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THE MOBILITY OF ACETYLENE IONS IN AIR

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Abstract

The mobilities in air of the positive and negative ions produced in acetylene by means of the alpha-rays from polonium have been measured by means of a blast method. It is found that in acetylene, as in air, carbon dioxide, hydrogen, and argon, only one negative ion is formed. This ion has the same mobility in air as have the negative ions formed in the other gases referred to. On the other hand, the positive ion formed in acetylene differs from those formed in the other gases in that it does not, at least up to an age of one second, change over into a more stable ion of smaller mobility. The positive ion of acetylene has a mobility slightly less than that of the negative ion and in this respect resembles the initial positive ion of hydrogen. The initial positive ions in air, carbon dioxide and argon have the same mobility as have the negative ions of these gases. It is also found that a neutral acetylene molecule is able to take up the charge of the final positive ion formed in air and in nitrogen. The resulting positive ion has the same mobility in air as the normal positive acetylene ion. This indicates that the process is of the nature of an electron interchange rather than a chemical oxidation effect.

IN EARLIER investigations[1] it was found that in air, carbon dioxide, hydrogen and argon, only one negative ion exists normally and its mobility in air is 1.87 cm/sec per volt/cm. It was also found that in these gases there is an initial positive ion which, except in hydrogen, has the same mobility in air as the negative ion and which in the course of an interval of the order of 1/50 sec. changes into a final positive ion which has a mobility of 1.36. According to the author's view the negative and the initial positive ions are each one molecule large and the final positive ion is two molecules large.

The results also indicate that although the final two molecule positive ion has a marked stability, nevertheless it does meet with conditions which cause it to disintegrate. The final positive ion may also become attached to other neutral molecules forming structures which are very unstable.

At the suggestion of Dr. S. C. Lind, the writer has investigated the ions formed in acetylene under the action of the alpha-rays from polonium. It was thought that a comparison of these ions with the very definite air ions would be of interest. This comparison was made through the measurement of the mobility of the acetylene ions in air at atmospheric pressure.

[1] Erikson, Phys. Rev. **20,** 117, (1922); **24,** 502 and 622 (1924); **26,** 465; **26,** 625; **26,** 629 (1925).
Wahlin, Phys. Rev. **20,** 267 (1922).

The arrangement of the apparatus was as shown in Fig. 1. A closed tank C, Fig. 1, was kept filled at about atmospheric pressure with acetylene gas from a commercial supply cylinder. From the tank C the acetylene passed through a tube about one meter long and 3.75 sq. cm cross-section, the tube terminating at E where the cross-section was $1/4 \times 1.5$ cm. From this tube the acetylene entered the space between two parallel plates A and B which were 5 cm wide and 3.5 cm apart and between which air was drawn by means of the fan H. In the plate B was an insulated strip F which was connected to an electrometer. The polonium was placed at points 1, 2, 3, etc., thus giving at E consecutively ions of different ages. These ions, passing from the tube at E, became subject to the electric field between A and B, those of one sign being

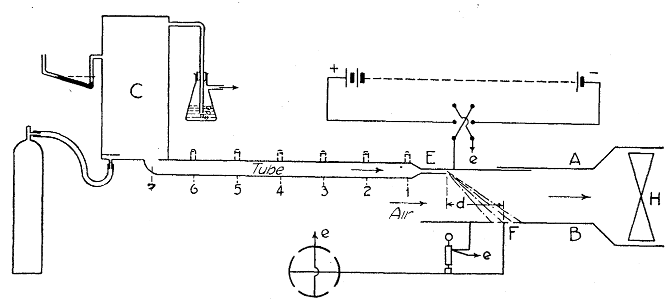
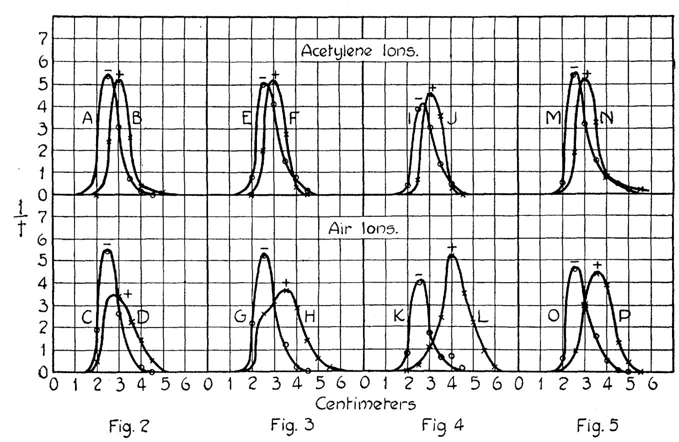


Fig. 1. Diagram of apparatus.

drawn to A and the other driven across the air stream to plate B. The tank C and tube were movable so that the down stream distance (d) from E to F could be altered. By plotting the ionic current to F against the distance d a curve is obtained the down stream distance of whose maximum depends upon the mobility of the ions. The velocity of the air stream was of the order of 1900 cm/sec. and the difference of potential between the plates A and B was of the order of 5000 volts.

In Fig. 2, curves A and B show the results obtained in the case of the acetylene ions when the polonium was placed at position 1. A is for the negative ions and B for the positive. Curves C and D are for the air ions and were obtained by passing air through the tube instead of acetylene, the conditions otherwise being identical.

The positive air ion curve D shows that the ion age for position 1 is a little too great to give the initial positive air ion alone. The curve has built out on the down stream side because of the presence of the final and slower positive air ion. It is definitely known that curves C and D would coincide if the ions were so young that only the initial positive ions were present. Curves A and B show that for this age only one negative acetylene and one positive acetylene ion are present. It is seen that the curve *A* for the negative acetylene ion and the curve *C* for the negative air ion coincide showing that these two ions have the same mobility in air. It is also seen that the positive acetylene ion has a mobility in air which is a little less than that of the negative acetylene or negative air ion. In earlier work it was found that in air, CO_2 and *A*, the negative and the initial positive ions, have identical velocities in air, but that in the case of hydrogen the initial positive ion has a slightly less mobility. Acetylene thus shows the same characteristic in this regard as does hydrogen. The writer has as yet found no satisfactory explanation for this difference.



Figs. 2, 3, 4, 5. Curves comparing the acetylene ions with air ions.

The results for the polonium at position 2, Fig. 1, are shown in Fig. 3 and involve ions of an increased age. Curves *E* and *F* are for the acetylene ions and *G* and *H* for the air ions. It is seen that there has been no change in the acetylene ions. The same is true of the negative air ion. Curve *H* shows, however, that the larger part of the initial positive air ions have had time to change over into the final positive air ion.

The curves in Fig. 4 are for the polonium at point 4, Fig. 1. The acetylene curves *I* and *J* show no change. From the air curves *K* and *L* it is seen that the negative air ion remains unchanged and of the same mobility as the negative acetylene ion. The positive air ions have now however, gone completely over into the final positive ion in contrast to the positive acetylene ion which is unchanged.

With the polonium at point 7, which was 99 cm from *E* the results obtained are shown in Fig. 5. It is seen that the ions have undergone no further change from those for point 4. These ions have now an age of the order of one second. In this as in previous work, the great constancy of the negative ions is outstanding. The constancy of the positive acetylene ion is also very outstanding as compared with the positive air ion. The fact that the mobility of this ion is nearly that of the initial positive ions in other gases leads to the inference that it is one molecule large. If this be the case, it shows a very marked aversion to union with another neutral acetylene molecule. It may be, however, that the attraction of a positive acetylene ion for another neutral acetylene molecule is so great that a union is formed so quickly that the first stage cannot be detected with the present apparatus. If, however, this be the case, then since the mobility does not appreciably change, the result of the union must be a natural molecular structure instead of a bimolecular

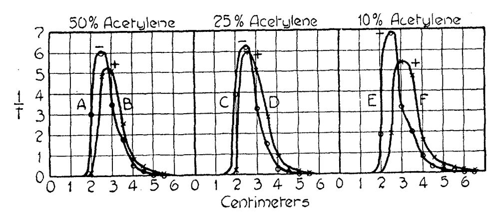


Fig. 6. Curves showing the effect of diminishing the amount of acetylene in the ionized acetylene-air mixture.

artificial cluster such as the final positive air ion. Earlier results have shown that all natural molecules singly charged have, at least very nearly, the same mobility in air, the mass having practically no effect.

By mixing air and acetylene it should be possible to detect the presence of both the positive acetylene ion and the final positive air ions as their mobilities are sufficiently different. By means of a blower air was forced into the acetylene in the tube passing to the tank *C*, Fig. 1. The results for different proportions are shown in Fig. 6. Both the air and the acetylene were ionized. The polonium was placed at point 7, Fig. 1. It is seen that the air ion does not come into evidence until the amount of acetylene has been reduced to about 10 percent of the whole. This must mean that a neutral acetylene molecule takes up the charge of the positive air ion.

In the above, the mixture was acted upon by the rays so that both acetylene and air ions were formed. Fig. 7 shows the result when 10 percent of acetylene is mixed with the ionized air, the acetylene not being itself acted upon by the rays. The polonium was at point 7, Fig. 1. The acetylene was admitted from a side tube immediately on the down stream side from the polonium. In order to obtain a close comparison, readings were taken alternately with and without the acetylene. In Fig. 7, curves A and B are for the acetylene-air mixture, and curves C and D are for air only. It is seen that while the negative ions remain identical in mobility, the final positive ions disappear when acetylene is admitted. The acetylene presumably takes up the charge of the positive two molecule air ion. This undoubtedly is accomplished by the acetylene molecule giving up an electron to the air ion.

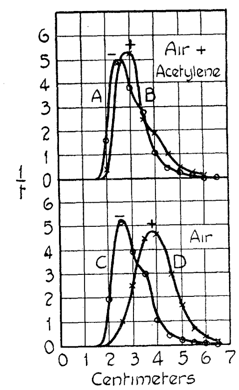


Fig. 7. Curves showing the effect of admitting 10% acetylene to ionized air.

In order to get an indication as to the speed with which the acetylene takes up the charge, the acetylene was admitted at different down stream points. The results are shown in Fig. 8, and are for a 10 percent acetylene-air mixture. The polonium was placed at point 7. Curves A, C, E, G, I, are for the positive ions when the acetylene was admitted respectively at points 1, 2, 3, 4, 6 and curves B, D, F, H, J are for the positive air ions alone. Curves N show the position of the negative. It is seen that the acetylene curve overlaps more nearly the air curve for position one than it does for the other positions. The final positive air ion disappears as the acetylene is given more time to act. The half value period apparently is of the order of three tenths second in the case of a 10 percent mixture.

In order to determine if the transfer of the positive charge may also take place from the acetylene to the air, the acetylene was ionized and admitted at point 6, Fig. 1, to the air passing through the tube. About 10 percent of ionized acetylene was used. As was to be expected, the results give no indication that the positive acetylene ion gives up its charge to form a final air ion.

The question whether the apparent transfer is due to a chemical union between the acetylene and oxygen is of course pertinent. In order to obtain evidence on this point a mixture of acetylene and nitrogen was used. Ionized nitrogen (99.9 pure) was passed through the tube. About 10 percent of non-ionized acetylene was admitted from a side tube.

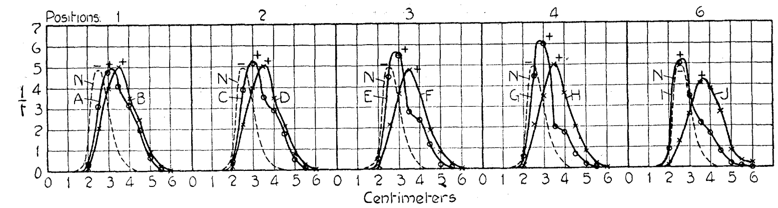


Fig. 8. Curves showing the effect of increasing the length of time the acetylene is mixed with ionized air.

The results are shown in Fig. 9. Curves *A* and *B* are for the acetylene-ionized nitrogen mixture, curves *C* and *D* are for ionized nitrogen only. It is seen that as quickly as neutral acetylene is admitted the positive nitrogen ion disappears and a positive ion appears which has the position of the positive acetylene ion.

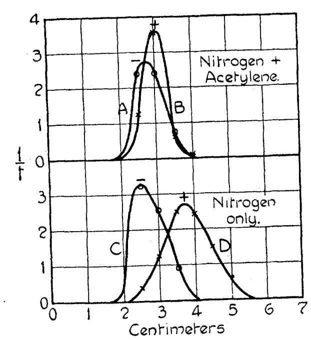


Fig. 9. Curves showing the effect of acetylene on nitrogen ions.

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