22.01 - Recitation #7

- Please grab a snack, get up off the sofa, look at something that isn't a screen for 5 mins!
- Please turn on your video (if possible) and mute yourself.
- These slides are at: *bit.ly/2201Rec7*

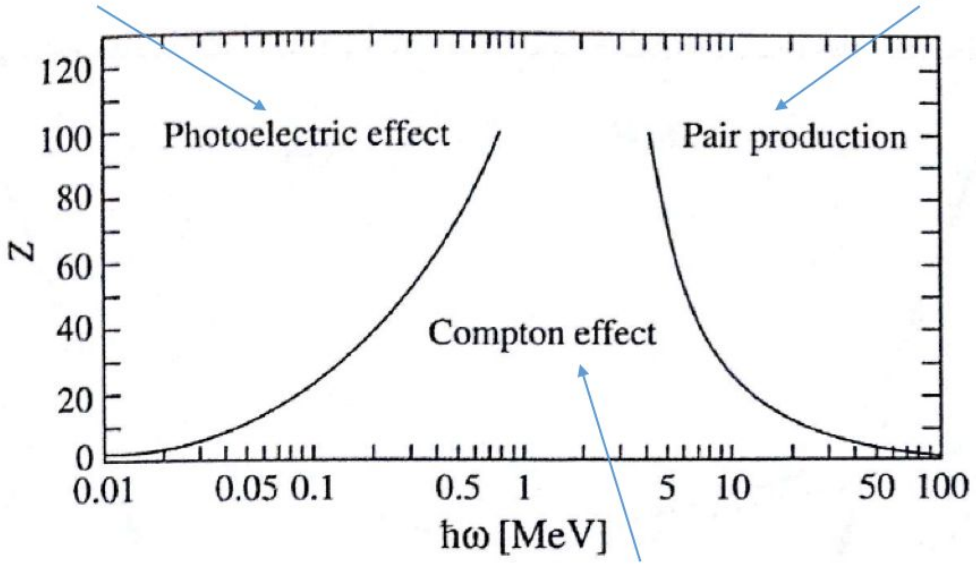
Outline + Intended Learning Outcomes (ILOs)

- 3+ photon interactions
- How they depend on Z, hv
- Understand Compton Scattering Eq.s
- Nuclear Activation Analysis

What Do These Gammas Do?

Yip, p. 217

Eject an outer electron ***Create a β^-/β^+ pair***



Scatter off of an electron

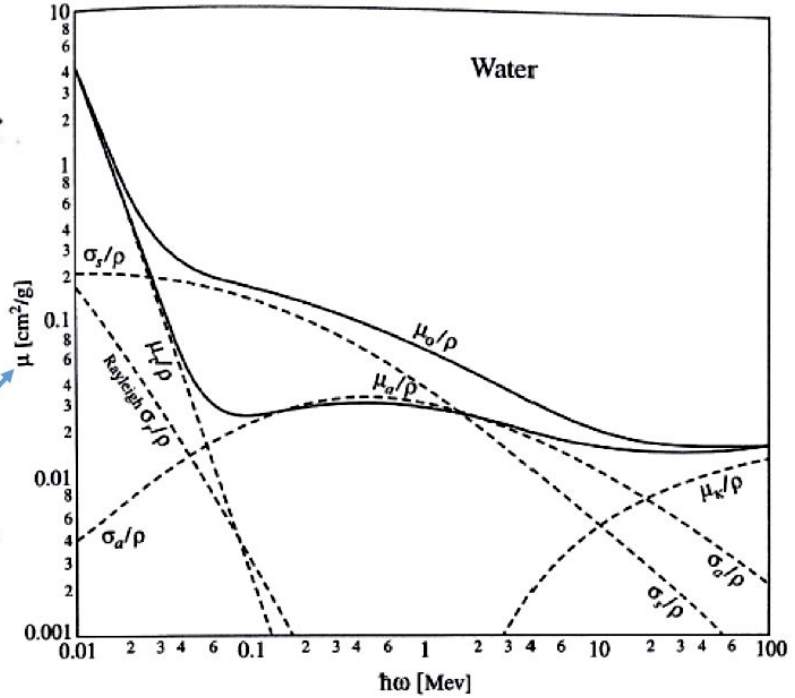
Mass Attenuation Coefficients

$$\mu = \mu_C + \mu_\tau + \mu_\kappa$$

C: Compton
τ: Photoelectric
ϰ: Pair production

Should be μ/ρ

$$I = I_0 e^{\left(\frac{\mu}{\rho}\right)\rho x}$$



Cross Sections for Photon Interactions

Yip, pp. 216-217

Photoelectric Effect:

$$\mu_\tau/\rho = (N_o/A)\,\sigma_\tau, \quad \sigma_\tau \sim Z^5/(\hbar\omega)^{7/2} \quad \textit{per atom} \qquad (10.44)$$

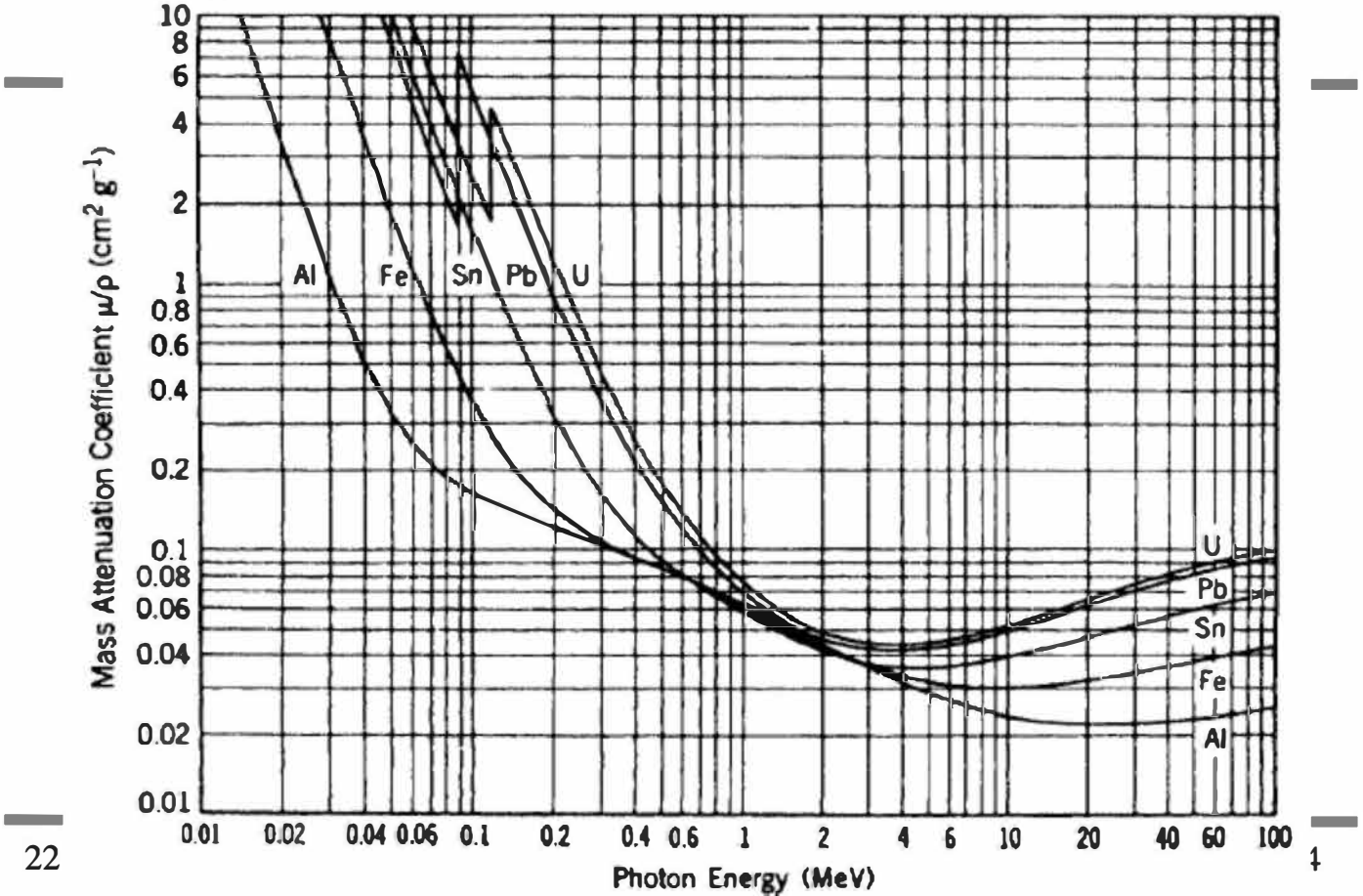
Compton Scattering:

$$\mu_C/\rho = (N_o/A)\,Z\sigma_C, \quad \sigma_C \sim 1/\hbar\omega \quad \textit{per electron} \qquad (10.43)$$

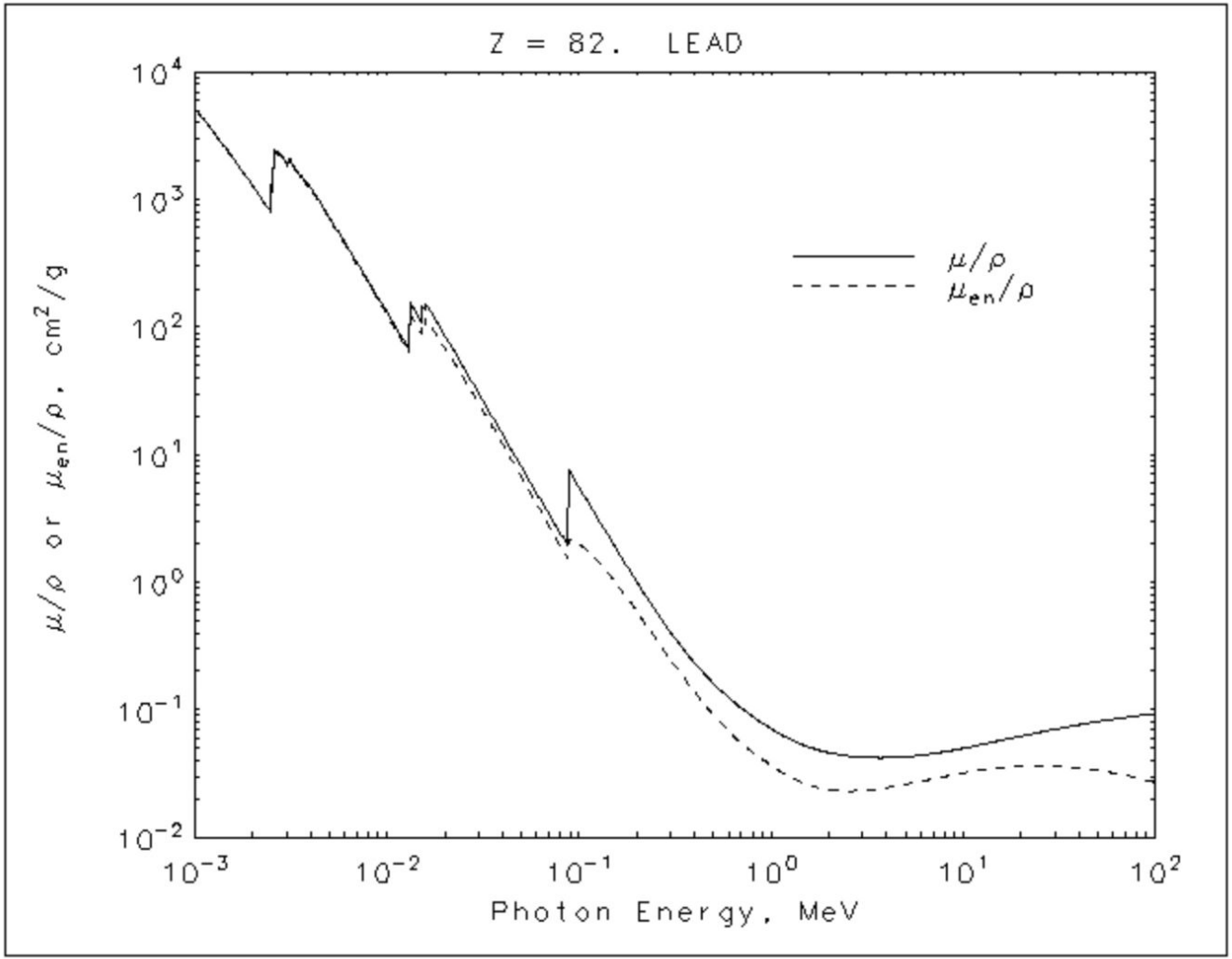
Pair Production:

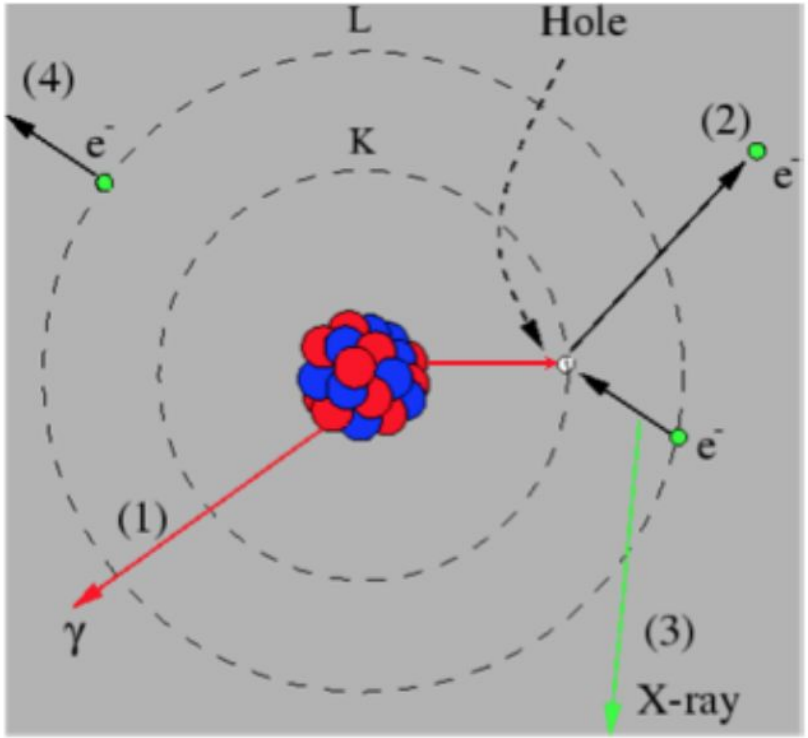
$$\mu_\kappa/\rho = (N_o/A)\,\sigma_\kappa, \quad \sigma_\kappa \sim Z^2 \ell n(2\hbar\omega/m_e c^2) \quad \textit{per atom} \qquad (10.45)$$

Comparative Mass Attenuations



Photoelectric Effect

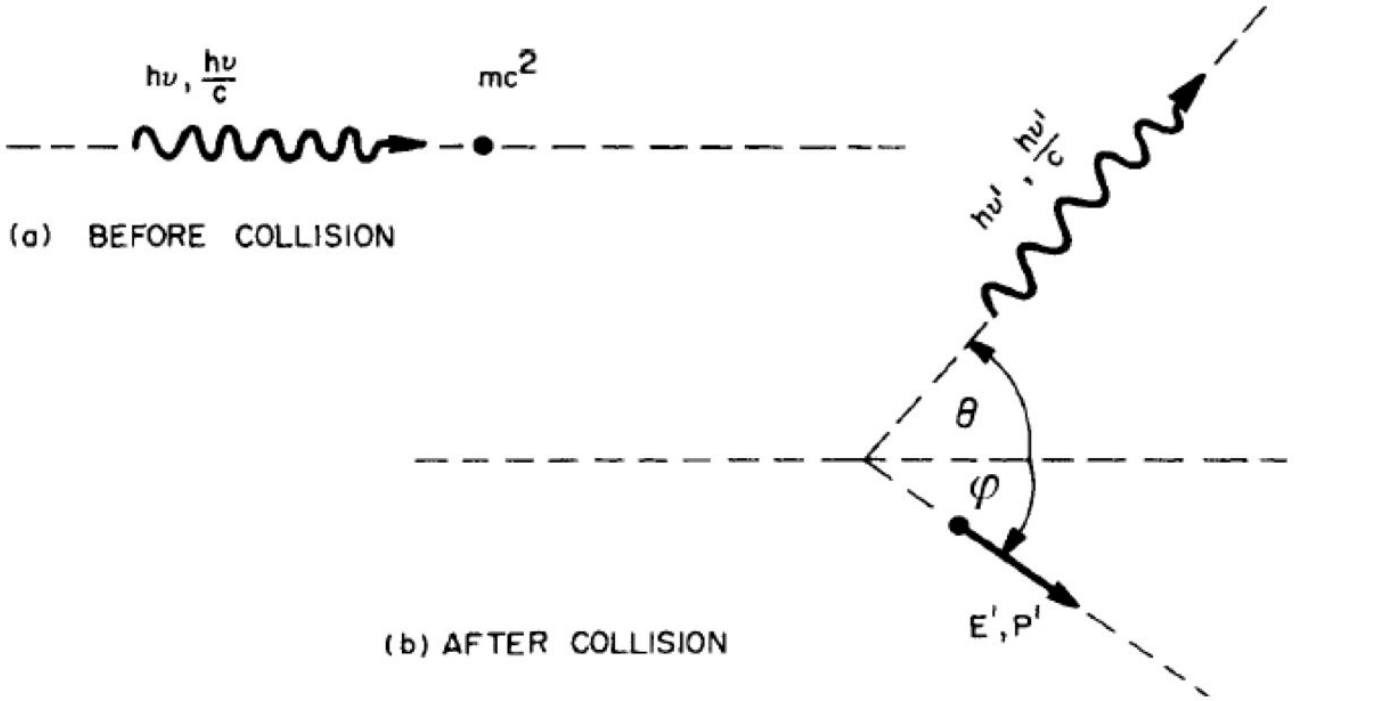

Z = 82. LEAD
μ/ρ
μ_{en}/ρ
μ/ρ or μ_{en}/ρ, cm^2/g
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
10^2
Photon Energy, MeV


L
Hole
(4)
e⁻
K
(2)
e⁻
e⁻
(1)
γ
(3)
X-ray

Compton Scattering

Compton Scattering

Turner, p. 179



Wavelength & Energy Shift

$$\Delta\lambda = \lambda' - \lambda = c\left(\frac{1}{\nu'} - \frac{1}{\nu}\right) = \frac{h}{mc}(1 - \cos\theta)$$

Electron recoil energy

$$T = h\nu - h\nu'$$

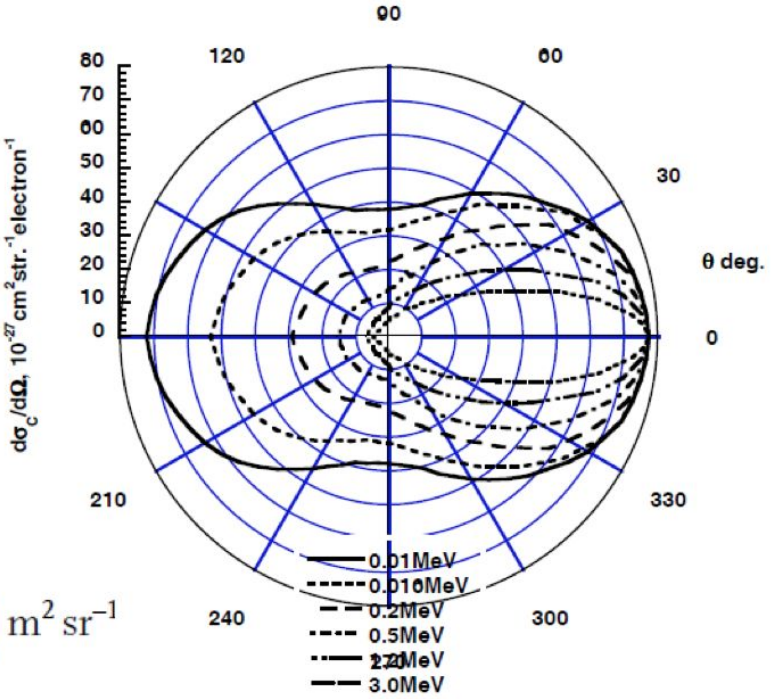
$$T = h\nu \frac{1 - \cos\theta}{mc^2/h\nu + 1 - \cos\theta}$$

When is the electron recoil energy maximized?

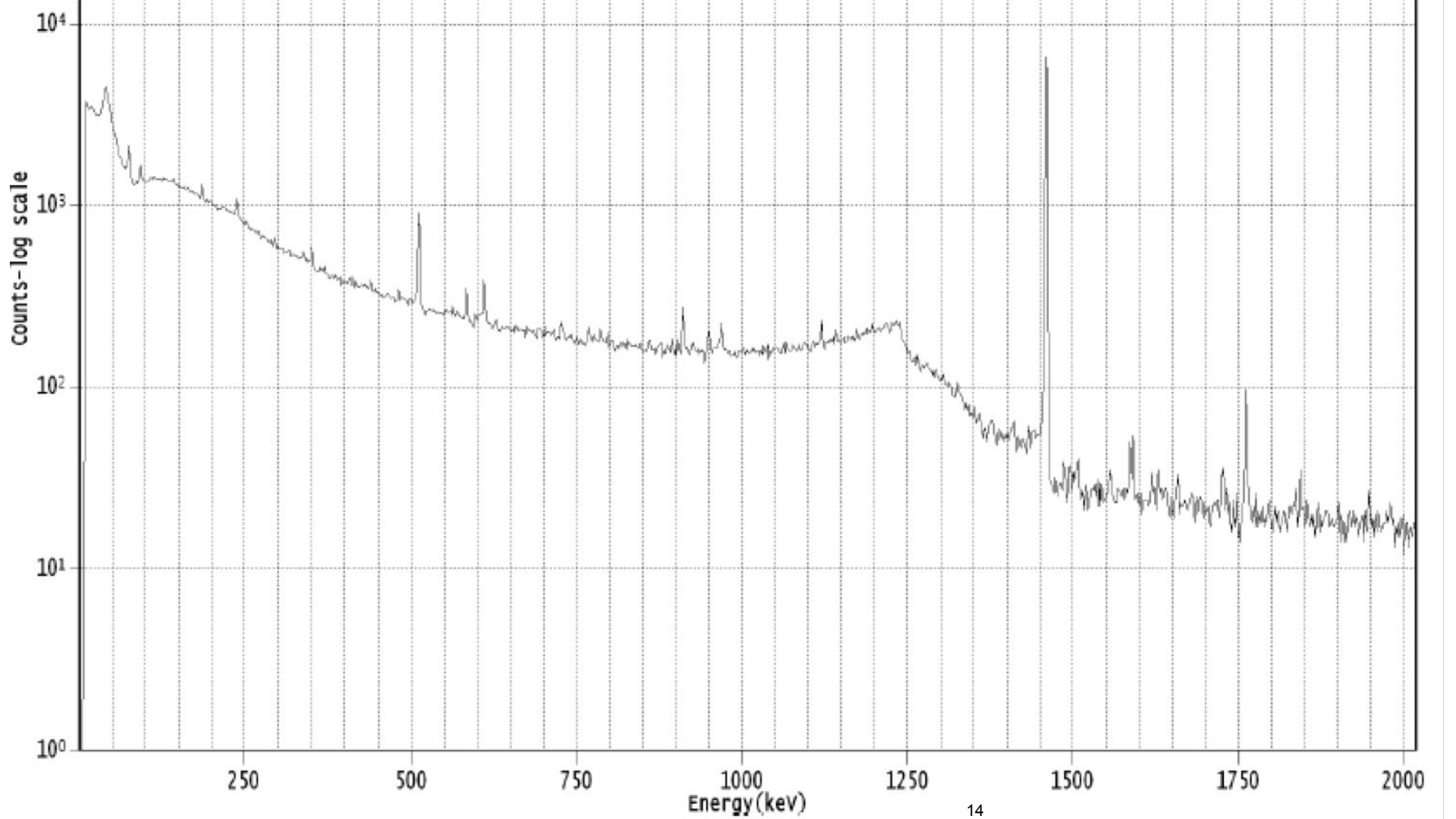
Angular Differential Cross Section: The Klein-Nishina Formula

R. D. Evans. "Compton Effect," in Handbuch der Physik XXXIV, Tlugge, Ed., Springer-Verlag, pp. 218-298 (1958)

Describes the probability of scattering into a given *angle*



$$\frac{d_e\sigma}{d\Omega} = \frac{k_0^2 e^4}{2m^2c^4}\left(\frac{\nu'}{\nu}\right)^2\left(\frac{\nu}{\nu'} + \frac{\nu'}{\nu} - \sin^2\theta\right) \text{ m}^2\,\text{sr}^{-1}$$


Counts-log scale
10⁴
10³
10²
10¹
10⁰
250
500
750
1000
1250
1500
1750
2000
Energy(keV)

Pair production

Determine original isotope concentration from NAA:

Stable Accumulating Decaying Counting

$$N_1(t) = \frac{\lambda_1 N_{10}}{\lambda_2 - \lambda_1}\left(e^{\lambda_1 t} - e^{-\lambda_2 t}\right)$$

$$A_i = \frac{\frac{C_i(E)}{t_{live,toenail}} - \frac{B(E)}{t_{live,background}}}{I_g \eta(E)};$$

22.01 - Recitation #7 - October 16th 2020

Office Hours 8.15-9am Monday

Office Hours 3-4pm Monday

Questions?

Please grab a snack, get up off the sofa, look at something that isn't a screen for ~X mins!

22.01 Introduction to Nuclear Engineering and Ionizing Radiation

Spring 2024