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Extraction of electron–ion differential scattering cross sections for C_2H_6 by laser-induced rescattering photoelectron spectroscopy

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[Abstract] We have measured angle-resolved rescattering photoelectron spectra of C_2H_6 molecule induced by intense femtosecond infrared (IR) laser pulses and extracted electron-ion differential cross sections (DCSs) from the spectra. We have compared the extracted DCSs with theoretical calculations and found fairly good agreement between the experimentally extracted DCSs and theoretical calculations.

[Introduction] When a molecule is exposed to an optical electric field whose magnitude matches the intramolecular Coulombic fields, the molecule can be tunnel ionized, releasing an electron. This electron is then placed in the oscillating electric field of the laser and may be driven back to its parent ion and then recombined or rescattered. These processes form the core of the rescattering theory [1,2] and are of current interest due to the possibility of using the returning electrons for self-imaging the target. Recently several experiments are carried out to extract structural information of small molecules by measuring angular distributions of rescattering electrons [3-7]. We have measured angular distributions of the rescattering electrons for C_2H_4 generated by intense infrared laser pulses and extracted DCSs of rescattering electrons from $C_2H_4^+$ [7]. The extracted DCSs are well reproduced by the theoretical calculations and geometrical structure is retrieved from the spectra. In the present study, we have extended this work to measure rescattering photoelectron spectra of another hydrocarbon molecule C_2H_6 and extracted DCSs. We compared these DCSs with theoretically calculated DCSs.

[Methods] Optical parametric amplifier pumped by Ti:Sapphire laser pulses at 800 nm (1kHz, 100fs durations) is used to obtain IR laser pulses at 1.3 μm, 1.65 μm, 1.85 μm. The IR pulses are focused onto a sample gas effusively introduced in a vacuum chamber and ejected photo electrons are detected with a linear time-of-flight spectrometer. Angular distributions of photoelectrons are obtained by continuously rotating the polarization direction of the optical fields using a half wave plate.

[Results and Discussion] Fig.1 shows an angle-resolved rescattering photoelectron spectrum of C_2H_6 measured using 1.3 μm laser light at laser intensity $I_0 = 7 \times 10^{13}$ Wcm^{-2}. Rescattering electrons having recollision momentum around upto 1.3 a.u. are observed. In the same way we have also measured the angle- resolved rescattering photoelectron spectrum of C_2H_6 using 1.65 μm ($I_0 = 1.1 \times 10^{14}$ Wcm^{-2}) and 1.85 μm ($I_0 = 5.0 \times 10^{13}$ Wcm^{-2}) laser light, and observed electrons having recollision momentum around 2.3 a.u. and 1.9 a.u. respectively. We have

extracted DCSs and compared them with theoretically calculated DCSs. We get fairly good agreement between the experimentally extracted DCSs and the theoretical calculations shown in Fig.2. (a), (b) and (c). But some disagreement are also observed, for example between 80 and 100 degree in Fig.2(b). Usually ionization happens from highest occupied molecular orbital (HOMO). But in case of C_2H_6 second highest occupied molecular orbital (HOMO-1) is very close to the HOMO and the contribution of ionization from

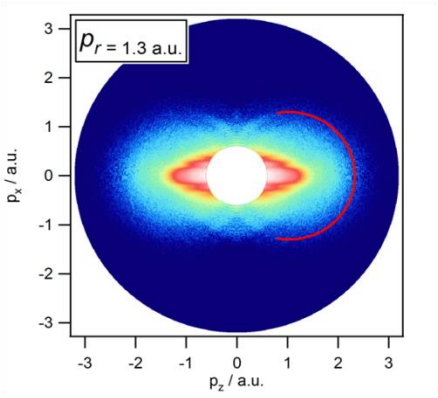

Fig. 1. An angle-resolved rescattering photoelectron spectrum of C_2H_6.

HOMO-1 can not be neglected. It may attributed to the disagreement between experimental and theoretical values. Ionization state of C_2H_6 is also degenerate and split into two states due to Jahn-Teller effect. This effect is not considered in theoretical calculations. It may also cause disagreement.

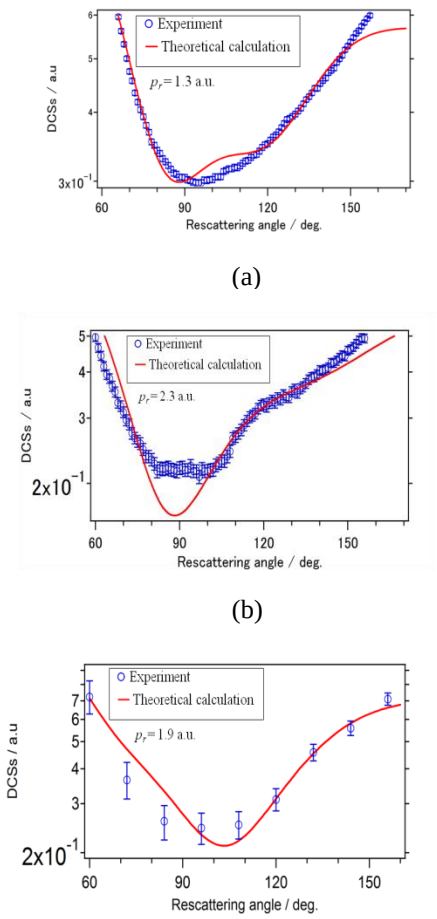

Fig. 2. Comparison of DCSs extracted from the experiment and theoretical calculations of C_2H_6, (a) for wavelength 1.3 μm at the laser intensity 7×10^{13} Wcm^{-2}, (b) for wavelength 1.65 μm at the laser intensity 1.1×10^{14} Wcm^{-2}, (c) for wavelength 1.85 μm at the laser intensity 5.0×10^{13} Wcm^{-2}.

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