Critical free electron densities and temperatures for spectral lines in hot and dense plasmas

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Synopsis A simple method of estimating the critical free electron densities and temperatures for the spectral lines in hot and dense plasmas is reported. The plasma screening effects on the nucleus are described using the ion sphere model, and the Fermi-Dirac distribution function is used to describe the spatial distribution of free electrons. The critical free electron densities and temperatures for one type spectral line can be estimated, that is corresponding to the classical turning point radius of a bound electron in the highest occupied orbit of the two atomic states for one transition is equal to the radius of the ion sphere. The obtained critical free electron densities and temperatures for the spectral lines of He-like C, Al and Ar ions are close to the experimental and other theoretical results.

As can be seen from the figure 1 that the classical turning point radius R_{ctp} increases with increasing free electron densities at a given free electron temperature. However, It has nothing to do with the free electron temperatures at the lower free electron densities, but decreases with the increase of free electron temperatures at the higher free electron densities and close to that of the UEDISM. (UEDISM is the results obtained with the uniform electron density ion sphere model.)

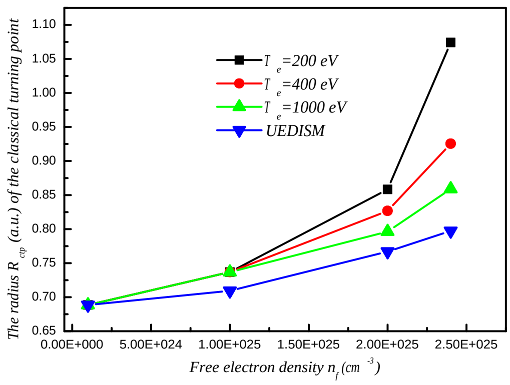

Figure 1. The variation of the classical turning point radius R_{ctp} of the bound electron in 2p orbit for the atomic state 1s2p (^{1}P) of He-like Al with free electron densities and temperatures.

The critical free electron densities and temperatures are simultaneously obtained by the ion sphere model with Fermi-Dirac distribution of free electrons. For example, if the spectral line He$_\alpha$ of C^{4+} ion can be observed at a given free electron density $7.00 \times 10^{23}/\mathrm{cm}^3$, the free electron temperature must be larger than or equal to 150 eV, or if the spectral line He$_\alpha$ of C^{4+} can be observed at a given electron temperature 150 eV, the free electron density must be less than or equal to $7.00 \times 10^{23}/\mathrm{cm}^3$. It can be seen from Table 1 that the critical free electron densities for different spectral lines of He-like C, Al and Ar obtained in this work are close to the experimental and other theoretical results.

Table 1. The critical fee electron densities n_f (in cm^{-3}) and temperatures T_e (in eV) for spectral lines He$_\alpha$, He$_\beta$ and He$_\gamma$ of He-like C, Al and Ar, along with experimental and other theoretical results. The notation $x(y)$ indicates $x \times 10^y$.

	He$_\alpha$		He$_\beta$		He$_\gamma$	
Z	n_f	T_e	n_f	T_e	n_f	T_e
6	7.00(23)	150	6.70(22)	50	1.30(22)	70
	7.10(23)	200	6.80(22)	60	1.35(22)	UEDISM
	7.20(23)	300	6.90(22)	100	1.88(22)^a	
	7.30(23)	400	7.00(22)	150		
	7.40(23)	700	7.10(22)	200		
	7.50(23)	1500	7.20(22)	400		
	7.60(23)	UEDISM	7.30(22)	UEDISM		
	8.05(23)^a		5.15(22)^a			
13	2.20(25)	200	2.20(24)	120	4.20(23)	100
	2.30(25)	400	2.30(24)	250	4.30(23)	150
	2.40(25)	700	2.40(24)	700	4.40(23)	200
	2.50(25)	1500	2.50(24)	1500	4.50(23)	400
	2.60(25)	5000	2.55(24)	UEDISM	4.60(23)	700
	2.65(25)	UEDISM	2.21(24)^a		4.65(23)	1200
	2.43(25)^a		2.20(24)^b	700^b	4.70(23)	UEDISM
			2.44(24)^c		5.00(23)^a	
			1.98(24) –		6.60(22) –	
			2.64(24)^d		1.32(23)^d	
18	9.00(25)	400	9.00(24)	200	1.70(24)	200
	9.50(25)	900	9.50(24)	600	1.75(24)	300
	1.00(26)	1900	1.00(25)	1500	1.80(24)	500
	1.05(26)	6000	1.02(25)	2700	1.85(24)	800
	1.09(26)	UEDISM	1.05(25)	UEDISM	1.90(24)	2300
	7.51(25)^a		7.64(24)^a		1.95(24)	UEDISM
					2.11(24)^a	

^{a}Reference [1] ^{b}Reference [2] ^{c}Reference [3] ^{d}Reference [4]

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