Chapter-12
Atoms
Class – XII
Subject – Physics

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.)

Sol.

a) No different from
b) Thomson's model; Rutherford's model
c) Rutherford's model
d) Thomson's model; Rutherford's model
e) Both the models

12.2. 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?

Sol.

There would be no large-angle scattering, because the alpha-particle has mass nearly four times than that of the target nuclei. No observable conclusion can be made in this solid hydrogen alpha-particle scattering experiment.

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

Sol.

Paschen series is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n^2}\right]$$

For shortest wavelength

$n = \infty$

Substituting and solving

$\lambda = 820$ nm

12.4. 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?

Sol.

Given:
E = 2.3 eV

We know
$\nu = E / h$
Substitution produces
$\nu = 5.55 \times 10^{14}$ Hz

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

Sol.

Given:
Ground state energy of hydrogen atom
E = -13.6 eV
For ground state,
n = 1

Radius for n = 1 is given by formula

$$r = \frac{h^2 \epsilon_o}{\pi m e^2}$$

Substituting the values and solving gives

$$r = 5.29 \times 10^{-11}\ m$$

Kinetic energy can be calculated by the formula

$$K = e^2/8\pi\epsilon_o r$$

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

$\epsilon_o = 8.85 \times 10^{-12}$

Substitution gives

$$K = 13.6\ eV$$

Now potential energy

$$U = -e^2 / 4\pi\epsilon_o r$$

Putting values and solving

$$U = -27.2\ eV$$

12.6. 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.

Sol.

Given:

n1 = 1

n2 = 4

Using the formula

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

$\lambda = 9.72 \times 10^{-8}$ m
Frequency, $\nu = c / \lambda = 3.1 \times 10^{15}$ Hz

12.7.

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.

Sol.

a) Bohr's angular postulate momentum gives

$$mv_n r_n = nh / 2\pi \ldots\ldots\ldots\ldots\ldots(1)$$

Radius is given by

$$r_n = \frac{n^2}{m}\cdot\left[\frac{h}{2\pi}\right]^2\cdot\frac{4\pi\epsilon_o}{e^2}\ldots\ldots\ldots\ldots(2)$$

where symbols carry usual meanings.

for n = 1

$r_1 = 5.29 \times 10^{-11}$ m

Substituting in eq. (1)

$v_1 = 2.19 \times 10^{6}$ m / s

for n = 2

Calculating radius using eq. (2)

$r_2 = 2.12 \times 10^{-10}$ m

Putting in eq. (1)

$v_2 = 1.09 \times 10^{6}$ m / s

for n = 3

Calculating radius using eq. (2)

$r_3 = 4.78 \times 10^{-10}$ m

Putting in eq. (1) gives

$v_3 = 7.27 \times 10^{5}$ m / s

b) Orbital period can be deduced by the simple relation of

= distance / speed

$= 2 \pi r_n / v_n$ ....(3)

for n = 1

Taking the corresponding values of r1 and v1 calculated above and substituting them in eq. (3)

Orbital period = 1.52×10^{-16} s

for n = 2

In similar fashion

Orbital period = 1.22×10^{-15} s

for n = 3

Orbital period = 4.11×10^{-15} s

12.8. 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?

Sol.

From the previous question

$$r_n = \frac{n^2}{m}.\left[\frac{h}{2\pi}\right]^2.\frac{4\pi\epsilon_o}{e^2}$$

Therefore

for n = 2

$$r_2 = 2.12 \text{ x } 10^{-10} \text{ m}$$

for n = 3

$$r_3 = 4.78 \text{ x } 10^{-10} \text{ m}$$

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

Sol.

From the formula

$E_n = - 13.6 / n^2$ eV

For n = 3 to n = 1

$E_3 – E_1 = 12.09$ eV ≈ 12.5 eV

This energy difference includes Lyman and Balmer series.
At room temperature, most of the hydrogen atoms are in ground state. So n = 1, and the energy difference indicates the final n to be 2 or 3.

Lyman series

for n = 2

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

$$\lambda = 122 \text{ nm}$$

for n = 3

$$\lambda = 103 \text{ nm}$$

Balmer series

for n = 3

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$\lambda = 656 \text{ nm}$$

12.10. 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 × 1011 m with orbital speed 3 × 104 m/s. (Mass of earth = 6.0 × 1024 kg.)

Sol.

Given:

$r = 1.5 \times 10^{11}$ m

v = 30000 m / s

$m = 6 \times 10^{24}$ kg

Using the expression

$mvr = nh / 2\pi$

Substituting and solving

$n = 2.56 \times 10^{74}$