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The Measurement of X-Ray Emission Wave-Lengths in the *M*-Series by Means of the Ruled Grating

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Measurements have been made by use of a plane ruled grating, of emission wave-lengths in the *M*-series for a number of elements having atomic numbers greater than (71). By making use of multiple positive orders, the correct determination of wave-lengths is secured even though uncertainties might exist in the position of the direct and reflected beams, or in the angle of incidence. The wave-lengths are found to be consistently greater than corresponding results obtained by means of the crystal method. The Moseley diagram for the results obtained are smooth curves.

INTRODUCTION

ABSOLUTE determinations of the wave-lengths of x-ray lines by the use of ruled gratings and the constants of the apparatus have been made by a number of investigators. In most cases the investigations have been carried out in the *K*- and *L*-series.[1, 2, 3] The results obtained for the wave-lengths of the x-ray lines have been consistently greater than the corresponding values found by the use of the usual crystal method. The magnitude of this difference as obtained in the more recent investigations seems to vary from 0.22 percent to 0.31 percent which is approximately ten times the probable error to be expected in the grating measurements.

In order to add to the existing data and thus possibly aid in the detection of the origin of this difference, it was considered desirable to carry out a series of measurements in the *M*-series by using a ruled grating. Prins and Takens,[4] using the grating method, have reported values of wave-lengths in this series for the elements Zr (40) to Sb (51). Prins[5] also secured values for two lines in the series for W (74). The present investigation was undertaken in order to obtain values of the wave-lengths in the *M*-series for the heavier elements, for which very little data now exist.

APPARATUS

The experimental arrangement as well as the method of procedure has been described previously in this journal.[2, 3] The elements studied, with the exception of osmium (76) were all obtainable as pure metals and could easily be attached to the face of the water-cooled target. In the case of osmium the oxide was employed. These stable targets allowed the application of considerable power to the x-ray tube so that on the spectrograms many measurable orders of the stronger lines were obtained. Reproductions of a few typical plates are shown in Fig. 1.

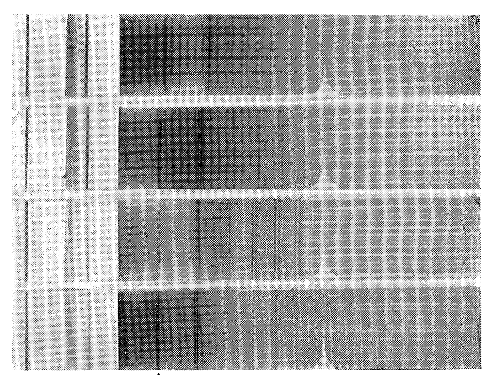

FIG. 1. Spectrograms of *M*-series.

[1] J. M. Cork, Phys. Rev. **35**, 1456 (1930).
[2] J. A. Bearden, Phys. Rev. **37**, 1210 (1931) *et seq.*
[3] R. B. Witmer and J. M. Cork, Phys. Rev. **42**, 743 (1932).
[4] J. A. Prins and A. J. Takens, Zeits. f. Physik **75**, 742 (1932).
[5] J. A. Prins, Physica **12**, 15 (1932).

In the M-series there are, for each element, two very strong lines of about the same intensity. These are denoted as the $\alpha_{1,2}$-line and the β-line and arise respectively from the electron transitions M_V to $N_{VI, VII}$ and M_{IV} to N_{VI}. As intimated, the former is a doublet consisting of the components α_1 and α_2 having an intensity ratio of about 20 to 1. In addition there are visible two weaker lines, one of shorter wave-length than the previously mentioned pair and one of longer wave-length. The former is usually denoted as $M\gamma$ and arises from the transition M_{III} to N_V. The line of longest wave-length is a rather broad doublet consisting of the components M_{IV} to N_{II} and M_V to N_{III}. Although these components could be observed separately the whole was so diffuse and weak except in the first order that it was not considered advisable to attempt to express their wave-lengths individually.

Calculations

Any attempt to determine the absolute wave-length of an emission line from measurements upon a single order, either outside or inside is unwarranted. Errors in expressing the grazing angle of incidence and the angle of diffraction must be expected of such magnitude as to place the final result outside the desired limits of accuracy. However, when several measurable orders of the same spectral line are available on the same photographic plate then, as has been previously shown, most of the uncertainties vanish. Errors of a general type such as those in determining the constant of the ruled grating and the distance between the grating and the photographic plate remain. The agreement that may be obtained for the results from the various orders is well illustrated by the figures in Table I which are averaged values from a set of five plates taken with platinum on the target.

TABLE I.

Order of spectral line		2	3	4	5	6
Wave-length (A)	$\alpha_{1,2}$	6.0601	6.0600	6.0601	6.0607	6.0591
	β	5.8415	5.8416	5.8417	5.8418	5.8417

TABLE II. *Collected values of wave-lengths of M-series lines in Angstroms. a, present investigation; b, crystal values, Lindberg.*

Element	Atomic number	Investigation	γ $M_{III}-N_V$	β $M_{IV}-N_{VI}$	α_1 M_V-N_{VII}	α_2 M_V-N_{VI}	$M_{IV}-N_{II}$	M_V-N_{III}
Hf	72	a		7.319	7.542			
		b		7.289	7.524			
Ta	73	a	6.330	7.040	7.271		9.347	
		b	6.299	7.008	7.237		9.297	9.311
W	74	a		6.774	7.004		9.001	
		b		6.743	6.969		8.943	8.977
Os	76	a		6.281	6.499		8.368	
		b		6.254	6.477		8.293	8.343
Ir	77	a	5.505	6.051	6.273		8.046	
		b	5.490	6.025	6.249	6.262	8.002	8.048
Pt	78	a	5.335	5.842	6.060		7.775	
		b	5.309	5.816	6.034	6.045	7.722	7.774
Au	79	a	5.150	5.642	5.859		7.529	
		b	5.135	5.612	5.828	5.842	7.451	7.507
Hg	80	a		5.441	5.655			
		b						
Tl	81	a	4.835	5.260	5.475		7.019	
		b	4.815	5.239	5.450	5.461	6.960	7.017
Pb	82	a	4.688	5.084	5.295		6.790	
		b	4.665	5.065	5.274	5.288	6.726	6.788
Bi	83	a	4.541	4.922	5.133		6.585	
		b	4.522	4.899	5.108	5.119	6.508	6.571
Th	90	a		3.941	4.148		5.323	
		b		3.934	4.130	4.143	5.229	5.329
U	92	a		3.723	3.911			
		b		3.708	3.902	3.916		

Results

The values obtained for the various wave-lengths are collected in Table II. Also noted here are the results for the same emission lines as reported by Lindberg[6] using the crystal method. With the spectrograph of this type it is possible to evaluate the wave-lengths of many of the fainter lines so that Lindberg reported as many as eighteen lines for several of the elements.

It may be observed that in every case the value obtained by the present grating method is greater than the corresponding value obtained by the use of crystals. The constancy of this difference which amounts to about 0.32 percent is shown in Fig. 2 which is a Moseley diagram representing the results for the two stronger lines in the M-series. The solid lines are drawn through the points as obtained with the crystal method, making the necessary interpolation between α_1 and α_2 when necessary. The lines appear to be smooth curves showing no discontinuities or irregularities for any element.

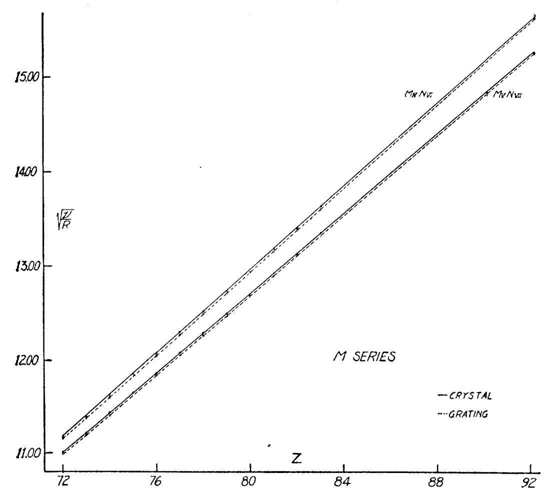

FIG. 2. Moseley diagram for M-series lines.

[6] E. Lindberg, *Dissertation*, Upsala, 1932.

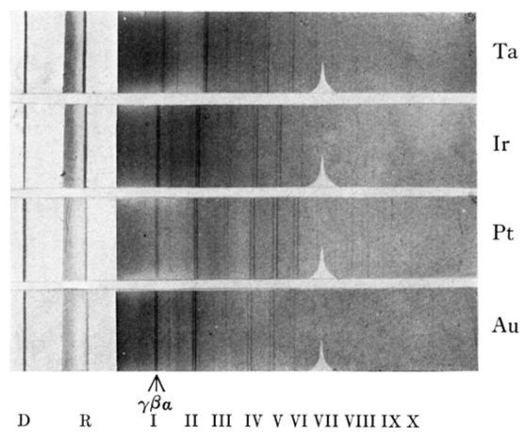

FIG. 1. Spectrograms of *M*-series.