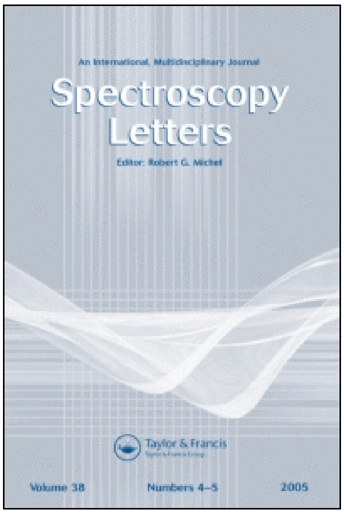

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RELATIVE INTENSITY METHOD FOR TEMPERATURE MEASUREMENT

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Introduction

A new method (1,2) has been elaborated for the determination of the discharge channel axis temperature in a cylindrically symmetrical transparent plasma of a transient electric discharge, using the calculated and normalized intensity values of spectrum lines as functions of channel axis temperature $\frac{I}{I_{max}} = f(T_o)$, the measured and normalized intensity values of the same spectrum lines as functions of discharge time $\frac{I}{I_{max}} = f(t)$, and from them the discharge channel axis temperature as functions of discharge time is derived $T_o = f(t)$. The method is valid in longitudinal time-resolved observations assuming local thermodynamical equilibrium, when an averaging of the light originating from different parts of the cross section of the discharge channel is performed. The procedure itself reminds one, in principle, of the method given by Fowler and Milne (3-5) but with the difference that, in the method used by Fowler and Milne the temperature is determined along the radius of a spherical light source, whereas this new method determines the axis temperature as a function of discharge time. In these papers (1, 2) the functions $I = f(T_o)$ have been calculated by using an approximate method. In this paper the normalized intensity values as functions of channel axis temperature $I = f(T_o)$ have been calculated exactly in the case of 10 spectrum lines of 5 elements.

The Method of Calculation

The determination of the function $I = f(T_o)$ requires the evaluation of the integral (6,7)

$$I(T_o) = \mathrm{const} \int_0^\infty \varepsilon\big(T(\varrho)\big)\varrho \, d\varrho \qquad (1)$$

The const does not play role because of the normalization ϱ is the channel radius, $\varepsilon(T)$ is the emission coefficient.

The relation between T and ϱ is defined by the equation (8-11)

$$T = \frac{T_o}{1+\varrho} \qquad (2)$$

T is the temperature at a distance ϱ from the axis. The emission coefficient is given as follows:

$$\varepsilon(T) = \frac{A}{4\pi} h\nu \frac{g_a}{U_r} n_r \left[\exp -\left(\frac{eU_a}{kT}\right)\right] \qquad (3)$$

where A is the transition probability, h is the Planck's constant, ν is the frequency of the line, g_α is the statistical weight of the upper term, u_r is the partition function of the r times ionized atom, n_r is the number of emitting atoms per cm^3 in the r stages of ionization, $r = 0, 1, 2, \dots$ the stages of ionization, e is the charge of electron, U_α is the excitation potential, k is the Boltzmann constant. n_r and u_r are temperature dependent, but u_r may be taken as temperature independent as follows:

$$u_r(T) = g_{r,0} + g_{r,1}\left[\exp -\left(\frac{eU_{r,1}}{kT}\right)\right] + g_{r,2}\left[\exp -\left(\frac{eU_{r,2}}{kT}\right)\right] + \dots \quad (4)$$

where $g_{r,0}$, $g_{r,1}$, $g_{r,2}$, ... are the statistical weights of the successive levels of the r times ionized atom, $U_{r,1}$, $U_{r,2}$, ... are the excitation potentials of the successive levels of the r times ionized atom. Very often the inequalities $\exp -\left(\frac{eU_{r,1}}{kT}\right)$, $\exp -\left(\frac{eU_{r,2}}{kT}\right)$, $\dots \ll 1$ hold. In this case the function $u_r(T)$ reduces to the statistical weight of the ground level $g_{r,0}$. So the equation (4) can be written in good approximation as follows:

$$u_r \cong g_{r,0} \equiv g_r = (2S+1)(2L+1) \quad (5)$$

where S and L are the resulting spin and orbital momenta, respectively, both expressed in units of $\hbar$. In the calculations g_r was used instead of u_r.

The temperature dependence of n_r can be derived using the Saha equation Namely,

$$n_r = \frac{1-x}{1+x+r}\ \frac{P}{kT} \qquad (6)$$

where P is the total pressure (1 atm), x is the degree of ionization Using the Saha equation

$$\frac{(x+r)x}{(1+x+r)(1-x)} = \frac{U_{r+1}}{U_r}\ \frac{2(2\pi m_e)^{3/2}(kT)^{\frac{5}{2}}}{h^3 P}\left[\exp -\left(\frac{eU_r}{kT}\right)\right] \equiv f(T) \qquad (7)$$

the temperature dependent part of equation (6) can be written as follows:

$$\frac{1-x}{1+x+r} = \frac{\left[1+\frac{1}{f}\right]^{1/2} - \left[1+\frac{r^2}{4(1+\frac{r}{2})^2}\,\frac{1}{f}\right]^{1/2}}{\left[1+\frac{1}{f}\right]^{1/2} + \left[1+\frac{r^2}{4(1+\frac{r}{2})^2}\,\frac{1}{f}\right]^{1/2}} \qquad (8)$$

In equation (7) m_e is the mass of electron and U_r is the ionization potential of an ion belonging to the ionization level r. The equation (3) can be written, by using equation (6) and (8), as follows

$$\varepsilon(T) \propto \frac{\left[\exp -\left(\frac{eU_a}{kT}\right)\right]}{T}\left\{\frac{\left[1+\frac{1}{f}\right]^{1/2} - \left[1+\frac{r^2}{4(1+\frac{r}{2})^2}\,\frac{1}{f}\right]^{1/2}}{\left[1+\frac{1}{f}\right]^{1/2} + \left[1+\frac{r^2}{4(1+\frac{r}{2})^2}\,\frac{1}{f}\right]^{1/2}}\right\} \qquad (9)$$

The equation (9) together with the equations (7) and (2) makes the evaluation of equation (1) possible with the aid of an electronic computer.

Results

The functions $\frac{I}{I_{max}} = f(T_o)$ have been calculated for 10 spectrum lines of 5 elements using Ural-2 electronic computer. The values of T_o run from 0·5x10^4 °K to 1x10^5 °K, with an interval of 0·1x10^4 °K. The Simpson quadrature has been used for the evaluation of the integral of equation (1). The calculated values have been divided with the value of I_{max} and these normalized $I = f(T_o)$ curves are shown in Fig. 1-5. Table I summarizes the data used for the calculation taken from (12-15).

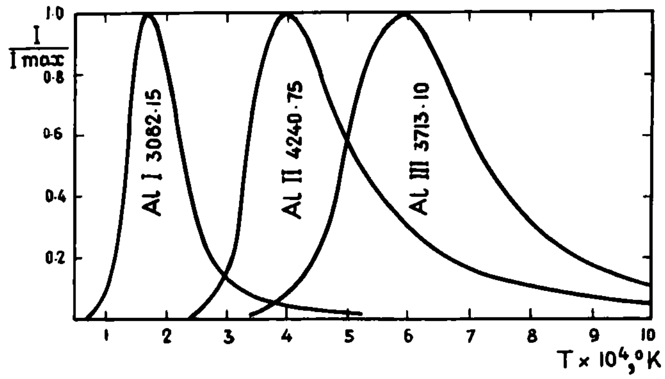

FIG. 1

The calculated and normalized $I = f(T_o)$ functions of Al

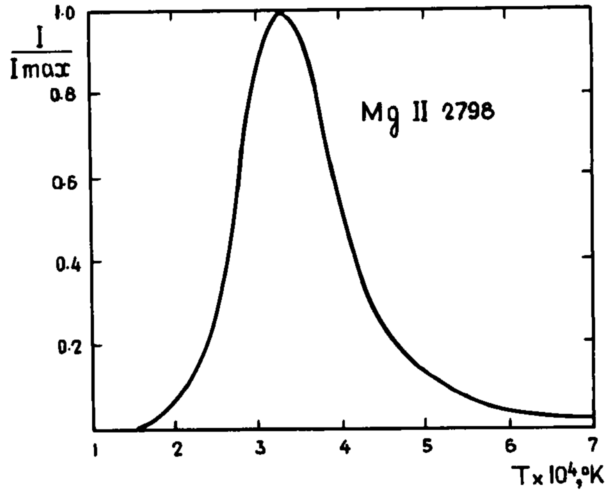

FIG. 2

The calculated and normalized $I = f(T_0)$ function of Mg.

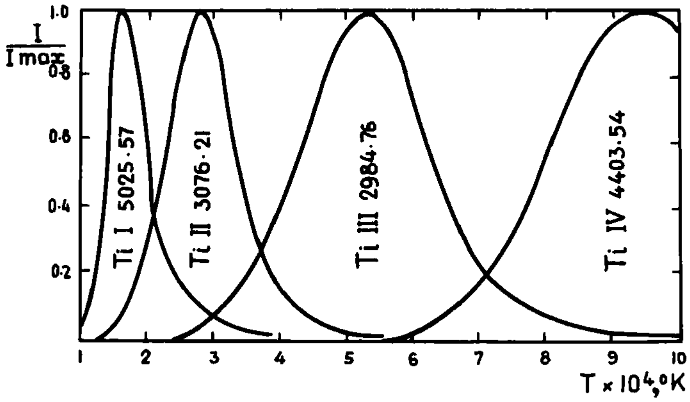

FIG. 3

The calculated and normalized $I = f(T_0)$ functions of Ti.

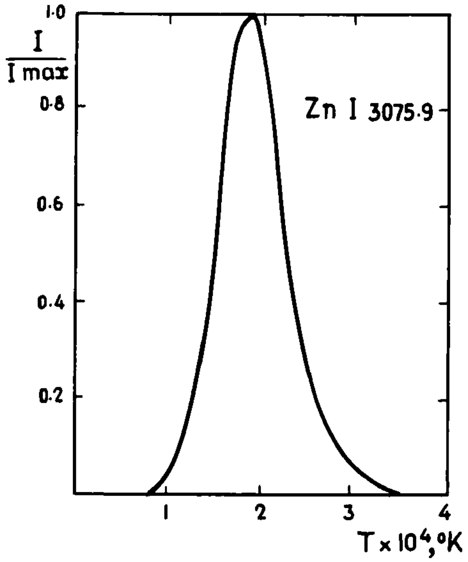

FIG. 4

The calculated and normalized $I = f(T_o)$ functions of Zn.

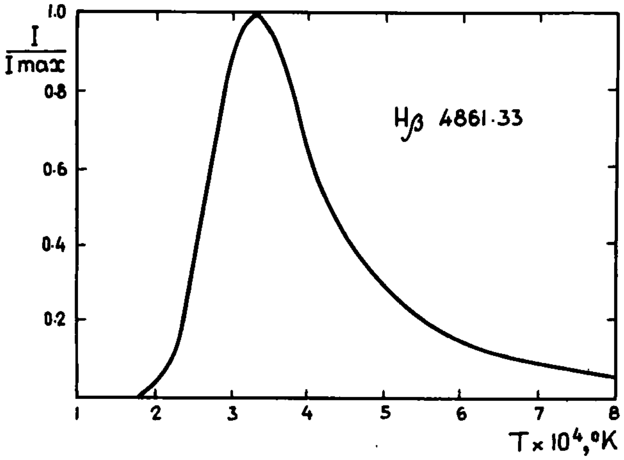

FIG. 5

The calc lated and normalized $I = f(T_o)$ functions of H_β

TABLE 1

Data used for the Calculation

Element	Line(Å)	Transition	r	eU_a(eV)	eU_r(eV)	$\frac{g_{r+1}}{g_r}$	T_o max x10^3 °K
Al I	3082·15	$3p\,^2P^o_{\frac{1}{2}} - 3d\,^2D_{\frac{1}{2}}$	0	4·02	5·985	1/6	17
Al II	4240·75	$5s\,^1S_0 - 9p\,^1P^o_1$	1	17·97	18·827	2	40
Al III	3713·10	$4p\,^2P^o_{\frac{3}{2}} - 5s\,^2S_{\frac{1}{2}}$	2	21·15	28·447	1/2	59
Mg II	2799·99	$3p\,^2P^o_{\frac{3}{2}} - 3d\,^2D_{\frac{5}{2}}$	1	8·86	15·034	1/2	33
Ti I	5025·57	$z\,^5G^o_6 - e\,^5F_5$	0	4·51	6·836	28/21	16
Ti II	3706·21	$b\,^2D_{\frac{3}{2}} - z\,^2P^o_{\frac{3}{2}}$	1	4·91	13·637	21/28	28
Ti III	2984·76	$b\,^1D_2 - z\,^1D^o_2$	2	9·32	28·143	10/21	53
Ti IV	4403·54	$4f\,^2F^o_{\frac{7}{2}} - 5d\,^2D_{\frac{5}{2}}$	3	32·09	43·245	1/10	94
Zn I	3075·9	$1\,^1S^o - 2\,^3P^o_1$	0	4·03	9·39	2	19
H_β	4861·33	$2p\,^2P^o - 4d\,^2D$	0	12·75	13·597	1/2	33

Conclusions

Having been measured the functions $\frac{I}{I_{max}} = f(t)$ experimentally, the calculated and normalized $I = f(T_o)$ curves makes to determine the discharge channel axis temperature as function of discharge time possible.

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