CHAPTER 2: ATOMIC PHYSICS

Test Your Concepts-I
(Based on Atomic Structure and Properties)

1. (a) $E_3 - E_1 = \frac{(-13.6)(3)^2}{(3)^2} - \left[\frac{(-13.6)(3)^2}{(1)^2}\right] = 108.8 \text{ eV}$

$\Rightarrow \quad \lambda = \frac{12375}{108.8} \text{ Å} = 113.74 \text{ Å}$

(b) Number of lines in emission spectrum is

$$N = \frac{n(n-1)}{2}$$

$$\Rightarrow \quad N = \frac{(3)(3-1)}{2} = 3$$

2. Since, $E_n = -\frac{(13.6)Z^2}{n^2}$ eV

So, ionisation energy, $n = 1$, for $Li^{++}(Z=3)$ is

$$IE = \frac{(13.6)(3)^2}{(1)^2} \text{ eV}$$

$$\Rightarrow \quad IE = 122.4 \text{ eV}$$

3. Energy of electron in ground state of hydrogen atom is -13.6 eV. Earlier it had a kinetic energy of 2 eV

Therefore, energy of photon released during formation of hydrogen atom,

$$\Delta E = 2 - (-13.6) = 15.6 \text{ eV}$$

$$\Rightarrow \quad \lambda = \frac{12375}{\Delta E} = \frac{12375}{15.6} = 793.3 \text{ Å}$$

4. For a deflection of $180°$, the α-particle must be approaching the nucleus head on. Since, we know that

$$r_0 = \frac{2}{4\pi\varepsilon_0}\left(\frac{2Ze^2}{m_\alpha v_\alpha^2}\right) = \frac{1}{4\pi\varepsilon_0}\left(\frac{2Ze^2}{K_\alpha}\right)$$

where, $K_\alpha = 12.5 \text{ MeV} = 12.5 \times 1.6 \times 10^{-13}$ J, $r_0 = ?$

$$\Rightarrow \quad r_0 = \frac{2(9\times 10^9)(79)(1.6\times 10^{-19})^2}{12.5\times 1.6\times 10^{-13}} = 1.82\times 10^{-14} \text{ m}$$

5. Since the frequency of revolution of an electron in n^{th} orbit is

$$f_n = \frac{\omega_n}{2\pi}$$

$$\Rightarrow \quad f_n = \frac{v_n}{2\pi r_n}$$

$$\Rightarrow \quad f_n = \frac{2.18\times 10^6\left(\frac{Z}{n}\right)}{2\times 3.14\times 0.529\times 10^{-10}\left(\frac{n^2}{Z}\right)} \text{s}^{-1}$$

Thus, number of revolutions completed in 10^{-8} second in $n = 2$ state are

$$N = f_n \times 10^{-8}$$

$$\Rightarrow \quad N = \frac{2.18\times 10^6\times 10^{-8}}{2\times 3.14\times 0.529\times 10^{-10}} \times \frac{Z^2}{n^3}$$

$$\Rightarrow \quad N = 8.2\times 10^6 \text{ revolutions}$$

6. The frequency of revolution of electron in n^{th} orbit is

$$\omega_n = \frac{v_n}{2\pi r_n}$$

ω_n is the number of revolutions made by electron in 1 second. For $n = 1$ orbit of hydrogen atom, we have

$$\omega_1 = \frac{2.18\times 10^6}{2\times 3.14\times 0.529\times 10^{-10}} \text{ rev/sec}$$

$$\Rightarrow \quad \omega_1 = 6.56\times 10^{15} \text{ rev/sec}$$

7. Since $U = -k\log_e r$

In the given situation, the centripetal force on electron in n^{th} orbit is given by

$$|F| = \left|-\frac{dU}{dr}\right| = \frac{k}{r_n}$$

If in n^{th} orbit speed of electron is v_n then, we have

$$\frac{mv_n^2}{r_n} = \frac{k}{r_n}$$

$$\Rightarrow \quad mv_n^2 = k \qquad \text{...(1)}$$

According to Bohr's Quantization Rule, we have

$$mv_n r_n = \frac{nh}{2\pi} \qquad \text{...(2)}$$

From (1) and (2), we get

$$r_n = \frac{nh}{2\pi\sqrt{mk}}$$

Energy of electron in n^{th} level is

$$E_n = KE_n + PE_n$$

$$\Rightarrow \quad E_n = \frac{1}{2}mv_n^2 - k\log_e r$$

$$\Rightarrow \quad E_n = \frac{k}{2} - k\log_e r$$

$$\Rightarrow \quad E_n = \frac{k}{2} - k\log_e\left(\frac{nh}{2\pi\sqrt{mk}}\right)$$

$$\Rightarrow \quad E_n = \frac{k}{2}\left[1 - \log_e\left(\frac{n^2h^2}{4\pi^2 mk}\right)\right]$$

8. (a) As the atoms finally emit radiation of only 3 different photon energies final excited state corresponds to $n = 3$.
So, the initial excited state corresponds to $n = 2$

$$\Rightarrow \quad Z^2(13.6)\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{12375}{1654}$$

$$\Rightarrow \quad Z = 2$$

Therefore, it is helium atom.

(b) Ionization energy is

$$IE = Z^2(13.6\text{ eV}) = (2)^2(13.6\text{ eV})$$

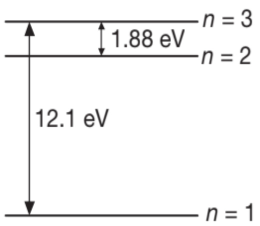
$$\Rightarrow \quad IE = 54.4\text{ eV}$$

(c) $N = \dfrac{n(n-1)}{2} = 6$

So, $E = E_4 - E_2 = (13.6)(4)\left(\dfrac{1}{4} - \dfrac{1}{16}\right) = 10.2\text{ eV}$

9. Energy of photon corresponding to $\lambda = 6563$ Å is

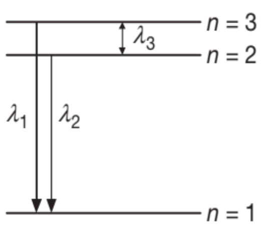
$$\Delta E = \frac{12375}{6563}\text{ eV} = 1.88\text{ eV}$$



This is the difference in energy between $n = 3$ and $n = 2$. Hence the single electron in the hydrogen atom should excite at least upto $n = 3$ and for this the minimum energy of the striking electron should be 12.1 eV.

10. Given $E_3 = 0$

$\lambda_1 = 460$ Å



$$\Rightarrow \quad E_3 - E_1 = \frac{12375}{460} = 26.9\text{ eV}$$

Since, $E_3 = 0$

$$\Rightarrow \quad 0 - E_1 = 26.9\text{ eV}$$

$$\Rightarrow \quad E_1 = -26.9\text{ eV}$$

Further, $\lambda_3 = 1035$ Å

$$\Rightarrow \quad E_3 - E_2 = \frac{12375}{1035}\text{ Å} = 12\text{ eV}$$

$$\Rightarrow \quad E_2 = -12\text{ eV}$$

11. When hydrogen atom is excited, then we have

$$eV = E_0\left(\frac{1}{1} - \frac{1}{n^2}\right) \qquad \ldots(1)$$

When ion is excited, then

$$eV = E_0 Z^2\left(\frac{1}{2^2} - \frac{1}{n_1^2}\right) \qquad \ldots(2)$$

Wavelength of emitted light is

$$\frac{hc}{\lambda_1} = E_0\left(\frac{1}{1} - \frac{1}{n^2}\right) \qquad \ldots(3)$$

$$\frac{hc}{\lambda_2} = E_0 Z^2\left(\frac{1}{1} - \frac{1}{n_1^2}\right) \qquad \ldots(4)$$

Further it is given that

$$\frac{\lambda_1}{\lambda_2} = \frac{5}{1} \qquad \ldots(5)$$

Solving the above equations, we get

$Z = 2$, $n = 2$, $n_1 = 4$ and $V = 10.2$ V

Energy of emitted photon by the hydrogen atom is

$$\Delta E = E_2 - E_1 = 10.2\text{ eV}$$

and by the ion is

$$\Delta E' = E_4 - E_1 = (13.6)(2)^2\left(1 - \frac{1}{16}\right) = 51\text{ eV}$$

12. Energy of photon of the first line of Lyman series is

$$E = E_2 - E_1 = (13.6)(2)^2\left(1 - \frac{1}{4}\right) = 40.8\text{ eV}$$

Energy required to ionize the hydrogen atom is 13.6 eV. Therefore, kinetic energy of electron emitted from the hydrogen atom is

$$K = (40.8 - 13.6)\text{ eV} = 27.2\text{ eV}$$

$$\Rightarrow \quad K = 4.352 \times 10^{-18}\text{ J}$$

Since, $K = \dfrac{1}{2}mv^2 = 4.352 \times 10^{-18}$

$$\Rightarrow \quad v=\sqrt{\frac{2\times 4.352\times 10^{-18}}{9.1\times 10^{-31}}}$$

$$\Rightarrow \quad v=3.1\times 10^{6}\ \text{ms}^{-1}$$

13. (a) From figure, we observe that

$$\begin{pmatrix}\text{Ionisation}\\ \text{Potential}\end{pmatrix}=15.6\ \text{eV}$$

(b) $\lambda_{\min}=\frac{12375}{5.3}=2335\ \text{Å}$

(c) $\Delta E_{31}=-3.08-(-15.6)=12.52\ \text{eV}$

Therefore, excitation potential for state $n=3$ is 12.52 V

(d) $\frac{1}{\lambda_{31}}=\frac{\Delta E_{31}}{12375}\ \text{Å}^{-1}=\frac{12.52}{12375}\ \text{Å}^{-1}$

$$\Rightarrow \quad \frac{1}{\lambda_{31}}\approx 1.01\times 10^{7}\ \text{m}^{-1}$$

(e) (i) $E_2-E_1=10.3\ \text{eV}>6\ \text{eV}$

Hence, the striking electron cannot excite the hypothetical atoms. So, the electron will keep its energy with itself.

$$\Rightarrow \quad K_{\min}=6\ \text{eV}$$

(ii) $E_2-E_1=10.3\ \text{eV}<11\ \text{eV}$

So, the electron can excite the atom.

$$\Rightarrow \quad K_{\min}=(11-10.3)\ \text{eV}=0.7\ \text{eV}$$

14. (a) $z=3$ for Li^{+2}. Further we know that $r_n=\frac{n^2}{z}a_0$

Substituting, $n=3$, $z=3$ and $a_0=0.529$ Å, we get r_3 for Li^{+2}

$$r_3=\frac{(3)^2}{(3)}(0.529)\ \text{Å}=1.587\ \text{Å}$$

(b) $z=2$ for He^{+}. Also, we know that

$$v_n=\frac{z}{n}v_1$$

Substituting $n=4$, $z=2$ and $v_1=2.19\times 10^{6}\ \text{ms}^{-1}$, we get for He^{+},

$$v_4=\left(\frac{2}{4}\right)(2.19\times 10^{6})\ \text{ms}^{-1}$$

$$\Rightarrow \quad v_4=1.095\times 10^{6}\ \text{ms}^{-1}$$

15. Magnetic moment $\mu=NiA=\left(\frac{e}{T}\right)(\pi r^2)$

$$\Rightarrow \quad \mu=\left(\frac{e}{2\pi r/v}\right)(\pi r^2)=\frac{evr}{2} \qquad \ldots(1)$$

We know that $mvr=\frac{nh}{2\pi}$ ...(2)

Solving equations (1) and (2)

$$\mu=\frac{neh}{4\pi m}$$

Magnetic induction, $B=\frac{\mu_0 i}{2r}=\frac{\mu_0 e}{2rT}$

$$\Rightarrow \quad B=\frac{\mu_0 ev}{(2r)(2\pi r)}=\frac{\mu_0 ev}{4\pi r^2} \qquad \ldots(3)$$

From Newton's Second Law, we have

$$\frac{e^2}{4\pi\varepsilon_0 r^2}=\frac{mv^2}{r}$$

$$\Rightarrow \quad v^2=\frac{e^2}{4\pi\varepsilon_0 mr} \qquad \ldots(4)$$

Solving these equations, we get

$$B=\frac{\mu_0\pi m^2e^7}{8\varepsilon_0 h^5n^5}$$

16. The force at a distance r is,

$$F=-\frac{dU}{dr}=-2ar$$

Suppose r be the radius of nth orbit. Then the necessary centripetal force is provided by the above force. Thus,

$$\frac{mv^2}{r}=2ar \qquad \ldots(1)$$

Further, the quantization of angular momentum gives,

$$mvr=\frac{nh}{2\pi} \qquad \ldots(2)$$

Solving equations (1) and (2) for r, we get

$$r=\left(\frac{n^2h^2}{8am\pi^2}\right)^{1/4}$$

17. The time period T of an electron in a Bohr orbit of principal quantum number n is

$$T=\frac{n^3h^3}{4\pi^2k^2Z^2e^4m}$$

$$\Rightarrow \quad T\propto n^3$$

$$\Rightarrow \quad \frac{T_1}{T_2}=\frac{n_1^3}{n_2^3}$$

Since $T_1=8T_2$

$$\Rightarrow \quad \left(\frac{n_1}{n_2}\right)^3=8$$

$$\Rightarrow \quad n_1=2n_2$$

Thus, the possible values of n_1 and n_2 are

$n_1 = 2$, $n_2 = 1$

$n_1 = 4$, $n_2 = 2$

$n_1 = 6$, $n_2 = 3$ and so on .....

18. Since, $E_1 = -13.60$ eV

Also, we know that

$$TE = -KE = \frac{PE}{2}$$

$\Rightarrow$ $K_1 = -E_1 = 13.60$ eV

$\Rightarrow$ $U_1 = 2E_1 = -27.20$ eV

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

$\Rightarrow$ $E_2 = \frac{E_1}{(2)^2} = -3.40$ eV

$\Rightarrow$ $K_2 = 3.40$ eV and

$\Rightarrow$ $U_2 = -6.80$ eV

Now $U_1 = 0$, i.e., potential energy has been increased by 27.20 eV. So, we will increase U and E in all energy states by 27.20 eV while kinetic energy will remain unchanged. So, we have

Orbit	K(eV)	U(eV)	E(eV)
First	13.60	0	13.60
Second	3.40	20.40	23.80

19. Wavelengths corresponding to minimum wavelength (λ_{min}) or maximum energy will emit photoelectrons having maximum kinetic energy.

(λ_{min}) belonging to Balmer series and Lying in the given range (450 nm to 750 nm) corresponds to transition from $(n = 4$ to $n = 2)$. Here,

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

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

$\Rightarrow$ $\Delta E = E_4 - E_2 = 2.55$ eV

So, K_{max} = Energy of photon – work function

$\Rightarrow$ $K_{max} = 2.55 - 2 = 0.55$ eV

20. For $0 \le x \le 1$, $PE = E_0$

$\Rightarrow$ (Kinetic energy K_1) = (Total energy) – (PE)

$\Rightarrow$ $K_1 = 2E_0 - E_0 = E_0$

$$\Rightarrow \lambda_1 = \frac{h}{\sqrt{2mE_0}} \qquad ...(1)$$

For $x > 1$, $PE = 0$

$\Rightarrow$ Kinetic energy K_2 = Total energy $= 2E_0$

$$\Rightarrow \lambda_2 = \frac{h}{\sqrt{2m(E_0)}} \qquad ...(2)$$

From equations (1) and (2), we get

$$\frac{\lambda_1}{\lambda_2} = \sqrt{2}$$

21. (a) Kinetic energy of electron in the orbits of hydrogen and hydrogen like atoms = |Total energy|

So, Kinetic energy = 3.4 eV

(b) The de-Broglie wavelength is given by

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2Km}}$$

where K is the kinetic energy of an electron

Substituting the values, we get

$$\lambda = \frac{(6.6 \times 10^{-34} \text{ Js})}{\sqrt{2(3.4 \times 1.6 \times 10^{-19} \text{ J})(9.1 \times 10^{-31} \text{ kg})}}$$

$\Rightarrow$ $\lambda = 6.63 \times 10^{-10}$ m

$\Rightarrow$ $\lambda = 6.63$ Å

22. The energy lost by the electron in exciting the hydrogen atom from ground state (–13.6 eV) to first excited state (–3.4 eV) equal to $\Delta E_{12} = 10.2$ eV

$\Rightarrow$ $\Delta E = 16.36 \times 10^{-19}$ J

Now, the initial energy of electron is 20 eV $= 32 \times 10^{-19}$ J. Hence the kinetic energy of the scattered electron is

$$E_K = 32 \times 10^{-19} \text{ J} - 16.36 \times 10^{-19} \text{ J}$$

$\Rightarrow$ $E_K = 15.64 \times 10^{-19}$ J

The velocity v of the scattered electron is given by

$$\frac{1}{2}mv^2 = E_K$$

$$\Rightarrow v = \left(\frac{2E_K}{m}\right)^{\frac{1}{2}} = \left(\frac{2 \times 15.64 \times 10^{-19}}{9.11 \times 10^{-31}}\right)^{\frac{1}{2}}$$

$\Rightarrow$ $v = 1.86 \times 10^6$ ms^{-1}

23. The maximum wavelength will correspond to the minimum energy transition of an electron. For ground state of hydrogen atom, the minimum energy transition is for $n = 1$ to $n = 2$, for which energy released will be

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$$\Delta E_{12} = E_2 - E_1$$

$$\Rightarrow \quad \Delta E_{12} = (-3.4 \text{ eV}) - (-13.6 \text{ eV})$$

$$\Rightarrow \quad \Delta E_{12} = 10.2 \text{ eV}$$

Thus 10.2 eV energy is absorbed in the form of a photon. So, if λ be the wavelength of photon, then

$$\lambda = \frac{12400}{10.2} \text{ Å}$$

$$\Rightarrow \quad \lambda = 1216 \text{ Å}$$

For next smaller wavelength, the possibility is for an electron transition from $n = 1$ to $n = 3$, for which the absorbed energy photon required is

$$\Delta E_{13} = E_3 - E_1$$

$$\Rightarrow \quad \Delta E_{13} = (-1.5 \text{ kV}) - (-13.6 \text{ eV})$$

$$\Rightarrow \quad \Delta E_{13} = 12.09 \text{ eV}$$

If λ' be its wavelength, then we have

$$\lambda' = \frac{12400}{12.09} \text{ Å}$$

$$\Rightarrow \quad \lambda' = 1026 \text{ Å}$$

24. Minimum wavelength is corresponding to transition from $\infty \to 1$ hence

$$\lambda_{\min} = \frac{12431}{13.6} \text{ Å}$$

and maximum wavelength is for transition $2 \to 1$

$$\Rightarrow \quad \lambda_{\max} = \frac{12431}{10.2} \text{ Å}$$

$$\Rightarrow \quad \frac{\lambda_{\min}}{\lambda_{\max}} = \frac{3}{4}$$

25. The ionization energy for a hydrogenic atom can be given as energy required to excite electron from $n_1 = 1$ to $n_2 \to \infty$ given as

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

$$\Rightarrow \quad E = Rch\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) \text{ joule}$$

$$\Rightarrow \quad E = (Rch) \text{ joule}$$

If motion of nucleus is considered, then the value of Rydberg constant can be given by

$$R' = \frac{e^4}{8\varepsilon_0^2 ch^3}\left(\frac{mM_H}{m + M_H}\right)$$

So, the ionization energy of hydrogen and deuterium atom can be given by

$$E_H = \frac{e^4}{8\varepsilon_0^2 h^2}\left(\frac{mM_H}{m + M_H}\right), \text{ where } M_H = 1840 \text{ m}$$

$$\text{and } E_D = \frac{e^4}{8\varepsilon_0^2 h^2}\left(\frac{mM_D}{m + M_D}\right), \text{ where } M_D = 3680 \text{ m}$$

The difference between the two energies E_D and E_H is

$$\Delta E = E_D - E_H$$

$$\Rightarrow \quad \Delta E = \frac{e^4}{8\varepsilon_0^2 h^2}\left[\frac{mM_D}{m + M_D} - \frac{mM_H}{m + M_H}\right]$$

$$\Rightarrow \quad \Delta E = \frac{e^4}{8\varepsilon_0^2 h^2}\left(\frac{3680}{3681} - \frac{1840}{1841}\right)$$

$$\Rightarrow \quad \Delta E = 5.88 \times 10^{22} \text{ J}$$

$$\Rightarrow \quad \Delta E = 6.68 \times 10^{-3} \text{ eV}$$

Test Your Concepts-II
(Based on X-rays and Properties)

1. For $\lambda_c = 1$ Å, we have

$$V = \frac{12400}{1} = 12.4 \text{ kV}$$

$$\text{Photon energy, } E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{10^{-10}}$$

$$\Rightarrow \quad E \approx 2 \times 10^{-15} \text{ J}$$

2. (a) Short wavelength is given as

$$\lambda_{\min} = 0.45 \text{ Å}$$

Maximum photo energy is given as

$$E_{\max} = h\nu_{\max} = \frac{hc}{\lambda_{\min}}$$

$$\Rightarrow \quad E_{\max} = \frac{12431}{0.45} = 27624.44 \text{ eV}$$

$$\Rightarrow \quad E_{\max} = 27.624 \text{ keV}$$

(b) The minimum accelerating voltage for electrons is

$$\frac{27.6 \text{ keV}}{e} = 27.6 \text{ kV}$$

i.e. of the order of 30 kV

3. If the short series limit of the Balmer series is corresponding to transition $n = \infty$ to $n = 2$ which is given by

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

$$\Rightarrow \quad R = \frac{4}{\lambda} = \frac{4}{3644} \text{ (Å)}^{-1}$$

The shortest wavelength corresponds to $n \to \infty$ to $n = 1$.

Therefore λ_c is given as

$$\frac{1}{\lambda_c} = R(Z-1)^2\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$$

$$\Rightarrow \quad (Z-1)^2 = \frac{1}{\lambda_c R} = \frac{1}{1\,\text{Å} \times \frac{4}{3644}\ (\text{Å})^{-1}}$$

$$\Rightarrow \quad (Z-1)^2 = \frac{3644}{4} = 911$$

$$\Rightarrow \quad Z - 1 = 30.2$$

$$\Rightarrow \quad Z = 31.2 \simeq 31$$

Thus, the atomic number of the element is 31 which is gallium.

4. Photons travel at speed of light, so time taken by both photons is

$$t = \frac{d}{c} = \frac{3 \times 10^3}{3 \times 10^8} = 10^{-5}\ \text{s} = 10\ \mu\text{s}$$

5. Using the equation, $\sqrt{f} = a(Z-b)$ $\qquad (b = 1)$

Since, $b = 1$, so we get

$$\frac{f_{La}}{f_{Cu}} = \left(\frac{Z_{La} - 1}{Z_{Cu} - 1}\right)^2$$

$$\Rightarrow \quad f_{La} = f_{Cu}\left(\frac{Z_{La} - 1}{Z_{Cu} - 1}\right)^2$$

$$\Rightarrow \quad f_{La} = 1.88 \times 10^{18}\left(\frac{57 - 1}{29 - 1}\right)^2$$

$$\Rightarrow \quad f_{La} = 7.52 \times 10^{18}\ \text{Hz}$$

6. Since, $\lambda = \frac{12375}{V}$, so we have

$$\lambda_1 - \lambda_2 = \frac{12375}{V_1} - \frac{12375}{V_2} = 12375\left(\frac{1}{V} - \frac{1}{1.5V}\right)$$

where $\lambda_1 - \lambda_2 = 26\ \text{pm} = 0.26\ \text{Å}$

$$\Rightarrow \quad 0.26 = (12375)\left(\frac{1}{3V}\right)$$

$$\Rightarrow \quad V = 15865\ \text{volt}$$

7. Cutoff wavelength $\lambda_{\min}$ is given by,

$$\lambda_{\min}(\text{in Å}) = \frac{12375}{V(\text{in volt})} = \frac{12375}{40 \times 10^3} = 0.31\ \text{Å}$$

8. When an electron of charge e is accelerated through a potential difference V_0, it acquires energy eV_0. If m be the mass of the electron and $v_{\max}$ the maximum speed of electron, then

$$\frac{1}{2}mv_{\max}^2 = eV_0$$

$$\Rightarrow \quad v_{\max} = \sqrt{\frac{2eV_0}{m}}$$

Substituting the given values, we get

$$v_{\max} = \sqrt{\frac{2 \times (1.6 \times 10^{-19}) \times 20000}{9 \times 10^{-31}}}$$

$$\Rightarrow \quad v_{\max} = 8.4 \times 10^7\ \text{ms}^{-1}$$

9. Since tungsten is a multielectron atom, so due to the shielding of the nuclear charge by the negative charge of the inner core electrons, each electron is subject to an effective nuclear charge Z_{eff}, which is different for different shells. For an electron in the K shell $(b = 1)$ thus effective nuclear charge is given as

$$Z_{\text{eff}} = (Z - b) = Z - 1$$

Since an electron jumps from M shell $(n = 3)$ to K shell $(n = 1)$, the radiated emission is called K_β X-ray and from Mosley's law the wavelength emitted of K_β X-ray is given as

$$\frac{1}{\lambda_{K_\beta}} = R(Z-1)^2\left(\frac{1}{1^2} - \frac{1}{3^2}\right)$$

$$\Rightarrow \quad \frac{1}{\lambda_{K_\beta}} = 10967800 \times (74-1)^2\left(\frac{8}{9}\right)$$

$$\Rightarrow \quad \lambda_{K_\beta} = 0.192\ \text{Å}$$

10. The binding energy for K shell in eV is

$$E_k = \frac{hc}{\lambda_k} = \frac{12400}{0.2}\ \text{eV} = 62\ \text{keV}$$

The energy of the incident photon in eV is

$$E = \frac{hc}{\lambda} = \frac{12400}{0.15} \approx 83\ \text{keV}$$

Therefore, the maximum energy of the photoelectrons emitted from the K shell is

$$E_{\max} = E - E_k = (83 - 62)\ \text{keV} = 21\ \text{keV}$$

11. Given that

$$2\left\{\frac{12375 \times 10^{-10}}{34.3 \times 10^3}\right\} = \frac{1}{1.09 \times 10^7 (Z-1)^2\left(1 - \frac{1}{4}\right)}$$

$$\Rightarrow \quad Z = 42$$

12. Energy of K_2 line $= 100 - 24 = 76$ keV

$$\Rightarrow \quad \lambda_{K_\alpha} = \frac{12375}{76 \times 10^3}\ \text{Å}$$

$$\Rightarrow \quad \lambda_{K_\alpha} = 0.163\ \text{Å}$$

Single Correct Choice Type Questions

1. $mvr = (2n)\frac{h}{2\pi}$

$\Rightarrow v = \frac{2n\hbar}{mr}$

$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{2n\hbar}{mr}\right)^2 = \frac{(2n\hbar)^2}{2mr^2}$

Since, $\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$

$\Rightarrow \frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{(2n\hbar)^2}{mr^2(r)}$

$\Rightarrow r = \frac{(2n\hbar)^2 4\pi\varepsilon_0}{mZe^2}$

Now, total energy of the atom is

$$E = KE + PE = -\frac{Ze^2}{8\pi\varepsilon_0 r} = -\frac{Z^2e^4m}{8\pi\varepsilon_0(2n\hbar)^2 4\pi\varepsilon_0}$$

$\Rightarrow E = -\frac{Z^2e^4m}{32\varepsilon_0^2n^2h^2}$

For the actual hydrogen atom, the binding energy is

$$E_0 = -\frac{me^4Z^2}{8n^2h^2\varepsilon_0^2} = -13.6\left(\frac{Z^2}{n^2}\right) \text{eV}$$

So, for the hypothetical hydrogen atom, we have

$$E = -\frac{Z^2e^4m}{32\varepsilon_0^2n^2h^2} = \frac{E_0}{4} = -3.4\left(\frac{Z^2}{n^2}\right) \text{eV}$$

The longest wavelength is obtained when the electron makes a transition from $n_i = 2$ to $n_f = 1$

$\Rightarrow \frac{hc}{\lambda} = \frac{12400}{\lambda} = 3.4\left(1 - \frac{1}{4}\right) = 2.55 \text{ eV}$

$\lambda = \frac{12400}{2.55} = 4863 \text{ Å} \approx 486 \text{ nm}$

Hence, the correct answer is (B).

2. First excitation energy is given by

$$\Delta E = Rch\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = Rch \times \frac{3}{4}$$

$\Rightarrow \frac{3}{4}Rch = V_0$

$\Rightarrow Rch = \frac{4V_0}{3}$

Hence, the correct answer is (C).

3. $B_n = \frac{\mu_0 I_n}{2r_n}$

$\Rightarrow B_n \propto \frac{I_n}{r_n} \propto \frac{f_n}{r_n}$

$\Rightarrow B_n \propto \frac{\left(\frac{v_n}{r_n}\right)}{r_n} \propto \frac{v_n}{(r_n)^2}$

$\Rightarrow B_n \propto \frac{\left(\frac{z}{n}\right)}{\left(\frac{n^2}{z}\right)^2} \propto \frac{z^3}{n^5}$

Hence, the correct answer is (D).

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

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

where, $\frac{h}{mv}$ = de-Broglie wavelength

Hence, the correct answer is (A).

6. $\Delta E = 13.6\left(\frac{1}{1^2} - \frac{1}{6^2}\right) = 13.22 \text{ eV}$

Since, $p = \frac{\Delta E}{c}$

$\Rightarrow v = \frac{\Delta E}{mc} = \frac{13.22 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27} \times 3 \times 10^8} = 4.2 \text{ ms}^{-1}$

Hence, the correct answer is (B).

7. Since, $E_{K_\alpha} < E_{K_\beta}$

$\Rightarrow \lambda_{K_\alpha} > \lambda_{K_\beta}$

Hence, the correct answer is (C).

8. Momentum of electron in different states

$$p_n = \frac{h}{\lambda_n}, \; p_g = \frac{h}{\lambda_g}$$

Kinetic energy, $K = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

Total energy in an orbit of hydrogen atom,

$$E = -K = -\frac{h^2}{2m\lambda^2}$$

$$E_n - E_g = \frac{h^2}{2m}\left(\frac{1}{\lambda_g^2} - \frac{1}{\lambda_n^2}\right)$$

$$\frac{h^2}{2m}\left(\frac{\lambda_n^2-\lambda_g^2}{\lambda_g^2\lambda_n^2}\right)=\frac{hc}{\Lambda_n}$$

$$\Rightarrow \quad \Lambda_n=\frac{2mc}{h}\left(\frac{\lambda_g^2\lambda_n^2}{\lambda_n^2-\lambda_g^2}\right)$$

$$\Rightarrow \quad \Lambda_n=\frac{2mc\lambda_g^2}{h}\left[1-\frac{\lambda_g^2}{\lambda_n^2}\right]^{-1}=\frac{2mc\lambda_g^2}{h}\left[1+\frac{\lambda_g^2}{\lambda_n^2}\right]$$

$$\{\because \lambda_g \ll \lambda_n\}$$

$$\Rightarrow \quad \Lambda_n=\frac{2mc\lambda_g^2}{h}+\left(\frac{2mc\lambda_g^4}{h}\right)\frac{1}{\lambda_n^2}=A+\frac{B}{\lambda_n^2}$$

where A and B are $A=\dfrac{2mc\lambda_g^2}{h}$, $B=\dfrac{2mc\lambda_g^4}{h}$

Hence, the correct answer is (A).

9. Since, $B=\dfrac{\mu_0 i}{2r}\propto\dfrac{i}{r}$

Magnetic field at the centre of hydrogen atom i.e. at nucleus, is found by calculating the current due to electron, given by

$$i=\frac{e}{T}=ef$$

Since, we know that $r\propto\dfrac{n^2}{Z}$ and $f\propto\dfrac{Z^2}{n^3}$

Since, $B\propto\dfrac{i}{r}\propto\dfrac{f}{r}$

$$\Rightarrow \quad B\propto\frac{\left(\dfrac{Z^2}{n^3}\right)}{\left(\dfrac{n^2}{Z}\right)}\propto\frac{Z^3}{n^5}$$

Hence, the correct answer is (B).

10. $t=\dfrac{2r}{v}=\dfrac{2\times10^{-15}\ \text{m}}{3\times10^{7}\ \text{ms}^{-1}}=\dfrac{2}{3}\times10^{-22}\ \text{s}$

Hence, the correct answer is (B).

11. Since, $\Delta\lambda=\lambda_{K_\alpha}-\lambda_{\min}$ …(1)

When V is made half, $\lambda_{\min}$ becomes two times, however λ_{K_α} remains the same.

$$\Rightarrow \quad \Delta\lambda'=\lambda_{K_\alpha}-2\lambda_{\min}$$

From (1), we have

$$\lambda_{\min}=\lambda_{K_\alpha}-\Delta\lambda$$

$$\Rightarrow \quad \Delta\lambda'=\lambda_{K_\alpha}-2\lambda_{K_\alpha}+2\Delta\lambda$$

$$\Rightarrow \quad \Delta\lambda'=2\Delta\lambda-\lambda_{K_\alpha}$$

$$\Rightarrow \quad \Delta\lambda'<2\Delta\lambda$$

Hence, the correct answer is (D).

12. Loss in $KE=[(-3.4)-(-13.6)]$ eV

$$\Rightarrow \quad \text{Loss in KE}=10.2\ \text{eV}$$

$$\Rightarrow \quad \frac{1}{4}m_H v^2=10.2\times1.6\times10^{-19}$$

$$\Rightarrow \quad v=6.25\times10^4\ \text{ms}^{-1}$$

Hence, the correct answer is (A).

13. Assuming that ionization occurs as a result of a completely inelastic collision, we can write

$$mv_0=(m+m_H)V$$

where m is the mass of incident particle, m_H the mass of hydrogen atom, v_0 the initial velocity of incident particle and V the final common velocity of the particle after collision. Prior to collision, the KE of the incident particle was

$$E_0=\frac{mv_0^2}{2}$$

The total kinetic energy after collision

$$E=\frac{(m+m_H)V^2}{2}=\frac{m^2v_0^2}{2(m+m_H)}$$

The decrease in kinetic energy must be equal to ionization energy, so we have

$$E_i=E_0-E=\left(\frac{m_H}{m+m_H}\right)E_0$$

$$\Rightarrow \quad \frac{E_i}{E_0}=\frac{m_H}{m+m_H}$$

i.e., the greater the mass m, the smaller the fraction of initial kinetic energy that will be used for ionization.

Hence, the correct answer is (B).

14. KE of α-particle is $K_\alpha=qV_0=(2e)V_0$

PE of α-particle is $U_\alpha=\dfrac{1}{4\pi\varepsilon_0}\dfrac{(Ze)(2e)}{r_0}$

By Law of Conservation of Energy, $U_\alpha=K_\alpha$

$$2eV_0=\frac{2Ze^2}{4\pi\varepsilon_0 r_0}$$

$$\Rightarrow \quad r_0=\frac{Ze}{4\pi\varepsilon_0 V_0}$$

$$\Rightarrow \quad r_0=\frac{(9\times10^9)(1.6\times10^{-19})(Z)}{V_0}$$

$$\Rightarrow \quad r_0 = 14.4\times 10^{-10}\left(\frac{Z}{V_0}\right)m$$

$$\Rightarrow \quad r_0 = 14.4\left(\frac{Z}{V_0}\right)\text{Å}$$

Hence, the correct answer is (A).

15. According to Ritz Combination Principle

$$\nu_{m\to n} = \nu_{m\to i} + \nu_{i\to n} \qquad \{\text{for } m < i < n\}$$

e.g., $\nu_{4\to 1} = \nu_{4\to 3} + \nu_{3\to 1}$ or

$$\nu_{4\to 1} = \nu_{4\to 2} + \nu_{2\to 1}$$

Hence, the correct answer is (A).

16. $R = n^2 R_0$

$$\Rightarrow \quad \log R = \log R_0 + 2\log n$$

$$\Rightarrow \quad \log\left(\frac{R}{R_0}\right) = 2\log n$$

$$\Rightarrow \quad y = mx$$

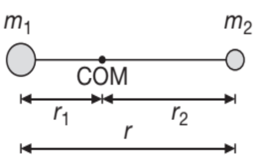
Hence, the correct answer is (D).

17. A diatomic molecule consists of two atoms of masses m_1 and m_2 at a distance r apart. Let r_1 and r_2 be the distances of the atoms from the centre of mass.

The moment of inertia of this molecule about an axis passing through its centre of mass and perpendicular to a line joining the atoms is

$$I = m_1 r_1^2 + m_2 r_2^2$$

As $m_1 r_1 = m_2 r_2$



$$\Rightarrow \quad r_1 = \frac{m_2}{m_1} r_2$$

$$\Rightarrow \quad r_1 + r_2 = r$$

$$\Rightarrow \quad r_1 = \frac{m_2}{m_1}(r - r_1)$$

On rearranging, we get $r_1 = \dfrac{m_2 r}{m_1 + m_2}$

Similarly, $r_2 = \dfrac{m_1 r}{m_1 + m_2}$

Therefore, the moment of inertia can be written as

$$I = m_1\left(\frac{m_2 r}{m_1+m_2}\right)^2 + m_2\left(\frac{m_1 r}{m_1+m_2}\right)^2 = \frac{m_1 m_2}{m_1+m_2} r^2 \qquad \ldots(1)$$

According to Bohr's quantisation condition

$$L = \frac{nh}{2\pi} = n\hbar \qquad \left\{\because \hbar = \frac{h}{2\pi}\right\}$$

$$\Rightarrow \quad L^2 = \frac{n^2h^2}{4\pi^2} = n^2\hbar^2 \qquad \ldots(2)$$

Rotational energy, $E = \dfrac{L^2}{2I}$

$$\Rightarrow \quad E = \frac{n^2}{8\pi^2 I} = \frac{n^2\hbar^2}{2I} \qquad \{\text{using (2)}\}$$

$$\Rightarrow \quad E = \frac{n^2h^2(m_1+m_2)}{8\pi^2(m_1m_2)r^2} = \frac{n^2\hbar^2}{2}\frac{(m_1+m_2)}{(m_1m_2)r^2} \qquad \{\text{using (1)}\}$$

$$\Rightarrow \quad E = \frac{n^2\hbar^2(m_1+m_2)}{2m_1m_2r^2}$$

Hence, the correct answer is (C).

18. Since $R' = \dfrac{\mu R}{m} = \dfrac{MR}{M+m}$

$$\Rightarrow \quad \frac{1}{\lambda} = R'\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\Rightarrow \quad \frac{1}{\lambda} = \frac{MR}{M+m}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Hence, the correct answer is (D).

19. $\dfrac{1}{\lambda} = R_H\left[\dfrac{1}{n^2} - \dfrac{1}{(n+1)^2}\right]$

$$\Rightarrow \quad \frac{1}{\lambda} = R_H\left[\frac{(2n+1)}{n^2(n+1)^2}\right]$$

$$\Rightarrow \quad \frac{1}{\lambda} \simeq R_H\frac{2n}{n^4}$$

$$\{\because \text{ for large } n,\ 2n+1 \simeq 2n \quad n^2(n+1)^2 \simeq n^4\}$$

$$\Rightarrow \quad \frac{1}{\lambda} \simeq R_H\frac{2}{n^3}$$

$$\Rightarrow \quad \nu = \frac{c}{\lambda} = \frac{2R_Hc}{n^3}$$

Hence, the correct answer is (A).

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

$$\Rightarrow \quad \frac{1}{\lambda_{\text{Lyman}}} = RZ^2\left(\frac{1}{1} - \frac{1}{4}\right) = \frac{3}{4}RZ^2$$

$$\Rightarrow \quad \frac{1}{\lambda_{\text{Balmer}}} = RZ^2\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5}{36}RZ^2$$

$$\Rightarrow \quad \frac{\lambda_{\text{Lyman}}}{\lambda_{\text{Balmer}}} = \left(\frac{5}{36}\right)\left(\frac{4}{3}\right) = \frac{5}{27}$$

Hence, the correct answer is (C).

22. $n=3$ ——— $2E$

$n=2$ ——— $\frac{4E}{3}$

$n=1$ ——— E

For $3 \to 1$, $\frac{hc}{\lambda} = 2E - E = E$

For $2 \to 1$, $\frac{4E}{3} - E = \frac{E}{3} = \frac{hc}{\lambda'}$

$\Rightarrow \quad \lambda' = 3\lambda$

Hence, the correct answer is (D).

24. $m_\alpha v_\alpha = m_D v_D$

$$\Rightarrow \quad v_D = \left(\frac{m_\alpha}{m_D}\right) v_\alpha = \left(\frac{4}{A-4}\right) v$$

Hence, the correct answer is (C).

25. $\lambda = 2\pi r$

where r = Radius of first orbit $= 0.53$ Å

$\Rightarrow \quad \lambda = 2\pi(0.53)$ Å $= 3.33$ Å

Hence, the correct answer is (D).

26. For UV radiation, $n_f = 1$

$\lambda = 1025$ Å

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

$$\Rightarrow \quad 1 - \frac{1}{n_i^2} = \frac{1}{\lambda R}$$

$$\sqrt{1 - \frac{1}{\lambda R}} = \frac{1}{n_i}$$

$$\Rightarrow \quad n_i = \frac{1}{\sqrt{1 - \frac{1}{\lambda R}}} = \frac{1}{\sqrt{1 - 0.89}} \approx 3$$

Hence, the correct answer is (C).

27. Since, $r_n \propto n^2$

Given, $r_{n+1} - r_n = r_{n-1}$

$\Rightarrow \quad (n+1)^2 - n^2 = (n-1)^2$

$\Rightarrow \quad n = 4$

Hence, the correct answer is (D).

28. $\frac{nh}{2\pi} = \frac{2h}{\pi}$

$\Rightarrow \quad n = 4$

In fourth orbit, $KE = -TE = \frac{13.6}{(4)^2}$ eV $= 0.85$ eV

Hence, the correct answer is (C).

29. Since $F = -\frac{dU}{dr}$

$$\Rightarrow \quad F = kr = \frac{mv^2}{r}$$

$$\Rightarrow \quad v^2 = \frac{k}{m} r^2$$

$$\Rightarrow \quad v = \sqrt{\frac{k}{m}} r \qquad \ldots(1)$$

Also, $mvr = \frac{nh}{2\pi}$ ...(2)

Solving (1) and (2), we get

$$m\left(\sqrt{\frac{k}{m}} r\right) r = \frac{nh}{2\pi}$$

$$\Rightarrow \quad r \propto \sqrt{n}$$

Since, $E = PE + KE$

$$\Rightarrow \quad E = \frac{1}{2}kr^2 + \frac{1}{2}m\left(\sqrt{\frac{k}{m}} r\right)^2$$

$\Rightarrow \quad E \propto r^2$

$\Rightarrow \quad E \propto n$

Hence, the correct answer is (B).

30. Since, $\frac{3h}{2\pi} = n\left(\frac{h}{2\pi}\right)$

$\Rightarrow \quad n = 3$

$$\Rightarrow \quad K_n = \frac{K_1}{(3)^2} = \frac{13.6}{9} = 1.51 \text{ eV}$$

Hence, the correct answer is (A).

31. $f = \frac{c}{\lambda} = \frac{3 \times 10^8}{0.0709 \times 10^{-9}} = 4.23 \times 10^{18}$ Hz

From Moseley's law

$$Z - 1 = \sqrt{\frac{4v}{3cR}} \approx 41$$

$\Rightarrow \quad Z = 42$

This Z corresponds to Molybdenum.

Hence, the correct answer is (D).

32. Let E_K, E_L, E_M, E_N be the binding energies of K, L, M and N shell. Let E_P be energy of incident photon, then

$E_P - E_K = 24$ keV ...(1)

$E_P - E_L = 100$ keV ...(2)

$E_P - E_M = 110$ keV ...(3)

$\Rightarrow \quad E(K_\alpha) = E_K - E_L = 100 - 24 = 76$ keV

Hence, the correct answer is (B).

33. $\lambda = \dfrac{hc}{eV_0}$

$\Rightarrow \quad \lambda = \dfrac{6.626\times10^{-24}\times3\times10^{8}}{\left(20\times10^{3}\right)\left(1.6\times10^{-19}\right)}$

$\Rightarrow \quad \lambda = 0.62$ Å

Hence, the correct answer is (B).

34. Atomic number and melting point both should be high.
Hence, the correct answer is (D).

36. Since, $\lambda \propto \dfrac{1}{(Z-1)^2}$

$\Rightarrow \quad \dfrac{\lambda_1}{\lambda_2} = \left(\dfrac{Z_2-1}{Z_1-1}\right)^2 = \dfrac{1}{4}$

$\Rightarrow \quad 2(Z_2-1) = (Z_1-1)$

$\Rightarrow \quad Z_2 = 1+\dfrac{Z_1-1}{2} = 1+\dfrac{11-1}{2} = 6$

Hence, the correct answer is (A).

38. The frequency of emitted photon making a transition from n to $(n-1)$ level is

$f \propto \left(\dfrac{1}{(n-1)^2}-\dfrac{1}{n^2}\right)$

$\Rightarrow \quad f \propto \left[\dfrac{n^2-(n-1)^2}{n(n-1)^2}\right]$

$\Rightarrow \quad f \propto \dfrac{(2n-1)}{n^2(n-1)^2}$

For $n \gg 1$, we have $n-1 \approx n$, $2n-1 \approx 2n$

$\Rightarrow \quad f \propto \dfrac{2n}{n^4}$

$\Rightarrow \quad f \propto \dfrac{1}{n^3}$

Hence, the correct answer is (A).

39. For $0 < E_K < 10.2$ eV, the collision of electron (having kinetic energy E_K) with a H-atom in its ground state will be elastic.
Hence, the correct answer is (A).

40. The binding energy is numerically equal to the kinetic energy of the electron, so

$$\frac{1}{2}mv^2 = E_1 \qquad \ldots(1)$$

Since, $mvr = \dfrac{nh}{2\pi}$ $\qquad \ldots(2)$

Dividing Equation (1) by Equation (2), we get

$$\frac{v}{2\pi r} = \frac{2E_1}{nh}$$

$\Rightarrow \quad f = \dfrac{2E_1}{nh} \qquad \left\{\because \dfrac{v}{2\pi r} = \dfrac{\omega}{2\pi} = f\right\}$

Hence, the correct answer is (D).

41. Number of orbits i.e. number of revolutions i.e. frequency (f) is proportional to $\dfrac{Z^2}{n^3}$

Since $T_0 \propto \dfrac{n^3}{Z^2}$

$\Rightarrow \quad T' = 8T_0$

$\Rightarrow \quad N = \dfrac{\text{Life Time of Excited state}}{\text{Time for one Revolution}}$

$\Rightarrow \quad N = \dfrac{10^{-8}}{8T_0}$

Hence, the correct answer is (C).

42. $\dfrac{\text{Magnetic moment}}{\text{Angular momentum}} = \dfrac{e}{2m}$

$\Rightarrow$ Magnetic moment $\propto$ Angular Momentum

$\Rightarrow \quad M \propto n \qquad \left\{\because L = n\dfrac{h}{2\pi}\right\}$

Hence, the correct answer is (B).

43. Since $v \propto \dfrac{1}{n}$ and $r \propto n^2$

$\Rightarrow \quad v \propto \dfrac{1}{\sqrt{r}}$

Since, $L = mvr$

$\Rightarrow \quad L \propto vr$

$\Rightarrow \quad L \propto \left(\dfrac{1}{\sqrt{r}}\right)r$

$\Rightarrow \quad L \propto \sqrt{r}$

Hence, the correct answer is (C).

44. Cut-off wavelength depends on the applied voltage not on the atomic number of the target. Characteristic wavelengths depend on the atomic number of target.
Hence, the correct answer is (B).

45. Bohr has assumed stationary orbits in which there is no gain or loss of energy and angular momentum in any orbit does not change.
Hence, the correct answer is (C).

46. $L = \sqrt{n(n+1)}\dfrac{h}{2\pi}$

$\Rightarrow \quad L = \sqrt{56}\left(\dfrac{h}{2\pi}\right)$

Hence, the correct answer is (D).

47. $a = \frac{v^2}{r} = \frac{Z^2}{n^2} \times \frac{Z}{n^2}$

$\Rightarrow \quad a \propto Z^3$

$\Rightarrow \quad \frac{a_{He^+}}{a_H} = \frac{Z^3_{He^+}}{Z^3_H} = \frac{2^3}{1^3} = \frac{8}{1}$

Hence, the correct answer is (B).

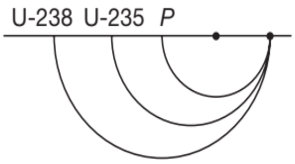
48. $R_n = n^2 R_0$

$\Rightarrow \quad R_2 = 4(0.528 \text{ Å})$

$\Rightarrow \quad R_2 = 2.112 \text{ Å}$

Hence, the correct answer is (B).

49.



$r_{235} = \frac{mv}{qB} = \frac{(235m_p)v}{eB} = 235 \times 10 = 2350 \text{ m}$

$r_{238} = \frac{(238m_p)v}{eB} = 2380 \text{ mm}$

The separation between the ions of U^{235} and U^{238} is

$\Delta r = 2(r_{238} - r_{235})$

$\Rightarrow \quad \Delta r = 2 \times (2380 - 2350)$

$\Rightarrow \quad \Delta r = 60 \text{ mm}$

Hence, the correct answer is (A).

50. Speed of electron in the nth orbit of H like atom is

$v_n = \frac{1}{137}\left(\frac{cZ}{n}\right)$

Hence, the correct answer is (C).

51. Since $v_n = \left(\frac{e^2}{2h\varepsilon_0}\right)\frac{Z}{n}$

$\Rightarrow \quad v = \left(\frac{e^2}{2h\varepsilon_0}\right)\left(\frac{2}{4}\right)$

$\Rightarrow \quad v = \frac{e^2}{4h\varepsilon_0}$

Hence, the correct answer is (B).

52. Since $\Delta p = \frac{h}{\lambda}$

$\Rightarrow \quad m_H v = hR_H\left(\frac{1}{1} - \frac{1}{25}\right)$

$\Rightarrow \quad v = \frac{hR_H}{m_H}\left(\frac{24}{25}\right)$

$\Rightarrow \quad v = 4 \text{ ms}^{-1}$

Hence, the correct answer is (C).

53. $r \propto n^2$

$\Rightarrow \quad \frac{5.3 \times 10^{-11}}{21.2 \times 10^{-11}} = \frac{1}{n^2}$

$\Rightarrow \quad n^2 = 4$

$\Rightarrow \quad n = 2$

Hence, the correct answer is (B).

54. (i) $a = \frac{v^2}{r} \propto \frac{Z^2}{n^2} \times \frac{Z}{n^2}$

$\Rightarrow \quad a \propto \frac{Z^2}{n^4}$

(ii) $L = mvr = \frac{nh}{2\pi}$

$\Rightarrow \quad L \propto n$

(iii) $KE = \frac{Ze^2}{8\pi\varepsilon_0 r}$

$KE \propto \frac{1}{r}$

$\Rightarrow \quad KE \propto \frac{1}{n^2}$

Hence, the correct answer is (C).

55. $R_H\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = R_H\left(\frac{9}{n_1^2} - \frac{9}{n_2^2}\right)$

Substituting $n_1 = 6$, $n_2 = 12$ makes both sides equal

Hence, the correct answer is (C).

56. Ionization energy, $E_0 \propto m$

$\Rightarrow \quad \frac{(E_0)_2}{(E_0)_1} = \frac{m_2}{m_1} = \frac{207me}{me}$

$\Rightarrow \quad (E_0)_2 = 207(E_0)_1$

$\Rightarrow \quad (E_0)_2 = 207 \times 13.6 \text{ eV}$

$\Rightarrow \quad (E_0)_2 = 2.82 \text{ keV}$

Hence, the correct answer is (C).

57. $a = \frac{v^2}{r}$

$\Rightarrow \quad a \propto \frac{(z)^2}{\left(\frac{1}{z}\right)} \qquad \{\text{for } n = 1\}$

$\Rightarrow \quad a \propto z^3$

$\Rightarrow \quad \frac{a_1}{a_2} = \left(\frac{2}{1}\right)^3 = 8$

Hence, the correct answer is (B).

58. $r_n = n^2 r_1$

$\Rightarrow \quad \log r_n = \log(n^2) + \log r_1$

$\Rightarrow \quad \log r_n - \log r_1 = 2\log n$

$\Rightarrow \quad \log\left(\frac{r_n}{r_1}\right) = 2\log n$

$\Rightarrow \quad y = kx$

So, $\log\left(\frac{r_n}{r_1}\right)$ vs $\log n$ is a straight line passing through origin, with slope $m = 2$

Hence, the correct answer is (A).

59. Maximum wavelength of Lyman series will correspond to the transition of electron from $n = 2$ to $n = 1$ and maximum wavelength of Paschen series will correspond to $n = 4$ to $n = 3$.

$$\Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{\left(\frac{1}{9} - \frac{1}{16}\right)}{\left(\frac{1}{1} - \frac{1}{4}\right)} = \frac{7}{108}$$

Hence, the correct answer is (D).

60. Rydberg constant $R \propto m$

For positronium atom, reduced mass is $\mu = \frac{mM}{m+M}$.

Here, $m = M =$ mass of positron $=$ mass of electron.

$\Rightarrow \quad \mu = \frac{m}{2}$

$\frac{R'}{R} = \frac{\mu}{m} = \frac{1}{2}$

$\Rightarrow \quad R' = \frac{R}{2}$

Hence, the correct answer is (C).

61. $v_n = \alpha\left(\frac{cZ}{n}\right)$ where $\alpha = \frac{e^2}{2h\varepsilon_0 c}$

is the fine structure constant $\left(\alpha \simeq \frac{1}{137}\right)$

$v_{He^+} = \alpha\left(\frac{c(2)}{2}\right) = \alpha c$

and $v_H = \alpha\frac{c(1)}{(1)} = \alpha c = v_{He^+}$

Hence, the correct answer is (B).

62. Since $r \propto \frac{n^2}{Z}$

$\Rightarrow \quad \frac{a}{a_0} = \frac{(3)^2}{(2)^2}$

$\Rightarrow \quad a = \frac{9}{4}a_0$

Hence, the correct answer is (B).

63. Momentum of striking electrons

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

Kinetic energy of striking electrons

$K = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

This is also, maximum energy of X-rays photons.

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

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

Hence, the correct answer is (A).

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

$\Rightarrow \quad Z = 3$

Hence, the correct answer is (B).

65. Total power drawn by Coolidge tube is VI.

$\Rightarrow \quad P_{total} = VI = 200$ W

Since only 0.5% is carried by X-rays, so

$P = \left(\frac{0.5}{100}\right)P_{total}$

$\Rightarrow \quad P = \frac{1}{200}(200)$W

$\Rightarrow \quad P = 1$ W

Hence, the correct answer is (B).

66. $evB = \frac{mv^2}{R}$

$\Rightarrow \quad v = \frac{eBR}{m}$

Maximum kinetic energy of photoelectron is

$K_{max} = \frac{1}{2}mv^2 = \frac{e^2B^2R^2}{2m} = 2.97 \times 10^{-15}$ J

$\Rightarrow \quad K_{max} = 2.97 \times 10^{-15}$ J $= 18.6$ keV

$\Rightarrow \quad (BE)_{Kshell} = (24.8 - 18.6)$ keV

$\Rightarrow \quad (BE)_{Kshell} = 6.2 \text{ keV}$

Hence, the correct answer is (A).

67. $f_n = \dfrac{v_n}{2\pi r_n} = \dfrac{\dfrac{e^2}{2h\varepsilon_0 c}\dfrac{cZ}{n}}{2\pi \dfrac{n^2h^2\varepsilon_0}{\pi me^2 Z}}$

$\Rightarrow \quad f_n = \left(\dfrac{me^4Z^2}{4\varepsilon_0^2 h^3}\right)\dfrac{1}{n^3}$

Hence, the correct answer is (B).

68. Frequency, $f = \left(\dfrac{E_0}{h}\right)\left(\dfrac{2}{n^3}\right)$

Since, $E_0 = 13.6$ eV and $n = 2$

$\Rightarrow \quad f = 0.823 \times 10^{15}$ rev/sec

Number of revolutions $N = f \times \Delta t = 8.23 \times 10^6$ rev

Hence, the correct answer is (A).

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

$\dfrac{1}{912} = R(1)\left(\dfrac{1}{1} - \dfrac{1}{\infty}\right)$ and $\dfrac{1}{\lambda} = R(1)\left(\dfrac{1}{4} - \dfrac{1}{\infty}\right)$

$\Rightarrow \quad \dfrac{\lambda}{912} = 4$

$\Rightarrow \quad \lambda = 912 \times 4 = 3648$ Å

Hence, the correct answer is (A).

71. $\dfrac{hc}{\lambda_1} + \dfrac{hc}{\lambda_2} = RchZ^2\left(\dfrac{1}{1^2} - \dfrac{1}{n^2}\right)$

Substituting $\lambda_1 = 1026.7$ Å, $\lambda_2 = 304$ Å and $Z = 2$, we get

$n = 6$

Hence, the correct answer is (B).

72. $\dfrac{1}{\lambda} = R_H\left(\dfrac{1}{4} - \dfrac{1}{16}\right)$

Since $c = \nu\lambda$

$\Rightarrow \quad \nu = \dfrac{c}{\lambda}$

$\Rightarrow \quad \nu = 3 \times 10^8 \times 10^7 \times \left(\dfrac{3}{16}\right)$

$\Rightarrow \quad \nu = \dfrac{9}{16} \times 10^{15}$ Hz

Hence, the correct answer is (C).

73. $J_n = mvr = \dfrac{nh}{2\pi}$

$\Rightarrow \quad J_n \propto n$

Since, $E_n \propto \dfrac{1}{n^2}$

$\Rightarrow \quad E_n \propto \dfrac{1}{J_n^2}$

Hence, the correct answer is (D).

74. $E = R_\infty hc\left(1 - \dfrac{1}{25}\right)$

Momentum of photon emitted is

$p = \dfrac{E}{c} = R_\infty h\left(\dfrac{24}{25}\right)$

Recoil momentum of H-atom will also be p.

$\Rightarrow \quad mv = p$

$\Rightarrow \quad v = \dfrac{p}{m} = \dfrac{(1.097 \times 10^7)(6.626 \times 10^{-34})24}{(25)(1.67 \times 10^{-27})}$

$\Rightarrow \quad v = 4.178 \text{ ms}^{-1}$

Hence, the correct answer is (C).

76. Since $E = -\dfrac{13.6}{n^2}$ eV

$\Rightarrow \quad E_1 = -13.6$ eV

$\Rightarrow \quad E_2 = -3.4$ eV

$\Rightarrow \quad E_3 = -1.50$ eV

$\Rightarrow \quad E_4 = -0.85$ eV

From above we can see that

$E_3 - E_1 = 12.1$ eV

i.e. the electron must be making a transition from $n = 3$ to $n = 1$ level.

$\Rightarrow \quad \Delta L = (3-1)\dfrac{h}{2\pi} = \dfrac{h}{\pi}$

$\Rightarrow \quad \Delta L = \dfrac{6.626 \times 10^{-34}}{3.14}$

$\Rightarrow \quad \Delta L = 2.11 \times 10^{-34}$ Js

Hence, the correct answer is (B).

77. $PE = 2(TE)$

$\Rightarrow \quad PE = 2 \times (-13.6) = -27.2$ eV

Hence, the correct answer is (A).

78. Change in angular momentum

$$\Delta L = (n_f - n_i)\frac{h}{2\pi}$$

Since velocity of electron is

$$v \propto \frac{1}{n}$$

Hence linear momentum changes and difference in energy between energy levels is released as electromagnetic energy.
Hence, the correct answer is (D).

79. For the fifth electron to act as a dopant it must lie in the valence shell of P.
So $n = 3$. (TRICKY HINT !)

$$Z = 15 \qquad \text{\{for Phosphorus\}}$$

Since $r_n = \frac{n^2h^2\varepsilon_0}{\pi me^2Z} = \frac{n^2}{Z}r_0$

where $r_0 = 0.529\ \text{Å} = 52.9$ pm

$$\Rightarrow \quad r_3 = \frac{9}{15}(52.9\ \text{pm}) \qquad \ldots(1)$$

When phosphorus acts as dopant in silicon, the expression for Bohr radius is

$$r_n' = \frac{n^2h^2\varepsilon}{\pi me^2Z} = kr_n$$

$$\Rightarrow \quad r_n' = 12r_n \qquad \{\because\ \varepsilon = k\varepsilon_0\}$$

$$\Rightarrow \quad r_3' = 12r_3 = 12\left[\frac{9}{15}(52.9)\text{pm}\right]$$

$$\Rightarrow \quad r_3' = 380.88\ \text{pm}$$

Hence, the correct answer is (A).

80. The energy difference between the energy levels in an atom remains fixed. Hence wavelength remains fixed and is given by

$$\lambda = \frac{hc}{\Delta E} = \frac{hc}{E_f - E_i}$$

Increasing number of atoms would increase the intensity absorbed.
Hence, the correct answer is (A).

81. Angular momentum, $L = n\left(\frac{h}{2\pi}\right) = mvr$

Magnetic moment, $\mu = iA = \left(\frac{e}{2\pi r}v\right)(\pi r^2)$

$$\Rightarrow \quad \mu = \frac{e(vr)}{2}$$

$$\Rightarrow \quad \mu = \frac{e}{2}\left(\frac{L}{m}\right)$$

$$\Rightarrow \quad \frac{\mu}{L} = \frac{e}{2m}$$

Hence, the correct answer is (AB).

82. Since, $T \propto n^3$ and $r \propto n^2$

$$\Rightarrow \quad T \propto r^{\frac{3}{2}}$$

Hence, the correct answer is (B).

83. $mvr = n\frac{h}{2\pi} = 2\left(\frac{h}{2\pi}\right)$

$$\Rightarrow \quad mvr = \frac{h}{\pi}$$

So, de-Broglie wavelength is

$$\lambda = \frac{h}{mv} = \pi r = (3.14)(2.116\ \text{Å}) = 6.64\ \text{Å}$$

Hence, the correct answer is (C).

84. λ is maximum

$\Rightarrow$ E_{min} i.e. transition from $3 \to 2$.

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

$$\Rightarrow \quad \frac{1}{\lambda_{\text{max}}} = R\left(\frac{5}{36}\right)$$

$$\lambda_{\text{max}} = \frac{36}{5R} = \frac{36}{5} \times 912\ \text{Å} = 6560\ \text{Å} = 656\ \text{nm}$$

Hence, the correct answer is (C).

85. Since, $r = \frac{\varepsilon_0 n^2h^2}{e^2\pi m}$

$$L = n\left(\frac{h}{2\pi}\right)$$

$$\Rightarrow \quad nh = 2\pi L$$

$$\Rightarrow \quad r = \frac{\varepsilon_0(2\pi L)^2}{e^2\pi m}$$

$$\Rightarrow \quad Lr^{-\frac{1}{2}} = \text{constant}$$

Hence, the correct answer is (D).

86. $\Delta E = 13.6\left(1 - \frac{1}{9}\right) = 12.1$ eV

Hence, the correct answer is (B).

87. Since K.E. = –T.E.
$\Rightarrow$ K.E. = +13.6 eV
Hence, the correct answer is (B).

88. The energy E_n of an electron in n^{th} orbit of positronium is given by

$$E_n = -\frac{\mu e^4}{8n^2h^2\varepsilon_0^2},$$

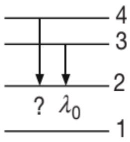
where $\mu_e = \frac{mM}{m+M} = \frac{m}{2} = \frac{m_e}{2}$ $\{\because M = m_e\}$

$$\Rightarrow \quad E_n = -\left(\frac{me^4}{8\varepsilon_0^2h^2}\right)\frac{1}{2n^2}$$

$$\Rightarrow \quad E_n = -\frac{13.6}{2n^2}\text{ eV} = -\frac{6.8}{n^2}\text{ eV}$$

Hence, the correct answer is (D).

90.



$$\frac{1}{\lambda_0} = R\left(\frac{1}{4}-\frac{1}{9}\right)$$

$$\lambda_0 = \frac{36}{5R} \qquad \ldots(1)$$

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

$$\lambda = \frac{16}{3R} \qquad \ldots(2)$$

$$\Rightarrow \quad \frac{\lambda}{\lambda_0} = \frac{16/3R}{36/5R} = \frac{20}{27}$$

$$\Rightarrow \quad \lambda = \frac{20}{27}\lambda_0$$

Hence, the correct answer is (B).

91. According to Ritz Combination Principle

$$E_{C\to A} = E_{C\to B} + E_{B\to A}$$

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

$$\Rightarrow \quad \lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$$

Hence, the correct answer is (B).

92. For 12.1 eV energy, the electron is excited to third orbit, so total lines $N = \frac{n(n-1)}{2}$

$$\Rightarrow \quad N = \frac{3\times 2}{2} = 3\text{ lines}$$

Hence, the correct answer is (C).

93. For each principal quantum number n, number of electrons permitted equals the number of elements corresponding to the quantum number.

$$\Rightarrow \quad \begin{pmatrix}\text{Total Number}\\ \text{of Elements}\end{pmatrix} = \sum 2n^2 = \frac{n(n+1)(2n+1)}{3}$$

Hence, the correct answer is (D).

94. Since $E = \frac{\Delta V}{\Delta r}$

$$\Rightarrow \quad \Delta V = E\Delta r$$

$$\Rightarrow \quad 10.5 = (1.5\times 10^6)\Delta r$$

$$\Rightarrow \quad \Delta r = \frac{10.5}{1.5\times 10^6} = 7\times 10^{-6}\text{ m}$$

$$\Rightarrow \quad \Delta r = 7\ \mu\text{m}$$

Hence, the correct answer is (A).

95. $I = I_0 e^{-\mu x}$

Where I_0 is intensity at $x = 0$,

I is intensity at a distance x and

$\Rightarrow$ μ is absorption coefficient; $[\mu] = L^{-1}$

μ is maximum for lead as lead has maximum ability to absorb radiations in a minimum distance.

Hence, the correct answer is (B).

96. $K_\alpha = 7.7$ MeV

$$r_0 = \frac{(79e)(2e)}{4\pi\varepsilon_0 K_\alpha} = \frac{9\times 10^9\times 79\times 2\times e^2}{7.7\times 10^6\times e}$$

$$\Rightarrow \quad r_0 = \frac{9\times 79\times 2\times 10^9\times 1.6\times 10^{-19}}{7.7\times 10^6}$$

$$\Rightarrow \quad r_0 = \frac{9\times 79\times 2\times 1.6}{7.7}\times 10^{-16}\text{ m} = 3\times 10^{-14}\text{ m}$$

Hence, the correct answer is (B).

97. Since $v = \frac{e^2}{2h\varepsilon_0}\left(\frac{Z}{n}\right)$

For fourth orbit of Be^{+++}, $n = 4$, $Z = 4$

$$\Rightarrow \quad v = \frac{e^2}{2h\varepsilon_0}$$

Hence, the correct answer is (D).

98. $\lambda = \frac{hc}{E}$

$$\Rightarrow \quad \lambda = \frac{(6.626\times 10^{-34})(3\times 10^8)}{1.6\times 10^{-16}\ E(\text{in keV})}$$

$$\Rightarrow \quad \lambda = \frac{1.242\times 10^{-9}}{E(\text{in keV})}\text{ m}$$

$$\Rightarrow \quad \lambda = \frac{12.42}{E(\text{in keV})}\text{ Å}$$

Hence, the correct answer is (B).

99. Since $B \propto \frac{i}{r}$ $i \propto \frac{f}{r}$

$\Rightarrow \quad B \propto \frac{Z^3}{n^5}$

$\Rightarrow \quad B' = \frac{B}{(2)^5} = \frac{B}{32}$

Hence, the correct answer is (C).

100. $\tau = \left|\frac{\Delta L}{\Delta t}\right| = \left|\frac{L_f - L_i}{\Delta t}\right|$

$\Rightarrow \quad \tau = \left|\frac{2\left(\frac{h}{2\pi}\right) - 3\left(\frac{h}{2\pi}\right)}{10^{-8}}\right|$

$\Rightarrow \quad \tau = 10^8\left(\frac{h}{2\pi}\right) = \frac{(10^8)(6.63\times10^{-34})}{2\times3.14}$

$\Rightarrow \quad \tau \approx 10^{-26}$ Nm

Hence, the correct answer is (B).

101. Let the electron be initially in the n^{th} orbit, then the max energy is liberated for transition from $n \to 1$ and the minimum energy for transition between $n \to (n-1)$. If E_1 be the energy of the electron in the first orbit, then we have

$$E_1 - \frac{E_1}{n^2} = 52.224 \text{ eV} \quad \ldots(1)$$

$$\frac{E_1}{(n-1)^2} - \frac{E_1}{n^2} = 1.224 \text{ eV} \quad \ldots(2)$$

Solving (1) and (2), we get

$E_1 = -54.4$ eV

Since, $E_1 = \frac{-13.6Z^2}{1^2}$

$\Rightarrow \quad Z = 2$

Hence, the correct answer is (C).

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

$\Rightarrow \quad E_2 = -3.4$ eV

Hence, the correct answer is (D).

103. Energy of emitted photon is

$$E = \frac{hc}{\lambda} = 2.5 \text{ eV}$$

The excitation energy is the energy required to excite the atom to a level just above the ground state. Therefore, energy of the level is

$$E = -13.6 + 10.2 = -3.4 \text{ eV}$$

Since, photon arises from transition between energy levels such that

$E_i - E_f = hv = 2.5$ eV

$\Rightarrow \quad E_i = 2.5 + E_f$

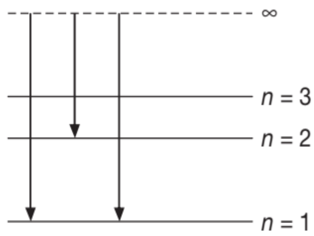
$\Rightarrow \quad E_i = 2.54 + E = 2.54 - 3.4 \text{ eV} = -0.9$ eV

Hence, the correct answer is (D).

104. Series limit (i.e. shortest wavelength) of Lyman implies transition from $\infty \to 1$

First line (or longest wavelength) of Lyman series implies transition from $2 \to 1$

Series limit of Balmer implies transition from $\infty \to 2$



According to Ritz Combination Principle

$E_{\infty\to1} = E_{\infty\to2} + E_{2\to1}$

$\Rightarrow \quad hv_1 = hv_3 + hv_2$

$\Rightarrow \quad v_1 - v_2 = v_3$

Hence, the correct answer is (A).

105. $\Delta E = E_2 - E_1 = 10.2 \text{ eV} = -3.4 \text{ eV} + 13.6$ eV

$\Rightarrow \quad n_2 = 2$ and $n_1 = 1$

$\Rightarrow \quad \Delta L = \frac{2h}{2\pi} - \frac{h}{2\pi} = \frac{h}{2\pi} = \frac{6.63\times10^{-34}}{2\times3.14}$ Js

$\Rightarrow \quad \Delta L = 1.05\times10^{-34}$ Js

Hence, the correct answer is (A).

106. $E_n \propto \frac{1}{n^2}$ and $r_n \propto n^2$

So, $E_n r_n$ is independent of n

$\Rightarrow \quad E_1 r_1 = (13.6 \text{ eV})(0.53 \text{ Å})$

$\Rightarrow \quad E_1 r_1 = 7.2$ eVÅ

$\Rightarrow \quad E_1 r_1 =$ constant

Hence, the correct answer is (C).

107. For Balmer series, $n_f = 2$ and $n_i = n(>2)$

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

$\Rightarrow \quad \frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{n^2}\right)$

$$\Rightarrow \quad \lambda = \frac{4n^2}{R(n^2-4)}$$

$$\Rightarrow \quad k = \frac{4}{R}$$

Hence, the correct answer is (D).

108. Since we assume the potential energy to be zero in the ground state. So,

Total Energy $= U + K =$ Kinetic Energy $\{\because U = 0\}$

$\Rightarrow$ Total Energy $= 13.6$ eV (in ground state)

If the potential energy is not assigned a zero value, then total energy is -13.6 eV.

So, we conclude that making potential energy zero increases the value of total energy by $13.6-(-13.6) = 27.2$ eV.

Now actual energy in second orbit $= -3.4$ eV

Hence new value is $(-3.4+27.2)$ eV $= 23.8$ eV

Hence, the correct answer is (C).

109. Loss in $KE = \frac{1}{2}\left[\frac{(m_H)(m_H)}{m_H+m_H}\right]v^2$

$$\Rightarrow \quad -\Delta K = \frac{1}{4}m_H v^2$$

This loss in kinetic energy must be equal to the energy required to take the electron from ground state to infinity i.e. 13.6 eV

$$\Rightarrow \quad \frac{1}{4}m_H v^2 = 13.6 \times 1.6 \times 10^{-19}$$

$$\Rightarrow \quad v = 7.2 \times 10^4 \text{ ms}^{-1}$$

Hence, the correct answer is (A).

110. Since, $E = -\frac{13.6}{n^2}$

$$\Rightarrow \quad -3.4 = -\frac{13.6}{n^2}$$

$$\Rightarrow \quad n = 2$$

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

Velocity of electron in second orbit is

$$v_2 = \frac{c}{2(137)} = \frac{c}{274}$$

$$\Rightarrow \quad \lambda = \frac{6.626 \times 10^{-34}}{(9.1 \times 10^{-31})\left(\frac{3 \times 10^8}{274}\right)}$$

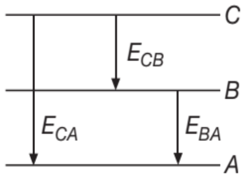
$$\Rightarrow \quad \lambda \sim 6.6 \times 10^{-10} \text{ m}$$

Further Kinetic Energy $= -(\text{Total Energy})$

$$\Rightarrow \quad E = -(-3.4 \text{ eV}) = 3.4 \text{ eV}$$

Hence, the correct answer is (B).

111. Since $E_{C\to A} = E_{C\to B} + E_{B\to A}$



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

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

$$\Rightarrow \quad \lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$$

Hence, the correct answer is (D).

112. Shortest wavelength of Brackett series corresponds to the transition of electron between $n_1 = 4$ and $n_2 \to \infty$ and the shortest wavelength of Balmer series corresponds to the transition of electron between $n_1 = 2$ and $n_2 \to \infty$. So,

$$(Z^2)\left(\frac{13.6}{16}\right) = \left(\frac{13.6}{4}\right)$$

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

Hence, the correct answer is (A).

113. $\Delta L = \frac{nh}{2\pi} - \frac{(n-1)h}{2\pi} = \frac{h}{2\pi}$

Hence, the correct answer is (C).

114. The longest wavelength in a series is obtained when a transition takes place between the lowest consecutive levels. Here transition must take place from $n=2$ to $n=1$

Hence, the correct answer is (A).

115. K_α wavelength is smaller for target having larger Z.

Cut-off wavelength is smaller for greater V.

Hence, the correct answer is (C).

116. $M = iA = \left(\frac{ev}{2\pi r}\right)\pi r^2 = \frac{evr}{2}$

Since, $v \propto \frac{1}{n}$ and $r \propto n^2$

$$\Rightarrow \quad M \propto n$$

Hence, the correct answer is (A).

117. Maximum angular speed will be in its ground state, so, we have

$$\omega_{max} = \frac{v_1}{r_1} = \frac{2.2 \times 10^6 \text{ ms}^{-1}}{0.529 \times 10^{-10} \text{ m}}$$

$$\Rightarrow \quad \omega_{max} = 4.1 \times 10^{16} \text{ rads}^{-1}$$

Hence, the correct answer is (B).

118. Since $v = \left(\dfrac{e^2}{2h\varepsilon_0}\right)\dfrac{Z}{n}$

$$\frac{v}{c} = \left(\frac{e^2}{2h\varepsilon_0 c}\right)\left(\frac{2}{1}\right) = \frac{e^2}{h\varepsilon_0 c}$$

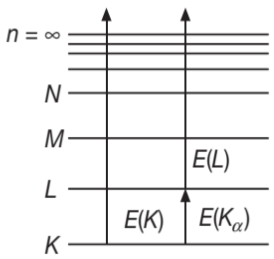
Hence, the correct answer is (C).

119. $\dfrac{hc}{\lambda} = Rhc\left(1 - \dfrac{1}{n^2}\right)$

$$\Rightarrow \quad n = \sqrt{\frac{\lambda R}{\lambda R - 1}}$$

Hence, the correct answer is (B).

120.



$$E(K) = \frac{hc}{\lambda_K} = \frac{12.4}{0.107} = 115.9 \text{ keV}$$

$$E(K_\alpha) = E(K) - E(L) = \frac{hc}{\lambda_\alpha} = 98.4 \text{ keV}$$

$$E_L = E(K) - E(K_\alpha) = 115.4 - 98.4$$

$$E_L = 17.5 \text{ keV}$$

$$\lambda_L = \frac{hc}{E_L} = \frac{12.4 \text{ keVÅ}}{17.5 \text{ keV}} = 0.709 \text{ Å}$$

Hence, the correct answer is (A).

121. According to Moseley's law, we have

$$\sqrt{v} \propto Z - 1$$

$$\Rightarrow \quad v \propto (Z-1)^2$$

$$\Rightarrow \quad \frac{\lambda_C}{\lambda_M} = \frac{(Z_M - 1)^2}{(Z_C - 1)^2}$$

$$\Rightarrow \quad \lambda_C = (0.71)\left(\frac{41}{28}\right)^2 = 1.52 \text{ Å}$$

Hence, the correct answer is (C).

122. When one electron is removed, the remaining atom is hydrogen like atom whose energy in first orbit is

$$E_1 = -(2)^2(13.6 \text{ eV}) \qquad (Z = 2)$$

$$\Rightarrow \quad E_1 = -54.4 \text{ eV}$$

Therefore, to remove the second electron an additional energy of 54.4 eV is required. Thus, to remove both the electrons $(24.6 + 54.4)$ eV $= 79$ eV energy is required.

Hence, the correct answer is (D).

123. Using $\dfrac{1}{\lambda} = R(Z-1)^2\left[\dfrac{1}{n_2^2} - \dfrac{1}{n_1^2}\right]$

For K_α radiation, $n_1 = 2$ and $n_2 = 1$

For metal A, we have

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

$$\Rightarrow \quad Z_1 = 26$$

For metal B, we have

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

$$\Rightarrow \quad Z_2 = 30$$

Therefore, 4 elements lie between A and B.

Hence, the correct answer is (D).

124. $|E_K| = \dfrac{hc}{\lambda_K} = \dfrac{12.4 \text{ KeV Å}}{0.15 \text{ Å}} = 82.7 \text{ keV}$

The energy of incident photon

$$E = \frac{hc}{\lambda} = \frac{12.4}{0.1} = 124 \text{ keV}$$

The maximum kinetic energy is

$$K_{\max} = E - |E_K| = 41.3 \text{ keV} \approx 41 \text{ keV}$$

Hence, the correct answer is (A).

125. Number of possible emission lines are $\dfrac{n(n-1)}{2}$ when electron jumps from nth state to ground state. In this question this value is

$$N = \frac{(n-1)(n-2)}{2}$$

$$\Rightarrow \quad 10 = \frac{(n-1)(n-2)}{2}$$

Solving this, we get

$$n = 6$$

Hence, the correct answer is (A).

126. Frequency corresponding to wavelength of 0.180 nm is

$$v = \frac{c}{\lambda} = 1.67 \times 10^{18} \text{ Hz}$$

From Moseley's law, we have

$$v = \frac{3}{4}Rc(Z-1)^2$$

$$\Rightarrow \quad Z - 1 = \sqrt{\frac{4v}{3cR}} \approx 26$$

$\Rightarrow \quad Z = 27$

Hence element is cobalt.

Hence, the correct answer is (B).

127. First excited state is $n = 2$ and second excited state is $n = 3$.

Also,

$$E_n \propto \frac{1}{n^2}$$

$$\Rightarrow \quad \frac{E_2}{E_3} = \frac{9}{4}$$

Hence, the correct answer is (D).

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

$$\Rightarrow \quad \frac{1}{\lambda_1} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5R}{36}$$

$$\Rightarrow \quad \frac{1}{\lambda_2} = R\left(\frac{1}{1} - \frac{1}{4}\right) = R\left(\frac{3}{4}\right) = \frac{3}{4}R$$

$$\Rightarrow \quad \frac{\lambda_2}{\lambda_1} = \frac{5/36}{3/4} = \frac{5}{36} \times \frac{4}{3} = \frac{5}{27}$$

$$\Rightarrow \quad \lambda_2 = \frac{5}{27}\lambda_1$$

$$\Rightarrow \quad \lambda_2 = \frac{5}{27} \times 6563 \text{ Å} = 1215.4 \text{ Å}$$

Hence, the correct answer is (A).

129. $\frac{1}{\lambda_B} = R_H\left(\frac{1}{4} - \frac{1}{9}\right)$

$$\frac{\lambda_L}{\lambda_B} = \frac{\frac{5}{36}}{\frac{3}{4}} = \frac{5}{27}$$

Hence, the correct answer is (B).

130. Considering rotation of nucleus about common centre of mass of nucleus and electron, we get different values of wavelength depending on mass of nucleus.

Hence, the correct answer is (C).

132. For Balmer series

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

When $n_i \to \infty$, $\frac{1}{\lambda_{\text{min}}} = \frac{R}{4}$

$$\Rightarrow \quad \lambda_{\text{min}} = \frac{4}{R}$$

When $n_i = 3$, $\frac{1}{\lambda_{\text{max}}} = R\left(\frac{5}{36}\right)$

$$\Rightarrow \quad \lambda_{\text{max}} = \frac{36}{5R}$$

$$\Rightarrow \quad \frac{\lambda_{\text{min}}}{\lambda_{\text{max}}} = \frac{(4/R)}{(36/5R)} = \frac{20}{36}$$

$$\Rightarrow \quad \frac{\lambda_{\text{min}}}{\lambda_{\text{max}}} = \frac{5}{9}$$

Hence, the correct answer is (A).

133. $\frac{1}{\lambda} = Z^2 R_\infty\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For K_α line, $n_1 = 1$ and $n_2 = 2$

$$\Rightarrow \quad \frac{1}{\lambda} = Z^2 R_\infty\left(\frac{3}{4}\right)$$

$$\Rightarrow \quad Z = \sqrt{\frac{4}{3\lambda R_\infty}}$$

$$\Rightarrow \quad Z = 39.9 \simeq 40$$

Hence, the correct answer is (B).

134. $R = R_0 A^{\frac{1}{3}}$

$$\Rightarrow \quad \frac{R}{R_0} = A^{\frac{1}{3}}$$

$$\Rightarrow \quad \log_e\left(\frac{R}{R_0}\right) = \frac{1}{3}\log_e A$$

$$\Rightarrow \quad y = \frac{1}{3}x$$

A straight line passing through origin with slope $\frac{1}{3}$

Hence, the correct answer is (D).

135. Since in Rutherford experiment

$$N \propto \frac{1}{\sin^4\left(\frac{\phi}{2}\right)}$$

$$\Rightarrow \quad \frac{N_{90}}{N_{60}} = \frac{\sin^4(30)}{\sin^4(45)}$$

$$\Rightarrow \quad \frac{N_{90}}{N_{60}} = \frac{\frac{1}{16}}{\frac{1}{4}}$$

$$\Rightarrow \quad N_{60} = 100$$

Hence, the correct answer is (A).

136. Energy of n^{th} orbit in H-atom is same as the energy of $3n^{th}$ state in Li^{++}.

So, $3 \to 1$ transition in H-atom would give same energy as the $3(3) \to 3(1) = 9 \to 3$ transition in Li^{++}.

Hence, the correct answer is (D).

137. Total Energy $= -(K.E.) = -13.6$ eV

Hence, the correct answer is (C).

138. $$\frac{\lambda_1}{\lambda_2} = \frac{\left(\frac{1}{9} - \frac{1}{16}\right)}{\left(\frac{1}{1} - \frac{1}{4}\right)} = \frac{7}{108}$$

Hence, the correct answer is (D).

139. $R_n \propto n^2$

$\Rightarrow \quad A_n \propto n^4$

Hence

$$\frac{A_2}{A_1} = \frac{n_2^4}{n_1^4} = \frac{16}{1}$$

Hence, the correct answer is (D).

140. λ_{min} corresponds to the maximum frequency, which occurs when all the electron's kinetic energy goes to photon.

$$\lambda_{min} = \frac{hc}{eV_0}$$

$$\Rightarrow \quad \lambda_{min} = \frac{1.24 \times 10^{-6}}{10^4} = 1.24 \times 10^{-10} \text{ m}$$

Hence, the correct answer is (A).

141. $$\frac{1}{\lambda} = R_H\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\Rightarrow \quad \lambda = \frac{36}{5R_H} = 6563 \text{ Å}$$

Hence, the correct answer is (A).

142. λ_{K_α} will not change.

Hence, the correct answer is (B).

143. For an elastic collision to take place there must be no loss in the energy of electron. The hydrogen atom will absorb energy from the colliding electron only if it can go from ground state to first excited state i.e. from $n = 1$ to $n = 2$ state. For this Hydrogen atom must absorb energy

$$E_2 - E_1 = -3.4 - (-13.6) = 10.2 \text{ eV}.$$

So, if the electron possesses energy less than 10.2 eV it would never loose it and hence collision would be elastic.

Hence, the correct answer is (B).

144. When number of electrons increases, then number of photons emitted also increases, thereby increasing the intensity. Energy, wavelength and frequency of photon are related to potential difference.

Hence, the correct answer is (A).

145. Continuous X-rays are produced by the deceleration of electrons whose K.E. depends on the potential difference. Discrete X-rays are produced when an electron makes transition between energy levels which have fixed values and hence does not depend on potential difference.

Hence, the correct answer is (B).

147. $$\frac{mv^2}{r} = \frac{3q^2}{4\pi\varepsilon_0 r^2}$$

$$\Rightarrow \quad mvr = \frac{3q^2}{4\pi\varepsilon_0 v}$$

According to Bohr's Quantisation rule, we have

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

For $n = 1$, we get

$$\frac{h}{2\pi} = \frac{3q^2}{4\pi\varepsilon v}$$

$$\Rightarrow \quad v = \frac{3q^2}{2\varepsilon_0 h}$$

Hence, the correct answer is (A).

148. $$L_1 = (1)\frac{h}{2\pi} \qquad \ldots(1)$$

{Using Bohr's Quantisation Rule}

In the first excited state of Li

$$L_2 = (2)\frac{h}{2\pi} \qquad \ldots(2)$$

$$\Rightarrow \quad \frac{L_2}{L_1} = 2$$

Hence, the correct answer is (C).

149. For $2 \to 1$ transition energy emitted is $\Delta E = (10.2)Z^2$ eV, which is maximum.

Hence, the correct answer is (C).

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

$n_f = 2$, $n_i = 3$ and $R = 1.097 \times 10^7 \text{ m}^{-1}$

$\Rightarrow \quad \lambda = 656$ nm

Hence, the correct answer is (A).

151. $\dfrac{e^2}{2h\varepsilon_0 c}$ = Fine structure constant $(\alpha) = \dfrac{1}{137}$

and $[\alpha] = M^0L^0T^0$

Hence, the correct answer is (C).

152. $\dfrac{1}{\lambda} = R\left[\dfrac{1}{n_f^2} - \dfrac{1}{n_i^2}\right]$

For Balmer Series, $n_f = 2$ and $n_i = 3, 4, 5....$

$$\frac{1}{\lambda} = 1.097\times10^7\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\Rightarrow \frac{1}{\lambda} = 1.097\times10^7\left[\frac{5}{36}\right]$$

$$\Rightarrow \lambda = \frac{36}{5}\times\frac{10^{-7}}{1.097}\ \text{m}$$

$$\Rightarrow \lambda = 6.56\times10^{-7}\ \text{m}$$

$$\Rightarrow \lambda = 656\times10^{-9}\ \text{m}$$

This wavelength falls in visible range.
Hence, the correct answer is (C).

153. The series in U-V region is Lymen series. Longest wavelength corresponds to minimum energy which occurs in transition from $n = 2$ to $n = 1$.

$$\Rightarrow 122 = \frac{1/R}{\left(\frac{1}{1^2} - \frac{1}{2^2}\right)} \quad ...(1)$$

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

$$\Rightarrow \lambda = \frac{1/R}{\left(\frac{1}{3^2} - \frac{1}{\infty}\right)} \quad ...(2)$$

Solving equations (1) and (2), we get

$$\lambda = 823.5\ \text{nm}$$

Hence, the correct answer is (B).

154. $V = \dfrac{12400}{0.1} = 124000\ \text{V} = 124\ \text{kV}$

Hence, the correct answer is (C).

155. $E = 13.6Z^2 = 13.6\times(11)^2\ \text{eV} = 13.6\times121\ \text{eV}$

$\Rightarrow E = 1645.6\ \text{eV} \approx 1.65\ \text{keV}$

Hence, the correct answer is (D).

156. $\lambda_n = \dfrac{(2\pi r)}{n}$

$\Rightarrow \lambda_n \propto n \qquad \{\because r \propto n^2\}$

and $J_n \propto n \qquad \left\{\because J_n = \dfrac{nh}{2\pi}\right\}$

$\Rightarrow \lambda_n \propto J_n$

Hence, the correct answer is (A).

157. $\Delta E = E_i - E_f$

$$\Rightarrow \Delta E = mZ^2E_0\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\Rightarrow \Delta E = (207)(82)^2\times13.6\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\Rightarrow \Delta E = (19\ \text{MeV})\times\frac{3}{4} = 14\ \text{MeV}$$

Hence, the correct answer is (B).

158. After absorbing a photon of energy 12.1 eV electron jumps from ground state $(n = 1)$ to second excited state $(n = 3)$. Therefore, change in angular momentum is

$$\Delta L = L_3 - L_1$$

$$\Rightarrow \Delta L = 3\left(\frac{h}{2\pi}\right) - \frac{h}{2\pi} = \frac{h}{\pi}$$

$$\Rightarrow \Delta L = \frac{6.6\times10^{-34}}{3.14}\ \text{Js} = 2.11\times10^{-34}\ \text{Js}$$

Hence, the correct answer is (C).

159. A rough estimate of size of the nucleus is given by the distance of closest approach r_0 of an α-particle incident head-on on a nucleus of charge Ze.

Since $r_0 = \dfrac{2Ze^2}{4\pi\varepsilon_0 K_\alpha}$, where $K_\alpha = 6\ \text{MeV}$

$$\Rightarrow r_0 = \frac{2\times100\times(1.6\times10^{-19})^2\times9\times10^9}{6\times10^6\times1.6\times10^{-19}}$$

$$\Rightarrow r = 5\times10^{-14}\ \text{m}$$

Hence, the correct answer is (B).

160. $r_{n+1} - r_n = r_{n-1}$

Since $r \propto n^2$

$$\Rightarrow (n+1)^2 - n^2 = (n-1)^2$$

$$\Rightarrow n^2 + 2n + 1 - n^2 = n^2 - 2n + 1$$

$$\Rightarrow n^2 - 4n = 0$$

$$\Rightarrow n(n-4) = 0$$

Since $n \neq 0$

$$\Rightarrow n = 4$$

Hence, the correct answer is (D).

161. $\dfrac{E_{2n} - E_n}{E_{4n} - E_{2n}} = \dfrac{\dfrac{E_1}{4n^2} - \dfrac{E_1}{n^2}}{\dfrac{E_1}{16n^2} - \dfrac{E_1}{4n^2}} = 4 = \text{constant}$

Hence, the correct answer is (D).

162. Since $N \propto \dfrac{1}{\sin^4\left(\dfrac{\theta}{2}\right)}$

$$\Rightarrow \frac{N_{120^\circ}}{N_{60^\circ}} = \frac{\sin^4(30^\circ)}{\sin^4(60^\circ)} = \frac{\frac{1}{16}}{\frac{9}{16}}$$

$$\Rightarrow N_{120^\circ} = \left(\frac{1}{9}\right)N_{60^\circ} = \frac{9\times10^6}{9} = 10^6$$

Hence, the correct answer is (C).

163. Since, $\Delta E = K\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right) = \dfrac{hc}{\lambda}$

In the given diagram, emission from $n=4 \to n=2$ would give photon of maximum energy (shortest wavelength) and $n=4 \to n=3$ transition would give photon of minimum energy (longest wavelength).

Hence, the correct answer is (C).

164. Since $E_0 = -\dfrac{me^4Z^2}{8\varepsilon_0^2h^2} = -13.6\left(\dfrac{Z^2}{n^2}\right)$ eV

When $m \to 2m$

$$\Rightarrow E_0 \to 2E_0 = -27.2 \text{ eV}$$

Also, $a_0 = \dfrac{h^2\varepsilon_0}{\pi me^2}$

When $m \to 2m$

$$\Rightarrow a_0 \to \frac{a_0}{2} = 0.27 \text{ Å}$$

Hence, the correct answer is (A).

165. Energy of photon is

$$E = 13.6\left(1 - \frac{1}{25}\right) \text{ eV}$$

$$\Rightarrow E = 13 \text{ eV}$$

Since, momentum is conserved, so we have

$$\frac{E}{c} = mv$$

$$\Rightarrow v = \frac{E}{mc}$$

$$\Rightarrow v = \frac{13\times1.6\times10^{-19}}{1.67\times10^{-27}\times3\times10^8} = 4 \text{ ms}^{-1}$$

Hence, the correct answer is (C).

166. $F = \dfrac{mv^2}{r} = \dfrac{Ze^2}{4\pi\varepsilon_0 r^2}$

Since $v \propto \dfrac{1}{n}$ and $r \propto n^2$

$$\Rightarrow F \propto \frac{1}{n^4}$$

Hence, the correct answer is (D).

167. Because radius of nth orbit is equal to $r_n = n^2r_0$ where $r_0 \simeq 0.529$ Å

$$\Rightarrow \frac{0.0001}{2}\times10^{-3} = (0.5\times10^{-10})n^2$$

$$\Rightarrow n^2 = 1000$$

$$\Rightarrow n \simeq 31$$

Hence, the correct answer is (D).

168. $\lambda_{max} = 2d\sin(90^\circ) = 2d$

Since, $d = 10^{-7}$ cm $= 10^{-9}$ m $= 10$ Å

$$\Rightarrow \lambda_{max} = 2d = 20 \text{ Å}$$

Hence, the correct answer is (D).

170. The short limit of the Balmer series is given by

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

$$\Rightarrow R = \frac{4}{\lambda} = \left(\frac{4}{3646}\right)\times10^{10} \text{ m}^{-1}$$

Further the wavelengths of the K_α series are given by the relation

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

The maximum wave number corresponds to $n \to \infty$ and therefore, we must have

$$\frac{1}{\lambda} = R(Z-1)^2$$

$$\Rightarrow (Z-1)^2 = \frac{1}{R\lambda} = \frac{3646\times10^{-10}}{4\times1\times10^{-10}} = 911.5$$

$$\Rightarrow (Z-1) = \sqrt{911.5} \cong 30.2$$

$$\Rightarrow Z = 31.2 \cong 31$$

So, the atomic number of the element concerned is 31. The element having atomic number $Z = 31$ is Gallium.

Hence, the correct answer is (B).

171. For incident electron, we have

$$\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2meV}}$$

For shortest wavelength of X-rays, we have

$$\lambda_2 = \frac{hc}{eV}$$

$$\Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{1}{c}\sqrt{\frac{eV}{2m}}$$

Substituting the values, we get

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

Hence, the correct answer is (D).

Multiple Correct Choice Type Questions

1. Since $L = \frac{nh}{2\pi} = \frac{3h}{2\pi}$

$$\Rightarrow \quad n = 3$$

Since, $r_n = a_0 \frac{n^2}{Z}$

$$\Rightarrow \quad 4.5a_0 = a_0 \frac{n^2}{Z}$$

$$\Rightarrow \quad Z = 2$$

Possible transitions are $3 \to 2$, $3 \to 1$ and $2 \to 1$

For $3 \to 2$, we have

$$\frac{1}{\lambda} = R(2)^2\left(\frac{1}{4} - \frac{1}{9}\right) = 4R\left(\frac{9-4}{36}\right) = \frac{5R}{9}$$

$$\Rightarrow \quad \lambda = \frac{9}{5R}$$

For $3 \to 1$, we have

$$\frac{1}{\lambda} = R(2)^2\left(1 - \frac{1}{9}\right) = 4R\left(\frac{8}{9}\right) = \frac{32R}{9}$$

$$\Rightarrow \quad \lambda = \frac{9}{32R}$$

For $2 \to 1$, we have

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

$$\Rightarrow \quad \lambda = \frac{1}{3R}$$

Hence, (A) and (C) are correct.

2. $r = \frac{mv}{qB} = \frac{\sqrt{2mE}}{qB}$

$$\Rightarrow \quad r \propto \frac{\sqrt{m}}{q}$$

$$\Rightarrow \quad \text{Deflection} \propto \frac{q}{\sqrt{m}}$$

Hence, (A) and (C) are correct.

3. Let electron jump from $n_1 \to n_2$.

So $\Delta L = (n_2 - n_1)\frac{h}{2\pi}$

(According to Bohr's Quantisation Rule)

Since, n_1 and n_2 are integers $(n_1, n_2 > 1)$, so $n_2 - n_1$ is also an integral value and hence ΔL must be an integral multiple of $\frac{h}{2\pi}$.

Hence, (B) and (C) are correct.

4. $U \propto \frac{1}{r} \propto \frac{1}{n^2}$

$$K \propto \frac{1}{r} \propto \frac{1}{n^2}$$

$$v \propto \frac{1}{n} \text{ and}$$

$$L \propto n$$

Hence, (B) and (C) are correct.

5. In Bohr's model of Hydrogen atom

$$R \propto n^2$$

$$V \propto \frac{1}{n}$$

$$T \propto n^3 \text{ and } E \propto \frac{1}{n^2}$$

$$\Rightarrow \quad VR \propto n$$

$$\Rightarrow \quad TE \propto n$$

$$\Rightarrow \quad \frac{T}{R} \propto n$$

$$\Rightarrow \quad \frac{V}{E} \propto n$$

Hence, (A), (C) and (D) are correct.

6. Characteristic X-rays depend upon the atomic number Z, so

$$\lambda_1 = \lambda_2 = \lambda_3$$

OR $\lambda_2 = \sqrt{\lambda_1 \lambda_3}$

Hence, (A) and (D) are correct.

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

$$\Rightarrow \quad \frac{Ke^2}{r^4} = \frac{mv^2}{r} \qquad \text{...(2)}$$

According to Bohr's Quantisation Rule, we have

$$mvr = \frac{nh}{2\pi} \quad \ldots(3)$$

From (2) and (3), we get

$$r = \left(\frac{4\pi^2 e^2 K}{h^2}\right)\frac{m}{n^2} = K_1\left(\frac{m}{n^2}\right) \quad \ldots(4)$$

Since total energy E is half the potential energy, so we have

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

So, total energy is $E \propto n^6$ and $E \propto m^{-3}$

Hence, (A) and (B) are correct.

8. Since, $\frac{hc}{\lambda} = \Delta E$

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

$$\lambda_{\min} = \frac{hc}{\Delta E_{\max}} \text{ and } \lambda_{\max} = \frac{hc}{\Delta E_{\min}}$$

Emission will take place when transition takes place from $n = 3$ to $n = 1$

$$\Rightarrow \quad \lambda_{\min} = \frac{12400}{10(\text{eV})} = 1240\ \text{Å} = 1.24 \times 10^{-7}\ \text{m}$$

Absorption will take place when transition takes place from $n = 3$ to $n = 4$.

$$\Rightarrow \quad \lambda_{\max} = \frac{12400}{2(\text{eV})} = 6200\ \text{Å} = 6.2 \times 10^{-7}\ \text{m}$$

Lowest frequency photon that can ionise the atom will have to remove the electron from $n = 3$ state, so we have $E = 15$ eV

$$\Rightarrow \quad 15 \times 1.6 \times 10^{-19} = 6.63 \times 10^{-31}\nu$$

$$\Rightarrow \quad \nu = 3.62 \times 10^{15}\ \text{Hz}$$

The total number of ways of de-excitation of atom to ground state is 2.

Hence, (A), (B) and (C) are correct.

9. Since reduced mass is

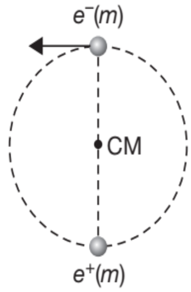
$$\mu = \frac{m_1 m_2}{m_1 + m_2} = \frac{m}{2}$$

Now, energy is directly proportional to mass, so

$$E_0 \propto m$$

$$\Rightarrow \quad E \propto \mu \propto \frac{m}{2}$$

$$\Rightarrow \quad \frac{E}{E_0} = \frac{1}{2}$$



Since, $E_0 = R_0 hc$

So, Rydberg constant is

$$R_0 = \frac{E_0}{hc} \propto m$$

$$\Rightarrow \quad R \propto \mu$$

$$\Rightarrow \quad \frac{R}{R_0} = \frac{\mu}{m} = \frac{1}{2}$$

Radius of orbit is

$$r = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2 Z}$$

So, for $n = 1$, $Z = 1$, we have

$$r_0 = \frac{h^2 \varepsilon_0}{\pi m e^2} \propto \frac{1}{m}$$

$$\Rightarrow \quad r \propto \frac{1}{\mu}$$

$$\Rightarrow \quad \frac{r}{r_0} = \frac{m}{\mu} = 2$$

Velocity of electron in first orbit is

$$v = \frac{e^2}{2h\varepsilon_0}$$

which is independent of mass, hence for positronium atom and hydrogen atom velocity of electron is same in both cases.

Hence, (A), (B), (C) and (D) are correct.

10. Under normal conditions, the total energy (E), kinetic energy (K) and potential energy (U) are

$$\left.\begin{aligned} E_1 &= -13.6\ \text{eV} \\ K_1 &= 13.6\ \text{eV} \\ U_1 &= -27.2\ \text{eV} \end{aligned}\right] \text{ for ground state}$$

$$\left.\begin{aligned} E_2 &= -3.4\ \text{eV} \\ K_2 &= 3.4\ \text{eV} \\ U_2 &= -6.8\ \text{eV} \end{aligned}\right] \text{ for first excited state}$$

If PE in ground state is taken to be zero, then KE remains unchanged, however new PE and TE are increased by 27.2 eV.

So, for ground state, we have

$$E_1 = (-13.6 + 27.2)\ \text{eV} = 13.6\ \text{eV}$$

$$K_1 = 13.6\ \text{eV (same)}$$

$$U_1 = (-27.2 + 27.2)\ \text{eV} = 0\ \text{eV}$$

For first excited state, we have

$$E_2 = (-3.4 + 27.2)\ \text{eV} = 23.8\ \text{eV}$$

$$K_2 = 3.4 \text{ eV (same)}$$

$$U_2 = (-6.8 + 27.2) \text{ eV} = 20.4 \text{ eV}$$

Hence, (A), (B), (C) and (D) are correct.

11. Ground state is $n = 1$

So, first excited state is $n = 2$

$$KE = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r} \qquad \{\text{for } Z = 1\}$$

$$\Rightarrow \quad KE = \frac{14.4 \times 10^{-10}}{2r} \text{ eV}$$

Since, $r = 0.53n^2$ Å

$$\Rightarrow \quad (KE)_1 = \frac{14.4 \times 10^{-10}}{2 \times 0.53 \times 10^{-10}} \text{ eV} = 13.58 \text{ eV}$$

$$\Rightarrow \quad (KE)_2 = \frac{14.4 \times 10^{-10}}{2 \times 0.53 \times 10^{-10} \times 4} \text{ eV} = 3.39 \text{ eV}$$

$\Rightarrow$ KE decreases by 10.2 eV

Now $PE = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} = -\frac{14.4 \times 10^{-10}}{r}$ eV

$$\Rightarrow \quad (PE)_1 = -\frac{14.4 \times 10^{-10}}{0.53 \times 10^{-10}} \text{ eV} = -27.1 \text{ eV}$$

$$\Rightarrow \quad (PE)_2 = -\frac{14.4 \times 10^{-10}}{0.53 \times 10^{-10} \times 4} = -6.79 \text{ eV}$$

$\Rightarrow$ PE increases by 20.4 eV

Now Angular momentum is $L = mvr = \frac{nh}{2\pi}$

$$\Rightarrow \quad L_2 - L_1 = \frac{h}{2\pi} = \frac{6.6 \times 10^{-34}}{6.28} = 1.05 \times 10^{-34} \text{ Js}$$

Hence, (B), (C) and (D) are correct.

13. Since, $v = CRZ^2\left(\frac{1}{n_2{}^2} - \frac{1}{n_1{}^2}\right)$

$$\Rightarrow \quad v_{3\to 2} = (3 \times 10^8)(1.1 \times 10^7)(1)\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\Rightarrow \quad v_{3\to 2} = (3.3 \times 10^{15})\left(\frac{5}{36}\right)$$

$$\Rightarrow \quad v_{3\to 2} = \frac{16.5}{36} \times 10^{15} = 4.6 \times 10^{14} \text{ Hz}$$

Similarly, for transition from 3 to 1, we have

$$v_{3\to 1} = (3 \times 10^8)(1.1 \times 10^7)\left(1 - \frac{1}{9}\right)$$

$$\Rightarrow \quad v_{3\to 1} = 2.9 \times 10^{15} \text{ Hz}$$

Please note that (D) is incorrect as it says "must be" because from second excited state i.e., $n = 3$, photons are emitted for electron transitions from $3 \to 2$, $2 \to 1$, $3 \to 1$.

Hence, (A) and (C) are correct.

14. $E \propto \frac{1}{r^2} \propto \frac{1}{n^2}$ ...(1)

$$P \propto v \propto \frac{1}{n} \qquad \text{...(2)}$$

$$r \propto n^2 \qquad \text{...(3)}$$

$$\Rightarrow \quad PEr \propto \frac{1}{n}$$

$$\Rightarrow \quad \frac{P}{E} \propto n$$

$$\Rightarrow \quad Er \propto n^\circ$$

$$\Rightarrow \quad Pr \propto n$$

Hence, (A), (B), (C) and (D) are correct.

15. Actually, in the ground state, we have

$KE = +13.6$ eV

$PE = -27.2$ eV and

$TE = -13.6$ eV

In the first excited state, we have

$KE = +3.4$ eV, $PE = -6.8$ eV, $TE = -3.4$ eV

Now PE and TE both will be increased by

$13.6 - (-27.2) = 40.8$ eV

KE remains unchanged being independent of reference.

Hence, (A), (B) and (D) are correct.

16. Since, $r \propto \frac{1}{m}$

and $E_n \propto m$

For an orbit, $mvr = \frac{nh}{2\pi}$ is a constant, because $n =$ constant

$\Rightarrow \quad v \propto m$

Hence, (B) and (D) are correct.

17. From $n = 3$ to $n = 2$

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

Since, $E = \frac{hc}{\lambda}$

$$\Rightarrow \quad E \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For a photon of energy E, momentum p is

$$p=\frac{E}{v}, \text{ where } v \text{ is the speed of light.}$$

$$\Rightarrow \quad \frac{\lambda_1}{\lambda_2}=\frac{\frac{1}{1^2}-\frac{1}{2^2}}{\frac{1}{2^2}-\frac{1}{3^2}}=\frac{\frac{3}{4}}{\frac{5}{36}}$$

$$\Rightarrow \quad \frac{\lambda_1}{\lambda_2}=a=\frac{27}{5}$$

Further, $\frac{E_1}{E_2}=\frac{\frac{hc}{\lambda_1}}{\frac{hc}{\lambda_2}}=\frac{\lambda_2}{\lambda_1}=\frac{5}{27}$

$$\Rightarrow \quad c=\frac{5}{27}=\frac{1}{a}$$

So, $b=\frac{p_1}{p_2}=\frac{E_1}{E_2}=c=\frac{5}{27}$

Hence, (A), (C) and (D) are correct.

18. $\Delta E=204=13.6\ Z^2\left(\frac{1}{1}-\frac{1}{4n^2}\right)$

$$\Rightarrow \quad 40.8=13.6\ Z^2\left(\frac{1}{n^2}-\frac{1}{4n^2}\right)$$

Satisfied for, $Z=4$ and $n=2$

Hence, (B) and (D) are correct.

19. $v \propto \frac{1}{n}$ $\quad \left\{\because v=\left(\frac{e^2}{2h\varepsilon_0}\right)\frac{Z}{n}\right\}$

$$E \propto \frac{1}{n^2}$$

$$r \propto n^2$$

$\Rightarrow \quad \frac{E}{v^2}$, Er, v^2r are independent of n.

Hence, (B), (C) and (D) are correct.

20. Intensity of incident light may increase by decreasing distance of source without increasing frequency.
Hence, (B) and (C) are correct.

21. Since, $E_n=-(13.6)\left(\frac{Z^2}{n^2}\right)$ eV

$$E_1=-13.6 \text{ eV for } Z=1 \text{ and } n=1$$

Similarly, for $Z=n$, we have

$$E=E_1=-13.6 \text{ eV}$$

i.e., for second orbit of He^+ and for third orbit of Li^{++}, we have energy equal to -13.6 eV

Hence, (A) and (D) are correct.

22. Let the transition in He^+ ion be from level $a \to b$ and that in H atom be from $p \to q$. Then $\lambda_1=\lambda_2$ gives

$$4\left(\frac{1}{b^2}-\frac{1}{a^2}\right)=\left(\frac{1}{q^2}-\frac{1}{p^2}\right)$$

$$\Rightarrow \quad \frac{4}{b^2}-\frac{4}{a^2}=\frac{1}{q^2}-\frac{1}{p^2}$$

This equation will be satisfied when

$$a=2p \text{ and } b=2q$$

So, a and b are even integers greater than 1, satisfied by (A) and (D).

Hence, (A) and (D) are correct.

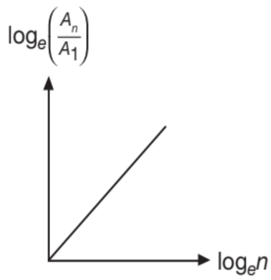
23. $E=E_0\frac{Z^2}{n^2}$, $r=a_0\frac{n^2}{Z}$, $v=v_0\frac{Z}{n}$

where E_0 is energy of electron in ground state, a_0 is radius of ground state orbit and v_0 is velocity of electron in ground state.

Hence, (C) and (D) are correct.

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

$$\Rightarrow \quad A=\pi r^2=\pi\frac{a_0{}^2n^4}{Z^2}$$



$$\Rightarrow \quad A_n=A_1n^4$$

$$\Rightarrow \quad \log_e A_n=\log A_1+\log n^4$$

$$\Rightarrow \quad \log_e A_n-\log_e A_1=4\log_e n$$

$$\Rightarrow \quad \log_e\left(\frac{A_n}{A_1}\right)=4\log_e N$$

So, the graph will be a straight line passing through origin having a slope of four units at all the points.
Hence, (A), (B) and (D) are correct.

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

Since, $E_1=-54.4$ eV

$$\Rightarrow \quad -\frac{13.6Z^2}{(1)^2}=-54.4$$

$\Rightarrow \quad Z^2 = 4$

$\Rightarrow \quad Z = 2$

Also, 40.8 eV is the difference between two energy levels $n=2$ and $n=1$.

Also, the electron cannot fall from the ground state and hence cannot emit photon. So,

$$-E = K \text{ and } E = \frac{U}{2}$$

Hence, (B), (C) and (D) are correct.

28. Since, $p = mv$ where $v \propto \frac{1}{n}$

$\Rightarrow \quad p \propto \frac{1}{n}$

Since, $KE \propto \frac{1}{r}$ and $r \propto n^2$

$\Rightarrow \quad KE \propto \frac{1}{n^2}$

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

$\Rightarrow \quad L \propto n$

Hence, (A), (C) and (D) are correct.

29. Any transition in the Balmer series must end up at $n=2$. This must be followed by the transition from $n=2$ to $n=1$ by emitting a photon of energy 10.2 eV. This 10.2 eV photon corresponds to a wavelength of about 122 nm, which belongs to the Lyman series.

Hence, (B) and (C) are correct.

30. According to Ritz Combination Principle, we have

$E_3 = E_1 + E_2$

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

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

$\Rightarrow \quad \frac{c}{\lambda_3} = \frac{c}{\lambda_1} + \frac{c}{\lambda_2} \qquad \left\{\because \nu = \frac{c}{\lambda}\right\}$

$\Rightarrow \quad \lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$

Hence, (B) and (C) are correct.

Reasoning Based Questions

1. Cut-off wavelength depends on the accelerating voltage, not the characteristic wavelengths. Further, approximately 2% kinetic energy of the electrons is utilised in producing X-ray. Rest 98% is lost in heat.

Hence, the correct answer is (B).

2. According to classical electromagnetic theory, an accelerated charge continuously emits radiation. As electrons revolving in circular paths are constantly experiencing centripetal acceleration, hence, they will be losing their energy continuously and the orbital radius will go on decreasing and form spirals and finally the electron will fall on the nucleus.

Hence, the correct answer is (D).

4. $\frac{1}{\lambda} \propto R \propto \mu$, where μ is the reduced mass of the system.

$\Rightarrow \quad \mu_D > \mu_H$

$\Rightarrow \quad R_D > R_H$

$\Rightarrow \quad \lambda_D < \lambda_H$

In the centre of mass frame both the nucleus and the electron revolve about the common axis passing through the centre of mass.

Hence, the correct answer is (D).

5. Since $\lambda = \frac{hc}{\Delta E}$, so the wavelength will be inversely proportional to the energy difference between the levels. The energy difference is more when the transition takes place from $n \to \infty$ to $n=2$ than when the transition takes place from $n=2$ to $n=1$.

Hence, the correct answer is (C).

7. Both Statement-1 & Statement-2 are correct & Statement-2 is the correct explanation of Statement-1.

Hence, the correct answer is (A).

8. Both Statement-1 and Statement-2 are true and Statement-2 is the correct explanation of Statement-1.

Hence, the correct answer is (A).

9. Total energy is negative because electron is bound to the atom due to coulomb attraction and in the bound system energy is negative.

Hence, the correct answer is (B).

10. At outermost orbit total energy is zero and electron is free from the influence of the nucleus of the atom.

Hence, the correct answer is (B).

11. Speed of electron in H like atom is $v_{H\text{ Like}} = \left(\frac{e^2}{2h\varepsilon_0}\right)\frac{Z}{n}$

Hence, the correct answer is (C).

12. No. of lines in emission spectrum is $N = \frac{n(n-1)}{2}$

$$N = \frac{4(4-1)}{2} = 6$$

and this depends on number of energy levels available for transition.

Hence, the correct answer is (C).

13. Lyman series - its energy is in the ultra violet region
Balmer series - its energy is in visible region
Hence, the correct answer is (C).

15. Statement–1 is false, the penetration power depends upon accelerating potential.
Statement–2 is true, increasing current increases the temperature of filament causing it to emit more electrons.
Hence, the correct answer is (D).

17. $hf_1 = 0 - E_2$ and

$hf_2 = 0 - E_3$

$\Rightarrow \quad h(f_1 - f_2) = E_3 - E_2$

So, Statement-1 and Statement-2 both are correct and Statement-2 correctly explains Statement-1.
Hence, the correct answer is (A).

Linked Comprehension Type Questions

1. $U = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r}$, where $q_1 = +2e$, $q_2 = 82e$

$\Rightarrow \quad U = \dfrac{(9\times10^9)(2e)(82e)}{6.5\times10^{-14}} = 5.82\times10^{-13}$ J

$\Rightarrow \quad U = 3.63$ MeV

Hence, the correct answer is (C).

2. Applying Law of Conservation of Energy, we get

$K_1 + U_1 = K_2 + U_2$

$\Rightarrow \quad K_1 + 0 = 0 + 3.63$ MeV

$\Rightarrow \quad K_1 = 3.63$ MeV

Hence, the correct answer is (C).

3. Total energy of the hydrogen like atom (atomic number Z) in the n^{th} Bohr orbit is

$$E_n = -\left(\frac{me^4}{8\varepsilon_0^2 h^2}\right)\frac{Z^2}{n^2} = -(13.6)\frac{Z^2}{n^2} \text{ eV}$$

$\Rightarrow \quad E_2 = -\dfrac{13.6}{4}Z^2 = -3.4Z^2$ eV

and $E_3 = -\dfrac{13.6}{9}Z^2 = -1.5Z^2$ eV

Since $E_3 - E_2 = 68$ eV

$\Rightarrow \quad E_3 - E_2 = -1.5Z^2 - (-3.4Z^2)$

$\Rightarrow \quad 1.9Z^2 = 68$

$\Rightarrow \quad Z = 6$

Hence, the correct answer is (D).

4. Total energy in the first Bohr orbit is

$E_1 = -13.6\times Z^2$ eV

$\Rightarrow \quad E_1 = -13.6\times 36 \text{ eV} = -489.6$ eV

Since $KE = -(TE)$

So, KE of electron in the first Bohr orbit is

$KE = -\text{Total energy} = +489.6$ eV

Hence, the correct answer is (C).

5. Energy required to eject the electron from the first Bohr orbit E_1 to infinity $(E_\infty \to 0)$ is

$\Delta E = E_\infty - E_1 = 489.6$ eV

$\Rightarrow \quad \lambda = \dfrac{12375}{489.6}$

$\Rightarrow \quad \lambda = 25.28$ Å

Hence, the correct answer is (B).

6. $eV = 3\times10^{-15}$

$\Rightarrow \quad V = \dfrac{3\times10^{-15}}{1.6\times10^{-19}} = 1.875\times10^4$ V

Hence, the correct answer is (A).

7. $\Delta E = 3\times10^{-15} - 0.3\times10^{-15}$ J

$\Rightarrow \quad \Delta E = 2.7\times10^{-15}$ J

Hence, the correct answer is (C).

8. The difference of the energy will be gained by the emitted electron as kinetic energy, so

$\text{KE} = 2.7\times10^{-15} - 3\times10^{-17}$

$\Rightarrow \quad \text{KE} = 2.67\times10^{-15}$ J

Hence, the correct answer is (D).

9. If n_E is the number of photons with energy E, then the distribution of n_E is given by

$$P(n_E) \approx \frac{I(E)}{E} = E^4 e^{-\frac{E}{k_B T}}$$

The most probable energy E_m of photons satisfies the equation

$$\left.\frac{dP}{dE}\right|_{E=E_m} = \left(4E^3 - \frac{E^4}{k_B T}\right)e^{-\frac{E}{k_B T}} = 0$$

$\Rightarrow \quad E_m = 4KT$

Hence, the correct answer is (D).

10. The Balmer lines of hydrogen are emitted when electrons transit from energy levels of $n > 3$ to that of $n = 2$. Thus, the maximum energy of the Balmer line

photons is when the electron makes transition from $n_i \to \infty$ to $n_f = 2$. So, we have

$$\Delta E_{max} = 0 - (-3.4) = 3.4 \text{ eV}$$

Hence, the correct answer is (B).

11. Given that the human eye is most sensitive to sunlight, the visible light is the most probable frequency band of the light emitted by the sun, and the visible light corresponds to the frequency range of the Balmer lines, the surface temperature of the Sun is given by

$$E_m = 4k_B T = 3.4 \text{ eV}$$

$$\Rightarrow \quad T = \frac{3.4}{4k_B} \text{ eV} = 1.06 \times 10^4 \text{ K}$$

Hence, the correct answer is (A).

12. $\sqrt{\frac{m^{-3} \times C^2 \times Nm^{-2}}{Kg \times C^2}} = \sqrt{s^{-2}}$ $\quad \{N = \text{kg ms}^{-2}\}$

Hence, the correct answer is (C).

13. $\lambda = \frac{2\pi C}{\omega}$

$$\Rightarrow \quad \lambda = \frac{2\pi C}{\sqrt{\frac{Ne^2}{m\varepsilon_0}}} \approx 600 \text{ nm}$$

Hence, the correct answer is (B).

14. The correct answer is (C).

15. The correct answer is (A).

16. The correct answer is (C).

17. The correct answer is (C).

Combined solution of 14, 15, 16 & 17

When hydrogen atom is excited, then we have

$$eV = E_0\left(\frac{1}{1} - \frac{1}{n^2}\right) \quad \ldots(1)$$

When ion is excited, then

$$eV = E_0 Z^2\left(\frac{1}{2^2} - \frac{1}{n_1^2}\right) \quad \ldots(2)$$

Wavelength of emitted light is

$$\frac{hc}{\lambda_1} = E_0\left(\frac{1}{1} - \frac{1}{n^2}\right) \quad \ldots(3)$$

$$\frac{hc}{\lambda_2} = E_0 Z^2\left(\frac{1}{1} - \frac{1}{n_1^2}\right) \quad \ldots(4)$$

Further it is given that

$$\frac{\lambda_1}{\lambda_2} = \frac{5}{1} \quad \ldots(5)$$

Solving the above equations, we get

$$Z = 2,\ n = 2,\ n_1 = 4 \text{ and } V = 10.2 \text{ V}$$

Energy of emitted photon by the hydrogen atom is

$$\Delta E = E_2 - E_1 = 10.2 \text{ eV}$$

and by the ion is

$$\Delta E' = E_4 - E_1 = (13.6)(2)^2\left(1 - \frac{1}{16}\right) = 51 \text{ eV}$$

Hence, the correct answer is (C).

18. $P = (1\%) \times 40 \times 10^3 \times 10 \times 10^{-3}$

$$\Rightarrow \quad P = 4 \text{ W}$$

Hence, the correct answer is (C).

19. Total power is $P = VI = 40 \times 10^3 \times 10 \times 10^{-3}$

$$\Rightarrow \quad P_{total} = 400 \text{ W}$$

So, heat produced per second is

$$P_{total} - P_{emitted} = 400 - 4 = 396 \text{ W}$$

Hence, the correct answer is (B).

20. $\lambda_{min} = \frac{12400}{40 \times 1000} = 0.3 \text{ Å}$

Hence, the correct answer is (A).

21. $K_{max} = \frac{12400}{855} - 13.6 = 0.9 \text{ eV}$

Hence, the correct answer is (A).

22. H_α in Balmer series corresponds to $n = 3$ to $n = 2$

$$\Rightarrow \quad E_3 - E_1 = 13.6\left(1 - \frac{1}{9}\right) = 12.09 \text{ eV}$$

Hence, the correct answer is (A).

23. Minimum wavelength for $n = 3$ to $n = 1$

$$\lambda = \frac{12400}{12.09} \approx 1026 \text{ Å} \approx 103 \text{ nm}$$

Hence, the correct answer is (B).

24. $F = -\frac{dU}{dr}$

$$\Rightarrow \quad F = \frac{4k}{r^5}$$

$$\Rightarrow \quad \frac{mv^2}{r} = \frac{4k}{r^5}$$

$$\Rightarrow \quad mv^2 = \frac{4k}{r^4} \quad \ldots(1)$$

Now, according to Bohr's Quantisation rule, we have

$$v = \frac{nh}{2\pi mr} \quad \ldots(2)$$

CHAPTER 2

$$\Rightarrow \quad m\left(\frac{n^2h^2}{4\pi^2m^2r^2}\right)=\frac{4k}{r^4}$$

$$\Rightarrow \quad \frac{n^2h^2}{4\pi^2m}=\frac{4k}{r^2}$$

$$\Rightarrow \quad r^2=\frac{16\pi^2mk}{n^2h^2}$$

$$\Rightarrow \quad r=\frac{4\pi}{nh}\sqrt{mk} \qquad \ldots(3)$$

Hence, the correct answer is (C).

25. Substituting (3) in (2), we get

$$v=\frac{nh}{2\pi m\left(\frac{4\pi}{nh}\sqrt{mk}\right)}$$

$$\Rightarrow \quad v=\frac{n^2h^2}{8\pi^2m\sqrt{mk}}$$

Hence, the correct answer is (D).

26. $KE=\frac{1}{2}mv^2=\frac{1}{2}m\left(\frac{n^4h^4}{64\pi^4m^3k}\right)$

$$\Rightarrow \quad KE=\frac{n^4h^4}{128\pi^4m^2k}$$

Hence, the correct answer is (B).

27. $PE=U=-\frac{k}{r^4}$

$$\Rightarrow \quad U=-\frac{k}{\left(\frac{16\pi^2mk}{n^2h^2}\right)^2}=-\frac{kn^4h^4}{256\pi^4m^2k^2}$$

$$\Rightarrow \quad U=-\frac{n^4h^4}{256\pi^4m^2k}$$

Hence, the correct answer is (D).

28. $TE=KE+PE$

$$\Rightarrow \quad TE=\frac{n^4h^4}{128\pi^4m^2k}-\frac{n^4h^4}{256\pi^4m^2k}$$

$$\Rightarrow \quad TE=\frac{n^4h^4}{256\pi^4m^2k}$$

Hence, the correct answer is (C).

29. The energy transitions for the given wavelengths are

$$\Delta E_1=\frac{12375}{\lambda_1}=\frac{12375}{1085}=11.40\text{ eV}$$

$$\Delta E_2=\frac{12375}{\lambda_2}=\frac{12375}{304}=40.70\text{ eV}$$

Total energy emitted $\Delta E=\Delta E_1+\Delta E_2=52.1$ eV

Hence, the correct answer is (C).

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

where, ΔE is the energy emitted

$$\Rightarrow \quad 52.1=13.6\times 2^2\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$$

$$\Rightarrow \quad n=5$$

Hence, the correct answer is (D).

31. The energy of electron after collision is

$$\Delta E=100-52.1=47.9\text{ eV}$$

Hence, the correct answer is (C).

32. Since, $\frac{1}{\lambda}=RZ^2\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$

$$\Rightarrow \quad \frac{hc}{\lambda}=(Rhc)Z^2\left(\frac{1}{4}-\frac{1}{9}\right)$$

where $Rhc=13.6$ eV

Also, given that $\frac{hc}{\lambda}=47.2$ eV

$$\Rightarrow \quad 47.2=13.6Z^2\left(\frac{5}{36}\right)$$

$$\Rightarrow \quad Z^2\approx 25$$

$$\Rightarrow \quad Z=5$$

Hence, the correct answer is (A).

33. Since, $r_n=(0.53)\frac{n^2}{Z}$ Å

$$\Rightarrow \quad r_1=\frac{0.53}{5}\text{ Å}$$

$$\Rightarrow \quad r_1=0.106\text{ Å}$$

Hence, the correct answer is (B).

34. Since, $E_2=\frac{E_1}{4}$

$$\Rightarrow \quad E_1=4E_2=4(-144)=-576\text{ eV}$$

So, ionization energy $=576$ eV

Hence, the correct answer is (B).

35. $E_1=-576$ eV

Hence, the correct answer is (D).

36. Since, $E_n = -\frac{E_1 z^2}{n^2}$

So, graph of E_n vs $\frac{1}{n^2}$ is a straight line passing through origin with negative slope. The distance between successive points is non-uniform.

Hence, the correct answer is (A).

37. $\frac{mv^2}{r} = evB$ ...(1)

$\Rightarrow \frac{v}{r} = \frac{eB}{m}$ ...(2)

According to Bohr Quantisation rule,

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

$\Rightarrow vr = \frac{nh}{2\pi m}$ ...(3)

From (2) & (3), we get

$r = \sqrt{\frac{nh}{2\pi Be}}$ ...(4)

Hence, the correct answer is (B).

38. Kinetic energy, $K = \frac{1}{2}mv^2$

$$\Rightarrow K = \frac{1}{2}m\left(\frac{n^2h^2}{m^2r^2}\right)$$

$$\Rightarrow K = \frac{1}{2}nh\left(\frac{Be}{m}\right)$$

Hence, the correct answer is (C).

39. Since, $T = \frac{2\pi r}{v}$

$$\Rightarrow i = \frac{e}{T} = \frac{e^2B}{2\pi m}$$

Since, Area $= \pi r^2 = \pi\left(\frac{nh}{Be}\right)$ $\left\{\because r^2 = \frac{nh}{Be}\right\}$

$$\Rightarrow M = i\text{Å} = \left(\frac{e^2B}{2\pi m}\right)\left(\frac{\pi nh}{Be}\right) = \frac{neh}{2m}$$

Since, $PE = U = MB\sin(90°)$

$$\Rightarrow U = \frac{nhBe}{2m}$$

Hence, the correct answer is (A).

40. $\phi = \pi r^2 B$

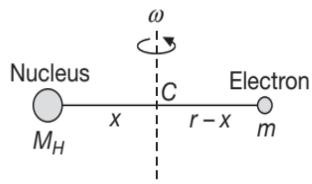
$$\Rightarrow \phi = \pi\left(\frac{nh}{Be}\right)B = \frac{\pi nh}{e}$$

Hence, the correct answer is (B).

41. Centre of mass of the atom

Hence, the correct answer is (C).

42. Let x be the distance of the nucleus from the common centre of mass C. The distance of the electron will be $(r-x)$.



$$x = \frac{mr}{M_H + m} \text{ and } r - x = \frac{M_H r}{M_H + m}$$

$$\Rightarrow L = \left[m(r-x)^2 + M_H X^2\right]\omega$$

$$\Rightarrow L = \left(\frac{M_H m}{M_H + m}\right)r^2\omega = \mu r^2 \omega$$

where $\mu = \frac{M_H m}{M_H + m}$ is called the reduced mass of the electron revolving around the heavy nucleus having finite mass.

Hence, the correct answer is (D).

43. Theoretically, the energy of the electron in the first orbit of the atom whose nucleus is assumed to be infinitely heavy is $E_0 = -\frac{me^4}{8h^2\varepsilon_0^2} = -13.6$ eV. However, practically the nucleus is heavy and has finite mass. So, the energy of the electron in the first orbit of the atom is $E = -\frac{\mu e^4}{8h^2\varepsilon_0^2}$, where $\mu = \frac{M_H m}{M_H + m}$ is the reduced mass of the electron and $\mu < m$. So, in the corrected model or the practical model of hydrogen atom, $E > E_0$ and hence the new ground state energy of electron will be more than that found with Bohr's theoretical model.

Hence, the correct answer is (A).

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

$$\Rightarrow 47.2 = 13.6\ Z^2\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\Rightarrow Z = 5$$

Hence, the correct answer is (C).

45. Total energy $TE = 13.6(5)^2 = 340$ eV

Since, $TE = KE$

$\Rightarrow KE = 340$ V

Hence, the correct answer is (C).

CHAPTER 2

46. $\frac{hc}{\lambda}=\frac{13.6(Z)^2}{n^2}$

$\Rightarrow \quad \lambda=\frac{hc\,n^2}{(13.6\,eV)Z^2}$

$\Rightarrow \quad \lambda=\frac{6.63\times10^{-34}\times3\times10^8\times9}{13.6\times25\times1.6\times10^{-19}}$

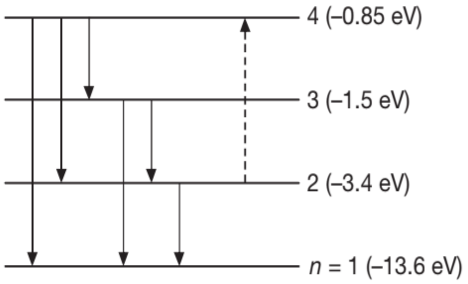
$\Rightarrow \quad \lambda=329\ \text{Å}$

Hence, the correct answer is (A).

47. $E_2-E_4=-2.5\ \text{eV}<2.7\ \text{eV}$

So, the electron will be making a transition to $n=4$.

$\Rightarrow \quad n=2$



Hence, the correct answer is (B).

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

$\Rightarrow \quad E_B=E_2=-3.4\ Z^2$

and $E_C=E_4=-0.85\ Z^2$

Now, $E_C-E_B=2.7\ \text{eV}$

$\Rightarrow \quad Z=1$

The ionisation energy is $IE=13.6\ \text{eV}$

Hence, the correct answer is (A).

49. $E_{max}=E_4-E_1=12.75\ \text{eV}$

and $E_{min}=E_4-E_3=0.66\ \text{eV}$

Hence, the correct answer is (A).

50. $100(E_n-E_1)=\left(\frac{4800}{49}\right)Rch$

$\Rightarrow \quad Rch\left(\frac{1}{1^2}-\frac{1}{n_i^2}\right)=\left(\frac{48}{49}\right)Rch$

$\Rightarrow \quad \frac{1}{n_i^2}=\frac{1}{49}$

$\Rightarrow \quad n_i=7$

So, the atoms are in the sixth excited state and hence $n=6$.

Hence, the correct answer is (B).

51. The maximum energy of the emitted photon is $\left(\frac{48}{49}\right)Rch$

Hence, the correct answer is (C).

52. $N=\frac{n(n-1)}{2}=\frac{7(7-1)}{2}=21$

So, maximum number of photons emitted is $100\ \text{N}=2100$

Hence, the correct answer is (D).

54. $E_4-E_2=\frac{hc}{\lambda}$

$\Rightarrow \quad -\frac{13.6\times(1)^2}{16}-\frac{(-13.6)\times(1)^2}{4}=\frac{hc}{\lambda}$

$\Rightarrow \quad -0.85+3.4=2.55\ \text{eV}=\frac{hc}{\lambda}$

$\Rightarrow \quad \lambda=\frac{12400}{2.55}=4862\ \text{Å}=486.2\ \text{nm}$

Hence, the correct answer is (C).

55. $\Delta E=\frac{hc}{\lambda}=\frac{12400}{1025}=12.09$

Hence, the correct answer is (D).

56. Since, $KE=\frac{Ze^2}{8\pi\varepsilon_0 r}$

As n increases, r increases, so kinetic energy decreases.

Hence, the correct answer is (B).

57. $E=-13.6 \quad E_n=-13.6\left(\frac{Z^2}{n^2}\right)\text{eV}$

$\Rightarrow \quad E_n=-13.6\left(\frac{2^2}{3^2}\right)\text{eV}=-\frac{54.4}{9}\ \text{eV}\approx6\ \text{eV}$

Hence, the correct answer is (A).

58. $E=3.4Z^2$

$\Rightarrow \quad E=3.4\times1^2=3.4\ \text{eV}$

Hence, the correct answer is (B).

Matrix Match/Column Match Type Questions

1. A $\rightarrow$ (q)
B $\rightarrow$ (r)
C $\rightarrow$ (s)
D $\rightarrow$ (p)

$$r\propto\frac{n^2}{Z},\ v\propto\frac{Z}{n}$$

Since, $i \propto \frac{v}{r}$

$\Rightarrow \quad i \propto \frac{Z^2}{n^3}$

Since, $B \propto \frac{i}{r}$

$\Rightarrow \quad B \propto \frac{Z^3}{n^5}$

2. A → (r)
B → (p)
C → (s)
D → (t)

$$E = -13.6\left(\frac{Z^2}{n^2}\right) \text{ eV}$$

(A) For second excited state $(n=3)$ of hydrogen atom $(Z=1)$, we have

$$E = -13.6\frac{(1)^2}{(3)^2} = -1.51 \text{ eV}$$

(B) For fourth state $(n=4)$ of $He^+ (Z=2)$, we have

$$E = -13.6\left(\frac{2}{4}\right)^2 = -3.4 \text{ eV}$$

(C) For first excited state $(n=2)$ of $Li^{++} (Z=3)$, we have

$$U = 2E = -27.2\left(\frac{Z^2}{n^2}\right)$$

$$\Rightarrow \quad U = -27.2\left(\frac{9}{4}\right) = -61.2 \text{ eV}$$

(D) For second excited state $(n=3)$ of $Li^{++} (Z=3)$, we have

$$K = -E = 13.6\left(\frac{Z^2}{n^2}\right) \text{ eV}$$

$$\Rightarrow \quad K = 13.6\left(\frac{3}{3}\right)^2 = 13.6 \text{ eV}$$

4. A → (r)
B → (s)
C → (p)
D → (q, s)

For H-like atom (atomic number Z), the energy of electron in n^{th} orbit is $E_n = -(13.6)\frac{Z^2}{n^2}$ eV

(A) For $Li^{++} (Z=3)$, so we have

$$E = -13.6 \times 9 = -122.4 \text{ eV}$$

So, ionisation energy is 122.4 eV

(B) For $Be^{+++} (Z=4)$ and $n=2$, we have

$$E = -\frac{13.6(4)^2}{(2)^2} = -54.4 \text{ eV}$$

$$\Rightarrow \quad |E| = 54.4 \text{ eV}$$

(C) For $B^{++++} (Z=5)$ and $n=1$, we have

$$E = -\frac{(13.6)(5)^2}{(1)^2} = -340 \text{ eV}$$

So, ionisation Energy is 340 eV

(D) For $He^+ (Z=1)$, the assembling energy is equal to ionisation energy i.e.

$$|E_n| = +13.6\left(\frac{Z^2}{n^2}\right) \text{ eV}$$

$$\Rightarrow \quad |E_n| = 13.6\frac{(2)^2}{(1)^2} = 54.4 \text{ eV}$$

For $He^+ (Z=1)$, in the third excited state i.e. $n=4$, we have

$$|E_n| = 13.6\left(\frac{2}{4}\right)^2$$

$$\Rightarrow \quad |E_n| = \frac{13.6}{4} \text{ eV} = 3.4 \text{ eV}$$

9. A → (p, s)
B → (u)
C → (r)
D → (t)

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

For $n=1$, $L = \frac{h}{2\pi}$

For $n=4$, $L = \frac{2h}{\pi}$

$$E_n = -13.6\left(\frac{Z^2}{n^2}\right) \text{ eV}$$

$$\Rightarrow \quad E_n = -13.6(2)^2 = -54.4 \text{ eV}$$

$\Rightarrow \quad U_n = 2E_n = -108.8 \text{ eV}$

Since, $K_n = -E_n = (13.6)\dfrac{Z^2}{n^2}$

$\Rightarrow \quad K_n = (13.6)\left(\dfrac{2}{2}\right)^2$

$\Rightarrow \quad K_n = 13.6 \text{ eV}$

11. A → (s)
B → (r)
C → (q)
D → (p)
For a given atomic number (Z), the energy and hence frequency of K-series is more than the L-series. In one series also, β-line has more energy or frequency compared to that of α-line.

12. A → (p, s)
B → (q, s)
C → (q, s)
D → (s)

$E \propto \dfrac{1}{n^2}$

$\Rightarrow \quad p \propto \dfrac{1}{n}$

$\Rightarrow \quad r \propto n^2$

$\Rightarrow \quad \dfrac{E}{p} \propto \dfrac{1}{n}$ and $Epr \propto \dfrac{1}{n}$

$\Rightarrow \quad \dfrac{r}{p} \propto n^3$ and $Er = \text{constant}$

13. A → (p, r, t)
B → (q, s)
C → (q, s)
D → (p, r, t)

$L \propto n\,,\ r \propto \dfrac{n^2}{Z}\,,\ v \propto \dfrac{Z}{n}$

$\Rightarrow \quad f \propto \dfrac{v}{r} \propto \dfrac{Z^2}{n^3}$

Since, $i \propto \dfrac{v}{r}$

$\Rightarrow \quad i \propto \dfrac{Z^2}{n^3}$

Also, $M = iA$

$\Rightarrow \quad M = i(\pi r^2)$

$\Rightarrow \quad M \propto \left(\dfrac{Z^2}{n^3}\right)\left(\dfrac{n^4}{Z^2}\right)$

$\Rightarrow \quad M \propto n$

15. A → (s)
B → (t)
C → (p)
D → (q)
E → (r)

Since, $\Delta E = \dfrac{hc}{\lambda}$

For $(n+1) \to n$ transition, $\lambda = \lambda_{\text{max}}$

$\Rightarrow \quad \lambda_{\text{max}} = \dfrac{n^2(n+1)^2}{(2n+1)R}$

For $\infty \to n$ transition, $\lambda = \lambda_{\text{min}}$

$\Rightarrow \quad \lambda_{\text{min}} = \dfrac{n^2}{R}$

For Lyman series, $n = 1$

$\Rightarrow \quad \lambda_{\text{max}} = \dfrac{4}{3R}$ and $\lambda_{\text{min}} = \dfrac{1}{R}$

Balmer series, $n = 2$

$\Rightarrow \quad \lambda_{\text{max}} = \dfrac{36}{5R}$ and $\lambda_{\text{min}} = \dfrac{4}{R}$

Paschen series, $n = 3$

$\Rightarrow \quad \lambda_{\text{max}} = \dfrac{144}{7R}$ and $\lambda_{\text{min}} = \dfrac{9}{R}$

Brackett series, $n = 4$

$\Rightarrow \quad \lambda_{\text{max}} = \dfrac{400}{9R}$ and $\lambda_{\text{min}} = \dfrac{16}{R}$

Pfund series, $n = 5$

$\Rightarrow \quad \lambda_{\text{max}} = \dfrac{900}{11R}$ and $\lambda_{\text{min}} = \dfrac{25}{R}$

16. A → (p, q, t)
B → (r)
C → (s)
D → (t)

$$v \propto \frac{1}{n},\ KE \propto \frac{1}{n^2},\ L \propto n,\ \omega = \frac{v}{r} \text{ and } i \propto \frac{v}{r}$$

Since, $r \propto n^2$ and $v \propto \dfrac{1}{n}$

$$\Rightarrow \quad \omega \propto \frac{1}{n^3} \text{ and } i \propto \frac{1}{n^3}$$

18. A → (p)
B → (p)
C → (q)
D → (s)

$$f \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\Rightarrow \quad f = k\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right), \text{ where } k \text{ is a constant}$$

For f_1, we have $n_1 = 1$ and $n_2 \to \infty$

$$\Rightarrow \quad f_1 = k$$

For f_2, we have $n_1 = 1$ and $n_2 = 2$

$$\Rightarrow \quad f_2 = \frac{3k}{4}$$

For f_3, we have $n_1 = 2$ and $n_2 \to \infty$

$$\Rightarrow \quad f_3 = \frac{k}{4}$$

$$\Rightarrow \quad f_1 - f_2 = f_3$$

19. A → (p)
B → (s)
C → (q)
D → (s)

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

$$\Rightarrow \quad \frac{\lambda_2}{\lambda_1} = \frac{\left(1/n_1^2 - 1/n_2^2\right)_i}{\left(1/n_1^2 - 1/n_2^2\right)_f}$$

$$\Rightarrow \quad \lambda_2 = \frac{\left(1/4 - 1/16\right)\lambda}{\left(1/n_1^2 - 1/n_2^2\right)_f}$$

$$\Rightarrow \quad \lambda_2 = \left(\frac{3}{16}\lambda\right)\left[\frac{1}{\left(1/n_1^2 - 1/n_2^2\right)_f}\right]$$

(A) For first line of Balmer series,

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

$$\Rightarrow \quad \lambda_2 = \left(\frac{27}{20}\right)\lambda$$

(B) For third line of Balmer series,

$$n_1 = 2,\ n_2 = 5$$

$$\Rightarrow \quad \lambda_2 = \left(\frac{25}{28}\right)\lambda$$

(C) For first line of Lyman series,

$$n_1 = 1,\ n_2 = 2,$$

$$\Rightarrow \quad \lambda_2 = \frac{\lambda}{4}$$

(D) For second line of Lyman series,

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

$$\Rightarrow \quad \lambda_2 = \left(\frac{27}{128}\right)\lambda$$

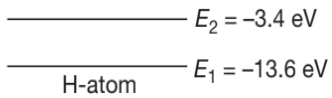
20. A → (r)
B → (p)
C → (s)
D → (q)

$$E_n = -13.6\left(\frac{Z^2}{n^2}\right) \text{eV}$$

21. A → (s)
B → (r)
C → (s)
D → (p)

For He⁺ atom, $Z = 2$ and $E_n = -13.6\left(\dfrac{Z^2}{n^2}\right)$ eV

$$\Rightarrow \quad E \propto \frac{Z^2}{n^2}$$



Ionization energy from first excited state of H-atom is given to be

$$E = |E_2| = 3.4 \text{ eV}$$

(A) For He^+ atom $(Z=2)$, so

$$|E_1| = (13.6\text{ eV})(2)^2 = 16(3.4\text{ eV}) = 16E$$

(B) $U_2 = 2E_2 = 2(-13.6)\dfrac{(2)^2}{(2)^2}$

$\Rightarrow \quad U_2 = -8(3.4\text{ eV}) = -8E$

(C) $K_1 = |E_1| = 16E$

(D) $|E_2| = (13.6)\dfrac{(2)^2}{(2)^2} = 4(3.4\text{ eV}) = 4E$

Integer/Numerical Answer Type Questions

1. Acceleration of the revolving electron is $a = \dfrac{v^2}{r}$. Since, we know that $v \propto \dfrac{Z}{n}$ and $r \propto \dfrac{n^2}{Z}$. So, for the same orbit of both the atoms, we have

$$a \propto \frac{Z^2}{(1/Z)}$$

$$\Rightarrow \quad a \propto Z^3$$

$$\Rightarrow \quad \frac{a_1}{a_2} = \left(\frac{Z_1}{Z_2}\right)^3 = \left(\frac{2}{1}\right)^3 = 8$$

2. After removing the first electron it will become He^+ ion. The ionization energy of single electron in He^+ ion $(Z=2)$ is

$$IE = 13.6(Z^2) = 54.4\text{ eV}$$

Therefore, total energy required to remove both the electrons is given by

$$E = (24.6 + 54.4)\text{ eV} = 79\text{ eV}$$

3. $v = \sqrt{\dfrac{2eV_0}{m}} = \sqrt{\dfrac{2(1.6\times10^{-19})(18000)}{9\times10^{-31}}}$

$\Rightarrow \quad v = 8\times10^7\text{ ms}^{-1}$

$\Rightarrow \quad x = 8$

4. $E_n - E_1 = \dfrac{12375}{1085} + \dfrac{12375}{304}$

$\Rightarrow \quad (13.6)(Z^2)\left(1 - \dfrac{1}{n^2}\right) = 52.1\text{ eV}$

$\Rightarrow \quad 1 - \dfrac{1}{n^2} = 0.96 \qquad \{\because Z=2\}$

$\Rightarrow \quad n \approx 5$

5. Since, we know that inside a material of coefficient of absorption μ, the intensity of X-rays decays exponentially with distance x as $I = I_0 e^{-\mu x}$. So, we have

$$\frac{I_0}{2} = I_0 e^{-\mu x}$$

$\Rightarrow \quad \mu x = \ell n 2$

$\Rightarrow \quad x = \dfrac{\ell n2}{\mu} = \dfrac{0.693}{50} = 0.01386\text{ cm}$

$\Rightarrow \quad x = 138.6\ \mu\text{m} \approx 139\ \mu\text{m}$

6. Since, $\dfrac{1}{\lambda} = R(Z-1)^2\left(\dfrac{1}{1^2} - \dfrac{1}{2^2}\right)$

$\Rightarrow \quad \dfrac{1}{0.76\times10^{-10}} = (1.09\times10^7)(Z-1)^2\left(\dfrac{3}{4}\right)$

$\Rightarrow \quad Z - 1 \approx 40$

$\Rightarrow \quad Z \approx 41$

7. $E = e\Delta V = \dfrac{hc}{\lambda}$

$\Rightarrow \quad E = \dfrac{hc}{\lambda} = \dfrac{12400}{3.1} = 4000\text{ eV}$

$\Rightarrow \quad \Delta V = \dfrac{E}{e} = \dfrac{4000\text{ eV}}{e} = 4000\text{ V} = 4\text{ kV}$

8. Let m_1 and m_2 be the mass of α-particle and hydrogen atom.

By Law of Conservation of Momentum, we get

$$m_1 u_1 = (m_1 + m_2)v$$

where u_1 is the initial velocity of the incident α-particle and v is the final common velocity (or velocity of centre of mass) of the particles.

By Law of Conservation of Energy, we get

$$\frac{1}{2}m_1 v_1^2 = \frac{1}{2}(m_1 + m_2)v^2 + \Delta E_0$$

where ΔE_0 is the Ionization Energy

The loss in KE of the α-particles must be gained by the atom as ionisation energy, so we have

$$\frac{1}{2}\left(\frac{m_1 m_2}{m_1+m_2}\right)v_1^2 = \Delta E_0$$

$$\Rightarrow K_1 = \frac{1}{2}m_1 v_1^2 = \left(\frac{m_1+m_2}{m_2}\right)\Delta E_0$$

$$\Rightarrow K_1 = \left(1+\frac{m_1}{m_2}\right)\Delta E_0$$

$$\Rightarrow K_1 = \left(1+\frac{4}{1}\right)(13.6)\text{ eV}$$

$$\Rightarrow K_1 = 68\text{ eV}$$

9. $P = VI$

Total power drawn by tube is $P = VI = 200$ W

As 0.5% of the energy is carried by the electrons, so power possessed by the X-ray beam is

$$P' = \left(\frac{0.5}{100}\right)(200) = 1\text{ W}$$

10. $U = -1.7$ eV

$$\Rightarrow E = \frac{U}{2} = -0.85\text{ eV} = \frac{-13.6}{n^2}$$

$$\Rightarrow n = 4$$

Ejected photoelectron will have minimum de-Broglie wavelength corresponding to transition from $n = 4$ to $n = 1$, so we have

$$\Delta E = E_4 - E_1 = -0.85 - (-13.6) = 12.75\text{ eV}$$

Using Einstein's Photo-Electric Equation, we get

$$K_{max} = \Delta E - W = 10.45\text{ eV}$$

$$\Rightarrow \lambda = \sqrt{\frac{150}{10.45}}\text{ Å} \quad \text{\{for an electron\}}$$

$$\Rightarrow \lambda = 3.8\text{ Å} \approx 4\text{ Å}$$

11. Shortest wavelength of Brackett is obtained when transition takes place from $n = 4$ to $n \to \infty$ and is obtained when transition takes place from $n = 2$ to $n \to \infty$.

$$\Rightarrow (13.6)Z^2\left(\frac{1}{16}-\frac{1}{\infty}\right) = 13.6\left(\frac{1}{4}-\frac{1}{\infty}\right)$$

$$\Rightarrow Z = 2$$

12. (a) Since, $N = \frac{n(n-1)}{2} = 6$

$$\Rightarrow n = 4$$

i.e., if $n_1 = n$, then $n_2 = n-4$

$$\Rightarrow \frac{(13.6)Z^2}{n^2} = 0.544 \quad \ldots(1)$$

$$\Rightarrow \frac{(13.6)Z^2}{(n-4)^2} = 0.85 \quad \ldots(2)$$

Solving equations (1) and (2), we get

$Z = 4$ and $n = 20$

(b) $\lambda_{min} = \frac{12375}{-0.544-(0.85)} = 40441$ Å

13. Given, $\lambda_1 = 4102$ Å, $\lambda_2 = 4861$ Å

For Balmer Series, we have

$$\Rightarrow \frac{1}{\lambda_1} = R\left(\frac{1}{2^2}-\frac{1}{n_1^2}\right)$$

Substituting values of λ_1 and R, we get

$n_1 = 6$

Similarly, for Balmer Series, we have

$$\frac{1}{\lambda_2} = R\left(\frac{1}{2^2}-\frac{1}{n_2^2}\right)$$

Substituting values of λ_2 and R, we get

$n_2 = 4$

Now difference of wave numbers of above two lines is

$$\frac{1}{\lambda_1}-\frac{1}{\lambda_2} = \frac{1}{\lambda} = R$$

$$\Rightarrow \frac{1}{\lambda_1}-\frac{1}{\lambda_2} = \frac{1}{\lambda} = R\left(\frac{1}{n_2^2}-\frac{1}{n_1^2}\right)$$

Transition $n_2 \to n_1$ or $6 \to 4$ corresponds to second line of Brackett series, whose wavelength is given by

$$\frac{1}{\lambda} = R\left(\frac{1}{4^2}-\frac{1}{6^2}\right)$$

Substituting the values, we get

$\lambda = 26206$ Å

14. $\frac{hc}{\lambda_1}+\frac{hc}{\lambda_2} = RchZ^2\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$

$$\Rightarrow n \approx 6$$

15. From the given conditions

$$E_n - E_2 = (10.2+17)\text{ eV} = 27.2\text{ eV} \quad \ldots(1)$$

and $E_n - E_3 = (4.25+5.95)\text{ eV} = 10.2\text{ eV} \quad \ldots(2)$

CHAPTER 2

Equation (1) – (2) gives

$$E_3 - E_2 = 17 \text{ eV}$$

$$\Rightarrow \quad Z^2(13.6)\left(\frac{1}{4}-\frac{1}{9}\right) = 17$$

$$\Rightarrow \quad Z^2(13.6)\left(\frac{5}{36}\right) = 17$$

$$\Rightarrow \quad Z^2 = 9$$

$$\Rightarrow \quad Z = 3$$

From equation (1), we get

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

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

$$\Rightarrow \quad \frac{1}{4}-\frac{1}{n^2} = 0.222$$

$$\Rightarrow \quad \frac{1}{n^2} = 0.0278$$

$$\Rightarrow \quad n^2 = 36$$

$$\Rightarrow \quad n = 6$$

16. The energy required to remove both the electrons from the atom is

$$E = 25.6 + 13.6(2)^2\left(\frac{1}{1^2}-\frac{1}{\infty}\right)$$

$$\Rightarrow \quad E = 25.6 + 54.4 = 80 \text{ eV}$$

$$\Rightarrow \quad N = 8$$

17. (a) 1 rydberg $= 2.2\times10^{-18}$ J $=$ Rhc

Ionisation energy is given as 4 rydberg, so

$$IE = 8.8\times10^{-18}\text{ J} = \frac{8.8\times10^{-18}}{1.6\times10^{-19}} = 55 \text{ eV}$$

$\Rightarrow$ Energy in first orbit is $E_1 = -55$ eV

Energy of radiation emitted when electron jumps from first excited state $(n=2)$ to ground state $(n=1)$ is

$$E_{21} = \frac{E_1}{(2)^2} - E_1 = -\frac{3}{4}E_1 = 41.25 \text{ eV}$$

So, wavelength of photon emitted in this transition is

$$\lambda = \frac{12375}{41.25} = 300 \text{ Å}$$

(b) Let Z be the atomic number of given element. Then

$$E_1 = (-13.6)(Z^2)$$

$$\Rightarrow \quad -55 = (-13.6)(Z^2)$$

$$\Rightarrow \quad Z \approx 2$$

(c) Since, $r = \frac{a_0}{Z}$, so the radius of first orbit of this atom is

$$r_1 = \frac{a_0}{2}$$

$$\Rightarrow \quad * = 2$$

18. According to Moseley's Law $\frac{1}{\lambda} \propto (Z-1)^2$

$$\Rightarrow \quad \frac{\lambda_2}{193} = \frac{(26-1)^2}{(29-1)^2} = \left(\frac{25}{28}\right)^2$$

$$\Rightarrow \quad \lambda_2 = 193\left(\frac{25}{28}\right)^2 \approx 154 \text{ pm}$$

19. $E_n = -\frac{(13.6)z^2}{n^2}$ eV

Substituting $z = 3$, we get

$$E_n = -\frac{122.4}{n^2} \text{ eV}$$

$$\Rightarrow \quad E_1 = -\frac{122.4}{(1)^2} = -122.4 \text{ eV}$$

and $E_3 = -\frac{122.4}{(3)^2} = -13.6$ eV

$$\Rightarrow \quad \Delta E = E_3 - E_1 = 108.8 \text{ eV}$$

The corresponding wavelength is

$$\lambda = \frac{12375}{\Delta E(\text{in eV})}\text{ Å} = \frac{12375}{108.8}\text{ Å} = 113.74 \text{ Å}$$

$$\Rightarrow \quad \lambda \approx 114 \text{ Å}$$

20. Total number of electrons striking the target per second

$$n = \frac{10\times10^{-3}}{1.6\times10^{-19}} = 6.25\times10^{16}$$

Kinetic energy of an electron is

$$K = 40\times10^3 \text{ eV} = 40\times10^3\times1.6\times10^{-19} = 6.4\times10^{-15}\text{ J}$$

$\therefore$ Total energy of electrons striking the target (per second) is

$$E = 6.25\times10^{16}\times6.4\times10^{-15} = 400 \text{ J}$$

(a) Total power emitted as X-rays is 1% of 400 W. So

$P = 4$ W

(b) Heat produced per second is

$H = (400 - 4)\ \text{Js}^{-1} = 396\ \text{Js}^{-1}$

21. $E_L - E_K = \dfrac{hc}{\lambda}$

$\Rightarrow \lambda = \dfrac{hc}{E_L - E_K} = \dfrac{12375}{\left(\dfrac{15.525}{1000}\right)}$

$\Rightarrow \lambda = 7.97 \times 10^{-11}\ \text{m} \approx 8 \times 10^{-11}\ \text{m}$

$\Rightarrow x = 8$

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1. Energy released by hydrogen atom

$$\Delta E_1 = 13.6 \times \left(\frac{1}{1} - \frac{1}{4}\right) = \frac{3}{4} \times 13.6\ \text{eV} = 10.2\ \text{eV}$$

Also, energy absorbed by He^+ ion in transition $n = 2 \rightarrow n = 4$ is

$$\Delta E_2 = 13.6 \times 4 \times \left(\frac{1}{4} - \frac{1}{16}\right) = 10.2\ \text{eV}$$

So, possible transition is $n = 2 \rightarrow n = 4$

Hence, the correct answer is (A).

2. $\dfrac{1}{\lambda_1} = R\left(\dfrac{1}{2^2} - \dfrac{1}{3^2}\right)$

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

$\Rightarrow \dfrac{5\lambda_1}{36} = \dfrac{12\lambda_2}{4 \times 16}$

$\Rightarrow \lambda_2 = \dfrac{5 \times 660 \times 64}{36 \times 12} = 489$ nm

Hence, the correct answer is (B).

3. $E_n = -\left(\dfrac{13.6Z^2}{n^2}\right)$ eV

For He^+ ion $(Z = 2)$ in first excited state $(n = 2)$, we get

$E_n = -13.6$ eV

$\Rightarrow$ Ionisation energy is 13.6 eV

Hence, the correct answer is (A).

4. $\Delta E = \dfrac{hc}{\lambda}$

$\Rightarrow \Delta E = (13.4)(3)^2\left(1 - \dfrac{1}{16}\right)$ eV

$\Rightarrow \lambda = \dfrac{1242 \times 16}{(13.4) \times (9)(15)}$ nm ≈ 10.8 nm

Hence, the correct answer is (D).

5. $\Rightarrow \Delta E_n = -\dfrac{13.6Z^2}{n^2}$

Let it start from n_1 to n_2 and from n_2 to ground.

Then $13.6 \times 4\left|1 - \dfrac{1}{n_2^2}\right| = \dfrac{hc}{30.4\ \text{nm}}$

$\Rightarrow 1 - \dfrac{1}{n_2^2} = 0.7498$

$\Rightarrow 0.25 = \dfrac{1}{n_2^2}$

$\Rightarrow n_2 = 2$

$13.6 \times 4\left(\dfrac{1}{4} - \dfrac{1}{n_1^2}\right) = \dfrac{hc}{108.5 \times 10^{-9}}$

$\Rightarrow n_1 \approx 5$

Hence, the correct answer is (A).

6. $\dfrac{1}{\lambda_1} = R\left(\dfrac{1}{9} - \dfrac{1}{16}\right) = R\dfrac{7}{144}$ ...(1)

$\dfrac{1}{\lambda_2} = R\left[\dfrac{1}{4} - \dfrac{1}{9}\right] = R\dfrac{5}{36}$ ...(2)

$\Rightarrow \dfrac{\lambda_1}{\lambda_2} = \dfrac{5 \times 144}{36 \times 7} = \dfrac{20}{7}$

Hence, the correct answer is (D).

7. $\Delta E = \dfrac{hc}{\lambda}$

$\Rightarrow \Delta E = \dfrac{12500}{980} = 12.76$ eV

$\Rightarrow E_n - E_1 = 12.76$

$\Rightarrow E_n = E_1 + 12.76$

$\Rightarrow E_n = -13.6 + 12.76$

Since $E_n = -\dfrac{13.6}{n^2}$ eV

$\Rightarrow E_n = -0.84\ \text{eV} = \dfrac{-13.6}{n^2}$ eV

$\Rightarrow \quad n = 4$

$\Rightarrow \quad r_n = 16a_0$

Hence, the correct answer is (D).

8. $\frac{1}{\lambda} = RZ^2\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5RZ^2}{36}$

$$\frac{1}{\lambda'} = RZ^2\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3RZ^2}{16}$$

$$\lambda' = \frac{16}{3RZ^2} \text{ and } \lambda = \frac{36}{5RZ^2}$$

$$\Rightarrow \quad \frac{\lambda'}{\lambda} = \frac{16 \times 5}{3 \times 36} = \frac{20}{27}$$

$$\Rightarrow \quad \lambda' = \frac{20}{27}\lambda$$

Hence, the correct answer is (C).

9. Since $F = -\frac{dU}{dr}$

$$\Rightarrow \quad F = kr = \frac{mv^2}{r}$$

$$\Rightarrow \quad v^2 = \frac{k}{m}r^2$$

$$\Rightarrow \quad v = \sqrt{\frac{k}{m}}r \qquad \ldots(1)$$

Also, $mvr = \frac{nh}{2\pi}$ ...(2)

Solving (1) and (2), we get

$$m\left(\sqrt{\frac{k}{m}}r\right)r = \frac{nh}{2\pi}$$

$$\Rightarrow \quad r \propto \sqrt{n}$$

Since, $E = PE + KE$

$$\Rightarrow \quad E = \frac{1}{2}kr^2 + \frac{1}{2}m\left(\sqrt{\frac{k}{m}}r\right)^2$$

$$\Rightarrow \quad E \propto r^2$$

$$\Rightarrow \quad E \propto n$$

Hence, the correct answer is (B).

10. Momentum of electron in different states

$$p_n = \frac{h}{\lambda_n}, \; p_g = \frac{h}{\lambda_g}$$

Kinetic energy, $K = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

Total energy in an orbit of hydrogen atom,

$$E = -K = -\frac{h^2}{2m\lambda^2}$$

$$E_n - E_g = \frac{h^2}{2m}\left(\frac{1}{\lambda_g^2} - \frac{1}{\lambda_n^2}\right)$$

$$\frac{h^2}{2m}\left(\frac{\lambda_n^2 - \lambda_g^2}{\lambda_g^2\lambda_n^2}\right) = \frac{hc}{\Lambda_n}$$

$$\Rightarrow \quad \Lambda_n = \frac{2mc}{h}\left(\frac{\lambda_g^2\lambda_n^2}{\lambda_n^2 - \lambda_g^2}\right)$$

$$\Rightarrow \quad \Lambda_n = \frac{2mc\lambda_g^2}{h}\left[1 - \frac{\lambda_g^2}{\lambda_n^2}\right]^{-1} = \frac{2mc\lambda_g^2}{h}\left[1 + \frac{\lambda_g^2}{\lambda_n^2}\right]$$

$$\{\because \lambda_g \ll \lambda_n\}$$

$$\Rightarrow \quad \Lambda_n = \frac{2mc\lambda_g^2}{h} + \left(\frac{2mc\lambda_g^4}{h}\right)\frac{1}{\lambda_n^2} = A + \frac{B}{\lambda_n^2}$$

where A and B are $A = \frac{2mc\lambda_g^2}{h}$, $B = \frac{2mc\lambda_g^4}{h}$

Hence, the correct answer is (A).

11. Frequency of emitted photon in a hydrogen atom is given by $v = Rc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For Lyman series, series limit condition is given by

$$n_2 = \infty, \; n_1 = 1.$$

$$\Rightarrow \quad v_L = Rc\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = Rc \qquad \ldots(1)$$

For Pfund series, series limit condition is given by,

$$n_2 = \infty, \; n_1 = 5$$

$$\Rightarrow \quad v_P = Rc\left(\frac{1}{5^2} - \frac{1}{\infty^2}\right) = \frac{Rc}{25} \qquad \ldots(2)$$

From equation (1) and (2), $v_P = \frac{v_L}{25}$

Hence, the correct answer is (D).

12. Energy required to remove an electron from singly ionized helium atom $= 54.4$ eV.

Energy required to remove the electron from helium atom be x eV

Given $54.4 \text{ eV} = 2.2x$

$$\Rightarrow \quad x = 24.73 \text{ eV}$$

Total energy required to ionize helium atom is

$$E = 54.4 + 24.73 = 79.13 \text{ eV}$$

Hence, the correct answer is (B).

14. As photon energy, $E = \frac{hc}{\lambda}$

$$\Rightarrow \frac{\lambda_N}{\lambda_A} = \frac{E_A}{E_N}$$

where E_A and E_N are energies of photons from atom and nucleus respectively. E_N is of the order of MeV and E_a in few eV.

So $\frac{\lambda_N}{\lambda_A} = 10^{-6}$

Hence, the correct answer is (B).

15. Since $\lambda = \frac{hc}{|\Delta E|}$, so from energy level diagram, we have

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

$$\lambda_2 = \frac{hc}{\left(\frac{E}{3}\right)}$$

$$\Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{1}{3}$$

Hence, the correct answer is (D).

16. Magnetic field at the centre, $B_n = \frac{\mu_0 I}{2r_n}$

For a hydrogen atom, radius of n^{th} orbit is given by

$$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2}$$

$$\Rightarrow r_n \propto n^2$$

$$I = \frac{e}{T} = \frac{e}{\frac{2\pi r_n}{v_n}} = \frac{ev_n}{2\pi r_n}$$

Also, $v_n \propto n^{-1}$

$\Rightarrow I \propto n^{-3}$ Hence, $B_n \propto n^{-5}$

Hence, the correct answer is (D).

17. For first orbit of hydrogen atom $(n=1)$,

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \quad \ldots(1)$$

$$mvr = \frac{h}{2\pi} \quad \ldots(2)$$

Squaring equation (2), we get $m^2v^2r^2 = \frac{h^2}{4\pi^2}$

Dividing both sides by r^3, we get

$$\frac{m^2v^2}{r} = \frac{h^2}{4\pi^2 r^3}$$

$$\Rightarrow \frac{v^2}{r} = \frac{h^2}{4\pi^2 r^3 m^2}$$

This is required acceleration of the electron.

Hence, the correct answer is (B).

18. Energy of emitted photon

$$E = \left[\frac{1}{1^2} - \frac{1}{2^2}\right] \times 13.6 \text{ eV} = \frac{3}{4} \times 13.6 \text{ eV}$$

Energy required to completely remove the electron from n^{th} excited state of doubly ionized lithium,

$$E' = \frac{13.6Z^2}{n^2}\text{eV} = \frac{13.6 \times 9}{n^2}\text{eV}$$

Since $E \geq E'$

$$\Rightarrow \frac{3}{4} \times 13.6 \geq \frac{13.6 \times 9}{n^2}$$

$$\Rightarrow n^2 \geq 3 \times 4$$

$$\Rightarrow n \geq \sqrt{12} = 3.5$$

$\Rightarrow$ Least quantum number for the excited state = 4.

Hence, the correct answer is (B).

19. $KE \propto \frac{z^2}{n^2}$

So, as n decreases, KE decreases, PE decreases and TE decreases.

Hence, the correct answer is (A).

20. $mvR = \frac{nh}{2\pi}$ ...(1)

and $qvB = \frac{mv^2}{R}$; $qB = \frac{mv}{R}$ ...(2)

From equations (1) and (2), we get $qB\left(\frac{nh}{2\pi mv}\right) = mv$

$$\frac{1}{2}mv^2 = \frac{1}{4\pi m}nhqB$$

$$\Rightarrow E = n\left(\frac{hqB}{4\pi m}\right)$$

Hence, the correct answer is (B).

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

$$\Rightarrow \lambda \propto \frac{1}{Z^2}$$

$$\Rightarrow \lambda Z^2 = \text{constant}$$

$$\Rightarrow \lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$$

Hence, the correct answer is (C).

22. $f \propto \left(\frac{1}{(n-1)^2} - \frac{1}{(n)^2}\right)$

$\Rightarrow \quad f \propto \frac{n^2-(n-1)^2}{n^2(n-1)^2}$

$\Rightarrow \quad f \propto \frac{n^2-n^2-1+2n}{n^2(n-1)^2}$

$\Rightarrow \quad f \propto \frac{2n-1}{n^2(n-1)^2}$

Since, $n \gg 1$

$\Rightarrow \quad f \propto \frac{1}{n^3}$

Hence, the correct answer is (D).

23. Number of spectral lines in the emission spectra,

$$N = \frac{n(n-1)}{2}$$

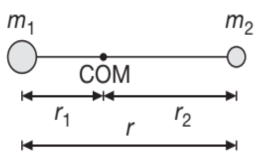
Here, $n = 4$

$\Rightarrow \quad N = \frac{4(4-1)}{2} = 6$

Hence, the correct answer is (C).

24. A diatomic molecule consists of two atoms of masses m_1 and m_2 at a distance r apart. Let r_1 and r_2 be the distances of the atoms from the centre of mass.
The moment of inertia of this molecule about an axis passing through its centre of mass and perpendicular to a line joining the atoms is

$$I = m_1 r_1^2 + m_2 r_2^2$$



As $m_1 r_1 = m_2 r_2$

$\Rightarrow \quad r_1 = \frac{m_2}{m_1} r_2$

$\Rightarrow \quad r_1 + r_2 = r$

$\Rightarrow \quad r_1 = \frac{m_2}{m_1}(r - r_1)$

On rearranging, we get $r_1 = \frac{m_2 r}{m_1 + m_2}$

Similarly, $r_2 = \frac{m_1 r}{m_1 + m_2}$

Therefore, the moment of inertia can be written as

$$I = m_1\left(\frac{m_2 r}{m_1+m_2}\right)^2 + m_2\left(\frac{m_1 r}{m_1+m_2}\right)^2 = \frac{m_1 m_2}{m_1+m_2} r^2 \quad \ldots(1)$$

According to Bohr's quantisation condition

$$L = \frac{nh}{2\pi} = n\hbar \qquad \left\{\because \hbar = \frac{h}{2\pi}\right\}$$

$\Rightarrow \quad L^2 = \frac{n^2h^2}{4\pi^2} = n^2\hbar^2 \quad \ldots(2)$

Rotational energy, $E = \frac{L^2}{2I}$

$\Rightarrow \quad E = \frac{n^2}{8\pi^2 I} = \frac{n^2\hbar^2}{2I} \quad$ {using (2)}

$\Rightarrow \quad E = \frac{n^2h^2(m_1+m_2)}{8\pi^2(m_1m_2)r^2} = \frac{n^2\hbar^2}{2}\frac{(m_1+m_2)}{(m_1m_2)r^2} \quad$ {using (1)}

$\Rightarrow \quad E = \frac{n^2\hbar^2(m_1+m_2)}{2m_1m_2r^2}$

Hence, the correct answer is (C).

25. Using, $E_n = \frac{13.6Z^2}{n^2}$ eV

Here, $Z = 3$ (For Li^{++})

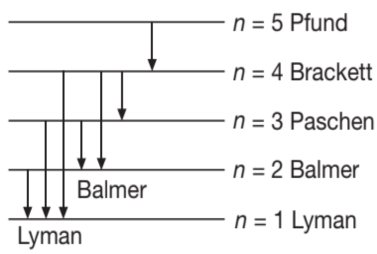
$\Rightarrow \quad E_1 = -\frac{13.6(3)^2}{(1)^2}$ eV

$\Rightarrow \quad E_1 = -122.4$ eV and $E_3 = \frac{-13.6\times(3)^2}{(3)^2} = -13.6$ eV

$$\Delta E = E_3 - E_1 = -13.6 + 122.4 = 108.8 \text{ eV}$$

Hence, the correct answer is (C).

26.



Transition $4 \to 3$ is in Paschen series. This is not in the ultraviolet region but this is in infrared region.
Transition $5 \to 4$ will also be in infrared region (Brackett).
Hence, the correct answer is (D).

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Single Correct Choice Type Problems

1. K_α transition takes place from $n_1 = 2$ to $n_2 = 1$

$$\Rightarrow \frac{1}{\lambda} = R(Z-b)^2\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right]$$

For K-series, $b = 1$

$$\Rightarrow \frac{1}{\lambda} \propto (Z-1)^2$$

$$\Rightarrow \frac{\lambda_{Cu}}{\lambda_{Mo}} = \frac{(z_{Mo}-1)^2}{(z_{Cu}-1)^2} = \frac{(42-1)^2}{(29-1)^2}$$

$$\Rightarrow \frac{\lambda_{Cu}}{\lambda_{Mo}} = \frac{41\times 41}{28\times 28} = \frac{1681}{784} = 2.144$$

Hence, the correct answer is (B).

2. $$\frac{1}{\lambda_1} = R\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\frac{1}{\lambda_2} = 4R\left[\frac{1}{4} - \frac{1}{16}\right]$$

$$\Rightarrow \frac{\lambda_2}{\lambda_1} = \frac{5}{27}$$

$$\Rightarrow \lambda_2 = 1215 \text{ Å}$$

Hence, the correct answer is (A).

3. Cut-off wavelength depends on the applied voltage not on the atomic number of the target. Characteristic wavelengths depend on the atomic number of target.
Hence, the correct answer is (B).

4. The series in U-V region is Lyman series. Longest wavelength corresponds to minimum energy which occurs in transition from $n = 2$ to $n = 1$.

$$\Rightarrow 122 = \frac{\frac{1}{R}}{\left(\frac{1}{1^2} - \frac{1}{2^2}\right)} \quad \ldots(1)$$

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

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

Solving Equations (1) and (2), we get

$\lambda = 823.5$ nm

Hence, the correct answer is (B).

5. $$\frac{1}{\lambda} \propto (Z-1)^2$$

$$\Rightarrow \frac{\lambda_1}{\lambda_2} = \left(\frac{Z_2-1}{Z_1-1}\right)^2$$

$$\Rightarrow \frac{1}{4} = \left(\frac{Z_2-1}{11-1}\right)^2$$

Solving this, we get, $Z_2 = 6$

Hence, the correct answer is (A).

6. The first photon will excite the hydrogen atom (in ground state) in first excited state (as $E_2 - E_1 = 10.2$ eV). Hence, during de-excitation a photon of 10.2 eV will be released. The second photon of energy 15 eV can ionise the atom.
Hence the balance energy i.e., $(15 - 13.6)$ eV $= 1.4$ eV is retained by the electron.
Therefore, by the second photon an electron of energy 1.4 eV will be released.
Hence, the correct answer is (C).

7. $$U = eV = eV_0 \log_e\left(\frac{r}{r_0}\right)$$

$$|F| = \left|-\frac{dU}{dr}\right| = \frac{eV_o}{r}$$

This force will provide the necessary centripetal force.

Hence, $$\frac{mv^2}{r} = \frac{eV_o}{r}$$

$$\Rightarrow v = \sqrt{\frac{eV_o}{m}} \quad \ldots(1)$$

Since by Bohr's Quantisation rule, we have

$$mvr = \frac{nh}{2\pi} \quad \ldots(2)$$

Dividing equation (2) by (1), we get

$$mr = \left(\frac{nh}{2\pi}\right)\sqrt{\frac{m}{eV_o}}$$

$$\Rightarrow r_n \propto n$$

Hence, the correct answer is (A).

8. Second excited state implies $n = 3$

$$\Rightarrow L_{\text{H}} = n\left(\frac{h}{2\pi}\right) = 3\left(\frac{h}{2\pi}\right)$$

$$\Rightarrow L_{\text{Li}} = n\left(\frac{h}{2\pi}\right) = 3\left(\frac{h}{2\pi}\right)$$

$$|E_H| = \frac{Z^2}{n^2}(13.6)\text{ eV}$$

$\Rightarrow \quad |E_H| = \frac{1^2}{9}(13.6)\text{ eV}$

$\Rightarrow \quad |E_{Li}| = \frac{3^2}{3^2}(13.6)\text{ eV}$

$\Rightarrow \quad |E_{Li}| = 13.6\text{ eV}$

$\Rightarrow \quad |E_{Li}| = 9|E_H|$

$\Rightarrow \quad |E_{Li}| > |E_H|$

Hence, the correct answer is (B).

9. $I = \frac{q}{t} = \frac{ne}{t}$

$\Rightarrow \quad 3.2\times10^{-3} = \left(\frac{n}{t}\right)\left(1.6\times10^{-19}\right)$

$\Rightarrow \quad \left(\frac{n}{t}\right) = 2\times10^{16}$

Hence, the correct answer is (A).

10. λ_C decreases with increase in accelerating voltage in accordance with the expression given by

$$\lambda_C = \frac{hc}{eV}$$

Wavelength for K_α line is not affected as it is due to the electronic transition between $n = 2$ and $n = 1$ in the target element. Hence $(\lambda_K - \lambda_C)$ increase with increase in the accelerating voltage.

Hence, the correct answer is (A).

11. Energy of infrared radiation is less than the energy of ultraviolet radiation. In options (A), (B) and (C), energy released will be more, while in option (D) only, energy released will be less.
Hence, the correct answer is (D).

12. $v_n \propto \frac{1}{n}$

$\Rightarrow \quad KE \propto \frac{1}{n^2}$ (with positive sign)

Since potential energy is given by $U_n = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$

$\Rightarrow \quad U_n$ is negative and $U_n \propto \frac{1}{r_n} \propto \frac{1}{n^2}$

$\left\{\text{because } r_n \propto n^2\right\}$

Similarly, total energy $E_n \propto \frac{1}{n^2}$ (with negative sign)

Therefore, when an electron jumps from some excited state to the ground state, value of n will decrease. Therefore, kinetic energy will increase (with positive sign), potential energy and total energy will also increase but with negative sign.
Thus, finally kinetic energy will increase, while potential and total energies will decrease.
Also, for hydrogen and hydrogen-like atoms, we have

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

$$U_n = 2E_n = -27.2\frac{Z^2}{n^2}\text{ eV}$$

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

From these three relations we can see that as n decreases, K_n will increase but E_n and U_n will decrease.
When an electron comes closer to the nucleus, the electrostatic force (which provides the necessary centripetal force) increases or speed (or KE) of the electron increases
Hence, the correct answer is (A).

13. $E_n = -\frac{me^4}{8n^2h^2\varepsilon_0^2}$, m = mass of electron

$\Rightarrow \quad E_n = -\frac{m_{\text{hypothetical}}e^4}{8n^2h^2\varepsilon_0^2}$

$\Rightarrow \quad E_n = -2\left(\frac{Rhc}{n^2}\right)$

The longest wavelength (or minimum energy) photon corresponds to transition between adjacent states.
i.e. $n = 3$ to $n = 2$

$\Rightarrow \quad \frac{hc}{\lambda_{\max}} = E_3 - E_2 = -2Rhc\left(\frac{1}{9}-\frac{1}{4}\right)$

$\Rightarrow \quad \frac{hc}{\lambda_{\max}} = 2Rhc\left(\frac{5}{36}\right)$

$\Rightarrow \quad \lambda_{\max} = \frac{18}{5R}$

Hence, the correct answer is (C).

14. $\lambda_0 = \frac{hc}{E} = 1.55\times10^{-11}$ m

$\Rightarrow \quad \lambda_0 = 0.155$ Å

is the minimum wavelength of continuous X-rays which carry energy equivalent to energy of incident electrons.
As this energy of incident radiation is more than that of K-shell electrons, the characteristic X-rays appear as peaks on the continuous spectrum.
Hence, the correct answer is (D).

15. $\frac{\Delta\lambda}{\lambda} = \mp\frac{v}{c}$

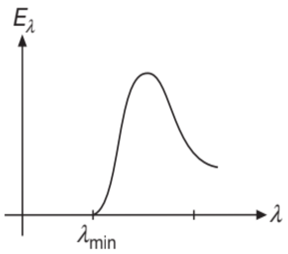
(–) sign to be used for approaching
(+) sign to be used for receding

$\Rightarrow \quad \frac{\Delta\lambda}{\lambda} = \frac{706-656}{656} = +\frac{v}{c}$

$\Rightarrow \quad v \approx 2\times 10^7 \text{ ms}^{-1}$

Hence, the correct answer is (B).

16. The continuous X-ray spectrum is shown in figure.



All wavelengths $\lambda > \lambda_{min}$ are found, where

$$\lambda_{min} = \frac{12375}{V\,(\text{in volt})} \text{Å}$$

Here, V is the applied voltage.

Hence, the correct answer is (B).

17. $E_n = \frac{Z^2}{n^2}(13.6 \text{ eV})$

$\Rightarrow \quad E_n = 9(13.6 \text{ eV})$

$\Rightarrow \quad E_n = 122.4 \text{ eV}$

Hence, the correct answer is (D).

18. $\lambda_{K_\alpha} = 0.021 \text{ nm} = 0.21 \text{ Å}$

Since, λ_{K_α} corresponds to the transition of an electron from L – shell to K – shell, therefore,

$$E_L - E_K = (\text{in eV}) = \frac{12375}{\lambda(\text{in Å})} = \frac{12375}{0.21} \approx 58928 \text{ eV}$$

$\Rightarrow \quad \Delta E \approx 59 \text{ keV}$

Hence, the correct answer is (C).

20. For quantum number n we have $2n^2$ electrons.

For $n=1$ we have 2 elements
For $n=2$ we have 8 elements
For $n=3$ we have 18 elements
For $n=4$ we have 32 elements
So, total number of elements is

$$2+8+18+32=60$$

Hence, the correct answer is (C).

21. Shortest wavelength or cut-off wavelength depend only upon the voltage applied to the Coolidge tube.

Hence, the correct answer is (B).

Multiple Correct Choice Type Problems

1. $\frac{hc}{\lambda_a} = (E_4 - E_1)$ and $\frac{hc}{\lambda_e} = (E_4 - E_m)$

$\Rightarrow \quad \frac{\lambda_a}{\lambda_e} = \frac{(E_4 - E_m)}{E_4 - E_1} = \frac{1}{5} = \frac{\frac{1}{m^2} - \frac{1}{16}}{\frac{15}{16}}$

$\Rightarrow \quad \frac{15}{16\times 5} = \frac{1}{m^2} - \frac{1}{16}$

$\Rightarrow \quad \frac{1}{m^2} = \frac{1}{4}$

$\Rightarrow \quad m = 2$

$\Delta p_a = \frac{(E_4 - E_1)}{c}$ and $\Delta p_e = \frac{(E_4 - E_m)}{c}$

$\Rightarrow \quad \frac{\Delta p_a}{\Delta p_e} = \frac{(E_4 - E_1)}{(E_4 - E_m)} = \frac{15\times 16}{16\times 3} = 5$

$\frac{hc}{\lambda_e} = (13.6 \text{ eV}) \times \frac{3}{16}$

$\Rightarrow \quad \frac{1242\times 16}{3\times 13.6} \text{ nm} = \lambda_e$

$\Rightarrow \quad \lambda_e \approx 487 \text{ nm}$

Hence, (C) and (D) are correct.

2. Since, $r_n = \left(\frac{n^2}{Z}\right) r_0$

$\Rightarrow \quad \frac{\Delta r_n}{r_n} = 2\left(\frac{\Delta n}{n}\right)$

Since, $\Delta n = 1$ (for two consecutive orbits)

$\Rightarrow \quad \frac{\Delta r_n}{r_n} \propto \frac{1}{n}$

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

$\Rightarrow \quad \frac{\Delta L}{L} = \frac{\Delta n}{n} = \frac{1}{n}$

$\Rightarrow \quad \frac{\Delta L}{L} \propto \frac{1}{n}$

Hence, (A), (B) and (D) are correct.

3. Since $L = \frac{nh}{2\pi} = \frac{3h}{2\pi}$

$\Rightarrow \quad n = 3$

CHAPTER 2

Since, $r_n = \left(\frac{n^2}{Z}\right)a_0$

$\Rightarrow \quad 4.5a_0 = \left(\frac{n^2}{Z}\right)a_0$

$\Rightarrow \quad Z = 2$

Possible transitions are $3 \to 2$, $3 \to 1$ and $2 \to 1$

For $3 \to 2$, we have

$$\frac{1}{\lambda} = R(2)^2\left(\frac{1}{4} - \frac{1}{9}\right) = 4R\left(\frac{9-4}{36}\right) = \frac{5R}{9}$$

$\Rightarrow \quad \lambda = \frac{9}{5R}$

For $3 \to 1$, we have

$$\frac{1}{\lambda} = R(2)^2\left(1 - \frac{1}{9}\right) = 4R\left(\frac{8}{9}\right) = \frac{32R}{9}$$

$\Rightarrow \quad \lambda = \frac{9}{32R}$

For $2 \to 1$, we have

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

$\Rightarrow \quad \lambda = \frac{1}{3R}$

Hence, (A) and (C) are correct.

4. $T \propto n^3$

$\Rightarrow \quad \frac{T_1}{T_2} = 8$

Satisfied by both (A) and (D)

Hence, (A) and (D) are correct.

5. $\lambda_m(\text{in Å}) = \frac{12375}{V(\text{in volts})}$

With increase in V, λ_m will decrease. With decrease in λ_m energy of emitted photons will increase. And hence intensity will increase even if number of photons emitted per second are constant. Because intensity is basically energy per unit area per unit time.

Hence, (A) and (D) are correct.

6. $r_n \propto \frac{n^2}{Z}$ and $|PE| = 2(KE)$

Hence, (A) and (D) are correct.

Reasoning Based Questions

1. Cut-off wavelength depends on the accelerating voltage, not the characteristic wavelengths. Further, approximately 2% kinetic energy of the electrons is utilised in producing X-rays. Rest 98% is lost in heat.

Hence, the correct answer is (B).

Comprehension Type Questions

1. $L = I\omega = \frac{nh}{2\pi}$

$\Rightarrow \quad \omega = \frac{nh}{2\pi I}$

$\Rightarrow \quad K = \frac{1}{2}I\omega^2 = \frac{1}{2}I\left(\frac{nh}{2\pi I}\right)^2 = \frac{n^2h^2}{8\pi^2 I}$

Hence, the correct answer is (D).

2. $h\upsilon = K_2 - K_1 = \frac{3h^2}{8\pi^2 I}$

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

$\Rightarrow \quad I = 1.87 \times 10^{-46}\ \text{kgm}^2$

Hence, the correct answer is (B).

3. $I = \mu r^2$ (where, $\mu =$ reduced mass)

$$\mu = \frac{m_1 m_2}{m_1 + m_2} = \frac{48}{7}\ \text{amu} = 11.43 \times 10^{-27}\ \text{kg}$$

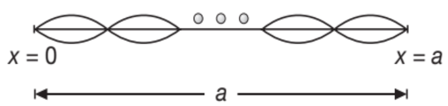
Substituting in $I = \mu r^2$ we get,

$$r = \sqrt{\frac{I}{\mu}} = \sqrt{\frac{1.87 \times 10^{-46}}{11.43 \times 10^{-27}}}$$

$\Rightarrow \quad r = 1.28 \times 10^{-10}\ \text{m}$

Hence, the correct answer is (C).

4. $a = \frac{n\lambda}{2}$



$\Rightarrow \quad \lambda = \frac{2a}{n} = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$ ...(1)

$\Rightarrow \quad \sqrt{E} \propto \frac{1}{a}$

$\Rightarrow \quad E \propto \frac{1}{a^2}$

Hence, the correct answer is (A).

5. From equation (1), we get

$$E = \frac{n^2h^2}{8a^2m}$$

In ground state $n=1$

$$\Rightarrow \quad E_1 = \frac{h^2}{8ma^2}$$

Substituting the values, we get

$$E_1 = 8 \text{ meV}$$

Hence, the correct answer is (B).

6. Since, we have already calculated that

$$\lambda = \frac{2a}{n} = \frac{h}{p} = \frac{h}{\sqrt{2mE}} \qquad \ldots(1)$$

From equation (1), we get

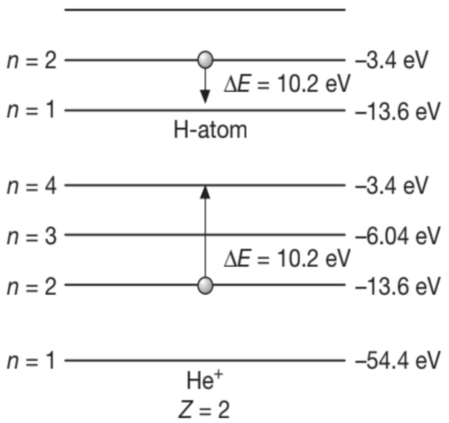
$$p \propto n$$

$$\Rightarrow \quad mv \propto n$$

$$\Rightarrow \quad v \propto n$$

Hence, the correct answer is (D).

7. Energy given by H-atoms in transition from $n=2$ to $n=1$ is equal to energy taken by He^+ atom in transition from $n=2$ to $n=4$.



Hence, the correct answer is (C).

8. Visible light lies in the range, $\lambda_1 = 4000$ Å to $\lambda_2 = 7000$ Å. Energy of photons corresponding to these wavelengths (in eV) would be

$$E_1 = \frac{12375}{4000} = 3.09 \text{ eV}, \; E_2 = \frac{12375}{7000} = 1.77 \text{ eV}$$

From energy level diagram of He^+ atom we can see that in transition from $n=4$ to $n=3$ energy of photon released will lie between E_1 and E_2.

$$\Delta E_{43} = -3.4 - (-6.04) = 2.64 \text{ eV}$$

Wavelength of photon corresponding to this energy,

$$\lambda = \frac{12375}{2.64} \text{ Å} = 4687.5 \text{ Å}$$

$$\lambda = 4.68 \times 10^{-7} \text{ m}$$

Hence, the correct answer is (C).

9. Kinetic energy $K \propto Z^2$

$$\Rightarrow \quad \frac{K_H}{K_{He^+}} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

Hence, the correct answer is (A).

Integer/Numerical Answer Type Questions

1. $$13.6\left(\frac{1}{1}-\frac{1}{4}\right)Z^2 = 74.8 + 13.6 \times \left(\frac{1}{4}-\frac{1}{9}\right)Z^2$$

$$\Rightarrow \quad 13.6Z^2\left(\frac{3}{4}-\frac{5}{36}\right) = 74.8$$

$$\Rightarrow \quad Z^2 = 9$$

$$\Rightarrow \quad Z = 3$$

2. $$\frac{120e \times e}{4\pi\varepsilon_0 (10 \times 10^{-15})} = \frac{p^2}{2m} = \frac{h^2}{\lambda^2 \times 2m}$$

$$\Rightarrow \quad \lambda^2 = \frac{h^2}{2m} \times \frac{4\pi\varepsilon_0 \times 10^{-14}}{120e^2}$$

$$\Rightarrow \quad \lambda = \frac{h}{e} \times \sqrt{\frac{4\pi\varepsilon_0 \times 10^{-4}}{2 \times 120 \times m}}$$

$$\Rightarrow \quad \lambda = 4.2 \times 10^{-15} \times \sqrt{\frac{10^{-14} \times 3}{9 \times 10^9 \times 2 \times 120 \times 5 \times 10^{-27}}}$$

$$\Rightarrow \quad \lambda = 7 \times 10^{-15} \text{ m}$$

$$\Rightarrow \quad \lambda = 7 \text{ fm}$$

3. Potential energy of hydrogen atom $(Z=1)$ in n^{th} orbit is

$$PE = U = -\frac{27.2}{n^2} \text{ eV}$$

$$\Rightarrow \quad \frac{U_f}{U_i} = \frac{-\frac{27.2}{n_f^2}}{-\frac{27.2}{n_i^2}} = \frac{1}{6.25}$$

$$\Rightarrow \quad 6.25 = \frac{n_f^2}{n_i^2}$$

$$\Rightarrow \quad \frac{n_f}{n_i} = 2.5 = \frac{5}{2}$$

Hence the answer is 5.

4. Energy available $E = \dfrac{hc}{\lambda} = \dfrac{1.237 \times 10^{-6} \text{ eVm}}{970 \times 10^{-10} \text{ m}} = 12.75$ eV

This energy corresponds to 4^{th} energy level of hydrogen atom.

Hence, the number of lines present in the emission spectrum is

$$N = {}^4C_2 = \frac{4(4-1)}{2} = 6$$

5. Kinetic energy of ejected electron is equal to the energy of incident photon minus the energy required to ionize the electron from n^{th} orbit (all in eV)

$$\Rightarrow \quad 10.4 = \frac{1242}{90} - |E_n|$$

Since, $E_n = -13.6\left(\frac{Z^2}{n^2}\right)$ eV, so for the nth orbit of hydrogen atom, we have,

$$E_n = -\left(\frac{13.6}{n^2}\right) \text{eV}$$

$$\Rightarrow \quad 10.4 = \frac{1242}{90} - \frac{13.6}{n^2}$$

Solving this equation, we get

$$n = 2$$

6. Angular momentum $= n\left(\frac{h}{2\pi}\right) = 3\left(\frac{h}{2\pi}\right)$

$$\Rightarrow \quad n = 3$$

Now, $r_n = \left(\frac{n^2}{Z}\right)a_0$

$$\Rightarrow \quad r_3 = \frac{(3)^2}{3}(a_0) = 3a_0$$

Now, $mv_3 r_3 = 3\left(\frac{h}{2\pi}\right)$

$$\Rightarrow \quad mv_3(3a_0) = 3\left(\frac{h}{2\pi}\right)$$

$$\Rightarrow \quad \frac{h}{mv_3} = 2\pi a_0$$

$$\Rightarrow \quad \frac{h}{p_3} = 2\pi a_0 \qquad \{\because p_3 = mv\}$$

$$\Rightarrow \quad \lambda_3 = 2\pi a_0 \qquad \left\{\because \lambda = \frac{h}{p_3}\right\}$$

$\Rightarrow$ Answer is 2.

7. $$\frac{120e \times e}{4\pi\varepsilon_0(10 \times 10^{-15})} = \frac{p^2}{2m} = \frac{h^2}{\lambda^2 \times 2m}$$

$$\Rightarrow \quad \lambda^2 = \frac{h^2}{2m} \times \frac{4\pi\varepsilon_0 \times 10^{-14}}{120e^2}$$

$$\Rightarrow \quad \lambda = \frac{h}{e} \times \sqrt{\frac{4\pi\varepsilon_0 \times 10^{-4}}{2 \times 120 \times m}}$$

$$\Rightarrow \quad \lambda = 4.2 \times 10^{-15} \times \sqrt{\frac{10^{-14} \times 3}{9 \times 10^9 \times 2 \times 120 \times 5 \times 10^{-27}}}$$

$$\Rightarrow \quad \lambda = 7 \times 10^{-15} \text{ m}$$

$$\Rightarrow \quad \lambda = 7 \text{ fm}$$