SOLUTIONS OF ATOMIC STRUCTURE & NUCLEAR CHEMISTRY

EXERCISE # 1

PART - I

A-2. Space occupied by the nucleus = $\frac{4}{3}\pi r^3 = \frac{4}{3} \times \frac{22}{7} \times (3.5 \times 10^{-15})^3 = 1.8 \times 10^{-43}$ m^3

A-3. $\frac{V_{nucleus}}{V_{atom}} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \left(\frac{1.5 \times 10^{-15}}{0.5 \times 10^{-10}}\right)^3 = 2.7 \times 10^{-14}$

A-4. (A) $R = R_0 A^{1/3} = 1.3 \times 10^{-15} \times (125)^{1/3} = 6.5 \times 10^{-15}$ m

(B) $r = \frac{4\ KZe^2}{m_\alpha v_\alpha^2}$, Z = 47 for Silver atom

$\Rightarrow$ $r = \frac{188\ Ke^2}{m_\alpha v^2}$

B-1. Total energy = No of photons × Energy of one photon = $100 \times \left(\frac{6.625 \times 10^{-34} \times 3 \times 10^8}{2000 \times 10^{-10}}\right)$

$= 9.937 \times 10^{-17}$ J $= \frac{9.937 \times 10^{-17}}{1.6 \times 10^{-19}}$ eV = 621.1 eV

B-2. Let number of photoelectrons emitted per second be n

$\therefore$ n × Energy of one photon = Total energy emitted

$\therefore$ $n \times \frac{12400}{\lambda_{(\text{Å})}} \times 1.6 \times 10^{-19} = 5 \times 10^{-3}$

$\therefore$ $n \times \frac{12400}{6200} \times 1.6 \times 10^{-19} = 5 \times 10^{-3}$

On solving, n = 1.56×10^{16} photoelectrons.

B-3. $C = \nu\lambda$

$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{1368 \times 10^3} = 219.3$ m

$\bar{\nu} = \frac{1}{\lambda} = \frac{1}{219.3} = 4.56 \times 10^{-3}$ m^{-1}

B-4. $E = \frac{hc}{\lambda} \times N_A = \frac{6.625 \times 10^{-34} \times 3 \times 10^8 \times 6.022 \times 10^{23}}{5000 \times 10^{-10}}$ J/mol = 239.4 KJ/mol

B-5. $\therefore$ n × Energy of one photon = Total energy

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

$\Rightarrow$ n = 1.35×10^5 photons

B-6. Let n be the no. of photons emitted by bulbs per second & W be wattage of yellow bulb.
For Red bulb no. of photons emitted per second × Energy of one photon = total energy

$\therefore \quad n \times \frac{12400}{8000} \times 1.6 \times 10^{-19} = 100$ ....(1)

For yellow bulb, $n \times \frac{12400}{4000} \times 1.6 \times 10^{-19} = W$ ....(2)

By (1) and (2), W = 200 watts.

B-7. For frequency 2.5×10^{16} Hz, $\quad h\nu = h\nu_o + KE_{max}$

$\therefore \quad h(2.5 \times 10^{16}) = h\nu_o + KE_{max}$ ....(1)

For frequency 4×10^{16} Hz,

$h(4 \times 10^{16}) = h\nu_o + 2\,KE_{max}$ ....(2)

Multiply eq^n (1) by 2 and subtract eq^n (2) from it.

$\therefore \quad 2h\nu_o - h\nu_o = h(5.0 \times 10^{16} - 4 \times 10^{16})$

$\therefore \quad h\nu_o = h(1 \times 10^{16})$

$\therefore$ threshold frequency, $\nu_o = 1 \times 10^{16}$ Hz

C-1. Radius of ground state of hydrogen atom = 0.529 Å

So, $\quad 0.529 = 0.529 \times \frac{n^2}{Z}$

$0.529 = 0.529 \times \frac{n^2}{4} \quad \therefore \quad n = 2$

C-2. $v_3 = v_1 \times \left(\frac{Z}{n}\right)$

$v_3 = 2.18 \times 10^6 \times \left(\frac{1}{3}\right) = 7.27 \times 10^5$ m/s

C-3. Angular momentum, $\ell = mvr = \frac{nh}{2\pi} \quad \therefore \quad \ell \propto n$

Radius, $r = 0.529\,\frac{n^2}{z}$ Å $\quad \therefore \quad r \propto n^2$ $\quad$ For same Z

Velocity, $v = 2.18 \times 10^6\,\frac{z}{n}$ m/s $\quad \therefore \quad v \propto \frac{1}{n}$

$\therefore \quad v\,r\,\ell \propto n \times n^2 \times \frac{1}{n}$

But, $v\,r\,\ell \propto n^x$ (given)

$\therefore \quad n^2 = n^x \quad \therefore \quad x = 2$

C-4. $$\frac{T_{He^+}}{T_{Li^{2+}}} = \frac{\left(\frac{n^3}{Z^2}\right)_{He^+}}{\left(\frac{n^3}{Z^2}\right)_{Li^{2+}}} = \frac{\left(\frac{2^3}{2^2}\right)}{\left(\frac{4^3}{3^2}\right)} = \frac{9}{32}$$

C-5.

x : n = 3 to n = 1 (12.09 eV)
y : n = 4 to n = 2 (2.55 eV)
z : n = 5 to n = 3 (0.967 eV)

Shortest wavelength $\Rightarrow$ maximum energy $\Rightarrow$ n = 3 to n = 1 (12.09 eV)

C-6. Clearly, $E_4 - E_2 = (-0.85) - (-3.4) = 2.55$ eV $\Rightarrow$ A = 2, B = 4

C-7. (a) $16.52 = (E_3 - E_2) \times Z^2$

$16.52 = 1.89 \times Z^2 \quad \Rightarrow \quad Z^2 = 9 \quad \text{or} \quad Z = 3$

(b) $(E_3 - E_1)_Z = 12.09 \times Z^2 = 12.09 \times 9 = 108.81$ eV

(c) $\lambda = \dfrac{12400}{\Delta E_{1\to\infty}} = \dfrac{12400}{13.6 \times 3^2} = 101.3$ Å $= 1.013 \times 10^{-8}$ m,

(d) $KE_1 = 13.6\ Z^2$ eV $= 13.6 \times 3^2 = 122.4$ eV

C-8. $40.8 = (\Delta E)_{2\to1} \times Z^2$

$\Rightarrow \quad 40.8 = 10.2 \times Z^2$

$\Rightarrow \quad Z^2 = 4 \quad \text{or} \quad Z = 2$

$IE = 13.6\ Z^2 = 13.6 \times 4 = 54.4$ eV

D-1. $\lambda_{3\to2} = \dfrac{12400}{\Delta E_{3\to2}} = \dfrac{12400}{1.89} = 6561$ Å ;

$\lambda_{4\to2} = \dfrac{12400}{\Delta E_{4\to2}} = \dfrac{12400}{2.55} = 4863$ Å

D-2. $\dfrac{1}{\lambda_H} = R(1)^2 \left[\dfrac{1}{1^2} - \dfrac{1}{2^2}\right]$ & $\dfrac{1}{\lambda_{He^+}} = R(2)^2 \left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$

But $\lambda_H = \lambda_{He^+}$

$\therefore$ from above 2 equations, $n_1 = 2$ & $n_2 = 4$.

D-3. $\Delta E_{6\to2} = h\nu$

$\nu = \dfrac{3.022 \times 1.6 \times 10^{-19}}{6.625 \times 10^{-34}} = 7.3 \times 10^{14}$ Hz

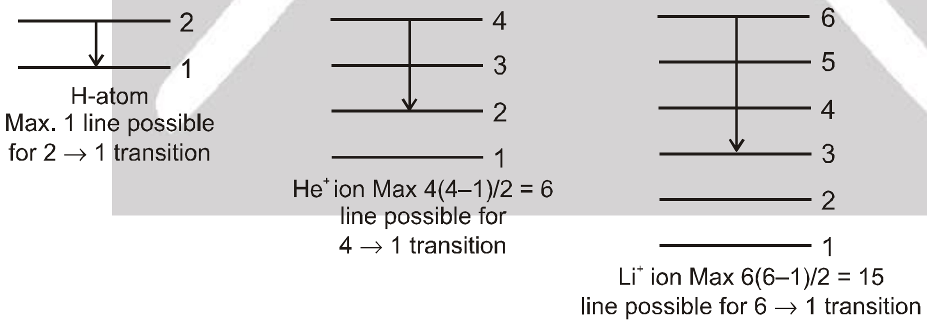
This frequency lies in visible spectrum.

D-4. $E = \dfrac{hc}{\lambda} = \dfrac{12400}{300} = \dfrac{124}{3} = 13.6\ Z^2$

$\Rightarrow \quad \dfrac{124}{3} = 13.6 Z^2 \left[1 - \dfrac{1}{4}\right]$

$\Rightarrow \quad Z = 2$

D-5.



But, $(H_2)_{2\to1} = (He^+)_{4\to2} = (Li^{2+})_{6\to3}$ are lines of same energy and so, will overlap each other.

$\therefore$ Total no. of lines observed = (1 + 6 + 15) – 2 = 20 lines.

E-1. Energy absorbed = 1.5 × 13.6 = 20.4 eV.

Energy used up in escaping = 13.6 eV

$\therefore$ Energy left as KE with electron = 20.4 – 13.6 = 6.8 eV

$\therefore$ Associated de-Broglie wavelength, $\lambda = \dfrac{12.27}{\sqrt{6.8}} = 4.71$ Å.

E-2. Debroglie wavelength associated with particle of mass (m) moving with velocity (v) is

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

$\lambda_p = \dfrac{h}{m_p v_p}$ and $\lambda_e = \dfrac{h}{m_e v_e}$

Given, $\lambda_p = \lambda_e$ $\Rightarrow$ $\dfrac{h}{m_p v_p} = \dfrac{h}{m_e v_e}$ $\Rightarrow$ $m_p\, v_p = m_e\, v_e$

$\dfrac{v_e}{v_p} = \dfrac{m_p}{m_e} = 1836$ $\Rightarrow$ $v_e = 1836\, v_p$

It means when velocity of electron will be 1836 times velocity of proton, then debroglie wavelength associated with electron would be equal to debroglie wavelength associated with proton.

E-3. $\lambda_1 = \dfrac{h}{\sqrt{2mq\ \ (100)}} = \dfrac{k}{10}$, $\lambda_2 = \dfrac{h}{\sqrt{2mq(81)}} = \dfrac{k}{9}$, $\lambda_3 = \dfrac{h}{\sqrt{2mq(49)}} = \dfrac{k}{7}$

$\dfrac{\lambda_3 - \lambda_2}{\lambda_1} = \left(\dfrac{\dfrac{k}{7} - \dfrac{k}{9}}{\dfrac{k}{10}}\right) = \dfrac{20}{63}$

E-4. Initial kinetic energy, $KE_i = 2$ eV

Increase in KE due to acceleration = q × V = e × 2v = 2eV.

$\therefore$ Final kinetic energy, $KE_f = 2 + 2 = 4$ eV.

$\therefore$ Associated de-Broglie wavelength, $\lambda = \dfrac{12.27}{\sqrt{4}} = 6.15$ Å.

E-5. $m = \dfrac{h}{4\pi\Delta x\Delta v} = \dfrac{6.625 \times 10^{-34}}{4 \times 3.14 \times 10^{-10} \times 5.27 \times 10^{-24}}$ **Ans.** $\approx$ 100 gm

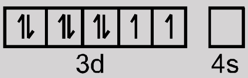
F-1. Number of radial nodes = $n - \ell - 1$

number of angular nodes = ℓ

total nodes = $n - 1$

G-1. Ni Atomic No : 28

Ni : [Ar] $3d^8\, 4a^2$; Ni^{2+} [Ar] $3d^8\, 4s^0$



No. of unpairecd electron = 2

G-2. Atomic No. 56

Electronic configuration : $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^2\, 3d^{10}\, 4p^6\, 5s^2\, 4d^{10}\, 5p^6\, 6s^2$.

G-3. (a) $n = 3$, $\ell = 1 \Rightarrow 3p$ (b) $n = 5$, $\ell = 2 \Rightarrow 5d$ (c) $n = 4$, $\ell = 1 \Rightarrow 4p$

(d) $n = 2$, $\ell = 0 \Rightarrow 2s$ (e) $n = 4$, $\ell = 2 \Rightarrow 4d$

G-4. Orbital angular momentum = $\sqrt{\ell(\ell+1)}\dfrac{h}{2\pi}$

For 4s orbital, $\ell = 0$ $\therefore$ Angular momentum = $\sqrt{0\,(0+1)}\dfrac{h}{2\pi} = 0$.

For 3p orbital, $\ell = 1$ $\therefore$ Angular momentum = $\sqrt{1\,(1+1)}\dfrac{h}{2\pi} = \dfrac{h}{\sqrt{2}\pi}$.

For 4th orbit, Angular momentum = $\dfrac{nh}{2\pi} = \dfrac{4h}{2\pi} = \dfrac{2h}{\pi}$.

G-5. (i) $\ell = 0 \Rightarrow m = 0$ ($m \neq 1$) (iii) $n = 1 \Rightarrow \ell = 0$ ($\ell \neq 2$) (vi) $s = +1/2$ or $-1/2$ ($s \neq 0$)

G-6. (i) $_{26}Fe^{3+}$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$

It contains 5 unpaired electrons $\therefore$ n = 5

$\therefore$ Total spin = $\pm \frac{n}{2} = \pm \frac{5}{2}$

Magnetic moment = $\sqrt{n(n+2)} = \sqrt{5(5+2)} = \sqrt{35}$ BM.

(ii) $_{29}Cu^{+}$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

It contains 0 unpaired electron

$\therefore$ Total spin = 0.

$\therefore$ Spin magnetic Moment = 0.

H-1. $\because$ $\Delta E = \Delta m \times 931.478$

$\therefore$ $\Delta m = \frac{\Delta E}{931.478} = \frac{17.25}{931.478} = 0.0185$ amu

$\Delta m = 3.07 \times 10^{-26}$ g.

H-5. Nuclear fission is a series reaction 3, 9, 27.......neutron and E, 3E, 9E......energy are emitted. Hence answer is 3^n, $3^{n-1}E$.

PART - II

A-1. Hydrogen atom contains 1 proton, 1 electron and no neutrons.

A-2. It constitute of electron.

A-3. $\frac{(e/m)_e}{(e/m)_\alpha} = \frac{e/m_e}{2e/4 \times 1836\ \ m_e} = \frac{3672}{1}$

A-4. Factual.

A-5. Volume fraction = $\frac{\text{Volume of nucleus}}{\text{Total vol. of atom}} = \frac{(4/3)\pi\ \ (10^{-13})^3}{(4/3)\pi\ \ (10^{-8})^3} = 10^{-15}$

A-6. $R = R_0\ A^{1/3} = 1.3 \times 64^{1/3} = 5.2$ fm

B-1. $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{400 \times 10^6} = 0.75$ m

B-2. Violet colour has minimum wavelength so maximum energy.

B-3. I.E. of one sodium atom = $\frac{hC}{\lambda}$

& I.E. of one mole Na atom = $\frac{hC}{\lambda} N_A = \frac{6.62 \times 10^{34} \times 3 \times 10^8 \times 6.02 \times 10^{23}}{242 \times 10^{-9}} = 494.65$ kJ.mol.

B-4. Power = $\frac{nhC}{\lambda \times t}$ $\Rightarrow$ $40 \times \frac{80}{100} = \frac{n \times 6.62 \times 10^{-34} \times 3 \times 10^8}{620 \times 10^{-9} \times 20}$ $\Rightarrow$ $n = 2 \times 10^{21}$

B-5. For photoelectric effect to take place, $E_{light} \geq W$ $\therefore$ $\frac{hc}{\lambda} \geq \frac{hc}{\lambda_0}$ or $\lambda \leq \lambda_0$.

B-6. Photoelectric effect is a random phenomena. So, electron It may come out with a kinetic energy less than ($h\nu$ – w) as some energy is lost while escaping out.

C-1. $r \propto \left(\frac{n^2}{Z}\right)$ As Z increases, radius of I orbit decreases.

C-2. Radius = $0.529 \frac{n^2}{Z}$ Å = 10×10^{-9} m

So, $n^2 = 189$ or, $n \approx 14$ **Ans.**

C-3. E_1 (H) = $-13.6 \times \frac{1^2}{1^2} = -13.6$ eV ; E_2 (He^+) = $-13.6 \times \frac{2^2}{2^2} = -13.6$ eV

E_3 (Li^{2+}) = $-13.6 \times \frac{3^2}{3^2} = -13.6$ eV ; E_4 (Be^{3+}) = $-13.6 \times \frac{4^2}{4^2} = -13.6$ eV

$\therefore$ $E_1(H) = E_2(He^+) = E_3(Li^{2+}) = E_4(Be^{3+})$

C-4. $V = 2.188 \times 10^6 \frac{Z}{n}$ m/s

Now, $V \propto \frac{Z}{n}$ so, $\frac{V_{Li^{2+}}}{V_H} = \frac{Z_1/n_1}{Z_2/n_2} = \frac{3/3}{1/1} = 1$ or, $V_{Li^{2+}} = V_H$

C-5. $r_1 - r_2 = 24 \times (r_1)_H$

$\frac{0.529 \times n_1^2}{1} - \frac{0.529 \times n_2^2}{1} = 24 \times 0.529$

$\therefore$ $\left(n_1^2 - n_2^2\right) = 24$

So, $n_1 = 5$ and $n_2 = 1$

C-6. (a) Energy of ground state of He^+ $= -13.6 \times 2^2 = -54.4$ eV (iv)
(b) Potential energy of I orbit of H-atom $= -27.2 \times 1^2 = -27.2$ eV (ii)
(c) Kinetic energy of II excited state of He^+ $= 13.6 \times \frac{2^2}{3^2} = 6.04$ eV (i)
(d) Ionisation potential of He^+ $= 13.6 \times 2^2 = 54.4$ V (iii)

C-7. **S_1 :** Potential energy of the two opposite charge system decreases with decrease in distance,
S_4 : The energy of I[st] excited state of He^+ ion $= -3.4\ Z^2 = -3.4 \times 2^2 = -13.6$ eV.
S_2 and S_3 are correct statement.

D-1. $E_n = E_1 \frac{Z^2}{n^2}$ $E_5 = -13.6 \times \frac{(1)^2}{(5)^2} = -0.54$ eV

D-2. $\lambda = \frac{hc}{\Delta E}$ $\therefore$ $\lambda \propto \frac{1}{\Delta E}$

D-3. Infrared lines = total lines – visible lines – UV lines = $\frac{6(6-1)}{2} - 4 - 5 = 15 - 9 = 6$.

(Visible lines = 4 $6\to2, 5\to2, 4\to2, 3\to2$) (UV lines = 5 $6\to1, 5\to1, 4\to1, 3\to1, 2\to1$)

D-4. When electron falls from n to 1, total possible number of lines = n – 1.

D-5. Visible lines $\Rightarrow$ Balmer series ($5 \rightarrow 2$, $4 \rightarrow 2$, $3 \rightarrow 2$). So, 3 lines.

D-6. According to energy, $E_{4\rightarrow 1} > E_{3\rightarrow 1} > E_{2\rightarrow 1} > E_{3\rightarrow 2}$.
According to energy, Violet > Blue > Green > Red.
$\therefore$ Red line $\Rightarrow$ $3 \rightarrow 2$ transition.

D-7. For 1st line of Balmer series

$$\bar{v}_1 = R_H (3)^2 \left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = 9R\left(\frac{5}{36}\right) = \frac{5}{4}R$$

For last line of Pachen series

$$\bar{v}_2 = R_H (3)^2 \left[\frac{1}{(3)^2} - \frac{1}{(\infty)^2}\right] = R \qquad \text{so,} \qquad \bar{v}_1 - \bar{v}_2 = \frac{5}{4}R - R = \frac{R}{4}.$$

E-1. $\lambda = \frac{h}{mv} = \frac{6.625\times10^{-34}}{0.2\times5} \times 3600 \approx 10^{-30}$ m.

E-2. $\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_1}} = \sqrt{\frac{200}{50}} = \frac{2}{1}$.

E-3. $r_1 = 0.529$ Å
$r_3 = 0.529 \times (3)^2$ Å = 9x
so, $\lambda = \frac{2\pi r}{n} = \frac{2\pi(9x)}{3} = 6\pi x$.

E-4. For an α particle, $\lambda = \frac{0.101}{\sqrt{V}}$ Å.

E-5. $\lambda \propto \frac{n}{Z}$ $\therefore$ $\frac{n_1}{Z_1} = \frac{n_2}{Z_2}$ or $\frac{2}{3} = \frac{4}{6}$ (n = 4 of C^{5+} ion)

E-6. For a charged particle $\lambda = \frac{h}{\sqrt{2mqV}}$, $\therefore$ $\lambda \propto \frac{1}{\sqrt{V}}$.

E-7. $\Delta p \, . \, \Delta x = \frac{h}{4\pi}$ $\Rightarrow$ $\Delta x = \frac{6.62\times10^{-34}}{4\times3.14\times1\times10^{-5}} = 5.27 \times 10^{-30}$ m.

F-1. Factual.

F-2. A has 0 nodes as ψ^2 is not zero anywhere so it's 1 s (n – 1 = 0)
B has 1 node so, it is 2s as n – 1 = 1

F-4. Dumbell lies at 45º to x & y axis.

F-5. Factual

F-6. Spherical node = $n - \ell - 1$
Non spherical = ℓ

F-7. Factual

F-8. (a) Electron density in the XY plane in $3d_{x^2-y^2}$ orbital is not zero

(b) Electron density in the XY plane in $3d_{z^2}$ orbital is not zero.

(c) 2s orbital has one nodal surface

(d) For $2p_z$ orbital, XY is the nodal plane.

F-9. Factual

F-10. n, ℓ and m.

G-1. Orbital angular momentum = $\sqrt{\ell(\ell+1)}\,\frac{h}{2\pi}$ = 0. ∴ ℓ = 0 (s orbital).

G-2. Cu : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$.

∴ Cu^{2+} : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$ or $[Ar]3d^9$.

G-3. Magnetic moment = $\sqrt{n(n+2)}$ = $\sqrt{24}$ B.M.

∴ No. of unpaired electron = 4.

X_{26} : $1s^2\ 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$.

To get 4 unpaired electrons, outermost configuration will be $3d^6$.

∴ No. of electrons lost = 2 (from $4s^2$).

∴ n = 2.

G-4.

Zn^{2+} : [Ar] $3d^{10}$ (0 unpaired electrons).

Fe^{2+} : [Ar] $3d^6$ (4 unpaired electrons) maximum.

Ni^{3+} : [Ar] $3d^7$ (3 unpaired electrons).

Cu^+ : [Ar] $3d^{10}$ (0 unpaired electrons).

G-5. d^7 : 3 unpaired electrons. ∴ Total spin = $\pm\frac{n}{2}$ = $\pm\frac{3}{2}$.

G-6. X_{23} : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$.

No. of electron with ℓ = 2 are 3 ($3d^3$).

G-7. Cr (Zn = 24)

Electronic configuration is : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

so, no of electron in ℓ = 1 i.e. p subshell is 12 and no of electron in ℓ = 2 i.e. d subshell is 5.

G-8. Orbital angular momentum = $\sqrt{\ell(\ell+1)}\,\frac{h}{2\pi}$ = 0 (since ℓ = 0 for s orbital).

G-9. Cl_{17}^- : [Ne] $3s^2\ 3p^6$.

Last electron enters 3p orbital.

∴ ℓ = 1 and m = 1, 0, –1.

G-10. Number of radial nodes = n – ℓ – 1 = 1, n = 3. ∴ ℓ = 1.

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

H-1. ${}^{11}_{6}C \longrightarrow {}^{11}_{5}B + {}^{0}_{+1}e$

H-2. $\frac{n}{p} > 1$

H-3. It is the order of penetrating power.

H-4. Nucleides having $\frac{n}{p}$ > 1 undergoes β-emission to decrease $\frac{n}{p}$ ratio in order to attain belt of stability.

H-5. $^{A}_{Z}X \longrightarrow ^{A-1}_{Z}X + ^{1}_{0}n$

H-6. $^{238}_{92}U \longrightarrow ^{214}_{82}Pb + m\,^{4}_{2}He + n\,^{0}_{-1}e$

∴ m = 6 and m = 2. Total 8.

PART - III

1. It is factual.

2. $f_n = \frac{v_n}{2\pi r_n}$, $f_n \propto \frac{Z^2}{n^3}$, $T_n = \frac{2\pi r_n}{v_n}$, $T_n \propto \frac{n^3}{Z^2}$.

$E_n = -13.6\,\frac{Z^2}{n^2}$, $E_n \propto \frac{Z^2}{n^2}$, $r_n \propto \frac{n^2}{Z}$.

3. It is factual.

4. Number of values of ℓ = total number of subshells = n.
Value of ℓ = 0, 1, 2 .... (n – 1).
ℓ = 2 ⇒ m = –2, –1, 0, +1, +2 (5 values)
m = – ℓ to + ℓ through zero.

EXERCISE # 2

PART - I

1. Factual.

2. $\frac{m}{e} = 1.5 \times 10^{-8}$ and $e = 1.6 \times 10^{-19}$

∴ $m = 1.5 \times 10^{-8} \times 1.6 \times 10^{-19}$
$m = 2.4 \times 10^{-24}$ g

3. Charge on oil drop = 6.39×10^{-19} C

∵ 1.602×10^{-19} C is charge on one electron

∴ 6.39×10^{-19} C is charge on = $\frac{6.39 \times 10^{-19}}{1.602 \times 10^{-19}}$ = 4 electrons.

5. $\frac{hc}{\lambda} = 1 + \phi$ ...(1)

$3 \times \frac{hc}{\lambda} = 4 + \phi$ ...(2)

from, e.q., (1) and (2) ϕ = 0.5 eV

6. $\frac{T_1}{T_2} = \frac{n_1^3}{n_2^3} = \frac{1^3}{2^3} = \frac{1}{8}$.

$\because$ $\left(T = \frac{2\pi r}{V}\right)$ so, $T \propto \frac{n^3}{Z^2}$

7. $\frac{r_1}{r_2} = \frac{n_1^2}{n_2^2} = \frac{R}{4R}$

$\Rightarrow$ $\frac{n_1}{n_2} = \frac{1}{2}$

$\therefore$ $\frac{T_1}{T_2} = \frac{n_1^3}{n_2^3} = \frac{1}{8}$.

8. Angular momentum J = mvr

$J^2 = m^2v^2r^2$

or $\frac{J^2}{2} = \left(\frac{1}{2}mv^2\right)mr^2$ or $K.E. = \frac{J^2}{2mr^2}$

9. $P.E. = \frac{Kq_1q_2}{r} = \frac{K(-e)(+4e)}{r} = \frac{1}{4\pi\varepsilon_0} \times -\frac{4e^2}{r} = -\frac{e^2}{\pi \epsilon_0 r}$.

10. $KE = \frac{1}{2}\frac{KZe^2}{r} = \frac{3e^2}{8\pi \epsilon_0 r}$.

11. $(He^+)_{2 \to 4} = (Li^{2+})_{n_4 \to n_3}$

$\therefore$ $\frac{Z_1}{Z_2} = \frac{n_2}{n_4} = \frac{n_1}{n_3}$ or $\frac{2}{3} = \frac{2}{n_4} = \frac{4}{n_3}$

$\therefore$ $n_4 = 3$ and $n_3 = 6$.

$\therefore$ Transition in Li^{2+} ion = $3 \to 6$

12. $\nu = RC\,Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$.

$\nu_1 = RC\,Z^2\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = RC\,Z^2$, $\nu_2 = RC\,Z^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3}{4}RC\,Z^2$.

$\nu_3 = RC\,Z^2\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{1}{4}RC\,Z^2$. $\therefore$ $\upsilon_1 - \upsilon_2 = \upsilon_3$.

13. Visible lines $\Rightarrow$ Balmer series $\Rightarrow$ 3 lines. ($5 \to 2$, $4 \to 2$, $3 \to 2$).

14. Shortest wave length of Lyman series of H-atom

$\frac{1}{\lambda} = \frac{1}{x} = R\left[\frac{1}{(1)^2} - \frac{1}{(\infty)^2}\right]$ so, $x = \frac{1}{R}$

For Balmes series

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

$\frac{1}{\lambda} = \frac{1}{x} \times \frac{5}{36}$ so, $\lambda = \frac{36x}{5}$.

15. Number of lines in Balmer series = 2. $\therefore$ n = 4 (lines will be $4 \rightarrow 2$, $3 \rightarrow 2$).

KE of ejected photoelectrons = $E_{photon} - BE_n = 13 - \frac{13.6}{4^2} = 13 - 0.85 = 12.15$ eV.

16. $\frac{\lambda_y}{\lambda_x} = \frac{m_x v_x}{m_y v_y}$. $\Rightarrow$ $\frac{\lambda_y}{1} = \frac{m_x v_x}{(0.25 m_x)\ (0.75\ v_x)} = \frac{16}{3}$.

$\therefore$ $\lambda_y = 5.33$Å.

17. $\lambda = \frac{h}{mV}$

$\frac{\lambda_p}{\lambda_\alpha} = \frac{m_\alpha V_\alpha}{m_p V_p}$ $m_\alpha = 4m_p$

$\frac{\lambda_p}{\lambda_\alpha} = \frac{4m_\alpha V_\alpha}{m_p V_p}$

$\frac{1}{2} = 4 \times \frac{V_\alpha}{V_p}$

$\frac{V_p}{V_\alpha} = \frac{8}{1}$

18. For an electron accelerated with potential difference V volt, $\lambda = \frac{h}{\sqrt{2mqV}} = \frac{12.3}{\sqrt{V}}$ Å.

19. $\lambda = v$

then $\lambda = \frac{h}{mV}$ or $\lambda^2 = \frac{h}{m}$ So, $\lambda = \sqrt{\frac{h}{m}}$.

20. $\Delta x = 2\Delta p$

$\Delta x.\Delta p = \frac{\hbar}{2} = \frac{h}{4\pi}$ $\Rightarrow$ $2\ \Delta p.\Delta p = \frac{\hbar}{2}$

$2(m\Delta V)^2 = \frac{\hbar}{2}$; $(\Delta V)^2 = \frac{\hbar}{4m^2}$ $\Rightarrow$ $\Delta V = \frac{\sqrt{\hbar}}{2m}$.

21. $2\pi r = n\lambda$ = circumference

22. s orbital is spherical so non-directional.

23. The lobes of $d_{x^2-y^2}$ orbital are alligned along X and Y axis. Therefore the probability of finding the electron is maximum along x and y-axis.

24. Factual.

25. Rb_{37} : [Kr] $5s^2$. $\therefore$ n = 5, ℓ = 0, m = 0, s = $\pm\frac{1}{2}$.

26. Magnetic moment = 2.83 so, no. of unpaired electrons = 2
so, Ni^{2+} is the answer.

27. For 1s, 3s, 3d and 2p orbital, ℓ = 0, 0, 2, 1 respectively.
Orbital angular momentum = $\sqrt{\ell\ (\ell + 1)}\ \hbar$.

28. After np orbital, (n + 1) s orbital is filled.

29. Total number of electrons in an orbital = 2 (2ℓ +1).
The value of ℓ varies from 0 to n – 1.

∴ Total numbers of electrons in any orbit = $\sum_{\ell=0}^{\ell=n-1} 2(2\ell+1)$.

30. Spin quantum number does not comes from Schrodinger equation.
$s = +\frac{1}{2}$ and $-\frac{1}{2}$ have been assigned arbitrarily.

31. Change in mass number = 32
Change in proton = 10
8α means 8 $_2He^4$ i.e., 32 mass number, 16 protons.
Now 6β = 6 neutrons changed to 6 proton.
So, net change in proton = 10
Answer is 8α, 6β.

PART - II

1. $\frac{(e/m)_p}{(e/m)_\alpha} = \frac{e_p/m_p}{2e_p/4m_p} = \frac{2}{1}$.

2. $\frac{E_1}{E_2} = \frac{hc}{\lambda_1} \times \frac{\lambda_2}{hc} = \frac{\lambda_2}{\lambda_1} = \frac{600}{300} = 2$.

3. Heat required for melting 1 mole (18 g) of ice = 330 × 18 = 5940 J
Energy of one photon = hν = 6.6 × 10^{-34} × 5 × 10^{13} = 33 × 10^{-21} J

∴ Total number of photons required = $\frac{5940}{33 \times 10^{-21}} \approx 1.8 \times 10^{23}$

4. $W_0 + K = h\nu$

$40 \times 1.6 \times 10^{-19} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{\lambda}$

λ = 31 nm

5. Energy of the photon = 0.6375 eV = $\frac{3}{4}$ × 0.85 eV = $\frac{3}{4} \times \frac{13.6}{4^2} = \frac{13.6}{4^2}\left(1-\frac{1}{4}\right) = 13.6\left(\frac{1}{4^2}-\frac{1}{8^2}\right)$

Thus, this photon coresponds to transition n = 8 to n = 4 (Brakett series)
∴ x = 8 Ans.

6. IP = 13.6Z2 = 16 (given).

1st excitation potential = 13.6 × $\frac{3}{4}$ × Z = 16 × $\frac{3}{4}$ = 12 V.

7. Diameter of Hydrogen atom = 16.92Å
Radius of an atom = 8.46Å

$r_n = \frac{0.529n^2}{Z}$ ⇒ $8.46 = \frac{0.529n^2}{1}$ ⇒ n = 4

Maximum number of electron = $2n^2 = 2 \times (4)^2 = 32$.

8. Number of spectral lines = $\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$

$6 = \frac{(n_2 - 3)(n_2 - 3 + 1)}{2}$ $\Rightarrow$ $12 = n_2^2 - 5n_2 + 6$

$\therefore$ $n_2^2 - 5n_2 - 6 = 0$.

$\therefore$ $n_2 = 6$ or -1.

Since $n_2 = -1$ is not possible. Hence $n_2 = 6$.

9. Total energy = $\frac{13.6\ Z^2}{n^2} = \frac{13.6\ (Z)^2}{(4)^2} = 3.4$ eV

Now K.E. = 3.4 – 1.4 = 2 eV

Now, Total energy = 2 + 4 = 6 eV i.e. potential = 6 V

For electron, $\lambda = \sqrt{\frac{150}{V}}$ so $\lambda = 5$ Å.

10. For an electron, de-Broglie wavelength $\lambda = \sqrt{\frac{150}{KE_{eV}}}$ Å

$\lambda^2 = \frac{150}{KE_{eV}}$ $KE = \frac{150}{\lambda^2} = \frac{150}{12.016} = \frac{13.6 \times 11}{144}$ eV (Using given relation)

$\left(E_{n_2 \to 6}\right)_{Li^{2+}} = \left(E_{3 \to \infty}\right)_H + KE_{electron}$

$13.6\ (3)^2 \left(\frac{1}{6^2} - \frac{1}{n_2^2}\right) = 13.6\ (1)^2 \left[\frac{1}{3^2} - \frac{1}{\infty^2}\right] + \frac{13.6 \times 11}{144}$

On solving, we get $n_2 = 12$.

12. $(2 - Zr)^2 = 0$

$Zr = 2$

$r = \frac{2}{z} = \frac{2}{2} = 1$Å

13. d_{xy}, d_{yz}, d_{xz}

The lobes of d_{xy} orbital are at an angle of 45º with X and Y axis. So along the lobes, angular probability distribution is maximum similarly for d_{yz} & d_{xz}.

14. Cr : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

$n + \ell = 3$

so the combinations are 2p, 3s. So 8 electrons.

15. $\sqrt{n(n+2)} = 4.9$

$\therefore$ No. of unpaired electrons, n = 4.

$_{25}Mn$: $[Ar]4s^2 3d^5$

For having 4 unpaired electrons, a Mn atom should lose 3 electrons (2 from 4s and 1 from 3d).

$\therefore$ a = +3.

16. ${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{139}_{54}Xe + {}^{94}_{38}Sr + x_0n^1$

Equating mass number

235 + 1 = 139 + 94 + x

x = 3

PART - III

1. No. of neutrons in ${}^{76}_{32}Ge$ = A – Z = 76 – 32 = 44.

No. of neutrons in ${}^{77}_{33}As$ = 77 – 33 = 44.

No. of neutrons in ${}^{78}_{34}Se$ = 78 – 34 = 44.

2. Ne contains 10 electrons
O^{2-} and F^{-} contain 10 electrons

3. Since most part of atom is empty space, so, when α particles are sent towards a thin metal foil, most of them go straight through the foil.

4. From α particle scattering experiment, distance of closest approach of α particle with nucleus came out to be of the order of 10^{-14} m.

5. $\nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{600 \times 10^{-9}} = 5 \times 10^{14}\ sec^{-1}$

$E = \frac{12400}{6000} = 2.07$ eV.

6. Li^{2+}, H and He^{+} are single electron species.

7. Velocity $\propto \frac{Z}{n}$; Frequency $\propto \frac{Z^2}{n^3}$; Radius $\propto \frac{n^2}{Z}$; Force $\propto \frac{Z^2}{n^4}$.

8. 1^{st} excitation potential = 10.2 Z^2 = 24 V $\therefore$ $Z^2 = 24/10.2$

$\therefore$ IE = 13.6 $Z^2 = \frac{13.6 \times 24}{10.2}$ = 32 eV.

Binding energy of 3^{rd} excited state = 0.85 $Z^2 = \frac{0.85 \times 24}{10.2}$ = 2eV.

2^{nd} excitation potential of sample = 12.09 $Z^2 = \frac{12.09 \times 24}{10.2} = \frac{32 \times 8}{9}$ V.

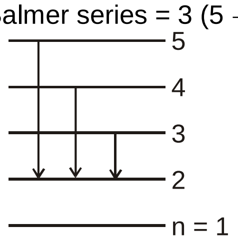
9. In all the given cases, only one quantum of energy is emitted since only one electronic transition occurs.

10. Transition is taking place from 5 $\rightarrow$ 2

$\Rightarrow$ $\Delta n = 3$

Hence maximum number of spectral line observed = $\frac{3(3+1)}{2}$ = 6.

(C) number of lines belonging to the Balmer series = 3 (5 $\rightarrow$ 2,4 $\rightarrow$ 2,3$\rightarrow$2) as shown in figure.



Number of lines belonging to Paschen series = 2 (5 $\rightarrow$ 3, 4 $\rightarrow$ 3).

11. Change in angular momentum for 3 → 2 transition = $(3 - 2)\frac{h}{2\pi} = \frac{h}{2\pi}$.

Change in angular momentum for 4 → 2 transition = $(4 - 2)\frac{h}{2\pi} = \frac{h}{\pi}$.

12. $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mKE}} = \frac{h}{\sqrt{2mqV}}$.

When v, KE and V are same, as m increasing, λ decreases. $\lambda_e > \lambda_p > \lambda_\alpha$ (if v, KE and V are same).

13. n = 4, m = 2
Value of ℓ = 0 to (n – 1) but m = 2. ∴ ℓ = 2 or 3 only
Value of s may be +1/2 or – 1/2.

14. $\sqrt{n(n+2)} = 1.732$
Number of unpaired electrons, n = 1.
$_{25}X$: [Ar] $4s^2 3d^5$
For having one unpaired electron, 6 electrons are to be removed (2 from 4s & 4 from 3d).
∴ Y = 6.

15. Spin angular momentum $S = \sqrt{s(s+1)}\frac{h}{2\pi}$.

$s = \frac{1}{2}$ ∴ $S = \frac{\sqrt{3}}{2} \times \frac{h}{2\pi}$.

16. (A) $_{24}Cr$: $[Ar]3d^5 4s^1$ (B) m = – ℓ to + ℓ through zero.
(C) $_{47}Ag$: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1 4d^{10}$.
Since only one unpaired electron is present.
∴ 23 electrons have spin of one type and 24 of the opposite type.

17. $_8O$: [He] $2s^2 2p^4$; $_{16}S$: [Ne] $3s^2 3p^4$

18. γ- rays are uncharged.

19. 1 neutron added increases mass number.

PART - IV

1. As the frequency of incident radiations increases, the kinetic energy of emitted photoelectrons increases.
Decreasing order of ν ⇒ Violet > Blue > Orange > Red
Decreasing order of KE of photoelectrons ⇒ Violet > Blue > Orange > Red

2. The interaction between photon and electron is always one to one for ejection of photoelectrons,
Frequency of incident radiations > threshold frequency
$5.16 \times 10^{15} > 6.15 \times 10^{14}$

3. The number of photoelectrons emitted depend on the intensity or brightness of incident radiation.

4. Last line of Bracket series for H-atom

$$\frac{1}{\lambda_1} = R\left[\frac{1}{(4)^2} - \frac{1}{(\infty)^2}\right] \quad \text{so,} \quad \lambda_1 = \frac{16}{R}$$

2^{nd} line of Lyman series

$$\frac{1}{\lambda_2} = R\left[\frac{1}{(1)^2} - \frac{1}{(3)^2}\right] \qquad \text{so,} \qquad \lambda_2 = \frac{9}{8R}$$

or, $\dfrac{128}{\lambda_1} = \dfrac{9}{\lambda_2}$

5. 1. Spectral lines of H atom only belonging to Balmer series are in visible range.
2. In the Balmer series of H-atom, first 4 lines are in visible region and rest all are in ultra violet region.
3. 2^{nd} line of Lyman series of He^+ ion has energy = $(E_{3\to1}) \times 2^2 = 12.1 \times 4 = 48.4$ eV.

6. $\bar{v} = R(4)^2 \left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right] = \frac{7R}{9}$.

7. $\Delta x = \frac{h}{4\pi \text{ Me}} \times \frac{1}{\Delta V} \qquad \Delta V = V \times \frac{0.001}{100} = 300 \times 10^{-5}$ m/s

$\Delta x = 5.8 \times 10^{-5} \times \frac{1}{300 \times 10^{-5}} = 1.92 \times 10^{-2}$ m

8. The maximum KE of potoelectron is corresponding to maximum stopping = 22 eV.

$E_{incident} = E_{thresold} + KE_{maxi} = 40 \text{ eV} + 22\text{eV} = 62$ eV

$\lambda_{incident} = \frac{12400 \text{ Å}}{62} = 200$ Å

9. Circumference = $2\pi r = n\lambda$

de-broglie $-\lambda = \frac{2\pi r}{n} = \frac{3\text{nm}}{3} = 1 \text{ nm} = 10\text{Å}$

$\lambda = \frac{12.3}{\sqrt{V}}$ Å $\Rightarrow$ KE = $\left(\frac{12.3}{10}\right)^2 = 1.51$ eV.

KE of electron in third orbit = 1.51 eV ≡ binding energy of third orbit in this atom

λ = of photon required to ionise = $\frac{1240 \text{ eV Å}}{1.51 \text{ eV}} = 821$ nm

10. Multiply Angular part and Radial part of 1s orbital and square this.

11. For s-orbital probability of finding an electron is same at all angles at specific radius.

12. Two unpaired electrons present in carbon atom are in different orbitals. So they have different magnetic quantum number.

13. Electronic configuration of Zn^{2+} ion is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$ so no electron in 4s orbital.

14. $\sqrt{s\,(s+1)}\ \frac{h}{2\pi} = \sqrt{\frac{1}{2}\left(\frac{1}{2}+1\right)}\ \frac{h}{2\pi} = \frac{\sqrt{3}}{2}\ \frac{h}{2\pi} = 0.866\ \frac{h}{2\pi}$

15. $Cu^+ \longrightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}$
$Fe^{+3} \longrightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5$
$Cr^{+3} \longrightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^3$
$Co^{+3} \longrightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6$
Cu^+ ion have maximum number of full filled orbital
Number of electrons related to $\ell = 2$ are 10
Number of electrons related to $\ell + m = 0$ are 12

16. $Cr^{+3} \longrightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^3$
Number of electrons related to $n + \ell = 5$ are 3
Magnetic moment u = $\sqrt{n(n+2)}$ B.M. = $\sqrt{3 \times 5}$ = $\sqrt{15}$ B.M.

17. $Co^{+3} \longrightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6$
Number of unpaired e^- = 4
Number of electrons related to $n + \ell = 5$ are 6.

EXERCISE # 3

PART - I

1. $r_n = 0.529 \dfrac{n^2}{Z}$ Å
For hydrogen, n = 1 and Z = 1 ; $\therefore$ $r_H = 0.529$
For Be^{3+}, n = 2 and Z = 4 ; $\therefore$ $r_{Be^{3+}} = \dfrac{0.529 \times 2^2}{4} = 0.529$
Therefore, (D) is correct option.

2. $\psi^2{}_{2s}$ = probability of finding electron with in 2s orbital
$\psi^2{}_{at\ node}$ = 0 (probability of finding an electron is zero at node)
For node at $r = r_0$, $\psi^2 = 0$
So, $\psi^2 = 0 = \dfrac{1}{4\sqrt{2\pi}}\left[\dfrac{1}{a_0}\right]^3\left[2-\dfrac{r_0}{a_0}\right] \times e^{r_0/2a_0}$
$\Rightarrow$ $\left[2-\dfrac{r_0}{a_0}\right] = 0$ or $2 = \dfrac{r}{a_0}$
$\Rightarrow$ $r = 2a_0$
(b) The wavelength can be calculated with the help of de-Broglie's formula i.e.,
$\lambda = \dfrac{h}{mv} = \dfrac{6.626 \times 10^{-34}}{100 \times 100 \times 10^{-3}} = \dfrac{6.626 \times 10^{-34}}{10{,}000 \times 10^{-3}} = 6.626 \times 10^{-35}$ m or 6.626×10^{-25} Å
(c) (i) The atomic mass of an element reduces by 4 and atomic number by 2 on emission of an α-particle.
(ii) The atomic mass of an element remains unchanged and atomic number increses by 1 on emission of a β-particle.
Thus change in atomic mass on emission of 8α–particles will be 8 × 4 = 32
New atomic mass = old atomic mass – 32 = 238 – 32 = 206
Similarly change in atomic number on emission of 8α-particle will be : 8 × 2 = 16
i.e., New atomic number = old atomic number – 16 = 92 – 16 = 76
On emission of 6β-particles the atomic mass remains unchanged thus, atomic mass of the new element will be 206.
The atomic number increases by 6 unit thus new atomic nubmer will be 76 + 6 = 82
Thus, the equation looks like : ${}_{92}X^{238} \xrightarrow[-6\beta]{-8\alpha} {}_{82}Y^{206}$

3. **(a)** For hydrogen atom, Z = 1, n = 1
$v = 2.18 \times 10^6 \times \dfrac{Z}{n}$ ms^{-1} = 2.18×10^6 ms^{-1}
De-broglie wavelength, $\lambda = \dfrac{h}{mv} = \dfrac{6.626 \times 10^{-34}}{9.1 \times 10^{-31} \times 2.18 \times 10^6}$ = **3.32×10^{-10} m** = 3.3 Å

(b) For 2p, $\ell = 1$

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

4.
$$\left.\begin{aligned} K_n &= \frac{KZe^2}{2r} \\ V_n &= -\frac{KZe^2}{r} \\ E_n &= -\frac{KZe^2}{2r} \end{aligned}\right\}$$

so, $\dfrac{V_n}{K_n} = -2$ and $E_n \propto \dfrac{1}{r}$.

5. $^{235}_{92}U + {}^{1}_{0}n$ (slow neutron) $\longrightarrow {}^{142}_{54}Xe + {}^{90}_{38}Sr + 4\,{}^{1}_{0}n$

6. For lower state (S_1)
No. of radial node = 1 = n – ℓ – 1
Put n = 2 and ℓ = 0 (as higher state S_2 has n = 3)
So, it would be 2s (for S_1 state)

7. Energy of state S_1 = $-13.6\left(\dfrac{3^2}{2^2}\right)$ eV/atom

$= \dfrac{9}{4}$ (energy of H-atom in ground state)
= 2.25 (energy of H-atom in ground state).

8. For state S_2
No. of radial node = 1 = n – ℓ – 1 .... (eq.-1)
Energy of S_2 state = energy of e^- in lowest state of H-atom
= – 13.6 eV/atom
$= -13.6\left(\dfrac{3^2}{n^2}\right)$ eV/atom

n = 3.
put in equation (1) $\ell = 1$
so, orbital $\Rightarrow$ 3p (for S_2 state).

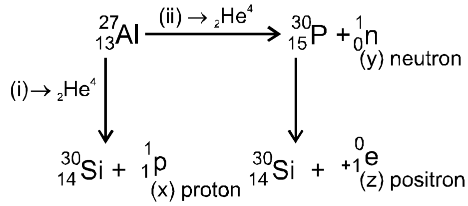
9. $E_{photon} = \dfrac{12400}{3000} = 4.13$ eV
Photoelectric effect can take place only if $E_{photon} \geq \phi$
Thus, Li, Na, K, Mg can show photoectric effect.

10.

3s	3p			3d				
↿⇂	↿⇂	↿⇂	↿⇂	↿⇂	↿⇂	↿⇂	↿⇂	↿⇂

So, electrons with spin quantum number = $-\dfrac{1}{2}$ will be 1 + 3 + 5 = 9.

11.



12. $mv\,(4a_0) = \dfrac{h}{\pi}$

so, $v = \dfrac{h}{4m\pi a_0}$

so, $KE = \dfrac{1}{2}mv^2 = \dfrac{1}{2}m.\dfrac{h^2}{16\,m^2\pi^2 a_0^2} = \dfrac{h^2}{32\,m\pi^2 a_0^2}$

13. $^{63}_{29}Cu + ^1_1H \rightarrow 6^1_0n + ^4_2\alpha + 2^1_1H + X$

64 = 6 + 4 + 2 + A $\Rightarrow$ A = 52

29 + 1 = 30 = 0 + 2 + 2 + z $\Rightarrow$ z = 26

Element X should be iron in group 8.

14. $^9_4Be + X \longrightarrow ^8_4Be + Y$

If X is $_0\gamma^0$ then Y is $_0n^1$

If X is $_1P^1$ then Y is $_1D^2$

15. n = 4, m_ℓ = 1, –1

Hence ℓ can be = 3, 2, 1

i.e. H_f ; 2 orbitals

H_d ; 2 orbitals

H_p ; 2 orbitals

Hence total of 6 orbitals, and we want $m_s = -\dfrac{1}{2}$, that is only one kind of spin. So, 6 electrons.

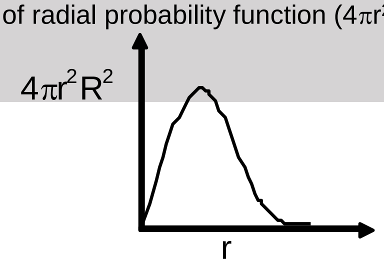
16. Energy order of orbitals of H is decided by only principle quantum number (n) while energy order of H^- is decided by (n + ℓ) rule :

Electronic configuration of 'H^-' is - $1s^2$ its Energy order is decided by n+ℓ rule.

$H^- = 1s^2 2s^0 2p^0$

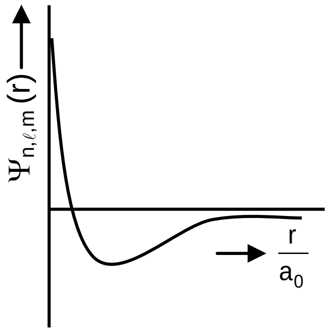
Its 2nd excited state is 2p and degenery 2p is '3'

17. For 1s electron in H-atom, plot of radial probability function ($4\pi r^2 R^2$) V/s r is as shown :



18. s-orbital is non directional so wave function will be independent of cos θ.

19. For 2s orbital no. of radial nodes = n –ℓ– 1 = 1



20. For 1s orbital Ψ should be independent of θ, also it does not contain any radial node.

$$\frac{E_4 - E_2}{E_6 - E_2} = \frac{\frac{E_1}{16} - \frac{E_1}{4}}{\frac{E_1}{36} - \frac{E_1}{4}} = \frac{-\frac{3E_1}{16}}{-\frac{8E_1}{36}} = \frac{3 \times 36}{8 \times 16} = \frac{27}{32}$$

21. $x_1 = \alpha$
$X_2 = \beta$
$X_3 = \beta$
$X_4 = \alpha$

22. $E_{He^+} = -13.6 \times \frac{(2)^2}{n^2} = -3.4 = \frac{-13.6}{4}$

$n^2 = 16$ so $n = 4$

quantum number are

$n = 4$, $\ell = 2$, $m = 0$

so subshell is = d.

angular node = ℓ = 2

Radial node = $[n-\ell-1] = 4 - 2 - 1 = 1$

24. $r_n = 0.529 \left(\frac{n^2}{Z}\right)$Å $\Rightarrow r_n \propto n^2$

Angular momentum (ℓ) = $\left(\frac{nh}{2\pi}\right) \Rightarrow \ell \propto n^1$

K.E. = $\frac{1}{2}mv^2 = \frac{1}{2}m\left[2.18 \times 10^6 \frac{Z}{n}\right]^2 \Rightarrow$ K.E. $\propto \frac{Z^2}{n^2} \Rightarrow$ K.E. $\propto n^{-2}$

P.E. = – 2K.E. $\Rightarrow$ P.E. $\propto \frac{Z^2}{n^2}$ $\Rightarrow$ P.E. $\propto n^{-2}$

PART - II

8. Following Aufbau principle for filling electrons.

9. De-broglie wavelength (for particles) = $\frac{h}{\sqrt{2m\,KE}}$

As temperature is same, KE is same. So, $\lambda \propto \frac{1}{\sqrt{m}}$.

Hence λ_{db} (electron) > λ_{db} (neutron)

10. $n = 5$
Possible subshell are
$\Rightarrow$ 5s, 5p, 5d, 5f, 5g
$\therefore$ Total number of orbital = 1 + 3 + 5 + 7 + 9 = 25

11. NaF: $Na^+ = 1s^2 2s^2 2p^6$
$F^- = 1s^2 2s^2 2p^6$

12. For shortest 'λ' of hydrogen
$n_1 = 1$ & $n_2 = \infty$

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

$$\frac{1}{A} = R(1)^2\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) \Rightarrow R = \frac{1}{A}$$

for longest 'λ' of He^+ $n_1 = 3$ $n_2 = 4$

$$\frac{1}{\lambda} = \frac{1}{A}(2)^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \frac{1}{A} \times \frac{7}{36} \text{ or } \lambda = \frac{36A}{7}$$

13. $r_n = 52.9\left(\frac{n^2}{1}\right)$ pm = 211.6 pm (for H-atom)

$\therefore$ n = 2
Higher orbit to n = 2 $\Rightarrow$ Balmer series

14. λ = 250 nm = 2500 Å

$$E = \frac{hc}{\lambda} = \frac{12400}{2500} = 4.96 \text{ eV}$$

KE = stopping potential = 0.5 eV
$E = W_0 + K.E.$
$4.96 = W + 0.5$
$W_0 = 4.46 \approx 4.5$ eV

15. $2\pi r = n\lambda$ $\qquad \lambda = \frac{2\pi r}{n} = \frac{2\pi \times 0.529\text{Å}}{1}$

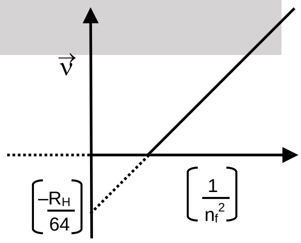
16. When temperature is increased, black body emit high energy radiation, from higher wavelength to lower wavelength.

17.

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

$$= R_H(1)^2\left(\frac{1}{n_f^2} - \frac{1}{8^2}\right)$$

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

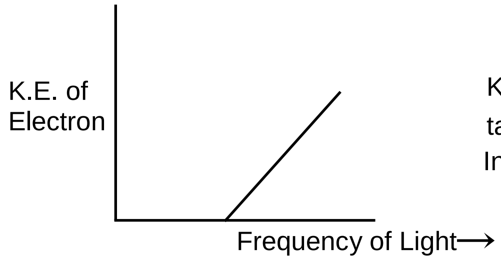


Slope for graph of $\bar{\nu}$ & $\frac{1}{n_f^2}$ is + R_H

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

According to wave mechanics, the ground state angular momentum is equal to $\frac{h}{2\pi}$.

19.



$KE_{max} = h\nu - h\nu_0$

$\tan\theta = h$

Intercept = $-h\nu_0$

20. $E = -13.6 \left(\frac{Z^2}{n^2}\right) = -13.6 \left(\frac{2^2}{3^2}\right) = -6.04$ eV

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

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

$\lambda = 9 \times 10^{-7}$ m

$\lambda = 900$ nm

22. $h\nu = h\nu_0 + \frac{1}{2}mv^2$

$h(\nu - \nu_0) = \frac{1}{2}mv^2$

$v = \left(\frac{2h(\nu - \nu_0)}{m}\right)^{1/2}$

$\lambda = \frac{h}{mv} = \frac{h}{m}\frac{\sqrt{m}}{\sqrt{2h(\nu - \nu_0)}} = \sqrt{\frac{h}{m(\nu - \nu_0)}}$

$\lambda \propto \frac{1}{(\nu - \nu_0)^{1/2}}$

23. $\frac{hc}{\lambda} = \phi + \frac{1}{2}mv^2$

$\frac{6.626 \times 10^{-34} \times 3 \times 10^8}{4000 \times 10^{-10}} = \phi + \frac{1}{2} \times 9 \times 10^{-31} \times (6 \times 10^5)^2$

$\therefore\ \phi = (4.97 - 1.62) \times 10^{-19}$ J

$= 3.35 \times 10^{-19}$ J ≈ 2.1 eV

24. $2\pi r = n\lambda \quad \Rightarrow \quad 2\pi a_0 \frac{n^2}{Z} = n\lambda$

$2\pi a_0 \frac{n^2}{Z} = n1.5\pi\ a_0$

$\frac{n}{Z} = \frac{1.5}{2} = \frac{3}{4} = 0.75$

25. From $n + \ell$ rule the increasing order of energies of electrons will be IV < II < III < I

26. As kinetic energy is much higher than work function so

$E = E_0 + KE \approx KE$

As $E = \frac{hc}{\lambda}$ & $kE = \left(\frac{P^2}{2m}\right)$

So $\frac{\lambda_2}{\lambda_1} = \left(\frac{P_1}{P_2}\right)^2 \Rightarrow \frac{\lambda_2}{\lambda} = \left(\frac{1}{1.5}\right)^2$

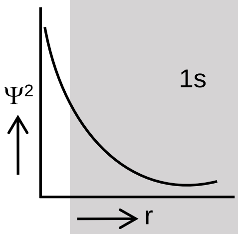
$\lambda_2 = \frac{4}{9}\lambda$

27. $$\frac{(\Delta\nu)\text{Lyman}}{(\Delta\nu)\text{Balmer}} = \frac{1-\left(1-\frac{1}{4}\right)}{\frac{1}{4}-\left(\frac{1}{4}-\frac{1}{9}\right)} = \frac{\frac{1}{4}}{\frac{1}{4}} = \frac{9}{4}$$

28. (1) Total energy of electron is minimum in first orbit i.e. at a_0 distance from nucleus.

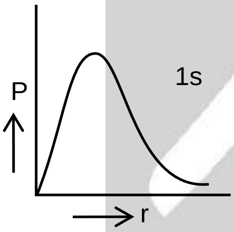
(2) $P.E. = -\frac{KZe^2}{r}$

$K.E. = \frac{1}{2}\frac{KZe^2}{r}$ $\qquad |P.E.| = 2|K.E.|$

(3) 

ψ^2 is maximum at nucleus

(4) Electron can be found at any distance from nucleus.



P $\Rightarrow$ Probability function.

29. By the graph since Ψ^2 is not zero at r = 0 it must be s orbital

also $n - \ell - 1 = 1$

$n = 2$ $(\because \ell = 0)$

it is 2s orbital

30. Shortest λ for lyman series : $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{\infty}\right) = R$; $\lambda = \frac{1}{R}$

Shortest λ for paschen series : $\frac{1}{\lambda'} = R\left(\frac{1}{3^2} - \frac{1}{\infty}\right) = \frac{R}{9}$; $\lambda' = \frac{9}{R}$

$\frac{\lambda'}{\lambda} = \frac{9}{R} \times \frac{R}{1} = 9$

31. $\psi^2_{(r)}$ is probability density of an electron and it is maximum at a & c.

32. Energies of the orbitals in the same subshell decrease with increase in the atomic number
$E_{2s}(H) > E_{2s}(Li) > E_{2s}(Na) > E_{2s}(K)$SS

34. Theory based.

35. ^1_1H $^2_1H(D)$ $^3_1H(T)$
Number of neutrons $0 + 1 + 2 = 3$

36. $r = \frac{a_0 n^2}{Z}$

For Li^{2+} $r = \frac{a_0(2)^2}{3} = \frac{4a_0}{3}$

37. $2\pi r = n\lambda$

$2\pi \times \frac{n^2}{Z} a_0 = n\lambda$

$2\pi \times \frac{4^2}{1} a_0 = 4\lambda$

$\lambda = 8\pi a_0$