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# UNIVERSITY OF TORONTO STUDIES

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## No. 33: ON THE ELECTRIC CHARGES ACQUIRED IN HIGH VACUA BY INSULATED POTASSIUM SALTS AND OTHER RADIO-ACTIVE SUBSTANCES, BY J. C. McLENNAN

(REPRINTED FROM THE BULLETIN OF THE ROYAL SOCIETY OF CANADA, 1909)



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# BULLETIN

OF THE

# ROYAL SOCIETY OF CANADA

No. 16 — PUBLISHED OCTOBER — 1909


# ON THE ELECTRIC CHARGES ACQUIRED IN HIGH VACUA BY INSULATED POTASSIUM SALTS AND OTHER RADIOACTIVE SUBSTANCES


By Prof. J. C. McLENNAN



OTTAWA

Published by the ROYAL SOCIETY OF CANADA

1909

*On the electric charges acquired in high vacua by insulated potassium salts and other radioactive substances.*

By PROF. J. C. McLENNAN.

(Read before the Royal Society of Canada, May 26, 1909.)

Since the discovery in 1907, by N. R. Campbell and A. Wood,[1] that potassium salts possess in a very definite though relatively small degree the property of radioactivity, the radiations from these salts have been examined by a number of investigators including among others Campbell,[2] McLennan and Kennedy,[3] and Levin and Ruer.[4]

Amongst other properties of the rays examined by these investigators was their absorption by different thicknesses of various substances. From the results of such measurements the view came to be held that the rays from potassium salts were heterogeneous and consisted of several types varying in penetrating power from the beta rays of uranium downwards. The average intensity of the rays, moreover, was found to be about 1/1000 of that of the radiation from uranium salts.

In a particular set of experiments which were carried out by Campbell the rays were passed between the plates of a large zinc grid and on emergence their intensity was ascertained from the conductivity they imparted to a mass of gas in an ionisation chamber. This grid was so arranged that alternate plates were metallically connected, and consequently when the two sets of plates were joined to the two terminals of a battery an electric field was established in the intervals between the plates. Campbell found when a field of 8,000 volts was applied to this condenser that the intensity of the emerging rays was diminished by approximately 14 per cent. This led him to the conclusion that the rays consisted of streams of electrically charged particles, and from additional experiments on the direction of the deviation of the deflected beams he concluded that the charge carried by the rays was a negative one.

It followed therefore from these experiments that the rays in all probability belonged to the beta type of radiation.

In some absorption experiments made by the writer, special care was taken to examine the rays from potassium salts for the presence of a

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1 Proc. Camb. Phil. Soc. No. 14-15, 1907.

2 Proc. Camb. Phil. Soc. No. 14-211, 1907.

3 Phil. Mag., Sept., 1908.

4 Phys. Zeit. 9 Jahr, No. 8, Seite 248.

radiation of the alpha type, but no evidence of the presence of such rays was obtained from the form of the experimental absorption-ionisation curves, and the conclusion was drawn that if any such radiation was present, it must have been emitted with a velocity considerably less than that possessed by the alpha rays from other well known radioactive substances.

More recently E. Henriot[1] made an examination of the rays emitted by potassium salts, and while the results of his experiments agree in the main with those of the earlier investigators, they differ from them in that they point to a complete homogeneity in the radiation. For on measuring the ionisation produced by the rays after passing through various layers of tinfoil, he found on plotting the logarithms of the ionisation current for the rays from potassium sulphate and potassium chloride against the thicknesses of tinfoil used that the points all lay on a straight line.

Henriot, in his paper on the subject, also claims that in the course of his measurements he found some slight evidence of the presence of feebly penetrating rays of the alpha type in the radiation from the potassium salts examined.

Quite recently an examination was made by Strutt[2] of the amount of helium present in a number of saline minerals, and the results of this examination which are given in Table I

TABLE I.

| Mineral. | Composition. | Helium, cmm. per 100 grammes. |
|---|---|---|
| Rock Salt | $NaCl$ | 0.0233 |
| Sylvine | $KCl$ | 0.55 |
| Carnallite | $K\,Mg\,Cl_3\,6H_2O$ | 0.151 |
| Kieserite | $Mg\,SO_4\,H_2O$ | 0.0179 |

make it clear that the potassium bearing minerals and especially sylvine are rather remarkable for the comparatively great amount of helium which they have been shown to contain. In discussing the origin of the gas Strutt considered that it was altogether improbable that the minute traces of uranium and radium present in sylvine could account for so much helium, and in view of Campbell and Wood's discovery of the radioactivity of potassium salts he was led to regard potassium itself as the source of the helium in the saline minerals examined.

[1] Henriot, Comptes Rendus, 148, pp. 910-912, 1909.
[2] Strutt, Proc. Roy. Soc., Series A, Vol. 87, No. A 547, p. 278.

In view of the identity established by Rutherford between the alpha particles and the atoms of helium, it would follow from the view taken by Strutt—that the origin of helium in the saline minerals is the potassium which they contain—that rays of the alpha rays should be present in the radiation from potassium salts.

With the exception of Henriot no one, however, seems to have observed any indication of the presence of such rays. Usually, however, these rays have been detected and identified either by their fluorescent and ionising action or by the deflections which they undergo in electric or magnetic fields. But for these methods to be applicable the alpha particles must have velocities which will take them away a few millimetres at least from the substances which emit them.

It is quite possible then that potassium and even other substances may be emitting alpha particles with exceedingly low velocities, and that these rays have hitherto escaped detection largely through the inadequacy of the means adopted to bring them into evidence.

In looking for a means of demonstrating the possible existence of these rays it seemed to the writer worth while to make an attempt to investigate the radiations emitted by the potassium salts, by examining them for the acquisition of an electric charge when placed on insulating supports within a highly exhausted vessel.

Amongst others M. and Mme Curie,[1] Paschen,[2] Strutt,[3] Aschkinass[4] and Makower[5] have applied this method with success to the investigation of different types of radiation. In Paschen's experiments it was found when a lead cylinder containing a small quantity of a radium salt was insulated in a vessel from which the air was removed that the lead cylinder acquired a positive charge through the action of the rays which were emitted. This effect was thought by Paschen to prove that the gamma rays from radium consisted of streams of rapidly moving negatively charged particles, but this was afterwards shown by Eve[6] to be due to the excitation and consequent emission of a secondary radiation of the beta type in the lead by the passage through it of the gamma rays.

The method, too, was applied by Strutt (loc. cit.) in his interesting experiment popularly known as the radium clock, and more recently it was applied by Aschkinass to demonstrate the existence of the delta rays

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[1] M. & Mme. Curie Comp. Rend. CXXX. p. 647, 1900.
[2] Paschen, Wied. Ann. 14, 1, pp. 164-171, 1904.
[3] Strutt, Phil. Mag., Nov. 1903.
[4] Aschkinass, Phys. Zeit. 8, p. 773, Oct. 24, 1907.
[5] Makower, Phil. Mag., Jan., 1909.
[6] Eve, Nature, Sept. 8, 1904.

from deposits of polonium, to which radiation attention was first drawn by the experiments of Sir J. J. Thomson,[1] Logeman,[2] Ewers,[3] and others.

Makower has also recently used it to measure the beta radiation from radium and from the measurements to deduce the number of beta particles emitted per gram of that substance.

By applying this method to the radiation from potassium salts the writer has observed in certain cases that potassium salts, when insulated in high vacua, acquire a positive charge, but up to the present it has not been found possible from the characteristics of the acquired charge to decide whether this charge arises from the radiation being wholly of the beta type or whether it is due to the emission of rays of both the alpha and beta type with the beta type of radiation in excess.

Among other phenomena observed when applying the method are those associated with the volta effect. If a metallic rod or vessel connected to an electrometer be placed within and insulated from a second metallic vessel, it will be found when both the containing vessel and the insulated vessel are joined to earth, that generally a potential difference will exist between them. This potential difference will, of course, be more marked when the two vessels are made of different metals. It will also, however, be observable ordinarily when the two vessels are made of metals supposedly the same, but in this case the existence of the effect only goes to show that some slight difference exists in the composition of the two pieces of metal used in the construction of the two vessels.

If now with the arrangement just described where one vessel is placed within and insulated from a second the earth connection of the electrometer be removed it will be found that the insulated body or vessel more or less rapidly acquires an electrical charge, the sign of the charge being determined by the direction of the potential gradient. This charge arises from the air or gas between the two vessels possessing a conductivity which is imparted to it either by radiations emitted from the walls of the containing and contained vessels or from the passage through the gas of the penetrating radiation which is known to be present at the surface of the earth. The conductivity possessed by the air will tend to diminish the potential difference set up between the two bodies when they were both joined to earth, and the charge acquired by the electrometer under the action of the conductivity when the earth connection to the inner vessel is removed, will give a measure of the magnitude of the volta effect.

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1 Thomson, Camb. Phil. Soc., Proc. 13, pp. 49-54, Feb. 18, 1905.
2 Logeman, Proc. Roy. Soc., Series A, Vol. 78, No. A. 523, p. 212.
3 Ewers, Phys. Zeit. March, 1906, pp. 148-152.

This then is one type of charge which is nearly always acquired by such an insulated system as that described. It has, however, certain definite characteristics which make it readily detectable. For example, the rapidity with which this charge is acquired depends largely on the degree of conductivity possessed by the intervening gas, and as this conductivity can be increased at will by bringing more or less near to the vessel a small quantity of radium or other radioactive body, it is possible to make the insulated system practically take up at once a charge which will suffice to annul the volta effect.

If, further, now the inner vessel or body in the arrangement described possesses in addition a radiating surface which emits alpha or beta rays, the charging action of these rays can generally be brought into evidence by a reduction of the pressure of the gas between the two bodies. This reduction of the pressure will produce a diminution in the conductivity of the gas, but it will not affect the rate of emission of charged particles from the radiating surface. Consequently as the pressure of the gas is reduced the insulated system should, under the action of its charged radiation, acquire a charge, and so set up a potential difference between the inner and outer vessels.

The actual current through a gas, however, at any particular pressure depends, so long as the saturation current has not been attained, upon the potential difference producing the current, and so it happens that at each pressure a state of equilibrium is brought about by virtue of which the insulated system is maintained at such a potential as will produce a current through the gas of such magnitude as to exactly counterbalance the gain of charge through the emission of the radiation.

But as the pressure of the gas is lowered the equilibrium potential of the insulated system becomes gradually greater and greater, and the sign of the charge on the free system corresponding to this gradually increasing potential difference will be the opposite of that of the emitted radiation which is in excess.

Further, the extent of the equilibrium potential corresponding to any particular pressure will give a measure of the magnitude of this excess radiation.

When applying the method to the investigation of any particular radiation, the earth connection to the insulated system should first be broken and time allowed for the free system to come into equilibrium under the action of the conduction current arising from the volta effect. When this equilibrium has been reached the scale reading corresponding to the position then assumed by the movable system may therefore be taken as the initial reading in considering the charging action due to the radiation itself. Two lines of procedure are then open. If the radiation from the insulated system be a strong one the movable system of the electrometer will take up the equilibrium position practically at once for any particular pressure and so the pressure may be lowered by stages and the corresponding scale readings observed. But if the radiation be a weak one it may take the movable system a long time to acquire the equilibrium potential corresponding to any particular pressure, and under these circumstances it is best, if the object of the investigation is to ascertain the character of the excess emitted radiation, to reduce the pressure as rapidly and as low as possible, and then, while maintaining the low pressure, to observe whether a movement occurs in the movable system of the electrometer.

If such a motion occurs, the direction of the motion will indicate the sign of the charge acquired and the rate of movement will give a measure of the magnitude of the intensity of the charge producing radiation.

## II. Charging Action of the Radiation from Polonium.

Some preliminary attempts were made to obtain a charging effect with some potassium salts in a high vacuum, but it was soon found that such charging action was exceedingly small, and it was thought best to carry out a few parallel experiments with some of the better known radioactive substances, in order to gain some information regarding the pressures at which a charging action would be exhibited by various types of rays from active substances placed in a number of differently shaped vessels.

The first experiment was made with polonium deposited on a strip of copper. The area of this deposit was about 6 sq. cms. The copper strip which carried it was supported by a piece of amber insulation at the centre of an air-tight brass cylinder 20 cms. long, and about 5 centimetres in diameter. This cylinder was connected to a McLeod Gauge and also to a Gæde mercury exhausting air pump. The insulated copper strip bearing the polonium was also connected to the free quadrants of a Dolazaleck electrometer, which gave about 200 mm. divisions deflection per volt. With this arrangement it was found repeatedly when the earth connection to the free quadrants was broken, that the needle moved slightly in the positive direction and came to rest about three centimetres from the zero reading. This deflection was taken as a measure of the volta effect. As the pressure was lowered no further change occurred in the electrometer reading until a pressure of approximately .4 mms. was reached. At this pressure the quadrants always commenced to gain a positive charge, and as the pressure was still further lowered the needle at once moved out and took up a definite position corresponding to each pressure. When the pressure was taken below 1/100 of a millimetre the charging action became very marked and produced rapid deflections beyond the limits of the scale.

A set of readings taken with this polonium coated copper strip in the neighbourhood of the initial rise due to the radiation is given in Fig. 1, and a curve drawn from the readings is shown in the same figure. This curve is typical of the different ones obtained with this active product.

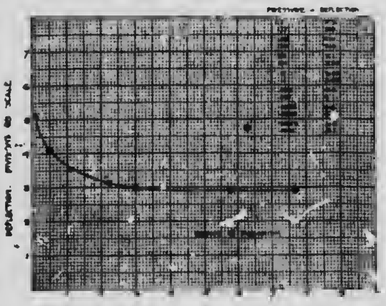


FIG. I.

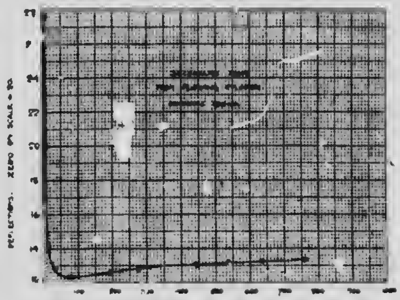


FIG. II.

It shows quite clearly that this substance emits an excess of negatively charged particles, and it also exhibits very definitely the pressure at which this excess comes into evidence.

### III. CHARGING ACTION OF SECONDARY RAYS EXCITED IN ALUMINIUM BY THE GAMMA RAYS FROM RADIUM.

In this experiment one milligram of radium was enclosed in a small sealed glass tube, whose walls were about 2 mms. thick. This glass tube was placed inside a tube of aluminium, which was then closed at the top and bottom. This tube, which was about 7 cm. in length and had walls about 2 mms. in thickness, was then insulated as before and suspended in the brass cylinder used in the last experiment. In this experiment the charging action was very much more marked than in the experiments with polonium. It also exhibited certain characteristics which were not observed in the measurements with that substance.

A set of results which illustrate its behaviour is given in Table II, and a curve plotted from them is shown in Fig. II. When the outside vessel and the free system were joined to earth the zero reading on the scale was 20, and as soon as the earth connection to the quadrants was removed the needle moved out at once in the negative direction and took up a position at 13.3. When the pressure was lowered the negative charge on the quadrants gradually increased, but ultimately at a pressure of about 80 mm. this acquisition of a negative charge ceased and when the pressure was reduced still further the charging action was reversed and for lower pressures the free system more and more rapidly

TABLE II.

| Pressure mm. | Deflection in mm. on scale |
|---|---|
| 755 | 13.3 |
| 632 | 13.3 |
| 535 | 13.2 |
| 447 | 13 |
| 375 | 12.95 |
| 323 | 12.9 |
| 275 | 12.8 |
| 231 | 12.7 |
| 192 | 12.6 |
| 135 | 12.5 |
| 112 | 12.45 |
| 82 | 12.37 |
| 72 | 12.35 |
| 58 | 12.37 |
| 52 | 12.4 |
| 40 | 12.6 |
| 22 | 13.5 |
| 13 | 14.4 |
| 11 | 15 |
| 7.5 | 17.4 |
| 5.0 | 20 |
| 3.3 | 22 |
| 1.18 | 25 |
| .24 | 27.2 |
| .033 | 27.6 |

gained a positive charge. In this experiment the volta effect would make the aluminium positive to the outside brass cylinder and consequently this would explain the acquisition of an initial negative charge when the earth connection to the free quadrants was broken. It is probable, however, that the difference between 20 and 13.3 did not represent the exact magnitude of the volta effect, for in this case the radiations present would include secondary rays from the walls of the brass outside cylinder as well as others from the walls of the inner aluminium tube. The reading 13.3 would then represent the equilibrium potential acquired by the free system through the agency of (1) the volta effect, (2) the conduction current, (3) the secondary rays from the aluminium tube, (4) the secondary rays from the brass outside vessel and also (5) any tertiary rays from the two opposing surfaces which might be present. The initial increase in the negative charge acquired by the aluminium tube in the range of pressures extending to 80 mm. was probably due to modifications produced by the lowering of the pressure in the amount of secondary rays coming to the aluminium tube from the walls of the brass outside vessel. The charging action of these would initially mask the charging action of the various excited secondary rays issuing from the surface of the aluminium tube. But ultimately, as the pressure was lowered, a point would be reached when these secondary rays from the outside vessel would exert their maximum effect. For lower pressures the conduction current through the gas would become less and less This would bring the secondary rays from the aluminium tube more into evidence and so account for the rapid increase in the positive charge acquired by the free system, which the curve shows took place at the lowest pressures. From this experiment it will be seen that the charging action of the secondary rays produced in aluminium by the gamma rays from radium was brought into evidence at a very much higher pressure, 80 mm., than a similar action by the rays from polonium.

## IV. On the Charges Acquired by Uranium Salts at Low Pressures.

In this experiment the form of the vessel used in making the examination is shown in Fig. III. A flat tray of brass BB was supported by an ebonite plug on the brass plate CC shown in the figure. A shallow brass cover FF was placed over the tray BB and rested on the lower plate. Over the whole a second cover DE was placed which fitted snugly in to a groove provided in the lower plate CC. In making the experiment the salt to be examined was placed on the tray BB, the covers were then placed in position, and finally all the joints made air-tight with sealing wax. The salt used in making the experiment was a sample of uranium nitrate. The measuring instrument used was again a quadrant electrometer, but in this case it possessed a sensibility of 600 divisions per volt.

In carrying out the experiment it was found that when the earth connection to the free quadrants was broken, the needle moved out in the positive direction on the scale for a distance which represented approximately 1/40 of a volt, and came to rest in this position. This deflection was taken to represent the deviation arising from the volta effect. The chamber was then slowly evacuated, but as the exhaustion proceeded no additional deflection of the needle was observed. An attempt was then made to reduce the pressure as low as possible, but although a pressure of .3 mm. was reached no indication was obtained of any additional charge being acquired by the insulated tray which carried the uranium nitrate.

As it is known that both alpha and beta rays are emitted by the salts, this result pointed to the conclusion that these rays carried away from the salt equal amounts of positive and negative electrical charges. In order to test this matter still further a second form of exposing chamber was constructed.

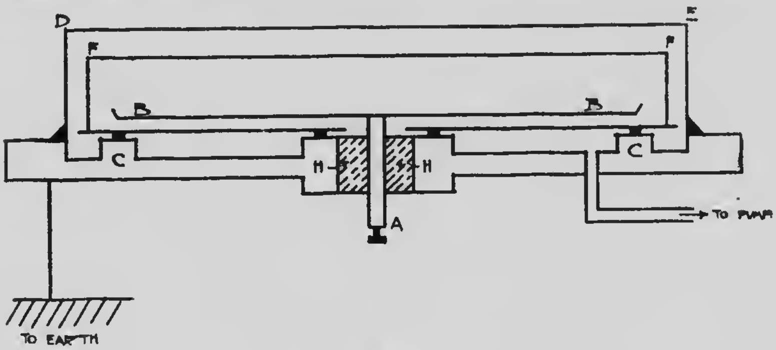



FIG III

Its design is shown in Fig. IV. The salt was spread out in thin layers some 3 or 4 mm. thick on a set of 12 brass trays AA whose diameters were about 9 cms. These were all fastened to a central brass rod C which was suspended in the outer brass cylinder by an insulating support of ebonite. This vessel carried a small tray of $P_2O_5$ in the bottom and it was also provided with a set of plates, DD, so arranged between the trays as to intercept the rays issuing from the salt. The apparatus was provided with a cover as shown in the figure, and all the joints were again made air-tight with solder and sealing wax.

With this form of apparatus the volta effect was again in the positive direction, but the corresponding displacement was greater in this case, and represented approximately one quarter of a volt. After the deflection resulting from the volta effect had become steady, the air was rapidly exhausted from the receiver, and although the pressure was reduced to .02 mm., no indication of any charging action was obtained.

From the fact that no charging action was obtained in either of the experiments with the two forms of apparatus, it seems clear that the alpha and beta rays from the nitrate of uranium carried away with them from the salt equal amounts of positive and negative electricity.

In order to test the accuracy of this conclusion an additional set of experiments was made with uranium nitrate when using this second form of apparatus. The salt on each tray was covered with two layers

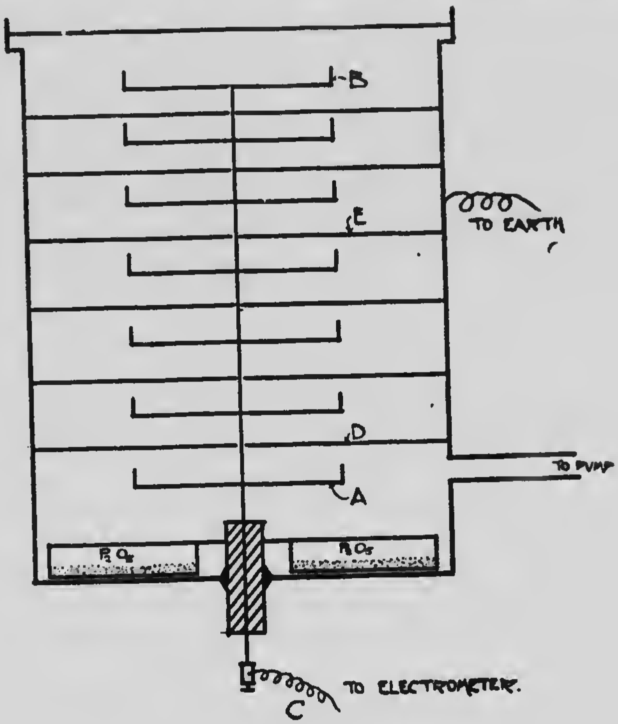


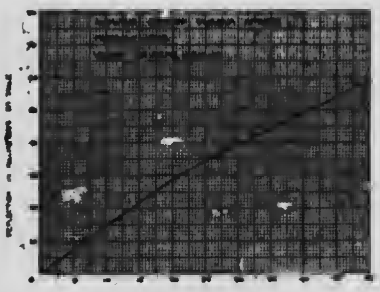

FIG. IV.

of aluminium leaf, each about .007 mms. in thickness. As this thickness was sufficient to cut off all the alpha rays,[1] but only a small proportion of the beta rays, it was evident that a charging action should occur, and some experiments were made to see at what pressure it could be observed.

As aluminium in the volta series is positive to brass, the charge acquired in this case through the annulling of the volta effect was a negative one. When the pressure was reduced it was found that the electro-

[1] Phys. Zeit. 8, p. 773, Oct. 24, 1907.

meter needle commenced to move away from the stationary position assumed under the influence of the volta effect, when a pressure of approximately 8 cms. of mercury was reached, and the direction of displacement was such as to correspond to the acquisition of a positive charge. The sign of the charge acquired, it will be seen, fitted in then with what was to be expected from the absorption of the rays. For the higher pressures the rate of motion of the needle as it moved to take up



F G. V.

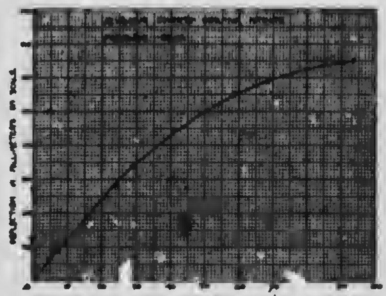


TABLE III.

| Time in Min. | Deflection in mm. |
|---|---|
| 0 | 0 |
| 7 | 11 |
| 12 | 17 |
| 17 | 24.5 |
| 27 | 35 |
| 34 | 42.5 |
| 39 | 48 |
| 50 | 58 |
| 58 | 65 |

the deflection corresponding to a selected pressure was slow, and on this account the second line of procedure mentioned above was followed. In taking the observations the pressure was reduced as low as possible and then the rate of motion of the needle noted as it moved out to take up the equilibrium position.

Examples of these movements of the needle are given in the numbers recorded in Tables III and IV, and in the curves drawn from them and shown in Figs. V and VI. In the one case the movement corresponds to a pressure of .15 mm. and in the second to a pressure of .08 mm. The rate of movement, as was to be expected, is greater for the lower pressure than it was for the higher one. The fact that positive charges were acquired under these circumstances lends further support to the conclusion drawn from the earlier experiments that equal quantities of opposite kinds of electricity were emitted with the rays from uranium nitrate when freely exposed.

TABLE IV.

| Time Min. | Time Secs. | Deflections in mm. on Scale. |
|---|---|---|
| 0 | .. | 0 |
| 5 | .. | 18 |
| 7 | 40 | 27 |
| 12 | 30 | 44 |
| 17 | 55 | 62.5 |
| 24 | 10 | 85 |
| 29 | 40 | 101 |
| 41 | 10 | 132 |
| 50 | 55 | 151 |
| 59 | 10 | 165 |
| 68 | 25 | 177 |
| 80 | 10 | 188 |
| 90 | 40 | 194 |
| 93 | 40 | 195 |

## V. Potassium Salts: Electrical Charging Action.

In making the observations with potassium salts pieces of apparatus similar in form and dimensions to the two shown in Figs. III and IV were used in turn. In the first experiment a layer of potassium chloride, about 4 mms. thick, was spread on the tray BB in Fig. III, and then the space surrounding the tray was as highly evacuated as possible.

Some preliminary observations had shown that extreme care had to be taken to see that no electrification was imparted by friction to the insulating support HH, during the operation of setting up the apparatus. Even touching it slightly with the finger or allowing its surface to be scraped with any object, was found to leave an electrification behind which gradually disappeared, but which in doing so brought irregularities into the results and often vitiated them.

In taking the readings given below, exceptional care was therefore taken to make certain that all the insulating supports were entirely free from electrification. The electrometer was also exceptionally well set up, the needle being so carefully adjusted and the suspension wire kept so free from torsional strain that when both pairs of quadrants were joined to earth no displacement from the zero took place for hours.

With the apparatus in this condition the test was made for a charging effect with the potassium chloride, first when the needle of the electrometer was positively charged to 240 volts, and secondly when it was negatively charged to the same voltage. The sensibility of the electro meter was such that a potential difference of 1 volt between the quadrants gave a deflection of 600 mm. divisions on the scale. In making the test the pressure was lowered to .003 mms., and maintained at this low pressure throughout the measurements.

TABLE V.

| Time in Min. | Deflection in Min. on Scale. |
|---|---|
| 0 | 0 |
| 6 | 2 |
| 11 | 3 |
| 15 | 4 |
| 23 | 7 |
| 30 | 10.5 |
| 34 | 12.2 |
| 38 | 14 |
| 55 | 23 |
| 78 | 34 |
| 97 | 43 |
| 115 | 52 |
| 124 | 55 |
| 142 | 63.8 |
| 148 | 66.5 |

The results obtained with the needle positively charged and also when it was negatively charged are given in Tables V and VI, and curves drawn from these numbers are shown in Fig. VII ...n these curves it will be seen that in both cases the tray con... the salt slowly ac-

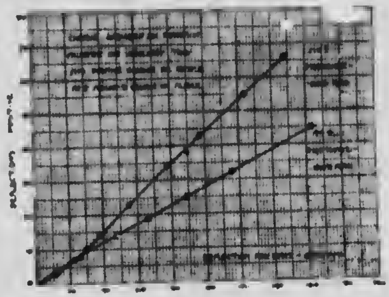


Fig. VII.

quired a positive charge. The rate at which this charge was acquired, moreover, was greater when the needle was positively charged than when

TABLE VI.

| Time in mins. | Deflection in mms. on Scale |
|---|---|
| 0 | 0 |
| 2 | 1 |
| 26 | 8 |
| 29 | 9 |
| 32 | 10 |
| 35 | 11 |
| 39 | 12.2 |
| 41 | 12.5 |
| 47 | 14.2 |
| 66 | 19 |
| 73 | 21 |
| 89 | 25 |
| 116 | 32 |
| 120 | 33 |
| 163 | 45 |
| 200 | 69 |

it was negatively charged, but this difference was probably due to the small conduction current which must have existed in the air between the needle of the electrometer and the free quadrants.

The effect it will be seen is a small one and the time required to make the readings was long. The readings, however, were quite regular, and with the precautions and care taken there seems no reason for interpreting the results otherwise than as representing a charging action produced by the radiation emitted by the insulated potassium salt on the tray. Observations were made under precisely the same conditions with the tray empty, but these failed to show any such charging action as that obtained with the salts. These experiments with the potassium chloride were made, as stated above, with the apparatus shown in Fig. III, but they were carried out before the apparatus was used in the uranium nitrate experiments, and consequently there was no possibility of a connection between the charging action observed with the potassium salt and any contamination of the apparatus through contact with the uranium nitrate. This charging action with a salt of potassium was

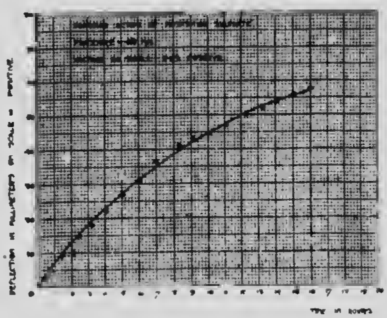


Fig. VIII.

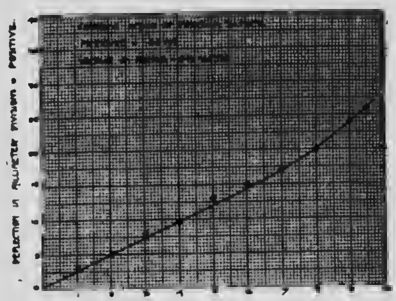


Fig. IX.

also observed with the apparatus shown in Fig. IV. In this set of observations the salt used was the sulphate of potassium. Two sets of measurements were again made. In the one the potential on the needle was positive and equal to 243 volts and the pressure of the residual air in the apparatus was .08 mm. In the second set the needle was kept at a negative potential of 243 volts, and the pressure of the air was maintained at .06 mm. In these two latter measurements it was not found possible to lower the pressure of the gas below the readings stated, although the Gæde pump used in the exhaustion was kept in action continuously. It is possible that the vessel containing the salt had some minute opening in its walls, but although careful search was made for such an opening none was detected. The readings taken in these observations are given in Tables VII and VIII, and curves plotted from them are given in Figs. VIII and IX.

Here again it will be seen the charging action was a positive one in both cases, and when the needle was positively charged its motion was somewhat more rapid than when it was negatively charged. In both of these two latter sets of observations the volta effect produced a deflection in the negative direction when the earth connection to the free quadrants

TABLE VII.

| Time. Hours. | Mins. | Deflections in mms on Scale. |
|---|---|---|
| .. | .. | 0 |
| .. | 42 | 2.3 |
| 1 | 15 | 5.3 |
| 1 | 31 | 7.0 |
| 1 | 55 | 9.0 |
| 2 | 20 | 11.0 |
| 2 | 30 | 12.0 |
| 2 | 53 | 15.0 |
| 3 | 25 | 18.0 |
| 3 | 51 | 20.5 |
| 4 | 07 | 22.0 |
| 4 | 35 | 24.5 |
| 5 | 05 | 27.0 |
| 5 | 35 | 29.5 |
| 6 | 05 | 31.0 |
| 6 | 38 | 34.0 |
| 7 | 05 | 36.5 |
| 7 | 28 | 38.0 |
| 7 | 50 | 39.0 |
| 8 | 25 | 41.0 |
| 8 | 38 | 41.5 |
| 9 | 10 | 43.0 |
| 9 | 35 | 44.0 |
| 10 | 10 | 45.0 |
| 10 | 35 | 45.5 |
| 11 | 10 | 47 |
| 11 | 35 | 48 |
| 12 | 10 | 49 |
| 12 | 35 | 50 |
| 13 | 05 | 51 |
| 13 | 35 | 52 |
| 14 | 05 | 54 |
| 15 | 05 | 56 |
| 15 | 35 | 57 |
| 16 | 05 | 57.5 |

was broken at atmospheric pressure; but in each case after these earth connections were broken the complete apparatus was left undisturbed for some 8 hours in order that the needle might take up its stationary position corresponding to the volta effect displacement. From time to time during this period observations on the scale readings were made and in this way the time was ascertained when the deflections became stationary. When these stationary states had been reached the exhaustions were then made and when the limiting pressures given above were reached, readings on the charging effect were commenced. These, it will

TABLE VIII.

| Time. Hours. | Min. | Deflection in mm. on Scale. |
|---|---|---|
| .. | 0 | 0 |
| .. | 30 | 2 |
| 1 | 00 | 3 |
| 1 | 30 | 3 |
| 2 | 00 | 5 |
| 2 | 30 | 6 |
| 3 | 00 | 8 |
| 3 | 30 | 8 |
| 4 | 00 | 9.5 |
| 4 | 30 | 11.5 |
| 5 | 00 | 13.0 |
| 5 | 30 | 14.0 |
| 6 | 00 | 15.0 |
| 6 | 30 | 16.0 |
| 7 | 00 | 17.0 |
| 7 | 30 | 19.0 |
| 8 | 00 | 20.0 |
| 8 | 30 | 22.0 |
| 9 | 00 | 24.0 |
| 9 | 30 | 26.0 |

be seen, confirm the results obtained with the potassium chloride in the earlier experiments.

These results show that in high vacua both potassium nitrate and potassium sulphate emit an excess of charged particles of the beta type.

The effect observed in all cases was small and it will be noted that it required exceptional conditions to bring it into evidence.

From the results obtained so far it has not been found possible to decide whether any radiation of the alpha type is emitted by the potassium salts or not. It is the intention of the writer, however, to examine the charging effect with the potassium salts covered with thin layers of aluminium. The use of such layers while preventing the emission of any alpha rays which might be present would probably not diminish to any great extent the intensity of the beta radiations.

The measurements made in this investigation demanded considerable patience and care, and I am indebted to Mr. M. E. Liezert and Mr. B. L. Cooke for kind assistance rendered on occasions during the progress of the observations.

Physical Laboratory, Toronto, May 20, 1909.