XXIX International Conference on Photonic, Electronic, and Atomic Collisions (ICPEAC2015) IOP Publishing
Journal of Physics: Conference Series **635** (2015) 072003 doi:10.1088/1742-6596/635/7/072003

Integral electron impact ionization cross section of molecules through Coulomb crystallization of the product ions

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Synopsis We present a new method for measuring electron impact ionization cross section of molecules through Coulomb crystallization of the product ions in a linear Paul trap.. The idea of electron impact ionization cross sections measurements is described, and the technique is analyzed in terms of its efficiency and some specific apparatus effects.

Trapped molecular ions have been subject of growing interest recently due to both studies of fundamental processes and various possible applications. Several methods of molecular ion production have been used: chemical reactions involving trapped atomic ions [1], laser ablation of a solid target [2], and photoionization [3]. Trapped molecular ions have been also observed as impurities (originating from residual gas in vacuum systems) of Coulomb crystals in experiments using high energy (∼1 keV) electron impact ionization of atoms [4, 5, 6]. Moreover, electron collisional induced ions in Paul trap were applied for mass spectroscopy of residual gas in vaccum system [7].

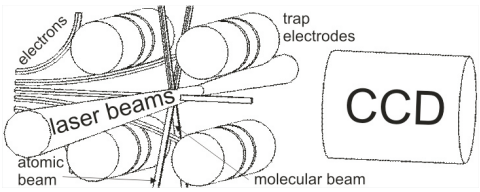

Figure 1. Schematic of the experimental geometry. All the beams are cross-fired in the central part of the trap.

In the proposed experiment (fig. 1) ionization of molecules (e.g. CO_2) with electrons of energies of the order of 10-100 eV will be studied. Molecules are ionized in both non-dissociative and dissociative channels. This way various ions are obtained from the same type of molecules. Additionally atomic ions (e.g. Ca^+) are prepared and laser-cooled to provide sympathetic cooling [1]. The ions form a multi-species Coulomb crystal. Example of numerically simulated ensemble of ions in equilibrium state is presented in fig. 2.

Composition of such crystal can be analyzed using images from CCD camera. The data derived for various electron impact energies can be used as a method to experimentally determine ionization integral cross sections (ICS). The accuracy of such ICS measurements is discussed with special attention to influence of the trap field on the geometry and energy of electron beam.

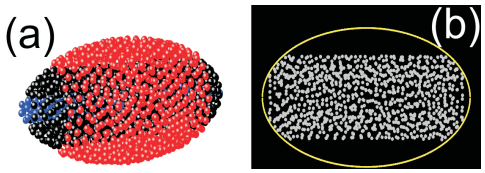

Figure 2. (a) Simulation of an ensemble of 3 species of ions (CO_2^+ – red, Ca^+ – black and CO^+ – blue) forming Coulomb crystal. (b) Expected image of such crystal - only the middle layer containing Ca^+ is visible. The loop denotes the crystal's edge.

In the future, experiments with higher electron energy resolution can be expected using digitally pulsed voltages on the trap electrodes [8] combined with gated electron beams coinciding with the zero voltage of the applied electrical pulses.

This work has been supported by the National Science Centre, Poland, project no. 2014/13/B/ST2/02684.

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