Fluorescence and Coster-Kronig Yields of L Subshells in Hg from the Decay of ^{198}Au and ^{204}Tl

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Coincidences between L x rays and $K\alpha$ x rays, emitted during the filling of K and L vacancies in Hg in the decay of ^{198}Au and ^{204}Tl, are measured with high-resolution Si(Li) and Ge(Li) x-ray spectrometers in a fast-coincidence arrangement. The following L-subshell fluorescence and Coster-Kronig yields are measured: $\omega_2 = 0.316 \pm 0.010$, $\omega_3 = 0.300 \pm 0.010$, and $f_{23} = 0.190 \pm 0.010$.

I. INTRODUCTION

Significant advances in studying the emission of L x rays from individual L subshells have been made recently because of the availability of high-resolution Si(Li) and Ge(Li) x-ray spectrometers. A review of the recent work employing these devices and the basic principles involved in these measurements is given elsewhere by one of the authors.[1] Previous investigations[2-8] on $Z = 80$ made use of proportional and scintillation counters as well as Si(Li) detectors with about 1 keV being the maximum resolution achieved in the L x-ray region. The present work is confined to the study of L_2 and L_3 subshells in Hg. K- and L-shell vacancies in Hg are formed during the internal conversion of the 412-keV transition in ^{198}Hg following the β decay of ^{198}Au and during the electron capture decay of ^{204}Tl to the ground state of ^{204}Hg (see Fig. 1). Coincidences between K and L x rays were measured with detectors capable of resolving the α_1 and α_2 components of K x rays and the Ll, $L\alpha$, $L\eta$, $L\beta$, and $L\gamma$ components of L x rays.

II. EXPERIMENTAL ARRANGEMENT

The ^{204}Tl source had been aged six years and was prepared by evaporating radioactive thallium nitrate onto a Mylar foil in vacuum.[3] The ^{198}Au source was prepared by evaporating a small drop of high specific activity solution of radioactive gold chloride onto a Mylar film.

L x-ray spectra were studied with a Si(Li) detector of 3.6-mm depletion depth at a resolution of 290 eV full width at half maximum (FWHM) for 6.4-keV Fe $K\alpha$ x rays from ^{57}Co. The photopeak efficiency of the detector was measured using calibrated sources of low-energy x rays and γ rays. The details of the calibration procedure are described in Ref. 9.

A fast-coincidence system ($2\tau \approx 80$ nsec) employed in measuring the coincidence rates is described elsewhere.[10] The K x rays were detected by a Ge(Li) x-ray detector with an FWHM of 470 eV at 6.4 keV. A single-channel analyzer was employed to set a window narrow enough to admit mostly either $K\alpha_1$ or $K\alpha_2$ x rays. Because of the low-energy tail following the photopeaks, the window always admitted events due to higher-energy radiations. A careful analysis of the composition of radiations admitted through the window was made by studying the shapes of photopeaks of monoenergetic γ rays in the range of energies 59.6 to 87.7 keV. Figure 2 shows the shape of the 59.6-keV line from ^{241}Am. The ratio of counts in

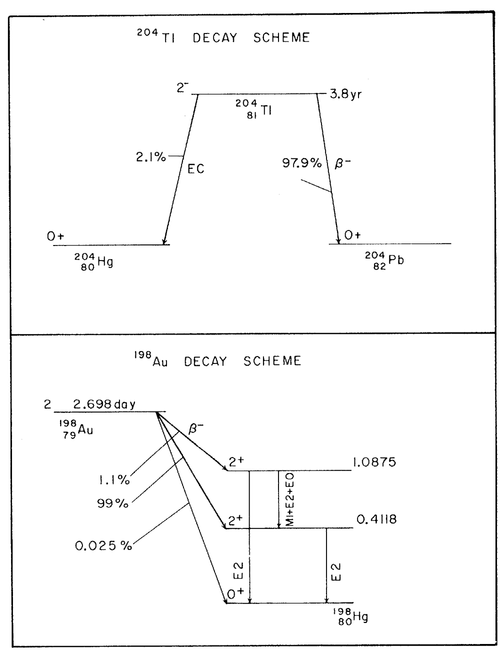

FIG. 1. The decay schemes of ^{198}Au and ^{204}Tl.

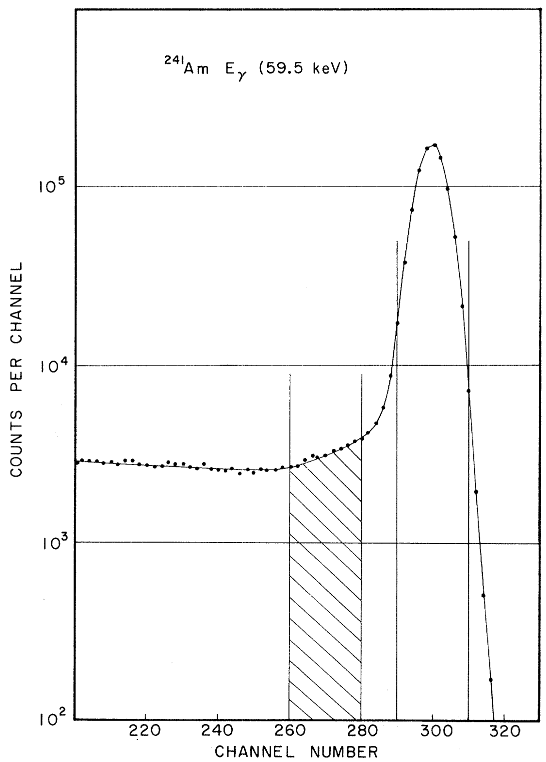

FIG. 2. The shape of the 59.6-keV γ spectrum observed in the Ge(Li) x-ray spectrometer. The shaded portion represents the position of a typical window to select the photopeak of a lower-energy radiation.

the low-energy tail in the region where a window normally is set to select a lower-energy photopeak, to those in the photopeak itself was measured and found to be relatively constant in this energy region as shown in Table I. In estimating the composition of the Hg $K\alpha_2$ x-ray gate, the shape of the Hg $K\alpha_1$ x-ray line was assumed to be that of the 59.6-keV line. It is found for the source detector configuration used that 7 to 10% of the total counts in the $K\alpha_2$ x-ray gate are due to the low-energy tail from the $K\alpha_1$ x ray depending upon the width of the window utilized. The relative pro-

TABLE I. Evaluation of tailing in the Ge(Li) spectrometer.

Source	E_γ (keV)	Ratio of counts in the windows set on the low-energy tail to the photopeak
^{159}Dy	58.0	0.036
^{241}Am	59.5	0.035
^{171}Tm	66.7	0.037
^{170}Tm	84.3	0.037
^{109}Cd	87.7	0.042

TABLE II. Composition of the $K\alpha$ x-ray gates.

	$K\alpha_1$ gate	$K\alpha_2$ gate
True $K\alpha_1$ gates	84.86%	8.01%
True $K\alpha_2$ gates	0	68.82%
Continuum	15.14%	23.17%

portions of the various contributions in the $K\alpha$ x-ray gates are listed in Table II.

The L x rays in coincidence with $K\alpha_1$ and $K\alpha_2$ x rays from the decay of ^{198}Au are shown in Fig. 3. The continuous background is due to the coincident β rays feeding the 411.8-keV level in ^{198}Hg. The possibility of β-excited L x rays from the source environment appearing in the coincident spectrum is found to be negligible by observing coincidences with $K\beta$ x rays. The measurement of L-x-ray–$K\beta$-x-ray coincidences also established that any additional L x rays present due to the cascade relationship of the 676- and 412-keV transitions are negligible.

III. RESULTS

The relations connecting the measured coincidence rates to the L-subshell fluorescence yields and Coster-Kronig yields are summarized in the Appendix by Wood, Palms, and Rao,[13] and the rele-

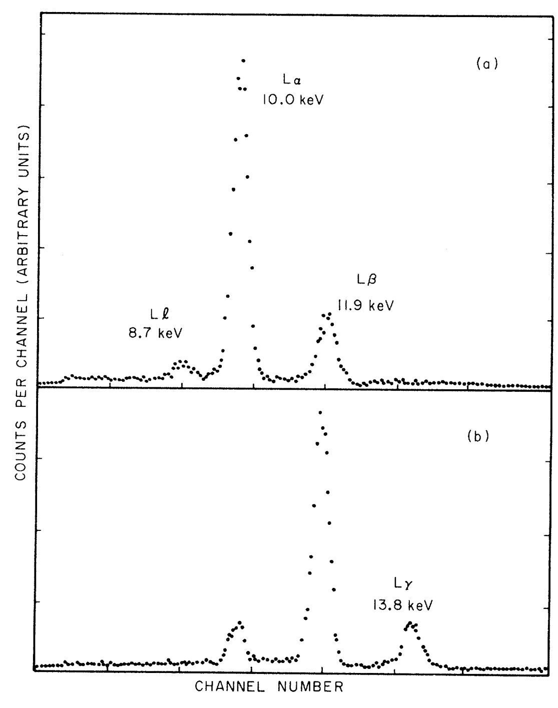

FIG. 3. The Hg L x rays observed in coincidence with (a) Hg $K\alpha_1$ x rays and (b) Hg $K\alpha_2$ x rays. The presence of $L\alpha$ in (b) is an indication of the transfer of vacancies from the L_2 subshell to the L_3 subshell.

TABLE III. Mercury L-subshell fluorescence and Coster-Kronig yields.

	Present work		Previous work				
	^{204}Tl decay	^{198}Au decay	a	b	c	d	e
ω_2	0.316 ± 0.010		0.39 ± 0.03	0.408 ± 0.079	0.58 ± 0.1	0.433 ± 0.090	
f_{23}	0.190 ± 0.010	0.192 ± 0.011	0.08 ± 0.02				0.22
ω_3	0.300 ± 0.010		0.40 ± 0.02	0.367 ± 0.05	0.32 ± 0.05	0.362 ± 0.10	

[a]See Ref. 4.
[b]See Ref. 7.
[c]See Ref. 6.
[d]See Ref. 11.
[e]See Ref. 12.

vant equations concerning the L_2 and L_3 subshells of present interest are Eqs. (A1) through (A6). Table III summarizes the results of the present investigation and the previous work.[11,12] The effect of the angular correlation present in $K-L$ x-ray transitions is taken into account in obtaining the yields for the L_3 subshell. The values for ω_2 and ω_3 are somewhat lower than from earlier studies. The significant result is the finite probability for the Coster-Kronig transitions of type L_2L_3X in agreement with other recent findings.[13-15] The method employed in the measurement of f_{23} is essentially that of Rao and Crasemann[4] who detected L x rays characteristic of the L_3 subshell in coincidence with an L_2 vacancy formation and interpreted this as an indication of transfer of vacancies from the L_2 subshell to the L_3 subshell. An average value of 0.191 ± 0.011 is adopted for f_{23} from the two present measurements.

TABLE IV. Relative intensities of L x-ray components from L_2 and L_3 subshells of Hg directly as observed in coincidence with $K\alpha_2$ and $K\alpha_1$ x rays, respectively.

	L_2 subshell		L_3 subshell	
	$L\eta,\beta$	$L\gamma$	Ll,α	$L\beta$
Present work	1	0.243 ± 0.012	1	0.217 ± 0.011
Scofield	1	0.223	1	0.212
Goldberg	1	0.313	1	0.231

Table IV summarizes the L x-ray emission rates from L_2 and L_3 subshells and compares them with previous experimental work by Goldberg[16] and recent calculations of Scofield.[17] The good agreement between present values and theoretical estimates is to be noted.

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