Measurement of mean excitation energy by energy loss

Liu Chang-Shi
(Basics Department, Xinjiang Petroleum College, Urumqi 830000)

Abstract The mean excitation energy (MEE) for Al, Ti, Fe, Cu and Ta has been determined experimentally by the Landan equation, which describes the most probable energy loss of electrons in the incidence direction, and the results are consistent with the values given in the literature. These provide a quick, easy and accurate evaluation method for the experimental MEE.

Keywords The most probable energy loss, Mean excitation energy, Landan equation

1 Introduction

One important subject for investigating the interaction between electrons and materials is to obtain accurate information about the energy loss of charged particles in many different materials. The energy loss can be derived from the mean excitation energy (MEE) describing the characteristics of the medium. The MEE, I, depends on the electronic structure of the medium, especially on the arrangement of the valence electrons. Therefore, I is influenced by molecular binding and by the physical state of aggregation of the medium. The accurate prediction of the I-value is difficult, and it relies on a combination of experimental data and theoretical considerations.[1] The I-data obtained through stopping-power and range data in past years were strongly influenced by different data analysis methods.[1~8]

In this paper, the MEE values have been measured by the detection of the most probable energy loss, which is described by Landan equation in transmissive direction of foils. Since accuracy and precision for measurement of the most probable energy loss and the measured thickness are higher so this should be a kind of quick, easy and accurate evaluation method for the data of MEE.

2 Experimental

In the experiment, the energy peaks $E_{0\mathrm{p}}$ and E_{p} correspond to the incident electron beam transmitting foils with thickness of 0 and X, respectively in energy spectrum. The difference $E_{0\mathrm{p}} - E_{\mathrm{p}}$ is the most probable energy loss ΔE_{p}. The Landan equation described below gives the experimental relationship among ΔE_{p}, I, the atomic number Z, the atomic mass A and the density ρ of material [9]

$$\Delta E_{\mathrm{p}} = \alpha X \left\{ \ln \left[\frac{m_{\mathrm{e}0} \cdot V^2 \cdot \alpha X}{I^2(1-\beta^2)} \right] - \beta + 1.12 \right\} \tag{1}$$

where α stands for $0.153\times(\rho Z/A\beta^2)$ (unit: MeV/cm).

The FWHM, Γ, increases with the increase in X, and can be expressed as

$$\Gamma = 3.98\alpha X \tag{2}$$

In this work, Al, Ti, Fe, Cu and Ta foils with 99.99% purity (mass fraction) were selected, and all prepared at Beijing Institute of Metals. The thickness of foil was ranged from 2 to 100μm. The foils were vertically irradiated by a ^{207}Bi source. The electrons after transmitting foil were detected by a Pt(Si) detector. The detection system was maintained at 1.33 mPa, the sensitive area of detector was 80 mm^2 and the FWHM of the detection system for electron of 975.6 keV from ^{207}Bi source was less than 16.31 keV.

3 Results and discussion

The experimental values of MEE in this work together with MEE values recomended by Ref.[1] are shown in Table 1. Fig.1 displays the comparison between experimental ΔE_{p} in

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this work and theoretical ΔE predicted by Landan formula Eq.(1) using the I_R of MEE recomended in Ref.[1]. Table 2 gives the comparison between experimental FWHM in this work and the values predicted by Eq.(2). Fig.1 shows that the experimental data for the most probable energy loss are close to the theoretical ΔE expected by the Landan equation Eq.(1) using the values of I_R recomended in other researchers' work, while Table 2 illustrates that the experimental results about FWHM are consistent well with theoretical calculation. These two results demonstrate that the experimental method used in this paper is satisfactory to the condition of Landan equation and is adaptable to measurement of MEE.

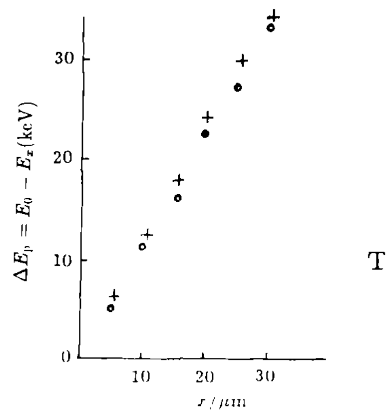

Fig.1 The comparison between experimental results and theoretical calculations for the most probable energy loss of Fe foil samples

o Experimental results, +Results of the Landan equation

Table 1 Mean excitation energy measured by the most probable energy loss

Z	Elements	Experimental value I	Recomended data[1] I_R
13	Al	161.6±3.0	166±2
22	Ti	230.7±5.6	233±5
26	Fe	288.38±8.46	286±9
29	Cu	328.0±8.60	322±10
73	Ta	703.76±24.6	718±30

The energy resolution of the Pt(Si) detector is quite good, the high ratio of signal to noise and the high sensitivity are ensured by nuclear electric circuit, and the thickness of foils is not over 100 μm to ensure a little distortion in energy spectrum. Therefore, the experimental values of MEE obtained by the Landan formula are relatively accurate.

Table 2 The comparison of FWHM (keV) between experimental results and theoretical calculation for Fe foil sample

Thickness/μm	Theoretical	Experimental
5	17.57	17.71
10	18.84	18.96
15	20.10	20.26
20	21.36	21.41
25	22.63	22.73
30	23.89	23.99

4 Conclusion

Mean excitation energy of Al, Ti, Fe, Cu and Ta foils have been experimentally determined by using Landan equation. Because the energy resolution of the energy spectrum system used in this experiment is good for electron with MeV energy and the pure metal foil is thinner, the experimental data are relative accurate. Meanwhile, the experimental method has the advantage of simplicity and ease. The MEE for compounds can also be measured in this way if the effective atomic number, effective atomic mass and effective density of the compound are known.

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