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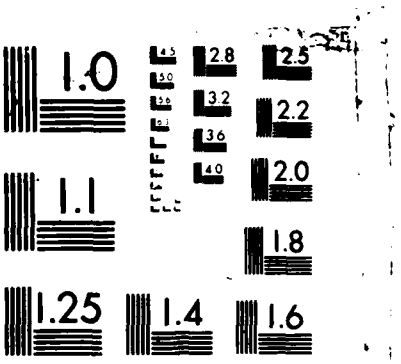

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19. ABSTRACT (Continue on reverse if necessary and identify by block number): Alkali-halogen and alkali-alkali systems have been studied including Na-Br, Na-Cl, Na-Na, and Na*-Na. All atoms were in the ground state except Na*, which represents Na in the first electronic state. Merging-beams techniques were used for the former systems and beam-gas for the latter. Laser radiation was employed to generate Na* either in the beam or the gas. Theoretical predictions of cross sections for Na-Br and Na-Cl have been made by Faist and Levine and are in good agreement with these experimental results. Comparisons of cross sections for Na-Na and Na* show that electronic excitation of Na greatly enhances ion-pair production. Keywords:

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28 May 1985

To: Dr. Ralph E. Kelley/AFOSR

AFOSR-TR- 87-0297

From: Dr. Roy H. Neynaber/La Jolla Institute

Subject: Final Technical Report on Low-Energy Collisions of Excited Atoms

Period: 1 May 1984 - 30 April 1985

Contract Number: F49620-84-C-0058

PROGRAM

Selected ion-pair production, chemi-ionization, and resonant and near-resonant charge-transfer reactions involving excited atoms will be experimentally studied in a range of relative energy from thermal, or threshold, to several hundred electron volts. Reactants of the processes include metastable rare-gas atoms, rare-gas ions, halogen atoms, ground-state and excited alkali atoms and alkali ions. Reactions leading to Li^- are of special interest. The studies will be conducted in merging-beams and beam-gas apparatuses. A laser system will be used in conjunction with this equipment for experiments involving some excited atoms such as Na ($3\,^2P_{3/2}$). Cross sections as a function of collision energy, threshold behavior where applicable, and product-energy distributions will be measured. Existing theories, such as the Landau-Zener-Stueckelberg curve-crossing model for ion-pair production and the Demkov approach for near-resonant charge transfer, will be used to explain the observed data. Attempts will be made to modify these theories to account for discrepancies, new theories will be discussed where possible and the need for additional theoretical effort will be noted.

ACCOMPLISHMENTS

The research accomplished on Contract F49620-84-C-0058 for the period 1 May 1984 - 30 April 1985 is cited below.

1. We prepared a manuscript of our measurements of the laser excited Na atoms in a fast (keV) beam entitled "Fractional Determination of Excited

Atoms Produced by Collinear Laser and Fast Na Beams." This is the first measurement of this type. The paper has been published in the Journal of Physics B.

2. Our primary goal during the past year has been to prepare for studying the reaction $Li + Na^* \rightarrow Li^- + Na^+$, where Na^* represents excited Na in the $3p\ ^2P_{3/2}$ state. This reaction could eventually result in the production of intense Li^- beams and finally, through stripping, to equally intense Li neutral beams. The latter are of importance in Air Force applications. One of the first requirements in achieving this goal was to produce a fast (several keV) Na^* beam. This was done by exciting a fast beam of ground-state (GS) Na atoms in a laser. A detailed description of the process has been published (see #1 above). The original intent was to use merging beams for studying the $Li + Na^*$ reaction, but it was decided to use a beam-gas method instead because the fraction of excited Na atoms was only about 6% rather than the expected 30%.

We decided to investigate the ion-pair producing reaction $Na^* + Na \rightarrow Na^- + Na^+$ before the Li reaction because we had a cell for producing Na vapor and not one for Li. The vapor in such a cell is the gas that is reacted with the fast Na^* beam. Not only did we measure absolute and relative cross sections, Q, for this process but also for $Na + Na \rightarrow Na^- + Na^+$, where all species are in the GS. The relative energy W of the measurements was in the range $500 \leq W \leq 2750$ eV. The results clearly show that ion-pair production is greatly enhanced by exciting the Na. The Q that were actually measured are given below:

$$Na + Na \xrightarrow{Q_1} Na^- + Na^+ \quad (1)$$

$$Na + Na \xrightarrow{Q_2} Na^+ + Na^{-*} \quad (2)$$

$$Na_a^* + Na_b \xrightarrow{Q_3} Na_a^+ + Na_b^- \quad (3)$$

$$Na_a^* + Na_b \xrightarrow{Q_4} Na_a^- + Na_b^+ \quad (4)$$

$$Na_a^* + Na_b \xrightarrow{Q_5} Na_a^+ + Na_b^{-*} \quad (5)$$

$$Na_a^* + Na_b \xrightarrow{Q_6} Na_a^{-*} + Na_b^- \quad (6)$$

The subscripts a and b identify a specific atom and relate each product to its parent. The Na, Na^+ and Na^- represent GS particles. The Na^* is laser excited Na in the $3p\ ^2P_{3/2}$ state. The Na^{-*} is excited Na^- in the $3s3p\ ^3P$ state and is a so-called shape resonance with a very short ($< 10^{-14}$ s) half life.

3. In #1 above we mentioned our work on exciting a fast (keV) beam of Na atoms. We have recently succeeded in exciting and measuring the excitation of Na vapor in a cell. We are now preparing a manuscript for publication of the results.

4. We have measured absolute and relative Q for the ion-pair production process $Na + Cl \rightarrow Na^+ + Cl^-$. The results can be explained by a theory of Faist and Levine which employs a modified Landau-Zener-Stueckelberg model. We have used this reaction to measure the fraction, f^*, of Na^* produced in a vapor of Na (see #3). The f^* is obtained by measuring the Cl^- product with the laser on and off. The technique works because the reaction proceeds with a GS Na reactant but not with a Na^* reactant. We are preparing a paper of this research for publication.

5. We have conducted some preliminary investigations of the reactions $Li + Na^* \rightarrow Li^-(Li^+) + Na^+(Na^-)$ and $Li + Na \rightarrow Li^-(Li^+) + Na^+(Na^-)$ in which a fast (keV) beam of Li passes through a vapor of GS Na or Na^*. The W was in the range 766 to 4214 eV. As expected, the production of a Li^- beam is greatly assisted by laser excitation of Na.

6. We have fabricated a cell for producing Li vapor and have briefly used the cell for studying $Na^* + Li \rightarrow Na^+(Na^-) + Li^-(Li^+)$ and $Na + Li \rightarrow Na^+(Na^-) + Li^-(Li^+)$. The experiments were for $234 < W < 1286$ eV. The Q results appear to be consistent with those in #5 in the W-region of overlap and show an increase of Li^- production when Na is excited.

PUBLICATIONS

1. R. H. Neynaber and S. Y. Tang, "Ion-Pair Production in Collisons of Na and Br," J. Phys. B17, 3565 (1984).

2. D. P. Wang, S. Y. Tang and R. H. Neynaber, "Fractional Determination of Excited Atoms Produced by Collinear Laser and Fast Na Beams," J. Phys. B18, L5 (1985).

PARTICIPANTS

The participants in the research described above are Dr. R. H. Neynaber, Dr. S. Y. Tang and Mr. D. P. Wang (graduate student).

USE OF RESULTS

The Air Force Weapons Laboratory at Kirtland Air Force Base is interested in the production of Li beams and, thus, in our results of the $Li\text{-}Na^{*}$ study. A copy of this report is being sent there to Capt. G. McHarg of Advanced Concepts/NTYP.

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