Angular Dependence of the Translational Energy Distribution of the Excited Hydrogen Atom (N=3) Produced in Electron-Hydrogen Collisions

Higo, Morihide  
Faculty of Engineering, Kagoshima University

Kamata, Satsuo  
Faculty of Engineering, Kagoshima University

Ogawa, Teiichiro  
Department of Molecular Science and Technology, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University

肥後, 盛秀  
鹿児島大学工学部

他

https://doi.org/10.15017/17591

出版情報：九州大学大学院総合理工学報告. 6 (1), pp.17-20, 1984-06-01. 九州大学大学院総合理工学研究科
バージョン：published
権利関係：
Angular Dependence of the Translational Energy Distribution of the Excited Hydrogen Atom (n=3) Produced in Electron-Hydrogen Collisions

Morihide HIGO*, Satsuo KAMATA* and Teiichiro OGAWA**

(Received February 3, 1984)

The Balmer-α line produced in e-H2 collisions was measured at 55° and 90° with respect to the electron beam (75 eV); the line shape was recorded at an optical resolution of about 0.04 Å with the use of an interferometer. The line shape measured at 55° disagreed with that measured at 90°. The translational energy distributions of H* (n=3) were calculated, and the results at 55° and 90° disagreed each other. These differences and positive polarization of the Balmer-α line indicate that the dissociation process of the hydrogen molecule is anisotropic.

1. Introduction

When a molecule is excited by an electron beam, the fragment atoms may have the angular distribution. This distribution is correlated with symmetries of the ground and the excited molecular states. The angular distributions of H*(n=4), H* and H (2s) produced by electron impact on H2 have been found to be anisotropic and have provided information on the excited states and their dissociation mechanism.

The Doppler line shape reveals the translational energy distribution of the emitting species and is useful for the investigation of the dissociation dynamics. The Doppler line shape and its angular dependence have been measured with a high resolution interferometer; some angular dependence of the line shape has been found for H* from HCl, but anisotropy in the line shape has been smaller than the experimental uncertainty for H* from H2. Meanwhile the Balmer lines from H2 have been found to be polarized.

The Doppler line shape and the polarization of the atomic line should be dependent on the angular distribution of the emissive atom. Since H2 is the most basic molecule, the angular dependence of the line shape of H* is worth studying for clarifying the molecular dissociation dynamics.

In the present report, we will show the angular dependence of the line shape and the translational energy distribution of H*(n=3) from H2 and the polarization of the Balmer-α line. They are found to be anisotropic and the results are compared with those of the angular dependence of the emission intensity.

2. Experimental

The apparatus is the same as that
described before\textsuperscript{10,14}. The H\textsubscript{2} gas was jetted into the collision region and collided with the electron beam. The Balmer-\( \alpha \) line was observed at 55° and 90° with respect to the electron beam. The angular resolution was estimated to be about 3°.

The spectrum was measured with a Fabry-Pérot interferometer (Mizoziri Optics). The finesse used was 70-75; the optical resolution was 0.040–0.043 Å. Photons were detected with a cooled photomultiplier (HTV R649) and counted with a photon counter (NF PC 545A). Polarization was measured at 90° with an optical polarizer (Fuji Optics) and a monochromator (Spex 1269).

The experimental conditions were identical with the previous paper\textsuperscript{9} for the Balmer-\( \beta \) line, where factors affecting the reliability of the results were discussed.

3. Results and discussion

The spectra of the Balmer-\( \alpha \) line from H\textsubscript{2} observed at 55° and 90° are shown in Fig. 1 (left). In the case of the Balmer-\( \beta \) line, disturbance from molecular radiation makes it difficult to investigate the angular dependence in detail\textsuperscript{10} However, the Balmer-\( \alpha \) line needs no such correction.

The translational energy distribution of H\( ^\ast \textsuperscript{\text{n}=3} \) was calculated as described in the previous papers\textsuperscript{9,10} as shown in Fig. 1 (right). These distributions were smoothed once using a three-point least-square routine; errors in the distribution are mainly due to random fluctuations.

The line shapes taken at two angles seem alike but are different. The difference is clearer in the translational energy distribution of the fast hydrogen atom (\( >2\text{ eV} \)); the distribution taken at

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig1.png}
\caption{High resolution (0.043 Å) spectra of the Balmer-\( \alpha \) line produced by electron impact (75 eV) on H\textsubscript{2} (left) and translational energy distribution of H\( ^\ast \textsuperscript{\text{n}=3} \) (right).
Electron-beam current: 800 \( \mu \text{A} \).
Operating pressure: \((4-5) \times 10^{-4}\) Torr.}
\end{figure}
90° has a sharp peak at about 7 eV, whereas that taken at 55° has a broad peak. The distribution of the slow hydrogen atom (<2 eV) seems to be isotropic within experimental uncertainties. Thus, we can conclude that the dissociation process for the formation of the fast H* atom is anisotropic. This conclusion is consistent with that of the angular dependence of the emission cross section.

The fast H* atom is produced by direct dissociation through Rydberg states, \((2\sigma_u) (3I)\) converging to the \(^7\Sigma_u^+ (2\sigma_u)\) state of H\(_2^+\), and by predissociation through a curve crossing from the \((2\sigma_u) (2I)\) state to the \((1\sigma_g) (3I)\) state. The slow H* atom is produced by direct dissociation and predissociation through Rydberg states, \((1\sigma_g) (3I)\). The dissociation through highly repulsive curves shows a noteworthy angular dependence; while, if many dissociation states with different symmetries are contributing, or if the 3s atom is produced, the anisotropy can disappear.

Polarization of the Balmer-α line is shown in Fig. 2. The result is consistent with the previous work within experimental uncertainty. The polarization depends on the electron energy; it rises above the threshold (at about 17 eV) to a maximum at about 35 eV, and then decreases with electron energies. Since the angular distribution and the polarization is closely related, the observed polarization is mostly due to the anisotropy of the fast H* atom.

The fast H* ion produced by electron impact is also anisotropic and has a forward-backward anisotropy; the distribution of H* observed at 23° has a peak at 8 eV, that at 42° has a broad peak and that at 90° has a peak at 6 eV.

The translational energy distribution can clarify the anisotropy in the formation of the excited atom, and the present result is the first report on the anisotropic distribution of H* from H\(_2\). There is a clear need for the angular measurement in investigating the dissociative excitation of molecules.

Acknowledgments

The authors thank Junichi Kurawaki for his cooperation and Professor Nobuhiko Ishibashi of Kyushu University for his encouragement. The present study was partially supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture.

References