Choices of Spectral Lines and Published A_g -values in the Measurement of Excitation Temperature of Spectroscopic Light Sources

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To secure a high degree of precision in the measurement of excitation temperatures from relative intensities of spectral lines, the choices of the lines and the best A_g -values deserve to be discussed. Twenty-three iron atom lines which satisfy requirements for thermometric lines were chosen out of spectra in a wavelength range 3000 to 4000 Å. Excitation temperatures of d.c. arcs and plasma jet flames were determined from the relative line intensities, which were obtained by a simplified procedure to calibrate the sensitivity of the emulsion over the wide range of wavelength, and the A_g -values cited from various literatures. A good agreement was found between the temperatures calculated with the A_g -values based on the NBS Monograph 53 and those with the A_g -values based on the American Institute Physics Handbook (second edition). This suggests that the A_g -values according to these literatures provide relatively reliable values of temperature. Line pairs and published A_g -values recommended for the practicable two-line method were also presented.

1. Introduction

The investigation of the nature of spectroscopic light sources has been carried out in many studies on the emission spectrochemical analysis. Especially, the temperature is one of the most important factors associated with the physical characteristics of light sources. Discussion in this paper is concerned with a method for measuring the so-called "excitation temperature," which describes the population of the various energy levels. The method, which is based on comparison of the

observed relative intensities of spectral lines of an element with known relative transition probabilities, has gained the greatest popularity in the spectrochemical field because of the simplicity and the relatively high precision. Actually, the excitation temperature of the conventional arc or spark has often been determined by this method¹⁾.

Now, a few fundamental discussions on the subjects described below are necessary for the temperature measurement. In the two-line method which uses only two spectral lines differing little in wavelength, the subjects to

be considered are

1) thermometric species and spectral lines utilized, and 2) A_g -values (A : transition probability, g : statistical weight) of the lines.

While in the temperature measurement using a large number of lines*, the subjects are

1), 2) described above, and

3) the correction for the relative intensities of the lines according to the spectral sensitivity calibrations of the emulsion and the optical arrangement.

Nowadays, relative transition probabilities of lines of a variety of atoms and ions are known. However, a great difference is observed among the relative values reported in various papers probably due to the difference of procedures used for the determinations. As various spectral lines and A_g -values are used for temperature measurements in numerous reports which describe excitation temperatures of spectroscopic light sources, the mutual and direct comparison of temperature values given in those papers are pretty difficult. Therefore, it is desirable that a suggested method, in which recommended spectral lines and A_g -values are given, is presented for a common use among different laboratories.

The influence of a change in the A_g -values on the resulting temperatures is remarkable in particular when the two-line method is utilized. Boumans²⁾ indicated that the different A_g -values for the line pairs of Cu and those of Zn give rise to large differences of temperature. The knowledge concerning the influence of the A_g -values on the temperature obtained by the multi-line method is only scarcely available in the literature. From the viewpoint of precision, the multi-line method is superior to the two-line method. The former method, however, involves the use of lines scattered in a wide range of wavelength, which necessitates the time-consuming and difficult operation of determining the spectral sensitivity curve of the emulsion including the optics. For that reason, it is also desirable to develop a simple and reliable procedure for the multi-line method. This paper describes the signifi-

cance of the choices of spectral lines and published A_g -values, and proposes practical conditions and procedures for the two-line method and multi-line method which high precision is attained.

2. Discussions based on Published Data

2.1 Choice of thermometric species

In order to obtain precise temperature, the thermometric species must satisfy the following requirements³⁾.

1) The thermometric species should be an element of high ionization potential to prevent the temperature of the light source from dropping when the species is introduced.

2) The boiling point should neither be too high nor too low to achieve a steady volatilization.

3) The energy difference between upper levels of thermometric lines to be measured, $E_{\max} - E_{\min}$, should be large. (where $E_{\max}$ and $E_{\min}$ are the maximum and the minimum excitation potentials of the upper levels, respectively.)

Table I. Comparison of properties of the thermometric species.

Ionization potential (eV)	Zn 9.36, Cd 8.96, Co 8.5 Fe 7.83, Cu 7.86, Mg 7.61 Sn 7.30 Ti 6.81, Cr 6.74, Ba 5.19
Boiling point (°C)	Ti 3313 Fe 2880, Cu 2663, Co 2375, Cr 2327, Sn 2190 Ba 1537, Mg 1088, Zn 907, Cd 767
Difference of the excitation potentials, $E_{\max} - E_{\min}$ (eV)	Cu 5.05 Cr 4.94, Fe 4.67, Zn 4.47 Cd 4.30, Co 3.88, Ti 3.60 Mg 2.58, Sn 2.21, Ba 1.74

Table I gives the properties of elements which have ever been used as thermometric species. The difference between $E_{\max}$ and $E_{\min}$ depends upon the wavelength range and spectral lines to be measured. The value [in

* This procedure is called "multi-line method" temporarily in this paper, distinguished from the two-line method.

eV] shown in Table I is the difference obtained by investigating excitation potentials of all spectral lines over a range from 2800 to 5000 Å, without considering whether the lines have sufficient intensities to be observed. It is easily imagined from requirements for the thermometric line* that the practical difference between $E_{\max}$ and $E_{\min}$ will become smaller than the value given in Table I. Therefore, such elements as magnesium, tin, and barium are not suitable for the thermometric species. Iron and copper are pretty satisfactory in all respects described above. When use of the multi-line method as well as the two-line method is taken into consideration, iron is more useful than copper because a large number of lines appear in the violet region. Thus, measurements in this paper were carried out using iron atom lines.

2. 2 Choice of iron atom lines

Firstly, it is necessary to examine whether the relative Ag -values of the lines of interest are known.

Numerous publications have appeared on the Ag -values (or the oscillator strengths: gf -values) of iron atom lines⁴⁾. In this study, eight individual papers^{5-9), 11-13)} and three comprehensive compilations^{10, 14, 15)} have been selected out of publications issued during the past twenty years. The number of iron atom lines of which Ag -values or gf -values are given in those publications is shown in Table II. It is also evident from Table II that spectral lines available for temperature measurements are especially in a wavelength region longer than

3000 Å.

Several line pairs which can be used for temperature measurements by the two-line method are listed in Table III. Under the co-existence of chromium, it is recommended to use the line pair Fe I 3705.57/Fe I 3709.25, since the lines Fe I 3017.63, Fe I 3024.03, and Fe I 3030.15 are influenced by adjacent chromium lines. A disadvantage of the line pair Fe I 3705.57/Fe I 3709.25 is the small value of $E_2 - E_1$.

The excitation temperature T is given by the equation

$$T = 5040(E_2 - E_1) / (\log A_1 g_1 \lambda_2 / A_2 g_2 \lambda_1 + \log I_1 / I_2) \quad (1)$$

Table II. Bibliographies on the atomic transition probabilities for Fe I lines.

Author or editor	wave-length region (Å)	Number of lines	Reference number
H.M. Crosswhite	3506—5424	43*	5)
H. Kopfermann <i>et al.</i>	3720—3737	2	6)
J. Aarts <i>et al.</i>	3815—5507	83	7)
E. Hinnov <i>et al.</i>	3581—3860	4	8)
K. Ziock	3705—3748	8	9)
D.E. Gray	2851—5455	437	10)
R. Hefferlin	3506—5424	45	11)
F.A. Korolev <i>et al.</i>	2983—3075	10	12)
R.R. Shvangiradze <i>et al.</i>	3017—3030	3	13)
C.H. Corliss <i>et al.</i>	2084—8999	658	14)
D.E. Gray	2706—5663	538	15)

* Values which Hefferlin calculated from the relative intensities given by Crosswhite.

Table III. Line pairs for the two-line method, energy differences of the upper excitation potentials, and log ratios of $(Ag)_2 \lambda_1$ to $(Ag)_1 \lambda_2$ calculated from the Ag -values according to several literatures.

Line pair I_1 (Å)/ I_2 (Å)	$E_2 - E_1$ (eV)	Log $(Ag)_2 \lambda_1 / (Ag)_1 \lambda_2$			
		AIPH(I) ¹⁰⁾	Shvangiradze ¹³⁾	NBS ¹⁴⁾	AIPH(II) ¹⁵⁾
Fe I 3017.63/Fe I 3030.15	2.305	2.36	1.66	2.03	1.88
Fe I 3025.03/Fe I 3030.15	2.314	2.36	1.58	1.93	1.73
Fe I 3024.03/Fe I 3031.22	2.333	2.30	—	1.93	1.66
Fe I 3705.57/Fe I 3709.25	0.859	0.842	—	0.882	0.842

* Firstly, the lines should have the sufficient observed intensities; secondly, the lines of which lower energy levels are the ground state should be excluded.

Fig. 1. Intensity ratio of line pairs Fe I 3017/Fe I 3030, Fe I 3024/Fe I 3030, Fe I 3024/Fe I 3031, and Fe I 3705/Fe I 3709 plotted as a function of the excitation temperature. Curves based on various Ag -values, i. e. AIPH(I)¹⁰⁾, Shvangiradze¹³⁾, NBS¹⁴⁾, and AIPH(II)¹⁵⁾ values are compared.

where E is the excitation potential (eV), A the relative transition probability, g the statistical weight, λ the wavelength, and I the relative intensity; the subscripts 1 and 2 refer to the lines 1 and 2 respectively. The graphical representation of equation (1) for the line pairs given in Table III is shown in Fig. 1. Evidently, large discrepancies are observed among the I_1/I_2 — T curves for different Ag -values according to various literatures. At high temperatures in particular, an error in the Ag -value can lead to a considerable error in the temperature obtained.

Spectral lines for the multi-line method were chosen out of iron atom lines satisfying the following conditions.

1) Wavelengths are in the range 3000–4000 Å. (A great variation in the sensitivity of the conventional emulsion such as the Kodak SA-1 is not observed in this wavelength range.)

2) Relative intensities expressed as “Arc Intensities” in the MIT Wavelength Tables¹⁶⁾

are larger than 150. (The relative intensities correspond to those larger than 14 in the NBS Monograph 32¹⁷⁾.)

3) Lower energy levels are not the ground state.

4) Excitation potentials scatter in a wide range of energies.

5) Influences of adjacent lines on the relative intensities are negligibly little.

Energy levels and $\log Ag/\lambda$ of twenty-three iron atom lines chosen, including six lines used for the two-line method, are listed in Table IV. Under the appearance of CN band spectra with band heads at 3591 and 3881 Å, it is undesirable to use the lines Fe I 3581.25 and Fe I 3820.43 because of the difficulty of the accurate background correction.

2.3 Choice of published Ag -values

The influence of the choice of published Ag -values on the temperature obtained by the multi-line method were investigated by the following procedure.

Table IV. Energy levels and log ratios of Ag to wavelength of Fe I spectral lines for temperature measurements.

wavelength (Å)	Energy level			Log Ag/λ			Adjacent line (Å)
	E_{lower} (K)	E_{upper} (K)	(eV)	AIPH(I)	AIPH(II)	NBS	
3008.14	888	34122	4.23	1.50	2.827	4.88	
3009.57	7377	40594	5.03	2.46	3.09	5.17	Sn I 3009.15
3017.63	888	34017	4.22	1.15	2.119	4.22	Cr I 3017.57
3024.03	888	33947	4.21	1.15	2.27	4.33	Cr I 3024.35
3030.15	19621	52613	6.52	3.51	4.00	6.25	Cr I 3030.25
3031.22	19788	52769	6.54	3.45	3.93	6.26	
3059.09	416	33096	4.10	1.51	2.901	4.82	
3083.74	7986	40405	5.01	2.50	3.0	5.09	V I 3083.54
3180.23	19757	51192	6.35	3.36	3.87	6.03	
3225.79	19351	50342	6.24	4.17	4.3	6.52	
3286.76	17550	47967	5.95	—	3.76	6.06	Ni I 3286.95
3407.46	17550	46889	5.81	—	3.94	5.99	
3413.14	17727	47017	5.83	—	3.67	5.88	
3475.45	704	29469	3.65	2.031	2.031	4.27	
3490.58	416	29056	3.60	1.971	1.971	4.22	Co I 3490.74
3565.38	7728	35768	4.43	2.99	2.99	5.34	
3581.20	6928	34844	4.32	3.6	3.7	5.81	
3705.57	416	27395	3.40	1.698	1.698	4.01	
3709.25	7377	34329	4.26	2.540	2.540	4.89	
3737.13	416	27167	3.47	2.408	2.408	4.60	Ni I 3736.81
3820.43	6928	33096	4.10	3.13	3.233	5.50	V I 3820.30
3930.30	704	26140	3.24	1.389	1.389	3.24	
3969.26	11976	37163	4.61	2.77	2.77	5.04	Co I 3969.12

Log ratios of Ag -values to wavelengths for many iron atom lines are plotted versus energies of the upper levels. Then a value called m -value in the present work, which corresponds to the slope of a linear function, is determined by the least squares method. Evidently, smaller m -values lead to higher temperature values. Table V provides the m -values calculated from Ag -values according to six kinds of literatures. When the number of lines to be used is only six, big differences appear among the m -values. This means that, to obtain the precise temperature value, as many spectral lines as possible should be used for a given measurement of temperature. The influence of the choice of Ag -values is not negligible even if nineteen or more lines are utilized. However, use of twenty-three iron

Table V. m -values calculated from the Ag -values according to some literatures.

Reference	Wavelength range of lines (Å)		
	3659—3984	3815—3970	3008—3970
Crosswhite ⁵⁾	1.01 (6)	—	—
Aarts ⁷⁾	—	0.87 (19)	—
AIPH(I) ¹⁰⁾	1.24 (6)	1.04 (19)	0.60 (20)
Hefferlin ¹¹⁾	1.39 (6)	—	—
NBS ¹⁴⁾	1.30 (6)	1.00 (19)	0.67 (23)
AIPH(II) ¹⁵⁾	0.95 (6)	1.04 (19)	0.68 (23)

() Number of lines used.

When spectral lines Fe I λ_1 , Fe I λ_2 , Fe I λ_3 , ..., and Fe I λ_n are used,

$$m = (n \sum_{i=1}^n E_i Y_i - \sum_{i=1}^n E_i \sum_{i=1}^n Y_i) / \{n \sum_{i=1}^n E_i^2 - (\sum_{i=1}^n E_i)^2\},$$

where $Y_i = \log(Ag/\lambda)_i$.

lines can be recommended for practical purposes, because a good agreement is observed between the m -values based on the NBS Monograph 53⁽⁴⁾ and the AIPH(II)⁽¹⁵⁾. If we use twenty-three iron lines listed in Table IV for temperature measurements, a good agreement will be obtained between temperature values calculated with the NBS Ag -values and the AIPH(II) Ag -values. From the statistical point of view, the Ag -values based on the AIPH(I)⁽¹⁰⁾ seems to provide less precise temperature values.

3. Temperature Measurements of Spectroscopic Light Sources

3.1 Apparatus

Excitation temperatures of d.c. arcs and plasma jet flames were determined by the two-line method and the multi-line method described in the previous section. Emission measurements were made using a 1.25-m Czerny-Turner spectrograph, JEOL Type 125, which was equipped with a 1200 line-per-mm grating blazed for 3000 Å, giving reciprocal linear dispersion of 6.2 Å/mm in the first order. Eastman Kodak SA-1 plates were developed for four minutes in a tray containing D-19 developer at 20°C. Densities of spectral lines were measured using a Shimadzu Microphotometer, Type 7A.

3.2 Plate calibration for the multi-line method

Strictly speaking, the spectroscopic sensitivity of the emulsion is not uniform over the entire range 3000 to 4000 Å. It is fairly difficult to determine the relative intensities of lines accurately, because the characteristics of the spectrograph and of the microphotometer employed as well as the sensitivity of the emulsion should be taken into account. To avoid the difficulty, the authors tried to determine the relative intensities and excitation temperatures by a rather simplified procedure described below.

According to the usual two-step method for the plate calibration, the density value of the "weak" step of a given line, as ordinate, is plotted against the corresponding value for the

Fig. 2. Preliminary curves for the plate calibration in the two-step method. D_w is the density of the "weak" step of a spectral line and D_s is the density of the "strong" step of the same line.

Fig. 3. Illustration of the principle of determining the excitation temperature from relations between $\log I\lambda/Ag$ and the upper excitation potential T_a , T_b , T_c , and T_o express excitation temperatures obtained using spectral lines in the wavelength range a, b, c, and a+b+c, respectively. T_m is the temperature calculated from the weighted mean of the slopes of three dotted lines.

“strong” step of the same line as abscissa. When this plotting is made using spectral lines over a wide wavelength range, points scatter along several curves of best fit. An example of the curves is shown in Fig. 2. Each curve indicates a short range where the spectral sensitivity of the emulsion plus optics varies little with the wavelength.

If the range 3000 to 4000 Å is divided into three, i.e. range “a” 3000 to λ_a Å, range “b” λ_a to λ_b Å, range “c” λ_b to 4000 Å, the relative intensities of spectral lines are obtained with three calibration curves prepared for the respective ranges of wavelength. Then the log ratio of intensity $\times \lambda$ to Ag -value for each line is plotted versus the upper excitation potential E . Dotted lines shown in Fig. 3 express the relations $\log I\lambda/Ag-E$ in the respective wavelength ranges. Thus, the excitation temperature T_m is given as a weighted mean of the slopes of the dotted lines, viz.

$$T_m = -5040n_o / (n_a k_a + n_b k_b + n_c k_c) \quad (2)$$

where n is the number of spectral lines and k is the slope; the subscripts o, a, b, and c refer to the entire wavelength range (3000 to 4000 Å in the present case), range “a,” range “b,” and range “c,” respectively.

If, for example, $k_a = 1.20$ ($T_a = 4200^\circ\text{K}$), $n_a = 4$, $k_b = 1.00$ ($T_b = 5040^\circ\text{K}$), $n_b = 3$, $k_c = 1.05$ ($T_c = 4800^\circ\text{K}$), and $n_c = 2$, T_m determined by means of the equation (2) is 4582°K . On the other hand, the excitation temperature T_o shown in Fig. 3, which is derived from the slope of the straight line of best fit obtained for all the plots without deviding the entire range, becomes 3677°K . This value is much lower than any temperature value of T_a , T_b , T_c , and T_m . When the sensitivity curve of the emulsion varies largely with the wavelength range, it is natural to produce a big difference between T_m and T_o . Clearly, T_m is more accurate than T_o .

3.3 Experimental results and discussions

An iron globule arc, of which advantages are the stability and low background intensities, was used as one of the spectroscopic light sources. Fig. 4 shows experimental relations between $\log I\lambda/Ag$ and E to obtain the exci-

Fig. 4. Temperature determinations of a 1.5-ampere of iron globule arc. The $\log I\lambda/Ag$ for various Ag -values are plotted versus the upper excitation potential.

tation temperature of the globule arc*. It is clear that use of the Ag -values according to the AIPH(I)¹⁰⁾ produces great differences among the slopes for different wavelength ranges, while use of the Ag -values according to the NBS Monograph¹⁴⁾ leads to small differences.

To eliminate the care on the self-absorption in the above experiment, a d.c. arc was burned using an aluminum alloy containing a small amount of iron (2.37 per cent) as the anode and a silver rod (6 mm ϕ) as the cathode. The experimental result on the arc is shown in Fig. 5. The scatter of the plotted points may be due to the fact that the background intensity, of which accurate correction is difficult, is higher than that of the globule arc.

Fig. 6 shows an example of the temperature measurements of the plasma jet light source developed for the analysis of solid samples¹⁸⁾.

* An image of the center portion of the arc (arc gap: 2 mm) was projected onto the slit of the spectrograph by means of a fused-quartz lens.

Fig. 5. Temperature determinations of a 1.5-ampere of d.c. arc burned between a silver cathode and an aluminum alloy anode.

Fig. 6. Temperature determinations of a plasma jet flame. Flow gas: N_2 7 l/min., Current: d.c. 13 A, Observed point in the flame: 25 mm above the cathode.

A 10 mg of soil sample containing 2.4 per cent of iron filled in a graphite cup electrode was evaporated and excited in the jet flame. The result indicates that the use of the NBS A_g -values reduces differences among the slopes for different wavelength ranges, as observed in Figs. 4 and 5.

The scatter of the points seen in Figs. 4–6 is caused by both the deviation of the measured A_g -values from the real A_g -values and the error of the observed relative intensities of the lines. The influence of the error of the relative intensities on the scatter is included equally in all the slopes plotted with various A_g -values, so that the differences of the degree of the scatter among the points plotted with the AIPH(I), AIPH(II), and NBS A_g -values mean that the different literature values lead to the different deviations of the measured A_g -values from the real A_g -values. Obviously, the NBS Monograph provided the least deviation. Thus, the NBS A_g -values are recom-

mended for the temperature measurement by the multi-line method.

Excitation temperatures measured under various conditions, including the results shown in Figs. 4–6, are summarized in Table VI. By the way, the m -values for the wavelength range 3008 to 3970 Å given in Table V suggested that a good agreement would be obtained between the temperatures determined with the NBS A_g -values and the AIPH(II) A_g -values, and in fact, as shown in Table VI, the A_g -values according to these literatures give rise to small differences (300°K or less) of temperature T_m . It is also evident that the temperature values determined by the two-line method on the basis of the A_g -values according to Shvangiradze¹⁸⁾ are higher by 1000°K on the average in comparison with the values T_m based on the NBS A_g -values. For the practical measurement, the following combinations of the line pair and the A_g -value are re-

Table VI. Results of temperature measurements of some light source.

Light source	Sample (Anode)	Reference for A_g -value	Two-line method				T_m Fe I 3008-3969
			$\frac{\text{Fe I } 3017}{\text{Fe I } 3030}$	$\frac{\text{Fe I } 3024}{\text{Fe I } 3030}$	$\frac{\text{Fe I } 3024}{\text{Fe I } 3031}$	$\frac{\text{Fe I } 3705}{\text{Fe I } 3709}$	
Globule arc 1.5 A gap: 1 mm	Pure iron	AIPH(I) ¹⁰⁾	4780	4660	4720	5800*	5230 [20]
		Shvangiradze ¹³⁾	6720	6770	—	—	—
		NBS ¹⁴⁾	5530*	5620*	5540*	5500*	5660 [23]
		AIPH(II) ¹⁵⁾	5960	6220	6350	5800*	5930 [23]
Globule arc 1.5 A gap: 2 mm	Pure iron	AIPH(I)	4620	4450	4710	5670*	4510 [20]
		Shvangiradze	6410	6350	—	—	—
		NBS	5320*	5330*	5530*	5390*	5490 [23]
		AIPH(II)	5710*	5870	6340	5670*	5620 [23]
D.C. arc 1.5 A gap: 1 mm	Al alloy containing Fe 2.37%	AIPH(I)	5180	4870	4850	5350*	4630 [20]
		Shvangiradze	7530	7230	—	—	—
		NBS	6070	5940	5720*	5100	5580 [23]
		AIPH(II)	6590	6620	6590	5350*	5770 [23]
D.C. arc 1.5 A gap: 2 mm	Al alloy containing Fe 2.37%	AIPH(I)	4530	4430	4230	5170*	4430 [20]
		Shvangiradze	6250	6310	—	—	—
		NBS	5210*	5300*	4880	4930	5220 [23]
		AIPH(II)	5580	5830	5500	5170*	5400 [23]
Plasma jet 13 A N_2 7 l/min	Soil containing Fe 2.4%	AIPH(I)	4240	4090	4240	4600*	4250 [18]
		Shvangiradze	5710	5630	—	—	—
		NBS	4830*	4810*	4900*	4410	4680 [21]
		AIPH(II)	5150	5250	5520	4600*	5050 [21]
Plasma jet 13 A N_2 7 l/min	Soil containing Fe 2.4% with BaCl_2	AIPH(I)	3880	3780	4090	4820*	4230 [18]
		Shvangiradze	5060	5060	—	—	—
		NBS	4360	4400	4690*	4620*	4650 [21]
		AIPH(II)	4620*	4750*	5260	4820*	4970 [21]

[] Number of lines used.

* The deviation from T_m based on the NBS A_g -value is within ± 5 per cent.

commended to secure reliable temperature values.

Line pair A_g -value
 Fe I 3024/Fe I 3031—NBS Monograph¹⁴⁾
 Fe I 3705/Fe I 3709—AIPH(II)¹⁵⁾

Temperature values, of which mean deviation from values T_m determined by the multi-line method using the NBS A_g -values is within ± 5 per cent, can be obtained by the two-line method using the combinations. Strictly speaking, the present method involves some problems in a theoretical aspect. The authors, however, propose it as a tentative method which can be used for the common purpose

to compare excitation temperatures of spectroscopic light sources among different laboratories.

4. Summary

A few fundamental studies were carried out on the measurement of the excitation temperature based on comparison of the observed relative intensities of spectral lines. Iron atom lines suitable for the two-line method and multi-line method were chosen out of spectra in a wavelength range 3000 to 4000 Å, and the influence of the choice of published A_g -values on the resulting value of temperature was in-

vestigated. A simplified procedure to calibrate the sensitivity of the emulsion plus optics over the wide range of wavelength was presented for the temperature determination by the multi-line method. When twenty-three selected iron lines were used for temperature measurements of a few light sources, a good agreement was found between the temperatures based on the A_g -values cited from the NBS Monograph 53 and those based on the A_g -values from the American Institute Physics Handbook (2nd edition). This means that the A_g -values according to these literatures provide relatively reliable temperature values. To obtain enhanced precision in the multi-line method, the use of the NBS A_g -values would be preferable, because the least scatter of the points was observed in the experimental plots of the $\log I\lambda/A_g$ versus the excitation potential.

On the basis of experimental results, line pairs and A_g -values recommended were also presented. Temperature values which coincide well with those determined by the multi-line method using the NBS A_g -values can easily be obtained by the two-line method using the combinations of the line pairs and A_g -values. Though, from a theoretical point of view, this method requires more discussions, it would be valuable as a practicable method for measuring the excitation temperature, especially in situations where the comparison of measured temperatures are desired among different laboratories.

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