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THE "K" AND "L" X-RAY SPECTRA OF TUNGSTEN

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This paper is a partial report on the complete investigation of the x-ray spectra of tungsten, both emission and absorption. It deals only with the emission and absorption spectra of the "K" and "L" regions. The "M" region is being investigated by Mr. R. V. Zumstein.

The x-ray spectrum of tungsten has been the most extensively investigated of any element. However the work has been done at different times by experimenters using different apparatus and methods. For this reason it seemed advisable to make a complete investigation using as near as possible the same apparatus and conditions throughout.

Previous work has been done either on the emission spectrum or the absorption spectrum and no attempt has been made to get both at the same time under the same conditions. In the present work both have been obtained on the same photographic plate at the same exposure. This furnishes a very accurate method ot measuring relative wave lengths.

The apparatus used in the work consisted of a high voltage transformer, Coolidge tube and x-ray spectrometer. A few improvements in the method of rotation of the crystal made it possible to greatly prolong the time of exposure.

When this work was begun there were twenty-two lines known in the "L" series of tungsten. Out of these twenty-two lines one had been found only by Siegbahn and Duane, three by Dershem and Overn, and one by Overn. In the present work all of the above lines except the one found by Siegbahn and Duane have been obtained. In addition three new lines have been found and two others have been resolved into two components. The most important result of the work on the "L" series is the slight shift obtained in the result given by Duane on the absorption wave lengths, which have been considered as the most accurate. This shift is sufficient to change the relative positions of two of the absorption lines with respect to that of the emission lines. Since both the emission and absorption spectra are obtained on the same plate at the same exposure there can be no question as to the relative positions of the lines. The results on the "K" series show

that the β line is made up of two components. The "K" absorption band has been obtained in the third order on the same plate with the emission lines.

The experimental results on the emission lines of tungsten are shown in the first column of Table 1. The wave length given for the "l" line is due to Siegbahn. This line was impossible to attainment with the apparatus used because of the absorption in the glass walls of the Coolidge tube.

TABLE I
"L" SERIES OF TUNGSTEN
Emission

Line	Wave Length	Frequency Measured	Frequency Calculated	Difference
l	1.6756×10^{-8}	1.7895×10^{18}	1.7897×10^{18}	$.0002 \times 10^{18}$
α_2	1.4844	2.0201	2.0190	.0011
α_1	1.4733	2.0353	2.0337	.0016
η	1.418	2.114	2.1140	.0000
new (1)	1.415	2.118		
β_4	1.2988	2.3088	2.3088	.0000
β_6	1.2875	2.3289	2.3290	.0001
β_1	1.2793	2.3440	2.3433	.0007
β_3	1.2602	2.3795	2.3795	.0000
new β'_2	1.2433	2.4118	2.4109	.0009
β_2	1.2421	2.4141	2.4141	.0000
β_8	1.2368	2.4246		
β_7	1.2219	2.4542	2.4549	.0007
new (2)	1.2166	2.4648	2.4685	.0037
β_5	1.2133	2.4715	2.4715	.0000
β_{10}	1.2098	2.4785	2.4801	.0016
β_9	1.2027	2.4932	2.4948	.0016
γ_5	1.1300	2.6536	2.6533	.0003
γ_1	1.0964	2.7350	2.7352	.0002
γ_8	1.0787	2.7799	2.7792	.0007
new (3)	1.0748	2.7899	2.7901	.0002
γ_6	1.0723	2.7965	2.7928	.0037
new (4)	1.0674	2.8092		
γ_2	1.0660	2.8129	2.8129	.0000
γ_3	1.0599	2.8291	2.8291	.0000
h	1.0444	2.8713	2.8720	.0007
γ_4	1.0266	2.9209	2.9209	.0000

The experimental values for the wave lengths of the absorption bands are compared with the results of Duane in Table 2.

According to Bohr's theory the atom is considered as made up of a positive nucleus about which electrons move in elliptical or-

TABLE II
"L" SERIES OF TUNGSTEN
Absorption

Measured		Duane
A(1)	1.2121×10^{-8}	1.2140×10^{-8}
A(2)	1.0716	1.0730
A(3)	1.0217	1.024

bits. The energy required to remove these electrons from the atom depends on two quantum numbers, the azimuthal and the radial quantum numbers, which determine the elliptical orbits of the electrons. The absorption in an atom is due to the removal of electrons from the orbits and the absorption limits in the spectra correspond to the energy required to remove electrons from the orbits. Since it requires different amounts of energy to eject electrons from different orbits we can think of the atom as made up of "energy levels". If an electron goes from one orbit to another of smaller total quantum number, that is if it goes from one energy level to a lower energy level, it radiates an amount of energy equal to the difference between the two energy levels. The energy radiated in these jumps between energy levels corresponds to emission lines while the energy required to remove an electron

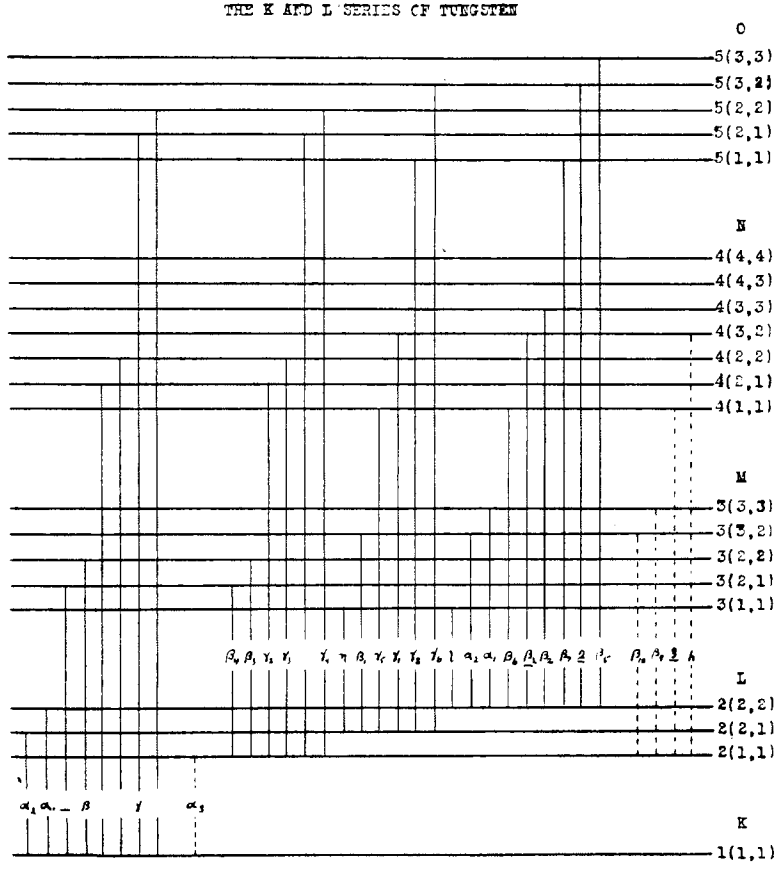

Fig. 1.—The K and L series of Tungsten. Solid lines are transitions predicted by Bohr and Coster. Broken lines are other transitions.

from one of the orbits to infinity corresponds to an absorption band. From this it is seen that the emission frequencies should be given by the difference between two absorption frequencies.

Figure 1 is an illustration of the energy levels within the atom. When an electron "falls" from one of the higher levels to a lower level it radiates the line shown in the figure by the vertical lines where the horizontal lines are the energy levels. It would appear that an electron could go from any level to any other level. However, according to the principle of selection this is not true. The solid lines represent the emission lines that are possible according to this principle. It is seen that for the "L" series all the lines predicted have been found except one. In addition four lines have been found representing other transitions. These are shown by broken lines. Three other lines have been found that do not fit in with the energy levels assumed. Two of these are new lines and may not be due to tungsten but to some impurity.

TABLE III
ABSORPTION FREQUENCIES
"L" Measured
"K", "M", "N" and "O" Calculated

O(1)	$.0022 \times 10^{18}$	M(1)	$.4401 \times 10^{18}$
O(2)	.0053	M(2)	.4548
O(3)	.0140	M(3)	.5554
O(4)		M(4)	.6261
O(5)	.0189	M(5)	.6841
N(1)		L(1)	2.4738
N(2)		L(2)	2.7981
N(3)	.0597	L(3)	2.9349
N(4)	.0629		
N(5)	.1058		
N(6)	.1220	K(1)	18.847
N(7)	.1448		

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