NOV 25 1964

C00-1277-7

CONCORDIA COLLEGE
MOORHEAD, MINNESOTA

MASTER

TECHNICAL STATUS REPORT NO. 6
Covering the period

August 1, 1964 to October 31, 1964

ANGULAR AND ENERGY DISTRIBUTION OF ELECTRONS
FROM GASES IONIZED BY PROTON IMPACT

by

M. Eugene Rudd

Carl L. Bailey

Contract No. AT(11-1)-1277

U.S. Atomic Energy Commission

November 1, 1964

LEGAL NOTICE

This report was prepared as an account of Government sponsored work, under the United States, and the Commission, for any person acting on behalf of the Commission.

A. Make any material of representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not be subject to patent rights.

B. Approve any information with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor. In the event that such employee or contractor of the Commission, or employee of such contractor prepared, disseminated, or provided access to, any information pursuant to the sponsorship or contract with the Commission, or the employment with such contractor.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

INTRODUCTION

Most of the measurements of cross sections for ionization of gases by proton impact have been confined to measurements of the total cross sections. The first Born approximation has been used to calculate these cross sections and for energies above a few hundred kev satisfactory agreement is obtained with experimental results.^{4,5} At lower energies, however, agreement becomes progressively poorer. A more detailed test of the theory over a wide range of proton energies would be desirable to find the limitations on the theory.

Kuyatt and Jorgensen¹ have made measurements of the angular and energy dependence of the differential cross sections for ejection of electrons during ionization by proton impact on hydrogen. Rudd and Jorgensen² have made absolute measurements of these differential cross sections for hydrogen gas with 100 kev incident protons and for helium gas using 50, 100, and 150 kev protons. Comparison² of these results with the Born approximation shows serious discrepancies especially at some angles and energies of ejection. Comparison² has also been made with the Gryzinski classical theory.³ This theory does not supply angular distributions of the ejected electrons but the energy distributions predicted by this theory show fair agreement with experiment. Additional measurements need to be made over a wider energy range both for their own interest and also to provide a basis for understanding the limitations of the present theories.

In addition to the theoretical interest in the proposed measurements, the cross sections themselves should be useful to investigators in a number of fields. In controlled fusion trapping experiments the distribution of electron energies is useful for calculations of the electron heating, electron contribution to beam trapping, and the plasma potential. The results should also be of use in connection with calculations of auroral brightness vs. altitude and for other atmospheric and astrophysical work.

DESCRIPTION OF THE PROJECT

A collimated beam of protons from the Concordia College Cockroft-Walton accelerator passes through the desired target gas at low pressure in a scattering chamber. The electrons ejected into a small solid angle pass into an electrostatic analyzer which can be placed at various angles with respect to the proton beam. The electrons passed by the analyzer are detected by an electron multiplier and individually counted.

The scattering chamber contains two sections. The inner chamber contains the gas to be bombarded while the outer chamber is kept evacuated. The proton beam is collected by a small shielded Faraday cup and is integrated by a high grade capacitor used with an operational amplifier. Electron ports are machined in the chamber at 10° , 20° , 30° , 50° , 70° , 90° , 110° , 130° , and 160° .

The electrostatic analyzer is of the parallel plate type described by Harrower.⁶ The plate spacing is made equal to half the distance between the entrance and exit slits thus making the analyzer voltage equal to the energy of the electrons passed. The electrons are accelerated by a small voltage (10 or 20 volts) before entering the analyzer. This is done by elevating the potential of the front plate of the analyzer by that amount. With this arrangement the voltage on the back plate (relative to ground) is still equal to the energy of the electrons before acceleration regardless of the value chosen for the acceleration voltage.

The entire apparatus is surrounded by three mutually perpendicular pairs of Helmholtz coils to null out the DC and 60 cycle AC magnetic fields. Gas is admitted to the inner chamber through a needle valve. The pressure is measured with a McLeod gauge and an ionization gauge.

In order to obtain absolute cross sections the efficiency of the electron multiplier must be measured. This is accomplished by doing an auxiliary experiment in which cross sections differential in angle (but not electron

energy) are measured with the same slit system. This is done by replacing the electrostatic analyzer with a Faraday cup and measuring the current of electrons to it with an electrometer. The electron current is great enough to measure accurately only at a few of the angles in the forward direction, but these are enough to determine the multiplier efficiency through a comparison of the cross sections integrated over ejected electron energy with those measured directly. This procedure has already been used² and appears to work well.

PRESENT STATUS OF THE PROJECT

As noted in the last quarterly report fine structure in the curves of cross section vs. ejected electron energy had been observed in the neighborhood of 35 ev. This was investigated more thoroughly under greater energy resolution during the last quarter. A number of peaks emerged which have been identified as being due to autoionization electrons ejected from highly excited states in helium. The levels have been measured previously by electron scattering⁷ and by ultraviolet absorption⁸ and have also been calculated theoretically.⁹ The agreement between the previous results and our results is very good. Figure 1 shows the results with proton bombardment while Fig. 2 shows the results with bombardment by hydrogen molecular ions. The energies marked in Fig. 2 are those calculated by Burke, et.al.⁹ The triplet level at 58.3 ev is not excited by the proton beam since an electron exchange is necessary to conserve spin. Since the proton bears no electrons no excitation of triplet levels takes place. The level at 62.9 ev had evidently never been observed before although it was predicted theoretically.

Additional fine resolution work has been done on neon and preliminary results are shown in Fig. 3. The lines marked "S" are ones observed by Simpson, et.al.⁷ and those marked "M" were observed by Madden and Codling.⁸ A line at 44.1 ev appears in the proton curve which had not been previously observed.

A new power supply for the electron multiplier has been installed which has reversible polarity. This will allow measurements to be made on positive ions as well as electrons. The necessary changes in connections have been made and some initial checks have been made with the multiplier operating in this mode.

Difficulty with the measurement of low energy electrons continues. Part of the trouble has been traced to the ion gauge which emits large numbers of electrons. These apparently pile up on insulating layers and affect the number of low energy electrons detected for a considerable time after the ion gauge has been turned off. To correct this an electron suppressor has been built and installed near the gauge. Tests indicate that this eliminates at least a part of the difficulty.

To eliminate reflected electrons inside the chamber an additional baffle has been constructed and placed in the inner chamber. This is so made that the electron pipe looks into an essentially "black body", ie. an aperture in a cavity. This reduces the problem of reflected electrons considerably.

Some difficulties associated with RF oscillations in one of the high voltage transformers of the accelerator has necessitated the purchase of a new power supply to supplement the present supply. This is being installed at the present time.

PUBLICATIONS

During the last quarter the following paper was published:

"Observation of Autoionization Levels in He by
Positive Ion Bombardment" Phys. Rev. Letters 13, 503 (1964)

TRAVEL

M. E. Rudd attended the Atomic Collision Cross Section meeting at AEC headquarters, Germantown, Md. October 29 and 30. On October 28 he presented

a seminar on the research project for the Atomic Physics Division at the National Bureau of Standards at Washington, D.C. No AEC funds were expended for the latter visit.

Respectfully submitted,

M. Eugene Rudd
Project Director

REFERENCES

1. C.E. Kuyatt and T. Jorgensen, Jr., Phys. Rev. 130, 1444 (1963)
2. M.E. Rudd and T. Jorgensen, Jr., Phys. Rev. 131, 666 (1963)
3. M. Gryzinski, Phys. Rev. 115, 374 (1959)
4. J.W. Hooper, et.al., Phys. Rev. 121, 1123 (1961)
5. J.W. Hooper, et.al., Phys. Rev. 125, 2000 (1962)
6. G.A. Harrower, Rev. Sci. Instr., 26, 850 (1955)
7. J. Arol Simpson, S.R. Mielczarek, and J. Cooper, J. Opt. Soc. Am. 54, 269 (1964)
8. R.P. Madden and K. Codling, Phys. Rev. Letters 10, 516 (1963)
9. P.G. Burke, D.D. McVicar, and K. Smith, Phys. Rev. Letters 11, 559 (1963)

Fig 1