Experimental scaling of plane-Born cross sections for the electron-impact excitation to the $b^1\Pi_u$ state of N_2 molecule

A. Tanaka*, H. Kato*, M. Hoshino*[1], and H. Tanaka*

*Department of Physics, Sophia University, Tokyo 102-8554, Japan.

Synopsis We report measurements on differential cross sections (DCSs) for electron-impact excitation to the optically-allowed $b^1\Pi_u$ state in molecular nitrogen in the impact energy range of 20 – 400 eV. Absolute excitation DCSs normalized by the relative flow technique were transformed to generalized oscillator strengths (GOSs) as a function of momentum transfer squared. Integral cross sections (ICSs) for the transitions to the $b^1\Pi_u$ state were compared with the BE*f*-scaled plane-Born ICS as well as previous experimental studies.

We have been measuring the electron impact electronic excitation cross sections of atomic and molecular targets [1]. Molecular nitrogen, N_2, is a major constituent of the Earth's atmosphere (~80%), so to obtain a quantitative understanding of the atmospheric behavior of our planet, the role of electron-driven processes is an important component [2]. In the present work, we focused on the N_2 molecule as the target, and measured the absolute DCS and ICS for the optically-allowed transition to the $b^1\Pi_u$ state. The experimental ICSs are compared with the BE*f*-scaled ICS based on the plane-Born approximation [3] to verify the validities of the BE*f*-scaling for optically-allowed excitation in N_2 molecule.

The present measurements were performed at Sophia University using a crossed-beam apparatus of a conventional electron spectrometer in the incident electron energies of 20 – 400 eV with total energy resolution of ~40 meV. The scattering angle range was $1° \leq \theta \leq 130°$. The true 0° scattering angle with respect to the incident electron beam was determined from the symmetry of the scattering intensities for the He 2^1P excitation. The absolute scale of the DCSs for the excitation to the $b^1\Pi_u$ state were obtained by the relative flow technique using the well-known elastic and 2^1P excitation DCSs of the He atom [4, 5]. Uncertainties in DCSs and ICSs were estimated ~25% and ~30%, respectively.

In this study, we measured angle-resolved electron energy loss (EEL) spectra in the EEL range of 12.0 – 15.0 eV, where it includes the excitation to the $b^1\Pi_u$ state. The EEL spectra of N_2 have shown rather complicated structures with many of the vibrational sublevels in an excited state overlapping with other vibrational sublevels in different excited states [2]. Thus, spectral deconvolution of the measured EEL spectra are necessary in order to obtain the absolute excitation DCSs, because the energy resolution of the electron spectrometer employed in the present measurements is ~40 meV that is not enough to resolve all of the vibrational sublevels in the final electronic states. The detailed of deconvolution procedure has been reported in ref. [2]. Excitation energies and Franck-Condon factors or relative intensity ratio between initial and final vibrational sublevels were referred in the literatures [6].

The GOSs as a function of the momentum transfer squared, K^2, were transformed from the measured absolute excitation DCSs and the scattering angles at each incident energy. Fitting the experimental GOSs at higher incident energies with the Vriens formula [7], where the Born approximation is satisfied, we obtained the optical oscillator strength (OOS) and apparent Born ICS for the excitation to the $b^1\Pi_u$ state. The present OOS is compared with the quasi-photon absorption measurement [8].

Finally, BE*f*-scaled Born ICS for $b^1\Pi_u$ excitation were estimated from the apparent Born ICS using the excitation and binding energies in the $b^1\Pi_u$ excited state of N_2 for the wide energy range. The comparison of the present BE*f*-scaled ICS with previous experimental data [9, 10] for this excitation, shows good agreement in the low energy region.

[1]E-mail: masami-h@sophia.ac.jp

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