yellow oxybromide, then to the oxide. It is decomposed by water with hissing and the evolution of heat. It is very hygroscopic and if allowed to stand in moist air absorbs considerable water before decomposition is complete. It dissolves readily in anhydrous ethyl bromide or alcohol with the liberation of heat.

An impure columbium iodide was prepared from the bromide. Further work is being done upon it. It is quite stable but is freed from bromide with difficulty.

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[CONTRIBUTION FROM THE JOHN HARRISON LABORATORY OF CHEMISTRY.]

THE ARC SPECTRUM OF COLUMBIUM.

BY JOEL H. HILDEBRAND.

Received August 15, 1908.

Part I.—Measurement of the Spectrum.

The arc spectrum of columbium has been measured between λ 2376 and λ 4700 by Exner and Haschek[1] who used for the purpose the ammonium columbium oxyfluoride upon gas-carbon electrodes. The spectrum they obtained was contaminated strongly by titanium, and also, the authors declare, by an unknown element common to columbium and titanium which they designated Ω. This state of affairs invited a further investigation of the spectrum of this element, and the abundance of very pure columbic oxide which has been obtained in this laboratory offered an exceptional opportunity. Moreover, it was desired to test spectroscopically the efficacy of the method of Smith and Balke[2] for obtaining columbium free from titanium, a most difficult analytical problem which it was thought had been finally solved.

The spectroscope used in this study is the property of the University of Pennsylvania, and was kindly put at my disposal by Prof. A. W. Goodspeed, to whom I here express my sincere thanks. The grating was ruled by a Rowland engine and is two inches long, seven-eighth inches high and contains 14,438 lines to the inch. The focal length is six feet. The mounting was made by Brashear, of Allegheny City, Pennsylvania, and is the usual type for a concave grating. The usual adjustments were made.

Inasmuch as the purity of the material was to be investigated, carbon electrodes, with their many impurities, were replaced by copper rods one-quarter inch in diameter. These were placed in an enclosed hand-feed lantern. The lower rod which was made the positive electrode was reamed out, making a cavity to receive the oxide. After a little practice it was found quite easy to start the arc, using a third rod held in the hand.

[1] Wellenlängentabellen-Bogenspektra-Frantz Deuticke, *Leipzig*, 1904,

[2] THIS JOURNAL, 30 (1908).

to scrape off the crust of copper oxide and make the initial contact; and also to maintain it playing from the surface of the fused columbic oxide instead of from the copper, thus diminishing the intensity of the copper spectrum. The current used was about 33 volts and 11 amperes.

The spectrum photographed was of the second order. A quartz condenser was used from λ 2600 to λ 3600 and above that glass. From λ 2600 to λ 5000 Cramer's "Process" plates were used, above that Cramer's "Isochromatic" and Wratten and Wainwright's "Panchromatic," which are sensitive well into the red. Color screens were used where necessary to cut out the third order spectrum. The time of exposure varied from 1/2 to 15 minutes.

For the purpose of measurement the iron spectrum was photographed on the same plate, so that it overlapped the columbium spectrum. It was produced by removing from the lantern case each time the stand holding the copper rods, and substituting one with carbons having iron cores.

The measurement was made by means of the "projection apparatus" of Exner and Haschek.[1] The image of the plates, after marking certain of the iron lines, was thrown upon a screen four meters away by an ordinary lantern. Upon the screen were two parallel scales each one meter long graduated into 0.2 cm.

The distance of the lantern was adjusted so that 0.2 cm. on the scale corresponded to 0.2 Angström unit. The iron lines being given their proper reading by adjusting first the plate then the screen, the wave length of the columbium lines could be determined very rapidly. This was found to be quite as accurate as the ordinary method with the microscope which was used in some preliminary observations, and far superior to the latter in time, saving of the eyes, freedom from errors and ease of estimating intensity. It fully confirms all the claims made by the authors of the method.

By comparison with the measurements of Exner and Haschek it can be seen that the wave lengths given have a probable error of something less than 0.1 Angström unit. This while inferior to the best measurements upon most of the other elements, is sufficient for analytical purposes and is the greatest accuracy attainable with the apparatus available.

In the table the lines before λ 4700 which do not appear in the measurements of Exner and Haschek are denoted by a star (*). Intensity is denoted by the numbers 1 (the faintest) to 10 (the brightest). Certain columbium lines are obscured by the brighter broad copper lines and so do not appear in the following tables. Lines which are hazy are denoted by "h," lines apparently double but not resolved, by "d."

[1] THIS JOURNAL, 30 (1908).

Part II.—Investigation of Various Materials.

Inasmuch as columbic oxide from various minerals was at hand, a comparative spectroscopic study was made on account of its interesting bearing on the elementary nature of columbium, especially in regard to the Ω lines of Exner and Haschek.

The first to be examined was oxide obtained from euxenite from Norway. The spectrum was photographed from λ 3050 to λ 4350. It was found that the purification from titanium had been incomplete so that the spectrum was contaminated by titanium lines to about the same extent as that of Exner and Haschek. A few iron lines were also present. In addition, the following faint lines besides those given in the table for the purest oxide were found.

3182.6—1	3682.1—1
3438.5—1 Zr?	3715.1—1
3441.9—1	3736.5—1
3528.6—1	3762.5—1
3573.5—1	3818.3—1
3574.6—1	3823.3—1

Since variations in the condition of the arc and the portion of it photographed are sufficient, as Exner and Haschek have shown, to produce considerable difference in the intensity of the lines, there is little reason to attribute these additional lines to anything other than columbium.

Columbic oxide from Australian tantalite, decomposed by a bisulphate fusion, showed between λ 3170 and λ 4350 some titanium lines, and the line 3438.5–1 Zr?. Otherwise the spectrum was practically identical with that of the oxide prepared by Balke in this laboratory.

The same mineral, decomposed by a fluoride fusion, gave the same results with the addition of two faint tin lines.

Finally, columbic oxide, from Balke's purest material, which had been converted into oxybromide and fractionated, showed also no variations.

It is of especial interest that the spectra of all these samples from different sources showed no variation in the Ω lines of Exner and Haschek. It is highly improbable, therefore, that they are due to any third unknown element. They are almost certainly only columbium lines which have the same wave length and intensity within the limits of error. A large number of equally coincident lines may be found by comparing any two fairly complex spectra. Thus there were found on comparing the spectra of columbium and zirconium fifteen lines between λ 3100 and λ 3500 of nearly the same intensity and differing in wave-length 0.03 A. U. or less.

A few corrections of the data of Exner and Haschek are possible on account of the purity of the material used. Their lines attributed to columbium, 3653.62–4 and 3900.67–1, are probably due to titanium, 3653.66–15 and 3900.72–5 respectively. Their line 4457.61–5 attributed to titanium is present in my spectrum with the same intensity and must, therefore, be due chiefly to columbium. Their line 3674.45–1, also, is probably a misprint and should be 3675.45.

Finally, oxides from several mother liquors from the recrystallization of the different samples of potassium fluocolumbate were examined to determine the nature of the impurities found, whether they could all be identified.

First, that obtained from the purification of the material from the American columbites from South Dakota by Balke, photographed between λ 3150 and λ 4260 showed 38 additional lines. All of these were, however, identified as belonging to tin, iron and titanium except the very faint line λ 3808.7–1.

The material from the euxenite mineral showed between λ 3110 and λ 4150, forty-four additional lines, which, with the exception of the unidentified lines 3847.5–1, 3880.5–1 and 3881.3–2, belonged to the elements titanium, tin, aluminium, molybdenum, tungsten, iron, and vanadium.

The material from the aeschynite showed 35 new lines between λ 3140 and λ 4250. All of these were identified as due to varying amounts of titanium, lead, aluminium, tungsten, molybdenum and potassium.

Summary.

1. The spectrum of columbium has been measured between the wave-lengths λ 2600 and λ 6000, the portion beyond λ 4700 probably for the first time.

2. The method of Smith and Balke for the production of titanium-free columbium is shown to be successful.

3. The existence of any element common to columbium and titanium is highly improbable.

4. The identity of the spectra of columbium obtained from different localities is strong evidence for its elementary character.

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
2601.3	2	2622.8	1	2649.6	5	2663.6	1*
02.0	3	23.5	4	51.2	2	65.3	3
03.4	2	26.5	1	51.9	1Cu	66.6	2
05.1	1Cu	27.5	5d, with Cu	53.0	1	67.3	2
09.0	5*	28.5	3	53.5	3	67.8	1
10.3	3	32.6	3	54.5	5	68.4	3
11.3	1	34.8	3	55.8	2	70.6	1*
12.5	3	38.0	2	56.1	4	71.4	1*
14.0	1*	38.8	1*	57.0	2	72.0	5
14.6	1*	41.0	4	57.7	3	73.6	4
18.5	8Cu	42.3	4	58.9	1*	74.7	1*
16.5	3	44.5	1	60.1	1*	76.1	4
20.6	3	46.3	4	61.2	1*	77.0	1
22.0	2	47.6	5	61.9	2	77.8	1

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
2678.8	2	2753.1	5	2829.8	2	2917.2	2
79.1	3	54.2	1	30.8	1*	18.9	1*
80.1	3	54.6	2	32.3	1*	19.9	1*
82.2	2	55.4	3	33.5	1	23.1	1
83.3	1*	55.7	3	35.2	4	27.9	10
83.8	1*	57.4	3	36.4	5	30.7	1*
86.5	2	58.7	6	39.9	2*	31.6	3
87.2	3	61.1	3	41.3	6	32.8	1
89.1	1*	62.5	1*	42.8	6	33.7	1
91.8	5	63.5	4	43.8	1*	35.4	2
95.1	4	64.6	2	44.6	1	36.7	1*
96.2	2	65.4	2	46.0	1	37.5	1
97.2	5	66.5	10Cu	46.4	6	38.2	2
98.9	4	68.2	4	47.4	1*	41.7	6
2700.3	1	69.7	1	48.5	2	46.1	2
02.3	3	71.6	1*	49.7	2	46.3	1
02.6	2	73.3	6	51.6	5	47.1	2
04.5	3*	75.0	1*	52.1	4	51.0	8
06.5	4	79.6	2d	54.4	2	53.0	1*
08.0	1	80.4	5	55.8	1*	54.2	1
12.3	1*	82.5	5	57.4	1	54.7	2
14.3	2	85.1	1	58.8	2Cu	57.0	1
15.6	a number	86.5	1	59.1	2	58.1	1*
to	of lines not	87.9	2	60.0	1	61.3	10Cu
16.8	resolved	89.2	1	61.2	5	63.8	1
17.6	1	90.7	2	64.4	3	65.6	3
20.2	3	91.8	4	65.7	3	68.5	1
21.1	1*	93.1	5	66.8	1	70.6	1
22.1	5	93.9	1	68.6	8	72.7	5
24.1	4	95.1	1	74.7	2	74.3	5
25.7	1*	95.9	2	75.5	6	77.8	3
26.2	2	97.7	3	77.1	6	79.1	1
27.5	1	99.3	3d?	78.8	2	80.0	1
28.2	2	2800.4	2	79.4	2	80.9	2
29.8	1	02.1	2	80.8	2	82.2	3
30.4	1	03.9	2	83.2	8d, with Cu	85.2	1
33.4	6	04.3	1	85.1	2	87.4	2
34.4	1	08.2	2	87.1	1	88.9	1
37.2	6	09.3	1	87.8	1	90.4	8
40.3	4	10.9	4	88.9	6	92.0	2
41.2	3	11.8	1	90.0	1	93.9	1*
42.8	1*	16.8	2	90.2	1	94.8	7
43.7	1*	19.3	2	94.3	1*	97.4	6Cu
45.4	3	20.9	2	97.9	6	98.4	1
45.8	3	22.2	1	99.4	6	3001.2	1*
47.0	5	24.5	8Cu	2903.8	3	02.3	2
48.9	5	25.3	1	08.4	6	05.9	2
49.9	1*	26.1	1*	09.1	1	08.5	1*
50.7	1*	26.6	1	10.7	6	09.2	1h*
51.4	1Cu	27.2	6	11.9	6	10.9	8Cu

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
3012.1	1Cu	3094.3	10d,withCu	3175.9	5	3266.2	1Cu
14.5	1	96.6	1	80.4	6	67.2	1
15.3	1	97.2	2	81.5	1	68.5	1Cu
19.0	3	98.6	1	84.3	2	70.7	3
20.8	2*	99.2	3	86.6	1hTi?	72.1	3
21.8	2Cu	3100.0	4Cu	87.7	4	74.1	100Cu
22.9	4d, with Cu	01.1	1	89.3	3	77.8	3d, with Cu
24.9	5d, with Cu	02.0	1	91.2	3	80.1	2d, with Cu
28.6	6	04.5	1*h	91.5	3d?	80.8	1Ag
30.0	1	07.1	2	93.0	1*	82.8	2Cu
32.9	7	08.7	8Cu	94.2	3Cu	83.6	4
34.1	1	09.8	1	95.1	4	85.7	3
35.0	1	11.6	2	98.3	1	87.1	1*
36.2	10Cu	13.7	1*Cu	3200.6	1	87.7	5
39.8	10d	16.5	6d, with Cu	01.5	1	88.0	3
41.9	1*h	19.5	1	03.4	3	90.7	4Cu
43.2	1h	20.6	2hCu	05.1	1	91.1	1
44.9	4	22.0	1	06.4	6	92.2	1
46.9	1*	22.8	2	07.3	2	94.5	1
48.2	6	26.2	6Cu	08.2	3Cu	96.2	5
49.7	1	27.6	4	10.3	2	97.4	1
51.8	1h	28.7	3Cu	15.7	5	98.6	1
53.2	3	29.8	1	16.3	1h	99.8	4
53.8	1	30.9	8	17.4	1	3301.7	1
55.6	4	32.2	1	17.9	1	02.4	1
56.7	2	33.1	2	18.9	1	03.5	1
59.4	1*	34.5	1	21.0	2	05.0	1
61.3	2	35.6	1	22.1	1*	08.2	6d, with Cu
62.1	1	36.1	1	23.0	1	10.2	1
63.5	10Cu	37.1	2	23.4	1	10.6	1
64.6	4	40.6	4d, with Cu	24.6	4d, with Cu	11.6	1
65.4	2	42.6	1Cu	25.6	8	12.7	5
66.3	1	44.5	1	27.6	1	15.3	3
67.6	1*h	45.5	4	29.7	2	17.3	2Cu
68.2	1*h	47.0	1d, with Cu	31.2	2Cu	19.1	3
69.1	1	50.5	1	32.8	1*	19.4	3
69.8	4	52.0	4	34.8	1Ti?	19.7	3d, with Cu
71.0	5	53.0	1	35.8	2Cu	21.0	1*
71.7	5	54.1	1	36.6	4	21.9	1h
72.6	2	54.9	1	38.2	1	23.1	1
73.4	2	56.0	1*	43.4	2d, with Cu	26.7	5
73.9	3Cu	56.8	2Cu	47.7	100Cu	28.4	1*
77.0	7	59.4	1	51.7	2	29.7	5d, with Cu
80.4	4	60.0	1h	54.2	4	32.3	3
81.9	1	61.3	1hTi?	57.2	1*	32.8	1
83.0	1	63.5	8	60.3	4	34.1	1
84.5	1	69.8	2Cu	60.7	2	35.5	2d, with Cu
85.6	1*	71.6	1	62.0	1	36.4	1
88.1	5	72.6	1	63.5	1	38.0	5Cu
90.3	1*	73.3	3	64.7	2	39.3	2

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
3341.7	3	3403.8	1	3478.1	1	3543.1	1
42.1	6	05.4	3	78.8	6	44.1	6
43.8	6	06.2	2	79.7	2	44.8	4
44.1	1	06.7	1	81.2	2	46.2	1
47.0	3	08.1	1	81.4	3	48.3	3
49.1	5	08.5	3	84.2	5	49.4	1
49.6	5	08.8	3	85.2	1	50.6	6
52.5	2	09.3	2	86.1	1	52.2	1*h
53.7	2	10.0	1	89.2	2	53.8	1*
54.8	4	13.0	4	91.2	5	54.8	9
55.5	1	14.2	2	91.6	1	56.2	1
57.1	3	16.1	3	93.6	1	58.2	1
58.5	8	18.0	2	96.2	2	59.3	1
61.0	1	20.8	4	97.9	4	60.6	1*
62.0	1	23.2	1*	98.7	8	61.3	1
63.0	1	23.9	4	3500.1	1	63.7	10
63.9	1	25.6	5	03.3	3	65.2	1*
65.7	4d, with Cu	26.0	3	05.9	2	66.2	1
67.1	7	26.7	4	07.1	1	68.2	1*
67.5	2	27.6	4	08.1	6	68.7	3
69.2	2*	29.2	5	08.6	1	69.6	3
70.0	1	31.2	1	10.4	3	71.6	1*h
71.5	2	32.1	1	11.3	2	75.3	2
72.3	1	32.7	5	12.3	1Cu	76.0	8
72.7	1	33.2	5	13.8	1*	77.9	2
74.4	1	37.1	3	15.5	5	80.4	10
75.1	4	40.1	1	16.3	1	82.5	2
76.5	1	40.8	5	17.0	2	85.1	6
76.9	3	42.8	5	17.9	3	86.9	1
80.2	2	44.4	1	19.5	1	89.2	6
80.6	6	45.8	4	20.2	4d, with Cu	91.1	1
83.0	2Ag.	48.3	1	20.8	2	92.0	1
83.9	2	50.5	4Cu	22.8	1*h	94.1	5
84.8	1Cu?	50.9	1	23.3	2	97.5	1
85.8	1	52.5	3	24.3	1Cu	98.5	1
86.4	1	55.0	1	25.4	3	99.4	2d, with Cu
87.1	1	56.7	2	26.0	1	3602.2	3Cu
87.7	3	57.9	2d, with Cu	27.2	1	02.7	5
89.1	1	58.9	2	27.6	1Cu	04.1	1
90.6	3	59.8	2	28.1	1	04.8	1
91.5	1	62.8	2	30.3	1d, with Cu	06.4	1
92.5	5	63.9	5	33.8	3d, with Cu	06.7	1
94.1	1	66.0	4	34.3	1	07.4	1
95.1	1	67.6	2	35.4	6	08.2	1
96.0	3	68.7	1	37.6	7	09.4	1*
98.4	2	69.6	3	39.8	3	10.1	1*
99.5	3	71.4	4	41.1	4	10.9	1
99.8	2	73.2	4	41.4	1	11.4	1
3401.4	1	75.7	2	42.1	1	12.8	1
[illegible]	1	76.1	4d. with Cu	42.7	1	15.6	2

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
3616.4	1	3677.2	1	3742.6	6	3830.1	1*
17.8	2	77.9	2	44.2	4	31.3	1*
19.0	1	78.9	1h	45.6	1*	32.0	4
19.6	6	81.8	1	47.1	3	33.4	1
21.2	3	83.1	1	48.7	3	34.1	1
23.3	1*	84.4	1*	50.8	1	35.3	5
24.5	1	85.2	1	53.3	4	36.6	4
25.2	1	86.7	1	55.9	6	37.2	3*
25.8	1	88.1	4	59.7	10	38.2	1
28.0	1	88.9	2	60.8	1	41.9	2
30.8	2	89.2	2	61.3	1	42.9	2*
31.8	1*	91.3	1	63.6	4	44.2	3*
33.1	2	93.5	4	64.2	2	46.1	4
33.8	2	94.8	3	65.2	2	49.9	1*
34.6	2	96.0	1	66.3	3*	53.6	2
35.5	2	97.5	2	69.3	2	55.4	2h
37.1	1	98.0	8	70.2	1	56.9	1*
37.7	4	99.1	1*	71.0	3	59.1	5
38.0	4	3700.1	1	72.0	4d, with Cu	63.5	6
38.9	2	02.1	1	73.3	1	65.1	1*
39.4	5	03.3	2	74.6	1	68.0	5
40.8	3	04.3	3	75.6	3	71.3	1*
41.7	1Cu	05.7	1*	76.6	1	75.9	2
43.5	2	08.0	1	77.8	2	77.1	1
43.8	3	09.6	3	81.2	8	77.7	4
45.1	2	10.6	2	84.0	2	79.0	6
47.4	1	11.5	4	86.4	1	83.3	5*
50.0	4	11.9	1	87.3	8	85.6	7
50.9	1	13.2	8	89.6	1	85.9	4
51.3	6	14.0	2	90.3	6	88.6	1*
54.6	1	16.3	1	91.4	8	89.9	1
56.1	1	17.2	6	94.6	1	91.5	5
57.2	1	17.7	4	95.7	2	94.2	9
58.8	1	18.6	1	96.8	2	96.1	4
59.7	2	20.6	3	98.3	8	98.6	3h
60.5	6	21.7	2	3801.4	3*	99.4	1
62.2	1	22.5	1	03.1	6	3902.1	1*
63.4	1	23.2	2	04.1	4	03.1	1
64.8	8	25.4	1	04.9	4	04.3	3
66.7	1	26.4	8	06.3	2	07.0	2
67.1	1	27.4	1	10.6	8	09.1	3
67.8	1	29.8	1*	11.2	4	09.7	1
68.7	1	31.6	1	13.6	1*	13.1	2
69.1	4	32.2	2	15.7	4	13.5	2
69.9	2	33.8	2	16.6	1*	14.9	8
71.5	1	35.0	1*	19.3	4	17.1	1
72.6	1	38.6	4	21.3	1*Cu?	19.1	2
74.9	6	40.0	8	25.0	8	19.3	2
75.5	1h	41.0	6	27.2	3*	20.3	5
76.4	1	42.0	1	28.4	3*	21.7	1

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
3922.5	2	4004.3	1*	4077.2	1	4161.0	1
23.9	1	06.1	1	78.5	1	61.4	1
24.6	1	08.4	3	79.9	10	63.0	1
25.1	3	09.8	3	84.2	1	63.8	8
26.8	2	12.3	1	85.0	4	64.9	8
29.4	3	13.4	2	86.8	1	66.1	1
31.6	1	15.1	1	90.3	3	68.3	10
33.5	1	16.2	1	92.6	1*	69.8	3
34.6	2	17.7	2	94.1	1	74.1	1
35.6	1	20.3	1	95.2	1	74.5	1
36.6	1	22.9	10Cu	95.7	1	79.9	1
37.7	8	22.5	2	96.1	1	81.5	1
38.1	1	23.2	3	98.4	1	84.6	4
41.5	4	27.4	1	99.2	3	86.3	1
43.8	6	28.1	1	4100.6	3	90.2	1
47.7	3	29.3	1	01.1	10	91.1	10
49.5	1	30.5	2h	04.3	1	92.2	8
49.9	1*	32.7	10	06.3	1	94.0	1
52.5	1	33.3	4	06.9	1	95.3	6
53.2	1	35.2	1	10.1	1	95.8	1
53.7	1	36.1	1	12.3	3	98.6	4
55.8	2	38.3	1	13.4	1	4201.7	4
56.9	1	39.2	1	14.1	4	03.6	1h
59.5	2	39.7	6	17.0	5	05.5	6
61.2	1	40.6	1	19.5	1	08.3	2
64.8	1	42.7	1	23.0	1	12.2	1
65.8	4	43.3	1	24.0	10	12.5	1
66.4	8	44.2	2	25.5	1	13.6	1
68.6	2*Ca?	44.9	2	27.1	1	14.9	5
70.8	1	46.4	1	27.6	1	18.1	8
72.1	3	49.9	2	29.6	7	22.9	2
72.7	3	51.7	3	30.1	8	24.9	1
73.8	2	53.3	1	31.7	1	26.5	4
75.4	1h	55.3	1Ag?	33.5	1*	27.6	1
76.8	2	56.1	1	34.8	3	27.9	1
78.1	2	57.4	1	35.6	1	29.3	8
78.9	1	59.1	10	37.3	10	30.5	2
79.5	2	59.6	1	38.5	1	32.1	5
80.7	4	61.0	2	39.9	10	37.0	1h
82.2	1	61.7	1	42.4	1	38.0	3
85.3	2	62.9	6Cu	43.4	4	41.6	4
88.3	1	65.0	1	46.1	1	42.8	4
90.8	1	66.3	1	47.4	2	46.4	4
91.8	2	67.3	2	48.9	1	47.9	1
94.6	1	68.4	2	50.3	5	49.2	1d, with Cu
97.4	1	70.2	1	52.2	1	49.6	5
98.6	1	71.1	2	52.8	10	53.2	4
99.3	4	72.2	1	55.0	1	53.9	4
4000.7	1	73.7	1	56.9	1	54.9	3
01.3	1	76.2	1	58.2	2	55.7	5

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
4256.1	2	4349.2	8	4470.0	5	4582.4	3
57.8	1*	50.5	2	71.6	5	83.6	1
59.1	2	51.8	10	72.8	5	85.1	1
62.2	8	53.4	2	75.5	1	87.2	8Cu
66.2	7	54.4	1	80.6	3Cu	92.2	2*
68.8	3	55.5	1	81.6	1	99.6	2
70.9	6	57.0	1	83.1	1	4600.4	5
72.3	2*	60.1	4	91.2	1	03.1	1
75.3	10Cu	61.8	2	94.7	3	04.0	1
77.6	4	68.6	7	97.4	1	05.8	1
79.7	4	70.4	2	98.5	1	07.0	10
80.8	5	75.0	3	4500.1	4	08.9	1
83.1	1*	78.2	8d, with Cu	03.3	7	11.9	1*
86.3	2	79.7	2	08.6	3	12.2	1
87.1	6	81.2	2	11.3	4	12.6	1
88.4	1	83.0	3*	12.4	1	15.1	1
89.6	5	84.1	3	13.6	1	16.3	7
91.4	3	87.9	2	14.2	2*	19.6	1*
92.7	5	88.5	4	21.1	1	22.0	1*
95.9	1Ti ?	91.6	2	22.6	1*	22.5	2*h
96.4	2	92.9	6	23.6	10	24.6	1*
98.1	1h	94.6	1	24.3	2	27.7	2
99.8	10	97.2	3	27.8	1	29.0	1*
4301.3	10	4400.6	2	29.6	1	30.3	8
04.1	1	01.1	3	31.0	6Cu	31.2	1*
06.5	3	02.2	2	32.7	1*	32.1	1*
08.3	2	04.8	2*	34.2	1	34.1	1*
08.8	2	06.7	3	35.0	1hTi?	38.3	4
09.7	3	10.5	7	36.2	1hTi?	40.6	1
11.5	8	11.7	4	37.7	1*	43.8	4h
11.9	2	15.1	2	40.0	7Cu	47.2	3
12.6	3	16.7	2h	43.0	2	49.3	10d
14.1	3	19.6	6	44.0	2	51.4	10Cu
16.6	1	20.8	5	47.0	8	58.5	1
18.2	2	24.0	2	48.1	1	64.1	8
19.4	1	26.8	5	52.5	1	66.4	6
20.9	1	29.6	5	54.0	5	67.4	6
22.1	1	37.5	9	57.0	3	70.1	2
23.7	1	39.5	1	59.6	1	72.3	10
26.6	8	40.6	1	64.7	10	73.7	1
27.6	3	42.0	3	66.9	1*	75.6	10d, with Cu
28.6	3	46.4	3	67.5	1	78.6	4
29.9	4	47.5	8	69.5	1	81.9	1*
31.6	8	57.0	4	71.2	1	85.3	8
36.7	1	57.6	5	73.3	8	89.3	1*
37.8	1	58.3	2	75.0	5	92.5	1*
39.0	1	60.6	6	75.6	2	94.6	2
43.0	6	64.4	4	77.4	1*	95.6	2
45.5	5	66.1	2	79.6	8	97.6	3d, with Cu
46.5	1*	66.4	1	81.8	8	4702.1	1

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
4703.9	1	4815.2	1	4963.3	3	5091.4	1h
04.8	5Cu	16.6	2	65.6	4	94.3	3
06.3	5	20.3	1	68.1	6	95.4	6
08.5	9	22.4	1	72.2	2	96.5	1
12.1	1	24.4	1	73.4	4	97.7	2
13.7	8	25.2	2	75.5	3	98.8	2
16.0	2	27.2	1	76.8	1	5100.2	5
18.2	3	29.6	6	81.5	1	02.3	3
20.3	1	32.3	1	89.2	6	05.7	10Cu
20.6	1	33.6	1	92.6	1	10.9	2
24.1	3	38.2	4	94.5	3	12.0	2
27.5	3	41.8	1	98.1	2	16.7	3
30.5	4	42.5	3	5001.2	5	18.1	2
34.0	9	45.5	3	02.5	3	20.4	5
35.6	1	48.6	7	08.2	2	21.9	4
36.7	2	52.4	2	11.9	1	24.2	2
40.8	3	54.2	1	13.4	3	25.1	1
42.7	2	61.4	1h	16.9	2	27.7	4
44.1	1	66.0	1	18.0	5	29.8	1
44.9	5	67.1	2	19.8	3	44.3	3Cu
47.2	2	69.3	5	26.6	4	33.5	3
50.0	8	72.8	1	29.0	1	34.9	7
51.8	3	76.6	1	30.3	2	37.5	2
55.5	3	78.7	1	32.1	2	39.0	2h
56.8	1	81.0	1	36.2	2	40.8	5
58.3	1	86.2	1	39.3	7	47.7	3
61.0	1h	89.9	2	42.0	1	49.5	2
64.0	1	91.0	6	43.2	2	53.3	10Cu
67.1	7	92.8	2	44.2	2	60.5	8
68.3	1	95.8	2	46.9	1	64.5	5
72.1	2	97.7	1	48.1	3	66.4	1
73.5	5	98.7	1	50.0	1	67.6	2
76.3	1	4900.9	5	51.7	1	74.5	3
77.9	2	04.7	5	53.2	1	78.4	2
80.1	1	08.0	1	54.9	2	80.5	8
81.5	1h	09.0	3	58.2	6	83.5	2
83.1	1	11.2	6	59.5	2	83.8	2
84.5	1	16.0	1	64.5	1	87.1	5
85.8	2	16.6	2	65.5	5	88.1	1
87.9	1	21.0	1h	68.3	1	89.4	6
90.1	5	25.1	3	71.8	2	93.3	7
93.1	1	29.2	4	72.7	2	96.0	5
94.7	1	33.4	1	76.2	4d, with Cu	97.5	1
97.2	1	36.9	1	77.5	3	98.8	1
4802.8	2	37.7	1h	79.1	10	5201.2	2Cu
06.0	1	39.2	7	82.4	1	02.2	2h
07.3	3	41.8	4	84.9	3	03.4	3
09.6	5	45.7	3	86.0	1	04.3	2
10.8	5	53.4	3	86.9	1	05.4	3
11.5	1	57.6	2	88.8	4	07.8	2

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
5210.5	1	5323.5	3	5443.3	3	5581.0	1
11.5	3	26.6	5	48.5	5	83.9	1
18.5	10Cu	29.5	1	53.0	3	87.1	6
20.3	6Cu	35.0	7	56.4	4	91.2	5d
25.4	5	36.9	3	58.3	8	94.9	3
29.5	2	38.0	2	61.0	3	97.0	2
30.1	1	40.1	1	62.2	1	99.7	4
32.9	6	41.0	7	63.2	2	5603.8	7
34.5	1	44.3	10	67.1	2	05.9	1
35.3	2	45.8	1	68.5	5	06.5	1
36.9	1	46.8	1	69.9	4	17.3	1
37.7	5	51.0	10	72.2	3h	18.9	2
46.6	4	52.9	1Cu	76.4	5	20.1	1
50.8	1Cu	53.5	4	77.5	1	28.5	3
52.0	6	55.2	5Cu	79.4	4	29.6	8
53.1	5	55.6	10	81.3	7	34.1	1
54.1	6	59.3	5	83.6	7	35.9	5d
55.6	2	60.3	1Cu	85.0	1	38.6	1
60.2	2	62.2	4	91.4	5	42.4	10
60.9	1	63.4	4	94.3	2	45.6	4
65.7	1	66.0	1	99.8	2	48.7	2
70.0	4	68.6	2	5504.8	6	50.2	1
71.7	10	71.3	2	09.3	2	54.4	3
72.5	2	75.5	5	13.0	4	65.0	8
76.3	10	76.1	1	14.8	1	66.0	10
77.5	2	77.0	2	17.6	3	67.1	3
78.6	2	78.0	2	22.1	2h	71.5	7
79.5	3	80.8	2	23.8	7	72.2	8
81.7	2	81.5	5	26.5	1	76.2	1
85.4	6	83.0	2	30.6	1	77.7	3
87.1	1	84.0	1	32.8	3	84.6	3
92.8	4Cu	88.4	4	36.1	3Cu	93.2	4
94.4	1	91.9	2Cu	39.0	2	98.1	3
96.4	4	94.5	2	41.7	4	5700.4	10Cu
98.1	3	95.8	2	45.8	3	04.5	1
98.9	3	96.3	5	47.8	1h	06.6	8
5301.5	3	5400.8	2	50.1	4hd	08.7	1
02.4	1	02.7	1	51.6	10	09.6	4
03.2	1	03.3	1	52.5	1	12.2	1
03.9	1	08.6	2Cu	53.4	1	13.9	9
06.6	5	09.7	1h	55.2	3Cu	15.8	1
08.1	1	11.4	5	57.5	1	16.6	5
14.4	2	16.4	5	59.6	1	19.8	1
15.7	6	22.6	8	63.2	5	22.9	1
17.1	2	24.2	1	66.2	1	25.9	3
17.9	2	28.0	1	71.7	4	29.5	8
18.7	10	31.4	5	72.9	1h	32.6	1Cu
19.6	4	32.5	2Cu	76.3	4	34.7	1
21.4	3	37.5	10	77.3	1	37.6	2
21.9	2	41.1	1	78.5	6	38.5	1

Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.	Wave length.	Intensity.
5744.1	1	5790.0	1	5838.7	8	5893.3	2
51.7	6	94.4	4	42.5	3	5900.5	8
54.7	1	98.3	2	46.1	2	03.7	3
58.4	1	5801.6	1	52.9	1	27.3	2
60.6	7	04.0	3	55.7	1	28.2	2
65.2	4	11.0	1	66.5	6	34.2	3
71.3	2	15.3	2	68.8	1	57.7	3
76.3	3	19.5	7	74.7	4	83.2	6
80.5	1	20.7	3	76.3	2	86.0	3
82.3	10Cu	34.9	4	77.8	3	97.7	3
87.7	6						

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[CONTRIBUTION FROM THE JOHN HARRISON LABORATORY OF CHEMISTRY.]

OCCURRENCE OF BORIC ACID IN VESUVIANITE.

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The observation of Jannasch[1] that the Wili vesuvianites contained boric acid and the discovery of it in specimens of the same mineral from Fritz Island, Pa., by Mr. Daniel L. Wallace, of this laboratory, led Dr. Edgar F. Smith to suggest to us that we enter upon a careful examination of specimens of the mineral from nearly all of the principal known localities of the world, the material having been procured by him years before for the purpose of carrying out a similar study. In this connection, however, we must also acknowledge the kindness of Mr. W. T. Schaller and other members of the United States Geological Survey to whom we are indebted for additional material upon which was tried the methods of determining boric acid which appear in the paper following this one.

As far as possible selected crystals were used for analysis and in every case, when boric acid was found, a thin section of the crystal under analysis was made and any inclusions shown by it were most carefully examined. The presence of tourmaline or other objectional minerals was not established in any of them, so there can be no doubt that the observed boric acid was actually a part of the vesuvianite itself.

Discussion of Results.—From the following table it is evident that boric acid, although not an essential constituent of vesuvianite, is present in this mineral much more frequently than is ordinarily supposed.[2] Its source, however, is evident enough. Vesuvianite is commonly produced by contact metamorphism—the effect of an intrusion of igneous rock upon the surrounding sedimentaries. Intrusive magmas, as is well known, often carry boric acid, which is given off during their solidification and, carried

[1] *Neues Jahrb. Min. Geol.*, 1, 269.

[2] Compare Klein, *Sitzb. Akad. Wiss.*, Berlin, 1904, p. 653.