On the K-Series of the Spectrum of Molybdenum.

By

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(With 1 Plate)

(Received April 11, 1923)

The K–Series of the spectrum of molybdenum was investigated by several authors, but some ambiguity still remains for the faint lines. In these experiments the wave lengths of the prominent lines were mostly determined by using the spectrum of the first or of the second order.

The object of the present work is to determine the wave lengths from the spectra of the higher order than the second. For this purpose a bent mica was employed as the crystalline reflector, as its grating constant is large and its reflecting power is very high.

The bent mica X–ray spectrometer used was essentially the same as that in the former work carried out by U. Yoshida and one of the writers ; but some modification has been done on the mode of photographing the spectrum.

Fig. 1 represents diagrammatically the essential features of the experimental arrangement. D is a large lead box with a slit S 0.2mm. wide. O is the center of a wooden cylinder 44.62mm. in radius and on its surface a sheet of mica MN 0.06mm. thick is carefully fastened.

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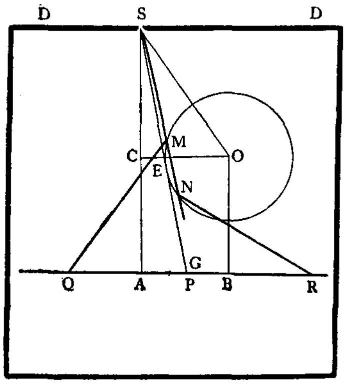
[1] Yoshida and Tanaka, These Memoirs **5**, 173 (1921)



P is a photographic plate.

The source of the X-ray was a coolidge tube with a molybdenum target, whose surface is perpendicular to the axis of the tube, and an induction coil was used to excite this tube. The pencil of rays which leaves the anticathode at a grazing angle is made to pass through the slit S in a slightly divergent form. The ray SM which impinges on the outer surface of the mica at M is partly reflected along MQ to the photographic plate. The part which is not reflected at M penetrates through the mica plate and impinges on the inner surface of the mica at N and here again reflected toward R on the photographic plate.

Let θ be the glancing angle of the ray SM to the cleavage face of the mica at M. If the thickness of the mica is vanishingly small, the glancing angle of reflection at N is approximately equal to θ.

Then the relation between the distance f of the spectral lines appearing on the photographic plate at Q and R and the glancing angle θ of the ray is given by the formula,

$$f = b[\tan(2\theta-\gamma)+\tan(2\theta+\gamma)] + r[\sin(\theta-\gamma)\tan(2\theta-\gamma) - \sin(\theta+\gamma)\tan(2\theta+\gamma)] + 2r\sin\theta\sin\gamma, \qquad (1)$$

where b is the perpendicular distance OB from O to the film side of the photographic plate P, r the radius of the cylinder of mica, and γ the angle CSM.

Denoting the perpendicular distance AS from S to the film side of the photographic plate by a, the perpendicular distance OC from O to this line by c, and the length of SO by d and that of SE which is tangent at E on the mica cylinder by e, we have,

$$d^2 = (a-b)^2 + c^2, \qquad e^2 = d^2 - r^2. \qquad (2)$$

Again let α, β and φ be the angle ASO, ESO and ESM respectively, then

$$\gamma=\alpha-\beta+\varphi. \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

But α, β and φ are given by the following expressions,

$$\left.\begin{aligned} &\sin\alpha=\frac{c}{d}\,, \qquad \sin\beta=\frac{r}{d}\,. \\ \text{and}\quad &\tan\varphi=\frac{r-r\cos(\theta-\varphi)}{e-r\sin(\theta-\varphi)} \quad \text{i.e.}\ \sin\varphi=\frac{r\sqrt{d^2-r^2\cos^2\theta}-er\cos\theta}{d^2} \end{aligned}\right\}(4)$$

Therefore, when a, b, c and r were known, the value of f corresponding to any value of θ can be calculated from the equation(1).

Hence if we represent the relation between the value of f and θ graphically, the value of θ corresponding to any observed value of f can be readily obtained from the graph. The wave lengths λ for the spectral lines can be calculated from the Bragg's formula $n\lambda=2d\sin\theta$.

The great advantage of this method lies in the fact that it is not necessary to determine the zero position, i.e. SEG, observation of which often leads to a great inaccuracy.

As the numerical value of d, the grating constant, 9.858°A.U. was taken, the value being that which we have found in the previous experiment by photographing the known wave lengths of the characteristic L-radiation of tungsten. For the value of r, 44.55mm. was taken which is the mean value of the two radii of the inner and the outer surface of the cylindrical mica. This value will introduce the error less than one tenth of a percent to the final result. The actual values of a, b and c in the experiment are as follows :

for the plate No. 1, a=169.43mm. b= 83.50mm. c=48.96mm.

for the plate No. 2, a=208.47mm. b=123.78mm. c=48.75mm.

The calculated value of γ are,

for the plate No. 1, from 2°53′37″ to 3°20′11″

for the plate No. 2, from 2°45′17″ to 3°11′51″

according to the value of θ. (from 1° to 10°)

The photographic plate No. 2 is reproduced in Fig. 2. The time of exposure was from 20 to 30 hours, the current through the X-ray tube was about 2.5 milliamperes and the potential difference applied was from 40 to 50 kilovolts.

All of the four lines are visible in the third, fourth and fifth orders on the both side, but in the second order the only two prominent lines are visible. The first order lines on the left hand side have been hidden in the dark portion of the photographic plate, and not observable even on the original plate.

In the fourth or the fifth order spectrum some very faint lines seem to be recognized standing close to some of the four lines on the right hand side of the original plate, but their wave lengths could not be determined, because of their absence on the left hand side.

It is here to be added that the higher spectra than the fifth appeared on the right hand side. The intensities of the spectral lines in the different orders show that the odd spectra are more intense than the even ones as is the case in the photographs of the L-series of tungsten in the former experiment.

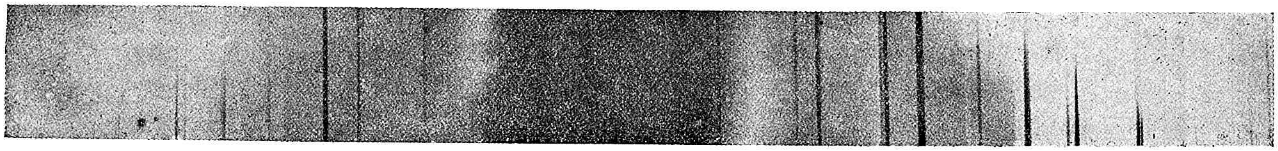
The values of the wave lengths calculated from the data mentioned above, are tabulated in the table 1. The values obtained by Overn[1], Duane and Patterson[2] and Leide[3] are, for the sake of reference, also given in the table.

In conclusion, the writers wish to express their sincere thanks to Prof. T. Mizuno and Prof. M. Ishino for the interest they have taken in the work.

1 Phys. R., **12**. 350, (1921)
2 Proc. Nat. Acad. Sci. U. S. A. **8**. **85** (1922). and Phys. R., **19**, 542 (1922).
3 Siegbahn, Jahrb. d Radioaktivität u. **18**, 240 (1922).

Table I. Wave lengths in Å. U.

	Order	α_2			α_1			β_1			β_2		
		f_{cm}	θ	λ	f_{cm}	θ	λ	f_{cm}	θ	λ	f_{cm}	θ	λ
Plate No. 1	2	—	—	—	2.410	4°7′17″	0.7085	2.148	3°40′39″	0.6323	—	—	—
	3	3.660	6°13′15″	0.7122	3.635	6°11′0″	0.7078	3.245	5°31′30″	0.6327	3.175	5°24′50″	0.6201
	4	4.596	8°18′50″	0.7127	4.908	8°14′50″	0.7072	4.355	7°21′20″	0.6310	4.268	7°13′0″	0.6192
	5	—			—	—	—	5.519	9°13′10″	0.6319	—	—	—
	Mean			0.7125			0.7078			0.6320			0.6197
		f_{cm}	θ	λ	f_{cm}	θ	λ	f_{cm}	θ	λ	f_{cm}	θ	λ
Plate No. 2	2	—	—	—	3.525	4°6′59″	0.7076	3.145	3°40′29″	0.6318	—	—	—
	3	5.375	6°13′0″	0.7116	5.337	6°10′50″	0.7076	4.745	5°30′50″	0.6312	4.662	5°24′50″	0.6201
	4	7.271	8°18′20″	0.7120	7.207	8°15′0″	0.7073	6.388	7°21′40″	0.6315	6.260	7°13′10″	0.6196
	5	9.250	10°24′25″	0.7123	9.175	10°19′30″	0.7069	8.090	9°11′30″	0.6297	7.936	9°1′30″	0.6186
	Mean			0.7120			0.7074			0.6311			0.6194
Mean		0.7122			0.7076			0.6316			0.6196		
Overn		0.7129			0.7085			0.6322			0.6212		
Duane & Patterson		0.71213			0.70783			0.63114			0.6198		
Leide		0.71196			0.70759			0.63065			0.61938		


5th 4th 3rd 2nd 1st 2nd 3rd 4th 5th 6th