IMPORTANT QUESTIONS CLASS – 12
PHYSICS CHAPTER – 12 ATOMS

Question 1.
A hydrogen atom in its excited state emits radiations of wavelengths 1218 Å and 974.3 Å when it finally comes to the ground state. Identify the energy levels from where transitions occur. Given Rydberg constant R = 1.1 × 10^7 m^{-1}. Also, specify the spectral series to which these lines belong.

Answer:
We know that $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

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

For $\lambda = 1218$ Å

$n_f = 1,\ n_i = ?$

$$\frac{1}{1218 \times 10^{-10} \times 1.1 \times 10^7} = \left(\frac{1}{1^2} - \frac{1}{n_i^2}\right)$$

On solving $n = 2$

For $\lambda = 974.3$ Å

$n_f = 1,\ n_i = ?$

$$\frac{1}{974.3 \times 10^{-10} \times 1.1 \times 10^7} = \left(\frac{1}{1^2} - \frac{1}{n_i^2}\right)$$

On solving n = 4
Lyman series.

Question 2.
Obtain the first Bohr's radius and the ground state energy of a muonic hydrogen atom, i.e. an atom where the electron is replaced by a negatively charged muon (μ⁻) of mass about 207 me that orbits around a proton. (Given for hydrogen atom, the radius of first orbit and ground state energy are 0.53 × 10^{-10}m and – 13.6 eV respectively)

Answer:
In Bohr's model of hydrogen atom the radius of n^{th} orbit is given by
r_n = n2h24π2e2mek

As n = 1
Therefore, we have 1

$r_n \propto \frac{1}{m}$

Therefore

$\frac{r_\mu}{r_e} = \frac{m_e}{m_\mu} = \frac{1}{207}$

Or $r_\mu = \frac{r_e}{207} = \frac{0.53 \times 10^{-10}}{207} = 2.56 \times 10^{-13}$ m

Energy of electron in the nth orbit

$$E = -\frac{2\pi^2 m e^4 k^2}{n^2 h^2}$$

For $n = 1$

$E \propto m$

$\frac{E_\mu}{E_e} = \frac{m_\mu}{m_e} = 207$

$E_\mu = E_e \times 207 = -13.6 \times 207$ eV $= -2.8$ k eV

Question 3.
The electron in a given Bohr orbit has a total energy of – 1.5 eV. Calculate Its
(a) kinetic energy.
(b) potential energy.
(C) the wavelength of radiation emitted, when this electron makes a transition

to the ground state.
(Given Energy in the ground state = – 13.6 eV and Rydberg's constant = 1.09 × 10^7 m^{-1})

Answer:
Total energy of the electron In a Bohr's orbit is – 1.5 eV

We know that kinetic energy of the electron in any orbt is half of the potential energy in magnitude and potential energy is negative
(a) Total energy = kinetic energy + potential energy
$-1.5 = E_k - 2E_k$
$1.5 = E_k$

(b) $E_p = -2 \times 1.5 = -3$ eV

(c) Energy released when the transition of this electron takes place from this orbit to the ground state
= – 1.5 – (- 13.6)
= 12.1 eV
= $12.1 \times 1.6 \times 10^{19} = 1.936 \times 10^{-18}$ J

Let be the wavelength of the Light emitted then,

$$E = \frac{hc}{\lambda} \text{ or } \lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{12.1 \times 1.6 \times 10^{-19}}$$
$$= 102.27 \text{ nm}$$

Question 4.
In a Geiger—Marsden experiment, calculate the distance of closest approach to the nucleus of Z = 80, when an a-particle of 8 MeV energy Impinges on it before It comes momentarily to rest and reverses its direction. How will the distance of the closest approach be affected when the kinetic energy of the a-particle is doubled?

Answer:
Given Z = 80, E = 8 MeV = $8 \times 10^6 \times 1.6 \times 10^{19}$ J, r_o =?
Using the expression

$$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{E_k}$$
$$= 9 \times 10^9 \times \frac{2 \times 80 \times (1.6 \times 10^{-19})^2}{8 \times 10^6 \times 1.6 \times 10^{-19}}$$
$$\text{or } r_0 = 2.88 \times 10^{-14} \text{ m}$$

When the kinetic energy of a-particle has doubled the distance of the closest approach becomes half its previous value, i.e. 1.44×10^{14} m

Question 5.
The ground state energy of the hydrogen atom is – 13.6 eV. If an electron makes a transition from an energy level – 0.85 eV to – 3.4 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong?
Answer:
Energy released = – 0.85 – (- 3.4) = 2.55 eV = $2.55 \times 1.6 \times 10^{-19}$ J
Using E = hc/λ we have
λ = hcE=6.62×10−34×3×1082.55×1.6×10−19 = 4.87×10^{-7} m
It belongs to the Balmer series.

Question 6.
A hydrogen atom in the third excited state de-excites to the first excited state. Obtain the expressions for the frequency of radiation emitted in this process. Also, determine the ratio of the wavelengths of the emitted radiations when the atom de-excites from the third excited state to the second excited state and from the third excited state to the first excited state.
Answer:
We know that

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

Also

$$\nu = \frac{c}{\lambda} = cR\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = cR\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3cR}{16}$$

Now $$\frac{1}{\lambda_{43}} = R\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \frac{7R}{144}$$

And

$$\frac{1}{\lambda_{42}} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R}{16}$$

$$\frac{\lambda_{43}}{\lambda_{42}} = \frac{144}{7R} \times \frac{3R}{16} = \frac{27}{7}$$

Question 7.
Obtain the expression for the ratio of the de Broglie wavelengths associated with the electron orbiting in the second and third excited states of the hydrogen atom.
Answer:
We know that
2πr = nλ ....(i)
For the second excited state (n = 3)
r = $0.529(n)^2$ A = $0.529(3)^2$

Putting in (i) we get $2\pi(0.529)(3)^2 = 3\lambda_2$

For third excited state n = 4
r = $0.529(4)^2$
Putting in (i) we get $2\pi(0.529)(4)^2 = 4\lambda_3$

$$\frac{3\lambda_2}{4\lambda_3} = \frac{(3)^2}{(4)^2}$$

Or $$\frac{\lambda_2}{\lambda_3} = \frac{3}{4}$$

Question 8.
(a) The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-10} m. Calculate its radius in n = 3 orbit.
(b) The total energy of an electron in the first excited state of the hydrogen atom is 3.4 eV. Find out its (i) kinetic energy and (ii) potential energy in this state.
Answer:
(a) The radius is given by
r_n = n2h24π2me2k = n^2ao

where n is the number of orbit, hence r3 = $5.3 \times 10^{-10} \times 32 = 4.77 \times 10^{-9}$ m

(b) Total kinetic energy = + 3.4 eV
Total potential energy = – 6.8 eV

Question 9.
Given the ground state energy E0 = – 13.6 eV and Bohr radius a0 = 0.53 Å. Find out how the de Broglie wavelength associated with the electron orbiting in the ground state would change when it jumps into the first excited state.
Answer:
The de-Broglie wavelength is given by $2\pi r n = n\lambda$.
In ground state, n = 1 and r_0 = 0.53 Å, therefore, $\lambda_0 = 2 \times 3.14 \times 0.53 = 3.33$ Å

In first excited state, n = 2 and $r_1 = 4 \times 0.53$ Å = 2.12 Å, therefore,
$r_1 = (2 \times 3.14 \times 2.12)/2 = 6.66$Å

Therefore, $\lambda_1 - \lambda_0 = 6.66 - 3.33 = 3.33$ Å.
In other words, the de-Broglie wavelength becomes double.

Question 10.
When is the H_α line in the emission spectrum of hydrogen atom obtained? Calculate the frequency of the photon emitted during this transition.
Answer:
Hα is obtained when $n_i = 3$ and $n_f = 2$

$$\nu = \frac{c}{\lambda} = cR_H\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

$$= 3 \times 10^8 \times 1.09 \times 10^7 \left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right]$$

$$\nu = 4.57 \times 10^{14} \text{ Hz}$$