SINGLE ELECTRON CAPTURE INTO EXCITED STATES IN COLLISION BETWEEN O^{5+} AND He*

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ABSTRACT

The emission spectra of OV singlet lines, OV triplet lines and HeII doublet lines have been measured and their emission cross-sections calculated. Only single-electron capture into excited states has been observed in the energy range 60—80 keV of the incident O^{5+} ions. Our experimental results on excitation levels are in agreement with those predicted by the diabatic potential diagram for O^{5+} + He collision system.

Keywords: single electron capture, excited states.

I. INTRODUCTION

In recent years the research on highly charged ions collisions with atoms or molecules has become very active in the fields of highly charged ion physics, plasma radiation and soft X-ray laser. For collisions between O^{6+} ions and atoms, for example, there are experiments on O^{6+} collision with H, H_2 and He by D. Dijkkamp et al.[1,2], on collision spectroscopy of O^{6+} colliding on a He target by R. Roncin et al.[3] and on subshell-selective electron capture (2—105 keV amu^{-1}) by C. J. Liu et al.[4] In their work they all made use of VUV spectroscopy in order to obtain more information. However, so far as we know no experiment has been performed on the O^{5+} collisions with atoms.

Recently, we have studied the single electron capture into excited states in collisions between O^{5+} and He, using a France-made ECR ion source-CAPRICE and LHT-30 VUV monochromator, with the energy range of incident ion being from 60 to 80 keV, the O^{5+} ion beam current about 20 μA and the wavelength range from 10 to 80 nm. Some new results have been obtained.

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II. Experimental Results

The schematic diagram of experimental set-up[5] is composed of three parts as shown in Fig. 1. Part one is electron cyclotron resonance (ECR) source, which can fully strip C. N. O and Ne atoms. Part two is a target chamber with base pressure 2×10^{-6} Pa. Part three is the light detection system consisting of an LHT-30 VUV monochromator made by JOBIN-YVON Company, France, an EMI-9789QB photomultiplier and an ND-686 multichannel analyser. 1. Fig. 2 shows the emission spectra of OV and HeII lines in collision between O^{5+} and He at 60 keV of ion impact energy.

The OV and HeII lines observed are listed in Tables 1 and 2.

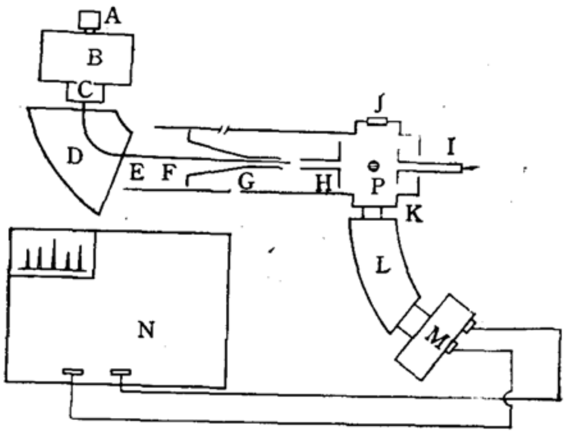

Fig. 1. Experimental set-up.
A, Microwave adapter; B, ECR source CAPRICE; C, extraction plates; D, analysing magnet; E, drift space; F, ion bean; G, gas resistor; H, collimation; P, centre target chamber; I, Faraday cup; J, window observer; K, port to VUV monochromator; L, spectrograph; M, photomultiplier; N, multichannel analyser.

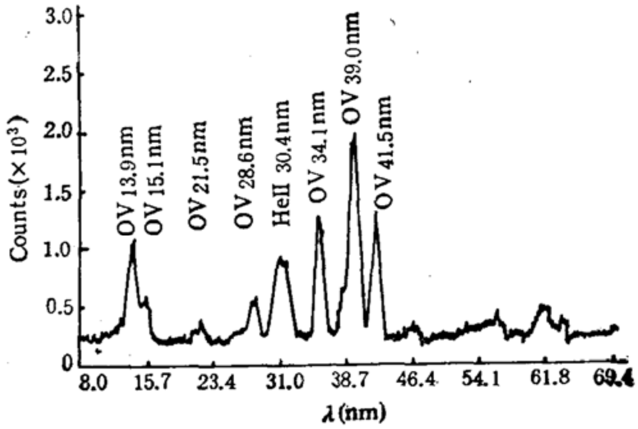

Fig. 2. The spectrum of OV and HeII lines in collision between O^{5+} and He at 60 keV energy.

Table 1

The Singlet and Triplet Lines of OV

Singlet		Triplet	
Transition	λ(nm)	Transition	λ(nm)
$2p3d\,^1P^0 \longrightarrow 2s^2\,^1S$	13.9	$2s4d\,^3D \longrightarrow 2s2p\,^3P^0$	15.1
$2s3p\,^1P^0 \longrightarrow 2p^2\,^1D$	28.6	$2s3s\,^3S \longrightarrow 2s2p\,^3P^0$	21.5
$2s3p\,^1P^0 \longrightarrow 2p^2\,^1S$	34.1	$2s5p\,^3P^0 \longrightarrow 2s3s\,^3S$	39.0
$2s5p\,^1P^0 \longrightarrow 2s3s\,^1S$	41.5		

Table 2

The Doublet Line of HeII

Transition	λ(nm)
$2p\,^2P^0 \longrightarrow 1s\,^2S$	30.4

The emission lines show that there is only one electron capture channel of excitation in the $O^{5+}+He$ collision system in the energy range 60—80 keV, i.e. single-electron capture into excited states:

$$O^{5+}+He \longrightarrow O^{4+*}(n,l)+He^{+*}(n,l)$$
$$\longrightarrow O^{4+}+He^{+}+h\nu(OV)+h\nu(HeII).$$

2. The definition of the emission cross-section is

$$\sigma_{em}=\frac{4\pi}{\omega}\frac{S(\lambda)}{NLK(\lambda)Q/qe},$$

where Q is the ion beam charge quantity, qe the projectile charge, Q/qe denotes the number of projectiles, N the target atom density, $K(\lambda)$ the quantum efficiency, $S(\lambda)$ the measured signal corrected for background, $S(\lambda)/K(\lambda)$ denotes the number

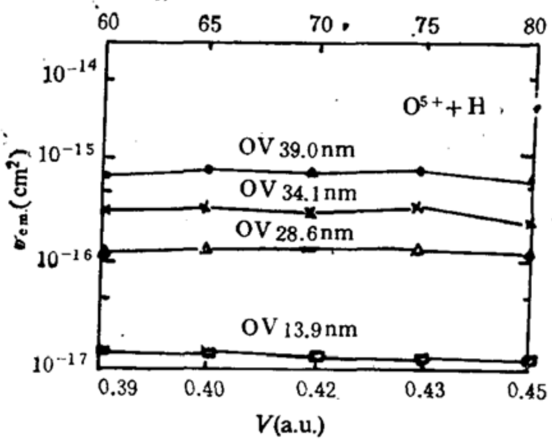

Fig. 3. Emission cross-sections for $O^{5+}+He$ as function of the velocity of projectile.

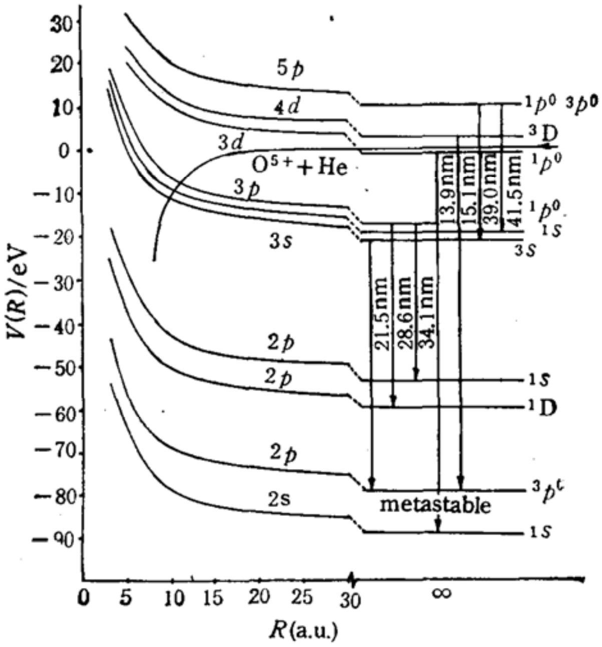

Fig. 4. The diabatic potential diagram for $O^{5+}+He$ collision.

Table 3
Emission Cross-Sections of OV, HeII Lines
(10^{-16} cm^2 in unit)

	OV Singlet			OV Triplet				HeII Doublet
E(keV) \ λ(nm) / σ_{em}	13.9	28.6	34.1	41.5	15.1	21.5	39.0	30.4
60	0.11	1.24	3.80	5.02	3.98	3.60	7.10	2.93
65	0.14	1.36	4.21	5.66	6.15	5.62	8.67	2.87
70	0.10	1.43	4.00	4.88	5.34	4.25	7.11	3.00
75	0.10	1.21	4.28	4.81	5.31	3.47	7.23	2.71
80	0.12	1.19	3.37	4.70	2.20	4.27	6.27	2.34

of emission photons, L the observation length, and ω the solid angle of emission seen by the spectrograph.

According to the definition of emission cross-section, the emission cross-sections of OV, HeII lines have been measured absolutely, as listed in Table 3.

Fig. 3. shows the line-emission cross-section σ_{em} for O^{5+} + He as a function of collision velocity.

III. Discussion

1. Fig. 4 shows the diabatic potential diagram for O^{5+} + He and the measured transitions. According to classical theory[6], the electron capture can occur if $R_c = \frac{2\sqrt{q}+1}{I}$, ($q$ is the number of charge of ion, I is the ionization potential of the target atom). The maximum crossing radius R_c is 6.1 a. u. in O^{5+} + He collision system, from which we can expect that in the case of O^{5+} + He, $n = 2$ and $n = 3$ are important excitation levels. The excitation levels shown in Fig. 4 are in agreement with our experimental results.

2. From Figs. 3 and 4 we can see that the emission cross-sections of $\lambda = 13.9$ nm line, the singlet line of OV $2p3d\,^1P^0 \longrightarrow 2s^2\,^1S$ are very small. This is a quasi-resonant reaction, the potential energy defect $\Delta E = 0.12$ eV, namely $\Delta E = 0$, only leading to small cross-sections[7].

3. The triplet lines of OV $2s5p\,^3P^0 \longrightarrow 2s3s\ ^3S(\lambda = 39.0\text{nm})$ have large cross-sections which is an endothermic reaction. The potential energy defect $\Delta E = -10.23$ eV. In the endothermic processes, transitions can only occur via a non-crossing type of coupling[8-10].

4. Fig. 3 shows that the emission cross sections have weak velocity dependence when the velocity of incident ions O^{5+} is within the range of 0.39—0.45 a.u. It means that the curves are smooth in the energy range of 60—80 keV.

5. Error estimation: The photon signal counts are about 2×10^2—10^4, the statistical error is less than 6%. The errors in the measurements of optics, charge quantity, gas target density are ±3% respectively. The uncertainty of quantum efficiency of optical detection system is about ±10%. The total error of emission cross-sections is about ±25%.

References

[1] Dijkkamp, D. et al., *J. Phys. B: At. Mol. Phys.*, **18**(1985), 737.
[2] Dijkkamp, D. et al., *ibid.*, **18**(1985), 4763.
[3] Roncin, R. et al., *ibid.*, **22**(1989), 509.
[4] Liu, C. J. et al., *ibid.*, **22**(1989), 1217.
[5] Pan Guangyan et al., *Acta Physica Sinica*, (to be published).
[6] Pan Guangyan et al., *Phys. Scripta*, **T3**(1983), 120.
[7] Bloemen, E. W. P., *Thesis*, 1980, p. 81.
[8] Demkov, Y. N., *Sov. Phys. JETP*, **18**(1964), 138.
[9] Olson, R. E., *Phys. Rev.*, **A6**(1972), 1822.
[10] Dinterman, T. R. & Delos, J. B., *ibid.*, **A15**(1977), 463.