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The Emission Cross Section of the Paschen-α Line Produced in Electron-Hydrogen Collisions

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The Paschen-α line (1875.1 nm) of the excited hydrogen atom produced in e-H_2 collisions was observed with a grating spectrometer equipped with a PbS detector. The emission cross section was determined to be 0.95×10^{-19} cm^2 at 100 eV .

Emission spectra in the infrared region induced in electron-molecule collisions have been scarcely investigated due to experimental difficulty, although there have been many investigations in the UV-VIS region. The largest difficulty arises from the lack of a high sensitive photodetector in the infrared region as a photomultiplier in the UV-VIS region, and a faint optical emission in the infrared region is difficult to measure. Nevertheless assignments and cross sections of the infrared emission are vital for understanding plasma processes, stratospheric phenomena, aurora and interstellar reactions.

There are a few papers dealing with the infrared emission induced in electron collisions. Vibrational excitation cross sections of HCl were measured in a low pressure cell.[1] Vibrationally excited OH radicals were observed in the electron impact of water vapor at 1×10^{-2} Torr.[2] Excitation function of the 5d levels of Xe was obtained at 4×10^{-3} Torr.[3] The emission cross section of the Paschen line of the excited hydrogen atom, however, has never been measured, although the hydrogen atom is the most basic species for the above applications. Its emission cross section would also be important for a discussion of the formation mechanism of various electronic levels in the electron-hydrogen collisions.[4] We have constructed an apparatus for a measurement of the optical emission in the infrared region produced in the electron-molecule collisions.

The schematic diagram of the experimental apparatus is shown in Fig. 1. The main chamber is a stainless-steel pipe (diameter: 40 mm) equipped with an electron gun, a Faraday cup and two quartz windows.

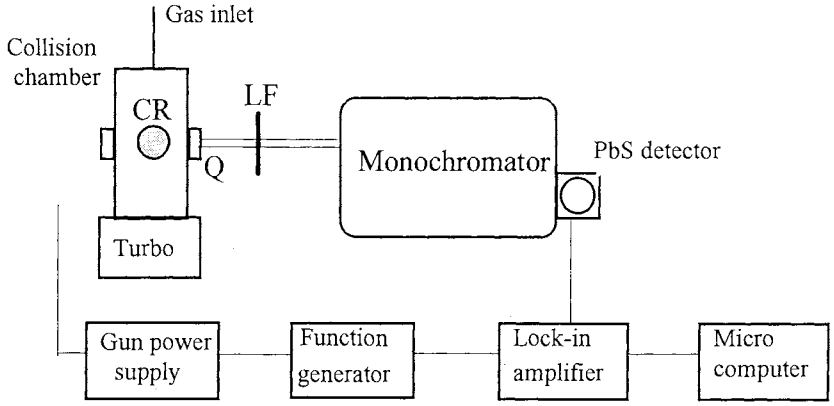

Fig. 1. Schematic diagram of the experimental apparatus.
CR.: collision region, FL: lens and filter, Q: quartz window.

The chamber was evacuated with a turbomolecular pump (Osaka Vac. TF150, 150 l/s), and the base pressure was about $2x10^{-6}$ Torr. The sample gas was introduced through a pipe (5 mm). The typical operating pressure measured at the wall of the collision chamber by an ionization gauge (ULVAC GI-TL2) was about $2x10^{-4}$ Torr. The electron gun has a tungsten filament coated with an oxide coating and a magnetic coil of about 2 mT for collimation. The electron beam was chopped at 130 Hz.

The optical radiation was measured with a monochromator (JASCO CT-50, 50 cm, f = 6.8) equipped with a grating (600 grooves/mm) blazed at 1600 nm. A color filter (Toshiba UV-37, 400-2000 nm) or an interference filter (Andover, 1000-2000 nm) was used to separate the optical radiation. Photons were detected with a PbS detector (Hamamatsu P3337-1) cooled at a dry-ice temperature and equipped with a preamplifier. The optical response of the apparatus was obtained with a halogen lamp (Ushio JC12-50), which was calibrated against a secondary standard lamp (Ushio JPD-100-500) calibrated at Electrotechnical Laboratory (Tsukuba, Japan). The preamplifier output was fed into a lock-in amplifier (NF 5584) and a microcomputer (EPSON PC286VG) for data processing.

The intensity of the Balmer-α and β line was proportional to the electron beam current (0.05 - 2 mA) and the gas pressure (0.5 - 4 x 10^{-4} Torr), and the intensity ratio of the Balmer-α to β lines was constant within this region. This finding indicates that the excited hydrogen atom (n=3,4) was produced in a one-electron-one-molecule primary collision process.

$$H_2 + e \rightarrow H^*(n=3,4) + H + e$$

The typical line profiles of the Paschen-α line and the second order of the Balmer-α line (appeared at 1312.56 nm) are shown in Fig. 2; the slit width of the monochromator was 5 mm and the optical resolution was about 12 nm at 1875 nm. The relative intensity of the Paschen-α line to the second order of the Balmer-α line was measured. The emission cross section of the Paschen-α line was obtained by normalizing its intensity to the reported emission cross section of the Balmer-α line.[5] The emission cross section of the Paschen-α line was determined to be (0.95±0.12) x 10^{-19} cm^2. The largest source of uncertainty was random scattering of the observed intensity of the Paschen line, because it is very weak.

The authors believe that this letter is the first publication on the emission cross section in the infrared region of an excited fragment species produced in electron-molecule collisions.

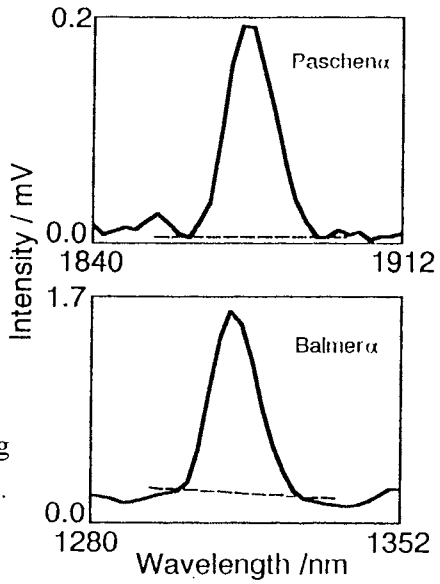

Fig. 2 Line profile and base line.

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