Letters to the Editor

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Structure of Ta I

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IN a recent report by Kamei[1] on the quadrupole moment of Ta^{181}, he makes the following remark in a footnote: "G. J. van den Berg [Dissertation, Univ. Amsterdam, 1951 (unpublished)] modified the energy matrix given by Marvin, but this modification is apparently incorrect, owing to his misinterpretation of the article of G. Racah [Phys. Rev. 63, 367 (1943)]. The table of the composition of the states of Ta I $5d^3 6s^2$ given in reference 8 is based on van den Berg's calculation, and is, therefore, invalid."[2]

We wish to point out that the substitution error which indeed was made in the energy matrices for the $J = 3/2$ and the $J = 5/2$ states of the configuration d^3 has only a very little influence on the final table of composition. This is shown by Table I, where we have compared the results (in percent) of a correct calculation (upper figures) with the previous results (lower figures in parentheses) for the 3/2 and 5/2 levels of the electron configuration $5d^3 6s^2$ in Ta I. The results for the other levels remain unchanged.

TABLE I. Composition of the states of Ta I $5d^3 6s^2$.

	^4F	^4P	^2F	$\alpha\,^2D$	$\beta\,^2D$	^2P
$^4F_{5/2}$	98.3	0.2	0.2	1.0	0.3	...
	(98.2)	(0.1)	(0.2)	(1.1)	(0.4)	
$^4P_{5/2}$	0.5	87.8	1.0	10.6	0.1	...
	(0.5)	(87.6)	(0.8)	(11.0)	(0.1)	
$^2F_{5/2}$	0.8	2.2	61.4	35.2	0.4	...
	(0.7)	(2.1)	(60.1)	(36.6)	(0.5)	
$\alpha\,^2D_{5/2}$	0.1	9.4	37.4	52.2	0.9	...
	(0.1)	(10.0)	(38.8)	(50.0)	(1.1)	
$\beta\,^2D_{5/2}$	0.2	0.2	0.2	1.2	98.2	...
	(0.3)	(0.3)	(0.3)	(1.4)	(97.7)	
$^4F_{3/2}$	93.5	0.4	...	4.4	1.3	0.4
	(93.7)	(0.3)		(4.3)	(1.3)	(0.4)
$^4P_{3/2}$	1.9	76.5	...	3.6	0.6	17.4
	(1.6)	(79.5)		(3.0)	(0.4)	(15.5)
$\alpha\,^2D_{3/2}$	3.5	15.9	...	55.0	3.0	22.6
	(2.5)	(15.2)		(57.1)	(2.9)	(22.3)
$\beta\,^2D_{3/2}$	0.6	0.3	...	1.6	93.6	3.9
	(0.7)	(0.2)		(0.9)	(93.8)	(4.4)
$^2P_{3/2}$	0.5	6.6	...	35.5	1.5	55.9
	(0.5)	(4.9)		(34.5)	(1.5)	(58.6)

It should be remarked that the deviations are insignificant relative to the uncertainties introduced by the neglect of configuration interaction $d^3 s^2 - d^4 s$ and by the arbitrariness in the choice of the particular levels used in determining the configuration parameters. This probably also accounts for the discrepancies between our results and those arrived at by Trees.[3]

We should like to thank Dr. Kamei for sending us a copy of his paper prior to publication.

[1] T. Kamei, Phys. Rev. 99, 789 (1955).
[2] van den Berg, Klinkenberg, and Van den Bosch, Physica 18, 221 (1952).
[3] R. E. Trees, Phys. Rev. 92, 308 (1953).

Frequency Dependence of Electroluminescent Brightness of Impurity-Quenched Phosphors

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THE electroluminescent brightness (Destriau effect) of a powdered phosphor embedded in an insulating medium in the usual plaque cell is dependent on the voltage and the frequency applied to the cell, in addition to other parameters. The brightness at a constant frequency but varying voltage can be well approximated by the equation[1]

$$L = AV \exp[B/(V + V_0)], \tag{1}$$

where L denotes the time average of the brightness, V is the voltage applied to the cell, and A, B, and V_0 are constants. The behavior of the brightness at a constant
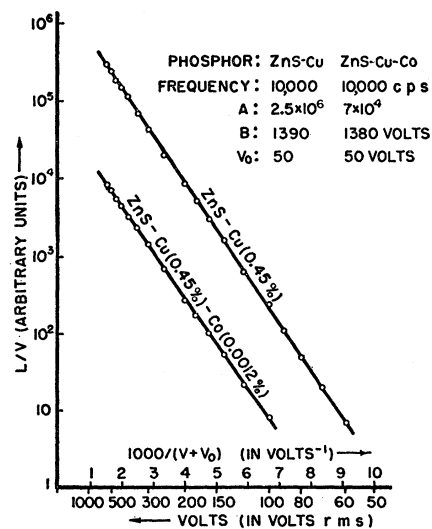

PHOSPHOR:	ZnS-Cu	ZnS-Cu-Co
FREQUENCY:	10,000	10,000 c p s
A:	2.5×10^6	7×10^4
B:	1390	1380 VOLTS
V_0:	50	50 VOLTS

FIG. 1. Dependence of $\log(L/V)$ on $1/(V + V_0)$ for a poisoned and an unpoisoned phosphor. L = electroluminescent brightness and V = applied voltage.
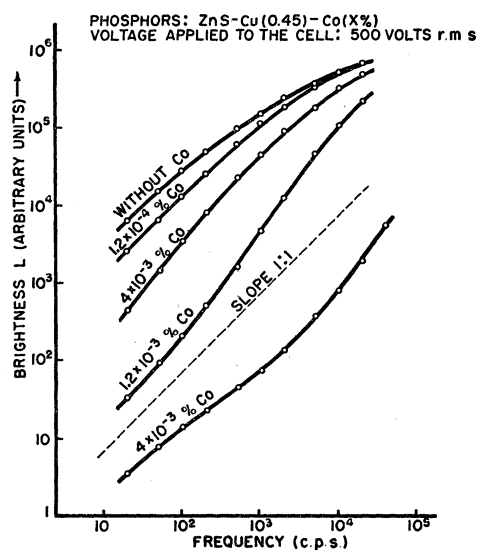
FIG. 2. Frequency dependence of electroluminescent brightness of some poisoned zinc sulfide phosphors.

voltage but varying frequency is more complex, but in general the brightness changes nearly linearly, or somewhat less than linearly, with low frequency and tends to saturate or to pass through a maximum at higher frequencies. An increase of brightness at a rate higher than proportional to the frequency has not been observed for normal "unpoisoned" electroluminescent zinc sulfides or related phosphors at room temperature.

The electroluminescent behavior of copper-activated zinc sulfides, which have been poisoned by the addition of Fe, Co, or Ni, is somewhat different. The brightness at a constant frequency but varying voltage can here also be described by Eq. (1); the poison lowers the value of the constant A, but the constants B and V_0 remain unchanged. An example of this voltage behavior is given in Fig. 1. Upon applying a constant voltage but varying frequency to the cell, it is observed

TABLE I. Comparison of the properties of an unpoisoned and a poisoned phosphor.

	Phosphor No. 297 ZnS−Cu(0.45%)	Phosphor No. 300 ZnS−Cu(0.45%) −Co(0.0012%)
Photoluminescence excited by 3650A (100 w mercury lamp)		
(a) at room temperature	Bright green	No visible luminescence
(b) at about −50°C	Bright bluish green	Moderate bluish green
(c) at about −180°C	Bright greenish blue	Bright greenish blue
Electroluminescence at room temperature		
(a) for frequency 60 cps	Green	Practically no visible light
(b) for frequency 10 000 cps	Bright blue green	Moderate blue green
(c) behavior with increasing frequency	Increases less than proportional	May increase faster than proportional
(d) behavior with increasing voltage	Expressed by Eq. (1)	Expressed by Eq. (1) but with lower value of A. The values of B and V_0 remain unchanged.

that in certain regions the brightness increases much faster than proportional to the frequency f. A rate of increase proportional to f^2 has actually been observed. Several examples of this behavior are given in Fig. 2. No significant difference could be observed between the action of Fe, Co, or Ni.

This behavior of electroluminescent brightness with increasing frequency seems to be similar to the strong increase of photoluminescent brightness with increasing ultraviolet intensity observed on poisoned phosphors by Urbach and his co-workers.[2] Probably both effects can be explained in the same manner. The concentration of free carriers in the phosphor increases either with increasing frequency during electroluminescence or with increasing exciting intensity during photoluminescence, and in both cases the bimolecular radiating recombination in activator centers is more strongly favored than the monomolecular radiationless recombination in centers of Fe, Co, or Ni.

It is also remarkable that strongly poisoned phosphors which are unable to photoluminesce even with high exciting ultraviolet intensity are still able to show good electroluminescence if a high frequency is applied to the cell. Some data of interest are given in Table I.

[1] Howard, Ivey, and Lehmann, Phys. Rev. 96, 799 (1954).
[2] Nail, Urbach, and Pearlman, J. Opt. Soc. Am. 37, 122 (1947).

Frequency Dependence of Electroluminescent Brightness

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THE brightness of normal electroluminescent ZnS phosphor at room temperature usually increases linearly, or less than linearly, as the frequency of the applied alternating field is increased. Increases faster than linear have not been observed at room temperature except with highly quenchable phosphors such as ZnS:Cu(Co or Ni or Fe).[1] It will be shown below that such observations cannot be used unambiguously for conclusions as to the frequency dependence of electroluminescence unless at the same time the temperature dependence of electroluminescence is considered.

Plots of electroluminescent brightness as a function of temperature usually exhibit one or even more peaks. As shown repeatedly,[2-4] these brightness curves shift as a whole to higher temperatures as the frequency is increased. Under the action of the alternating field, a certain number of activators and traps (or donors) are emptied and filled periodically. Electrons and holes at the same time are subjected to a probability of thermal transitions to the conduction band or the valence band, respectively. Since obviously the number of transitions is affected by the period of the applied voltage, a