ATOMS

26

1. Energy E of a hydrogen atom with principal quantum number n is given by $E = \frac{-13.6}{n^2} eV$. The energy of a photon ejected when the electron jumps from n = 3 state to n = 2 state of hydrogen is approximately

(a) 1.5 eV (b) 0.85 eV
(c) 3.4 eV (d) 1.9 eV

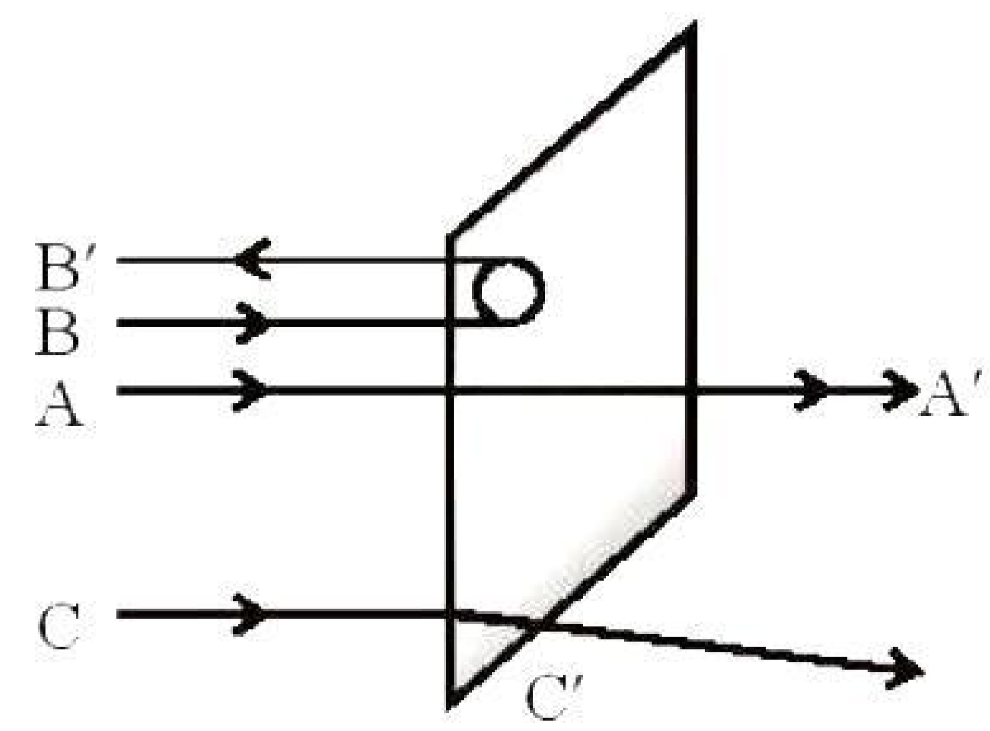
2. An alpha nucleus of energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to

(a) $1/m$ (b) $1/v^4$
(c) $1/Ze$ (d) v^2

3. The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer) is

(a) 1802 nm (b) 823 nm
(c) 1882 nm (d) 1648 nm

4. A beam of fast moving alpha particles were directed towards a thin film of gold. The parts A', B' and C' of the transmitted and reflected beams corresponding to the incident parts A, B and C of the beam, are shown in the adjoining diagram. The number of alpha particles in



(a) B' will be minimum and in C' maximum
(b) A' will be maximum and in B' minimum
(c) A' will be minimum and in B' maximum
(d) C' will be minimum and in B' maximum

5. The wavelength of radiation is λ_0 when an electron jumps from third to second orbit of hydrogen atom. For the electron to jump from the fourth to the second orbit of the hydrogen atom, the wavelength of radiation emitted will be

(a) $\frac{16}{25}\lambda_0$ (b) $\frac{20}{27}\lambda_0$
(c) $\frac{27}{20}\lambda_0$ (d) $\frac{25}{16}\lambda_0$

6. The distance of the closest approach of an alpha particle fired at a nucleus with kinetic energy K is r_0. The distance of the closest approach when the α particle is fired at the same nucleus with kinetic energy 2K will be

(a) $\frac{r_0}{2}$ (b) $4r_0$

(c) $\frac{r_0}{4}$ (d) $2r_0$

7. The energy of electron in the nth orbit of hydrogen atom is expressed as $E_n = \frac{-13.6}{n^2}$ eV. The longest wavelength of Lyman series will be

(a) 1213 Å (b) 7858 Å

(c) 1530 Å (d) None of these

8. The ionization energy of the electron in the hydrogen atom in its ground state is 13.6 eV. The atoms are excited to higher energy levels to emit radiations of 6 wavelengths. Maximum wavelength of emitted radiation corresponds to the transition between

(a) n = 3 to n = 1 states

(b) n = 2 to n = 1 states

(c) n = 4 to n = 3 states

(d) n = 3 to n = 2 states

9. A hypothetical atom has only three energy levels. The ground level has energy, $E_1 = -8$ eV. The two excited states have energies, $E_2 = -6$ eV and $E_3 = -2$ eV. Then which of the following wavelengths will not be present in the emission spectrum of this atom?

(a) 207nm (b) 465nm

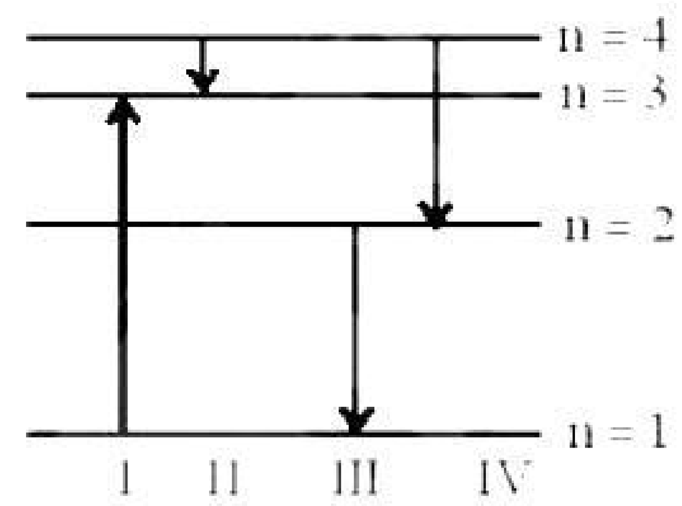
(c) 310nm (d) 620nm

10. In hydrogen atom, an electron changes its position from orbit $n = 4$ to the orbit In hydrogen atom, $n = 2$ of an atom. The wavelength of the emitted radiation is (R = Rydberg's constant)

(a) $\frac{16}{R}$ (b) $\frac{16}{3R}$

(c) $\frac{16}{5R}$ (d) $\frac{16}{7R}$

11. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy?



(a) IV

(b) III

(c) II

(d) I

12. The wavelength of the first spectral line in the Balmer series of hydrogen atom is 6561 Å. If the wavelength of the spectral line in the Balmer series of singly-ionized helium atom is 1215Å when electron jumps from n_2 to n_1, then n_2 and n_1 are

(a) 4, 2 (b) 5, 3

(c) 6, 3 (d) 6, 2

13. In the Bohr model of a hydrogen atom, the centripetal force is furnished by the coulomb attraction between the proton and the electron. If a_0 is the radius of the ground state orbit, m is the mass, e is the charge on the electron and ε_0 is the vacuum permittivity, the speed of the electron is

(a) 0 (b) $\frac{e}{\sqrt{\varepsilon_0 a_0 m}}$

(c) $\frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$ (d) $\frac{\sqrt{4\pi\varepsilon_0 a_0 m}}{e}$

14. A hydrogen atom, initially in the ground state is excited by absorbing a photon of wavelength 980Å. The radius of the atom in the excited state, in terms of Bohr radius a_0, will be:

(a) $25a_0$ (b) $9a_0$

(c) $16a_0$ (d) $4a_0$

15. A He^+ ion is in its first excited state. Its ionization energy is:

(a) 48.36eV (b) 54.40 eV

(c) 13.60eV (d) 6.04 eV

16. In Li^{++}, electron in first Bohr orbit is excited to a level by a radiation of wavelength λ. When the ion gets deexcited to the ground state in all possible ways (including intermediate emissions), a total of six spectral lines are observed. What is the value of λ?

(Given : $h = 6.63 \times 10^{-34}$ Js; $c = 3 \times 10^8$ ms^{-1})

(a) 11.4nm (b) 9.4nm

(c) 12.3nm (d) 10.8nm

17. The electron in a hydrogen atom first jumps from the third excited state to the second excited state and subsequently to the first excited state. The ratio of the respective wavelengths, λ_1 / λ_2, of the photons emitted in this process is :

(a) 20/7 (b) 27/5

(c) 7/5 (d) 9/7

18. The time period of revolution of electron in its ground state orbit in a hydrogen atom is 1.6×10^{-16} s. The frequency of revolution of the electron in its first excited state (in s^{-1}) is:

(a) 1.6×10^{14} (b) 7.8×10^{14}

(c) 6.2×10^{15} (d) 5.6×10^{12}

19. The electron in the hydrogen atom jumps from excited state (n = 3) to its ground state (n = 1) and the photons thus emitted irradiate a photosensitive material. If the work function of the material is 5.1 eV, the stopping potential is estimated to be (the energy of the electron in nth state $E_n = -\frac{13.6}{n^2}$eV)

(a) 5.1 V (b) 12.1 V

(c) 17.2 V (d) 7 V

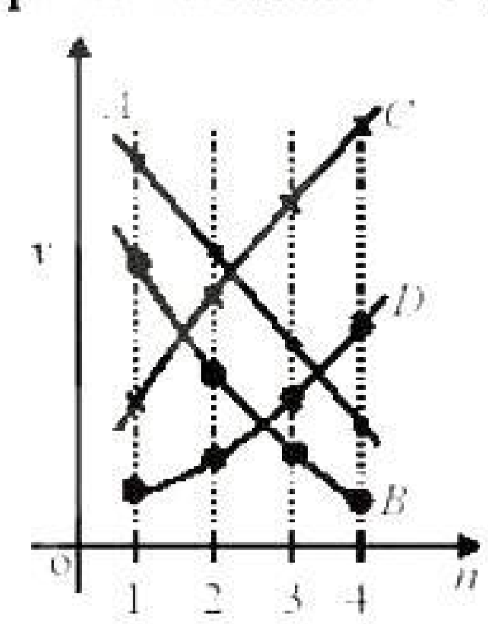
20. Which of the plots shown in the figure represents speed (v) of the electron in a hydrogen atom as a function of the principal quantum number (n)

(a) B

(b) D

(c) C

(d) A



21. One of the lines in the emission spectrum of Li^{2+} has the same wavelength as that of the 2nd line of Balmer series in hydrogen spectrum. The electronic transition corresponding to this line is n = 12 → n = x. Find the value of x.

(a) 8 (b) 6

(c) 7 (c) 5

22. The ionisation energy of hydrogen atom is 13.6 eV. An electron in the ground state of a hydrogen atom absorbs a photon of energy 12.75 eV. How many different spectral lines can one expect when the electron make a downward trnasition

(a) 1 (b) 4

(c) 2 (d) 6

23. In a hypothetical system, a particle of mass m and charge –3q is moving around a very heavy particle of charge q. Assume that Bohr's model is applicable to this system, then velocity of mass m in the first orbit is

(a) $\frac{3q^2}{2\varepsilon_0 h}$ (b) $\frac{3q^2}{4\varepsilon_0 h}$

(c) $\frac{3q}{2\pi\varepsilon_0 h}$ (d) $\frac{3q}{4\pi\varepsilon_0 h}$

24. A hydrogen atom makes a transition from n = 2 to n = 1 and emits a photon. This photon strikes a doubly ionized lithium atom (z = 3) in excited state and completely removes the orbiting electron. The least quantum number for the excited state of the ion for the process is :

(a) 2 (b) 4

(c) 5 (d) 3

25. If 13.6 eV energy is required to ionize the hydrogen atom, then the energy required to remove an electron from $n=2$ is

(a) 10.2 eV (b) 0 eV

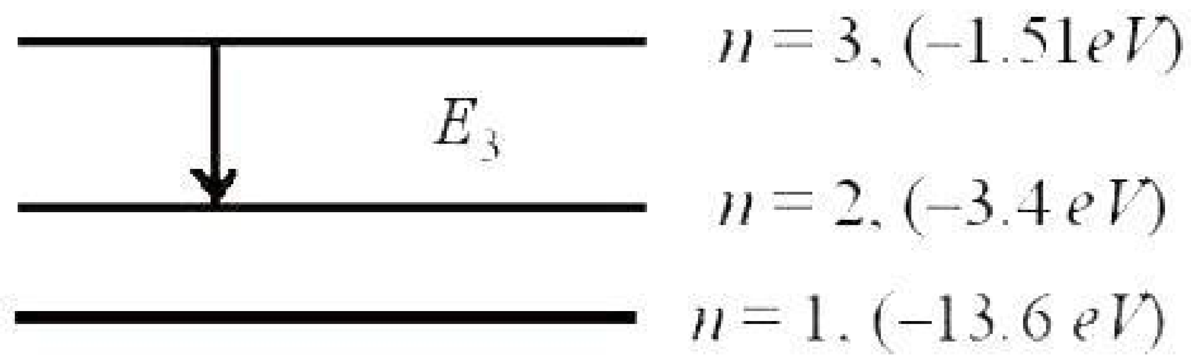
(c) 3.4 eV (d) 6.8 eV

ANSWER KEY

1	(d)	4	(b)	7	(a)	10	(b)	13	(c)	16	(d)	19	(d)	22	(d)	25	(c)
2	(a)	5	(b)	8	(c)	11	(b)	14	(c)	17	(a)	20	(a)	23	(a)		
3	(b)	6	(a)	9	(b)	12	(a)	15	(c)	18	(b)	21	(b)	24	(b)		

26 Atoms

1. (d)



$E_{3\to 2} = -1.51 - (-3.4) = 1.89$ eV

$\Rightarrow |E_{3\to 2}| \approx 1.9$ eV

2. (a)

3. (b) The smallest frequency and largest wavelength in ultraviolet region will be for transition of electron from orbit 2 to orbit 1.

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

$$\Rightarrow \quad \frac{1}{122 \times 10^{-9}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$$

$$\Rightarrow \quad R = \frac{4}{3 \times 122 \times 10^{-9}}$$

The highest frequency and smallest wavelength for infrared region will be for transition of electron from ∞ to 3rd orbit.

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

$$\Rightarrow \quad \frac{1}{\lambda} = \frac{4}{3 \times 122 \times 10^{-9}}\left(\frac{1}{3^2} - \frac{1}{\infty}\right)$$

$$\therefore \quad \lambda = \frac{3 \times 122 \times 9 \times 10^{-9}}{4} = 823.5 \text{ nm}$$

4. (b)

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

$$\frac{1}{\lambda_0} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5R}{36}$$

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = R\left(\frac{1}{4} - \frac{1}{16}\right) = \frac{3R}{16}$$

$$\frac{\lambda}{\lambda_0} = \frac{5}{36} \times \frac{16}{3} = \frac{20}{27}$$

6. (a)

7. (a) $\frac{1}{\lambda_{max}} = R\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right]$

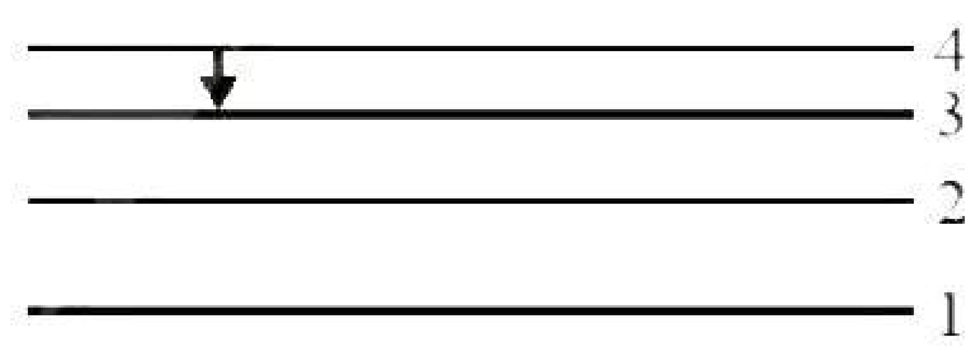
$$\Rightarrow \quad \lambda_{max} = \frac{4}{3R} \approx 1213 \text{Å}$$

8. (c) $\frac{n(n-1)}{2} = 6$

$n^2 - n - 12 = 0$

$(n - 4)(n + 3) = 0$

or $\quad n = 4$



9. (b) $E = \frac{hc}{\lambda}$

10. (b)

11. (b) $E = Rhc\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

E will be maximum for the transition for which $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ is maximum. Here n_2 higher energy level.

Clearly, $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ is maximum for the third transition, $1 \to 3$. I transition represents the absorption of energy.

12. (a) We know that $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

The wave length of first spectral line in the Balmer series of hydrogen atom is 6561Å. Here $n_2 = 3$ and $n_1 = 2$

$\therefore \frac{1}{6561} = R(1)^2\left(\frac{1}{4}-\frac{1}{9}\right) = \frac{5R}{36}$ ...(i)

For the second spectral line in the Balmer series of singly ionised helium ion $n_2 = 4$ and $n_1 = 2$; Z = 2

$\therefore \frac{1}{\lambda} = R(2)^2\left[\frac{1}{4}-\frac{1}{16}\right] = \frac{3R}{4}$ ...(ii)

Dividing equations (i) and (ii), we get

$\frac{\lambda}{6561} = \frac{5R}{36}\times\frac{4}{3R} = \frac{5}{27}$ $\therefore \lambda = 1215$ Å

So, $n_2 = 4$

$n_1 = 2$ is verified.

13. **(c)** Centripetal force = Coulombian force

$$\frac{mv^2}{a_0} = \frac{1}{4\pi\varepsilon_0}.\frac{e\times e}{a_0^2}$$

$$\Rightarrow v^2 = \frac{e^2}{4\pi\varepsilon_0.a_0.m} \Rightarrow v = \frac{e}{\sqrt{4\pi\varepsilon_0.a_0.m}}$$

14. **(c)** Energy of photon $= \frac{hc}{\lambda} = \frac{12500}{980} = 12.75\text{eV}$

Energy of electron in n^{th} orbit is given by

$$En = \frac{-13.6}{n^2} \Rightarrow E_n - E_1 = -13.6\left[\frac{1}{n^2}\ \frac{-1}{1^2}\right]$$

$$\Rightarrow 12.75 = 13.6\left[\frac{1}{1^2}\ \frac{-1}{n^2}\right] \Rightarrow n = 4$$

$\therefore$ Electron will excite to n = 4

We know that 'R' $\propto n^2$

$\therefore$ Radius of atom will be $16a_0$

15. **(c)** $E_n = -13.6\frac{Z^2}{n^2}$

For He^+, $E_2 = \frac{-13.6(2)^2}{2^2} = -13.60\text{eV}$

Ionization energy = 0 – E2 = 13.60 eV

16. **(d)** Spectral lines obtained on account of transition from nth orbit to various lower orbits is $\frac{n(n-1)}{2}$

$$\Rightarrow 6 = \frac{n(n-1)}{2} \Rightarrow n = 4$$

$$\Delta E = \frac{hc}{\lambda} = \frac{-Z^2}{n^2}(13.6eV)$$

$$\Rightarrow \frac{1}{\lambda} = Z^2\left(\frac{13.6eV}{hc}\right)\left(\frac{1}{n_2^2}-\frac{1}{n_1^2}\right)$$

$$= (13.4)(3)^2\left[1-\frac{1}{16}\right]eV$$

$$\Rightarrow \lambda = \frac{1242\times16}{(13.4)\times(9)(15)}\text{nm} = 10.8\text{nm}$$

17. **(a)** $\frac{1}{\lambda_1} = R\left(\frac{1}{3^2}-\frac{1}{4^2}\right) = \frac{7R}{16\times9}$

And $\frac{1}{\lambda_2} = R\left(\frac{1}{2^2}-\frac{1}{3^2}\right) = \frac{5R}{36}$

Now $\frac{\lambda_1}{\lambda_2} = \frac{(5R/36)}{7R/(16\times9)} = \frac{20}{7}$

18. **(b)** For first excited state n' = 3

Time period $T \propto \frac{n^3}{z^2}$

$$\Rightarrow \frac{T_2}{T_1} = \frac{n'^3}{n^3}$$

$\therefore$ T2 = 8T1 = 8 × 1.6 × 10–16s

$\therefore$ Frequency, $v = \frac{1}{T_2} = \frac{1}{8\times1.6\times10^{-16}}$

≈ 7.8 × 1014 Hz

19. **(d)** V = (12.1 – 5.1) volt

$V_{stopping} = 7V$

20. **(a)** Velocity of electron in n^{th} orbit of hydrogen atom is given by :

$$v_n = \frac{2\pi KZe^2}{nh}$$

Substituting the values we get,

$$v_n = \frac{2.2\times10^6}{n}\text{m/s}$$

or $v_n \propto \frac{1}{n}$ Hyperbolic relation.

21. **(b)** For 2^{nd} line of Balmer series in hydrogen spectrum

$$\frac{1}{\lambda} = R\ (1)\left(\frac{1}{2^2}-\frac{1}{4^2}\right) = \frac{3}{16}R$$

For Li^{2+} $\left[\frac{1}{\lambda} = R\times9\left(\frac{1}{x^2}-\frac{1}{12^2}\right) = \frac{3R}{16}\right]$

which is satisfied by n = 12 → n = 6.

22. **(d)**

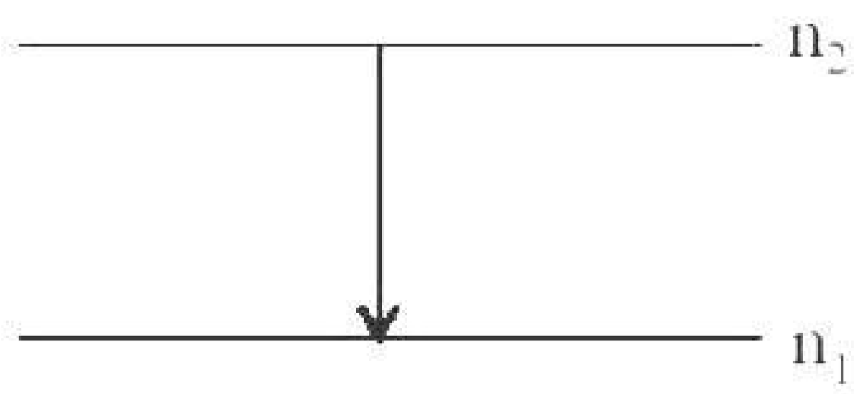
23. **(a)** $\frac{mv^2}{r} = \frac{3q^2}{4\pi\varepsilon_0 r^2} \Rightarrow mvr = \frac{3q^2}{4\pi\varepsilon_0 v}$ ...(i)

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

Using (i) and (ii) and putting n = 1

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

24. **(b)** A hydrogen atom makes a transition from n = 2 to n = 1



Then wavelength

$$= Rcz^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = Rc(1)^2\left[1 - \frac{1}{4}\right]$$

$$\lambda = Rc\left[\frac{3}{4}\right] \quad ...(1)$$

For ionized lithium

$$\lambda = Rc(3)^2\left[\frac{1}{n^2}\right] = Rc\,9\left[\frac{1}{n^2}\right] \quad ...(2)$$

$$Rc\left[\frac{3}{4}\right] = Rc\,9\left[\frac{1}{n^2}\right]$$

$$\Rightarrow \frac{3}{4} = \frac{9}{n^2} \Rightarrow n = \sqrt{12} = 2\sqrt{3}$$

∴ The least quantum number must be 4.

25. **(c)** The energy required to remove the electron from the n^{th} orbit of hydrogen is given by

$$E_n = \frac{13.6}{n^2} \text{ eV/atom}$$

For $n = 2$, $E_n = \frac{13.6}{4} = 3.4eV$

Therefore the energy required to remove electron from $n = 2$ is + 3.4 eV.