NCERT Solutions for Class-XII Physics

Chapter-12

NCERT Physics Class 12

1. Choose the correct alternative from the clues given at the end of the each statement:
(a) The size of the atom in Thomson's model is .... the atomic size in Rutherford's model. (much greater than/no different from/much less than.)
(b) In the ground state of .... electrons are in stable equilibrium, while in .... electrons always experience a net force. (Thomson's model/ Rutherford's model.)
(c) A classical atom based on .... is doomed to collapse. (Thomson's model/ Rutherford's model.)
(d) An atom has a nearly continuous mass distribution in a .... but has a highly non-uniform mass distribution in .... (Thomson's model/ Rutherford's model.)
(e) The positively charged part of the atom possesses most of the mass in .... (Rutherford's model/both the models.)

1. (a) The sizes of the atoms taken in Thomson's model and Rutherford's model have the same order of magnitude.
(b) In the ground state of Thomson's model, the electrons are in stable equilibrium. However, in Rutherford's model, the electrons always experience a net force.
(c) A classical atom based on Rutherford's model is doomed to collapse.
(d) An atom has a nearly continuous mass distribution in Thomson's model, but has a highly non-uniform mass distribution in Rutherford's model.
(e) The positively charged part of the atom possesses most of the mass in both the models.

2. Suppose you are given a chance to repeat the alpha-particle scattering experiment using a thin sheet of solid hydrogen in place of the gold foil. (Hydrogen is a solid at temperatures below 14 K.)
What results do you expect?

2. In alpha-particle scattering experiment, if we use a thin sheet of solid hydrogen in place of the gold foil, then the mass of Hydrogen will be lesser than that of incident alpha particle and the scattering angle will be not large enough. As mass of the scattering particle is more than the target nucleus, the alpha particles will not bounce while using solid Hydrogen.

3. What is the shortest wavelength present in the Paschen series of spectral lines?

3. Rydberg's formula is given as:

$$\frac{hc}{\lambda} = 21.76 \times 10^{-19}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Where,

h = Planck's constant = 6.6×10^{-34} Js and c = Speed of light = 3×10^8 m/s. (n_1 and n_2 are integers)

The shortest wavelength present in the Paschen series of the spectral lines is given for values $n_1 = 3$ and $n_2 = \infty$.

$$\frac{hc}{\lambda} = 21.76 \times 10^{-19}\left[\frac{1}{(3)^2} - \frac{1}{(\infty)^2}\right]$$

$$\lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^8 \times 9}{21.76 \times 10^{-19}}$$

$= 8.189 \times 10^{-7}$ m

= 818.9 nm

4. A difference of 2.3 eV separates two energy levels in an atom. What is the frequency of radiation emitted when the atom make a transition from the upper level to the lower level?

4. Given: energy = 2.3 eV

In joules, Energy E = $2.3 \times 1.6 \times 10^{-19} = 3.68 \times 10^{-19}$ J

Energy is given as:

E = hv

Where h is Planck's constant

v is frequency of the radiation

Or $v = \frac{E}{h} = \frac{3.68 \times 10^{-19}\,J}{6.62 \times 10^{-34}\,J-s}$

On calculating, we get

Frequency $v = 0.55 \times 10^{-15}$

Or Frequency $v = 5.55 \times 10^{-14}$ Hz.

5. The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of the electron in this state?

5. Ground state energy of hydrogen atom E = –13.6 eV

This is the total energy of a hydrogen atom. Kinetic energy is equal to the negative of the total energy.

Kinetic energy = – E = – (–13.6) = 13.6 eV

Potential energy is equal to the negative of two times of kinetic energy.

Potential energy = $-2 \times (13.6) = -27.2$ eV

6. A hydrogen atom initially in the ground level absorbs a photon, which excites it to the n = 4 level. Determine the wavelength and frequency of photon.

6. For ground level: $n_1 = 4$

Energy for the ground level of hydrogen atom, $E_1 = -13.6/n_1^2$

Substituting the value, we get

$E_1 = -13.6/1^2 = -13.6$ eV

When the hydrogen atom is excited to $n_2 = 4$, then the energy absorbed by the photon is given as:

$E_2 = -13.6/4^2$

$E_2 = -13.6/16$

The energy absorbed by the photon can be calculated by the following:

$E = E_2 - E_1$

Or, $E = (-13.6/16) - (-13.6/1)$

On calculating, we get

E = 12.75 eV

In Joules, Energy is = $12.75 \times 1.6 \times 10^{-19}$ Joules

Or $E = 2.04 \times 10^{-18}$ J

Energy is given by the relation, $E = hc/\lambda$

Or $\lambda = hc/E$

Where h is Planck's constant and is equal to 6.64×10^{-34} Js

c is speed of light and is equal to 3.0×10^8 m/s

substituting the values we get

$$\lambda = \frac{6.64\times10^{-34}\,\text{J}-\text{sec}\times3.0\times10^{8}\,\text{ms}^{-1}}{2.04\times10^{-18}\,\text{J}}$$

On calculating, we get

$\lambda = 9.7 \times 10^{-8}$ m

or $\lambda = 97$ nm

Frequency can be calculated as follows:

$v = c/\lambda$

substituting the values, we get

$$v = \frac{3.0\times10^{8}\,\text{ms}^{-1}}{9.7\times10^{-8}\,\text{m}}$$

$v = 3.1 \times 10^{15}$ Hz

7. (a) Using the Bohr's model calculate the speed of the electron in a hydrogen atom in the n = 1, 2 and 3 levels.

(b) Calculate the orbital period in each of these levels.

7. (a) Let v_1 be the orbital speed of the electron in a hydrogen atom in the ground state, $n_1 = 1$. For charge (e) of an electron, v_1 is given by the relation,

$$v_1 = \frac{e^2}{n_1 4\pi \in_0 (h/2\pi)} = \frac{e^2}{2 \in_0 h}$$

Where, $e = 1.6 \times 10^{-19}$ C

$\in_0$ = Permittivity of free space = $8.85 \times 10^{-12}\ N^{-1}\ C^2\ m^{-2}$

h = Planck's constant = 6.62×10^{-34} Js

$$\therefore v_1 = \frac{(1.6\times10^{-19})^2}{2\times8.85\times10^{-12}\times6.62\times10^{-34}}$$

$= 0.0218 \times 10^8 = 2.18 \times 10^6$ m/s

For level $n_2 = 2$, we can write the relation for the corresponding orbital speed as:

$$v_2 = \frac{e^2}{n_2 2 \in_0 h}$$

$$= \frac{(1.6\times10^{-19})^2}{2\times2\times8.85\times10^{-12}\times6.62\times10^{-34}}$$

$= 1.09 \times 10^6$ m/s

And, for $n_3 = 3$, we can write the relation for the corresponding orbital speed as:

$$v_3 = \frac{e^2}{n_3 2 \in_0 h}$$

$$= \frac{(1.6\times10^{-19})^2}{3\times2\times8.85\times10^{-12}\times6.62\times10^{-34}}$$

$= 7.27 \times 10^5$ m/s

Hence, the speed of the electron in a hydrogen atom in n = 1, n = 2 and n = 3 is 2.18×10^6 m/s, 1.09×10^6 m/s, 7.27×10^5 m/s respectively.

(b) Let T_1 be the orbital period of the electron when it is in level $n_1 = 1$

Orbital period is related to orbital speed as:

$$T_1 = \frac{2\pi r_1}{v_1}$$

Where r_1 = Radius of the orbit

$$= \frac{n_1^2 h^2 \in_0}{\pi m e^2}$$

h = Planck's constant = 6.62×10^{-34} Js and e = Charge on an electron = 1.6×10^{-19} C

$\in_0$ = Permittivity of free space = $8.85 \times 10^{-12}\ N^{-1}\ C^2\ m^{-2}$

m = Mass of an electron = 9.1×10^{-31} kg

$$\therefore T_1 = \frac{2\pi r_1}{v_1}$$

$$= \frac{2\pi \times (1)^2 \times (6.62 \times 10^{-34})^2 \times 8.85 \times 10^{-12}}{2.18 \times 10^6 \times \pi \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}$$

$= 15.27 \times 10^{-17} = 1.527 \times 10^{-16}$ s

For level $n_2 = 2$, we can write the period as:

$$T_2 = \frac{2\pi r_2}{v_2}$$

Where, r_2 = Radius of the electron in $n_2 = 2$

$$= \frac{(n_2)^2 h^2 \in_0}{\pi m e^2}$$

$$\therefore T_2 = \frac{2\pi r_2}{v_2}$$

$$= \frac{2\pi \times (2)^2 \times (6.62 \times 10^{-34})^2 \times 8.85 \times 10^{-12}}{1.09 \times 10^6 \times \pi \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}$$

$= 1.22 \times 10^{-15}$ s

And, for level $n_3 = 3$, we can write the period as:

$$T_3 = \frac{2\pi r_3}{v_3}$$

Where, r_3 = Radius of the electron in $n_3 = 3$

$$= \frac{(n_3)^2 h^2 \in_0}{\pi m e^2}$$

$$\therefore T_3 = \frac{2\pi r_3}{v_3}$$

$$= \frac{2\pi \times (3)^2 \times (6.62 \times 10^{-34})^2 \times 8.85 \times 10^{-12}}{7.27 \times 10^5 \times \pi \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}$$

$= 4.12 \times 10^{-15}$ s

Hence, the orbital period in each of these levels is 1.52×10^{-16} s, 1.22×10^{-15} s and 4.12×10^{-15} s respectively.

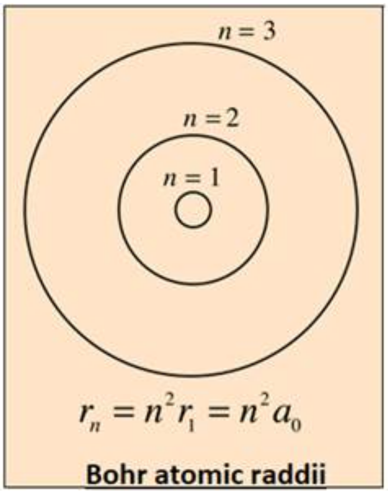
8. The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What are the radii of the n = 2 and n =3 orbits?

8. Given, radius of innermost orbit, $r_1 = 5.3 \times 10^{-11}$ m

Then, let r_2 be the radius of orbit at n = 2.

Then, $r_2 = (n)^2 r_1$

As shown in the diagram:



$\Rightarrow r_2 = 2^2 \times 5.3 \times 10^{-11}$ m
$\Rightarrow r_2 = 2.12 \times 10^{-10}$ m
For n = 3, we have,
$\Rightarrow r_3 = (n)^2 r_1$
$\Rightarrow r_3 = 3^2 \times 5.3 \times 10^{-11}$ m
$\Rightarrow r_3 = 4.77 \times 10^{-10}$ m
Hence, the radii of an electron for n = 2 and n = 3 orbits are 2.12×10^{-10} m and 4.77×10^{-10} m.

9. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. What series of wavelengths will be emitted?

9. It is given that the energy of the electron beam used to bombard gaseous hydrogen at room temperature is 12.5 eV. Also, the energy of the gaseous hydrogen in its ground state at room temperature is –13.6 eV.
When gaseous hydrogen is bombarded with an electron beam, the energy of the gaseous hydrogen becomes –13.6 + 12.5 eV i.e., –1.1 eV.
Orbital energy is related to orbit level (n) as:

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

For n = 3, $E = \frac{-13.6}{9} = -1.5$ eV

This energy is approximately equal to the energy of gaseous hydrogen. It can be concluded that the electron has jumped from n = 1 to n = 3 level.
During its de-excitation, the electrons can jump from n = 3 to n = 1 directly, which forms a line of the Lyman series of the hydrogen spectrum.
We have the relation for wave number for Lyman series as:

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

Where,

R_y = Rydberg constant = $1.097 \times 10^7\ m^{-1}$

λ = Wavelength of radiation emitted by the transition of the electron.

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{3^2}\right)$$

$$= 1.097 \times 10^7 \left(1 - \frac{1}{9}\right) = 1.097 \times 10^7 \times \frac{8}{9}$$

$$\lambda = \frac{9}{8 \times 1.097 \times 10^7} = 102.55 \text{ nm}$$

If the electron jumps from n = 2 to n = 1, then the wavelength of the radiation is given as:

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$= 1.097 \times 10^7 \left(1 - \frac{1}{4}\right) = 1.097 \times 10^7 \times \frac{3}{4}$$

$$\lambda = \frac{4}{1.097 \times 10^7 \times 3} = 121.54 \text{ nm}$$

If the transition takes place from n = 3 to n = 2, then the wavelength of the radiation is given as:

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$= 1.097 \times 10^7 \left(\frac{1}{4} - \frac{1}{9}\right) = 1.097 \times 10^7 \times \frac{5}{36}$$

$$\lambda = \frac{36}{5 \times 1.097 \times 10^7} = 656.33 \text{ nm}$$

This radiation corresponds to the Balmer series of the hydrogen spectrum.

Hence, in Lyman series, two wavelengths i.e., 102.5 nm and 121.5 nm are emitted. And in the Balmer series, one wavelength i.e., 656.33 nm is emitted.

10. In accordance with the Bohr's model, find the quantum number that characterises the earth's revolution around the sun in an orbit of radius 1.5×10^{11} m with orbital speed 3×10^4 m/s. (Mass of earth = 6.0×10^{24} kg.)

10. Angular momentum is given by the relation:

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

Where M is the mass of Earth and is equal to 6.0×10^{24} kg.

v is the orbital speed of Earth = 3×10^4 m/s.

r is the orbital radius of Earth = 1.5×10^{11} m

n is the quantum number

$$\Rightarrow n = \frac{mvr2\pi}{h}$$

substituting the values, we get

$$n = \frac{\left[6.0 \times 10^{24}\,\text{Kg} \times 3 \times 10^{4}\,\text{ms}^{-1} \times 1.5 \times 10^{11}\,\text{m} \times 2 \times 3.14\right]}{6.63 \times 10^{34}\,\text{J} - \text{sec}}$$

on calculating, we get

$n = 2.6 \times 10^{74}$