JUNE, 1928 PHYSICAL REVIEW VOLUME 31

ON THE ACTION OF THE GEIGER COUNTER*

BY L. F. CURTISS

ABSTRACT

Experiments performed with a Geiger point counter show that when the point is negative the sensitive surface is on the point, and not on the inner wall of the chamber, as suggested by Kutzner (Zeits f. Physik **23**, 117, 1924). It is further shown that this sensitive surface can only be obtained when the point has been treated in a way which makes it *catalytic*. Such catalysts as iron oxide, copper oxide and platinum black work very well. Their activity is destroyed by catalytic "poisons" such as Hg, SO_2 and H_2S. The experiments indicate that the gas layer usually adsorbed by such catalytic surfaces plays an important role in the action of the counter. The gas layer is demonstrated quite positively by observing the point during operation through a microscope in a darkened room. With a vacuum tube amplifier connected to the counter to actuate a relay at each count, a faint flash on the surface of the point is readily discernible for each click of the relay. When the point is positive no special treatment is needed to make it work. This is shown to be consistent with the explanation offered for the action of the chamber when the point is negative.

THE electrical counter devised by Geiger[1] affords a powerful means of studying phenomena involving individual atoms and electrons. Despite its great usefulness very little is known regarding the real nature of its action. Many attempts have been made to explain its behavior but no one of these explanations possesses the merit of including all observed facts concerning the operation of the counter. There is general agreement that the chamber is in a peculiarly sensitive condition when counting, but conflicting views exist as to the location of the sensitive area, and almost nothing is known or postulated regarding the nature of this sensitive surface. Whereas most observers agree that the point itself must be in a specially activated condition in order to function, Kutzner[2] has suggested that it really is a sensitive layer on the *inner wall* of the chamber which is responsible for the operation of the counter. In any case a theory of the counter must account for a condition such that, when the voltage applied to the chamber is properly adjusted, an α-particle on entering the chamber will start a glow discharge which automatically and almost instantaneously ceases, although the counting chamber is at once restored to its former condition. It is the purpose of this paper to develop a detailed picture of the action of the counter and to describe the experiments which led the writer to this view of its behavior. Since the experiments, which were undertaken in an effort to devise more satisfactory methods of preparing points, preceded an attempt to formulate an explanation they will be described first.

---

* Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[1] H. Geiger, Verh. h. D. Phys. Gessel. **15**, 534 (1913).

[2] W. Kutzner, Zeits. f. Physik **23**, 117 (1924).

In the general absence of definite ideas as to why the counter works, and in particular why one point will work and another almost identical one will not, many methods of preparing sensitive points have been tried. The greatest success has been obtained in the past with platinum and steel points which have been activated by heating in a Bunsen burner. Geiger[3] has called attention to the fact that the action of the counter might be understood if it is supposed that the point has a surface film of high electrical resistance. Acting on this view, the author has prepared points by coating them with insulating and semi-insulating varnishes. These were unsuccessful save in a few cases. Even such points as worked were not reliable. Other substances too numerous to mention in detail were tried. In the course of these experiments a steel needle, coated with metaphosphoric acid, gave very good results. This accidental experience led to the series of experiments which are described.

In order to secure a permanent record of the behavior of the points, a vacuum tube amplifier was used in connection with the counting chamber to operate a chronograph pen. A diagram of the arrangement is shown in Fig. 1. The only novel feature of the two-stage amplifier is the use of a gas-filled[4] tube, 2, in the second stage. The biasing battery, C_2, for this tube is adjusted so that the plate current is normally zero. By using a relatively high plate voltage a rush of current is secured when the grid potential is momentarily raised by the impulse communicated through the first stage by the counting chamber. This current ceases as soon as the grid potential falls to its normal value. The large momentary current in the second tube is mainly the result of ionization of the gas which the tube contains, as is evidenced by the glow accompanying each impulse. This arrangement gives the most satisfactory amplification of all the many tried in this laboratory for the purpose. With any of the usual types of radio tubes in the first

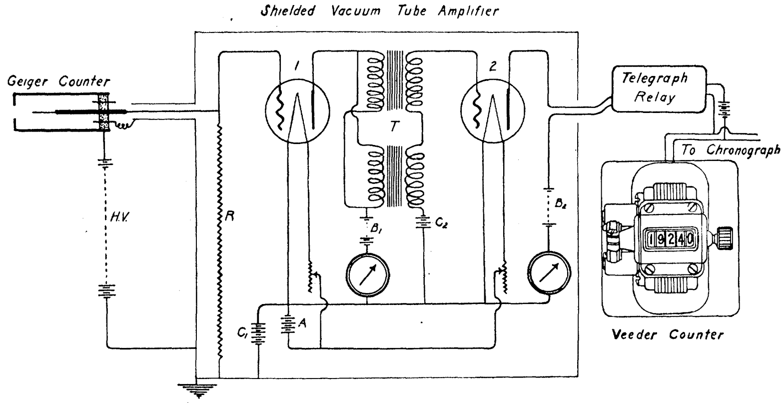


Fig. 1. Diagram of amplifier used with Geiger counter.

---

[3] H. Geiger, Zeits. f. Physik **27**, 7 (1924).

[4] This tube was kindly loaned by the Research Laboratory of the General Electric Company.

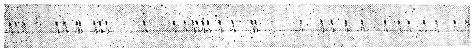
stage, and a similar gas-filled tube in the second, there is an instantaneous current of several milliamperes in the output circuit for each impulse. A further reason for the marked success of this arrangement is that the gas tube tends slightly to prolong the very brief impulse which is communicated to it. Therefore, the amplifier very easily operates an ordinary telegraph relay of about 1200 ohms resistance. This relay in turn actuates a Veeder electrical counter and chronograph pen as indicated in the figure.

In an effort to learn why a steel needle treated with metaphosphoric acid should work, several points were prepared in this way. Best results were obtained by using cold concentrated acid, coating the point well with it, and wiping it thoroughly with cloth. About nine out of every ten points prepared in this way would count at once. Some typical records taken with these points are shown in Fig. 2. Line 1 is a record made with a freshly sharpened steel point. This record represents a more or less continuous succession of rapid discharges which set in as soon as the voltage is raised above a certain value, depending on the sharpness of the point and its distance from the walls of the chamber. If the voltage is raised a very little higher after this stage is reached a true arc strikes melting the needle point. Therefore this behavior, which is quite characteristic of a freshly sharpened metal point when it is the negative electrode, seems to be of the nature of an incipient arc. Nearly all freshly sharpened metal points behave in this way as soon as the voltage applied to the counting chamber is raised to the stage where a permanent discharge sets in. In this condition no noticeable effect can be produced on the discharge by allowing α-particles or β-particles to enter. Line 2 is a record which shows how the same point counts α-particles after being dipped in metaphosphoric acid and wiped. The portion of the

No. 1. Freshly sharpened. 1300 volts.

No. 2. No. 1 dipped in phosphoric acid. 134/min. bl. 0. 1440 volts.

No. 3. Freshly sharpened. 1220 volts.



No. 4. Point No. 3 dipped in H_2SO_4. 124/min. bl. 0. 1320 volts.

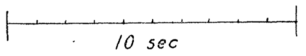
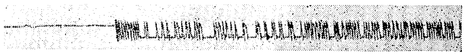


Fig. 2. Chronograph records showing behavior of steel points when treated with acid.

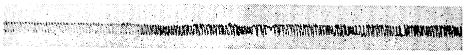
record shown represents about fifteen seconds, as can be seen from the time scale included in the figure. This point gave a natural effect or blank (i.e., with the source of α-particles removed) of zero when timed for one or two minutes.

Since metaphosphoric acid attacks steel, though slowly, it was first thought that the phosphate thus formed supplied the electrically resistant layer which enables these points to function. But steel points were coated with phosphate by other methods and failed to work. It was then observed that most of the steel points, when examined under a microscope, were still undergoing a slow attack from the film of acid left on them. Minute bubbles of hydrogen were still forming an hour or more after the point had been treated. This observation led to the following considerations and experiments.

No. 1. Freshly sharpened. 1200 volts.



No. 2. Point No. 1 dipped in H_3PO_4. 1240 volts.



No. 3. Freshly sharpened. 1300 volts.

No. 4. Point No. 3 dipped in H_2SO_4. 1300 volts.

No. 5. Freshly sharpened. 1360 volts.

No. 6. No. 5 electrolyzed in H_2SO_4. 124/min. bl. 7. 1200 volts.

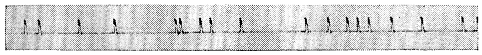
Fig. 3. Chronograph records comparing the behavior of platinum points when treated by acids and when electrolyzed.

If the hydrogen formed as a result of the chemical action was responsible for the action of the steel point, an obvious check was to dip the point in some other acid, as dilute sulphuric, which also attacks steel readily. This was tried with success. Fig. 2, line 3, shows a freshly sharpened steel point, and line 4 the same point counting α-particles after being dipped for a few seconds in sulphuric acid. Further, points made of metals not attacked by acids with which they were treated should show no effect. Some records taken to test this view are shown in Fig. 3. Line 1 is the record of a freshly sharpened platinum point. Line 2 is a record obtained after dipping it in phosphoric acid, showing no improvement. A similar result is shown in lines 3 and 4 after dipping in sulphuric acid. A further check resulted from experiments with nickel and copper. Nickel is less readily attacked by the acid than steel and this is even more true of copper. Nickel would only work after prolonged treatment with cold acid and it was found necessary to warm the acid in the case of copper. As soon as the temperature was raised sufficiently to induce chemical action, the copper likewise became a good counting point. These experiments indicate strongly that it is the hydrogen formed by the chemical action and adhering in part at least to the point that enables it to count. If this is so, one might expect a layer of hydrogen applied by different means to work. Accordingly a platinum point was prepared by using it as an electrode in a dilute acid solution. The results of these experiments, shown in Fig. 3, lines 5 and 6, confirm the supposition that a layer of gas is responsible for the action of the point. After repeated trials it was found that it made little difference whether the platinum was used as anode or cathode in the electrolysis. We infer from this that a layer of gas is necessary but it may be either hydrogen or oxygen. Points prepared in this way usually do not retain their sensitive condition for more than a few hours, indicating that the layer is not held very firmly. It must also be borne in mind that a point working in air at atmospheric pressure presumably would not retain a heavy layer of hydrogen very long, so that most points owe their sensitivity to a layer of oxygen.

The foregoing experiments suggest that a layer of gas adhering to a metal point puts it in condition to count. In fact, from the evidence presented above, this layer seems necessary. However, it is also important to note that all treatments discussed so far will also produce *catalytic* surfaces. Recent investigations of this subject have brought forward the idea that such surfaces are very rough and have a loose and open metallic structure. This structure adsorbs gas very readily. The efficiency of the catalyst has been attributed to the existence of free metal ions in this surface layer. If it is true that the success of the previous methods is to be attributed to the catalytic nature of the surfaces and their consequent ability readily to acquire a layer of gas, good points should result from other surfaces which are catalytic. To test this idea points were prepared by coating platinum needles with platinum black by electrolysis in a platinum solution. They worked very successfully. Since the platinum black *surface* is all that is required on the views here presented, one would expect steel points coated with platinum black to work equally well, and this was found to be true. Since it is a very simple matter to coat steel needles with platinum black, merely by dipping them into a platinum solution, points were usually prepared in this way. This method of preparation always gives very satisfactory points, many of which last for several days. Some typical results with such points are shown in Fig. 4, lines 1 and 2. After standing for some time they often work as well as initially, and of course redipping a point for a few minutes in the platinum solution also restores it. Since iron oxide is a catalyst for some reactions and has been used successfully also in point-counters, oxidized steel needles were also tried. By using great care not to carry the oxidation too far, very satisfactory results were obtained, as shown in lines 3 and 4 of Fig. 4. While not quite as sure a method as that using platinum black, the iron oxide points once prepared were most permanent, sometimes holding for weeks.

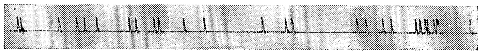
To make quite certain that it is the *catalytic* nature of the metallic surface with which we are dealing a series of experiments were undertaken at the suggestion of Dr. J. H. Hibben. In the first place a good test of the catalytic theory is provided by some metallic point which does not work in the Geiger counter at all under ordinary treatment but which by special manipulation may be put into a catalytic condition. Copper is an example. All ordinary flame treatment of copper fails to produce a point which will work. However by repeated slow oxidation and reduction at about 250°C copper becomes a very good catalyst. Consequently points were prepared by this method and found to work very well.

No. 1. Freshly sharpened. 1350 volts.

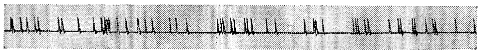


No. 2. Point No. 1 platinized. 80/min. bl. 1. 1420 volts.

No. 3. Freshly sharpened. 1330 volts.



No. 4. Point No. 3 oxidized in flame. 85/min. bl. 0. 1330 volts.



No. 5. Point No. 4 counting B-particles. 200/min. bl. 0. 1330 volts.

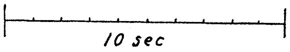


Fig. 4. Chronograph records of platinized and oxidized steel points.

A further test is provided by so-called catalytic "poisons." It is well known for example that mercury vapor, sulphur dioxide or hydrogen sulphide will ruin the activity of most metallic catalysts. It should therefore be interesting to admit these substances to the counting chamber while in operation. The results of some of these experiments are shown in Fig. 5. As soon as the poison in question is admitted to the chamber, as indicated by the position of the arrow, the counter ceases to function *at once.* This is regarded as an extremely emphatic confirmation of the catalytic theory since all points which have been tried have responded in the way indicated by the records shown in Fig. 5.

In the light of these results there can be little question that points used previously by other investigators, however prepared, have depended for their sensitivity on a gas layer held to the surface by virtue of its catalytic nature. The exceptional behavior of some metals which fail to yield good points with the usual simple treatments is to be referred to the difficulty with which they can be put into a catalytic condition. In this connection the behavior of palladium is interesting. Its well-known affinity for hydrogen led the writer to try palladium points since one might expect a heavy adsorbed layer of hydrogen. However, glowing in a flame, electrolysis, or any other simple treatment failed. One seems forced to the conclusion that it is not as easy to develop a catalytic surface on palladium as on platinum, for example. If the adsorbed gas exists, as presumably it does, it is in a different condition from that existing on a catalytic surface. This difference, in part at least, is to be attributed to the very loose structure of a catalytic surface which enables metallic ions to become a part of the adsorbed gas layer and in particular permits the free electrons of the metal to enter the gas layer more readily. This is substantiated by the observation that *palladium black,* a good catalyst, also makes a good surface for a point. The idea that the electrons from the metal form a part of the gas layer adsorbed on a catalytic surface is an important feature of one of the explanations of the action of the counter to be offered in this paper.

No. 1. Oxidized steel point poisoned by Hg.

No. 3. Oxidized steel point poisoned by H_2S.

No. 2. Oxidized steel point poisoned by SO_2.

No. 4. Platinum black point poisoned by SO_2.

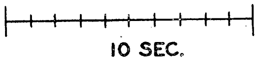


Fig. 5. Chronograph records showing that sensitive points are destroyed by catalytic "poisons."

On the basis of the foregoing experiments, and other well established facts concerning the operation of these counters, the following discussion of the action of the counter is offered. In presenting these ideas it will be assumed at the outset that the sensitive area is on the point, in agreement with the experimental evidence presented above and with the experience of most other investigators. The anomalous results obtained by Kutzner are capable of an entirely different interpretation from that which he gives them, as will be shown. Furthermore the main discussion will be restricted to what may be termed the "normal" method of using the counter, i.e., with the chamber walls at a positive potential. All investigators agree that the counting chamber works most satisfactorily this way. However, the views discussed here are equally applicable to the reversed potential as will be pointed out. Before going into more detail it is perhaps well to recall that under the conditions which a counter operates, i.e., high pressure and moderate voltage, only the electrons can acquire enough energy to ionize in the volume of the chamber. The positive ions never acquire kinetic energy greater than a few hundredths of a volt. This is a very important fact which must be considered in explaining the action of the counter, and which has been generally overlooked.

It seems desirable to present two alternative views of the sensitive area on the point both of which depend on a heavy layer of adsorbed gas on the surface of the point. One may be termed the "ionization" theory of the gas layer and the other the "evaporation" theory. On the ionization theory the action of the counter may be described in the following manner. The voltage on the chamber is raised to a point just below which a permanent discharge will set in. At this stage no electrons can be drawn from the point for all ions initially present in the counter have been swept out on applying the voltage, and there is no mechanism for releasing the electrons undoubtedly present in the layer of gas. If now an α or β-particle enters the chamber and produces a few ions, the positive ions are drawn down to the point. As mentioned above, since the counter works at atmospheric pressure or a considerable fraction of an atmosphere, there is no opportunity for the positive ions, as a result of their great mass and low mean free path, to acquire enough energy to ionize the gas in the chamber. It may now be recalled, however, that an adsorbed gas layer has a considerably lower ionization potential than the same gas in the free condition. This may be due to the fact that it exists there in an *excited* state. Kistiakowsky[5] has noted that nitrogen in the adsorbed condition has its ionization potential reduced by about five volts. He worked at fairly low gas pressures and it may be that at atmospheric pressure the gas layer assumes a condition in which it is even more readily ionized, although there is at present, I believe, no evidence for this. Nevertheless, as the positive ions approach the layer of gas they may be able to pull electrons from parent atoms in the layer by electrostatic attraction arising from their elementary positive charge. It would only be necessary for them to approach within a distance of the order of an atomic diameter to provide ionizing energy corresponding to several volts.* *Once a few electrons are thus released* it is relatively easy to account for the remainder of the process. These electrons are liberated in the very intense field existing near the point and as a result of the great mobility and comparatively large mean free path, they soon acquire energy enough to ionize the gas and the ionization current then builds up exponentially until the disturbance thus started has moved out of the strong electric field. It soon passes a region beyond which very little new ionization is produced. The positive ions, initially

[5] G. B. Kistiakowsky, Jour. Phys. Chem. **30**, 2356 (1926).

* *Note added in Proof.* Professor J. Franck has called my attention to the fact that under the conditions here postulated the *potential* energy of the positive ion also becomes available to help ionize the adsorbed gas layer as soon as the positive ion strikes it.

formed during this rush of current, move to the point and release additional electrons by ionizing the gas layer as the original ions did. This process can continue only so long as un-ionized gas atoms exist on the very tip of the point where the strong field is concentrated. Since it is reasonable to assume that these atoms remain ionized for a period perhaps of the order of 10^{-4} of a second before recombining by pulling electrons through the metal surface, there is a brief instant during which the returning positive ions can release no more electrons from the gas layer. Also, a layer of positive charge is formed on the tip of the point which reduces the field between the point and the chamber walls. These two process together then account for the automatic cessation of the current. To restore the counter so that it may respond to the next particle it is only necessary for the atoms of the gas layer to recombine at the expense of the abundance of free electrons in the metal of the point. If these processes may occur in about 10^{-3} of a second or less, as seems probable, they account for the action of the counter very readily.

At this stage of the work it occurred to the writer that, if such ionization existed in the gas layer, the recombination might produce a visible though faint flash for each particle counted. Accordingly a chamber was prepared for observation by cutting a narrow slot in one side opposite the point. A microscope with a magnifying power of about one hundred was carefully focussed on the very tip of the point. The amplifier was connected so that a click could be heard for each particle counted. The room was completely darkened. After allowing time for the eyes to adjust themselves, varying for different observers, a tiny flash could be seen on the tip of the point coincident with each click! Four different observers had an opportunity to view this action and all agreed that the clicks were simultaneous with the flashes within the limits of observation, and that there was complete coincidence between them. Furthermore this observed glow did not extend into the gas but appeared as a luminous cap on the tip of the magnified point.

The experiment described in the foregoing paragraph was regarded as a conclusive proof of the "ionization" theory when first observed. However, on second thought it was apparent that this glow on the point may be accounted for in a slightly different manner. The positive ions formed in the volume of the chamber have no opportunity to recombine until they reach the point since the intense field keeps this region swept clean of electrons. Consequently the recombination observed is certainly partly and may be wholly due to the recombination of these ions on their arrival at the point. On the assumption that they contribute the whole effect observed, the "evaporation" theory of the gas layer has been developed. In many respects it is more satisfactory than the ionization theory. Davisson and Germer[6] have shown in their experiments on reflecting electrons from a metal surface that an adsorbed gas layer begins by forming a lattice pattern on the surface. The character of this lattice pattern is determined by the crystal structure of the metal on which the gas adsorbs. They have further shown

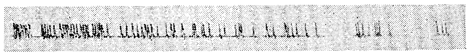
---

[6] Davisson and Germer, Phys. Rev. **30**, 705 (1927).

that adsorption of gas will continue at higher pressures until this simple structure of the layer has been destroyed. It is with such heavier layers of gas that we are dealing in the point counter. We may now assume that the sensitive condition of the point consists of such a heavy layer into which some of the free electrons of the metal have diffused. For with such a layer on the surface it may be that the sharp boundary conditions between metal and gas have been partially removed so that such ideas as "work function" and "image force" no longer apply as far as getting electrons into this gas layer. This assumption becomes even more reasonable when we recall that the metal surface is in a catalytic condition. We may now picture the process as follows. The positive ions formed by the α or β-particle on impinging on the point, drive off or "evaporate" the gas layer. The energy required to do this is much less than to ionize the gas, so it is easy to see how this may happen. As the gas layer is evaporated the excess electrons which have diffused into it are released and the remainder of the process occurs much as before. The rush of current ceases as soon as all the detachable gas molecules are driven off the point. The brief time required to readsorb a fresh layer provides the short lag necessary to interrupt the current. Since this readsorption will occur very readily with a catalytic or activated surface in gas at a considerable portion of an atmosphere pressure, the point quickly secures a fresh layer of gas into which the electrons diffuse and the chamber is ready to repeat. In fact, the positive ions which are drawn to the point, once they have recombined, automatically provide this adsorbed layer.

When the counter is operated with the potential reversed, the gas layer is less important and the operation may be regarded as follows: As the first electrons produced initially proceed to the point, they must approach within a few millimeters before they reach the intense field where they may quickly acquire sufficient energy to produce new ions. They then ionize the gas and the current builds up exponentially until the disturbance reaches the point. Since the positive ions produced in this process cannot ionize by impact, there is no way in which any part of the gas can contribute to this rush of current other than that between the place where the electrons first began to ionize as a result of energy acquired from the field and the point itself. Consequently the disturbance merely travels down to the point and must stop until a fresh supply of electrons are provided from the outer volume of the chamber. In this case any glow at the surface of the point must be due to an ionized gas layer on the surface. Observations on the glow, with the potential reversed, indicate that it is still there but much fainter. There does not seem to be such a sharp correlation between the flashes and the clicks of the relay, however. The fact that glow still persists seems to favor the ionization theory. On the view presented in this paragraph of the operation of the counter with the point positive, it should not matter what the nature of the metal surface of the point is. We have found this to be the case. Freshly sharpened metal points work at once when positive which would not work at all if negative. This fact seems to support the explanation presented above. Furthermore we have found that the action of the chamber with the point positive is entirely independent of the presence of catalytic poisons.

Attention should be called to the fact that, although somewhat different processes are involved in the operation of the counter in the opposite directions, the major contribution to the current is obtained in the same way in each case from about the same region of the counter. That is, the great bulk of the current in both cases builds up exponentially in a fairly small volume of gas in the neighborhood of the point where the intense field exists. Consequently one would expect the counter to operate at about the same voltage in each case but be somewhat more difficult to control when the point is positive. This has been observed to be the case by Bothe,[7] who reports that the voltage is about the same in each case but that the working range of voltages is smaller for the positive point and the quantity of charge passing for each discharge somewhat less. This latter fact is to be anticipated from the above description since presumably a smaller volume of gas is active in this case. Furthermore, since, on the basis of the above consideration, the ionization current for each impulse will be produced in the same volume of gas at constant voltage and gas pressure, one would expect approximately the same quantity of electricity to pass for each impulse. Geiger[3] has made observations which show that this is true.



No. 1. Steel point, freshly sharpened. 1100 volts.

No. 2. Pt point, freshly sharpened. 200/min. bl. 63 1220 v.

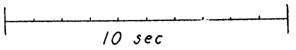


Fig. 6. Chronograph records of points showing recovery during operation.

When the counter is working with the point negative one would expect a bad point to pick up a gas layer under the action of the discharge and begin to count properly; at least occasionally when conditions were just right. We have succeeded in obtaining records of this kind in the case of steel and platinum, as shown in Fig. 6. Both give initially a very rapid series of pulses but soon quiet down and count normally, although such points never become fully reliable. It is undoubtedly something of this kind that accounts for the action of an ordinary discharge tube at much lower gas pressures. In such a case one is also confronted with the difficulty of getting electrons from the cold cathode.

---

[7] W. Bothe, Zeits. f. Physik **37**, 552 (1926).

It is now of some interest to return to the work of Kutzner[2] which led him to suppose that the sensitive layer was on the inside face of the chamber. He bases his conclusion principally on the observation that an α-particle in his experiments must pass through a region very close to the face or it is not counted. The explanation for this curious condition is as follows: In the case of a sharp point, as Kutzner used, the volume through which an α-particle must pass to be counted is of the form indicated in Fig. 7(b) as experiments in this laboratory have shown. The sharper the point the more constricted this volume becomes, particularly in the neighborhood of the point. Hence, the chance that an α-particle will traverse this active region when shot towards it at right angles is very slight; and, even if it went through it, enough positive ions might not be produced to start the counter off. However, if particles are shot through the volume near the face, even at right angles to the axis of the chamber, counts are readily obtained as we have repeatedly observed. Kutzner's negative result even under these conditions appears to be caused by the aluminum foil used to cover the slot in his chamber. The path which an α-particle must traverse in the foil when shot in at this angle would be relatively large so that under these conditions the stopping power of the foil would exceed the range of the α-particle. If a ball point is used the active volume has the form indicated in Fig. 7(a), and under proper conditions counts can be obtained fairly close to the point. All that these active volumes mean is that ions produced outside them never reach the sensitive part of the point, nor the region of intense fields, as a result of the shape of the electrostatic field. Therefore, Kutzner's results do not indicate that the sensitive area is on the inner side of the face but rather conclusively prove it to be on the point.

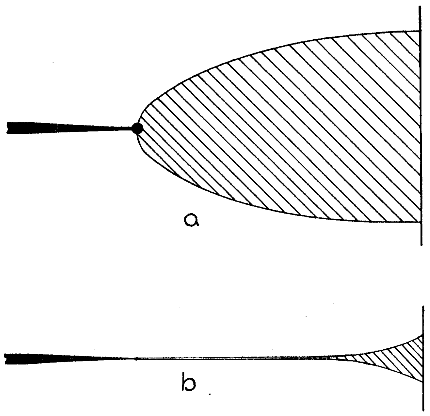


Fig. 7. Diagrams showing the volume through which an α-particle must pass to be registered by the Geiger counter. (a) Ball point. (b) Sharp needle point.

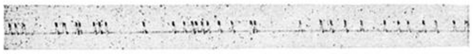
In conclusion I should like to thank Mr. H. L. Martin who helped build the apparatus and assisted in the observations. I am also indebted to the Kelly Hospital of Baltimore for the old radon tubes from which the sources were extracted.

Bureau of Standards,
Washington, D. C.,
February 15, 1928.

No. 1. Freshly sharpened. 1300 volts.

No. 2. No. 1 dipped in phosphoric acid. 134/min. bl. 0. 1440 volts.

No. 3. Freshly sharpened. 1220 volts.



No. 4. Point No. 3 dipped in H_2SO_4. 124/min. bl. 0. 1320 volts.

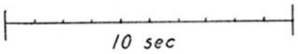
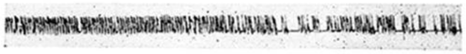
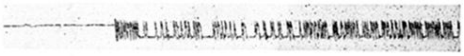


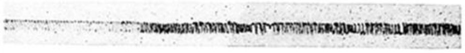
Fig. 2. Chronograph records showing behavior of steel points when treated with acid.



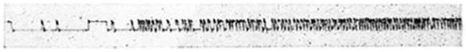
No. 1. Freshly sharpened. 1200 volts.



No. 2. Point No. 1 dipped in H_3PO_4. 1240 volts.

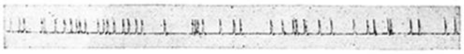


No. 3. Freshly sharpened. 1300 volts.



No. 4. Point No. 3 dipped in H_2SO_4. 1300 volts.

No. 5. Freshly sharpened. 1360 volts.



No. 6. No. 5 electrolyzed in H_2SO_4. 124/min. bl. 7. 1200 volts.

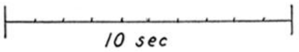
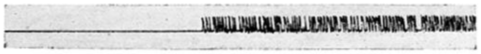
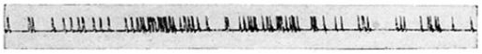


Fig. 3. Chronograph records comparing the behavior of platinum points when treated by acids and when electrolyzed.

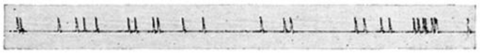


No. 1. Freshly sharpened. 1350 volts.

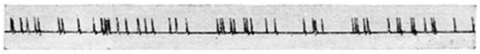
No. 2. Point No. 1 platinized. 80/min. bl. 1. 1420 volts.



No. 3. Freshly sharpened. 1330 volts.



No. 4. Point No. 3 oxidized in flame. 85/min. bl. 0. 1330 volts.



No. 5. Point No. 4 counting B-particles. 200/min. bl. 0. 1330 volts.

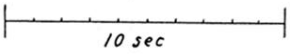
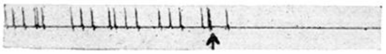
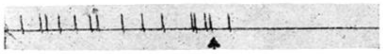


Fig. 4. Chronograph records of platinized and oxidized steel points.

No. 1. Oxidized steel point poisoned by Hg.



No. 2. Oxidized steel point poisoned by SO_2.



No. 3. Oxidized steel point poisoned by H_2S.

No. 4. Platinum black point poisoned by SO_2.

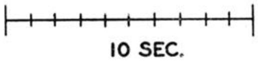
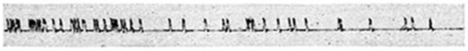


Fig. 5. Chronograph records showing that sensitive points are destroyed by catalytic "poisons."

No. 1. Steel point, freshly sharpened. 1100 volts.



No. 2. Pt point, freshly sharpened. 200/min. bl. 63 1220 v.

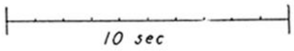


Fig. 6. Chronograph records of points showing recovery during operation.