Energy Spectrum of Electrons Emitted from Gases Bombarded by Positive Ions*

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The energy spectrum of electrons emitted during ionization of gases bombarded with positive ions has been studied for electrons emitted parallel and perpendicular to the incident ion beam. The observed spectra are not strongly dependent upon the direction of electron emission.

INTRODUCTION

THE authors recently have described an experimental determination of the energy spectrum of electrons ejected during ionization of neon, argon, and krypton by bombardment with potassium ions.[1] The method employed a 180° magnetic spectrometer, and only those electrons emitted nearly perpendicular to the incident ion beam were analyzed.

The dependence of electron energy and ionization cross section upon direction of electron emission has subsequently been investigated by modifying the experimental arrangement to analyze only those electrons emitted nearly parallel to the path of the incident ion beam. This paper presents the results of the modified experiment, and compares them with the results of the previous experiment.

EXPERIMENTAL APPARATUS

Except for modification of the ion gun, the experimental apparatus and procedures employed in the present experiment are the same as those described in reference 1.

A section of the 180° magnetic spectrometer and the modified ion gun are shown in Fig. 1. Potassium ions from the thermionic source S are accelerated through two focusing electrodes. After passing through the collision chamber A containing the target gas, ions are collected in a Faraday cup P. Those ionization electrons emitted in the forward direction with the proper energy are accepted by the baffle system and collected in a Faraday cup Q. A 0.814 mm$\times$3.68 cm slit in the collision chamber A serves as the first defining baffle. The essential difference between this arrangement and the previous one is that formerly the ion traveled through the collision chamber in a direction perpendicular to the plane of Fig. 1. Hence the results of the two experiments permit comparison of the energy spectrum of electrons emitted parallel to the incident ion beam with the spectrum of those emitted perpendicular to the incident ion beam.

As before, the pressure differential between the collision chamber and spectrometer was maintained by continuous high-speed pumping. Again a linear dependence of ionization signal upon target gas pressure was observed within the range of pressure used (10^{-4} mm Hg to 10^{-3} mm Hg).

EXPERIMENTAL RESULTS

Energy Spectra

The observed energy spectra of electrons emitted from neon, argon, and krypton are shown in Fig. 2. For comparison, the dashed lines produce the corresponding spectra from the previous experiment when only electrons ejected nearly perpendicular to the incident ion beam were collected.

For each of the three gases studied, the observed energy range of electrons coming off in the direction

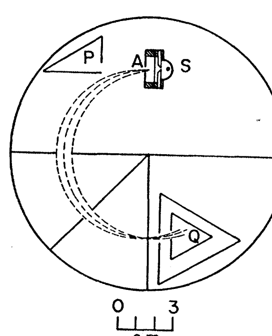

FIG. 1. Ion gun and electron velocity selector. Ions from S are accelerated into the collision chamber containing the target gas. Some electrons ejected during ionizing collisions pass through slit A in the collision chamber. A uniform magnetic field perpendicular to the plane of the figure focuses electrons of a given energy onto the electron collector Q. Ions are collected in P

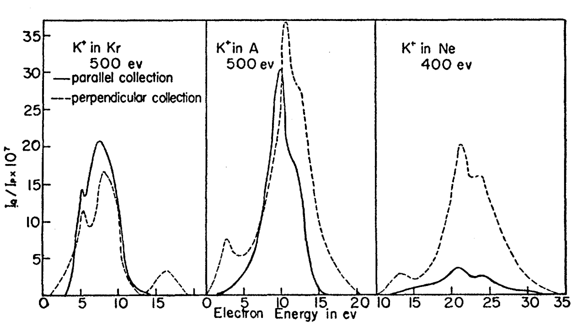

FIG. 2. Energy spectrum of electrons emitted by inert gases bombarded with potassium ions. Each pair of curves was obtained by collecting the electrons ejected respectively perpendicular to and parallel to the incident ion beam. Each curve corresponds to a unique energy of the incident potassium ions. I_Q is the electron current reaching the Faraday cage Q. I_P is the ion beam current.

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[1] D. Moe and O. Petsch, Phys. Rev. 110, 1358 (1958).

TABLE I. Ionization cross section for parallel and perpendicular collection.

Ionization cross section in units of 10^{-17} cm^2	K^+ in Kr 500 ev	K^+ in A 500 ev	K^+ in Ne 400 ev
Parallel collection, $\sigma_{\parallel}$	3.0	3.2	0.26
Perpendicular collection, $\sigma_{\perp}$	2.4	3.1	0.80
$\sigma_{\perp}/\sigma_{\parallel}$	0.80	0.97	3.1

of the incident ion beam is narrower than the energy range of perpendicularly ejected electrons. The differences observed at the low end of the spectrum may be instrumental due to the difficulty of focusing electrons of energy less than about 5 ev.

The general structure of the observed spectra however is independent of direction of electron emission. The small observed differences in the position of the maxima are probably within the uncertainty introducted by the different electron source geometries of the two modes of electron collection. Similar results were obtained for ion energies from 200 to 900 ev. The apparent absence of the high-energy peak for parallel collection with krypton is a curious exception to the general similarity of spectra.

Ionization Cross Sections

Absolute ionization cross sections have been calculated by the method described in reference 1. Results from both experiments are presented in Table I.

Comparison of the ratios in the last row suggests that as the atomic number of the target gas is decreased. the relative number of electrons ejected perpendicular to the incident ion beam increases. However, the 180° magnetic spectrometer used in this experiment is designed primarily to measure electron energies, and is inherently not well suited to the measurement of absolute cross sections. Hence the cross section results should be regarded as tentative, and these measurements should be repeated with apparatus primarily designed to measure cross section as a function of direction of electron emission.