The Stark Effect in the Molecular Spectrum of Hydrogen

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IV—The Stark Effect in the Molecular Spectrum of Hydrogen

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[PLATES 2–4]

INTRODUCTION

In considerations of the effect of electric fields on band spectra one finds attention focussed on the secondary spectrum of hydrogen, which alone shows appreciable Stark effect. Following some rather limited observations by early writers,* KIUTI† has given a more extensive analysis under low dispersion but high fields. This has remained the standard reference in all but the blue and violet regions where MACDONALD‡ has given better resolutions, and has succeeded in correlating some of the observed patterns with theory.

The rapid advances made by RICHARDSON and others in the classification of the normal H_2 spectrum together with the recent publication by MACDONALD§ of a complete theory for the Stark effect in H_2 have increased enormously the interest attached to further experimental information. In addition, the Stark patterns have been shown to depend upon the rotational quantum numbers, so that the possibility of obtaining new information which may be of assistance in the analysis of the spectrum must not be overlooked.

In the present investigation a large stigmatic concave grating spectrograph has been employed to obtain a more complete and accurate analysis of the region between H_β and H_α, where nearly the entire strength of the triplet bands is known to be concentrated, and which contains also a large proportion of the singlets. Despite the high dispersion, it has been found possible to obtain sufficient intensity to record practically all of the lines given in the tables of GALE, MONK, and LEE,|| with the exception of some of the faintest near H_β. Some 350 lines have been

* TAKAMINE and YOSHIDA, 'Mem. Coll. Sci. Kyoto,' vol. 2, p. 137 (1917) and vol. 2, p. 321 (1917); TAKAMINE and KOKUBU, *ibid.*, vol. 3, p. 271 (1918); NITTA, *ibid.*, vol. 2, p. 350 (1917).

† 'Jap. J. Phys.,' vol. 1, p. 29 (1922) and vol. 4, p. 13 (1925).

‡ 'Proc. Roy. Soc.,' A, vol. 123, p. 103 (1929), and vol. 131, p. 146 (1931).

§ 'Proc. Roy. Soc.,' A, vol. 138, p. 183 (1932).

|| 'Astrophys. J.,' vol. 67, p. 89 (1928).

found to be displaced in a field of about 90,000 volts per cm. A number of interesting regularities appear, and in general, the patterns observed fall within the restrictions of theory.

Experimental

The light source was of the Lo Surdo type, with slight modifications from the design of Foster.* The arrangement of the cathode parts is indicated in fig. 1. A was a lavite plug sealed in the pyrex glass, and drilled as shown to accommodate the aluminium cathode B. The latter was about 3 mm in diameter, and was firmly held by a set screw in the brass collar C which in turn was pressed against the lavite by the coil spring D. At its far end (not shown) the brass rod E was held by a tungsten rod sealed in the glass ; this also served to make the necessary electrical connection. The hole F was 1·3 mm in diameter, and widened at G as indicated. This widening had the effect of concentrating the discharge toward the centre ; it increased the light intensity and also stabilized the discharge. The light escaped through a narrow slit H, about 0·5 mm wide and 2 mm long, and passed through a Wollaston prism which separated the Stark components polarized parallel to the field from those polarized perpendicular to the field. The two images were then focussed upon the slit of the spectrograph by a suitable condensing lens.

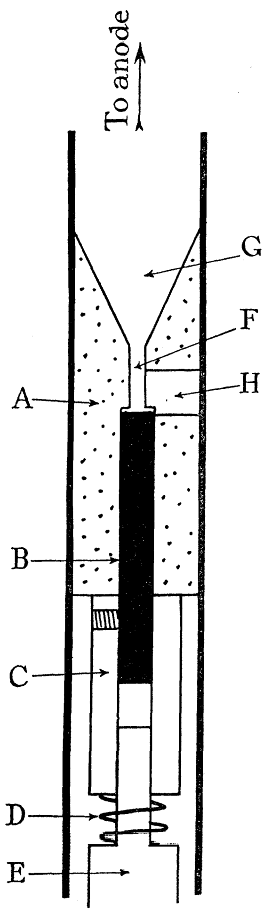


Fig. 1

To enhance the secondary spectrum as much as possible a stream of fresh hydrogen was drawn continuously through the discharge tube. The gas was generated electrolytically and entered the vacuum system through a long capillary ; it was then purified by passage through phosphorus pentoxide and through a trap immersed in liquid air. It entered the discharge tube behind the lavite plug and streamed past the cathode toward the anode and then out to the pump.

The tubes were run at a potential of about 12,000 volts, supplied by a Kipp and Sonen proton apparatus fitted with large condensers made by the General Electric Company. The pressure (about 1 mm of mercury) was such as to limit the current to 5 mA.

A fast 28-foot grating in stigmatic mounting was used to photograph the spectrum. The dispersion in the first order was 3·8 A per mm at H_α. Eastman Hypersensitive Panchromatic plates were used ; they were sensitized in ammonia before exposure.

The nature of the investigation made the simultaneous requirements of high dispersion, high field strength, and intense light exceptionally stringent ; this was found to increase the experimental difficulties very materially.

* 'Proc. Roy. Soc.,' A, vol. 114, p. 47 (1927).

Experimental Results

Two plates which showed the best combination of light intensity with high field strength were selected for detailed measurement. One plate covers the range λ 4860–5780 (ν 20560–17290), and the other the range λ 5780–6620 (ν 17290–15100). These plates show slightly different maximum field strengths, so that in the following tables the displacements of all lines with wave numbers less than 17290 have been measured at F = 89,700 volts per cm, while those with wave numbers greater than 17290 have been measured at F = 92,500 volts per cm. This means that the displacements in the latter set of lines may be appreciably higher than they would have been if measured at the same field strength as the former set. This difference is often insignificant.

The measurements of the displaced lines are set out in the following tables. Lines which have been classified in published works by Richardson and his co-workers and by Sandeman are arranged in their various band systems. The rotational numbers given by the classifiers for the lines in all of the singlet systems except those ending in $2p^1\pi$ have been reduced by 1; this means that the lines in the tables are numbered throughout according to the K-values of the final levels. The wave-lengths, wave numbers, and intensities are for the most part those of Gale, Monk, and Lee; those taken from other tables are marked as follows:— A, Allibone*; D, Deodhar†; M, Merton and Barratt‡; T, Tanaka§. A few lines among those in the table of unclassified displaced lines have not been reconciled with any given in the foregoing wave-length tables; their wave-lengths have been roughly determined from neighbouring lines, and are marked S. They may be new lines brought into existence by the electric field, but they exist at very low field strengths.

It is important from the theoretical standpoint also to know which lines are *undisplaced* in an electric field of this intensity. Classified lines of this type are accordingly given explicitly in the tables. Any classified line in the spectral region covered which does not appear in the tables may, therefore, be concluded to be too faint or too confused by neighbouring lines to enable one to draw any definite conclusions as to its behaviour in the field. Undisplaced unclassified lines are not given explicitly; broadly speaking, they include all of the remaining lines given by Gale, Monk, and Lee with an intensity of 0 or more, except in the region λ 4860–5500 where (owing principally to lower plate sensitivity) any lines with intensity 1 or less must be regarded as doubtful. Unresolved lines are bracketed. For patterns, visual estimates of the relative intensities of the components are given by the figures in Roman numerals; the scale runs from I (very faint) to V (black). In the case of blends, the relative intensities give an indication of the origin of the

* 'Proc. Roy. Soc.,' A, vol. 112, p. 196 (1926).
† 'Proc. Roy. Soc.,' A, vol. 113, p. 420 (1926).
‡ 'Phil. Trans.,' A, vol. 222, p. 369 (1922).
§ 'Proc. Roy. Soc.,' A, vol. 108, p. 592 (1925).

components. The letter *d* means "diffuse"; *c* means "confused." When used with undisplaced lines, *c* means that the line is a partner in a blend, and does not strictly preclude the possibility of a small displacement. Sometimes a component which is definite at higher fields is so faint at zero field that there is some doubt as to its identification; such components are marked *a*.

The accuracy of the measurement of displacements depends to a large extent upon the appearance of the line. For sharp, strong lines the displacements are given to the second decimal place in cm^{-1}; they are correct within about $\pm 0\cdot07$ cm^{-1}. Most of the displacements are given to the first decimal place only, and are believed to be correct within $\pm 0\cdot1$ cm^{-1}, though for *c*- and *d*-components and blends the possible error is greater. A few could not be measured to within 1 cm^{-1}; no decimal places are given for these.

$3p\ {}^3\Pi_{ab}$—$2s\ {}^3\Sigma$* (3³ P — 2³ S, or H_α bands)

Band	Line	ν	I.	Displacements in cm^{-1}: Parallel			Perpendicular		
0′—0″	P′ 2	16479·06	7	− 2·50 III − 0·46 I	—	—	− 2·5 II	0 I	—
	P′ 3	16399·79	10	− 2·78 IV − 0·50 III	—	—	− 3·30 III − 1·67 III	0 I	—
	P′ 4	16314·99	4	—	—	+ 1·1			+ 0·7
	P′ 5	16225·06	8	—	0 III	+ 4·6 IV*c* + 2·0 II*c*	— —	0 III 0 III	+ 4·35 III + 2·24 III
	P′ 7	16031·77 16032·26	2 1	—	—	+ 1·1	—	—	+ 1·1
	Q 1	16611·43	10	− 8·1 V − 0·54 II	—	—	− 8·1 III − 0·96 V	—	—
	Q 2	16596·37	10	− 1·03 III	—	+ 0·76 V	− 1·17 IV	—	+ 0·76 II
	Q 3	16573·94 16575·12	10 5	− 1·5 V	—	+ 1·6 III + 0·6 IV	− 1·1 IV	—	+ 1·6 IV
	Q 4	16544·31	2	− 3·28 III − 0·95 II	—	+ 0·76 I	—	—	+ 1·5 II wide + 0·6 I
	Q 5	16507·71	2	− 3·71 III − 2·31 III	—	—	− 2·7 I*d*	0 III	—
	Q 6	16464·49	0	. . . . . confused			− 0·7*a*	—	—
	R′ 0†	16678·57	10	− 12·6 IV rough − 2 I*d*		—	− 2·05 IV	—	—
	R′ 1‡	16730·55	10	− 6·55 V	—	+ 0·75 V	− 6·95 III − 4·01 IV	—	+ 0·88 V
	R′ 2	16774·42 16774·97 16772·74	6 4 1	− 2·8 IV	—	—	− 2·8 II	0 IV	—

$3p\,{}^3\Pi_{ab} - 2s\,{}^3\Sigma$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Displacements in cm⁻¹ Perpendicular		
0′—0″	R′ 3	16809·70	6	− 5·16 III	—	+ 6·04 III	− 5·1 I ?	—	+ 6·45 II
				− 2·6 II ?		+ 3·06 II	− 2·9 I ?		+ 3·95 II
						+ 1·5 I ?	− 0·7 I ?		+ 0·83 III
	R′ 5	16853·01	1	—	0 III	+ 2·0 III	—	0 III*c*	—
		16852·22	3						
	R′ 6§	16860·14	0	. . . . . .confused	. . . . . .		—	—	+ 4 ? ?*c*

Undisplaced : P′ 6, 16130·47 (2) ; R′ 7, 16856·91 (1).

* Richardson and Das, ‘ Proc. Roy. Soc.,’ A, vol. 122, p. 688 (1928).
† Also R 4 of 3′—3″ ($3d\,{}^3\Pi - 2p\,{}^3\Pi_{ab}$)
‡ Also R 1 of 2′—2″ ($3d\,{}^3\Pi_a - 2p\,{}^3\Pi_{ab}$)
§ Also P′ 1 of 1′—1″ ($3s\,{}^3\Sigma_b - 2p\,{}^3\Pi_{ab}$)

Band	Line	ν	I.	Parallel			Perpendicular		
1′—1″	P′ 3	16126·19	10	− 2·31 V	0 V	—	− 2·31 V	0 V	—
	P′ 4	16039·18	5	− 4·56 II	0 II	—	− 4·8 I ?*d*	0 II	—
				− 2·50 II			− 2·9 I*		
				− 1·74 II					
	Q 1	16330·59	10	—	0	—	− 0·37	—	—
	Q 2	16316·05	6	− 1·41	—	—	− 1·18	—	—
	Q 3	16294·37	10	− 2·8 V	—	+ 0·2 V	− 2·8 II	—	+ 1·5 IV
		16295·02	3						+ 0·2 V
	Q 4	16265·75	3	− 3·23	—	—	− 0·61	—	—
	Q 5	16230·41	2	− 2·9	—	—	− 0·8	—	—
	R′ 1	16440·72	10	− 2·44 V	0 II	—	− 2·13 III	0 IV	—
	R′ 2†	16476·10	7	− 4·41 III	—	—	− 2·92 II	—	+ 0·38 III
				− 2·92 IV					
				− 1·8 I					

Undisplaced : P′ 2, 16203·93 (7) ; R′ 0, 16393·70 (9) ; R′ 3, 16501·67 (00).

* Other components exist, but they are too diffuse to measure.
† Also R 3 of 3′—3″ ($3d\,{}^3\Pi_b - 2p\,{}^3\Pi_{ab}$)

Band	Line	ν	I.	Parallel			Perpendicular		
2′—2″	P′ 2	15941·22	5	− 1·78	—	—	− 1·78	—	—
	P′ 3	15870·10	10	− 1·3 IV	—	+ 0·81 V	− 1·30 IV	—	+ 0·81 IV
	P′ 5	15712·79	6	− 0·49	—	—	− 0·49	—	—
	P′ 6	15626·94	1	− 1·9 III	—	—	− 1·9 II	0 II	—
				− 0·8 I ?					
	Q 1	16060·31	10	− 1·5	—	—	− 1·4	—	—
	Q 2	16046·28	7	− 2·17 IV	—	—	− 2·17 II	—	—
				− 0·69 III			− 0·48 IV		
	Q 3	16025·36	10	− 2·46 V	—	—	− 2·43 II	—	—
				− 1·05 V			− 0·81 V		
	Q 4	15997·73	2	− 2·0 III	—	—	− 1·7 I	—	—
				wide			− 0·77 III		
	Q 5	15963·63	2	− 2·5 IV	—	—	− 2·4 I	—	—
				wide			− 0·99 III		

$3p\,^3\Pi_{ab} - 2s\,^3\Sigma$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Displacements in cm⁻¹ Perpendicular		
2′—2″	R′ 0	16121·52	8	− 1·43	—	—	− 1·73	—	—
	R′ 1	16168·95	10	—	—	+ 1·0 V wide	− 1·49 IV	—	+ 0·71 III
	R′ 2	16208·92	4	—	—	+ 0·38	—	0	—
	R′ 3	16240·81	5	− 0·40	—	—	0·40	—	—
	R′ 4	16263·87	1	—	—	+ 0·4	—	—	+ 0·4 *c*

Undisplaced: P′ 4, 15793·89 (5) *c*.

Band	Line	ν	I.	Parallel			Perpendicular		
3′—3″	P′ 3	15621·96	10	− 1·12	—	—	− 1·12	—	—
	P′ 4	15549·47	3	− 0·94	—	—	− 0·94	—	—
	Q 2	15787·23	5	− 0·41 IV	—	+ 1·37 II	− 0·41 II	—	+ 1·73 IV
	Q 3	{15767·10 15768·26	7 0	− 3·1 I	0 IV	+ 1·9 III	—	0 II	+ 3·3 III + 1·9 II
	Q 4*	15740·49	1	—	—	+ 2·2 *c*	—	—	+ 5·1
	R′ 0	15859·86	5	− 5·2 II*a*	0 I ?	—	− 3·2 I*a*	0 I ?	+ 1·7 I*a*
	R′ 1	15905·53	10	− 1·35	—	—	− 1·05	—	—
	R′ 2	15943·20	3	− 1·03	—	—	− 0·79	—	—

Undisplaced: Q 1, 15800·76 (10); Q 5, 15707·53 (1); R′ 3, 15973·65 D; P′ 5, 15473·43 D.

* Also P 4 of 4′ ?—1″ ($2s\,^1\Sigma - 2p\,^1\Sigma$).

Band	Line	ν	I.	Parallel			Perpendicular		
4′—4″	Q 1	15552·37	10	− 0·97	—	—	− 0·70	—	—
	Q 2	15539·38	3	− 1·53 III − 0·27 I	—	+ 6·5 I	—	0 III	+ 6·5 I
	Q 3	15520·05	3	− 1·76 III − 0·68 II	—	—	—	0	—
	Q 4	15494·65	0	− 1·2 *d*	—	—	− 0·6	—	—

Undisplaced: Q 5, 15463·12 (0) M.

5′—5″ Undisplaced: Q 1, 15315·91 (3); Q 3, 15285·11 (2).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—0″	P′ 2	18718·52	4	. . . . . diffuse			—	0	—
	P′ 3	{18631·03 18632·68	7 0	—	0 I*c*	+ 1·3 III*c*	—	0 I*c*	+ 1·3 III*c*
	Q 1	{18851·66 18851·17	9 4	− 0·8 IV	—	—	− 2·0	—	—
	Q 2	18830·58	5	− 2·0	—	—	− 2·0	—	—
	Q 3*	18799·23	5	− 1·2	—	—	—	—	+ 5 *c*
	Q 4	18757·83	1	?	—	?	—	0	—
	Q 5	18706·54	1	. . . . . . diffuse			—	0	—
	R′ 1	18961·78	10	− 2·52 III	0 II	—	− 2·52 II	0 IV	—
	R′ 2	18990·67	2	—	—	+ 0·4	—	—	+ 0·4

Undisplaced: R′ 0, 18918·02 (9).

* Also R 2 of 0′—0″ ($4d\,^1\Delta_b - 2p\,^1\Pi$).

$3p\,^3\Pi_{ab} - 2s\,^3\Sigma$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
2′—1″	P′ 2*	18320·06	6	− 1·7	—	—	− 2·0	—	—
	P′ 3†	18239·51	10	− 1·66 II	—	+ 0·91 IV	− 1·66 IV	—	+ 0·91 IV
	P′ 5	18054·39	3	− 0·3 V	—	—	− 0·3 V	—	+ 0·5 III
		18053·90	10						
	Q 1	18445·44	10	− 4·8 I ?	—	—	− 1·54 V	—	+ 4·3 I ?
				− 1·69 V					
	Q 2‡	18423·06	8	− 16 II wide	—	—	− 16 I ?	—	
				− 4·8 I*d*			− 12·2 III		
							− 1·11 I		
	Q 3	18394·77	10	− 2·89 IV	—	—	− 1·68 ?II	—	—
				− 1·68 III			− 0·88 V		
	Q 4	18354·75	2	− 3·4 *d*	—	—	− 1·1	—	—
	Q 5	18305·25	2	− 3·3 *d*	—	—	− 1·6	—	—
	R′ 0	18509·78	8	− 1·7	—	—	− 2·1	—	—
	R′ 1	18554·05	10	− 2·0 IV*c*	—	—	− 2·00 IV	—	+ 0·45 IV
	R′ 3	18610·24	4	− 0·3	—	—	− 0·3	—	—

Undisplaced: P′ 4, 18150·87 (3); P′ 6, 17949·95 (2); R′ 2, 18587·77 (5).

* Also R 3 of 0′—3″ ($3p\,^1\Pi_a - 2p\,^1\Sigma$).
† Also R 1 of 0′—0″ ($4d\,^1\Sigma_a - 2p\,^1\Pi$).
‡ Also R 3 ? of 0′—0″ ($4d\,^1\Pi_b - 2p\,^1\Pi$)

Band	Line	ν	I.	Parallel			Perpendicular		
3′—2″	P′ 3	17859·74	10	− 1·25	—	—	− 1·25	—	—
	Q 1	18053·90	10	− 0·27 V	—	—	− 0·27 V	—	+ 0·47 III
		18054·39	3						
	Q 2	18034·15	7	—	0	—	—	—	+ 2·04
	Q 3	18004·84	8	—	—	+ 3·82 I	—	0 I	+ 3·82 III
						+ 2·28 II			+ 2·3 II
						+ 0·31 IV			+ 0·60 I
	Q 4*	17966·06	4	—	—	+ 0·54	—	—	+ 0·38
	R′ 1	18158·55	10	− 1·51	—	—	− 0·83	—	—
	R′ 2†	18190·12	8	− 1·44 II	—	+ 0·54 IV	− 1·8 I	—	+ 0·40 IV

Undisplaced: R′ 3, 18211·64 (0).

* Also P 5 of 0′—4″ (^{1}M − 2^1S), and R 3 of 1′ — 5″ ($3d\,^1\Pi_a - 2p\,^1\Sigma$).
† Also R 3 of 0′—4″ (^{1}M − 2^1S).

Band	Line	ν	I.	Parallel			Perpendicular		
4′—3″	Q 1	17676·23	9	− 0·89	—	—	− 0·52	—	—
	Q 2	17657·24	2	− 1·1	—	—	− 2·8	0 ?	—
		17657·88	3						
	Q 3	17628·90	4	− 2·0 II	—	+ 1·2 III	—	0 IV	—
		17629·46	1						
		17630·93	1						
	Q 4 ?*	17591·22	4	—	—	+ 0·45	—	—	+ 0·45

* Also R 3 of 1′—1″ ($3d\,^3\Delta - 2p\,^3\Pi$).

$3p\ {}^3\Pi_{ab} - 2s\ {}^3\Sigma$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Perpendicular		
5′—4″	Q 1	17312·48	3	—	—	+ 0·4	—	—	+ 0·4
		17311·08	9						
	Q 2	17294·13	1	− 3·7 ?	—	—	− 2·9 ?	—	—
	Q 4	17230·99	1	—	—	+ 0·2	—	—	+ 0·3

6′—5″ Undisplaced : Q 1, 16962·63 (1).

Band	Line	ν	I.						
8′—7″	Q 1	16307·76	0	− 2·5 I*c*	0 II	—	− 2·51 *c*	0 II	—
		16307·00	00						
		16308·84	0						

2′—0″ Undisplaced : P′ 5, 20530·48 (4).

3′—1″ Undisplaced : Q 4, 20323·15 (5) ; P′ 3, 20229·13 (2).

4′—2″ Undisplaced : Q 1, 19929·31 (1) ; Q 3, 19866·70 (1).

5′—3″ Undisplaced : Q 1, 19436·36 (3).

Band	Line	ν	I.						
7′—5″	Q 3*	18437·81	2	− 0·5	—	—	− 0·5	—	—

* Also R 2 of 0′—0″ ($4d\ {}^1\Pi_b - 2p\ {}^1\Pi$)

$4p\ {}^3\Pi_{ab} - 2s\ {}^3\Sigma$* ($H_\beta$ bands)

0′—1″ Undisplaced : Q 1, 19742·22 (6).

1′—2″ Undisplaced : Q 1, 19566·76 (4) ; Q 2, 19557·39 (1).

3′—4″ Undisplaced : Q 2, 19227·90 (1).

4′—5″ Undisplaced : Q 1, 19082·27 (4).

* Richardson and Das, ‘Proc. Roy. Soc.,’ A, vol. 122, p. 688 (1928).

$3p\ {}^3\Sigma - 2s\ {}^3\Sigma$ ($2^3S' - 2^3S$)*

Band	Line	ν	I.	Parallel			Perpendicular		
2′—0″	P 1	15528·92	3	− 4·8 I*d*†	—	—	− 0·3 III	—	—
				− 0·3 III					
	P 2	15443·06	2	− 0·7	—	—	− 0·7	—	—
	P 3	15338·61	3	—	—	+ 2·1 II	—	—	+ 0·7 I
	R 0	15642·48	1	− 0·4	—	—	—	0	—
	R 1	15669·39	4	− 0·5	—	—	− 0·5	—	—
		15669·10	0						
	R 2	15676·02	1	− 0·6	—	—	− 0·6	—	—
	R 3	15662·53	2	—	—	+ 2·7 *c*	—	—	+ 2·7 *c*
	R 4	15629·10	00	—	—	+ 0·7	—	—	+ 0·7

* Richardson and Das, ‘Proc. Roy. Soc.,’ A, vol. 122, p. 688 (1928) ; vol. 125, p. 309 (1929).

† This faint component may be the line λ 6436·24 T, which otherwise does not appear. Its displacement would then be − 8·6 cm⁻¹.

3′—0″ Undisplaced : P 2, 17229·24 (0) ; P 3, 17118·79 (1) ; R 1, 17449·52 (1).

$3p\,^3\Sigma - 2s\,^3\Sigma$—(continued)

Band	Line	ν	I.	Displacements in cm^{-1} Parallel			Perpendicular		
4′—1″	P 3*	16251·79	4	—	0 III	+ 5·0 I†	—	0 III	+ 5·0 I†

Undisplaced : P 2, 16356·44 (0) ; P 4, 16130·47 (2).

* Also P′ 3 of 3′—3″ ($3d\,^3\Pi_a - 2p\,^3\Pi$).

† Possibly a separate unclassified line λ 6150·8 S.

Band	Line	ν	I.	Parallel			Perpendicular		
x′—1″ (5′?—1″)	R 1*	18035·41	4	− 3·6	—	—	− 3·6	—	—

x′—2″ (5′?—2″) Undisplaced : R 1, 15650·27 (1) ; P 3, 15351·49 (0).

* Also R 4 of 0′—0″ ($4d\,^1\Sigma - 2p\,^1\Pi$).

Band	Line	ν	I.	Parallel			Perpendicular		
y′—2″	P 2	16743·17	3	− 1·0c	—	—	—	—	+ 0·8c
(6′?—2″)	P 3	16642·14	2	− 0·88	—	—	− 0·73	—	—

Undisplaced : P 4, 16532·87 (0) ; R 1, 16940·99 (1).

$4p\,^3\Sigma - 2S\,^3\Sigma$ $(3^3S' - 2^3S)$*

0′—0″ Undisplaced : P 1, 20459·24 (2) ; P 3, 20285·06 (4)c ; P 5, 20078·30 (2).

1′—1″ Undisplaced : P 2, 20008·60 (2)c ; P 3, 19926·18 (5) ; R 1, 20240·71 (5)c.

Band	Line	ν	I.	Parallel			Perpendicular		
—1″	P 2	17589·17	3	. . . . . confused			− 2·41	—	—
	P 3	17497·72	5	− 3·40	—	—	− 3·99	—	—
	P 4	17400·48	1	− 3·8	—	—	− 4·2 I I	0 I ?	—
	R 0	17778·92	4	− 7·6	—	—	− 6·7	—	—
	R 1	17812·31	10	− 3·79 III − 2·88 III	— —	— —	− 2·56 V	—	—
	R 2	{ 17837·29 { 17838·32	3 1	− 3·9	—	—	− 3·4	—	—

* RICHARDSON and DAS, ' Proc. Roy. Soc.,' A, vol. 125, p. 309 (1929).

$3d\,^3\Sigma - 2p\,^3\Pi_{ab}$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—0″	P 2†	16734·20	4	− 0·8 II	—	+ 5·6 Ic + 2·5 I + 0·6 II	− 0·8 II	—	+ 5·6 Ic
	Q 1	16854·86	10	− 1·0 Ic	—	+ 5·28 V	− 1·0 IV	—	+ 5·28 III
	Q′ 2	16764·12	4	− 3·84 III	0 III	—	− 3·84 I	0 III	+ 1·74 I
	Q 3	16654·24	9	− 0·25 IV	—	+ 4·05 II + 2·58 III	− 0·25 II	—	+ 4·36 IV + 2·58 II
	Q′ 4	16536·89	1	—	—	+ 0·4 II	− 3·7 I	0 I	—
	Q 5	16416·35	2	—	0	—	− 1·0	—	—
	Q′ 6‡	{ 16295·02 { 16294·37	3 10	− 2·8 V	—	+ 0·2 V	− 2·8 II	—	+ 1·5 IV + 0·2 V
	R′ 1	{ 16884·94 { 16885·83	4 5	—	0 IV	+ 4·1 IV + 2·1 III	− 4·0 III	—	+ 4·0 III + 0·3 III

$3d\ {}^3\Sigma - 2p\ {}^3\Pi_{ab}$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
0′—0″	R 2	16834·27	10	− 0·62 I	—	+ 4·56 V + 2·54 V	− 0·62 IV	—	+ 4·56 IV + 2·99 IV
	R′ 3§	16774·97 16774·42 16772·74	4 6 1	− 2·8 IV	—	—	− 2·8 II	0 IV	—
	R 4	16710·63	6	− 4·15 IV − 2·36 III − 0·30 III	—	—	− 4·15 III − 2·36 III	—	+ 0·21 IV

Undisplaced : P 1, 16856·91 (1) ; R′ 5, 16643·08 (1) ; R 6 ?, 16573·23 (2)*c*.

* Richardson and Davidson, ‘ Proc. Roy. Soc.,’ A, vol. 140, p. 25 (1933).
† Also Q 3 of 2′—2″ ($3d\ {}^3\Pi_a - 2p\ {}^3\Pi$).
‡ Also R 2 of 2′—2″ ($3d\ {}^3\Sigma - 2p\ {}^3\Pi$).
§ Also P 3 of 0′—4″ ($3d\ {}^1\Pi_a - 2p\ {}^1\Sigma$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—1″	P 2	16488·15	8	− 6·5 III − 1·6 II	0 II	—	− 6·5 I − 1·6 I ?	0 III	—
	Q 1	16603·20 16602·48	9 0	− 1·5 V	—	—	− 1·5 III	—	+ 0·3 IV
	Q′ 2	16515·45	5	− 0·32	—	—	− 0·62	—	—
	Q 3*	16413·37	7	− 0·21	—	—	− 0·46	—	—
	Q′ 4	16303·84	1	—	0	—	− 0·36	—	—
	R′ 1	16630·47	3	− 4·7 I† − 0·5 IV	—	—	− 5·2 I† − 0·35 IV	—	—
	R 2	16584·72	10	− 0·64	—	—	− 0·43	—	—
	R′ 3	16530·23	5	− 0·56	—	—	− 0·34	—	—

Undisplaced : P′ 1?, 16605·89 (1)*c* ; Q 5, 16190·17 (3) ; Q′ 6, 16074·39 (0) ; R 4, 16469·93 (8) ; R′ 5, 16405·53 (0) ; R 6, 16338·02 (1).

* Also R 3?? of 1′—6″ ($3d\ {}^1\Sigma - 2p\ {}^1\Sigma$).
† Possibly 16633·03, P′ 5 of 1′—1″ ($3s\ {}^3\Sigma - 2p\ {}^3\Pi$) and R′ 3 of 3′—3″ ($3d\ {}^3\Pi_a - 2p\ {}^3\Pi$) displaced − 7·3 cm⁻¹ in parallel and − 7·8 cm⁻¹ in perpendicular.

Band	Line	ν	I.	Parallel			Perpendicular		
2′—2″	Q 1	16297·25	5	− 0·3	—	—	—	0	—
	Q′ 4	16032·26 16031·77	1 2	—	—	+ 1·1	—	—	+ 1·1
	R 2*	16295·02 16294·37	3 10	− 2·8 V	—	+ 0·2 V	− 2·8 II	—	+ 1·5 IV + 0·2 V

Undisplaced : P′ 1, 16287·69 (1)*c* ; P 2, 16187·50 (1)*c* ; Q′ 2, 16222·72 (2) ; Q 3, 16132·09 (5) ; Q 5, 15926·52 (3) ; R′ 1, 16332·11 (1) ; R′ 3, 16247·26 (2) ; R 4, 16192·25 (6).

* Also Q′ 6 of the 0′—0″ band.

$3d\ {}^3\Sigma - 2p\ {}^3\Pi_{ab}$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹					
				Parallel			Perpendicular		
3′—3″	Q 1	15931·94	2	− 6·6 II	—	+ 1·4 I	− 3·5 I?	0 IV	—
		15932·26	3	− 3·5 I?					
	Q 1?	15933·16	0	− 0·1 IV					

Undisplaced : P′ 1, 15913·37 (00) ; P 2, 15827·48 (1) ; Q′ 2?, 15872·20 (1) ; Q 3, 15795·05 (2)*c* ; Q′ 4, 15706·57 (1)*c* ; Q 5?, 15610·91 (1) ; R′ 1?, 15976·14 (0) ; R 2, 15949·72 (3) ; R′ 3, 15910·77 (0) ; R 4, 15862·86 (1).

1′—0″ Undisplaced : Q 3, 18737·96 (1)*d* ; R 2, 18918·02 (9).

2′—0″ Undisplaced : P 4, 18108·03 (3)*c* ; Q 1, 18514·02 (2) ; Q 3, 18335·03 (2) ; Q 5, 18104·92 (2)*d*.

3′—2″ Undisplaced : Q 1, 18030·02 (3)*c* ; Q 3, 17879·60 (4).

$3d\ {}^3\Pi_b - 2p\ {}^3\Pi_{ab}$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—0″	P 3	16898·48	5	—	—	+ 0·6	—	—	+ 0·6
	P′ 4†	16784·56	1	− 0·8 I	—	+ 0·4 IV	—	—	+ 0·4 IV
		16783·74	2						
	Q 4‡	16961·69	0	− 1·1 II	—	+ 0·4 IV	—	—	+ 0·4 IV
		16961·25	0						
	Q 6	16831·97	0	—	—	+ 0·8	—	0	
	R 1	17199·28	10	—	—	+ small	—	—	+ small
		17200·19	1						
	R′ 2	17202·51	4	− 0·8	—	—	− 0·4	—	—
	R 3	17199·28	See R 1 above.						
	R 5	17179·50	3	—	—	+ 0·4	—	—	+ 0·7

Undisplaced : P′ 2, 17004·40 (3) ; P 5, 16667·33 (1) ; Q′ 1, 17125·07 (2) ; R′ 4, 17191·46 (1).

* Richardson and Davidson, ' Proc. Roy. Soc.,' A, vol. 140, p. 25 (1933).
† Also P′ 2? of 1′—1″ ($3d\ {}^3\Pi_b - 2p\ {}^3\Pi_{ab}$).
‡ Also P 6 of 0′ — 4″ ($3d\ {}^1\Pi_a - 2p\ {}^1\Sigma$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—1″	P′ 2 ?*	16784·56	1	− 0·8 I	—	+ 0·4 IV	—	—	+ 0·4 IV
		16783·74	2						
	P 3	16692·00	5	− 1·57	—	—	− 1·57	—	—
	P 5	16484·00	1	—	—	+ 0·2	—	—	+ 0·2
	Q 2	16863·40	1	− 1·3 ? *a*	—	—	− 1·3 *ca*	—	—
	R 1†	16978·52	10	− 1·6	—	—	− 1·6	—	—
	R′ 2‡	16988·72	8	—	—	+ 0·25	—	0	—

Undisplaced : P′ 4, 16590·90 (1) ; R 3, 16990·71 (6) ; R′4, 16986·10 (1).

* Also P′ 4 of the 0′—0″ band.
† Also P 5? of 4′?—0″ ($2s\ {}^1\Sigma - 2p\ {}^1\Sigma$).
‡ Also Q 1 of 1′—1″ ($3d\ {}^3\Pi_a - 2p\ {}^3\Pi_{ab}$).

$3d\ ^3\Pi_b - 2p\ ^3\Pi_{ab}$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Perpendicular		
2′—2″	P′ 2	16538·98 16539·82	2 00	− 0·9 I	—	+ 0·9 III	− 0·9 I	—	+ 0·9 III
	P 3	16458·03	5	—	—	+ 0·56	—	—	+ 0·56
	P′ 4	16367·90	1	—	—	+ 0·3	—	—	+ small
	P 5	16271·37	2	—	—	+ 0·6	—	—	+ 0·5
	Q′ 1	16648·40	2	—	—	+ 0·9 III	− 0·8 II	—	+ 1·2 II
	R 1*	16730·55	10	− 6·55 V	—	+ 0·75 V	− 6·95 III − 4·01 IV	—	+ 0·88 V
	R′ 2 R 5†	16746·56	2	—	0 III	+ 3·7 III rough	—	0 III	+ 3·7 II rough
		16746·17	1			+ 1·6 IV rough	—	—	+ 1·6 III rough
		16747·70	1						
	R 3 R′ 4	16753·44 16752·69	4 0	—	0 V	+ 3·6 II	—	0 V	+ 3·6 I

Undisplaced : P 7, 16068·21 (2).

* Also R′ 1 of 0′—0″ ($3p\ ^3\Pi - 2s\ ^3\Sigma$).
† Also Q′ 4 of 2′—2″ ($3d\ ^3\Pi_a - 2p\ ^3\Pi_{ab}$).

Band	Line	ν	I.	Parallel			Perpendicular		
3′—3″	P′ 2	16259·53	1	− small	—	—	—	0	—
	P 3	16186·63	3	− 1·1	—	—	− 1·1	—	—
	P′ 4	16105·59	1	− 0·9*d*	—	—	− 0·6*d*	—	—
	P 5	16018·16	1	− 3·1 I*d*	0 I	+ 0·6 I	− 3·1 I*d*	0 I	—
	Q′ 1	16363·49	1	− 0·3	—	—	− 0·2	—	—
	Q 2	16341·29 16340·34	0 0	—	—	+ 3·2 ?*c*	—	0	—
	R 1	16445·80	3	− 0·8 IV	—	—	− 0·8 I	0 III	—
	R′ 2	16465·55	2	− 1·8	—	—	—	—	+ 0·3
	R 3*	16476·10	7	− 4·41 III − 2·92 IV − 1·8 I	—	—	− 2·92 II	—	+ 0·38 III

* Also R′ 2 of 1′—1″ ($3p\ ^3\Pi - 2s\ ^3\Sigma$).

2′—1″ Undisplaced : P 3, 18660·93 (2) ; R 1, 18947·44 (1).

Band	Line	ν	I.	Parallel			Perpendicular		
3′—2″	Q 2	18434·00	2	− 1·3*d*	—	—	− 0·4	—	—

Undisplaced : P 3, 18271·27 (3) *d* ; R 1, 18543·80 (3) *c*.

$3d\ ^3\Pi_a - 2p\ ^3\Pi_{ab}$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—0″	P 2	17091·29	8	—	—	+ 0·53	—	—	+ 0·28
	P′ 3	17068·60	1	—	—	+ 0·7	—	0	—
	P 4†	17023·67	—	− 0·7 II	—	—	− 0·7 I	0 I	—
	Q 1	17212·01	1	—	—	+ 0·5	—	0	—

$3d\ ^3\Pi_a - 2p\ ^3\Pi_{ab}$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Perpendicular		
0′—0″	R′ 1	17369·32	5	—	—	+ 0·6	—	0	—
	R 2‡	17441·32	8	—	—	+ 0·67	—	—	+ 0·44
	R′ 3	17498·65	2	—	—	+ 1·2	—	—	+ 0·8
		17499·09	2						
	R 4?	17547·00	2	− 2·9 III	—	—	− 2·9 III	0 III	—
		17546·60	2	− 1·9 III?	—	—	− 1·9 II?	—	—

Undisplaced : Q′ 2, 17248·55 (1) ; Q 3, 17261·34 (0) blended with Q′ 4, 17260·69 (4) ; Q 5 ?, 17252·65 (2) ; Q′ 6 ?, 17233·19 (2).

* Richardson and Davidson, ‘Proc. Roy. Soc.,’ A, vol. 140, p. 25 (1933).
† Also Q′ 2 ? of 1′—1″ ($3d\ ^3\Pi_a - 2p\ ^3\Pi_{ab}$).
‡ Also P 3 of 2′—7″ ($3d\ ^1\Pi_a - 2p\ ^1\Sigma$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—1″	P 2	16873·46	9	—	—	+ 0·47	—	—	+ 0·47
	P′ 3	16852·22	3	—	0 III	+ 2·0 III	—	0 III*c*	—
		16853·01	1						
	Q 1*	16988·72	8	—	—	+ 0·25	—	0	—
	Q′ 2 ?†	17023·67	1	− 0·7 II	—	—	− 0·7 I	0 I	—
	R 4	17335·25	2	—	0 II	+ 0·9 IV	—	0 II	+ 0·5 IV

Undisplaced : P 4, 16820·99 (2) ; Q 3, 17047·15 (5) ; Q′ 4, 17056·70 (1) ; Q 5, 17055·50 (1) ; R′ 1, 17138·90 (4) ; R 2, 17218·50 (8) ; R′ 3, 17282·98 (1).

* Also R′ 2 of 1′—1″ ($3d\,^3\Pi_b - 2p\,^3\Pi$).
† Also P 4 of 0′—0″ ($3d\ ^3\Pi_a - 2p\ ^3\Pi_{ab}$).

Band	Line	ν	I.	Parallel			Perpendicular		
2′—2″	P 2	16575·12	5	− 1·5 V	—	+ 1·6 III	− 1·1 IV	—	+ 1·6 IV
		16573·94	10			+ 0·6 IV			
	P′ 3*	16548·90	3	− 1·5	—	—	− 1·1	—	—
	P 4	16517·89	6	− 0·88 IV	—	+ 0·36 III	− 1·05 III	—	+ 0·36 III
	Q 1	16684·88	1	− 1·6	—	—	− 2·1	—	—
		16683·88	0						
	Q 3†	16734·20	4	− 0·8 II	—	+ 5·6 I*c* + 2·5 I + 0·6 II	− 0·8 II	—	+ 5·6 I*c*
	Q′ 4‡	16746·17	1	—	0 III	+ 3·7 III rough	—	0 III	+ 3·7 II rough
		16746·56	2			+ 1·6 IV rough			+ 1·6 III rough
	Q 5 ?§	16747·70	1						
	R 2	16897·19	5	− 0·7 IV	—	—	− 0·7 II	—	+ 0·3 II
	R′ 3	16961·25	0	− 1·1 II	—	+ 0·4 III	—	—	+ 0·4 III
		16961·69	0						

Undisplaced : R′ 1, 16822·00 (2)*c* ; R 4, 17013·50 (1).

* Also R 4 ? of 0′—1″ ($3d\,^1\Sigma - 2p\,^1\Sigma$).
† Also P 2 of 0′—0″ ($3d\,^3\Sigma - 2p\,^3\Pi$).
‡ Also R 5 of 2′—2″ ($3d\,^3\Pi_b - 2p\,^3\Pi_{ab}$).
§ Also Q 5 ? of progression starting from λ 4142·801.

$3d\ {}^3\Pi_a - 2p\ {}^3\Pi_{ab}$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
3′—3″	P 2	16283·83	2	—	0	—	— small	—	—
	P′ 3*	16251·79	4	—	0 III	+ 5·0 I†	—	0 III	+ 5·0 I†
	Q 1	16388·32	1	− 0·6	—	—	− 0·6	—	—
	R′ 3‡	16633·03 16633·48	0 0	− 1·9 I	—	+ 0·5 I	− 1·5 I	—	—
	R 4§	16678·57	10	− 12·6 IV rough − 2 Id	—	—	− 2·05 IV	—	—

Undisplaced : P 4, 16218·29 (1) ; Q′ 4, 16428·77 (0) ; R′ 1, 16511·46 (1) faint ; R 2, 16579·03 (2).

* Also P 3 of 4′—1″ ($2p\ {}^3\Sigma - 2s\ {}^3\Sigma$).
† Possibly a separate unclassified line, λ 6150·8 S.
‡ Also P′ 5 of 1′—1″ ($3s\ {}^3\Sigma - 2p\ {}^3\Pi_{ab}$). See also R′ 1 of 1′—1″ ($3d\ {}^3\Sigma - 2p\ {}^3\Pi$).
§ Also R′ 0 of 0′—0″ ($3p\ {}^3\Pi - 2s\ {}^3\Sigma$).

Band	Line	ν	I.	Parallel			Perpendicular		
2′—1″	P 2	18786·49	2	− 1·3d	—	—	− 1·3d	—	—

Undisplaced : P 4, 18710·30 (4) d.

Band	Line	ν	I.	Parallel			Perpendicular		
3′—2″	P 2	18376·62	2	—	0 II	—	− 9·8 I?	0 II	—

$3s\ {}^3\Sigma - 2p\ {}^3\Pi_{ab}$* ($3{}^3Z - 2p\ {}^3\Pi_{ab}$)

Band	Line	ν	I.	Parallel			Perpendicular		
1′—1″	P′ 1†	16860·14	0	. . . . . confused			—	—	+ 4 ?? c
	P 2	16802·37	10	—	—	+ 2·8 V wide	—	0 I	+ 2·81 V
	P′ 3	16744·92	5	Displaced, but very confused.			Displaced, but very confused.		
	P 4	16688·40	4	—	—	+ 4·1	—	—	+ 4·1
	P′ 5‡	16633·03 16633·48	0 0	− 1·9 I	—	+ 0·5 I	− 1·5 I	—	—
	Q 1	16917·50	3	—	—	+ 4·1	—	—	+ 4·3
	Q′ 2	16916·57	0	. . . . . confused			. . . . . confused		
	Q 3	16915·33	3	. . . . . confused			. . . . . confused		
	Q′ 4	16913·48	0	—	—	+ 2·8 a	—	0	—
	Q 5	16910·79	1	—	0 II	+ 2·5 I	—	0 II	—
	R′ 1	17031·67	1	. . . . . confused			. . . . . confused		

Undisplaced : P 6, 16579·03 (2) ; R′ 3, 17139·77 (5) c.

* Richardson and Davidson, ‘ Proc. Roy. Soc.,’ A, vol. 140, p. 25 (1933).
† Also R′ 6 of 0′—0″ ($3p\ {}^3\Pi - 2s\ {}^3\Sigma$).
‡ Also R′ 3 of 3′—3″ ($3d\ {}^3\Pi_a - 2p\ {}^3\Pi$). See also R′ 1 of 1′—1″ ($3d\ {}^3\Sigma - 2p\ {}^3\Pi$).

$3d\ {}^3\Delta_b - 2p\ {}^3\Pi$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—0″	P 3	17271·56	4	—	0	—	—	—	+ 0·2
	Q 2	17451·59	10	—	—	+ 0·34	—	—	+ 0·52
	Q′ 3	17489·90	3	—	—	+ 0·3	—	—	+ 1·0

$3d\ {}^3\Delta_b - 2p\ {}^3\Pi$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
0′—0″	Q 4	17527·44	4	− 2·2 I − 1·6 II	—	+ 0·5 III	− 3·1 IV	0 I	—
	Q 6	17593·01	3	—	—	+ 0·4	—	0	—
	R 1	17572·31	10	—	—	+ 0·51	—	—	+ 0·40
	R′ 2†	17669·81	2	—	—	+ 0·7	—	—	+ 0·3
	R 3	17765·17	3	—	—	+ 0·9 IV	− 4·8 I	—	+ 0·7 IV

Undisplaced: P′ 4, 17251·99 (0) *c*; P 5, 17233·19 (2); P 6, 17213·82 (0) *c*; Q′ 5, 17562·23 (3) *c*.

* Sandeman, 'Proc. Roy. Soc.,' A, vol. 138, p. 395 (1932).
† Also R′ 4 of 1′—1″ ($3d\ {}^3\Delta - 2p\ {}^3\Pi$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—1″	P′ 4*	17111·01	2	—	—	+ small	—	—	+ small
	P 5	17084·56	2	—	—	+ 0·3	—	—	+ 0·3
	Q 2	{ 17311·08	9	—	—	+ 0·4	—	—	+ 0·4
		{ 17312·48	3						
	Q′ 3	17337·39	3	—	—	+ 0·6	—	—	+ 0·6
	Q 4	17364·30	5	—	—	+ 0·53	—	—	+ 0·38
	Q′ 5	17389·47	2	—	—	+ 0·7	—	—	+ 0·5
	Q 6	17411·21	5	—	—	+ 0·7	—	—	+ 0·7
	R 1	17426·25	10	—	—	+ 0·52	—	—	+ 0·30
	R′ 2†	17508·99	5	—	—	+ 0·4	—	—	+ 0·4
	R 3‡	17591·22	4	—	—	+ 0·5	—	—	+ 0·5
	R′ 4§	17669·81	2	—	—	+ 0·7	—	—	+ 0·3

Undisplaced: P 3, 17139·77 (5) *c*; Q′ 7, 17428·63 (1).

* Also R 3 of 0′—4″ ($3d\ {}^1\Pi_a - 2p\ {}^1\Sigma$).
† Also P 5 of 0′—3″ ($3d\ {}^1\Sigma - 2p\ {}^1\Sigma$).
‡ Also Q 4 ? of 4′—3″ ($3p\ {}^3\Pi - 2s\ {}^3\Sigma$).
§ Also R′ 2 of 0′—0″ ($3d\ {}^3\Delta_b - 2p\ {}^3\Pi$).

Band	Line	ν	I.	Parallel			Perpendicular		
2′—2″	P 3	17006·43	10	—	0 V	+ 3·17 III	—	0 V	+ 3·17 III
	Q′ 3	17184·46	3	—	—	+ small	—	0	—
	Q 4	{ 17200·19	1	—	—	+ small	—	—	+ small
		{ 17199·28	10						
	Q 6	17224·94	1	—	—	+ small	—	—	+ small
	R′ 2	17348·12	3	—	—	+ 0·4	—	—	+ 0·4
	R′ 4	17481·61	1	—	—	+ 1·0 *d*	—	—	+ 1·0 *d*
	R 5	17541·45	2	—	—	+ 0·5	—	—	+ 0·5

Undisplaced: P′ 4, 16969·39 (1); P 5, 16934·41 (1); P 7, 16864·10 (1) *c*; Q 2, 17169·22 (10); Q′ 5, 17214·05 (U); R 1, 17279·01 (7); R 3, 17416·51 (3).

Band	Line	ν	I.	Parallel			Perpendicular		
3′—3″	P 3	16870·70	2	—	—	+ 0·24	—	—	+ 0·24
	P′ 4	16825·98	1	. . . . .	confused	. . . . .	. . . . .	confused	. . . . .
	P 5	16781·72	1	—	—	+ 7·9 II ? + small II	—	—	+ small II

Undisplaced: Q 2, 17025·41 (6) *c*; R 1, 17129·89 (8) *c*; R′ 2, 17186·00 (2); R 3, 17239·70.

$3d\ {}^3\Delta_a - 2p\ {}^3\Pi$*

Band	Line	ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
0′—0″	P′ 3	17287·27	2	—	—	+ 1·1	—	—	+ 0·7
	P 4	17299·30	4	+ 2·5 IV	—	—	− 2·5 III	—	+ 0·6 III
	Q′ 2	17467·13	6	—	—	+ 0·6	—	—	+ 0·3
	Q 3	17537·02	4	—	—	+ 0·6	—	—	+ 0·4
	R′ 1†	17588·00	5	. . . . . broadens	. . . . .		—	—	+ 0·4
	R 2	{17717·06	3	—	—	+ 0·5	—	0	—
		{17716·35	5						

Undisplaced : P′ 5, 17318·92 (1) ; Q′ 4, 17612·63 (1) faint.

* SANDEMAN, 'Proc. Roy. Soc.,' A, vol. 138, p. 395 (1932).
† Also R 1 of 1′—5″ ($3d\ {}^1\Sigma - 2p\ {}^1\Sigma$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—1″	Q′ 2	17316·56	5	—	—	+ 0·31	—	—	+ 0·31
	Q 3	17357·64	6	—	—	+ 0·74	—	—	+ 0·37
	Q′ 4	17407·51	1	—	—	+ 0·5	—	—	+ 0·2
	Q 5	17459·76	2	—	—	+ 0·4	—	—	+ 0·2
	R′ 1	17431·57	6	—	—	+ 0·69	—	—	+ 0·57
	R 2	17529·00	5	—	—	+ 0·4	—	—	+ 0·4
	R′ 3	17633·88	1	—	—	+ 0·7	—	—	+ 0·3

Undisplaced : P′ 3, 17144·93 (4) *c* ; P 4, 17130·78 (3) *c* ; P′ 5, 17127·12 (0), blended with P 6, 17127·97 (1).

Band	Line	ν	I.	Parallel			Perpendicular		
2′—2″	R 2	17355·14	6	—	—	+ 0·44	—	—	+ 0·35
	R′ 3	17433·50	1	—	—	+ 0·6	—	—	+ 0·3

Undisplaced : P′ 3, 17007·59 (1) *c* ; P 4, 16976·03 (5) *c* ; P′ 5, 16950·98 (0) ; Q′ 2, 17171·27 (4) ; Q 3, 17192·31 (6) ; Q′ 4, 17218·50 (8) ; R′ 1, 17280·68 (3).

3′—3″ Undisplaced : Q′ 2, 17026·36 (2) *c* ; Q 3, 17033·21 (4) ; Q′ 4, 17040·75 (1) ; R 2, 17187·90 (4).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—2″	Q 2	15099·79 A	—	—	—	+ 0·5	—	0 *c*	—

$3d\ {}^1\Sigma - 2p\,{}^1\Sigma$ $(3\,{}^1C - 2\,{}^1S)$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—1″	P 6†	19895·10	1	. . . . . Too faint	. . . . .		—	—	+ 2 *a*

Undisplaced : P 2, 20172·92 (6) ; P 3, 20086·15 (1) ; P 4, 20007·03 (3) ; R 0, 20283·29 (8), blended with R 5, 20283·93 (9) ; R 1, 20269·03 (7) ; R 2, 20260·90 (10) ; R 3, 20263·88 (4) ; R 5, 20323·15 (5).

* RICHARDSON and DAVIDSON, 'Proc. Roy. Soc.,' A, vol. 123, p. 54 (1929).
† Also Q 6 ? of 1′—4″ ($3d\ {}^1\Delta_b - 2p\ {}^1\Sigma_a$).

Band	Line	ν	I.	Parallel			Perpendicular		
0′—2″	R 1	18989·26	3	—	—	+ 0·4	—	—	+ 0·4

Undisplaced : P 2, 18896·35 (0) ; P 4, 18741·52 (6) ; R 0, 19001·86 (7) ; R 2, 18984·32 (10) ; R 4, 19018·39 (7) ; R 5, 19065·14 (2).

$3d\ {}^1\Sigma - 2p\ {}^1\Sigma$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
0′—3″	P 4*	17508·99	5	—	—	+ 0·4	—	—	+ 0·4
	R 4	17785·83	5	—	—	+ 0·4	—	0	—

Undisplaced: P 2, 17654·00 (3); P 3, 17576·22 (1); P 5, 17457·57 (00); R 0, 17755·11 (4); R 1, 17743·95 (3), blended with 17743·02 (1); R 2, 17741·92 (8); R 3, 17753·95 (2); R 5, 17839·31 (1).

* Also R′ 2 of 1′—1″ ($3d\ {}^3\Delta - 2p\ {}^3\Pi$).

Band	Line	ν	I.	Parallel			Perpendicular		
0′—4″	P 4	16308·84	0	− 2·5 Ic	0 II	—	− 2·5 Ic	0 II	—
		16307·76	0						
		16307·00	00						
	R 3?*	16548·90	3	− 1·5	—	—	− 1·1	—	—

Undisplaced: R 2, 16532·87 (0).

* Also P′ 3 of 2′—2″ ($3d\ {}^3\Pi_a - 2p\ {}^3\Pi$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—3″	R 2	19942·45	10	—	—	+ 0·6	—	—	+ 0·6 *c*

Undisplaced: P 2, 19879·73 (2); P 4, 19709·41 (2); P 5, 19632·10 (1); P 6, 19576·33 (1); R 0, 19980·86 (9); R 1, 19962·54 (8); R 3, 19928·69 (6); R 4, 19934·35 (8); R 6, 20002·69 (5).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—4″	R 2	18733·29	5	—	0 III	—	− 4·2 Ia	0 III	—
	R 4	18734·30	1						

Undisplaced: P 6, 18389·66 (0); R 0, 18767·87 (4); R 1, 18750·84 (2); R 3, 18723·53 (2); R 5, 18655·10 (0).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—5″	R 0*	17588·00	5	. . . . . broadens			—	—	+ 0·41

Undisplaced: P 1, 17570·26 (0); P 4, 17341·26 (1); R 2, 17557·05 (5); R 3, 17550·78 (3); R 4, 17566·27 (3); R 5, 17603·80 (1); R 6, 17660·45 (1).

* Also R′ 1 of 0′—0″ ($3d\ {}^3\Delta_a - 2p\ {}^3\Pi$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—6″	R 2??*	16413·37	7	− 0·21	—	—	− 0·46	—	—
	R 3?	16410·14	0	—	0	—	− 0·41	—	—

Undisplaced: R 4, 16430·10 (0).

* Also Q 3 of 1′—1″ ($3d\ {}^3\Sigma - 2p\ {}^3\Pi$).

Band	Line	ν	I.	Parallel			Perpendicular		
2′—5″	R 0	19588·70	4	− 1·7 II	—	—	—	0 II	—
		19589·79	0						
2′—5″	R 2	19552·08	7	− 1·5 II	—	—	− 2·2 I	0 IV	—
		19551·47	0	− 3·8 III					

Undisplaced: R 1, 19573·06 (3).

Band	Line	ν	I.	Parallel			Perpendicular		
2′—6″	R 0	18441·19	1	− 1·3	—	—	—	0	—
	R 2	18408·15	3	− 1·2	—	—	− 1·8 I?	—	+ 1·1 II

Undisplaced: R 3, 18381·39 (3).

Band	Line	ν	I.	Parallel			Perpendicular		
2′—7″	R 2	17296·19	2	—	—	+ 1·2?	—	—	+ 1·2

Undisplaced: R 4, 17239·70 (2).

3′—6″ Undisplaced: R 0, 20256·79 (3); R 2, 20238·91 (4) *c*.

3′—7″ Undisplaced: R 0, 19141·31 (3) *c*; R 1, 19138·80 (2); R 2, 19126·96 (6).

$3d\ {}^1\Pi_a - 2p\ {}^1\Sigma$ $(3\,{}^1\mathrm{A} - 2\,{}^1\mathrm{S})$*

Band	Line	ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
0′—2″		Undisplaced : P 2, 19226·51 (4) ; P 3, 19268·84 (2) ; P 4, 19319·42 (6).							
0′—3″	R 2†	18320·06	6	− 1·7	—	—	− 2·0	—	—
		Undisplaced : P 2, 17984·12 (2) ; P 4, 18086·52 (3) ; P 6, 18224·10 (2).							

* Richardson and Davidson, 'Proc. Roy. Soc.,' A, vol. 123, p. 466 (1929).
† Also P′ 2 of 2′—1″ ($3p\ {}^3\Pi - 2\mathrm{S}\ {}^3\Sigma$).

Band	Line	ν	I.	Parallel			Perpendicular		
0′—4″	P 2*	{16774·97	4	− 2·8 IV	—	—	− 2·8 II	0 IV	—
		16774·42	6						
		16772·74}	1						
	P 5†	{16961·69	0	− 1·1 II	—	+ 0·4 III	—	—	+ 0·4 III
		16961·25}	0						
	R 2‡	17111·01	2	—	—	+ small	—	—	+ small

* Also R′ 3 of 0′—0″ ($3d\ {}^3\Sigma - 2p\ {}^3\Pi_{ab}$).
† Also Q 4 of 0′—0″ ($3d\ {}^3\Pi_b - 2p\ {}^3\Pi_{ab}$).
‡ Also P′ 4 of 1′—1″ ($3d\ {}^3\Delta_b - 2p\ {}^3\Pi$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—3″		Undisplaced : P 2, 20072·80 (6) ; P 4, 20118·28 (5) ; R 0, 20174·02 (1) *c* ; R 2, 20351·33 (1).							
1′—4″	P 4	18918·02	9	− small	—	—	− small	—	—
		Undisplaced : P 2, 18863·74 (2) ; P 3, 18897·03 (0) ; R 2, 19142·24 (1) *c*.							
1′—5″	R 2*	17966·06	4	—	—	+ 0·5	—	—	+ 0·4
		Undisplaced : P 2, 17687·41 (3) ; P 3, 17724·28 (2) ; P 4, 17750·16 (2) *c* ; R 1, 17879·60 (4).							

* Also P 4 of 0′—4″ ($^1\mathrm{M} - 2\,{}^1\mathrm{S}$) and Q 4 of 3′—2″ ($3p\ {}^3\Pi - 2\mathrm{S}\ {}^3\Sigma$).

Band	Line	ν	I.	Parallel			Perpendicular		
1′—6″	R 0	{16633·48	0	− 1·9 I	—	+ 0·5 I	− 1·5 I	—	—
		16633·03}	0						
2′—5″	P 3	19719·71	1	− 0·6	—	—	− 0·6	—	—
		Undisplaced : P 1, 19690·44 (1) ; P 2, 19697·24 (4).							
2′—6″	R 0	18643·27	1	?	?	?	—	—	+ 1·8 *a*
2′—7″	P 2*	17441·32	8	—	—	+ 0·67	—	—	+ 0·44
		Undisplaced : P 3 ?, 17470·40 (1).							

* Also R 2 of 0′—0″ ($3d\ {}^3\pi_a - 2p\ {}^3\pi_{ab}$).

2′—8″	Undisplaced : P 2, 16360·00 (00).
3′—6″	Undisplaced : P 3, 20256·59 (3) ; P 4, 20250·78 (2) *c*.
3′—7″	Undisplaced : P 2, 19147·64 (1) *c* ; P 4, 19146·47 (1) ; R 2, 19346·69 (1).
3′—8″	Undisplaced : R 2, 18265·45 (1).

$3d\,{}^1\Pi_b - 2p\,{}^1\Sigma \qquad (3\,{}^1B - 2^1\,S)$*

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Perpendicular		
0′—1″		Undisplaced ; Q 1, 20514·19 (2), blended with Q 2, 20515·48 (8) ; Q 3, 20530·48 (4) ; Q 4, 20563·05 (3).							
0′—2″		Undisplaced : Q 2, 19238·85 (8) ; Q 3, 19258·66 (2) ; Q 4, 19297·49 (7) ; Q 5, 19356·75 (1).							
0′—3″		Undisplaced : Q 2, 17996·46 (3) ; Q 4, 18064·93 (3).							
0′—4″		Undisplaced : Q 2, 16787·38 (0) ; Q 4, 16864·70 (1), blended with 16863·40 (1).							
0′—5″		Undisplaced : Q 2, 15610·91 (0).							
1′—3″	Q 4	20168·72	5	—	—	+ 0·6	—	0	—
		Undisplaced : Q 1, 20088·33 (3) ; Q 2, 20101·74 (8) ; Q 3, 20127·64 (6) ; Q 5, 20226·86 (3) ; Q 6, 20302·96 (3).							
1′—4″		Undisplaced : Q 1, 18876·62 (3) ; Q 2, 18892·67 (9) ; Q 3, 18922·37 (3) ; Q 4, 18968·59 (4) ; Q 5, 19033·23 (1).							
1′—5″	Q 2	{ 17716·35 { 17717·06	5 3	—	—	+ 0·5	—	0	—
	Q 4	17800·63	2	—	—	+ 0·6	—	—	+ 0·3
		Undisplaced : Q 3, 17749·72 (1), blended with 17750·16 (2).							
2′—5″	Q3	19694·55	1	− 4·2 I ?	—	+ 0·5 I	—	0 II	—
		Undisplaced : Q 1, 19640·06 (1) ; Q 2, 19660·83 (9) ; Q 4, 19742·22 (6).							
2′—6″		Undisplaced : Q 2, 18516·91 (4) ; Q 5, 18606·12 (2), blended with 18604·98 (2).							
2′—7″		Undisplaced : Q 1, 17379·39 (0) ; Q 2, 17404·90 (2) ; Q 4, 17501·97 (1).							
3′—6″		Undisplaced : Q 2, 20283·29 (8) and 20283·93 (9) ; Q 3, 20318·18 (1).							
3′—7″		Undisplaced : Q 2, 19171·51 (6) ; Q 3, 19209·46 (1).							

* RICHARDSON and DAVIDSON, ' Proc. Roy. Soc.,' A, vol. 123, p. 54 (1929).

$3\,{}^1K - 2p\,{}^1\Sigma \qquad ({}^1K - 2^1\,S)$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—1″		Undisplaced : R 0, 20128·48 (1), blended with R 2, 20127·64 (6).							
0′—2″	R 2	{ 18851·17 { 18851·66	4 9	− 0·8 IV	—	—	− 0·8 IV	—	—
		Undisplaced : P 1, 18790·26 (2) ; P 2, 18741·52 (6) ; P 4, 18608·34 (3) ; R 0, 18846·99 (5) ; R 1, 18855·19 (2).							
0′—3″	P 2	{ 17499·09 { 17498·65	2 2	—	—	+ 1·2	—	—	+ 0·8
		Undisplaced : P 4, 17375·75 (1).							
1′—3″	R 0	19829·35	8	—	—	+ 1·3	− 1·4	—	—
		Undisplaced : P 3, 19668·85 (1) ; R 1 and R 2, 19836·46 (9) *d*.							

$3^1\mathrm{K} - 2p\,^1\Sigma$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Perpendicular		
1′—5″		Undisplaced : P 1, 17387·14 (1) ; R 0, 17436·24 (1).							
1′—6″	P 4	16099·13	0	− 0·4	—	—	—	0	—
	R 2	16307·00 16307·76 16308·84	00 0 0	− 2·5 I*c*	0 II	—	− 2·5 I*c*	0 II	—
		Undisplaced : R 0, 16288·82 (0) *c*.							
2′—5″	R 2	19677·66	7	—	—	+ 1·4	—	—	+ 1·0
	R 3	19675·87	1	—	—	+ 0·9	—	—	+ 0·5
	R 4	19672·11	2	—	—	+ 0·4	—	—	+ 0·4
		Undisplaced : R 0, 19660·83 (9) ; R 5, 19668·85 (1).							
2′—6″	P 4	18325·66	4	. . . . . too faint			—	—	+ 1·3 rough
		Undisplaced : P 6, 18215·57 (1) *c*.							

$3\,^1\mathrm{L} - 2p\,^1\Sigma$ $(^1\mathrm{L} - 2\,^1\mathrm{S})$*

Band	Line	ν	I.						
0′—3″		Undisplaced : R 0, 19227·90 (1).							

$3\,^1\mathrm{M} - 2p\,^1\Sigma$ $(^1\mathrm{M} - 2\,^1\mathrm{S})$*

Band	Line	ν	I.						
0′—4″	P 4†	17966·06	4	—	—	+ 0·5	—	—	+ 0·4
	R 2‡	18190·12	8	− 1·4 II	—	+ 0·54 IV	− 1·8 I	—	+ 0·40 IV
		Undisplaced : P 2, 18058·64 (5) ; P 3, 18013·87 (2) *c* ; P 4, 17966·06 (4) *c* ; P 5, 17920·33 (3) ; R 0, 18155·85 (4) ; R 3, 18205·74 (1).							
0′—5″		Undisplaced : R 0, 16976·03 (5) ; R 1, 16996·32 (1).							

* Richardson and Davidson, ' Proc. Roy. Soc.,' A, vol. 124, p. 50 (1929).
† Also Q 4 of 3′—2″ ($3p\,^3\Pi - 2s\,^3\Sigma$) and R 2 of 1′—5″ ($3d\,^1\Pi_a - 2p\,^1\Sigma$).
‡ Also R′ 2 of 3′—2″ ($3p\,^3\Pi - 2s\,^3\Sigma$).

$3\,^1\mathrm{N} - 2p\,^1\Sigma$ $(^1\mathrm{N} - 2\,^1\mathrm{S})$*

Band	Line	ν	I.						
0′—4″	P 2	19776·54	9	− 8·3 III − 0·6 IV	—	—	− 8·3 V − 0·6 III	—	—
	P 4	19725·70	7	—	—	+ 0·6	—	—	+ 0·6
	P 6	19717·24	1	− 1·3	—	—	− 0·9	—	—
	R 0	19873·74	9	− 1·0	—	—	− 9·0	—	—
	R 1	19911·82	4	—	—	+ 0·5 I	− 2·7 II rough	0 I	—

$3^1N - 2p\,^1\Sigma$—(continued)

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Perpendicular		
0′—4″	R 2	19949·79	8	—	—	+ 1·2	—	—	+ 0·5
		Undisplaced : P 3, 19750·59 (4) ; P 5, 19708·20 (1) *c*.							
0′—6″	R 2	17629·46	1	− 2·0 II	—	+ 1·2 III	—	0 IV	—
		17628·90	4						
		17630·93	1						
		Undisplaced : P 2, 17456·16 (3) ; P 3 and P 6, 17437·27 (1) *c*.							
1′—6″	R 2	19551·47	0	− 1·6 II	—	—	− 2·2 I	0 IV	—
		19552·08	7	− 3·8 III					
		Undisplaced : P 2, 19425·89 (5) ; P 4, 19343·59 (4) ; R 0, 19515·98 (4).							

* Richardson and Davidson, ' Proc. Roy. Soc.,' A, vol. 124, p. 50 (1929).

$3^1O - 2p\,^1\Sigma$ $(^1O - 2\,^1S)$*

Band	Line	ν	I.	Parallel			Perpendicular		
1′—4″	P 2	19936·73	4	?	?	?	—	—	+ 5
1′—7″	P 2	16504·37	0	—	—	+ 4·4 rough	. . . . . too faint		
2′—7″	R 0	18632·68	0						
		18631·03	7	—	0 I*c*	+ 1·3 III*c*	—	0 I*c*	+ 1·3 III*c*

* Richardson and Davidson, ' Proc. Roy. Soc.,' A, vol. 124, p. 69 (1929).

$3d\,^1\Delta_b - 2p\,^1\Sigma_a$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—2″		Undisplaced : Q 4, 19866·70 (1).							
1′—4″	Q 6 ?†	19895·10	1	. . . . . too faint			—	—	+ 2 *a*

* Richardson and Davidson, ' Proc. Roy. Soc.,' A, vol. 142, p. 63 (1933).
† Also P 7 of 0′—1″ ($3d\,^1\Sigma - 2p\,^1\Sigma$).

$3d\,^1\Delta_b - 2p\,^1\Sigma$

(Progression starting from λ 4142·801*)

Band	Line	ν	I.	Parallel			Perpendicular		
—3″		Undisplaced : Q 6 ?, 20262·54 (0) *c*.							
—5″		Undisplaced : Q 4 ?, 17883·85 (3) *d*.							
—6″	Q 4 ?†	16747·70	1	—	0 III	+ 3·7 III rough		0 III	3·7 II rough
		16746·17	1			+ 1·6 IV rough			+ 1·6 III rough
		16746·56	2						

* Richardson and Davidson, ' Proc. Roy. Soc.,' A, vol. 124, p. 69 (1929).
† Also Q 5 ? of 2′—2″ ($3d\,^3\Pi_a - 2p\,^3\Pi_{ab}$).

$2s\,^1\Sigma - 2p\,^1\Sigma$ (infra-red)*

Band	Line	ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
3 ?′—0″	P 1	15142·64	2	− 0·2	—	—	− 0·2	—	—
		Undisplaced : P 2, 15095·67 (4).							
4 ?′—0″	P 4 ?†	16978·52	10	− 1·55	—	—	− 1·55	—	—
		Undisplaced : P 2 ?, 17129·89 (8) *c* ; P 3 ?, 17047·15 (4).							
4 ?′—1″	P 2	15817·47	3	—	—	+ 0·4	—	0	—
	P 3‡	15740·49	1	—	—	+ 2·2 *c*	—	—	+ 5·1
	P 4	15679·29	1	− 0·6	—	—	− 0·6	—	—
	R 0	15927·80	1	—	—	+ 4·0 I?	—	0 I	+ 4·0 I
						+ 2·2 I*c*			
	R 2	15933·16	0	− 6·6 II	—	+ 1·4 I	− 3·5 I?	0 IV	—
		15931·94	2	− 3·5 I?					
		15932·26	3	− 0·1 IV					

* Richardson and Davidson, 'Proc. Roy. Soc.,' A, vol. 124, p. 69 (1929).
† Also R 1 of 1′—1″ ($3d\,^3\Pi_b - 2p\,^3\Pi$).
‡ Also Q 4 of 3′—3″ ($3p\,^3\Pi - 2s\,^3\Sigma$).

$4d\,^1\Sigma - 2p\,^1\Pi$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—0″	Q 1	18260·26	5	− 1·3	—	—	− 2·9	0 ?	—
	R 1†	18239·51	10	− 1·7 II	—	+ 0·9 IV	− 1·7 IV	—	+ 0·9 IV
	R 2‡	18178·16	9	− 2·6 IV	—	—	− 3·2 IV	—	—
				wide			wide		
		18179·38	1						
	R 3	18108·03	3	. . . . . too faint			—	0	—
	R 4§	18035·41	4	− 3·6	—	—	− 3·6	—	—
		Undisplaced : Q 2, 18119·22 (1) *d*.							

* Richardson and Davidson, 'Proc. Roy. Soc.,' A, vol. 142, p. 63 (1933).
† Also P′ 3 of 2′—1″ ($3p\,^3\Pi_{ab} - 2s\,^3\Sigma$).
‡ Also P 4 of 0′—0″ ($4d\,^1\Pi_a - 2p\,^1\Pi$).
§ Also R 1 of x'—1″ ($2^3\,S' - 2\,^3S$).

$4d\,^1\Pi_b - 2p\,^1\Pi$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—0″	R 1	18452·56	6	− 2·2	—	—	− 2·2	—	—
	R 2†	18437·81	2	− 0·5	—	—	− 0·5	—	—
	R 3‡	18425·06	8	− 16 II *c*	—	—	− 1·6 I ?	—	—
				wide					
				− 4·8 I *c*			− 12·2 III		
							− 1·11 I		

* Richardson and Davidson, 'Proc. Roy. Soc.,' A, vol. 142, p. 63 (1933).
† Also Q 3 of 7′—5″ ($3p\,^3\Pi_{ab} - 2s\,^3\Sigma$).
‡ Also Q 2 of 2′—1″ ($3p\,^3\Pi_{ab} - 2s\,^3\Sigma$) and Q 3 of 0′—0″ ($4d\,^1\Pi_a - 2p\,^1\Pi$).

$4d\ {}^1\Pi_a - 2p\ {}^1\Pi$*

Band	Line	ν	I.	Displacements in cm⁻¹ Parallel			Perpendicular		
0′—0″	P 2	18414·66	2	− 3·4 I	—	—	− 2·5 II	—	—
				− 1·6 I					
	P 4†	18178·16	9	− 2·6 IV wide	—	—	− 3·2 IV wide	—	—
		18179·38	1						
	Q 1	18539·87	6	. . . . . confused			—	—	+ 8·0
	Q 3	18427·39	4	− 2·4	—	—	− 0·4	—	—
	Q 3‡	18425·06	8	− 1·6 II*a* wide	—	—	− 1·6 I?*a*	—	—
				− 4·8 I*c*			− 12·2 III*a*		
							− 1·11 I		

Undisplaced : R 2, 18604·98 (2) *c*.

* RICHARDSON and DAVIDSON, ' Proc. Roy. Soc.,' A, vol. 142, p. 63 (1933).
† Also R 2 of 0′—0″ ($4d\ {}^1\Sigma - 2p\ {}^1\Pi$).
‡ Also R 3 of 0′—0″ ($4d\ {}^1\Pi_b - 2p\ {}^1\Pi$) and Q 2 of 2′—1″ ($3p\ {}^3\Pi_{ab} - 2s\ {}^3\Sigma$).

$4d\ {}^1\Delta_b - 2p\ {}^1\Pi$*

Band	Line	ν	I.	Parallel			Perpendicular		
0′—0″	P 3	18381·39	3	. . . . . too faint			− 10·3 ? *a*	—	—
	R 2†	18799·23	5	− 1·2	—	—	—	—	+ 5 *c*

Undisplaced : Q 2, 18558·93 (2) *d*.

* RICHARDSON and DAVIDSON, ' Proc. Roy. Soc.,' A, vol. 142, p. 63 (1933).
† Also Q 3 of 1′—0″ ($3p\ {}^3\Pi_{ab} - 2s\ {}^3\Sigma$).

UNCLASSIFIED DISPLACED LINES

λ		ν	I.	Displacements in cm⁻¹ Parallel			Perpendicular		
6619·768		15102·10	1	—	—	+ 0·3 rough	− 0·8 I*c*	—	+ 0·7 I*c*
6610·0	S	15145	—	− 2·6	—	—	− 2·6	—	—
6597·782		15152·44	1	?	—	?	—	0	—
6545·1	T	15274·4	—	lost in H_α			− 0·6	—	—
6537·6	S	15292	—	—	—	+ 1·5 ?	—	—	+ 1·5 ?
6522·50	M	15327·31	—	—	—	+ 1·5	—	—	+ 1·5
6520·949		15330·95	1	− 1·8	0	—	− 1·8 *c*	0	—
6511·4	S	15353	—	—	—	+ 2·0	—	—	+ 0·4
6509·455		15358·03	1	. . . . . Too faint			—	—	+ 0·5
6502·065		15375·49	1	—	0 ?	+ small	—	0	—
6499·816		15380·80	0	—	—	+ small	—	0	—
6472·189		15446·46	0	—	—	+ 0·6 *d*	—	—	+ 0·6 *d*

Unclassified Displaced Lines (continued)

λ		ν	I.	Displacements in cm⁻¹: Parallel			Perpendicular		
6446·77	D	15507·36	—	—	—	+ 0·5	—	—	+ 0·5
6411·783		15591·98	2	—	—	+ 0·3	—	—	+ small
6381·816		15665·20	0	—	—	+ 0·3	—	—	+ 0·3
6380·226		15669·10	0	− 0·5	—	—	− 0·5	—	—
6380·110		15669·39	4						
6370·125		15693·95	1	− 1·6 III	—	+ 1·0 II	− 0·4 II	—	+ 1·2 II
6363·52	D	15710·23	—	− 1·3 I?	—	+ 0·1 I?	− 1·3 I?	—	+ 0·1 I?
6340·104		15768·26	0	− 3·1 I	0 IV	+ 1·9 III	—	0 II	+ 3·3 III
6340·574		15767·10	7						+ 1·9 II
6331·4	S	15790		—	—	+ 0·4	—	—	+ 0·4?
6323·789		15808·94	0	—	0 II	+ 6 I?	− 0·3 I	—	+ 1·6 I
6296·627		15877·13	0	− 2·5 I	—	+ 1·1 I	− 1·2 I	—	+ 1·1 I
6293·8	S	15884 (*d*)		− 0·8	—	—	—	0	—
6291·80	M	15889·31		− 1·4 I?	—	+ 0·9 I	—	0 I	—
6289·715		15894·58	1	− 2·7 I?*c*	—	+ 1·3 II	− 1·5 I?*c*	—	+ 1·3 II
6278·32	M	15923·44		− 3·5 *d*	—	—	− 1·6	—	—
6274·841		15932·26	3	− 6·6 II	—	+ 1·4 I	− 3·5 I?	0 IV	—
6274·967		15931·94	2	− 3·5 I?					
6274·486		15933·16	0	− 0·1 IV					
6255·147		15982·42	0	− 0·9 I	—	+ 1·3 I?	. . . . . Too faint		
6246·9	S*	16004		—	0	—	—	0	—
6246·4	S*	16005		− 3·7 I?	—	+ 0·9 II	—	—	+ 0·9 I
6237·450		16027·77	0	− 4 *c*	—	—	—	0	—
6216·524		16081·72	0	− 0·9	—	—	− 0·9	—	—
6214·45	D	16087·08		− 2·4 *d*	—	—	− 0·4	—	—
6193·800		16140·72	0	− 2·7 II wide	—	+ 1·2 I?	− 0·9 II	—	—
6186·52	M	16159·71		− 1·8 *d*	—	—	− 0·9?	—	—
6184·90	D	16163·95		. . . . . very diffuse			. . . . . diffuse		
6177·534		16183·22	0	− small	—	—	− small	—	—
6150·8	S	16254		—	—	+ 3·5†	—	—	+ 3·5†
6140·974		16279·56	0	− 0·8	—	—	+ 1·4 wide	—	—
6125·8	S	16320		—	—	+ 2	. . . . . too faint		
6118·135		16340·34	0	—	—	+ 3·2? *c*	—	0	—
6117·778		16341·29	0						
6112·785		16354·65	1	− 0·4	—	—	—	0	—
6106·3	S	16372		—	—	+ 0·5	—	—	+ 0·5
6105·49	D	16374·17		—	—	+ 0·6	—	0	—
6099·2	S	16391		− 7·3 II	0 I	—	− 7·3 I	0 I	—
6073·00	D	16461·77		− 1·7 *a*	—	—	+ 0·5 *a*	—	—
6044·344		16539·82	00	− 0·9 I	—	+ 0·9 III	− 0·9 I	—	+ 0·9 III
6044·651		16538·98	2						

* Apparently two lines in place of Gale, Monk, and Lees, λ 6246·561 (16004·39) (0) (Unclassified).

† These components may belong to the line 6151·470 (16251·79) (4), which is classified both as P′ 3 of 3′—3″ ($3d\,^3\Pi_a - 2p\,^3\Pi$) and as P 3 of 4′—1″ ($3p\,^3\Sigma - 2s\,^3\Sigma$). Displacements would then be + 5·0 in both polarizations.

Unclassified Displaced Lines (continued)

λ	ν	I.	Displacements in cm^{-1}					
			Parallel			Perpendicular		
6039·9 S	16552		− 1·0 I	—	—	− 1·4 I?	—	+ 1·5 I
6035·9 S	16563		− 0·9 *d*	—	—	− 0·9	—	—
6035·047	16565·30	0	—	—	+ 1·7	—	—	+ 1·7
6034·6 S	16567		− 3·1	—	—	− 3·1	—	—
6021·532	16602·48	0	− 1·5 V	—	—	− 1·5 III	—	+ 0·3 IV
6021·273	16603·20	9						
6014·850	16620·92	1	—	—	+ 0·9	—	—	+ 0·9
5992·154	16683·88	0	− 1·6	—	—	− 2·1	—	—
5991·793	16684·88	1						
5980·866	16715·37	0	—	—	+ 0·6	—	—	+ 0·2
5980·0 S*	16718		—	—	+ 0·9	—	—	+ 0·9
5978·9 S*	16721		—	—	+ 0·8	—	—	+ 0·8
5978·035	16723·28	1	—	—	+ 0·8 *c*	—	—	+ 0·4 *c*
5970·113	16745·48	0	Displaced, but very confused.			Displaced, but very confused.		
5960·407	16772·74	1	− 2·8 IV	—	—	− 2·8 II	0 IV	—
5959·806	16774·42	6						
5959·615	16774·97	4						
5956·502	16783·74	2	− 0·8 I	—	+ 0·4 IV	—	—	+ 0·4 IV
5956·210	16784·56	1						
5941·977	16824·76	3	—	—	+ 0·5	—	0 *c*	—
5936·027	16841·63	4	—	—	+ 10 I*a*	—	—	+ 10 I*a*
								+ 3 I*a*
5920·489	16885·83	5	—	0 IV	+ 4·1 IV	− 4·0 III	—	+ 4·0 III
5920·799	16884·94	4			+ 2·1 III			+ 0·3 III
5918·078	16892·70	5	—	—	+ 4·5	—	—	+ 4·5 *c*
5914·940	16901·67	1	—	—	+ 2·8 I *d*	—	0 I	—
					+ 0·5 I			
5887·346	16980·89	1	− 1·1 I	—	+ 1·2 II	—	—	+ 1·2 II
5883·385	16992·32	0	—	0 V	+ 1·96 I	—	0 V	—
5874·886	17016·90	0	—	—	+ 0·8	—	—	+ 0·8
5859·808	17060·68	5	—	0 I	+ 1·8 III	—	0 I	+ 1·8 III
5804·677	17222·72	2	—	—	+ 0·7	—	—	+ 0·7
5780·269	17295·44	0	− 1·0 ?	—	—	—	0 ?	—
5778·1 S	17302		—	—	+ 0·8	− 0·7	—	—
5770·154	17325·77	1	− 0·9 *d*	—	—	—	0	—
5720·8 S	17475		—	0	—	—	0 II	+ 4·5 I
5701·5 S	17534		. . . . . too faint			—	—	+ 2·8
5697·531	17546·60	2	− 2·9 III	—	—	− 2·9 III	0 III	—
5697·402	17547·00	2	− 1·9 III*a*			− 1·9 II*a*		
5687·459	17577·68	2	− 1·1 *c*	—	—	− 2·5	—	—
5670·281	17630·93	1	− 2·0 II	—	+ 1·2 III	—	0 IV	—
5670·930	17628·90	4						
5670·756	17629·46	1						
5661·626	17657·88	3	− 1·1	—	—	− 2·8	0 ?	—
5661·835	17657·24	2						

*Apparently two lines in place of Gale, Monk, and Lee's 5979·114 (16720·26) (2), (Unclassified).

Unclassified Displaced Lines (continued)

λ	ν	I.	Displacement in cm^{-1} Parallel			Perpendicular		
5654·761	17679·32	2	− 0·4 I	—	+ 1·1 II*d*	− 0·4	—	—
5618·287	17794·10	1	—	—	+ 3·5*a* rough	—	—	+ 3·5*a* rough
5616·772	17798·89	1	− 0·9	—	—	− 0·9	—	—
{ 5604·356	{ 17838·32	1	− 3·9	—	—	− 3·4	—	—
{ 5604·685	{ 17837·29	3						
5601·704	17846·77	3	− 4·8	—	—	− 4·8	—	—
5600·416	17850·87	7	− 4·66 IV − 1·7 I	—	+ 0·29 III	− 4·1 V	0 II	—
5566·193	17960·64	1	− 2·3	—	—	− 2·7	—	—
{ 5499·213	{ 18179·38	1	− 2·6 wide	—	—	− 3·2 wide	—	—
{ 5499·581	{ 18178·16	9	—	—	—	—	—	—
5497·3 S	18186		—	—	+ 0·9	—	—	+ 0·4
5409·692	18480·23	4	—	—	+ 3·4 *c*	—	—	+ 3·4
5386·195	18560·82	3	. . . . . too faint			—	—	+ 7·9
5362·835	18641·69	2	. . . . . too faint			− 5·6*a*	—	—
5355·912	18665·78	7	− 17·7	—	—	− 16·1	—	+ 5·4
5319·162	18794·74	3	—	—	+ 14	—	—	+ 4·4
{ 5103·282	{ 19589·79	0	− 1·7	—	—	—	0	—
{ 5103·566	{ 19588·70	4						

Discussion of Results

The displacement of an energy level in a given field depends upon the proximity of its neighbouring levels and the probabilities of transition between them. This is known to be true in atomic spectra (see, for example, the work of Harkness and Heard*) and MacDonald's theory indicates that it holds for H_2. A quantitative comparison of theory and experiment, therefore, requires an accurate knowledge of the structure of the normal spectrum, and will not be attempted here.

A qualitative comparison is possible on the basis of the patterns shown by individual lines. As pointed out by Kronig† and by MacDonald, the component of the total angular momentum vector K along the direction of the external field is quantized, and assumes values specified by the quantum number M. $M = 0, 1, \ldots K$. The energy perturbations associated with $+ M$ and $- M$ are identical, so that an energy level with a given K is split in the electric field into $K + 1$ sub-levels characterized by the different M-values. In transitions $\Delta M = 0, \pm 1$ for parallel and perpendicular components respectively. Taking into consideration

* 'Proc. Roy. Soc.,' A, vol. 139, p. 416 (1933).

† 'Band Spectra and Molecular Structure,' p. 35, Camb. Univ. Press, 1930.

the splitting of both initial and final levels, this means that the maximum possible numbers of components for P-, Q-, and R-lines are as follows :—

$$\left.\begin{array}{lll} \mathrm{P}\ (\mathrm{K}) : \mathrm{K} \text{ parallel components,} & 2\mathrm{K} - 1 \text{ perpendicular components} \\ \mathrm{Q}\ (\mathrm{K}) : \mathrm{K} + 1 & 2\mathrm{K} \\ \mathrm{R}\ (\mathrm{K}) : \mathrm{K} + 1 & 2\mathrm{K} + 1 \end{array}\right\} \quad (1)$$

If there were a complete representation of the components in a band, one would be able to find the displacements and M-values for all of the sub-levels in the initial and final rotational states. In such a process one would start with the R 0 line to determine the displacements of the initial K = 1 level, then take the Q 1 line to determine the displacements of the final K = 1 level, then the R 1 line for the initial K = 2 level, and so on. The extra data supplied by the P-lines would be used to check the process, and the displacements would all be subject to a small correction due to a possible displacement of the final K = 0 level. In practice the rapidly increasing number of possible components, together with the ambiguities introduced by missing and coincident components soon set a limit to the process.

A simplification is introduced by the probability that the final levels are undisplaced. This is generally true in atomic spectra, and appears to be frequently true in H_2. Under these circumstances, the lines would follow the following scheme of patterns :—

P (K) : K components in the parallel, and the same K components in the perpendicular.

Q (K) : K + 1 components in the parallel, and the same K + 1 components in the perpendicular. (2)

R (K) : for K > 0, K + 1 components in the parallel, and in the perpendicular the same K + 1 components + one new one. For K = 0, one parallel component, and one perpendicular component.

A very large number of lines show agreement with this type of pattern. Examples in the system $3d\,{}^3\Pi - 2s\,{}^3\Sigma$ are the $1' - 1''$ P′ 3 and Q 3 lines, the $2' - 2''$ P′ 3 line, and the $1' - 0''$ R′1 and P′ 3 lines. Many others are included if one allows for small perturbations of the final levels.

A further correlation between theory and experiment can be obtained in a slightly different way. In transitions not involving a Σ state the lines P (K + 2), Q (K + 1), and R (K) in each band originate from the same initial level, fig. 2, and if (2) holds their Stark effects should show some components in common. The lines P′ (K + 2), Q′ (K + 1), and R′ (K) should also show some resemblance, but since the transitions take place between levels with symmetry characteristics opposite to those of the former set, there will be a difference in the perturbations caused by neighbouring levels, and there should be only a fortuitous resemblance between these lines and those of unprimed set. Similarly in $\Pi \rightarrow \Sigma$ transitions the P (K + 2) and R (K) lines should have components in common, but probably different from those of the Q-lines; and in $\Sigma \rightarrow \Sigma$ transitions with P- and R-branches P (K + 2) should show similarities with R (K). Furthermore, there should be a resemblance between the respective lines in the various bands originating from the same initial vibration level.

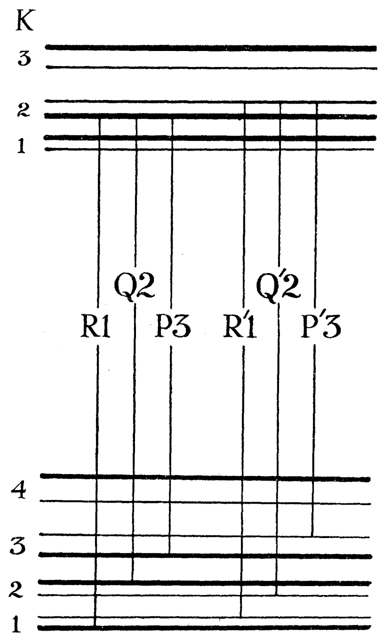


FIG. 2—Examples of transitions from common initial levels, for band systems not involving a Σ-state. Unprimed letters refer to transitions between asymmetric states, and primed letters to transitions between symmetric states. (This notation has not been used exclusively; exceptions occur in the earlier classifications, and include the system $3p\,{}^3\Pi - 2s\,{}^3\Sigma$.)

In the $3p\,{}^3\Pi - 2s\,{}^3\Sigma$ system this type of agreement is very evident in the $1' - 1''$, $2' - 2''$, and $2' - 1''$ bands, while the P′- and R′-lines of $1' - 1''$ show some resemblance to those of $1' - 0''$, and $2' - 2''$ resembles $2' - 1''$. In the $3s\,{}^3\Sigma - 2p\,{}^3\Pi$ $1' - 1''$ band the lines R′ 1, Q′ 2, and P′ 3 are so diffuse that they have no components strong enough to measure. The many undisplaced lines in $3d\,{}^1\Sigma - 2p\,{}^1\Sigma$, $3d\,{}^1\Pi_a - 2p\,{}^1\Sigma$, and $3d\,{}^1\Pi_b - 2p\,{}^1\Sigma$ afford further illustrations, and many other cases of common components are scattered among the data. On the other hand, some bands, while agreeing with the conditions (1) and (2), show no inter-resemblance between the lines; such bands are given by $3p\,{}^3\Sigma - 2s\,{}^3\Sigma$, $2' - 0''$ and most of the bands of $3d\,{}^3\Pi - 2p\,{}^3\Pi$.

Strangely enough, the strongest band of all, viz., $0' - 0''$ of $3p\,{}^3\Pi - 2s\,{}^3\Sigma$ shows apparent anomalies. The difference of $10 \cdot 5$ cm^{-1} between the parallel and perpendicular displacements of the R′ 0 line gives the separation of the $M = 0$ and $M = 1$ sub-levels in the initial $K = 1$ state, fig. 3. This difference should appear in the displacements of the P′ 2 line, but it does not. Furthermore, the small dis-

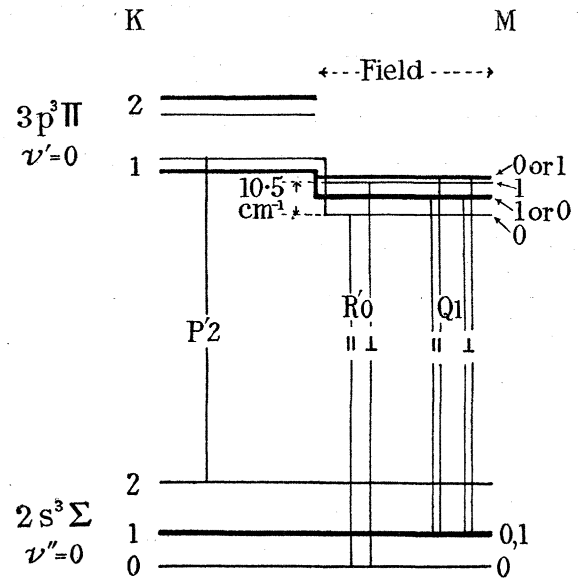


FIG. 3—Effect of electric field upon K = 1 level of $3p\ ^3\Pi$, $v' = 0$

placements of the Q 1 line should be equal, fig. 3, and finally, there is a lack of the similarity one would expect between the P′- and R′-lines.

A few other features may be noted :—

(1) The very large number of small displacements to the blue which occur in the system $3d\ ^3\Delta - 2p\ ^3\Pi$ is remarkable, and suggests that the perturbation is almost purely electronic, and occurs in the initial level $3d\ ^3\Delta$.

(2) The first examination of the plates revealed the surprising fact that the strong lines νν 15688·81 (5), 17935·73 (6), and 18115·94 (8) are entirely missing, and the line ν 15859·86 (5) is unexpectedly weak. These lines were later found respectively to be $3p\,^3\Pi - 2s\,^3\Sigma$ 3′ — 3″ P′ 2, 3′ — 2″ P′ 2, 3′ — 2″ R′ 0 and 3′ — 3″ R′ 0 : *i.e.*, they all come from the same initial level $3p\,^3\Pi$ $v' = 3$ K = 1.

(3) The lines of only a few band branches resemble one another. Examples are the Q-lines of 2′ — 2″ $3p\ ^3\Pi - 2s\ ^3\Sigma$ and the P- and R-lines of (— 2^3 S) ?′ — 1″. See Plates 2 and 3.

(4) No new lines brought into existence by the electric field can definitely be said to be on the plates. The S-lines in the table of unclassified displaced lines may be of this type (for H_α and H_β show that a small residual field is present at the " zero " field region of the plates), but it is more probable that they are lines of the hydrogen molecule ion, enhanced in the Lo Surdo source.

(5) It frequently happens that if a component in a pattern appears in both polarizations it is strong in the one and weak in the other. Examples of this are numerous ; among them are the lines νν 16654·24, 16611·43, 16596·37, 16488·15, 16440·72, 16046·28, and 15787·23. See plates 2 and 3.

(6) In a few instances, double classifications of lines are corroborated by the appearance of more Stark components than are allowed by the restrictions (1). One example is the R′ 0 line of 0′ — 0″ $3p\,^3\Pi - 2s\,^3\Sigma$, where the displacement of

the single parallel component has revealed the fainter R4 line of $3' - 3''$ $3d\,{}^3\Pi_c - 2p\,{}^3\Pi$. Other examples are $3d\,{}^3\Sigma - 2p\,{}^3\Pi$ $0' - 0''$ P 2, and possibly $3p\,{}^3\Pi - 2s\,{}^3\Sigma$ $2' - 1''$ Q 2.

Many of the unclassified displaced lines may be classified in the future. When this is done, their Stark patterns may be of assistance in determining their K-values.

Plates 2, 3 and 4 are reproductions of the more interesting regions of the spectrograms. Selected lines are marked.

The writer is greatly indebted to Dr. J. S. Foster for the interest he has shown during the course of his supervision of the work. The earlier part of the research was carried out under the awards of a Bursary and a Studentship from the National Research Council of Canada.

Summary

A study has been made of the Stark effect for the molecular spectrum of hydrogen in the region between the lines H_α and H_β. The spectrum was photographed in the first order of a large concave grating giving a dispersion of 3·8 A per mm. About 350 lines were found to show measurable displacements in a field of 90,000 volts per cm.

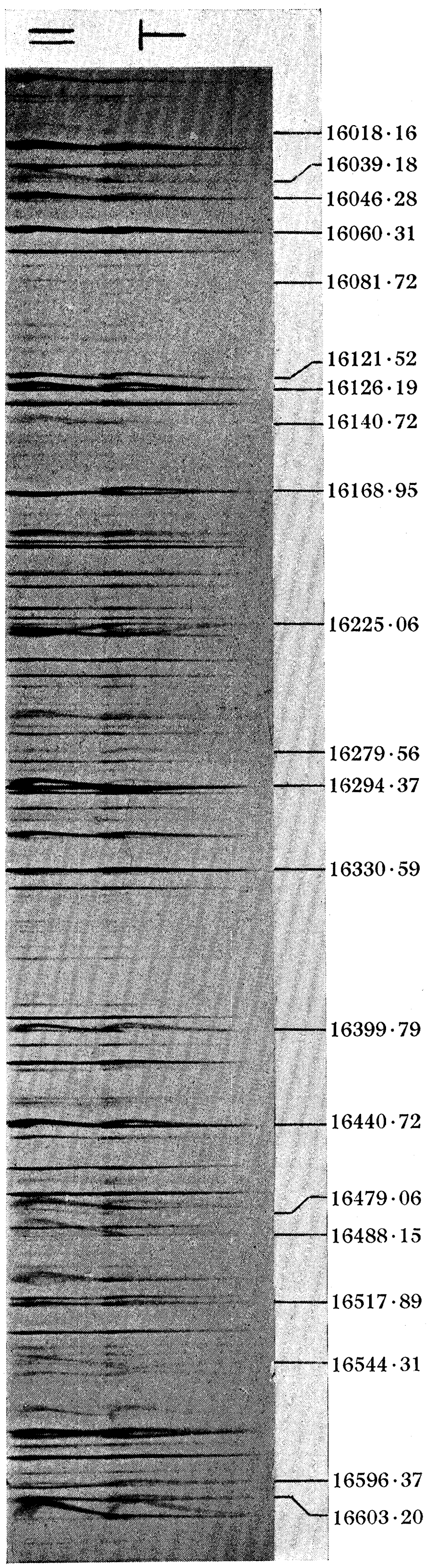
Nearly all of the lines recorded in the published tables appear on the plates, with the exception of a short region near H_β in which the representation is slightly less complete.

A few new lines have been found. They are displaced in the field.

Measurements of the displacements of the lines are given to an accuracy of about $\pm\,0{\cdot}1$ cm^{-1}. Undisplaced lines which belong to known band systems have also been recorded.

The patterns observed do not violate the restrictions imposed by theory. Lines with low rotational numbers (0, 1) show simple patterns which are in agreement with theory. For lines with higher rotational numbers a close comparison with theory is prevented by the increasing complexity of the patterns and the possible occurrence of coincident components and of components of very low intensity.

Lines which originate from the same initial state often show components with equal displacements. One apparent confliction is noted.



16018·16
16039·18
16046·28
16060·31
16081·72
16121·52
16126·19
16140·72
16168·95
16225·06
16279·56
16294·37
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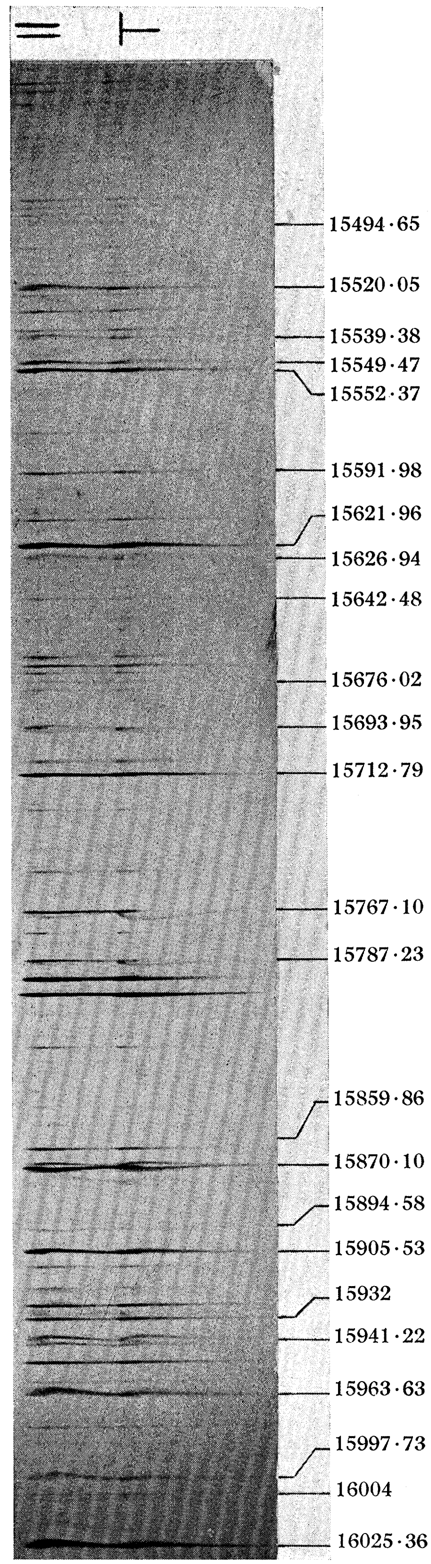
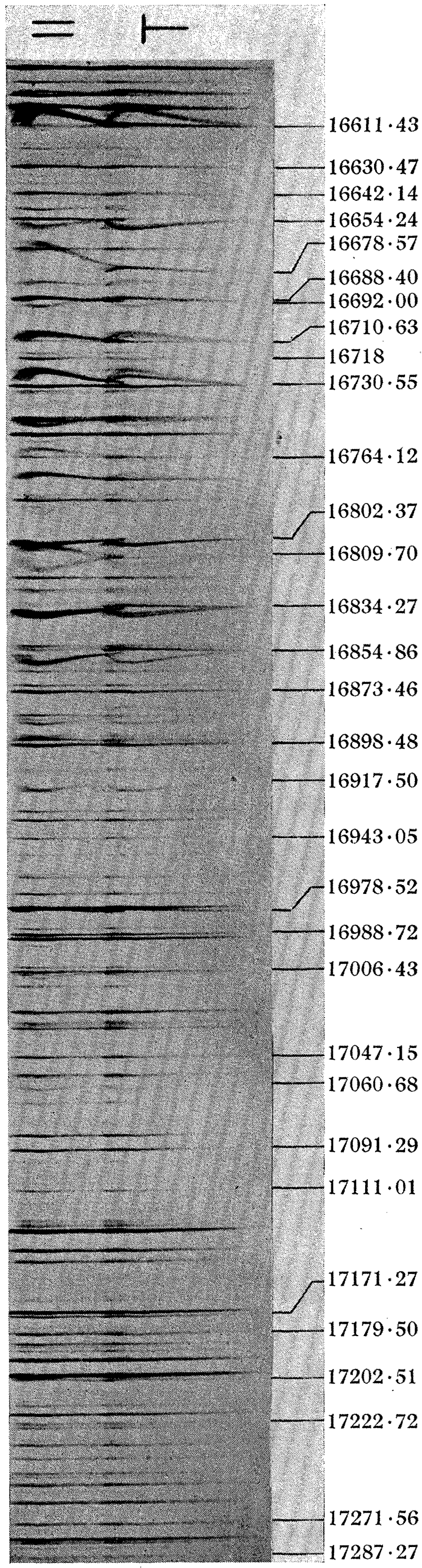
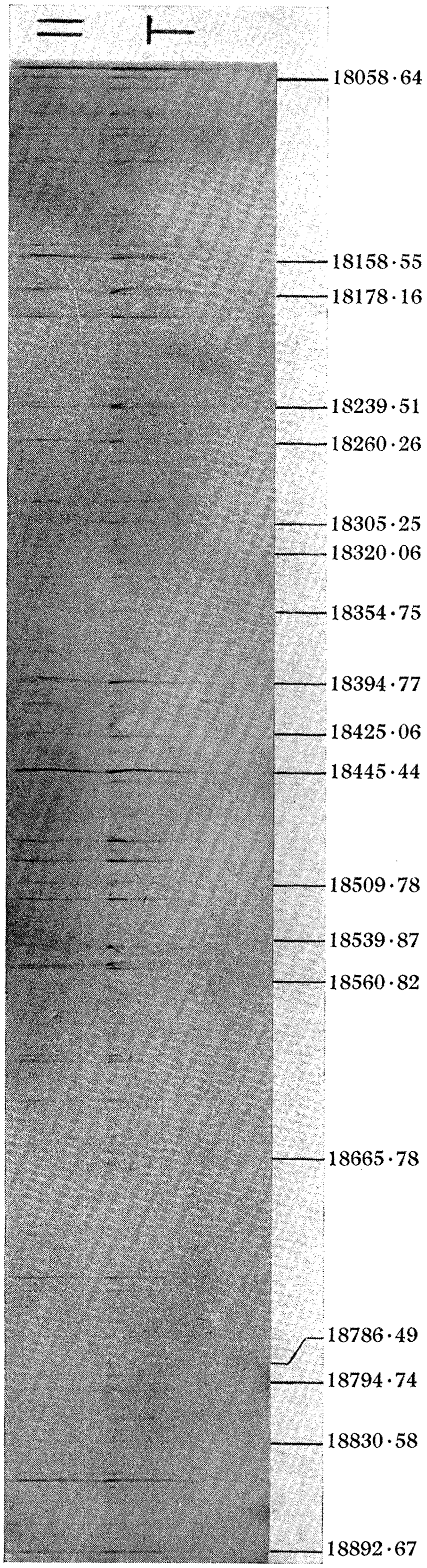
16544·31
16596·37
16603·20

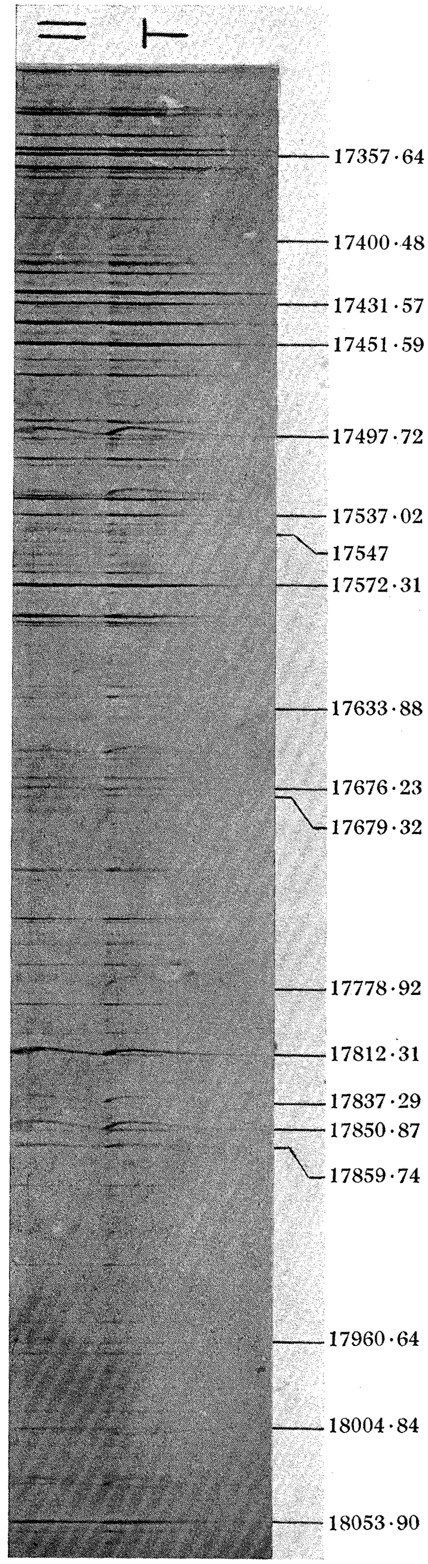


15494·65
15520·05
15539·38
15549·47
15552·37
15591·98
15621·96
15626·94
15642·48
15676·02
15693·95
15712·79
15767·10
15787·23
15859·86
15870·10
15894·58
15905·53
15932
15941·22
15963·63
15997·73
16004
16025·36



PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES





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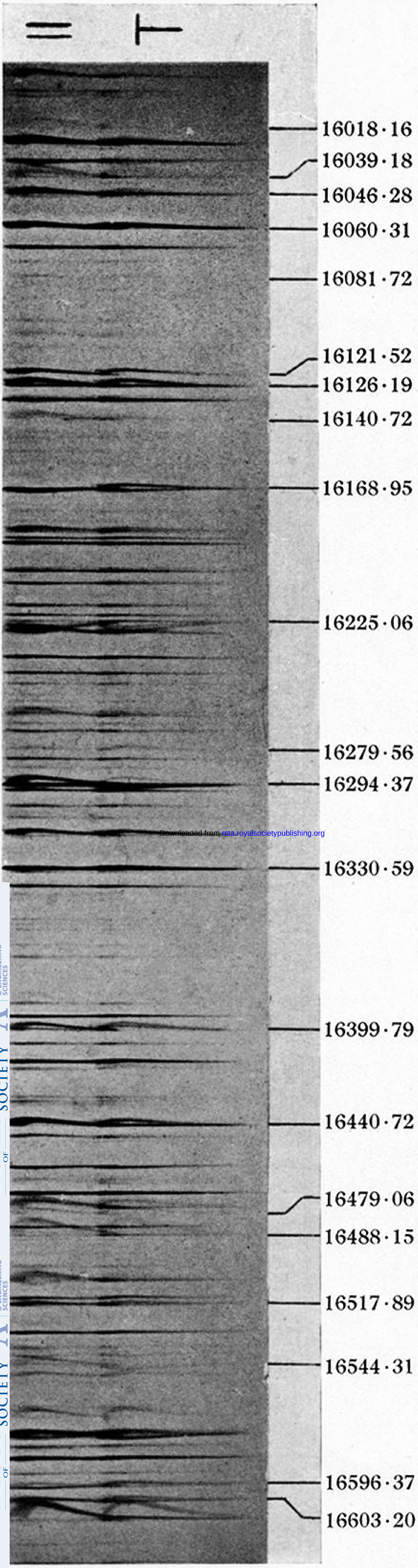
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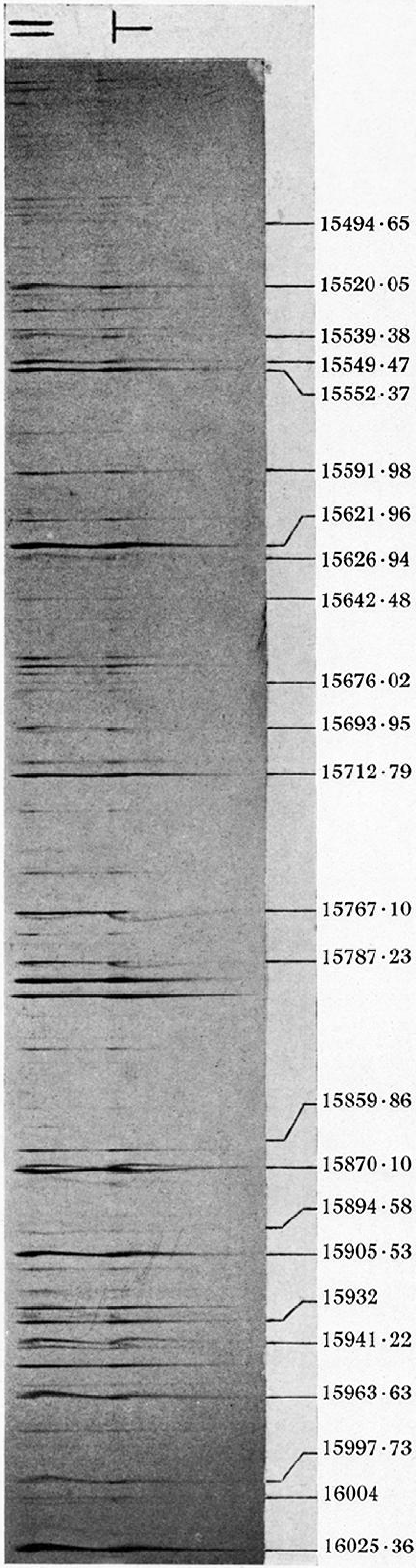
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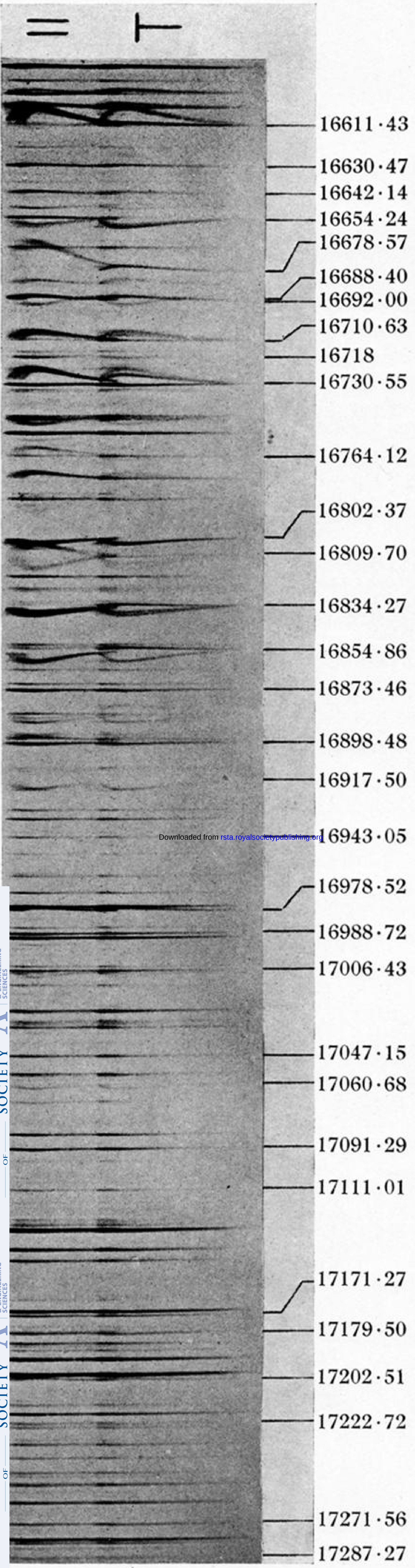
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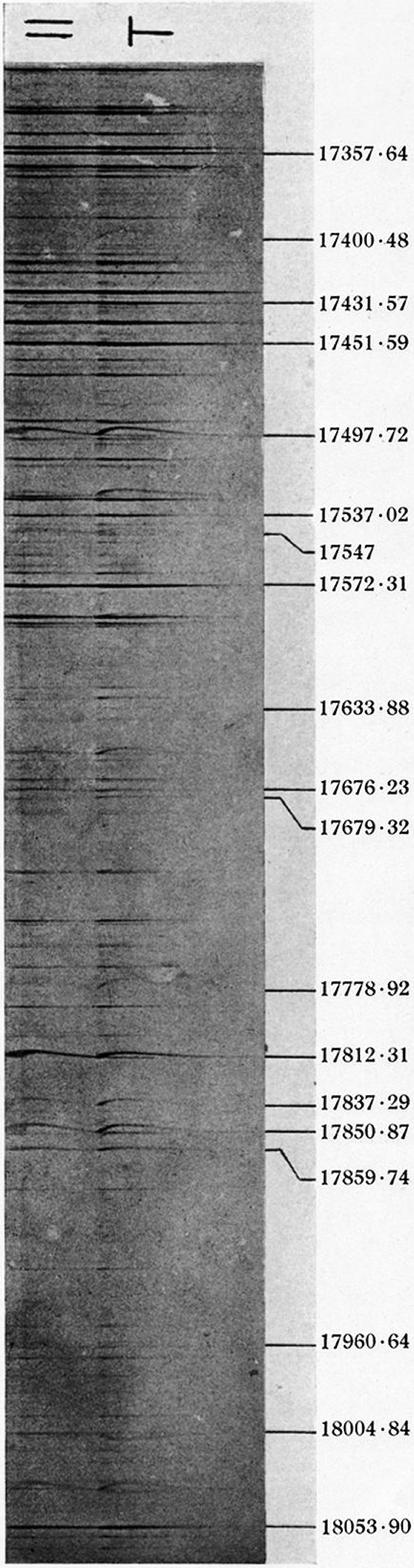
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