Total photon-absorption cross-section measurements at 52.4, 60, 72.2, and 84.4 keV in Al, Fe, Mo, Ag, W, and Pt: Photoelectric cross sections deduced

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The total absorption cross sections for 52.4-, 60-, 72.2-, and 84.4-keV photons in Al, Fe, Mo, Ag, W, and Pt have been measured. Also, the photoelectric cross sections at these photon energies have been deduced by subtracting the scattering cross sections from the measured values of total absorption cross sections. The results so obtained have been compared with the corresponding theoretical values as interpolated from the work of (i) Schmickley and Pratt and (ii) Scofield.

I. INTRODUCTION

Explicit measurements of photoelectric cross sections below 100 keV are rare in the literature.[1-3] Recently several investigators[4-7] have attempted to determine the photoelectric cross sections at various photon energies, below 100 keV, from the measured total absorption cross sections. Since the direct measurements in the low-energy region (<100 keV) are difficult, the indirect method is preferred because the scattering cross sections to be subtracted are small and can be obtained from the compilation work of Veigele.[8] Gowda and Sanjeevaiah[5] have determined the photoelectric cross sections at 72.1 keV in Al, Cu, Zr, Ag, Sn, Ta, Au, and Pb. Parthasaradhi and Hansen[6] following the indirect method have determined the photoelectric cross sections in Al, V, Cu, Mo, Sn, Ta, Au, and Pb from 3.3 to 165.8 keV. Recently, Gowda *et al.*[7] have made the measurements at 52.2 and 84.3 keV in the elements Al, Cu, Zr, Ag, Sn, Ta, Au, and Pb and their results tally with theoretical values. We have deduced the photoelectric cross sections from the measured values of total absorption cross sections at 52.4-, 60-, 72.2-, and 84.4-keV photon energies in Al, Fe, Mo, Ag, W, and Pt. Measurements for Fe, Mo, W, and Pt at 52.4, 72.2, and 84.4 keV and for Pt at 60 keV have been carried out for the first time. The results have been compared with the interpolated values of (i) Schmickley and Pratt[9] and (ii) Scofield.[10]

TABLE I. Energy and origin of the photons used.

Photon energy (keV)	Photons	Origin
52.4	*K*x rays	^{170}Tm
60.0	γ rays	^{241}Am
72.2	*K*x rays	^{203}Hg
84.4	γ rays	^{170}Tm

II. EXPERIMENTAL DETAILS

The conventional transmission experiment with a good geometry[5,6,11,12] setup can be used to measure the total γ-ray-absorption cross sections in different elements. In the present investigation a similar good geometry setup was used. The detector system consisted of a 3.8-cm-diam by 1.0-cm-thick NaI(Tl) crystal mounted over a high-gain RCA 7265 photomultiplier tube. The voltage at the focusing electrode was optimized

TABLE II. Total absorption cross sections in b/at.

Elements	52.4 keV Present	52.4 keV McCrary *et al.* (Ref. 11)	60 keV Present	60 keV McCrary *et al.* (Ref. 11)	72.2 keV Present	72.2 keV McCrary *et al.* (Ref. 11)	84.4 keV Present	84.4 keV McCrary *et al.* (Ref. 11)
Al	15.2 ± 0.2	15	12.4 ± 0.2	12.3	9.82 ± 0.2	9.62	8.4 ± 0.2	8.5
Fe	158 ± 4	160	108 ± 4	112	67 ± 3	69	48 ± 2	49
Mo	990 ± 10	995	695 ± 8	688	422 ± 8	415	277 ± 6	271
Ag	1478 ± 16	1492	1015 ± 12	1022	615 ± 10	624	408 ± 8	412
W	1580 ± 18	1588	1118 ± 15	1106	3008 ± 40	⋯	2082 ± 20	2100
Pt	2031 ± 26	⋯	1442 ± 20	⋯	859 ± 10	⋯	2572 ± 28	⋯

with the help of a potentiometer so as to give the maximum output. To avoid the gain shift[13] in such photomultiplier tubes at high counting rates, the dc potentials at the last two dynode stages were stabilized with the help of Zener diodes. Pulses from the eighth dynode, as the higher dynode pulses were observed to show nonlinearity and saturation in the pulse size, were derived and after proper amplification were fed to an Ortec Timing SCA model 420A, where 15-keV window selection around the photopeak in question was made and the final spectrum was recorded in an ND-512 channel analyzer, following the sequence described by McCrary *et al*.[11] To be more precise about the duration of accumulation of the spectrum in each sequence the "Timer" associated with the MCA was used.

The target foils used were circular in shape (1.6-cm diam) and each foil was of uniform thickness. The maximum thickness (t) for each foil was chosen such that the condition $\mu t < 1$ is satisfied.[14] The individual thicknesses varied from element to element. The purity of the target materials was better than 99.8%. The radioactive sources ^{170}Tm (15 mCi), ^{203}Hg (15 mCi), and ^{241}Am (10 mCi) were obtained from BARC Trombay, Bombay, India. The energies and origin of photons used are shown in Table I.

The total photon-absorption cross sections were calculated using expressions

$$\mu = -(\ln I/I_0)/t$$

and

$$\sigma_{tot} = \mu(A/N) \times 10^{24} ,$$

where I_0 is the photon intensity without the foil, I is the transmitted photon intensity, t is the thickness of the foil expressed in g/cm^2, μ is the mass attenuation coefficient, A is the atomic weight, N is the Avogadro's number, and σ_{tot} is the total photon-absorption cross section in b/at. The photoelectric cross sections τ were obtained by subtracting the scattering (coherent plus incoherent) cross sections as interpolated from the compilation work of Veigele.[8]

III. RESULTS AND DISCUSSION

The total absorption cross sections for 52.4, 60, 72.2, and 84.4 keV have been listed in Table II and compared with those obtained from interpolation of the experimental values of McCrary *et al*.[11] The errors quoted are mainly due to counting statistics, since the sample impurity corrections are negligible. There is a good agreement between the two within the experimental errors. The photoelectric cross sections have been obtained by subtracting

TABLE III. Photoelectric cross sections in b/at.

Elements	52.4 keV Present	52.4 keV Schmickley and Pratt (Ref. 9)	52.4 keV Scofield (Ref. 10)	60 keV Present	60 keV Schmickley and Pratt (Ref. 9)	60 keV Scofield (Ref. 10)	72.2 keV Present	72.2 keV Schmickley and Pratt (Ref. 9)	72.2 keV Scofield (Ref. 10)	84.4 keV Present	84.4 keV Schmickley and Pratt (Ref. 9)	84.4 keV Scofield (Ref. 10)
Al	6.67 ± 0.2	6.42	6.64	4.28 ± 0.2	4.16	4.28	2.24 ± 0.2	2.32	2.3	1.24 ± 0.2	1.3	1.28
Fe	135 ± 4	132	137	87 ± 4	90	91	48 ± 3	50	51	31 ± 2	32	31
Mo	944 ±10	920	935	646 ± 8	633	632	381 ± 8	375	384	242 ± 6	236	238
Ag	1407 ±16	1425	1402	954 ±12	976	972	565 ±10	575	569	363 ± 8	372	374
W	1387 ±18	1456	1460	958 ±15	986	974	2882 ±40	2985	2944	1974 ±20	2015	1992
Pt	1824 ±26	1785	1820	1268 ±20	1240	1226	722 ±10	745	738	2459 ±28	2512	2448

the coherent plus incoherent scattering cross sections obtained by interpolation from the atomic data compiled by Veigele[8] and are given in Table III together with the interpolated theoretical values of Schmickley and Pratt[9] and Scofield.[10] The errors on the estimated photoelectric cross sections are the same as those on the measured total-absorption cross sections. The disagreement between our experimental values and the theoretically predicted values of Schmickley and Pratt in the case of 52.4 keV is less than 3% except in Al and W where it is less than 4% and 5%, respectively. For 60 keV it is less than 3% for all the elements and 4% for Fe. In the case of 72.2 keV it is less than 2% for Mo and Ag, 3% for Pt, and about 4% for Al, Fe, and W. The disagreement in the case of 84.4 keV is less than 3% for all and 5% for Al. The overall agreement improves and is better with the Scofield values rather than those of Schmickley and Pratt.

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