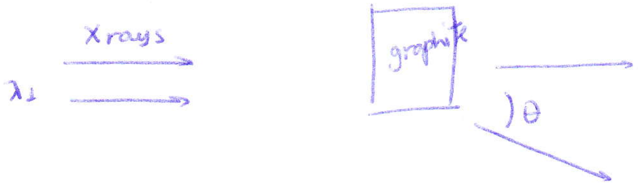
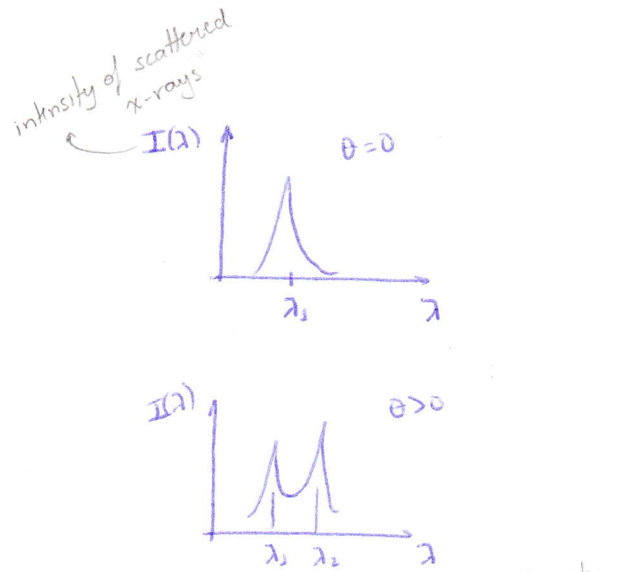
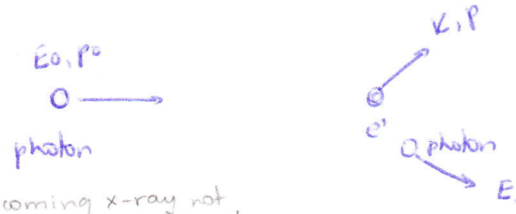
Compton Effect







incoming x-ray not a wave, but collection of photons with $E = h\nu$. They collide with free e^-

$\Delta\lambda = \lambda_2 - \lambda_1 \rightarrow$ Compton shift → quantum effect

classically: oscillating $\vec{E} \Rightarrow e^-$ oscillates at the same $\nu \Rightarrow$ can only explain λ_1

$$\boxed{\lambda_2 - \lambda_1 = \frac{h}{mc}(1 - \cos\theta)}$$

$\frac{h}{mc} \rightarrow 0.00243\,\text{nm}$

→ explains λ_2 (collision with free electrons) $(\theta > 0)$

$\lambda_1 \Rightarrow$ collision with electrons strongly bound to atom (electron not ejected) $(\theta = 0)$

└→ collision between photon and atom

HW
3, 34, 37, 38, 39

Exercise (X rays from TV)

e^- in TV: $K = 25$ keV

$\lambda_{min} = ?$ $\quad h\nu = K - K' \Rightarrow \frac{hc}{\lambda_{min}} = K \Rightarrow \lambda_{min} = \frac{1240\text{ eV nm}}{25 \times 10^3\text{ eV}} = \boxed{0.050\text{nm}}$

(TV with protection against it)

Exercise In Compton scattering we find that λ_1 is shifted by 1.5 percent when $\theta = 120°$

a) $\lambda_1 = ?$ $\quad$ b) what is λ_2 when $\theta = 75°$

a) $\Delta\lambda = 1.5\%\ \lambda_1$

$\lambda_2 - \lambda_1 = 0.015\lambda_1 = \frac{h}{mc}(1 - \cos 120) \Rightarrow \lambda_1 = \frac{0.00243(1 - \cos 120)}{0.015} = \boxed{0.243\text{nm}}$

b) $\lambda_2 - 0.243 = \frac{h}{mc}(1 - \cos 75) \Rightarrow \boxed{\lambda_2 = 0.245\text{nm}}$

low energies	medium energies	high energies
UV	x-ray	very short x-rays, γ-rays
small ν, large λ		
$\lambda \sim 10^{-8}$ m	$\lambda \sim 10^{-10}$ m	$\lambda \sim 10^{-12}$ m
photoelectric effect	Compton effect	pair production
(photon absorbed and e^- released)	(photon scattered)	(photon loses all its energy)

interaction of photons with matter

(pair production →) photon collides with nucleus, loses all $h\nu$, creating one e^- (electron) and one e^+ (positron)

conversion of energy (photon) into rest mass (e^-, e^+) and K

(cosmic rays or particle accelerators)

Proton and anti-proton can also be created for higher energy photons.

- in interaction with matter:

  radiation / light → localized particles / photons

- when propagating

  radiation / light → wave (diffraction, interference)

wave - particle DUALITY } also extends to other particles: e^-, atoms, etc (Louis de Broglie)

Classical physics fails when ν is large (λ is short): blackbody, Compton effect

↳ relates to the size of h

- $h\nu$ small ($\nu \to 0$) ⇒ indistinguishable from continuum
- $h\nu$ large ($\nu \to \infty$) ⇒ quantum effects cannot be neglected