DPP – 3

CLASS – 12th

TOPIC – De Broglie's wavelength

Q.1 Plot a graph showing the variation of stopping potential (Vo) with the frequency (v) of the incident radiation for a given photosensitive material. Hence state the significance of the threshold frequency in photoelectric emission.

Or

Sketch a graph between frequency of incident radiation and stopping potential for a given photosensitive material. What information can be obtained from the intercept on the potential axis?

Q.2 Define the terms threshold frequency' and `stopping potential' for photo-electric effect. Show graphically how the stopping potential for a given metal varies with frequency of the incident radiations. Mark threshold frequency on this graph.

Q.3 The graph in Fig 1.14 shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals A and B.

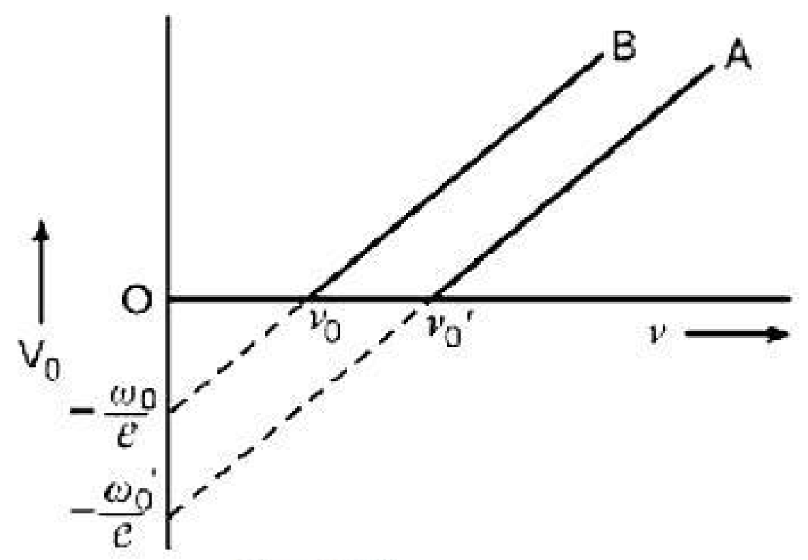

Fig.1.14

Which one of the two has higher value of work function? Justify your answer.

Q.4 Fig. 1.17 shows the variation of stopping potential Vo with the frequency v of incident radiation for two photosensitive metals X and Y.

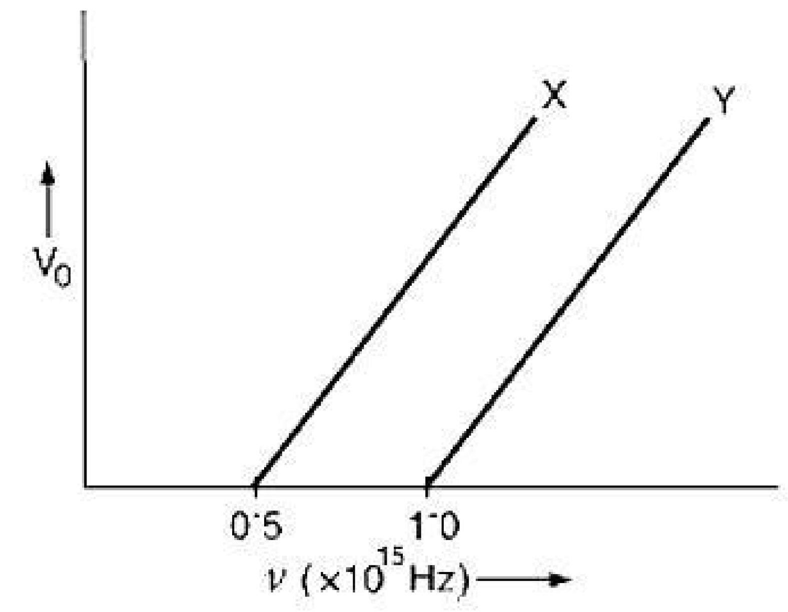

Fig. 1.17

(i) Which of the metals has smaller threshold wavelength? Give reason.

(ii) Explain, giving reason, which metal gives out electrons, having smaller kinetic energy.

(iii) If the distance between the light source and metal X is doubled, how will the stopping potential change?

Q.5 Two metals X and Y when illuminated with appropriate radiation emit photoelectrons. The work function of X is higher than that of Y. Which metal will have higher value of threshold frequency and why?

Q.6 It is harder to remove a free electron from copper than from sodium. Which metal has greater work function? Which has higher threshold wavelength?

Q.7 For photoelectric effect in a metal, Fig 1.18 shows the plot of cut off voltage versus frequency of incident radiation. Calculate (i) the threshold frequency and (ii) the work function for the given metal.

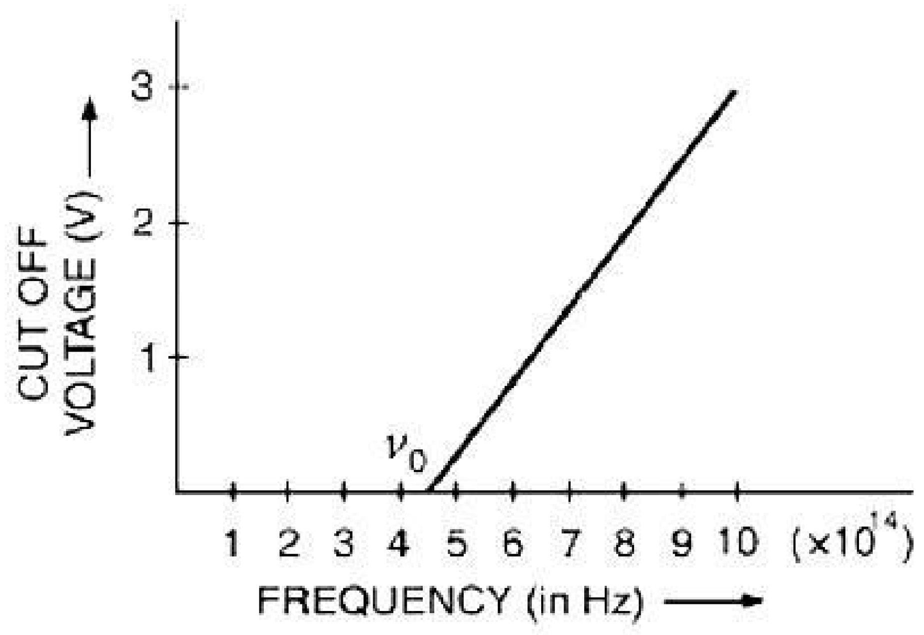

Fig. 1.18

Q.8 Find the momentum of an X-ray photon c wavelength λ.

Q.9 Calculate the momentum of electrons ; their wavelength is 2 A. Given that Planck' constant, h = 6.626×10^{-34} J s; mass of electron m = 9.1×10^{-31} kg

Q.10 Calculate the de-Broglie wavelength for electron moving with speed of 6×10^5 ms^{-1}

Q.11 The de-Broglie wavelengths, associated with a proton and a neutron, are found to be equal. Which of the two has a higher value for kinetic energy?

Q.12 An electron and a proton are moving with the same speed. Which will have more wavelength?

Q.13 A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has

(a) greater value of de-Broglie wavelength associated with it and

(b) less momentum ?

Give reasons to justify your answer.

SOLUTION

(PHYSICS) DUAL NATURE OF RADIATION OF MATTER

DPP – 3

CLASS – 12th

TOPIC – De Broglie's wavelength

Sol.1. The graph between frequency of incident radiation and stopping potential is as shown in Fig.1.13.

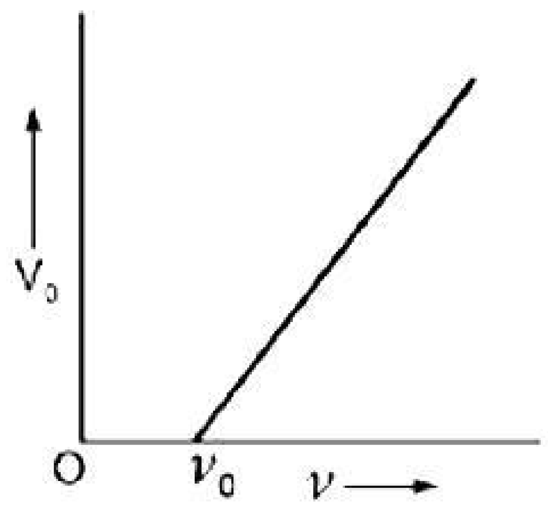

Fig. 1.13

The graph tells that the emission of photoelectrons does not take place, till the frequency of the incident light is above the threshold frequency (v) for the metal.

Sol.2. There is no time lag between the instant the photon of light falls on the metal surface and the instant a photoelectron is emitted from the metal surface. It can not be explained by assuming wave nature of radiation. If wave nature of radiation is assumed, then it will take quite a long time (about an year) for electron to come out of the metal surface.

Sol.3. work function of a metal,

$\omega = h\nu_0$,

where vo is threshold frequency for the metal.

Since $v_0' > v_0$ the metal A has the higher value of work function.

Sol.4.(i) As explained in SAQ 1.24, it follows that the metal Y has larger threshold frequency and hence smaller threshold wavelength.

(ii) Since the metal Y has largler threshold frequency i.e. larger work function, it gives out electrons, having smaller kinetic energy.

(iii) If the distance between the light source and metal X is doubled, the intensity of the incident radiation will become one fourth. However, the kinetic energy of electrons emitted will remain unchanged, as the change in is the intensity of the incident radiation does not affect the kinetic energy of the emitted electrons hence the stopping potential will remains the same

Sol.5. The work function of a metal is given by

$$\omega = h\,\nu_0,$$

where v_0 is threshold frequency. Since work function of metal X is higher, it will also have higher value of the threshold frequency.

Sol.6. The graph showing the variation of stopping potential with the frequency of incident radiation for two different materials having work functions @ and w, is as shown in Fig. 1.19.

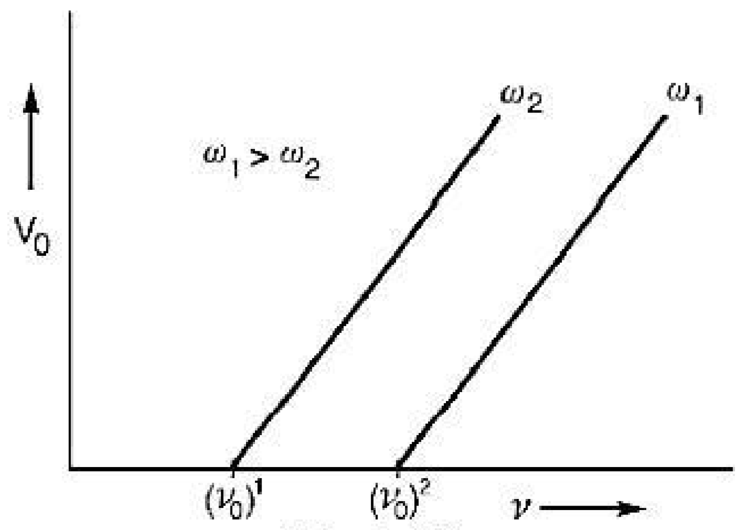

Fig. 1.19

from Eistein's Photoelectric equation, we have

$$h\nu = h\nu_0 + m\frac{1}{2}\,m\,v_{max}^{2}$$
$$= h\nu_0 + e\,V_0$$
or $$V_0 = \frac{h\nu}{e} - \frac{h\nu_0}{e}$$

Since v is potted along x-axis and v_0 along Y-axis; it represent a straight line.

Sol.7. As it is harder to remove an electron from copper than sodium, the work function of copper is greater

Now, $$\omega = h\nu_0 = \frac{hc}{\lambda_0}$$
or $$\lambda_0 \propto \frac{1}{\omega}$$

As threshold wavelength is inversely proportional to the work function, its value will be more for sodium.

Sol.8. The threshold frequency (v_0) is equal to the intercept made by the graph on the frequency-axis.

Thus, $\nu_0 = \mathbf{4{\cdot}5 \times 10^{14}\ Hz}$

(ii) Work function of the metals,

$\omega = h\nu_0 = 6{\cdot}62 \times 10^{-34} \times 4{\cdot}5 \times 10^{14}$

$= 2{\cdot}98 \times 10^{-19}$ J

$= \dfrac{2{\cdot}98 \times 10^{-19}}{1{\cdot}6 \times 10^{-19}} = \mathbf{1{\cdot}86\ eV}$

Sol.9. Let p be the momentum of the X-ray photon of wavelength λ. Then, energy of the x=ray photon,

$$E = pc$$

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

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

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

Sol.10. Here , $\lambda = 2 = 10^{-10}$ m ; h = 6.626×10^{-34} J s;

m = 9.1×10^{-31} kg

Momentum of the electron,

$$p = \frac{h}{\lambda} = \frac{6{\cdot}626 \times 10^{-34}}{2 \times 10^{-10}}$$

Sol.11. The de-Broglie wavelength of a particle of mass m and having kinetic energy E is given by

$$\lambda = \frac{h}{\sqrt{2mE}}$$

As the de-Broglie wavelengths associated with the proton and neutron are equal,

$$m_p E_p = m_n E_n$$

or $$\frac{E_p}{E_n} = \frac{m_n}{m_p} > 1 \qquad (\because m_n > m_p)$$

or $$\mathbf{E_p > E_n}$$

Sol.12. According to de-Broglie relation:

$$\lambda = \frac{h}{mv}$$

$\therefore$ $$\lambda_e = \frac{h}{m_e v_e} \quad \text{and} \quad \lambda_p = \frac{h}{m_p v_p}$$

or $$v_e = \frac{h}{m_e \lambda_e} \quad \text{and} \quad v_p = \frac{h}{m_p v_p}$$

Since $v_e = v_p$,

$$\frac{h}{m_e \lambda_e} = \frac{h}{m_p v_p} \quad \text{or} \quad m_e \lambda_e = m_p \lambda_p$$

or $$\frac{\lambda_e}{\lambda_p} = \frac{m_p}{m_e}$$

As $m_p > m_e$, it follows that $\boldsymbol{\lambda_e > \lambda_p}$.

Sol.13. In terms of accelerating potential V, the de- Broglie wavelength of a charged particle is given by

$$\lambda = \frac{h}{\sqrt{2\, m\, e\, V}},$$

where e is charge and m, mass of the particle.

The de-Broglie wavelengths of proton and the deutron are given by

$$\lambda_p = \frac{1}{\sqrt{m_p\, e_p\, V}} \qquad \text{......(i)}$$

and $$\lambda_d = \frac{1}{\sqrt{m_d\, e_d\, V}} \qquad \text{...(ii)}$$

From the equations (*i*) and (*ii*) , we have

$$\frac{\lambda_p}{\lambda_d} = \frac{\sqrt{m_d\, e_d}}{\sqrt{m_p\, e_p}}$$

Now, $m_d = 2\, m_p$ and $e_d = e_p$

$$\therefore \quad \frac{\lambda_p}{\lambda_d} = \frac{\sqrt{2\, m_p \times e_p}}{\sqrt{m_p\, e_p}} = \sqrt{2}$$

or $\boldsymbol{\lambda_p > \lambda_d}$

(*b*) The momentum of a particle having de-Broglie wavelength λ is given by

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

As p is inversely proportional to λ, ***the proton will possess less momentum.***