Electron impact excitation of zinc vapor at 40 eV

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Differential and integral electron impact cross sections for elastic scattering and for the excitation of the $4p\ ^3P$, $4p\ ^1P$, $5s\ ^1S$, and $5p\ ^1P$ states of zinc have been determined for the first time at 40 eV impact energy. The measurements were normalized to the absolute scale by utilizing the optical f value of the $4p\ ^1P$ transition. We find that the integral cross section for the $4p\ ^1P$ excitation is quite large (1.0×10^{-15} cm^2) and exceeds that for elastic scattering (2.1×10^{-16} cm^2) by a factor of nearly 5.

The two lowest electronic states of zinc 3077 Å ($4p\,^3P$) and 2139 Å ($4p\,^1P$) have been observed in absorption spectra.[1,2] A recent study of the electron impact excitation of zinc vapor in the 50–150 eV impact energy and 0° to 11° angular range by Newell and Ross[3] yielded relative generalized oscillator strengths for several transitions in zinc. We report here the first set of normalized differential (0° to 140°) and integral cross sections for elastic scattering and excitation of the four lowest states at 40-eV impact energy. We find that the integral cross section for the $4p\,^1P$ excitation (1.0×10^{-15} cm^2) exceeds that for elastic scattering (2.1×10^{-16} cm^2) by a factor of 5!

The electron impact spectrometer used in these experiments has been described earlier.[4] Briefly, an energy selected electron beam is scattered off a zinc target beam. The zinc beam was produced by heating a tantalum crucible containing zinc by electron bombardment. The scattered electron intensities at $E_0 = 40$ eV and at various scattering angles θ were determined as a function of energy loss using pulse counting by multichannel scaling techniques. The impact energy is known to within ±0.5 eV and the angular resolution is between 1.7° and 3.2°.

The elastic-scattering intensity as a function of angle (10° to 130°) was measured in a time short compared to the instrumental drift. An effective path-length correction appropriate to our scattering geometry converted the elastic intensities into differential cross sections (DCS) in arbitrary units. At fixed angles from 10° to 130° ratios of the inelastic intensities to elastic intensities were taken from energy-loss spectra (Fig. 1). Products of these ratios and the elastic DCS gave the DCS for each inelastic transition in the same arbitrary units.

The elastic intensity could not be determined below 10° because of direct beam contamination; therefore a low-angle calibration (−10° to 30°) was

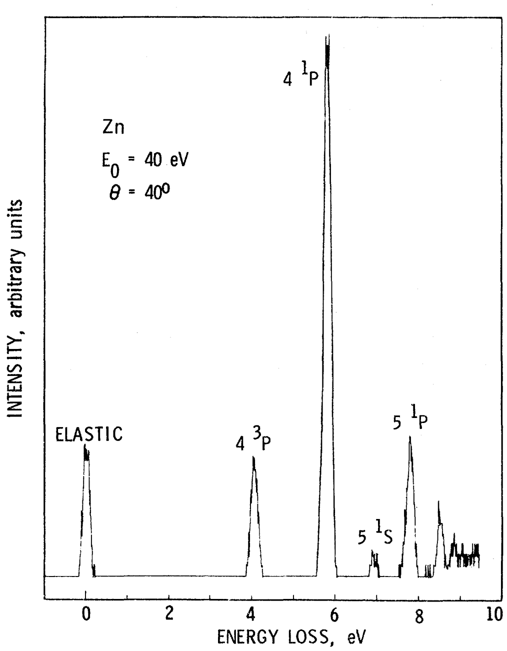

FIG. 1. Energy-loss spectra of atomic Zn at 40-eV impact energy and 40° scattering angle.

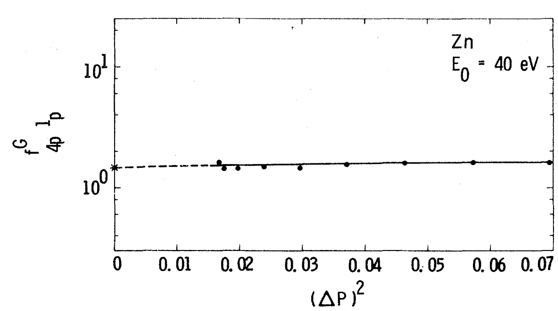

FIG. 2. Normalized generalized oscillator strengths for the $4p\,^1P$ state as a function of ΔP^2. The optical f value of Lurio (*) is shown at $\Delta P^2 = 0$.

TABLE I. Summary of integral cross sections (in units of 10^{-16} cm^2).

E_0	Elastic	$4p\,^3P$	$4p\,^1P$	$5s\,^1S$	$5p\,^1P$
40 eV	2.1	0.086	10.0	0.20	1.3

performed for the $4p\,^1P$ transition. The intensity symmetry around 0° determined true zero scattering angle. The effective path-length correction converted the $4p\,^1P$ intensities to DCS's. The low-angle DCS's were normalized to DCS's obtained from elastic ratio data by matching curves in the overlapping angular region. From ratios of other inelastic intensities to the $4p\,^1P$ transition at low scattering angles and values of the low angle $4p\,^1P$ DCS, the other low-angle inelastic DCS's were obtained.

Lassettre[5] has shown that the generalized oscillator strength at zero momentum transfer is equal to the optical f value. The generalized oscillator strength defined by Bethe[6] is

$$f_{0n} = \frac{W}{2}\frac{K_0}{K_n}(\Delta P)^2\left(\frac{d\sigma}{d\Omega}\right)_{0n}(\theta);$$

W is the excitation energy and K_0 and K_n are the momenta of the electron before and after collision, respectively. ΔP is the momentum transfer and $d\sigma/d\Omega$ is the DCS. The generalized oscillator strength's for the $4p\,^1P$ transition versus momentum transfer squared was plotted (Fig. 2) and extrapolated to zero and the limiting value was normalized to the optical f value of Lurio.[7] Good agreement exists between the calculations of Bates and Damgaard[8] and the experimental value of Lurio. The factor obtained from this normalization put all cross sections on the absolute scale. All cross sections were extrapolated to 0° and to 180° and integrated to obtain integral cross sections. See Table I.

The elastic DCS possesses two minima (40° and 100°) characteristic of high-Z elements in this impact energy range. The elastic DCS drops more than $2\frac{1}{2}$ orders of magnitude from 15° to 40° scattering angle. The $4p\,^1P$ and $5p\,^1P$ DCS's are very strongly forward-peaked and at 40° scattering angle the $4p\,^1P$ transition is 4 times as strong

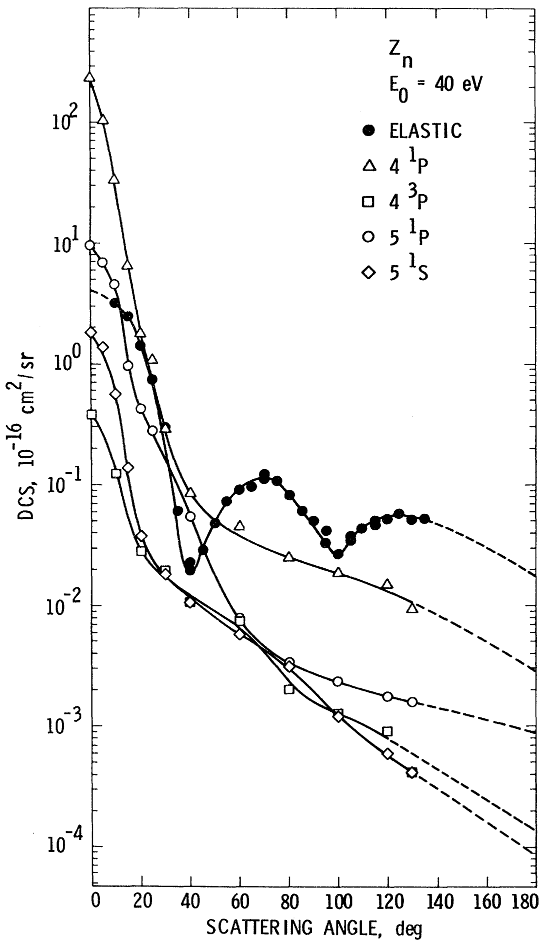

FIG. 3. Differential cross sections for elastic and inelastic transitions in Zn at 40 eV.

as the elastic differential cross section.

The $5s\,^1S$ cross section also exceeds the elastic DCS at this angle (see Fig. 3). The $4p\,^3P$ and $5s\,^1S$ states are less strongly forward-peaked. The experimental points cover 6 orders of magnitude.

The DCS's relative to each other are estimated to be given within ±20%. The integral cross sections are believed to be given with a factor of 2. When more accurate absolute measurements and/or calculations become available, these values can be renormalized.

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