Publ. Astron. Obs. Belgrade No. 84 (2008), 75 - 78 *Contributed Paper*

EXCITATION CROSS SECTIONS AND POLARIZATION OF EMISSION IN Ar-Ar COLLISIONS

S. Yu. KURSKOV[1] and A. S. KASHUBA[2]
Department of Physics and Engineering, Petrozavodsk State University,
Lenin 33, 185910 Petrozavodsk, Russia
E–mail: [1]kurskov@psu.karelia.ru
E–mail: [2]alekscomp@onego.ru

Abstract. The present work is devoted to study of Ar($3p^5 4p$) states excitation in binary low-energy Ar–Ar collisions. The results of the experimental investigation of excitation cross sections of Ar I $4p'[1/2]_1$, $4p'[3/2]_1$, $4p'[3/2]_2$ and $4p[3/2]_2$ levels in the collision energy range from threshold up to 500 eV (centre of mass system) and degree of polarization for $4s[3/2]^0_2 - 4p'[1/2]_1$ and $4s[3/2]^0_2 - 4p[3/2]_2$ transitions in this energy range are represented.

1. INTRODUCTION

The importance of the study of non-elastic collisions of argon atoms was conditioned by their significant role in different scientific and technical applications. Among the numerous research aspects of non-elastic collision of neutral particles the determining of quantitative scattering characteristics in the conditions of a beam experiment plays considerable role. The low collision energy range is a special interest since the theoretical treatment of non-elastic processes at such energies is rather complicated and, therefore, the quantitative data as well as the information on mechanisms of population of atomic levels can be obtained in an experiment mainly (see e.g. Breno et al. 1975, Kempter et al. 1976). The development of plasma physics, plasma chemistry, and astrophysics requires clarification of the idea of lowenergy atoms interactions, that is a significant interest of quantum theory of scattering.

The purpose of this work is the research of mechanisms of Ar($3p^5 4p$) atomic levels excitation at collision energies that corresponds of the adiabatic approximation conditions.

2. SETUP AND MEASUREMENT PROCEDURE

The measurements of the cross sections at interaction of an atomic beam with a gas target were carried out by optical methods on setup, controlled by computer. Experimental setup outline is shown on figure 1.

The neutral atoms beam was produced by means of charge exchange of Ar ions in own gas in an extending electrode channels of ion source. The density of the atom

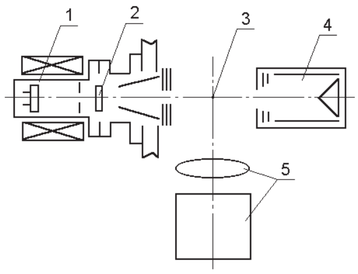

Figure 1: Experimental setup: 1 – ion source; 2 – multi-channel charge exchange cell; 3 – gas target; 4 – detector of fast atoms; 5 – optical recording system.

beam was defined by secondary electron emission from the detector surface. The dependence of the secondary emission coefficient from the energy of atoms was measured. The flux density of fast atoms in the collision chamber reached 10^{16} particle/(m^{2}s). The angular divergence of the neutral beam did not exceed 3×10^{-4} sr.

The target gas pressure in the collision chamber was equal to 4.5×10^{-1} Pa, the residual gas pressure did not exceed 3×10^{-4} Pa. The gas pressure at the ion source varied in the range $10 \div 20$ Pa.

The emission of exited particles was observed at right angle respectively to the atomic beam; therefore, radiating particles of the beam and the target were not distinguished.

The analysis of polarization was implemented using the Glan – Taylor prism. The compensators from the quarter-wave mica plates were applied to remove the influence of polarizing effect of the optical monochromator.

The measurement procedure was described in detail in the work (Kurskov 1995).

The emission cross section was measured in the experiment directly. Note that the emission cross section is determined by measuring of the spectral line intensity, the flux density of fast atoms and target particle density (Wolterbeek Muller et al. 1970).

With taking angular divergence of the dipole radiation into account, emission cross section is equal to

$$\sigma_{ij} = \frac{4\pi}{\Omega} \frac{S(\lambda)}{K(\lambda)} \frac{G}{I_p N_t L} \frac{1}{1+\eta} , \tag{1}$$

where Ω – a solid angle, defined by the optical system aperture; $S(\lambda)$ – photon count rate; $K(\lambda)$ – absolute sensitivity of the registration system at the given wavelength; I_p – beam intensity of the fast particles; N_t – target particle density, and L – observation zone length. The coefficient G – considers the angular distribution of dipole emission:

$$G = \frac{3 - P}{3(1 - P\cos^2\Theta)} , \tag{2}$$

where P – a degree of polarization, Θ – an angle between a beam of fast particles and an optical axis of system. The degree of polarization is determined by the following expression

$$P = (P_\parallel - P_\perp)/(P_\parallel + P_\perp) , \tag{3}$$

where $P_\parallel$ and $P_\perp$ – intensities of components which are polarized in parallel and transversely to the beam of fast particles respectively. The value η – takes into account a part of the excited fast atoms, which irradiate before leaving the observed zone. It is equal to

$$\eta = 1 - \frac{x_i}{L} exp(-l/x_i)(1 - exp(-L/x_i)) \ , \tag{4}$$

where l – the distance between the point of fast particles enter the collision chamber before the observation zone and $x_i = v\tau_i$, where v – colliding particle velocity, τ_i – excited state life time. The multiplier $1/(1+\eta)$ was obtained from the condition that excitation cross sections of fast and slow particles in symmetric collisions are equal.

The atom beam intensity in the observation zone was defined in the following way:

$$I_p = \frac{J}{e\gamma^0(E) exp(\sigma_s(E) N_t d)} \ , \tag{5}$$

where J – detector current, e – charge of electron, $\gamma^0(E)$ – coefficient of secondary electron emission from the detector surface under the action of fast atoms, $\sigma_s(E)$ - cross section of decrease of fast atoms from atomic beam, d – a distance from the observation zone up to the detector surface.

3. RESULTS AND DISCUSSION

The excitation cross sections of Ar I $4p'[1/2]_1$, $4p'[3/2]_1$, $4p'[3/2]_2$ and $4p[3/2]_2$ levels and degree of polarization for $4s[3/2]^0_2 - 4p'[1/2]_1$ and $4s[3/2]^0_2 - 4p[3/2]_2$ transitions are represented in the figures 2 – 5.

Taking into account the inaccuracy of measurements of the absolute spectral sensitivity, the inaccuracy of the definition of the secondary electron yield from the detector surface of the fast particles, and the inaccuracy of the definition of the gas pressure of the target the systematic error could reach ±55 %.

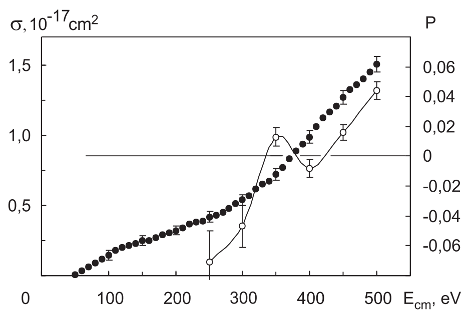

Figure 2: Ar I $4p'[1/2]_1$ level excitation cross section (•) and degree of polarization for $4s[3/2]^0_2 -$ $4p'[1/2]_1$ transition (∘) plotted against collision energy of Ar atoms.

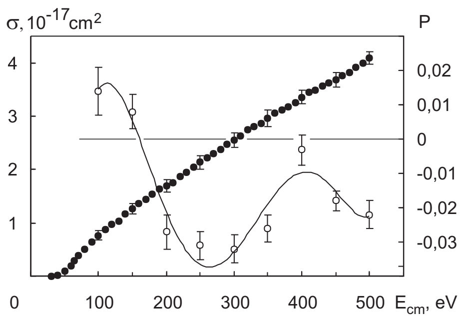

Figure 3: Ar I $4p[3/2]_2$ level excitation cross section (•) and degree of polarization for $4s[3/2]^0_2 - 4p[3/2]_2$ transition (∘) plotted against collision energy of Ar atoms.

The obtained results demonstrate that the polarization degree of emission significantly depends on collision energy – when the latter goes up, the former changes its sign. The fact that the sign of the polarization degree changes, as well as does

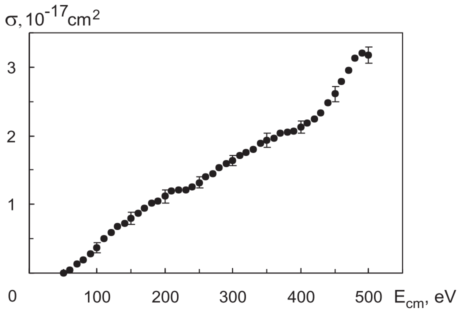

Figure 4: Ar I $4p'[3/2]_1$ level excitation cross section plotted against collision energy of Ar atoms.

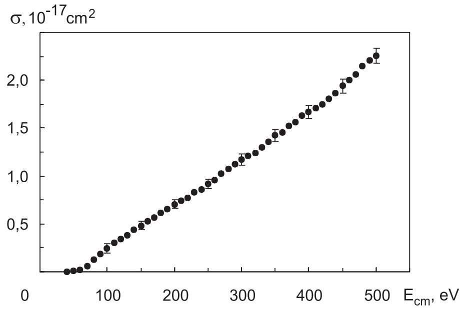

Figure 5: Ar I $4p'[3/2]_2$ level excitation cross section plotted against collision energy of Ar atoms.

interaction energy, proves that the mechanism of level population changes too (Blum 1981).

For instance, since the angular momentum of $4p'[1/2]_1$ excitation level is equal to 1, the positive polarization degree shows that the magnetic sublevel σ_0, that is zero momentum projection onto internuclear axis of the Ar_2 quasimolecule, is mostly populated. Negative polarization degree, in its turn, means that there is a dense population at magnetic sublevels σ_1, corresponding to ± 1 projections. Therefore, according to the data obtained, if collision energy is higher than 400 eV, the population at the mentioned above level is determined by $\Sigma_g - \Sigma_g'$ transactions. If collision energy is equal to or lower than 300 eV, level population is guided by $\Sigma_g - \Pi_g$ transactions due to radial coupling of even terms of the Ar_2 quasimolecule.

It is important to note that since output Σ_g terms of the Ar_2 quasimolecule are actually double excited terms, supposedly, the other interacting atom is excited too. This fact agrees with Wigner's law (system spin unchanged at collision) and with the research results described in works (Martin et al. 1978, Moorman et al. 1987).

The diabatic molecular orbital diagram for homonuclear system (Barat et al. 1972) and measurement results of the polarization of emission lead to the following conclusion: if collision energy is less or equal to 300 eV, the population of $4p'[1/2]_1$ level is determined by $4p\sigma - 4p\pi$ transactions due to rotational coupling at small nuclear distances. In case of higher energies, the population is governed by $5f\sigma - 5d\sigma$ transactions due to non-adiabatic radial coupling.

References

Barat, M., Lichten, W.: 1972, *Phys. Rev.*, **A6**, 211.
Blum, K.: 1981, Density Matrix Theory and Applications, New-York: Plenum Press.
Breno, J. C., Dhuicq, D., Gauyacq, J. P. et al.: 1975, *Phys. Rev.*, **A11**, 1245.
Kempter, V., Riecke, G., Veith, F., Zehnle, L.: 1976, *J. Phys.*, **B9**, 3081.
Kurskov, S. Yu.: 1995, *PhD thesis*, Petrozavodsk State University, Petrozavodsk.
Martin, P. J., Riecke, G., Hermann, J. et al.: 1978, *J. Phys.*, **B11**, 1991.
Moorman, L., van Hoegaerden, V., van Eck, J. et al.: 1987, *J. Phys.*, **B20**, 6267.
Wolterbeek Muller, L., de Heer, F. J.: 1970, *Physica*, **48**, 345.