RADIATIVE CORRECTIONS TO INTENSITIES OF DIELECTRONIC SATELLITE LINES EMITTED FROM HELIUM- AND LITHIUM-LIKE ARGON*

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The process of dielectronic recombination has been the subject of intense theoretical activity mainly because of the pioneering work by Burgess (1964), who demonstrated that this process can be the dominant recombination mechanism for multiply-charged atomic ions in low-density high-temperature astrophysical and laboratory plasmas. Recent attempts to measure dielectronic recombination cross sections and rate coefficients have renewed interest in the development of a rigorous quantum-mechanical theory of the resonant electron-ion recombination process. A precise theory is clearly required for the interpretation of the dielectronic satellite lines, which have been found to be of great value in the spectroscopic determination of temperatures, densities, and departures from ionization equilibrium.

In order to develop a rigorous quantum-mechanical theory of dielectronic recombination, it is necessary to treat the electron-ion collision and radiation processes in a unified manner by employing the methods of multi-channel scattering theory and quantum electrodynamics. Unified quantum-mechanical treatments of electron-ion recombination, which describe both the resonant and the non-resonant processes, have been developed by Davies and Seaton (1969) and by Shore (1969); but approximations to the scattering matrix are employed in these theories, leading to expressions in which the autoionization and radiative decay rates are additive. Armstrong, Theodosiou, and Wall (1978) were the first to investigate the effects of the electromagnetic interaction between the final continuum states which result from the autoionization and radiative decay modes. Using a two-level atom model, they demonstrated that the final-state interaction can alter the relative probabilities for an autoionizing state to decay into the two alternative continuum channels. They obtained approximate expressions for the Auger and fluorescence yields which they believed were valid only when the final-state continuum-continuum coupling is weak.

Recently, Haan and Cooper (1983) have rederived the results obtained by Armstrong, Theodosiou, and Wall (1978). By taking advantage of the separable form of the final-state interaction, they were able to obtain an exact closed-form solution for the two-level atom problem. Most significantly, they demonstrated that the approximate expressions for the Auger and fluorescence branching ratios first obtained by Armstrong, Theodosiou, and Wall (1978) remain valid even when the continuum-continuum coupling is strong and, therefore, have a wider region of validity than originally recognized.

In this investigation the two-level atom model has been extended to the case in which each of the atomic levels may consist of a set of degenerate magnetic sublevels. In the case where the final-state interaction involves only a single term in the partial-wave expansion for the electron-continuum state, the expressions obtained for the Auger and fluorescence yields are in agreement with those derived in the previous investigations. When several terms in the electron-continuum

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partial-wave expansion are involved, the Auger and fluorescence branching ratios contain terms corresponding to the interference between different partial-wave components. Finally, the isolated-resonance approximation is employed to obtain the corrected expressions for the intensities of the dielectronic satellite lines resulting from the radiative decay of autoionizing states of multiply-charged ions in low-density plasmas. The modifications to the conventional expression for the satellite line intensities may be interpreted as terms corresponding to the interference between the direct radiative recombination and dielectronic recombination processes together with radiative corrections to the dielectronic recombination process.

In order to investigate the significance of the radiative corrections, we have evaluated the corrected expressions for the relative intensities of the dielectronic satellite lines emitted from autoionizing states of the type $2\ell\,2\ell'$ in helium-like argon. In the total-electronic angular-momentum J representation, 24 electric-dipole radiative transitions are allowed between the doubly-excited states and the bound states. In addition to the autoionization and radiative decay rates, which are all the quantities that are required in the evaluation of the traditional expressions for the branching ratios, it is now necessary to obtain the photoionization cross sections of each bound level in order to incorporate the final-state interaction. The radiative corrections may also be expressed in terms of the Fano line-profile parameter Q_F. A selection of our preliminary results for helium-like argon, which were obtained using the relativistic atomic structure program of Cowan (1967), are presented in Table I and in Figure 1. The corrected rates we denoted by using the tilde. It is found that the effects of the final-state interaction are most important for radiative transitions with relatively small values of Q_F. However, the most intense satellite lines at low-densities correspond to very large values of Q_F. Calculations for autoionizing states of the type $1s2\ell\,2\ell'$ in lithium-like argon are now in progress.

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SELECTED RESULTS FOR ARGON XVII

RADIATIVE TRANSITION a → f	FANO PARAMETER Q_F	RADIATIVE DECAY RATES (Sec^{-1})		DIELECTRONIC RECOMBINATION RATES ($cm^3\ sec^{-1}$) (K_BT_e = 1.6 Kev)	
		Ar	$\tilde{A}r$	α_{DR}	$\tilde{\alpha}_{DR}$
$2s2p\ ^1P_1 \rightarrow 1s^2\ ^1S_0$	0.74	2.3 (10)	4.7 (10)	1.5 (-17)	3.0 (-17)
$2s2p\ ^3P_1 \rightarrow 1s^2\ ^1S_0$	0.73	1.3 (8)	5.0 (9)	2.0 (-20)	7.5 (-19)
$2p^2\ ^3P_0 \rightarrow 1s2p\ ^1P_1$	4.4	6.3 (11)	3.0 (11)	1.4 (-18)	6.6 (-19)
$2p^2\ ^1D_2 \rightarrow 1s^2p\ ^3P_1$	1.7	8.9 (8)	7.9 (8)	9.3 (-19)	8.2 (-19)

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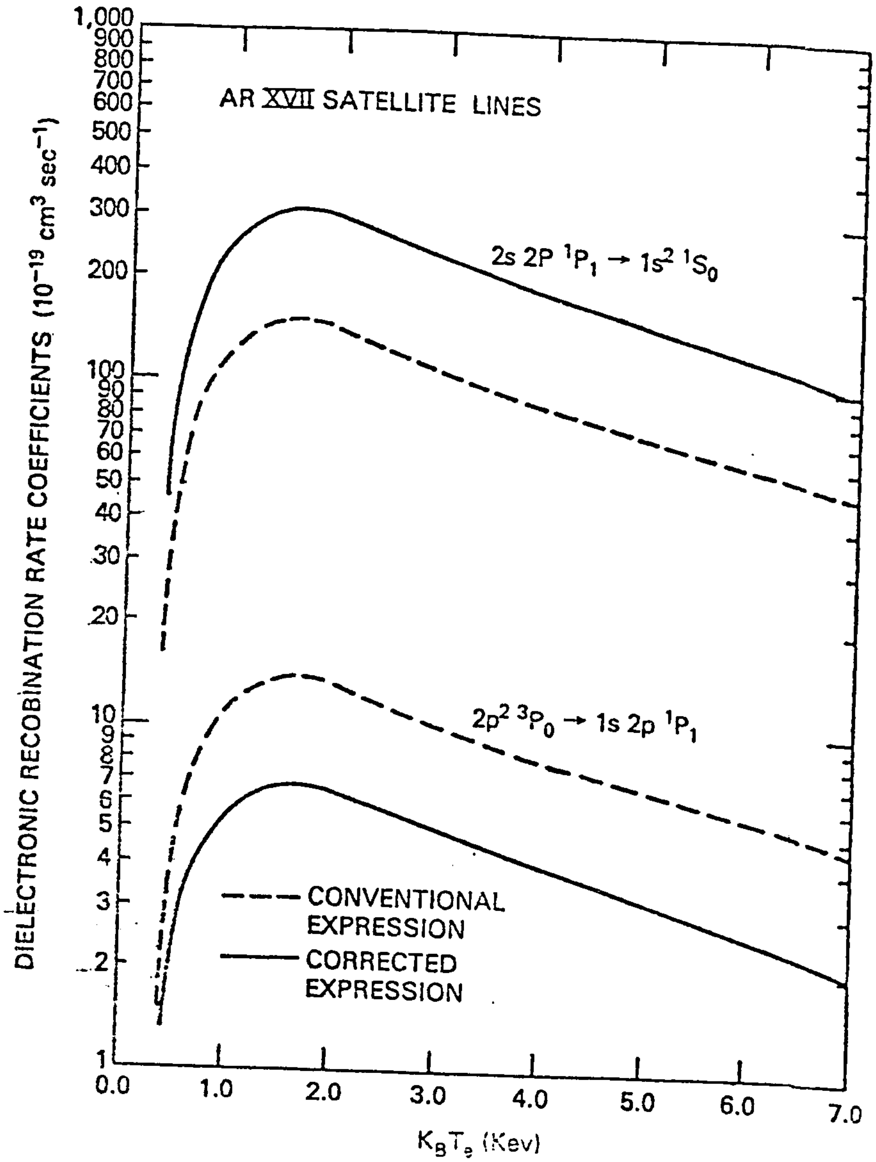

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