ABSORPTION LINES OF THE INFRA-RED SOLAR SPECTRUM

(WITH FIVE PLATES)

BY

G. G. ABBOT AND H. B. FREEMAN

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In the decade 1890 to 1900, the bolometer was used under Langley's direction at the Astrophysical Observatory of the Smithsonian Institution to feel out the positions of lines and bands in the infra-red solar spectrum. The results were published in Volume I of the Annals of the Observatory. In the spectral region A to Ω, about 550 lines were recorded as observed in the spectrum of a 60° prism of ordinary telescope flint.

At Mount Wilson, in the summer of 1928, Dr. H. D. Babcock urged that further bolographic studies of the infra-red solar spectrum should be undertaken with apparatus of higher resolving power. Our
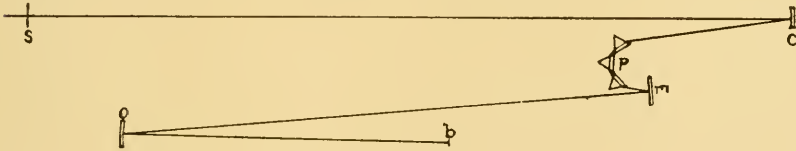

Fig. 1.

vacuum bolometer equipment, then on Mount Wilson, presents a sensitive strip of approximately 0.1 mm. width, and the combined outfit of bolometer and galvanometer was certainly not less than five times as sensitive as the most sensitive outfit employed at Washington 30 years before.

It appeared practicable to undertake a brief bolographic study of the upper infra-red solar spectrum from A to Ω in the time available. Accordingly we set up a spectroscope (fig. 1) comprising a slit 6 cm. high and (usually) 0.4 mm. wide; a collimating cylindric mirror of 543 cm. focal length; a set of three telescope flint-glass prisms, two of 60°, the third of 64° angle, and all presenting faces approximately 6 cm. square. From thence a plane silver-on-glass mirror reflected the spectrum to an image-forming spherical mirror of 230 cm. focal length. The vacuum bolometer, above mentioned, whose sensitive strip was 16 x 0.1 mm. received the rays at focus. The spectroscope

was fed by a two-mirror coelostat with silver-on-glass mirrors. The solar rays were not concentrated on the slit. Hence they represented the integrated rays of the entire solar disk.

The infra-red solar energy spectrum was recorded on moving photographic plates 8 x 24 in. in surface. The clockwork was arranged so that 4 cm. of plate corresponds to 5' of spectrum, and the plate passed the recording light-spot of the galvanometer at the rate of 2 cm. in 1 minute.

The three prisms were set according to computations so that the beam of rays of wave-length 1.05μ would pass through each one of the prisms approximately in minimum deviation. This same setting was continued unchanged in all the observations. The total deviation of the rays of this wave-length was roughly 180° and the dispersion from A to Ω was about 5° 25'. Hence we were obliged to use five 61-cm. plates to cover the entire region with overlap sufficient for identification.

Generally three curves of each of the five regions were impressed on a single photographic plate. Care was taken to arrange them vertically in close superposition, so as to facilitate comparison. Plates 1 to 5 give reproductions of some of the most satisfactory observations.

Linear scales are drawn on plates 1 to 5 parallel to the direction of motion of the recording photographic plate. They have numbers closely agreeing with those of the extensive table 3 of linear measures and wave-lengths, given below. In each group of three curves the air-mass of observation decreases as between the several curves from the bottom upward and in each curve (except in pl. 5) from left towards right. In most plates there is a very considerable increase of air-mass between the upper and lower curves. This will facilitate the discrimination, by those interested, of solar and telluric lines. Details of times of observation and air-mass and notes on the conditions are given in table 2.

A very considerable increase of detail appeared in these energy curves when compared with those taken 30 years ago with a single glass prism. In the A line, for instance, not only could the doubles be recognized, but in many of them the individual components were resolved separately in the energy curve. Some of the bands near wavelength 0.82μ showed as many as five veridical lines in the new curves where only one broad band could be distinguished in the older work.

The identification of lines was done entirely by Mr. Freeman, and in the following manner. A series of several bolographs was superposed, either on millimeter cross-section paper or on a comparator

in which a stretched wire was displaceable over a milk-glass background. Lines were considered provisionally veridical when found as deflections of similar form and similar setting in three or more bolographs. After completing this preliminary study, the positions of all deflections considered possibly veridical were measured on three bolographs with the excellent Warner and Swasey comparator described on page 64 of Volume I of the Annals. Mean values were computed of positions on three (or in some cases two) of these bolographs on which the deflections were found. When found on only two of the three they were questioned, and rejected unless supported by further evidence.

In assigning intensities, Mr. Freeman used practically the same system that was used in Volume I of the Annals. Grades a, b, c, d, and d? were employed. All lines falling within great bands like A, $\rho\sigma\tau$, ϕ, ψ, and Ω are joined in a bracket and designated as a whole with " a." Bands hardly reaching this first-class prominence are similarly bracketed and marked " b." Individual deflections, or composites of several small deflections which altogether make a depression of 5 mm. or more in bolographs are marked " c." Smaller individual deflections, whether in the bands or outside of them, are marked " d." When considerable doubt remains as to the veridical character of such a deflection, it is marked " d?." We do not guarantee that all the lines included in the table are veridical, but we believe a very large proportion of them are so. The curves are very free from accidental deflections as deep as a single half millimeter, and the repetition on several bolographs of similar configurations of intensity " d " is regarded as strong presumptive evidence of reality of corresponding solar or terrestrial absorption lines.

To determine the wave-lengths of the lines observed, the advice of Dr. Babcock was sought. From his studies of all existing laboratory determinations of infra-red line spectra, amplified by his own extensive photographic work in the upper infra-red spectrum as far as $\lambda=$ 1.1018 Angstroms, he sent a list of 112 identifications of wave-length places, given according to our bolographic work in Volume I of the Annals, as compared to more recent determinations. A curve of correction to the wave-lengths given in Volume I of the Annals has been prepared from this material. In summary it is as indicated in table 1.

The data for corrections beyond 1.18μ are so scanty and so conflicting that there seemed no justification for applying any corrections in that region.

TABLE 1.—*Corrections to Wave-Lengths of Annals, Volume I*

(*Corrections are stated in Angstroms, wave-lengths in microns.*)

Wave-lengths...	0.76 to 0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91
Corrections.....	0	+5	+5	+5	+3	+2	0	—2

Wave-lengths...	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00
Corrections.....	—2	—1	0	+2	+2	+1	0	—3	—5

Wave-lengths...	1.01	1.02 to 1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13
Corrections.....	—8	—10	—9	—7	—6	—5	—4	—3	—1

Wave-lengths...	1.14 to end
Corrections.....	0

In further determination of wave-lengths, Mr. Freeman identified 81 deflections as corresponding each to each in the old and the new bolometric work. These deflections covered fairly uniformly the range from 0.76μ to 1.80μ. Having taken out from the tables of Volume I of the Annals the corresponding wave-lengths, he then applied to these values the corrections fixed by table 1. He then plotted on a sufficiently large scale the observed linear places of these 81 deflections as ordinates, and the corrected wave-lengths as abscissae. The curves thus defined could easily be read off to a single Angstrom. From them were read all the wave-lengths given in table 3, which contains over 1200 lines.

TABLE 2.—*Circumstances of Observation*

Date 1928	Curve	Time		Air-mass		Notes
		Start	Finish	Start	Finish	
Sept. 4.........	1	9:39	10:09	1.31	1.23	
	2	10:17	10:47	1.21	1.16	
	3	10:52	11:22	1.15	1.12	
Sept. 4.........	1	6:28	6:58	4.85	3.23	
	2	7:59	8:29	1.97	1.69	
	3	8:51	9:21	1.54	1.38	
Sept. 5.........	1	6:34	7:04	4.49	3.05	Slight earthquake
	2	9:11	9:41	1.43	1.31	
	3	9:50	10:20	1.28	1.20	
Sept. 1.........	1	6:29	6:59	4.70	3.15	
	2	9:19	9:49	1.36	1.27	
	3	9:58	10:28	1.24	1.17	
Sept. 1.........	3	3:34	3:54	1.82	2.18	Ends off plate
	2	2:58	3:28	1.54	1.76	
	1	1:13	1:43	1.17	1.23	

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum*

Linear measures	Intensity			Wave-length	Linear measures	Intensity		Wave-length
—34.130	d	⎫	⎫	7582	—25.233	d		7727
34.035	d?			7583	.122	d?		7728
33.103	d?			7598	25.019	d		7730
32.858	d	⎬b		7602	24.831	d	⎫	7733
.767	d			7604	.418	d		7740
.682	d			7606	.322	d		7741
32.575	d?			7608	.233	d		7743
31.911	d	⎭		7618	.153	d	⎬c	7744
.306	d	⎫		7628	24.036	d		7746
31.191	d			7630	23.801	d		7750
30.819	d			7636	.696	d		7752
.747	d			7638	.573	d		7754
.516	d			7641	.461	d?	⎭	7755
.451	d			7642	.176	d?		7760
.264	d			7645	23.079	d		7762
.190	d			7646	22.964	d	⎫	7764
30.119	d?			7647	.690	d		7769
29.895	d			7651	.621	d		7770
.827	d?			7652	.272	d		7776
.576	d		A	7656	.178	d	⎬c	7778
.499	d			7658	22.046	d		7780
.266	d	⎬b	⎬a	7661	21.906	d		7782
29.185	d			7662	.807	d		7784
28.921	d			7665	.696	d		7786
.846	d			7668	.472	d	⎭	7790
.581	d			7672	.343	d		7792
.508	d			7674	.240	d		7794
.415	d?			7675	21.095	d?		7796
28.069	d			7680	20.871	d		7800
27.847	d			7684	.687	d		7803
.701	d			7686	.521	d		7806
.377	d			7691	.318	d?		7809
.281	d			7692	20.114	d		7812
27.173	d			7695	19.935	d		7816
26.898	d	⎭	⎭	7698	.826	d		7817
.769	d			7701	.756	d		7818
.664	d			7703	.650	d		7820
.545	d			7705	.547	d		7822
.431	d			7707	.226	d	⎫	7827
.242	d			7710	19.111	d		7829
.146	d			7711	18.951	d		7832
26.059	d			7712	.837	d	⎬c	7834
25.929	d			7714	.755	d		7835
.696	d			7718	18.080	d		7846
.477	d			7722	17.949	d	⎭	7849
.361	d			7725	.830	d		7850

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity	Wave-length	Linear measures	Intensity	Wave-length
—17.726	d	7852	—5.692	d?	8069
16.273	d?	7878	5.570	d	8071
15.621	d	7889	4.896	d	8084
.322	d	7894	.784	d	8086
15.136	d	7898	.635	d	8088
14.932	d	7901	.500	d?	8091
.823	d	7903	.400	d	8093
.644	d	7906	.286	d	8095
.470	d	7909	4.153	d	8097
14.207	d	7914	3.747	d	8106
13.910	d	7919	.645	d	8108
.625	d	7924	.543	d	8109
.509	d?	7926	.384	d	8112
.406	d?	7928	.296	d	8114
.196	d	7932	3.105	d?	8118
13.050	d	7934	2.967	d	8120
12.861	d	7937	.658	d	8126
.764	d	7939	.537	d	8129
.676	d	7941	.378	d	8132
.450	d	7945	2.255	d	8134
.275	d	7948	1.839	d	8142
12.055	d ⎫	7952	.536	d ⎫	8148
11.844	d ⎟	7956	.338	d ⎬ c	8152
.720	d? ⎟	7958	.238	d ⎟	8154
.604	d ⎬ c	7960	.142	d ⎭ ⎬ b	8156
.324	d ⎟	7966	1.062	d	8157
.208	d ⎟	7968	0.812	d	8162
11.004	d ⎭	7972	.739	d?	8164
10.619	d	7979	0.000	c	8178
9.866	d ⎫	7992	.123	d	8181
.765	d ⎟	7994	.469	d	8188
.688	d ⎬ c	7996	.601	d	8190
.389	d ⎭	8001	0.775	d	8193
.283	d	8003	+1.037	d	8199
9.102	d	8006	.349	d ⎭	8206
8.998	d	8008	.751	d	8214
8.249	d	8022	1.854	d ⎫	8216
7.982	d?	8027	2.220	d?	8224
.818	d	8029	.296	d	8225
.530	d ⎫	8035	.392	d	8228
.311	d ⎟	8038	.468	d? ⎬ b	8229
7.011	d ⎟	8044	.700	d	8233
6.927	d ⎬ c	8045	2.800	d	8235
.769	d ⎟	8048	3.028	d	8240
.647	d ⎟	8051	.243	d	8244
6.541	d ⎭	8053	.336	d	8246
5.955	d	8063	.463	d ⎭	8249
.856	d	8065	.569	d	8251

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity	Wave-length	Linear measures	Intensity	Wave-length
+3.612	d	8252	+12.086	d	8430
.691	d ⎫	8253	12.518	d	8440
.820	d ⎪	8256	13.006	d	8450
3.927	d ⎬ c	8258	.128	d?	8453
4.036	d ⎭	8260	.243	d	8455
.706	d ⎫	8274	.675	d	8465
.794	d ⎪	8275	13.948	d	8470
4.892	d ⎪	8277	14.416	d	8480
5.108	d ⎪	8282	14.599	d	8484
.191	d ⎪	8283	15.042	d ⎫	8494
.421	d ⎪	8288	.132	d ⎪	8496
.482	d ⎪	8289	.231	d ⎬ c	8498
.566	d? ⎪	8291	.333	d ⎪	8500
5.829	d ⎪	8297	.694	d ⎭	8508
6.124	d ⎪	8303	15.937	d	8513
.233	d ⎬ c	8305	16.046	d	8516
.304	d? ⎪	8307	.132	d ⎫	8517
.476	d ⎪	8310	.369	d ⎪	8523
.505	d ⎪	8311	16.468	d ⎬ b	8525
.668	d ⎪	8314	17.033	d ⎪	8537
6.996	d ⎪	8321	.218	d ⎭	8541
7.163	d ⎪	8325	17.947	d	8558
.431	d ⎪	8330	18.144	d	8562
.549	d ⎪	8333	.260	d?	8565
.666	d ⎪	8335	.456	d	8569
7.755	d ⎭	8337	.556	d	8572
8.003	d	8342	.761	d	8576
.209	d	8346	18.864	d	8579
.490	d	8352	19.044	d?	8583
.743	d	8358	.138	d	8585
8.888	d	8361	.242	d	8587
9.204	d	8368	19.722	d	8590
.317	d	8370	20.251	d	8611
.394	d?	8372	.398	d	8614
.467	d	8373	20.610	d	8620
.575	d	8376	21.060	d	8630
9.731	d	8379	.201	d	8633
10.023	d	8385	.488	d ⎫	8640
.260	d	8391	.591	d ⎪	8642
.499	d	8396	21.692	d ⎪	8645
.697	d	8400	22.256	d? ⎬ b	8658
10.814	d	8403	.381	d ⎪	8662
11.043	d	8407	.464	d ⎪	8663
.288	d	8413	22.625	d ⎭	8667
.590	d	8420	23.056	d?	8677
11.966	d	8428	.254	d	8682

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity	Wave-length	Linear measures	Intensity			Wave-length
+23.472	d	8687	+32.148	d			8895
.562	d	8689	.226	d			8897
.684	d?	8692	.348	d?			8900
23.783	d	8694	.526	d?			8904
24.568	d?	8713	.733	d	⎫	⎫	8909
25.223	d	8728	32.961	d			8915
.392	d	8732	33.101	d			8918
.510	d	8735	.419	d			8926
.596	d?	8737	33.860	d			8937
.682	d	8739	34.014	d			8941
25.823	d	8742	.222	d?			8946
26.181	d?	8750	.414	d			8951
.288	d	8753	.746	d			8959
.460	d	8757	34.891	d	⎬b		8962
.705	d	8763	35.090	c			8967
.802	d	8766	.448	d	⎫		8976
26.931	d?	8768	35.791	d	⎬c		8984
27.052	d	8772	36.049	d	⎭		8990
.143	d	8774	.553	d			9004
.261	d	8777	.775	d			9010
.494	d	8782	36.895	d			9014
.689	d	8787	37.060	d			9018
27.996	d	8794	.680	d	⎭		9036
28.105	d	8797	37.819	d			9039
.223	d ⎫	8800	38.094	d			9047
.332	d ⎪	8803	.180	d?	⎫		9049
.385	d ⎬c	8804	.562	d			9060
.687	d ⎪	8811	.892	d			9069
.783	d ⎭	8813	38.974	d?			9071
.879	d	8816	39.582	d			9087
28.973	d	8818	.783	d	⎬b		9092
29.247	d?	8824	.878	d			9095
.402	d	8829	39.892	d			9096
.524	d	8832	40.040	d?			9100
.720	d	8837	.192	d		ρ	9104
.823	d	8839	.273	d	⎭	σ	9106
29.903	d	8841	40.603	d	⎫	τ	9115
30.036	d	8844	41.062	d			9127
.166	d?	8847	.120	d	⎬c		9129
.395	d ⎫	8852	41.423	d	⎭		9137
.540	d ⎪	8856	42.046	d			9154
.667	d ⎪	8859	.165	d	⎬c ⎬b	⎬a	9157
.843	d ⎬c	8864	.255	d			9160
30.941	d ⎪	8866	.800	d	⎫		9175
31.128	d ⎪	8870	42.985	d			9179
.247	d ⎭	8873	43.047	d	⎬c		9181
31.881	d	8880	.431	d			9192
32.064	d?	8893	.513	d? ⎭	⎭		9194

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity	Wave-length	Linear measures	Intensity	Wave-length
+43.711	d	9200	+55.674	d	9548
43.884	d	9204	56.010	c	9558
44.101	d	9210	.369	c >b	9568
.278	d	9215	56.738	d	9580
.347	d? >c	9217	57.254	d	9596
.525	d	9222	57.503	d }b	9604
.623	d	9225	58.073	d	9621
.776	d	9229	.245	d	9626
44.977	d	9234	.352	d	9620
45.101	d	9238	.534	d	9634
.235	d >b	9241	58.667	d	9639
.310	d c	9244	59.058	c	9651
.429	d	9247	.472	d	9663
.540	d?	9250	.568	d	9666
.729	d	9255	59.642	d	9668
.854	d	9258	60.482	d	9694
45.949	d?	9261	.773	d	9704
46.221	d	9269	60.975	d?	9710
.337	d a	9272	61.069	d	9713
.836	d	9286	.544	d	9727
46.907	d	9288	61.931	d	9739
47.101	d	9294	62.229	d	9749
.212	d	9296	.532	d	9758
.533	d	9305	.634	d	9761
47.637	d	9308	62.745	d >b	9765
48.205	d	9324	63.103	d	9777
.295	d	9327	.666	d	9795
.509	d >b	9333	63.956	d >c	9804
48.817	d	9342	64.252	d	9814
49.124	d	9351	.724	d	9829
49.648	d }b	9366	.898	d	9834
50.022	d	9376	64.985	d	9837
51.122	d	9409	65.224	d	9845
.204	d	9412	.342	d	9848
.328	d	9415	.464	d	9853
.421	d	9418	.561	d	9856
51.737	d	9427	65.693	d	9860
52.107	c	9439	66.141	d	9874
52.523	c	9451	.285	d	9870
53.039	c	9467	.421	d	9883
.487	d	9480	.617	d?	9890
53.963	d	9495	66.923	d	9900
54.060	d	9498	67.250	d	9910
.174	d? >c	9502	.486	d	9917
54.278	d a	9506	.675	d?	9924
55.098	b	9529	67.772	d	9927

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity	Wave-length	Linear measures	Intensity	Wave-length
+68.099	d	9937	+74.504	d	10150
.248	d	9942	.626	d	10154
.643	d	9954	.750	d	10159
.751	d	9958	74.912	d	10164
.870	d	9962	75.211	d	10175
68.997	d	9966	.341	d?	10179
69.098	d	9969	.526	d	10186
.235	d	9973	.708	d	10192
.375	d	9978	75.830	d	10194
.517	d	9983	76.001	d?	10202
.615	d	9986	.108	d	10206
.772	d	9991	.329	d	10214
.863	d	9994	.519	d	10221
69.972	d?	9997	.631	d	10224
70.060	d	10000	76.765	d	10229
.179	d?	10004	77.033	d	10239
.401	d?	10010	.227	d	10245
.509	d	10014	.333	d	10249
.634	d	10018	.470	d	10254
.796	d	10024	.732	d	10263
70.944	d	10028	77.855	d	10268
71.061	d	10032	78.019	d	10274
.452	d ⎤	10044	.150	d	10278
.562	d ⎟	10048	.289	d	10283
.676	d ⎬b	10053	.368	d?	10286
.780	d ⎟	10056	.517	d	10292
.878	d ⎦	10060	.649.	d	10296
71.983	d	10063	.757	d?	10300
72.088	d	10067	.827	d?	10302
.220	d	10072	78.961	d	10308
.313	d	10075	79.088	d	10312
.389	d?	10077	.217	d?	10316
.494	d?	10081	.346	d	10321
.603	d	10084	.534	d	10327
.719	d	10088	.727	d	10334
72.821	d?	10092	.842	d	10338
73.023	d	10099	79.998	d?	10344
.139	d	10103	80.219	d?	10352
.238	d	10106	.320	d?	10356
.317	d?	10109	.521	d	10363
.401	d?	10112	.619	d	10367
.514	d	10116	.721	d?	10370
.691	d	10122	.833	d?	10374
73.990	d	10132	80.988	d	10379
74.208	d	10140	81.105	d	10384
.323	d	10144	.220	d	10388

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity	Wave-length	Linear measures	Intensity	Wave-length
+81.324	d	10392	+89.892	d?	10714
.450	d	10396	89.995	d	10719
.569	d	10400	90.139	d	10724
81.680	d?	10405	.336	d	10732
82.016	d	10417	.441	d	10736
.120	d?	10421	.533	d	10740
.343	d	10428	90.753	d	10749
.444	d	10432	91.091	d?	10762
.560	d	10437	.249	d	10768
.671	d?	10441	.344	d	10772
82.933	d	10450	.467	d	10777
83.024	d?	10453	.566	d?	10781
.124	d	10457	.667	d	10785
.246	d	10462	.776	d	10789
.396	d	10467	91.953	d?	10796
.731	d	10479	92.269	d	10808
83.846	d	10484	.472	d	10816
84.002	d	10490	.556	d	10820
.122	d?	10494	.654	d	10823
.229	d	10498	.782	d	10828
.547	d	10510	.866	d?	10832
.788	d	10518	92.980	d	10836
84.957	d	10525	93.046	d?	10839
85.279	d	10537	.232	d	10845
.592	d	10547	.393	d	10852
.787	d	10556	.487	d?	10855
85.909	d	10561	.731	d ⎫	10866
86.356	d	10578	93.962	d ⎬c	10874
.551	d	10585	94.050	d ⎭	10878
.772	d	10594	.469	d	10894
86.959	d	10601	.554	d?	10808
87.134	d	10607	.679	d	10902
.233	d	10611	94.777	d ⎫ ⎫	10906
.472	d	10621	95.373	d	10930
.582	d	10623	.506	d ⎬c	10936
87.851	d	10636	.625	d	10941
88.047	d	10643	95.860	d ⎭	10950
.233	d	10650	96.124	d	10960
.557	d	10662	.234	d	10964
88.832	d ⎫	10673	.353	d	10969
89.009	d	10680	96.782	d	10986
.130	d ⎬c	10684	97.003	d	10996
.245	d	10688	.119	d	11000
.359	d	10694	.272	d	11006
.453	d ⎭	10697	.383	d	11011
.721	d?	10708	.485	d	11015

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity		Wave-length	Linear measures	Intensity		Wave-length
+97.673	d		11023	+112.005	d		11634
97.898	d		11032	.187	d		11642
98.211	d	} b	11045	.292	d		11646
.293	d		11048	112.888	d } b		11670
.400	d		11052	113.051	d		11678
.509	d?		11057	.152	d		11682
98.737	d		11066	.466	d		11696
99.101	d		11081	.614	d		11702
.435	d		11094	113.948	d } b		11716
.767	d		11106	114.119	d		11723
99.896	d		11113	.823	d		11754
100.387	d		11133	114.916	c		11758
.473	d		11137	115.428	d		11780
100.900	d } c		11155	115.821	c } b		11797
101.102	d		11165	116.084	d		11808
101.704	c		11190	.397	d		11822
102.378	d } c	φ	11217	116.914	d		11845
.447	d		11220	117.034	d } b		11850
.862	d	} a	11238	.140	d		11855
102.960	d } c		11242	117.726	d		11881
103.224	d		11254	118.034	d		11895
.761	d		11278	.154	d		11900
.832	d } c		11281	.322	d		11908
103.934	d		11285	.448	d		11914
105.179	b		11340	.600	d		11921
105.993	d		11376	.720	d		11927
106.242	d		11388	118.828	d?		11931
.595	d		11404	119.133	d		11945
.684	d } c		11407	.211	d } c		11949
106.790	d		11412	.334	d?		11954
107.588	d } b		11448	.440	d		11959
107.855	d		11460	119.738	d?		11972
108.607	d		11491	120.059	d } c		11988
.723	d } c		11496	.232	d		11996
108.808	d		11499	120.424	d		12000
109.102	d		11511	121.127	d		12038
.389	c		11524	.200	d		12042
109.702	d		11537	.303	d		12046
110.141	d		11555	.427	d		12052
.237	d		11559	.821	d		12071
.572	d		11574	121.914	d		12075
110.912	d		11588	122.022	d		12080
111.116	d		11596	.134	d		12085
.587	d		11616	.248	d		12091
111.669	d?		11620	.406	d?		12098

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity	Wave-length	Linear measures	Intensity		Wave-length
+122.514	d	12104	+128.914	d		12416
.612	d	12108	129.009	d		12422
122.759	d?	12115	.219	d		12432
123.132	d	12133	.319	d		12437
.277	d	12140	.437	d		12443
.480	d	12150	.564	d ⎫		12450
.594	d	12156	129.903	d? ⎪		12468
.720	d?	12162	130.009	d ⎪		12473
.842	d	12168	.112	d ⎪		12478
123.957	d	12173	.248	d ⎪		12485
124.044	d?	12177	.338	d ⎪		12489
.177	d?	12183	.545	d ⎪		12501
.438	d	12196	130.767	d ⎪		12512
124.918	d	12219	131.216	d ⎪		12536
125.023	d	12224	.409	d ⎪		12546
.197	d	12232	.526	d ⎪		12552
.311	d?	12236	.620	d ⎪		12556
.396	d	12242	.711	d ⎪		12562
.495	d	12247	.838	d ⎪		12568
.627	d	12254	131.927	d ⎬ a		12572
.707	d	12257	132.006	d ⎪		12577
125.859	d?	12265	.193	d ⎪		12586
126.113	d	12277	.311	d ⎪		12593
.294	d	12286	.367	d ⎪		12596
.411	d	12294	.473	d ⎪		12601
.579	d	12300	.600	d ⎪		12608
.700	d	12306	.698	d ⎪		12613
.799	d	12310	132.799	d ⎪		12618
126.941	d	12317	133.551	b ⎪		12658
127.047	d	12322	134.119	d ⎪		12688
.173	d?	12329	.304	d ⎪		12698
.303	d	12335	134.469	d ⎪		12707
.406	d	12340	135.049	d ⎭		12739
.536	d	12347	.201	d		12748
.644	d	12352	.311	d		12753
.734	d	12356	.401	d		12759
.839	d	12362	.507	d		12764
127.914	d	12366	.629	d ⎫		12770
128.025	d	12372	135.961	d ⎪		12788
.111	d	12376	136.071	d ⎪		12794
.222	d	12381	.186	d ⎬ c		12799
.309	d	12386	.619	d ⎪		12822
.415	d	12391	.807	d? ⎪		12833
.546	d	12398	136.937	d? ⎭		12839
.667	d	12404	137.031	d		12845
.783	d	12409	.150	d		12851

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

Linear measures	Intensity	Wave-length	Linear measures	Intensity	Wave-length
+137.264	d	12858	+143.603	d	13198
.411	d	12866	.727	d	13205
.493	d	12870	.834	d	13210
.578	d?	12874	143.940	d }c	13217
137.878	d	12891	144.013	d	13221
138.016	d	12898	.114	d	13226
.111	d	12903	.867	d	13267
.231	d	12909	144.959	d	13272
.301	d?	12913	145.434	d }b	13299
.427	d	12920	.508	d	13302
.806	d	12940	.732	d?	13314
138.930	d	12945	145.820	d	13319
139.048	d	12953	146.484	d	13355
.212	d	12962	146.565	d	13360
.324	d	12968	147.020	c	13385
.489	d	12976	.199	c	13396
.599	d	12983	147.738	c	13425
.735	d	12990	148.417	c	13464
.835	d	12995	.905	d?	13491
139.942	d	13001	148.991	d	13495
140.038	d	13006	149.095	d	13501
.114	d	13010	.350	d	13516
.210	d }c	13015	.446	d	13522
.313	d	13020	.549	d? }c	13527
.424	d	13026	.651	d	13532
.625	d	13037	149.744	d	13538
.719	d	13042	150.069	d	13555
.834	d	13048	.144	d	13560
.926	d	13053	.461	d	13578
140.997	d?	13057	.598	d }c	13586
141.086	d	13061	.793	d	13597
.308	d	13074	150.910	d	13604
.412	d }c	13080	151.259	d?	13623
.520	d	13085	.358	d }c	13628
.617	d	13090	.442	d	13634
141.877	d	13104	.815	d	13654
142.120	d	13118	151.920	d	13660
.236	d	13124	152.024	d? }c	13667
.339	d }c	13129	.284	d?	13681
.449	d	13136	.393	d	13687
.564	d	13142	.545	d?	13696
.708	d	13150	152.895	d?	13716
.844	d	13158	153.024	d }c	13724
142.962	d	13163	.163	d	13732
143.070	d }c	13170	.273	d?	13738
.216	d	13178	.467	d	13749
.331	d	13183	.866	d	13772
.446	d	13190	153.956	d	13777

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

| Linear measures	Intensity			Wave-length	Linear measures	Intensity		Wave-length
+154.208	d?			13781	+169.987	d		14708
.296	d			13796	170.791	d	} c	14756
.617	d			13815	170.883	d		14760
.724	d	} b	ψ	13821	171.330	c		14788
154.898	d		a	13833	.618	d		14804
155.010	d			13838	171.996	d		14826
.113	d			13843	172.090	d	} b	14832
.222	d			13850	.501	c		14855
.408	d			13860	172.604	d		14862
.507	d			13866	173.270	c		14901
155.936	d	} b		13890	.369	d		14907
156.826	d			13942	173.918	d	} c	14938
157.693	b			13994	174.011	d		14944
158.425	c			14036	.311	d		14962
.759	d	} c		14057	.436	d		14969
158.859	d			14060	174.805	d?		14991
159.280	c			14086	175.205	d	} b	15014
.587	d?			14103	.332	d		15021
159.691	d			14109	175.987	d		15060
160.140	b			14135	176.097	c		15070
.632	d	} b		14164	.589	d		15100
160.969	c			14184	.842	d		15112
161.049	d?			14188	176.967	d		15120
.379	d?			14206	177.361	d		15144
.534	d?			14216	.467	d		15150
161.675	c			14225	.677	d		15162
162.033	d			14245	177.799	d		15169
.104	d			14250	178.131	d?		15189
162.476	b			14271	.269	d		15198
163.155	b			14312	.498	d		15211
163.520	d			14333	.597	d		15217
164.095	c			14366	.715	d		15224
.433	d			14385	.775	d		15228
.515	d?			14390	.883	d		15234
.755	d			14404	178.980	d		15240
164.973	d?			14416	179.115	d		15248
165.479	b			14447	.201	d		15253
166.341	b			14495	.314	d?		15260
167.125	c			14542	.424	d?		15267
167.435	d			14560	.588	d		15276
168.031	c			14594	179.866	,d		15293
.119	d			14599	180.145	d?		15310
.495	c			14621	.269	d		15317
168.933	d			14646	.389	d?		15324
169.060	b			14655	.766	d?		15347
.765	b			14696	180.902	d		15356

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

| Linear measures	Intensity	Wave-length	Linear measures	Intensity	Wave-length
+181.173	d	15371	+193.742	d	16122
.615	d	15397	193.897	d	16132
.690	d?	15402	194.049	d	16141
.824	d	15410	.245	d	16154
181.930	d	15416	.431	d	16165
182.058	d	15424	.507	d	16170
.266	d	15436	.682	d?	16180
.481	d	15447	.854	d	16190
182.959	d	15478	194.981	d	16198
183.182	d	15491	195.111	d	16206
.297	d	15499	.398	d	16223
.478	d	15509	.557	d	16232
.782	d?	15527	.789	d	16246
183.881	d	15533	195.958	d?	16256
184.429	d	15566	196.103	d?	16265
184.707	d	15583	.207	d	16272
185.016	d	15601	196.697	d	16301
.644	d	15639	197.052	d	16322
185.745	d	15644	.234	d?	16333
186.197	d ⎫	15671	.503	d	16350
.353	d	15680	.640	d	16358
.493	d	15689	.770	d	16362
186.705	d ⎬b	15702	.900	d?	16373
187.001	d	15719	197.994	d	16379
.365	c	15740	198.157	d?	16390
187.759	d ⎭	15764	.312	d	16399
188.458	d	15806	.449	d?	16407
.661	d	15818	.825	d?	16430
188.908	d	15833	198.964	d	16438
189.338	c	15859	199.344	d?	16462
190.081	d	15904	.544	d	16473
.479	c	15927	.660	d	16481
190.754	d	15944	199.923	d?	16497
191.205	d ⎫	15971	200.085	d	16507
.313	d	15977	.235	d	16516
.551	d ⎬c	15991	.365	d	16524
.694	d	16000	.521	d	16534
191.889	d ⎭	16012	.678	d	16543
192.065	d ⎫	16022	200.950	d	16560
.297	d	16037	201.054	d?	16566
.563	d	16052	.282	d	16580
192.713	d ⎬c	16062	.695	d ⎫c	16605
193.051	d	16082	201.778	d ⎭	16610
.148	d?	16088	202.134	d	16632
.278	d ⎭	16095	.244	d	16651
.501	d?	16108	202.775	d	16672

TABLE 3.—*Lines and Bands in the Infra-Red Solar Spectrum.*—Continued

| Linear measures	Intensity		Wave-length	Linear measures	Intensity		Wave-length
+203.065	d		16689	+214.210	d		17380
.225	d		16699	214.591	c		17404
203.421	d		16711	215.326	c		17449
204.042	d		16748	215.855	d?		17482
.365	d		16768	216.083	d		17495
.417	d?		16772	.207	d	}c	17504
.550	d?		16780	.322	d?		17510
204.851	d		16798	.754	d		17537
205.087	d		16812	.835	d		17542
.443	d		16834	216.959	d		17550
.517	d		16839	217.123	d		17560
.678	d		16848	217.662	c		17593
.789	d		16858	218.336	c		17634
205.982	d		16865	218.958	d		17673
206.140	d		16877	219.168	d		17686
206.630	d		16907	.288	d		17692
207.242	d		16944	.455	d		17704
.320	d		16950	219.697	c		17718
.630	d		16969	220.119	d		17744
207.863	d		16984	.724	c		17782
208.031	d?		16994	.857	d?	}b	17790
.245	d		17006	220.988	d		17797
.492	d		17022	221.105	d		17805
208.960	d		17051	.743	d		17843
209.367	d		17077	221.933	d	}c	17855
.490	d		17084	222.043	d		17862
209.758	d?		17102	222.538	d		17892
210.031	d		17119	223.297	d	}c	17937
.544	d		17150	223.529	d		17952
.846	d		17168	224.172	c		17992
210.965	d	Ω	17176	.692	d		18024
211.706	d		17223	224.994	d	}c	18042
211.822	d	}a	17229	225.155	d		18052
212.284	c		17258	.742	d		18088
.889	d		17299	225.917	d		18100
212.981	d	}c	17304	226.318	d		18124
213.537	d		17338	.469	d		18132
.668	d		17347	226.816	d		18154
.765	d	}c	17353	227.152	d		18174
213.910	d?		17362	227.486	d		18194

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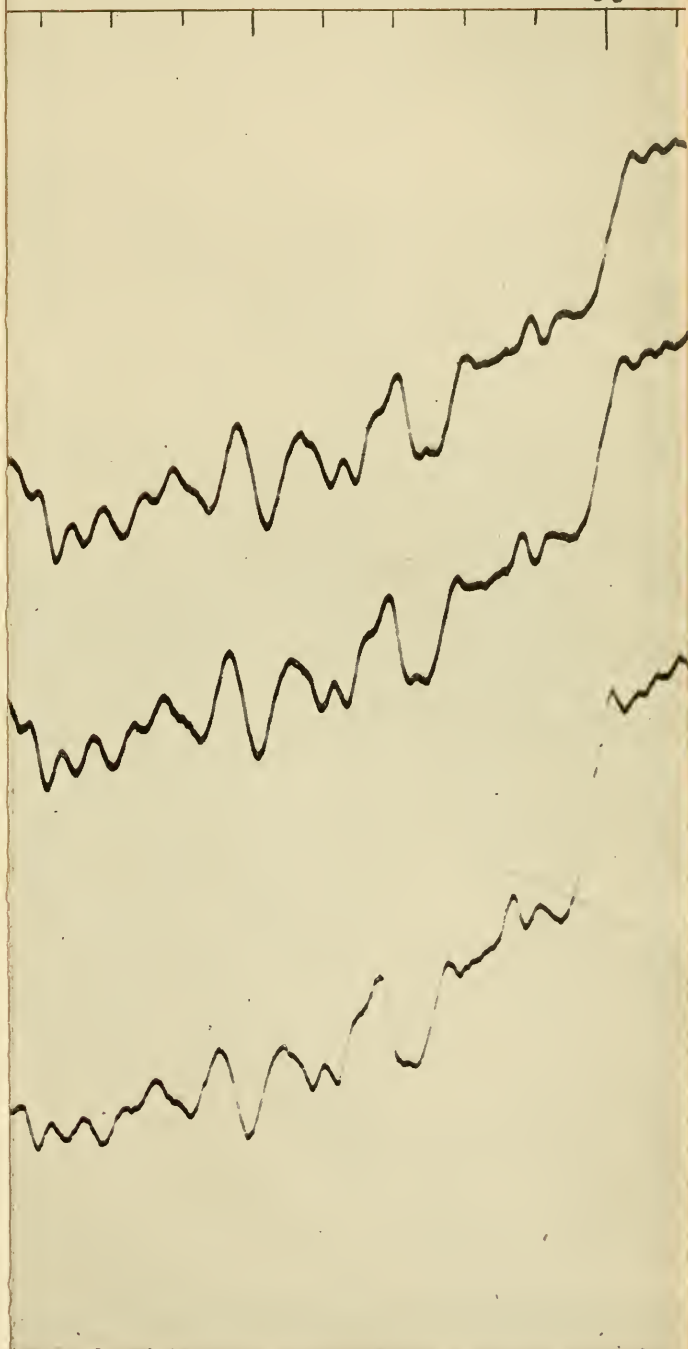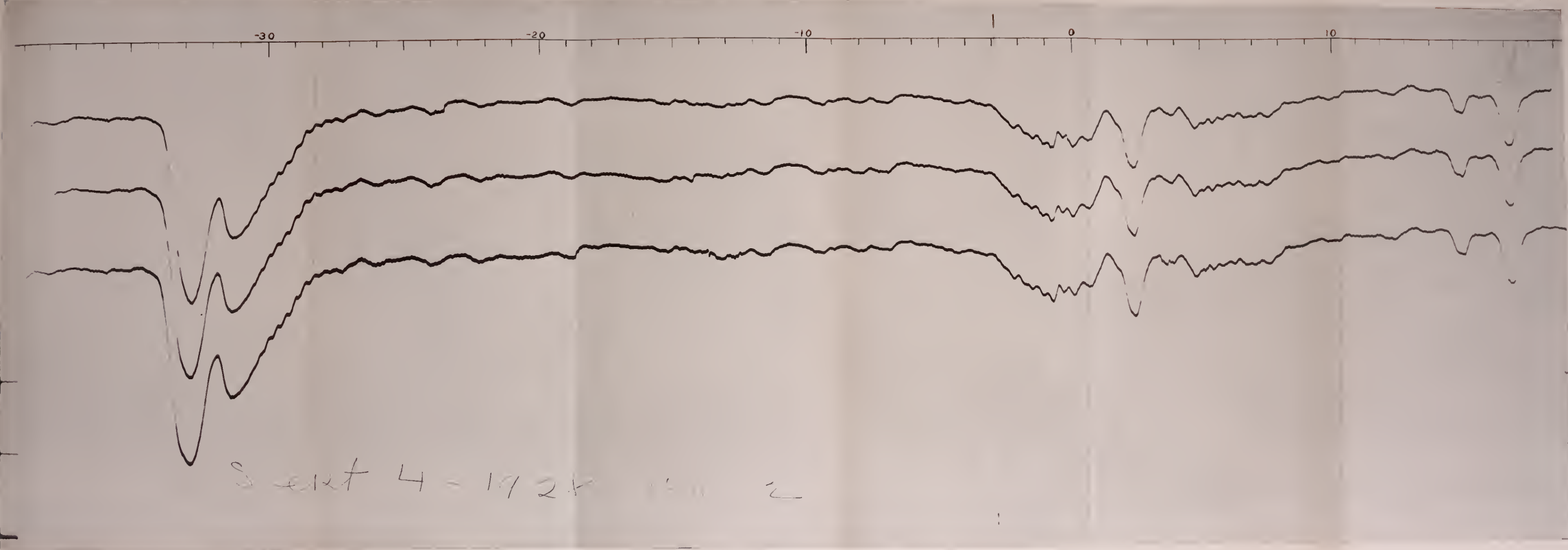
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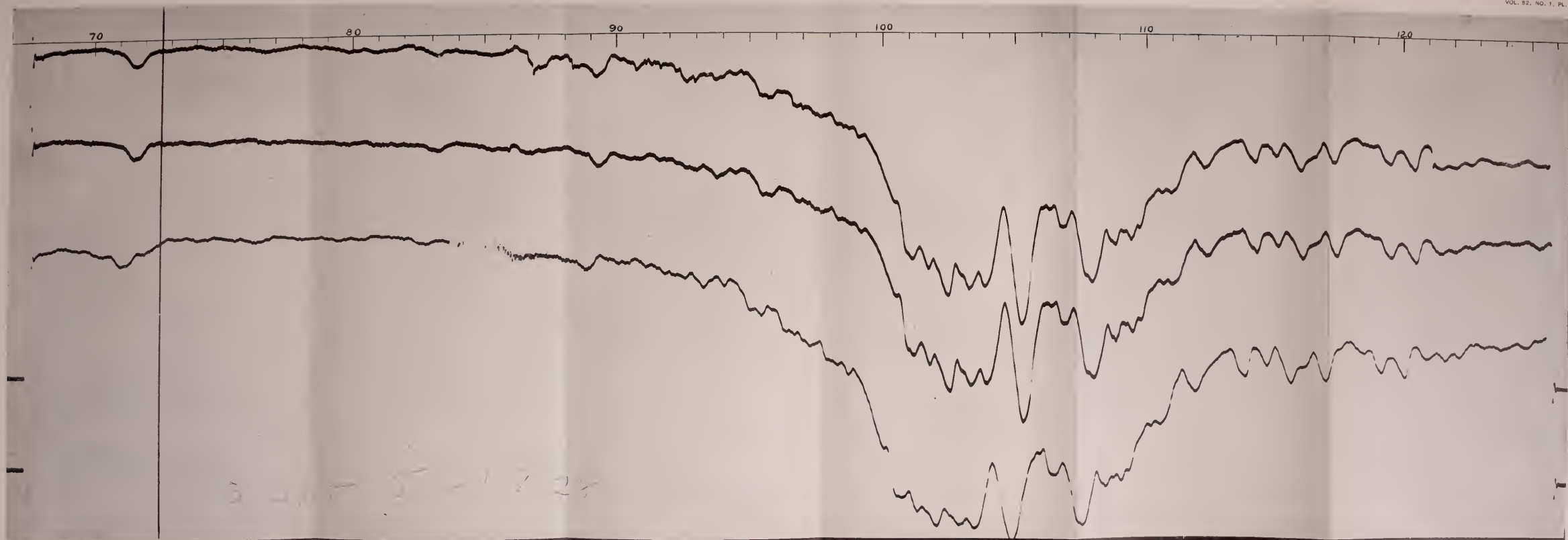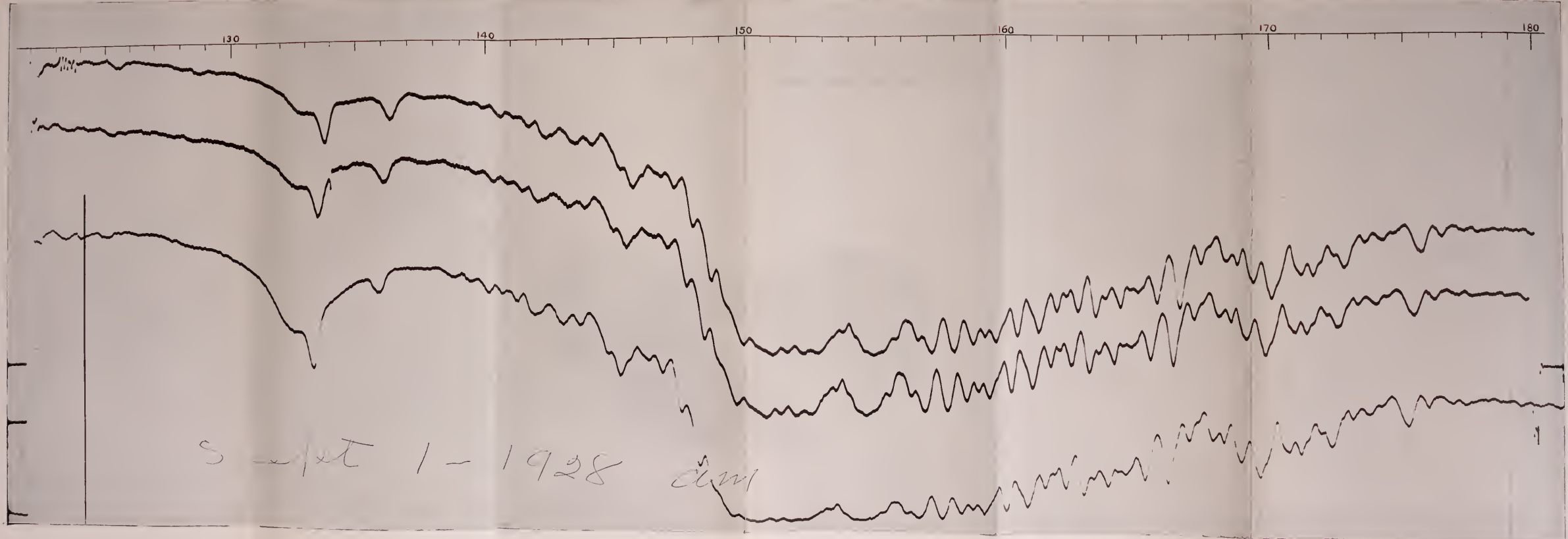The A region. Wave-lengths 7600 to 8600 Angstroms.
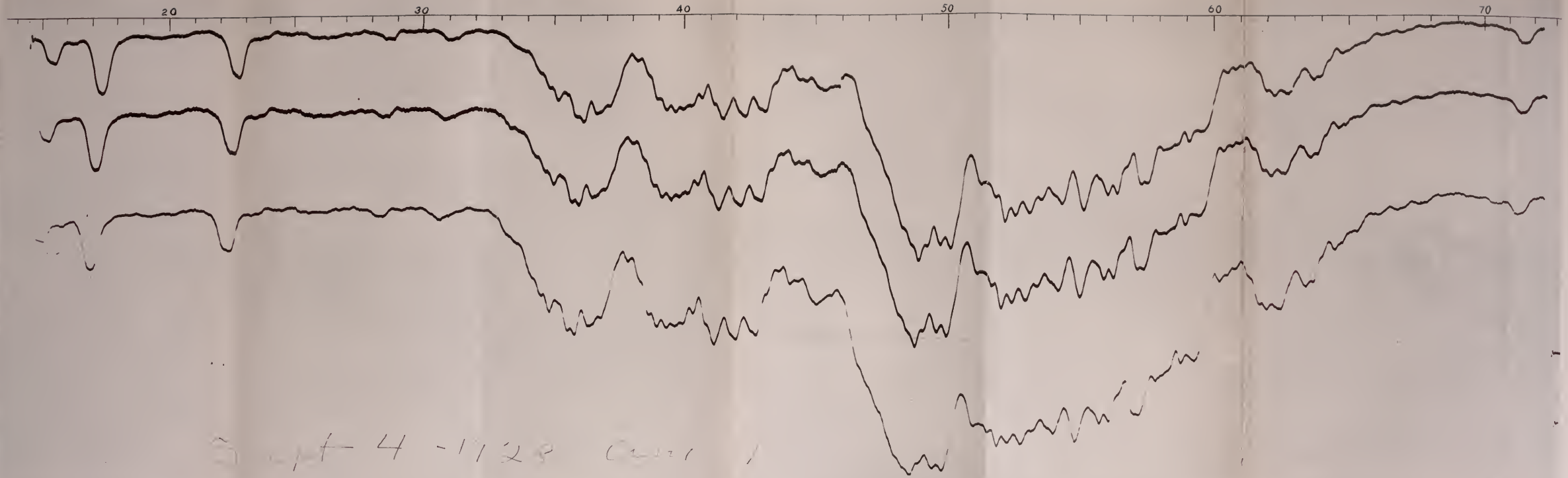
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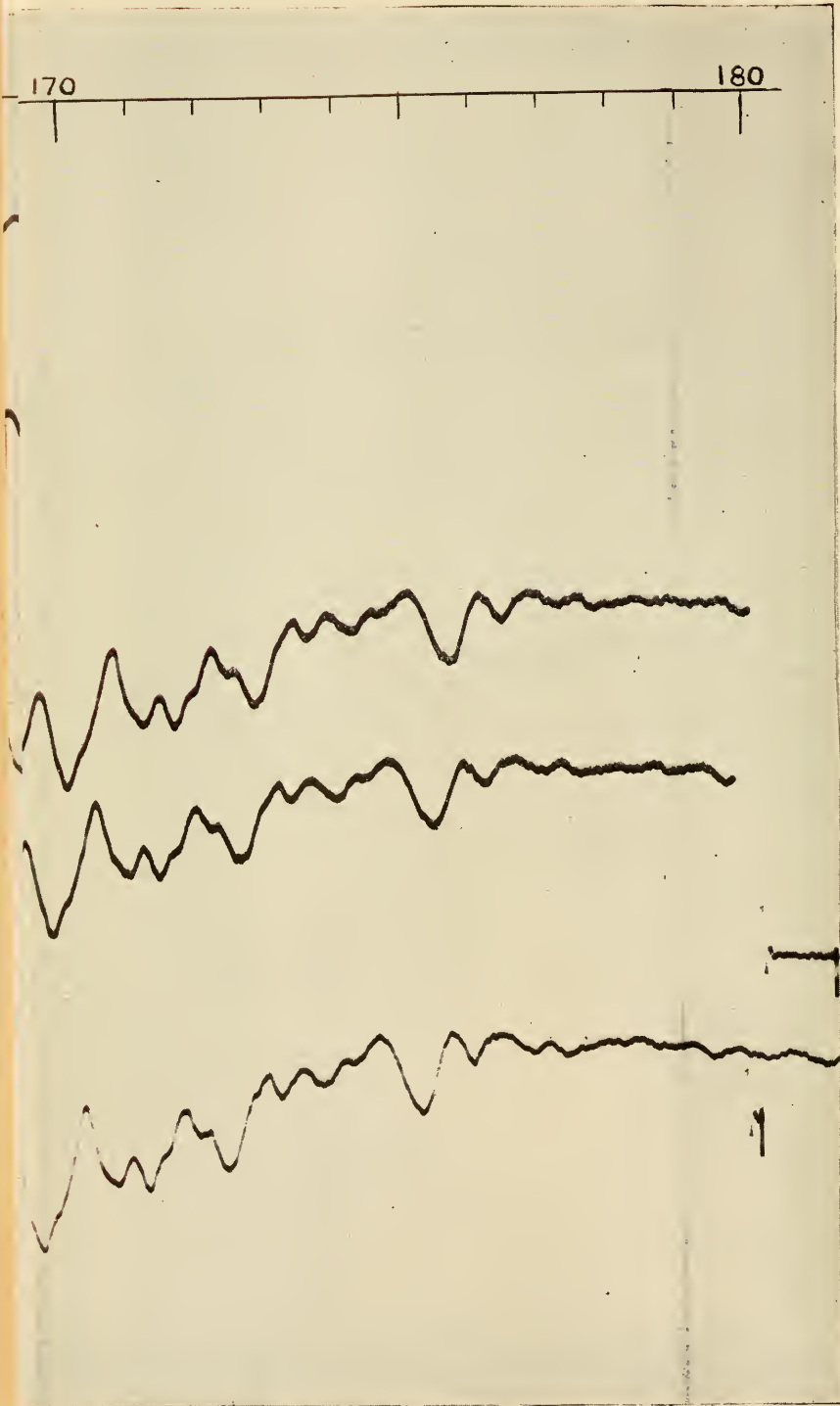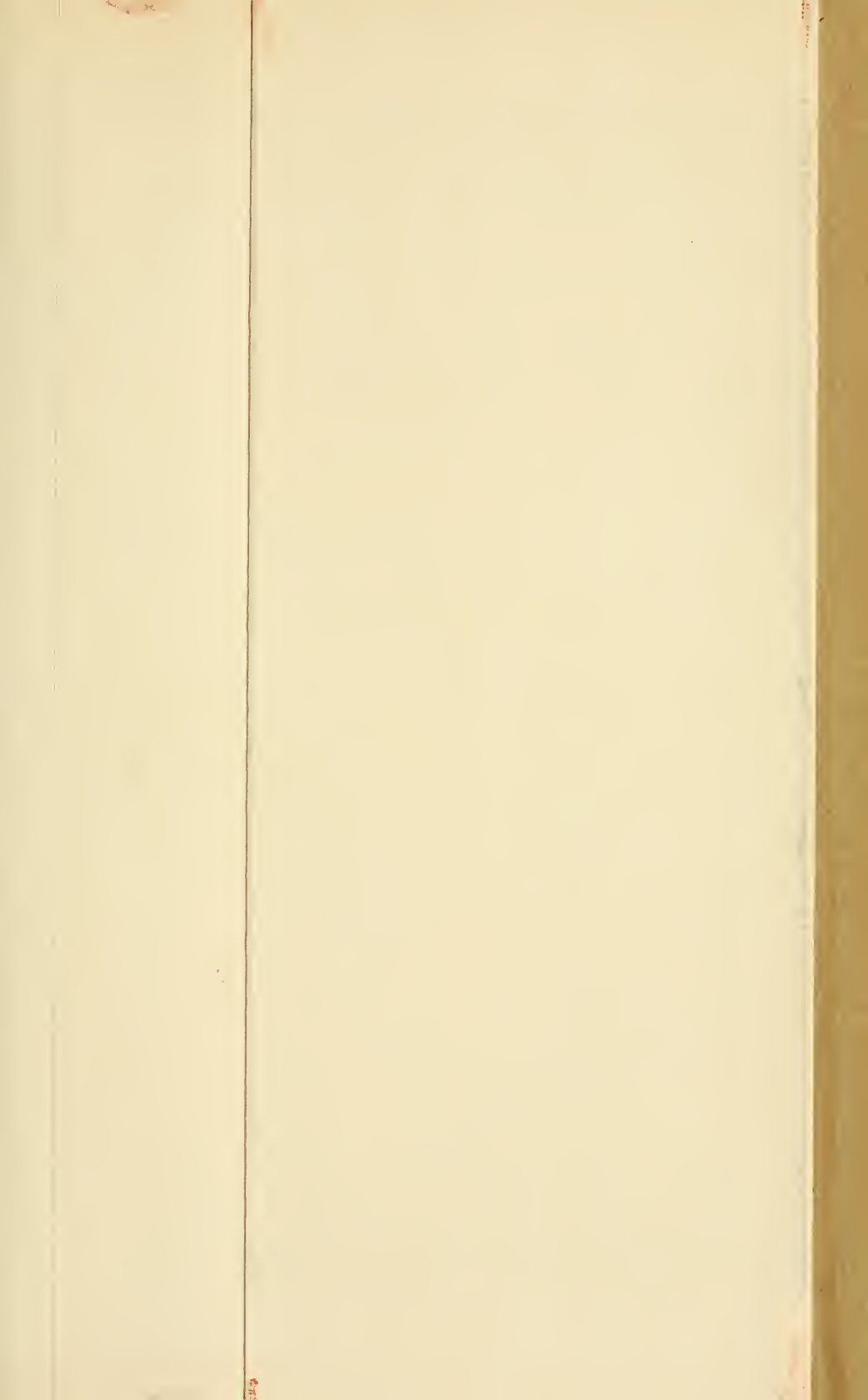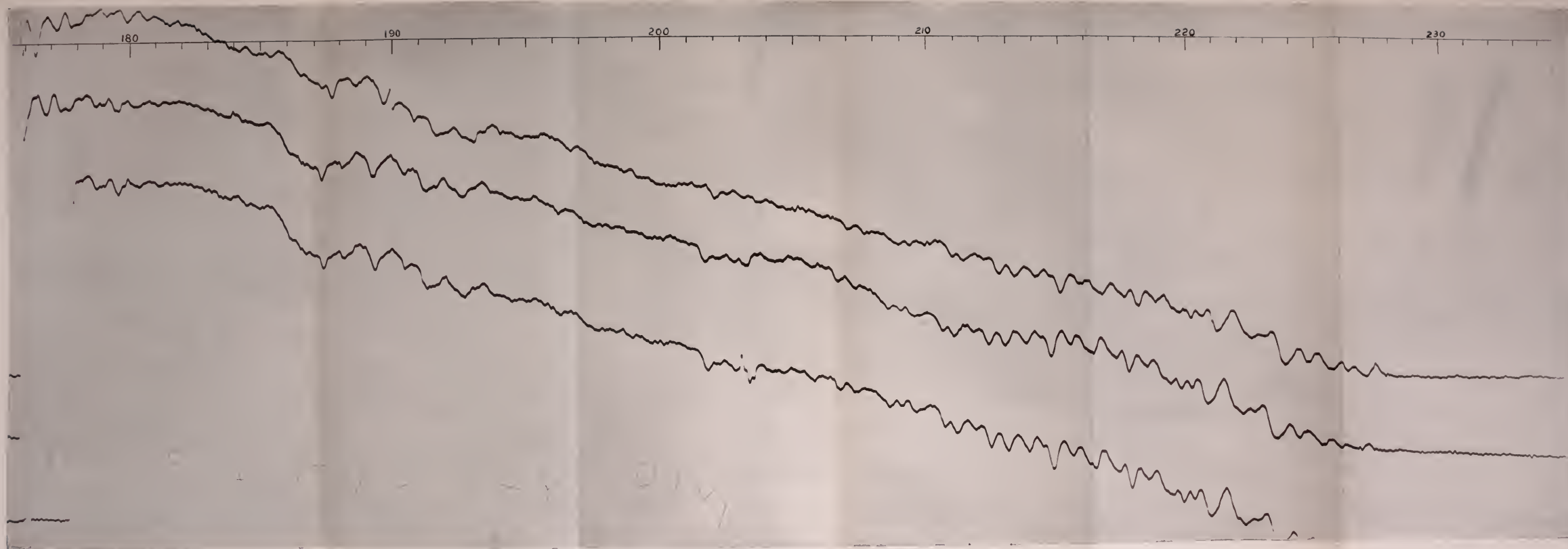The ρστ region. Wave-lengths 8500 to 10000 Angstroms.
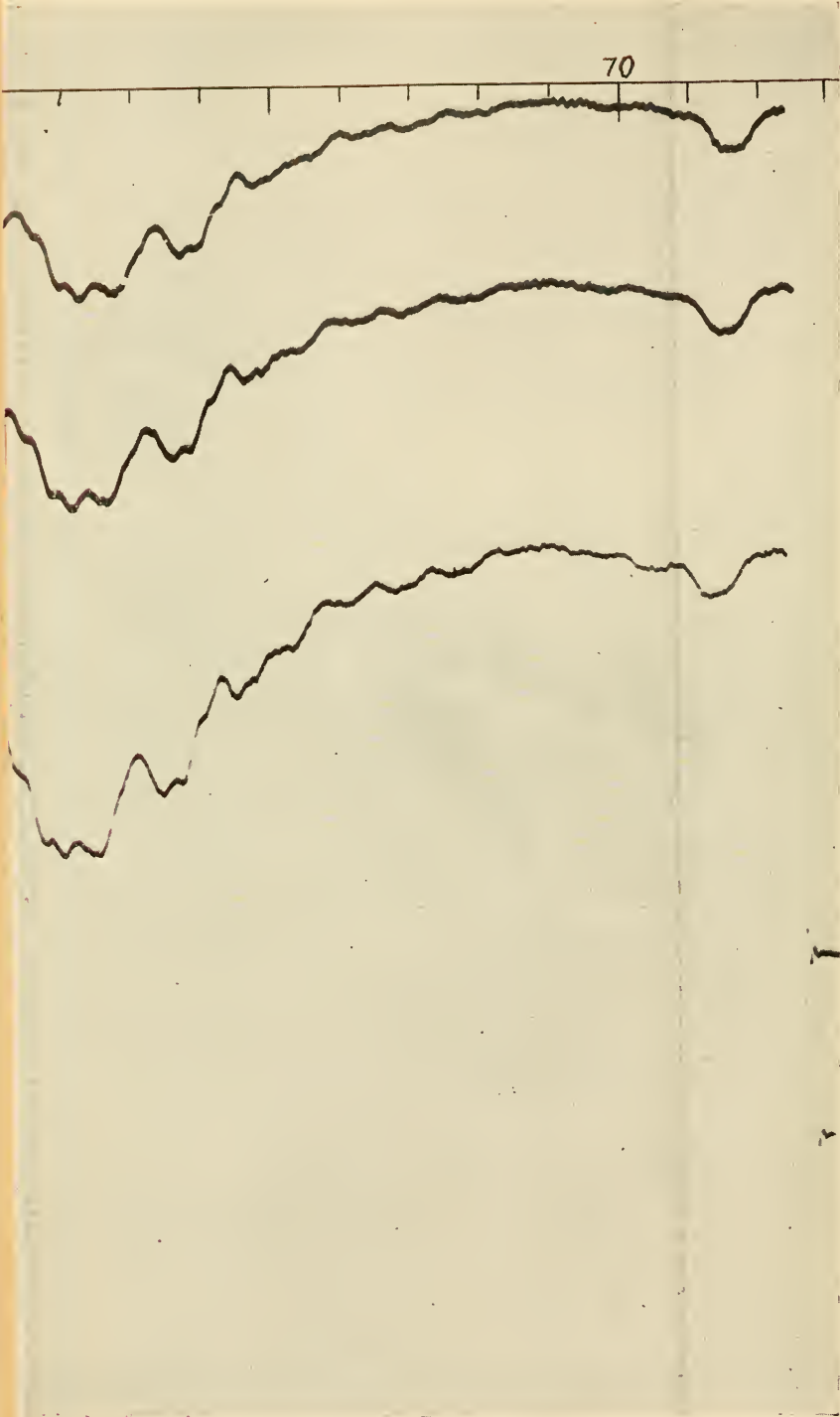
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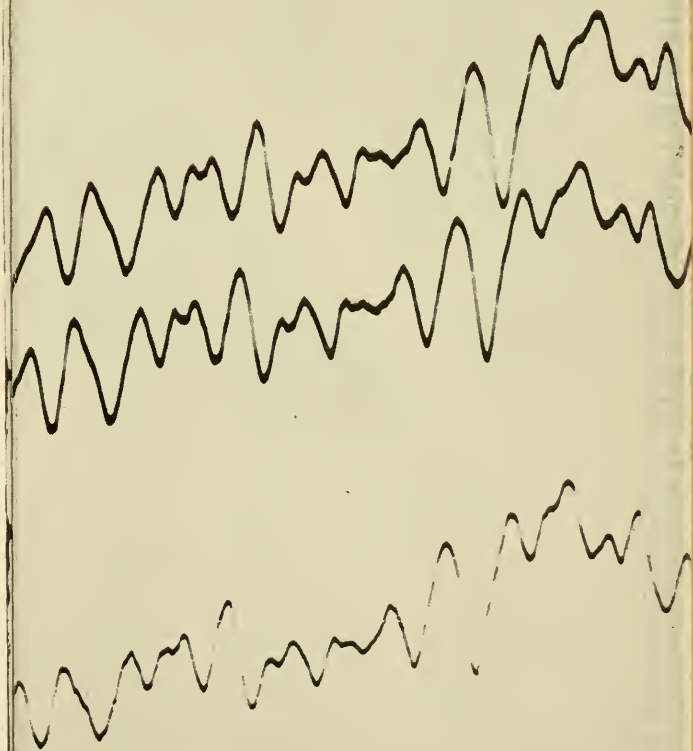
BOLOGRAPHS OF THE INFRA-RED PRISMATIC SOLAR SPECTRUM.
The φ region. Wave-lengths 10000 to 12220 Angstroms.

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Bolographs of the Infra-Red Prismatic Solar Spectrum.
The ψ region. Wave-lengths 12200 to 15300 Angstroms.

BOLOGRAPHS OF THE INFRA-RED PRISMATIC SOLAR SPECTRUM.
The Ω region. Wave-lengths 15,200 to 18,200 Angstroms.