Electron Induced Excitation of H_2 and D_2 Leading to Continuum Radiation

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The need for the improvement of fundamental data on the electron – molecule interactions due to the interest in subject, mainly in fusion physics, led us to the re-investigation of the hydrogen molecule excitation reactions. Low energy (0-100eV) electron interaction with hydrogen molecule can lead to excitation of the molecule and subsequent emission of fluorescence radiation. In range 200 – 670 nm at 14 eV electron impact energy, the radiation originating from $a^3\Sigma_g^+ \rightarrow b^3\Sigma_u^+$ transition were observed. In previous experimental studies the emission from this transition was reported to be present at wavelengths less than 500 nm. We observed the fluorescence above this limit. Further, we extended our investigation to D_2.

1. Introduction

Hydrogen molecule has been examined in detail in the past, both theoretical and experimental studies have been performed [1-3]. Electronic structure of the molecule is well described in literature [4], as well as different types of cross sections [5] which are an important parameter in modelling in the plasma physics field. Electron-hydrogen molecule collisions at the plasma edge in fusion reactors puts hydrogen on the top of the list of molecules whose behaviour is important to understand at fundamental level [6]. Due to the plans for hydrogen and its isotopes to be used in new generation of electrical power plants, it is crucial to obtain precise cross sections for electron interactions.

For examination of elementary processes between electrons and molecules in gas phase, we are using the electron induced fluorescence apparatus (EIFA). Electron induced fluorescence is a cross – beam technique. Collimated monochromatic low energy (0 – 100 eV) electron beam encounters the molecules emerging into the vacuum chamber through the effusive capillary inside the reaction chamber where the single electron/molecule collision occurs. Such reaction can lead to generation of excited species which subsequently emit a photon. With this technique we are able to observe both neutral and charged species deexcitation.

2. Experiment

EIFA (Figure 1) consists of a vacuum chamber where trochoidal electron monochromator (TEM) is placed, optical system and gas inlet system. Electron beam is created within the TEM: electrons are thermally emitted from the hairpin filament and led through the series of electrodes until they reach the dispersion region where crossed magnetic and electric field separate emerging electrons based on their energy. The energy resolution at hundreds of nanoamperes is 0.5 eV. Monoenergetic electrons encounter molecules led through the effusive capillary form the gas inlet system. The base pressure inside the vacuum chamber is not higher than 10^{-8} mbar, and working pressure is set to 10^{-4} mbar so the single electron/molecule interaction event is observed.

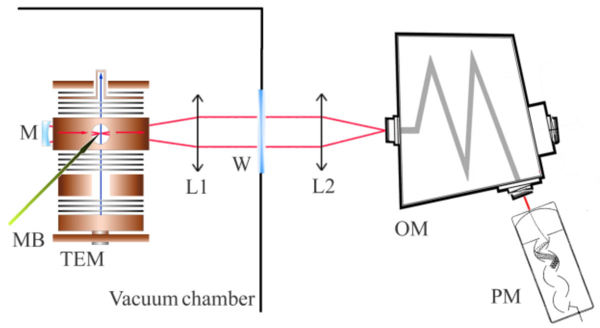

Figure 1. The scheme of the EIFA. MB-molecular beam, TEM-trochoidal electron monochromator, M-mirror, L1-lens, W-window, L2-lens, OM-Czerny-Turner optical monochromator, PM-photomultiplier [7]

Photons emitted as a result of deexcitation of species produced in these interactions are guided through the optical system (mirror, lenses, window and Czerny Turner optical monochromator) to the photomultiplier. Optical resolution of the monochromator is 0.4 nm at 200 µm slits. Based on the response range of the photomultiplier and the optical monochromator working range, with EIFA we can observe photon signals from 200 – 670 nm.

EIFA is able to perform two modes of measurement: 1) emission spectrum scanning at fixed electron energy and 2) photon efficiency curve (PEC) measurement, when the wavelength is set to a certain value and the electron energy changes in time, so the cross sections can be estimated and threshold energies can be found.

2.2. Results and discussion

The emission spectrum of hydrogen molecule was measured in range 200 – 670 nm (Figure 2). Emission spectra measurements at various energies have been performed (14 eV, 25 eV, 50 eV and 100 eV). In this paper we present the 14 eV electron impact energy emission spectrum, which shows the detection of continuum radiation, originating from the H_2 ($a^3\ \Sigma_g^+ \rightarrow b^3\ \Sigma_u^+$) transition, measured for the first time above 500 nm.

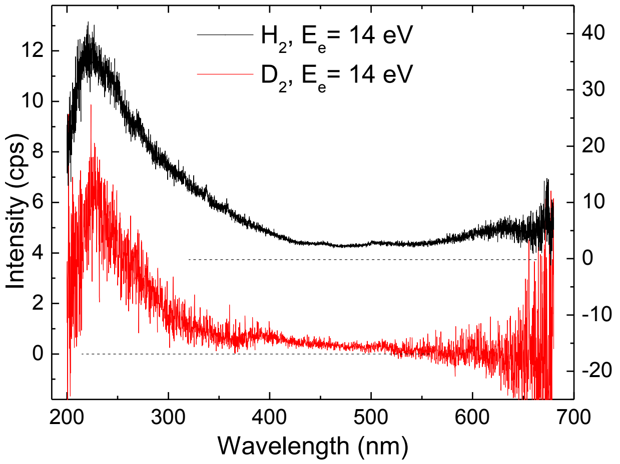

Figure 2. Emission spectrum of H_2 and D_2 at 14 eV electron impact energy originating from H_2 (black) and D_2 (red) ($a^3\ \Sigma_g^+ \rightarrow b^3\ \Sigma_u^+$) radiative transitions.

Below 500 nm the spectrum of H_2 is in reasonable agreement with data obtained by James et al. [8]. For further comparison, deuterium spectrum was measured at the same electron impact energy. In Figure 2 relative intensities of the continua radiation from both hydrogen and deuterium are shown. There we can see the higher intensity of the radiation towards the shorter wavelengths in both H_2 and D_2. Intensity of the H_2 ($a^3\ \Sigma_g^+ \rightarrow b^3\ \Sigma_u^+$) peaks at 194 nm which is under our detection limit. Nevertheless, we are able to observe the emission at wavelengths corresponding to visible light range.

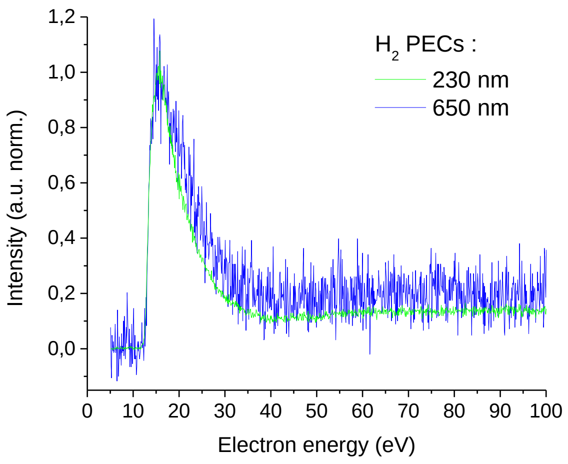

Figure 3. PECs of H_2 ($a^3\ \Sigma_g^+ \rightarrow b^3\ \Sigma_u^+$) at 230 nm (green) and 650 nm (blue).

We performed various PEC measurements in hydrogen and deuterium at different wavelengths. In Figure 3 the comparison of the shape of PECs measured in hydrogen at 230 nm and 650 nm is shown which proves the presence of the continuum radiation in visible range of electromagnetic radiation.

3. Acknowledgement

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