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POLARIZATION OF LIGHT EMITTED FROM THE EXCITATION OF H_2 BY ELECTRON IMPACT*

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During the last few years several experimental investigations[1] have been made on the polarization of atomic line radiation excited by electron impact. We report for the first time the measurement of the polarization of molecular line radiation excited by electrons in a single collision process. This observation of polarization affords a convenient experimental technique for the study of the fine and hyperfine structure in short-lived molecular states.

The orthohydrogen emission line at $\lambda = 6226$ Å, corresponding to the first rotational Q-branch transition from the $^3\Pi_u$ $(1s3p) \rightarrow {}^3\Sigma_g$ $(1s2s)$ electronic states, was excited in a gas-filled tube by a cylindrical electron beam. Over 30 lines were observed by scanning the spectral region around 6200 Å and were assigned to the $^3\Pi_u \rightarrow {}^3\Sigma_g$ band system.[2] For polarization measurements, the transition at 6226 Å was chosen since it could easily be isolated from neighboring lines by means of an interference filter with a full bandwidth of 8 Å.

The experimental technique is similar to that used for the excitation of atoms by electron impact, and the schematic of the apparatus is shown in Fig. 1. The electron gun consisted of an oxide-coated cathode, two gold-plated accelerating grids, a field-free interaction region, and an anode. The current collected at the anode was usually from 1 to 10 μA, and constant anode current was maintained during a sweep of the electron energy by means of a Kepco operational amplifier between the plate and the first accelerating grid. A magnetic field of at least 50 G parallel to the direction of the electron beam was used in order to avoid surface charge effects due to the walls of the surrounding glass tube. The system was continuously pumped, and typical pressures were approximately 1 μ.

The intensity of radiation from the interaction region polarized in a direction parallel, $I_{\parallel}$, and perpendicular, $I_{\perp}$, to the electron beam

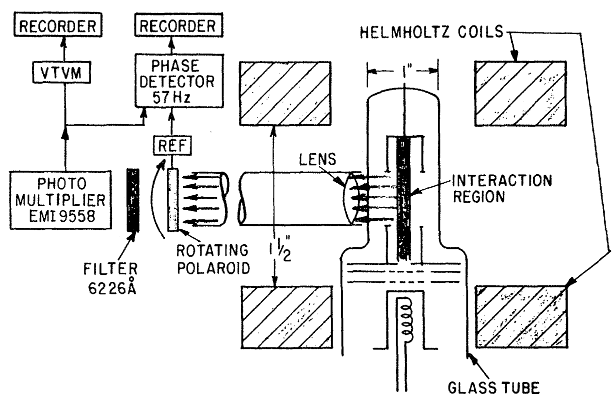

FIG. 1. Schematic diagram of experimental apparatus.

was measured as a function of the electron energy. The emitted light was first passed through the interference filter, then through a polaroid rotating at 57 Hz, and finally into a photomultiplier. The dc signal from the photomultiplier, proportional to $I_{\parallel}+I_{\perp}$, was measured with a vacuum-tube voltmeter, and the ac signal, proportional to $I_{\perp}-I_{\parallel}$, was simultaneously observed as the output of a 57-Hz phase detector. The detection system, i.e., the phase detector versus vacuum-tube voltmeter, was calibrated at the beginning and end of each sweep of the electron energy by inserting polaroid sheets into the path of the light beam, thereby allowing only $I_{\perp}$ or $I_{\parallel}$ radiation to be detected. Polarization measurements at various values of the electron energy made with the rotating polaroid were in agreement with those obtained by manual rotation of the polaroid.

The following points substantiate the view that the polarization of light was due to molecular radiation from H_2 and not due to an instrumental effect.

(1) The observed polarization of light decreased with increasing electron energy. The authors believe that their results on polarization are correct within the limits of electron beam resolution, which, of course, excludes great detail on threshold behavior but gives a correct over-all result.

(2) The background radiation, where there was no emission line by appropriate rotation of the filter and at 6226 Å below 14 eV, was polarized with $I_{\perp}$ greater than $I_{\parallel}$ and was independent of electron energy. The signal at 6226 Å above threshold showed an increase of $I_{\parallel}$ over $I_{\perp}$.

(3) The angular aperture of the apparatus was less than 6°; consequently, angular corrections to the observed polarization would be small.

(4) The contribution of the intensity of neighboring lines at 6226 Å was approximately 12% of the total signal, but by rotation of the filter to shorter wavelengths it was possible to reduce this contribution to less than 1% and still observe the 6226-Å line. The polarization of the observed signal was independent of the filter's position within 1%.

(5) Several electron guns of different geometry were used, employing various collecting grids, and again there was no difference in the observed polarization at the particular pressure range studied.

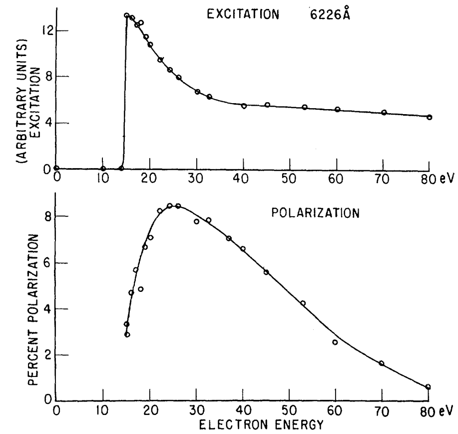

FIG. 2. Excitation and polarization curves.

Polarization and excitation curves, corrected for background, for the line at 6226 Å are shown in Fig. 2. An excitation threshold of approximately 14.7 eV was observed which is about 0.3 eV above the experimental spectroscopic values. The intensity of the excited hydrogen line was proportional to the gas pressure as well as to the electron beam current. A maximum polarization of about 8% is observed just above threshold, and the polarization decreases continuously as the electron energy is increased.

A more detailed description of the experimental apparatus, additional information on the pressure dependency, and theoretical calculations of the polarization will be published shortly.

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[2]E. W. Foster and Sir Owen Richardson, Proc. Roy. Soc. (London) A189, 149 (1947).