RP 11

STANDARD SOLAR WAVE LENGTHS (3592–7148A)

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ABSTRACT

In order to determine a series of solar wave lengths in the international system to serve as standards for a new table of solar wave lengths and to find the exact corrections which should be applied to Rowland's classical table of solar spectrum wave lengths, the Bureau of Standards and the Allegheny Observatory cooperated in measuring the wave lengths corresponding to selected dark (Fraunhofer) lines in the solar spectrum. The wave lengths were compared with those of standard neon lines by the Fabry and Perot étalon-interferometer method, both spectra being photographed simultaneously. More than 11,000 observations were made on 729 solar lines in the wave-length interval (octave) from 3592.027A in the ultra-violet to 7148.159A in the red. The majority of these standard solar wave lengths have individual probable errors smaller than 1 part in 4,500,000.

CONTENTS

I. INTRODUCTION

The classical spectroscopic investigations of Professor Rowland culminating in his Preliminary Table of Solar Spectrum Wave Lengths,[1] formed the foundation of the so-called Rowland scale of wave lengths which has been in more or less universal use for the past 35 years. Beginning with the best available value of the wave lengths corresponding to the sodium yellow lines,[2] the relative wave lengths of a selected list of solar absorption lines [3] were determined by the method of overlapping spectra from diffraction gratings.

Early in the present century it was recognized that Rowland's standards were too large by approximately 1 part in 30,000, and relative errors of the order of 1 part in 100,000 were detected in different spectral regions. The International Union for Cooperation in Solar Research,[4] later replaced by the International Astronomical

[1] Rowland, Preliminary Table of Solar Spectrum Wave Lengths, The Univ. of Chicago Press; 1896.

[2] Rowland, Phil. Mag. (5), **23**, p. 257; 1887 and **27**, p. 479; 1889.

[3] Rowland, Phil. Mag. (5), **36**, p. 49; 1893.

[4] International Union for Cooperation in Solar Research, Trans. I, p. 230; 1906; II, pp. 109–174; 1908; III, p. 139; 1911; IV, p. 59; 1914.

Union,[5] has dealt with the situation since 1905, and as a result of recommendations a new set of standard wave lengths has been determined and adopted to form the basis of the so-called international scale. This international system consists (1) of a primary standard—viz, the wave length of cadmium red radiation which had previously been compared with the meter, and (2) several hundred secondary standards (3370–6750A) derived from the emission spectrum of the iron arc. These secondary standards were measured relative to the primary standard by means of the Fabry and Perot[6] étalon-interferometer method. Certain neon lines which have been compared with cadmium by the same method have also been adopted as secondary standards.

This international system has gradually been displacing the older Rowland system, but there has been a tendency, especially in astrophysics, to retain the latter. The solar spectrum tables of Rowland are an almost inexhaustible mine of astrophysical study, but they could not be translated to the international scale without accurately determined corrections. On the other hand, the use of two different systems of standards caused considerable confusion in spectroscopy, and the only remedy for this double standard appeared to lie in a redetermination of solar spectrum wave lengths on the international scale. In 1922 the International Astronomical Union expressed itself as follows:[7]

> It is believed that the time has arrived for the determination of a series of solar wave lengths in the international system to serve as standards for a new table of solar wave lengths. It is recommended, therefore, that efforts be made to obtain at least three independent determinations of the wave lengths of a selected list of solar lines.

In 1923 the spectroscopy section of this bureau united with the Allegheny Observatory in a cooperative program of solar wave-length determinations, and results for one octave of the spectrum (3592–7148A) were completed in 1927. These results were obtained in four overlapping spectral intervals. They were published in three installments according as the work in different spectral regions reached completion.[8] In order that these results may be presented as a unified whole, they are republished here with the wave lengths (Table 1) in consecutive order and mean values replacing those reported twice in the slightly overlapping regions covered by the first publications. Similarly, the corrections to Rowland's wave

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[5] International Astronomical Union, Trans. I, p. 35; 1922; II, p. 40; 1925.

[6] Fabry and Perot, Ann de Chim, et de Phys., **25**, p. 98; 1902; Astrophys. J., **15**, pp. 73 and 261; 1902.

[7] I. A. U. Transactions I, p. 36; 1922.

[8] Burns and Meggers, Standard solar wave lengths (4073—4754A), Pub. Allegheny Observatory, **6**, No. 7; 1925. Burns and Kiess, Standard solar wave lengths (5805–7142A), Pub. Allegheny Observatory, **6**, No. 8; 1927. Burns, Standard solar wave lengths (3592–4107A and 4761–5892A) Pub. Allegheny Observatory, **6**, No. 9; 1927.

lengths, previously reported in four sections, are now collected in one table (Table 2). A large number of additional "sun-arc" observations are included in Table 1, but the discussion of these is reserved for another paper. The main purpose of the one in hand is to present in complete and final form our observations on standard solar wave lengths. Only the essential facts relating to the method of observing, the description of the apparatus, and of the comparison sources will be given here. Further details may be found in the earlier publications.

II. METHOD OF OBSERVING

The method of observing is essentially that devised and first used by Fabry and Perot [9] in 1902 for the measurement of 33 solar wave lengths (4643–6471A). It involves the use of a Fabry and Perot étalon interferometer combined with a prismatic or grating dispersing system, so that the orders of interference at various points in the spectrum may be compared. The method has become more or less familiar on account of its repeated use for the establishment of the international system of secondary standards in the emission spectrum of the iron arc. In the case of an absorption spectrum like that of the sun interference patterns similar to those produced by bright lines are obtained for dark (Fraunhofer) lines by a choice of order of interference and slit width such that a practical disappearance of the channeled spectrum from the continuous background is accomplished and interference fringes appear on the dark lines. The theory of interferences produced by the dark lines of the solar spectrum was discussed in some detail by Fabry and Buisson [10] in 1910, but no further measurements of solar wave lengths were published until ours appeared. Similar observations have recently been made by this method at the Mount Wilson Observatory, and a portion of the results have been published. [11]

In order that solar spectrum standards may be placed on the same footing as the international secondary standards, they must be compared with the primary standard or its equivalent. Recognizing certain advantages of neon lines for such comparisons the International Astronomical Union [12] considers the mean of eight or more well-determined neon wave lengths as practically equivalent to the primary standard. Our method of observing was arranged so that the solar spectrum and neon comparison spectrum could be recorded simultaneously. This procedure eliminates, or reduces to a minimum, the small uncontrollable disturbances which otherwise are likely to introduce systematic errors in precise comparisons of wave lengths.

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[9] Fabry and Perot, see reference No. 6.

[10] Fabry and Buisson, J. de Phys., 9, p. 197; 1910.

[11] Babcock, Astrophys. J., 65, p. 140, 1927.

[12] I. A. U. Transactions II, p. 47; 1925.

III. DESCRIPTION OF APPARATUS

All of the spectrograms were made at the Allegheny Observatory where the coelostat and spectrograph described by Schlesinger [13] were employed, but the location and mounting of the latter instrument was changed. The former vertical mounting of the spectrograph proved to be too unstable for the rather long exposures required in this work. The instrument was, therefore, mounted horizontally on concrete piers in the basement of the observatory, where ideal stability and freedom from temperature changes were obtained. A coelostat mirror reflected the sunlight down the polar axis to another mirror which sent the light into the solar telescope and interferometer. The optical arrangement from this point onward is shown diagrammatically in Figure 1. After leaving the second coelostat mirror, the beam of sunlight passed through a color filter which was placed immediately in front of the solar lens. This filter reduced the heating effect of the sun in the interferometer, and at the same time removed the part of the solar spectrum corresponding to the neon comparison source, so that the spectrum of the latter could be simultaneously recorded in an auxiliary spectrograph camera. In the interval 5,800–6,500A the two spectra were photographed superposed, higher orders than the second being removed by a yellow-glass filter.

A telescope of 40 cm focal length forms an image of the sun in the interferometer, which is of the Fabry-Perot type. A diaphragm 6 mm in diameter near the first plate of the interferometer restricts the beam of the comparison spectrum to the size of the solar image. The sunlight from the telescope passes through a diagonal mirror, which serves to reflect the light of the laterally situated neon comparison lamp into the path of the solar beam. From this point on the solar and comparison beams follow identical paths until the grating separates them into spectra. For observing the photographic region of the solar spectrum this diagonal mirror is lightly silvered, reflecting rather more light than it transmits. For the longer solar wave lengths a thinner coat of silver is used, and for the region longer than 6600A a clear-glass mirror has been used for some of the observations.

The interferometer is so mounted on a stand as to permit the necessary adjustments or to allow it to be lowered out of the path of the light so that the centering of the solar image and the comparison source on the grating may be more readily effected. The interferometer is turned 90°, in order to adjust the parallelism of the plates by means of a mercury lamp. The interferometer plates are thinly coated with silver, deposited cathodically. Some 10 to 15 images of a 40-watt lamp can be seen through a pair of plates. While a thicker

[13] Schlesinger, Pub. Allegheny Obs., 3, p. 99; 1914.

coat would give slightly better interference, the increase in exposure time necessitated by the use of dense films more than offsets the slight gain in resolving power. The separators, or étalons, are made of invar.

A telescope of 25 cm focal length projects the ring system upon the slit of the spectrograph. The objective, of quartz and fluorite, is achromatic for the whole region of the solar spectrum observable at Allegheny Observatory. The interferometer is set at such a distance from this objective that the image of the diaphragm, 6 mm in diameter, is slightly smaller than the grating.

A gauge plate, or repère, having five fine parallel slots extending at right angles to the slit, is mounted on ways which allow it to slide almost in contact with the latter. Before the interferometer is placed in position this repère plate is slid in front of the slit. The intersections of the slit and the slots in this plate give five point-sources

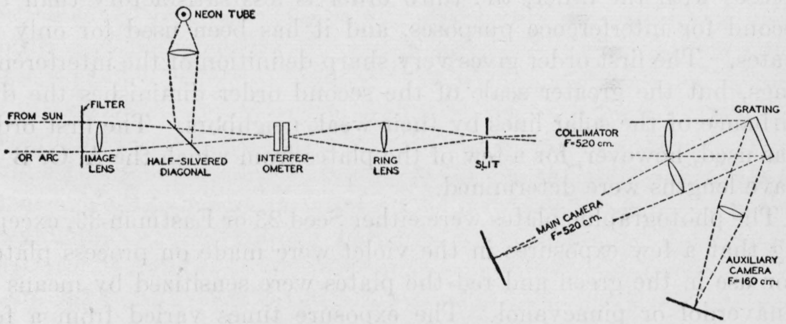

FIG. 1.—*Diagram of interferometer and grating spectrograph for observing solar wave lengths*

of light whose images are photographed in both the solar and comparison spectra. This furnishes a means of making sure that the same scale is used in computing the ring diameters in solar and comparison spectra, a matter of considerable importance when the two spectra differ greatly in wave length, but of little consequence when both spectra are of nearly the same wave length.

The collimator and camera lenses of the spectroscope are of 19 cm aperture and 520 cm focal length. Since parallel light falls upon the grating and the rulings are only 10 cm long, only the central 10 cm of each lens is useful in connection with the interferometer. The lenses are corrected for the photographic region, having minimum focal length at 4500A, at which point in the spectrum the plate is perpendicular to the axis of the camera. The grating, by Michelson, is ruled with 500 lines per millimeter, giving a linear scale of 3.65A per mm in the first order.

To photograph the comparison spectrum, an auxiliary camera has been installed as shown in Figure 1. The lens of this camera is of 10 cm aperture and 160 cm focal length. The field is good over an angle of 5°, which is more than is required to photograph the neon spectrum in the region 5852 to 6598A. Since the solar camera is fixed with respect to the collimator, it is necessary to move the auxiliary camera as the various regions of the spectrum are brought into the solar camera. This comparison camera is arranged to rotate around an axis passing through the center of the grating; consequently the focus for the neon spectrum remains constant as the camera is rotated. For the region shorter than 6600A the comparison spectrum is observed in the first order on the side of zero opposite from that on which the solar spectrum is photographed. For the longer region it is preferable to observe the comparison and solar spectra in the first and second orders, respectively, on the same side of zero.

The greater portion of the observing has been done with the grating adjusted to photograph the solar spectrum in the second order, giving a scale of 1.82A per mm. Because of a slight astigmatism that increases with the order, the third order is less satisfactory than the second for interference purposes, and it has been used for only 10 plates. The first order gives very sharp definition of the interference rings, but the greater scale of the second order diminishes the disturbance of the solar lines by their weak neighbors. The first order was used, however, for a few of the plates from which the A. O. B. S. wave lengths were determined.

The photographic plates were either Seed 23 or Eastman 33, excepting that a few exposures in the violet were made on process plates. For use in the green and red the plates were sensitized by means of pinaverdol or pinacyanol. The exposure times varied from a few minutes to over two hours, depending on the condition of the sky, the state of the various silver coats, and the slit width.

Spectrograms were made in each portion of the solar spectrum with a variety of étalons and with two or more sets of interferometer plates. The various étalons were made of invar and had lengths of 3.75, 5, 6, 7.5, 8, 10, 12, 15, and 20 mm.

IV. COMPARISON SOURCES

The wave lengths of Table 1 were derived by simultaneous comparison with the red lines of neon, as already stated. The neon source was a lamp of the type described by Nutting.[14] Its electrodes are aluminum disks 25 mm in diameter; the capillary is 10 cm long and has a bore of 2.5 mm. An exciting current of about 50 m. a. was delivered by 5,000 v. a. c. without capacity. The tube was observed exactly side on. The particular tube used in this investigation had been used previously in a comparison of neon wave lengths with the primary cadmium standard.

[14] Nutting, Bull. Bureau of Standards, 4, p. 511; 1908.

The maximum pressure in the solar reversing layer where the Fraunhofer lines originate has been demonstrated to be so low that for spectroscopic purposes it may be regarded comparable with laboratory vacuum sources. For comparison of solar with terrestrial wave lengths we have employed the very convenient type of vacuum arc designed and built by Curtis.[15] Using currents of 6 amp. or less, this arc operates without a cooling system and is in other respects so simple to manipulate that it would seem that this or a similar type of source should become a standard piece of laboratory equipment wherever wave lengths of a high order of accuracy are being determined. This arc was used as the source for all the sun-arc comparisons listed in Table 1. It was usually operated at pressures corresponding to 1 to 6 cm of mercury. All the vacuum arc wave lengths were derived from the neon standards by simultaneous comparison exactly in the same manner as the solar wave lengths.

V. MEASUREMENT AND REDUCTION

The diameters of two or, more often, three innermost fringes were measured for each of the wave lengths on a number of spectrograms ranging from 2 to 33. In addition to the solar and neon spectra, each plate had on it the images of the slots in the repére plate at the slit, measurement of which furnished the scale factor used in the reductions.

The method of reduction employed by Buisson and Fabry [16] was followed for about half of the plates, the remainder being reduced by the method described by Childs.[17] In the former method the fractional order of interference at the center of the interference pattern is derived from measurements of the repère images and ring diameters, while in the latter it is deduced from ring diameters alone when three or more are available. Practically the same results are obtained from both methods, but the latter has the advantage of involving considerably less labor.

The order of interference was invariably obtained with the aid of the neon interferences,[18] and the thickness of the interferometer, or double separation of the plates, was computed from each of six or more neon lines, the mean optical distance thus found being used to derive the solar wave lengths from their measured orders of interference. The values used for the neon lines were those compared with the primary cadmium standard; [19] their mean value is regarded as practically equivalent to the primary standard itself.

Corrections for dispersion of phase upon reflection in the interferometer surfaces were made by the well-known device of comparing

[15] Curtis, J. Opt. Soc. Am., **8**, p. 697; 1924.

[16] Buisson and Fabry, J. de Phys., **7**, p. 169; 1908, Astrophys. J., **28**, p. 169; 1908.

[17] Childs, J. Sci. Inst., **3**, pp. 97 and 129; 1926.

[18] Meggers, Bull. Bureau of Standards, **12**, p. 203; 1915.

[19] Burns, Meggers, and Merrill, Bull. Bureau of Standards, **14**, p. 765; 1918. I. A. U. Trans. I., p. 40, 1922. II, p. 44, 1925.

wave lengths first with low orders of interference and then with high values in which the differential phase change plays a proportionately smaller part.[20] For this purpose wave lengths of the iron arc in vacuo were compared with neon standards by means of interferometers of 3.75, 6, 10, and 20 mm separation.

Observations made under conditions of temperature and pressure of air which deviated from normal were corrected to their values at 15° C. and 760 mm Hg by the tables of Meggers and Peters.[21]

The proper corrections for motion of the earth relative to the sun were made for each spectrogram.

VI. RESULTS

The first column of Table 1 contains the wave lengths of solar lines compared with red neon standards by means of simultaneous exposures as described above. The second column indicates the probable error of measurement. These probable errors are expressed in parts per million; thus "A" denotes a probable error of 1 part in 6,000,000; "B," 1 part in 4,500,000; "C," 1 part in 3,000,000; and "D" probable errors greater than 1 part 3,000,000. The number of independent comparisons of each line with the neon standards is indicated in column 3. The fourth, fifth, and sixth columns contain Rowland's wave length, chemical identification, and intensity for each line. An "s" attached to Rowland's wave length means that it was one of his standards. Column 7 shows the wave-length difference between Rowland and A. O. B. S. for the individual lines, and the next column gives the value of this difference interpolated from Table 2. In the ninth column are shown the differences between the wave lengths in the solar spectrum and the laboratory vacuum-arc values for the same lines, the unit being 0.001A. The final column gives the temperature class according to King and the pressure class to which the line belongs. The A. O. B. S. wave-length values are for air at 15° C. and 760 mm Hg pressure, while those of Rowland apply to air at 20° C. and normal pressure. In both cases the source was integrated solar light.

In Table 2 are listed the corrections which must be applied to Rowland's wave lengths to reduce them to the international scale. These are taken from a smooth curve drawn through the plotted values of column 7 in Table 1. The differences, Rowland minus A. O. B. S., run smoothly for the most part, but there are several marked discontinuities, notably at 4142A, at 5220A, and at 6870A. The smaller irregularity near 5800A may not be real, as the observations between 5740 and 5850A are of slightly inferior quality.

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[20] Meggers, Bull. Bureau of Standards, **12**, p. 199; 1915.

[21] Meggers and Peters, Bull. Bureau of Standards, **14**, p. 724; 1918.

A most encouraging feature of this comparison is an entire lack of an intensity equation. The values of the differences, Rowland minus A. O. B. S., are quite independent of the intensity of the solar line. After applying the interpolated corrections to Rowland's values, the mean of the residuals, Rowland minus A. O. B. S., is only ± 0.0015A.

TABLE 1.—*A. O. B. S. solar wave lengths*

[3592–7148A]

A. O. B. S. λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden.	Int.	Obs.	Mean		
3592.027	C	3	.169	V?	2	142	141		VE
3600.736	C	3	.880	V	3	144	141		
15.661	C	3	.802	Fe	3	141	141		
35.470	C	3	.608 s	Ti, Fe	4	138	141		
50.539	C	3	.681		2	142	141		
61.366	C	6	.506	Fe	3	140	140		
72.712	C	6	.851	Fe	3	139	140		IV
81.648	B	8	.787	Fe	3	139	140		IV
3695.056	B	6	.194 s	Fe	5	138	140	+6	IV
3710.291	A	10	.431	Y	3	140	140		
25.495	A	10	.638		3	143	140		
41.064	A	10	.205	Ti	4	141	140	+5	I
52.419	A	7	.556	Fe	3	137	140		
60.537	A	10	.679	Fe	4	142	140		III
69.993	A	9	0.132 s	Fe	4	139	140	+6	IV
81.190	A	10	.330 s	Fe	3	140	140		IV
3793.877	A	10	4.016 s	Fe	2	139	140		IV
3802.285	B	10	.424	Fe	2	139	140		
04.014	A	9	.151 s	Fe	3	137	140		
21.187	A	9	.328 s	Fe	4	141	140		IV
36.090	A	10	.229 s		2	139	140		
43.264	B	9	.404 s	Fe	4	139	140	+7	IV
59.219	C	8	.355	Fe	3	136	140		III
64.302	B	8	.438 s	C	3	136	140		
73.764	B	8	.903	Fe	4	139	140	+3	IV
85.516	A	14	.657	Fe	4	141	140	+2	III b
3897.458	A	14	.596 s	Fe	2	138	140		IV
3906.751	A	17	.890	Fe	4	139	140		
16.736	A	18	.879 s	Fe	5	141	140	+5	IV b
37.336	A	9	.479 s	Fe	3	143	140	+8	IV b
49.958	A	18	0.102 s	Fe	5	144	141	+5	III b
53.859	A	19	4.002 s	Fe	3	143	142		
58.739	B	6	.877	Fe	1	138	142		
60.283	A	17	.422 s	Fe	4	139	142		
63.690	A	14	.831	Cr	3	141	143		
76.866	B	8	7.009	Fe	2	143	145		
77.747	C	16	.891	Fe	6	144	145	+6	III b4
78.658	A	9	.809	Co, Cr	3	151	145		
81.770	A	11	.917	Ti	4	147	146	+9	II
87.609	A	9	.755	Ti?	2	146	147		
91.120	A	13	.333	Cr, Zn	3		147		
3993.099	A	8	.246	Fe	2	147	148		
4000.253	C	5	.403	Fe	2	150	149	±0	
00.460	C	6	.611	Fe	2	151	149		b
03.768	A	11	.912 s	Co, Fe, Ti	3	144	150		
10.174	C	5	.327	Fe	1	153	151		
11.713	B	8	.865	Fe	2	152	151		
16.421	A	11	.574	Fe	2	153	151		
22.736	A	8	.893	Fe	2	156	152		
29.639	A	10	.796	Fe, Zn	5	157	154		
4030.187	A	12	.339	Fe	2	152	154		
31.962	A	6	2.117	Fe	2	155	154		
37.119	B	5	.268		2	149	154		
47.306	A	7	.461		2	155	155		
49.327	B	7	.482	Fe	2	155	155	−1	

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TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A. O. B. S. λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden.	Int.	Obs.	Mean		
4050.675	A	8	.830	Fe	2	155	155		
53.824	A	12	.981	Fe, Ti	3	157	155		
59.718	A	8	.872	Fe	2	154	155		
62.446	A	11	.599 s	Fe	5	153	155	+6	III b
66.585	A	6	.742	Fe	2	157	155		
73.766	A	31	.921 s	Fe	4	155	155	+6	
79.841	A	41	.966	Fe	3	155	155	+3	IV b
80.879	A	35	1.033	Fe	2	154	155		
82.941	A	25	3.095	Mn	4	154	155	+4	
84.499	A	25	.647	Fe	5	148	155	+8	IV d
85.007	A	28	.161	Fe	4	154	155		IV b
91.556	A	38	.711	Fe	3	155	156		
94.938	A	22	5.094	Ca?	4	156	156		
4098.179	B	26	.335	Fe	5	156	156	+3	IV b
4100.744	A	32	.901	Fe	4	157	156	+5	IIA
01.267	A	10	.421	Fe	2	154	156		d
06.260 [1]	A	10	.420	Fe	2	160	156	±0	
06.431 [1]	B	10	.583	Fe	2	152	156	+9	
07.492	A	25	.649	Ce-Fe-Zr	5	157	156	+4	III b
12.321	B	20	.478	Fe	2	157	156		
14.450	B	17	.606 s	Fe	4	156	156	+5	IV b
20.212	C	13	.368	Fe	4	156	155	+6	IV b
26.190	B	17	.344	Fe	4	154	154	+7	IV b
36.527	A	20	.678	Fe	4	151	152		d
37.000	C	18	.156	Fe	6	156	152	+3	IV b
39.936	A	23	0.089	Fe	6	153	152	+9	IIA a
43.876	C	6	4.038	Fe	15	162	163	+9	b1
47.675	C	13	.836	Fe	4	161	163	+6	III b
49.371	A	7	.533	Fe	4	162	163	+6	V e
54.505	C	12	.667	Fe	4	162	164	+6	III b
54.814	A	17	.976	Fe	4	162	164	+8	IV d
58.794	B	19	.959	Fe	5	165	164	+1	V d
63.651	C	11	.818	Ti, Cr —	4	167	164		
68.619	C	8	.784		2	165	163		
78.858	B	13	9.025		3	167	162		
82.387	A	25	.548	Fe	3	161	162		IV b
84.898	B	12	5.058 s	Fe, Cr	4	160	162	+6	III b
87.046	C	8	.204	Fe	6	158	162	+8	III d
91.683	C	11	.843	Fe	3	160	161		e?
4198.639	C	16	.800	Fe	3	161	161		V d
4202.041	C	8	.198	Fe	8	157	160	+12	I b1
07.132	B	26	.291	Fe	3	159	160		IV b
08.608	B	20	.766	Fe	3	158	160	+3	V b
13.651	B	26	.812	Fe	3	161	160	+4	IV b
20.348	B	30	.509	Fe	3	161	159	+8	IV b
22.219	B	22	.382 s	Fe	5	163	159	+7	III d
24.175	C	9	.337	Fe	4	162	159	+4	IV e
25.461	C	16	.619	Fe	3	158	159	+7	IV d
25.961	B	16	6.116	Fe	2	155	159		IV b
26.742	C	6	.904 sg	Ca	20d?	160	159	+13	I
27.432 [2]	C	9	.606	Fe	4	174	159	+6	III d
31.023	C	11	.183	Ni	4N	160	159		
32.731	B	17	.887	Fe	2	156	159	+6	IA
33.612	C	13	.772	Fe	6	160	159	+10	III d5
35.947	C	10	6.112	Fe	8	165	159	+10	III d5
4238.025	D	5	.188	Fe	3	163	159	+3	IV d?
41.121	B	25	.285	Fe-Zr	2	164	159		
43.815 [3]	D	4	.981		2	166	159		
46.838	B	10	.996	Y?	5	158	158		
4248.233 [4]	B	11	.384	Fe	2	151	158		IV b

[1] 4106.2 and 4106.4. These lines are too close together for the most accurate measurement with moderate resolution. The mean wave length of these two lines is probably quite correct.

[2] 4227.4. The A. O. B. S. and laboratory values of this wave length agree. This is a line of much greater solar intensity than 4, the figure in Rowland's table. Perhaps there is a typographical error in Rowland's value of the wave length.

[3] 4243.8. A close companion renders the interference measurements of this line rather uncertain.

[4] 4248.2. The laboratory value of this line agrees with Rowland.

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A.O.B.S.λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden.	Int.	Obs.	Mean		
4250.129	C	7	.287	Fe	8	158	158	+10	III c5
54.347	C	5	.505 s	Cr	8	158	158	+10	II
57.660	A	11	.815	Mn	2	155	158		II
60.488	C	7	.640 s	Fe	10	152	158	+14	III c2
65.264	B	20	.418	Fe	2	154	158		
66.967	C	11	7.122	Fe	3	155	158	+2	IV b
68.754	A	17	.915	Fe	2	161	158	+10	IV b
71.160	C	7	.325	Fe	6	165	158	+7	III d
71.774	C	7	.934 s	Fe	15	160	158	+14	II b1
76.678	B	13	.836	Zr	2	158	158		
82.411	B	19	.565	Fe	5	154	158	+8	III b1
90.384	C	7	.542	Fe	1	158	158		
4291.471	B	26	.630	Fe	2	159	158	+7	IA a3
4318.658	B	12	.817	Ca, Mn?	4	159	160		
21.797	B	9	.961	Fe	2	164	161		
25.773	D	5	.939 s	Fe	8	166	161	+12	II b1
26.758	B	14	.923	Fe	2	165	161		
27.110	A	18	.274	Fe	3	164	161		V b
31.649	B	18	.811	Ni	2	162	162		II
37.055	C	20	.216	Fe	5	161	162	+9	II b3
37.927	A	17	8.084	Ti	4	157	162	+11	VE
38.265	C	17	.430	Fe	1	165	162	+2	
43.703	B	18	.861	Fe	2	158	162		
46.557	C	13	.725	Fe	2	168	162	+4	
47.238	B	17	.403	Fe	1	165	162	+5	
48.946	B	16	9.107	Fe	2	161	162	+10	
51.548	B	12	.711	Fe	2	163	162	+6	IV b
58.504	B	13	.670	Fe	2	166	161	+4	IV b
59.621	D	6	.748 s	Cr	3	163	161		I
60.799	A	11	.958	Fe, Zr	1	159	161		
65.903	B	28	6.061	Fe	2	158	161		
67.910	A	24	8.071	Fe	2	161	161	+4	IIIA a
69.779	C	16	.941 s	Fe	4	162	161	+7	III b3
73.564	B	18	.727	Fe	2	163	161	+1	
75.947	C	25	6.107 s	Fe	6	160	160	+17	I a3
77.793	B	18	.948	Fe	1	155	160		
79.241	D	5	.396	V	4	155	159		
83.563	C	9	.720 s	Fe	15	157	159	+19	II b1
87.897	C	22	8.057	Fe, Co	2	160	159		IV b
88.414	C	7	.571	Fe	3	157	159	+7	IV d?
89.252	A	18	.413	Fe—	2	161	159		IIA a
94.066	A	10	.225	Ti?	2	159	159		
98.020	B	16	.178		1	158	150		
4399.775	A	15	.935	Ti, Cr	3	160	160		
4404.767	C	9	.927 s	Fe	10	160	160	+17	II b1
08.204	B	14	.364	V	2	160	160		
15.144 [5]	B	13	.263 s	Fe	8	149	161	+22	II b1
16.829	B	17	.985		2	156	161		
22.572	B	16	.741	Fe, Y	3	169	161	+3	III b3
4425.445	B	19	.608 s	Ca	4	163	161		I
27.323	B	16	.482	Fe	5	159	162	+13	I a3
30.195	D	6	.356	Fe	1	161	162		IV
30.621	B	29	.785	Fe	3	164	162	+7	III c4
32.572	B	16	.736	Fe	1	164	162		
33.230	C	16	.390	Fe	3	160	162	+10	IV e
33.783	C	7	.948	Fe	1	165	162	+1	d
35.157	D	5	.321	Fe	2	164	162	+9	IIA a
35.688	B	15	.851 s	Ca	4	163	162		I
39.888	A	24	0.054	Fe	1	166	163		IV
4442.353	B	20	.510	Fe	6	157	163	+13	IV c4

[5] 4415.1. The wave length of this line is no doubt affected by close companions. The laboratory value agrees with Rowland.

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A.O.B.S.λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden	Int.	Obs.	Mean		
4443.202	B	13	.365	Fe	3	163	163	+8	III b3
43.812	B	15	.976	Ti	5	164	163	+10	VE
45.476	B	13	.641	Fe	1	165	163	+6	IA
47.737 [6]	A	16	.892 s	Fe	6	155	163	+20	III c4
51.588	B	16	.752	Mn	3	164	163		II
54.388	A	30	.552	Fe	3	164	163	+7	III b3
56.332	B	10	.497	Fe	1	165	163		
59.756	A	15	.922	V	1	166	163		
61.661	B	24	.818	Fe	4	157	163	+8	I a3
66.566	B	22	.727	Fe	5	161	163	+14	II b4
70.136	D	6	.300	Mn	1	164	163		III
70.486	A	12	.648	Ni-Zr	2	162	163		
81.617	A	13	.782	Fe	1	165	163		
84.229	A	17	.392	Fe	4	163	163	+9	IV d
85.682	A	17	.846	Fe	3	164	163	+6	IV e?
91.410	B	16	.570		2	160	164		
94.575	A	14	.738 s	Fe	6	163	164	+12	III c4
4496.864	B	17	7.023 s	Cr	3	159	164		
4501.280	A	16	.448 s	Ti−	5	168	165		
02.220	A	15	.388	Mn	2	168	165		III
04.834	B	16	5.003	Fe	1	169	165	+6	d
08.290	A	23	.455 s	Fe?−	4	165	165		
12.741	A	22	.906	Ti	3	165	165	+7	II
17.536	A	17	.702	Fe	3	166	166	+12	
25.149	A	16	.314	Fe	5	165	167	+11	IV d?
26.934	B	15	7.101	Ca?	3	167	167		
28.631	B	13	.798	Fe	8	167	167	+17	II c4
31.631	A	21	.801	Fe	2	170	167		II b3
34.785	A	17	.953	Ti	4	168	167		
41.524	A	22	.690	Cr	2	166	168		
47.855	A	17	8.024	Fe	3	169	168	+8	b
48.772	A	16	.938	Ti	2	166	168	+8	II
50.775	A	15	.942	Fe?	2	167	168	+5	d
54.042	B	8	.211 s	Ba	8	169	169		II
58.653	A	7	.827	Cr?	3	174	169		
60.094	B	10	.266	Fe	2	172	170	+7	d
63.769	B	20	.939 s	Ti	4	170	171	+8	VE
71.103	A	20	.275 s	Mg	5	172	172		IA
71.983	A	15	.156 s	Ti−	6	173	172		
74.727	B	10	.899	Fe	2	172	172		
76.340	A	15	.512		2	172	172		
78.560	A	17	.732 s	Ca	3	172	172		II
4587.135	B	20	.308	Fe	2	173	172	+7	
88.207	A	16	.381 s		3	174	173		
89.955	A	15	0.126 s		3	171	173		
95.367	A	21	.540	Fe	2	173	173	+9	
4598.127	A	14	.303	Fe	3	176	174	+10	d
4602.008	A	17	.183 s	Fe	3	175	174	+7	
02.951	A	17	3.126	Fe	6	175	174	+10	IB
07.657	A	23	.831	Fe	4	174	174	+11	V
16.133	A	17	.305	Cr	4	172	174		I
17.277	A	16	.452	Ti	3	175	174	+8	II
20.520	A	21	.693	Fe	1	173	174		
25.055	A	19	.227	Fe	5	172	174	+10	d
30.128	A	17	.306	Fe	4	178	174	+8	
35.855	A	15	6.027	Fe	2	172	173	+8	
37.511	C	7	.685 s	Fe	5	174	173	+6	IV d
38.019	A	16	.193 s	Fe	4	174	173	+11	IV b
43.472	A	23	.645 s	Fe	4	173	173	+8	
47.443	C	7	.617	Fe	4	174	173	+9	IV b
48.660	B	10	.835 s	Ni	4	175	173		III
52.170	A	16	.343	Cr	5	173	172		I
56.475	A	22	.644	Ti	3	169	172	+7	I
64.795	B	17	.965	Cr	3	170	172		III
4673.174	C	7	.347	Fe	4	173	173	+11	

[6] 4447.7. One series of measurements gives .730 for the fractional part of this wave length. The results from many other plates are in good agreement and give the value tabulated. A companion affects the wave length as measured by the interferometer.

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A.O.B.S.λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun–arc	Temperature and pressure classes	
			λ	Iden.	Int.	Obs.	Mean			
4678.171	B	17	.347 s	Cd	3N	176	173			
78.855	B	19	9.027 s	Fe	6	172	173	+9	V	
83.567	A	22	.745 s	Fe	3	178	173	+4		
86.221	A	20	.395 s	Ni	3	174	173		III	
4690.146	A	22	.317 s	Fe?	4	173	173	+8		
4700.164	A	15	.337	(Fe)	4	173	174	+7		d
03.006	B	11	.177 s	Mg	10	171	174		V	
03.817	C	11	.994 s	Ni	3	177	174			
04.956	A	20	5.131	Fe	4	175	174	+9		
09.718	A	13	.896	Mn	2	178	175		III	
15.774	B	13	.946	Ni	4	172	175		II	
18.428	B	13	.601	Cr	3	173	175		III	
21.001	C	5	.179	Fe?	2	178	175			
22.166	A	22	.342 s	Zn	3	176	176			
28.554	B	11	.732	Fe	4	178	176	+7	IV	
33.602	A	19	.779	Fe	4	177	177	+11	IB	a
36.785	C	14	.963	Fe	6	178	178	+12	II	d
41.537	A	18	.718	Fe	3	181	179	+6	V	b
45.808	B	17	.992	Fe	4	184	180	+7	V	b
52.431	C	8	.613	Ni	3	182	181			
54.047	C	12	.225 s	Mn	7	178	182		I	
4761.534	B	9	.718	Mn	3	184	183		III	
66.430	B	9	.621	Mn	4	181	183		III	
72.826	C	8	3.007	Fe	4	181	183	+10	III	b
79.985	C	10	.169	Co	2	184	184		III	
86.820	C	8	7.003	Fe	2	183	185	+14	IV?	b
88.766	A	10	.952	Fe	3	186	185	+9		
4789.659	C	11	.849	Fe	3	190	185	+9	V	
4802.888	A	10	3.072	Fe	2	184	185	+6		
10.539	B	7	.724 s	Zn	3	185	185			
23.516	B	7	.697 s	Mn	5	181	184	+7	I	
24.145	D	8	.325 s	Fe	3	180	184			
32.718	B	9	.905	Fe	3	187	183			
39.551	B	9	.734	Fe	3	183	182	+6		
48.257	D	8	.438		2	181	181			
54.875	A	6	5.059	Fe	1	184	179			
59.751	B	5	.928 s	Fe	4	177	179	+10	III	c5
70.824	B	7	.996	Ni, Cr	3	172	177			
82.154	D	9	.336	Fe	3	182	176	+9		d
85.437	D	7	.620	Fe	3	183	175	+7	V	
4892.867	B	8	3.030	Fe	1	163	175			
4904.424	C	12	.597		3	173	173			
17.239	A	10	.410	Fe	2	171	172			
24.784	A	12	.956 s	Fe	3	172	171	+11	V	b
38.184	A	7	.350	Fe	2	166	171	+10		
38.825	D	7	.997	Fe	4	172	171	+13	IV	d
39.697	B	13	.868	Fe	3	171	171	+11	IB	a
46.401	B	10	.568	Fe	3	167	171	+14	IV	d
50.117	B	13	.291	Fe	2	174	171	+11		d
53.217	C	8	.392	Ni	2	175	171		V?	
62.583	B	12	.751	Fe	2	168	171			
66.102	B	12	.270	Fe	4	168	171	+13	V	d
67.909	C	14	8.080	Fe	3	171	171	+10		e
73.110	C	12	.281 s	Ti, Fe	4	171	171		V	
83.262	B	14	.433	Fe	3	171	171	+14	V	d
4994.140	B	16	.316 s	Fe	3	176	171	+10	IB	a
5001.876	C	15	2.044	Fe	5	168	171	+12	V	d
02.802	A	19	.976	Fe	2	174	171	+10		
14.954	C	14	5.123	Fe	3	169	171	+12	V	d
28.135	A	17	.308	Fe	2	173	171	+ 8		
39.968	B	20	0.138	Ti	3	170	171	+ 9	I	a
48.448	A	13	.612	Fe	3	164	171			
49.834	B	13	0.008 s	Fe	6	174	171	+15	III	a
60.080	A	21	.258 s	Fe	3	178	170			
5067.160	B	20	.336	Fe	3	176	170			

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A.O.B.S.λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden.	Int.	Obs.	Mean		
5068.779	C	15	.944 s	Fe	5	165	169	+13	V d
74.762	C	15	.932	Fe	5	170	169	+14	V e
76.278	B	15	.450	Fe	3	172	169		
79.241	C	14	.409	Fe	4	168	169		IV b
79.749	B	15	.921	Fe	4	172	169	+ 8	IB a
83.351	A	21	.518 s	Fe	4	167	168	+13	IB a
90.787	A	18	.954 s	Fe	5	167	168	+12	
5099.941	A	21	0.108	Ni	2	167	167		V
5109.661	B	17	.827 s	Fe	2	166	167		
15.401	B	16	.566	Ni	2	165	166		
26.204	C	18	.371 s	Fe, Co	2	167	166		
37.394	B	16	.588	Fe	3	164	165	+12	V d
50.852	C	17	1.020 s	Fe	4	168	165	+12	IB a
59.067	B	19	.231 s	Fe	2	164	165		
73.752	A	21	.917 s	Ti	2	165	164	+10	I
85.911	A	20	6.073	Ti	2	162	163		
5198.723	B	21	.888 s	Fe	3	165	162	+11	IV a
5210.396	A	23	.555 s	Ti	3	169	161	+10	I a
17.403	B	21	.552 s	Fe	3	149		+15	V d
25.537	A	23	.695 s	Fe	2	158	155		IA
42.502	A	22	.658 s	Fe	2	156	159	+12	IV a
53.471	A	24	.633 s	Fe	2	162	162		
63.318	A	23	.486	Fe	4	168	165	+13	V d
73.391	C	14	.558 s	Fe, Cr	2	167	167		
5288.536	A	24	.705 s	Fe	2	169	170		
5300.753	A	22	.929 s	Cr	2	176	172		I
07.370	A	23	.541 s	Fe	3	171	173	+10	III? a
22.051	A	14	.227	Fe	3	176	177		
32.909	A	13	3.089 s	Fe	4	180	179	+8	IB? a4
48.327	A	16	.511	Cr	4	184	183		I
65.409	A	16	.596	Fe	3	187	187		V a
79.583	A	14	.775 s	Fe	3	192	192		a
89.487	A	14	.683 s	Fe	3	196	195	+7	
5398.290	A	14	.486	Fe	3	196	197		
5409.799	A	14	0.000 s	Cr	4	201	201		I
15.215	C	11	.416 s	Fe, V	5	201	202		
5432 956	B	14	3.160	Fe	2	204	203		
45.055	A	16	.259	Fe	4	204	204	+13	V e
62.971	A	15	3.174 s	Fe	3	203	204		e
73.909	A	18	4.113	Fe	3	204	204		d
5487.754	B	19	.959 s	Fe	3	205	205	+ 7	
5501.477	A	18	.683 s	Fe	5	206	206	+11	IB a3
12.989	B	18	3.198 s	Ca	4	209	209		III
25.552	A	17	.765	Fe	2	213	212		
34.848	A	22	5.061 s	Fe	2	213	214		
46.516	B	20	.732	Fe	2	216	216		
60.217	A	24	434	Fe	2	217	216		
76.104	A	24	.320 s	Fe	4	216	217		IV d5
5590.125	A	24	.343 s	Ca	3	218	217		III
5601.286	A	22	.505 s	Ca	3	217	217		III
18.640	A	19	.858	Fe	1	218	218		
24.558	A	20	.769 s	Fe, V	4	211	218		IV
41.447	A	18	.667 s	Fe	2	220	218		
55.499	B	18	.715 s	Fe	2	216	217		V
67.525	B	15	.739	Fe	2	214	216		
79.032	A	17	.249 s	Fe	3	217	216		
5690.433	A	15	.646	Si	3	213	215		
5701.557	A	17	.772 s	Fe	4	215	214	+ 9	III?
17.839	A	16	8.055	Fe	4	216	214		
31.772	A	14	.984 s	Fe	4	212	213		
41.856	C	9	2.068 s	Fe	2	212	212		
52.042	C	13	.254 s	Fe	4	212	211		
60.841	B	10	1.052	Ni	2	211	211		IV
72.156	C	10	.364 s	Si	3	208	210		
5783.871	C	11	4.080 s	Cr	3	209	209		III

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A. O. B. S. λ	Probable error	No. obs.	Rowland λ	Rowland Iden.	Rowland Int.	Correction to Rowland Obs.	Correction to Rowland Mean	Sun−arc	Temperature and pressure classes
5797.870	B	9	8.077 s		3	207	209		
5805.226	C	6	.441 s	Ni	4	215	214		V
06.738	D	6	.950 s	Fe	5	212	214		
09.227	B	19	.439 s	Fe	4	212	214		
16.379	C	6	.601 s	Fe	5	222	214	±0	
47.012	D	4	.221	Ni	1	209	213		
48.129	C	14	.342	Fe	3	213	213		
52.235	D	7	.443	Fe	3	208	213		
53.688	A	17	.902 s	Ba	5	214	213	+9	III
55.087	D	4	.300	Fe	1	213	213		
56.101	B	8	.312	Fe	2	211	213		
57.459	B	12	.674 s	Ca	8	215	213	+8	III
57.762	C	6	.976	Ni	3	214	213		IV
59.596	A	25	.809 s	Fe	5	213	213	+3	V
62.368	B	15	.582 s	Fe	6	214	213	+11	V
66.461	A	23	.675	Ti	3	214	213	+8	II
67.573	B	6	.785	Ca	2	212	213		
85.978	D	7	6.193	Air	5	215	215		
87.217	C	4	.445	Air	5	228	215		
91.656	B	4	.878	Air	4	222	215		
92.884	B	19	3.097 s	Ni	4	213	215	+6	II
98.166	B	8	.378 s	Air	4	212	216		
5899.007	C	2	.215	Air	2	208	216		
5901.462	B	12	.682 s	Air	6	220	216		
05.681	A	17	.895 s	Fe	4	214	216	+8	V
08.999	C	2	9.213	Air	3	214	216		
16.257	B	17	.475 s	Fe	3	218	216		
18.441	D	4	.635	Air	4	194	216		
19.052	C	8	.276	Air	5	224	216		
19.645	B	13	.860 s	Air	7	215	216		
24.268	D	5	.490	Air	4	222	216		
27.797	B	15	8.013	Fe	2	216	216		
29.689	C	12	.898	Fe	2	209	216		
30.192	A	16	.406 s	Fe	6	214	216	+11	V
32.092	C	10	.306	Air	5	214	216		
34.665	A	18	.881 s	Fe	5	216	216	+7	V
41.074	C	4	.290	Air	5	216	217		
42.568	C	3	.789	Air	3	221	217		
46.005	C	11	.223	Air	3	218	217		
47.057	D	2	.283	Air	2	226	217		
48.544	B	14	.765 s	Si	6	221	217		
52.726	A	18	.943	Fe	4	217	217		V
53.170	C	6	.386	Ti	1	216	217	+8	II
56.706	B	17	.923 s	Fe	4	217	217		b
75.357	C	9	.575 s	Fe	3	218	218		V b4
76.788	B	17	7.007 s	Fe	4	219	218	+9	V
78.564	C	3	.768	Ti	1	204	218		II
83.689	B	18	.908	Fe	5	219	218	+5	V
84.826	B	19	5.040 s	Fe	6	214	218	+9	IV
87.067	A	18	.290 s	Fe	5	223	218	−3	V
91.382	C	9	.600		2	218	218		
5997.786	C	11	8.002	Fe	2	216	217		
6003.023	B	19	.239 s	Fe	6	216	217	+10	V
05.552	D	6	.770	Fe	1	218	217		
07.321	D	7	.540	Fe	1	219	217		
07.965	A	22	8.186 s	Fe	4	221	217	+6	
08.565	A	21	.785 s	Fe	6	220	217	+7	V
13.497	A	21	.715 s	Mn	6	218	216	+7	III
16.646	B	21	.861 s	Mn	6	215	216	+7	III
21.800	A	22	2.016 s	Mn	6	216	216	+3	
24.069	A	24	.281 s	Fe	7	212	212	+9	V
27.058	A	26	.274 s	Fe	4	216	215	+10	V b4
42.104	B	24	.315 s	Fe	3	211	215	+13	V e
56.005	B	27	.227 s	Fe	5	222	214	+1	V
6065.495	A	28	.709 s	Fe	7	214	214	+12	III b4

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A.O.B.S.λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden.	Int.	Obs.	Mean		
6078.499	A	26	.710 s	Fe	5	211	213	+3	V
79.016	A	23	.227 s	Fe	2	211	213		
82.717	C	17	.930	Fe	1	213	213		
84.121	D	3	.325		0	204	213		
85.255	C	20	.470	Fe-Ti	2	215	213		
86.287	B	17	.500	Ni	1	213	212		V
89.572	C	18	.787	Fe	1	215	212		
90.215	C	12	.429	Fe	2	214	212		
93.649	B	12	.864	Fe	2	215	212		
6096.673	B	17	.880	Fe	3	207	212		
6102.182	A	26	.392 s	Fe	6	210	212	+7	V
02.726	A	22	.937 s	Ca	9	211	212	+6	II
03.207	C	12	.400 s	Fe	4	193	212	+13	V
08.120	A	26	.334 s	Ni	6	214	211	−1	II
11.078	C	15	.290 s	Ni	2	212	211		
16.197	B	17	.397 s	Ni	4	200	211		V
22.226	B	21	.434 s	Ca	10	208	211	+10	II
25.021	C	8	.236		1	215	211		
26.228	B	8	.435	Ti	1	207	210	+11	II
27.912	B	22	8.124	Fe	3	212	210		b
28.983	C	9	9.190	Ni	1	207	210		
36.621	B	21	.829 s	Fe	8	208	210	+4	III b4
37.000	A	24	7.210	Fe	3	210	210		b
37.701	A	21	.915	Fe	7	214	210	+7	III b4
41.729	A	24	.938 s	Fe-Ba	7	209	210		V
45.021	B	14	.228		2	207	210		
49.248	B	17	.458		2	210	210		
51.623	A	24	.834	Fe	4	211	210		
54.229	A	12	.438 s	Na	2	209	210		
55.142	B	16	.350		7	208	210		
57.733	B	25	.945	Fe	5	212	210	+1	V b4
60.750	A	23	.956 s	Na	3	206	210		
61.294	B	21	.503	Ca	4	209	210		III
62.181	C	16	.390 s	Ca	15	209	210	+9	II
63.759	C	4	.968	Ca	3	209	210		III
65.363	B	24	.577	Fe	3	214	210		b
66.440	A	25	.651	Ca	5	211	211		III
69.040	A	25	.249 s	Ca	6	209	211		III
69.563	A	23	.778 s	Ca	7	215	211	+9	III
70.517	B	21	.730	Fe-Ni	6	213	211	+7	V
73.339	A	27	.553 s	Fe	5	214	211		III b4
6175.370	A	23	.584	Ni	3	214	211		V
76.816	A	27	7.027 s	Ni	5	211	212	+3	
80.208	A	26	.420 s	Fe	5	212	212		
86.717	C	13	.928	Ni	2	211	212		V
87.994	A	18	8.210	Fe	4	216	212		
91.181	A	26	.393 s	Ni	6	212	211		I
6191.570	A	20	.779 s	Fe	9	209	211	+11	II b4
6200.320	A	25	.527 s	Fe	6	207	210		IV b4
04.619	D	3	.825	Ni	1	206	210		III
13.436	B	26	.644 s	Fe	6	208	209	+3	III b4
15.147	A	16	.360	Fe	5	213	209		b4
16.359	B	12	.567	V?	1	208	209		
19.286	A	28	.494 s	Fe	6	208	209	±0	III b4
23.986	C	10	4.198	Ni	1	212	209		V
26.740	B	12	.951	Fe	1	211	209		
29.229	B	19	.437	Fe	1	208	210		
30.736	B	25	.943 s	V–Fe	8	207	210		III b4
32.645	A	27	.856	Fe	3	211	210	+1	V
37.322	C	16	.534 s		3	212	210		
38.387	B	14	.598		2	211	210		
40.652	B	20	.863	Fe	3	211	210		
43.114	D	6	.320	V	1	216	210		
43.813	C	12	4.033		2	213	210		
6244.476	C	12	.686		2	210	210		

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A. O. B. S. λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden.	Int.	Obs.	Mean		
6245.621	A	11	.832		1	211	210		
46.328	B	22	.535 s	Fe	8	207	210	+10	V
47.558	B	20	.774	V	2	216	210		
52.562	A	22	.773 s	Fe	7	211	210	+6	III b4
54.254	B	20	.456 s	Fe	5	202	210		III b4
56.366	A	22	.572 s	Ni–Fe	6	206	210		III b
58.110	B	20	.322	Ti	2	212	210	+4	II
58.712	B	19	.927	Ti	3	215	210	+6	II
61.103	A	19	.316 s	Ti	1	213	210	+2	II b4
65.138	A	19	.348 s	Fe	5	210	209	+8	
70.231	A	20	.442	Fe	3	211	209		III b
71.280	C	7	.486	Fe	0	206	209		
78.093	B	23	.303	Air	4	210	208		
78.881	A	8	9.084	Air	2	203	208		
79.102	A	9	.308	Air	3	206	208		
79.897	A	2	0.108	Air	2	211	208		
80.393	A	9	.598	Air	2	205	208		
80.623	C	6	.833	Fe	3	210	208		IA a
81.178	A	14	.387	Air	1	209	208		
81.955	A	15	2.164	Air	2	209	208		
82.730	A	3	.933	Air	2	203	208		
83.797	A	8	4.002	Air	1	205	208		
87.750	A	3	.953	Air	1	203	208		
89.398	C	10	.606	Air	1	208	208		
90.220	A	26	.427	Air	2	207	208		
90.967	C	13	1.184	Fe	4	217	208		e?
92.161	A	26	.373	Air	2	212	208		
92.959	A	26	3.170	Air	3	211	208		
95.178	A	23	.389	Air	3	211	209		
95.959	A	26	6.170	Air	3	211	209		
97.797	A	19	8.007	Fe	5	210	209	+7	III b4
6298.453	A	26	.666	Air	2	213	210		
6299.227	A	26	.436	Air	3	209	210		
6301.505	A	18	.718	Fe	7	213	211	+4	IV
01.998	A	21	.209	Air	2	211	211		
02.497	B	14	.709	Fe	5	212	211	+4	V
02.764	A	16	.975	Air	2	211	211		
05.810	A	20	6.024	Air	2	214	212		
06.564	A	20	.780	Air	2	216	212		
09.887	A	18	0.101	Air	2	214	213		
10.663	A	12	.848	Air	1	215	213		
14.663	B	16	.876	Ni	4	213	213	−3	II
15.314	B	13	.517	Fe	2	203	213		b
15.814	C	8	6.028	Fe	1	214	213		
18.025	B	17	.239	Fe	6	214	214	+7	III b4
18.710	A	4	.919		1	209	214		
22.693	B	19	.907	Fe	4	214	214	+5	III b
27.604	C	13	.820	Ni	2	216	215		II
30.098	B	12	.316	Cr	1	218	215		IA
30.852	C	11	1.067	Fe	2	215	215		
35.337	A	20	.554	Fe	6	217	215	+12	III b4
36.830	A	20	7.048	Fe	7	218	215	+6	V
38.874	B	5	9.096	Fe	2	212	215		
39.115	D	5	.335	Fe	2	220	215		
44.157	A	19	.371	Fe	4	214	215		III b
47.087	D	10	.310		2	223	215		
55.036	B	20	.246	Fe	4	210	215	+5	III b
58.685	B	18	.898	Fe	6	213	214		IA
62.869	B	7	3.090	Cr-Fe	2	221	214		
78.256	C	11	.468	Ni	2	212	211		IV
80.751	C	19	.958	Fe	4	207	211	+5	V b
6393.611	B	19	.820 s	Fe	7	209	211	+10	III b4
6400.005	B	17	.217 s	Fe	8	212	211	+3	III
00.326	C	13	.538 s	Fe	2	212	211		
6408.026	B	20	.233 s	Fe	5	207	211	+8	V

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A. O. B. S. λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden.	Int.	Obs.	Mean		
6411.656	B	20	.865 s	Fe	7	209	211	+8	IV
14.995	C	9	5.199		1	204	211		
16.930	C	11	7.133	Fe	1	203	211		
19.954	A	20	0.169 s	Fe	4	215	211	+5	V
21.360	B	21	.570 s	Fe	7	210	211	+10	III b
30.854	B	21	1.066 s	Fe	5	212	211	+10	III b4
32.686	B	13	.895	Fe	1	209	211		
39.085	A	22	.293 s	Ca	8	208	211	+13	II
49.820	B	23	0.033 s	Ca	6	213	212	+10	II
55.605	B	23	.820	Ca	2	215	213	+7	II
56.391	B	22	.603	Fe	3	212	213		
62.559	D	3	.784 s	Ca	5	225	214	−6	II
62.733	D	3	.965	Fe	3	232	214	+8	b
69.189	B	15	.408	Fe	2	219	216		V
71.668	A	23	.885 s	Ca	5	217	216	+8	II
75.632	D	7	.846	Fe	2	214	217		IV b
80.057	A	22	.285 s	Air	1	218	218		
81.875	B	25	2.098	Fe	3	223	218		IV
82.810	B	13	3.027	Ni	1	217	219		V
83.239	A	8	.468	Air	1	229	219		
86.777	C	3	7.005	Air	0	228	219		
6490.790	A	29	1.015	Air	1	225	220		
91.574	C	13	.800	Air	1	226	220		
92.903	A	13	3.130	Air	1	227	221		
93.789	A	31	4.004 s	Ca	6	215	221	+9	II
94.995	B	31	.213 s	Fe	8	218	221	+14	II b4
96.469	A	22	.688	Fe	2	219	222	+5	
96.911	A	33	7.128	Fe	4	217	222		
98.945	A	28	9.168	Fe	1	223	222		
6499.654	A	32	.880 s	Ca	4	226	222	+6	II
6504.193	D	3	.415	Air	0	222	223		
08.596	D	5	.826	Air	0	230	224		
14.730	A	28	.956	Air	2	226	226		
16.084	A	20	.311 s	Fe	2	227	226		
18.374	B	20	.599 s	Fe	2	225	227		b
23.839	B	12	4.080	Air	1	241	229		
32.352	C	13	.595 s	Air	1	243	232		
33.946	C	15	4.172 s	Air	2	226	232		
43.904	A	26	4.140	Air	2	236	235		
46.247	A	28	.479 s	Ti-Fe	6	232	235	+8	III b
47.692	B	10	.945	Air	0	253	235		
48.619	B	15	.855	Air	1	236	236		
52.626	B	20	.865 s	Air	1	239	236		
55.463	C	8	.700		1	237	236		
64.197	C	5	.450	Air	0	253	237		
69.223	A	28	.460 s	Fe	5	237	238	+9	V
72.083	C	11	.330	Air	1	247	238		
72.786	B	15	3.030	Ca	1	244	238		IA
74.234	C	13	.468 s	Fe	1	234	238		
75.022	C	12	.270 s	Fe	2	248	238		b
86.317	C	13	.550	Ni	1	233	239		II
92.926	A	29	3.161 s	Fe	6	235	240	+13	III b
93.881	A	29	4.121 s	Fe	4	240	240	+6	
6597.561	B	19	.807	Cr? Fe?	1	246	240		
6604.594	B	17	.837	Fe	1	243	240		
09.118	A	27	.360 s	Fe	3	242	241		IV b
27.551	C	12	.797	Fe	0	246	242		
33.753	A	27	.995 s	Fe	2	242	243	+1	V
43.638	A	31	.876 s	Ni	5	238	243	−3	I
63.451	A	30	.701 s	Fe	3	250	245		IV b
6677.996	B	31	8.235 s	Fe	5	239	246	+9	III b4
6703.569	C	17	.820 s	Fe	1	251	248		
05.108	C	19	.352 s	Fe	1	244	248		
15.387	D	4	.635	Cr? Fe?	1	248	248		
6717.686	B	20	.940 s	Ca	5	254	249		III

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A. O. B. S. λ	Probable error	No. obs.	Rowland λ	Rowland Iden.	Rowland Int.	Correction to Rowland Obs.	Correction to Rowland Mean	Sun−arc	Temperature and pressure classes
6721.849	C	10	2.096 s		2	247	249		
26.667	C	14	.925 s	Fe	2	258	249		
33.157	C	9	.410	Fe	1	253	249		
50.161	B	21	.407 s	Fe	3	246	250	+10	IV b
52.708	C	11	.965 s	Fe	1	257	250		
67.781	B	23	8.028 s	Ni	4	247	250	+3	I
6772.325	C	17	.568 s	Ni	2	243	251		V
6806.849	C	10	7.103 s	Fe	1	254	252		
10.268	B	21	.519 s	Fe	3	251	252		
20.375	B	13	.630 s	Fe	2	255	252		
28.600	B	21	.850 s	Fe	2	250	253		V
6839.826	C	8	.086	Fe	1	250	253		
41.344	A	23	.598 s	Fe	3	254	253		V
42.690	C	9	.945	Fe	1	255	253		
43.658	B	21	.913 s	Fe	3	255	253		V
55.169	B	24	.419 s	Fe	3	250	254	+10	V
57.250	D	4	.515	Fe	0	265	254		
58.154	A	24	.415	Fe	2	261	254		
62.496	D	4	.760	Fe	1	264	254		
67.221	A	26	.457 s	Air	6	236	254		
67.545	A	29	.800 s	Air	5	255	254		
69.936	C	4	.116	Air	7	180	254		
70.945	A	17	1.180 s	Air	8	235	242		
71.289	A	18	.532 s	Air	10	243	242		
72.247	A	31	.486 s	Air	11	239	242		
72.843	A	31	3.080 s	Air	12	237	243		
73.795	A	31	4.037 s	Air	12	242	243		
74.652	A	31	.899 s	Air	13	247	243		
75.592	A	31	.830 s	Air	13	248	243		
76.718	A	31	.958 s	Air	13	240	243		
77.637	A	30	.882 s	Air	12	245	243		
79.044	A	31	.288 s	Air	12	244	243		
79.929	A	34	0.172 s	Air	6	243	243		
83.833	A	31	4.076 s	Air	10	243	244		
85.756	A	31	6.000 s	Air	11	244	244		
86.744	B	31	.990 s	Air	12	246	244		
88.948	A	31	9.192 s	Air	13	244	245		
89.903	A	31	0.151 s	Air	14	248	245		
92.372	A	31	.618 s	Air	14	246	245		
93.310	A	31	.560 s	Air	15	250	245		
96.040	A	30	.289 s	Air	14	249	246		
96.965	A	31	7.208 s	Air	15	243	246		
6899.955	A	31	0.199 s	Air	14	244	246		
6900.869	A	31	1.117 s	Air	15	248	246		
04.118	A	31	.362 s	Air	14	244	246		
05.025	A	31	.271 s	Air	14	246	246		
08.535	A	30	.783 s	Air	13	248	247		
09.432	A	31	.676 s	Air	13	244	247		
13.201	A	33	.448 s	Air	11	247	247		
14.092	A	32	.337 s	Air	11	245	247		
14.573	B	20	.823 s	Ni	4	250	247		
16.686	B	21	.948 s	Fe	2	262	248		
18.121	A	33	.370 s	Air	9	249	248		
19.002	A	33	9.250 s	Air	9	248	248		
23.302	A	31	.553 s	Air	9	251	249		
24.173	A	31	.427 s	Air	9	254	249		
28.729	A	21	.977 s	Air	4	248	249		
29.595	B	13	.840 s	Air	4	245	249		
33.615	C	5	.887	Fe	2	272	250		
33.804	D	7	4.075	Air	2	271	250		
34.422	B	13	.670 s	Air	2	248	250		
35.280	B	14	.530 s	Air	2	250	250		
37.703	B	19	.957	Air	2	254	251		
39.618	B	13	.875	Air	2	257	251		
6940.190	B	6	.436	Air	2	246	251		

TABLE 1.—*A. O. B. S. solar wave lengths*—Continued

A.O.B.S.λ	Probable error	No. obs.	Rowland			Correction to Rowland		Sun−arc	Temperature and pressure classes
			λ	Iden.	Int.	Obs.	Mean		
6942.152	A	5	.402	Air	2	250	251		
43.802	B	15	4.060	Air	3	258	251		
45.214	B	17	.477	Fe	5	263	252	+10	IV
47.534	B	14	.782 s	Air-Fe	5	248	252		
51.248	B	13	.518	Fe	1	270	252		
56.426	C	7	.660 s	Air	4	234	253		
59.452	A	16	.704 s	Air	3	252	253		
61.260	A	16	.515 s	Air	4	255	254		
78.403	C	3	.670 s	Cr	1	267	257		
78.862	B	13	9.120	Fe	2	258	257	+4	IV
86.580	C	14	.833 s	Air	3	253	259		
88.518	D	4	.805	Fe	0	287	259		
88.986	B	14	9.237 s	Air	3	251	259		
90.373	C	7	.632	Air	1	259	259		
93.517	C	10	.776	Air	2	259	260		
94.107	D	7	.360	Air	2	253	260		
98.963	C	12	9.223	Air	2	260	261		
6999.882	C	9	0.155 s	Fe	1	273	261		
7003.574	C	4	.837	Si?	1	263	262		
04.747	C	12	.995	Air	2	248	262		
11.330	D	11	.590 s	Air	2	260	263		
22.956	B	8	3.230 s	Fe	2	274	265		
23.504	C	10	.770 s	Air	2	266	266		
27.479	B	10	.740 s	Air	2	261	266		
34.909	C	8	5.170 s		2	261	267		
38.219	C	9	.500 s	Fe	1	281	267		
39.796	B	11	.053 s	Air	1	267	268		
50.858	D	6	1.115	Air	0	257	269		
56.999	C	4	7.260	Air	0	261	269		
7084.981	C	4	5.265	Co	2	284	271		
7122.206	D	5	.484	Ni	4	278	275		IV
30.928	D	5	1.204	Fe	3	276	276	±0	
32.988	D	5	3.263	Fe	1	275	276		
7148.159	D	5	.435	Ca	3	276	277	+14	II

TABLE 2.—*Corrections to Rowland's wave lengths (3590–7142)*

Wave length	Correction	Wave length	Correction	Wave length	Correction
3590–3650	−0.141A	4165–4176	.163	4567–4587	.172
3651–3940	.140	4177–4187	.162	4588–4597	.173
3941–3952	.141	4188–4199	.161	4598–4634	.174
3953–3960	.142	4200–4213	.160	4635–4648	.173
3961–3970	.143	4214–4244	.159	4649–4671	.172
3971–3975	.144	4245–4295	.158	4672–4690	.173
3976–3978	.145	4296–4310	.159	4691–4708	.174
3979–3985	.146	4311–4320	.160	4709–4721	.175
3986–3992	.147	4321–4330	.161	4722–4729	.176
3993–3997	.148	4331–4357	.162	4730–4734	.177
3998–4000	.149	4358–4373	.161	4735–4738	.178
4001–4007	.150	4374–4378	.160	4739–4744	.179
4008–4018	.151	4379–4397	.159	4745–4749	.180
4019–4024	.152	4398–4414	.160	4750–4753	.181
4025–4028	.153	4415–4426	.161	4754–4760	.182
4029–4037	.154	4427–4435	.162	4761–4773	.183
4038–4090	.155	4436–4488	.163	4774–4785	.184
4091–4116	.156	4489–4500	.164	4786–4815	.185
4117–4123	.155	4501–4514	.165	4816–4825	.184
4124–4129	.154	4515–4523	.166	4826–4835	.183
4130–4135	.153	4524–4535	.167		
4136–4141	.152	4536–4550	.168	4836–4842	.182
4142	(1)	4551–4558	.169	4843–4848	.181
4143–4152	.163	4559–4562	.170	4849–4853	.180
4153–4164	.164	4563–4566	.171	4854–4860	.179

[1] Discontinuity.

TABLE 2.—*Corrections to Rowland's wave lengths (3590–7142)*—Continued

Wave length	Correction	Wave length	Correction	Wave length	Correction
4861–4865	−0.178	5497–5502	.206	6513–6516	.226
4866–4877	.177	5503–5506	.207	6517–6519	.227
4878–4884	.176	5507–5511	.208	6520–6522	.228
4885–4892	.175	5512–5515	.209	6523–6524	.229
4893–4900	.174	5516–5519	.210	6525–6528	.230
4901–4907	.173	5520–5524	.211	6529–6531	.231
4908–4920	.172	5525–5528	.212	6532–6534	.232
4921–5050	.171	5529–5532	.213	6535–6537	.233
5051–5067	.170	5533–5537	.214	6538–6541	.234
5068–5080	.169	5538–5543	.215	6542–6547	.235
5081–5095	.168	5544–5565	.216	6548–6553	.236
5096–5110	.167	5566–5604	.217	6554–6566	.237
5111–5130	.166	5605–5650	.218	6567–6581	.238
5131–5160	.165	5651–5660	.217	6582–6592	.239
5161–5175	.164	5661–5681	.216	6593–6604	.240
5176–5188	.163	5682–5700	.215	6605–6617	.241
5189–5200	.162	5701–5725	.214	6618–6631	.242
5201–5212	.161	5726–5737	.213	6632–6643	.243
5218	(1)	5738–5748	.212	6644–6656	.244
5224–5225	.155	5749–5762	.211	6657–6669	.245
5226–5230	.156	5763–5772	.210	6670–6681	.246
5231–5234	.157	5773–5795	.209	6682–6695	.247
5235–5238	.158	5805–5819	.214	6696–6718	.248
5239–5242	.159	5820–5870	.213	6719–6738	.249
5243–5246	.160	5871–5882	.214	6739–6767	.250
5247–5250	.161	5883–5894	.215	6768–6794	.251
5251–5254	.162	5895–5937	.216	6795–6822	.252
5255–5258	.163	5938–5972	.217	6823–6847	.253
5259–5262	.164	5973–5991	.218	6848–6869	.254
5263–5266	.165	5992–6007	.217	6870	(1)
5267–5271	.166	6008–6024	.216	6870–6872	.242
5272–5275	.167	6025–6044	.215	6873–6879	.243
5276–5280	.168	6045–6066	.214	6880–6886	.244
5281–5286	.169	6067–6084	.213	6887–6895	.245
5287–5291	.170	6085–6104	.212	6896–6907	.246
5292–5297	.171	6105–6123	.211	6908–6913	.247
5298–5302	.172	6124–6162	.210	6914–6920	.248
5303–5307	.173	6163–6176	.211	6921–6929	.249
5308–5311	.174	6177–6189	.212	6930–6937	.250
5312–5316	.175	6190–6196	.211	6938–6943	.251
5317–5320	.176	6197–6203	.210	6944–6952	.252
5321–5324	.177	6204–6240	.209	6953–6959	.253
5325–5329	.178	6241–6263	.210	6960–6964	.254
5330–5333	.179	6264–6272	.209	6965–6969	.255
5334–5338	.180	6273–6292	.208	6970–6974	.256
5339–5342	.181	6293–6297	.209	6975–6980	.257
5343–5346	.182	6298–6300	.210	6981–6985	.258
5347–5350	.183	6301–6303	.211	6986–6990	.259
5351–5354	.184	6304–6307	.212	6991–6996	.260
5355–5358	.185	6308–6315	.213	6997–7001	.261
5359–5361	.186	6316–6327	.214	7002–7006	.262
5362–5365	.187	6328–6355	.215	7007–7010	.263
5366–5369	.188	6356–6361	.214	7011–7016	.264
5370–5373	.189	6362–6368	.213	7017–7022	.265
5374–5376	.190	6369–6375	.212	7023–7028	.266
5377–5379	.191	6376–6444	.211	7029–7036	.267
5380–5383	.192	6445–6453	.212	7037–7049	.268
5384–5386	.193	6454–6459	.213	7050–7061	.269
5387–5389	.194	6460–6463	.214	7062–7073	.270
5390–5393	.195	6464–6467	.215	7074–7085	.271
5394–5396	.196	6468–6473	.216	7086–7096	.272
5397–5399	.197	6474–6477	.217	7097–7107	.273
5400–5402	.198	6478–6482	.218	7108–7118	.274
5403–5405	.199	6483–6486	.219	7119–7129	.275
5406–5408	.200	6487–6490	.220	7130–7141	.276
5409–5412	.201	6491–6495	.221	7142	.277
5413–5422	.202	6496–6499	.222		
5423–5438	.203	6500–6504	.223		
5439–5487	.204	6505–6508	.224		
5488–5496	.205	6509–6512	.225		

[1] Discontinuity.

WASHINGTON, May 23, 1928.