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Photoabsorption Cross Section Measurements of CO_2 and N_2

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Introduction

Our laboratory research program is organized around the measurement of VUV molecular photoabsorption cross sections with the highest practical resolution. It is explicitly designed to support current efforts to interpret, model, and understand observations of planetary atmospheres. In this user report, we describe new measurements on carbon dioxide (CO_2) and molecular nitrogen (N_2).

Carbon Dioxide

Carbon dioxide is the principal constituent of the atmospheres of Mars and Venus. The photodissociation of CO_2 by ultraviolet solar radiation initiates the production of non-thermal atoms that may escape these atmospheres. The analyses of recent high-quality VUV observations of emission features in the Martian atmosphere and the modeling of non-thermal escape mechanisms from the Martian and Venusian atmospheres are limited by poorly and incompletely characterized CO_2 photoabsorption cross sections. In 2002 we initiated new laboratory measurements, at the Photon Factory, of CO_2 photoabsorption cross sections in the 106 to 120 nm region. In this reporting cycle, we completed our measurements of the 106 – 120 nm region at 295 K and 195 K. A manuscript detailing our results is in preparation.

CO_2 photoabsorption cross sections were measured in the 106 to 120 nm region at a resolution of 0.05 Å. All measurements were carried out on the 3-meter normal-incidence vacuum monochromator on the BL-20A beam line. A 1200 l/mm grating was used in the 1st order to achieve the desired resolution of 0.05 Å. A 12-cm stainless steel absorption cell, mounted behind the exit slit of the monochromator, could be cooled to 195 K by immersion in a dry ice-methanol slush. LiF windows were employed on the cell. Our new results indicate significant spectral structure in the CO_2 absorption cross section that was not resolved in previous, lower-resolution results [1]. There is also clear evidence of systematic underestimation of peak absorption cross sections for the strongest CO_2 features in the earlier measurements – a result of inadequate instrumental resolution.

Molecular Nitrogen

We are measuring fundamental parameters of the absorption spectrum of N_2 in the 80 to 100 nm spectral region to support the analyses of occultation and airglow observations of the N_2-rich atmospheres of Titan, Triton, and Pluto. High-resolution absorption measurements are used to determine band and line oscillator strengths, and line widths. In this reporting cycle, we continued our Photon Factory measurement program on this atmospherically important molecule. In particular, we focused on the determination of accurate line widths for the unusually broad b(3) – X(0) transition at 97.2 nm. The spectroscopic details of this band are needed to guide ongoing theoretical efforts to understand the mechanisms of predissociation in the molecule.

A supersonic jet apparatus was used on the BL-20A beam line to cool the nitrogen molecules to approximately 20 K. With the rotational cooling provided by the expansion jet, the line shapes of the lowest rotational levels of the b(3) state were directly observed for the first time. Preliminary analyses of the measurements reveal a much larger line width for the lowest-J levels than is seen for the higher-J levels accessed in a room temperature measurement. This trend has been theoretically predicted in a recent coupled Schrödinger equation model of the interacting $^1\Pi$ levels of N_2 [2]. A manuscript describing the spectroscopy of the b(3) level of $^{14}N_2$ is now being prepared.

References

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