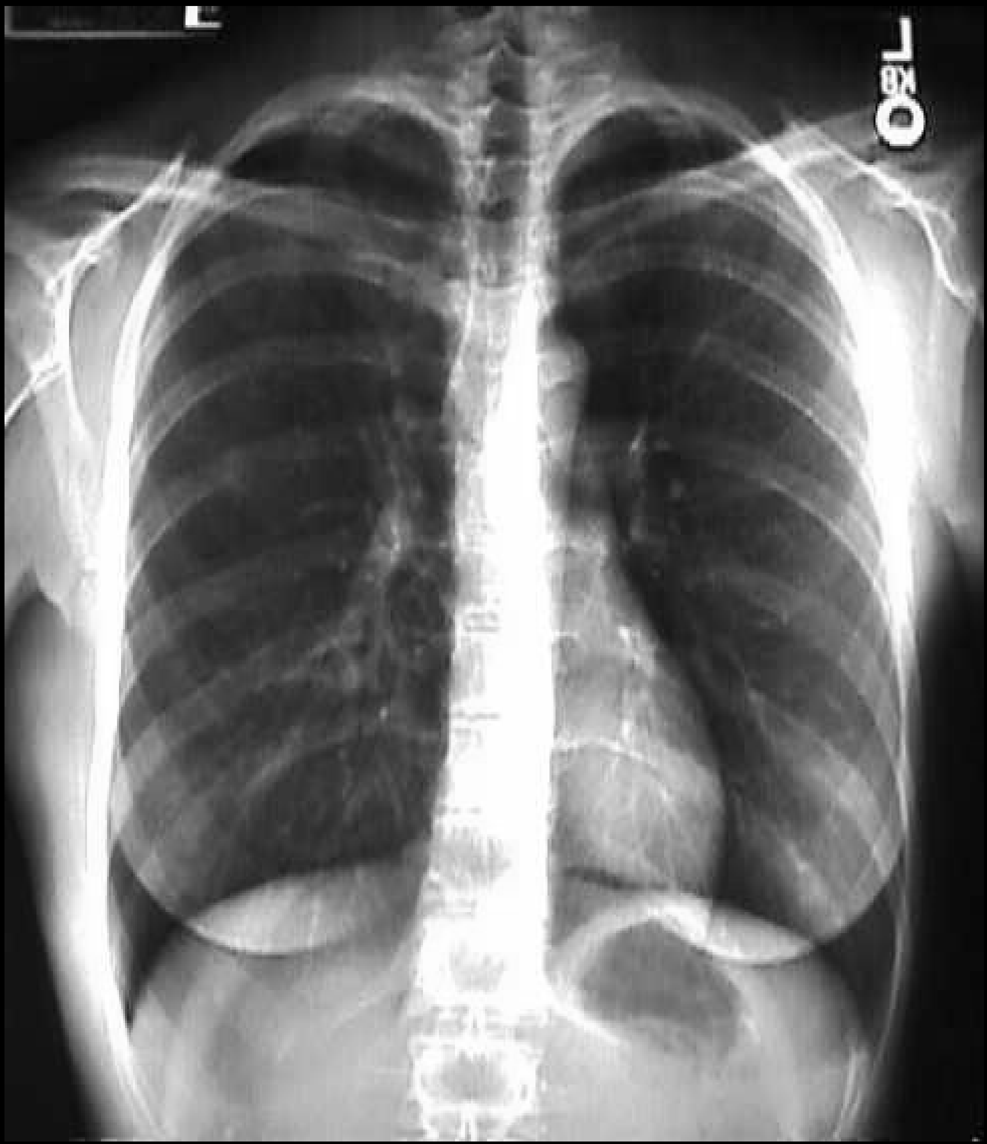
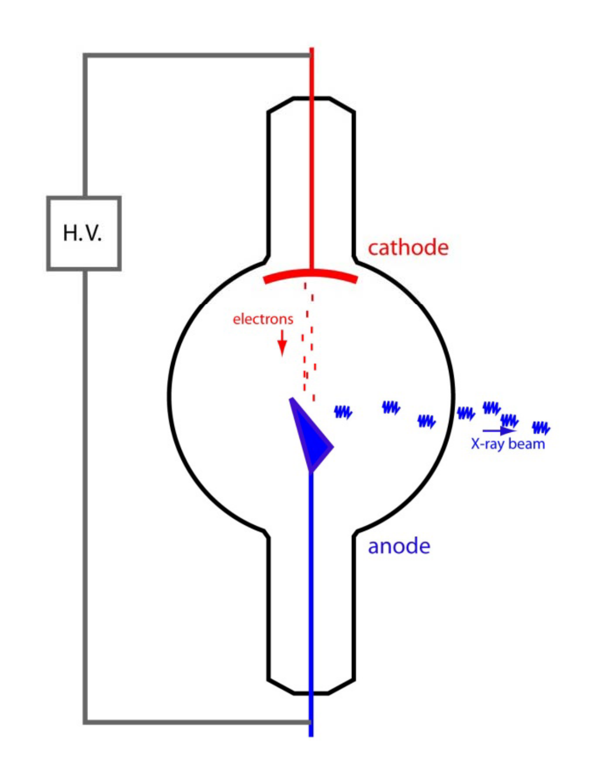
A normal chest X-ray

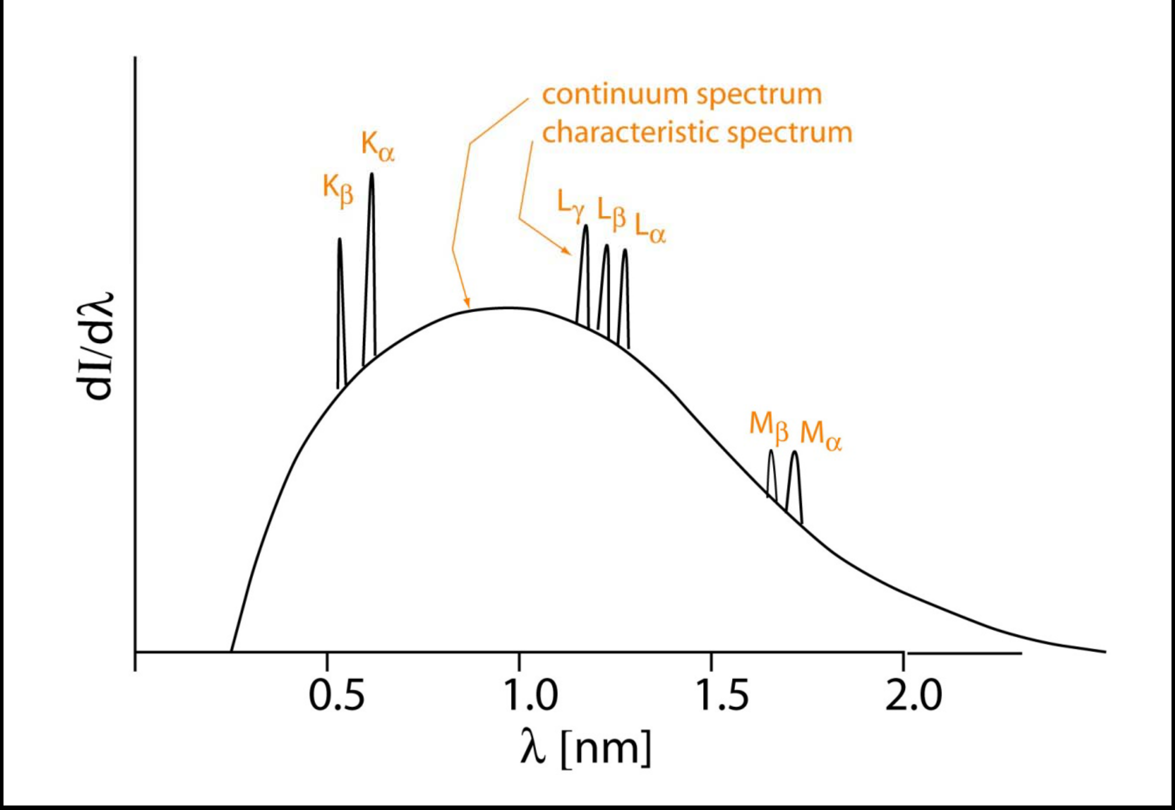


Interactions of X rays and matter

Production of X rays

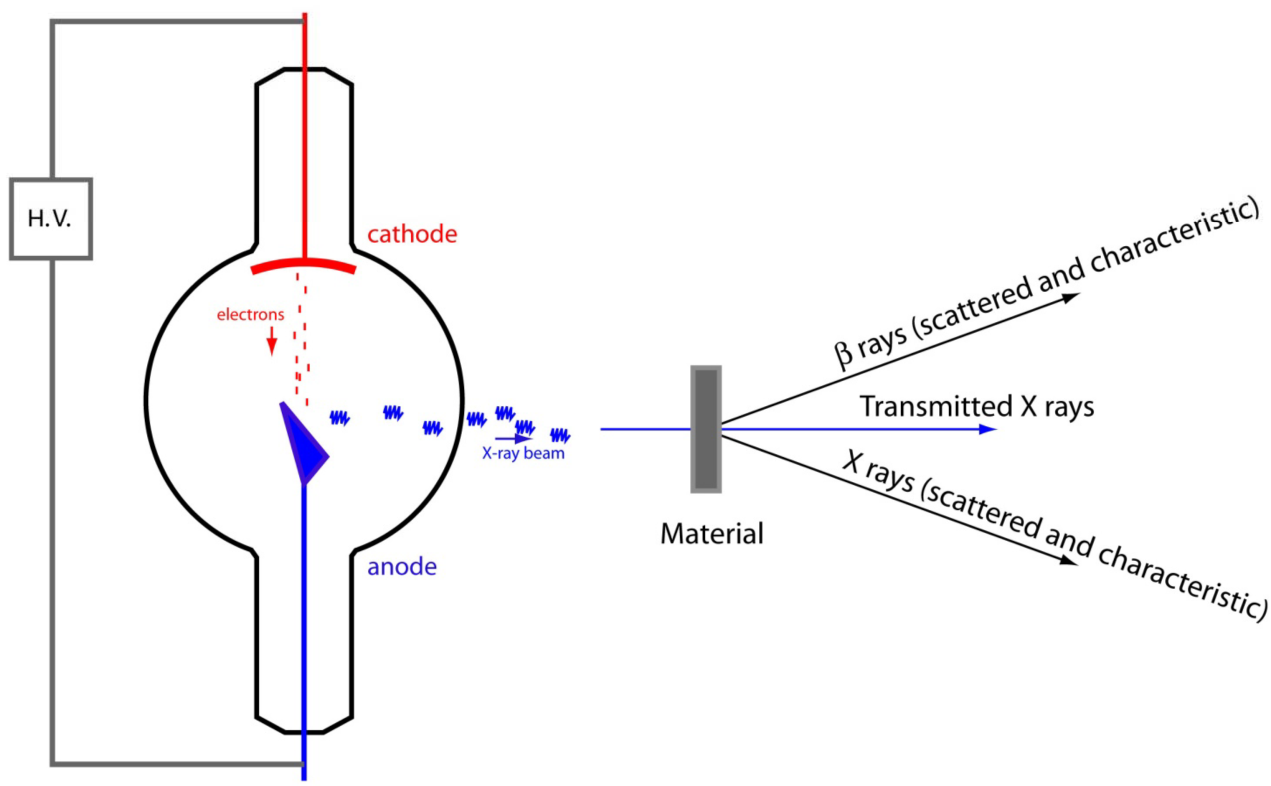


Example.
Suppose H.V. = 10 kV.
Then calculate λ_{min}.



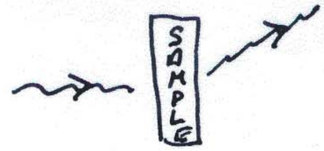
Interactions of X rays and matter

FIGURE 17 Interaction of X rays with matter



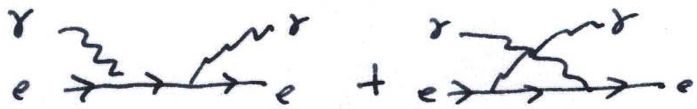
Interaction of X-rays with matter

Scattering



- Thomson scattering

$$\gamma + e \rightarrow \gamma + e \quad \text{with } E_\gamma \ll mc^2$$



$$\frac{d\sigma}{d\Omega} = \frac{1}{2} r_e^2 \left(1 + \cos^2\theta\right) \quad \text{where} \quad r_e = \frac{e^2}{4\pi\epsilon_0 \, mc^2}$$

$$\sigma_T = \int \frac{d\sigma}{d\Omega} \sin\theta \, d\theta \, d\varphi = \frac{8\pi}{3} r_e^2$$

(J.J. Thomson, theory, published ~1906)

$r_e = 2.8 \times 10^{-15}$ m

$\sigma_T = 6.6 \times 10^{-29}$ m^2 = 0.66 barns

- Compton scattering ($E_\gamma \gtrsim mc^2$)

The X-ray loses some energy

$$\frac{E_\gamma'}{E_\gamma} = \frac{mc^2}{mc^2 + E(1-\cos\theta)}$$

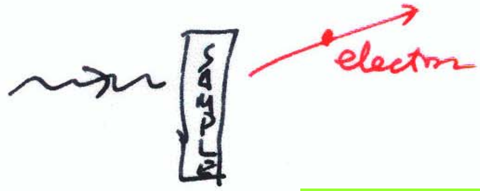
$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$$

$$E = hf = \frac{hc}{\lambda}$$

(Arthur Compton, 1923)

Interactions of X-rays with matter

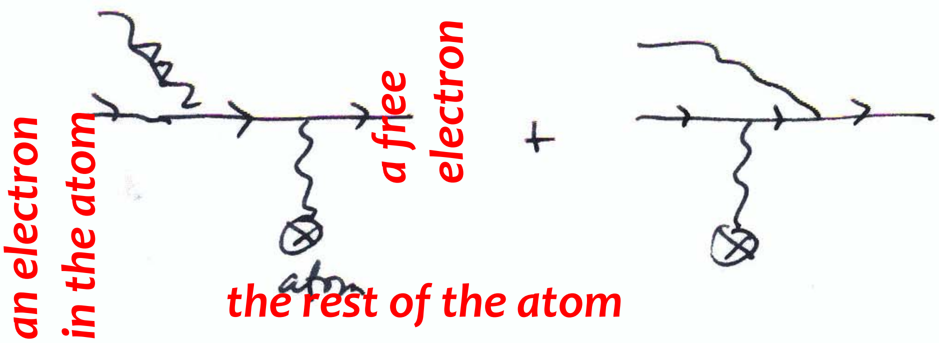
Absorption



… on an atomic scale

- Photo-electric effect

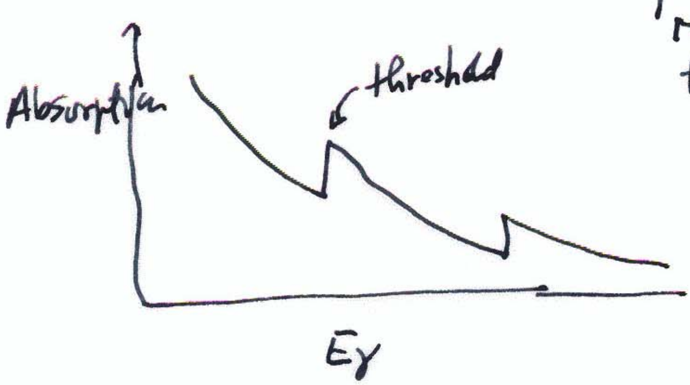
$$\gamma + \text{atom} \rightarrow e + \text{~~atom~~ ion}$$



$$hf - B = \tfrac{1}{2}mv^2$$ (neglecting recoil energy of the atom)

$$hf = B + \tfrac{1}{2}mv^2 \geq B$$

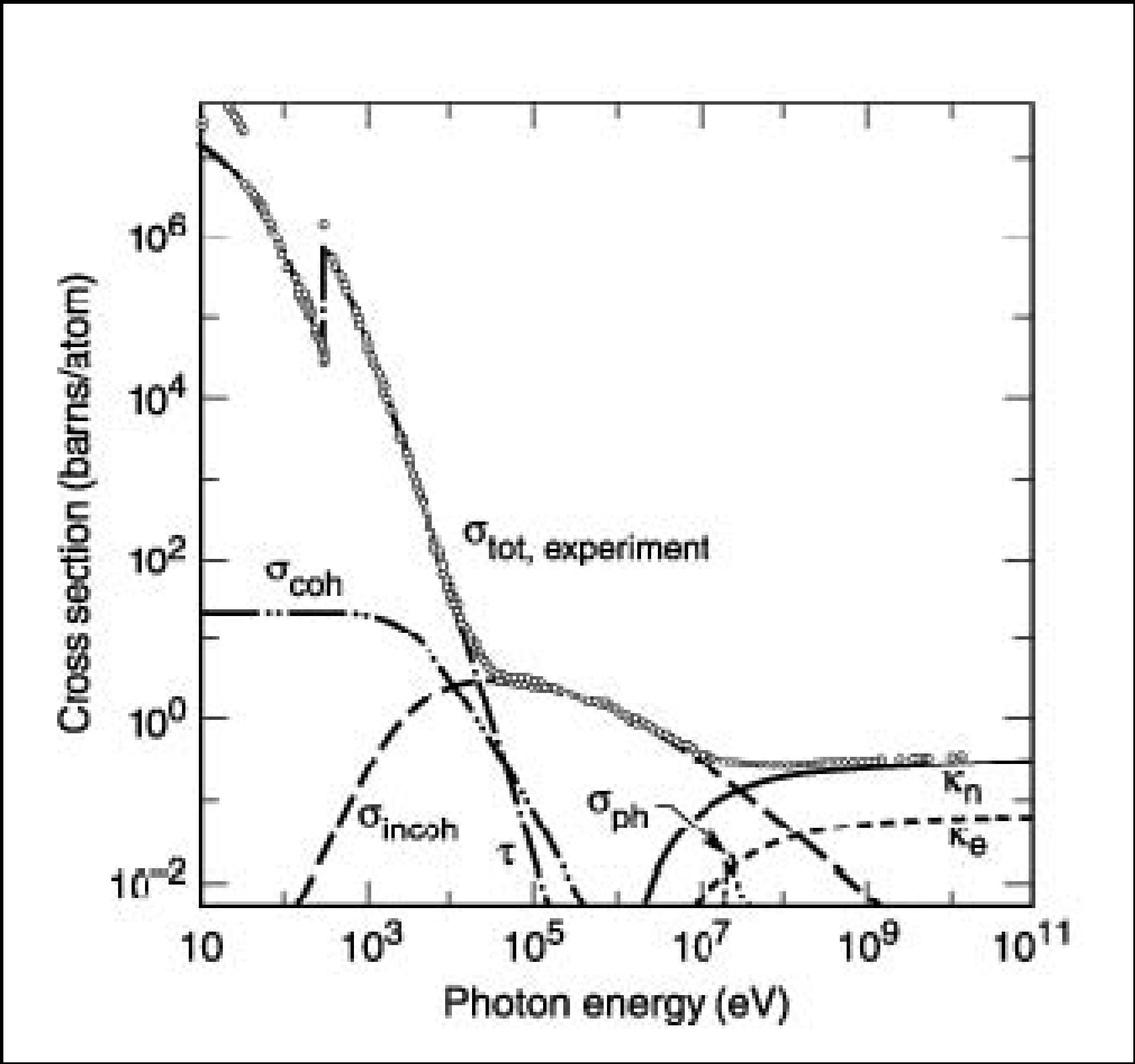
↑ minimum γ energy for this process.



- Pair Production: $\gamma + \text{atom} \rightarrow e^- e^+ + \text{atom}$

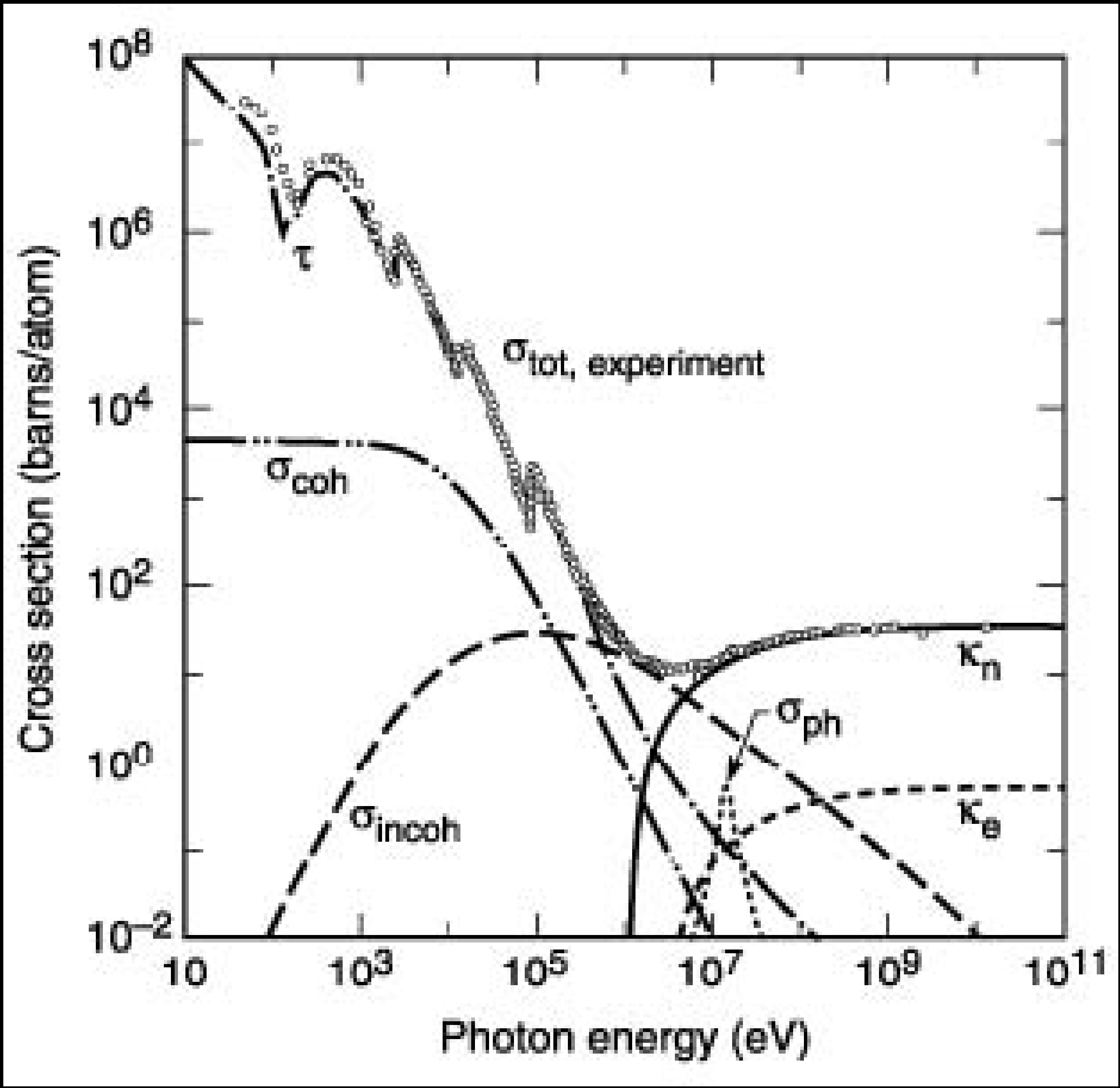
Can occur if $E_\gamma > 2mc^2 = 1.02$ MeV

Carbon cross sections



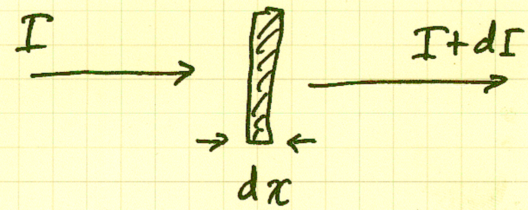
X-ray Data Booklet
xdb.lbl.gov

Lead cross sections



X-ray Data Booklet
xdb.lbl.gov

The X-ray absorption coefficient (Sec 1.18)



(dI is negative)

Intensity = # ~~X rays~~ photons per unit area per unit time

$= \dfrac{d^2N}{dA\,dt}$ (units : $m^{-2}\,s^{-1}$)

dI is negative because photons are absorbed; e.g., the photoelectric effect $\gamma + \text{atom} \rightarrow e + \text{ion}$.

This is a random process so $dI = -\mu I\,dx$

where μ is a constant [units for μ : m^{-1}]

$\mu(dx) = \underbrace{\text{fraction of intensity absorbed}}_{|dI|/I}$ in length dx

$$\boxed{\frac{dI}{dx} = -\mu I}$$

μ : linear absorption coefficient
units : m^{-1}