

The Band Spectra of MgO, CaO and SrO

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(Received September 9, 1932)

New measurements of the wave-lengths of the band heads attributed to the oxides of Mg, Ca and Sr have been made from moderate dispersion spectrograms. For each of these molecules the bands have been classified into two systems. The equations of the band heads in terms of half-quantum numbers for the different systems are as follows:

MgO, red bands:

$$\nu = 16,418.06 + \left\{ 821.95(v' + \frac{1}{2}) - 4.05(v' + \frac{1}{2})^2 \right\} \\ - \left\{ 665.74(v'' + \frac{1}{2}) - 4.41(v'' + \frac{1}{2})^2 \right\}$$

MgO, green bands:

$$\nu = 19,944.82 + \left\{ 811.67(v' + \frac{1}{2}) - 3.74(v' + \frac{1}{2})^2 \right\} \\ - \left\{ 771.42(v'' + \frac{1}{2}) - 4.81(v'' + \frac{1}{2})^2 \right\}$$

CaO, blue bands:

$$\nu = 23,817.62 + \left\{ 726.53(v' + \frac{1}{2}) - 11.66(v' + \frac{1}{2})^2 \right\} \\ - \left\{ 811.28(v'' + \frac{1}{2}) - 6.60(v'' + \frac{1}{2})^2 \right\}$$

CaO, ultraviolet bands:

$$\nu = 28,849.13 + \left\{ 565.06(v' + \frac{1}{2}) - 4.48(v' + \frac{1}{2})^2 \right\} \\ - \left\{ 725.37(v'' + \frac{1}{2}) - 3.56(v'' + \frac{1}{2})^2 \right\}$$

SrO, blue bands:

$$\nu = 24,702.81 + \left\{ 519.09(v' + \frac{1}{2}) - 3.50(v' + \frac{1}{2})^2 \right\} \\ - \left\{ 653.47(v'' + \frac{1}{2}) - 4.02(v'' + \frac{1}{2})^2 \right\}$$

SrO, ultraviolet bands:

$$\nu = 28,622.18 + \left\{ 497.81(v' + \frac{1}{2}) - 5.97(v' + \frac{1}{2})^2 \right\} \\ - \left\{ 679.13(v'' + \frac{1}{2}) - 9.13(v'' + \frac{1}{2})^2 \right\}.$$

INTRODUCTION

THE earliest spectroscopic workers¹ noticed in the spectrum of Mg, Ca and Sr or their salts subjected to a variety of conditions of excitation, a class of bands, which were ascribed by them either to the metals or to their oxides. Kayser was, however, of opinion that both types of bands are present in the spectrum. He has collected the old measurements of wave-lengths of the band heads but no satisfactory agreement is to be found among the various data. With the improvement of the experimental technique, it has however been found that some of these bands, although they appear in the ordinary arc or flame spectrum of Mg, Ca and Sr or their salts, fail to show themselves if the arcing is conducted in vacuum or in a dry hydrogen or nitrogen atmosphere

¹ Kayser, *Handbuch der Spectroscopie* 5, 252, 717 (1910); 7, 172 (1924); 6, 551 (1912).

but increase in their intensity depending on the amount of oxygen present. It is these bands which have been ascribed to the oxides and they form the subject of the present investigation.

In 1927, Mecke and Guillery² analyzed one system in the case of CaO and SrO from the old data then available. The present analysis however discloses that they have used parts of two different systems for CaO. For SrO they have not published any data of band heads analyzed by them. More recently a vibrational quantum analysis³ of the well-known green bands of MgO from measurements on low dispersion spectrograms (about 23A/mm at λ 5000) has been published.

The present paper deals with the vibrational quantum analysis of the bands of MgO, CaO and SrO from new measurements of the wave-lengths of band heads, believed to be more accurate than existing data. For each of these molecules, the spectrum has been investigated between the region λ 7500– λ 2300, and the bands have been found to form two different systems. Only the bands of MgO lying in the red region appear to offer the best possibilities for a fine structure analysis. Such an analysis is being undertaken and will be reported in a subsequent paper.

EXPERIMENTAL

The spectra herein described, except that of magnesium, were produced in electric arcs between carbon electrodes with some salt of the element under investigation. In the case of magnesium the lower electrode (+) was drilled to hold magnesium rods about $\frac{1}{8}$ inch in diameter. During a single exposure several rods had to be used. The salts employed were pure anhydrous calcium chloride and strontium chloride. The arc was operated on a 220 volt d.c. circuit with the current varying from six to seven amperes but in the case of magnesium, the current was about an ampere.

Spectrograms were taken with the Hilger-Littrow-mounted E.1 prism spectrograph, having a dispersion with the glass optical system of approximately 35A/mm at λ 7500 to 6A/mm at λ 4400, and with the quartz system of 17A/mm at λ 4500 to 2A/mm at λ 2300 as well as in the first and second orders of a 15 ft. Rowland concave grating set up in a Paschen mounting. The dispersion in the first order is about 3.52A per mm. Ilford Empress and green sensitive orthochromatic plates as well as special rapid panchromatic plates freshly dyed with pinacyanol were used.

The heads are apparently single and fairly sharp except where they are greatly superposed by the structure lines of the preceding bands. With a Gaertner comparator (MI201a), the intense band heads were measured on grating plates while prism spectrograms of moderate dispersion were used for the measurement of the weaker ones. For standards, iron and neon lines were taken.

Eye estimates of the intensities of the heads were made from the plates taken with the prism spectrographs.

² Mecke and Guillery, *Phys. Zeits.* **28**, 514 (1927).

³ Ghosh, Mahanti and Mukherjee, *Phys. Rev.* **35**, 1491 (1930).

The band head data and their vibrational quantum assignments are given in Tables I–VI. λ is the wave-length in air in international angstroms, I the visual estimate of the relative photographic intensity of the band heads, and ν the vacuum wave-number in cm^{-1} . $O-C$ is the difference between the wave-number observed and that calculated from the empirical equation for each system.

Magnified reproductions of typical sequences in the band systems of MgO, CaO and SrO are given in Figs. 1, 2 and 3.

MAGNESIUM OXIDE

In the spectrum of magnesium arc in air the band groups lying between $\lambda 7000$ – $\lambda 5250$ and also extending as far as $\lambda 4700$ as well as those at $\lambda 5205$ and $\lambda 5007$, which are given in the excellent reproduction of Eder and Valenta,⁴ have been attributed to the oxide of magnesium while the ultraviolet bands and a number of visible bands at $\lambda 5125$ and $\lambda 4819$ have been ascribed to the metal. The bands at $\lambda 5007$ were observed by each one of the earliest spectroscopic workers⁵ in the spectrum of magnesium or its salts under various modes of excitation. Lockyer⁶ found them also present in the spectrum of nebulae. The band group at $\lambda 5205$ was obtained only by Eder⁷ in the flame and spark spectra of magnesium and by Brooks⁸ in the anode spectrum in oxygen when a high voltage unidirectional but pulsating discharge was passed between magnesium electrodes. In addition to the above two groups of bands, the latter also observed a number of bands at the red end of the same spectrum and gave approximate measurements of seven band heads between $\lambda 6600$ – $\lambda 5250$. In the present investigation as many as twenty-five heads have been measured in this region and the measurements extended on both sides thus bringing the total number of heads measured to forty-seven for the red bands. Spectrograms taken with the glass spectrograph as well as in the first order of the 15 ft. concave grating were used for measurements which are correct to $\pm 0.05\text{\AA}$. The two band groups at $\lambda 5205$ and $\lambda 5007$ were also measured from the glass prism spectrograms as well as from those taken in the second order of the same grating. They form, respectively, $\Delta\nu = +1$, and 0 sequences of the green system, which includes twenty-three band heads.

The red bands are not of perceptible intensity in the usual flame surrounding the magnesium arc in air. But they are fairly intense if the arc bursts out into a vigorous flame. With an exposure for about an hour with this type of flame, they are well developed on the plates taken with the glass spectrograph, but the band heads lying below $\lambda 5210$ are very much superposed by the green bands.

So far as the writer is aware, no new measurements or vibrational quantum analysis of the red bands have yet been published, while for the green

⁴ Eder and Valenta, *Atlas Typischer Spektren*, Wien (1924).

⁵ Kayser, *Handbuch der Spectroscopie* **5**, 717 (1910).

⁶ Lockyer, *Proc. Roy. Soc.* **48**, 167 (1890).

⁷ Eder, *Denkschr. Wien. Akad.* **74**, 45 (1903).

⁸ Brooks, *Astrophys. J.* **29**, 177 (1909).

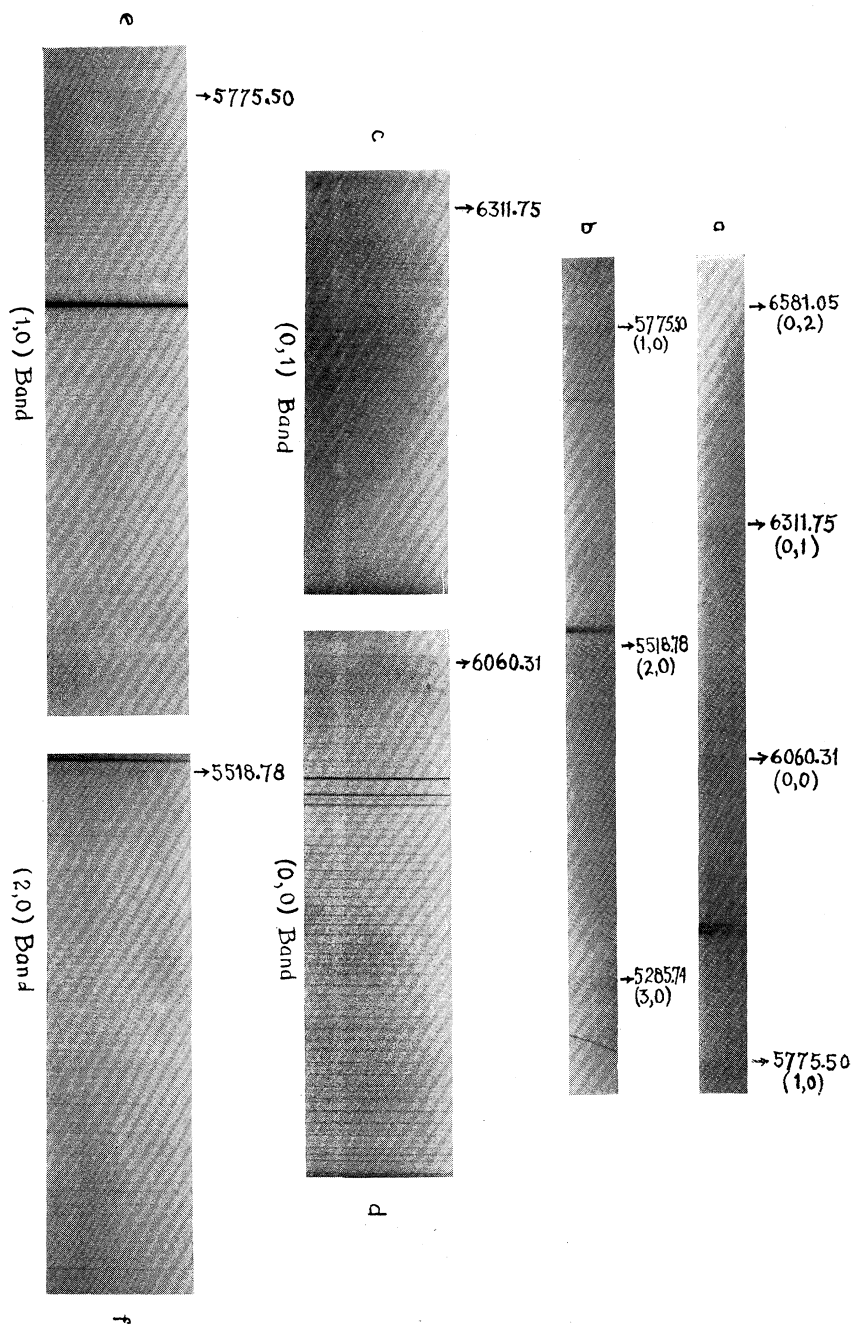
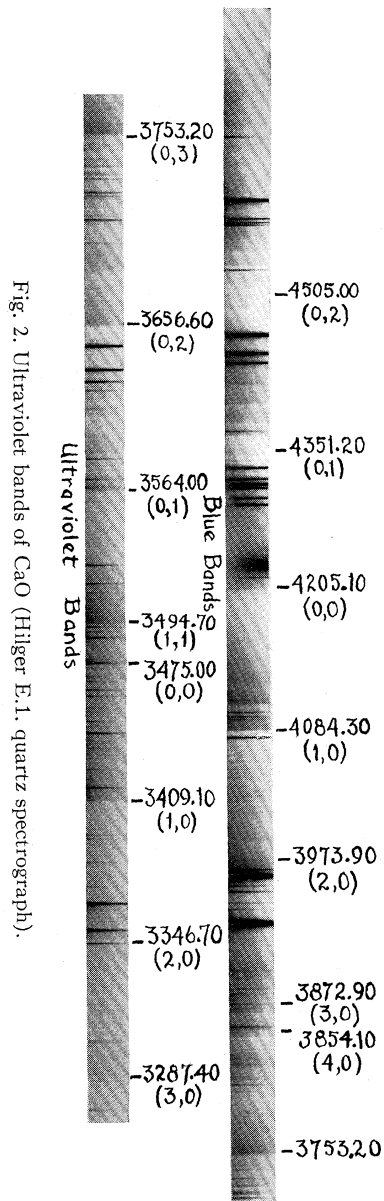


Fig. 1 Red bands of MgO: a, b, Hilger E. 52, glass spectrograph; c, d, e, f, 15 ft. grating first order.



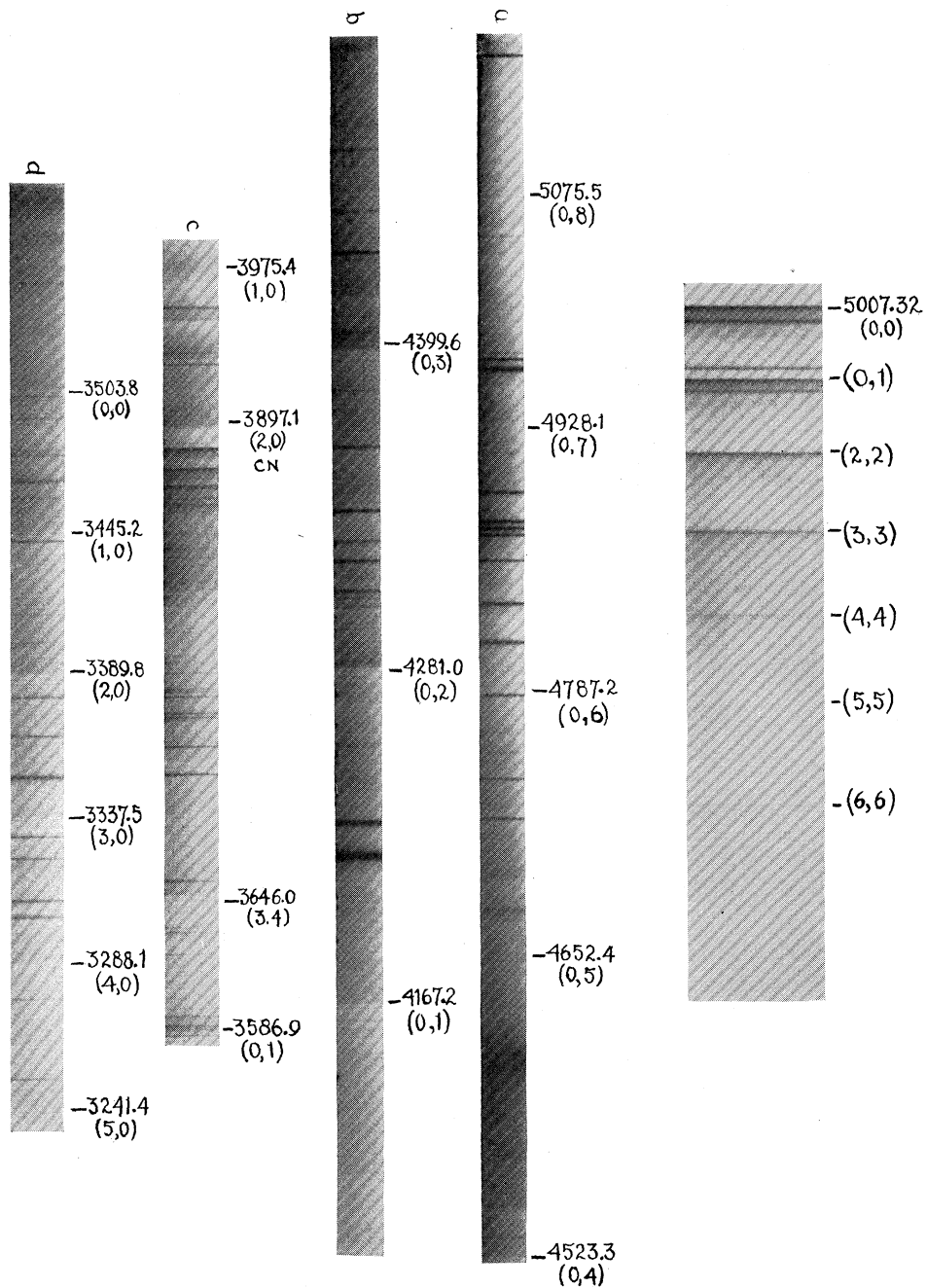


Fig. 3. Right half of figure, green bands of MgO (15 ft. grating second order). Left half, bands of SrO; a, b, Hilger E. 52. glass spectrograph; c, d, Hilger E.1. quartz spectrograph.

bands the analysis has only been done from measurements on low dispersion spectrograms. New measurements of band heads as well as their vibrational assignments are given in Tables I and II.

TABLE I. *The red bands. New data and vibrational quantum analysis.*

v'	v''	$\lambda_{\text{hd.}}(\text{\AA.})$	I	ν (cm^{-1})	$O-C$ (cm^{-1})
0	3	6870.19	2	14,551.63	-0.35
1	4	6783.61	1	14,737.35	+1.97
2	5	6699.97	1	14,921.33	+1.83
3	6	6617.78	0	15,106.64	+2.29
0	2	6581.05	3	15,190.95	-0.29
4	7	6537.37	0	15,292.46	+2.56
1	3	6506.26	2	15,365.58	-0.25
2	4	6432.12	1	15,542.69	+1.57
3	5	6359.64	1	15,719.82	+2.68
0	1	6311.75	4	15,839.35	+0.01
4	6	6289.93	0	15,894.04	+0.16
1	2	6246.38	3	16,004.95	-0.14
5	7	6220.59	0	16,071.21	+0.12
2	3	6181.84	2	16,171.95	+0.38
3	4	6118.47	1	16,339.45	+0.69
0	0	6060.31	6	16,496.25	+0.00
1	1	6003.26	2	16,552.99	-0.20
2	2	5947.18	1	16,810.05	-0.78
1	0	5775.50	5	17,309.73	-0.37
2	1	5726.34	3	17,458.33	-0.60
3	2	5677.03	2	17,609.97	+1.50
4	3	5629.06	1	17,760.04	+1.30
2	0	5518.78	4	18,114.93	-0.91
3	1	5475.94	3	18,256.65	+0.08
4	2	5433.39	2	18,399.61	+1.61
5	3	5391.74	1	18,541.74	+1.57
6	4	5349.78	0	18,687.17	+4.12
3	0	5285.74	3	18,913.58	+0.10
4	1	5249.58	2	19,043.86	-2.24
5	2	5212.44	1	19,179.55	+0.12
4	0	5073.95	2	19,703.03	+0.02
5	1	5041.44	1	19,830.09	+2.56
10	7	5034.12	0	19,858.92	+2.00
6	2	5010.39	1	19,952.98	+0.22
10	6	4887.09	1	20,456.38	-4.52
11	7	4855.54	1	20,589.30	-0.43
6	1	4851.49	1	20,606.49	+5.63
7	2	4825.94	1	20,715.58	-2.40
12	8	4824.39	1	20,722.23	+2.94
8	3	4797.98	0	20,836.30	+0.46
13	9	4794.59	1	20,851.03	+1.47
9	4	4772.07	1	20,949.42	-4.98
14	10	4764.61	1	20,982.23	+1.68
10	5	4744.02	1	21,073.06	-0.63
15	11	4736.21	1	21,108.04	-4.22
11	6	4717.73	1	21,190.72	-2.99

The equations of the band heads in terms of half-quantum numbers for the two systems are as follows.

For the red system:

$$\nu = 16,418.06 + \left\{ 821.95(v' + \frac{1}{2}) - 4.05(v' + \frac{1}{2})^2 \right\} - \left\{ 665.74(v'' + \frac{1}{2}) - 4.41(v'' + \frac{1}{2})^2 \right\} \quad (1)$$

TABLE II. *The green bands. New data and vibrational quantum analysis.*

v'	v''	$\lambda_{\text{hd.}}(\text{\AA.})$	I	ν (cm ⁻¹)	$O-C$ (cm ⁻¹)
0	1	5205.96	4	19,203.42	+0.03
1	2	5191.98	4	19,255.13	+0.00
2	3	5177.37	3	19,309.46	+0.01
3	4	5162.50	3	19,365.50	-0.16
4	5	5146.85	3	19,423.96	-0.03
5	6	5130.58	2	19,485.56	+1.12
6	7	5113.75	1	19,549.69	+2.68
7	8	5097.04	1	19,613.74	+2.04
8	9	5081.45	0	19,673.95	-4.56
0	0	5007.32	10	19,965.21	0.00
1	1	4996.71	9	20,007.60	+0.02
2	2	4985.92	8	20,050.90	-1.17
3	3	4974.47	7	20,097.06	-1.62
4	4	4962.10	6	20,147.15	-0.26
5	5	4949.53	5	20,198.32	+0.06
6	6	4935.30	4	20,256.56	+5.53
7	7	4923.87	3	20,303.58	-2.74
8	8	4908.61	2	20,366.70	+3.17
9	9	4895.20	2	20,422.49	-0.37
10	10	4880.69	2	20,483.20	-1.11
11	11	4865.41	1	20,547.53	-0.35
12	12	4849.63	0	20,614.39	+0.82
13	13	4834.05	0	20,680.82	-0.56

and for the green system:

$$\nu = 19,944.82 + \left\{ 811.67(v' + \frac{1}{2}) - 3.74(v' + \frac{1}{2})^2 \right\} - \left\{ 771.42(v'' + \frac{1}{2}) - 4.81(v'' + \frac{1}{2})^2 \right\}. \quad (2)$$

The intensity distribution among the band heads of the red system follows a typical wide Condon⁹ parabola as is usual for high temperature emission spectra. The bands associated with either $v'=0$ or $v''=0$ are developed strongly but those associated with $v'=0$ are more intense than those with $v''=0$. On the other hand, for the green system, the intensity distribution lies on a very narrow Condon parabola. The distribution of the bands in a $\Delta v=0$ sequence with only weaker $\Delta v=+1$ sequence is in theoretical accordance with the very small change in vibrational frequency as is indicated by Eq. (2), and with correspondingly small change in moment of inertia which it accompanies. In fact, in the extreme case, the small percentage change in moment of inertia is indicative of a very narrow Condon parabola in the v', v'' array of bands and only the $\Delta v=0$ sequence is to be expected. Probably for the green bands, the sequence $\Delta v=-1$ is present but the bands are too weak to be measured under the high magnification of the comparator.

It is evident from Eqs. (1) and (2) that while $\omega_e' > \omega_e''$, $\omega_e' \chi_e' < \omega_e'' \chi_e''$. As a result of this, the successive heads in a sequence diverge with increasing quantum number. The heats of dissociation calculated for the lower levels of the two systems are, respectively, 3.06 and 3.76 volts.

CALCIUM OXIDE

In 1906 Olmsted,¹⁰ during the course of his investigation of the spectra of the flame of the oxy-hydrogen blow-pipe fed with calcium salts, measured

⁹ Condon, Phys. Rev. **23**, 1182 (1926).

¹⁰ Olmsted, Zeits. f. Wiss. Photo. **4**, 255 (1906).

thirty-two heads between the region $\lambda 4400$ – $\lambda 3300$ and attributed them to the metal. Later on Eder and Valenta¹¹ photographed the spectra of the flame of the arc as also of the oxy-coal gas with different salts of calcium introduced into it and published measurements of a number of band heads lying between $\lambda 6650$ – 5300 and also between $\lambda 4600$ – $\lambda 3400$. They, however, ascribed all these bands to the oxide. In 1914 Harnack¹² was led to the same view from a systematic investigation into the spectra of the flame arc in the atmosphere of oxygen and hydrogen as also of the flame formed by spraying finely powdered salts of calcium across an uncondensed spark. In the present investigation only the bands lying between $\lambda 4600$ – $\lambda 3200$ have been definitely ascribed to the oxide while those between $\lambda 6750$ – $\lambda 5300$ are probably emitted by the metal. They are very much superposed by the well-known CaCl bands lying in this region. Seventy-seven heads have been measured on prism spectrograms for the oxide bands and the wave-lengths are correct to $\pm 0.1\text{\AA}$. Their analysis is presented in Tables III and IV. In 1927, Mecke and Guillery² classified twenty-eight heads from the measurements of Olmsted into a single system but it now appears that they used parts of two different systems.

TABLE III. *The blue bands. New data and vibrational quantum analysis.*

v'	v''	$\lambda_{\text{hd.}}$ (I.A.)	I	ν (cm ⁻¹)	$O-C$ (cm ⁻¹)
5	7	4597.0	0	21,747.24	-0.23
4	6	4573.9	0	21,857.07	+0.65
3	5	4553.4	1	21,955.48	+0.23
2	4	4535.1	2	22,044.07	+0.10
1	3	4519.1	3	22,122.12	-0.43
0	2	4505.0	4	22,191.35	+0.33
5	6	4449.9	2	22,466.13	-0.22
4	5	4425.8	3	22,588.46	-0.04
3	4	4403.9	6	22,700.79	+0.26
2	3	4384.3	6	22,802.27	-0.17
1	2	4366.7	5	22,894.18	-0.05
0	1	4351.2	5	22,975.73	-0.17
6	6	4336.7	0	23,052.55	-0.41
5	5	4309.5	1	23,198.04	-0.39
4	4	4284.6	1	23,332.86	-0.92
3	3	4261.8	2	23,457.68	-1.33
2	2	4240.8	3	23,573.84	-0.28
1	1	4221.9	5	23,679.37	+0.26
0	0	4205.1	6	23,773.97	-0.01
5	4	4175.4	1	23,943.08	-0.63
4	3	4149.8	2	24,090.77	-1.49
3	2	4126.0	3	24,229.74	-0.95
2	1	4104.1	4	24,359.03	+0.03
1	0	4084.3	5	24,477.11	-0.08
6	4	4075.5	0	24,529.96	-0.36
5	3	4047.3	1	24,700.88	-1.31
4	2	4020.9	1	24,863.05	-0.89
3	1	3996.5	2	25,014.85	-0.72
2	0	3973.9	3	25,157.11	+0.03
6	3	3953.4	0	25,287.55	-1.25
5	2	3924.6	1	25,473.12	-0.75
4	1	3897.8	1	25,648.26	-0.56
3	0	3872.9	2	25,813.15	-0.50

¹¹ Eder and Valenta, *Atlas typischer Spektren*, Wien (1924).¹² Harnack, *Phys. Zeits.* **15**, 578 (1914).

TABLE IV. *The ultraviolet bands. New data and vibrational quantum analysis.*

v'	v''	$\lambda_{\text{hd.}}(\text{\AA.})$	I	ν (cm $^{-1}$)	$O-C$ (cm $^{-1}$)
2	7	4000.0	1	24,992.96	-0.79
1	6	3979.5	1	25,121.71	-0.44
0	5	3959.4	2	25,249.23	+0.53
4	8	3937.3	0	25,390.95	-1.80
3	7	3915.7	1	25,531.01	-0.93
2	6	3894.7	2	25,668.67	-0.62
1	5	3874.2	2	25,804.49	-0.31
5	8	3858.3	1	25,910.83	-2.18
0	4	3854.1	2	25,939.07	+0.60
4	7	3836.2	1	26,060.10	-1.06
3	6	3814.7	1	26,206.97	-0.49
2	5	3793.7	2	26,352.04	+0.11
1	4	3773.2	2	26,495.20	+0.64
5	7	3761.2	0	26,579.73	-1.68
0	3	3753.2	3	26,636.39	+1.04
4	6	3739.2	1	26,736.12	-0.56
3	5	3717.8	1	26,890.01	-0.10
2	4	3696.9	2	27,042.02	+0.32
1	3	3676.5	3	27,192.07	+0.62
5	6	3667.9	0	27,255.82	-1.12
0	2	3656.6	4	27,340.05	+0.69
4	5	3646.1	1	27,418.78	-0.55
3	4	3624.8	2	27,579.90	+0.02
2	3	3604.0	2	27,739.06	+0.47
1	2	3583.7	3	27,996.19	+0.73
0	1	3564.0	5	28,050.38	-0.11
4	4	3556.6	0	28,108.74	-0.36
3	3	3535.4	1	28,277.29	+0.52
2	2	3514.8	2	28,443.02	+0.42
1	1	3494.7	3	28,606.60	+0.01
0	0	3475.0	6	28,768.77	+0.03
4	3	3470.5	0	28,806.07	+0.08
3	2	3449.6	1	28,980.59	-0.19
2	1	3429.1	2	29,153.84	+0.11
1	0	3409.1	4	29,324.87	+0.03
4	2	3387.7	0	29,510.11	+0.11
3	1	3366.9	1	29,692.41	+0.50
2	0	3346.7	3	29,872.52	+0.53
5	2	3329.0	1	30,030.44	+0.18
4	1	3308.0	2	30,221.08	-0.05
3	0	3287.4	3	30,410.45	+0.29
6	2	3273.3	0	30,541.44	-0.12
5	1	3252.0	1	30,741.47	+0.08
4	0	3231.2	2	30,939.35	-0.03

The equations of the band heads in terms of half-quantum numbers for the two systems are as follows. Blue bands:

$$\nu = 23,817.62 + \left\{ 726.53(v' + \frac{1}{2}) - 11.66(v' + \frac{1}{2})^2 \right\} - \left\{ 811.28(v'' + \frac{1}{2}) - 6.60(v'' + \frac{1}{2})^2 \right\} \quad (3)$$

and ultraviolet bands:

$$\nu = 28,849.13 + \left\{ 565.06(v' + \frac{1}{2}) - 4.48(v' + \frac{1}{2})^2 \right\} - \left\{ 725.37(v'' + \frac{1}{2}) - 3.56(v'' + \frac{1}{2})^2 \right\}. \quad (4)$$

As in the case of MgO band systems, the bands of CaO forming a sequence diverge with increasing quantum number. This is evident from Eqs. (3) and (4) that while $\omega_e' < \omega_e''$, $\omega_e' \chi_e' > \omega_e'' \chi_e''$.

The relative intensities of the bands in each system lie on a wide Condon parabola as in the case of the red bands of MgO.

The heats of dissociation calculated for the lower levels of the two systems are respectively 3.03 and 4.56 volts.

STRONTIUM OXIDE

The earliest spectroscopists¹³ noticed a class of bands between $\lambda 7000$ – $\lambda 5800$ in the flame and spark spectra of strontium salts and attributed them to the oxide. In 1905 Hagenbach and Konen,¹⁴ in addition to these, measured another class of bands between $\lambda 4500$ – $\lambda 3600$ and attributed them both to the metal as their emitter. Later on, Olmsted¹⁵ pointed out that the bands lying below $\lambda 3800$ were due to the oxide. He photographed the spectrum of the oxy-coal gas flame fed with different salts of strontium and published measurements of sixty-six heads between $\lambda 4800$ – $\lambda 3600$ with a concave grating of one meter radius. Afterwards Hartley¹⁶ noticed these bands in the spark spectrum of $\text{Sr}(\text{NO}_3)_2$ in solution as well as in that of oxy-hydrogen flame fed with SrCl_2 and ascribed a part of the spectrum to the oxide. The bands were also measured by Auerbach,¹⁷ Eder and Valenta,¹⁸ and by Harnack,¹⁹ who extended the measurements up to $\lambda 3200$. These authors ascribed all the bands to the oxide. Kayser²⁰ was, however, of opinion that the bands in the long wave-length region might be due to the metal. In the present investigation the bands lying between $\lambda 7100$ – $\lambda 5300$ have been definitely attributed to the metal and those between $\lambda 5300$ – $\lambda 3200$ to the oxide. In the latter region as many as 108 heads have been measured from prism spectrograms and analyzed into two systems (Tables V and VI). The analysis of Mecke and Guillery² is essentially correct for the blue system. It may here be pointed out that the metal bands in the long wave-length region are very much superposed by the well-known SrCl band systems as in the case of calcium.

TABLE V. *The blue bands. New data and vibrational quantum analysis.*

v'	v''	$\lambda_{\text{Ha.}} (\text{\AA.})$	I	$\nu (\text{cm}^{-1})$	$O-C (\text{cm}^{-1})$
3	12	5279.5	0	18,935.93	-0.57
2	11	5263.0	0	18,995.30	-0.10
1	10	5246.5	1	19,055.04	-0.30
0	9	5229.8	1	19,115.88	-0.44
4	12	5146.0	0	19,427.17	-0.42
3	11	5128.6	0	19,493.08	-0.41
2	10	5111.0	1	19,560.21	-0.22
1	9	5093.3	1	19,628.18	-0.23
0	8	5075.5	1	19,697.02	-0.41
5	12	5021.0	0	19,910.81	-0.87
4	11	5002.6	0	19,984.05	-0.53

¹³ Kayser, *Handbuch der Spectroscopie* 6, 544 (1912).¹⁴ Hagenbach and Konen, *Atlas der Emission Spectra*, Jena, bei Fischer (1905).¹⁵ Olmsted, *Zeits. f. Wiss. Photo.* 4, 255 (1906).¹⁶ Hartley, *Trans. Roy. Soc. Dublin* 9, (2), 85 (1908).¹⁷ Auerbach, *Zeits. f. Wiss. Photo.* 7, 30 (1909).¹⁸ Eder and Valenta, *Atlas Typischer Spektren*, Wien (1924).¹⁹ Harnack, *Zeits. f. Wiss. Photo.* 10, 281 (1912).²⁰ Kayser, *Handbuch der Spectroscopie* 6, 551 (1912).

TABLE V. (Continued).

v'	v''	$\lambda_{\text{Hd.}}(\text{\AA.})$	I	ν (cm ⁻¹)	$O-C$ (cm ⁻¹)
3	10	4983.9	0	20,059.03	+0.51
2	9	4965.6	0	20,132.95	-1.55
1	8	4946.9	1	20,209.06	-0.46
0	7	4928.1	1	20,286.15	-0.43
6	12	4903.5	0	20,387.92	+0.15
5	11	4884.3	0	20,468.06	-0.61
4	10	4864.8	0	20,550.11	+0.50
3	9	4845.5	1	20,631.96	+0.37
2	8	4826.1	1	20,714.89	+0.28
1	7	4806.7	1	20,798.50	-0.17
0	6	4787.2	2	20,883.22	-0.55
6	11	4773.1	0	20,944.91	-0.85
5	10	4752.8	0	21,034.36	+0.66
4	9	4732.9	1	21,122.81	+0.13
3	8	4712.8	2	21,212.89	+0.19
2	7	4692.7	5	21,303.75	-0.01
1	6	4672.6	4	21,395.39	-0.47
0	5	4652.4	3	21,488.28	-0.72
6	10	4647.4	0	21,511.40	+0.61
5	9	4626.9	1	21,606.71	-0.06
4	8	4606.2	2	21,703.81	+0.02
3	7	4585.5	3	21,801.78	-0.07
2	6	4564.8	5	21,900.65	-0.30
1	5	4544.1	5	22,000.41	-0.68
6	9	4526.9	1	22,084.00	+0.14
0	4	4523.3	4	22,101.58	-0.69
5	8	4505.7	1	22,187.91	+0.03
4	7	4484.5	3	22,292.80	-0.14
3	6	4463.3	4	22,398.68	-0.36
2	5	4442.1	3	22,505.58	-0.60
1	4	4420.9	5	22,613.50	-0.86
6	8	4410.9	0	22,664.77	-0.20
0	3	4399.6	6	22,722.98	-0.60
5	7	4389.2	1	22,776.72	-0.31
4	6	4367.6	2	22,889.46	-0.67
3	5	4345.9	3	23,003.75	-0.52
2	4	4324.3	3	23,118.65	-0.80
1	3	4302.7	4	23,234.71	-0.96
6	7	4299.2	0	23,253.62	-0.50
0	2	4281.0	5	23,352.48	-0.45
5	6	4277.2	0	23,373.23	-0.99
4	5	4255.1	1	23,494.62	+0.26
3	4	4233.2	2	23,616.16	-1.38
2	3	4211.2	3	23,739.54	-1.22
1	2	4189.1	4	23,864.77	-0.25
0	1	4167.2	5	23,990.19	-0.13
4	4	4147.0	1	24,107.04	-1.59
3	3	4124.7	2	24,237.37	-1.48
7	6	4110.6	0	24,320.51	+0.11
2	2	4102.3	2	24,369.72	-0.39
6	5	4087.9	0	24,455.56	+0.02
1	1	4080.1	2	24,502.31	-0.10
5	4	4065.4	0	24,590.91	-1.81
0	0	4058.0	3	24,635.75	0.00
4	3	4042.8	1	24,728.37	-1.57
3	2	4020.1	2	24,868.00	-0.20
7	5	4010.8	0	24,925.66	-0.97
2	1	3997.7	2	25,007.34	-0.16
6	4	3988.0	0	25,068.16	-0.65
1	0	3975.4	3	25,147.61	-0.23
5	3	3965.2	1	25,212.30	-0.73
4	2	3942.3	1	25,358.75	-0.54
3	1	3919.6	2	25,505.61	+0.02
7	4	3914.6	0	25,538.19	-1.71

TABLE V. (Continued).

v'	v''	$\lambda_{\text{Hd.}}(\text{I.A.})$	I	ν (cm ⁻¹)	$O-C$ (cm ⁻¹)
2	0	3897.1	3	25,652.86	-0.07
6	3	3891.6	0	25,689.12	-2.00
5	2	3868.5	0	25,842.51	-0.87
4	1	3845.6	1	25,996.40	-0.28
3	0	3822.4	2	26,150.76	-0.26
6	2	3798.4	0	26,319.43	-1.04
5	1	3775.3	0	26,480.47	-0.30
4	0	3752.4	1	26,642.07	-0.04

TABLE VI. The ultraviolet bands. New data and vibrational quantum analysis.

v'	v''	$\lambda_{\text{Hd.}}(\text{I.A.})$	I	ν (cm ⁻¹)	$O-C$ (cm ⁻¹)
2	4	3708.5	0	26,957.44	-0.72
1	3	3690.2	1	27,091.12	+0.79
0	2	3671.5	2	27,229.10	+0.28
3	4	3646.0	2	27,419.53	-0.63
2	3	3627.0	1	27,563.17	-1.10
1	2	3607.1	2	27,715.22	+0.53
0	1	3586.9	3	27,871.30	-0.14
3	3	3567.1	1	28,026.00	-0.27
2	2	3546.6	2	28,187.99	-0.64
1	1	3525.4	3	28,357.50	+0.19
0	0	3503.8	6	28,532.31	0.00
3	2	3489.3	1	28,650.87	-0.39
2	1	3467.5	2	28,830.99	-0.89
1	0	3445.2	4	29,017.61	-1.20
4	2	3435.3	1	29,101.23	-0.10
3	1	3412.8	2	29,293.08	-0.85
2	0	3389.8	4	29,491.83	-0.92
4	1	3361.2	1	29,742.76	-0.56
3	0	3337.5	3	29,953.96	-0.16
5	1	3312.4	0	30,180.93	-0.52
4	0	3288.1	2	30,403.97	-0.22
5	0	3241.4	1	30,842.00	-0.32

Besides the bands included in the two systems, there are a few unidentified heads. These were also measured by Olmsted and others, strongest of these are $\lambda 4135.0$ (4), 4113.6 (5) and 4092.6 (4).

The equations representing the band heads of the two systems are as follows.

For the blue bands:

$$\nu = 24,702.81 + \left\{ 519.09(v' + \frac{1}{2}) - 3.50(v' + \frac{1}{2})^2 \right\} - \left\{ 653.47(v'' + \frac{1}{2}) - 4.02(v'' + \frac{1}{2})^2 \right\} \quad (5)$$

and for the ultraviolet bands:

$$\nu = 28,622.18 + \left\{ 497.81(v' + \frac{1}{2}) - 5.97(v' + \frac{1}{2})^2 \right\} - \left\{ 679.13(v'' + \frac{1}{2}) - 9.13(v'' + \frac{1}{2})^2 \right\}. \quad (6)$$

Unlike the band systems of MgO and CaO, the bands of SrO in a sequence converge with increasing quantum number as is to be expected from the coefficients of ω_e' , $\omega_e'\chi_e'$, ω_e'' and $\omega_e''\chi_e''$ in Eqs. (5) and (6). On the other hand, the distribution of intensity among the various heads of the two band systems is very much similar to that of CaO. The heats of dissociation calculated for the lower levels of the two systems are, respectively, 3.24 and 1.52 volts.

My best thanks are due to Professor P. N. Ghosh for offering me all the facilities to carry out this investigation.

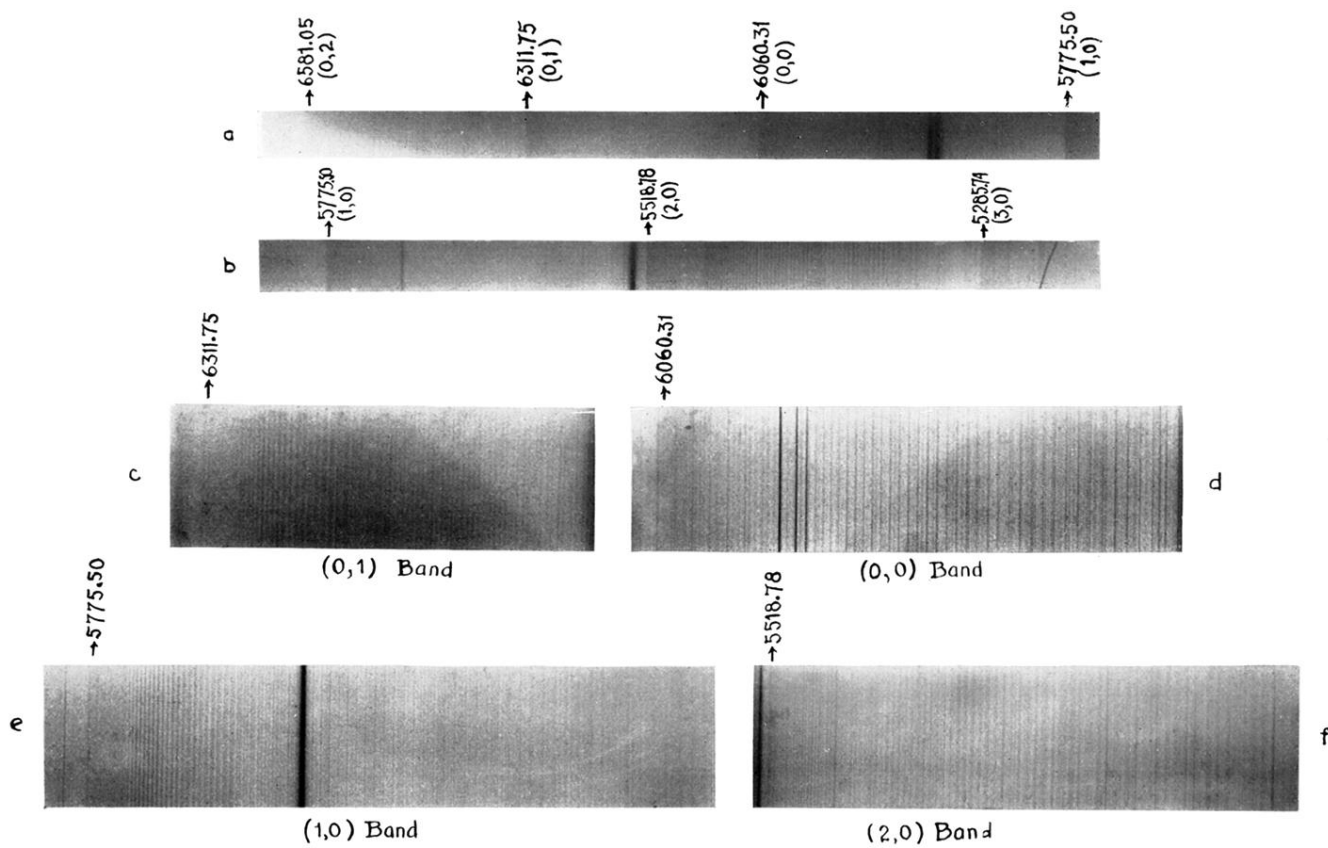


Fig. 1 Red bands of MgO: a, b, Hilger E. 52. glass spectrograph; c, d, e, f, 15 ft. grating first order.

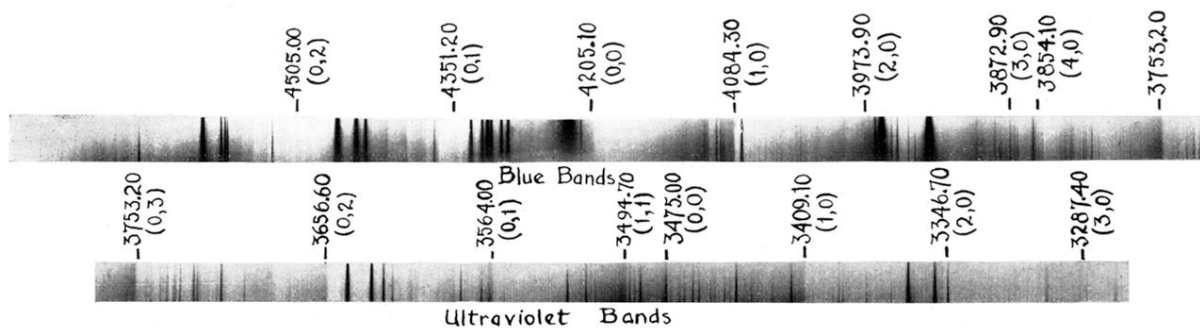


Fig. 2. Ultraviolet bands of CaO (Hilger E.1. quartz spectrograph).

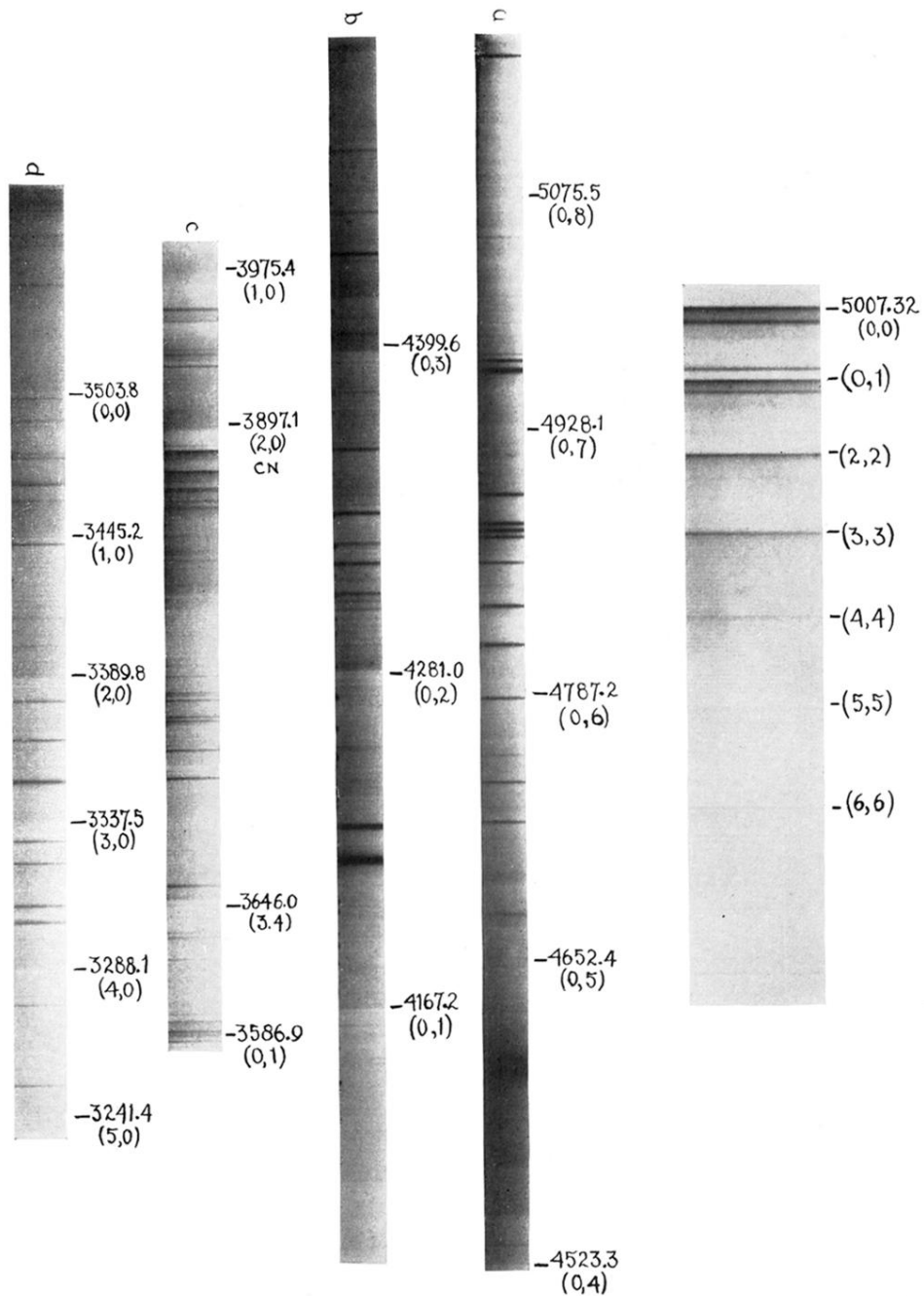


Fig 3. Right half of figure, green bands of MgO (15 ft. grating second order). Left half, bands of SrO; a, b, Hilger E. 52. glass spectrograph; c, d, Hilger E.1. quartz spectrograph.