$$mvr_n = \frac{nh}{2\pi}$$

$$mv = \frac{nh}{2\pi r_n}$$

for 2^{nd} orbit, $n = 2$,

$$\therefore mv = \frac{2h}{2\pi (2)^2 r_0} \qquad [\because r_n = n^2 r_0]$$

$$mv = \frac{2h}{4 \times 2\pi r_0}$$

$$\therefore \lambda = \frac{h}{mv} = \frac{h}{h} \times 8\pi r_0$$

$$= 8\pi (0.5)$$

$$\boxed{\lambda = 6.28 Å}$$

14. Solution :

De Broglie wavelength is given by,

$$\lambda = \frac{h}{mv} \quad \text{—— (1)}$$

$$K.E. = \frac{1}{2} mv^2 = E$$

$$\therefore mv = \frac{2E}{v}$$

$\therefore$ eq^n (1) becomes

$$\lambda = \frac{hv}{2E} \quad \text{—— (2)}$$

Similarly, $\lambda' = \frac{hv}{2E'}$; putting $E' = \frac{E}{4}$

$$\therefore \lambda' = \frac{hv}{2} \times \frac{4}{E}$$

$$= \frac{2hv}{E}$$

From eq^n (2)

$$\boxed{\lambda' = 2\lambda}$$

15. Given :

$$\lambda = 0.5 \times 10^{-10} \text{ m}$$

To Find : v, P.

Solution :

By de Broglie hypothesis,

$$\lambda = \frac{h}{mv}$$

$$v = \frac{h}{m\lambda}$$

$$\therefore v = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 0.5 \times 10^{-10}}$$

$$= \frac{6.63 \times 10^{-34}}{4.55 \times 10^{-41}}$$

$$v = 1.457 \times 10^{7} \text{ m/s.}$$

$$P = \frac{h}{\lambda}$$

$$= \frac{6.63 \times 10^{-34}}{0.5 \times 10^{-10}}$$

$$P = 1.326 \times 10^{-23} \text{ kg m}^2/\text{s.}$$

16. Data :

$R = 1.097 \times 10^7\ m^{-1}$

To find : (i) 1st line Lyman Series $\lambda_{L1} = ?$
(ii) 3rd line of Balmer Series $\lambda_{B3} = ?$

Solution :

Spectral lines of hydrogen atom:

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] m^{-1}$$

(i) 1st. line of Lyman series: $n_1 = 1,\ n_2 = 2.$

$$\frac{1}{\lambda_{LI}} = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}.$$

$$\text{Or, } \lambda_{LI} = \frac{4}{3R} = \frac{4}{3 \times 1.097 \times 10^7}$$

$= 1215$ A.U.

(ii) 3rd line of Balmer Series $n_1 = 2,\ n_2 = 5$

$$\frac{1}{\lambda_{B3}} = R\left[\frac{1}{2^2} - \frac{1}{5^2}\right]$$

$$= R\left[\frac{1}{4} - \frac{1}{25}\right] = \frac{21R}{100}$$

$$\text{Or, } \lambda_{B3} = \frac{100}{21R} = \frac{100}{21 \times 1.097 \times 10^7}$$

$= 4341$ A.U.

17. DATA:

Balmer series longest wavelength

$\lambda_{BL} = 6563 \times 10^{-10}$ m

To Find: Paschen series shortest wavelength $\lambda_{PS} = ?$

Solution:

Spectral lines of hydrogen atom:

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] m^{-1}$$

Balmer series longest wavelength:

$n_1 = 2, \quad n_2 = 3.$

$$\frac{1}{\lambda_{BL}} = R\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\frac{1}{\lambda_{BL}} = \frac{5R}{36} \quad \text{------ (1)}$$

Paschen series shortest wavelength:

$n_1 = 3, \quad n_2 = \infty$

$$\frac{1}{\lambda_{PS}} = R\left[\frac{1}{9} - \frac{1}{\infty}\right] = \frac{R}{9} \quad \text{------ (2)}$$

Dividing eqn. (1) by (2):

$$\frac{\lambda_{PS}}{\lambda_{BL}} = \frac{5R}{36} \times \frac{9}{R} = \frac{5}{4}$$

Or, $\lambda_{PS} = \frac{5}{4} \times \lambda_{BL} = \frac{5}{4} \times 6563$

$= 8203.75$ AU.

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18. DATA :

$r_0 = 0.5 A^\circ = 0.5 \times 10^{-10}$

H_2 atom : $n = 3$ and $n = 4$.

To find : (i) de Broglie wavelength $(n=1) = ?$
(ii) de Broglie wavelength $(n=3) = ?$
(iii) de Broglie wavelength $(n=4) = ?$

Solution :

de Broglie wavelength : $\lambda = \frac{h}{mv}$

Also for an electron in the orbits of H_2 atom:

$mvr = \frac{nh}{2\pi}$ combining above two equations:

We get: $\lambda = \frac{2\pi r}{n}$

For H_2 atom radius of orbit varies as n^2.

(i) de Broglie wavelength for ground state.

$(n=1)$: $\lambda = \frac{2\pi r}{1} = 2\pi r$

$= 2\pi \times 0.5 = \pi A^\circ$

(ii) de Broglie wavelength $(n=3)$;

$\lambda = \frac{2\pi (3)^2 r}{3} = 6\pi r$

$= 6\pi \times 0.5 = 3\pi A^\circ$

(iii) de Broglie Wavelength (n=4):

$$\lambda = \frac{2\pi(4)^2 r}{4} = 8\pi r.$$

$$= 8\pi \times 0.5$$

$$= 4\pi A^{\circ}.$$

19\. (i) DATA :

(i) K.E. of Proton = K.E. of electron.

(ii) de Broglie λ of proton = de Broglie λ of electron.

To find : (i) To compare K.E. of proton and electron.

Solution :

For an electron: $\lambda e = \frac{h}{\sqrt{2mE}}$

$$\therefore E = \frac{h^2}{(\lambda e)^2 \times 2m} \quad \text{- - - - (1)}$$

For a proton: $\lambda p = \frac{h}{\sqrt{2ME}}$

$$\therefore E = \frac{h^2}{(\lambda p)^2 \times 2M} \quad \text{- - - (2)}$$

$$\frac{\lambda p}{\lambda e} = \sqrt{\frac{m}{M}} < 1 \qquad [\because M > m]$$

$\lambda_e > \lambda_p$, electron has more de Broglie wavelength.

(ii) For an electron: $\lambda = \frac{h}{\sqrt{2mE_e}}$

$\therefore E_e = \frac{h^2}{(\lambda)^2 \times 2m}$ . . . (1)

For a proton: $\lambda = \frac{h}{\sqrt{2ME_p}}$

$\therefore E_p = \frac{h^2}{(\lambda)^2 \times 2M}$ . . . . (2)

Taking ratio of eqn (1) and (2)

$\frac{E_e}{E_p} = \frac{M}{m} > 1$ $[\because M > m]$

$E_e > E_p$, electron has more kinetic energy.

20. Data:

K.E. = 144 eV.

$h = 6.62 \times 10^{-34}$ J-s.

$m = 9.11 \times 10^{-31}$ kg

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

$1 \text{ eV} = 1.6 \times 10^{-19}$ J.

$v_p = 2 \times 10^5$ m/s.

$m_p = 1.67 \times 10^{-27}$ kg.

To Find: (electron) $\lambda = ?$

Solution:

(i) Energy of the electron:

$E = 144$ eV.

$= 144 \times 1.6 \times 10^{-19} = 2.304 \times 10^{-17}$ J.

(de Broglie) $\lambda = \frac{h}{\sqrt{2mE}}$

$$= \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 2.304 \times 10^{-17}}}$$

$= 1.02 \times 10^{-10}$ m $= 1.02$ Å.

(ii) proton:

(de Broglie) $\lambda = \frac{h}{mv}$

$$= \frac{6.62 \times 10^{-34}}{1.67 \times 10^{-27} \times 2 \times 10^5}$$

$= 1.98 \times 10^{-12}$ m.