Photoelectric cross sections of gamma rays in Al, Cu, Sn, W, Au and Pb in the energy region 50-208 keV

1968 J. Phys. A: Gen. Phys. 1 256

(http://iopscience.iop.org/0022-3689/1/2/310)

J. PHYS. A (PROC. PHYS. SOC.), 1968, SER. 2, VOL. 1. PRINTED IN GREAT BRITAIN

Photoelectric cross sections of gamma rays in Al, Cu, Sn, W, Au and Pb in the energy region 50–208 kev

K. PARTHASARADHI
The Laboratories for Nuclear Research, Andhra University, Waltair, India
MS. received 26th October 1967

Abstract. Total photoelectric cross sections of gamma rays are determined by subtracting the theoretical scattering cross sections from the experimental total gamma-ray cross sections of Wiedenbeck in the elements Al, Cu, Sn, W, Au and Pb in the energy region 50–208 kev. These values are compared with the latest theoretical values of Rakavy and Ron, Schmickley and Pratt and the compiled data of Hubbell and Berger. Agreement is observed between the theoretical and experimental values within 5%, except in lead at 50 and 105 kev energies. A systematic measurement of total gamma-ray cross sections in lead at these energies is suggested.

1. Introduction

One of the methods for the experimental determination of the total photoelectric cross sections is to subtract the other theoretically calculated partial cross sections from the respective experimental total gamma-ray cross sections. If the investigations are restricted to gamma rays of energy less than 1·02 Mev the partial cross section that is to be subtracted is the scattering cross section (coherent and incoherent) only. But the accuracy of the resultant photoelectric cross section is dependent on the accuracy of the theoretically calculated scattering cross sections (coherent and incoherent). These cross sections are calculated on the basis of the Thomas–Fermi model and the data were reported by Brown (1966 a, b). If this method is utilized for the calculation of the total photoelectric cross sections at low energies, good accuracy can be expected because of the smallness of the scattering cross-section (coherent and incoherent) contribution in comparison with that of the photoelectric cross-section. The accuracy of the resultant total photoelectric cross section is also a function dependent on the accuracy of the experimental total gamma-ray cross section. Very accurate measurements on the total gamma-ray cross sections have been made and the results are available in the literature. The set of results measured by Wiedenbeck (1962) have been selected because these are the data measured utilizing a bent crystal spectrometer in the required energy region of the present investigations. Using these data, an attempt is made to determine the photoelectric cross sections of low-energy gamma rays in elements Al, Cu, Sn, W, Au and Pb. These results are presented in this paper, and are compared with recent theoretically determined cross sections.

2. Photoelectric cross sections

Theoretical data on photoelectric cross sections were first compiled by Grodstein (1957), and the reported values were determined with an accuracy ranging from 5 to 15%. Using most of the latest data, a compilation was also made by Hubbell and Berger (1967) with an accuracy ranging from 2 to 3% up to 200 kev (except in the vicinity of absorption edges where it ranged from 5 to 10%), and from 3 to 5% up to 100 Mev. Recently very accurate data on total photoelectric cross sections were reported by Rakavy and Ron (1965, 1967, private communication) and Schmickley (1966, see also Schmickley and Pratt 1968) with an accuracy of 0·5% in most of the elements. With the availability of such accurate data on total photoelectric cross sections, it is of interest to compare these with the experimentally determined photoelectric cross sections, so that some useful conclusions can be drawn.

3. Results

The scattering cross sections (coherent and incoherent) at energies of 50, 105, 123, 158 and 208 kev in the elements Al, Cu, Sn, W, Au and Pb are interpolated from the reported data of Brown (1966 a, 1966 b). These cross sections are subtracted from the measured total gamma-ray cross sections of Wiedenbeck (1962) at the above-mentioned energies for the given elements, and the resultant experimental photoelectric cross sections, together with the theoretical data of Rakavy and Ron (1965, 1967, private communication) and Schmickley and Pratt (1968) and the compiled data of Hubbell and Berger (1967), are given in table 1.

Table 1. Photoelectric cross sections in bn/atom

Energy (kev)		Al	Cu	Sn	W	Au	Pb
50	Expt	7·32 ±0·40	237 ±5	2047 ±43			2328 ±53
	HB	7·65 ±0·23	247 ±8	1931 ±96			2419 ±120
	SP	7·49 ±0·15	247 ±1	2040 ±10			2530 ±13
	RR	7·52 ±0·03		2026 ±10			
105	Expt				1086 ±24		1484 ±32
	HB				1109 ±33		1651 ±80
	SP				1110 ±6		1606 ±8
	RR				1114 ±6		
123	Expt					911 ±20	
	HB					917 ±27	
	SP					940 ±5	
	RR						
158	Expt				365 ±9		532 ±12
	HB				364 ±11		550 ±16
	SP				375 ±2		550 ±3
	RR				364 ±2		
208	Expt				176 ±4·5		259 ±7
	HB				176 ±5·0		269 ±8
	SP				179 ±1·0		264 ±1
	RR				174 ±1·0		

Expt, experimental values; HB, values of Hubbell and Berger; SP, values of Schmickley and Pratt; RR, values of Rakavy and Ron.

As it has been a well-established fact that the incoherent scattering cross sections based on the Thomas–Fermi model are overestimates, the present experimental photoelectric cross sections are minimum values. However, in the present investigations, as the energy increases from 50 to 208 kev, the contribution due to the incoherent-scattering cross section ranges from 1% to 12% in lead, the heaviest element in the present investigations, but the overestimate in the same cross sections decreases. It is expected that the error due to this effect in the photoelectric cross sections will be within the errors quoted in the present results.

4. Discussion

Because of the interpolations made to obtain some of the theoretical data, 1% deviations exceeding the error limits already mentioned in table 1 are neglected. It can be seen from table 1 that the agreement between the present experimental data and the theoretical values of Rakavy and Ron (1965, 1967, private communication) and Schmickley and Pratt (1968) and the compiled data of Hubbell and Berger (1967) is satisfactory within the range of errors, except at 50 and 105 kev energies in lead. Even in lead, the present value at 50 kev is in agreement with the value of Hubbell and Berger (1967) within the range of errors. This may be due to the very large error reported in the values of Hubbell and Berger. However, at 105 kev the experimental value is in disagreement with both the values of Schmickley and Pratt (1968) and Hubbell and Berger (1968). This discrepancy at these two energies has been attributed in part to the theoretical inaccuracies in the scattering cross sections by Schmickley and Pratt (1968). But the total gamma-ray cross sections of Wiedenbeck at 50 and 105 kev energies are 2566 ± 51 and 1579 ± 31 bn/atom respectively, which are of the order of the theoretical photoelectric cross sections. The disagreement at these energies may be due to two possible causes: (i) either the theoretical photoelectric cross sections are overestimates, or (ii) the theoretical scattering cross sections (coherent and incoherent) at these energies are negligible. As far as (ii) is concerned, the incoherent scattering cross sections may be negligible owing to severe electron binding effects, but the coherent scattering cross sections cannot be zero. Thus it may be concluded that the theoretical photoelectric cross sections of Schmickley and Pratt (1968) at 50 and 105 kev and of Hubbell and Berger (1967) at 105 kev may be overestimates. However, another possibility is that the experimental values of total gamma-ray cross sections are inaccurate, and it is of interest to note that, if one makes a comparison of the total cross sections of Wiedenbeck (1962) used in the present paper with the other experimental values of Jones (1936) and of McCrary *et al.* (1967), given in table 2, the differences between the three sets of values are considerable. The photoelectric cross sections determined using these values will therefore vary from worker to worker. For this reason further systematic measurements of total gamma-ray cross sections in lead at low energies are desirable, so that there should be repeatability of the result by any worker within the specified accuracy. Only then can one draw meaningful conclusions on the accuracy of the theoretical photoelectric cross sections at low energies in lead.

Table 2. Total gamma-ray cross sections in lead in bn/atom

Author	Energy (kev)	
	50	105
Jones 1936	—	1676 ± 33†
Wiedenbeck 1962	2566 ± 51	1579 ± 32
McCrary *et al.* 1967	2734 ± 13	1726 ± 9†

† Interpolated values.

Acknowledgments

The author is very grateful to Professor S. Jnanananda and Professor V. Lakshminarayana for their useful suggestions.

References

Brown, W. D., 1966 a, *Boeing Co. Rep.*, D2-125136-1.

—— 1966 b, *Boeing Co. Rep.*, D2-125137-1.

Grodstein, G. W., 1957, *Natn. Bur. Stand. Circ.* NBS 583 (Washington: U.S. Govt Printing Office), p. 54.

Hubbell, J. H., and Berger, M. J., 1967, *Engineering Compendium on Radiation Shielding*, Ed. R. G. Jaeger (Vienna: International Atomic Energy Agency).

Jones, M. T., 1936, *Phys. Rev.*, **50,** 110.

McCrary, J. H., *et al.*, 1967, *Phys. Rev.*, **153,** 307.

Rakavy, G., and Ron, A., 1965, *Phys. Lett.*, **19,** 292.

Schmickley, R. D., 1966, *Doct. Diss.*, Stanford University.

Schmickley, R. D., and Pratt, R. H., 1968, *Phys. Rev.*, to be published.

Wiedenbeck, M., 1962, *Phys. Rev.*, **126,** 1009.