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DYNAMICS OF COLLISION PROCESSES

Progress Report

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I. ABSTRACT

Investigations have been carried out of two– and three–photon detachment of the negative hydrogen ion (H^-) including effects of electron correlations, of two–color detachment of H^- with excitation of H(n=2), and of the $^3P^e$ state of H^-. Striking effects of long–range dipole field interactions have been demonstrated. Electron correlation effects on detachment cross sections have been quantified. Variational R–matrix calculations of photodetachment of Li^- have provided state–of–the–art agreement with recent experimental results. Electric Field effects on photodetachment of H^- above the H(n=2) threshold have also been elucidated.

II. COMPLIANCE

Neither the scope of investigations nor the effort of the principal investigator to this project have deviated from what was proposed. During the present project period the principal investigator devoted 25% of time to this project during 1 August 1992 – 31 July 1993.

III. BIBLIOGRAPHY

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2. C.R. Liu, B. Gao, and A.F. Starace, VARIATIONALLY STABLE–TREATMENT OF TWO– AND THREE–PHOTON DETACHMENT OF H^- INCLUDING ELECTRON–CORRELATION EFFECTS, Phys. Rev. A **46**, 5985 (1992).

3. N.Y. Du, A.F. Starace, and N.A. Cherepkov, RESONANT TWO–COLOR DETACHMENT OF H^- WITH EXCITATION OF H(n=2), Phys. Rev. A (in press).

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5. C. Pan, A.F. Starace, and C.H. Greene, PHOTODETACHMENT OF Li^-, Bull. Am. Phys. Soc. **38**, xxx (1993).

6. N.Y. Du, A.F. Starace, and M.Q. Bao, PHOTODETACHMENT OF THE $^3P^e$ STATE OF H^-, Bull. Am. Phys. Soc. **38**, xxx (1993).

IV. SUMMARY OF OVERALL PROGRESS

A. Variationally Stable Treatment of Two– and Three–Photon Detachment of H^- Including Electron–Correlation Effects [Bibliography Item No. 2].

We have recently presented a variationally stable, adiabatic hyperspherical treatment of two– and three–photon detachment of H^-. Results were compared with analytic predictions of a zero–range potential model of H^-. Detailed comparisons were made also with other theoretical results which include the effects of electron correlations. We predicted analytically (and demonstrated numerically) an extreme sensitivity of the theoretical predictions to any errors in the value of the electron affinity employed. We also showed that the low–intensity limit of the Keldysh treatment [Sov. Phys. JETP **20**, 1307 (1965)] of detachment of an electron bound in a zero–range potential agrees with the results of a perturbative treatment. Our calculated two– and three–photon detachment cross sections for H^- agree best with those of Mercouris and Nicolaides [Phys. Rev. A **45**, 2116 (1992)].

B. Resonant Two–Color Detachment of H^- with Excitation of H(n=2) [Bibliography Item No. 3].

We have calculated the cross sections for resonant two–color, two–photon detachment of H^- with excitation of the degenerate H(2s) and H(2p) levels within a semiempirical adiabatic hyperspherical representation. The first photon, with energy $\omega_1 = 0.4017$ a.u., was chosen to be resonant with the well–known Feshbach $^1P^o$ resonance below the H(n=2) threshold. The second photon, with energy $\omega_2 \geq 0.12605$ a.u., was chosen to scan the energy region above the H(n=2) threshold over which long–range dipole–field–induced cross section oscillations are predicted to occur. Such Gailitis–Damburg oscillations have not yet been observed experimentally. Results for various pairs of light polarization for the two–photons were calculated. Our resonant two–color, two–photon detachment cross sections are 8–9 orders of magnitude greater than the corresponding nonresonant, single–color, two–photon detachment cross sections obtained by C.R Liu, N.Y. Du, and A.F. Starace [Phys. Rev. A **43**, 5891 (1991)]. Unmistakable evidence of long–range dipole field effects was demonstrated over the 5 meV energy range above the H(n=2) threshold. Furthermore, the differential cross sections for right– and left–circularly polarized, copropagating photons and especially the circular dichroism differential cross sections were found to have nearly a full cycle of a greatly enhanced dipole–field–induced oscillation extending over the region from threshold to $\approx$ 34 meV above.

C. Electric–Field Effects in H^- Photodetachment with Excitation of H(n=2) [Bibliography Item No. 4.].

Our adiabatic hyperspherical transition amplitudes for photodetachment of H^- were recently employed in a frame transformation theory approach to the calculation of photodetachment of H^- in an external electric field. We found that in the shape resonance region above H(n=2), the cross section increases with increasing electric field. The cross section for linearly polarized light along the electric field is much stronger than that for circularly polarized light. The width of the $^1P^o$ shape resonance is not found to change monotonically with the electric field.

D. Photodetachment of Li^- [Bibliography Item No. 5.].

In the past 6 months we have developed a variational R–matrix description of negative alkali metal systems. The first application of this description to photodetachment of Li^- has provided state–of–the art agreement with recent data of D.J. Pegg's group [J. Dellwo et al., Phys. Rev. A **45**, 1544 (1992)]. We are now able to obtain accurate results beyond the Li (n=3) threshold.

E. Photodetachment of the $^3P^e$ State of H^- [Bibliography Item No. 6].

The $^3P^e$ state of H^- has been predicted theoretically to be bound below the H(n=2) threshold. However, it has never been observed experimentally. We have calculated the photodetachment cross section for this state using an adiabatic hyperspherical representation. The inverse process, the radiative capture process, may play a significant role in astrophysical plasmas. Its cross section is related to the photoionization process that we calculate by the Principle of Detailed Balance. Our results for detachment to the H(2p) state agree well with previous results of Jacobs, Bhatia, and Temkin [Astrophys. J. **242**, 1278 (1980)]. A slight disagreement for detachment to the H(2s) state is currently being investigated further.

F. Hyperspherical Coordinate Description of Single– and Multiphoton Processes in Two–Electron Systems [Bibliography Item 1].

Much of our research that has been supported by DOE over many years was recently reviewed critically and placed in context with the theoretical work of others and with experimental measurements.

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