Photoelectric cross sections of Al, Cu, Zr, Ag, Sn, Ta and Pb for 145 keV γrays

1973 J. Phys. A: Math. Nucl. Gen. 6 1041

(http://iopscience.iop.org/0301-0015/6/7/024)

J. Phys. A: Math., Nucl. Gen., Vol. 6, July 1973. Printed in Great Britain.

Photoelectric cross sections of Al, Cu, Zr, Ag, Sn, Ta and Pb for 145 keV γ rays

Ramakrishna Gowda and B Sanjeevaiah

Department of Physics, University of Mysore, Manasagangotri, Mysore 570006, India

Received 29 December 1972, in final form 26 February 1973

Abstract. Measurements of photoelectric cross sections of aluminium, copper, zirconium, silver, tin, tantalum and lead for 145 keV γ rays have been carried out using the well-type plastic scintillation spectrometer. The cross sections in these materials are found to be $0{\cdot}261 \pm 0{\cdot}018$, $10{\cdot}32 \pm 0{\cdot}62$, $37{\cdot}82 \pm 2{\cdot}27$, $79{\cdot}83 \pm 4{\cdot}80$, $98{\cdot}97 \pm 5{\cdot}90$, $430{\cdot}9 \pm 25{\cdot}00$ and $671{\cdot}0 \pm 40{\cdot}00$ b/atom respectively. These values are found to be in good agreement with the predicted values of Schmickley and Pratt.

1. Introduction

The direct measurements of photoelectric cross sections using scintillation spectrometers are very few. Titus (1959) has used a plastic scintillator $1\frac{1}{2}''$ long, $\frac{5}{32}''$ diameter axial hole in a $\frac{5}{8}''$ diameter crystal, which is coupled to the photomultiplier with a $6''$ long plastic light guide, and measured the cross sections at 662 keV in copper, molybdenum, silver, tantalum and gold. Titus (1965) has also measured the photoelectric cross sections at 2·62 meV in tin, tantalum and gold. The data of Titus (1959, 1965) were consistently below the theoretical values of Schmickley and Pratt (1967), usually not even within the stated limits of experimental error. Parthasaradhi *et al* (1964a, b) have used a plastic scintillator of $1''$ diameter, $\frac{1}{8}''$ thickness, having a well of $\frac{1}{16}''$ depth and $\frac{3}{8}''$ diameter, and measured the photoelectric cross sections in copper, silver, tin, tantalum and platinum for 145 keV γ rays; the errors were as high as 10% in high Z materials. Parthasaradhi *et al* (1966) have also measured the photoelectric cross sections in lead, tin and silver for 320 keV γ rays by the same method. There is a wide discrepancy in the cross sections of platinum and lead for 145 keV and 320 keV γ rays respectively between these measured values and the predicted values of Schmickley and Pratt (1967) which have been confirmed by the data on absorption coefficients.

It is therefore desirable to measure the photoelectric cross sections in high Z materials, particularly at low energy, with improved accuracy. With this end in view, absolute photoelectric cross sections of aluminium, copper, zirconium, silver, tin, tantalum and lead for 145 keV γ rays have been determined using a well-type plastic scintillation spectrometer.

2. Experimental details

The experimental set-up is shown in figure 1. A 60 mCi ^{141}Ce source in the form of a radiographic capsule yielding 145 keV γ rays was obtained from Bhabha Atomic Research

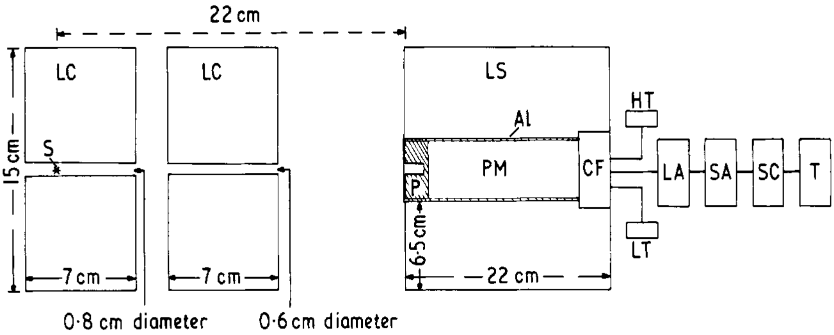

Figure 1. Schematic diagram of experimental set-up. S source, LC lead collimators, LS lead shielding, P plastic scintillator, PM photomultiplier, Al aluminium lining, CF cathode follower, HT high tension power supply, LT low tension power supply, LA linear amplifier, SA single channel analyser, SC scaler, T timer.

Centre, Bombay, India. It was housed in a lead cylinder with a collimating hole of 8 mm diameter and 70 mm in length. The radiation leaving this collimator passed through another collimator of hole diameter 6 mm and length 70 mm, and then traversed a well 12 mm deep and 7 mm in diameter in a plastic scintillator 15 mm thick and 28 mm in diameter. The plastic scintillator was optically coupled to the face of a 6199 RCA photomultiplier with the help of silicon grease. The scintillator was covered with a thin aluminium foil except at the top of the well. This aluminium foil was further covered with black french tape. The scintillator was carefully centred on the photon beam.

Thin converter foils of mass 9·275, 7·650, 9·800, 9·100, 12·000 and 8·050 mg of aluminium, copper, zirconium, silver, tin, tantalum and lead respectively of high purity (99·9 %) were punched to the well diameter. Then the converter foil under investigation was placed inside the well in the scintillator intercepting the entire photon beam. Plastic strips were used to insert the converter foils into the well. On the basis of the measurements of the beam profile it was confirmed that the converter foil at all times intercepted the entire photon beam. After inserting the foil, the well top was covered with thin black french tape.

The pulses from the photomultiplier were coupled to the cathode follower which then fed these pulses to the single channel analyser. The experiment was performed in an air conditioned room. The mains voltage was also stabilized and the drift in the spectrometer gain was negligible.

3. Procedure

When a low energy photon beam is incident on a converter material electrons are ejected due to photoelectric absorption and Compton collisions. The γ background spectrum and the spectrum with an aluminium converter were recorded. Typical pulse height spectra are given in figure 2. The γ background spectrum is subtracted from the spectrum with the aluminium converter to get the electron spectrum as shown in figure 3(*a*) (full curve). As can be seen from this figure there is a small hump which is due to the photoelectron spectrum superimposed on the Compton continuum. The Compton continuum is interpolated by curve fitting (shown by broken curve). For the purpose of checking this interpolation the continuum was also measured with the aluminium converter

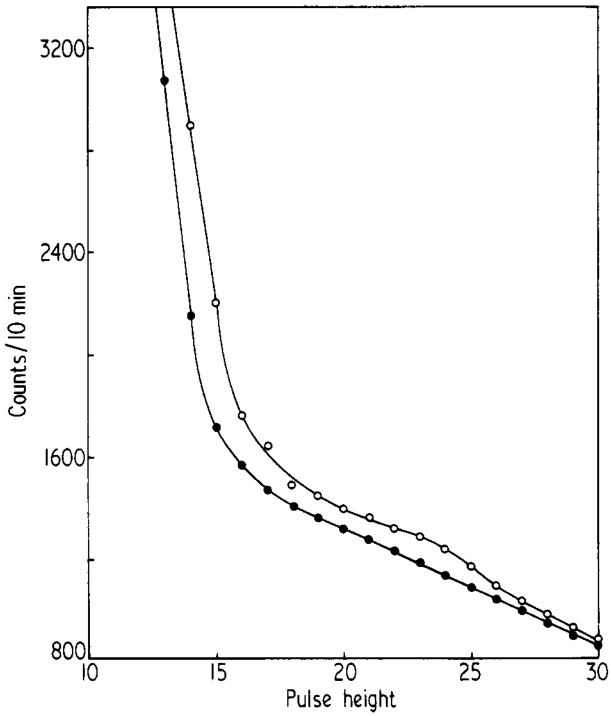

Figure 2. Typical pulse height spectra. ○ Aluminium; ● γ background.

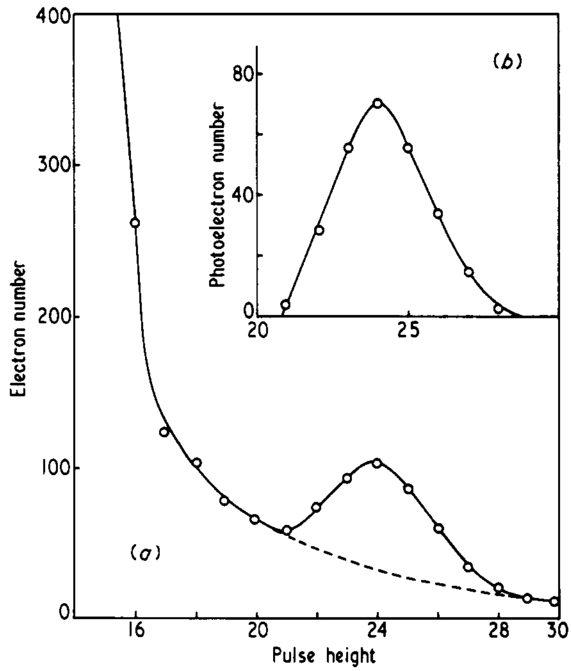

Figure 3. (*a*) Resolved electron spectrum of aluminium converter. The broken curve is the interpolated Compton continuum. (*b*) Resolved photoelectron spectrum.

replaced by a carbon converter having the same number of electrons as in aluminium. No significant error in the interpolation procedure could be detected, due to the general smoothness of the continuum. This interpolated continuum under the observed peak is subtracted to obtain the resolved photoelectron spectrum shown in figure 3(*b*). The plot of interpolated electron spectrum together with the ratio of the number of electrons in the high Z converter material to that in aluminium was used to estimate the Compton continuum in that material. The Compton continuum so obtained was subtracted from the observed electron spectrum in the high Z converter. The resolved photoelectric spectrum was plotted and the number of photoelectrons was estimated from the area under the peak. The estimated number in each case is corrected for self-absorption in the converter foil. This corrected number (N_p) was used in the calculations of the photoelectric cross sections.

The number of atoms (N) in the converter foil is given by

$$N = \frac{mL}{A}.$$

Here m and A are respectively the mass and the atomic weight of the converter foil and L is Avogadro's number. The mass of the converter foil was determined using an electrical balance.

To determine the number of photons that are incident on the converter foil a scintillation spectrometer was assembled with a 38 mm diameter and 38 mm thick NaI(Tl) crystal which was coupled to the RCA 6292 photomultiplier. The spectrum of ^{141}Ce was taken in a good geometry set-up (Gopal and Sanjeevaiah 1973). The peak-to-total ratio was determined experimentally by recording the complete pulse height spectrum resulting from 145 keV γ rays. The intrinsic efficiency for the size of the crystal employed was taken from the theoretically computed values of Wolicki *et al* (1956). The product of peak-to-total ratio and intrinsic efficiency gives the photopeak efficiency for point-source geometry. This was further corrected for the geometry of the set-up. Accepting the photopeak the counts were registered. The number of counts was corrected for photofraction and absorption in the aluminium shield of the NaI(Tl) crystal. A transmission experiment was also conducted accepting the photopeak of the ^{141}Ce γ source using aluminium absorbers in the same geometry. The interpolated value to zero thickness of the absorber is corrected for photofraction, and this gives the total number of photons incident on the crystal in this geometry. The values obtained by both the methods agree within experimental error. Using this value the number of photons (S) incident on unit area of the converter foil was calculated.

4. Results and discussion

The photoelectric cross sections (σ_T) calculated using the relation

$$\sigma_T = \frac{N_p}{NS}$$

are given in table 1.

In the estimation of photoelectrons the error comes mainly from the subtraction procedure and the statistical uncertainties in the estimated Compton electrons and the total number of electrons beneath the peak. This is estimated to be about 7% in the aluminium and about 6% in other materials. The error involved in the estimation of the number of atoms is negligible (< 0·2%). In the estimation of photon flux the error is found to be less than 1%. Therefore, the error involved in the photoelectric cross sections is about 6% in all materials except aluminium where it is about 7%.

The present experimental values are in good agreement with the interpolated values of Schmickley and Pratt (1967).

Table 1. Photoelectric cross sections (b/atom)

Converter material	Present	Schmickley and Pratt
Aluminium	0·261 ± 0·018	0·25
Copper	10·32 ± 0·62	9·90
Zirconium	37·82 ± 2·27	39·50
Silver	79·83 ± 4·80	79·00
Tin	98·97 ± 5·90	99·00
Tantalum	430·90 ± 25·00	431·00
Lead	671·00 ± 40·00	680·00

Acknowledgments

One of the authors (RKG) thanks the University of Mysore, Mysore, for awarding the UGC Junior Research Fellowship.

References

Gopal S and Sanjeevaiah B 1973 *Nucl. Instrum. Meth.* **107** 221–5
Parthasaradhi K, Lakshminarayana V and Jnanananda S 1964a *Ind. J. pure appl. Phys.* **2** 306
—— 1964b *Ind. J. pure appl. Phys.* **3** 223–4
—— 1966 *Phys. Rev.* **142** 9–11
Schmickley R D and Pratt R H 1967 *Phys. Rev.* **164** 104–16
Titus W F 1959 *Phys. Rev.* **115** 351–6
—— 1965 *Nucl. Phys.* **69** 171–85
Wolicki E A, Jastrow R and Brooks F 1956 *Naval Research Laboratory Report*-4833