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Electron induced excitations of water relevant for cometary comas

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Abstract

Electron induced processes are abundant in planetary and small body atmospheres. The Rosetta mission to comet 67P/Churyumov-Gerasimneko has revealed the significance of electron induced excitation in the cometary coma. We report the spectra and cross sections for the electron induced fluorescence (EIF) of water.

1. Introduction

The EIF is a useful remote tool for detection of gases present in atmospheres of small bodies and planets. The spectral fingerprint is specific for each atom or molecule and depends on electron energy. The emission spectroscopy was used to identify gases in the coma of comet 67P [1] as well as water plumes at Europa [2]. One of the drawbacks of the mentioned method is the lack of reliable data for electron induced reactions. We report the first results of dissociative electron impact reactions on water molecules which are one of the main constituents of cometary comae.

2. Experiment

The apparatus used for the experiment was described in detail in previous publications [3]. It utilized a crossed beams configuration. The sources of electron (trochoidal electron monochromator) and molecular beams (effusive capillary) are placed in a vacuum chamber with background pressure of ~ 10^{-8} mbar. The experiments were carried out at ~ $1.5x10^{-4}$ mbar. We have checked the linearity of the spectral line intensities with respect to the pressure so that single collision conditions were maintained. The fluorescence radiation was collected by an optical system located perpendicularly to the crossing beams which focused the fluorescence signal onto the entrance slit of an Oriel Cornerstone 260 Czerny-Turner ¼ m optical monochromator. After passing through the optical monochromator, the signal was detected by a low-noise, Peltier-cooled photomultiplier working in the photon counting regime. The measurement was done in two modes: spectral measurement at constant electron energy or cross section measurement at specific wavelength corresponding to one deexcitation. The energy of the electron beam was absolutely calibrated by introducing a mixture of N_2 and H_2O into the apparatus and by measuring the intensity profile of the N_2 ($C\ ^3\Pi_u$–$B\ ^3\Pi_g$)(0–0) band at 337 nm which exhibits relatively sharp maximum at 14.1 eV [4] and intensity profile of the H_β line. Subsequently the profile of the H_β line was aligned with the same measurement in pure water vapour to calibrate the electron energy.

3. Results

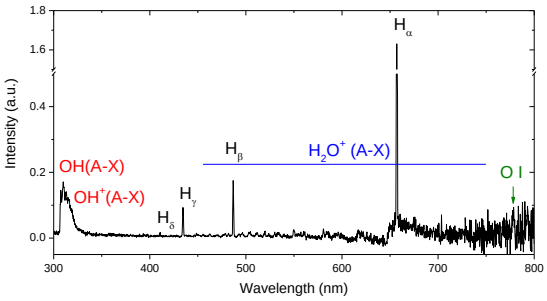

Figure 1: Emission spectrum of water induced by 50 eV electrons impact.

We studied the spectral region between 200 nm and 900 nm. The spectrum shown in figure 1 is corrected for the spectral sensitivity of the experimental device. In the spectrum measured at electron energy 50eV the emission corresponding to deexcitation of atomic hydrogen (Balmer series), OH ($A^2\Sigma^+$-$X^2\Pi$), OH^+ ($A\ ^3\Pi$-$X\ ^3\Sigma^-$) and H_2O^+ ($\tilde{A}^2A_1$-X^2B_1) have been detected. The O I ($3s^5S^0$ – $3p^5P$) at 777 nm line is

very faint, almost hidden within the detector noise. We could not identify any emission features in the spectral region between 800 nm and 900 nm, likely due to the relatively low detector sensitivity in this region.

The detail of the OH (A-X) transition is shown in the figure 2 including the region below 300 nm. All the detected water cation band correspond to the various vibrational transitions of H_2O^+ (A-X) and are present between 450 nm and 750 nm.

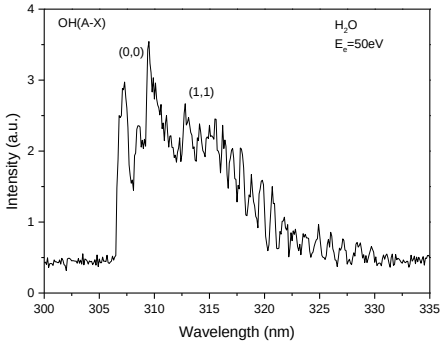

Figure 2: Spectral band corresponding to the deexcitation of OH ($A\ ^2\Sigma^+$-$X\ ^2\Pi$) at impact electron energy 50 eV.

Apart from the spectral measurement the cross sections for the most intensive transitions were determined as well. The energy dependence curves for the Balmer series were measured for transitions H (3-2) to H (7-2). For each cross section the threshold energy was determined by a simple fitting procedure. These values were compared to theoretical thresholds based on enthalpy of formation.

Acknowledgements

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