ON THE MERCURY LINE 2270A ($1S-2p_1$)

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ABSTRACT

Excitation of the mercury line λ2270.—In a previous experiment by Hansen, Takamine and Werner, the line λ2270 ($1S-2p_1$) was found to be excited either in a condensed discharge or in a strong magnetic field. By using the method employed by Metcalfe and Venkatesachar for the study of the absorption of mercury lines, it was found that the glow in the branched arc of a special kind of mercury lamp emits this line with considerable intensity. Under best circumstances, its intensity was stronger than the arc line 2302 ($2p_2-9d_2$), but fainter than 2323 ($2p_2-8d_2$).

Shift of the mercury arc lines 2270, 2345 and 2564 in a condensed vacuum tube discharge.—When analyzed by a large Hilger quartz spectograph of the Littrow type, it was found that in a heavy condensed discharge the lines 2270 ($1S-2p_1$) and 2345 ($2p_3-5s$) are shifted about 0.1A towards the red, whereas the line 2564 ($2p_2-4S$) is displaced about 0.1A towards shorter wave-lengths relative to their positions in an ordinary arc spectrum.

PART I. THE LINE 2270

IT is a remarkable fact that, of the three transitions of an electron in a mercury atom, represented by $1S-2p_1$, $1S-2p_2$ and $1S-2p_3$, we see optically only $1S-2p_2$ (2536), while the other two, namely $1S-2p_1$ (2270) and $1S-2p_3$ (2655), have not been observed at all except by the indirect method of measuring the ionization by impacts of electrons on atoms by Franck and Einsporn.[1]

In 1922, at the suggestion of Prof. N. Bohr, one of the authors[2] in conjunction with Prof. H. M. Hansen and Dr. S. Werner tried to find out how to make the transitions from these two meta-stable states $2p_1$ and $2p_3$ to the normal state $1S$ possible. As the result, it was found that neither a homogeneous electric field nor a magnetic field produces the line $1S-2p_1$ or $1S-2p_3$. On the other hand, the line $1S-2p_1$ is excited with considerable intensity by passing a condensed discharge in a Geissler tube whereas the line $1S-2p_3$ has not been detected at all.

In the experiment above cited, it is to be remarked that there is always the possibility that the line 2270 we observed may be one of the numerous spark lines of mercury; nevertheless that chance of coincidence is very

[1] Franck and Einsporn, Zeits. f. Phys. **2**, 18 (1920)

[2] H. M. Hansen, T. Takamine and S. Werner, Kgl. Danske Videnskab. Selskab, Math.-fys. Medd. **3**.

small, and moreover, there was an indication that the line 2270 behaves to a certain extent as though independent of the spark lines.

In the present experiment we tried to examine the conditions favorable for the excitation of the line 2270 in more detail, our special effort being made to produce it in a pure mercury arc spectrum.

We have tried by quite a variety of methods to excite the line 2270, either in a spark spectrum, or in an arc spectrum. As the source of light, we used a large number of Geissler tubes of different forms, as well as vacuum arc, arc in air, arc in argon etc.

For taking the spectrograms, we used Hilger quartz spectrographs of the sizes E_1, E_2 and E_3.

In the case of spark spectra, there were always a large number of lines that came out and behaved similarly to the line 2270, making it rather difficult to distinguish the line 2270 from spark lines.

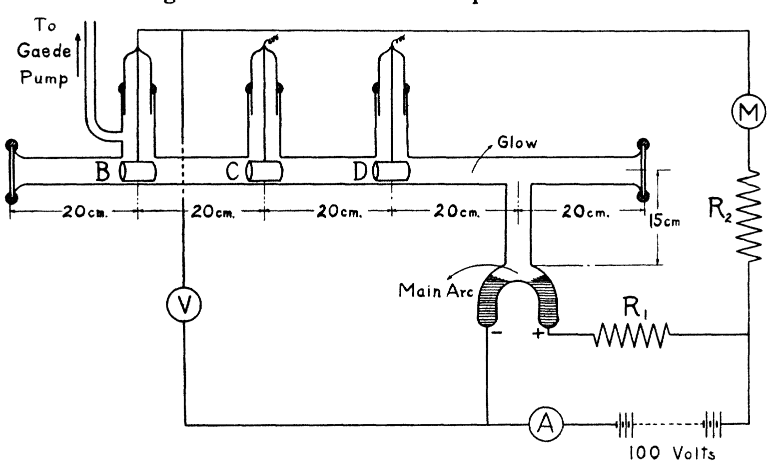

Fig. 1.

Of the many ways tried for getting the line 2270 in an arc spectrum, the method we finally adopted was that found by Metcalfe and Venkatesachar[3] for the study of absorption of mercury lines.

Our experimental arrangement is sketched in Fig. 1. It differs from that employed by Metcalfe and Venkateschar only in that we used a stronger current in the glow of the branched arc.

In Fig. 1, A is the ammeter, V the voltmeter and M the milliammeter; $R_1 R_2$ are the resistances for the main and the branched arcs respectively; B, C, D are the three auxiliarly electrodes, consisting of iron cylinders, to make the branched arc of different lengths. It was the glow of this

[3] Metcalfe and Venkatesachar, Proc. Roy. Soc. A **100**, 149-166 (1921); A **105**, 520-531 (1924).

side arc in the horizontal tube which showed the line 2270 with considerable intensity. Four tubes having the diameters 1, 1.7, 2, and 3 cm were tried with the lengths of 20, 40 and 60 cm. The electrodes of the main arc were cooled by immersing them in water, while all the joints of the upper electrode, as well as the quartz windows at both ends of the tube, which were all cemented on with de Khotinsky cement, were cooled by wet cotton.

To start the glow, the main arc was first lighted and kept at about 2 amperes at 12 volts, then the vertical part of the tube and also the horizontal part near it were heated either by a Bunsen burner or electrically. When long glow was used, it was found necessary to keep the tube hot electrically. The tube was kept continually evacuated by means of a Gaede mercury pump.

The current passing through the glow was varied from 10^{-3} to 2 or 3 amperes, with a terminal voltage of 50 to 90 volts. The spectrum of this glow was very nearly the same as that of the ordinary arc except that it showed the line 2270 and a few bands, especially one at 2345 quite strongly.

With the quartz spectrograph E_1, fairly strong images of the line 2270 could be obtained with an exposure of 10 or 15 minutes. The relative intensity of the line 2270 to that of the ordinary arc lines varied greatly according to the current intensity in the glow. When tubes having different diameters of bore were tried, it was found that there is an optimum current density for a certain diameter of the tube. A very convenient way for getting an estimation of the intensity of 2270 was to compare it with diffuse series lines ($2p_2-md_2$). Starting with a very weak current in the branched arc, we get at first 2270 fainter than a high diffuse term such as $2p_2-12d_2$ or $2p_2-11d_2$. Then by decreasing R_2 we could strengthen the line 2270 gradually so that its intensity came to fall between $m=8$ and $m=9$. But above this point increase of current density only weakened the relative intensity of 2270.

One of the photographs showing the line 2270 stronger than 2303 ($2p_2-9d_2$,), but fainter than 2323 ($2p_2-8d_2$), is reproduced in Plate IA. It is to be remarked here that close to the line 2303 ($2p_2-9d_2$), comes the line 2302 ($2p_3-6d_3$), which being not quite well resolved on the reproduction, renders the estimation of the intensity rather difficult.

As the question of a new line is always associated with that of the purity of the source, great care was taken to use distilled mercury and to keep the discharge tube as clean as possible. In the case of the condensed discharge which was used in our experiment at Copenhagen, impurity lines due to carbon and silica appeared on many occasions. In the present experiment, however, the lines were almost entirely those of the Hg arc spectrum. Moreover filling the tube with other gases like argon or bromine did not particularly enhance the line 2270.

As to the line 2655 ($1S-2p_3$), we failed to see any trace of it in the spectrum due to the glow of the branched arc.

PART II. CHANGE OF WAVE-LENGTH FOR CERTAIN MERCURY LINES IN A CONDENSED DISCHARGE

While studying the conditions for exciting the line 2270 strongly, we noticed that the line 2270 as produced by a condensed discharge has a slightly longer wave-length than when produced in the side glow of an arc. The amount of this small shift was about 0.1 A.

As the condensed source of light we used an ordinary Geissler tube of the end-on form, having a quartz window at one end. The tube was made of Jena glass and was provided with tungsten electrodes. The capillary part had the diameter of 8 mm and was 6 cm long. For excitation, two 0.4 kw transformers connected in parallel were used, with 220 volt, 3 phase alternating current in the primary. The primary current was usually 9 or 10 amperes. In the secondary circuit, a capacity of four small (200 cc) and two large (400 cc) Leyden jars were put in parallel with the discharge tube. With this arrangement, the capillary portion of the tube appeared faint violet in colour, showing the red mercury line 6149 quite strongly. As the source was very bright, an exposure of several minutes was quite sufficient for most cases.

In order to determine the small differences in wave-lengths of these particular lines, a screen having a suitable shape was made to slide over the slit of the spectrograph, enabling the spectrum of a condensed discharge to be taken in the middle, and that of an ordinary arc, or of a glow in the side-arc, on each side. To obtain the ordinary arc spectrum of mercury, we used an Arons mercury lamp provided with a quartz window. All the lines coming from this source showed perfect coincidence with those due to the glow of the branched arc described in Part I, thus showing that the small shift in the wave-length of certain lines is to be taken as characteristic of a condensed discharge.

As the amount of difference in wave-length under discussion is very small, the question naturally arises if this is not due to the method of projection of the image of the source of light on the slit of the spectrograph; however, this is clearly shown not to be the case when we examine the lines such as 2378, 2302, which are very narrow and sharp, showing perfect coincidence of wave-length on the same spectrogram.

The line 2270, as excited by a condensed discharge, shows a very faint companion on the red side of the main line, at a distance of about 0.2 A.

The amount of shift differed slightly on different plates. The mean of measurements on four different plates is given in Table I.

TABLE

Shift of wave-length in condensed discharge

Wave-length	Series	Shift
2270A	$1S-2p_1$	+0.1A
2345	$2p_3-5s$	+0.1
2464	$2p_3-4s$	+0.3
2564	$2p_2-4S$	−0.1

Looked at from the series relation, it seems worthy of note that $2p_3-4s$ and $2p_3-5s$ show shifts in the same direction, namely toward the red, while $2p_2-4S$ is displaced to the violet. Further, on a few plates there is an indication that the line 2441 ($2p_2-5S$) is also displaced to the violet. From these data, we may safely conclude that the discrepancies of wave-length in the lines of the mercury arc spectrum, when produced by a condensed discharge as compared with an ordinary arc, seem to have a certain definite connection with the series relations.

In the case of the line 2464, we see a single strong line in the glow spectrum, whereas in the spectrum due to a condensed discharge, a faint line is seen in the original position and a much stronger line on its red side at a distance of about 0.3 A.

Photographs showing the shift of the lines 2270, 2345 and 2464 are reproduced in Plate I (B, C and D). The short middle part is due to the condensed discharge, while the upper and lower parts are due either to the ordinary arc, or to the glow in the branched arc.

A trial was made to see if the amount of shift varied as we changed the mode of excitation from a slightly condensed discharge to a very heavy one by increasing the capacity; but so far, we did not get any definite results. Further experiments in the same direction in which the terminal potential of the discharge is changed by increasing the length of the capillary part and also the influence of foreign gases in the tube is determined, will be tried in the near future.

In many cases, we are confronted with the problem whether or not the lines in a pure arc spectrum undergo a change in their structure as we go from arc to spark spectrum. As a typical case, we may take that of the triplet 2482 ($2p_2-5d_i$), where, close to the original triplet in the arc, we see a group of 8 or 9 lines clustering together in the spectrum due to the condensed spark. It would seem that a further study dealing with the manner of transition from the arc to the spark spectrum would be of much interest.

It must be admitted that there is always the possibility that the lines excited by a condensed discharge are not physically related to the corresponding arc lines, or in other words that their proximity in the arc and spark spectra may be entirely accidental. The question remains open so

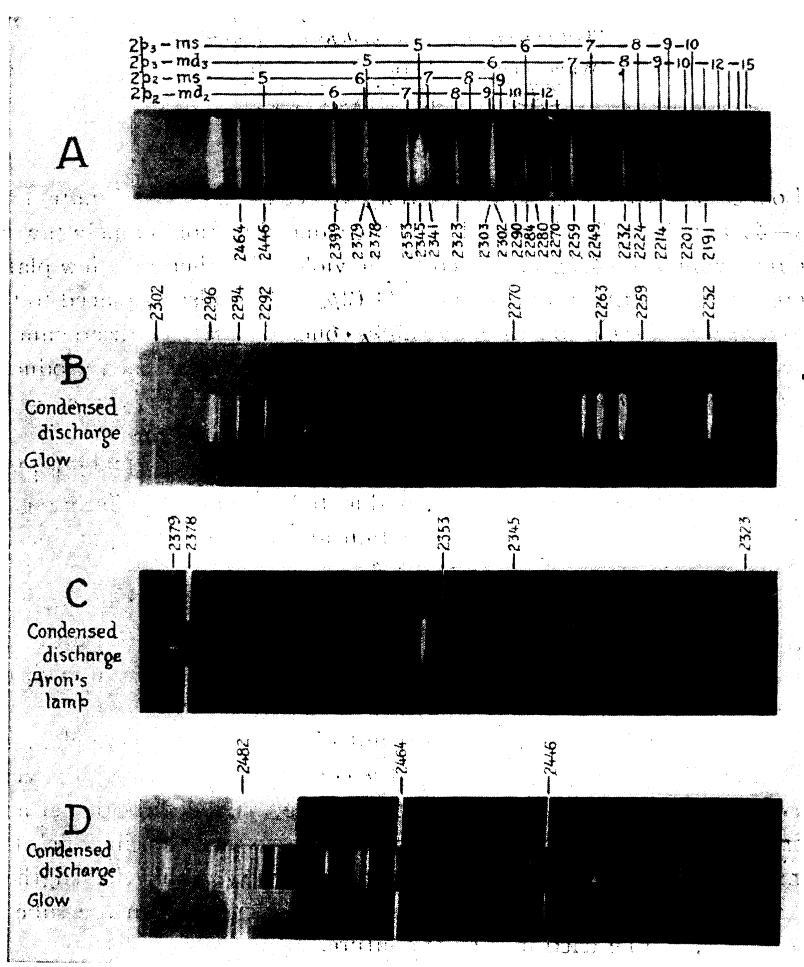

Plate I.

long as we do not have evidence that the lines are physically related, such as might be given by their behavior in an electric or a magnetic field.

As to the cause of this small discrepancy in wave-length of these mercury lines, it seems difficult to draw any definite conclusion at the present stage of our experiment. The interpretation that this may be due to a Doppler effect seems not to be the right one, for, in the condensed discharge, which was fairly well rectified, we could see no change as to the amount and direction of the shift when the positive and negative electrodes were interchanged.

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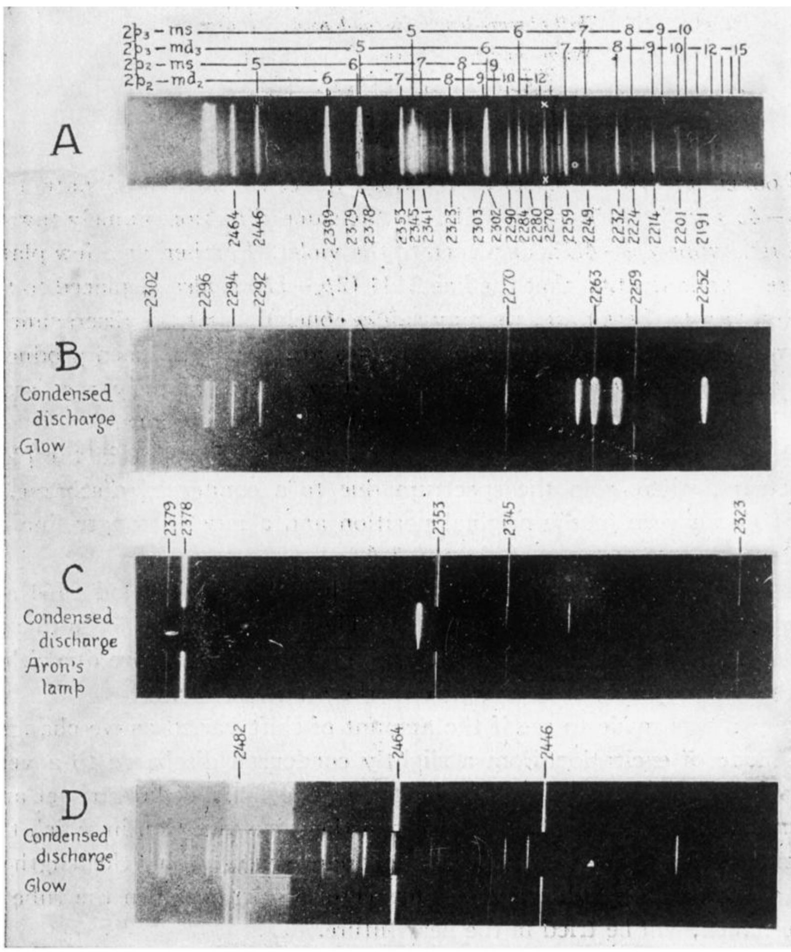

A
B
Condensed discharge Glow
C
Condensed discharge Aron's lamp
D
Condensed discharge Glow

Plate I.