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FINAL REPORT OF CONTRACT AT(30-1)-2403

"CHEMICAL REACTIONS OF ATOMIC BEAMS AND RELATED PROBLEMS"

I. ABSTRACT

Modifications were made to the atomic beam apparatus to improve the operating characteristics and to permit operation using argon as well as helium beams. An electron bombardment ionizer was added, together with a beam chopper. This system is designed to permit measurement of inelastic scattering of neutral particles by measurement of the ion current.

Experiments to measure the cross sections for scattering helium ions from helium gas were carried out. The results were affected by charging of surfaces in the vacuum system. The measurements will be repeated using a modified vacuum pumping system.

A number of papers have been published on theoretical chemical kinetics and beam instrumentation. In addition, a paper on the calculation of elastic scattering cross sections has been prepared for publication.

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1. SCATTERING MEASUREMENTS

The scattering apparatus consists of an arc-discharge ion source from which ions are extracted and accelerated by an electric field to kinetic energies of 200 - 2000 e.v. A fraction of the ions are neutralized by charge exchange collisions, and either the resulting fast neutral beam or the remaining ion beam can be used in scattering experiments by suitable adjustment of the potentials. The ion source operates at pressures of .025-.050 mm Hg.

The beam passes into a differentially pumped section of the apparatus in which a scattering gas cell is positioned. The pressure of the scattering gas is measured with a thermistor manometer located close to the beam path. An electrode placed in the scattering gas cell is used to collect the slow ions produced from charge exchanging collisions. This addition permits measurement of charge exchange cross sections in experiments with the ion beam. The ion beam then passes into the entrance slit of a 90° sector field magnetic mass spectrometer having a secondary electron multiplier detector. The neutral beam can be detected by placing the electron multiplier directly in the beam, or by using a thermocouple detector directly in the beam path.

Experiments with a helium ion beam have shown that operating the arc discharge with helium gas purified by diffusion through Vycor glass for an extended period is needed before the mass spectrum shows helium ions as the major component.

Several modifications were made to the ion source to improve its stability and performance:

- a. An anode plate was placed 3mm from the filament. This enabled operation of the arc at lower anode voltages than possible previously (below 30 volts).
- b. Ten equally spaced accelerating electrode plates were added between the cathode and the high voltage electrode. The accelerating potential was divided into ten equal steps by a resistance network and was applied to the plates. This charge permitted more stable beam operation with fewer arc-over difficulties.

c. All the machine screws used in the construction of the ions source were slotted to speed up outgassing and to eliminate impurities in the beam from gases being ionized in the arc.

d. A charcoal column was fabricated to allow experiments using pure argon in the ion source. To date difficulties with arcing over in the ion source when using argon have prevented scattering experiments with the argon beam.

An rf mass spectrometer used in conjunction with the beam apparatus for measuring the purity of various gases is attached to the system. Two publications have resulted from refinements in the associated electronic instrumentation.^{1,2}

Mr. Edward Fonder has undertaken the measurement of total scattering cross sections for He^+ on helium using the ion beam from the arc discharge source and the mass spectrometer detector. The initial results indicated an apparent cross section about three orders of magnitude too high. This result was traced to the deflection of the ion beams by metal surfaces on which an insulating deposit forms and builds up a charge. It is planned to repeat these measurements under cleaner vacuum conditions, such that any back-streaming of diffusion pump oil is prevented.

A universal electron beam ionizer was added to the system in an effort to allow detection of the neutral beam by the mass spectrometer ion detector. The ionizer consists of a tungsten ribbon filament, electron accelerating and centering electrodes and an ion accelerating or decelerating electrode. The ionizer was placed in the apparatus and used to detect ions formed from the residual gas. A beam chopper was placed between the beam source and the ionizer, so that ions formed by ionizing fast beam atoms could be distinguished from ions formed by ionization of the residual gas. To date no ion signal has been detected from ionization of beam atoms. These experiments will be repeated after modifications to the vacuum system to attain a lower pressure of residual gas in order to reduce the background ion current.

2. Studies on Theoretical Chemical Kinetics.

In conjunction with Prof. A. G. Turner, of this institute, a numerical

method was developed for computing the cross section for elastic scattering from a known intermolecular potential. In this work a new, more accurate, rapidly convergent method was developed for numerically evaluating the integrals which arise in the computations.³

Professor Marcus, during the remaining time he was associated with this research group completed several parts of a theoretical approach to an analytical representation of the classical and quantum mechanics of a point moving on a saddle shaped potential energy surface.⁴⁻⁷ It is expected that this approach will obviate the need of numerical machine calculations of chemical reaction rates in which the rate is mainly influenced by the shape of the surface near the saddle point.

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Respectfully submitted,

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