II. Short Answer Type Questions

Question 1. The uncertainty in the position of a moving bullet of mass 10 g is 10^{-5} m. Calculate the uncertainty in its velocity?
Answer: According to uncertainty principle,

$$\Delta x.\ m\Delta v = \frac{h}{4\pi} \text{ or } \Delta v = \frac{h}{4\pi m \Delta x};\ h = 6.626 \times 10^{-34} \text{ kg m}^2\text{s}^{-1};\ m = 10 \text{ g} = 10^{-2} \text{ kg}$$

$$\Delta x = 10^{-5} \text{ m};\ \Delta v = \frac{(6.626 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1})}{4 \times 3.143 \times (10^{-2} \text{ kg}) \times (10^{-5} \text{ m})} = \mathbf{5.27 \times 10^{-28} \text{ mv}}$$

Question 2. The uncertainty in the position and velocity of a particle are 10^{-10}m and 5.27×10^{-24} ms^{-1} respectively. Calculate the mass of the particle. (Haryana Board 2000)
Answer: According to uncertainty principle,

$$\Delta x.\ m\Delta v = \frac{h}{4\pi} \text{ or } m = \frac{h}{4\pi\ \Delta x\ \Delta v};\ h = 6.626 \times 10^{-34} \text{ kg m}^2\text{s}^{-1}$$

$$\Delta x = 10^{-10} \text{ m};\ \Delta v = 5.27 \times 10^{-24} \text{ ms}^{-1}$$

$$m = \frac{(6.626 \times 10^{-34} \text{ kg m}^2\text{s}^{-1})}{4 \times 3.143 \times (10^{-10} \text{m}) \times (5.27 \times 10^{-24} \text{ ms}^{-1})} = \mathbf{0.1 \text{ kg}}$$

Question 3. With what velocity must an electron travel so that its momentum is equal to that of a photon of wavelength = 5200 A?
Answer:

According to de Broglie equation, $\lambda = \frac{h}{mv}$

Momentum of electron, $mv = \frac{h}{\lambda} = \frac{(6.626 \times 10^{-34} \text{kg m}^2 \text{ s}^{-1})}{(5200 \times 10^{-10} \text{m})}$

$= 1.274 \times 10^{-27} \text{ kg ms}^{-1}$ ...(*i*)

The momentum of electron can also be calculated as $= mv = (9.1 \times 10^{-31} \text{ kg}) \times v$ ...(*ii*)

Comparing (*i*) and (*ii*)

$$(9.1 \times 10^{-31} \text{ kg}) \times v = (1.274 \times 10^{-27} \text{ kg ms}^{-1})$$

$$v = \frac{(1.274 \times 10^{-27} \text{kg ms}^{-1})}{(9.1 \times 10^{-31} \text{kg})} = \mathbf{1.4 \times 10^3 \text{ ms}^{-1}}$$

Question 4. Using Aufbau principle, write the ground state electronic configuration of following atoms.
(i) Boron (Z = 5)
(ii) Neon (Z = 10),
(iii) Aluminium (Z = 13)
(iv) Chlorine (Z = 17),
(v) Calcium (Z = 20)
(vi) Rubidium (Z = 37)
Answer:
(i) Boron (Z = 5) ; $1s^2\ 2s^2\ 1p^1$
(ii) Neon (Z = 10) ; $1s^2\ 2s^2\ 2p^6$
(iii) Aluminium (Z = 13) ; $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
(iv) Chlorine(Z = 17) ; $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
(v) Calcium (Z = 20) ; $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
(vi) Rubidium (Z = 37) ; $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10} 4s^2\ 4p^6\ 5s^1$.

Question 5. Calculate the de Broglie wavelength of an electron moving with 1% of the speed of light?
Answer:

According to de Broglie equation, $\lambda = \frac{h}{mv}$

Mass of electron $= 9.1 \times 10^{-31}$ kg ; Planck's constant $= 6.626 \times 10^{-34}$ kgm^{2}s^{-1}
Velocity of electron = 1% of speed of light $= 3.0 \times 10^8 \times 0.01 = 3 \times 10^6$ ms^{-1}

$$\text{Wavelength of electron } (\lambda) = \frac{h}{mv} = \frac{(6.626 \times 10^{-34} \text{ kg m}^2\text{s}^{-1})}{(9.1 \times 10^{-31} \text{ kg}) \times (3 \times 10^6 \text{ ms}^{-1})}$$
$$= 2.43 \times 10^{-10} \text{ m.}$$

Question 6. The kinetic energy of an electron is 4.55 x 10^{-25} J. The mass of electron 9.1 x 10^{-1} kg. Calculate velocity, momentum and the wavelength of the electron?(Haryana Board, 2004, All CBSE 2000)
Answer:

Step I. Calculation of the velocity of electron
Kinetic energy $= 1/2\, mv^2 = 4.55 \times 10^{-25}$ J $= 4.55 \times 10^{-25}$ kg m^2 s^{-2}

or $$v^2 = \frac{2 \times \text{KE}}{m} = \frac{2 \times (4.55 \times 10^{-25} \text{ kg m}^2\text{s}^{-2})}{(3 \times 10^6 \, ms^{-1})} = 10^6 \text{ m}^2 \text{ s}^{-2}$$

or Velocity $(v) = (10^6 \text{ m}^2 \text{ s}^{-2})^{1/2} = \mathbf{10^3}$ **ms^{-1}**

Step II. Calculation of the momentum of the electron
Momentum of electron $= mv = (9.1 \times 10^{-31}$ kg$) \times (10^3$ m s$^{-1}) = 9.1 \times 10^{-28}$ kg m^{-1}
Step HI. Calculation of the wavelength of the electron
According to de Broglie equation:

$$\lambda = \frac{h}{mv} = \frac{(6.626 \times 10^{-34} \text{ kg m}^2\text{s}^{-1})}{(9.1 \times 10^{-31} \text{kg}) \times (10^3 \text{ m s}^{-1})}$$
$$= 0.728 \times 10^{-6} \text{ m} = \mathbf{7.28 \times 10^{-7} \text{ m}}$$

Question 7. What is the wavelength for the electron accelerated by 1.0 x 10^4 volts?
Answer:

Step I. Calculation of the velocity of electron
Energy (kinetic energy) of electron $= 1.0 \times 10^4$ volts.
$= 1.0 \times 10^4 \times 1.6 \times 10^{-19}$ J $= 1.6 \times 10^{-15}$ J
$= 1.6 \times 10^{-15}$ kg m^2 s^{-2}

or $1/2\, mv^2 = 1.6 \times 10^{-15}$ kg m^2 s^{-2}

or $$v = \left(\frac{2 \times 1.6 \times 10^{-15} \text{ kg m}^2\text{s}^{-2}}{9.1 \times 10^{-31} \text{kg}}\right)^{1/2} = 5.93 \times 10^7 \text{ ms}^{-1}$$

Step II. Calculation of the wavelength of electron
According to de Broglie equation,

$$\lambda = \frac{h}{mv}; \lambda = \frac{(6.626 \times 10^{-34} \text{ kg m}^2\text{s}^{-1})}{(9.1 \times 10^{-31} \text{ kg}) \times (5.93 \times 10^7 \text{ m s}^{-1})} = \mathbf{1.22 \times 10^{-11} \text{ m.}}$$

Question 8. In a hydrogen atom, the energy of an electron in first Bohr's orbit is 13.12 x 10^5 J mol^{-1}. What is the energy required for its excitation to Bohr's second orbit?
Answer: The expression for the energy of electron of hydrogen is:

$$E_n = -\frac{2\pi^2 m_e^4}{n^2 h^2}$$

When $$n = 1, E_1 = -\frac{2\pi^2 m_e^4}{(1)^2 h^2} = -13.12 \times 10^5 \text{ J mol}^{-1}$$

When $$n = 2, E_2 = -\frac{2\pi^2 m_e^4}{(2)^2 h^2} = -\frac{13 \cdot 12 \times 10^5}{4} \text{ J mol}^{-1}$$
$$= -3.28 \times 10^5 \text{ J mol}^{-1}.$$

The energy required for the excitation is :
$$\Delta E = E_2 - E_1 = (-3.28 \times 10^5) - (-13.12 \times 10^5) = \mathbf{9.84 \times 10^5 \text{ J mol}^{-1}}.$$

Question 9. What are the two longest wavelength lines (in manometers) in the Lyman series of hydrogen spectrum?
Answer: According to Rydberg-Balmer equation.

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{1^2}, \frac{1}{n_2^2}\right]$$

The wavelength (λ) will be the longest when n_2 is the smallest *i.e.*, n_2 = 2 and 3 for two longest wavelength lines.

For $n_2 = 2$:
$$\frac{1}{\lambda} = (1.097 \times 10^{-2}\ \text{nm}^{-1})\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$
$$= (1.097 \times 10^{-2}\ \text{nm}^{-1}) \times \frac{3}{4} = 8.228 \times 10^{-3}\ \text{nm}^{-1} \text{ or } \lambda = \mathbf{121.54\ nm}$$

For $n_2 = 3$:
$$\frac{1}{\lambda} = (1.097 \times 10^{-2}\ \text{nm}^{-1})\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$$
$$= (1.097 \times 10^{-2}\ \text{nm}^{-1}) \times (8/9) = 9.75 \times 10^{-3}\ \text{nm}^{-1}\ ;\ \lambda = \mathbf{102.56\ nm}$$

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