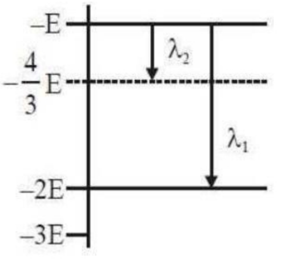
Atoms

1. Taking the wavelength of first Balmer line in hydrogen spectrum ($n=3$ to $n=2$) as 660 nm, the wavelength (in nm) of the 2^{nd} Balmer line ($n=4$ to $n=2$) will be;
2. A He^{+}ion is in its first excited state. Its ionization energy (in eV) is:
3. In Li^{++}, electron in first Bohr orbit is excited to a level by a radiation of wavelength 1. 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 1 (in nm) ? (Given: $h=6.63\times10^{-34}$Js; $c=3\times10^{8}$ ms^{-1})
4. An excited He^{+}ion emits two photons in succession, with wavelengths 108.5 nm and 30.4 nm, in making a transition to ground state. The quantum number n, corresponding to its initial excited state is (for photon of wavelength λ, energy $E=\frac{1240\text{eV}}{\lambda(\text{innm})}$
5. Consider an electron in a hydrogen atom, revolving in its second excited state (having radius 4.65Å). The de-Broglie wavelength (in Å) of this electron is :
6. 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
7. A hydrogen atom in its ground state is irradiated by light of wavelength 970Å. Taking hc/e = 1.237×10^{-6}eVm and the ground state energy of hydrogen atom as -13.6 eV, the number of lines present in the emission spectrum is
8. The energy of an excited hydrogen atom is -3.4 eV. Calculate the angular momentum (in Joule-second) of the electron according to Bohr's theory.
9. An electron in hydrogen like atom makes a transition from n^{th} orbit and emits radiation corresponding to Lyman series. If de-Broglie wavelength of electron in n^{th} orbit is equal to the wavelength of radiation emitted, find the value of n. The atomic number of atom is 11.
10. Some energy levels of a molecule are shown in the figure. The ratio of the wavelengths $r=\lambda_1/\lambda_2$, is given by



11. Ratio of the wavelengths of first line of Lyman series and first line of Balmer series is
12. As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of doubly ionized Li atom ($Z=3$) is
13. The ionisation energy of hydrogen atom is 13.6 eV. Following Bohr's theory, the energy (in eV) corresponding to a transition between the 3rd and the 4th orbit is
14. If the binding energy (in eV) of the electron in a hydrogen atom is 13.6 eV, the energy (in eV) required to remove the electron from the first excited state of $Li^{++}$is
15. An electron in hydrogen atom jumps from a level $n=4$ to $n=1$. The momentum (in kgm/s) of the recoiled atom is

SOLUTIONS

1. **(488.9)** $\frac{1}{\lambda_1} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$

$$\frac{1}{\lambda_2} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R}{16}$$

$$\therefore \frac{\lambda_2}{\lambda_1} = \frac{80}{108}$$

$$\lambda_2 = \frac{80}{108}\lambda_1 = \frac{80}{108} \times 660 = 488.9\text{nm.}$$

2. **(13.60)** $E_n = -13.6\frac{Z^2}{n^2}$

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

Ionization energy = $0 - E_2$ = 13.60 eV

3. **(10.8)** Spectral lines obtained on account of transition from n^{th} orbit to various lower orbits is $\frac{n(n-1)}{2}$

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

$$\Rightarrow n = 4$$

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

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

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

$$\Rightarrow \lambda = \frac{1242 \times 16}{(13.4) \times (9)(15)}\text{nm} \simeq 10.8\text{nm}$$

4. **(5)** $E = E_1 + E_2$

$$13.6\frac{z^2}{n^2} = \frac{1240}{\lambda_1} + \frac{1240}{\lambda_2}$$

or $\frac{13.6(2)^2}{n^2} = 1240\left(\frac{1}{108.5} + \frac{1}{30.4}\right) \times \frac{1}{10^{-9}}$

On solving, $n = 5$

5. **(9.7)** $v = \frac{c}{137n} = \frac{c}{137 \times 3}$

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\left(\frac{m \times c}{3 \times 137}\right)} = \frac{h}{mc} \times (3 \times 137) = 9.7\ \text{Å}$$

6. **(823.5)** The smallest frequency and largest wavelength in ultraviolet region will be for transition of electron from orbit 2 to orbit 1.

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

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

$$\Rightarrow R = \frac{4}{3 \times 122 \times 10^{-9}} m^{-1}$$

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

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

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

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

7. **(6)** $E = \frac{hc}{\lambda} = \frac{1.237 \times 10^{-6}}{970 \times 10^{-10}} \text{eV} = 12.75 \text{ eV}$

$\therefore$ The energy of electron after absorbing this photon $= -13.6 + 12.75 = -0.85\text{eV}$

This corresponds to $n = 4$

Number of spectral line $= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

8. **(2.11×10^{-34})** If given energy is corresponding to the n^{th} state of the atom, then

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

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

$$\therefore \quad n = 2$$

The angular momentum, for $n = 2$

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

$$= \frac{6.63}{\pi} \times 10^{-34} = 2.11 \times 10^{-34} J - s$$

9. **(25)** If λ is the de-Broglie wavelength, then for n^{th} orbit

$$2\pi r_n = n\lambda$$

where $$r_n = \frac{\epsilon_0 h^2 n^2}{\pi m e^2 Z}$$

$$\therefore \quad \frac{1}{\lambda} = \frac{me^2 Z}{2\epsilon_0 h^2 n} \quad \ldots(i)$$

For Lyman series

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

From equations (i) and (ii), we have

$$Z^2 R\left(1-\frac{1}{n^2}\right) = \frac{me^2 \; Z}{2\epsilon_0 h^2 \; n} \quad \ldots(iii)$$

where $$R = \frac{me^4}{8\epsilon_0^2 ch^3} \quad \ldots(iv)$$

After substituting the values in (iii) & (iv), we get

$$n = 25$$

10. (0.34) From energy level diagram, using $\Delta E = \frac{hc}{\lambda}$

For wavelength $\lambda_1 \Delta E = -E-(-2E) = \frac{hc}{\lambda_1}$

$$\therefore \quad \lambda_1 = \frac{hc}{E}$$

For wavelength $\lambda_2 \Delta E = -E-\left(-\frac{4E}{3}\right) = \frac{hc}{\lambda_2}$

$$\therefore \quad \lambda_2 = \frac{hc}{\left(\frac{E}{3}\right)} \qquad \therefore \quad r = \frac{\lambda_1}{\lambda_2} = \frac{1}{3}$$

11. **(0.18)** Wavelength of first line of Lyman series

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

or $$\frac{1}{\lambda_1} = \frac{3R}{4}$$

or $$\lambda_1 = \frac{4}{3R}.$$

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

or $$\lambda_2 = \frac{36}{5R}$$

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

12. (122.4)

$$E = 13.6 Z^2 \text{ eV}$$
$$= 13.6 \times (3)^2$$
$$= 122.4 \text{ eV}$$

13. (0.66)

$$E_3 = \frac{-13.6}{3^2} = -1.51 eV$$

and

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

$$\therefore \quad E_4 - E_3 = 0.66 \text{ eV}$$

14. (30.6) For lithium, $E_2 = -13.6 \frac{z^2}{n^2}$

$$= -\frac{13.6 \times 3^2}{2^2}$$
$$= -30.6 \text{ eV}$$

So energy needed to remove the electron

$$= 30.6 \text{ eV.}$$

15. (6.8×10^{-27}) $\Delta E = 13.6\left(1 - \frac{1}{16}\right) = \frac{13.6 \times 15}{16} = \frac{51}{4}$

$$= 12.75 \text{ eV} = \frac{12.75 \times 1.6 \times 10^{-19}}{3 \times 10^8}$$

Photon will take away almost all of the energy

$$\frac{hc}{\lambda} = 12.75 \text{ eV}$$

$$\Rightarrow \frac{h}{\lambda} = \left(\frac{12.75}{c}\right) = P_{\text{photon}} = P_{\text{revoled atom}}$$

$$= 6.8 \times 10^{-27} \text{ kg m/s}$$