Atomic Structure

SOLUTIONS

Exercise - I (JEE Main Pattern)

SECTION–A

1. **Ans. (3)**

$^{14}_{7}N$ $\quad n = 7, p = 7, e = 7$

Mass of proton = Half of its original value

$= \frac{7}{2} = 3.5$

New atomic mass = 7 + 3.5 ⇒ 10.5

Change in atomic mass = 14 – 10.5 = 3.5

$\Rightarrow \frac{3.5}{14} \times 100 \Rightarrow 25\%$

Atomic mass reduced by 25%.

2. **Ans. (4)**

Neutron because it has zero charge.

3. **Ans. (1)**

$V = 2.18 \times 10^6 \times \frac{z}{n}$

$= 2.18 \times 10^6 \times \frac{2}{3}\ m = 1.45 \times 10^6\ m$

4. **Ans. (2)**

$r_n = 0.529 \times \frac{n^2}{z} Å$

$r_3 = 0.529 \times \frac{9}{1} = x$

$r_4 = 0.529 \times \frac{16}{3} = \frac{x}{9} \times \frac{16}{3} = \frac{16x}{27}$

5. **Ans. (3)**

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

$E_n = -KE_n$

$KE_n = 13.6 \times \frac{Z^2}{n^2} \qquad (KE_n = y, n^2 = x^2)$

$\underbrace{y = \frac{c}{x^2}}_{\text{Hyperbolic graph}}$

6. **Ans. (3)**

${}_3Li^7 \longrightarrow \left[{}_3Li^7\right]^{\oplus} + e^{\ominus}$

$e^{\ominus} = 2$

$p = 3$

$n = 4$

7. Ans. (1)

transition will be $3 \rightarrow 2$

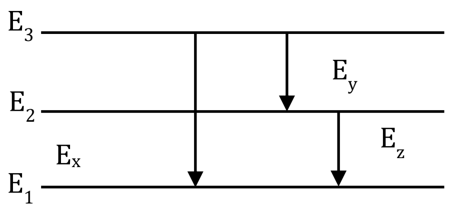
$$\frac{1}{\lambda} = R \times Z^2 \left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\underbrace{\frac{1}{\lambda}}_{\text{Wave number}} = \frac{5 \times R \times 1}{36}$$

8. Ans. (4)

Spin quantum number has independent identity and is not related to Schrodinger equation.

9. Ans. (3)



$E_x = E_y + E_z$

$E_{3\rightarrow 1} = E_{3-2} + E_{2-1}$

Energies liberated due to de-excitation

$\Rightarrow E_x = E_y + E_z$

$X \Rightarrow 3 \rightarrow 1$

$Y \Rightarrow 3 \rightarrow 2$

$Z \Rightarrow 2 \rightarrow 1$

$E = h\nu$

$h\nu_3 = h\nu_2 + h\nu_1$

$\Rightarrow \quad \nu_3 = \nu_2 + \nu_1$

Also, $E = hc/\lambda$

$hc/\lambda_3 = hc/\lambda_2 + hc/\lambda_1$

$$\frac{1}{\lambda_3} = \frac{1}{\lambda_2} + \frac{1}{\lambda_1}$$

Option is (3)

10. Ans. (3)

K.E. is $\frac{1}{2}mv^2 = q \times V$

$$\alpha = \sqrt{\frac{2qV}{m}}$$

de Broglie wavelength = $\frac{h}{mv} \Rightarrow \frac{h}{\sqrt{2qVm}}$

($m_\alpha = 4m_p$, charge of α-particle = 2 × |charge on electron|)

$$\Rightarrow \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 2 \times 1.6 \times 10^{-19} \times V \times 4 \times 1.67 \times 10^{-27}}}$$

$$\lambda \Rightarrow \frac{0.101}{\sqrt{V}} \text{Å}$$

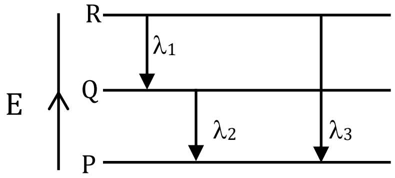
11. Ans. (1)

Angular momentum = $\left(\sqrt{\ell(\ell+1)}\right)\frac{h}{2\pi}$

for s-orbital $\ell = 0$

Angular momentum will be zero for s-orbital.

12. Ans. (2)



Here $E_{R\to P} = E_{R\to Q} + E_{Q\to P}$

$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

$$\therefore \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

13. Ans. (1)

Volume fraction = $\dfrac{\text{Volume of nucleus}}{\text{Total volume of atom}} = \dfrac{\frac{4}{3}\pi(10^{-13})^3}{\frac{4}{3}\pi(10^{-8})^3} \Rightarrow 10^{-15}$

14. Ans. (3)

Bohr's theory is applicable for single electron species.

$He^{2\oplus}$ has zero electrons.

15. Ans. (2)

Number of lines bracket series

$n = n_2 - 4$

where $n_2 \to$ higher energy level (9^{th} excited level = 10)

$= 10 - 4 = 6$

16. Ans. (1)

Initial state (A) $\longrightarrow$ final state (B)

$r_1 - r_2 \Rightarrow \frac{0.529}{z}(n_1^2 - n_2^2)$ ...(1)

$(r_1 - r_2) = 24\left(\frac{0.529}{z} \times 1\right)$

Put the value of $r_1 - r_2$ in equation (1)

$\frac{0.529 \times 24}{z} = \frac{0.529}{z}(n_1^2 - n_2^2)$

$\Rightarrow \ 24 = (n_1^2 - n_2^2)$ ...(2)

$\Rightarrow \ n_1 \to n_2$

5 → **1**, will satisfy the above equation (2)

17. Ans. (4)

For Rydberg equation

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

For, p-fund series (λ_{min})

$n_1 = 5 \quad n_2 = \infty$

So $$\frac{1}{\lambda_{min}} = R_H (Z)^2 \left(\frac{1}{5^2} - \frac{1}{\infty}\right)$$

$$\frac{1}{\lambda_{min}} = \frac{4R_H}{25}$$

$$\lambda_{min} = \frac{25}{4R_H}$$

18. Ans. (2)

Intensity of radiation α no. of photon ejected.

19. Ans. (1)

For Lyman series $\lambda_{min} = \frac{1}{R}$

For Balmer series $\lambda_{max} = \frac{36}{4 \times 5R_n} = \frac{9}{5}\lambda_{min}$

20. Ans. (3)

$$\lambda_d = \frac{h}{\sqrt{2km}}$$

λ_d : de broglie wavelength

$h \rightarrow$ planck constant

$k \rightarrow$ kinetic energy

$m \rightarrow$ mass of particle

$h = 6.22 \times 10^{-36}$ J-sec

$k = 2.8 \times 10^{-23}$ J

$m_e = 9.1 \times 10^{-31}$ kg

$$\lambda = \frac{6.22 \times 10^{-36}}{\sqrt{2 \times 2.8 \times 10^{-23} \times 9.1 \times 10^{-31}}}$$

$= 9.28 \times 10^{-8}$ m

SECTION–B

1. Ans. (0.20)

$\nu = \frac{C}{\lambda}$ Wave No. $= \frac{1}{\lambda} = \bar{\nu}$

$\nu = C\bar{\nu}$

$$\frac{\nu_1}{\nu_2} = \frac{\bar{\nu}_1}{\bar{\nu}_2}$$

$$\frac{\nu_1}{\nu_2}=\frac{4\times10^6\,m^{-1}}{\frac{2\times10^5}{10^{-2}}m^{-1}}=\frac{4\times10^6}{2\times10^7}$$

$$\frac{\nu_1}{\nu_2}=\frac{1}{5}$$

2. **Ans. (2.30)**

$$d=\frac{\text{mass}}{\text{volume of one nucleus}}$$

$$=\frac{A}{N_A\left[\frac{4}{3}\pi\left(r_0A^{1/3}\right)^3\right]}$$

$$=\frac{A\times3}{N_A\times4\times\pi\times A\times r_0^3}$$

Put the values

$$=\frac{3}{6\times10^{23}\times4\times(1.2)^3\pi\times10^{-45}}$$

$$=\frac{1}{\frac{1000}{23}\times10^{-22}}\text{ or } 2.3\times10^{17}\,kg/m^3$$

3. **Ans. (0.41)**

$$V_{(s)}=\frac{h\nu}{e}-\frac{h\nu_0}{e}$$

A/C to curve

Threshold freq. $\nu_0=1\times10^{14}$ Hz

Work function $w=\frac{h\nu_0}{e}eV$

$$=\frac{6.62\times10^{-34}\times10^{14}}{1.6\times10^{-19}}$$

= 0.41375 eV

4. **Ans. (6200)**

$Br_{2(g)} \longrightarrow 2Br_{(g)}$

$Br_{2(g)}$ is decompose into free Br atom by a absorption of light, one photon dissociate one bond, one mole photon dissociate one mole bond, energy of one mole photon E = $\frac{hc}{\lambda\times10^3}\times N_A kg/mole$

It is equal to bond dissociation energy

$$\left(1\frac{eV}{atom}=96kJ/mol\right)$$

Energy of photon (ev) = $\frac{192}{96}=2ev$

Energy of one photon = $\frac{12400}{\lambda Å} = 2$

$\lambda = \frac{12400}{2} = 6200Å$

5. **Ans. (0.62)**

$E = eV_0 = \frac{hc}{\lambda}$

Given, $V_0 = 2 \times 10^4$ V

$1.6 \times 10^{-19} \times 2 \times 10^4 = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{\lambda}$

$\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{3.2 \times 10^{-15}} = 6.21 \times 10^{-11}$ m

$= 0.621Å$

6. **Ans. (7.50)**

Wave number :- No. of waves present in unit length.

$\bar{\nu} = \frac{5000}{20} = 250\,cm^{-1} = 25000\,m^{-1}$

$\nu = C\bar{\nu}$

$= 3 \times 10^8 \times 25000$

$= 7.5 \times 10^{12}$ Hz

7. **Ans. (2.66)**

Radio waves travel at the speed of light

$\Rightarrow$ Distance = speed × time

$\Rightarrow$ $8 \times 10^5 \times 10^3$ m $= 3 \times 10^8 \frac{m}{s} \times$ time

$\Rightarrow$ $\frac{8}{3}$ S = time

time = 2.66 sec.

8. **Ans. (4862.96)**

Balmer series starts from n = 2

$3 \rightarrow 2 \Rightarrow H_\alpha$ line

$4 \rightarrow 2 \Rightarrow H_\beta$ line

$5 \rightarrow 2 \Rightarrow H_\gamma$ line

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

for H_α line $(3 \rightarrow 2)$

$\Rightarrow \frac{1}{\lambda_\alpha} = RZ^2\left(\frac{1}{4} - \frac{1}{9}\right)$

$\Rightarrow \frac{1}{\lambda_\alpha} = RZ^2\left(\frac{5}{36}\right)$ ...(1)

for H_β line $(4 \rightarrow 2)$

$\Rightarrow \frac{1}{\lambda_\beta} = RZ^2\left(\frac{1}{4} - \frac{1}{16}\right)$

$\Rightarrow \frac{1}{\lambda_\beta} = RZ^2\left(\frac{12}{64}\right)$ ...(2)

$\Rightarrow$ dividing equation (1) by equation (2), we get

$$\frac{\lambda_\beta}{\lambda_\alpha} = \frac{5\times64}{36\times12}$$

$$\lambda_\beta = \frac{20}{27} \times 6565 \text{ Å}$$

$$\lambda_\beta = 4862.96 \text{ Å}$$

9. Ans. (6.03)

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

$$V = \frac{h^2}{2me\lambda^2}$$

$$= \frac{(6.62\times10^{-34})^2}{2\times9.1\times10^{-31}\times1.6\times10^{19}\times(500\times10^{-10})^2}$$

$\Rightarrow$ $6.03 \times 10^{-4} = (y \times 10^{-4})$

$y = 6.03$

10. Ans. (28)

Energy of n-photons $\Rightarrow \frac{nhc}{\lambda}$

$$\Rightarrow \frac{nhc}{\lambda} = 10^{-17}$$

$$\Rightarrow \frac{n\times6.626\times10^{-34}\times3\times10^{8}}{550\times10^{-9}} = 10^{-17}$$

$$\Rightarrow n = \frac{10^{-17}\times550\times10^{-9}}{6.626\times3\times10^{-34}\times10^{8}}$$

$$n \simeq 28$$

Exercise - II (JEE Main PYQs)

1. Ans. (2)

Limiting line of Balmer series ($\infty \to 2$)

$$v = 3.29 \times 10^{15} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) s^{-1}$$

$$= 3.29 \times 10^{15} \times \frac{1}{4} = 8.22 \times 10^{14} \text{ s}^{-1}$$

2. Ans. (2)

$$\lambda = \frac{h}{\sqrt{2K.E.m}}$$

K.E. $\to$ 4 K.E.

$$\lambda_1 = \frac{h}{\sqrt{2(4K.E.)m}}$$

$$\lambda_1 = \left(\frac{\lambda_2}{2}\right)$$

3. Ans. (1)

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

$mvr = \frac{nh}{2\pi} \Rightarrow \frac{h}{mv} = \frac{2\pi r}{n}$

$\lambda = \frac{2\pi r}{n}$

$r = a_0 \times \frac{n^2}{1}$

$\therefore \lambda = 2\pi a_0 \times n$

For 3^{rd} orbit n = 3

$\therefore \lambda = 6\pi a_0$

4. Ans. (1)

$E_1 = \frac{hc}{\lambda} = 2.178 \times 10^{-18} \left[\frac{1}{1^2}\right]$

$E_2 = \frac{hc}{\lambda} = 2.178 \times 10^{-18} \left[\frac{1}{2^2}\right]$

So, $E = E_2 - E_1$

$E = \frac{hc}{\lambda} = 2.178 \times 10^{-18} \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$E = \frac{hc}{\lambda} = 2.178 \times 10^{-18} \left(\frac{3}{4}\right)$

$\Rightarrow \lambda = 1.214 \times 10^{-7}$ m

5. Ans. (4)

$r = 0.529 \times \frac{n^2}{z} Å$

$\Rightarrow 0.529 \times \frac{(2)^2}{1}$

$\Rightarrow 2.12$ Å

6. Ans. (4)

For emission line. $(n_i = 8 \rightarrow n_f = n)$

$\bar{\nu} = R_H Z^2 \left(\frac{1}{n^2} - \frac{1}{64}\right)$ {z = 1, for H}

$\bar{\nu} = \frac{R_H}{n^2} - \frac{R_H}{64}$

y = mx + c

graph of $\bar{\nu}$ us $\frac{1}{n^2}$ will be linear with slope R_H and intercept

7. Ans. (2)

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

Here if $n_f = 3$ and $n_i = \infty$

$\frac{1}{\lambda} = 10^7 \times 1^2 \left(\frac{1^2}{3^2} - \frac{1}{\infty^2}\right)$

$\lambda = 900$ nm

8. Ans. (2)

$$\frac{\frac{1}{\lambda_2} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)Z^2}{\frac{1}{\lambda_1} = R_H\left(\frac{1}{m_1^2} - \frac{1}{m_2^2}\right)Z^2}$$

As for shortest wavelengths both n_2 and m_2 are ∞

$\therefore \frac{\lambda_1}{\lambda_2} = \frac{9}{1} = \frac{m_1^2}{n_1^2}$

$m_1 = 3$

$n_1 = 1$

9. **Ans. (3)**

The theory given by the Dalton was for the atoms and its properties, it does not depend on volume. C option is wrong.

10. **Ans. (2)**

$\bar{v} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

(I) As the wavelength decreases the energy increases and formed a converging series.

(II) For Balmer series $n_1 = 2$

(III) At longest wavelength, the higher state energy will be minimum therefore excited state will be $n_2 = 3$.

(IV) $E = 13.6\frac{z^2}{n^2}$ for H atom z = 1

So, we cannot find ionization energy directly by only wave number, we also required transition state(n) value.

11. **Ans. (4)**

$a_0 = 0.529\ \text{Å}$

$r = a_0 \times \frac{n^2}{z}$ (n = 2, z = 3)

$\Rightarrow a_0 \times \frac{4}{3} \Rightarrow \frac{4a_0}{3}$

12. **Ans. (1)**

According to Bohr's postulates, radii of the n^{th} and 1^{st} orbit are related to

$r_n = n^2 r_1$ ...(1)

$2\pi r_n = n\lambda_n$

$2\pi(n^2 r_1) = n\lambda_n \longrightarrow$ from equation (1)

$\Rightarrow 2\pi r_1 n = \lambda_n$

For n = 4

$2\pi r_1 \times 4 = \lambda_4$ $r_1 = a_0$

$8\pi a_0 = \lambda_4$

13. **Ans. (2)**

Total energy per sec. = 50 J

$50 = \frac{n \times 6.63 \times 10^{-34} \times 3 \times 10^8}{798 \times 10^{-9}}$

$n = 1998.49 \times 10^{17}$ [n = no. of photons per second]

$= 1.998 \times 10^{20}$

$\simeq 2 \times 10^{20}$

$= x \times 10^{20}$

x = 2

14. Ans. (3)

W = h$\nu_\circ$

= 6.6 × 10^{-34} × 1.3 × 10^{15}

= 8.58 × 10^{-19} J

15. Ans. (2)

For H: $\frac{1}{\lambda} = R_H \times 1^2 \left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)$ ...(1)

$\frac{1}{\lambda_{He^+}} = R_H \times 2^2 \times \left(\frac{1}{4} - \frac{1}{9}\right)$ ...(2)

From (1) & (2) $\frac{\lambda_{He^+}}{\lambda} = \frac{9}{5}$

$\lambda_{He^+} = \lambda \times \frac{9}{5}$

$\lambda_{He^+} = \frac{9\lambda}{5}$

16. Ans. (798)

For one photon E = hv

For one mole photon,

$E = 6\cdot023 \times 10^{23} \times 6\cdot626 \times 10^{-34} \times 2 \times 10^{12}$

= 798·16 J

$\approx$ 798 J

17. Ans. (4)

At node $\Psi_{2s} = 0$

$\therefore 2 - \frac{r_0}{a_0} = 0$

$\therefore$ $r_0 = 2a_0$

18. Ans. (4)

$E_n = \frac{-2.18 \times 10^{-18} Z^2}{n^2}$

i.e. $E_n \propto \frac{1}{n^2}$

19. Ans. (0)

Orbital angular momentum = $\sqrt{l(l+1)}\frac{h}{2\pi}$

Value of l for s = 0

20. Ans. (1)

According to Bohr's model the angular momentum is quantised and equal to $\frac{nh}{2\pi}$.

Heisenberg uncertainty principle explains orbital concept, which is based on probability of finding electron.

Exercise - III (JEE Advanced Pattern)

SECTION–I

1. Ans. (D)

(A) 2^{nd} excited state implies n = 3 from Bohr's atomic theory. energy in n^{th} orbit of Z^{th} hydrogen like atom is given by $E_n = \dfrac{-13.6z^2}{n^2}eV$

Given is that for n=4 E = –13.6 eV

So $-13.6\,eV = \dfrac{-13.6z^2}{4^2}eV$

$\Rightarrow$ Z =4 so (A) is correct

(B) If $e^{\ominus}$ is at n=3 then possible transition are
$$\begin{tikzcd} n=3 \arrow[r, "\lambda_1"] \arrow[rr, bend right, "\lambda_3"'] & n=2 \arrow[r, "\lambda_2"] & n=1 \end{tikzcd}$$

So '3' distinct line can be seen by minimum $2e^{\ominus}$ so (B) is correct.

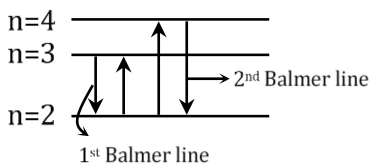
(C) As Z=4 so energy of $e^{\ominus}$ at 2^{nd} excited state i.e n = 3 will be $E_n = \dfrac{-13.6z^2}{n^2} = \dfrac{-13.6\times16}{9}eV$

$$E_n = -24.17\,ev$$

So, on striking a photon of 25 eV will surely ionise the $e^{\ominus}$ from 2^{nd} excited state.

So (C) is correct

(D) For Balmer series base line is n=2

So 

So, for 2^{nd} Balmer line n_1=2 to n_2=4

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

$$\Delta E = 13.6\times16\left(\frac{1}{4}-\frac{1}{16}\right) = 13.6\times3 = 40.8\,eV$$

& For first excitation energy of H n_1=1 to n_2=2 z=1 Hence

$$\Delta E = 13.6\times1\left(1-\frac{1}{4}\right) = \frac{13.6\times3}{4} = 10.2\,eV \text{ so (D) is wrong}$$

2. Ans. (A)

$$Li_{(g)} \xrightarrow{I.E_1} \overset{\oplus}{Li}_{(g)} \xrightarrow{I.E_2} \overset{2\oplus}{Li}_{(g)} \xrightarrow{I.E_3} \overset{3\oplus}{Li}_{(g)}$$

As $Li^{2\oplus}_{(g)}$ is an hydrogen like atom so energy of last $e^{\ominus}$ in its. 1^{st} orbital will be given by Bohr's energy expression & it will be 3^{rd} I.E only.

So $I.E_3 = E_n = \dfrac{13.6\times z^2}{n^2}eV = 13.6\times9\,eV$

& 13.6 eV = 1312 KJ

So $I.E_3$ = 1312 × 9 = 11808

Now $\Delta H = I.E_1 + I.E_2 + I.E_3$

$19800 = 520 + 11808 + I.E_2$

So $I.E_2 = 7472$ KJ

So, option (A) is correct.

3. **Ans. (B)**

A = no. of proton + no. of neutron

$^{A}_{Z}X$

Z = no. of proton = no. of electron

So, $Y = {}_8O^{18} + {}_1H^1$

n_{proton} in 'Y' = 8+1 = 9

$n_{proton} + n_{neutron} = 19$

$n_{neutron} = 10$

So, it will be ${}_9Y^{19}$

So, for $X = {}^{19}_{9}Y + {}_2He^4$

It will be ${}^{23}_{11}X$

So, no. of neutron = 23–11 = 12 in 1atom

Given wt = 4.6gm Atomic wt. = A = 23

$n_{moles} = \frac{4.6}{23} = 0.2$

So total neutron = $0.2\times12\times N_A = (2.4N_A)$ so (A) is correct

4. **Ans. (A)**

Correct option is A $\left[\frac{h\lambda\lambda_0}{2mc(\lambda_0-\lambda)}\right]^{0.5}$

$E = E_0 + \frac{1}{2}mv^2$

$\Rightarrow \frac{hc}{\lambda} = \frac{hc}{\lambda^0} + \frac{1}{2}mv^2$

$\Rightarrow \frac{1}{2}mv^2 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda^0}\right)$

$\Rightarrow mv^2 = 2hc\left(\frac{\lambda^0-\lambda}{\lambda.\lambda^0}\right)$

$\Rightarrow m^2v^2 = 2hmc\left(\frac{\lambda^0-\lambda}{\lambda.\lambda^0}\right)$ ...(1)

Now,

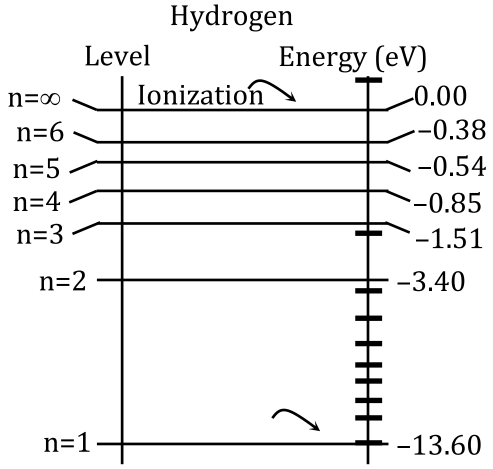
De-Broglie wavelength, $\lambda = \frac{h}{mv}$

From equation (1)

$$\lambda = \frac{h}{(2hmc)\left(\frac{\lambda^0-\lambda}{\lambda.\lambda^0}\right)^{\frac{1}{2}}}$$

$$\Rightarrow \lambda = \left(\frac{h\lambda\lambda^0}{2mc(\lambda^0-\lambda)}\right)^{0.5}$$

5. **Ans. (A)**



Energy Levels for the Hydrogen Atom

As we can see from the diagram that

$\Delta E_{2\to1} = -13.6 + 3.4 = -10.2\,eV$

& $\Delta E_{5\to2} = -3.40 + 0.54 = -2.86\,eV$

So, statement 1 is true; these values can also be calculated from

$\Delta E_{n_2\to n_1} = 13.6z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ & from diagram statement–2 is

Also, true & correct explanation.

6. **Ans. (C)**

(I) $2e^{\ominus}$ in K shell $\Rightarrow n = 1 \Rightarrow 1s^2$

$8e^{\ominus}$ in L shell $\Rightarrow n = 2 \Rightarrow 2s^2 \quad 2p^6$

$6e^{\ominus}$ in M shell $\Rightarrow n = 3 \Rightarrow 3s^2 \quad 3p^4$

$\Downarrow$

$6e^{\ominus}$ are present in s-subshell

(II) maximum number of $e^{\ominus}$ in a subshell is $2(2\ell + 1)$

(III) for s-orbital, l = 0, so m will have only one value i.e. zero.

(IV) for 3p orbital

radial node = $n - \ell - 1$

$\Rightarrow 3 - 1 - 1 \Rightarrow 1$

7. **Ans. (C)**

$\lambda = 310Å \Rightarrow 310 \times 10^{-10}$ m $\Rightarrow 31$ nm

$\phi = 12.8$ eV

$KE_{max} = \frac{hc}{\lambda} - \phi$

$\Rightarrow \frac{1240}{31} - 12.8$

$\Rightarrow 40 - 12.8$

$KE_{max} \Rightarrow 27.2$ eV

$\Rightarrow \frac{1}{2}mv^2 = 27.2 \times 1.6 \times 10^{-19}$ J

$\Rightarrow \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 27.2 \times 1.6 \times 10^{-19}$

$\Rightarrow v^2 = \dfrac{43.52}{4.55} \times 10^{12}$

$v = 2.18\sqrt{2} \times 10^6$ m/s

8. **Ans. (B)**

$\lambda_x = 1Å = \dfrac{h}{m_x v_x}$

$m_y = \dfrac{25}{100} \times m_x = \dfrac{m_x}{4}$

$v_y = \dfrac{75}{100} \times v_x = \dfrac{3v_x}{4}$

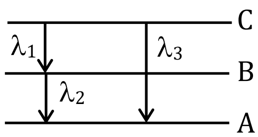
$\Rightarrow \lambda_y = \dfrac{h}{m_y v_y} \Rightarrow \dfrac{h}{\frac{m_x}{4} \times \frac{3v_x}{4}} \Rightarrow \dfrac{16}{3}\left(\dfrac{h}{m_x v_x}\right)\left\{\because \dfrac{h}{m_x v_x} = 1\right\}$

$\lambda_y = \dfrac{16}{3} \Rightarrow 5.33\ Å$

SECTION–II

9. **Ans. (D)**

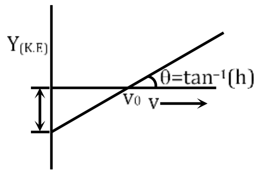
$E_A < E_B < E_C$



$\dfrac{hc}{\lambda_3} = \dfrac{hc}{\lambda_1} + \dfrac{hc}{\lambda_2}$

$\dfrac{1}{\lambda_3} = \dfrac{1}{\lambda_1} + \dfrac{1}{\lambda_2} \quad \Rightarrow \quad \lambda_3 = \dfrac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$

10. **Ans. (A,D)**



$KE = h\nu - \phi$

$Y = mx + c \qquad c = -\phi,\ m = h$

So, a St. line with slope = h

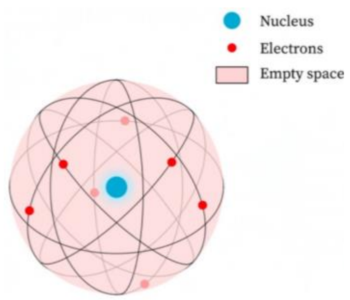
When Y=0 i.e., K.E. = 0

$h\nu = \phi = h\nu_0$

$\nu = \nu_0$

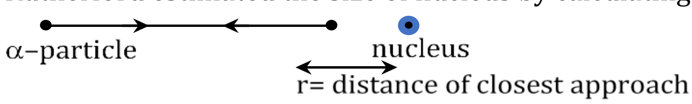
when x = 0, $Y = -\phi$

11. **Ans. (A,B)**



Rutherford's atomic model: as we see, the electrons revolve around the nucleus, and most space in the atom is empty.

Rutherford estimated the size of nucleus by calculating the distance of close approach.



The initial kinetic energy of α–particle must be equal to potential energy at distance of closest approach.

$$K.E.=\frac{1}{4\pi\varepsilon_0}.\frac{q_1.q_2}{r}=\frac{1}{4\pi\varepsilon_0}.\frac{(2e)(Ze)}{r}$$

$r=\dfrac{2Ze^2}{(4\pi\varepsilon_0)(K.E.)}$n. The radius of the atom 10^{-10} m, where that of nucleus is 10^{-15} m.

where Z = atomic number of element used in foil.

Nothing was about radius of electron & it's position in Rutherford theory.

12. Ans. (A)

(A) is correct factual statement

(B) UV Range of 'λ' is 100Å order where as yellow light has λ in 5500 Å to 5900 Å

& $E=\dfrac{hc}{\lambda}$ more 'λ' less Energy.

So $E_{Yellow} < E_{UV}$

(C) $He^{\oplus}$ & H have different energy level as $He^{\oplus}$ has z=2 & 'H' has z=1

(D) Total energy is (–ve) has energy of free $e^{\ominus}$ is taken to zero, so in bounded state it has lesser (–ve) energy than zero.

13. Ans. (A,B,D)

Graph A does not have any radial node, it may represent : 1s, 2p, 3d.....

Graph B is having one node, it may represent : 2s, 3p, 4d.....

Graph B is having two node, it may represent : 3s, 4p, 5d.....

SECTION–III

14. Ans. (C)

Orientation → m

Shape → l

Radial function → R(r) → n, l

Angular function → $A(\theta,\phi)$ → l, m

Wave function Ψ → n, l, m

Schrodinger wave equation y → n, l m

(C) Incorrect B $\not\leftrightarrow$ P

15. Ans. (D)

(A) s $\not\leftrightarrow$ Ψ [Ψ → depends only on 'n', 'l', 'm']

(B) Probability density $[R(r)]^2$ $\not\leftrightarrow$ m [Only depend on n, l]

(C) Energy of e^- in H-like atom can be determined by Schrodinger in equation.

16. Ans. (D)

In presence of external electric field or magnetic field degeneracy of p-orbitals & d-orbitals will be lost hence energy of electron of H-like species will now depend on 'n', 'l' & 'm'. (D) Incorrect.

SECTION–IV

17. Ans. (0.36)

Energy gained by $e^{\ominus}$ due to acceleration = 4.5 ev

Wave number of emitted photon = $\bar{\nu}=\dfrac{1}{\lambda}$

Where λ = wavelength of emitted photon for a photon ; $E=\dfrac{hc}{\lambda}(\text{in J})$

$$E = \frac{1240}{\lambda\,(\text{in nm})}(\text{in eV})$$

$$\frac{1}{\lambda}(\text{in nm}) = \left(\frac{4.5}{1240}\right) \times 10^{9}\ m^{-1}$$

$$\bar{\nu} = \frac{1}{\lambda} = 3.63 \times 10^{6}\ m^{-1}$$

18. Ans. (1.35)

Total energy = 3.15×10^{-14} J

$$E = \frac{n(hc)}{\lambda}$$

$$3.15 \times 10^{-14} = \frac{n(6.6\times10^{-34})\times(3\times10^{8})}{850\times10^{-9}}$$

$n = 1.35 \times 10^{5}$

19. Ans. (300303)

General format of any wave equation ; $\Psi(r) = a.(e^{-b.r}).r^{\ell}.$(Polynomial in r) ; $A(\theta,\phi)$

Where a and b are constants.

ℓ = no of angular nodes ;

$n-\ell-1$ = highest power of polynomial will give no. of radial nodes.

$A(\theta,\phi)$ = Angular past wave function comparing the given equation with the general equation :–

$n-\ell-1 = 2$; $\ell = 0 \Rightarrow n = 3$; $\ell = 0$

$\Rightarrow$ The orbital is 3s

$\Rightarrow$ Info A : 3

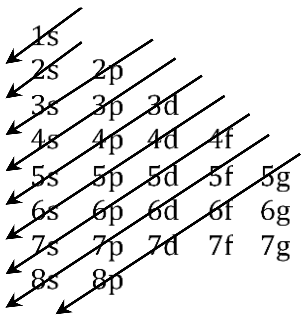
$\Rightarrow$ Info B : 0

$\Rightarrow$ Info C : m=0

$\Rightarrow$ Info D : (n+5)s = 8s

(n+5)p = 8p

$\therefore$ between 8s and 8p ; there are 5g, 6f and 7d



$\Rightarrow$ Info E : 0

$\Rightarrow$ Info F : Calculating radial node's distance ;

$\Psi_{(r)} = (r^2 - 5k_3r + 6) = 0$

When $k_3 = 0 \Rightarrow \Psi_{(r)} = (r^2 - 5r + 6) = 0$

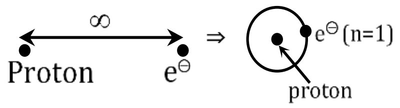
$(r^2 - 3r - 2r + 6) = 0$

r = 2, r = 3

Radial distance of the spherical node which is farthest from the nucleus $\Rightarrow$ r = 3.

20. Ans. (91)

A proton and an electron as in rest and are combining to form H–atom in ground state means both are separated by large distance form each other



Means $e^{\ominus}$ is coming (∞ to 1)

$n_2 = \infty \qquad n_1=1$

$$E_{\infty} - E_1 = \frac{hc}{\lambda}$$

$$0-\left(\frac{-13.6\times1^2}{1^2}\right)=\frac{1237.6}{\lambda}$$

$$\lambda=\frac{1237.6}{13.6}=91\,\text{nm}$$

Exercise - IV (JEE-Advanced PYQs)

1. **Ans. (D)**

Rutherford used α–particles in his experiment.

2. **Ans. (D)**

Radius as per Bohr's model

$$r = 0.529\ \frac{n^2}{z}\text{Å}$$

Radius of first orbit of hydrogen

$r = 0.529(1)^2 = 0.529$Å

Radius of n=2 for $Be^{3\oplus}$

$$r = 0.529\times\left(\frac{2^2}{4}\right)=0.529\,\text{Å}$$

[same as first orbit of H–atom]

3. **Ans. (A)**

At node $e^{\ominus}$ finding probability is zero

$\Rightarrow |\Psi^2| = 0$ so $\Psi = 0$

$$\Rightarrow 2-\frac{r_0}{a_0}=0$$

$$\Rightarrow r_0 = 2a_0$$

4. **Ans. (A)**

$V = 2.197 \times 10^6$ m/s ;

5. **Ans. (B)**

$2\pi r = n\lambda$, $\lambda = 3.32$ Å ;

6. **Ans. (C)**

Orbital angular momentum $= \dfrac{h}{2\pi}\sqrt{\ell(\ell+1)} = \sqrt{2}.\dfrac{h}{2\pi}$

7. **Ans. (D)**

(A) P.E = -2 K.E

$$\frac{P.E}{K.E} = -2$$

(B) $r_n \propto \dfrac{n^2}{Z}$, $E\ \alpha\ \dfrac{Z^2}{n^2}$

$r_n \propto n^2,\ E\ \alpha\ \dfrac{1}{n^2}$

$\dfrac{1}{r_n}\ \alpha\ E^x$

$x = 1$

(C) $r_n \propto \dfrac{n^2}{Z}$

$r_n\ \alpha\ Z^{-1}$

$r_n\ \alpha\ Z^y$

$y = -1$

(D) For n = 1 $\ell = 0$

Angular momentum = 0

8. Ans. (A)

(A) Q, R ; (B) P, Q, R, S ; (C) P, Q, R ; (D) P, Q

(A) Orbital angular momentum (L) = $\sqrt{\ell(\ell+1)}\dfrac{h}{2\pi}$

L depends on azimuthal quantum number

(B) To describe hydrogen like one electron atom's obeying Pauli's principle as a wave function all four quantum numbers i.e. n, ℓ, m, s are needed.

(D) To describe shape, size and orientation only n, ℓ, and m are needed.

(D) Probability density (Ψ^2) can be determined is n, ℓ, and m are known.

9. Ans. (B)

Since s, is spherically symmetrical (ℓ=0), it corresponds to s–subshell and since it has one radial node

$\Rightarrow$ n – ℓ – 1 = 1 [No. of radial nods]

$\Rightarrow$ n – 0 – 1 = 1

$\Rightarrow$ n = 2

$\Rightarrow$ 2s

10. Ans. (C)

Energy of $e^{\ominus}$ in ground state of H – atom.

$\Rightarrow E = -13.6\dfrac{z^2}{n^2} = -13.6\,eV/atom$

For S_1 of $Li^{2\oplus}$ i.e., 2s orbital

$\Rightarrow E = -13.6\dfrac{3^2}{2^2} = -\dfrac{9}{4}\times 13.6\ eV/atom$

Energy of S_1 = $\dfrac{9}{4}$ × Energy of ground state of H – atom

= 2.25 × Energy of ground state of H – atom

11. Ans. (B)

At state S_2, energy is equal to ground state energy of H – atom

$$\Rightarrow Es_2 = -13.6\frac{3^2}{n^2} = -13.6\left(\frac{1^2}{1^2}\right)$$

$\Rightarrow n = 3$

Since state S_2 has one radial node $\Rightarrow n - \ell - 1 = 1$

$\Rightarrow 3 - \ell - 1 = 1$

$\Rightarrow \ell = 1$

$\Rightarrow 3p$

12. Ans. (9)

For n = 3 $\Rightarrow$ 3s, 3p, 3d

subshell is possible each subshell's orbital can have $1e^{\ominus}$ each with s = $-\frac{1}{2}$

$\Rightarrow 3s \quad \Rightarrow 1e^{\ominus}$

$\Rightarrow 3p \quad \Rightarrow 3 \times 1 = 3e^{\ominus}$

$\Rightarrow 3d \quad \Rightarrow 5 \times 1 = 5e^{\ominus}$

Total electrons = 5 + 3 + 1 = $9e^{\ominus}$

13. Ans. (4)

Energy associated with λ = 300nm

$$\Rightarrow E = \frac{1240}{300} = 4.13 eV$$

For photoelectric effect to take place, $E \geq \phi$

Metals which will show photoelectric effect : Li, Na, K, Mg

14. Ans. (C)

According to Bohr's model

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

$$\Rightarrow mv = \frac{nh}{2\pi r}$$

$$\Rightarrow mv^2 = \frac{n^2h^2}{(2\pi r)^2 m} = \frac{n^2h^2}{4\pi^2 r^2 m}$$

$$\Rightarrow K.E. = \frac{1}{2}mv^2 = \frac{n^2h^2}{8\pi^2 r^2 m}$$

For H – atom, $r = n^2a_0$

$$\Rightarrow K.E. = \frac{n^2h^2}{8\pi^2 n^4 a_0^2 m} = \frac{h^2}{8\pi^2 n^2 a_0^2 m}$$

For n = 2 (second orbit)

$$\Rightarrow K.E. = \frac{h^2}{32\pi^2 m a_0^2}$$

15. **Ans. (B)**

Radial probability distribution graph for 1s orbital is represented by (B).

16. **Ans. (D)**

For H – like species D is correct

In (A) For $3d_{z^2}$ xy plane is not a nodal plane

In (B) $2p_z$ orbital has no radial node

In (C) 1s orbital has no radial node

17. **Ans. (A)**

For 1s orbital is non-directional so Ψ will not depend upon $\cos\theta$**.**

18. **Ans. (C)**

For H – atom 1s orbital $\Psi \propto \left(\frac{Z}{a_0}\right)^{3/2} e^{-\left(\frac{Zr}{a_0}\right)}$

In hydrogen $E_4 - E_2 = \frac{3}{16}$

$E_6 - E_2 = \frac{2}{9}$

Hence $(E_6 - E_2) \times \frac{27}{32} = E_4 - E_2$

19. **Ans. (A,C)**

For $He^{\oplus}$ atom, $E = -13.6\left[\frac{2^2}{n^2}\right] = -3.4$

$n = 4$

and since $\ell = 2, m = 0$

$\Rightarrow$ It represents 4d subshell $\Rightarrow$ 4d orbital which will have 2 angular nodes, 1 radial node.

20. **Ans. (C)**

Radius of n^{th} orbit : $r_n = 0.529 \frac{n^2}{z}$ Å

Angular momentum of e^- in n^{th} orbit : $\frac{nh}{2\pi}$

K.E. energy of $e^{\ominus}$ in n^{th} orbit : $13.6\frac{z^2}{n^2}$ eV / atom

P.E. energy of $e^{\ominus}$ in n^{th} orbit : $-27.2\frac{z^2}{n^2}$ eV / atom

Option (C) is correctly matched

21. **Ans. (D)**

(A) Radius of the n^{th} orbit

$r_n \propto \frac{n^2}{z}$

(B) Angular momentum

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

(C) Kinetic Energy of the electron $\propto \frac{z^2}{n^2}$

(D) Potential Energy of the electron $\propto \frac{z^2}{n^2}$

22. Ans. (30)

$\lambda = \frac{h}{p} \Rightarrow p = \frac{6.6\times10^{-34}}{330\times10^{-9}} = \frac{4\times10^{-3}}{6\times10^{23}}\times v \;\; (p = m \times v)$

$v = 0.3$ m/s = 30 cm/s

23. Ans. (30)

For single electron system

$r = 52.9 \times \frac{n^2}{Z}$ pm

Given Z = 2 for $He^{\oplus}$

$r_2 = 105.8$ pm

So, $105.8 = 52.9 \times \frac{n_2^2}{2}$

$n_2 = 2$

$r_1 = 26.45$

So, $26.45 = 52.9 \times \frac{n_1^2}{2}$

$n_1 = 1$

So, transition is from 2 to 1.

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

So $\lambda = 30 \times 10^{-9}$ m = 30 nanometer.

Here 'R_H' is given in terms of energy value.

Important Notes