Atomic Structure

DPP-4 Solutions

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1. **1215Å**

Sol. $\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)Z^2$

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

$\frac{1}{\lambda} = \frac{3}{4}R_H$

$\lambda = \frac{4}{3} \times \frac{1}{R_H}$

$= \frac{4}{3} \times 911.5$

= 1215Å

2. **7.31×10^{14} Hz, visible spectrum**

Sol. $E_{6\to2} = +\ 13.6\left(\frac{1}{4} - \frac{1}{36}\right)eV$

$= 13.6 \times \frac{8}{36} eV = 3.022 eV$

$V_{6\to2} = \frac{E}{h} = \frac{3.022 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 7.31 \times 10^{14} Hz.$

This line is the visible region of the spectrum. It is the fourth line of the Balmer series.

3. **$5 \to 2$**

Sol. For Balmer we know that $n_1 = 2$, and for first line of Balmer $n_2 = 3$, for second line $n_2 = 4$ & for third line $n_2 = 5$

$\therefore$ The transition is $5\to2$ **Ans.**

4. **$\lambda = 1.2157 \times 10^{-7}$m, $\lambda = 9.1176 \times 10^{-8}$ m**

Sol. We know that for Lyman series $n_1 = 1$

Now, for first Line $n_2 = 2$

& for Limiting Line $n_2 = \infty$

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

$\therefore \lambda_{first} = \frac{1}{R} \times \frac{4}{3} \Rightarrow \lambda_{first} = 1.2157 \times 10^{-7} m$ **Ans.**

& $\frac{1}{\lambda_{Limit}} = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right].$

$\therefore \lambda_{Limit} = \frac{1}{R} = 9.117 \times 10^{-8}$ m

5. **(a) Z = 5, (b) 16.53 eV, (c) 146.25 Å, (d) KE = 340 eV, PE = –680 eV, $l = 1.056 \times 10^{-34}$ J-s, (e) 340 eV.**

Sol. **(a)** The transition is $n_1 = 2$ to $n_2 = 3$ by absorbing a photon of energy 47.2 eV.

$\Rightarrow$ $\Delta E = 47.2$ eV

using the relation :

$\Delta E = 13.6Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)eV$

$\Rightarrow$ $47.2 = 13.6Z^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow Z = 5$

(b) The required transition is $n_1 = 3$ to $n_2 = 4$ by absorbing a photon of energy ΔE.

Find ΔE by using the relation :

$\Delta E = 13.6Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$\Rightarrow$ $\Delta E = 13.6\ (5)^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$

$\Rightarrow$ $\Delta E = 16.53$ eV

(c) The required transition is $n_1 = 2$ to $n_2 = \infty$ by absorbing a photon of energy ΔE.

Find ΔE by using the relation :

$\Delta E = 13.6\ (5)^2\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$

$\Rightarrow$ $\Delta E = 85$ eV

Find λ of radiation corresponding to energy 85 eV.

$\Rightarrow$ $\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{85\,(1.6 \times 10^{-19})}$

$= 146.25 \times 10^{-10} = 146.25$Å

(d) If energy of electron be E_n, then $KE = -E_n$ and $PE = 2E_n$

$E_n = \frac{-13.6Z^2}{n^2} = \frac{-13.6 \times 5^2}{1^2} = -340$ eV

KE = – (–340 eV) = 340 eV

PE = 2 (–340 eV) = – 680 eV

angular momentum = n (h/2π)

⇒ = 1 × (6.63 × 10^{-34}/2π)

= 1.056 × 10^{-34} J-s

(e) The ionisation energy (IE) is the energy required to remove the elctron from ground state to infinity. So the required transition is 1 → ∞. Or the ionisation energy (IE) = – E_n = 13.6 $(Z)^2$

= + 13.6 × 5^2 = 340 eV.

6. **(a) $\lambda_{shortest}$ = 9.115×10^{-8}m, (b) 13.601eV.**

(c) 0.529, 2.116, and 4.76 Å.

Sol. **(a)** $\lambda_{shortest}$ occurs when ΔE is Largest i.e n_2 = ∞

∴

$$\frac{1}{\lambda_{shortest}} = R\left[\frac{1}{1^2} - \frac{1}{\infty}\right] \Rightarrow \lambda_{shortest} = 9.115 \times 10^{-8}\text{m}.$$

(b) I.P. Of ^{2}H = 13.6 Z^2 $\left(\frac{1}{1^2} - \frac{1}{\infty}\right)$

= 13.6 eV

(c) Z = 1

r = 0.529 $\frac{n^2}{Z}$ Å

First Bohr orbit : $r = 0.529\,\frac{(1)^2}{1}$

= 0.529Å

Second Bohr orbit : $r = 0.529\,\frac{(2)^2}{1}$

= 2.116 Å

Third Bohr orbit : $r = 0.529\,\frac{(3)^2}{1}$

= 4.76 Å

7. **λ (3 → 1) = 256.38 Å, λ (3 → 2) = 1640.8 Å, λ (2 → 1) = 303.85 Å**

Sol. He^+ ions contains only one electron, so Bohr's model is applicable here. Let it jumps to an excited state n_2.

Using the relation :

$$\frac{1}{\lambda} = R\,Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Substitute for λ = 256.38 Å = 256.38 × 10^{-10} m, R = 1.097 × 10^7 m^{-1}, Z = 2 for He^+ ion, n_1 = 1

$$\frac{1}{256.38 \times 10^{-10}} = 1.097 \times 10^7 (2)^2 \left(\frac{1}{1_1^2} - \frac{1}{n_2^2}\right)$$

⇒ n_2 = 3

From n = 3, the electron can fall back to the ground state in three possible ways (transitions) :

3 → 1, 3 → 2, 2 → 1

Hence three possible radiations are emitted.

Find the wavelengths corresponding to these transitions.

The wavelength (λ) for transition, 3 → 1 will be same

i.e., 256.38Å.

Find λ for 3 → 2 and 2 → 1 using the same relation.

λ (3 → 1) = 256.38 Å, λ (3 → 2) = 1640.8 Å, λ (2 → 1) = 303.85 Å

8. **infrared, 5**

Sol. Paschen series lies in Infrared Region.

c = νλ

$$\nu = \frac{3 \times 10^8}{1285 \times 10^{-9}}$$

$$\nu = 2.33 \times 10^{14} \text{ hz}$$

$$\nu = 3.29 \times 10^{15}\left(\frac{1}{9} - \frac{1}{n^2}\right)$$

2.33 × 10^{14} = 3.29 × 10^{15} $\left(\frac{1}{9} - \frac{1}{n^2}\right)$

∴ n = 5.

9. **$^{81}_{35}$Br**

Sol. p + n = 81

n = p + $\frac{31.7}{100}$p

n = 1.317 p

∴ p + 1.317 p = 81

p = 35

Element is $^{81}_{35}$Br

10 **$^{37}_{17}Cl^{-1}$**

Sol. p + n = 37

n = e + $\frac{11.1}{100}$e

N = 1.111e

Now e = p + 1

∴ n = 1.111 (p + 1)

∴ p + 1.111 (p + 1) = 37

p + 1.111 p + 1.111 = 37

p =17

Ion is $^{37}_{17}Cl^{-1}$

11. **$^{56}_{26}Fe^{3+}$**

Sol. p + n = 56

e = p – 3

$n = e + \frac{30.4}{100}e$

$n = 1.304\ e$

$n = 1.304\ (p - 3)$

$\therefore\ p + 1.304\ (p - 3) = 56$

$p = 26$

Ion is $^{56}_{26}Fe^{+3}$

12. **(d)**

Sol. $E_n = -\ 2.18 \times 10^{-18}\ \frac{Z^2}{n^2}\ J/atom$

$= -\ 2.18 \times 10^{-18}\ \frac{(2)^2}{(2)^2}$

$- 2.18 \times 10^{-18}$ J/atom.

13. **(a)**

Sol. Ionization energy = 13.6 Z^2 eV

For H-atom, I.E. = 13.6 eV

Now to ionize the H-atom from excited state, e^- may be at n = 2 or even higher.

To ionize the e^- from n = 2

$E_n = 13.6\frac{Z^2}{n^2}\ eV$

$= \frac{13.6}{4}\ eV$

= 3.4 eV

If electron is at level higher than n = 2, energy will be less than 3.4 eV.

14. **(d)**

Sol. Highest wavelength correspond to minimum ΔE

$\therefore\ 5 \rightarrow 4$ transition

15. **(d)**

Sol. Balmer series $\Rightarrow n_1 = 2$

first time of Balmer series $\Rightarrow n_2 = 3$

$\bar{v} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)Z^2$

$\bar{v} = R_H\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$\bar{v} = \frac{5}{36}R_H\ cm^{-1}$

16. **(b)**

Sol. Red end $\Rightarrow$ visible region $\Rightarrow$ Balmer series $\Rightarrow n_1 = 2$

Third line from Balmer series $\Rightarrow n_2 = 5$

$\therefore$ Transition is $5 \rightarrow 2$