CRITICAL POTENTIALS OF THE THORIUM M SERIES LINES

By P. A. Ross

Abstract

M-series of x-ray lines of thorium.—Spectrograms taken with various potentials decreasing in steps from 10 kv to 3.2 kv, are reproduced which show six lines, α to ϵ of Stenström and a *new line* ϵ_2 of wave-length 2.85 A. By use of screens made of tissue paper soaked in thorium nitrate, five absorption limits, M_1 to M_5, were found, checking the results of Stenström and Coster. The *critical potentials* of the six lines were determined and found to agree with the values predicted by the quantum law from the corresponding absorption limits M_1 to M_5, both δ and ϵ_1 corresponding to M_4, and ϵ_2 to M_5.

Vacuum x-ray spectrograph is described in which a screen with a slit is rotated in front of the plate at twice the angular speed of the crystal so as to prevent scattered rays from striking the plate.

PREVIOUS work on the M series by Karcher,[1] Stenström,[2] and Coster,[3] has been directed toward the determination of the wave-lengths of the lines and of the absorption limits in the x-ray M spectrum. Information as to the source of a particular line has been sought from the law that the frequency of a line is equal to the difference in frequencies of two absorption limits. The relations between lines and limits can probably best be studied by comparison of the critical potentials required

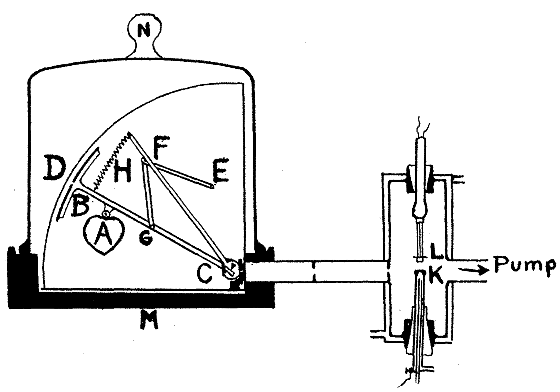

Fig. 1. Vacuum x-ray spectrograph.

[1] Karcher, Phys. Rev. **15**, 285, 1920.
[2] Stenström, Doc. Dis., Lund, 1919.
[3] Coster, Zeit. fur Phys. **5**, 139, 1921.

to excite the lines with the voltages required to excite general radiation of the frequencies of the absorption limits.

The x-ray tube used in this work was a water cooled brass cylinder with a water-cooled copper target K, Fig. 1, having a thorium button embedded in its face. The target was kindly furnished by the Westing-

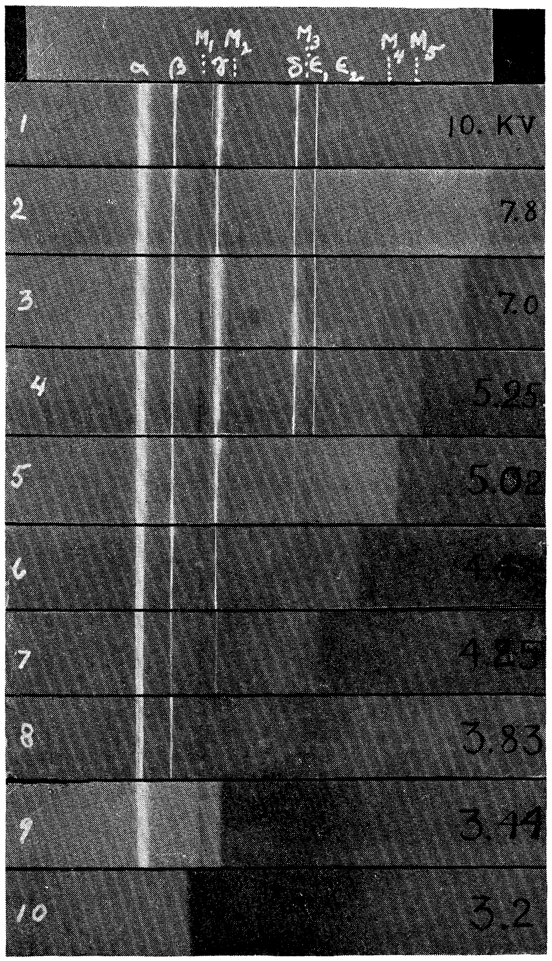

Fig. 2. Spectrograms taken with various potentials decreasing from 10kv to 3.2kv.

house Research Laboratories. The cathode L was a tungsten spiral identical with those used in standard Coolidge tubes. By overheating the spiral, electron currents up to 25 milliamperes could be obtained at from 3 to 5 kv. The direct current at constant voltage was supplied by the high tension apparatus described elsewhere by D. L. Webster.[4] The x-ray tube was exhausted by means of a diffusion pump kept running constantly. The spectrometer was separated from the x-ray tube by a bit of aluminium foil cemented over the slit at J and was exhausted by the two stage oil-sealed pump supporting the diffusion pump. The spectrometer consisted of a cast iron base *M* with a large glass bell jar *N* of 33 cm inside diameter, ground to a close fit. A little heavy stopcock grease made a sufficiently good seal, though mercury was usually poured in the channel between the foot of the bell jar and the rim of the base. The gypsum crystal at *C* was rotated by means of the arm *F*. The arm *G* carried a screen *B* which served to cut off the scattered radiation, allowing only the regularly reflected beam to pass through a slit *D* at its center. This greatly improved the contrast between lines and background. The arm *F* was made to move with half the angular velocity of *G* by means of the pantograph device *EFG*. *E* is a pivot attached to the brass quadrant carrying the device. At *F* is a sliding contact between the pin and the arm, which is maintained by the light spring *H*. *A* is a cam giving approximately uniform velocity to the arm *BG*. It was driven by means of clock work that gave one oscillation in about six minutes.

For work with the critical potentials it was desirable to reduce the time of exposure as much as possible. This could be done by using the stationary crystal method with the slit system removed and the x-ray tube brought up into direct contact with the iron base.

The absorption spectrum was obtained by using absorption screens made of thin tissue paper soaked in thorium nitrate solution. In Fig. 2, which contains a few typical pictures, the short wave-length limit of the general radiation is shown in all the spectrograms except No. 1. It will be noticed that as the limit of the general radiation passes successive M absorption limits, lines and groups of lines appear. The voltages used were as follows: No. 1, 10 kv; No. 2, 7.8; No. 3, 7.0; No. 4, 5.25; No. 5, 5.02; No. 6, 4.47; No. 7, 4.25; No. 8, 3.83; No. 9, 3.44; No. 10, 3.2. They were measured by an electrostatic voltmeter and checked by the relation V(in kv) = 12.345/λ (in Angstroms) at the limit of the general radiation. The critical voltages recorded below are the average of the lowest measured voltage at which a line appeared and the highest measured voltage at which the line did not appear. Six M series lines corresponding to α, β, γ, δ, and ϵ of Stenström and a new line ϵ_2 of wave-length 2.85 A and five absorption limits were found. Two of the limits, 2.571 A and

[4] Webster, Proc. Nat. Acad. Sci. **6**, 269, May, 1920

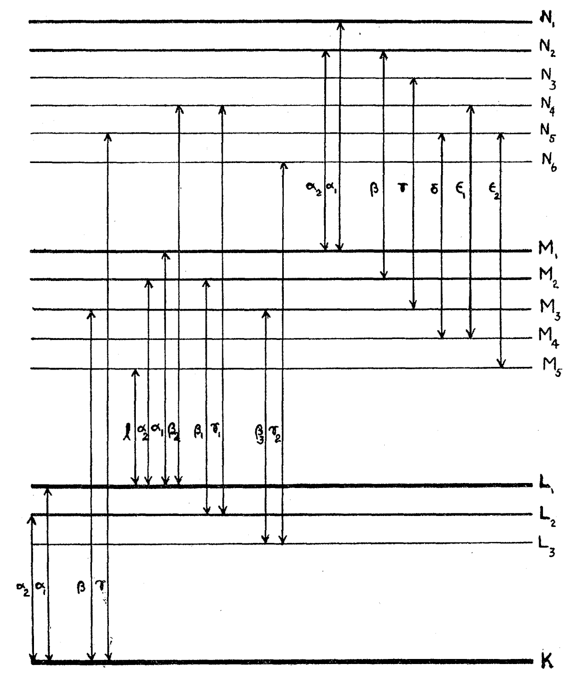

Fig. 3. Relations between M, L and K series.

M					L				
	λ	$\frac{1}{\lambda}$	$\frac{1}{\lambda_{ab2}}-\frac{1}{\lambda}$			λ	$\frac{1}{\lambda}$	$\frac{1}{\lambda_{ab2}}-\frac{1}{\lambda}$	
M_1	3.721	.2687			L_1	.7596	1.316		
α	4.1292	.2422	.0265	N_1	l	1.117	.896	.420	M_5
M_2	3.552	.2812			α_2	.969	1.032	.284	M_2
β	3.9333	.2542	.0270	N_2	α_1	.957	1.045	.271	M_1
M_3	3.058	.3269			β_2	.797	1.255	.061	N_4
γ	3.6565	.2736	.0533	N_3	L_2	.6286	1.591		
M_4	2.571	.3889			β_1	.766	1.305	.286	M_2
δ	3.127	.3200	.069	N_5	γ_1	.654	1.530	.061	N_4
ϵ_1	3.006	.3330	.056	N_4	L_3	.6044	1.654		
M_5	2.388	.4188			β_3	.758	1.319	.335	M_3
ϵ_2	2.85	.351	.068	N_5	γ_2	.635	1.575	.079	N_6

K

	λ	$\frac{1}{\lambda}$	$\frac{1}{\lambda_{ab2}}-\frac{1}{\lambda}$	
K	.1124	8.889		
α_2	.1368	7.310	1.589	L_2
α_1	.1323	7.559	1.319	L_1
β	.1169	8.559	.330	M_3
γ	.1134	8.820	.079	N_6

2.388 A were not reported by Stenström but have recently been found by Coster.[5] The critical potentials of the lines agree well with the values predicted by the quantum law for the absorption limits M_1, M_2, M_3, M_4, M_5, respectively.

There are faint lines at 4.40 A and at 3.70 A that are possibly due to impurities. The 3.70 line may be the β line of uranium.

Relations between the M, L and K series are summarized in the following table and are also shown graphically in Fig. 3. λ_a refers to the absorption limit. The values in the table are taken from Duane's "Data Relating to X-ray Spectra," National Research Council Bulletin. The values for the K series were computed from Moseley's law $\nu = A(N-b)^2$ plus a correction which was determined by the deviation of the computed K absorption limit from the measured value given by Duane for higher orders than the first, and from the deviation of the computed values of α_2 by Moseley's law from that given by $(K-L_2)$ using measured values of K and L_2. The values of the correction for α_1, β and γ were then obtained by interpolation.

Line	Wave-length in angstroms	Critical voltage	Absorption limit related to line	Product of voltage and limit
α	4.1292	3.3 kv	M_1 3.721	12.25
β	3.9333	3.5	M_2 3.552	12.40
γ	3.6565	4.0	M_3 3.058	12.00
δ	3.127	4.8	M_4 2.571	12.30
ϵ_1	3.006	4.8	M_4 2.571	12.30
ϵ_2	2.85	5.2	M_5 2.388	12.35

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[5] Coster, Phys. Rev. **19**, 20, 1922.

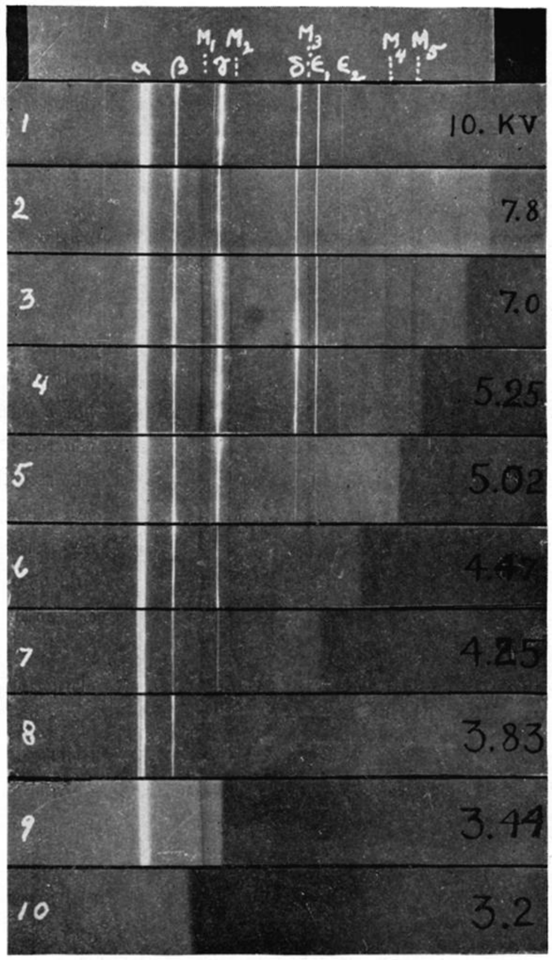

Fig. 2. Spectrograms taken with various potentials decreasing from 10kv to 3.2kv.