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Photoionization of Ar VIII

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HIGHLIGHTS

- The photoionization cross sections of Ar VIII are investigated.
- It contains the excitation of 2s, 2p and 3s electron.
- The energy levels and widths of 22 series of Ar VIII have been calculated.

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ABSTRACT

The photoionization cross section, energy levels and widths of 22 Rydberg series (in the autoionization region) for Na-like Ar VIII were investigated by using of *R*-matrix method. The relativistic distorted-wave method is used to calculate the radial functions, and QB method of Quigly–Berrington [Quigley et al. 1998] is employed to calculate the resonance levels and widths. We have identified the formant in the figure of the photoionization cross section.

1. Introduction

The photoionization of positive ions is very important in numerous domains of physical, such as: hot plasmas, understanding and modeling of astrophysical, analyze electron correlation and relativistic effects in atoms or ions, resonance ionization spectroscopy, one-atom detection and laser applications etc.

Experimental studies of the photoionization of highly charged ions are scarce owing to the difficulty of producing sufficient densities of ions to perform photoionization experiments. Thus, accurate theoretical methods are very important. Accurate photoionization cross sections are needed to properly interpret the information obtained from spectral lines emitted from plasmas. Comparison to laboratory measurements can then be used to test the fundamental physics underlying the calculations.

Sodiumlike ions, with ground configuration $1s^22s^22p^63s$, have one electron outside of closed shells and it's be called the "quasi-one-electron" system due they are similar to hydrogen. But this system is not so simple as it may appear at first sight, because there are several non-negligible processes activating inner-shell electrons during photoionization, electron-impact ionization or recombination.

In 1972, Datla et al. (1972) studied the excitation rate coefficients of sodiumlike Ar VIII ions by using the Coulomb-Born approximation. Bliman et al. (1989) have studied the doubly excited Ar VIII $(2p^53snl)\,^{2,4}\boldsymbol{L}$ ions by using of the charge exchange collision $Ar^{+8}(2p^53s)\ ^3P_0+\ H_2$ at 2 keV amu^{-1} and obtained the autoionisation probabilities, transition probabilities and the branching ratios for the doubly excited Ar VIII $(2p^53snl)\,^{2,4}L$ ions. The energy levels, electric dipole transition rates, oscillator strengths and radiative lifetimes was calculated by Natarajan et al. (2001) by using of multi-configuration Dirac–Fock and relativistic configuration-interaction calculations with the inclusion of the Breit interaction, quantum electrodynamics and finite nuclear mass corrections. Liang et al. (2009) has studied the inner-shell electron-impact excitation of all Na-like ions from Mg^+ to Kr^{25+} (included the Ar VIII) by using the intermediate-coupling frame transformation *R*-matrix method with both Auger and radiation damping included via the optical potential approach. Breit–Pauli *R*-matrix electron-impact excitation calculations have been carried out for a number of ion stages along the argon isonuclear sequence by Ludlow et al. (2010). However there is not the investigation of the photoionization process for Ar VIII according to our knowledge.

In the present work, we investigate the photoionization process

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Table 1
Fine-structure energies (Ryd) of target ion Ar IX.

i	Configuration	Theoretical (*R*-matrix)	NIST (Ralchenko et al., 2008)	Error (compare to NIST) (%)
1	$2s^22p^6\ ^1S$	0.0000	0.0000	0.00
2	$2s^22p^53s^3P$	18.4162	18.5057	0.48
3	$2s^22p^53s^1P$	18.5606	18.6972	0.73
4	$2s^22p^53p^3S$	19.4765	19.5862	0.56
5	$2s^22p^53p^3D$	19.6886	19.7894	0.51
6	$2s^22p^53p^3P$	19.8063	19.9381	0.66
7	$2s^22p^53p^1P$	19.8063	19.9495	0.72
8	$2s^22p^53p^1D$	19.7830	20.0028	1.10
9	$2s^22p^53p^1S$	20.7344	20.6411	0.45
10	$2s2p^63s^3S$	23.9290	23.9415	0.05
11	$2s2p^63s^1S$	24.2086	24.3771	0.69
12	$2s2p^63p^3P$	25.1846	25.4058	0.87
13	$2s2p^63p^1P$	25.2775	25.4315	0.61
14	$2s2p^63d^3D$	26.8765	27.2742	1.45
15	$2s2p^63d^1D$	27.0301	27.4175[a]	1.41

[a] Calculated by AS

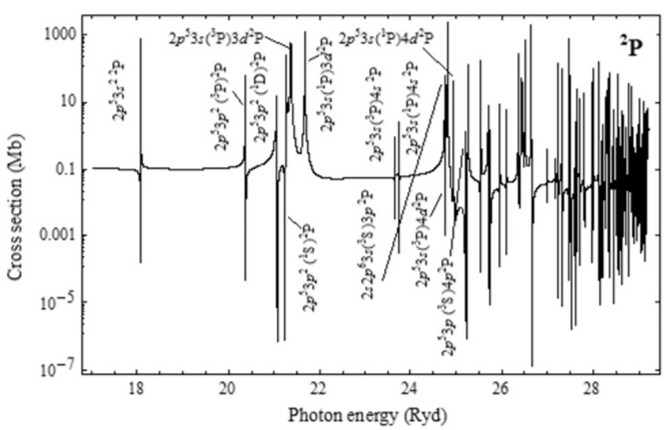

Fig. 1. Total photoionization cross section from ground state $2s^22p^63s\ ^2S$ as a Function of photon energy between the $2p^6\ ^1S$ and $2p^53s\ ^3P$ thresholds.

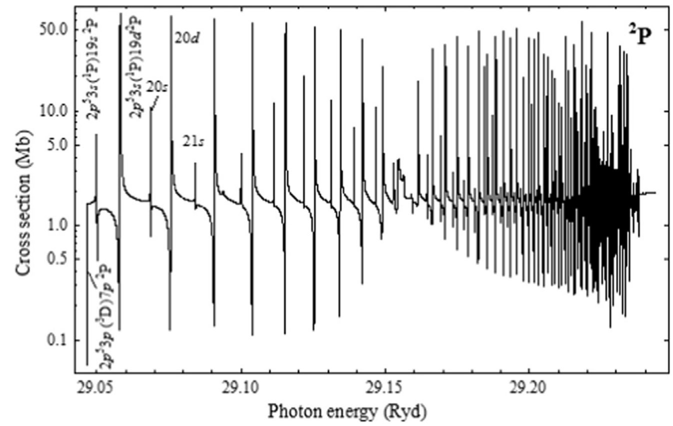

Fig. 2. Total photoionization cross section from ground state $2s^22p^63s\ ^2S$ as a Function of photon energy between the $2p^53s\ ^3P$ and $2p^53s\ ^1P$ thresholds.

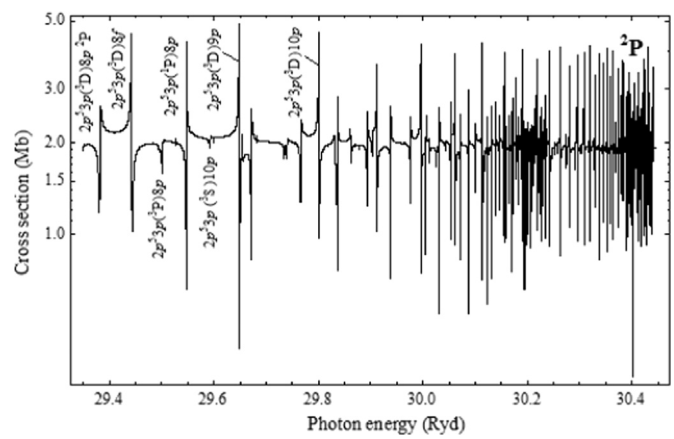

Fig. 3. Total photoionization cross section from ground state $2s^22p^63s\ ^2S$ as a Function of photon energy between the $2p^53s\ ^1P$ and $2p^53p\ ^1D$ thresholds.

from the ground state of Ar VIII with fifteen target states and twenty-three photoionization channels by using the *R*-matrix and combine with the QB method (Quigley et al., 1998) and Breit-Pauli relativistic distorted-wave method (Badnell, 2011). The photoionization process from the ground state of Ar VIII includes the excitation of the 2*s* and 2*p* electron.

2. Theory

The R-matrix approach is a most sophisticated and widely used method in atomic physics and the detailed theoretical description sees Badnell et al. (2001), Burke et al. (2007) and Berrington et al. (1995).

In order to more clearly show the formant on the diagram of the photoionization cross section, we neglect the relativistic effects and the calculation was carried out with the *LS* coupling. In our *R*-matrix calculations, the final *N*+1 electron system continuum wave function is expressed in the form

$$\Psi_k(x_1, x_2, \cdots, x_{N+1}) = A\sum_{ij} c_{ijk}\Phi_i(x_1, x_2, \cdots, x_{N+1}; \hat{r}_{N+1}\sigma_{N+1})\frac{1}{r_{N+1}}u_{ij}(r_{N+1}), + \sum_j d_{jk}\chi_j(x_1, x_2, \cdots, x_{N+1}) \quad (1)$$

where the Φ_i are the channel functions obtained by coupling the target state and the angular and spin functions of the continuum electron to form states of the same total angular momentum and parity, the x_i denote the spatial $\hat{r}_i$ and the spin σ_i coordinates of the *i*th electron, and *A* is the antisymmetrization operator, which takes

Table 2
The $2s^22p^53sns,nd$ of Ar VIII: energies *E* (relative to the $2s^22p^63s\ ^2S$ of Ar VIII), widths Γ.

	$2s^22p^5\ 3s\ (^3P)ns\ -^2P$		$2s^22p^5\ 3s\ (^3P)nd\ -^2P$		$2s^22p^5\ 3s\ (^1P)ns\ -^2P$		$2s^22p^5\ 3s\ (^1P)nd\ -^2P$	
n	E_r(Ryd)	Γ(Ryd)	E_r(Ryd)	Γ(Ryd)	E_r(Ryd)	Γ(Ryd)	E_r(Ryd)	Γ(Ryd)
3	18.1236	4.983E-05	21.4029	8.180E-03	–	–	21.7103	2.264E-03
4	23.7059	3.232E-06	24.8554	1.059E-03	23.7962	8.907E-05	24.9920	1.464E-05
5	26.0016	1.458E-05	26.4047	3.998E-04	26.1462	2.358E-05	26.6881	2.788E-04
6	27.0460	4.531E-07	27.3575	3.568E-05	27.2242	1.922E-06	27.5112	3.617E-05
7	27.6812	2.523E-04	27.8483	8.815E-06	27.8538	1.852E-06	28.0181	1.982E-05
8	28.0497	1.896E-06	28.1700	4.251E-05	28.2348	1.210E-05	28.3577	4.942E-04
9	28.3044	9.140E-06	28.3910	2.805E-05	28.4919	3.363E-06	28.5729	3.225E-05
10	28.4784	1.147E-04	28.5437	1.371E-06	28.6703	7.739E-05	28.7314	4.144E-07