Gamma & X-ray Interactions
Gamma Ray Interactions

- Photoelectric effect
- Compton effect
- Pair production
Gamma Ray Interactions

\[ I = I_0 e^{-\mu x} \]

\[ \mu = N\sigma \quad \mu_m = \mu / \rho \]

\[ \sigma = \sigma_{PE} + \sigma_{CE} + \sigma_{PP} \]
Gamma Ray Interactions
Example

What fraction of 0.20 MeV x-rays penetrate through 2 mm of lead?

Look up linear attenuation coefficient; \( \mu = 1000 \text{ m}^{-1} \) for this case

\[
\frac{I}{I_0} = e^{-\mu x} = e^{-(1000 \text{ m}^{-1})(2.0 \times 10^{-3} \text{ m})}
\]

\[
= e^{-2.0} = 0.135
\]
Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients from 1 keV to 20 MeV for Elements $Z = 1$ to 92 and 48 Additional Substances of Dosimetric Interest* 

http://www.nist.gov/pml/data/xraycoef/index.cfm
Photoelectric Effect

\[ K_e = E_\gamma - B_e \]

\[ \sigma_{PE} \propto \frac{Z^5}{E_\gamma^{3.5}} \]
Compton Effect

\[ K_e = E_\gamma - E'_\gamma \]

\[ E'_\gamma = \frac{E_\gamma}{1 + (E_\gamma / m_e c^2)(1 - \cos \theta)} \]

\[ \sigma_{CE} \propto \frac{Z}{A} \]
Compton Effect

Outgoing $\gamma$ Energy (MeV)

$\theta$

$E_\gamma = 0.1$ MeV
Compton Effect

Outgoing $\gamma$ Energy (MeV)

$E_\gamma = 1.0$ MeV

$\theta$

$0$ $30$ $60$ $90$ $120$ $150$ $180$

$0.0$ $0.2$ $0.4$ $0.6$ $0.8$ $1.0$ $1.2$
Compton Effect

\[ E_\gamma = 10 \text{ MeV} \]
Compton Effect

\[ E_\gamma = 100 \text{ MeV} \]
Figure 5.8  Differential cross section $\sigma_c(\theta)$ for Compton scattering by electrons in the energy range $E_\gamma = 0$ to 5 MeV, given by the Klein–Nishina formula. See Siegbahn (1966), p. 51.
Pair Production

\[ K_+ + K_- = E_\gamma - 2m_e c^2 \]

\[ E_\gamma (\text{min}) = 2m_e c^2 = 1.022 \text{ MeV} \]

\[ \sigma_{PP} \propto Z \]
Pb

L edges

K edge

http://physics.nist.gov/PhysRefData/Xcom/tmp/graph_321832.png
Fractions of Different Interactions

![Graph showing the fractions of different interactions as a function of energy (E in MeV). The graph includes curves for Lead, Pair Production, Photoelectric, and Compton interactions. The x-axis represents E (MeV) and the y-axis represents Fraction.](image-url)
Comparison of Al and Pb

Gamma-ray Attenuation (NIST data)

$$E_\gamma = 0.662 \text{ MeV}$$
A Question

The attenuation curve for gammas in Al shows that only half of the original radiation will reach a depth of 3.5 cm.

Is the radiation intensity at that depth half of the intensity at the surface?