ART. XXXIII.—*The Spectrum of Helium**; by
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IN the Chemical News for March 29th last (vol. lxxi, p. 151) I published the results of measurements of the wave-lengths of the more prominent lines seen in the spectrum of the gas from clèveite, now identified with helium. The gas had been given to me by the discoverer, Professor Ramsay; and being from the first batch prepared, it contained other gases as impurities, such as nitrogen and aqueous vapor, both of which gave spectra interfering with the purity of the true helium spectrum. I have since, thanks to the kindness of Professors Ramsay and J. Norman Lockyer, had an opportunity of examining samples of helium from different minerals and of con-

* From an advanced proof sent by the author.

siderable purity as far as known contamination is concerned. These samples of gas were sealed in tubes of various kinds and exhausted to the most luminous point for spectrum observations. In most cases no internal electrodes were used, but the rarefied gas was illuminated solely by induction, metallic terminals being attached to the outside of the tube.* For photographic purposes, a quartz window was attached to the end of the tube, so that the spectrum of the gas could be taken "end on."

My examinations have chiefly been made on five samples of gas.

1. A sample from Professor Ramsay in March last. Prepared from clèveite.

2. A sample from Professor Ramsay in May last. Prepared from a specimen of uraninite sent to him by Dr. W. F. Hillebrand. Gas obtained by means of sulphuric acid; purified by sparking.

3. A sample from Professor Ramsay in June last. Prepared from bröggerite.

4. A sample from Professor Lockyer in July last. Prepared by a process of fractional distillation from a sample of bröggerite sent to him by Professor Brögger.

5. A sample of gas from Professor Ramsay "helium purissimum." This was obtained from mixed sources, and had been purified to the highest possible point.

In the following table the first four samples of gas will be called: 1. "clèveite, R."; 2. "uraninite, R."; 3. "bröggerite, R."; and 4. "bröggerite, L." Only the strongest of the lines, and those about which I have no doubt, are given. The wave-lengths are on Rowland's scale.

The photographs were taken on plates bent to the proper curvature for bringing the whole spectrum in accurate focus at the same time. The spectrum given by a spark between an alloy of equal atoms of mercury, cadmium, zinc, and tin, was photographed at the same time on the plate, partially overlapping the helium spectrum; suitable lines of these metals were used as standards. The measurements were taken by means of a special micrometer reading approximately to the $\frac{1}{100,000}$ th inch, and with accuracy to the $\frac{1}{10,000}$ th of an inch. The calculations were performed according to Sir George Stokes's formula, supplemented by an additional formula kindly supplied by Sir George Stokes, giving a correction to be applied to the approximate wave-lengths given by the first formula, and greatly increasing the accuracy of the results.

* Journal of the Institution of Electrical Engineers, Part 91, vol. xx, Inaugural Address by the President, William Crookes, F.R.S., Jan. 15th, 1891.

Wave-length.	Intensity.	
7065·5	5	A red line, seen in all the samples of gas, Young gives a chromospheric line at 7065·5.
6678·1	8	A red line, seen in all the samples of gas. Thalén gives a line at 6677 and Lockyer at 6678. Young gives a chromospheric line at 6678·3.
5876·0	30	The characteristic yellow line of helium, seen in all the samples of gas. Thalén makes it 5875·9, and Rowland 5875·98. Young gives a chromospheric line at 5876.
5062·15	3	
5047·1	5	A yellow-green line, only seen in "helium puriss." and in "bröggerite, R," and "L." Thalén gives the wave-length as 5048.
5015·9	7	A green line seen in all the samples of gas. Thalén gives the wave-length 5016. Young gives a chromospheric line at 5015·9.
4931·9	3	
4922·6	10	A green line, seen in all the samples of gas. Thalén gives the wave-length 4922. Young gives a chromospheric line at 4922·3.
4870·6	7	A green line, only seen in "uraninite, R." Young gives a chromospheric line at 4870·4.
4847·3	7	A green line, only seen in "uraninite, R." Young gives a chromospheric line at 4848·7.
4805·6	9	A green line, only seen in "uraninite, R." Young gives a chromospheric line at 4805·25.
4764·4	2	There is a hydrogen line at 4764·0.
4735·1	10	A very strong greenish blue line, only seen in "uraninite, R."
4713·4	9	A blue line, seen in all the samples of gas. Thalén's measurement is 4713·5. Young gives a chromospheric line at 4713·4
4658·5	8	A blue line, only seen in "uraninite, R."
4579·1	3	A faint blue line, seen in "uraninite, R." Lockyer gives a line at 4580, from certain minerals. I can see no traces of it in the gas from bröggerite. A hydrogen line occurs at 4580·1.
4559·4	2	Young gives a chromospheric line at 4558·9.
4544·1	5	
4520·9	3	A faint blue line, seen in "uraninite, R." Lockyer gives a line at 4522, seen in the gas from some minerals. Young gives a chromospheric line at 4522·9. It is absent in the gas from bröggerite.
4511·4	5	A blue line, seen in "uraninite, R." but not in the others. It is coincident with the strong head of a carbon band in the CO ₂ and Cy spectrum.
4497·8	2	There is a hydrogen line at 4498·75.

Wave-length.	Intensity.	
4471·5	10	A very strong blue line, having a fainter line on each side, forming a close triplet. It is a prominent line in all the samples of gas examined. Young gives the wave-length 4471·8 for a line in the chromosphere, and Lockyer gives 4471 for a line in gas from bröggerite.
4435·7	9	Seen in "helium puriss."
4437·1	1	Young gives a chromospheric line at 4437·2.
4428·1	10	{ These two lines form a close pair. I can only see them in "uraninite, R." No trace of them can be seen in the gases from other sources. Young gives chromospheric lines at 4426·6 and 4425·6.
4424·0	10	
4399·0	10	A strong line, only seen in "uraninite, R." Absent in the gas from the other sources. Lockyer gives a line at 4398 in gas from certain minerals. Young gives a chromospheric line at 4398·9.
4386·3	6	Seen in all the samples of gas. Young gives a chromospheric line at 4385·4.
4378·8	8	{ These two lines form a pair seen in "uraninite, R," but entirely absent in the others.
4371·0	8	
4348·4	10	Seen in "uraninite, R." Lockyer finds a line at 4347 in the gas from certain minerals.
4333·9	10	Probably a very close double line. Seen in "uraninite, R" and "clèveite, R." Not seen in the other samples. Lockyer gives a line in the gas from certain minerals at 4338.
4298·7	6	Only seen in "uraninite, R." Young gives a chromospheric line at 4298·5.
4281·3	5	Only seen in "uraninite, R."
4271·0	5	Only seen in "uraninite, R." The strong head of a nitrogen band occurs close to the line.
4258·8	7	Seen in all the samples of gas.
4227·1	5	Only seen in "uraninite, R." Young gives a chromospheric line at 4226·89.
4198·6	9	{ These three lines form a prominent group in "uraninite, R," they are very faint in "clèveite, R," and in "bröggerite, L," but are not seen in "bröggerite, R."
4189·9	9	
4181·5	9	
4178·1	1	An extremely faint line. Lockyer gives a line at 4177, seen in the gas from certain minerals, and Young gives a chromospheric line at 4179·5.
4169·4	6	Seen in "helium puriss."
4157·6	8	A strong line in "uraninite, R," very faint in bröggerite, R," and "L," not seen in "clèveite, R."
4143·9	7	Strong in "clèveite, R," in "helium puriss.," and in "bröggerite, L." It is faint in "uraninite, R," and not seen in "bröggerite, R." Lockyer gives a line at 4145 in gas from certain minerals.

Wave-length.	Intensity.	
4121·3	7	Present in all the gases except "clèveite, R."
4044·3	9	Present in "uraninite, R," and "clèveite, R." Absent in the others.
4026·1	10	These lines form a very close pair, seen in all the samples of gas, except "bröggerite, R." Lockyer find a line in bröggerite gas at 4026·5.
4024·15	6	
4012·9	7	Seen in all the samples of gas.
4009·2	7	Seen in "helium puriss."
3964·8	10	The center line of a dense triplet. Only seen in "clèveite, R," in "helium puriss.," and "bröggerite, L." Hale gives a chromospheric line at 3964.
3962·3	4	Seen in all the samples of gas.
3948·2	10	Very strong in "uraninite, R," very faint in "clèveite, R," and not seen in the others. Lockyer finds a line in gas from bröggerite at 3947. There is an eclipse line at the same wave-length.
3925·8	2	Seen in "helium puriss."
3917·0	2	Seen in "helium puriss."
3913·2	4	Only seen in "uraninite, R," and "helium puriss." Hale gives a chromospheric line at 3913·5.
3890·5	9	A very strong triplet, seen in all the samples of gas. Lockyer finds a line having a wave-length 3889 in gas from bröggerite. Hale gives a chromospheric line at 3888·73. There is a strong hydrogen line at 3889·15.
3888·5	10	
3885·9	9	
3874·6	6	Only seen in "uraninite, R."
3867·7	8	Seen in "helium puriss."
3819·4	10	Seen in all the samples of gas. Deslandres gives a chromospheric line at 3819·8.
3800·6	4	Seen in "helium puriss."
3732·5	5	Seen in "helium puriss." Hale gives a chromospheric line at 3733·3.
3705·4	6	Seen in all the samples of gas. Deslandres gives a chromospheric line at 3705·9.
3642·0	8	Only seen in "uraninite, R."
3633·3	8	Seen in "helium puriss."
3627·8	5	Only seen in "uraninite, R."
3613·7	9	Seen in "helium puriss."
3587·0	5	Seen in "helium puriss."
3447·8	8	Seen in "helium puriss."
3353·8	5	Seen in "helium puriss."
3247·5	2	Seen in "helium puriss."
3187·3	10	The center line of a close triplet. Very faint in "clèveite, R," and "uraninite, R," and strong in "helium puriss." and in "bröggerite, L." It is not seen in "bröggerite, R."

Wave-length.	Intensity.	
2944·9	8	A prominent line, only seen in "helium puriss." and in "bröggerite, L."
2536·5	8	Seen in "helium puriss." A mercury line occurs 2536·72.
2479·1	4	Seen in "helium puriss."
2446·4	2	Seen in "helium puriss."
2419·8	2	Seen in "helium puriss."

Some of the more refrangible lines may possibly be due to the presence of a carbon compound with the helium. To photograph them a long exposure, extending over several hours, is necessary. The quartz window has to be cemented to the glass with an organic cement, and the long-continued action of the powerful induction current on the organic matter decomposes it, and fills the more refrangible end of the spectrum with lines and bands in which some of the flutings of hydrocarbon, cyanogen, and carbonic anhydride are to be distinguished.

There is a great difference in the relative intensities of the same lines in the gas from different minerals. Besides the case mentioned by Professor Kayser of the yellow and green lines 5876 and 5016, which vary in strength to such a degree as to render it highly probable that they represent two different elements, I have found many similar cases of lines which are relatively faint or absent in gas from one source and strong in that from another source.

Noticing only the strongest lines which I have called "intensity 10," "9," or "8," and taking no account of them when present in traces in other minerals, the following appear to be special to the gas from uraninite:

4735·1	4424·0	4371·0	4189·9	3948·2
4658·5	4399·0	4348·4	4181·5	3642·0
4428·1	4378·8	4198·6	4157·6	

The following strong lines are present in all the samples of gas:

7065·5	4922·6	4258·8	3885·5
6678·1	4713·4	4012·9	3885·9
5876·9	4471·5	3962·3	3819·4
5015·9	4386·3	3890·5	3705·4

The distribution assigned to some of the lines in the above tables is subject to correction. The intensities are deduced from an examination of photographs, taken with very varied exposures; some having been exposed long to bring out the fainter lines, and some a short time to give details of structure in the stronger lines. Unless all the photographs have been exposed for the same time, there is a liability of the relative

intensities of lines in one picture not being the same as those in another picture. Judgment is needed in deciding whether a line is to have an intensity of 7 or 8 assigned to it; and as in the tables I have not included lines below intensity 8, it might happen that another series of photographs with independent measurements of intensities would in some degree alter the above arrangement.

In the following table I have given a list of lines which are probably identical with lines observed in the chromosphere and prominences :

Wave-length observed of helium.	Intensities.	Wave-lengths of chromospheric lines,* Rowland's scale.
7065·5	10	7065·5
6678·1	10	6678·3
5876·0	30	5876·0
5015·6	6	5015·9
4922·6	10	4922·3
4870·6	7	4870·4
4847·3	7	4848·7
4805·6	9	4805·25
4713·4	9	4713·4
4559·4	2	4558·9
4520·9	3	4522·9
4471·5	10	4471·8
4437·1	1	4437·2
4428·1	10	4426·6
4424·0	10	4425·6
4399·0	10	4398·9
4386·3	6	4385·4
4298·7	6	4298·5
4227·1	5	4226·89
4178·1	1	4179·5
3964·8	10	3964·0 H.†
3948·2	10	3945·2 H.
3913·2	4	3913·5 H.
3888·5	10	3888·73 H.
3819·4	10	3819·8 D.
3732·5	5	3733·3
3705·4	6	3705·9 D.

* A Treatise on Astronomical Spectroscopy, by Dr. J. Scheiner, translated by E. B. Frost, Boston, 1894.

† The wave-lengths to which the initials D. and H. are added are wave-lengths of lines photographically detected in the spectrum of the chromosphere by Deslandres (D) and Hale (H). Their photographs do not extend beyond wave-length 3630. Professor Lockyer (Roy. Soc. Proc., vol. lviii, p. 116, May, 1895) has already pointed out fourteen coincidences between the wave-lengths of lines in terrestrial helium and in those observed in the chromosphere, the eclipse lines, and stellar spectra.