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X-RAY ATTENUATION MEASUREMENTS OF MEDIUM-Z ELEMENTS AROUND THEIR K-EDGE

M. KEFI, J.M. ANDRE and C. BONNELLE

Laboratoire de Chimie-Physique, Université Pierre et Marie Curie, CNRS UA-176, 11, Rue Pierre et Marie Curie, F-75231 Paris Cedex 05, France

Résumé: Les coefficients de photoatténuation Z des éléments de numéro atomique 46 à 50 sont mesurés dans le domaine spectral 13 à 45 keV à l'aide du rayonnement de freinage émis par un tube à rayons X et dispersé par un spectromètre de type Cauchois. Une régression logarithmique est utilisée pour déterminer les paramètres de la loi de variation empirique du coefficient Z en fonction de l'énergie du rayonnement.

Abstract: X-ray attenuation coefficients Z in the medium-Z elements (46 to 50) are measured using the continuous radiation of an X-ray tube dispersed by means of a Cauchois - type spectrometer. A logarithmic regression is used to obtain the parameters in the empirical variation law of the coefficient Z versus the photon energy.

INTRODUCTION:

According to a recent compilation of X-ray photoabsorption and attenuation coefficients (1), the majority of the measurements for the medium-Z elements around their K-edge are carried out by using some discrete photon energies. These energies correspond either to characteristic X-ray emission lines or to radioactive source emissions. The empirical laws giving the variation of the attenuation coefficients versus the photon energy are therefore based upon a restricted number of experimental data. To increase the number of data it can be advantageous to monochromatize the continuous radiation of an X-ray tube.

We have made such measurements between 13 and 45 keV using a bent-crystal transmission spectrometer and a commercial tube.

EXPERIMENTAL:

The experimental mounting used in the present investigation is described in detail elsewhere (2). It consists of a 40-cm bent crystal transmission spectrometer in the Cauchois geometry. The dispersive element is a (100) mica for which the first order of Bragg reflection is predominant. The detector is an ion-implanted passivated silicon detector giving sufficient energy resolution ΔE at room temperature (ΔE=2.6 keV at 14.4 keV) to eliminate possible higher harmonics by means of a controlled discrimination of the signal amplitude. This type of detector was preferred to a NaI(Tl) scintillator in spite of its lower efficiency, because an anomalous response of the NaI crystal is expected in the vicinity of the I-K threshold at ~33.2 keV, i.e.
in the spectral region of interest. The source is a sealed X-ray tube with a tungsten anode, supplied by a highly stabilized generator (kV and mA stability better than 10^-3 % per 1% mains voltage variation). The spectrometer is computer-controlled and allows repeated scans of the spectral region with various configurations: different positions of the sample, different thicknesses of absorber sheets...
The spectra were recorded in 50 eV steps and the data acquisition was carried out in the following sequence: (i) background noise without radiation, (ii) transmission spectrum, (iii) incident continuous radiation spectrum.
The linear attenuation coefficient $\tau$ is given by:

$$\tau = -\frac{1}{t} \cdot \log(T)$$

where $t$ is the average thickness of the sample and $T$ the transmittance; $T$ is deduced from the ratio $I/I_0$, where $I$ and $I_0$ are respectively the intensities with and without the sample, after background substraction.

The metallic samples consist of chemically pure foils. The thicknesses of the sheet are chosen so that the ratios $T$ range from 0.1 to 0.7 in the whole spectral domain of interest to avoid saturation effects. The typical value of the thickness depends upon the material, but in all cases, it ranges from 15 to 50 $\mu$m. This value is known with an absolute precision better 0.4 $\mu$m corresponding to the deviation from the average value.

RESULTS:

Figure 1 shows, as an example, the experimental variation of $\tau$ versus the photon energy $E$ for Palladium compared to the linear photo-absorption coefficient $\mu$ computed according to the variation law $\mu = K \cdot E^{-m}$

The difference between our experimental values of $\tau$ and the values of $\mu$ deduced from reference (3) can be due in part to scattering. However, the relative contribution of the scattering effects is weak in the spectral range of interest. In practice, these effects amount to a small energy quasi-independent term in the variation law. Thus we assume:

$$\log(\tau) = -n \cdot \log(E) + C$$

A logarithmic least-square regression is used to determine the values of $n$ on each side of the $K$ threshold. The results are listed in Table 1, in comparison with data by K. Grosskurth (4), S. Lauber (5) and Leroux and Think (3).

<table>
<thead>
<tr>
<th>Element</th>
<th>$E &lt; E_K$</th>
<th>$E &gt; E_K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pd</td>
<td>2.75</td>
<td>2.722 (3)</td>
</tr>
<tr>
<td>Ag</td>
<td>2.61</td>
<td>2.714 (3); 2.7442 (5); 2.7376 (4)</td>
</tr>
<tr>
<td>Cd</td>
<td>2.70</td>
<td>2.706 (3); 2.7452 (5); 2.712 (4)</td>
</tr>
<tr>
<td>In</td>
<td>2.89</td>
<td>2.698 (3); 2.983 (4)</td>
</tr>
<tr>
<td>Sn</td>
<td>2.80</td>
<td>2.690 (3); 2.7210 (5); 2.7375 (4)</td>
</tr>
</tbody>
</table>
CONCLUSION:

Our values of the power n are given to two decimal figures, though it should be noted that many authors claim a much higher precision. In our opinion there is some uncertainty on even the first decimal figure depending on the number of data used to perform the regression and to the energy range considered. This is confirmed by the large dispersion of the published data. In our investigations the main source of errors in the energy calibration of the spectrometer. Compared to these, the variations in beam intensity and counting statistics are negligible.

Measurements for Iodine and Xenon are underway. These data will be used for the determination of the atomic scattering factors using the Kramers-Kronig transformation.

![Figure 1](image)

**Figure 1**

Palladium: attenuation coefficient (rough curve—this work); photoabsorption coefficient (solid curve) from Ref. (3)

REFERENCES


(4) Neubestimmung der Massenschwäschungskoeffizienten monochromatischer