RESEARCH PROJECT TECHNICAL COMPLETION REPORT

Institution: University of Connecticut Date of Report: August 9, 1972

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Project Title: The Velocity Dependence of the Total Cross Section for Alkali-Water Scattering

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PROJECT OBJECTIVES

To determine the long range interaction between an alkali atom and a water molecule.

ACHIEVEMENT OF OBJECTIVES:

To date the velocity dependence of the total cross sections for the scattering of K, Rb, and Cs by water molecules has been measured and comprises the major portion of a Ph.D. thesis already completed. In addition the laboratory has refined its techniques sufficiently to allow similar measurements to be made with both the Na and Li beams.

RESEARCH PROCEDURES USED:

Atomic beam techniques were used to measure the velocity dependence of the total cross sections for the scattering of alkali atoms by water molecules. In measurements of this type[1] the three basic problems involve production of a velocity selected beam, the scattering of the beam by water molecules, and finally the detection of the surviving beam.

Beam production is accomplished by heating a sample of the alkali metal in a small oven and allowing atoms from the resulting vapor to pass through a slit in the wall of the oven. The beam generated is then passed through a set of rotating circular disks which transmit those atoms whose velocity are compatible with both the spacing of radial slits cut into the disks and the unit's angular velocity.

Beam scattering occurs when the velocity selected atomic beam passes through a scattering cell containing water vapor at a low pressure. The surviving beam (I) is related to the incident beam (I_o), the water vapor density (n), the length of the scattering cell (l), and to the velocity dependent total cross section ($\sigma(v)$), by $I = I_o e^{-n\sigma l}$.

The surviving beam is detected by surface ionization on a tungsten wire followed by a measurement of the resulting ion current. This was easily accomplished for K, Rb, and Cs beams but proved troublesome in the Na and Li cases. A mass spectrometer and electron multiplier were recently added to our detector and we are currently continuing and refining our studies on the remaining alkali elements.

1. Molecular Beams, Norman F. Ramsey, Oxford Press, New York, 1956.

RESULTS:

The long range interaction between atomic systems is describable by a potential of the form $V(r) = -c/r^s$. In this expression $V(r)$ is the potential energy, r the internuclear separation, c a constant, and s a pure number. Although a potential of this form is valid only for spherically symmetric systems it yields good average values when used to describe non spherically symmetric systems such as an alkali-H_2O system. It has been shown[2] that the velocity dependence of the total cross section is given by

$$\sigma(v) = p(s) \left(\frac{c}{v}\right)^{2/s-1}$$

for a potential of the form assumed. In this equation $\sigma(v)$ is the total cross section, $p(s)$ a known function, and v the relative velocity. In plotting our cross section data in the form $\ln \sigma$ vs $\ln v$ the slope m of the resulting curves is related to s by $m = \frac{-2}{s-1}$ and thus $s = \frac{-2}{m} + 1$.

Our results to date are summarized by the following table.

	m	stand dev.	s	stand dev.
K-H_2O	-0.40	$\pm$.03	6.00	$\pm$.38
Rb-H_2O	-0.41	$\pm$.02	5.88	$\pm$.24
Cs-H_2O	-0.39	$\pm$.02	6.13	$\pm$.26

2. Advances in Atomic and Molecular Physics, D. R. Bates and I. Estermann Eds. Vol L. "The Study of Intermolecular Potentials with Molecular Beams at Thermal Energies," H. Pauly and J. P. Toennies, P. 282.

PUBLICATIONS:

1. "The Velocity Dependence of the Total Cross Section for Alkali Atoms on Water," J. A. Della Valle, L. F. McGuire, E. Pollack, and T. I. Moran, Bull. Am. Phys. Soc. Series II. 14:609 (1969).

2. "Velocity Dependence of the Total Cross Section of K on Ar," J. A. Della Valle, E. Pollack, T. I. Moran, and L. McGuire, Bull. Am. Phys. Soc. Series II. 14:971 (1969).

3. Ph.D. Thesis, J. A. Della Valle: "The Velocity Dependence of the Total Cross Section for K-Ar and K, Rb, Cs-H_2O Collisions," (Univ. of Conn., 1970).

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ABSTRACT:

The experiments studied and quantified the long range interactions between K, Cs, Rb atoms and H_2O molecules, using atomic beam scattering techniques. In these studies the alkali beam was thermally generated, subsequently velocity filtered, and directed upon target H_2O molecules. The ensuing collisions between the incident alkali atoms and water molecules results in a diminution of alkali beam intensity at the beam detector. Measurements of the amount of alkali beam attenuation resulting from collision (and deflection) of the alkali beam as a function of the beam velocity provides the experimental information from which we obtain the power of r in the expression for the interaction potential $V(r) = \frac{-c}{r^s}$. Results are reported for each of the alkali-water systems mentioned above. The values of s are 6.00, 5.88 and 6.13 for K, Rb, and Cs respectively.

KEYWORDS:

Alkali
Attenuation
Atomic beam scattering
Long range interaction