Chemical Effects on Internal Conversion of Outer-Shell Electrons in 125Te

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In the case of nuclear magnetic dipole (M1) transitions, the internal conversion coefficient α is dominated by the matrix elements which are proportional to the magnitude of the s-orbital electron wave function. Therefore, one expects that the internal conversion coefficient of valence s-shell electrons is proportional to their charge density at the nucleus, $|\psi_v(0)|^2$, and, in general, differs slightly for different chemical states of the same element. Chemical effects on internal conversion of outer-most shell electrons were investigated by several groups in the past.[1)]

For experiments of this type with a high resolution β-ray spectrometer, it is necessary that the transition energy is less than about 50 keV for the conversion lines of the electrons in the outer-most shell to be separated from that of the electrons in the next-inner shells. We have already reported on the chemical effect on the internal conversion process in ^{119}Sn.[2)] In the present study we chose the 35.46 keV M1 transition of ^{125}Te that follows the decay of ^{125}I ($T_{1/2}$ = 60 d).

For the measurement of low energy conversion electrons (35.46 keV) with a high resolution, extremely thin sources (less than ~10 $\mu g/cm^2$) are required. The source samples in this work were prepared by implanting ^{125}I into metals (Cu, Zn, Sn and Pt) by means of the Tohoku University electromagnetic isotope separator. Implantation of radioactive ^{125}I was carried out at an acceleration potential of 20 kV at room temperature. For the case of copper the implanted depth was 6.4 $\mu g/cm^2$ under this condition. The dose rate was 3×10^8 atoms/cm^2/s for the mass number 125. From the radioactivity of the implanted sample, the number of implanted ^{125}I atoms was determined to be 3×10^{13} atoms/cm^2 (~100 $\mu Ci/cm^2$). After implantation, in order to identify the chemical state of the implanted sample, emission Mössbauer spectra were measured by keeping both the source and absorber (96 % enriched Zn^{125}Te) at liquid nitrogen temperature.

The internal conversion spectra were observed with high-resolution iron-free β-ray spectrometers at RIKEN and INS with an instrumental momentum resolution of 0.10 %. The detector was a gas-flow proportional counter having a thin Mylar window of about 4 μm thickness. The L, M, N- and O-conversion lines of the 35.46 keV transition were measured. A typical conversion spectrum in the region of N and O lines obtained for the Sn host is shown Fig. 1. The N_I line

and O line with an energy difference of 156 eV could be completely resolved from each other. For the evaluation of the relative conversion intensity ratio, $R(O/N_I)$, the conversion electron spectra were analyzed using the computer code, ACSEMP[3], whose function was essentially a least-squares analysis of the spectra using empirical profiles.

Results of the analyses of four different host metals are listed in Table 1. Each of the Mössbauer spectra of Cu, Zn, Sn and Pt hosts showed a single line indicating a unique implantation site. When the effect of the change in 5s electron density on the inner s-electron densities is negligible, one can deduce the 5s electron density at the nucleus from the observed O/N_I ratio $R(O/N_I)$ by using the formula

$$|\psi_{5s}(0)|_x^2 = |\psi_{4s}(0)|^2 \, R(O/N_I)_x \, , \qquad (1)$$

where $|\psi_{5s}(0)|^2$ is the 5s electron density at the nucleus for the chemical state x and $|\psi_{4s}(0)|^2$ is the 4s electron density of the Te atom. The contribution of $O_{II,III}$ conversion to $R(O/N_I)$ is estimated to be less than 5 % for the present M1 transition. Assuming that the 4s electron density $|\psi_{4s}(0)|^2$ is unaffected by the chemical state, we can obtain the 5s electron densities at the nucleus by using the relativistic value of Band et al.[4] for the theoretical 4s density $|\psi_{4s}(0)|^2$ = 928 a.u. in eq. (1). The 5s electron densities for the samples evaluated in the present work are listed in Table 1.

The results show that the tellurium atom in the zinc host metal has a valence s-electron density at the nucleus smaller by about 20 % than the case of the platinum host metal. In other words the zinc atoms around the tellurium atom are more electrophilic than the platinum atoms surrounding the tellurium atoms.

References

1) See, for example, Bocquet J. P., Chu Y. Y., Kistner O. C., Perlman M. L. and Emery G. T., Phys. Rev. Lett. 17 (1966) 809; Martin B. and Schule R., Phys. Lett. 46B (1973) 367.
2) Muramatsu H., Miura T., Nakahara H., Fujioka M., Tanaka E. and Hashizume A., Hyp. Int. 15/16 (1983) 269.
3) Fujioka M. and Takashima M., J. Phys. 40 (1979) C2-32.
4) Band I. M. and Fomichev V. I., Atom. Data and Nucl. Data Tables, 23 (1979) 295.

Table 1. Results of conversion measurement and analysis for ^{125}I implanted into different host metals

Host	$R(O/N_I)$	$\lvert\psi_{5s}(0)\rvert^2$
Pt	0.145 ± 0.010	135 ± 9 a.u.
Sn	0.138 ± 0.003	128 ± 3 a.u.
Cu	0.128 ± 0.004	119 ± 4 a.u.
Zn	0.119 ± 0.007	110 ± 6 a.u.

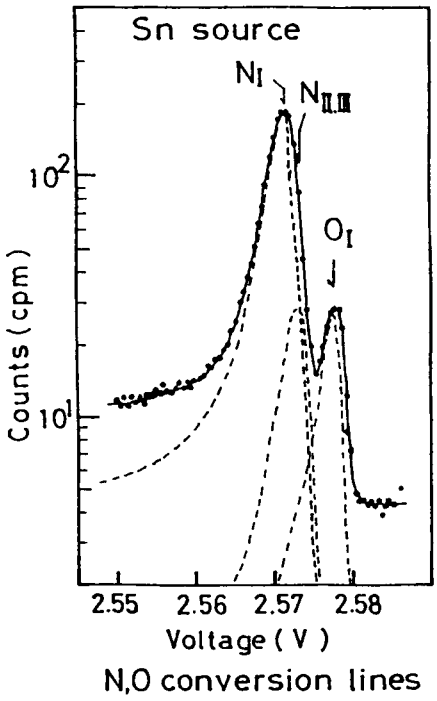

Fig. 1. The N and O conversion lines of the 35.46 keV M1 transition in ^{125}Te implanted in Sn. The solid curve is the result of least-squares fit, yielding the components shown by dashed lines.