Photon interaction cross sections in the low energy region in Mg and V

V.R.K. Murty*, K.R.S. Devan

Radiation Physics Laboratory, Department of Physics, University of Botswana, Private Bag 0022, Gaborone, Botswana

1. Introduction

The interaction of photons with matter has been extensively studied over the past several decades in view of its importance in basic radiation physics research, medical, industrial and other applied fields. Large amounts of data have been complied on photon cross sections mostly in tabular and graphical forms (Hubbell, 1999, 1994; Berger and Hubbell, 1987). A careful survey of the latest bibliography (Hubbell, 1994) of experimental investigations shows gaps in the cross section data, especially in certain low-Z elements. These are mainly attributed to the difficulty in procuring thin absorbers in suitable form for low energy experiments. It was also evident from the bibliography that the cross section data was sparse for elements Mg and V, especially, using high resolution solid state detectors in the photon energy region below 100 keV. In the case of Mg, there was only one measurement made by Nathuram et al. (1988) in the energy region 6–20 keV in the past two decades. On the other hand, in the case of V, no single measurement has been reported in the energy region 10–60 keV. In fact, in low energy attenuation experiments, where characteristic X-rays are normally used, it is essential to use high resolution solid state detectors, or crystal spectrometers, to avoid unwanted scattering contributions in the transmitted intensities. Further, the latest photon attenuation cross-section data of Hubbell and Seltzer (1995) were not extensively tested by experiments with reliable data from high resolution detectors. In the present study, in view of the paucity of experimental cross section data in Mg and V, attenuation measurements have been made using photons from ^{241}Am and ^{109}Cd to cover the photon energy range 10–60 keV in the two low Z elements Mg and V and the measured total photon interaction cross sections are compared with the latest tabulated data of Hubbell and Seltzer (1995) together with other theoretical tabulations.

*Corresponding author. Tel.: +267-3552139; fax: +267-585097.

E-mail address: murtyvrk@mopipi.ub.bw (V.R.K. Murty).

2. Experimental details

Total photon interaction cross sections were measured using a narrow beam graded collimated geometry set-up (Murty and Devan, 1996) with minor changes to accommodate intensity considerations, and using the established procedures (Tajuddin et al., 1995). The alignment of the geometry has been accomplished using a He–Ne Laser. The system is coupled to a cooled Canberra Si(Li) detector (horizontal configuration) and a System 100 PC-based Canberra multichannel analyser. The absorbers were pure, thin uniform foils of 1 and 2 cm diameter and were obtained from Goodfellow (UK) and Micromatter (USA). The absorbers had differing thicknesses and further thicknesses were obtained by stacking the foils together.

3. Results and discussion

The total photon interaction cross sections, measured at different photon energies, for the two elements Mg and V are shown in Tables 1 and 2, along with the latest theoretical values of Hubbell and Seltzer (1995) as well as other theoretical values (Robouch and Cicerchia, 1980;

Table 1
Total photon interaction cross sections in magnesium (Barns per atom)

Energy (keV)	Present exptal. work	Storm and Israel	Robouch and Cicerchia	Hubbell and Seltzer
13.9	317±3	313	326	321
17.8	154±3	152	161	156
20.8	99±3	98	104	100
22.1	83±1	82	88	84
25.0	58±1	59	61	60
26.4	51±1	51	55	52
59.5	10.3±0.3	10.4	10.9	10.5

Table 2
Total photon interaction cross sections in vanadium (Barns per atom)

Energy (keV)	Present exptal. work	Storm and Israel	Robouch and Cicerchia	Hubbell and Seltzer
13.9	4100±70	4130	4467	4148
17.8	2090±30	2069	2128	2098
20.8	1330±20	1333	1405	1344
22.1	1130±50	1122	1169	1136
25.0	800±40	789	788	801
26.4	665±8	675	663	684
59.5	73±1	72	77	73

Storm and Israel, 1970). The present experimental total photon interaction cross sections are of approximately 3% accuracy. The error due to counting statistics was maintained at less than 1% in most cases. The error in the total photon interaction cross section was mainly due to counting statistics and peak area determination. As can be seen from the two tables, there is, in general, good agreement between the present experimental values and the theoretical data of Hubbell and Seltzer (1995) and that of Storm and Israel (1970). However, it is found that the values of Robouch and Cicerchia (1980) appear to be overestimated in comparison with all other theoretical values as well as the values measured in the present study.

4. Conclusions

Attenuation experiments in the photon energy region 10–60 keV, selecting photons emitted from Am-241 and Cd-109 radioisotopes were conducted and total photon interaction cross sections evaluated in the elements Mg and V were compared with the theoretical data including that of Hubbell and Seltzer. The present study contributes fourteen values to the pool of cross section data using a high resolution Si(Li) detector.

References

Berger, M.J., Hubbell, J.H., 1987. XCOM: photon cross sections on a personal computer. Report No. NBSIR 87-3597.

Hubbell, J.H., 1994. Bibliography of photon total cross section measurements 10 eV–13.5 GeV. NISTIR Report No. 5437, pp. 1907–1993.

Hubbell, J.H., 1999. Compilation of photon cross sections: some historical remarks and current status. X-ray Spectrometry 28, 215–223.

Hubbell, J.H., Seltzer, S.M., 1995. Tables of X-ray mass attenuation coefficients 1 keV–20 MeV for elements $Z=1$–92. NISTIR Report No. 5632.

Murty, V.R.K., Devan, K.R.S., 1996. The role of geometry in low energy photon attenuation experiments. J. Appl. Sci. Southern Africa 2, 103–107.

Nathuram, R., Rao, I.S.S., Mehta, M.K., 1988. Photoelectric cross sections for 6–20 keV photons in Be, C, Mg, Al, Si, Cu, Ag and Pb. Phys. Rev. A37, 4978–4981.

Robouch, B.V., Cicerchia, A., 1980. X-ray mass absorption coefficients in the range 62 eV–1.24 MeV of photon energy. CNEN - Edizioni Scientifiche, Italy.

Storm, E., Israel, H.I., 1970. Photon cross sections from 1 keV to 100 MeV for elements $Z=1$–100. Nuclear Data Tables A7, 565–681.

Tajuddin, A.A., Chong, C.S., Shukri, A., Bandyopadhyay, T., Bradley, D.A., 1995. Measurement of mass attenuation coefficients of moderate to high atomic number elements at low photon energies. Appl. Radiat. Isot. 46, 113–115.