The Reversal of Spectrum Lines produced by a Spark under Water.

By

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From the researches of P. Konen[1], H. Konen[2], Sir N. Lockyer[3], G. H. Hale[4] and H. Finger[5], it has been generally established that many lines are reversed in the spectrum of a spark under water. Moreover G. H. Hale found that the number of reversed lines increased in the more refrangible region. It may be remarked here that in all these researches the region examined extended only down to λ 2000 Å.U., so that data for the extreme ultra-violet region are entirely lacking.

In 1913, V. Henri[6] reported that, if we employ an aluminium spark of high frequency under water as the source of light, a continuous spectrum extending to λ 2150 Å.U. could be obtained with a fairly strong intensity.

On experimenting with Henri's method, using several different metals as electrodes, the writer found that the metallic lines due to the electrode appeared mingled with the continuous spectrum; and further, that some of those lines were always reversed while others remained unreversed, so that Henri's method affords us a convenient

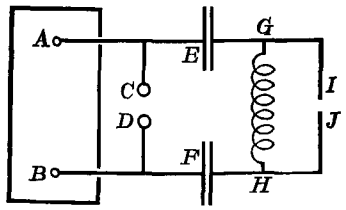
1 P. Konen, Phys. ZS., **3**, 537 (1901–1902).
2 H. Konen, Ann. d. Phys., **9**, 742 (1902).
3 Sir N. Lockyer, Proc. Roy. Soc., **70**, 31 (1902).
4 G. E. Hale, Astrophys. Jour., **15** 132 (1602), **17**, 154 (1903).
Publications of the Yerkes Observ., Vol. 3, Part 2, p. 29.
5 H. Finger, Ber. d. deutsch. phys. Gesell., **4**, 369 (1909).
ZS. f. wiss. Photogr., **7**, 329 (1909).
6 V. Henri, Phys. ZS., **14**, 516 (1913).

means for studying the behaviour of different lines in the spectrum of a spark under water.

Although the phenomenon is very complicate and depends greatly upon the mode of excitation of the spectrum, still it may serve as a means whereby to examine the difference in the conditions under which different lines are excited.

The arrangement for producing the Henri spark is shown in Fig. 1. The terminals A, B of a 70 cm induction coil were joined to the spark gap at C, D and to the inside coatings of two leyden jars E, F. The outside coatings of these jars were joined to the aluminium rods I, J, which were immersed to a depth of 2 or 3 cm. in distilled water. A coil of small self-induction G, H, was inserted in parallel with the spark gap I, J which served as the source of light.

Fig. 1.



The light from the spark under water passed directly to the slit of a quartz spectrograph of size A made by Hilger. The collimator of the spectrograph was held in a vertical position. A Schumann photographic plate prepared by Hilger was employed. It may be remarked here that the photographic reversal was carefully eliminated from that of the true reversal of the line.

In the present experiment, the metals used for electrodes of a spark under water were *Al*, *Zn*, *Cd* and the amalgum of zinc.

In the following, detailed accounts are given for each of these metals.

(1) *Aluminium.*

Among the metal spectra, that of aluminium extends far more to the extreme ultra-violet region than those of other metals.

For this metal, Finger found certain relations between the term number and the type of lines.

In the following table, we notice that the non-series lines appear always as the emission lines. On examining the photograph, the writer also noticed that the lines belonging to the first subordinate series were more easily reversed than those belonging to second subordinate one.

It may be worthy of mention that of the six lines lying in the most refrangible part, the type of lines 1930 and 1935 are different from the remaining four lines.

TABLE I.

ALUMINIUM.

Term number	λ in Å.U.	Intensity (Condensed (spark in air)	Result obtained by using Henri's method		Finger's result
			Type of line. "e" signifies emission "a" signifies absorption	Intensity	
	1854	5	e	1	
	1857	4	e	1	
	1862	6	e	2	
	1930	5	a	3	
	1935	7	a	3	
	1990	8	e	4	
I. N. II, 8	2205	2	a	1	
I. N. I, 8	2210	2	a	1	
I. N. II, 7	2263	3	a	2	
I. N. I, 7	2268	3	a	2	
I. N. II, 6	2367	6	a	3	
I. N. I, 6	2378	6	a	3	
I. N. II, 5	2567	3	a	2	a
I. N. I, 5	2575	3	a	2	a
	2632	4	e	2	e
II. N. II, 4	2653	3	a	2	a
II. N. I, 4	2661	3	a	2	a
N.	2816	5	e	4	
	3057	3	e	3	
	3065	2	e	2	
I. N. II, 4	3082	5	a	3	a
I. N. I, 4	3093	5	a	3	a
	3587	5	e	4	
II. N. II, 3	3944	5	a	2	a

(2) *Zinc.*

The non-reversal of 3076 Å.U. is noticeable. McLennan investigated the absorption spectra of zinc vapour at this region. In his first experiment[1] he found no absorption line at λ 3076 contrary to his expectation that he would obtain a pair of absorption lines at λ 2139

[1] McLennan, Phil. Mag. **28**, 361 (1914).

TABLE 2.

ZINC.

Term number	λ in Å.U.	Intensity (Condensed spark in air)	Result obtained by using Henri's method		Finger's result
			Type of Line. "e" signifies emission "a" signifies absorption	Intensity	
P. 2	2026	3	a	2	
P. 2	2062	3	a	2	
	2064	3	e	2	
	2087	2	a	1	
	2097	3	a	1	
	2100	3	e	2	
	2102	3	a	1	
	2105	2	a	1	
II. n.	2139	5	a	2	
	2265	3	e	2	
	2288	2	a	1	
II. N. I, 7	2487	2	e	1	
	2491	2	e	1	
P. I	2502	5	e	4	
II N. III, 5	2557	6	e	5	
I. N. II, 5	2771	2	e	2	
I. N. I, 5	2801	3	e	2	
	2832	1	a?	1	
	3076	2	e	1	
I. N. III, 4	3282	4	e	2	e
I. N. II, 4	3303	5	e	2	a
I. N. I, 4	3345	5	e	2	a

and 3076 Å,U. But in his second experiment[1], he observed that, in the absorption spectrum of non-luminous zinc vapour, there is a strong symmetrically spaced absorption band at λ 2139·3 Å.U. and a very narrow sharply defined one at $\lambda = 3075{\cdot}99$ Å.U. In the present experiment, the line λ 2139 appeared as a reversed line.

(3) *Cadmium.*

Lines λ 2288 and 3261 Å.U. which appeared as absorption lines

[1] McLennan & Edwards, Phil. Mag., **30**, 695 (1915).

in the experiment of R. W. Wood and D. V. Guthrie[1], and later, confirmed by McLennan and Edwards[2], were also found as reversed lines in the present experiment.

TABLE 3.

CADMIUM.

Term number	λ in Å.U.	Intensity (Condensed spark in air)	Result obtained by using Henri's method		Finger's result
			Type of Line. "e" signifies emission "a" signifies absorption	Intensity	
	2144	7	a	4	
	2195	5	e	4	
	2240	3	e	2	
	2265	6	e	3	
	2288	4	a	2	
	2313	4	e	4	
	2321	3	e	2	
	2329	2	e	1	
	2470	1	e	1	
	2573	4	e	5	
	2749	4	e	5	
I. N. I, 5	2981	3	e	1	
	2987	1	e	1	
	3069	2	a	1	
	3089	2	e	1	
	3095	2	a?	1	
II. N. II, 4	3133	2	e	1	
II. N. I, 4	3253	3	e	2	
N	3261	2	a	2	
I. N. III, 4	3404	4	e	2	
I. N. II, 4	3468	4	e easily reversible	2	a
I. N. I, 4	3613	5	e easily reversible	2	a
Cd 7	4416	1	e	1	a

1 R. W. Wood & D. V. Guthrie, Astrophys. Jour., **29**, 211 (1901).
2 McLennan & Edwards, Phil. Mag., **30**, 695 (1915).

TABLE 4.

MERCURY.

Term number	λ in Å.U.	Intensity (Condensed spark in air)	Result obtained by using Henri's method		Finger's result
			Type of Line. "e" signifies emission "a" signifies absorption	Intensity	
	2052	2	e	1	
	2225	4	e	2	
	2260	3	e	2	
	2264	2	e	2	
I. N. III, 6	2378	2	e	1	
	2398	1	e?	1	
I. N. II, 6	2482	1	a	1	
I. N. III, 5	2537	3	a	3	
	2603	1	e	1	
	2605	1	e	1	
	2848	4	e	2	
I. N. III, 4	2967	4	e	3	
I. N. II, 3	3132	3	e	3	
	3145	3	e	3	
I. N. I, 4	3655	4	e	3	
II. N. III, 3	4047	2	e	2	
	4078	2	e	2	
	4340	4	e	3	
II. N. II, 3	4359	4	e	3	

(4) *Mercury.*

To obtain the spark spectrum of mercury under water, zinc amalgum was employed as the electrode, lines belonging to zinc being excluded afterwards.

Among the mercury lines, 2537 appeared always reversed as had already been observed by Wood and several other investigators.

It is interesting to note that in several instances the appearance of the spectrum lines of various metals, obtained when using the metal itself as the electrode of Henri's spark under water, resembled in some respects the absorption spectra of non-luminous metallic vapours as observed by McLennan and Edwards.

Comparing the writer's data with those of Konen and Finger, it will be seen that the latter examined the lines in the region between λ 2000 and 4700 Å.U., while the former extended his examination down to λ 1850 Å.U., and, in agreement with Hale, found that reversed lines increase as we advance in the more refrangible region. As regards the relationship between the reversal and the term number of lines in the spectral series, which was discussed by Finger, the present experiment does not give sufficient data for an opinion.

As mentioned above, V. Henri recommended the use of the high frequency spark spectrum of aluminium under water as a convenient source for giving a continuous spectrum in the ultra-violet region down to 2150 Å.U. Recently E. P. Lewis[1] has shown that the Geissler tube discharge of hydrogen gives a continuous spectrum extending to a still more refrangible part.

In the present experiment, the statement of Lewis was found to be quite true; and the writer believes that probably the Geissler tube discharge of hydrogen may be recommended as one of the most convenient sources for obtaining a continuous back ground in the absorption experiment at the extreme ultra-violet region.

The writer's cordial thanks are due to Prof. Mizuno and Assist. Prof. Takamine for their kind advice.

[1] E. P. Lewis, Science, **41**, 977 (1916).