Autoionization selectivity of Ne^+ Rydberg states converging to $Ne^{2+}(^1S^e)$

Yasumasa HIKOSAKA*[1], Tomohiro AOTO[2], Eiji SHIGEMASA[1] and Kenji ITO[2]
[1]UVSOR facility, IMS, Okazaki, Aichi 444-8585, Japan
[2]KEK-PF, Tsukuba, Ibaraki 305-0801, Japan

Introduction

The absorption of a single photon by an atom often induces ejection of two valence electrons if the photon energy is high enough. The two electrons share the available energy, according to the double ionization mechanism. When two electrons are ejected simultaneously (direct double ionization), a continuous kinetic energy distribution of each electron arises through energy sharing between the two emitted electrons as their kinetic energy distribution is peaked with one electron having low kinetic energy and the other having correspondingly high kinetic energy. In contrast, indirect double ionization, where singly-charged ionic states are formed and then subsequently decay to doubly-charged ions through autoionization processes, leads to discrete structures in the energy distributions of ejected electrons.

A detailed understanding of indirect double ionization processes can be derived directly by the coincidence detection between the primary photoelectron and the electron emitted through the autoionization process, although even in an ordinary coincidence detection it is difficult to distinguish between photoelectrons and autoionization lines. The threshold-photoelectron–photoelectron coincidence (TPEPECO) method utilizing advantages offered by synchrotron radiation is one of the most powerful method in this kind of electron–electron coincidence experiment, since this method can unambiguously define intermediate singly-charged ionic states with high resolution. In this report, we present an application of the TPEPECO method to study the indirect double photoionization of Ne [1]. The observation of one of the pair of electrons produced by the double ionization is restricted to threshold electrons in this method and electron energy spectra are measured in coincidence with the threshold electrons in order to determine the energies of the second-step electrons (autoionization electrons).

Experimental results

Figure 1(a) shows a threshold photoelectron spectrum measured in the 65.5-68.3 eV photon energy range where some Ne^+ Rydberg states converging to $Ne^{2+}(^1S^e)$ are exhibited. The main peaks are attributable to three Rydberg series converging to $Ne^{2+}(^1S^e)$, as indicated in the figure. Direct double photoionization to $Ne^{2+}(^3P^e)$ and $Ne^{2+}(^1D^e)$ always results fractionally in the formation of threshold electrons, via the energy sharing of available energy by the two photoelectrons; the background in figure 1(a) mainly corresponds to this process.

All the Ne^+ states shown in figure 1(a) are energetically able to autoionize into both the $Ne^{2+}(^3P^e)$ and $Ne^{2+}(^1D^e)$ states, since the ionization energies are 62.527-62.664 and 65.740 eV, respectively. In order to reveal the decay features of the Ne^+ states, we measured electron energy spectra in coincidence with threshold photoelectron detections. The coincident electron spectra, measured with 10 meV intervals in the 65.5-68.3 eV photon energy range, were assembled as a two-dimensional plot shown in figure 1(b). Two diagonal stripes are seen in the two-dimensional plot, corresponding to the final formations of $Ne^{2+}(^3P^e)$ and $Ne^{2+}(^1D^e)$. Regions of enhancement within each diagonal stripe are seen at the photon energies corresponding to the Ne^+ threshold electron peaks, which are attributable to the autoionization of the Ne^+ states.

The Ne^+ states appearing as enhancements on the diagonal stripes indicate a notable selectivity for the final Ne^{2+} channels. The selectivity is quite similar among identical Rydberg series. The *n*d states autoionize preferably to $Ne^{2+}(^1D^e)$ and less to $Ne^{2+}(^3P^e)$, although we cannot judge the behavior of the 4d state. It is likely that the selectivity of the *n*s states is similar to that of the *n*d, though it is somewhat ambiguous due to their low intensity. Antithetically, the *n*p states strongly favor $Ne^{2+}(^3P^e)$ over $Ne^{2+}(^1D^e)$ in their autoionization processes.

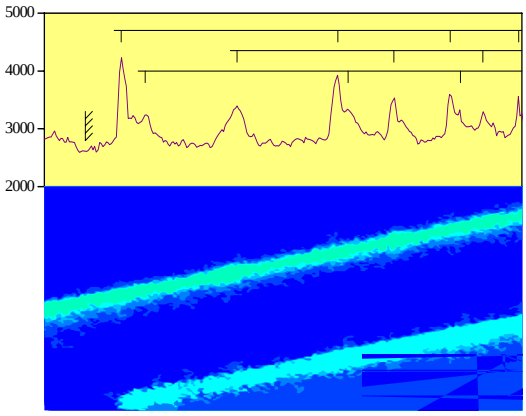

Figure 1 (a) a threshold photoelectron spectrum of Ne measured in the 65.5-68.3 eV photon energy range where three Rydberg series converging to $Ne^{2+}(^1S^e)$ are exhibited. (b) a two-dimensional plot of threshold-photoelectron–photoelectron coincidence yields from Ne as a function of both the incident photon energy and the energy of the fast electron.

Reference

[1] Y. Hikosaka et al., J. Phys. B, 37, 2823 (2004).

* hikosaka@ims.ac.jp