

# Electron, Photon, Photoelectric Effect and X-rays

# SET Self Evaluation Test -25

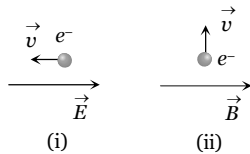
1. Which of the following will have the least value of  $\frac{q}{m}$

- (a) Electron (b) Proton  
(c)  $\alpha$ -particle (d)  $\beta$ -particle

2. When green light is incident on the surface of metal, it emits photo-electrons but there is no such emission with yellow colour light. Which one of the colour can produce emission of photo-electrons

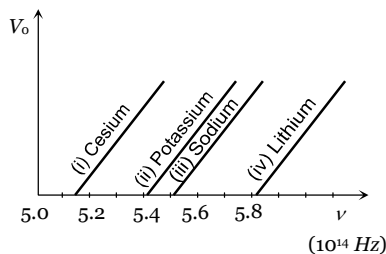
- (a) Orange (b) Red  
(c) Indigo (d) None of the above

3. An electron is moving through a field. It is moving (i) opposite an electric field (ii) perpendicular to a magnetic field as shown. For each situation the de-Broglie wave length of electron



- (a) Increasing, increasing (b) Increasing, decreasing  
(c) Decreasing, same (d) Same, Same

4. The figure shows different graphs between stopping potential ( $V_0$ ) and frequency ( $\nu$ ) for photosensitive surface of cesium, potassium, sodium and lithium. The plots are parallel. Correct ranking of the targets according to their work function greatest first will be



- (a) (i) > (ii) > (iii) > (iv) (b) (i) > (iii) > (ii) > (iv)  
(c) (iv) > (iii) > (ii) < (i) (d) (i) = (iii) > (ii) = (iv)

5. The  $K_\alpha$  X-rays arising from a cobalt ( $z = 27$ ) target have a wavelength of  $179 \text{ pm}$ . The  $K_\alpha$  X-rays arising from a nickel target ( $z = 28$ ) is

- (a)  $> 179 \text{ pm}$  (b)  $< 179 \text{ pm}$   
(c)  $= 179 \text{ pm}$  (d) None of these

6. If a voltage applied to an X-ray tube is increased to 1.5 times the minimum wavelength ( $\lambda_{\min}$ ) of an X-ray

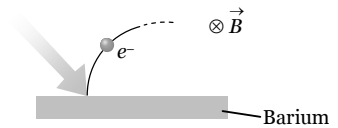
continuous spectrum shifts by  $\Delta\lambda = 26 \text{ pm}$ . The initial voltage applied to the tube is

- (a)  $\approx 10 \text{ kV}$  (b)  $\approx 16 \text{ kV}$   
(c)  $\approx 50 \text{ kV}$  (d)  $\approx 75 \text{ kV}$

7. Light of wavelength  $2475 \text{ \AA}$  is incident on barium. Photoelectrons emitted describe a circle of radius  $100 \text{ cm}$  by a magnetic field of flux density  $\frac{1}{\sqrt{17}} \times 10^{-5} \text{ Tesla}$ . Work

function of the barium is (Given  $\frac{e}{m} = 1.7 \times 10^{11}$ )

- (a)  $1.8 \text{ eV}$   
(b)  $2.1 \text{ eV}$   
(c)  $4.5 \text{ eV}$   
(d)  $3.3 \text{ eV}$



8. Five elements  $A, B, C, D$  and  $E$  have work functions  $1.2 \text{ eV}, 2.4 \text{ eV}, 3.6 \text{ eV}, 4.8 \text{ eV}$  and  $6 \text{ eV}$  respectively. If light of wavelength  $4000 \text{ \AA}$  is allowed to fall on these elements, then photoelectrons are emitted by

- (a)  $A, B$  and  $C$  (b)  $A, B, C, D$  and  $E$   
(c)  $A$  and  $B$  (d) Only  $E$

9. If light of wavelength  $\lambda_1$  is allowed to fall on a metal, then kinetic energy of photoelectrons emitted is  $E_1$ . If wavelength of light changes to  $\lambda_2$  then kinetic energy of electrons changes to  $E_2$ . Then work function of the metal is

- (a)  $\frac{E_1 E_2 (\lambda_1 - \lambda_2)}{\lambda_1 \lambda_2}$  (b)  $\frac{E_1 \lambda_1 - E_2 \lambda_2}{(\lambda_1 - \lambda_2)}$   
(c)  $\frac{E_1 \lambda_1 - E_2 \lambda_2}{(\lambda_2 - \lambda_1)}$  (d)  $\frac{\lambda_1 \lambda_2 E_1 E_2}{(\lambda_2 - \lambda_1)}$

10. If maximum velocity with which an electron can be emitted from a photo cell is  $4 \times 10^8 \text{ cm/sec}$ , the stopping potential is (mass of electron =  $9 \times 10^{-31} \text{ kg}$ )

- (a)  $30 \text{ volt}$  (b)  $45 \text{ volt}$   
(c)  $59 \text{ volt}$  (d) Information is

insufficient

11. Three particles having their charges in the ratio of  $1 : 3 : 5$  produce the same spot on the screen in Thomson's experiment. Their masses are in the ratio of

- (a)  $5 : 3 : 1$  (b)  $3 : 1 : 5$   
(c)  $1 : 3 : 5$  (d)  $5 : 1 : 3$



# AS Answers and Solutions

(SET -25)

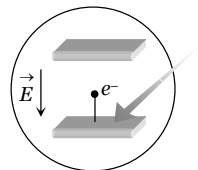
- (c) Mass of  $\alpha$ -particle is maximum so  $\left(\frac{q}{m}\right)_\alpha$  is least.
- (c) Wave length of green light is threshold wave length. Hence for emission of electron, wave length of incident light < wavelength of green light.
- (c)  $\lambda = \frac{h}{mv}$ . Since  $v$  is increasing in case (i), but it is not changing in case (ii). Hence, in the first case de-Broglie wavelength will change, but in second case, it remain the same
- (c) The graph between  $V_0$  and  $v$  cut the  $v$ -axis at  $v_0$ . For the given graphs  $(v_0)_{(iv)} > (v_0)_{(iii)} > (v_0)_{(ii)} > (v_0)_{(i)}$ .  $\therefore (W_0)_{(iv)} > (W_0)_{(iii)} > (W_0)_{(ii)} > (W_0)_{(i)}$ .
- (b)  $\lambda_{K\alpha} \propto \frac{1}{(Z-1)^2} \Rightarrow \frac{\lambda_{Ni}}{\lambda_{Co}} = \left(\frac{Z_{Co}-1}{Z_{Ni}-1}\right)^2 = \left(\frac{27-1}{28-1}\right)^2$   
 $\Rightarrow \lambda_{Ni} = \left(\frac{26}{27}\right)^2 \times \lambda_{Co} = \left(\frac{26}{27}\right)^2 \times 179 = 165.9 \text{ pm} < 179 \text{ pm}$ .
- (b)  $\lambda_{\min} = \frac{hc}{eV} \Rightarrow \lambda_1 = \frac{hc}{eV_1}$  and  $\lambda_2 = \frac{hc}{eV_2}$   
 $\therefore \Delta\lambda = \lambda_2 - \lambda_1 = \frac{hc}{e} \left[ \frac{1}{V_2} - \frac{1}{V_1} \right]$ . Given  $V_2 = 1.5 V_1$   
 on solving we get  $V_1 = 16000 \text{ volt} = 16 \text{ kV}$ .
- (c) Radius of circular path described by a charged particle in a magnetic field is given by  $r = \frac{\sqrt{2mK}}{qB}$ ; where  $K =$  Kinetic energy of electron  $\Rightarrow$   
 $K = \frac{q^2 B^2 r^2}{2m} = \left(\frac{e}{m}\right) \frac{eB^2 r^2}{2}$   
 $= \frac{1}{2} \times 1.7 \times 10^{11} \times 1.6 \times 10^{-19} \times \left(\frac{1}{\sqrt{17}} \times 10^{-5}\right)^2 \times (1)^2$   
 $= 8 \times 10^{-20} \text{ J} = 0.5 \text{ eV}$   
 By using  $E = W_0 + K_{\max}$   
 $\Rightarrow W_0 = E - K_{\max} = \left(\frac{12375}{2475}\right) \text{ eV} - 0.5 \text{ eV} = 4.5 \text{ eV}$
- (c)  $E = \frac{12375}{4000} = 3.09 \text{ eV}$  Photoelectrons emits if energy of incident light > work function.
- (c)  $E = W_0 + K_{\max} \Rightarrow \frac{hc}{\lambda_1} = W_0 + E_1$  and  $\frac{hc}{\lambda_2} = W_0 + E_2$   
 $\Rightarrow hc = W_0 \lambda_1 + E_1 \lambda_1$  and  $hc = W_0 \lambda_2 + E_2 \lambda_2$   
 $\Rightarrow W_0 \lambda_1 + E_1 \lambda_1 = W_0 \lambda_2 + E_2 \lambda_2 \Rightarrow W_0 = \frac{E_1 \lambda_1 - E_2 \lambda_2}{(\lambda_2 - \lambda_1)}$ .
- (b)  $v_{\max} = 4 \times 10^8 \text{ cm/sec} = 4 \times 10^6 \text{ m/sec}$ .  
 $\therefore K_{\max} = \frac{1}{2} m v_{\max}^2 = \frac{1}{2} \times 9 \times 10^{-31} \times (4 \times 10^6)^2$

$$= 7.2 \times 10^{-18} \text{ J} = 45 \text{ eV}.$$

Hence, stopping potential

$$|V_0| = \frac{K_{\max}}{e} = \frac{45 \text{ eV}}{e} = 45 \text{ volt}.$$

- (c) Since spot is same, hence  $\frac{e}{m}$  should be same i.e.,  
 As  $q_1 : q_2 : q_3 = 1 : 3 : 5$ . Hence  $m_1 : m_2 : m_3 = 1 : 3 : 5$
- (c)  $\lambda = \frac{h}{p} \Rightarrow \lambda - \frac{0.5}{100} \lambda = \frac{h}{p + \Delta p} \Rightarrow \frac{199\lambda}{200} = \frac{h}{p + \Delta p} = \frac{199}{200} \frac{h}{p}$   
 $\Rightarrow p + \Delta p = \frac{200}{199} p \Rightarrow p = 199 \Delta p$
- (b) For the incident electron  $\frac{1}{2} m v^2 = eV$  or  $p^2 = 2m eV$   
 $\therefore$  de-Broglie wavelength  $\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2m eV}}$   
 Shortest X-ray wavelength  $\lambda_2 = \frac{hc}{eV}$   
 $\therefore \frac{\lambda_1}{\lambda_2} = \frac{1}{c} \sqrt{\left(\frac{V}{2}\right) \left(\frac{e}{m}\right)} = \frac{\sqrt{10^4 \times 1.8 \times 10^{11}}}{3 \times 10^8} = 0.1$
- (a) Energy of the electron, when it comes out from the second plate =  $200 \text{ eV} - 100 \text{ eV} = 100 \text{ eV}$   
 Hence accelerating potential difference =  $100 \text{ V}$   
 $\lambda_{\text{Electron}} = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{100}} = 1.23 \text{ \AA}$
- (d) According to Bohr's theory  $\Delta E = 0$ , since  $\Delta E \cdot \Delta t \geq \hbar \Rightarrow \Delta t \rightarrow \infty$
- (b)  $\frac{n}{t} = \frac{I A \lambda}{hc} = \frac{150 \times 10^{-3} \times 4 \times 10^{-4} \times 3 \times 10^{-7}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 9 \times 10^{13} \frac{1}{\text{sec}}$
- (c)  $\therefore E(K_\gamma) > E(K_\beta) > E(K_\alpha) \Rightarrow \lambda(K_\gamma) < \lambda(K_\beta) < \lambda(K_\alpha)$
- (b)  $\therefore E = W_0 + \frac{1}{2} m v_{\max}^2 \Rightarrow v_{\max} = \sqrt{\frac{2(hf - W_0)}{m}}$   
 If frequency becomes  $4f$  then  
 $v' = \sqrt{\frac{2(h \times 4f - W_0)}{m}} = 2 \sqrt{\frac{2\left(hf - \frac{W_0}{4}\right)}{m}} \Rightarrow v' > 2v$
- (d) Peaks on the graph represent characteristic X-ray spectrum. Every peak has a certain wavelength, which depends upon the transition of electron inside the atom of the target. While  $\lambda_{\min}$  depends upon the accelerating voltage (As.  $\lambda_{\min} \propto 1/V$ ).
- (b) In electric field photoelectron will experience force and accelerate opposite to the field so it's K.E. increases (i.e. stopping potential will increase), no change in photoelectric current, and threshold wavelength.



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