The Spectra of Metallic Arcs Started in Chlorine.

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(Received April 25, 1927)

ABSTRACT.

In the foregoing experiment it was found that enhanced lines of tin were observed in its arc started in chlorine. In the present experiment, the object was to study the change called forth in the spectra of various metallic arcs and of metal flames from an electric furnace, when chlorine was introduced into the arc and furnace chambers. It was found that in chlorine arcs spark lines were enhanced and some super spark lines also made their appearance, and that in flames from the furnace, spark lines were also detected when chlorine was introduced. Thus the presence of chlorine in arcs and furnaces facilitates the emission of enhanced lines of metals.

In the foregoing experiment it was found that enhanced lines of tin were detected in light emitted from an arc in chlorine gas started between a tin electrode and a water-cooled copper one. In the present experiment, the spectra emitted from various metal arcs started in chlorine were examined.

Experimental method.

Arcs were started in the chlorine atmosphere in two different ways.

(1) In the case of metals having rather high melting points the arc was started between metal electrodes, but in the case of metals of low boiling-points the following method was used to obtain their arc :– A piece of a metal whose arc spectrum was to be studied was placed upon the flat surface of a water-cooled copper cylinder having a diameter of

5 cm. and a height of 2 cm. and this was used as the lower electrode. The upper electrode consisted of a water cooled copper tube provided with a copper cap. As is shown in Fig. 1, A, the lower electrode was fixed on the bottom of a glass-case of about two litres capacity, and this was connected to a negative terminal of 110-volts D. C. circuit, a choking coil being connected in the circuit. The air in the glass-case was displaced by chlorine and then the arc was started, the current being about 7 amperes.

(2) A small arc furnace having a base of $2{\cdot}5 \times 3$ cm^2. and a height of 3 cm. was constructed with bricks, and a window of about 1 square cm. was opened, as shown in Fig. B, so that it allowed flame to pass, but not the direct light from carbon electrodes. A small quantity of a

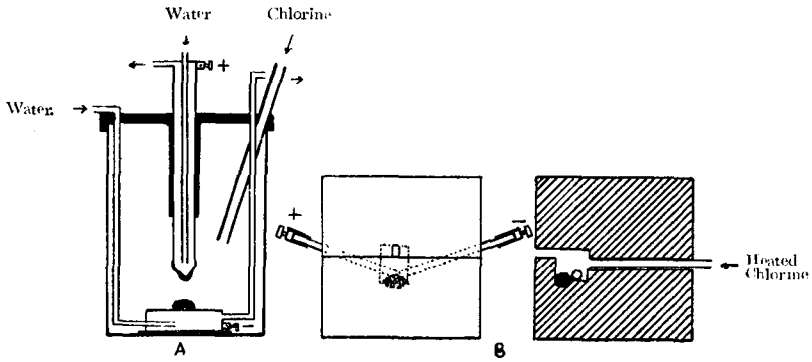

Fig. 1.

metal was placed in this furnace and this was heated by means of a 20 ampere arc in a chlorine atmosphere, the latter being introduced into the furnace through the tube shown in Fig. 1, B.

The lights emitted from the arc in the first apparatus and flame from the window in the second, were studied with a spectrograph having a large direct vision prism and a photographic lens of 60 cm. focus. The spectra thus photographed were compared with those obtained in an atmosphere of air instead of chlorine.

Results.

1 Sodium.

This metal in the molten state combines spontaneously with chlorine emitting light. By means of the arc apparatus (Fig. 1, A) mentioned above, an arc was started in air between metallic sodium and the water cooled copper electrode. Next, a similar experiment was carried out in an atmosphere of chlorine. In the latter case the light emitted was very

brilliant, giving a large quantity of sodium chloride-smoke. Examining the spectra of these lights it was found that in the former case combination lines λλ, 4918, 4914, 4633, 5629, etc. appeared feebly as shorter lines in the neighbourhood of the metallic sodium electrode while in the latter case they became enhanced as long lines. Besides this change unclassified feeble lines appeared at λλ, 4573, 4569, 4564, 4552, 4485, 4482, etc. To examine the nature of these lines, sparks were first passed between the electrodes consisting of this metal, placed in air and then sparks were passed in chlorine between the carbon electrodes, boiled in concentrated solution of NaCI and their spectra were examined. In the former case above mentioned lines were hardly detected, while in the latter they appeared clearly.

Next, when a piece of metallic sodium was heated in the furnace without passing chlorine, only reversed D_{12} lines and λλ, 6161, 6154 were observed. But when chlorine gas was introduced, the above feeble lines appeared with weak intensity. Thus the presence of chlorine facilitates the emission of these lines. (Fig. 2, D, E, Pl. XIV.)

2 Potassium.

When a piece of metallic potassium was put into the heated furnace it soon burned out. In the spectrum of this light, many arc lines of potassium were obtained without accompanying enhanced lines. But when chlorine gas was introduced, potassium suddenly combined with chlorine giving a bright light. Enhanced lines λλ, 4829, 4466, 4388, etc. were detected in this light as already observed by Ramades.[1] (Fig. 2, F, G, Pl.XIV.)

These enhanced lines were clearly observed in the light emitted from the arc in chlorine, but not detected in the arc in air. (Fig. 2, H, I, Pl. XIV.)

3 Copper.

When an arc was started between copper electrodes placed in chlorine, lines at λλ, 5067, 4955, 4932, 4919, and 4910 were enhanced and at the same time lines of CuIII λλ 5381, 5369, etc. were also detected. In the spark spectrum the lines of the former group were longer than those of the latter group. (Fig. 3, O, P, Pl. XV.)

Next, an arc was started in air between the carbon and the copper electrode placed in the furnace, and the flame thus produced was examined. Only a few arc lines were detected in this light, but when chlorine was introduced, chemical combination took place suddenly and lines λλ, 5067, 4955, 4932, etc. with reversed band spectra of copper chloride were observed in the flame. (Fig. 3, L, M, Pl. XV.)

(1) Nature, **115**, 2893 (1925).

4 Magnesium.

In the furnace experiment some arc lines and the oxide band were observed in the flame. But when chlorine was introduced into the furnace, the magnesium united with the chlorine explosively giving an intense spark line λ 4481 without an accompanying oxide band. (Fig. 2, J, K, Pl. XV.) This line was also enhanced in the arc started in chlorine.

5 Zinc and Cadmium.

Spark lines of ZnII, $\lambda\lambda$ 4925, 4912 and those of CdII, $\lambda\lambda$ 5379, 5339, 4693 were enhanced in the lights emitted from the arcs in chlorine. Besides this, the following lines not observed in ordinary arcs were also detected in these lights :– ZnIII, $\lambda\lambda$ 5579, 5564, 5463, 5336, 5250, 5234, 5158, 5075, 5050, 4971, 4879, etc., and CdIII, $\lambda\lambda$ 6005, 5959, 5914, 5791, 5688, 5641, 5612, etc. In the furnace experiment the introduction of chlorine gave rise to the emission of enhanced lines of ZnII, and CdII.

6 Calcium and Barium.

As these metals could not be obtained, carbon electrodes boiled in a concentrated solution of $CaCl_2$ and of $BaCl_2$ were used as electrodes in the arc experiments, and their salts were used in the furnace experiment. The lines of BaII, $\lambda\lambda$ 4934, 4900, 4525 and those of CaII, $\lambda\lambda$ 3969, 3934 usually appearing in an air arc were found to be enhanced in the chlorine arc.

7 Mercury.

When an arc was started in air between the carbon and the mercury electrodes the line of HgIII, λ 5426 was observed only in the neighbourhood of the mercury electrode. They are not observed in the flame from the air furnace. But when chlorine was sent through the furnace this line was detected in the flame, and the lines of HgII, $\lambda\lambda$ 5679, 4959 were also observed, the former being absent in the flame when chlorine was not introduced in the furnace.

8 Aluminium.

The spark line of AlII, λ 5592 could be observed neither in the arc nor in the flame from the furnace in air, but this was detected in the arc and flame produced in the chlorine atmosphere.

9 Tin.

In the light emitted from the arc in chlorine, the lines of SnII, $\lambda\lambda$ 5800, 5590, 5563 and 5333 were enhanced as compared with those in an air arc and those of SnIII, $\lambda\lambda$ 4934, 4858, 4586, etc. were also detected. When chlorine gas was introduced into the furnace intense arc flames came out with heavy white smoke. Enhanced lines of SnII

appeared feebly in this light but not those of SnIII. (Fig. 2, A, B, Pl. XIV.)

10 Lead.

Spark lines of PbII, $\lambda\lambda$ 5609, 5545, 5273, 5043, 4387, etc. and traces of lines $\lambda\lambda$, 5857, 4798, 4761 belonging to PbIII were detected in the light emitted from a lead arc in chlorine, but in an air arc, only lines of PbII were observed accompanied by no traces of super spark lines. In the furnace spectrum, the lines of PbII made their appearance only when chlorine gas was introduced. (Fig. 3, O, P, Pl. XV.)

11 Antimony.

In the flame obtained by heating the metal in the furnace only arc lines were observed. But when chlorine was introduced into the furnace spark lines, $\lambda\lambda$ 6080, 6005 were detected in the flame. (Fig. 3, R, S, Pl. XV.) In the arc spectrum of this metal, spark lines of SbII, $\lambda\lambda$ 6157, 6130, 6080, 6005, 5644, 5640, 5568, 5464, 5394, 5381, 5240, 5179, 5142, 5114, 4949, 4834, 4765, 4758, 4735, 4712, 4679, 4658, 4507, 4515, etc. were observed as shorter lines. By introducing the gas into the arc chamber, these lines of SbIII, $\lambda\lambda$ 6287, 6247, etc. were also observed with feeble intensities.

12 Bismuth.

In the case of bismuth it was very difficult to photograph the spectrum, for when an arc was started in chlorine gas the glass case was soon filled up with white smoke of its chloride, screening the light emitted from the arc. But the lines of BiII, $\lambda\lambda$ 5719, 5656, 5451, 5397, 5209, 5202, etc. and traces of some of BiIII could be detected in this light. The former lines appeared also in the light emitted from the furnace when chlorine was introduced.

Thus arc and furnace spectra of fourteen elements were examined in the present experiment. In the experiment with the air arc, spark lines were detected at the neighbourhood of the electrodes, but super spark lines were not observed except in a few cases. In the experiment with air only arc lines were observed without accompanying enhanced lines. But, when chlorine was introduced into the arc chamber, spark lines and some super spark lines made their appearance in the arc and in the case of the furnace spark lines were also observed. Thus the presence of chlorine in arc and furnace facilitates the emission of enhanced lines of metals in their spectra.

In conclusion, the writer wishes to express his hearty thanks to Prof. M. Kimura under whose guidance the present experiments was carried out.

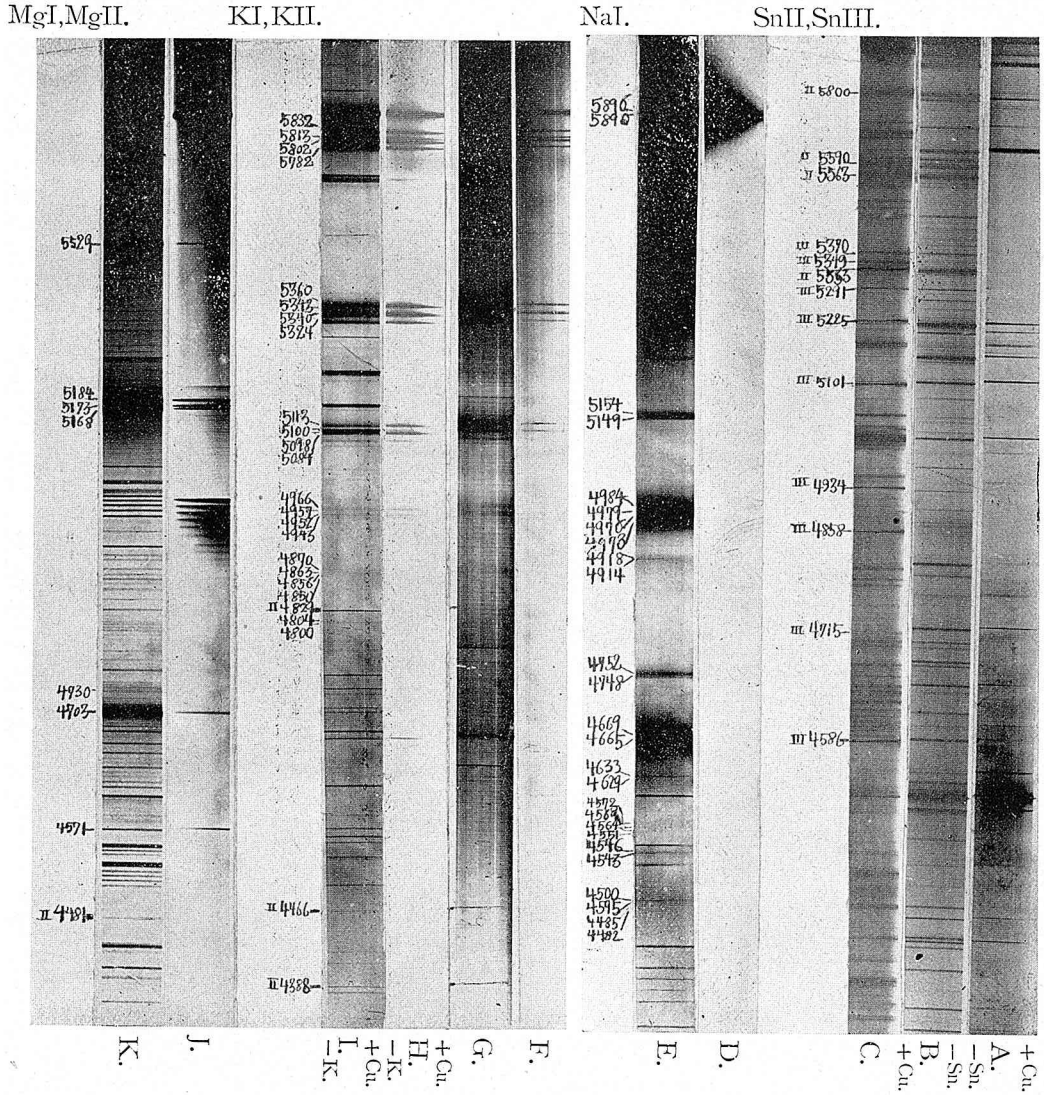

Fig. 2, Sn, Na, K, Mg Spectra.

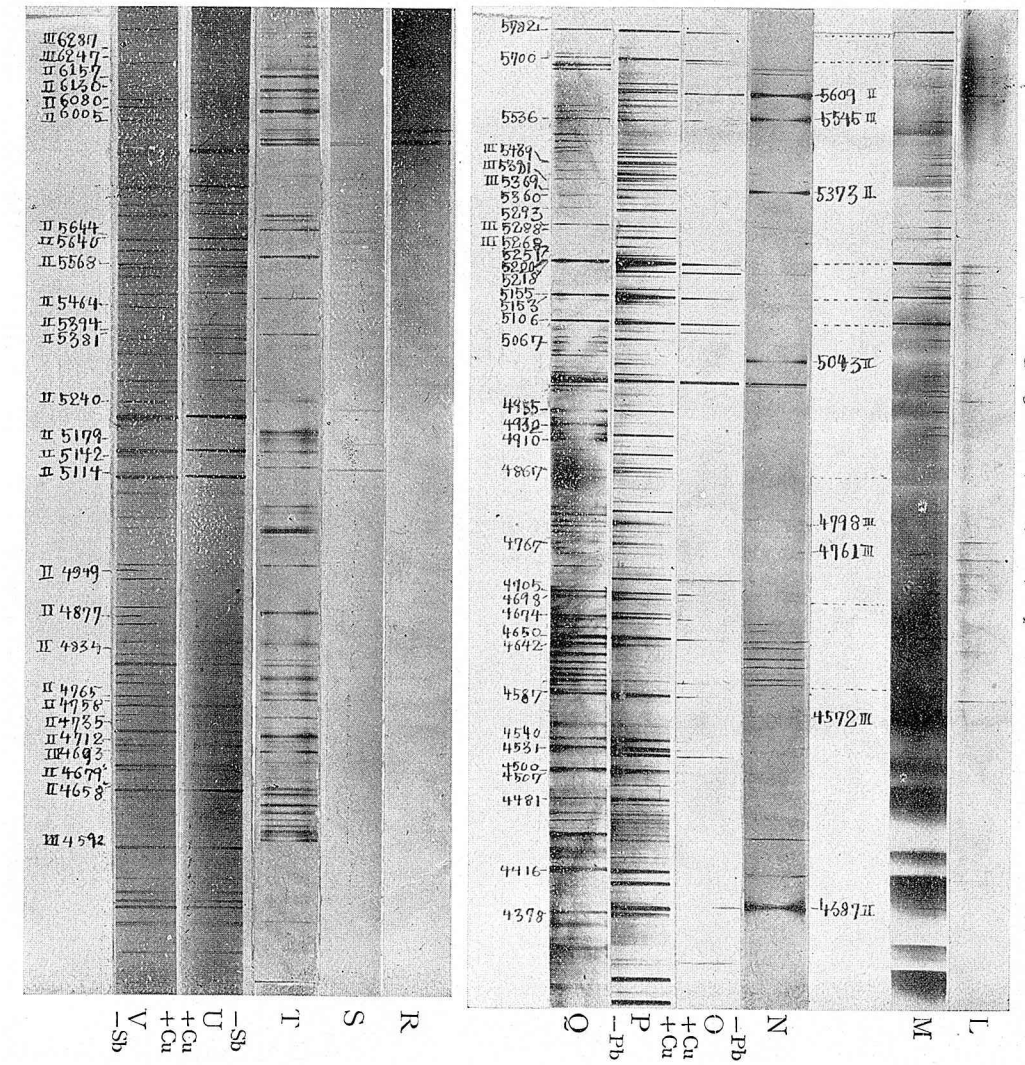

Fig. 3. Cu, Pb, Sb, Spectra.