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MASTER

"ELECTRON TRANSFER EXPERIMENTS AND ATOMIC MAGNETISM VALUES"

Progress Report

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Progress Report

Special Research Support Agreement E(11-1)-2562

I. "Electron Transfer Processes"

J.E. Bayfield, Principal Investigator

ABSTRACT

Progress in the first seven months of this new research is described. A new apparatus was constructed, tested and moved to Oak Ridge National Laboratory for studies using the Penning ion source test facility. Preliminary electron transfer cross section results for N^{4+}, N^{5+}, He^{2+} and C^{5+} ions on gases were obtained. Energy loss measurements made to date support our expectations that single electron transfer for multiply-charged ions colliding with gas atoms produces excited final state ions.

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I. "Electron Transfer Processes"

J.E. Bayfield, Principal Investigator

A. Developmental Effort on the Research Apparatus.

With the arrival of first ERDA support in April 1975, a major effort of the Yale research group (J.E. Bayfield, P.M. Koch and L.D. Gardner) resulted in the construction of a new six foot, three stage scattering apparatus. The ultrahigh vacuum system was tested in early August, and the experimental components installed inside and aligned mid-August. The unit was transported intact to the ORNL cyclotron building and coupled to the Penning test bench ion source facility in late August. From April through August about 70% of Bayfield's research time and all of Gardner's time was spent on this project. Yale effort at ORNL totaled eight man weeks and involved the entire group; a similar level of participation of ORNL personnel made possible two weeks of serious running of experiments in early September. The efforts of D.H. Crandall, M.L. Mallory and J. Hale of ORNL were supplemented by those of the group of I.A. Sellin from the University of Tennessee. Enough is now known about the apparatus that changes necessary for accurate cross section measurements can be made in preparation for future runs at ORNL. The apparatus is schematically shown in Figure 1.

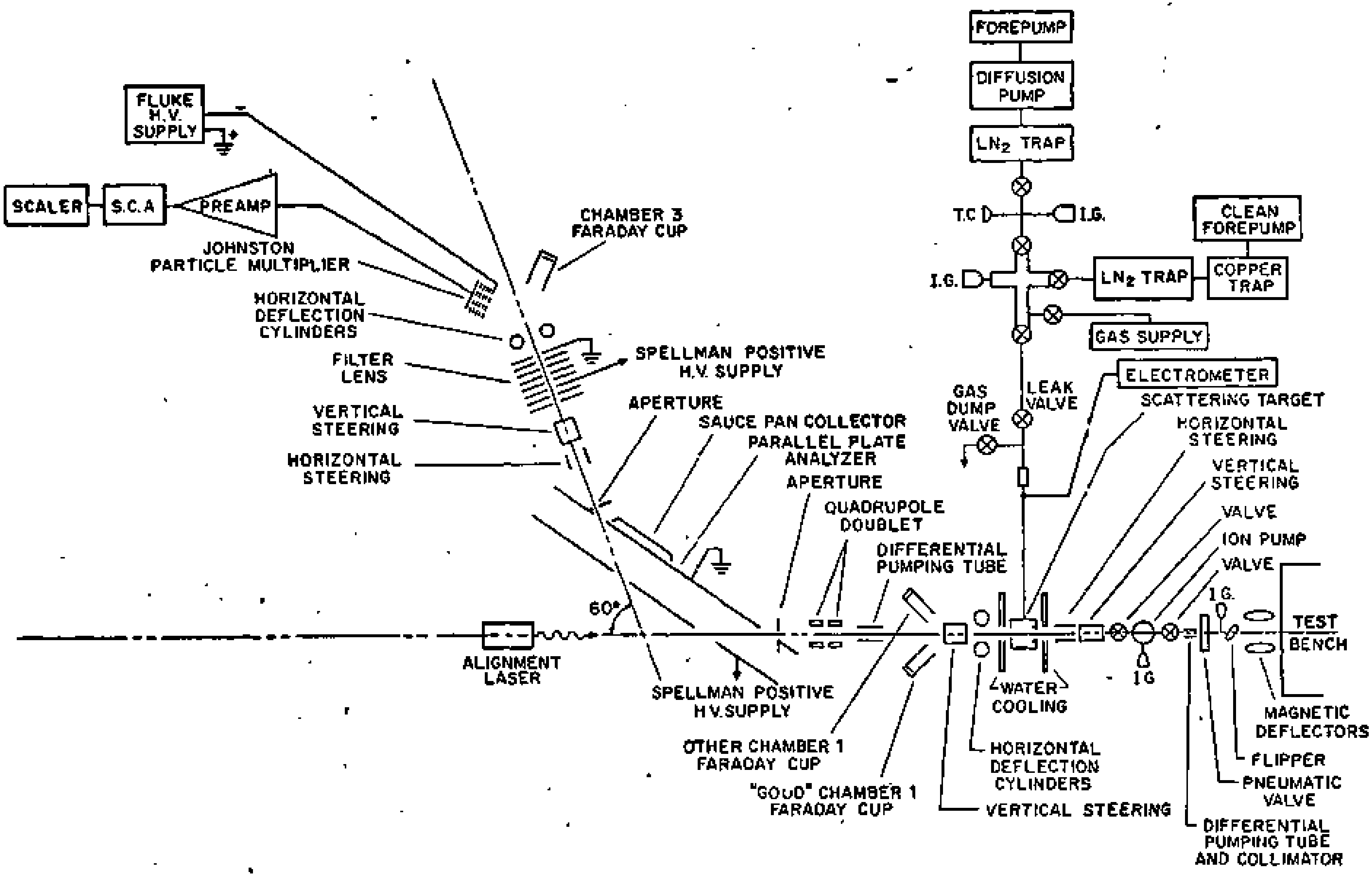

FLUKE H.V. SUPPLY
SCALER
S.C.A
PREAMP
JOHNSTON PARTICLE MULTIPLIER
CHAMBER 3 FARADAY CUP
HORIZONTAL DEFLECTION CYLINDERS
FILTER LENS
SPELLMAN POSITIVE H.V. SUPPLY
VERTICAL STEERING
HORIZONTAL STEERING
APERTURE
SAUCE PAN COLLECTOR
PARALLEL PLATE ANALYZER
APERTURE
QUADRUPOLE DOUBLET
DIFFERENTIAL PUMPING TUBE
60°
ALIGNMENT LASER
SPELLMAN POSITIVE H.V. SUPPLY
OTHER CHAMBER 1 FARADAY CUP
"GOOD" CHAMBER 1 FARADAY CUP
FOREPUMP
DIFFUSION PUMP
LN_2 TRAP
T.C
I.G.
I.G.
CLEAN FOREPUMP
LN_2 TRAP
COPPER TRAP
GAS SUPPLY
ELECTROMETER
GAS DUMP VALVE
LEAK VALVE
SCATTERING TARGET
HORIZONTAL STEERING
VERTICAL STEERING
VALVE
ION PUMP
VALVE
I G.
TEST BENCH
WATER COOLING
I G
MAGNETIC DEFLECTORS
FLIPPER
PNEUMATIC VALVE
HORIZONTAL DEFLECTION CYLINDERS
VERTICAL STEERING
DIFFERENTIAL PUMPING TUBE AND COLLIMATOR

Figure 1

B. Scope of Investigations Undertaken, and Significant Results Obtained.

Most of the experiments to date employed N^{4+}, N^{5+}, C^{4+} and C^{5+} beams readily obtained from the test bench. A primary objective was to determine the energy resolutions of the Yale parallel plate and filter lens energy analyzers (see Figure 1) when used to study test bench ion beam energy spreads. Both analyzers worked as expected, with resolutions of 0.2% to 0.5%. The transmission through the parallel plate analyzer was found not to be unity; this unit will be altered to provide total transmission with looser requirements on alignment of the Yale apparatus relative to the test bench beam. The FWHM observed energy width of the C^{5+} beam was less than 200 eV, with a probably large contribution coming from the analyzer resolution. This width is less than the 600 eV energy gain expected in electron transfer collisions of C^{5+} or C^{6+} on atoms with production of ground final state ions. Measurements on the energy of scattered C^{4+} ions formed in C^{5+}-Ar collisions found no energy gain or loss within experimental accuracy of ±300 eV. We hope the accuracy will be improved somewhat in future runs through the use of a precision digital voltmeter not yet available at ORNL. However, we already can conclude that the final product ions are not made directly into the ground state.

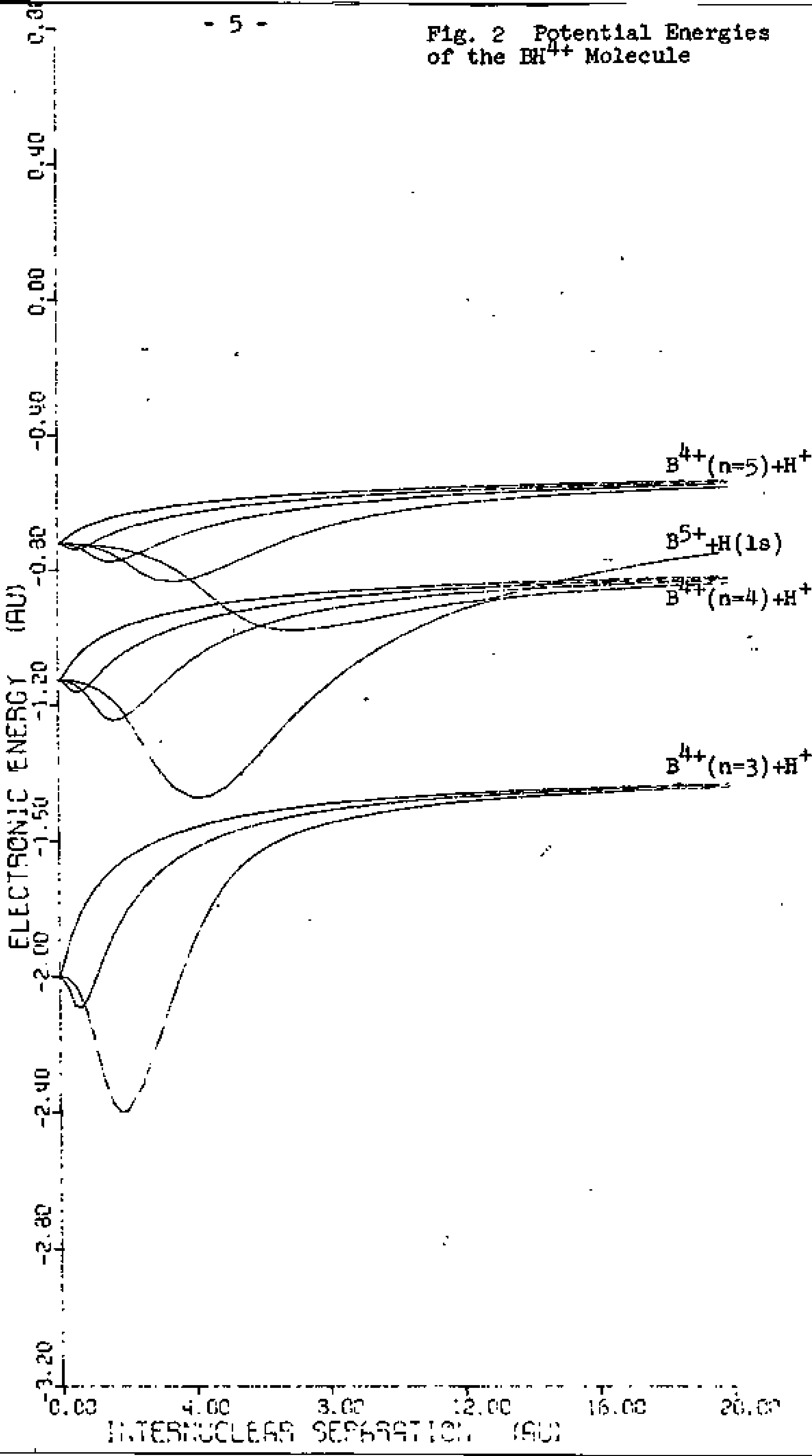
Our preliminary values of cross sections for single and double electron transfer in N^{4+}, N^{5+}, C^{4+} and C^{5+} collisions in He and Ar gases are in the range 10^{-16} to 10^{-15} cm^2 at energies near 30-45 keV. Single and double transfer were found to be quite competitive processes. A check was made on the well known $^4He^{2+}$-^4He single electron transfer cross section (See Appendix A), with values obtained being too large. This bears further investigation in search of systematic error, probably arising from H_2^+ contamination of the incident ion beam. This can be either avoided by using $^3He^{++}$ ions, or by studying H_2^+ dissociation in the gas target. It is not known whether the test bench will operate with $^3He^{++}$ (M/Q = 1.5) [operation with $^4He^{++}$ (M/Q = 2.0) required considerably development effort]. If not, the H_2^+ dissociation will be studied.

The present status for electron transfer measurements in the He^{++}-H system has been reported by us (See Appendix B). A recent change is the adjustment of the $He^+(2s)$ data of Shah and Gilbody shown in Figure 3 of Appendix B upward a factor of two, in agreement with the Yale results. (Shah and Gilbody, Private Communication.)

C. Probable Events for the Remainder of the Present Research Period.

During the past September run, the atomic hydrogen scattering target was successfully operated. A two week run at ORNL is scheduled on the test bench in November, 1975, with primary objectives being a study of C^{5+}, C^{6+}, B^{4+} and B^{5+} collisions with H. If successful, a run on the ORNL EH tandem accelerator is scheduled for December, with the objective being to study H^{+}-H electron transfer in the MeV collision energy range. This tight schedule may slip a month or two because of additional time needed on the test bench. Eight to ten Yale man weeks at ORNL are anticipated, much of it time of the principal investigator. The entire group is presently spending 50% of their research effort at Yale in data analysis and in further design improvements of the apparatus. The above-mentioned late year runs will go far towards compliance with our original program objectives. A change has been the introduction of runs using B^{4+} and B^{5+} beams, which should be more easily obtained at the test bench than carbon beams. Additional motivation for B^{5+}-H studies comes from the parallel theoretical effort at Yale on this system by the group of W.L. Lichten, G. Hatton and N. Ostrove. Their work is supported by the NSF. Figure 2 shows potential energy curves obtained by them for the BH^{4+} system, exhibiting the sigma state level crossings expected to produce large cross sections for final excited B^{4+} production. Calculation of the radial coupling matrix elements for the level crossing transitions are in progress. The physics for C^{6+}-H collisions is expected to be similar, and calculations could be forthcoming.

Fig. 2 Potential Energies of the BH^{4+} Molecule



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III. Atomic Magnetism or g-Values: Data Compilation of Experimental and Theoretical Values, and Critical Review

V.W. Hughes, Principal Investigator

In the classic three volumes Atomic Energy Levels by C.E. Moore-Sitterly,[1] available information is included on g-values. Experimental values are given from optical spectroscopy, but information was often scarce. Theoretical Landé g-values are tabulated.

We had planned to make a modern data compilation of experimental and theoretical g-values. Much work has been done in the past two decades. On the experimental side the newer techniques of atomic beam spectroscopy, microwave spectroscopy, and optical pumping spectroscopy have been used. On the theoretical side many more detailed calculations of g-values, including configuration interactions and relativistic corrections, have been made. Our plan was to start with ground state and low-excited state g-values and to continue with more highly excited states. We planned towards a publication in the Journal Atomic Data, edited by Katherine Way.[2] Funds were sufficient only to begin a preliminary literature search on the many calculations and modern experiments in atomic magnetism that have been completed in the 20 years since the initial compilation[1] was published.

References for Part III

1. Atomic Energy Levels, Vols. I-III, edited by C.E. Moore, Circular of the National Bureau of Standards 467, Washington, D.C. (1949-1958).

2. Atomic Data, Vols. I-IV, edited by Katharine Way (Academic Press, New York, 1969-1973).

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