



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:

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

Where,

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

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 $n_2 = \infty$.

$$\begin{aligned} \frac{hc}{\lambda} &= 21.76 \times 10^{-19} \left[\frac{1}{(3)^2} - \frac{1}{(\infty)^2} \right] \\ \lambda &= \frac{6.6 \times 10^{-34} \times 3 \times 10^8 \times 9}{21.76 \times 10^{-19}} \\ &= 8.189 \times 10^{-7} \text{ m} \\ &= 818.9 \text{ nm} \end{aligned}$$

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,

$E = 2.3 \text{ eV}$

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

$= 3.68 \times 10^{-19} \text{ J}$

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 = 6.62×10^{-34} Js

$$\begin{aligned} \therefore \nu &= \frac{E}{h} \\ &= \frac{3.68 \times 10^{-19}}{6.62 \times 10^{-34}} = 5.55 \times 10^{14} \text{ Hz} \end{aligned}$$

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, $E = -13.6 \text{ eV}$

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

Kinetic energy = $-E = -(-13.6) = 13.6 \text{ eV}$

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

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

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 wavelength λ , the expression of energy is written as:

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

Where,

h = Planck's constant = $6.6 \times 10^{-34} \text{ Js}$

c = Speed of light = $3 \times 10^8 \text{ m/s}$

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

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.04 \times 10^{-18}}$$

$$= 9.7 \times 10^{-8} \text{ m} = 97 \text{ nm}$$

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

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