NOTE ON THE SPARK SPECTRUM OF IRON IN LIQUIDS AND IN AIR AT HIGH PRESSURES.

By George E. Hale.

In a study of the spark spectrum of iron and other metals in liquids, undertaken in connection with investigations of the spectra of temporary and red stars, I have encountered certain phenomena of which some preliminary notice seems desirable. It is to be understood that most of the results here presented are derived from a general reconnaissance, and that only a prolonged quantitative investigation, which is now in progress, can be expected to yield data suitable for study in connection with related astronomical and physical phenomena.

The transformer employed is wound to give either 15,000 or 30,000 volts when supplied with an alternating current of 110 volts, but in the present work a resistance of about four ohms was inserted in the circuit of the 3 K. W. alternator (133 cycles), reducing the voltage of the primary current to about 25 and the current to about 20 amperes. Under these conditions, with a condenser of 0.0015 microfarads capacity, electrodes (in water) of Bessemer steel 1 mm in diameter, with flat ends, separated from each other by a distance of about a millimeter; and auxiliary electrodes (in air, connected in series with the electrodes in water and the terminals of the transformer) of Bessemer steel, 1 mm in diameter, with flat ends, separated from each other by a distance of about 12 millimeters: the spark in water gives a spectrum of the type shown in Plate XI, Fig. 2. By changing the diameter or separation of the electrodes, the capacity of the condenser, etc., or by replacing the water by some other liquid, as will be explained below, spectra like those shown in Figs. 3 and 4 can be obtained. With the above transformer this degree of absorption has been surpassed in pure water, but if the spark is taken in a solution of 1 part of common salt in 800 parts of distilled water the effect is intensified,
Photographs of the spark spectrum of iron in air (1), in water (2, 3, 4), and in sodium chloride solutions (5, 6).

Made with a one-prism spectrograph by George E. Hale.

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and the spectrum becomes like that shown in Fig. 5. A 4 per cent. solution of common salt gives the absorption phenomena shown in Fig. 6, while an 8 per cent. solution further increases the intensity of the dark lines. A 9.5 per cent. solution of \( \text{BaCl}_2 \) produces the strongest absorption effect hitherto observed. The accompanying illustrations give some of the more marked stages in the process of reversal, but many intermediate steps have been recorded.

Within certain limits, it may be said that the reversals tend to increase in number and intensity (1) with the length of the auxiliary (air) spark; (2) with the diameter of the electrodes at either spark gap; (3) with the capacity of the condenser; (4) with the pressure of the water (other things being equal, spectra photographed with the spark 2.5 cm and 615 cm below the surface of the water respectively show a very distinct difference); (5) in solutions of sodium chloride and other salts, with the strength of the solution. On the other hand, the reversals tend to decrease in a very striking way as the length of the spark in the liquid is increased. Thus with an auxiliary spark gap of 12 mm, a spark in water 0.2 mm long gives a spectrum similar to Fig. 4, while an increase of the length to 1 mm changes the spectrum to the type shown in Fig. 2. In this case the electrodes were of iron wire 2.3 mm in diameter, with flat ends; the auxiliary electrodes of Bessemer steel were of 0.5 mm and 3 mm diameter respectively, with flat ends. It is perhaps well to point out that all of the changes referred to relate to the iron lines of the spark, and not to lines due to substances present in the particular liquid employed.

Other experiments, to be described in detail later, may be briefly referred to here. Spectra containing no dark lines were obtained from the spark which occurs in a Wehnelt interrupter (iron rod in \( \text{KOH} \) solution; direct current, 110 volts); from a rotating arc with iron poles in water (direct current, 110 volts); from the discharge between iron poles in water of an Apps induction coil wound to give a 30 cm spark (alternating current of 11 amperes through primary); and from the discharge
in water of a high frequency coil whose primary was connected with the secondary of the 15,000-volt transformer. All of these spectra, except for certain changes in the relative intensities of the lines, resemble the spectrum of the iron spark in air, and contain no reversals.

The blue region of the spectrum of the transformer spark in air has also been observed at pressures up to twenty atmospheres, with results which harmonize well with those of Humphreys and Mohler, obtained with the arc at lower pressures. The iron lines remain fairly sharp, and are shifted toward the red by an amount which seems from preliminary measurement to be directly proportional to the pressure. The phenomena are thus very different from those observed in water.

In order to study the shifts of the lines of the spark in water the spectrum under various conditions has been photographed with a concave grating spectroscope of 21 ft. focal length. Portions of some of the spectra, in each case accompanied by a comparison spectrum of the iron spark in air, are reproduced in Plate XII. It will be seen that during the transition from the bright line to the dark line conditions represented in Plate XI, the spectra show both bright and dark lines simultaneously. The scale of the photographs is sufficient to render visible the shifts of the lines, which are now under investigation.

In repeating these experiments it will be interesting to follow the changes of the iron triplet $\lambda 3763.95, 3765.69, 3767.34$. In the spark in air and in the 110-volt arc or high frequency spark in water, the two outer lines are much more intense than the central line. Kayser and Runge give all these lines the same intensity in their table of the arc spectrum of iron, but the photographic map which accompanies the table shows the central line to be decidedly fainter than the others. Hemsalech's table of spark lines gives the intensities as 8, 7, 8, and shows that self-induction increases the intensities of the two outer lines to 10, but does not affect the central line. With the transformer spark in water it is possible to obtain the lines of equal intensities. The general effect of the water is to strengthen the
PLATE XII.

PHOTOGRAPHS OF THE SPARK SPECTRUM OF IRON IN WATER.

Made with the 21-foot Concave Grating Spectroscope of the Yerkes Observatory, by George E. Hale.
central line and to weaken the other two. Intermediate effects are shown in Figs. 7 and 8, Plate XII, while Fig. 9 represents fairly strong absorption, which would be further intensified in a salt solution. The scale of the reproductions is sufficient to show the peculiar shifts of the various lines under these conditions. Professor Crew, who has very kindly confirmed some of these results in his own laboratory, informs me that the relative intensities of the lines of the triplet in the arc are not affected by an atmosphere of hydrogen or of oxygen.

Although it appears not improbable that the energy of the discharge is the principal variable concerned, a discussion of the results in the absence of quantitative data would be premature. It does not seem from the experiments so far made that the electrical conductivity of the solution is a dominant factor (e.g., kerosene oil gives an effect closely resembling that obtained with a 4 per cent. NaCl solution). Experiments to test the effect of self-induction (with and without iron cores in the coils) have given negative results, so far as the absorption is concerned, though the lines seem to stand out more clearly against the background of continuous spectrum when self-induction alone is used. A direct current spark in water and in a 5 per cent. solution of BaCl₂ gave similar effects at the positive and negative poles. These experiments, and those on self-induction, are regarded as inconclusive, and will be repeated with better apparatus.

The investigation will be continued with the assistance of Dr. N. A. Kent, to whom I am indebted for efficient aid in the work described above.

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PLATE XIII

SPARK DISCHARGE IN WATER (LOCKYER)

Mg 3829, 3832, 3838
Mg 4481