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Polarization Spectroscopy and Collisions in NaK
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Abstract

We report current work to study transfer of population and orientation in collisions of NaK molecules with argon and potassium atoms using polarization labeling (PL) and laser-induced fluorescence (LIF) spectroscopy. In this experiment, a circularly polarized pump laser excites a specific NaK \( A^2\Sigma^+(v=16, J=1) \) transition, creating an orientation (non-uniform \( M_\text{J} \) level distribution) in both levels. The linearly polarized probe laser is scanned over various 3\( \Sigma^+(v=16, J') \) transitions. The probe laser passes through a crossed linear polarizer before detection, and signal is recorded if the probe laser polarization has been modified by the vapor (which occurs when it comes into resonance with an oriented level). In addition to strong direct transitions \( J=J' \), we also observe weak collisional satellite lines \( J=J'+\pm 1 \) with \( n=1, 2, 3, \ldots \) indicating that orientation is transferred to adjacent rotational levels during a collision. An LIF experiment (with linear polarized pump and probe beams) gives information on the collisional population of different rotational states in the NaK molecule. From these data, cross sections for the process can be determined. We experimentally distinguish collisions of NaK with argon atoms from collisions with alkali atoms.

Polarization Spectra

In order to use polarization spectroscopy on collisionally populated level, collision must (at least partially) preserve \( M_\text{J} \) orientation.

Transfer of Population (Fluorescence Spectroscopy)

Population transfer rates can be modeled using:

\[
\frac{I_{\text{coll}}}{I_{\text{dir}}} = \frac{n_{\text{coll}}}{n_{\text{dir}}} = \frac{4\pi\langle J | m_\text{J} | m_\text{J} \rangle^2}{\langle J | m_\text{J} | m_\text{J} \rangle^2} \]

Density Matrix Model

Necessary to develop a model for the transfer of orientation in a collision between the NaK molecule and an Argon or Potassium atom. We need to solve the density matrix equations of motion for the system of energy levels in question:

\[
\dot{\rho} = -i\sum_a\mu_{aJ_\text{in},J_\text{out}}(\rho_{aJ_\text{out},J_\text{in}} - \rho_{aJ_\text{in},J_\text{out}}) + \text{relaxation terms}
\]

Model input includes collisional population transfer rates \( k_q \) and \( k_p \), along with various other critical experimental parameters (laser power, beam width, temperature, pressure, decay rates, etc.) and outputs \( m_{\text{J}_{\text{dir}}}, m_{\text{J}_{\text{coll}}} \) distribution of level 2 and collisional level. Input transfer rates are varied until agreement with experiment is reached.

Current Computer Model Results

Calculation for \( m_{\text{J}_{\text{dir}}} \) population distribution of directly populated level, given typical experimental parameters.

Modeling of Collisional Orientation Transfer

It is necessary to develop an empirical model for the transfer of population between individual magnetic sublevels of directly populated level and collisionally populated level.

\[ R(m_{\text{J}_{\text{dir}}}, m_{\text{J}_{\text{coll}}}) = f \] for \( \Delta m = 0 \)

Future Plans

Future plans for research include:

- Find an appropriate model for the change in orientation during a collision.
- Take precise data under more controlled conditions as a function of temperature and pressure in order to get more precise values for \( k_q \) and \( k_p \).
- Adjust collisional rate model in order to observe various experimental orientations of collisional levels.
- Look for vibrational transitions in collisions.
- Collaborating group at Temple U. has observed ground state collisional lines for large \( |J| \) in polarization spectroscopy on the RbK molecule.
- Investigate these further.