

A few determinations were also made with the grain of both block and plate horizontal, the other circumstances, curvature and height, being the same as in the above table.

These results are given as they be of interest but very little reliance can be placed upon them as they were somewhat hastily made and time did not permit of repetition.

| <i>Material.</i> | <i>Value of e.</i> | <i>Duration of Contact.</i> |
|--------------------|--------------------|-----------------------------|
| White poplar | .42 | .0024 seconds. |
| Cherry | .49 | .0014 “ |
| Hard maple..... | .56 | .0012 “ |

These seem to show in a more pronounced manner the connection between duration of contact and the coefficient of restitution, but for reasons above stated we hesitate to regard the law as established.

It may be added, by way of a postscript of less serious content, that the length of time of contact of a base ball with a bat and the corresponding value of the coefficient of restitution, were determined by this method. These values are for the duration of contact $\frac{1}{160}$ seconds, and for the coefficient of restitution $\frac{3}{5}$.

VARIATIONS IN THE SPECTRUM OF THE OPEN AND CLOSED ELECTRIC ARC.

BY ARTHUR L. FOLEY.

[Abstract.]

The image of a normal electric arc appears to consist of three regions—a central violet portion, an outer yellow sheath or flame and an intermediate sheath of blue. By means of a Rowland grating and a Brashear mounting, and a concave mirror to focus the image of the arc upon the slit, a photographic study was made of the spectra of these regions under four conditions: (1) A vertical arc and a vertical slit, (2) a vertical arc blown out by a horseshoe magnet, (3) a horizontal arc and a vertical slit, (4) a horizontal arc and a horizontal slit.

The accompanying table gives the results of a study of the three regions of the arc with the slit vertical and through the center of each region. Two exposures were made in each position, three seconds and thirty seconds in the violet and blue regions, ten seconds and thirty seconds in the outer or yellow sheath. An exposure of three seconds in the latter brought out only ten lines.

| ELEMENTS. | REGION 1. CENTRAL VIOLET. | | REGION 2. BLUE. | | REGION 3. OUTER YELLOW' | |
|-------------------------------|---------------------------------------|--|---------------------------|----------------------------|----------------------------|----------------------------|
| | Plate 1. Exposure 3 Seconds. | Plate 2. Exposure 30 Seconds. | Plate 3. 3 Seconds. | Plate 4. 30 Seconds. | Plate 5. 10 Seconds. | Plate 6. 30 Seconds. |
| | C..... | 313 | 450 | 60 | 274 | 1 |
| Fe..... | 84 | 107 | 29 | 91 | 47 | 74 |
| Ca..... | 14 | 17 | 3 | 15 | 8 | 15 |
| Ti..... | 0 | 20 | 0 | 1 | 0 | 1 |
| K..... | 3 | 4 | 2 | 3 | 2 | 3 |
| Al..... | 2 | 3 | 2 | 2 | 2 | 2 |
| Mn..... | 2 | 2 | 0 | 2 | 1 | 1 |
| Cu..... | 0 | 2 | 0 | 0 | 0 | 0 |
| Ba..... | 1 | 2 | 0 | 1 | 1 | 1 |
| Na..... | 1 | 1 | 0 | 1 | 0 | 1 |
| Si..... | 1 | 1 | 1 | 1 | 0 | 1 |
| Not identified..... | 4 | 50 | 0 | 1 | 0 | 0 |
| Faint or blurred..... | 29 | 37 | 38 | 29 | 6 | 13 |
| To. No. lines identified..... | 421 | 709 | 97 | 391 | 62 | 107 |
| To. No. lines visible..... | 454 | 796 | 135 | 421 | 68 | 120 |

Whole number of lines visible, 1994.

Whole number of lines measured, 1842.

Whole number of lines identified, 1787.

The table shows that the lines rapidly decrease in number as the slit is moved from the center of the arc to the outer edge. This is due chiefly to the fading out of the carbon bands, only a few of the stronger carbon heads being visible in the outer sheath. But the fading out is not confined to the carbon, as the lines of all the other elements of the table show the same tendency, though to a much smaller degree.

The lines of the table (which extends from $\lambda = 3092$ to $\lambda = 5015$) were not only measured and identified, but their intensity was estimated at three points—at the upper end near the positive carbon, at the center and at the lower end near the negative carbon. The Ca and Fe lines were relatively much stronger in the outer regions than the lines of any other element. All the lines of any one element did not fade out at the same rate. Neglecting for the present the thickening of the lines at the poles and considering each region as a whole, it may be concluded that the differences observed in the spectra are due chiefly, if not entirely, to temperature differences, and that there are no lines having maxima in the outer regions. A study of the photographs taken under the three other conditions before mentioned confirms the conclusion.

The spectrum of the inclosed electric arc (a Helios Electric Co. lamp) did not differ from that of the open arc when the arc was first started. But after a minute or two the arc shortened and the metallic lines began

to disappear. After ten minutes 100 volts would maintain an arc scarcely one cm. long. The metallic lines had disappeared almost completely. The carbon and cyanogen bands were even stronger than in the first photograph. Air was then passed through the hollow carbon into the arc and globe. The arc lengthened and the metallic lines reappeared. When the current of air was shut off and a stream of CO_2 turned on the metallic lines were weakened, but they did not disappear as long as the CO_2 was flowing.

It appears that a comparatively rapid disintegration of the carbon poles is necessary to furnish enough material in the arc to bring out clearly the metallic lines, which are due to very small quantities of the metals contained in the carbons as impurities. The rapidity of the disintegration depends upon the amount of O present in the globe. After the O had become exhausted by allowing the arc to burn a few minutes the wasting away of the poles was very slow, indeed. When CO_2 was introduced the wasting of the poles increased, and, as noted before, the metallic lines appeared. Air still further increased the disintegration of the poles and the brilliancy of the metallic spectra. When pure O was passed into the globe and arc the poles were rapidly consumed. The metallic spectrum was very bright, likewise the carbon and cyanogen bands. When the lower hollow carbon was replaced by a carbon with a sulphur core (made by pouring hot sulphur into a hollow carbon) S vapor filled the globe and displaced the air very soon after the arc was started. The metallic lines did not appear, but the carbon and cyanogen bands were strong.

THE SPECTRUM OF CYANOGEN. BY ARTHUR L. FOLEY.

[Abstract.]

This investigation was made with the grating and accessories described in a previous paper and with a Helios enclosed arc lamp. The lamp was modified to allow the lower carbon to project below and outside the globe. A solid upper carbon was used. The lower carbon, which was hollow, had several small holes bored through its walls near the upper end, so that a gas blown in at the lower end would be introduced into both the arc and the globe. The lamp was not air-tight, but the circulation was

very slow when the lower end of the hollow carbon was closed. When a gas was blown into the globe the admission of air was prevented by the escaping gas.

By the term carbon bands will be meant those heading near $\lambda = 4737$ and $\lambda = 4382$. The bands heading near $\lambda = 3883$, $\lambda = 4216$ and $\lambda = 3590$ will be called the cyanogen bands, though the researches of Augström and Thalèn, Lockyer, Liveing and Dewar, Kayser and Runge, Crew and others are very conflicting on this question.

When the spectrum was photographed immediately after starting the arc it was identical with the spectrum of the open arc. After ten minutes the metallic lines had disappeared almost completely. The cyanogen and carbon bands remained strong even when O, CO_2 and S vapor were forced into the arc and globe.

It was thought that the cyanogen bands might have been due to the nitrogen of the air contained in the porous carbon poles. To remove the air the carbons were placed in a small air-tight iron cylinder, which was connected by tubes with an air pump, and a cylinder of CO_2 . The cylinder containing the carbons was placed in a furnace and kept red hot for two hours; the air pump was worked continuously. The carbons were then allowed to cool in an atmosphere of CO_2 , in which they remained for several days. The operation was then repeated and the carbons cooled as before.

When the treated carbons were placed in the lamp and a continuous stream of CO_2 was passed into the arc and globe, the cyanogen bands appeared to be a trifle weaker and the carbon bands a little stronger than with the untreated carbon poles. However, the difference was very slight. A like result was obtained when, instead of CO_2 , O and the vapor of S were passed into the arc. A continuous stream of S vapor was obtained by attaching to the end of the hollow carbon a glass tube sealed at the lower end and filled with S. A Bunsen burner kept the S boiling vigorously, the vapor passing into the globe and arc through the hollow carbon, which was heated by a second burner to prevent condensation of the vapor before reaching the arc.

It appears that the weight of evidence favors the view that the three bands in question are intimately connected with the presence of N in the arc. But there are reasons for hesitating to accept the conclusion that they are due to cyanogen or to any other compound of C and N. One

reason is that the bands are found in the spectrum of the sun. It is difficult to believe that a carbon nitrogen compound exists at so high a temperature, or even at the temperature of the arc. Another reason is that the strength of the bands does not vary much when the quantity of N in the arc is varied.

All the investigations on this subject show that a mere trace of N is sufficient to bring out the cyanogen bands quite clearly while the carbon bands are weak. Flooding the arc with N does not greatly increase the strength of the cyanogen bands or weaken the carbon bands. The following experiment emphasizes this point:

Mercuric cyanide (30 gms.) was placed in a three-bulb combustion tube. One end of the tube was sealed and the other connected by a rubber tube to the hollow carbon of the inclosed arc. The tube was heated by gas burners, and as soon as the cyanogen had displaced all the air in the globe the arc was started. The three cyanogen bands were very slightly, if any, stronger than in the arc in air, and not very much stronger than when treated carbons were used with CO_2 streaming into the arc and globe. Yet the quantity of cyanogen in the arc must have been hundreds of times greater in the first case. That the two spectra should be at all comparable in intensity is not in agreement with our knowledge of spectra in general.

The author inclines to the view that the so-called cyanogen bands are due to carbon in the presence of nitrogen, but not combined with it. It is well known that the spectrum of an element is sometimes greatly changed in the presence of another element, though there be no tendency for the elements to combine. The statement need not be confined to spectra. A very familiar instance is the addition of MnO_2 to KClO_3 in the generation of O. The temperature at which the O is given off is greatly reduced, although the MnO_2 does not decompose nor does it combine with the K.

It has been shown that cyanogen is produced by an arc in air or N. However, the compound may be formed in the outer cooler portions of the arc and not in the central hot region, where the cyanogen bands are strongest. The fading out of these bands in the outer regions is more rapid than would be expected if cyanogen were a stable compound in the arc. And to account for their production by a mere trace of N there must be a decided tendency for the compound to form. But experiments show that cyanogen may be decomposed in the arc.

Copper rods were substituted for the carbons of the inclosed lamp. The lower rod was hollow. Cyanogen was passed through it into the arc and globe. The cyanogen bands were strong. The carbon bands at $\lambda = 4737$ and $\lambda = 4382$ appeared as bright as in the inclosed arc between carbon terminals.

It may be urged that the decomposition of the cyanogen was brought about by the presence of Cu, and not by heat alone. If this be true it would seem that the metallic impurities ordinarily present in carbon would prevent the formation of cyanogen in an arc where N was present in traces only.

Many substances besides N appear to affect the spectrum of carbon. Sulphur is an instance. When sulphur vapor was forced into the arc it seemed to tend to equalize the band spectrum, somewhat diminishing the intensity of the lines on the side of the bands next the heads and strengthening the weaker lines on the more refrangible side. The bands were widened until the "grating effect" became continuous in the region of the spectrum photographed. S vapor alone, when forced into an arc between copper poles, gave a faint "grating effect" in the same region.

THE ELECTROLYTIC NATURE OF THE ELECTRIC ARC. BY ARTHUR L. FOLEY.

[Abstract.]

The spectra of twelve elements were studied to determine the nature of the lines near the carbons and directly between them. The spectrum was obtained by removing the core of one or both of the carbons and replacing it by the salt of the metal to be studied. The salts used were barium carbonate, sodium nitrate, the chlorides of zinc, calcium, strontium, potassium and lithium, the sulphates of chromium, cadmium, and aluminum and the oxides of rubidium and titanium.

Six photographs were taken of the spectrum of each element. The conditions were as follows:

No. I, upper carbon plain (containing no metallic salt) and positive, salt in lower carbon.

No. II, upper carbon plain and negative, salt in lower carbon.

No. III, salt in upper negative carbon, lower carbon plain.

No. IV, salt in upper positive carbon, lower carbon plain.

No. V, salt in both carbons, upper carbon positive.

No. VI, salt in both carbons, lower carbon positive.

The following conclusions were arrived at:

The arc is electrolytic. The electropositive elements seek the negative pole and the electronegative the positive pole. Hence the thickening of the metallic lines at the negative carbon. Convection currents due to heated gases in the arc may be sufficiently strong to mask the true nature of the lines.

In photograph No. IV the Ca lines were as strong at the lower negative carbon as at the upper positive carbon, which contained the salt. In No. III 47 Ca lines appeared at the upper negative carbon and only 14 at the lower positive pole. The 14 were not due to the salt contained in the upper pole, but to impurities in the lower carbon, for they were present when a plain carbon was substituted for the one containing the salt. The Ca traveled with, but not against, the current.

Ca photographs were chosen to illustrate the above effects because they represent about an average for the elements experimented upon. Ti did not show the effects at all. The lines extended across the spectrum with almost uniform intensity. Sometimes they were slightly intensified at the positive carbon, probably because of the higher temperature.

The Zn lines were slightly stronger at the negative carbon. The lines of Rb, K, Na, Li, Ba and Sr showed a much more decided preference for the negative pole than did the Ca lines. The preference was most marked in the case of Rb, though the most striking photographs were obtained with Ba, which has a large number of strong lines in this region of the spectrum.

As far as it could be determined the order of the elements, as regards the tendency of their spectral lines to cling to the negative carbon, is the same as their order in the electropositive-negative series.

The following experiment is more conclusive: The negative carbon of a horizontal arc was filled with calcium chloride. A new plain carbon formed the positive pole. A horizontal arc was used, otherwise the heat convection currents might have thrown doubt upon the results of the experiment. The slit was horizontal and extended from pole to pole. The carbons were placed one cm. apart and an arc was formed by passing between them a third carbon, which served to bring the poles in momentary contact. After one minute the current was shut off, and the carbon containing the Ca was replaced by a new plain carbon. The arc

was then formed again by means of a third carbon, and the spectrum was photographed. No Ca lines appeared except those always present in the ordinary arc.

In the second part of the experiment a plain carbon was used as a negative pole, and the Ca was placed in the positive pole. The arc was formed as before and allowed to continue for one minute. The positive pole containing the Ca was then replaced by a new plain carbon, the arc was formed and the spectrum photographed. The Ca lines came out very clear and strong, almost as strong as if the negative carbon had been filled with the salt. There can be but one conclusion. In the first case the Ca was in the negative pole, and there was no tendency for it to pass over to the positive pole. In the second case it was placed in the positive pole, and it freely passed over to the plain negative pole. The latter became so impregnated with it that it was capable of giving a strong spectrum of Ca when it was afterwards used in an arc with a plain carbon.

Any of the elements, which show a marked tendency to cling to the negative pole, may be used instead of Ca in the above experiment. The result was doubtful in the case of Zn.

The electrolytic nature of the arc was further confirmed by a series of measurements of the voltage necessary to maintain an arc of given length between unlike electrodes. It was found that a much higher voltage was required when the metallic salt was placed in the negative pole than was necessary when the salt was in the positive pole.

When Ca was placed in the upper pole only and it was made positive, the average of several readings gave 49 volts between the upper and lower carbons. With the same length of arc and the current reversed in direction the average reading was 65 volts. With a slightly shorter arc the readings were 35 and 48 volts, respectively. With the salt in the positive carbon of a horizontal arc the reading was 34 volts, and when in the negative carbon, 45 volts.

Similar results were obtained when Li and K were used instead of Ca.

An arc was formed between a carbon and a copper rod of the same size and shape. An average of many readings showed that about 10 volts more were required to maintain an arc with the current from the carbon to the copper rod than were required when the current was reversed.

When a third carbon was held with its point midway between the poles and in an arc maintained at 55 volts, the potential difference between

it and the negative carbon was about 15 volts and between it and the positive carbon about 40 volts. The introduction of Ca or K into the negative carbon did not change the voltage between it and the third carbon. When the salt was introduced into the positive pole the voltage between the positive pole and the third carbon fell to 25 volts, but the voltage between the negative and third carbons remained 15. It appears that the current passes from pole to pole, in part, at least, as a convective discharge of charged particles.

NOTE ON CHARLES SMITH'S DEFINITION OF MULTIPLICATION. BY ROBERT
J. ALEY.

"To multiply one number by a second is to do to the first what is done to unity to obtain the second."

This definition covers the multiplication of positive and negative integers, fractions and imaginary numbers. Accepting it as true, the law of signs follows as a result. We can easily show that it includes the multiplication of imaginaries. Suppose we are to multiply a by $b i$. We are to do to a what is done to unity to obtain $b i$. To obtain $b i$ from unity we take unity b times and turn it counter clock-wise through an angle of 90 degrees. By performing this operation upon a we obtain $ab i$. Suppose we are to multiply $a i$ by $b i$. By the same process as above we readily see that the result is $-ab$. This shows that the definition includes practically all of Quaternion multiplication.

If we undertake to apply it to the multiplication of b by a^2 we encounter our first difficulty. a^2 has been obtained from unity by taking unity a times and squaring. If we do this to b we obtain $a^2 b^2$, a result manifestly wrong. If, however, we remember that $a = a a$ and is obtained from unity by taking it $a a$ times, our difficulty disappears and we obtain the correct result $a^2 b$. If we undertake to multiply b by $a^{1/2}$ we find a difficulty which seems to be insurmountable. The only way we can obtain $a^{1/2}$ from unity is by taking unity a times and extracting the square root. If we do this to b we obtain the incorrect product $a^{1/2} b^{1/2}$. The definition seems to fail utterly when applied to irrationals. Perhaps, after all, it is better to follow the custom of most algebras and make only symbolic definitions.

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