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THE STUDY OF THE L-SHELL FLUORESCENCE YIELDS OF TIN AND ANTIMONY*

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From the spectra of electrons generated in proportional counter by photoelectric excitations of admixed gases the average L-shell fluorescence yields of tin and antimony were extracted as $\overline{\omega} = 0.066 \pm 0.003$ and $\overline{\omega} = 0.070 \pm 0.003$, respectively. Separately, L_3 subshell fluorescence yield of tin was determined as $\omega_3 = 0.071 \pm \pm 0.005$ and L_2L_3 average fluorescence yield of antimony as $\omega_{23} = 0.078 \pm 0.005$.

1. Introduction

The proportional counter method with gaseous radiator and internal photoelectric excitation has been extensively used for the determination of the K-shell fluorescence yields of low and medium Z elements. The method has already proved to be useful in the study of transitions to the separate L subshells[1]. In the present work the method has been applied to the study of L fluorescence yields of tin and antimony. No reliable experimental values have so far been available to be compared to extended theoretical calculations of Mc Guire and Chen et al[2].

2. Experimental procedure and results

Tin tetramethyl Sn $(CH_3)_4$ and antimony hydride SbH_2 with the pressures of 0.35 torr and 0.17 torr, respectively, were used as admixtures to 100 torr methane

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in a special wall-less proportional counter with the anticoincidence operation between the central counter and the ring counters. The counter gas was irradiated with monochromatic K_α X-rays of a series of targets including Sc, Ti, V, Cr, Mn, Fe and Cu, excited by an X-ray tube. By the use of appropriate filters K_β lines were eliminated from the exciting radiations. The photon energies are given in Tables 1 and 2 as related to L_1, L_2 and L_3 absorption edges of tin and antimony, respectively.

The L_3 subshell in tin is excited selectively by Sc K_α radiation. The excitation of both L_2 and L_3 in antimony is achieved by Ti K_α radiation. All three subshells L_1, L_2 and L_3 are excited by K_α rays from other targets.

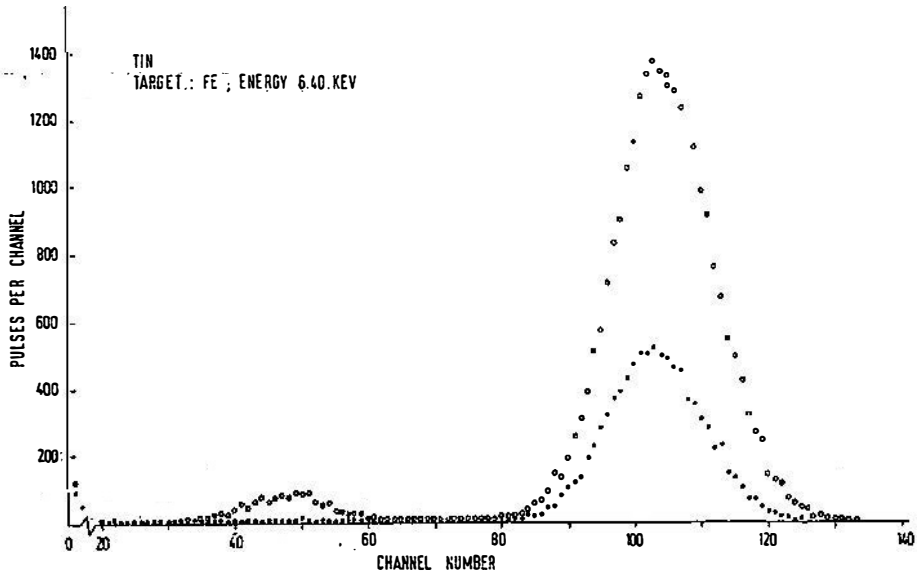

Fig. 1 The spectrum of pulses from the proportional counter filled with methane and a small admixture of tin methyle; the spectrum of pulses from the methane-filled counter. The gas was excited by Fe K_α radiation with the photon energy of 6.4 keV.

The typical spectrum of pulses obtained from the central counter is shown in Fig. 1. In the spectrum the main peak at full energy comprises pulses generated by photoelectrons from the L-shell of the admixed atoms followed by Auger deexcitation, and by the photoelectrons from M and higher shells of admixed atoms as well as from methane. The pulses in the escape peak are generated in photoelectric events in the L shell, followed by radiative deexcitation. The emitted photons, mainly LM and LN radiation, escape from the counter. Coster-Kronig transitions do not interfere with gross features of the spectra as the emitted electrons are fully absorbed in the counter, the corresponding pulses being simultaneous with the photoelectron and Auger pulses leading to the main or to the escape peaks.

The contribution of the methane absorption events is determined separately with pure methane filling. Spectra are analysed for the ratios $N_e/(N_e + N_m)$ where N_e and N_m represent the number of counts in the escape and in the main peak,

respectively. The ratios have to be corrected for the escape of the L, M and N photoelectrons and Auger electrons from the main counter and for the absorption of LM and LN photons in the main counter and in the ring. The corrections are computed from the geometry of the counter; by the choice of the counter filling the total correction can be minimized to 1 — 2%.

Experimental and corrected data are given in Tables 1 and 2 for tin and antimony, respectively. The results from experiments from complete L — shell excitation exhibit a monotonic increase with incident photon energies. The extrapolated values at the energy of the corresponding L_1 edge are determined by linear extrapolation.

TABLE 1.

Absorption edge (keV)	Exciting radiation Target	Energy (keV)	$N_e/(N_e + N_m)$ Experimental	Corrected	Fluorescence yield determined
L_3 3.929					
	Sc	4.09	0.051 ± 0.003	0.050 ± 0.003	$\omega_3 = 0.071 \pm 0.005$
L_2 4.156					
L_1 4.465			extrapolated	0.054 ± 0.002	$\bar{\omega} = 0.066 \pm 0.003$
	Ti	4.51	0.054 ± 0.004	0.053 ± 0.004	
	Va	4.95	0.057 ± 0.001	0.056 ± 0.002	
	Cr	5.41	0.055 ± 0.002	0.055 ± 0.002	
	Mn	5.90	0.059 ± 0.002	0.060 ± 0.002	
	Fe	6.40	0.063 ± 0.001	0.064 ± 0.001	

The $L-$ shell fluorescence yields of tin

TABLE 2.

Absorption edge (keV)	Exciting radiation Target	Energy (keV)	$N_e/(N_e + N_m)$ Experimental	Corrected	Fluorescence yield determined
L_3 4.132					
L_2 4.381					
	Ti	4.51	0.063	0.062 ± 0.002	$\omega_{23} = 0.078 \pm 0.003$
L_1 4.697			extrapolated	0.056 ± 0.002	$\bar{\omega} = 0.070 \pm 0.003$
	Va	4.95	0.0575	0.057 ± 0.001	
	Cr	5.41	0.0597	0.059 ± 0.004	
	Fe	6.40	0.063	0.062 ± 0.001	
	Cu	8.04	0.070	0.070 ± 0.001	

The $L-$shell fluorescence yields of antimony

Fluorescence yields are obtained from corrected ratios taking into account the relative probability P of the photoelectric absorption in the corresponding subshell(s):

$$\omega = P^{-1}\,(N_e/(N_e + N_m))_{corr.}$$

Probabilities P can be obtained in the vicinity of the absorption edges, from the jump values S_1, S_2 and S_3 of the photoelectric absorption coefficient:

$$P_3 = (S_3 - 1)/S_3 \quad (\text{at } L_3 \text{ edge})$$

$$P_{23} = (S_2S_3 - 1)/S_2S_3 \quad (\text{at } L_2 \text{ edge})$$

$$P_L = (S_1S_2S_3 - 1)/S_1S_2S_3 \quad (\text{at } L_1 \text{ edge}).$$

The jump values extracted from NDT compilation[3] of absorption coefficients are given in Table 3 together with the corresponding P values. The fluorescence yields as determined, are given in Tables 1 and 2. The extrapolated values of the corrected ratios were used for the determination of the average fluorescence yields at the energy of L_1 absorption edges.

TABLE 3.

Element	Absorption jump ratio	L—shell absorption probability		Primary vacancy distribution
Sn	$S_1 = 1.18 \pm 0.02$	$P_L = 0.82 \pm 0.02$		$n_1' = 0.19$
	$S_2 = 1.44 \pm 0.02$	$P_{23} = 0.79 \pm 0.02$	$n_2 = 0.39$	$n_2' = 0.32$
	$S_3 = 3.26 \pm 0.03$	$P_3 = 0.69 \pm 0.01$	$n_3 = 0.61$	$n_3' = 0.449$
Sb	$S_1 = 1.16 \pm 0.02$	$P_L = 0.80 \pm 0.02$		$n_1' = 0.17$
	$S_2 = 1.38 \pm 0.02$	$P_{23} = 0.77 \pm 0.02$	$n_2 = 0.36$	$n_2 = 0.30$
	$S_3 = 3.14 \pm 0.03$	$P_3 = 0.68 \pm 0.01$	$n_3 = 0.64$	$n_3' = 0.53$

TABLE 4.

Element	Fluorescence yields	This experiment	Mc Guire	Chen et al.
Sn	ω_3	0.071 ± 0.005	0.0737	—
	ω_{23}	—	0.075	—
	$\bar{\omega}_L$	0.066 ± 0.003	0.075	—
Sb	ω_3	—	—	0.0633
	ω_{23}	0.78 ± 0.003	—	0.066
	$\bar{\omega}_L$	0.070 ± 0.003	—	0.065

The experimental values were compared to the theoretical values of Mc Guire[4] and Chen et al.[5,6]. Average fluorescence yields were calculated from the data for particular subshells using the following relations as defined in Ref. 2:

$$\omega_{23} = n_2 \nu_2 + n_3 \omega_3; \quad n_2 + n_3 = 1$$

$$\bar{\omega} = n_1' \nu_1 + n_2' \nu_2 + n_3' \omega_3; \quad n_1' + n_2' + n_3' = 1$$

where n-s and n'-s denote relative numbers of primary vacancies in separate subshells, in L_2,L_3 and full L-shell excitation experiments, respectively. The relative numbers of vacancies as determined from the corresponding jump values are given in Table 3.

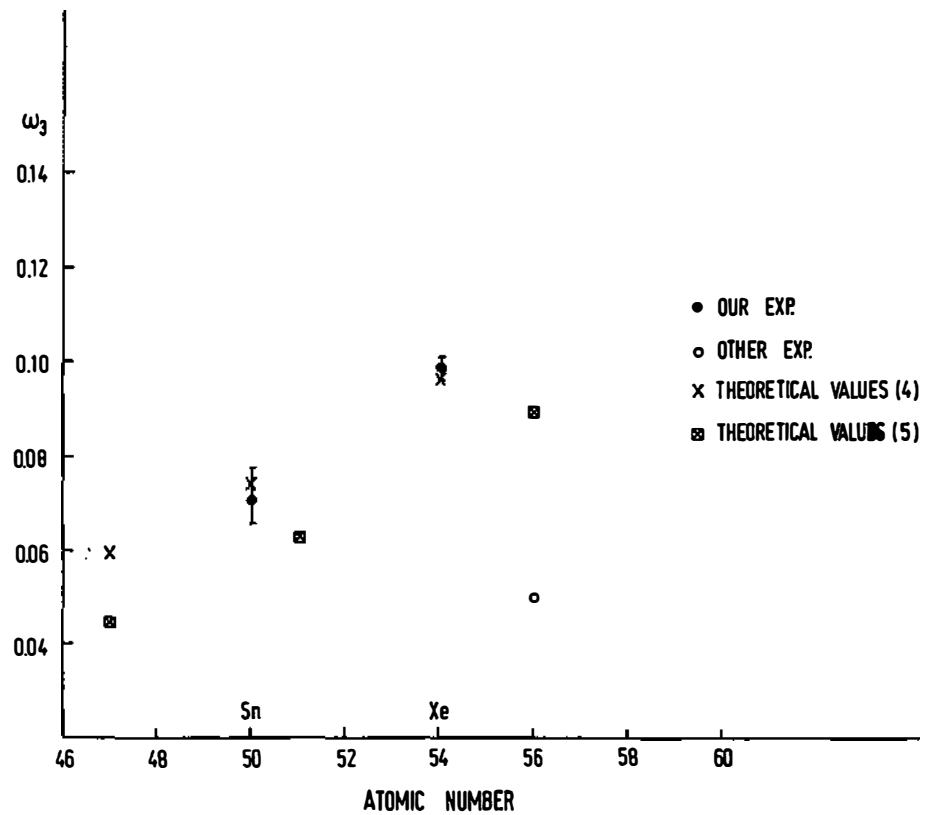

Fig. 2 The comparison of the values of ω_3 determined in this laboratory with other experimental values as well as with theoretical values.

Table 4 gives the experimental data in comparison to the theoretical data as extracted from the calculated values of the separate subshell fluorescence yields and Coster-Kronig transition probabilities. It is evident, that better agreement is

achieved with the data based on Mc Guire's calculations as has already been shown in the case of Xe[1]. The experimental values as given in the present report, are in good agreement with the values for neighbouring elements in the periodic table, as can be seen in Fig. 2. and Fig. 3.

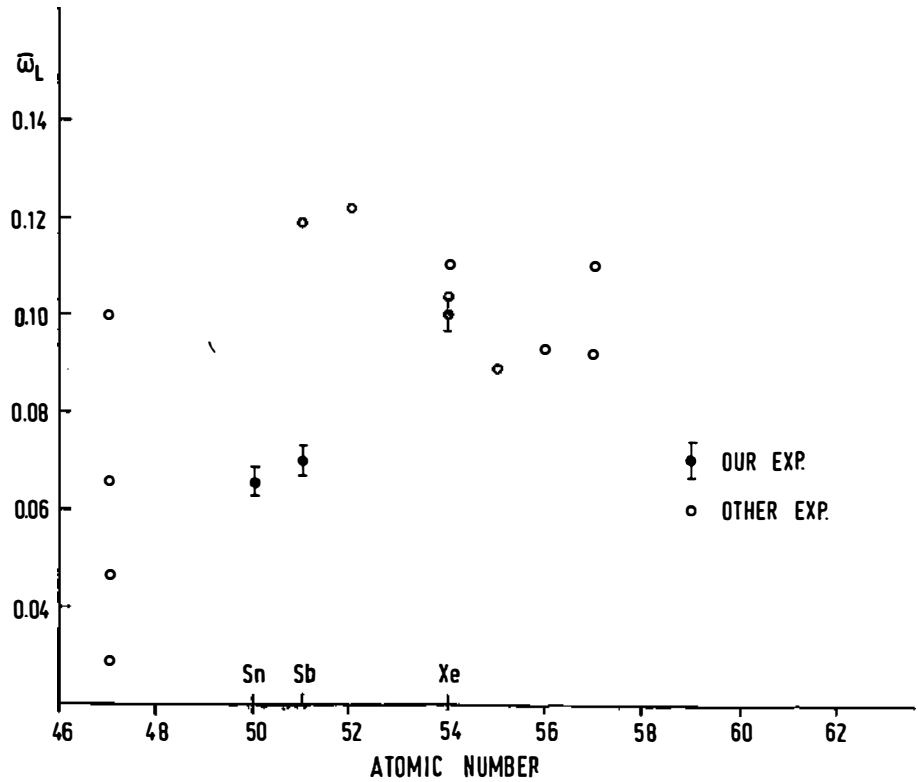

Fig. 3 Average L shell fluorescence yields determined in this laboratory as compared to other experimental values.

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ŠTUDIJ FLUORESCENČNIH PRIDELKOV LUPINE L PRI KOSITRU IN ANTIMONU

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S študijem elektronskih spektrov iz proporcionalnega števca pri fotoelektričnem vzbujanju primešanih plinov sta bila določena povprečna fluorescenčna pridelka $\bar{\omega}_L = 0.066 \pm 0.003$ za lupino L pri kositru in $\bar{\omega}_L = 0.070 \pm 0.003$ za lupino L pri antimonu. Dodatno je bil določen fluorescenčni pridelek $\omega_3 = 0.071 \pm 0.005$ za podlupino L_3 pri kositru in povprečni fluorescenčni pridelek $\omega_{23} = 0.078 \pm 0.005$ za podlupino L_2 in L_3 pri antimonu.