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ISOTOPE SPECTRUM SHIFT DATA ON URANIUM SPECTRUM LINES

BY

D. D. Smith

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ISOTOPE SPECTRUM SHIFT DATA ON URANIUM SPECTRUM LINES

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October 6, 1952

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ABSTRACT

Isotope spectrum shift data on more than 400 lines of uranium are included in this report.

ISOTOPE SPECTRUM SHIFT DATA ON URANIUM SPECTRUM LINES

D. D. Smith

Considerable data on isotope shifts in the spectra of uranium have been accumulated. Interest in such data is engendered from considerations of isotope shift theory involving the volume and possibly the shape of the nucleus, as well as from measurement problems associated with hyperfine structure studies of mixed isotope samples.[1]

The data were obtained by measurement of uranium spectra taken on a Jarrell-Ash 21 foot, 15,000 line per inch, Wadsworth mounted spectrograph using various isotopic mixtures of the oxides of U 235 and U 238 in graphite. Samples were loaded in deep cratered, thin walled 3/16" graphite electrodes and burned with a high current d. c. arc. Measurements were made by means of an Applied Research Laboratories densitometer and using either a Bausch and Lomb eyepiece or the rate of scanning (peak to peak). Spectrum dispersions were measured at various points on the plates and suitable dispersions or plate factors introduced to give the resulting data in angstrom units. Wavenumbers were then computed by the well known relation

$$\Delta\sigma = \frac{\Delta\lambda}{\lambda^2} \cdot$$

A note of caution should be introduced regarding some of these measurements in that the high density of uranium spectra, the presence of CN bands and other variable excitation effects introduce the possibility of identification errors. It is hoped that these data will soon be remeasured at much higher dispersions and resolutions.

The data of other workers is also included where it supplements these earlier measurements. Thus, data on U 233, U 235 and U 238 for eleven lines is based on work of Burkhart, Stukenbroeker and Adams[2] and data on U 233, U 234, U 235, U 236 and U 238 for the widely split 4244 A line

1. See, for example, Stukenbroeker, G. L., and J. R. McNally, Jr., JOSA 40, 336 (1950); McNally, J. R., Jr., JOSA 39, 271 (1949).
2. Burkhart, L. E., G. L. Stukenbroeker and S. Adams, Phys. Rev. 75, 83, (1949).

is taken from Smith, Stukenbroeker and McNally.[3] Except for these other data which have been measured to about ±0.003 A, the data of this report are believed to be good to about ±0.010 A for shifts listed on two figures after the decimal and ±0.005 A for shifts listed to three figures after the decimal.

Tables I and II list isotope spectrum shift data from these other re-

TABLE I

ISOTOPE SPECTRUM LINE SHIFTS IN URANIUM, U 233, U 235, AND U 238

Wavelength	U 238-U 235 Shift		U 238-U 233 Shift	
	A	cm^{-1}	A	cm^{-1}
2565.406	0.075	1.14	0.145	2.20
2802.157	0.018	0.23	0.038	0.48
3313.94	0.016	0.14	0.052	0.47
3633.29	0.104	0.79	0.168	1.27
3670.072	0.009	0.06	0.018	0.13
3890.364	0.036	0.24	0.091	0.60
3944.130	0.057	0.37	0.148	0.95
4244.372	0.248	1.37	0.373	2.07
4252.426	0.168	0.93	0.257	1.42
4365.553	0.208	1.09	0.281	1.47
4609.864	0.077	0.36	0.131	0.62

3. Smith, D. D., G. L. Stukenbroeker and J. R. McNally, Jr., Phys. Rev. 84, 383 (1951).

TABLE II

ISOTOPE SHIFTS IN 4244 A LINE OF URANIUM

Isotope	Wavelength	(A)	(cm^{-1})
U 238	4244.373	0.000	0.00
U 236	4244.226	0.147 ± 0.010	0.82
U 235	4244.122	0.251 ± 0.010	1.39
U 234	4244.075	0.300 ± 0.010	1.66
U 233	4243.977	0.396 ± 0.005	2.20

ports.[2,3] Table III lists only data on U 235 and U 238 with further isotope data on those lines followed by an asterisk listed in Table I or II. In Table III the first column gives the U 238 wavelength, the second column the isotope shift in angstroms (+ indicates U 238 wavelength larger that that of U 235), the third column the isotope shift in wave numbers, followed by the ionic state of the uranium atom emitting the radiation (I is the neutral atom and II the singly-ionized atom), the combining energy levels where known, and remarks in a few cases which may be helpful in the interpretation. The spectrum classification of U II is based on the level notation of McNally[4] and that of U I on notation of Kiess, Humphreys and Laun.[4]

4. See Chapter II, The Chemistry of Uranium, McGraw-Hill Book Company, Inc., New York (1951).

TABLE III

ISOTOPE SPECTRUM LINE SHIFTS IN URANIUM, U-235 AND U-238

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
2351.2 A	0.07 A	1.3 cm^{-1}	-	-	-
2402.1	0.08	1.4	-	-	-
2406.435	0.06	1.0	II	$^4I_{4\frac{1}{2}}$-333 $A_{3\frac{1}{2},4\frac{1}{2}}$	-
2418.377	0.06	1.0	-	-	-
2422.637	0.06	1.0	-	-	-
2423.703	0.08	1.4	-	-	-
2427.454	0.06	1.0	-	-	-
2427.622	0.07	1.2	-	-	-
2428.476	0.07	1.2	-	-	-
2431.602	0.08	1.4	II	$^4I_{5\frac{1}{2}}$-335 $A_{6\frac{1}{2}}$	-
2433.786	0.08	1.4	-	-	-
2441.4	0.06	1.0	-	-	-
2448.93	0.08	1.3	-	-	-
2451.48	0.07	1.2	-	-	-
2454.361	0.07	1.2	II	$^4I_{4\frac{1}{2}}$-331 $A_{3\frac{1}{2}}$	-
2455.680	0.07	1.2	-	-	-
2468.0	0.08	1.3	-	-	-
2468.261	0.08	1.3	-	-	-
2469.4	0.08	1.3	-	-	-
2470.6	0.07	1.1	-	-	-
2472.8	0.09	1.5	-	-	-
2474.9	0.08	1.3	II	$^4I_{4\frac{1}{2}}$-330 $A_{4\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
2477.2 A	0.08 A	1.3 cm^{-1}	II	$^4I_{4\frac{1}{2}}$-329 $A_{4\frac{1}{2}}$	-
2484.0	0.08	1.3	-	-	-
2489.79	0.07	1.1	-	-	-
2491.317	0.07	1.1	-	-	-
2500.9	0.09	1.4	-	-	-
2514.8	0.08	1.3	II	$^4I_{5\frac{1}{2}}$-334 $A_{6\frac{1}{2}}$	-
2515.8	0.07	1.1	-	-	-
2528.0	<0.02	<0.3	-	-	-
2533.1	0.08	1.2	-	-	-
2537.2	0.08	1.2	-	-	-
2538.4	0.08	1.2	-	-	-
2541.0	<0.02	<0.3	-	-	-
2549.2	0.07	1.1	-	-	-
2564.424	0.06	0.9	-	-	-
2565.4 *	0.06	0.9	II	$^4I_{4\frac{1}{2}}$-326 $A_{5\frac{1}{2}}$	-
2567.108	0.08	1.2	-	-	-
2567.955	0.10	1.5	-	-	-
2570.302	0.10	1.5	-	-	-
2570.668	0.09	1.4	-	-	-
2575.422	0.08	1.2	-	-	-
2577.32	0.09	1.4	II	$^4I_{4\frac{1}{2}}$-323 $A_{5\frac{1}{2}}$	-
2579.437	<0.02	<0.3	-	-	-
2579.572	0.07	1.1	-	-	-
2583.48	0.08	1.2	-	-	-
2584.42	0.09	1.4	II	$^4I_{4\frac{1}{2}}$-322 $A_{3\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
2584.90 A	0.08 A	1.2 cm^{-1}	-	-	-
2586.201	0.05	0.8	-	-	-
2587.07	0.08	1.2	-	-	-
2591.252	0.09	1.4	II	$^4L_{4\frac{1}{2}}$-321 $A_{4\frac{1}{2}}$	-
2592.572	0.09	1.4	-	-	-
2593.57	0.08	1.2	-	-	-
2594.275	<0.02	<0.3	-	-	-
2594.98	0.09	1.3	-	-	-
2597.689	0.08	1.2	-	-	-
2599.71	0.03	0.4	-	-	-
2599.805	-0.02	-0.3	-	-	-
2601.54	0.07	1.0	-	-	-
2603.55	0.09	1.3	-	-	-
2604.31	0.08	1.2	-	-	-
2606.52	0.08	1.2	-	-	-
2606.72	0.08	1.2	-	-	-
2608.197	0.09	1.3	-	-	-
2609.258	0.08	1.2	-	-	-
2621.809	0.08	1.2	-	-	-
2624.925	0.065	0.95	-	-	-
2625.263	0.047	0.68	-	-	-
2628.504	0.09	1.3	-	-	-
2628.928	0.08	1.2	-	-	-
2632.657	0.08	1.2	-	-	-
2632.99	0.08	1.2	--	-	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
2635.528 A	0.07 A	1.0 cm^{-1}	II	$^4I_{4\frac{1}{2}}$-318 $A_{4\frac{1}{2}}$	-
2641.9	0.06	0.9	II	$^6L_{5\frac{1}{2}}$-319 $A_{4\frac{1}{2},5\frac{1}{2}}$	-
2651.8	0.10 ?	1.4 ?	-	-	One line in 235, two in 238.
2652.828	0.08	1.1	II	$^4I_{4\frac{1}{2}}$-315 $A_{5\frac{1}{2}}$	-
2690.509	0.08	1.1	-	-	-
2701.545	0.074	1.02	-	-	-
2727.335	0.07	1.0	-	-	-
2733.772	0.07	0.9	-	-	-
2744.274	0.05	0.7	-	-	-
2746.66	0.07	0.9	-	-	-
2766.9	0.06	0.8	-	-	-
2770.044	0.07	0.9	II	$^4I_{4\frac{1}{2}}$-299 $A_{4\frac{1}{2},5\frac{1}{2}}$	-
2771.550	0.08	1.0	II	$^4I_{4\frac{1}{2}}$-298 $A_{4\frac{1}{2}}$	-
2780.040	0.07	0.9	II	$^4I_{4\frac{1}{2}}$-296 $A_{4\frac{1}{2}}$	-
2802.157 *	0.02	0.3	-	-	-
2819.8	0.05	0.6	-	-	-
2822.7	<0.02	< 0.3	-	-	-
2826.193	0.09	1.1	II	$^4I_{4\frac{1}{2}}$-290 $A_{4\frac{1}{2},5\frac{1}{2}}$	-
2847.3	0.11	1.4	II	$^4I_{4\frac{1}{2}}$-285 $A_{4\frac{1}{2},5\frac{1}{2}}$	-
2858.9	0.077	0.94	-	-	-
2862.56	-0.015	-0.18	-	-	-
2865.14	0.088	1.05	-	-	-
2865.68	0.07	0.9	II	$^4I_{4\frac{1}{2}}$-280 $A_{5\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
2928.599 A	0.06 A	0.7 cm^{-1}	-	-	-
2928.6	0.03	0.3	-	-	-
2956.06	0.078	0.89	-	-	-
2957.229	0.098	1.12	-	-	-
2960.9	0.15	1.7	II	$^6K_{4\frac{1}{2}}$-277 $A_{5\frac{1}{2}}$	-
2974.463	0.07	0.8	-	-	-
2993.355	0.093	1.04	-	-	-
3023.9	0.10	1.1	-	-	-
3025.5	0.15	1.6	-	-	-
3035.51	0.093	1.01	-	-	-
3037.280	0.098	1.07	II	$^6L_{6\frac{1}{2}}$-276 $A_{6\frac{1}{2}}$	-
3048.63	0.10	1.1	I	$^5K^o_5$-334_6	-
3050.20	0.093	1.00	-	-	-
3073.50	0.098	1.03	-	-	-
3098.804	0.062	0.65	-	-	-
3153.120	0.086	0.87	-	-	-
3157.2	0.09	0.9	-	-	-
3157.446	0.098	0.98	-	-	-
3189.2	<0.02	<0.2	-	-	-
3229.502	0.089	0.85	-	-	-
3267.05	-0.04	-0.4	-	-	-
3287.3	0.10	0.9	-	-	-
3322.1	-0.06	-0.5	II	$^6M_{6\frac{1}{2}}$-277 $A_{5\frac{1}{2}}$	Two lines in U-235, one in U-238.
3325.76	0.14	1.3	II	$^4I_{4\frac{1}{2}}$-228 $A_{5\frac{1}{2}}$	-
3330.399	0.15	1.4	-	-	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
3334.82 A	0.03 A	0.3 cm^{-1}	-	-	-
3339.446	0.03	0.3	-	-	-
3339.716	0.11	1.0	-	-	-
3345.89	0.03	0.3	I	$^5K^o_5$-304_4	-
3346.05	-0.03	-0.3	-	-	-
3346.198	0.02	0.2	-	-	-
3351.66	0.12	1.1	II	$^4I_{4\frac{1}{2}}$-209 $A_{4\frac{1}{2}}$	Two lines in 235, one in 238.
3373.8	0.12	1.1	II	$^4I_{5\frac{1}{2}}$-267 $A_{6\frac{1}{2}}$	Two lines in 238, one in 235.
3400.467	<0.02	<0.2	-	-	-
3430.5	0.07	0.6	-	-	Two lines in 235, one in 238.
3438.3	-0.09	-0.8	-	-	Two lines in 235, one in 238.
3439.43	<0.02	<0.2	-	-	-
3550.8	0.10	0.8	II	$^4I_{4\frac{1}{2}}$-185 $A_{5\frac{1}{2}}$	-
3555.3	0.10	0.8	II	$^4L_{6\frac{1}{2}}$-271 $A_{5\frac{1}{2},6\frac{1}{2}}$	-
3569.0	0.09	0.7	-	-	-
3571.6	0.14	1.1	-	-	Two lines in 238, one in 235.
3890.364	0.04	0.3	II	$^6L_{5\frac{1}{2}}$-159 $A_{6\frac{1}{2}}$	-
3894.923	0.12	0.79	-	-	-
3900.799	0.095	0.63	-	-	-
3914.3	0.08 to 0.16	0.52 to 0.105	-	-	Two lines separate as U-235 increases.
3915.884	0.03	0.2	II	$^6I_{4\frac{1}{2}}$-112 $B_{5\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
3921.5 A	0.13 A	0.85 cm^{-1}	II	$^4I_{4\frac{1}{2}}$-150 $A_{5\frac{1}{2}}$	-
3922.037	0.110	0.72	-	-	-
3924.272	0.04	0.3	II	$^6M_{6\frac{1}{2}}$-219 $A_{5\frac{1}{2}}$	-
3931.0	0.13	0.84	-	-	-
3933.030	0.10	0.65	-	-	-
3943.498	0.09	0.58	-	-	-
3943.8	0.05	0.32	-	-	-
3944.130 *	-0.05	-0.32	II	$^6M_{6\frac{1}{2}}$-211 $A_{7\frac{1}{2}}$	-
3954.663	0.07	0.45	II	$^6I_{5\frac{1}{2}}$-110 $B_{5\frac{1}{2}}$	-
3985.795	0.084	0.53	II	$^6L_{7\frac{1}{2}}$-230 $A_{7\frac{1}{2}}$	-
3989.953	0.125	0.79	II	$^4I_{5\frac{1}{2}}$-205 $A_{6\frac{1}{2}}$	-
4004.063	0.09	0.51	II	$^6L_{6\frac{1}{2}}$-167 $A_{6\frac{1}{2}}$	-
4017.723	0.03	0.19	II B	$^6I_{4\frac{1}{2}}$-102 $B_{4\frac{1}{2}}$	-
				OR	
			II	$^6I_{4\frac{1}{2}}$-243 $A_{4\frac{1}{2}}$?	-
4019.203	0.06	0.37	-	-	-
4030.76	0.126	0.78	-	-	-
4033.427	0.156	0.96	II	$^4I_{4\frac{1}{2}}$-197 $A_{5\frac{1}{2}}$	-
4044.416	0.06	0.37	II	$^6M_{6\frac{1}{2}}$-198 $A_{5\frac{1}{2}}$	-
4047.6	0.07	0.43	-	-	-
4050.039	0.10	0.61	II	$^4I_{4\frac{1}{2}}$-142 $A_{4\frac{1}{2}}$	-
4062.549	0.10	0.61	II	$^4I_{4\frac{1}{2}}$-141 $A_{5\frac{1}{2}}$	-
4071.108	-0.09	-0.55	-	-	Two lines in 235, one in 238.

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4088.254 A	0.198 A	1.20 cm^{-1}	II	$^4I_{4\frac{1}{2}}$-140 $A_{4\frac{1}{2}}$	-
4095.7	0.156	0.93	-	-	Two lines in 235, one in 238.
4106.931	0.10	0.60	II	$^4I_{4\frac{1}{2}}$-139 $A_{3\frac{1}{2}}$	-
4116.097	0.156	0.92	II	$^4I_{4\frac{1}{2}}$-136 $A_{5\frac{1}{2}}$	-
4124.725	0.025	0.15	II	$^6L_{6\frac{1}{2}}$-159 $A_{6\frac{1}{2}}$	-
4128.336	0.173	1.02	II	$^4I_{5\frac{1}{2}}$-192 $A_{6\frac{1}{2}}$	-
4136.8	0.19	1.11	II	$^4I_{5\frac{1}{2}}$-191 $A_{5\frac{1}{2}}$	-
4139.140	0.16	0.94	II	$^4I_{4\frac{1}{2}}$-134 $A_{5\frac{1}{2}}$	-
4153.6	0.24	1.39	-	-	-
4163.7	0.20	1.16	I	$^5K^o_6$-283_7	-
4204.371	0.246	1.40	II	$^4I_{4\frac{1}{2}}$-130 $A_{5\frac{1}{2}}$	-
4204.4	0.14	0.79	-	-	-
4211.6	-0.07	-0.40	I	$^7M^o_6$-299_6	-
4212.3	0.18	1.02	II	$^4I_{5\frac{1}{2}}$-185 $A_{5\frac{1}{2}}$	-
4213.9	0.20	1.13	-	-	-
4214.4	<0.02	<0.1	II	$^6H_{3\frac{1}{2}}$-201 $A_{4\frac{1}{2}}$ $^6L_{5\frac{1}{2}}$-132 $A_{5\frac{1}{2}}$	-
4222.36	0.05	0.28	I	A^o_7-274_8	-
4241.669	-0.063	-0.35	II	$^6M_{6\frac{1}{2}}$-185 $A_{5\frac{1}{2}}$	-
4244.372 *	0.251	1.39	II	$^4I_{4\frac{1}{2}}$-127 $A_{5\frac{1}{2}}$	-
4246.261	0.050	0.28	I	$^5L^o_6$-235_7	-
4252.426 *	0.154	0.85	II	$^4I_{5\frac{1}{2}}$-184 $A_{5\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4255.70 A	<0.02 A	<0.1 cm^{-1}	II	$^4I_{5\frac{1}{2}}$-183 $A_{5\frac{1}{2}}$	-
4260.58	0.25	1.38	-	-	-
4266.33	<0.02	<0.1	I	$^5L^o_6$-234_5	-
4276.47	<0.02	<0.1	-	-	-
4278.17	<0.02	<0.1	-	-	-
4280.212	-0.09	-0.49	-	-	-
4280.66	0.06	0.33	-	-	-
4282.03	<0.02	<0.1	II	$^6L_{5\frac{1}{2}}$-128 $A_{6\frac{1}{2}}$	-
4282.45	-0.02	-0.1	II	$^6M_{6\frac{1}{2}}$-184 $A_{5\frac{1}{2}}$	-
4283.91	<0.02	<0.1	-	-	-
4287.869	0.12	0.65	II	$^4I_{4\frac{1}{2}}$-126 $A_{4\frac{1}{2}}$	-
4289.56	0.13	0.71	-	-	-
4289.88	0.19	1.03	II	$^4I_{5\frac{1}{2}}$-182 $A_{5\frac{1}{2}}$	-
4295.35	-<0.02	-<0.1	II	$^4L_{6\frac{1}{2}}$-206 $A_{5\frac{1}{2}}$	-
4297.11	0.12	0.65	II	$^6L_{5\frac{1}{2}}$-127 $A_{5\frac{1}{2}}$	-
4299.39	0.07	0.38	-	-	-
4301.47	0.07	0.38	II	$^4I_{4\frac{1}{2}}$-125 $A_{5\frac{1}{2}}$	-
4302.09	<0.02	<0.1	II	$^6K_{4\frac{1}{2}}$-134 $A_{5\frac{1}{2}}$	-
4306.78	0.06	0.33	-	-	Two lines in 238, one in 235.
4309.69	0.15	0.81	I	$^5L^o_6$-231_7	-
4310.39	-0.05	-0.27	II	$^4L_{6\frac{1}{2}}$-205 $A_{6\frac{1}{2}}$	-
4313.15	0.08	0.43	I	A^o_7-270_8	-
4313.88	< 0.02	< 0.1	II	$^6L_{6\frac{1}{2}}$-143 $A_{6\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4319.52 A	0.15 A	0.81 cm^{-1}	-	-	-
4323.76	0.08	0.43	-	-	-
4331.83	0.15	0.81	II	$^4I_{5\frac{1}{2}}$-178 $A_{5\frac{1}{2}}$	-
4333.52	<0.02	<0.1	-	-	-
4335.28	<0.02	<0.1	-	-	-
4347.19	0.06	0.32	II	$^6K_{4\frac{1}{2}}$-131 $A_{4\frac{1}{2}}$	-
4347.42	-0.10	-0.53	-	-	-
4348.22	0.07	0.37	-	-	Two lines in 238, one in 235.
4352.80	<0.02	<0.1	-	-	-
4354.15	-0.13	-0.69	-	-	-
4354.356	0.19	1.01	-	-	Not in 235.
4354.548	-	-	-	-	Negligible shift; sharp in 238, diffuse in 235.
4356.54	0.09	0.47	-	-	-
4357.62	<0.02	<0.10	-	-	-
4357.86	0.08	0.42	I	$^5K^o_5$-235_4	-
4358.65	0.20	1.05	II	$^4I_{5\frac{1}{2}}$-173 $A_{5\frac{1}{2}}$	-
4361.16	-0.09	-0.47	II	$^4L_{6\frac{1}{2}}$-197 $A_{5\frac{1}{2}}$	-
4362.05	0.21	1.11	I	$^5L^o_6$-229_7	Intensity much stronger in 235, one line in 235, two in 238.
4362.262	-	-	II	$^4L_{4\frac{1}{2}}$-124 $A_{5\frac{1}{2}}$	Intensity of this line in U 235 is much stronger than 4362.05 in 238; this line not in 238.
4362.93	-0.09	-0.47	II	$^6M_{6\frac{1}{2}}$-178 $A_{5\frac{1}{2}}$	-
4364.29	0.17	0.90	-	-	-
4371.06	0.15	0.78	-	-	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4371.76 A	<0.02 A	<0.10 cm^{-1}	I	C_7^o-309_8	-
4373.99	<0.02	<0.10	-	-	-
4375.75	0.23	1.20	-	-	-
4380.27	0.15	0.78	-	-	-
4381.82	0.23	1.20	-	-	-
4382.34	0.03	0.16	I	$^5K_5^o$-234_5	-
4383.27	0.06	0.32	I	A_7^o-266_7	-
4383.63	-	-	-	-	In 238 only, not in 235.
4395.58	<0.02	<0.10	-	-	-
4400.53	0.20	1.04	-	-	-
4402.44	<0.02	<0.10	-	-	-
4405.73	0.21	1.09	I	A_7^o-265_8	-
4410.87	0.23	1.19	-	-	-
4415.241	0.190	0.97	II	$^4I_{4\frac{1}{2}}$-121 $A_{4\frac{1}{2}}$	-
4415.87	0.12	0.62	II	$^6K_{4\frac{1}{2}}$-127 $A_{5\frac{1}{2}}$	-
4422.98	0.23	1.17	-	-	-
4423.74	-0.09	-0.46	-	-	-
4426.94	<0.02	<0.10	I	$^5L_6^o$-225_6	-
4427.653	0.105	0.53	II	$^6L_{5\frac{1}{2}}$-123 $A_{4\frac{1}{2}}$	-
4434.95	0.05	0.26	-	-	-
4440.74	0.09	0.46	I	A_7^o-263_8	-
4447.98	0.07	0.35	II	$^6L_{5\frac{1}{2}}$-122 $A_{5\frac{1}{2}}$	-
4448.33	-	-	I	A_7^o-262_7	In 238 only, not in 235.
4455.88	0.20	1.01	-	-	-
4457.10	0.15	0.75	II	$^4I_{4\frac{1}{2}}$-120 $A_{4\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4462.760 A	0.29 A	1.46 cm^{-1}	-	-	-
4465.133	-	-	II	$^6K_{5\frac{1}{2}}$-142 $A_{4\frac{1}{2}}$	This line disappears as 235 increases and two more appear, one 0.06A to high side, one 0.19A to low side.
4468.895	0.28	1.30	-	-	-
4469.32	<0.02	<0.10	I	$^5L^o_6$-223_7	-
4475.681	<0.02	<0.10	-	-	-
4477.710	-0.09	-0.45	II	$^6K_{4\frac{1}{2}}$-125 $A_{5\frac{1}{2}}$	-
4480.346	<0.02	<0.10	II	$^6K_{5\frac{1}{2}}$-141 $A_{5\frac{1}{2}}$	-
4482.678	-0.09	-0.45	II	$^6M_{6\frac{1}{2}}$-169 $A_{7\frac{1}{2}}$	-
4485.215	<0.02	<0.10	-	-	-
4493.044	0.19	0.95	-	-	-
4494.75	0.05	0.25	I	$^5K^o_5$-228_6	-
4510.32	0.162	0.80	II	$^4I_{4\frac{1}{2}}$-119 $A_{4\frac{1}{2}}$	-
4511.158	0.21	1.03	II	$^4L_{6\frac{1}{2}}$-188 $A_{5\frac{1}{2}}$	-
4515.280	-0.06	-0.29	II	$^6L_{5\frac{1}{2}}$-120 $A_{4\frac{1}{2}}$	-
4516.725	0.02	0.10	I	$^5K^o_5$-227_6	-
4521.591	<0.02	<0.10	-	-	-
4523.344	0.20	0.98	II	$^4I_{4\frac{1}{2}}$-118 $A_{4\frac{1}{2}}$	-
4529.707	<0.02	<0.10	-	-	-
4536.608	<0.02	<0.10	I	$^7M^o_6$-283_7	-
4537.116	-0.09	-0.44	-	-	-
4543.632	0.04	0.19	II	$^6K_{4\frac{1}{2}}$-124 $A_{5\frac{1}{2}}$	-
4545.41	0.25	1.20	II	$^4I_{5\frac{1}{2}}$-a 165 A	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4545.580 A	<0.02 A	<0.10 cm^{-1}	II	$^6K_{5\frac{1}{2}}$-136 $A_{5\frac{1}{2}}$	-
4553.858	0.117	0.56	II	$^6K_{4\frac{1}{2}}$-123 $A_{4\frac{1}{2}}$	-
4556.008	<0.02	<0.10	-	-	-
4556.33	-0.1	-0.49	-	-	-
4557.805	-	-	-	-	Not in 235.
4557.89	-	-	-	-	Not in 238, in 235 only.
4558.048	-	-	I	$^5K^o_6$-261_7	Not in 235.
4561.224	<0.02	<0.10	-	-	-
4563.955	0.09	0.43	I	A^o_8-295_9	-
4567.687	0.02	0.10	II	$^6L_{6\frac{1}{2}}$-128 $A_{6\frac{1}{2}}$	-
4569.913	<0.02	<0.10	II	$^6L_{5\frac{1}{2}}$-119 $A_{4\frac{1}{2}}$	-
4571.683	0.05	0.24	-	-	-
4573.276	0.21	1.01	-	-	-
4573.687	0.02	0.10	II	$^6K_{5\frac{1}{2}}$-134 $A_{5\frac{1}{2}}$	-
4576.635	<0.02	<0.10	I	$^5K^o_5$-224_6	-
4581.724	0.06	0.28	II	$^1A_{7\frac{1}{2}?}$-230 $A_{7\frac{1}{2}}$	-
4583.274	<0.02	<0.10	II	$^6M_{6\frac{1}{2}}$-164 $A_{6\frac{1}{2}?}$	-
4584.847	0.12	0.57	II	$^6L_{6\frac{1}{2}}$-127 $A_{5\frac{1}{2}}$	-
4591.730	-0.06	-0.29	-	-	-
4594.294	<0.02	<0.10	-	-	-
4601.130	<0.02	<0.10	II	$^6K_{4\frac{1}{2}}$-121 $A_{4\frac{1}{2}}$	-
4601.794	0.05	0.24	II	$^6K_{5\frac{1}{2}}$-133 $A_{5\frac{1}{2}}$	-
				$^6I_{3\frac{1}{2}}$-170 $A_{4\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4603.665 A	0.03 A	0.14 cm^{-1}	II	$^6K_{5\frac{1}{2}}$-132 $A_{5\frac{1}{2}}$	-
4608.813	0.10	0.47	-	-	-
4609.864 *	0.13	0.61	II	$^6L_{5\frac{1}{2}}$-117 $A_{6\frac{1}{2}}$	-
4611.436	0.272	1.28	-	-	-
4614.678	0.20	0.94	II	$^4I_{5\frac{1}{2}}$-160 $A_{5\frac{1}{2}}$	-
4615.571	-0.03	-0.14	-	-	-
4620.23	<0.02	<0.09	I	$^7M^o_6$-278_7	-
4624.710	-<0.02	-<0.09	II	$^6K_{5\frac{1}{2}}$-131 $A_{4\frac{1}{2}}$	-
4631.62	0.08	0.37	I	$^5L^o_6$-215_6	-
4631.798	<0.02	<0.09	-	-	-
4635.510	<0.02	<0.09	II	$^4K_{5\frac{1}{2}}$-173 $A_{5\frac{1}{2}}$	-
4637.940	0.23	1.06	II	$^4I_{4\frac{1}{2}}$-112 $A_{4\frac{1}{2}}$	-
4640.349	<0.02	<0.09	-	-	-
4641.658	-0.08	-0.37	II	$^6M_{7\frac{1}{2}}$-211 $A_{7\frac{1}{2}}$	-
4643.623	-0.08	-0.37	-	-	-
4646.603	-0.06	-0.28	II	$^6K_{4\frac{1}{2}}$-120 $A_{4\frac{1}{2}}$	-
4647.870	<0.02	<0.09	-	-	-
4650.00	-0.08	-0.37	II	$^6M_{6\frac{1}{2}}$-160 $A_{5\frac{1}{2}}$	-
4651.546	-0.10	-0.46	II	$^6L_{6\frac{1}{2}}$-125 $A_{5\frac{1}{2}}$	-
4653.442	<0.02	<0.09	II	$^6K_{5\frac{1}{2}}$-130 $A_{5\frac{1}{2}}$	-
4654.836	<0.02	<0.09	-	-	-
4663.755	0.07	0.32	I	$^5K^o_5$-220_6	-
4674.228	<0.02	<0.09	-	-	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4681.183 A	0.06 A	0.27 cm^{-1}	-	-	-
4682.054	0.10	0.46	-	-	-
4682.133	-0.10	-0.46	-	-	-
4684.644	<0.02	<0.09	-	-	-
4685.718	0.07	0.32	II	$^4K_{5\frac{1}{2}}$-170 $A_{4\frac{1}{2}}$	-
4689.074	0.212	0.97	II	$^4I_{4\frac{1}{2}}$-111 $A_{3\frac{1}{2}}$	-
4700.710	<0.02	<0.09	-	-	-
4700.980	0.03	0.14	II	$^6L_{5\frac{1}{2}}$-112 $A_{4\frac{1}{2}}$	-
4701.234	<0.02	<0.09	-	-	-
4702.047	-0.03	-0.14	II	$^6H_{2\frac{1}{2}}$-158 $A_{3\frac{1}{2}}$	-
4702.517	0.129	0.58	II	$^6K_{5\frac{1}{2}}$-127 $A_{5\frac{1}{2}}$	-
4704.476	<0.02	<0.09	II	$^6K_{4\frac{1}{2}}$-119 $A_{4\frac{1}{2}}$	-
4706.404	<0.02	<0.09	-	-	-
4706.76	0.02	0.09	I	B^o_7-285_7	-
4710.189	0.08	0.36	-	-	-
4712.150	-0.06	-0.27	II	$^4L_{6\frac{1}{2}}$-178 $A_{5\frac{1}{2}}$	-
4713.943	0.19	0.86	-	-	-
4715.669	0.17	0.77	I	$^5I^o_4$-256_4	Two lines in 235, one in 238.
4718.7	0.12	0.54	-	-	Two lines in 238, one in 235 $\Delta\lambda$ 1.0.
4720.015	0.02	0.09	-	-	-
4722.726	<0.02	<0.09	II	$^6L_{6\frac{1}{2}}$-124 $A_{5\frac{1}{2}}$	-
4730.685	<0.02	<0.09	I	$^7M^o_6$-273_5	-
4730.988	0.12	0.54	-	-	Two lines in 235, one in 238.

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4731.599 A	-0.08 A	-0.36 cm^{-1}	II	$^6M_{6\frac{1}{2}}$-153 $A_{6\frac{1}{2}}$	-
4740.285	-<0.02	-<0.09	-	-	-
4742.333	<0.02	<0.09	-	-	-
4755.729	0.17	0.75	II	$^4I_{4\frac{1}{2}}$-110 $A_{3\frac{1}{2}}$	-
4756.803	-	-	II	$^4I_{5\frac{1}{2}}$-149 $A_{4\frac{1}{2}}$	This line disappears in 235, two more appear in 235 at 4756.72 and 4756.57.
4762.903	0.04	0.18	-	-	-
4768.667	0.06	0.26	I	$^5K^o_5$-215_6	-
4769.260	0.17	0.75	II	$^4I_{4\frac{1}{2}}$-109 $A_{3\frac{1}{2}}$	-
4772.701	-0.12	-0.53	II	$^6K_{5\frac{1}{2}}$-125 $A_{5\frac{1}{2}}$	-
4777.680	<0.02	<0.09	I	$^5K^o_5$-215_4	-
4778.102	0.08	0.35	-	-	-
4779.632	0.02	0.09	II	$^6K_{4\frac{1}{2}}$-115 $A_{4\frac{1}{2}}$	-
4790.063	0.08	0.35	I	A^o_7-246_6	-
4796.259	0.03	0.13	-	-	-
4807.614	< 0.02	<0.09	-	-	-
4808.874	<0.02	<0.09	II	$^6H_{2\frac{1}{2}}$-151 $A_{3\frac{1}{2}}$	-
4810.889	<0.02	<0.09	I	A^o_7-245_8	-
4811.699	-0.12	-0.52	-	-	Two lines in 235, one in 238.
4815.702	0.12	0.52	I	B^o_8-314_8	-
4819.544	0.23	0.99	II	$^4I_{5\frac{1}{2}}$-145 $A_{6\frac{1}{2}}$	-
4824.668	0.07	0.30	-	-	-
4825.930	0.07	0.30	-	-	-
4844.70	0.20	0.85	-	-	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
4859.750 A	0.18 A	0.75 cm^{-1}	II	$^4I_{4\frac{1}{2}}$-144 $A_{5\frac{1}{2}}$	-
4910.339	<0.07	<0.29	I	$^7M^o_6$-266_7	-
4928.44	<0.07	0.29	I	$^5K^o_6$-245_7	-
4933.063	<0.07	<0.28	I	A^o_7-240_7	-
4944.50	0.12	0.49	I	$^5L^o_6$-202_6	-
4955.78	0.07	0.28	I	A^o_8-278_8	-
5011.44	<0.07	<0.28	I	$^5K^o_5$-205_4	-
5027.38	<0.07	<0.27	I	$^5L^o_6$-198_7	-
5164.14	<0.07	<0.26	I	C^o_7-274_8	-
5216.92	0.12	0.44	I	$^5K^o_5$-197_6	-
5234.16	0.07	0.26	I	$^7M^o_6$-253_6	-
5241.7	0.09	0.33	-	-	Shifts .6 mm. to violet as 235 increases.
5414.4	0.12	0.41	-	-	-
5431.35	<0.05	<0.17	I	$^5L^o_6$-184_5	-
5455.6	0.09	0.31	-	-	-
6010.907	0.33	0.91	I	D^o_7-269_8	-
6051.745	-0.165	-0.45	II	$^6K_{4\frac{1}{2}}$-102 $A_{5\frac{1}{2}}$	-
6062.30	<0.05	<0.14	I	$^5K^o_6$-207_7	-
6065.84	-0.28	-0.76	-	-	-
6087.338	0.165	0.446	I	A^o_9-295_9	-
			II	$^6I_{4\frac{1}{2}}$-123 $A_{4\frac{1}{2}}$	-
6117.84	0.235	0.628	-	-	-
6132.6	0.165	0.440	-	-	-
6181.3	-0.142	-0.371	II	$^6K_{4\frac{1}{2}}$-107 $B_{3\frac{1}{2}}$	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
6234.32 A	0.110 A	0.284 cm^{-1}	I	$^5K^o_6$-203_5	-
6246.52	0.165	0.423	I	$^7K^o_5$-217_6	-
6298.55	0.235	0.594	I	A^o_3-197_4 and	-
			II	$^2A_{7\frac{1}{2}}$-145 $A_{6\frac{1}{2}}$	-
6322.36	0.330	0.828	-	-	-
6375.984	0.52	1.28	-	-	-
6379.6	-0.165	-0.406	I	B^o_3-227_3	-
6465.2	0.145	0.348	-	-	-
6470.55	-0.110	-0.263	-	-	-
6495.3	-0.275	-0.652	-	-	-
6534.59	0.500	1.175	-	-	-
6587.834	0.500	1.150	-	-	-
6621.77	-0.120	-0.274	II	$^6K_{5\frac{1}{2}}$-101 $A_{4\frac{1}{2}}$	-
6768.64	-0.36	-0.786	-	-	-
6873.5	-0.110	-0.234	II	$^6K_{4\frac{1}{2}}$-103 $B_{4\frac{1}{2}}$	-
6948.58	-0.235	-0.486	II	$^6K_{4\frac{1}{2}}$-102 $B_{4\frac{1}{2}}$	-
7020.71	-0.235	-0.478	-	-	-
7128.91	0.165	0.325	I	$^5K^o_5$-146_6	-
7209.30	-0.375	-0.723	-	-	-
7218.04	-0.350	-0.673	-	-	-
7510.27	0.141	0.251	-	-	-
7631.7	-0.17	-0.29	I	A^o_7-169_7	-
7770.4	0.28	0.46	-	-	One line in 235, two in 238.
7771.5	0.25	0.41	-	-	-
7832.5	0.20	0.33	-	-	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
7981.9 A	0.17 A	0.27 cm^{-1}	-	-	-
7960.3	0.30	0.47	I	B_7^o-198_7?	Two lines in 235, one in 238.
7964.6	0.23	0.36	-	-	-
7976.8	0.32	0.50	II	$^6H_{3\frac{1}{2}}$-103 $A_{4\frac{1}{2}}$	One line in 238, two in 235.
7988.8	0.12	0.19	-	-	-
7991.3	0.53	0.83	I	$^7M_6^o$-187_6	One line in 235, two in 238.
8019.3	0.23	0.36	I	$^7K_6^o$-194_5	-
8055.8	0.23	0.35	I	C_7^o-204_6	-
8175.20	-0.42	-0.68	-	-	-
8178.4	0.23	0.34	-	-	-
8210.15	0.33	0.49	-	-	-
8223.09	0.20	0.30	I	$^7M_6^o$-184_5	-
8307.8	-0.500	-0.726	-	-	-
8329.73	0.280	0.404	-	-	-
8340.9	-0.300	-0.433	-	-	-
8357.07	-0.190	-0.273	-	-	-
8381.86	0.46	0.66	I	$^7K_6^o$-189_5	Two lines in 238, one in 235.
8385.05	0.690	0.981	-	-	-
8387.4	-0.32	-0.46	-	-	-
8424.7	-0.300	-0.424	-	-	-
8540.19	0.25	0.34	I	$^7K_5^o$-174_4	One line in 235, two in 238.
8567.73	0.23	0.31	I	$^5I_4^o$-161_4	One line in 235, two in 238.
8574.59	0.65	0.89	I	$^7M_6^o$-179_5	-

U-238 Wavelength	$\Delta\lambda$	$\Delta\sigma$	Atom	Transition	Remarks
8570.5 A	0.39 A	0.53 cm^{-1}	I	-	-
8618.96	0.67	0.90	-	-	-
8692.28	0.34	0.45	-	-	-
8702.6	0.25	0.33	-	-	-
8757.75	0.210	0.274	-	-	-
8758.7	0.232	0.303	-	-	-