APPENDIX H. ABSORPTION OF RADIATION IN MATTER

1. Absorption of Photons in Matter

The decrease in intensity of a parallel beam of photons traversing an absorber of thickness *d* is given by [1]

$$I = I_0 2^{\frac{-d}{d_{1/2}}}, \tag{1}$$

where I_0 and I are the beam intensity before and after passing through the absorber, and $d_{1/2}$ is the half-thickness of the absorber. The quantity $d_{1/2}$ can be expressed in terms of the photon energy and the properties of the absorbing material[1]:

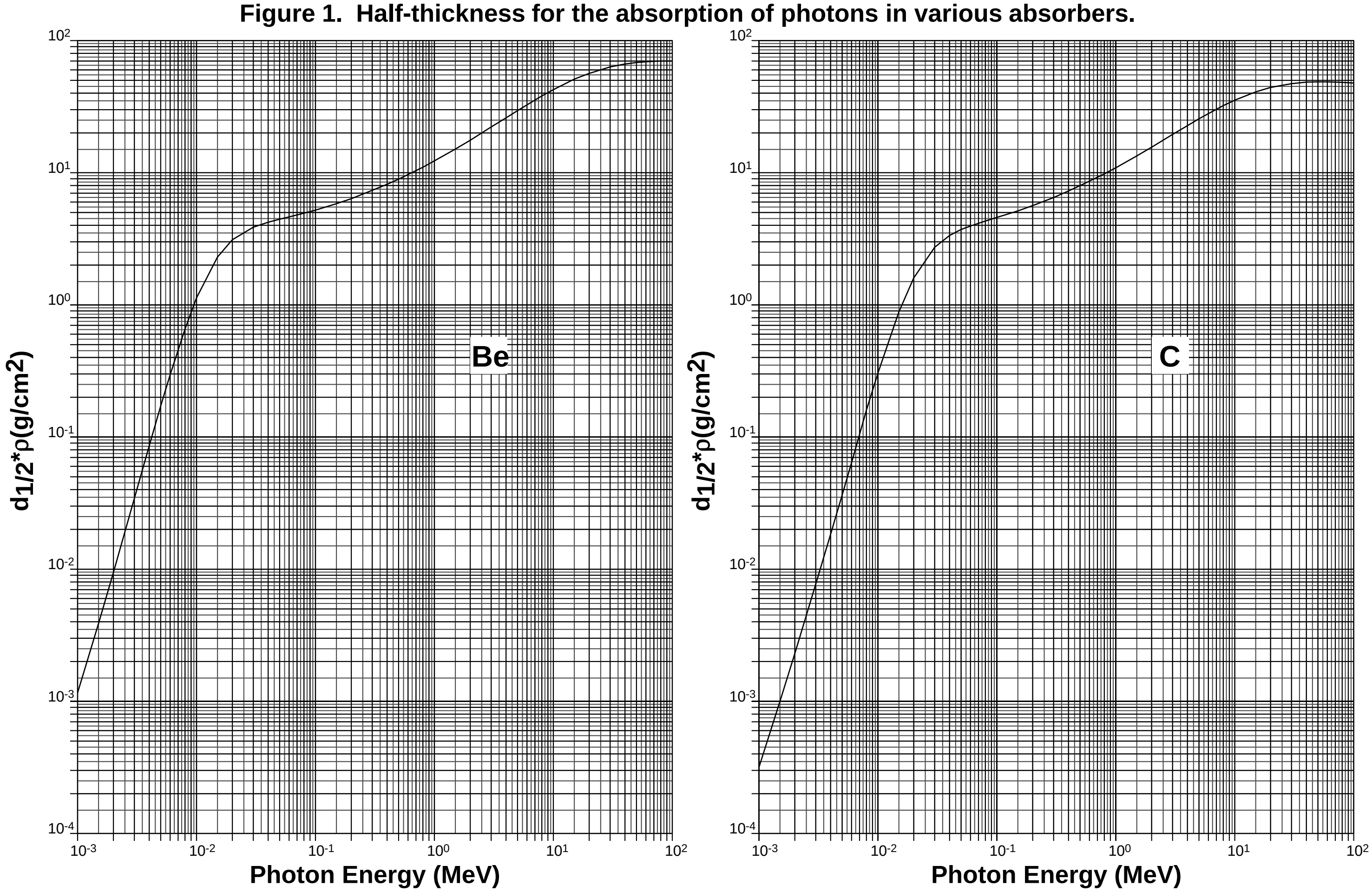
$$d_{1/2} = \frac{ln 2}{N_\rho} \sum_i \frac{A_i}{p_i \sigma_i(E)} , \tag{2}$$

where N is Avogadro's number, ρ is the density of the material, and A_i, p_i, and $\sigma_i(E)$ are, the (average) atomic masses, the fractions by mass, and the "atomic cross sections" of the elements of which the absorber is composed. The atomic cross section includes contributions from the coherent (Rayleigh) and incoherent (Compton) scattering, as well as absorption by photoelectric effect and by positron-electron pair production.

The graphs in Figure 1 give values of the half-thickness expressed in terms of mass per unit area ($\rho \times d_{1/2}$) for some commonly used elemental absorbers. These curves are based on the tables of Storm and Israel.[2] The accuracy of the half-thickness is better than 5% between 0.2 MeV and 5 MeV, 10% for lower energies where the photoelectric effect dominates, and 10% for higher energies where pair production dominates.

Two points should be noted: (1) the cross sections do not include photonuclear effects, which can be as large as 5 to 10% of the atomic cross section between 10 and 30 MeV,[3] and (2) the attenuation calculated by the above formula gives only the decrease in intensity of the original beam. The total radiation downstream of the absorber is larger, due to the presence of scattered photons, and to the creation of secondary photons by a variety of processes, including fluorescence (x-rays) and positron annihilation radiation.

Figure 1. Half-thickness for the absorption of photons in various absorbers.



[1]A.H. Wapstra, G.J. Nijgh, and R. van Lieshout *Nuclear Spectroscopy Tables*, North-Holland Publ. Co., Amsterdam (1959).

[2]E. Storm and H.I. Israel, *Nucl. Data Tables* **A7**, 565 (1970).

[3]J.H. Hubbell, *Radiat. Res.* **70**, 58 (1977).

Figure 1. Half-thickness for the absorption of photons in various absorbers (continued)