

Self-Reversal in the Spectral Lines of Uranium

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(April 12, 1966)

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 published¹ 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 Sugar² 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
$5f^3 6d^1 7s^2$	$^5K_3^o$	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 Diringer⁴ 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	$5I_{-6}^{\circ}$	22754.05 ₆
4362.05	300	22918.56	$5I_{-6}^{\circ}$	22918.54 ₇
4153.97	150	24066.57	$5I_{-6}^{\circ}$	24066.57 ₇
3948.45	35	25319.23	$5I_{-6}^{\circ}$	25319.25 ₅
3943.82	200	25348.95	$5I_{-6}^{\circ}$	25348.96 ₆
3894.12	120	25672.47	$5I_{-6}^{\circ}$	25672.44 ₇
3876.13	60	25791.62	$5I_{-6}^{\circ}$	25791.58 ₆
3871.04	120	25825.53	$5I_{-6}^{\circ}$	25825.54 ₆
3854.22	100	25938.23	$5I_{-6}^{\circ}$	25938.20 ₆
3839.62	120	26036.86	$5I_{-7}^{\circ}$	29837.61 ₇
3812.00	150	26225.51	$5I_{-6}^{\circ}$	26225.54 ₆
3765.35	40	26550.41	$5I_{-6}^{\circ}$	26550.40 ₆
3731.45	100	26791.62	$5I_{-6}^{\circ}$	26791.63 ₆
3692.75	30	27072.38	$5I_{-6}^{\circ}$	27072.36 ₆
3685.78	40	27123.58	$5K_5^{\circ}$	27743.91 ₆
3682.46	30	27148.03	$5I_{-6}^{\circ}$	27148.06 ₇
3679.38	60	27170.76	$5K_5^{\circ}$	27791.12 ₅
3677.39	60	27185.46	$5I_{-7}^{\circ}$	30986.26 ₈
3659.58	50	27317.76	$5K_5^{\circ}$	27938.06 ₅
3659.16	100	27320.90	$5K_5^{\circ}$	27941.22 ₆
3644.24	60	27432.75	$5K_5^{\circ}$	28053.03 ₆
3639.49	30	27468.55	$5K_6^{\circ}$	31744.23 ₅
3638.20	150	27478.29	$5I_{-7}^{\circ}$	31279.09 ₈
3636.31	15	27492.57	$5I_{-4}^{\circ}$	31945.94 ₅
3626.36	15	27568.00	$5K_5^{\circ}$	28188.34 ₆
3620.08	60	27615.82	$5I_{-6}^{\circ}$	27615.76 ₆
3605.28	40	27729.19	$5I_{-6}^{\circ}$	27729.20 ₅
3603.36	30	27743.96	$5I_{-6}^{\circ}$	27743.91 ₆
3598.94	30	27778.03	$5I_{-6}^{\circ}$	27777.97 ₇
3591.74	50	27833.72	$5K_5^{\circ}$	28453.97 ₄
3584.88	250	27886.98	$5I_{-6}^{\circ}$	27886.96 ₇
3578.33	15	27938.02	$5I_{-6}^{\circ}$	27938.06 ₅
3577.92	30	27941.22	$5I_{-6}^{\circ}$	27941.22 ₆
3574.76	50	27965.92	$5I_{-6}^{\circ}$	27965.89 ₇
3566.60	200	28029.90	$5K_5^{\circ}$	28650.26 ₅
3563.66	50	28053.03	$5I_{-6}^{\circ}$	28053.03 ₆
3561.41	40	28070.75	$5I_{-7}^{\circ}$	31871.52 ₆
3557.84	50	28098.92	$5I_{-6}^{\circ}$	28098.92 ₆
3555.32	60	28118.83	$5I_{-6}^{\circ}$	28118.81 ₇
3546.55	25	28188.36	$5I_{-6}^{\circ}$	28188.34 ₆
3534.33	30	28285.82	$5I_{-6}^{\circ}$	28285.75 ₇
3514.61	200	28444.53	$5I_{-6}^{\circ}$	28444.53 ₅
3513.68	50	28452.06	$5I_{-6}^{\circ}$	28452.12 ₇
3511.44	30	28470.20	$5I_{-6}^{\circ}$	28470.14 ₆
3507.34	80	28503.48	$5I_{-6}^{\circ}$	28503.42 ₅
3500.07	80	28562.68	$5I_{-6}^{\circ}$	28562.66 ₅
3489.37	80	28650.27	$5I_{-6}^{\circ}$	28650.26 ₅
3466.30	40	28840.94	$5I_{-6}^{\circ}$	28840.90 ₅
3462.22	30	28874.93	$5I_{-6}^{\circ}$	28874.90 ₆
3459.92	50	28894.12	$5I_{-6}^{\circ}$	28894.11 ₅
3454.61	30	28938.54	$5K_5^{\circ}$	29558.81 ₆
3442.95	20	29036.54	$5I_{-6}^{\circ}$	29036.60 ₅
3434.28	10	29109.84	$5I_{-6}^{\circ}$	29109.80 ₆
3413.25	20	29289.19	$5K_5^{\circ}$	29909.50 ₄

reported by Diringer, plus the following new levels: 27148.06₇, 27938.06₅, 28452.12₇, and 29036.60₅.

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.

My thanks go to Jack Sugar of the National Bureau of Standards who made the uranium spectrograms available to me for the above analysis.