MSE228 Engineering Quantum Mechanics
Quiz 1 Duration: 30 minutes Open Book Quiz

1. The maximum wavelength for photoelectric emission in tungsten is 230 nm. What wavelength of light must be used in order for electrons with a maximum energy of 1.5 eV to be ejected?

Photoelectric effect: $h\nu = KE_{max} + \phi$ ~ work function

Maximum wavelength → minimum frequency/energy of incoming light

That is KE_{max} should be equal to zero. $h\nu = 0 + \phi$, $\frac{hc}{\lambda_{max}} = \phi$ | since $1eV \equiv 1.602\times10^{-19} J$

$\phi = (6.626\times10^{-34} J.s)(3\times10^8 m/s)/(230\times10^{-9} nm) = 8.64\times10^{-19} J = 5.39 eV$

$\phi_{tungsten} = 5.4$ eV Now, we can solve for λ of $KE = 1.5$ eV

$h\nu = 1.5eV + \phi$, $\frac{hc}{\lambda} = 1.5eV + 5.4eV \Rightarrow \lambda = \frac{6.626\times10^{-34} J.s}{1.602\times10^{-19} J/eV} \frac{3\times10^8 m/s}{6.9 eV} = 1.8\times10^{-7} m$

$\boxed{\lambda = 180 nm}$

2. Electrons are accelerated in television tubes through potential differences of about 10 kV. Find the highest frequency of the electromagnetic waves emitted when these electrons strike the screen of the tube. What kind of waves are these?

Potential difference $V \rightarrow qV = U = KE_{max}$ of the $\bar{e}$s → $(1.602\times10^{-19} C)(10000 V)$

$KE = 1.602\times10^{-14} J = \frac{1.602\times10^{-14} J}{1.602\times10^{-19} J/eV} = 10$ keV (as a note 10 keV << 0.51 MeV rest mass energy)

$\bar{e}$s strike the screen and all the energy given to the emitted em wave

$\Rightarrow 10 keV = h\nu_{max} \rightarrow \nu_{max} = \frac{10 keV}{\frac{6.602\times10^{-34} J.s}{1.602\times10^{-19} J/eV}} = \boxed{2.43\times10^{18} Hz}$

From Figure 2.2

X-rays

3. Gamma rays of energy 0.662 MeV are Compton scattered.
   (a) What is the energy of the scattered photon observed at a scattering angle of 60°?
   (b) What is the kinetic energy of the scattered electrons?

i) Compton effect $\lambda' - \lambda = \left(\frac{h}{mc}\right)(1 - \cos\phi)$ — Compton wavelength; λ' scattered photon, λ incident photon; ϕ scattered photon

$m_e = 9.1\times10^{-31} kg$

Gamma rays of energy: $0.662 MeV \equiv h\nu \equiv \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{0.662 MeV}$

$\frac{hc}{E_{scat}} - \frac{hc}{0.662 MeV} = \frac{hc}{m_e c^2}(1 - \cos\phi)$ { $m_e c^2 = 0.511 MeV$, $\phi = 60°$

$\frac{1}{E_{scat}} = \frac{1}{0.662 MeV} + \frac{1}{0.511 MeV}\left(1 - \frac{1}{2}\right) \longrightarrow E_{scat} = \frac{0.662 MeV \times 2 \times 0.511 MeV}{0.662 MeV + 2.0511 MeV}$ $\boxed{0.401 MeV}$

ii) $E_{initial} = E_{final} \Rightarrow E_{incident\ photon} = E_{scattered\ photon} + E_{scattered\ electron}$

$\rightarrow E_{scattered\ electron} = KE_{electron} = 0.662 MeV - 0.401 MeV = \boxed{0.261 MeV}$