ELECTRON-IMPACT IONIZATION CROSS-SECTIONS OF Sr ATOMS FROM GROUND- AND METASTABLE STATES

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Electron-impact ionization of Sr atoms from ground- and triplet metastable states has been investigated using a crossed atomic and electron beam technique. The value of the total ionization cross section from the ground- and metastable states was determined. It has been found that ionization cross sections from the metastable and ground states differ considerably.

Introduction

The processes of electron-impact ionization from metastable atomic states are of considerable importance in artificial and natural plasma due to their low thresholds and high effective cross sections. Meanwhile, experimental data on ionization from metastable states have been obtained only for a limited number of atomic species. Present paper deals with experimental study of ionization of Sr atoms from ground- and triplet metastable states in the energy range from threshold up to 40 eV (for ground-state atoms) and to 20 eV (for metastable-states atoms).

Experimental

The process was studied in the normally crossed atomic and electron beams with ion detection in the analog mode. The idea of the experiment is presented in [1] (see Fig.1). The metastable Sr atom beam was produced in the discharge chamber (Fig.1) through which the ground-state Ca atom beam was transmitted. The beam of normal atoms was formed by a thermal effusion source and a system of collimating slits. The ground state and metastable-state concentrations in the region of interaction of the atoms with the electron beam were determined by an absorption method. The reliability of this method of investigation was confirmed by the fairly good consistency of our results on ground-state atom ionization with data of other paper [2] (see Table 1).

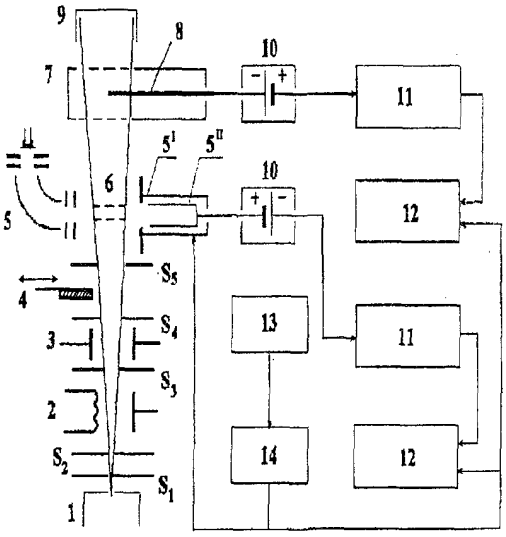

Fig.1. Experimental layout:. 1 – ground-state atomic beam source; 2 – discharge chamber; 3 – capacitor; 4, – atomic beam flag; 5 – electron monochromator; 5^{I} and 5^{II} – electron collector electrodes; 6 – collision region; 7 – ion collector; 8 – axial electrode (probe); 9 – atom collector; 10 – voltage sources; 11 – electrometer; 12 – X-Y recorder; 13 – D/A converter (DAC); 14 – voltage amplifier; S_1-S_5 – atomic beam collimating slits

Table 1. Effective ionization cross section for the Sr atom from the ground state (10^{-16} cm^2) at the 20eV incident electron energy

Present paper	Okuno [2]
7,6	7,8

The uncertainties of measuring the metastable atom ionization cross sections are as follows: 5% - for the energy dependence of ionization cross section from the threshold up to 6.1 eV (the ground – state atom ionization threshold); 12% - for that within the 6.1÷20 eV energy range; 60% - for the absolute ionization cross section. These values of uncertainties correspond to the 0.9 reliability. The vacuum in the collision chamber was about $1 \cdot 10^{-7}$ Torr.

Results

The results of the experiments are presented in Figs. 2 and 3. In these figures the ionization cross section in arbitrary units (Y – axis) is plotted against the incident electron energy in eV (X – axis).

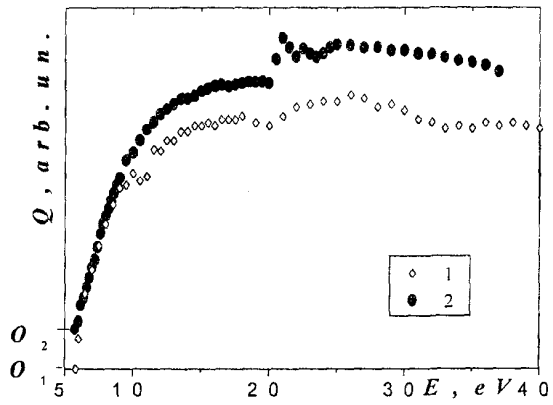

Fig.2. Effective ionization cross sections from the ground state: Okuno [2] (1); present paper (2)

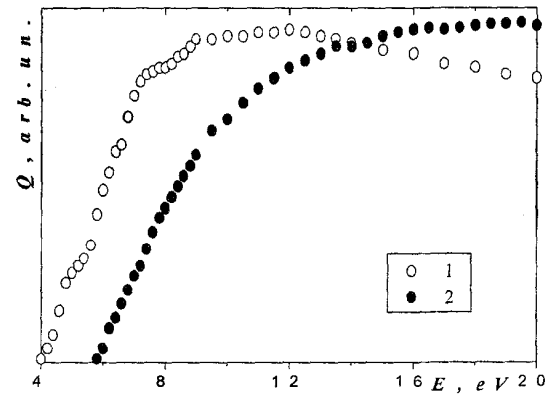

Fig.3. Effective ionization cross sections for Sr atoms from the triplet metastable states (1) and the ground-state (2)

The use of the electron monochromator allowed the structure in the energy dependence of ionization cross section for normal atoms (see Fig.2) to be revealed in more detail within the 20-25 eV energy region.

Upon starting the analysis, one should note that the Sr atom has two metastable terms: the singlet $5s4d\,^1D_2$ – term with the 2.50 eV excitation energy and the triplet one $5s5p\,^3P_{0,2}$, the excitation energies of components being 1.78 eV and 1.85 eV, respectively. The working concentrations of the triplet metastable $5s5p\,^3P_{0,2}$ – states in the collision region were $6 \cdot 10^9$ cm^{-3}. The singlet metastable $5s4d\,^1D_2$ – state concentration due do its small value was not measured experimentally however, we estimate it to be about $3 \cdot 10^8$ cm^{-3}, which corresponds to the sensitivity of our absorption technique of measuring the atomic beam concentrations.

Table 2. Effective ionization cross sections for the Sr atoms from the metastable states

Initial state	$Q^m \cdot 10^{-15}$, cm^2	Q^m/Q^o
$5s5p\,^3P_{0,2}$	2,1	2,8

As is seen from curve 1 of Fig. 3, the energy dependence of the ionization cross section from the metastable state reveals a flat maximum at E~11 eV, a structure at E~4.4-5.7 eV, shoulders at E~5.7 and 6.8 eV. The energy dependence of the ground-state atom ionization cross section has the form a structureless monotonically increasing curve. Table 2 lists the absolute ionization cross sections from the metastable states (Q_i^m) and the ratio of the ionization cross sections from the metastable and ground-state SrI atoms (Q_i^m / Q_i^o) at the 12.5 eV incident electron energy. Presence of the structure, shoulders and additional maxima in the curve 1 (Fig. 3) testifies to the occurrence of different mechanisms of ion production from the metastable states.

References

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2. Y.Okuno, *J. Phys. Soc. Jap.* **31**, 1189 (1971).

ПЕРЕРІЗИ ІОНІЗАЦІЇ АТОМІВ Sr ЕЛЕКТРОННИМ УДАРОМ З ОСНОВНОГО ТА МЕТАСТАБІЛЬНИХ СТАНІВ

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Досліджено процес іонізації атомів Sr електронним ударом з основного та метастабільних станів із застосуванням техніки перехресних атомного та електронного пучків. Визначено абсолютні величини повного перерізу іонізації атомів з основного та з метастабільних станів та показано, що вони дуже відрізняються.