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Self-Reversal in the Spectral Lines of Uranium

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In 1946, spectrum analysis indicated that the outer-electron configuration of normal uranium atoms was $5f^3\,6d^1\,7s^2$, with an energy level designated $^5L_6^o$ representing the normal state. Now that conclusion is experimentally verified by the observation of self-reversed lines in uranium spectra emitted by a high-current pulsed arc between metallic electrodes. Fifty-four reversed lines were observed; thirty-eight involve the normal state and sixteen are distributed among four low metastable states of the same configuration.

Key Words: Uranium, spectrum of; spectrum, of uranium; self-reversal, in uranium spectrum.

In 1946, Kiess, Humphreys, and Laun published[1] a "Preliminary description and analysis of the first spectrum of uranium" in which relative intensities and magnetic splitting of strong lines indicated that the outer-electron configuration of normal uranium atoms was $5f^3\,6d^1\,7s^2$ with an energy level designated $^5L_6^o$ representing the ground state. At that time efforts to confirm this conclusion by observing self-reversal in uranium lines emitted by conventional underwater sparks or d-c arcs failed. However, a high-current pulsed arc (75 A peak current) recently developed by Sugar[2] produced many absorbed or partially reversed lines in uranium spectra, thus providing for the first time a direct experimental verification of the low energy levels of the uranium atom. Those spectrograms were loaned to me for study.

The observations of self-reversed lines in uranium spectra cover the region from 3200 to 4400 Å in the second order of a concave grating with a reciprocal dispersion of 0.86 Å per mm. Spectrograms made in the first order beyond 4100 Å did not show self-reversals, probably because of insufficient resolving power. Between 3413.25 and 4393.60 Å, fifty-four U I lines that show self-reversal were identified; about a dozen of these are indicated in reproductions that appear in Sugar's paper. The distribution of reversed and classified U I lines among low energy levels is shown in table 1. Since 70 percent of these lines involve $^5L_6^o$ they prove that this is indeed the ground state of neutral uranium; the remainder verify the reality of four metastable states with low energy.

TABLE 1. *Distribution of reversed lines among low-energy levels of* U I

Electron configuration	Level symbol	Level value	Reversed lines
		cm−1	
$5f^3\,6d^1\,7s^2$	$^5L_6^o$	0.00	38
$5f^3\,6d^1\,7s^2$	$^5K_5^o$	620.32	10
$5f^3\,6d^1\,7s^2$	$^5L_7^o$	3800.81	4
$5f^3\,6d^1\,7s^2$	$^5K_6^o$	4275.69	1
$5f^3\,6d^1\,7s^2$	$^5I_4^o$	4453.40	1

This proof is presented in detail in table 2 which is based mainly upon our 1946 publication (see footnote 1) but includes some additional and revised data. The wavelengths and estimated relative intensities represent our original observations of uranium spectra emitted by a d-c (5 A) arc. The corresponding wavenumbers are taken from a "*Table of Wavenumbers*".[3]

In table 2, the final column displays numerical values of high energy levels (even parity) that combine with the low energy levels (odd parity), symbolized in the preceding column and evaluated in table 1. In both tables the subscripts represent *J*-values.

In our first paper (see footnote 1), the relative values of energy levels were given to six figures, ending with one decimal. In 1964 Michèle Diringer[4] recalculated the energy levels of U I to seven figures, including two decimals, and reported some new ones. In constructing table 2, I have adopted the energy-level values

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[1] C. C. Kiess, C. J. Humphreys, and D. D. Laun, J. Res. NBS., 37, 57; (1946).

[2] J. Sugar, J. Res. NBS., 66A, (Phys. and Chem.) No. 4, 321; (1962).

[3] C. D. Coleman, W. R. Bozman, and W. F. Meggers, Table of Wavenumbers, NBS Mono. 3, Volume 1, 1960.

[4] Michèle Diringer, Thèse de Paris, Serie A, No. 4232; 1964.

TABLE 2. *Self-reversed lines of* U I

Wavelength Å (air)	Intensity in arc	Wavenumber K (vac)	Odd level	Even level
4393.60	200	22753.99	$^5L_6^o$	22754.05_6
4362.05	300	22918.56	$^5L_6^o$	22918.54_7
4153.97	150	24066.57	$^5L_6^o$	24066.57_7
3948.45	35	25319.23	$^5L_6^o$	25319.25_5
3943.82	200	25348.95	$^5L_6^o$	25348.96_6
3894.12	120	25672.47	$^5L_6^o$	25672.44_7
3876.13	60	25791.62	$^5L_6^o$	25791.58_6
3871.04	120	25825.53	$^5L_6^o$	25825.54_6
3854.22	100	25938.23	$^5L_6^o$	25938.20_6
3839.62	120	26036.86	$^5L_7^o$	29837.61_7
3812.00	150	26225.51	$^5L_6^o$	26225.54_6
3765.35	40	26550.41	$^5L_6^o$	26550.40_6
3731.45	100	26791.62	$^5L_6^o$	26791.63_6
3692.75	30	27072.38	$^5L_6^o$	27072.36_6
3685.78	40	27123.58	$^5K_5^o$	27743.91_6
3682.46	30	27148.03	$^5L_6^o$	27148.06_7
3679.38	60	27170.76	$^5K_5^o$	27791.12_4
3677.39	60	27185.46	$^5L_7^o$	30986.26_8
3659.58	50	27317.76	$^5K_5^o$	27938.06_5
3659.16	100	27320.90	$^5K_5^o$	27941.22_6
3644.24	60	27432.75	$^5K_5^o$	28053.03_6
3639.49	30	27468.55	$^5K_6^o$	31744.23_5
3638.20	150	27478.29	$^5L_7^o$	31279.09_6
3636.31	15	27492.57	$^5I_4^o$	31945.94_5
3626.36	15	27568.00	$^5K_5^o$	28188.34_6
3620.08	60	27615.82	$^5L_6^o$	27615.76_6
3605.28	40	27729.19	$^5L_6^o$	27729.20_5
3603.36	30	27743.96	$^5L_6^o$	27743.91_6
3598.94	30	27778.03	$^5L_6^o$	27777.97_7
3591.74	50	27833.72	$^5K_5^o$	28453.97_4
3584.88	250	27886.98	$^5L_6^o$	27886.96_7
3578.33	15	27938.02	$^5L_6^o$	27938.06_5
3577.92	30	27941.22	$^5L_6^o$	27941.22_6
3574.76	50	27965.92	$^5L_6^o$	27965.89_7
3566.60	200	28029.90	$^5K_5^o$	28650.26_5
3563.66	50	28053.03	$^5L_6^o$	28053.03_6
3561.41	40	28070.75	$^5L_7^o$	31871.52_8
3557.84	50	28098.92	$^5L_6^o$	28098.92_6
3555.32	60	28118.83	$^5L_6^o$	28118.81_7
3546.55	25	28188.36	$^5L_6^o$	28188.34_6
3534.33	30	28285.82	$^5L_6^o$	28285.75_7
3514.61	200	28444.53	$^5L_6^o$	28444.53_5
3513.68	50	28452.06	$^5L_6^o$	28452.12_7
3511.44	30	28470.20	$^5L_6^o$	28470.14_6
3507.34	80	28503.48	$^5L_6^o$	28503.42_5
3500.07	80	28562.68	$^5L_6^o$	28562.66_5
3489.37	80	28650.27	$^5L_6^o$	28650.26_5
3466.30	40	28840.94	$^5L_6^o$	28840.90_5
3462.22	30	28874.93	$^5L_6^o$	28874.90_6
3459.92	50	28894.12	$^5L_6^o$	28894.11_5
3454.61	30	28938.54	$^5K_5^o$	29558.81_6
3442.95	20	29036.54	$^5L_6^o$	29036.60_5
3434.28	10	29109.84	$^5L_6^o$	29109.80_6
3413.25	20	29289.19	$^5K_5^o$	29909.50_4

reported by Diringer, plus the following new levels: 27148.06_7, 27938.06_5, 28452.12_7, and 29036.60_5.

Although the uranium wavelengths reported (see footnote 1) in 1946 were limited to six figures, the corresponding wavenumbers were given to seven figures. The same is true in the present paper. Now the average difference between observed and computed wavenumbers in table 2 is less than ±0.03 K, which corresponds to an average error in wavelength of about ±0.005 Å. Up to the present time no lists of uranium wavelengths of higher accuracy have been published.

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