Double photoionization of O_2 studied by threshold electron-electron coincidence spectroscopy

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Introduction

Threshold for molecular double photoionization generally lies around 30 - 40 eV measured with respect to neutral ground state. Direct double photoionization, where two electrons are simultaneously ejected into double ionization continuum, undergoes above the threshold. In addition, indirect double photoionization via intermediate singly-charged ion state occurs when the ion state autoionizes or produces autoionizing fragment:

$AB + h\nu \rightarrow AB^+ + e^- \rightarrow AB^{2+} + 2e^-$ or

$AB + h\nu \rightarrow AB^+ + e^- \rightarrow A^* + B^+ + e^- \rightarrow A^+ + B^+ + 2e^-$.

One of the most useful methods to study molecular double photoionization is threshold electron-electron coincidence spectroscopy [1,2]. This is because, on this coincidence spectroscopy, threshold electron detection allows to choose singly-charged ion state, and the decay can be discussed from the kinetic energy of the coincident electron. On handling threshold electron-electron coincidence spectra, two-dimensional plot of the coincidence yields, as a function of both incident photon energy and electron kinetic energy, is the most powerful representation. The two-dimensional plot, however, has not come out yet, because of unfavorable coincidence rate had been achieved hitherto.

Experimental results

In order to get effective coincidence rate on threshold electron-electron coincidence measurement, we have developed a coincidence spectrometer which consists of a high-luminosity threshold electron analyzer and a hemispherical electrostatic electron analyzer equipped with a position sensitive detector [3]. We have applied the spectrometer to the study on double photoionization of molecular oxygen in the photon energy region of 46 - 50.5 eV. The achieved coincidence rate allows us to plot the coincidence yields in two-dimensional presentation (Fig. 1). Two electrons ejected on each double photoionization event share energy difference between incident photon energy and ionization energy for O_2^{2+}, and kinetic energy of one of electrons observed is restricted to essentially zero. The available energy increases linearly with the incident photon energy, and therefore formation of O_2^{2+} states results in diagonal lines on the two-dimensional plot. Besides the diagonal lines due to formation of O_2^{2+} states, we can see on the two-dimensional plot three or more vertical stripes running parallel to the photon energy axis. These are assignable to autoionization from O*[converging to $O^+(^2D)$] into $O^+(^4S)$ [4]. This manifests that O_2^+ state(s) lying in the ionization energy region of 46 - 50 eV dissociates into fragment pair, one of which is O*[converging to $O^+(^2D)$], before molecular autoionization into O_2^{2+}. Intensity enhancements assignable to vibrational structure of O_2^+ cannot be recognized on each vertical stripe, which may imply the O_2^+ state(s) has repulsive potential energy curve shapes in the Franck-Condon region from the neutral ground O_2.

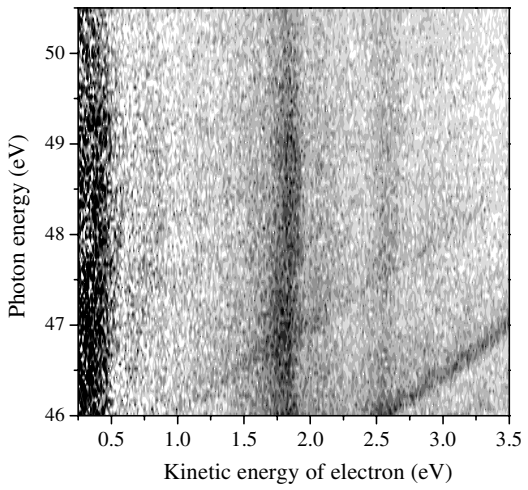

Figure 1. Two-dimensional plot of threshold electron-electron coincidence yields. Intensities are presented by the plots from light to dark on a linear scale.

References

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