Question 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.)

Answer

(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.

Question 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?

Answer

In the alpha-particle scattering experiment, if a thin sheet of solid hydrogen is used in place of a gold foil, then the scattering angle would not be large enough. This is because the mass of hydrogen (1.67×10^{-27} kg) is less than the mass of incident α−particles

(6.64×10^{-27} kg). Thus, the mass of the scattering particle is more than the target nucleus (hydrogen). As a result, the α−particles would not bounce back if solid hydrogen is used in the α-particle scattering experiment.

Question 12.3:

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

Answer

Rydberg's formula is given as:

$$\frac{hc}{\lambda} = 21.76\times10^{-19}\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

Where,

h = Planck's constant = 6.6×10^{-34} Js

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 $n_2 = \infty$.

$$\frac{hc}{\lambda} = 21.76\times10^{-19}\left[\frac{1}{(3)^2}-\frac{1}{(\infty)^2}\right]$$

$$\lambda = \frac{6.6\times10^{-34}\times3\times10^{8}\times9}{21.76\times10^{-19}}$$

$$= 8.189\times10^{-7}\text{ m}$$

$$= 818.9\text{ nm}$$

Question 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 makes a transition from the upper level to the lower level?

Answer

Separation of two energy levels in an atom,

E = 2.3 eV

= $2.3 \times 1.6 \times 10^{-19}$

= 3.68×10^{-19} J

Let ν be the frequency of radiation emitted when the atom transits from the upper level to the lower level.

We have the relation for energy as:

$E = h\nu$

Where,

h = Planck's constant $= 6.62 \times 10^{-34}$ Js

$$\therefore \nu = \frac{E}{h}$$

$$= \frac{3.68\times10^{-19}}{6.62\times10^{-32}} = 5.55\times10^{14}\text{ Hz}$$

Hence, the frequency of the radiation is 5.6×10^{14} Hz.

Question 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?

Answer

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 × (13.6) = − 27 .2 eV

Question 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 the photon.

Answer

For ground level, $n_1 = 1$

Let E_1 be the energy of this level. It is known that E_1 is related with n_1 as:

$$E_1 = \frac{-13.6}{n_1^2} \text{ eV}$$
$$= \frac{-13.6}{1^2} = -13.6 \text{ eV}$$

The atom is excited to a higher level, $n_2 = 4$.

Let E_2 be the energy of this level.

$$\therefore E_2 = \frac{-13.6}{n_2^2} \text{ eV}$$
$$= \frac{-13.6}{4^2} = -\frac{13.6}{16} \text{ eV}$$

The amount of energy absorbed by the photon is given as:

$E = E_2 - E_1$

$$= \frac{-13.6}{16} - \left(-\frac{13.6}{1}\right)$$
$$= \frac{13.6 \times 15}{16} \text{ eV}$$
$$= \frac{13.6 \times 15}{16} \times 1.6 \times 10^{-19} = 2.04 \times 10^{-18} \text{ J}$$

For a photon of wavelengthλ, the expression of energy is written as:

$$E = \frac{hc}{\lambda}$$

Where,

h = Planck's constant = 6.6×10^{-34} Js

c = Speed of light = 3×10^8 m/s

$$\therefore \lambda = \frac{hc}{E}$$
$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.04 \times 10^{-18}}$$
$$= 9.7 \times 10^{-8} \text{ m} = 97 \text{ nm}$$

And, frequency of a photon is given by the relation,

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