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High-energy X-ray fluorescence measurements using a Compton spectrometer

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Introduction

It is significant to explore the energy levels of 4f and valence electrons of lanthanides through the detailed spectral features of K X-ray fluorescence [1]. Although a conventional Ge detector can resolve $K\beta_1$ and $K\beta_2$ in Kβ spectra, further high-resolution experiments in 40-60keV region are of great interest. This report describes the preliminary measurements of lanthanides performed with a Compton spectrometer.

Experimental

Lanthanide's K-emission spectra were measured by a Compton spectrometer at PF-AR BLNE1A1 [2]. The incident X-ray energy was set as 70 keV. The fluorescent X-rays were dispersed by a Si(422) analyzer and observed by an imaging plate (IP) at a scattering angle of 160 degrees. The image on the IP was read by an imaging analyzer (FUJI BAS-2000, spatial resolution of read-out 100 μm). The samples measured were lanthanide metals in a pellet with a diameter of 10 mm and thickness of 5 mm.

Results and Discussion

The Compton spectrometer used was originally designed for Compton scattering measurements, and a typical experiment consists of observing the detection window of 40-60keV with 60keV excitation. First, a spectrum of $_{65}$Tb metal was measured with 60keV excitation, as shown in Fig. 1(A). Note that the intensity of Kα lines recorded in the IP is saturated, because the research is mainly for Kβ lines to see come chemical effects. One can see that $K\beta_3$, $K\beta_1$, $K\beta_5$ and $K\beta_2$, $KO_{II,III}$ are clearly separated, that is much better than the spectra obtained with a Ge detector. However, Compton scattering at 60keV excitation was observed at around 48keV and could distort lanthanide's Kβ lines.

Then the excitation energy was changed to 70keV to escape the Compton scattering, even though the number of input photons halved. One example of the $_{64}$Gd metal spectrum is shown in Fig. 1(B). A Compton peak with 70keV excitation is observed at around 55keV at a distance from Gd K-emissions. The energy resolution was 47.5eV in FWHM at Gd $K\alpha_1$. Under this experimental condition, Kβ lines of lanthanides from $_{59}$Pr to $_{64}$Gd can be measured without any influence from Compton scattering.

Another example of $_{62}$Sm metal is shown in Fig. 1(C). As is the case with Gd, Sm Kβ lines are observed free of Compton scattering. Since the Kα lines are at almost the low-energy-limit of the spectrometer, their intensity was observed obviously too small. It is necessary to calibrate possible non-uniform efficiency of the spectrometer over this energy range. When quantitative discussion is crucial, another problem would be that there are only quite few data-points for each peak, due to the limitation of the spatial resolution of the detector. However, the present experiments clearly demonstrate that the Compton spectrometer can be used also for measuring high-resolution Kβ spectra of a few lanthanides (Gd and Sm).

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Reference

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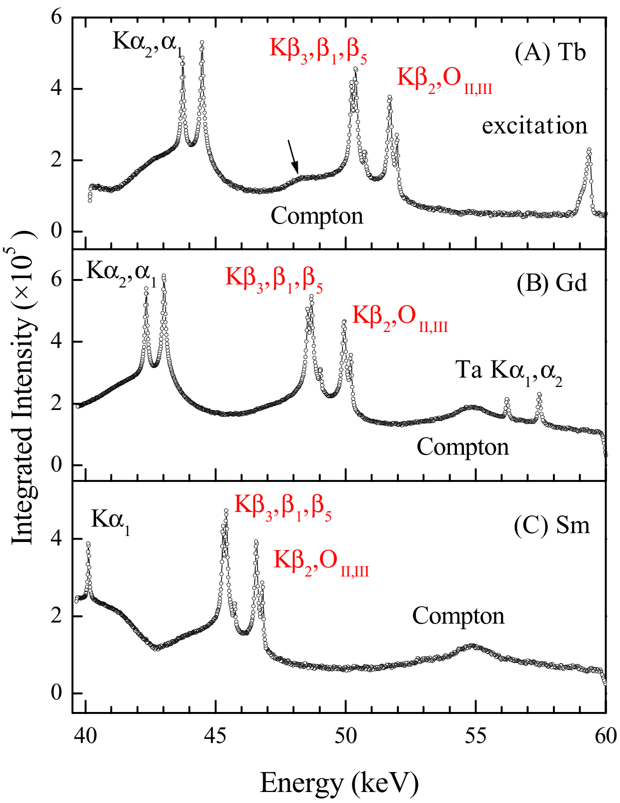

Figure 1 K-emission spectra of lanthanide metals. Excitation energy, 60keV for (A), 70keV for (B) and (C).