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CROSS SECTIONS FOR ELECTRON IMPACT EXCITATION OF O VI LINES

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Abstract. Radiative atomic data and electron impact excitation cross sections for the $2s-2p$ transitions in O VI for transitions among the fine structure levels belonging to the $1s^2nl$ ($2 \leq n \leq 5$) configurations have been calculated. We have extended the calculations of fine structure collision strengths up to 140 Ry and have compared our results at energies below 63 Ry to the R-matrix ones.

Key words: impact excitation by electrons, cross sections, distorted wave method, plasma diagnostics, oscillator strengths

1. INTRODUCTION

Transitions in O VI have been observed in stellar spectra, in white dwarfs, in the solar corona and in the solar transition region, where the two resonance lines at 1031.924 Å and 1037.614 Å are among the brightest emitted (Lozano et al. 2001). Excitation cross sections for this ion are very important for the spectroscopic diagnostics. In this paper, for the O VI ion we present energy levels, oscillator strengths, electron impact collision strengths and cross sections. Atomic data are compared to NIST (physics.nist.gov) and to Aggarwal & Keenan (2004) results. Cross sections for energies near the excitation threshold are compared to the experimental results of Lozano et al. (2001). Collision strengths are compared to the results of Aggarwal & Keenan (2004) at energies up to 63 Ry. We extend our calculations up to 140 Ry.

2. COMPUTATIONAL PROCEDURE

The atomic structure has been computed using the UCL (University College, London) computer package SUPERSTRUCTURE (SST) of Eissner et al. (1974). This code takes into account configuration interaction. Relativistic corrections (spin-orbit, mass, Darwin and one-body) are introduced according to the Breit-Pauli. The electron scattering calculation has been performed in the distorted wave

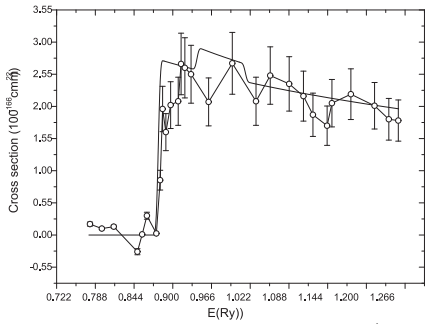

Fig. 1. Present cross sections (solid line) of the $2s\ ^2\mathrm{S}{-}2p\ ^2\mathrm{P^o}$ transition as a function of electron energy near the excitation threshold. Experimental results of Lozano et al. (2001) are also plotted (the solid line + circles)

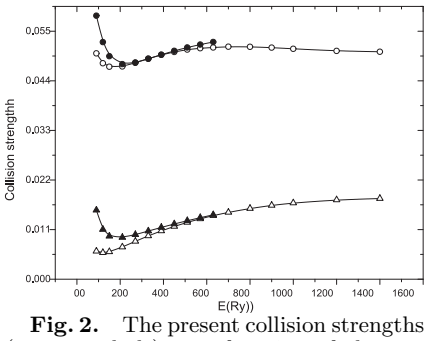

Fig. 2. The present collision strengths (open symbols) as a function of electron energy, compared to R-matrix DARC results (solid symbols) for the two transitions: $2p\ ^2\mathrm{P^o_{1/2}} - 3p\ ^2\mathrm{P^o_{3/2}}$ (circles) and $2p\ ^2\mathrm{P^o_{1/2}} - 4s\ ^2\mathrm{S_{1/2}}$ (triangles).

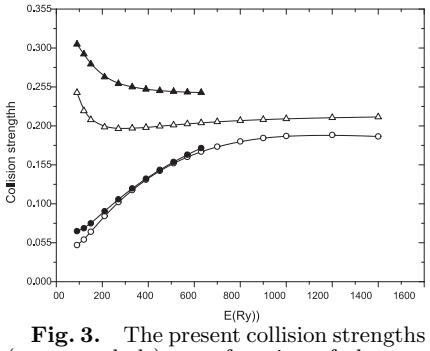

Fig. 3. The present collision strengths (open symbols) as a function of electron energy, compared to R-matrix DARC results (solid symbols) for the two transitions: $2s\ ^2\mathrm{S_{1/2}} - 2p\ ^2\mathrm{P^o_{1/2}}$ (circles) and $2s\ ^2\mathrm{S_{1/2}} - 2p\ ^2\mathrm{P^o_{3/2}}$ (triangles).

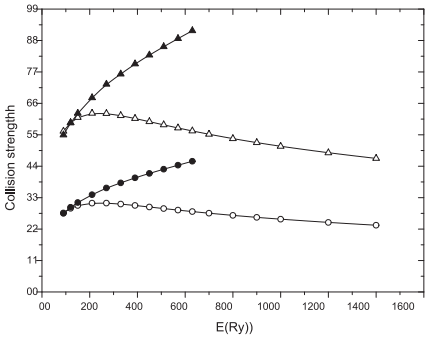

Fig. 4. The present collision strengths (open symbols) as a function of electron energy, compared to R-matrix DARC results (solid symbols) for the two transitions: $2p\ ^2\mathrm{P^o_{3/2}} - 3s\ ^2\mathrm{S_{1/2}}$ (circles) and $2p\ ^2\mathrm{P^o_{1/2}} - 2p\ ^2\mathrm{P^o_{3/2}}$ (triangles).

approximation using the DISTORTED WAVE code (Eissner 1998). Fine structure collision parameters have been obtained by the JAJOM code (Saraph 1978) for low partial wave l of the incoming electron ($l = 29$). This code transforms the transition matrix elements from LS into LSJ coupling using Term Coupling Coefficients given by the SST code. Contributions to collision strengths for $30 \leq l \leq 50$ have been taken into account through the Coulomb-Bethe approximation for the dipole transitions and a geometric series for the non-dipole ones.

3. RESULTS AND DISCUSSIONS

Energies of the 24 fine structure levels belonging to the $1s^2nl$ ($2 \leq n \leq 5$) configurations and oscillator strengths of some allowed transitions are presented in Table 1. Comparison with NIST results and with those of Aggarwal & Keenan

Table 1. O VI energy levels and oscillator strengths of some allowed transitions compared to NIST and GRASP results.

Level designation			Energy (Ry)			Transition	f_{ij}		
i	Conf.	level	Present	NIST	GRASP	$i-j$	Present	NIST	GRASP
1	$1s^2 2s$	$^2S_{1/2}$	0.00000	0.0000	0.00000	$1-2$	0.0667	0.0661	0.0673
2	$1s^2 2p$	$^2P^o_{1/2}$	0.88049	0.8782	0.88628	$1-3$	0.1342	0.1327	0.1355
3	$1s^2 2p$	$^2P^o_{3/2}$	0.88522	0.8831	0.89103	$1-5$	0.0893	0.0885	0.0873
4	$1s^2 3s$	$^2S_{1/2}$	5.82305	5.8325	5.82511	$1-6$	0.1782	0.1770	0.1704
5	$1s^2 3p$	$^2P^o_{1/2}$	6.05983	6.0701	6.06464	$1-10$	0.0263	0.0247	0.0244
6	$1s^2 3p$	$^2P^o_{3/2}$	6.06122	6.0715	6.06604	$1-11$	0.0526	0.0494	0.0488
7	$1s^2 3d$	$^2D_{3/2}$	6.13463	6.1476	6.13912	$2-4$	0.0289	0.0289	0.0287
8	$1s^2 3d$	$^2D_{5/2}$	6.13505	6.1481	6.13954	$2-7$	0.6590	0.6576	0.6595
9	$1s^2 4s$	$^2S_{1/2}$	7.75846	7.7703	7.76151	$2-9$	0.0058	0.0057	0.0056
10	$1s^2 4p$	$^2P^o_{1/2}$	7.85449	7.8673	7.85910	$3-4$	0.0290	0.0290	0.0288
11	$1s^2 4p$	$^2P^o_{3/2}$	7.85508	7.8679	7.85969	$3-7$	0.0660	0.0656	0.0660
12	$1s^2 4d$	$^2D_{3/2}$	7.88581	7.8996	7.89029	$3-8$	0.5936	0.5915	0.5940
13	$1s^2 4d$	$^2D_{5/2}$	7.88599	7.8998	7.89046	$3-9$	0.0058	0.0057	0.0057
14	$1s^2 4f$	$^2F^o_{5/2}$	7.88710	7.9014	7.89157	$4-5$	0.1106	0.1114	0.1122
15	$1s^2 4f$	$^2F^o_{7/2}$	7.88719	7.9015	7.89166	$4-6$	0.2226	0.2239	0.2259
16	$1s^2 5s$	$^2S_{1/2}$	8.63249	8.6451	8.63594	$4-10$	0.0946	0.0922	0.0917
17	$1s^2 5p$	$^2P^o_{1/2}$	8.68047	8.6942	8.68501	$4-11$	0.1886	0.1849	0.1827
18	$1s^2 5p$	$^2P^o_{3/2}$	8.68077	8.6942	8.68531	$5-7$	0.0473	0.0492	0.0470
19	$1s^2 5d$	$^2D_{3/2}$	8.69644	8.7104	8.70091	$5-9$	0.0644	0.0637	0.0641
20	$1s^2 5d$	$^2D_{5/2}$	8.69653	8.7104	8.70100	$6-7$	0.0046	0.0048	0.0046
21	$1s^2 5f$	$^2F^o_{5/2}$	8.69716	8.7115	8.70163	$6-8$	0.0420	0.0435	0.0418
22	$1s^2 5f$	$^2F^o_{7/2}$	8.69721	8.7115	8.70168	$6-9$	0.0647	0.0638	0.0643
23	$1s^2 5g$	$^2G_{7/2}$	8.69722	8.7116	8.70169	$7-10$	0.0127	0.0127	0.0127
24	$1s^2 5g$	$^2G_{9/2}$	8.69724	8.7116	8.70171	$7-11$	0.0025	0.0025	0.0025

(2004) where the authors used the fully relativistic GRASP code of Dally et al. (1989) gives an agreement better than 1% for level energies and does not exceed 2% for oscillator strengths.

The calculated cross sections for energies near the excitation threshold of the $2s-2p$ transition are in good agreement with the experimental results of Lozano et al. (2001) as it is shown in Figure 1. Figures 2 and 3 display the collision strengths for some transitions. We find that some of them agree well with the DARC R-matrix calculations, where the authors adopted the Dirac Atomic R-matrix Code (DARC) of Norrington & Grant (private communication). Other transitions have the same behavior with energy, but they are not in good agreement with the R-matrix results. Figure 4 shows also that for some other transitions, the present collision strengths are not in agreement with the R-matrix calculations. In Table 2 we present our collision strengths for three energies above thresholds and compare them to the DARC results. The two calculations agree within about 24%, 11% and 12%, respectively for 15, 45 and 63 Ry. We have extended in the present work our fine structure collision strengths for electron energies up to 140 Ry.

Since the collision parameters are used in our *ab initio* calculations of line broadening (Elabidi et al. 2008, 2009; Elabidi & Sahal-Bréchot 2011), their comparison with experimental and other theoretical results can be a powerful tool to check our line broadening calculations.

Table 2. O VI collision strengths, compared to R-matrix DARC results.

Transition		Energy						
		15 Ry		45 Ry		63 Ry		140 Ry
i	j	Present	DARC	Present	DARC	Present	DARC	Present
1	2	$2.751-0$	$2.846-0$	$2.703-0$	$3.772-0$	$2.557-0$	$4.158-0$	$2.123-0$
1	3	$5.552-0$	$5.685-0$	$5.418-0$	$7.537-0$	$5.122-0$	$8.311-0$	$4.249-0$
1	4	$1.384-1$	$1.982-1$	$1.897-1$	$2.234-1$	$2.000-1$	$2.276-1$	$2.220-1$
1	5	$5.831-2$	$6.395-2$	$1.525-1$	$1.492-1$	$1.850-1$	$1.824-1$	$2.278-1$
1	6	$1.175-1$	$1.272-1$	$3.033-1$	$2.970-1$	$3.681-1$	$3.631-1$	$4.536-1$
1	7	$1.602-1$	$1.618-1$	$2.165-1$	$2.266-1$	$2.271-1$	$2.392-1$	$2.326-1$
1	8	$2.410-1$	$2.427-1$	$3.257-1$	$3.399-1$	$3.415-1$	$3.587-1$	$3.493-1$
1	9	$2.563-1$	$3.833-2$	$3.760-2$	$4.320-2$	$4.056-2$	$4.415-2$	$4.614-2$
1	10	$1.158-2$	$1.697-2$	$3.257-2$	$3.415-2$	$4.054-2$	$4.118-2$	$5.549-2$
2	3	$2.078-1$	$2.793-1$	$1.996-1$	$2.452-1$	$2.039-1$	$2.428-1$	$2.115-1$
2	4	$3.173-2$	$3.725-2$	$7.018-2$	$7.132-2$	$8.256-2$	$8.524-2$	$9.255-2$
2	5	$1.519-1$	$2.161-1$	$1.895-1$	$2.438-1$	$2.007-1$	$2.483-1$	$2.233-1$
2	6	$4.284-2$	$4.496-2$	$4.581-2$	$4.604-2$	$4.672-2$	$4.783-2$	$4.585-2$
2	7	$1.131-0$	$1.159-0$	$2.134-0$	$2.117-0$	$2.430-0$	$2.449-0$	$2.726-0$
2	8	$6.040-2$	$6.556-2$	$4.590-2$	$4.852-2$	$4.649-2$	$4.879-2$	$4.857-2$
2	9	$5.531-3$	$8.699-3$	$1.064-2$	$1.114-2$	$1.282-2$	$1.298-2$	$1.627-2$
2	10	$2.743-2$	$4.177-2$	$3.403-2$	$4.580-2$	$3.626-2$	$4.684-2$	$4.124-2$
3	4	$6.413-2$	$7.493-2$	$1.423-1$	$1.436-1$	$1.670-1$	$1.716-1$	$1.865-1$
3	5	$4.303-2$	$4.516-2$	$4.609-2$	$4.633-2$	$4.703-2$	$4.814-2$	$4.606-2$
3	6	$3.568-1$	$4.775-1$	$4.351-1$	$5.344-1$	$4.570-1$	$5.450-1$	$4.975-1$
3	7	$2.843-1$	$3.113-1$	$4.771-1$	$4.829-1$	$5.385-1$	$5.496-1$	$6.001-1$
3	8	$2.128-0$	$2.145-0$	$3.900-0$	$3.860-0$	$4.427-0$	$4.458-0$	$4.953-0$
3	9	$1.107-2$	$1.745-2$	$2.162-2$	$2.239-2$	$2.598-2$	$2.608-2$	$3.279-2$
3	10	$1.104-2$	$1.412-2$	$9.843-3$	$1.038-2$	$1.006-2$	$1.050-2$	$1.017-2$

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