Determination of Particle Parameters in the K, L, and M Shells in Pb^{207} †

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An angular-correlation setup was applied to measure the e-γ angular correlations involving the 570- and 1064-keV transitions in Pb^{207}. The use of a Si(Li) semiconductor counter as an electron detector allowed the separation of the three K, L, and M conversion lines for both transitions. γ-γ angular correlations were also performed. Particle parameters b_2 were thus esperimentally determined. The values obtained for the K, L, and M shells were 1.19(7), 1.13(7), and 1.41(11) for the 570-keV transition and 1.05(5), 1.06(12), and 1.16(15) for the 1064-keV transition. Particle parameters b_4 were calculated from the b_2 values through a recursion relation. The coefficients $A_4(e)$ could not be determined directly from experiment owing to the lack of statistics, but they were obtained through the b_4 particle parameters and the $A_4(\gamma)$ coefficients. The values for the K, L, and M shells one $-0.020(8)$, $-0.025(9)$, and ~ -0 are for the $e(570)$-$\gamma(1064)$ angular correlations; and $-0.049(16)$, $-0.051(30)$, and $-0.072(40)$ for the $e(1064)$-$\gamma(570)$ angular correlations.

I. INTRODUCTION

It is usual nowadays to experimentally determine angular correlations which involve conversion electrons in the three main shells. Furthermore, particle parameters are now being experimentally determined for each main shell.

Electron-γ angular correlations have primarily been carried out by Gerholm *et al.*,[1] using a setup developed by them. An improved version of this setup has been made by Kleinheinz *et al.*[2] A complete picture of the work done prior to 1965 is given in Ref. 3.

Recent theoretical calculations have been made of the conversion coefficients and particle parameters for the K, L, and M shells.[4,5] Taking into account these theoretical results as well as the new experimental arrangements using semiconductor counters with high resolution,[6–8] it is now possible to make complete studies of the properties of the electron conversion process for the three main shells.

Table I. Electron-γ angular-correlations $A_2(e)A_2(\gamma)$ coefficients in Pb^{207}.

Cascade	$A_2(e)A_2(\gamma)$ Present work	a
$e(570)$-$\gamma(1064)$	K 0.261(15)	K 0.275(13)
	L 0.248(15)	
	M 0.310(24)	
$e(1064)$-$\gamma(570)$	K 0.231(10)	K 0.223(4)
	L 0.233(27)	
	M 0.256(30)	

[a] Reference 9.

Table II. $\gamma(570)$-$\gamma(1064)$ angular-correlations $A_2(\gamma)$ and $A_4(\gamma)$ coefficients in Pb^{207}.

Coefficient	Present work	a	Theory
$A_2(\gamma)$	0.220(3)	0.230(4)	0.2207
$A_4(\gamma)$	$-0.038(4)$	$-0.027(8)$	-0.0180

[a] Reference 9.

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TABLE III. Particle parameters b_2 for both transitions of 1064 and 570 keV in Pb^{207}.

Transition	Present work	b_2 particle parameters Theory[a]	b_{expt}/b_{theory}	Kleinheinz *et al.*[b]
$E2$ (570 keV)	K 1.19(7)	1.215	0.98(7)	1.21(3)
	L 1.13(7)	1.104	1.02(7)	1.18(7)[c]
	M 1.41(11)	1.100	1.28(11)	
$M4$ (1064 keV)	K 1.05(5)	1.047	1.00(3)	0.99(2)
	L 1.06(12)	1.038	1.02(12)	1.02(4)[c]
	M 1.16(15)	1.030	1.12(15)	

[a] Reference 5.
[b] Reference 9.
[c] Value of $L+M$ shell.

The present work deals separately with the experimental determination of the particle parameters involved in the 570- and 1064-keV transitions in Pb^{207}, for the K, L, and M shells, and it constitutes an extension of the work done by Kleinheinz *et al.*[9] which provided values of the particle parameters for the K and $L+M$ shells corresponding to the same transitions.

II. EXPERIMENTAL PROCEDURES

The experimental arrangement used for the electron-γ angular correlation consisted of a cylindrical rotating vacuum chamber containing a Si(Li) semiconductor counter and associated electronics.[7] Optimization of the electron-detection system was obtained by varying the temperature of the counter and of the field-effect transistor. Three scintillation counters set at right angles to each other were employed. By selecting the same γ-ray energy, three fast-slow electron-γ coincidences were obtained. The three coincidence outputs were sent through a logic and routing system in order to display in a multichannel analyzer three different electron spectra in coincidence with a given γ-ray energy.

The radioactive source Bi^{207} of 10-μCi activity was provided by Nuclear Enterprises. A spot of 3 mm diam was deposited on a 0.0025-in. Mylar film supported by an aluminum ring. A thin acrylic film covered the source.

III. MEASUREMENTS

The complete series of electron-γ coincidences was carried out for the $e(1064)$-$\gamma(570)$ and $e(570)$-$\gamma(1064)$ cascades. The χ^2 test was applied to the total intensities of the lines for each run. About 25% of the runs were discarded. Those retained passed the test for the three shells simultaneously. These coincidence measurements enabled us to obtain values of the $A_2(e)A_2(\gamma)$ coefficients of the angular-correlation function for the three main shells. It was found that effects like backscattering were negligible both in the source backing and in the scintillation counters. No corrections for solid angle subtended by the semiconductor counters were necessary.

γ-γ angular correlations were also performed with the same scintillation arrangement, using the same source.

IV. RESULTS

A. Determination of $A_2(e)A_2(\gamma)$ Coefficients

Using the results of the electron-γ coincidences performed for the two cascades already mentioned, values of the $A_2(e)A_2(\gamma)$ coefficients were derived with good precision for the three shells (see Table I).

TABLE IV. Particle parameters b_4 for both transitions of 1064 and 570 keV in Pb^{207}.

Transition	b_4 particle parameter
$E2$ (570 keV)	K 0.52(17)
	L 0.67(17)
	M −0.02(20)
$M4$ (1064 keV)	K 1.28(28)
	L 1.34(68)
	M 1.90(85)

TABLE V. Electron-γ angular-correlations $A_4(e)A_4(\gamma)$ coefficients in Pb^{207}.

Cascade	$A_4(e)A_4(\gamma)$ Present work	a
$e(570)$-$\gamma(1064)$	K −0.020(8)	−0.012(4)
	L −0.025(9)	
	M ~0	
$e(1064)$-$\gamma(570)$	K −0.049(16)	−0.020(4)
	L −0.051(30)	
	M −0.072(40)	

[a] Reference 9.

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B. Determination of $A_2(\gamma)$ and $A_4(\gamma)$ Coefficients

The $\gamma(570)$-$\gamma(1064)$ angular-correlation measurements yielded the results shown in Table II for the $A_2(\gamma)$ and $A_4(\gamma)$ coefficients, which are compared there with the values given by other authors.[9]

C. Determination of $b_2(K)$, $b_2(L)$, and $b_2(M)$ Particle Parameters

From Tables I and II, experimental values of the particle parameters $b_2(K)$, $b_2(L)$, and $b_2(M)$ were derived for both cascades and are quoted in Table III.

D. Determination of $A_4(e)A_4(\gamma)$ Coefficients

The b_4 particle parameters were derived from a recurrent relation taking the experimental values obtained for the b_2 parameters (see Table IV). Accordingly, from the values of the $A_4(\gamma)$ coefficients, the corresponding $A_4(e)$ coefficients were obtained and are quoted in Table V.

V. DISCUSSION

Experimental determination of particle parameters for the three main shells corresponding to the 570- and 1064-keV transitions in Pb^{207} are presented. Previous work performed by Kleinheinz *et al.*[9] is in fairly good agreement for the K shell and $L+M$ shells. The method introduced for measuring electron-γ angular correlations, turns out to be comparable with methods in which magnetic β-ray spectrometers have been used.

Furthermore, agreement is found with the theoretical values of particle parameters obtained by Hager and Seltzer[5] for the three main shells. Accordingly, the conversion process in Pb^{207} seems to exhibit neither anomalous behavior nor an interaction with the K hole when the 1064-keV conversion occurs.

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Reaction $^{116}Sn(\alpha, {}^3He)$ at 65.7 MeV*

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Differential cross sections for $^{116}Sn(\alpha, {}^3He)$ with 65.7-MeV α particles were measured from 15° to 80°. Data were obtained for ^3He groups corresponding to excitation energies of 0.0, 0.16, 0.32, 0.72, 1.03, 1.25, 1.58, and 3.20 MeV in ^{117}Sn. The angular distributions were well fitted by zero-range distorted-wave predictions. The spectroscopic factors are generally in good agreement with those obtained in a (d, p) experiment.

I. INTRODUCTION

In a previous paper,[1] spectroscopic factors from distorted-wave analyses of $^{90,91,92}Zr(\alpha, {}^3He)$ experiments at 65 MeV were compared with similar results from $Zr(d, p)$ experiments at 15 MeV. The spectroscopic factors agree for $l=2$ transfers to states of low excitation, but large discrepancies were observed for transfers assigned by the (d, p) experiment as $l=4$. For these transitions, the $(\alpha, {}^3He)$ spectroscopic factors were consistently twice as large as the (d, p) spectroscopic factors. The present study of $^{116}Sn(\alpha, {}^3He)$ at 65.7 MeV was undertaken in order to check the validity of the distorted-wave theory for $(\alpha, {}^3He)$ reactions. Two considerations led to this choice. First, the residual nucleus has well-separated levels populated by $l=0$, 2, 3, 4, and 5 transfers; and second, data are

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