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ABSTRACT

A calibration procedure for iron-free magnetic electron spectrometers is described. It involves the application of a known voltage to the electron source. This calibration technique yields the electron kinetic energy directly in eV.

* * * * * * * * * *

The calibration of any electron spectrometer requires the accurate determination of a constant connecting electron kinetic energy (T) to the quantity measured experimentally, by means of the characteristic equation of the spectrometer. We here describe a direct voltage calibration technique that has been applied to an iron-free magnetic spectrometer, but this technique could in principle be applied to other types as well. For the case of a magnetic spectrometer, the calibration constant is derived from the relation

$$T = [(m_0c^2)^2 (\frac{e}{m_0c})^2 (B\rho)^2 + (m_0c^2)^2]^{1/2} - m_0c^2 , \qquad (1)$$

where $B\rho$ = electron magnetic rigidity,

m_0 = electron rest mass,

c = velocity of light,

e = electronic charge.

For an iron-free spectrometer the magnetic field B is strictly proportional to coil current (I) and ρ is fixed, so the characteristic equation becomes

$$T = [A(CI)^2 + D^2]^{1/2} - D \quad , \tag{2}$$

with obvious replacement of constants.

The simplest technique for determining C is to measure the current corresponding to some primary Bρ standard.[1,2] Another method is to measure the current ratios of two conversion electron lines whose energy difference is very accurately known.[3] These two techniques have been applied to the Berkeley iron-free spectrometer and have given consistent results.[4] A third technique involves measuring the current corresponding to electrons emitted from an electron gun with precisely known accelerating voltage.[5] The method described below combines the principles of the last two and gives a determination of C dependent <u>only on current and voltage measurements</u>.

With the aid of an apparatus designed for x-ray photoelectron spectroscopic work,[6] the current of a certain photoelectron line (I_0) is measured. A retarding field is then applied to the photoelectron source by means of an accurately measured voltage ΔT. The current of the shifted photoelectron line (I_-) is then measured. The same is done for ΔT_+ ($= \Delta T_-$) and I_+. The three equivalent equations for T are then

$$T_1 = [A(CI_+)^2 + D^2]^{1/2} - D - \Delta T, \tag{3}$$

$$T_2 = [A(CI_0)^2 + D^2]^{1/2} - D, \tag{4}$$

$$T_3 = [A(CI_-)^2 + D^2]^{1/2} - D + \Delta T. \tag{5}$$

These equations are solved self-consistently for C and T by means of a trial-and-error computer program. The self-consistency or error parameter is

$$\alpha = |T_1 - T_2| + |T_3 - T_2| \; ; \qquad (6)$$

α is minimized by varying C in steps of 0.0001 G-cm/A about a previously determined calibration constant for the spectrometer. Defining α in this way gives a cusp at the minimum and therefore permits very accurate determination of C (and thus T). The method could in principle be applied to radioactive electron sources and/or electron spectrometers with different characteristic equations.

The photoelectron line used for calibration was that from carbon 1s electrons expelled from a powdered graphite sample by aluminum Kα radiation [denoted C1s, graphite (AlKα)]. This line has an energy of about 1200 eV. Δ T was varied from 100 to 600 eV with no systematic change in the C values obtained. Variation of the x-ray flux by a factor of 20 also did not change C significantly. The average values from nine measurements are C = 78.6949 ± 0.0057 G-cm/A, T = 1197.80 eV, and α = 0.05 eV. The error quoted on C includes both random and systematic contributions.

As a check of the voltage calibration technique, several calibrations were made by using the Mg1s, MgO(CrKα_1) line as a primary standard.[2] This line has an energy of approximately 4100 eV. Because MgO is an insulator, one might expect that the emission of electrons would result in a net surface charge in the sample and concomitant decrease in the electron kinetic energy. Previous x-ray photo-electron spectroscopic measurements have shown that although no large charging effects occur,[2] an effect of the order of 1 eV is possible.[6] Such charging effects should decrease with decreasing x-ray flux, and we have found such a variation, as indicated in Figure 1. Here the change in kinetic energy

(or C) is plotted against the counts at peak intensity, the latter being proportional to x-ray flux. This change could be due to a charging of the sample, and introduces a possible error of a few parts in 10^4 in C. The C value obtained from eight measurements on MgO is C = 78.7058 ± 0.0047 G-cm/A. The discrepancy between the two values obtained for C is not serious, especially in view of the possible charging effect.

In using some ionic crystals as photo-electron sources for the voltage calibration technique,[7] we have found that the accelerating or retarding potentials are screened in some fashion. The effective potential was found to vary between 0.2 and 0.9 Δ T. Further investigations are necessary to determine the exact cause of this screening and of course it strongly affects the calibration results. However, in the case of the C1s, graphite line, the stability of T with respect to both x-ray flux and Δ T variations indicates that there was no screening effect of greater than a few parts in 10^4. In fact, a check for such stability could be used as an indicator of the presence of both charging and screening, two very important effects in any precise electron energy measurement.

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Figure Caption

Fig. 1. The effect of x-ray flux variation (as indicated by peak counts) on the location of the photoelectron line Mgls, MgO($CrK\alpha_1$). Both the shift in line kinetic energy and the fractional change in calibration constant are shown.

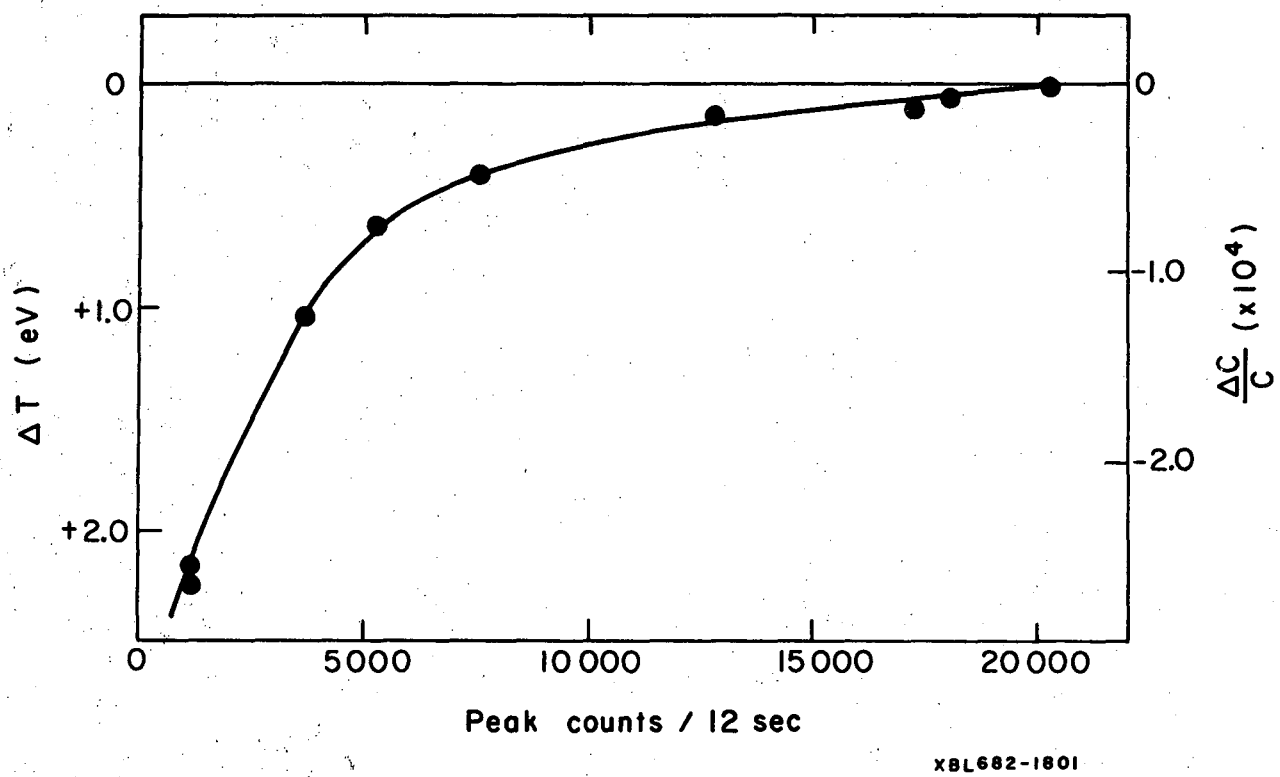
0
+1.0
+2.0
ΔT (eV)
0
-1.0
-2.0
ΔC/C (x10⁴)
0
5000
10000
15000
20000
Peak counts / 12 sec
XBL682-1801

Fig. 1

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