WAVE-LENGTH MEASUREMENTS IN THE *M* SERIES OF SOME HIGH-FREQUENCY SPECTRA.

By J. C. Karcher.

Synopsis.

Wave-length Measurements in the M Series of Some High Frequency Spectra: a New Vacuum X-ray Spectrograph.—The paper contains a description ρf an X-ray spectograph designed to be used in the same chamber containing the source of X-rays, also a description of the *vacuum chamber*, the *method of sealing*, and *details of manipulation* of the apparatus.

A method is described of determining the position of the photographic plate upon which the lines are photographed.

Experimental data. Some measurements are made of lines in *the M series of bismuth, lead, thallium, mercury, gold, and platinum.*

As only a small amount of work has been done in the measurement[1] of wave-lengths, in the *M* series of X-ray spectra, the writer was led to attempt some of these measurements by the photographic method. The *M* series lines are almost entirely absorbed by the walls of an ordinary X-ray tube, and even, suffer considerable absorption in passing through 20 or more centimeters of air, hence it is necessary to arrange the X-ray source and spectrograph so that the amount of material in the path of the X-rays is reduced to a minimum. Accordingly a spectrograph was devised that could be used in the same chamber with the X-ray generator. In this way the amount of absorption of the rays, was sufficiently reduced to make photography of the lines feasible.

A diagram of the spectrograph, together with the chamber and parts of the X-ray generator, is shown in Fig. 1. The spectrograph is constructed of brass with the exception of the lead strip *hh* and the iron armature *a*.

The dimensions are apparent when it is noted that the distances from the axis of rotation of the crystal to the photographic plates *gg′*, and the lead strip *h*, are 10 cm. and the angles made by the normals to these plates with the plane through *s* and *k*, are 30°, 90° and 150°. The plates *c* and *d* are 2 cm. apart, and are held in position by means of screws and posts. Slots in *c* and *d* receive the photographic plates. A brass plate slid behind each photographic plate holds it in position by means of springs. A piece of "carbon" paper 0.006 cm. thick is placed in front

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[1] M. Sieghahn, Jahr. d. Radioakt, 13, 1916.

of the plate to absorb the ordinary light. This was found to be quite opaque to ordinary light and showed no appreciable absorption of the X-rays in the region investigated. This is the only material which the rays had to penetrate before reaching the plate.

The slits *s* and *s′* are adjustable. The opening *s* was about 0.2 mm. in width, and *s′* about 1 mm. wide, when photographs were taken.

The crystal is supported on the crystal mounting shown in Fig. 2; it is rotated in the chamber *l*. The position of the crystal is indicated approximately by a pointer moving along the scale *p*. Rotation is produced by means of a magnet (not shown) placed beneath the glass plate. The rotating magnet actuates the armature *a* which rotates the crystal through a gear train with a speed reduction of 5,000 to 1.

The cathode and water-cooled anode are housed in a glass shield *t* which has a 2 cm. opening "*o*" between the anode and slit *s*. The face of the anode consists of a piece of electrolytic copper, into which a specimen of the element being investigated, is imbedded. Each specimen is mounted on a separate piece of copper. The mercury specimen had to be frequently renewed because of evaporation.

The whole is mounted on a glass plate 50 cm. × 50 cm. × 3.1 cm. thick, then covered by a bell jar 40 cm. in diameter. The joint between the jar and plate is sealed by means of vacuum wax and mercury. A strip of "fiberboard" *n* is placed on edge about the edge of the jar and about 1 cm. distant thus forming a reservoir for the mercury.

Before placing the jar on the plate, a thread of vacuum wax is run around the edge of the jar, the jar is then set in place and the annular reservoir is filled to a depth of about 2 cm. with mercury. When it is desired to open the chamber, after the vacuum has been relieved, a two-way connection on the suction side of the supporting pump, and suitable traps, permit the mercury to be quickly removed from the reservoir by suction, after which the jar can be lifted from place.

Evacuation was accomplished by means of a Gaede Molecular pump supported by a single-stage oil pump. The pressure in the chamber could be reduced from atmospheric to that required for the operation of the X-ray generator, in about 12 minutes. The vacuum was regulated by varying the speeds of the pumps.

The source of power for the X-ray generator consisted of a transformer operating on 60-cycle alternating current and a Coolidge tube used as a rectifier. The potential drop between the electrodes of the X-ray generator was kept sufficiently low so that the *L* series of the metal under investigation did not appear. This was necessary to prevent confusion of the weak lines of the *M* series with the strong lines of the *L* series in the third and fourth orders.

Exposures were made by rotating the crystal at the rate of 1° to 1.°25 per hour, while a current of 6 milliamperes was flowing through the X-ray generator. A selenite crystal was used for the measurements here noted.

Since all the lines photographed were on plates in the position (*gg*, Fig. 1), the angular position of the plates was determined by the following simple method: thus

$$N\lambda = 2d \sin\frac{\theta}{2}.^{1} \tag{1}$$

If a line appears on the plate in both the first and second order, we have

$$2 \sin\frac{\theta_1}{2} = \sin\frac{\theta_2}{2}. \tag{2}$$

Where $\theta_1/2$ and $\theta_2/2$ are the glancing angles for the first and second order reflections respectively.

Also (Fig. 3)

$$\theta_1 = \alpha + \tan^{-1}\left(\frac{x_1 - a \tan\alpha}{a}\right) \tag{3}$$

and similarly:

$$\theta_2 = \alpha + \tan^{-1}\left(\frac{x_2 - a \tan\alpha}{a}\right), \tag{4}$$

which reduce to

$$\text{Cot. } \theta_1 = \frac{a}{x_1 \cos^2\alpha} - \tan\alpha, \tag{5}$$

$$\text{Cot. } \theta_2 = \frac{a}{x_2 \cos^2\alpha} - \tan\alpha. \tag{6}$$

Where x_1 and x_2 are the respective distances of the first and second order lines from the 0 line, a is the perpendicular distance of the plate from the axis of rotation of the crystal and α is the angle between the perpendicular line along which a is measured and the plane passing through the slit and axis of the crystal.

From (2), (5) and (6), we have

$$2 \sin\left[\tfrac{1}{2}\,\text{Cot}^{-1}\left(\frac{a}{x_1 \cos^2\alpha} - \tan\alpha\right)\right] = \sin\left[\tfrac{1}{2}\,\text{Cot}^{-1}\left(\frac{a}{x_2 \cos^2\alpha} - \tan\alpha\right)\right], \tag{7}$$

which expresses α in terms of x_1, x_2 and a. Since α is approximately known, a graphic solution of (7) will easily determine α to the nearest 0.1 min. If an average of several determinations is taken, the probable error in a wave-length measurement, due to error in α will be less than

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[1] W. H. and W. L. Bragg, Proc. Roy. Soc., A, 88, 1913, p. 428.

the probable error due to error in x for that measurement. The L Series lines of tin shown in Fig. 4 were used in the determination of α.

The M series spectrum was photographed from one to four times for each of the elements, bismuth, lead, thallium, mercury, gold and platinum. The results of the measurements are given in the following table. As many as 12 lines were found on a plate in the region of the M Series but only those which were sufficiently identified are noted. Measurements on the plates were made with the aid of a traveling microscope.

Constants entering into the computations are:

$$a = 10.030 \text{ cm.}, \qquad \alpha = 29^\circ\, 27.'6,$$

$$\log 2d = 1.18300 \text{ for selenite.}$$

λ *in Ångstrom Units.*

Element.	At No.	α_1.	β_1.	β_3.	γ_1.	γ_2.	γ_3.
Bi	83	5.124	4.915	[1]4.604	4.534	[1]3.932	[1]3.840
Pb	82	5.290	5.078		4.675	[1]4.073	
Tl	81	5.468	5.254				
Hg	80	5.649	5.439				
Au	79	5.848	5.632	[1]5.446	5.154	[1]4.530	[1]4.439
Pt	78	6.049	5.831	[1]5.649	5.329	[1]4.733	[1]4.623

[1] New lines.

The work is being continued.

I am indebted to the University of Pennsylvania for the use of apparatus.

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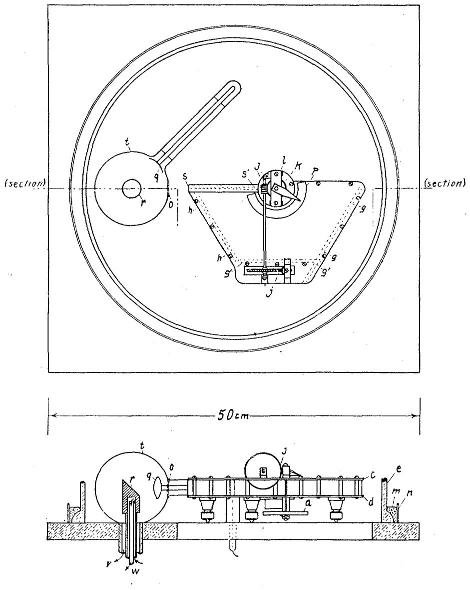

Fig. 1.

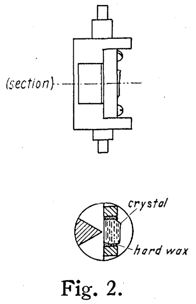

Fig. 2.

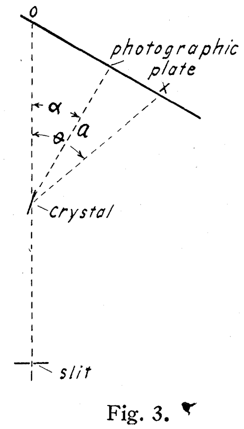

Fig. 3.

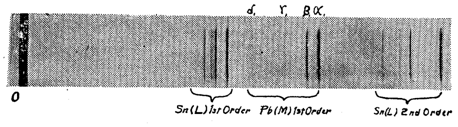

Fig. 4.

Spectrum of Lead-tin Alloy.

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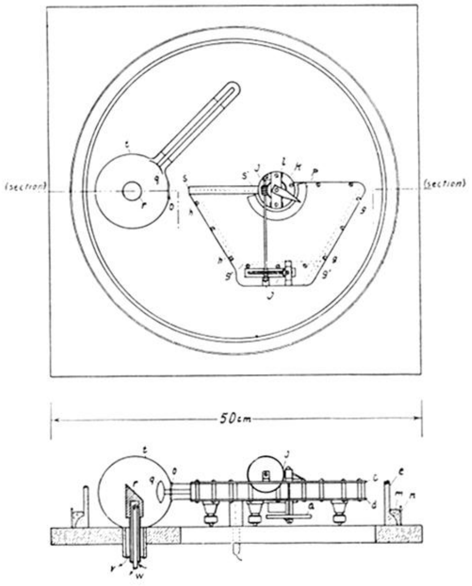

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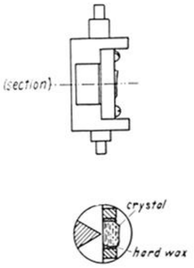

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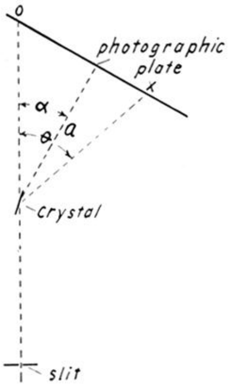

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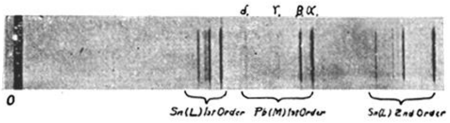

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