THE ABSORPTION LINES IN THE SPECTRUM OF THE METALLIC SPARK IN WATER

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Abstract

Absorption spectra of twenty elements, 4500 to 2000 A, obtained with condensed spark in water.—These spectra, seven of which are reproduced, consist of a continuous background crossed by bright and dark lines characteristic of the metal. For Al, Bi, Cd, Au, Ir, Pb, Mg, Pt, Rd, Ag, Sn and Zn, the absorption lines are those which are reversed in the arc. For Sb, Co, Cr, Cu, Fe, Mo, Ni and W, the water spark shows as absorption lines all the lines reversed in the arc and in addition about four hundred absorption lines, in all, which are not listed as reversed in the arc. Some of these are mentioned.

Introduction

EXPERIMENTS by Hale,[1] Bloch[2] and others[3] have shown that the spectrum of the condensed spark under water between metallic electrodes exhibits a continuous spectrum crossed by bright and dark lines characteristic of the metal. Although many metals have been considered in these investigations throughout various regions of the spectrum, no complete record of the absorption lines has been reported and in only a few instances have the observations been extended below 2500 A. It appeared of interest, therefore, to investigate these spectral phenomena more extensively. The earlier experimenters found that in many cases the number of lines which appeared as absorption lines depended upon the type of electrical excitation and perhaps upon such circumstances as the size of the electrodes, the depth of the spark in the water, the purity of the water, the temperature, etc. They found further that many kinds of absorption lines occurred, the different lines being intense, weak, narrow, broad, asymmetric, bright on one edge, displaced, etc., and that the character of the absorption line sometimes varied with the circumstances of the experiment.

Examination of these details has not been attempted in the present investigation. Attention has been directed to the presence or absence of an absorption line rather than to its behavior and character. Spectra were photographed throughout the region 4500 to 2000 A of the con-

[1] Hale, Publications of the Yerkes Observatory, **3**, Part 2 (1907)
[2] Bloch, Journ. de Phys., **3**, 309 (1922)
[3] See Baly, Spectroscopy, p. 413 (1912)

densed spark under water between electrodes of twenty different metallic elements. Guided by preliminary experiments, conditions of electrical excitation were chosen to bring out as many absorption lines as possible. In the main the purpose of this paper has been to present experimental results and to leave possible discussion of their bearing upon spectral series to others.

Experimental Details

The arrangement of apparatus is indicated in Fig. 1. The condenser C of capacity 0.01 microfarad was charged by the 25 kv, 1 kw, transformer T, and discharged through the quenched gap Q and the water spark S. S was placed in a jar of distilled water, at all times about four centimeters below the surface of the water. The electrodes of S, which were usually about a millimeter apart, could be approached to each other

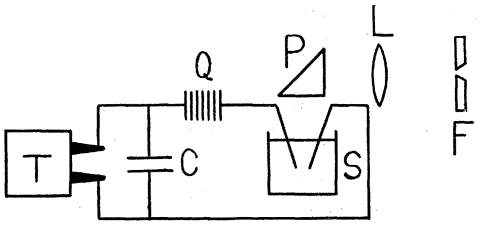

Fig. 1. Diagram of apparatus.

by a screw adjustment as they splintered away during the passage of the spark. In case very rapid disintegration of the electrodes occurred the water was changed continually. The quenched gap served to ensure an abrupt discharge. The current through the spark was between 5 and 10 amp. as measured by a hot wire ammeter, and was oscillatory, heavily damped, of a frequency about 10^5. The light from the spark S passed upward across the surface of the water, was directed by the quartz prism P through the quartz lens L, and came to a focus on the slit F of the spectrograph. A grating spectrograph of dispersion 8.8 A per mm served for the region from 4500 to 2400 A and a small quartz spectrograph for the region from 2400 to 1850 A. The water spark spectra usually extended nearly to 2000 A but rarely below this. The times of exposure were from 2 to 15 minutes. Seed plates, L Ortho, were used for the photography of the longer wave-length region and Schumann plates for the shorter wave-length region. On the same plate with each water spark spectrum an air spark spectrum was taken for comparison. Wave-lengths are from Kayser's Handbook and from the later tables of Watts.

The condensed spark under water takes place with explosive violence, the light being brilliant and the sound intense. Upon the passage of the

spark, vapor of the metal is thrown off, probably in an excited or partially excited condition. It is this envelope of metallic vapor which produces the line absorption in the continuous spectrum from the core of the spark. On all the spectrograms there appeared a group of fine absorption lines near 3100 A which is attributed to water vapor.[4] This group may be seen superimposed on the doublet $1\pi-2\delta$ of the aluminum spectrogram of Plate I.

General Conclusions

The following statements may be made for the spectral region 4500 to about 2000 A and for the conditions of the present experiments:

(1) The absorption lines which appeared in the water spark spectra of the metals Al, Bi, Cd, Au, Ir, Pb, Mg, Pt, Rd, Ag, Sn, and Zn were those which were reversed in the arc, no more and no less. The identification of about one hundred and fifty lines contributed to this conclusion.

(2) For the metals Sb, Co, Cr, Cu, Fe, Mo, Ni and W all the lines reversed in the arc appeared as absorption lines in the water spark spectra. This conclusion resulted from the identification of over two hundred lines. In addition, the water spark spectra of these metals exhibited altogether more than four hundred absorption lines which were not listed as reversed in the arc. The actual numbers were: Sb, 7; Cu, 8; Mo, 3; W, 6; and Co, Cr, Fe, and Ni more than 100 each.

There were a few doubtful instances where it was uncertain whether a line which was reversed in the arc, actually appeared as an absorption line in the water spark. These instances, about twenty in number, occurred when the line was of low intensity, or was over-shadowed by a neighboring stronger line, or was one of a complex group of lines.

Further Details

Aluminum. In the aluminum spectrogram of Plate I the first four members of the $1\pi-m\delta$ diffuse doublet series[5] and the first two members of the $1\pi-m\sigma$ sharp doublet series were brought out as absorption lines in very pretty fashion.

Antimony. The water spark reversals included the arc reversals throughout the range of observation which extended to 2070 A. In addition there were seven water spark absorption lines which were not reversed in the arc, namely, 2224.98, 2220.80, 2207.7, 2145.03, 2141.8, 2139.76, and 2127.55. This last line is reversed in the spark but not in the arc.

[4] Konen, Ann. der Phys. **9**, 779 (1902)
[5] Fowler's notation.

Cobalt, chromium, iron and nickel. The water spark spectra of these metals were extremely complex, possessing many emission and absorption lines. As has been said, besides showing as absorption lines all the arc reversals the water spark spectra of these metals exhibited hundreds of other absorption lines. These were especially numerous in the extreme ultraviolet. Spectrograms with higher dispersion would be necessary to obtain more exact data. The chromium triplets 4289.98, 4274.95, 4254.50 and 3605.48, 3593.63, 3578.81 were strongly reversed. Some of the absorption groups of cobalt and nickel are given in Plate I.

Copper. The important pair of lines 3274.08 and 3247.66 appeared prominently reversed in the water spark. All the water spark absorption lines, including the line 2104.73, were arc reversals with the exception of the eight ultraviolet lines 2135.92, 2130.87, 2125.97, 2122.91, 2112.02, 2054.92, 2043.74, and 2037.06. These were not reversed in the arc. Some of these lines may be seen in the copper spectrogram of Plate I. This spectrogram was chosen because it was more suitable for reproduction than a number of others which extended farther into the ultraviolet.

Lead. The water spark absorption lines matched the arc reversals throughout the region of observation, which extended to 2190 A. Grotrian[6] has observed about fifteen absorption lines in a continuous spectrum passed through lead vapor heated above 1200°C. All of these lines were included in the water spark reversals.

Magnesium. The water spark and arc reversals were in agreement. The magnesium spectrogram of Plate I illustrates various types of absorption lines. In the upper portion, which is of the water spark, the quintette group around 2780 is strikingly reversed. The two lines 2802.80 and 2795.62 of the quadruplet are strongly absorbed and overshadow their weaker neighbors 2798.17 and 2790.99 to such an extent that the reversals of these are seen with difficulty. The $1S-1P$ line, 2852.29, is very diffusely reversed. The lower portion of the spectrogram gives for comparison the condensed magnesium spark in air.

McLennan[7] found absorption in magnesium vapor at 2852.22 and 2026.46. The first of these lines is reversed in both the arc and water spark and the second in neither. The $1S-1p_2$ line 4571.24 is of interest. McLennan did not observe its absorption in magnesium vapor whereas Barratt[8] did very readily. This line is not reversed in the arc or water spark.

[6] Grotrian, Zeit. f. Phys. **18,** 169 (1923)
[7] McLennan, Roy. Soc. Proc. **A 92,** 574 (1916)
[8] Barratt, Roy. Soc. Proc. **A 105,** 221 (1924)

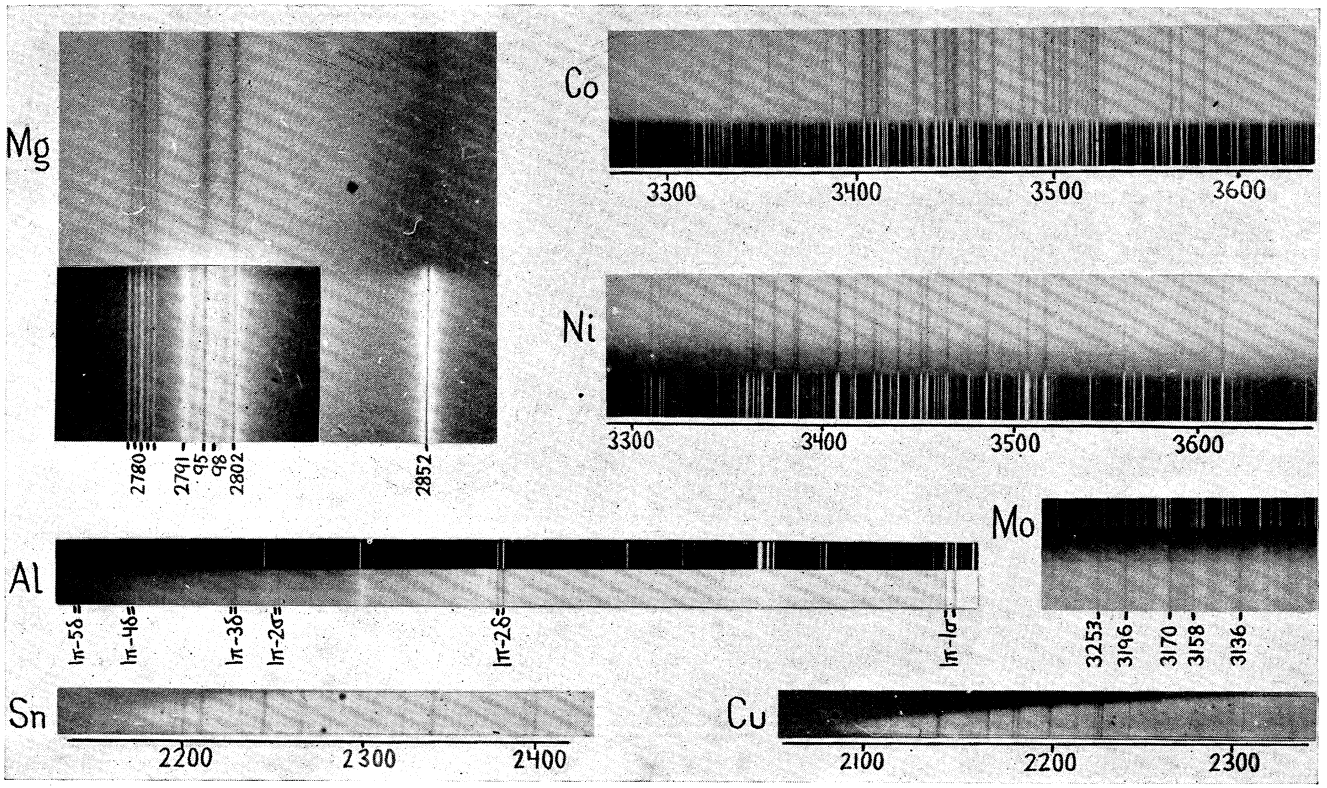

Plate I. Water spark spectra of various metals

Molybdenum. The seven arc reversals listed by Kayser are included in the water spark reversals as well as three more lines, 3253.89, 2816.22, and 2775.74. The spectrogram of Plate I shows the character of the molybdenum water spark spectrum.

Tungsten. There are no arc reversals reported by Kayser for tungsten. In the water spark we find six lines appearing as absorption lines, namely, (2947.50, 2947.10), 2944.50, 2896.56, (2879.51, 2879.21), 2852.21 and 2830.24. The first and fourth of these lines are doublets and it was not possible to say whether the absorption line referred to one member or to both.

Concluding Remarks

It seems that all the investigations of water spark spectra, including the present one, have been concerned primarily with accumulating data for a large number of metals. These data are often conflicting, which is no doubt to be ascribed to differing experimental conditions. In only one instance has a thorough consideration of a single metal been attempted. Hale[1] has dealt with iron under a great variety of circumstances and found important changes in the character of the water spark spectrum with experimental conditions. It might not be fruitless to study other metals as he has done The difference in the water spark spectra from a high potential source, as a Tesla coil, and from a relatively low potential transformer, as used in the present work, might be examined. Those lines which appear as emission and those which disappear altogether in the water spark perhaps deserve as much scrutiny as the absorption lines.

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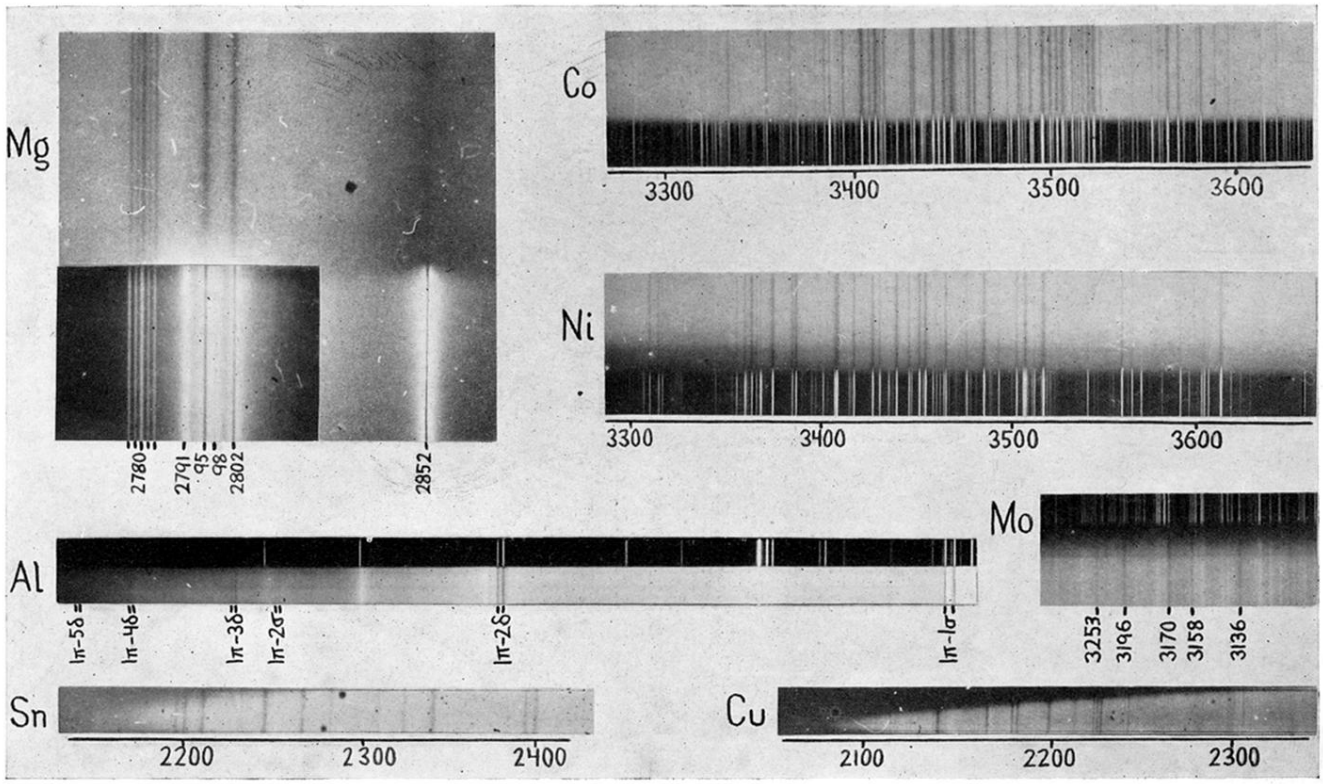

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