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

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

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The Balmer-α line produced in e-H_2 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[1)~4)]. This distribution is correlated with symmetries of the ground and the excited molecular states[2)3)]. The angular distributions of H*(n=4)[5)], H^{+}[6)] and H (2s)[7)] produced by electron impact on H_2 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 dustribution 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 [8)9)], but anisotropy in the line shape has been smaller than the experimental uncertainty for H* from H_2[10)]. Meanwhile the Balmer lines from H_2 have been found to be polarized[11)].

The Doppler line shape and the polarization of the atomic line should be dependent on the angular distribution of the emissive atom[12)13)]. Since H_2 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 H_2 and the polarization of the Balmer-α line. They are compared with those of the angular dependence of the emission intensity.

2. Experimental

The apparatus is the same as that

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described before[10)14)]. The H_2 gas was jetted into the collision region and collided with the electron beam. The Balmer-α 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 Opitics). The finesse used was 70–75; the optical resolution was 0.040–0.043 Å. Photons were detected with a cooled photomultiplier (HTV R 649) 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[10)] for the Balmer-β line, where factors affecting the reliability of the results were discussed.

3. Results and discussion

The spectra of the Balmer-α line from H_2 observed at 55° and 90° are shown in **Fig. 1 (left)**. In the case of the Balmer-β line, disturbance from molecular radiation makes it difficult to investigate the angular dependence in detail[10)] However, the Balmer-α line needs no such correction.

The translational energy distribution of H*(n=3) was calculated as described in the previous papers[9)15)] 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 eV); the distribution taken at

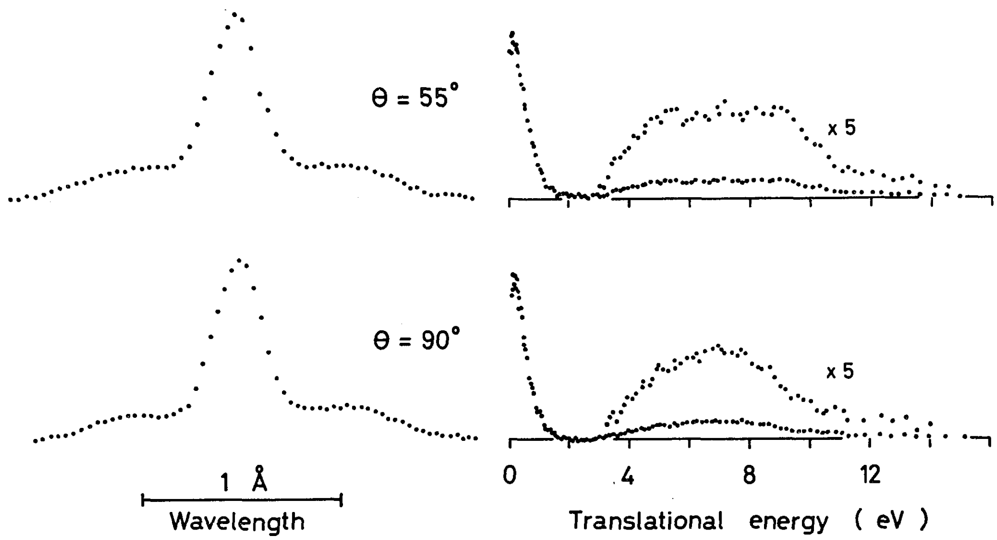

Fig. 1 High resolution (0.043 Å) spectra of the Balmer-α line produced by electron impact (75 eV) on H_2 (left) and translational energy distribution of H* (n=3) (right).

Electron-beam current: 800 μA.
Operating pressure: $(4-5)\times10^{-4}$ Torr.

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 prosess 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[5].

The fast H* atom is produced by direct dissociation through Rydberg states, $(2p\sigma_u)(3l)$ converging to the $^2\Sigma_u^+(2p\sigma_u)$ state of H_2^+, and by predissociation through a curve crossing from the $(2p\sigma_u)(2l)$ state to the $(1s\sigma_g)(3l)$ state[16]. The slow H* atom is produced by direct dissociation and predissociation through Rydberg states, $(1s\sigma)(3l)$[16]. 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[11] 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[17], 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; [6] 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[18].

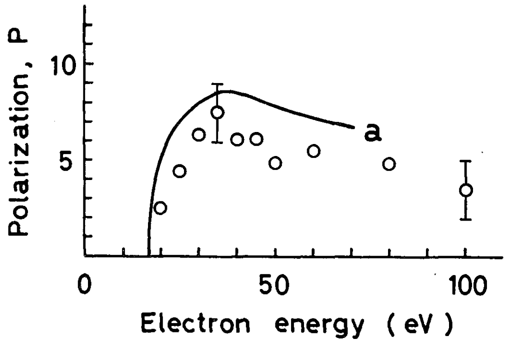

Fig. 2 Polarization of the Balmer-α line. $P = (I_{11} - I_\perp)/(I_{11} + I_\perp) \times 100$.
(a) Karolis and Harting[11]

Spectral resolution:	8 Å
Electron-beam current:	100 μA.
Operating pressure:	$(4-5)\times10^{-4}$ Torr.

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.

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