CC/NUMBER 51
DECEMBER 17, 1990

This Week's Citation Classic®

Hubbell J.H. Photon mass attenuation and energy-absorption coefficients from 1 keV to 20 MeV. *Int. J. Appl. Radiat. Isot.* 33:1269-90, 1982.
[Center for Radiation Research, National Bureau of Standards, Washington, DC]

The penetration and energy-deposition properties of X-ray or gamma-ray photons traversing materials are expressible as mass attenuation and mass energy-absorption coefficients, respectively. These coefficients are here described and tabulated for 40 elements over the range Z = 1 to 92, also for 45 multielement materials, for photon energies 1 keV to 20 MeV. [The *SCI*® indicates that this paper has been cited in more than 200 publications.]

X-Ray Cross Sections and Crossroads

John H. Hubbell
National Institute of Standards and Technology
US Department of Commerce
Gaithersburg, MD 20899*

Some papers become highly cited due to the creativity, genius, and vision of the authors, presenting seminal work stimulating and opening up new and multiplicative lines of research. Another, more pedestrian class of papers is "house-by-the-side-of-the-road" works, highly cited simply because these papers provide tools required by a substantial number of researchers in a single discipline or perhaps in several diverse disciplines, as is here the case.

This paper, an invited contribution to editor Bill McLaughlin's *International Journal of Applied Radiation and Isotopes* special issue "Trends in Radiation Dosimetry," is clearly in the latter class, I think. The citation time profiles of such side-of-the-road papers have been the subject of a study[1] by Katharine (Kay) Way (former editor, *Atomic Data and Nuclear Data Tables*), who concludes, "The moral is easily seen to be that if you want your name to make a splash in the Citation Index, publish a table." Kay's study included as one of her examples an earlier NBS/NIST tabulation of photon mass attenuation and energy-absorption coefficients,[2] and another NBS/NIST review and tabulation, of X-ray scattering data,[3] has also subsequently made its splash in a *Citation Classic* commentary.

There is a further and profoundly career-satisfying dimension to this supportive-role table-making work. This process of collecting measured and theoretical data, evaluation, filling gaps by hook or by crook, and publishing tables has developed into a kind of international crossroads of such information, funneling and synthesizing the intellectual productivity of an army of globally distributed scientists, including many talented Third World researchers, into tables fanning back out to similarly geographically and discipline-distributed user communities.

This data crossroads has sometimes been a dynamic, rather than passive, enterprise. For example, I instigated an International Union of Crystallography (IUCr) X-Ray Attenuation Project,[4] graciously chaired by Dudley Creagh of the University of New South Wales, Australia, to resolve some serious discrepancies in the existing data. In this project, Dudley fabricates and distributes well-characterized absorber samples to a dozen or so globally distributed participating laboratories, where the measurements are made using diverse but well-described techniques and reported back to Dudley. This IUCr project will contribute some additional reliability to the X-ray attenuation coefficient tables[5] in the latest *International Tables for Crystallography*.

The spawning of a global "radiation physics family" with strong personal and apolitical friendships from this crossroads enterprise has also led in part to the founding of a new International Radiation Physics Society, which will hold its Fifth International Symposium on Radiation Physics in Dubrovnik, Yugoslavia, June 10-14, 1991, following the earlier symposia in India, Malaysia, Italy, and Brazil.

Recognition of this X-ray data compilation work, performed under the guidance and vision of Martin J. Berger, long-time NBS/NIST Radiation Theory group leader, has been given by the American Nuclear Society in the form of its Radiation Industry (1985) and Professional Excellence (1990) Awards, and also by the Society of Nuclear Medicine by its Paul C. Aebersold Award (1985).

For more recent compilations in this topical area, the interested reader is directed to the 100 eV to 100 keV work with Saloman and Scofield[6] and to the 10 eV to 100 GeV collaborative effort with D.E. ("Red") Cullen and others at the Lawrence Livermore National Laboratory.[7]

1. **Way K.** Citation counts for tables. (Nolen J A & Benenson W, eds.) *Atomic masses and fundamental constants.* New York: Plenum Press, 1980. Vol. 6. p. 541-6.
2. **Hubbell J H.** *Photon cross sections, attenuation coefficients, and energy absorption coefficients from 10 keV to 100 GeV.* Washington, DC: US Government Printing Office, August 1969. NSRDS-NBS Report No. 29. 80 p. (Cited 490 times.) [See also: **Hubbell J H.** Citation Classic. (Thackray A, comp.) *Contemporary classics in physical, chemical, and earth sciences.* Philadelphia: ISI Press. 1986. p. 54.]
3. **Hubbell J H, Veigele W J, Briggs E A, Brown R T, Cromer D T & Howerton R J.** Atomic form factors, incoherent scattering functions, and photon scattering cross sections. *J. Phys. Chem. Ref. Data* 4:471-538, 1975; and Erratum. *J. Phys. Chem. Ref. Data* 6:615-6, 1977. (Cited 350 times.) [See also: **Hubbell J H.** X-ray scattering data for atoms. Citation Classic. *Current Contents/Physical, Chemical & Earth Sciences* and *CC/Engineering, Technology & Applied Sciences* 9 January 1989, p. 14.]
4. **Creagh D C & Hubbell J H.** Problems associated with the measurement of x-ray attenuation coefficients. I. Silicon. Report on the International Union of Crystallography X-Ray Attenuation Project. *Acta Crystallogr. A—Found. Crys.* 43:102-12, 1987. (Cited 10 times.)
5. ———. X-ray absorption (or attenuation) coefficients, section 4.2.4. (Wilson A J C, ed.) *International tables for crystallography. Volume C. Mathematical, physical, and chemical tables.* International Union of Crystallography/Reidel. (In press.)
6. **Saloman E B, Hubbell J H & Scofield J H.** X-ray attenuation cross sections for energies 100 eV to 100 keV and elements Z=1 to Z=92. *At. Data Nucl. Data Tables* 38:1-197, 1988. (Cited 20 times.)
7. **Cullen D E, Chen M H, Hubbell J H, Perkins S T, Plechaty E F, Rathkopf J A & Scofield J H.** *Tables and graphs of photon-interaction cross sections from 10 eV to 100 GeV derived from the LLNL Evaluated Photon Data Library (EPDL). Part A: Z=1 to 50, and Part B: Z=51 to 100.* Livermore, CA: Lawrence Livermore National Laboratory, 1989. UCRL-50400. Vol. 6. Rev. 4.

*Received June 1, 1990

1-22