THE ORDER OF APPEARANCE OF CERTAIN LINES IN THE SPARK SPECTRA OF CADMIUM AND MAGNESIUM

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The double refraction of carbondisulphide in an electric field was used so effectively by Abraham and Lemoine[1] and others for the measurement of short time intervals, that Prof. C. M. Sparrow suggested it would be well to try to extend the method to the field of spectroscopy and atomic structure, in an effort to measure the time between the excitation of the atom and the emission of the resulting radiation. The following constitutes a preliminary report on this work.

The apparatus as used by Abraham and Lemoine, Lord Rayleigh and others did not give a complete shutter effect. In the present instance their apparatus was modified by removing the double image prism, and reducing to a minimum the resistance and inductance in the circuit containing the Kerr cell. This modification makes it possible to intercept the light emitted by a spark gap directly in front of the device, although connected in parallel with it. The arrangement is as follows: (See Fig. 1)

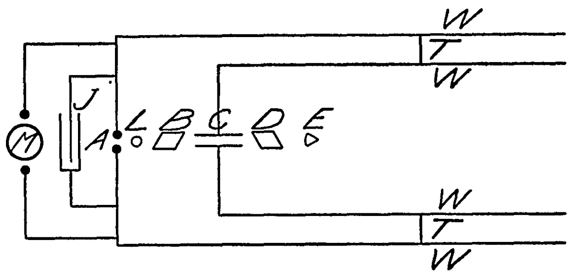

Fig. 1

The Kerr cell C made by immersing two copper plates in a tube of carbondisulphide, is placed between two crossed nicols, B and D, their short diagonals making an angle of 45° with the plates. This device will be referred to as the "shutter." An incandescent light L can be viewed by the eye at E through the shutter only when the field is applied. The potential which was supplied by a motor driven static machine M can be regulated by a spark gap A in parallel with the Kerr cell C. As the voltage reaches a maximum the light L comes into view, but as soon as the spark discharges across the gap the condenser is

[1] Comptes Rendus, 1899.

also discharged and the light entirely cut off. If now the light *L* be removed and the spark gap itself aligned with the shutter, the light emitted by the discharge of the spark at the gap will reach the shutter after it has closed even though the gap be only a few centimeters in front of the shutter. However, by increasing by a few meters the length of wire in each lead between spark gap and Kerr cell the closing of the shutter can be delayed sufficiently to allow the light to pass through. Apparently the drop of potential occurring first at the gap moves back along the lead wires to the cell.

The long parallel wires *W*, *W*, *W*, *W*, and the cross pieces *T*, *T*, hereafter called the trolley, make it possible to increase or decrease at will the length of this delay-wire within certain limits. If the terminals of the spark are made of the metal whose spectrum is to be examined, it is possible to determine the order of appearance of different bright lines in that spectrum by properly manipulating the trolley. Starting with short lengths of wire, the nicols are crossed so that no light comes through when the gap discharges. As the trolley is moved back lines appear in succession.

The sequence[2] in the appearance of a few of the bright lines of cadmium and magnesium has been observed with a direct vision spectroscope, and photographed with a spectrograph using a 60 degree carbondisulphide prism. This spectrograph was assembled rather hastily for student use but was pressed into service for this work for want of a better one. It will cover with fair definition the range 6600 to 3850 AU on the long dimension of a 4 by 5 plate. However, the shutter used did not transmit wave lengths less than 4200 AU, so that it has not been possible to reach anything outside the visual region. The photographs were taken on Wratten and Wainwright panchromatic plates hypersensitised with ammonia.

For cadmium the lines observed were the red line 6438, the spark doublet 5378 and 5337; and the first members of the sharp series, 5086, 4800 and 4678. In order to make the spark brighter a half-gallon Leyden Jar J is connected to the spark gap using short leads. There were no oscillations in the circuit large enough to affect the shutter. The air lines appeared first with from 3 to 5 meters of wire, (B and S gauge No. 12 bare copper), in each lead. The two Cd spark lines

[2] Schuster and Hemsalech while measuring the duration of lines in metallic sparks noted that the air lines came on first, and that the H and K calcium spark lines seemed to begin after the air lines had gone out. Phil. Trans. *193A*, p. 212, 1900. Schenck in Astrophysical Journal, *14*, 1901, noted that on some of his photographs the Mg arc triplet at 3833 began later than the spark doublet at 4481.

appeared next with about 16 meters of wire in each lead and the arc lines appeared later with about 17.5 meters of wire. The spark was roughly 1 meter in front of the light shutter. Although the delay in seconds can be given only very approximately, there is no question as to the sequence. If to the photographic record are added the visual observations made by both of us, and also observed by other members of the staff here, one would be inclined to place the order of appearance of the metallic lines as follows: first the spark lines[3] $5d_1-4f_1$, $5d_2-4f_2$, followed[4] by 4800, $2p_2-2s$, followed immediately by 5086, $2p_1-2s$ and 4678, $2p_3-2s$ together, last of all line 6438, $2P-3D$. The lack of sensitiveness of the eye to the red as compared to the yellow green may account for the late appearance of the red line, but it certainly appears later than the spark pair.

In the case of magnesium the only lines available are the spark doublet 4481 which Fowler assigns to a combination type; and the first term of the sharp triplet series 5184, $2p_1-2s$, 5172, $2p_2-2s$, and 5167, $2p_3-2s$. Neither the doublet nor the triplet are resolved on the plates, for the lines of the doublet were too close together and an air line at 5180 blurrs the triplet. When, however, the spark is viewed through the direct vision spectroscope it is possible to adjust it so that the short air lines appear at the bottom of the field and the longer metallic lines extend beyond them into the upper part of the field; the triplet is then easily resolved. Again the air lines appeared first with from 3 to 5 meters of wire, the spark lines appeared with 15.5 meters and the triplet with 17 meters. In the photographs the region about 5180 shows a great increase in brightness with anything over 17 meters of wire and this is taken to confirm the appearance of the triplet, at about that time. On account of the extreme brightness of the line 4481, the length of exposures, (60 minutes) and the sensitiveness of the plates in this region, some stray light which does not traverse the Kerr cell directly but is reflected by the condenser plates shows in all the exposures, but the line increases in density in no uncertain manner when the length of wire exceeds 15.5 meters, and to the eye when viewing the lines directly the flashing out of this bright line leaves no doubt as to the time of its appearance.

A preliminary examination of the air lines indicates that the green group at 5002-06 appear before the yellow group at 5667-80 though both are assigned to Nitrogen in Kayser's "Handbuch der Spectroscopie." Other substances are being examined and all show sequence

[3] Salis, Annalen der Physik, *76*, p. 145, 1925.

[4] Revised Paschen Notation.

in the appearance of the lines. The possible effect of the dispersion of the double refraction as the cause of this sequence had been studied. The effect is at most very small and will not explain the observations, for in the case of cadmium the spark lines are on the long wave length side of the sharp series triplet, in magnesium the spark lines are on the short wave-length side of the corresponding triplet yet in both cases the spark lines appear first.

A method for determining the actual time interval between the appearance of different lines is being developed and has been applied in a few cases. Briefly it consists of the following: (See Fig. 2.) *A* is

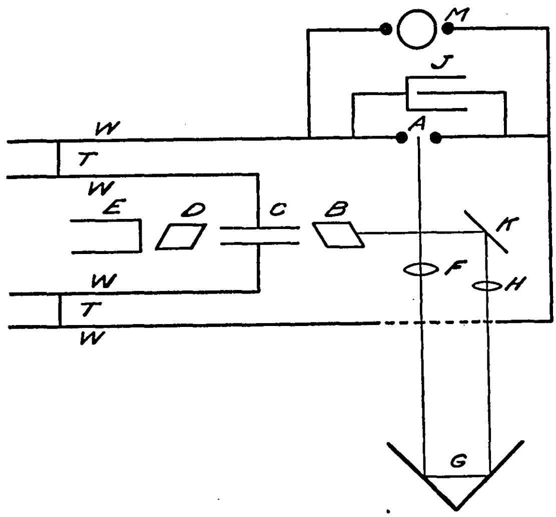

FIG. 2

the spark gap connected to the Kerr Cell *C* and to the static machine *M* as shown in Fig. 1. *F* is a lens which renders the light parallel. *G* is a double mirror for returning the light to the lens *H* which brings it to a focus at the middle point of the shutter. *K* is a plane mirror; *BCD* is the shutter and *E* a direct vision spectroscope. The mirror *G* is mounted on a table on wheels. It can move backwards and forwards and is guided by tracks so as to remain in alignment with the two lenses *F* and *H*. This makes it possible to increase or decrease the distance traversed by the light in going from the spark to the shutter. To measure the delay of the arc lines over the spark lines, the mirror *G* would be brought in as close to *H* as possible and then the trolley moved out till first the spark and finally the arc lines just came through the shutter. *G* is then moved back until both arc and spark lines disappear; it is now brought forward again slowly until the spark lines just appear, the position being noted, then forward again until the arc lines just appear and this position noted. The difference in light path divided by the velocity of light will give the delay in seconds. The observations have been checked by noting the mirror settings when the lines just disappear. The size of the room limits the intervals which can be measured to light paths of 18 meters or about 6×10^{-8} seconds. This method gives as a provisional value for the delay between the Cd spark and arc lines 3×10^{-8} seconds.[5]

The question has been raised as to whether the value of the delay in seconds is a function of the potential gradient at the spark gap. This question cannot be answered conclusively from the present data—however it is possible to state definitely that the sequence in the first appearance of the lines is not changed by altering the electrical constants of the circuit or by using a transformer instead of the static machine.

It might be suggested that for those atoms from which two electrons have been removed it is apparently necessary for the spark lines to be emitted before the arc lines since the first electrons to return will give the spark lines, while second electrons give the arc lines. This would seem to be borne out by the work of Schenck[6] and Milner[7] who found that the arc lines persisted much longer than the spark lines. However there is no guarantee that all the atoms involved have two or more electrons removed by the first passage of the spark, and since it is the relative first appearances of lines that are being measured and not their duration, the correct explanation of the facts is not so obvious.

Incidentally the method of change in light path has been used to calibrate the trolley in terms of time and indicates that the velocity of the electromagnetic waves in the leads is less than the velocity of light, is not directly proportional to the length of wire used, and depends on the potential, i.e., the length of the spark gap. The work has not been carried far enough to warrant any definite statements regarding these relations or even to allow of ready and certain transformation from lengths of lead wires to intervals of time. But it seems to hold promise of better things when the technique has been more fully developed.

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[5] Since the above was written measurements taken with the same circuit but with an improved mirror system indicate a longer time for this interval.

[6] Loc. cit.

[7] Phil. Trans. *209*A, p. 71, 1909.