Compton Scattering

Appendix D

Gamma-ray Attenuation Coefficients

Source: US National Bureau of Standards and Technology
http://www.nist.gov/pml/data/xraycoef/index.cfm/

X-Ray Mass Attenuation Coefficients

2. The Mass Attenuation Coefficient, μ/ρ

A narrow beam of mono-energetic photons with an incident intensity I_o, penetrating a layer of material with mass thickness x and density ρ, emerges with intensity I given by the exponential attenuation law

$$I/I_o = \exp[-(\mu/\rho)x] \ . \qquad \text{(eq 1)}$$

Equation (1) can be rewritten as

$$\mu/\rho = x^{-1} \ln(I_o/I) \qquad \text{(eq 2)}$$

from which μ/ρ can be obtained from measured values of I_o, I and x.

Note that the mass thickness is defined as the mass per unit area, and is obtained by multiplying the thickness t by the density ρ, i.e., $x = \rho t$.

The various experimental arrangements and techniques from which μ/ρ can be obtained, particularly in the crystallographic photon energy/wavelength regime, have recently been examined and assessed by Creagh and Hubbell (1987, 1990) as part of the International Union of Crystallography (IUCr) X-Ray Attenuation Project. This has led to new tables of μ/ρ in the 1992 *International Tables for Crystallography* (Creagh and Hubbell, 1992). The current status of μ/ρ measurements has also been reviewed recently by Gerward (1993), and an updated bibliography of measured data is available in Hubbell (1994).

Present tabulations of μ/ρ rely heavily on theoretical values for the total cross section per atom, σ_{tot}, which is related to μ/ρ according to

$$\mu/\rho = \sigma_{tot}/uA \ . \qquad \text{(eq 3)}$$

In (eq 3), u (= 1.660 540 2 × 10^{-24} g Cohen and Taylor 1986) is the atomic mass unit (1/12 of the mass of an atom of the nuclide ^{12}C), A is the relative atomic mass of the target element, and σ_{tot} is the total cross section for an interaction by the photon, frequently given in units of b/atom (barns/atom), where b = 10^{-24} cm^2.

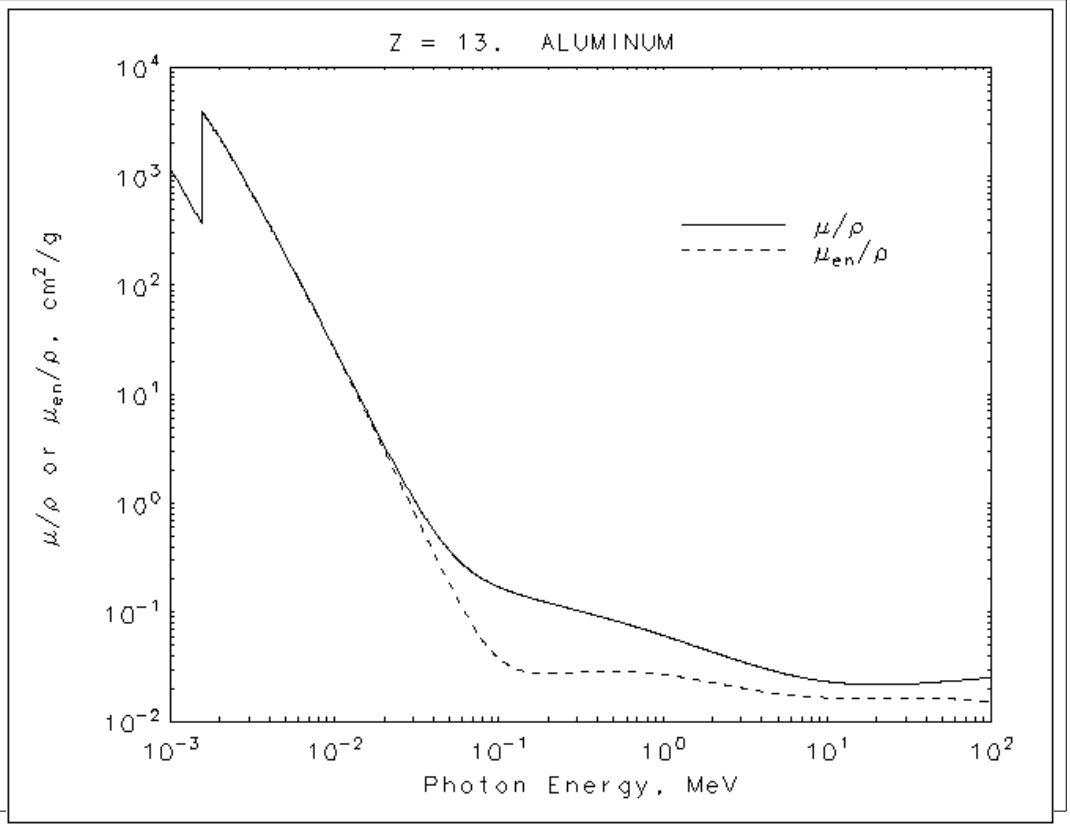
The attenuation coefficient, photon interaction cross sections and related quantities are functions of the photon energy. Explicit indication of this functional dependence has been omitted to improve readability.

The total cross section can be written as the sum over contributions from the principal photon interactions,

$$\sigma_{tot} = \sigma_{pe} + \sigma_{coh} + \sigma_{incoh} + \sigma_{pair} + \sigma_{trip} + \sigma_{ph.n.} \qquad \text{(eq 4)}$$

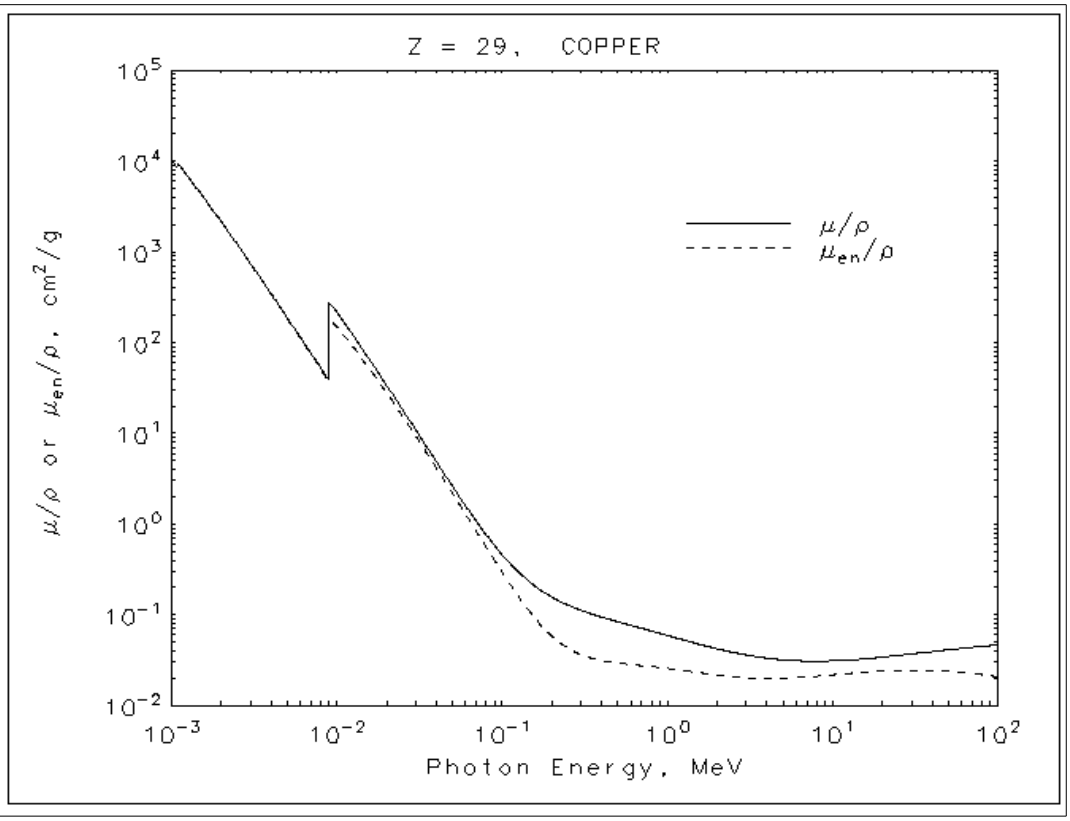
where σ_{pe} is the atomic photo-effect cross section, σ_{coh} and σ_{incoh} are the coherent (Rayleigh) and the incoherent (Compton) scattering cross sections, respectively, σ_{pair} and σ_{trip} are the cross sections for electron-positron production in the fields of the nucleus and of the atomic electrons, respectively, and $\sigma_{ph.n.}$ is the photonuclear cross section.

Aluminium
Z=13



Energy	μ/ρ	μ_{en}/ρ
(MeV)	(cm^2/g)	(cm^2/g)
1.00000E-03	1.185E+03	1.183E+03
1.50000E-03	4.022E+02	4.001E+02
1.55960E-03	3.621E+02	3.600E+02
1.55960E-03	3.957E+03	3.829E+03
2.00000E-03	2.263E+03	2.204E+03
3.00000E-03	7.880E+02	7.732E+02
4.00000E-03	3.605E+02	3.545E+02
5.00000E-03	1.934E+02	1.902E+02
6.00000E-03	1.153E+02	1.133E+02
8.00000E-03	5.033E+01	4.918E+01
1.00000E-02	2.623E+01	2.543E+01
1.50000E-02	7.955E+00	7.487E+00
2.00000E-02	3.441E+00	3.094E+00
3.00000E-02	1.128E+00	8.778E-01
4.00000E-02	5.685E-01	3.601E-01
5.00000E-02	3.681E-01	1.840E-01
6.00000E-02	2.778E-01	1.099E-01
8.00000E-02	2.018E-01	5.511E-02
1.00000E-01	1.704E-01	3.794E-02
1.50000E-01	1.378E-01	2.827E-02
2.00000E-01	1.223E-01	2.745E-02
3.00000E-01	1.042E-01	2.816E-02
4.00000E-01	9.276E-02	2.862E-02
5.00000E-01	8.445E-02	2.868E-02
6.00000E-01	7.802E-02	2.851E-02
8.00000E-01	6.841E-02	2.778E-02
1.00000E+00	6.146E-02	2.686E-02
1.25000E+00	5.496E-02	2.565E-02
1.50000E+00	5.006E-02	2.451E-02
2.00000E+00	4.324E-02	2.266E-02
3.00000E+00	3.541E-02	2.024E-02
4.00000E+00	3.106E-02	1.882E-02
5.00000E+00	2.836E-02	1.795E-02
6.00000E+00	2.655E-02	1.739E-02
8.00000E+00	2.437E-02	1.678E-02
1.00000E+01	2.318E-02	1.650E-02
1.50000E+01	2.195E-02	1.631E-02
2.00000E+01	2.168E-02	1.633E-02

Copper
Z=29



Energy (MeV)	μ/ρ (cm^2/g)	μ_{en}/ρ (cm^2/g)
1.00000E-03	1.057E+04	1.049E+04
1.04695E-03	9.307E+03	9.241E+03
1.09610E-03	8.242E+03	8.186E+03
1.09610E-03	9.347E+03	9.282E+03
1.50000E-03	4.418E+03	4.393E+03
2.00000E-03	2.154E+03	2.142E+03
3.00000E-03	7.488E+02	7.430E+02
4.00000E-03	3.473E+02	3.432E+02
5.00000E-03	1.899E+02	1.866E+02
6.00000E-03	1.156E+02	1.128E+02
8.00000E-03	5.255E+01	5.054E+01
8.97890E-03	3.829E+01	3.652E+01
8.97890E-03	2.784E+02	1.824E+02
1.00000E-02	2.159E+02	1.484E+02
1.50000E-02	7.405E+01	5.788E+01
2.00000E-02	3.379E+01	2.788E+01
3.00000E-02	1.092E+01	9.349E+00
4.00000E-02	4.862E+00	4.163E+00
5.00000E-02	2.613E+00	2.192E+00
6.00000E-02	1.593E+00	1.290E+00
8.00000E-02	7.630E-01	5.581E-01
1.00000E-01	4.584E-01	2.949E-01
1.50000E-01	2.217E-01	1.027E-01
2.00000E-01	1.559E-01	5.781E-02
3.00000E-01	1.119E-01	3.617E-02
4.00000E-01	9.413E-02	3.121E-02
5.00000E-01	8.362E-02	2.933E-02
6.00000E-01	7.625E-02	2.826E-02
8.00000E-01	6.605E-02	2.681E-02
1.00000E+00	5.901E-02	2.562E-02
1.25000E+00	5.261E-02	2.428E-02
1.50000E+00	4.803E-02	2.316E-02
2.00000E+00	4.205E-02	2.160E-02
3.00000E+00	3.599E-02	2.023E-02
4.00000E+00	3.318E-02	1.989E-02
5.00000E+00	3.177E-02	1.998E-02
6.00000E+00	3.108E-02	2.027E-02
8.00000E+00	3.074E-02	2.100E-02
1.00000E+01	3.103E-02	2.174E-02
1.50000E+01	3.247E-02	2.309E-02
2.00000E+01	3.408E-02	2.387E-02