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Resonant excitation rates for the $2p^53s$ and $2p^53p$ levels in Ne-like Fe XVII

The 17Å 2p-3s X-ray emission lines of neon-like Fe XVII are observed in astrophysical settings as diverse as the solar corona (e.g., Loulergue and Nussbaumer 1973), supernova remnants (e.g., Hamilton, Sarazin and Chevalier 1983), and accretion disks (e.g., Kahn et al. 1984). Their intensities in the solar corona have been extensively studied and used as temperature diagnostics (e.g., Rugge and McKenzie 1985, Raymond and Smith 1986). Resonant excitation makes a significant contribution to the population of the $2p^53s$ levels at temperatures below threshold for their direct collisional excitation (Smith, Raymond, Mann and Cowan 1985; Raymond 1978). In this regime, the 2p-3s line intensities are very sensitive to resonant excitation, and their utility as a diagnostic depends on accurately accounting for this process. Previous calculations of resonant excitation in Fe XVII adopted a non-relativistic, LS configuration average approach (Omar and Hahn 1988), or extrapolated the results of a subset of detailed calculations to determine the contribution of each autoionizing series (Smith et al. 1985). Configuration average energies were apparently used to determine energetically allowed autoionization channels. This is a gross approximation for energetically broad configurations, and easily leads to incorrect results.

We present the results of a new calculation, in a detailed level accounting scheme, of the resonant excitation rate of $2p^53s$ and $2p^53p$ levels of Fe XVII. These rates are significantly lower than those in the literature. The present results are similar to those recently reported by Chen and Reed (1989), who also use a detailed level accounting scheme, but a different, multiconfigurational Dirac-Fock (MCDF), atomic model.

In the isolated resonance approximation rate coefficients for resonant excitation is given by,

$$\alpha^{\text{res.exc.}}(\text{final})=\sum_{C_{\text{auto}}}\ \sum_{\text{lev}\,\varepsilon\, C_{\text{auto}}} R^{\text{capt.}}(2p^6\rightarrow\text{lev}) \times \frac{A^{\text{auto.}}(\text{lev}\rightarrow\text{final})}{\Sigma_j\,[A^{\text{auto.}}(\text{lev}\rightarrow j)+A^{\text{rad.}}(\text{lev}\rightarrow j)]} \qquad (1)$$

where "final" is a neon-like level and the sodium-like "lev" belongs to the autoionizing configuration C_{auto}. R^{capt} is obtained by detailed balancing the corresponding autoionization rate, A_{auto}, and the last factor is the branching ratio for "lev". The atomic data for Eq. (1) was calculated in the relativistic, multiconfigurational parametric potential model of Klapisch (1971, 1977) and Bar-Shalom and Klapisch (1988).

Table I The set of autoionizing configurations included in the present calculation, with the autoionization and radiative decay branches for each.

C_{auto}	C_{Ne} (autoion. channels)	C_{Na} (rad.channels)
$2s2p^63l5l'$, $l\leq2, l'\leq4$ $(2s2p)^73lnl'$, $l\leq2, l'\leq4$, $6\leq n\leq10$	$2p^6$, $2p^53l$, $2s2p^63l$	$(2s2p)^8nl'$(E1), $(2s2p)^73l''nl'$(E1), including 2p-2s cascade followed by autoionization.
$2p^53dnl$, $l\leq4$, $11\leq n\leq15$	$2p^6$, $2p^53l$,	$2p^6nl$(E1), $2p^63d$(E1)
$2p^53pnl$, $l\leq4$, $11\leq n\leq20$	$2p^6$, $2p^53l$,	$2p^63p$(E1), $2p^6nl$(E1,E2), $2p^53snl$(E1)
$(2s2p)^74l4l'$, $l,l',\leq3$	$2p^6$, $2p^53l$, $2s2p^63l$	$(2s2p)^84l$(E1), $(2s2p)^73l4l'$(E1) including 2p-2s cascade followed by autoionization.
$2p^54lnl'$, $l\leq3,l',\leq4$ n=5,6,7	$2p^6$, $2p^53l$, $2s2p^63l$	$2p^6nl$(E1), $2p^53lnl'$(E1),

The autoionizing configurations included in the outer summation in Eq.(1), and the radiative and autoionization channels included in the branching ratios, are listed in Table I. Our calculations are in intermediate coupling, and for given n, configuration interaction (CI) among the different values of l is included. All CI within the $(2s2p)^74l4l'$ configurations was included since they were treated in a single structure calculation. For the $2p^54lnl'$ series, CI was included for fixed l and n; i.e., the 4snl', 4pnl', 4dnl' and 4fnl' were treated independently. All CI among neon-like levels was included.

The importance of accounting explicitly for each level (both "final" and "lev") in Eq. (1) has been noted previously, and large errors have been shown to result from the use of average, rather than detailed level-by-level weighted, fluorescence yields in the calculation of resonant processes (Chen and Craseman 1974; Chen, Craseman and Matthews 1975; Bhalla 1975a, 1975b; Chen 1985, 1989). Inaccuracies can be traced to neglecting, in the average treatment, the effect of selection rules on branching ratios for Auger and X-ray processes.

The results of the present calculation, at an electron temperature of 200 eV, are summarized in Table II, along with total rates for ≈200 eV reported by Smith et al. (1985)

and Chen and Reed (1989). The discrepancies with the former calculation have been remarked on previously (Goldstein 1988), and have been confirmed by the independent calculations of the latter.

Table II. Total resonant excitation rate coefficients (units of 10^{-13} cm^3 sec^{-1}) for the $2p^53s$ and $2p^53p$ levels of FeXVII. Levels are listed in energy order. Values for this calculation are at an electron temperature of 200 eV, while those of Smith *et al.* (1985) are at 217 eV and include an extrapolation of n to 100. The results of Chen and Reed (1989) are for T_e=200 eV and were extrapolated beyond n=15 to n=200 for the $2p^53ln l'$ configurations.

	TOTAL RATE ($\times10^{-13}$ cm^3 sec^{-1}) @ 200 eV		
final state	*this calc.*	*Smith* et al.	*Chen & Reed*
$[(2p^5)_{3/2}3s]_2$	12.97	50.0	12.2
$[(2p^5)_{3/2}3s]_1$	16.11	38.0	14.4
$[(2p^5)_{1/2}3s]_0$	2.48	11.0	1.9
$[(2p^5)_{1/2}3s]_1$	15.12	48.0	14.2
All $2p^53s$	46.68	147.0	42.7
$[(2p^5)_{3/2}3p_{1/2}]_1$	5.17	5.7	
$[(2p^5)_{3/2}3p_{1/2}]_2$	4.09	4.8	
$[(2p^5)_{3/2}3p_{3/2}]_3$	5.07	6.9	
$[(2p^5)_{3/2}3p_{3/2}]_1$	3.75	3.1	
$[(2p^5)_{3/2}3p_{3/2}]_2$	4.08	5.0	
$[(2p^5)_{3/2}3p_{3/2}]_0$	3.36	2.8	
$[(2p^5)_{1/2}3p_{1/2}]_1$	3.61	3.5	
$[(2p^5)_{1/2}3p_{3/2}]_1$	4.25	13.0	
$[(2p^5)_{1/2}3p_{3/2}]_2$	4.39	12.0	
$[(2p^5)_{1/2}3p_{1/2}]_0$	2.98	1.7	
All $2p^53p$	40.75	58.5	

The overall reduction in the excitation rate for $2p^53s$ levels of Fe XVII implied by the present results suggests that the 3s/3d line ratio observed in solar active regions and flares (Rugge and McKenzie 1985) ought to be reconsidered. A modeling effort is presently underway that apparently succeeds in matching the observed ratios when dielectronic recombination of Fe XVIII is included (Liedahl et al. 1989).

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