Absorption Spectra of Cerium, Neodymium and Samarium

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A modified King electric furnace, charged with rare earth salts, has been used to observe the absorption spectra of cerium, neodymium and samarium in the region 12,000A to 2500A with a 21-ft. concave grating giving dispersion of 2.5A/mm in the first order. The observations include 600 lines in cerium, 450 in neodymium, and 1500 in samarium. In general the absorption data confirm the line types as given by King's temperature classification in that, of those lines which are absorbed, the class I lines are more strongly absorbed than class II lines, which are in turn stronger than class III lines, and provide additional data in that only those lines of each class which involve the lowest levels appear in absorption.

INTRODUCTION

TEMPERATURE classifications for the spectra of cerium, neodymium and samarium have been published by A. S. King.[1, 2, 3] His emission data do not extend to wave-lengths shorter than 2900A, and absorption data are desirable to supplement these data to aid in the analysis of these spectra. For this reason the absorption spectra of cerium, neodymium and samarium have been photographed with a 21-foot concave grating in the first and second orders at dispersions of 2.5 and 1.25A/mm, over the range 12,000 to 2500A, in extension of the work reported at a meeting of the American Physical Society.[4]

APPARATUS

A vacuum furnace of the type described by King,[5] with modifications introduced by Harrison, has been used to vaporize oxides and oxalates of cerium, neodymium and samarium, to obtain the absorption spectra. The design of the furnace used is shown in Fig. 1. The graphite tube T is held by graphite blocks B which fit into tapered holes in the graphite shields bolted to the water cooling chambers J_1 and J_2. Water and electric current connections are made through the copper tubes $O_{1,2,3,4}$, of which O_1 and O_2 are insulated from the base F at I. The heads carrying the water-cooling chambers J_3 and J_4, the shields D_1 and D_2, and the windows W_1 and W_2 are held to the cover C by air pressure and made vacuum tight with soft vacuum wax. The fitted blocks to hold the tube and the easily removable heads make it possible to recharge the furnace or to replace the tube without removing the cover C.

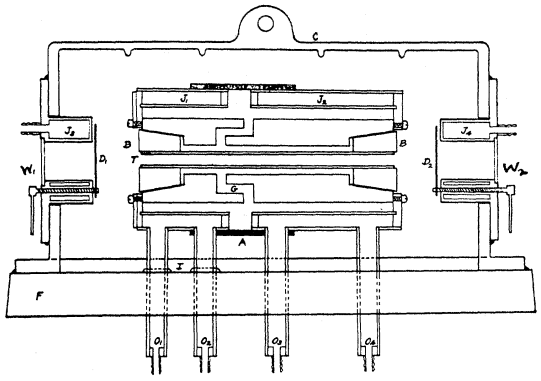

FIG. 1. Vacuum furnace.

The sources of continuous radiation used were: (1) A 500-watt tungsten filament lamp, (2) the positive crater of a carbon arc, and (3) a hydrogen lamp. The first was especially useful in the region 3400 to 8000A. The second, which was arranged in a convenient form with the positive electrode held horizontal, the negative vertical, and the two constantly fed into the arc by clockwork, was used in the short wave-length region from 2900 to 3400A, and was especially valuable from 8000 to 12,000A, because of the high intensity. The third source, a high current, "end-on" hydrogen discharge of conventional type, was operated with a transformer supplying approximately one ampere at 5000 volts, and gave a good continuous background from 2500 to 3500A.

[1] A. S. King, Ap. J. **68**, 194 (1928).
[2] A. S. King, Ap. J. **78**, 9 (1933).
[3] A. S. King, Ap. J. **82**, 140 (1935).
[4] F. W. Paul, Phys. Rev. **47**, 799 (1935).
[5] A. S. King, Trans. A. E. S. **54** (1929).

Experimental Procedure

Since exposure times were rather long in the less easily accessible regions of the spectrum, investigations were carried out to determine in what way the duration of a single charge of salt could most easily be extended. It was found that by concentrating the charge in the central three to five inches of the tube and placing at either end of the packed portion a short half-round graphite plug, a single charge could be made to supply a strongly absorbing column of vapor for an exposure lasting two hours.

A wide range of exposure times was needed to bring out most clearly the different spectral regions. Between 4000 and 6000A, where the grating concentrates a large fraction of the light incident on it, exposure times of the order of one minute gave the best contrast, while between 10,000 and 12,000A exposures of eight hours were necessary to produce a satisfactory blackening of the plates.

Exposures were made at furnace temperatures ranging from 1700° to 2300°C as measured with a Leeds and Northrup optical pyrometer.

The light incident on the slit was observed throughout the exposure by means of a quartz plate which reflected about 8 percent of the light incident upon it, on the slit of a Hilger constant deviation spectrometer. It was necessary to vary this procedure when using the hydrogen lamp as a source because it furnishes no continuous background in the visible region, by replacing the hydrogen lamp by the tungsten filament lamp at regular intervals to observe the absorption lines and make sure there was an absorbing column of vapor.

The use of the type Z plates recently developed by the Eastman Kodak Company permitted photographic investigations between 10,000 and 12,000A.

All the absorption lines were measured against the lines of an international standard iron arc superposed upon part of the absorption picture. For the most part these measurements were used only as a means of identifying the lines, the wave-lengths given in Tables I–III being those obtained in emission by the authors indicated in the references. However, in the short wave-length region (<3000A), many lines are observed which have not been found in emission. The wave-lengths of these lines given in the tables are those determined by the author. Intensity estimates were made on a scale ranging from 1 to 20.

Results

Table I contains approximately 600 lines observed in the absorption spectrum of cerium. Below 3200A the intensity of the absorption lines falls off very rapidly and very few are observed. The wave-lengths with whose emission intensities temperature classifications are given are those recorded by King.[1] The wave-lengths recorded with emission intensities but without temperature classifications to 4670A are those given by King in an unpublished list, and are probably class III lines. Wave-lengths accompanied by emission intensities but without temperature classifications beyond 5500A are those given by Kiess, Hopkins and Kremers.[6] The notations following the emission intensities are those given by these authors. It is seen that the lines listed as possible band structures appear strongly in absorption, and here also they present the appearance of unresolved bands.

Table II contains about 450 lines which were observed in the absorption spectrum of neodymium. This spectrum was somewhat easier to observe between 2600 and 3200A than that of cerium, a more characteristic variation of intensity being apparent. Here again the wave-length recorded with emission intensities and temperature classifications are those given by King.[2] Wave-lengths recorded with emission intensities but without temperature classifications are those given by Kiess.[7]

Table III contains nearly 1500 lines observed in the absorption spectrum of samarium. All wave-lengths with emission intensities are those given by King.[3] This spectrum is remarkable for the number and intensity of the absorption lines. Especially noteworthy are the great number of lines of wave-length shorter than 3000A. The chief absorption lines in the long wave-length region are class I and II lines as one would expect. However, as one goes to shorter wave-

[6] Kiess, Hopkins and Kremers, Bur. Standards Pub. **17**, 318 (1921).
[7] Kiess, Bur. Standards Pub. **18**, 201 (1922).

TABLE I. *Spectra of cerium.*

Wave-length (I.A.)	Intensity Absorption	Intensity Emission
2743.30	1	
2743.47	1	
2757.49	1	
2757.70	1	
2757.82	1	
2758.24	1	
2770.07	1	
2773.57	1	
2811.17	1	
2819.01	1	
2941.85	1	
3001.12	1	
3015.01	1	
3026.27	1	
3030.232	1	6 II
3057.80	1	
3061.236	1	5 II
3082.42	1	
3236.859	1	10 I
3240.393	1	4 II
3240.98	1	
3244.42	1	
3244.69	1	
3247.90	1	
3266.86	1	
3267.18	1	
3272.939	1	8 II
3283.85	1	
3292.35	1	
3294.97	1	
3299.83	1	
3316.539	1	8 II
3325.09	1	
3325.91	1	
3341.292	1	10 I
3355.60	1	
3369.44	1	
3371.20	1	
3371.81	2	
3383.25	1	
3389.636	1	10 I
3408.382	1	6 II
3416.701	1	12 I
3417.11	1	
3420.52	1	
3423.94	1	
3424.36	1	
3435.198	1	20 I
3437.66	1	
3459.01	1	
3461.304	1	8 II
3462.437	1	12 II
3578.831	1—	1
3593.612	1—	1
3606.129	3	12 I
3614.250	3	5 II
3616.469	3	8 I
3625.373	3	10 I
3628.618	1	15 I
3629.807	3	8 I
3637.574	3	12 I
3642.620	8	1
3643.453	8	15 I
3648.530	5	10 II
3654.977	5	8 II
3655.848	5	12 IV
3658.789	5	12 I
3660.640	3	8 IV
3666.023	10	25 I
3667.403	2	2
3671.303	3	6 II
3672.176	5	15 I
3679.075	2	10 IA
3686.050	1	12 I
3687.062	1	2
3688.481	2	2
3689.677	3	15 I
3690.121	5	12 I
3702.636	3	1
3706.932	5	6 II
3723.668	5	15 I
3726.030	3	4 II
3731.192	3	5 II
3732.560	3	10 II
3738.012	1	1
3742.228	8	6 II
3750.067	1—	2
3756.264	8	6 II
3759.757	5	15 I
3763.932	1	1
3766.068	10	15 I
3766.850	1	6 II
3782.524	8	4 IV
3785.016	1	8 II
3789.469	5	10 I
3791.961	3	10 I
3799.098	3	5 I
3884.987	1	3
3885.236	1	8 I
3886.736	3	1
3926.917	3	1
3927.440	1	8 I
3943.906	10	15
3956.768	3	20 I
3957.203	3	15 I
3961.404	10	1—
3967.642	3	5 II
3973.996	3	12 I
3976.256	20	4
3982.164	3	15 I
3986.138	3	5 II
3995.992	1	1
4006.665	20	1
4007.428	3	6
4007.969	12	1—
4011.29	5	6 II
4013.952	2	6 II
4014.847	1	1
4017.791	1	4
4019.195	1	6 II
4044.322	5	1—
4045.976	1	5 I
4051.508	3	1
4055.839	6	20 I
4060.713	3	15 I
4066.576	2	10 I
4068.050	1	8 I
4068.989	2	15 IA
4074.559	1	4
4080.033	1	10 I
4083.159	1	2
4084.785	1	2
4086.373	3	10 I
4088.151	1	1
4093.278	2	15 I
4095.122	4	10 I
4095.449	1	10 II
4096.093	1	8 II
4098.144	1	10 II
4100.901	2	12 I
4103.722	1	2
4105.139	3	3
4107.804	2	3
4112.474	3	2
4114.910	3	15 I
4115.656	3	10 II
4117.573	2	3
4118.319	3	10 II
4122.825	3	3
4126.375	2	10 I
4132.447	3	8 II
4137.956	3	1
4142.113	5	1
4142.719	5	12 I
4144.100	1	1
4150.143	1	10 IA
4151.721	2	8 IA
4156.407	1	1
4157.516	1	4
4162.474	2	5 II
4175.504	1	1
4182.101	1	1
4185.518	2	6 I
4186.821	2	5 I
4188.384	2	10 I
4194.106	3	8 I
4194.854	1	3
4209.366	3	10 I
4211.724	3	7
4217.740	1	2
4221.632	3	10 I
4224.225	2	6 II
4231.606	1	1
4237.153	1	2
4238.071	1	1
4240.053	2	1
4240.594	2	6 II
4241.259	2	6 IIA
4242.280	5	12 II
4247.674	1	6 IIA
4254.371	8	5 II
4254.690	3	15 I
4258.224	2	3
4258.326	2	6 II
4259.034	2	4
4262.810	1	10 II
4266.702	1	8 II
4271.932	1	1
4273.789	2	6 IIA
4279.328	1	12 II
4282.811	3	5 II
4285.783	1	1
4285.847	1	10 IIA
4287.005	2	6 II
4290.289	2	10 II
4293.137	2	15 I
4301.541	2	12 I
4303.63	1	1
4305.425	1	10 I
4324.598	8	25 I
4325.308	2	8 II
4343.567	10	20 I
4351.815	4	15 I
4353.457	2	6 II
4363.51	2	1
4364.502	1	6 II
4368.879	1	8 IIA
4371.694	1	1
4390.382	1	1
4395.052	1	5 II
4396.036	3	20 I
4396.190	3	15 II
4401.523	2	20 I
4403.062	8	15 II
4423.452	10	25 I
4439.515	5	15 I
4447.701	2	15 I
4449.365	1	15 II
4458.601	1	2
4467.319	3	15 I
4475.315	2	4 II
4476.370	1	1
4478.000	1	10 IIA
4479.985	2	15 II
4480.973	2	1
4484.813	1	15 II
4491.539	1	1—
4501.103	2	15 I
4505.121	3	10 I
4506.417	5	25 I
4514.064	2	8 II
4518.023	5	20 I
4521.961	3	10 II
4527.338	5	15 II
4531.308	4	20 I
4532.016	1	8 II
4536.210	1	4 II
4540.632	2	10 I
4541.558	1	2
4545.452	2	8 IIA
4546.064	4	20 I
4548.888	2	20 I
4552.066	2	12 IA
4553.060	3	15 I
4556.351	3	1
4557.973	2	1
4559.607	2	2
4565.242	3	30 I
4570.645	2	10 II
4608.492	2	20 I
4615.195	3	20 I
4624.225	1	10 II
4625.071	3	1
4632.329	3	30 I
4641.071	1	10 II
4643.175	2	6 II
4645.475	5	2
4649.885	1	12 I
4650.514	2	15 I
4661.137	1	1
4670.902	10	8 II
4684.55	1	15 I
4688.90	8	15 I
4696.53	3	15 IIA
4700.62	1	10 IIA
4703.77	1	8 IIA
4705.58	1	15 I
4707.03	1	10 II
4715.07	3	15 I
4719.72	1	8 IIA
4724.30	2	12 I
4724.84	2	20 I
4733.92	3	15 I
4734.67	3	10 I
4743.25	5	15 I
4747.07	5	20 I
4750.23	1	8 I
4750.85	2	10 I
4751.42	1	6 II
4752.59	1	8 II
4758.52	1	5 II
4764.73	20	6 II
4773.84	2	10 II
4775.06	4	25 IA
4776.23	1	8 I
4776.47	1	10 I
4780.73	2	8 II
4781.71	3	8 I
4782.22	3	12 I
4786.53	2	20 I
4803.09	1	5 II
4805.93	3	25 I
4807.66	4	15 I
4820.02	2	15 I
4820.61	2	10 I
4822.53	3	40 I
4836.66	3	25 I
4845.47	2	40 I
4847.72	3	50 I
4852.61	1	6 I
4859.46	1	15 I
4861.72	2	10 I
4863.24	2	12 I
4872.92	10	5 II
4881.52	3	8 IA
4889.57	3	20 I
4892.87	2	10 I
4896.92	3	7 IA
4898.19	1	5 II
4899.91	1	10 II
4901.67	2	12 I
4904.85	8	10 I
4913.40	2	6 IA
4915.30	3	15 I
4919.90	3	10 IA
4924.56	2	8 I
4930.56	3	6 IA
4939.13	2	12 I
4948.67	1	10 I
4958.24	1	4 IIA
4965.25	2	4 II
4970.10	1	5 II
4970.64	1	8 II
4971.66	2	5 II
4974.09	2	6 I
4987.52	1	5 II
4988.68	1	6 I
4990.65	1	6 II
4992.39	1	6 II
4994.61	1	5 II
4995.26	3	4 IIA
4998.12	1	8 I
5009.07	10	15 I
5009.44	1	4 IIA
5016.49	5	10 I
5021.42	2	10 I
5028.31	3	10 I
5036.65	3	8 I
5037.99	1	4 II
5039.74	1	4 II
5040.85	1	12 I
5042.09	1	4 II
5050.98	1	4 II
5053.27	1	5 II
5054.15	3	12 I
5055.77	1	6 II
5063.92	2	6 II
5071.73	1	6 II
5084.81	1	6 IIA
5091.76	3	6 I
5097.29	2	3 II
5099.40	3	5 II
5107.47	1	5 II
5111.59	1	5 II
5115.23	1	6 II
5122.39	2	12 I
5122.68	2	3 II
5125.00	1	6 II
5150.39	2	6 I
5169.74	3	8 IA
5174.58	3	10 II
5177.73	2	4 II
5180.88	5	10 I
5181.91	3	8 I
5183.18	1	5 II
5187.38	2	6 II
5188.64	2	5 II
5191.70	5	5 II
5194.74	3	6 I
5201.39	2	10 I
5211.92	3	12 II
5221.94	1	5 II
5223.48	3	8 II
5229.76	2	12 I
5230.13	1	5 II
5233.79	1	6 IIA
5238.49	2	6 I
5243.06	1	4 II
5244.48	3	10 I
5245.26	3	5 IIA
5245.89	3	10 II
5250.10	2	4 IIA
5261.69	2	6 I
5264.18	1	6 I
5271.87	3	12 I
5276.9	2	4 IIA
5277.49	1	8 IIA
5281.35	1	7 IIA
5290.92	1	8 I
5296.58	3	10 II
5303.31	2	8 I
5335.72	5	10 I
5336.21	5	7 I
5357.21	5	10 IA
5359.91	5	6 IIA
5397.65	5	25 I
5414.15	2	5 II
5418.71	5	10 IA
5426.43	3	10 IIA
5427.29	1	5 II
5433.37	2	4 IIIA
5438.46	2	8 IA
5445.46	3	10 IA
5449.28	1	8 II
5456.40	3	15 IA
5457.22	3	7 IIA
5458.86	5	10 IA
5460.09	5	12 IIA
5465.35	2	20 I
5473.53	3	12 I
5478.61	2	10 I
5498.19	10	10 II
5506.48	1	5 III
5527.15	1	6 III
5527.93	2	6 IIA
5529.48	1	<1
5531.53	1	<1
5535.25	1	20 II
5535.84	1	1
5537.52	1	8 II
5548.81	5	30 I
5551.40	2	12 IIA
5552.30	3	1
5556.26	5	5
5564.26	3	3
5564.99	1	15 I
5567.82	1	3
5582.70	3	4
5590.52	1	4 IIIA
5593.72	1	2
5594.97	1	6 II
5595.89	1	8 II
5597.96	1	8 IIIA
5598.96	2	12 IIA
5601.29	1	25 II
5604.39	1	8 IIA
5606.47	2	12 II
5620.38	1	8 II
5623.76	2	8 IIA
5624.84	1	1
5626.01	1	1
5633.09	1	20 IIA
5634.48	1	6 IIA
5638.18	1	12 I
5646.60	1	4 III
5650.59	1	20 II
5655.17	3	50 I
5662.72	1	1
5664.00	2	7 III
5669.97	5	15 I
5671.92	3	8 I
5675.10	1	10 IA
5676.38	2	1
5677.76	1	12 I
5688.48	1	4 IIIA
5692.98	1	12 I
5695.88	1	20 III
5697.02	2	15 I
5699.24	2	25 I
5702.34	1	8 III
5718.42	2	10 IIA
5719.09	2	20 I
5721.97	4	15 IIA
5725.85	1	10 I
5743.52	2	15 I
5804.42	1	15 I
5810.73	1	5 II
5812.93	1	15 I
5825.22	1	1
5828.00	1	<1
5830.03	1	15 IA
5839.36	1	15 I
5843.73	12	6 II
5863.86	3	1
5871.61	1	15 I
5910.13	1	15 I
5926.28	2	30 I
5927.31	2	1
5940.84	1	25 I
5942.66	1	20 I
5975.25	1	2
6005.85	1	12 I
6139.03	3	3
6162.14	1	25 IA
6269.80	2	20 IIA
6273.71	1	12 IIA
6276.45	1	10 II
6277.10	1	10 II
6295.58	3	50 I
6300.23	1	30 I
6306.63	1	15 IIA
6308.08	1	10 IIA
6310.03	5	30 I
6332.00	3	20 IA
6399.90	3	3 III
6424.47	1	15 IIA
6429.04	1	1
6434.38	5	40 IA
6439.95	2	15 IIA
6441.02	1	8 IIA
6451.38	3	<1
6456.84	2	4 IIA
6458.06	5	60 I
6467.40	1	40 IA
6649.32	10	<1
6679.84	1	8 III
6704.38	1	40 I
6778.23	5	30 IA
6780.15	8	1
6780.72	5	4 III
6785.06	3	<1
6795.46	5	1
6807.83	3	4 III
6818.20	1	20 IA
6850.77	1	1
6857.05	8	1
6867.15	4	<1
6873.86	1	1
6875.43	3	1
6901.50	5	<1
6903.11	6	1
6909.31	2	1
6933.32	1	1
6939.40	5	15 IA
6948.29	4	<1
6956.28	3	1
6957.75	5	1
6959.11	5	1
6960.69	12	2
6963.08	1	1
6981.24	1	1
6985.98	3	15 I
6999.85	3	15 I
7189.40	5	1 n?
7191.70	2	1
7235.70	15	2 n
7241.69	15	2 n
7252.72	5	2
7275.57	10	1 P?
7277.92	10	1 n
7379.64	2	<1
7397.76	3	2
7424.84	8	1 n?
7508.12	2	<1
7509.43	3	1 b
7562.47	4	1
7563.52	2	1
7670.89	5	2
7732.32	1	2
7748.35	1	1
7797.73	2	2
7842.57	5	2
7859.05	10	2
7860.54	8	2
7899.03	6	2 n?
7904.84	6	1 n?
7927.53	10	2 n?
7975.49	8	2 b
8018.94	6	1 b
8109.09	3	1
8114.53	5	1
8120.32	3	2
8171.32	5	1
8220.65	3	1
8223.69	1	2 bd?
8226.94	1	1
8234.12	10	3
8245.10	5	2
8252.52	5	1
8258.35	4	1 b
8261.03	5	2
8310.22	3	2
8352.39	3	2
8363.82	1	2
8368.55	1	1
8371.90	4	2
8503.57	3	1 b
8523.32	2	1
8560.60	3	2
8564.56	3	1
8567.36	3	1
8583.87	7	2 b
8612.62	2	2
8633.25	3	<1
8636.40	2	1
8647.59	3	2
8672.45	1	1
8756.26	1	1
8810.77	3	1
8891.14	1	1
8927.42	3	1

TABLE II. *Spectra of neodymium.*

WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion
2613.35	1		3359.35	1		4343.497	2	20 IA	4778.40	1	15 IA	5213.20	1	8 I	6082.02	1	25 IA
2623.97	1		3359.85	2		4357.789	1	5 IIIA	4779.463	2	40 I	5214.27	1	8 IA	6109.68	1	40 IA
2626.19	1		3360.36	1		4381.878	1	5 IIA	4787.40	1	12 IA	5240.58	0	4 IIIA	6148.60	1	40 IA
2650.73	1		3362.88	1		4393.352	1	6 IIA	4792.62	0	8 IA	5249.30	0	5 IA	6149.28	1	100 IIA
2653.83	1		3363.11	1		4397.320	1	6 IIA	4806.62	1	30 IA	5270.09	1	8 IIIA	6167.40	1	20 IIA
2691.47	1		3363.99	1		4401.063	1	5 IIIA	4833.50	1	8 IIA	5276.27	0	5 IIIA	6174.30	2	50 IA
2712.73	1		3364.46	1		4402.478	1	8 IA	4835.66	1	15 I	5284.11	0	3 IIIA	6223.38	1	40 III
2717.85	1		3373.093	1	8 IIA	4432.220	1	8 IA	4836.62	1	20 I	5298.88	1	6 IA	6225.25	2	30 IA
2733.93	1		3376.83	1		4444.988	2	50 rIA	4845.88	1	8 IIA	5334.33	1	10 IA	6226.50	1	50 IIA
2743.72	1		3379.72	1		4456.132	2	20 rI	4853.33	1	15 IA	5336.84	1	8 IA	6237.34	1	25 IA
2747.72	1		3386.57	1		4469.571	1	8 IIA	4854.22	1	5 IIA	5349.57	1	8 IA	6288.03	4	80 I
2754.20	1		3397.441	1	6 IIA	4477.879	1	50 RI	4855.31	2	15 I	5377.78	1	8 I	6291.48	1	6 IIA
2764.98	3		3410.38	2		4480.972	2	60 RIA	4859.58	2	15 I	5398.11	0	6 IA	6310.48	1	150 I
2765.27	1		3416.18	1		4481.898	2	30 rI	4862.22	0	3 IIIA	5523.88	1	15 IA	6348.78	1	30 IIA
2765.52	1		3416.41	1		4497.379	2	20 rIA	4863.55	0	4 IIIA	5529.07	1	10 I	6360.11	1	30 IA
2765.86	3		3422.02	1		4527.252	1	30 rI	4865.27	1	5 IIIA	5561.16	3	50 I	6372.80	1	5 III
2766.29	1		3431.88	1		4529.944	1	40 rI	4866.74	3	30 I	5576.70	0	4 III	6375.96	1	8 III
2766.78	5		3432.87	1		4542.055	2	30 rI	4869.27	1	6 II	5620.51	3	100 I	6380.40	1	20 IA
2767.28	1		3438.96	2		4548.244	1	20 rI	4875.73	1	8 IIA	5623.70	0	2 IIIA	6385.17	5	300 IA
2768.58	1		3451.84	1		4559.189	1	20 rIA	4879.79	1	10 I	5624.22	0	3 IIIA	6397.84	5	100 IA
2769.40	1		3454.76	3		4559.672	1	40 RI	4881.71	1	5 IA	5651.50	0	4 IIIA	6403.22	1	8 IIIA
2770.04	1		3458.22	1		4560.423	1	20 rI	4883.81	10	60 I	5663.28	2	6 IIA	6408.49	3	25 IA
2771.62	1		3463.60	1		4561.855	1	20 rI	4885.01	1	8 II	5669.77	1	60 IIA	6439.646	0	2 III
2772.29	1		3464.36	5		4562.346	1	8 IA	4887.33	0	4 IIIA	5675.92	3	100 I	6451.21	1	15 IIIA
2780.13	1		3465.43	8		4567.352	1	10 IA	4889.04	0	3 III	5681.16	0	15 IIIA	6455.06	0	10 IIIA
2785.79	1		3466.74	10		4586.617	2	50 RI	4891.07	3	50 I	5686.55	0	5 III	6456.22	5	40 IA
2787.90	2		3467.29	1		4594.676	1	20 rI	4893.23	2	12 I	5693.88	0	5 IIIA	6457.14	1	15 IIA
2792.05	1		3469.93	1		4603.819	1	20 I	4896.93	3	100 I	5702.49	0	3 IIIA	6581.84	1	1
2802.42	1		3474.38	1		4607.378	8	8 IV	4901.53	1	15 I	5704.33	0	3 IIIA	6588.82	0	3 IIIA
2820.41	1		3475.29	2		4607.71	0	4 IVA	4901.84	3	60 I	5710.22	0	3 III	6628.71	2	15 IA
2820.98	1		3529.059	1	4 IIIA	4609.872	2	20 rI	4907.26	1	5 II	5712.94	1	10 IIIA	6630.14	3	60 I
2824.26	1		3585.692	1	6 I	4621.940	1	80 RI	4907.78	1	6 IIA	5727.86	0	30 IIIA	6648.99	2	30 IA
2824.51	3		3593.527	1	3 III	4622.150	1	6 IVA	4910.05	1	30 IA	5729.30	2	60 I	6655.64	1	40 II
2826.75	1		3596.092	1	6 IIIA	4624.210	1	20 rI	4913.41	3	40 I	5734.20	1	20 IIIA	6664.61	3	30 IA
2827.77	1		3610.218	1	3 IIA	4626.034	1	5 IIA	4921.14	0	6 IIA	5749.14	2	40 III	6695.62	1	15 IA
2832.27	2		3658.108	1	10 IIA	4626.498	1	20 rI	4922.45	1	8 IIA	5749.63	2	30 IA	6699.22	1	20 IA
2842.07	1		3701.982	1	6 III	4627.979	1	30 rI	4924.53	8	150 rI	5750.62	0	2 IIIA	6722.72	1	20 IA
2844.82	1		3745.466	1	8 IA	4634.236	5	200 RI	4940.30	1	20 IIIA	5752.36	1	10 IIIA	6753.99	1	15 IA
2923.22	1		3773.338	1	6 I	4636.297	1	12 IIA	4944.83	5	60 I	5772.14	2	20 IA	6770.94	1	12 IIA
2953.32	1		3783.060	1	8 IIIA	4637.198	1	30 rIA	4950.29	0	6 IIIA	5776.10	2	50 I	6784.70	2	20 IA
2968.50	1		3793.64	1	4 I	4639.143	1	40 RIA	4950.67	1	6 IIIA	5784.96	2	25 I	6792.28	1	8 IIA
2968.69	1		3806.540	1	5 IA	4641.103	1	80 RI	4952.46	2	15 IIIA	5788.19	3	30 I	6822.91	2	15 IA
2971.83	1		3807.539	1	4 IA	4646.400	1	50 rI	4954.78	3	40 II	5800.07	0	20 I	6851.79	2	10 IA
3044.44	1		3812.852	1	15 IIA	4649.673	1	60 RI	4963.02	0	4 IIIA	5820.36	2	25 IIA	6904.75	1	8 IA
3061.53	1		3820.866	1	10 IA	4651.020	1	25 rIA	4963.33	0	8 II	5825.11	1	15 IIA	6923.86	5	30 IA
3075.81	1		3830.915	1	10 IA	4651.189	1	12 IA	4969.75	1	8 IIA	5826.75	2	40 IA	6985.26	5	20 I
3082.66	1		3834.404	2	15 IA	4652.390	1	30 rI	4975.50	1	10 II	5829.75	2	15 IIA	6995.27	2	10 IIA
3089.97	2		3840.775	1	5 IA	4654.726	1	50 RI	4982.89	1	8 III	5839.08	2	40 IA	7093.98	3	1
3146.12	1		3842.695	1	4 I	4664.368	1	8 IIA	4988.65	2	8 IIA	5869.57	2	40 IIA	7148.23	1	1
3146.68	1		3887.837	1	6 IIA	4664.613	1	4 IIA	4998.44	1	5 IIIA	6461.86	0	8 IIIA	7183.60	1	1
3203.36	1		3889.214	1	4 IIA	4671.100	1	30 rI	5014.51	1	8 IIA	6463.57	2	20 IIA	7189.42	1	3
3204.82	1		3913.546	1	5 I	4673.971	1	15 IA	5026.42	0	6 IIA	6481.57	3	40 IA	7192.01	1	2
3206.96	1		3935.917	1	4 I	4683.447	3	150 RI	5027.12	1	8 II	6485.69	8	100 I	7198.83	1	2
3215.77	1		3972.753	1	6 IIA	4684.039	1	40 RI	5029.42	2	8 I	6493.54	0	15 IIA	7215.32	0	1
3216.89	2		3981.689	1	4 I	4690.35	2	30 I	5040.17	1	10 II	6500.15	1	15 II	7266.22	1	1
3222.63	1		3982.269	1	4 I	4692.97	0	6 IIA	5045.03	1	5 IIIA	6501.11	1	2 IIIA	7279.36	3	1
3229.73	1		4009.377	1	15 IA	4696.440	3	30 I	5045.52	1	12 IIIA	6516.49	0	4 IIA	7311.91	2	1
3230.43	1		4047.159	1	12 IIIA	4698.30	1	8 II	5051.06	1	8 II	6535.28	1	2 IIIA	7313.70	2	1
3231.84	1		4051.623	1	4 IIA	4706.54	0	4 III	5056.85	3	15 I	5873.33	1	15 IIA	7334.56	5	2
3236.14	1		4053.519	1	4 IA	4706.955	3	40 I	5060.01	1	6 IIIA	5878.88	1	4 IIIA	7378.26	3	2
3259.38	1		4062.897	1	5 IA	4709.53	1	10 IIA	5071.84	1	8 II	5883.66	1	15 IIIA	7401.31	2	3
3279.99	1		4066.860	2	15 IA	4713.05	1	20 IIA	5073.84	0	6 IIIA	5887.89	3	50 IA	7404.78	2	2
3288.50	1		4083.916	1	5 I	4714.233	1	10 IIA	5074.49	1	10 IIA	5896.65	0	3 IIIA	7481.37	1	2
3292.88	1		4100.003	1	4 IIIA	4719.02	2	80 rII	5079.05	0	6 II	5901.59	1	8 IIIA	7547.00	1	3
3293.64	1		4109.162	1	10 IA	4726.550	1	12 I	5081.18	0	8 IIA	5914.91	1	10 IIIA	7555.63	1	1
3313.646	1	5 III	4112.742	1	4 IIIA	4731.770	2	40 I	5089.71	1	4 II	5921.20	1	40 IA	7623.93	2	1
3316.911	1	5 IIId	4122.998	1	10 IA	4734.903	1	10 I	5100.08	0	4 IIIA	5966.01	3	30 IIA	7729.21	1	1
3320.421	1	3 IV	4183.134	1	8 IIA	4749.751	2	30 I	5103.13	2	12 I	5968.30	2	15 IIA	7777.11	2	1
3321.400	2	4 III	4210.988	0	15 IA	4755.847	2	20 I	5105.32	1	10 I	5994.77	2	40 III	7827.90	1	1
3325.732	2	8 II	4256.474	1	30 rIA	4758.49	1	15 IIA	5115.72	0	10 IIIA	6000.09	3	30 IIA	7829.66	4	1
3333.058	2	6 II	4258.106	1	6 IA	4758.89	0	8 IIA	5144.92	0	5 IIIA	6006.44	0	20 IIIA	7842.77	1	1
3346.589	10	4 II	4301.215	1	6 II	4759.34	1	10 IIA	5149.55	2	10 I	6007.67	1	100 II	7858.93	3	4
3353.521	1	5 III	4305.81	1	20 IIA	4760.45	8	10 IA	5178.75	1	8 IIA	6025.54	2	25 IIA	8007.72	2	3
3354.059	1	6 II	4311.254	1	20 IA	4768.96	1	8 IIA	5198.07	1	6 I	6049.92	1	30 IA	8043.33	2	4
3354.534	1	3 IIIA	4329.917	1	5 IIA	4770.20	3	20 I	5199.73	1	6 I	6071.71	1	20 IIA	8082.18	4	1
3358.514	8	8 II	4337.231	1	6 IIA	4772.26	2	10 I	5204.43	2	10 I	6073.96	1	50 I	8164.97	2	3

lengths the class III lines become more and more important in absorption, then the class IV lines appear, and at the shortest wave-lengths many lines appear which are not observed in emission. This is exactly the behavior one would expect if the long wave-length lines correspond to transitions between the ground states and the first excited states, and the shorter wave-lengths to transitions involving progressively higher stages of excitation for the upper state; for then the excitation in ordinary sources would not be sufficient to populate the higher levels enough to

TABLE III. *Spectra of samarium.*

WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion
2503.89	0		2658.99	1		2719.14	2		2777.22	3		2880.30	5		2939.36	1	
2518.26	1		2661.05	0		2720.09	1		2777.94	1		2880.60	3		2939.52	1	
2518.60	1		2662.43	0		2720.40	0		2778.90	0		2881.64	8		2939.75	1	
2522.55	0		2665.03	1		2721.65	2		2779.38	1		2882.20	0		2939.95	3	
2522.90	0		2665.98	2		2721.94	2		2779.67	1		2882.26	0		2940.46	3	
2523.84	1		2666.77	0		2722.32	1		2780.91	1		2884.12	0		2941.08	1	
2525.99	0		2667.03	1		2722.59	1		2781.02	0		2884.39	0		2941.77	8	
2528.61	0		2667.42	0		2722.83	2		2781.14	1		2884.86	2		2942.11	1	
2529.24	0		2668.40	0		2723.06	2		2782.20	1		2885.13	1		2943.73	2	
2535.77	1		2668.77	3		2724.00	2		2782.64	1		2885.71	3		2943.88	1	
2536.08	0		2670.74	0		2724.09	1		2783.17	2		2885.96	1		2944.31	1	
2551.49	0		2671.98	1		2724.38	1		2784.04	3		2886.52	1		2944.86	3	
2563.84	1		2672.44	0		2725.62	1		2784.32	1		2888.15	1		2945.35	2	
2566.44	1		2673.03	1		2725.94	2		2784.77	1		2888.54	0		2946.23	2	
2567.98	2		2673.48	1		2727.13	10		2785.45	1		2889.92	2		2946.420	3	1 IV
2568.47	0		2674.42	2		2728.14	0		2786.12	3		2890.31	4		2947.50	0	
2568.65	0		2674.79	0		2728.36	4		2786.58	1		2891.60	2		2948.04	1	
2570.96	0		2676.97	2		2728.92	0		2787.33	1		2892.18	0		2948.80	0	
2577.06	0		2677.33	0		2729.45	1		2788.32	1		2893.01	2		2950.78	2	
2577.16	0		2678.08	0		2729.69	3		2788.45	0		2893.72	5		2951.41	0	
2586.57	0		2679.23	0		2730.08	1		2788.89	0		2894.76	2		2951.96	1	
2587.88	1		2680.51	0		2730.63	0		2790.29	0		2895.80	1		2952.27	1	
2588.13	0		2681.13	0		2731.26	1		2792.80	1		2896.47	1		2952.47	4	
2589.55	0		2681.75	0		2731.54	2		2793.02	2		2896.89	1		2952.91	1	
2592.75	0		2682.56	1		2732.38	3		2793.10	2		2898.28	1		2954.83	1	
2598.50	1		2683.28	0		2732.54	1		2793.98	1		2898.56	3		2954.96	0	
2600.44	0		2684.37	0		2732.67	1		2796.30	2		2898.79	5		2955.31	0	
2602.46	1		2685.40	2		2733.02	0		2797.47	0		2898.86	5		2955.75	0	
2603.11	1		2685.59	1		2734.10	1		2797.68	1		2899.81	5		2955.92	1	
2603.84	1		2685.85	1		2734.43	5		2798.03	1		2899.86	5		2956.22	0	
2605.60	0		2686.19	1		2735.77	3		2798.18	1		2900.25	0		2956.52	2	
2609.49	1		2686.37	0		2735.95	2		2798.50	0		2903.25	1		2958.05	1	
2610.04	1		2687.62	1		2736.65	3		2799.88	0		2905.33	2		2958.34	0	
2610.43	0		2687.75	1		2736.80	1		2801.28	1		2905.58	2		2959.82	1	
2610.80	0		2689.01	1		2737.36	2		2801.87	1		2905.83	1		2961.70	1	
2612.46	0		2691.08	1		2737.62	4		2803.21	1		2905.94	1		2962.032	3	1 IV
2614.95	1		2691.17	0		2737.92	1		2803.86	0		2906.03	1		2962.65	5	
2615.82	0		2691.55	2		2739.35	1		2804.09	0		2906.77	1		2963.34	1	
2618.16	1		2691.89	1		2739.50	0		2805.93	0		2906.99	1		2963.92	4	
2618.99	1		2692.06	0		2739.65	0		2807.52	1		2907.61	2		2964.40	2	
2619.41	0		2692.34	1		2739.79	2		2807.87	0		2909.80	1		2964.72	0	
2620.24	0		2693.14	1		2740.26	0		2808.79	0		2911.298	2	1 IV	2964.90	1	
2621.17	2		2693.76	1		2741.16	3		2809.90	1		2911.79	1		2965.13	1	
2621.93	0		2693.89	3		2741.35	0		2811.07	3		2912.564	4	1 IV	2965.90	1	
2624.43	2		2694.15	1		2742.37	2		2811.39	1		2912.81	2		2966.27	2	
2624.92	0		2694.30	1		2742.60	0		2811.83	0		2913.28	1		2970.483	2	1 IV
2625.25	1		2695.78	1		2742.98	1		2813.13	0		2914.76	8		2972.65	2	
2626.10	0		2695.93	0		2743.26	1		2814.04	0		2915.45	1		2972.92	1	
2626.44	0		2696.14	1		2744.86	5		2815.32	2		2915.70	2		2973.72	3	
2627.27	1		2696.36	0		2745.27	5		2815.65	1		2916.15	1		2974.60	2	
2627.56	0		2696.52	1		2745.68	2		2816.24	1		2916.68	3		2975.81	0	
2630.18	1		2697.27	1		2747.82	2		2817.37	1		2917.386	3	1 IV	2975.48	1	
2630.48	1		2698.85	0		2748.50	0		2818.77	1		2917.97	2		2976.92	1	
2630.09	1		2699.19	1		2749.04	1		2819.22	1		2919.29	2		2977.23	1	
2632.05	1		2699.68	1		2749.97	1		2820.86	1		2919.77	2		2978.97	3	
2632.45	1		2700.67	3		2750.41	2		2821.88	1		2920.828	3	1 IV	2979.59	1	
2633.94	1		2700.82	1		2750.57	1		2822.44	0		2921.07	1		2979.79	1	
2637.15	1		2700.97	1		2751.21	2		2823.50	0		2921.23	1		2981.47	2	
2637.38	1		2701.23	2		2751.88	1		2824.49	2		2922.82	3		2982.894	4	1 IV
2638.01	1		2703.75	1		2752.43	3		2827.43	1		2923.54	1		2983.42	2	
2638.57	0		2703.88	1		2752.64	1		2829.16	2		2924.28	1		2986.57	1	
2638.95	0		2704.06	1		2753.15	2		2832.68	2		2924.681	1	1 IV	2986.89	3	
2639.98	1		2704.34	1		2753.89	2		2833.94	1		2924.93	2		2988.14	1	
2640.87	0		2705.22	1		2754.78	1		2834.45	1		2925.45	1		2988.409	5	1 IV
2641.48	0		2705.51	1		2754.81	0		2836.46	1		2926.654	5	2 IV	2989.18	1	
2641.87	1		2705.70	2		2755.08	3		2839.02	3		2927.745	2	1 IV	2989.44	3	
2643.10	1		2707.82	3		2758.27	1		2839.34	1		2928.258	5	1 IV	2990.62	2	
2643.32	1		2708.01	0		2758.95	1		2841.64	1		2929.800	2	1 IV	2992.521	5	2 IV
2644.66	1		2708.19	1		2759.10	0		2841.78	1		2929.29	1		2992.99	3	
2644.89	1		2708.41	1		2759.26	0		2855.64	1		2931.13	0		2994.203	3	1 IV
2645.08	0		2708.63	0		2760.64	1		2860.20	0		2931.49	0		2994.67	0	
2645.45	1		2708.78	0		2761.20	0		2860.27	2		2931.65	1		2994.75	0	
2645.70	0		2709.02	2		2761.89	2		2863.68	1		2932.056	2	1 IV	2995.160	3	1 IV
2647.63	1		2709.60	1		2764.37	3		2864.22	1		2933.064	1	1 IV	2995.56	1	
2647.75	0		2709.82	0		2766.62	1		2864.58	1		2933.23	1		2995.874	1	1 IV
2647.89	0		2710.01	1		2766.80	0		2864.86	1		2933.40	0		2996.18	1	
2649.51	1		2711.24	0		2767.60	1		2865.56	1		2933.63	2		2996.32	0	
2650.66	1		2711.53	0		2768.51	0		2866.10	0		2933.92	1		2996.68	2	
2651.96	1		2712.10	4		2768.79	0		2867.19	1		2934.19	1		2997.16	1	
2652.66	1		2712.33	1		2769.47	3		2867.46	1		2934.74	1		2998.263	5	2 IV
2653.17	2		2713.31	2		2770.37	1		2868.54	2		2934.94	0		2999.54	0	
2654.40	3		2713.53	1		2770.62	0		2870.91	1		2935.413	1	V	2999.73	1	
2654.56	1		2714.21	1		2771.14	1		2871.04	1		2935.90	2		3001.14	1	
2655.60	1		2714.44	0		2771.31	0		2874.37	2		2936.21	0		3003.66	1	
2655.87	1		2714.73	1		2772.15	1		2874.56	1		2936.43	1		3004.17	1	
2656.70	1		2715.07	1		2772.41	1		2877.00	2		2937.48	2		3004.48	0	
2657.75	1		2716.64	1		2773.71	4		2878.89	1		2937.63	1		3004.914	1	1 IV
2658.46	3		2717.22	2		2774.26	1		2879.05	0		2938.06	1		3007.85	1	
2658.80	1		2718.38	0		2774.79	1		2879.41	1		2938.94	3		3009.02	1	
			2718.40	1		2775.73	1		2879.73	0		2939.17	1		3010.128	1	1 IV

TABLE III.—*Continued.*

WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion	WAVE-LENGTH (I.A.)	INTENSITY Absorp-tion	Emis-sion
3010.327	3	2 IV	3123.029	5	3 IV	3345.763	1	6 IVA	3521.513	2	15 III	3709.023	2	10 III	3972.272	2	8 IIA
3011.862	1	2 IV	3124.307	1	2 IV	3350.664	2	10 III	3522.81	2	6 IIIA	3716.780	3	8 IIIA	3974.665	8	80 RI
3012.183	3	3 IV	3126.002	1	2 IV	3351.689	1	5 IV	3523.416	3	20 III	3719.300	2	6 IIIA	3978.116	2	8 IIA
3012.53	1		3128.864	1	2 IV	3352.727	1	8 IV	3524.108	1	6 IIIA	3719.451	2	6 IIIA	3978.244	2	10 IA
3013.123	1	2 IV	3129.950	4	3 IV	3353.118	0	6 IV	3525.089	1	8 IIIA	3720.345	2	8 III	3990.025	5	50 rI
3013.514	1	3 IV	3132.288	1	1 IV	3356.52	0	4 IVA	3526.779	2	15 III	3721.028	5	50 III	3991.019	3	15 I
3014.52	1		3132.751	4	5 IV	3358.562	0	5 IV	3527.066	2	12 III	3722.026	5	40 III	3998.350	2	15 I
3015.075	3	2 IV	3134.620	8	4 IV	3360.688	1	6 IVA	3530.003	4	10 III	3722.566	0	3 IV	4001.612	1	5 IIA
3015.49	1		3135.985	2	2 IV	3360.938	2	6 IV	3535.143	2	10 IIIA	3728.162	2	20 III	4016.004	2	4 IIA
3016.075	3	2 IV	3142.037	2	3 IV	3363.167	0	3 IVA	3539.88	2	12 IIIA	3730.737	4	25 III	4016.111	2	4 IIA
3016.584	0	1 IV	3142.794	4	4 IV	3366.522	0	4 IVA	3540.525	1	5 III	3737.362	1	4 IIIA	4051.822	1	6 IIA
3017.554	2	2 IV	3144.374	1	2 IV	3376.246	0	2 IVA	3541.390	1	15 III	3737.873	0	3 IIIA	4054.512	3	25 IIA
3019.719	2	2 IV	3147.010	1	2 IVA	3376.817	4	10 III	3545.416	4	10 III	3739.42	1	6 IIIA	4062.320	4	40 IIA
3021.227	2	3 IV	3147.580	3	4 IV	3382.070	1	4 IVA	3546.818	4	8 IIIA	3739.993	3	8 IIIA	4069.751	3	8 IIA
3021.39	1		3148.817	5	5 IV	3384.857	0	3 IV	3550.216	5	40 II	3740.750	3	12 III	4079.834	3	40 IIA
3022.02	1		3149.027	0	2 IVA	3385.017	1	6 IIIA	3552.206	4	10 III	3745.465	10	80 rII	4087.505	2	10 IIA
3023.075	1	1 IV	3150.216	0	1 IV	3385.970	1	12 III	3558.873	2	12 IIA	3747.360	1	15 III	4099.959	1	15 IIA
3025.53	1		3156.784	1	3 IV	3386.609	3	15 III	3562.224	4	15 II	3747.521	1	12 III	4101.317	1	3 III
3026.04	1		3156.977	1	1 IV	3391.024	1	5 III	3563.591	2	6 III	3748.521	10	80 rII	4106.284	1	8 IIA
3026.588	8	3 IV	3157.688	1	1 IV	3394.815	1	6 IV	3564.216	5	8 III	3755.352	1	6 III	4125.233	1	20 IIA
3027.474	3	3 IV	3159.497	1	2 IVA	3395.802	2	8 III	3566.468	2	8 III	3756.411	10	100 RII	4126.117	1	10 IIA
3028.009	1	1 IV	3160.522	0	3 IV	3401.278	0	4 IVA	3569.477	3	6 III	3760.169	2	15 III	4129.994	2	8 IIA
3029.31	0		3165.392	0	3 IV	3406.547	3	8 III	3571.785	5	8 ?III	3760.785	1	6 III	4133.796	1	4 IIA
3029.90	0		3174.507	1	5 IV	3408.049	2	6 III	3573.845	3	8 III	3761.144	1	10 III	4135.505	2	20 IA
3031.06	1		3177.748	1	3 IV	3410.037	1	12 III	3575.451	4	12 III	3763.161	1	6 IIIA	4138.734	1	12 IIA
3031.59	0		3179.507	0	1 IV	3410.286	1	10 III	3586.360	5	40 III	3765.615	0	3 IVA	4142.969	1	4 IIA
3033.393	1	1 IV	3179.725	0	2 IVA	3410.396	2	5 III	3589.301	3	8 ?IIIA	3765.752	0	3 IVA	4145.236	4	30 I
3033.52	1		3181.985	1	4 IV	3412.18	0	4 IVA	3591.679	1	4 IIIA	3766.923	2	20 III	4145.594	1	6 IA
3034.62	1		3182.623	1	3 IV	3412.567	1	8 III	3592.497	1	6 IIIA	3768.311	1	15 III	4146.636	1	4 I
3035.58	0		3182.802	1	2 IVA	3413.609	0	3 IVA	3592.894	2	8 III	3768.807	3	12 IIIA	4147.974	1	6 IA
3035.95	1		3184.192	1	4 IV	3416.198	2	12 III	3594.004	2	12 III	3770.936	1	10 IIIA	4151.135	2	5 IA
3036.60	1		3184.652	1	2 IVA	3416.880	1	6 IVA	3594.508	1	4 IIIA	3772.136	2	15 IIIA	4151.213	2	8 IA
3036.682	2	2 IV	3185.195	1	2 IV	3421.304	1	8 III	3595.929	2	10 IVA	3773.331	8	80 rII	4158.854	1	5 IIA
3038.02	2		3187.566	1	3 IV	3422.067	2	12 III	3596.659	2	8 IIIA	3774.127	1	15 III	4164.790	2	8 IIA
3038.307	1	1 IV	3189.447	1	1 IV	3422.467	0	4 IVA	3597.05	3	15 IIIA	3775.459	2	15 III	4183.333	4	50 rI
3038.52	0		3190.584	2	4 IV	3422.768	2	8 III	3604.714	2	8 IIIA	3775.846	2	12 III	4205.779	3	40 I
3039.705	1	1 IV	3191.031	2	3 IV	3423.499	1	5 III	3606.324	2	8 IIIA	3781.330	1	5 IIIA	4207.250	2	6 IIA
3040.380	5	3 IV	3191.470	1	3 IV	3424.254	3	10 III	3607.644	2	12 III	3782.149	1	10 III	4218.632	4	50 IIA
3041.817	2	2 IV	3196.549	0	3 IV	3427.855	0	6 IVA	3611.055	3	10 IIIA	3782.683	2	20 III	4219.306	4	40 IA
3043.528	3	2 IV	3199.802	1	4 IV	3429.798	1	8 III	3613.910	2	4 IIIA	3783.804	2	20 III	4226.178	4	60 rI
3043.759	1	2 IV	3202.201	2	4 IV	3431.890	3	20 III	3618.531	2	6 III	3787.359	5	30 III	4226.858	3	10 IIA
3046.514	3	3 IV	3209.726	2	5 IV	3434.521	1	8 III	3622.64	1	2 IV	3791.839	2	10 III	4230.727	2	10 IA
3047.254	1	2 IV	3211.227	0	2 IVA	3436.133	1	10 III	3624.414	4	15 IVA	3793.160	1	10 III	4240.450	4	40 IA
3050.20	1		3212.224	0	3 IVA	3438.982	5	10 III	3625.225	1	3 III	3793.334	1	10 IIIA	4244.246	2	12 IA
3051.651	1	2 IV	3213.448	1	3 IV	3441.232	2	6 III	3628.501	1	4 IIIA	3802.416	2	8 III	4248.392	2	4 IIIA
3052.44	0		3214.613	1	4 IVA	3446.58	0	4 IVA	3628.620	1	4 IIIA	3803.942	5	100 RII	4256.209	2	12 IIIA
3053.24	0		3216.234	0	2 IV	3447.790	2	15 III	3628.970	2	6 III	3806.467	1	20 III	4258.168	2	6 IIIA
3053.634	10	5 IV	3216.393	1	3 IV	3448.726	0	4 IVA	3629.120	2	8 III	3809.954	3	30 III	4266.309	5	20 I
3054.313	1	2 IV	3218.260	1	2 IV	3448.868	2	12 III	3629.480	4	40 III	3810.973	3	8 III	4271.862	4	40 I
3054.43	1		3219.041	1	4 IV	3451.533	2	6 III	3636.106	2	8 III	3812.836	3	12 IIIA	4274.011	2	12 IIA
3057.229	2	2 IV	3220.646	3	4 IV	3451.892	1	10 III	3637.563	1	3 IIIA	3813.827	3	30 III	4275.641	1	8 IIIA
3060.054	1	2 IV	3225.622	1	3 IV	3454.784	3	20 III	3641.628	2	10 IIIA	3816.846	2	8 III	4277.404	1	8 IIIA
3060.656	2	2 IV	3231.031	1	6 IV	3457.570	1	8 III	3643.997	3	15 III	3818.363	4	20 III	4282.202	8	100 rI
3060.969	1	1 IV	3232.489	3	6 IV	3458.277	1	6 III	3645.789	3	15 III	3822.972	3	15 ?III	4282.833	8	80 rI
3061.141	3	4 IV	3233.791	1	4 IV	3461.225	0	3 IV	3646.975	2	6 IIIA	3824.811	1	8 III	4283.500	8	80 rI
3063.335	1	2 IV	3234.069	1	2 IV	3463.609	2	10 III	3651.423	5	15 III	3832.808	2	20 III	4283.772	0	8 I
3069.409	5	6 IV	3239.366	2	8 IV	3465.466	3	30 III	3651.516	5	3 III	3834.476	4	80 rII	4290.832	1	8 IIA
3069.78	1		3245.802	2	10 IV	3466.739	5	10 III	3651.825	3	8 IIIA	3834.945	1	8 III	4293.743	1	15 IIA
3070.199	0	2 IV	3247.370	2	6 IV	3466.796	5	20 III	3653.113	1	8 III	3846.277	2	15 II	4296.743	10	300 RI
3070.874	2	3 IV	3249.042	1	4 IV	3469.927	0	8 III	3653.462	3	4 ?III	3846.761	2	15 II	4299.141	4	40 IA
3072.637	2	3 IV	3251.138	0	3 IV	3471.291	1	10 III	3657.312	3	15 III	3853.295	4	50 r?II	4301.275	1	15 IIA
3073.915	5	5 IV	3252.648	2	8 IV	3471.550	1	4 IVA	3661.05	0	4 III	3854.556	4	? II	4305.113	2	10 IIA
3075.309	1	3 IV	3259.418	2	5 III	3472.032	2	12 III	3664.011	1	6 III	3857.339	1	8 II	4312.854	4	30 I
3077.433	1	2 IV	3264.137	2	10 III	3473.05	0	6 IVA	3665.377	2	8 III	3858.517	5	40 ?II	4314.871	4	30 IIA
3084.907	1	1 IV	3265.043	1	3 IV	3473.718	1	8 III	3666.265	1	10 III	3858.737	5	100 r?II	4317.418	1	8 IIIA
3085.017	2	3 IV	3274.430	2	4 IVA	3474.381	2	10 III	3666.972	1	6 IIIA	3860.140	2	30 II	4319.530	10	100 rI
3085.791	1	3 IV	3275.744	1	4 IV	3477.436	3	15 III	3667.932	5	40 III	3873.724	2	15 II	4324.460	5	60 rI
3086.736	1	1 IV	3277.354	2	6 III	3478.445	1	8 III	3668.170	1	4 III	3877.486	2	? II	4325.163	2	30 IIA
3086.867	1	2 IV	3280.218	1	4 IV	3478.955	2	12 III	3668.887	2	10 III	3883.987	1	8 II	4326.145	2	30 IIA
3088.184	3	5 IV	3282.728	0	3 IV	3481.523	1	10 III	3674.345	1	6 III	3886.040	1	8 II	4330.016	10	150 RI
3088.821	5	4 IV	3283.892	3	8 III	3482.828	1	12 III	3675.115	3	8 III	3891.955	1	8 II	4331.447	4	50 I
3089.625	1	3 IV	3287.693	1	3 IV	3483.485	1	12 III	3677.248	5	20 III	3901.046	2	4 II	4336.137	8	125 RI
3090.442	3	8 IV	3291.429	4	10 III	3483.014	1	10 III	3678.081	2	4 III	3904.189	1	3 III	4338.965	5	60 IA
3092.316	1	3 IV	3293.605	1	3 IV	3484.57	1	6 IIIA	3680.983	2	15 III	3908.260	2	8 II	4339.924	2	20 IIA
3094.665	1	4 IV	3294.189	0	4 IV	3484.72	1	8 III	3684.776	1	5 III	3909.946	2	12 I	4344.843	1	8 IIIA
3098.328	1	1 IV	3298.996	4	8 III	3487.3	2	5 III	3687.878	3	20 III	3917.959	1	3 IIIA	4350.815	4	50 IA
3101.927	1	3 IV	3303.606	0	4 IV	3487.612	1	8 III	3688.129	1	10 III	3923.680	1	5 II	4355.835	4	40 IA
3102.867	1	2 IV	3305.434	1	2 IV	3487.049	1	6 III	3689.606	2	12 III	3925.216	5	60 rI	4357.896	2	40 IIA
3103.695	1	1 IV	3307.346	1	3 IVA	3490.705	1	6 III	3690.084	4	50 III	3926.325	2	20 II	4362.912	10	150 RI
3109.964	1	2 IV	3308.546	1	3 IV	3491.040	2	8 III	3690.653	4	15 III	3927.420	1	3 III	4365.954	2	25 IA
3113.407	3	3 IV	3324.022	1	4 IV	3491.995	1	6 III	3694.814	1	10 III	3935.463	1	4 IIIA	4380.423	8	100 rI
3113.496	3	1 IV	3324.615	2	5 IV	3492.898	2	12 III	3695.82	1	6 IIIA	3945.252	2	8 IIA	4381.257	1	8 IIA
3114.629	1	2 IV	3326.984	0	4 IV	3494.826	2	8 III	3699.037	0	2 IV	3949.849	1	10 IA	4386.219	4	60 I
3114.782	5	5 IV	3331.074	2	6 IV	3499.9	0	1 IV	3700.432	3	8 IIIA	3951.887	6	60 rIA	4391.35	0	4 IIIA
3115.542	1	2 IV	3331.935	1	4 IV	3502.848	2	6 IIIA	3701.688	5	20 III	3957.301	1	4 IIIA	4393.170	1	20 IIA
3115.666	2	2 IV	3333.045	1	4 IV	3507.715	2	4 IIIA	3705.995	3	10 IIIA	3960.501	2	8 IIA	4393.354	2	30 IIA
3118.204	1	2 IV	3333.744	0	2 IVA	3508.690	2	12 IIIA	3707.167	4	30 III	3962.136	2	12 I	4397.341	4	60 I
3118.862	2	2 IV	3334.311	1	12 III	3510.15	1	4 IIIA	3707.629	2	12 III	3964.882	2	15 IIA	4401.174	4	60 I?
3120.254	1	2 IV	3338.864	2	8 IV	3511.41	3	8 IIIA	3707.850	4	40 III	3966.144	1	3 IIIA	4403.116	8	150 RI
3121.417	1	1 IV	3341.835	1	10 III	3518.663	1	8 IIIA	3708.77	2	10 III	3968.110	1	4 IIIA	4405.224	1	8 IIIA

TABLE III.—*Continued*

Wave-length (I.A.)	Intensity Absorption	Intensity Emission	Wave-length (I.A.)	Intensity Absorption	Intensity Emission	Wave-length (I.A.)	Intensity Absorption	Intensity Emission	Wave-length (I.A.)	Intensity Absorption	Intensity Emission	Wave-length (I.A.)	Intensity Absorption	Intensity Emission	Wave-length (I.A.)	Intensity Absorption	Intensity Emission
4411.585	5	60 rIA	4684.196	2	4 IIA	5287.66	2	1 IV	5720.19	1	60 II	6016.80	0	15 III	6588.91	10	300 I
4419.332	8	150 RIA	4688.733	8	100 I	5299.21	5	15 IA	5721.38	0	20 III	6018.15	2	15 IIA	6661.37	0	40 II
4423.383	4	20 IA	4716.097	5	80 I	5320.572	12	100 I	5726.06	0	10 IIA	6027.16	8	150 I	6671.51	10	400 I
4429.664	8	80 rI	4717.071	10	125 I	5341.265	10	50 I	5729.30	0	20 III	6027.52	8	100 IA	6678.00	3	60 IIA
4433.076	4	30 IA	4718.641	8	30 I	5348.067	5	30 IA	5732.95	5	150 II	6041.40	1	40 III	6725.88	15	200 I
4433.344	5	50 IIA	4728.433	10	100 I	5349.116	5	40 IA	5741.19	0	4 I	6042.84	0	10 III	6775.30	8	150 IA
4441.812	8	150 RI	4750.725	3	50 II	5350.592	4	20 II	5745.50	2	20 III	6045.00	8	150 I	6779.16	10	200 IA
4442.276	5	100 rI	4760.033	5	60 II	5353.701	3	5 IIA	5746.50	5	50 IIA	6045.39	0	50 II	6790.88	5	60 IA
4443.270	2	15 IA	4760.291	8	150 rI	5368.352	8	80 II	5763.91	0	12 III	6057.69	0	30 III	6802.96	12	150 IA
4445.153	5	125 rI	4770.20	4	20 I	5400.85	0	4 III	5773.77	1	30 III	6059.88	0	20 III	6827.81	5	150 IA
4445.881	0	8 IIIA	4783.125	8	200 I	5402.05	2	20 IIA	5778.33	2	50 III	6070.06	10	200 I	6853.92	8	150 IIA
4452.953	5	50 I	4785.884	7	125 I	5403.70	10	80 I	5779.24	5	100 I	6075.72	0	60 III	6860.93	15	300 I
4456.708	5	40 IA	4789.977	5	50 II	5405.23	5	125 rII	5788.38	5	80 I	6084.12	10	250 I	6864.60	3	15 IIA
4459.290	4	60 I	4841.701	5	150 I	5411.15	5	40 IIA	5790.91	5	50 IA	6088.62	0	40 III	6867.11	0	20 III
4463.897	3	15 IIA	4848.309	8	100 I	5411.39	5	50 II	5800.52	1	50 III	6091.40	1	50 III	6880.86	5	200 II
4470.475	4	4 IIA	4883.763	10	100 II	5415.78	2	4 IIA	5801.24	0	15 III	6096.55	5	80 IA	6912.79	3	100 IIA
4470.886	5	100 rI	4883.971	8	100 II	5419.47	0	8 III	5802.84	10	100 I	6099.90	10	200 IA	7002.03	2	60 IA
4471.504	3	8 IIA	4904.963	10	80 II	5421.57	8	30 I	5814.89	2	60 II	6103.95	1	15 IIA	7026.62	15	200 IA
4477.505	4	15 IA	4910.400	10	100 II	5433.82	5	20 II	5818.32	0	20 III	6117.79	10	150 IA	7051.52	0?	40 II
4480.316	5	60 IA	4918.994	10	100 I	5453.00	10	150 rII	5822.61	3	40 IA	6135.85	0	50 II	7056.55	0	40 I
4490.019	5	30 IIA	4924.044	4	30 II	5466.72	10	125 rII	5830.51	1	60 III	6159.56	10	200 I	7088.30	15	250 I
4490.758	1	10 IIA	4946.305	10	60 II	5470.29	0	6 III	5860.42	0	30 III	6174.45	8	150 I	7091.16	10	150 I
4499.108	10	150 RI	4975.949	12	60 I	5485.42	10	100 rII	5860.78	1	40 IIA	6194.39	12	200 I	7095.50	18	200 I
4503.378	12	125 rI	5010.88	8	10 I A	5493.72	10	200 rII	5866.23	1	20 IIIA	6196.83	1	25 IIA	7096.33	18	150 I
4504.321	0	6 IIA	5044.275	10	40 I	5498.21	10	150 rII	5867.79	3	80 II	6198.37	10	125 IA	7101.46	5	50 I
4511.327	8	40 I	5049.503	10	30 IA	5500.90	5	25 IIA	5868.61	7	125 I	6204.72	1	15 IIA	7104.54	18	200 I
4522.546	5	30 I	5060.916	8	30 IIA	5501.75	3	20 IIA	5871.06	8	125 I	6218.23	10	150 IA	7106.23	18	150 I
4523.182	4	30 I	5071.205	10	60 I	5511.09	10	40 I	5874.21	8	150 I	6222.55	5	30 IA	7114.50	10	80 I
4527.418	4	15 IA	5072.46	1	2 IV	5512.10	10	100 I	5875.92	5	100 IA	6226.70	1	20 II	7115.97	0	30 II
4532.444	10	40 IA	5079.851	2	3 III	5516.09	15	300 rII	5883.68	3	50 IIA	6229.07	2	20 IIA	7131.80	15	150 I
4533.799	4	50 II	5088.347	8	30 I	5517.87	0	4 IIIA	5890.61	1	15 IIIA	6242.39	12	200 IA	7141.13	15	100 I
4534.839	3	20 IA	5091.81	0	2 ?IV?	5535.51	5		5891.41	1	20 III	6273.29	10	80 IA	7172.67	5	30 I
4536.161	4	20 IA	5100.40	2	2 III	5548.95	8	125 I	5895.35	2	20 IA	6295.97	8	80 IIA	7210.95	0(b)?	100 I
4537.570	2	10 IA	5113.32	0	1 IV	5550.40	10	200 rII	5898.96	1	30 II	6345.86	0	30 III	7213.82	18	100 I
4539.840	1	5 IIA	5115.396	1	2 IV	5561.37	5	20 II	5902.60	2	40 I	6367.41	12	250 I	7225.62	1(b)?	25 II
4550.032	5	20 IA	5117.188	12	80 I	5573.42	8	60 II	5903.50	2	40 III	6371.01	8	150 I	7262.69	3	20 IIA
4556.628	8	40 IA	5122.159	10	60 I	5574.89	5	30 II	5906.05	2	40 I	6373.29	3	60 IIA	7279.25	15	100 I
4566.767	3	25 IA	5132.221	1	1 III	5575.59	3	20 I	5909.04	2	40 I	6373.50	5	100 IIA	7290.23	1	15 II
4569.579	3	20 IA	5135.86	1	1 IV	5581.83	3	20 II	5910.83	1	25 III	6380.05	0	50 II	7332.65	15	100 I
4580.188	2	12 IIA	5143.29	2	2 ?III	5588.20	5	30 II	5912.61	1	30 III	6387.79	10	100 IA	7367.9	1	4 IIA
4581.581	5	100 rI	5145.16	0	1 IV	5591.17	5	40 IA	5913.56	0	15 III	6425.90	12	250 I	7378.04	12	60 IA
4581.729	5	80 I	5145.834	5	12 I	5591.68	0	6 III	5914.91	5	40 IA	6428.94	1	80 III	7403.30	15	60 IA
4596.743	5	100 rI	5155.863	3	4 III	5621.79	10	100 I	5915.36	1	8 III	6435.34	1	60 II	7446.2	2	5 IIA
4598.285	3	8 IA	5157.260	8	30 I	5626.01	10	150 rII	5916.36	8	150 IA	6437.62	1	60 II	7470.72	1	30 II
4602.024	2	10 IA	5172.750	10	40 I	5640.25	0	10 III	5921.01	1	12 III	6471.59	15	60 II	7479.37	1	15 II
4611.248	10	50 IA	5175.443	10	80 I	5641.59	2	10 II	5923.34	0	15 III	6483.39	0	50 IA	7513.3	2	8 IIA
4616.615	1	12 IIA	5185.550	4	6 IA	5642.67	3	20 IIA	5924.23	0	25 III	6491.28	8	100 IA	7554.14	10	60 IA
4618.228	2	10 IIA	5187.131	5	15 I	5644.10	1	20 III	5924.66	0	25 III	6492.05	1	25 IA	7580.91	8	60 IA
4629.430	3	20 IA	5194.722	1	4 III	5652.84	5	40 I	5927.89	5	60 IIA	6501.00	5	100 IA	7590.43	1	25 II
4632.770	2	8 IA	5200.592	12	100 I	5656.34	0	20 III	5936.92	1	8 IIA	6509.44	15	300 IA	7686.70	4	60 IA
4640.518	2	8 IA	5201.454	2	6 III	5659.86	10	200 rII	5938.86	0	20 III	6528.02	12	250 IA	7755.4	4	80 IA
4643.59	0	1 III	5209.924	1	4 III	5678.74	2	15 IIA	5946.37	1	30 III	6532.25	15	300 I	7787.02	2	60 IA
4645.405	8	100 rI	5210.738	4	10 I	5686.98	3	20 I	5960.09	1	40 II	6533.96	15	300 I	7801.54	1	100 II
4648.078	3	40 I	5216.44	0	4 IV	5693.68	0	10 III	5969.49	0	40 III	6536.83	12	150 IA	7907.48	2	40 IA
4649.491	5	80 rI	5218.388	1	8 III	5696.73	1	40 III	5979.38	10	200 I	6544.95	12	150 IA	7940.31	1	150 I
4663.556	5	80 rI	5221.287	1	6 III	5699.61	0	6 III	5984.29	1	30 III	6551.80	15	300 I	8027.5	0	15 IIA
4664.509	2	10 IIA	5251.912	10	100 I	5706.20	10	100 rII	5989.68	8	150 IA	6558.17	3	50 IA	8065.16	1	150 I
4670.747	6	60 ?I	5265.646	5	25 I	5706.75	5	80 I	5995.09	8	100 I	6562.64	5	80 IA	8203.98	1	150 IA
4670.834	6	80 ?I	5269.96	6	10 IA	5707.22	3	25 IA	6001.94	1	40 III	6563.52	10	200 I	8267.45	1	100 IA
4678.114	3	4 I	5271.388	12	125 I	5709.73	0	6 III	6004.18	15	200 I	6566.36	8	100 I	8301.34	0?	200 IA
4681.551	5	40 II	5282.891	8	50 I	5711.45	5	60 II	6009.89	0	20 III	6580.53	8	200 IA			

produce lines observable in emission, but the lines should appear in absorption, in a manner analogous to the appearance of the higher members of the principal series of sodium in absorption, and their absence in emission. This behavior should be exhibited by cerium and neodymium also, but the data do not indicate it as clearly as those for samarium.

Spectrograms were taken for all three of these elements from 2500 to 10,000A, and for cerium the region was extended to 12,000A; but no absorption lines were observed beyond the extent of the tables.

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