LASER PROBING of

TRANSPORT PROPERTIES and

ROTATIONAL ALIGNMENT of

N_2^+ DRIFTED in He

by

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Laser Probing of Transport Properties and Rotational Alignment of N_2^+ Drifted in He

Thesis directed by Professor Adjoint Stephen R. Leone
and Research Professor Veronica M. Bierbaum

Results of transport property and rotational alignment experiments of the atmospherically important molecule N_2^+ are presented, as measured in a flow-drift apparatus using the technique of single-frequency laser-induced fluorescence (LIF). A trace amount of N_2^+ is drifted in helium as a buffer gas; the external axial electric field of the drift tube varies the center-of-mass collision energy of the ion-neutral pair. The net effect over hundreds of buffer gas collisions is to establish a steady-state anisotropic ion velocity distribution, the precise character of which is determined by the ion-neutral interaction potential, mass ratio, and field strength. A single-frequency ring dye laser is used to probe Doppler profiles of various rotational lines of the $(v', v'') = (0,0)$ band in the $B\ ^2\Sigma_u^+ - X\ ^2\Sigma_g^+$ system at 390 nm. The single-frequency cw laser technique allows one to measure the velocity component distribution function (VCDF) along the laser propagation direction **k**; the VCDF is a projection of the *complete* ion velocity distribution function. Additionally, the rotational alignment of the ions as a function of one component of sub-Doppler laboratory velocity is probed by polarized LIF.

Drift velocities and ion mobilities are determined from the shift of the first moments of the coaxial LIF Doppler profiles, while perpendicular and parallel translational temperatures are determined from the widths or second central moments of the profiles in the direction probed. Drift velocities measured up to a field strength

of 16 Td appear to be in good agreement with data derived from earlier arrival-time measurements. A small but definite increase in mobility with increasing rotational state from J=13.5 to J=22.5 is observed. A significant difference of over 100 K between the parallel and perpendicular temperatures is measured at the highest field strength employed (16 Td). A small degree of positive skewness or third central moment is observed as well in the parallel VCDF's, which is of particular interest since a high-velocity tail has not been previously reported for any molecular ion system. Additionally, by probing with linearly polarized light and measuring the degree of polarization of the resultant LIF, the collision-induced quadrupole rotational alignment parameter $A_0^{(2)}$ is determined as a function of field strength and velocity subgroup. A strong correlation is found between the degree of rotational alignment and the velocity subgroup when probed parallel to the field direction, with the alignment parameters generally increasing monotonically across the distribution. A dramatic difference in velocity-selected alignment as a function of rotational state is observed as well, for experiments conducted on various rotational lines at a fixed field strength of 12 Td. For sufficiently low rotational state (J about 9), it appears that $A_0^{(2)}$ changes sign across the Doppler profile.

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This thesis is dedicated to the memory of my late grandfather C. Herbert Baxley, who always encouraged me to pursue my highest educational goals regardless of their cost.

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