Dual Nature of Radiation and Matter

CHAPTER 11

NCERT FOCUS

ANSWERS

Topic 1

1. (a) Maximum energy of X-ray photon = Maximum energy of an accelerated electron

$h\upsilon_{max} = eV$

$\therefore \quad \upsilon_{max} = \frac{eV}{h} = \frac{1.6\times10^{-19}\times30\times10^{3}}{6.63\times10^{-34}}$

$= 7.24 \times 10^{18}$ Hz

(b) $\lambda_{min} = \frac{c}{\upsilon_{max}} = \frac{3\times10^{8}}{7.24\times10^{18}} = 0.0414 \times 10^{-9}$

$= 0.0414$ nm.

2. Here $W_0 = 2.14$ eV, $\upsilon = 6 \times 10^{14}$ Hz

(a) $K_{max} = h\upsilon - W_0$

$= 6.63 \times 10^{-34} \times 6 \times 10^{14}$ J $- 2.14$ eV

$= \frac{6.63\times6\times10^{-20}}{1.6\times10^{-19}}$ eV $- 2.14$ eV

$= 2.48 - 2.14 = 0.34$ eV.

(b) As $eV_0 = K_{max} = 0.34$ eV

$\therefore$ Stopping potential, $V_0 = 0.34$ V.

(c) $K_{max} = \frac{1}{2}mv_{max}^2 = 0.34$ eV

$= 0.34 \times 1.6 \times 10^{-19}$ J

or $v_{max}^2 = \frac{2\times0.34\times1.6\times10^{-19}}{m}$

$= \frac{2\times0.34\times1.6\times10^{-19}}{9.1\times10^{-31}} = 119560.4 \times 10^{6}$

or $v_{max} = 345.8 \times 10^{3}$ m s^{-1} = 345.8 km s^{-1}.

3. Here, $V_0 = 1.5$ V

$K_{max} = eV_0 = 1.5$ eV $= 1.5 \times 1.6 \times 10^{-19}$ J

$= 2.4 \times 10^{-19}$ J

4. Here $\lambda = 632.8$ nm $= 632.8 \times 10^{-9}$ m,

$P = 9.42$ mW $= 9.42 \times 10^{-3}$ W

(a) Energy of each photon,

$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{632.8\times10^{-9}} = 3.14\times10^{-19}\text{ J}$$

Momentum of each photon,

$$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{632.8\times10^{-9}} = 1.05 \times 10^{-27}\text{ kg m s}^{-1}.$$

(b) Number of photons arriving per second at the target,

$$N = \frac{P}{E} = \frac{9.42\times10^{-3}}{3.14\times10^{-19}}$$

$= 3 \times 10^{16}$ photons per second.

(c) As $mv = p$

$\therefore$ Velocity, $v = \frac{p}{m} = \frac{1.05\times10^{-27}\text{ kg m s}^{-1}}{1.67\times10^{-27}\text{ kg}}$

$= 0.63$ m s^{-1}.

5. Given, slope of graph $= 4.12 \times 10^{-15}$ V s

slope $= \frac{h}{e}$

$4.12\times10^{-15} = \frac{h}{1.6\times10^{-19}}$

or $h = 6.592 \times 10^{-34}$ J s

6. According to Einstein's relation

$$h\upsilon = h\upsilon_0 + \frac{1}{2}mv_{max}^2$$

Maximum kinetic energy of emitted electron

$$\frac{1}{2}mv_{max}^2 = h(\upsilon - \upsilon_0)$$

$= 6.63 \times 10^{-34}(8.2 \times 10^{14} - 3.3 \times 10^{14})$

$= 32.49 \times 10^{-20}$ joule $\simeq 2$ eV

$\therefore$ Cut off potential for emitted electron will be 2 volt.

7. Let us calculate the energy associated with photons incident

$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{330\times10^{-9}} = 6.027\times10^{-19}\text{ J}$$

$$E = \frac{6.027\times10^{-19}}{1.6\times10^{-19}}\text{ eV} = 3.77\text{ eV}$$

Since, energy of incident photons *i.e.*, 3.77 eV is less than work function, hence no emission will take place.

8. According to Einstein's equation

$$h\upsilon = h\upsilon_0 + \frac{1}{2}mv_{max}^2$$

So, threshold frequency

$$\upsilon_0 = \frac{h\upsilon - \frac{1}{2}mv_{max}^2}{h} \quad \text{or} \quad \upsilon_0 = \upsilon - \frac{mv_{max}^2}{2h}$$

$$\upsilon_0 = 7.21 \times 10^{14} - \frac{9.1 \times 10^{-31} \times (6 \times 10^5)^2}{2 \times (6.63 \times 10^{-34})}$$

$\upsilon_0 = 4.74 \times 10^{14}$ Hz.

9. Energy of incident radiation

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{488 \times 10^{-9} \times 1.6 \times 10^{-19}} \text{ eV} = 2.55 \text{ eV}$$

Now using Einstein's relation

$E = W_0 + eV_0$

where V_0 is stopping potential

$2.55 \text{ eV} = W_0 + e \times 0.38 \text{ V}$

$\Rightarrow \quad W_0 = 2.55 - 0.38$

$\Rightarrow \quad W_0 = 2.17$ eV.

Topic 2

1. de Broglie wavelength $\lambda = \dfrac{h}{mv}$

(a) Wavelength associated with bullet

$$\lambda_{\text{bullet}} = \frac{6.63 \times 10^{-34}}{0.04 \times 10^3} = 1.7 \times 10^{-35} \text{ m}$$

(b) Wavelength associated with ball

$$\lambda_{\text{ball}} = \frac{6.63 \times 10^{-34}}{0.06 \times 1} = 1.1 \times 10^{-32} \text{ m}$$

(c) Wavelength associated with dust particle

$$\lambda_{\text{particle}} = \frac{6.63 \times 10^{-34}}{10^{-9} \times 2.2} = 3 \times 10^{-25} \text{ m}$$

2. For a photon, de Broglie wavelength,

$$\lambda = \frac{h}{p}.$$

For an electromagnetic radiation of frequency υ and wavelength λ' $(= c/\upsilon)$,

Momentum,

$$p = \frac{E}{c} = \frac{h\upsilon}{c} \quad \text{or} \quad p = \frac{h}{c} \cdot \frac{c}{\lambda'} = \frac{h}{\lambda'}$$

Then, $\lambda' = \dfrac{h}{p} = \lambda$

Thus the wavelength of the electromagnetic radiation is the same as the de Broglie wavelength of the photon.

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