The M Series of Element 91-Protactinium

W. C. PIERCE AND A. V. GROSSE, *Department of Chemistry, University of Chicago*

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Fourteen lines of the M series have been identified and their wavelength determined. The corresponding M lines for uranium were measured and Lindberg's values confirmed.

THE L series of protactinium was measured in 1930,[1] but no measurements have been reported for the M series. The recent isolation of larger quantities of protactinium[2] and the availability of a vacuum spectrograph now make possible the determination of the M series. As a check on the experimental accuracy the M series of uranium has also been measured and the values of Lindberg[3] confirmed.

A high vacuum Bragg spectrograph was used with a gypsum crystal. Ordinary typist's carbon paper was used as a slit cover to exclude light. About four milligrams of pure protactinium pentoxide (Pa_2O_5), was used as a source. It was rubbed onto the target in the usual manner and adhered well.[4]

The spectrograph is designed for x-ray film which is held in a curved casette about the crystal axis. Its radius is *ca.* 15 cm. Wavelengths are determined by the distance of a line from a selected reference line, in this case Cu $K\alpha_1^{\mathrm{II}}$. Distances are measured by a Gaertner comparator to 0.01 mm except for the weaker lines that are invisible under magnification. Measurement of several known lines gave the factor: 1 mm on film $= 11.29_2$ minutes (crystal rotation). $2d$ for the gypsum crystal is taken as 15.158_1A for first order and 15.166_6A for second order.

Weaker lines were registered in a series of three-hour exposures, each with crystal rocking of three degrees. Separate shorter exposures were taken for the stronger lines. Longer exposures were useless for at three hours the background, due to general radiation and to fluorescence from the crystal, was quite strong. The x-ray tube was operated at 10–15 ma with a peak voltage of about 9–10 kv. Full wave kenotron rectification was used without smoothing.

Results are summarized in Table I. The calculated values for element 91 are from the arithmetic mean of Lindberg's $(\nu/R)^{\frac{1}{2}}$ values for thorium and uranium. Relative intensity values are based on visual observation only (f = faint, s = strong).

The agreement is good for all strong lines, except $M_{\mathrm{II}}N_{\mathrm{IV}}$, where we could not check Lindberg's value for uranium. Among the weaker lines the agreement is as good as may be expected from the uncertainty in measuring their position on the film. The three short wave satellites could not be detected for either protactinium or

TABLE I. *Wavelengths (X.U.) of uranium and protactinium M series.*

Line	Uranium Obs.	Uranium Lindberg	Protactinium Obs.	Protactinium Calc.	Int.
$M_{\mathrm{II}}O_{\mathrm{IV}}$	2436	2440	2522	2523	ff
$M_{\mathrm{I}}N_{\mathrm{III}}$	—	2745	—	2839	—
$M_{\mathrm{II}}N_{\mathrm{IV}}$	2810	2813	2904	2907	s
$M_{\mathrm{III}}O_{\mathrm{V}}$	2942	2941	3032	3031	s
$M_{\mathrm{III}}O_{\mathrm{I}}$	3106	3114	3238	—	ff
$M_{\mathrm{II}}N_{\mathrm{I}}$	3322.5	3322	3434	—	ff
γ'	—	3463	—	—	—
$M_{\mathrm{III}}N_{\mathrm{V}}(\gamma)$	3473	3473	3570	3571	s
$M_{\mathrm{III}}N_{\mathrm{IV}}$	3514	3514	3607	3609	s
$M_{\mathrm{IV}}O_{\mathrm{II}}$	3568	3570	3683	3683	f
β'	—	3698	—	—	—
$M_{\mathrm{IV}}N_{\mathrm{VI}}(\beta)$	3708	3708	3819	3818	ss
α'	—	3886	—	—	—
$M_{\mathrm{V}}N_{\mathrm{VII}}(\alpha_1)$	3902	3902	4014	4015	ss
$M_{\mathrm{V}}N_{\mathrm{VI}}(\alpha_2)$	3916.5	3916	4027	4026	f
$M_{\mathrm{III}}N_{\mathrm{I}}$	4319	4322	4441	4434	f
$M_{\mathrm{IV}}N_{\mathrm{III}}$	—	4615	—	4754	—
$M_{\mathrm{V}}N_{\mathrm{III}}$	4936	4937	{ 5081	5079	s
			{ 5066		s
$M_{\mathrm{IV}}N_{\mathrm{II}}$	5040	5040	5182	5179	s

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[1] H. Beuthe and A. V. Grosse, Zeits. f. Physik **61**, 170 (1930).

[2] A. V. Grosse and M. S. Agruss, J. Am. Chem. Soc. **56**, 2200 (1934); Ind. Eng. Chem. April (1935).

[3] E. Lindberg, Nova Acta Reg. Soc. Scient. Upsaliensis [4] **7**, No. 7 (1931).

[4] Best results were obtained by pricking the surface of a copper target with a small sewing needle clamped to an electric massage vibrator. The sample was floated onto the target in suspension in alcohol and was finally pressed into the pits with a smooth agate pestle. Any grinding motion must be avoided as this covers the sample with copper. Some 95 percent of the sample was recovered after the determination.

uranium, because of intense "spark spectra" on the short wave side of the strong lines. In addition to these $M_{I}N_{III}$ and $M_{IV}N_{III}$ could not be detected for either element. $M_{II}N_{I}$ for Pa is very doubtful for the line does not have the typical diffuse appearance of other M lines. It is not reported for thorium by Lindberg. Pa $M_{V}N_{III}$ shows an anomalous doublet structure for in addition to the line at 5081 X.U. there is another equally strong line at 5066 X.U.

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The Constancy of the Velocity of Light

ROY J. KENNEDY, *University of Washington, Seattle*
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It is shown that hypotheses of variable velocity of light of the sort advanced by several recent writers are in conflict with experimental and astronomical data which greatly outweigh in probability the data correlated by these authors.

THE hypothesis that the velocity of light is a variable with time has appeared in several forms during the last few years, its basis being correlations of the results of direct measurements of the velocity. It is the purpose of this paper to demonstrate the great lack of plausibility of such a supposition.

De Bray's theory[1] that the velocity is a linear function of time has been shown by Wilson[2] and by the present writer[3] to be quite untenable; if it were correct the interference pattern in a fixed interferometer would shift with time at a rate about a thousand times as great as an observed (and presumably accidental) rate. However, by a curious coincidence, the more accurate of the interference data invoked against De Bray are quite useless as evidence for or against the recent theory of Edmondson.[4] This hypothesis is based on the measurements correlated by De Bray together with those of several other investigators. The data are surprisingly accurately represented by the relation

$$c = 299{,}885 + 115 \sin (2\pi/40)(t - 1901),$$

where c stands for the velocity of light and t is the date, A.D. This function evidently has a minimum sometime in 1931, and at that time would be approximately constant. The writer's interference data referred to above were mainly gathered during this time and so are irrelevant to this latter theory.

But in 1934, according to this equation, c should vary at rate of about 9 km per second per year, or about one part in 10^{13} per second, whereas some incidental observations of the writer during last summer indicated that no interference shift exists corresponding to a change in velocity of one part in about 4×10^{14} per second. It is practically certain that no effect 40 times as great (that required by the theory) could have escaped notice.

It is not surprising that the interferometer test is so far superior to the direct measurement in deciding as to the constancy of velocity. Small variations in any quantity are not customarily sought by taking differences between measurements of the whole, but rather by some such differential method as that provided by the interferometer.

The facts set forth above would be a complete refutation but for one possibility. It is to be emphasized that the velocity of light is an inferred rather than a directly measured quantity, and likewise its constancy is inferred from observation of other things. In the determination of the velocity we come finally to taking the

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1 De Bray, Nature **120**, 602 (1927); **133**, 464, 759, 948 (1934) and elsewhere.
2 Wilson, Nature **130**, 25 (1932).
3 Kennedy, Nature **130**, 277 (1932).
4 Edmondson, Nature **133**, 759 (1934).