RADIO-ACTIVITY OF SPRINGS NEAR WILLIAMSTOWN, MASSACHUSETTS.

BY J. E. SHRADER.

THERE is a warm spring near Williamstown called Sand Spring whose waters issue from its sandy bottom at the rate of forty gallons a minute into a large cement basin. From all portions of the bottom bubbles of gas arise. This gas has been analyzed by Professor L. Mears, of Williams College, and has been found to consist of air containing an excess of nitrogen, and a small per cent. of carbon dioxide. Since the spring is thermal, its waters must come from a considerable depth.

It is well known that all springs are more or less radioactive, due to the fact that their waters carry with them radium emanation which is released from the rocks and soil about which they circulate. To determine the amount of radium whose emanation would produce the activity observed in the gas and water of Sand Spring was the purpose of this experiment. Subsequently investigations were extended to other springs in the vicinity.

APPARATUS AND METHOD OF PROCEDURE.

The diagram (Fig. 1) represents the apparatus used for determining the radio-activity of the water. It consists, essentially, of an emanation electroscope, a gas pipette, and a glass flask for containing the water to be investigated.

The gas chamber of the electroscope was made of a brass cylinder of about eight centimeters inside diameter and fourteen centimeters long. Brass ends were turned and soldered into the ends of the cylinder. Two gas-tight stopcocks were also soldered into the cylinder, one communicating with the gas pipette and the other with a filter pump for exhausting the air. The gold-leaf was mounted on a central electrode with inner insulation of amber, a guard ring, and an outer insulation of hard rubber. The gold-leaf was protected by a second brass cylinder of smaller dimensions. The guard ring was connected by means of a fine wire, *b* (Fig. 1), and a small rod, *d*, to the negative pole of a storage battery, the positive pole being earthed. The battery was of the test tube type of 480 volts, about 240 of which were used. The wire, *b*, was bent so that the spring

in the wire always kept it pressed against the rod, *d*. The rod, *d*, also carried a wire, *c*, bent at right angles and carried along parallel with it. By turning *d*, contact could be made with the gold-leaf support so that the electroscope could be easily charged. The wire could then be turned to a definite position when measurements were being made. This arrangement made it easy to keep the central electrode charged for any length of time desired and so concentrate the excited activity of the gas upon it. The various parts of the insulation and guard ring were cemented together and secured in the cylinder with Khotinsky cement. The electroscope was fastened securely to a heavy iron base, *N*.

The gas pipette, *D*, was made of a glass vessel fitted with a three-way stopcock, *e*. Connected to it was a mercury reservoir, *E*, for displacing

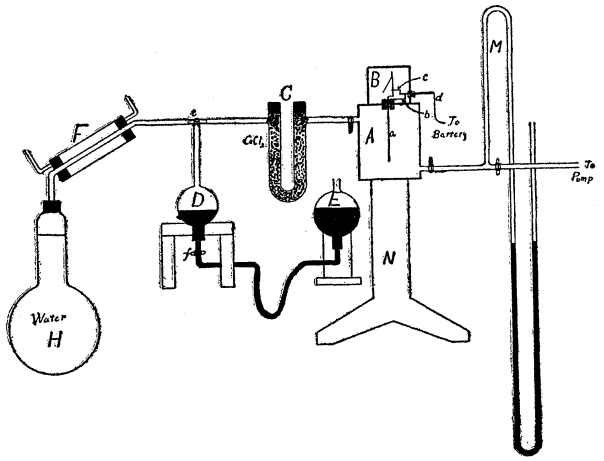

Fig. 1.

the gas. The gas was dried by passing it through the U-tube, *C*, filled with calcium chloride. The glass flask, *H*, of about two liters capacity, was connected to the gas pipette by a bent tube and rubber stopper. The glass tube was surrounded by a water jacket, *F*, so that the steam could be condensed when the water in *H* was being boiled.

When a determination of the activity of the water was to be made, the water was taken from the spring as near the source as possible and carried to the laboratory where it was introduced into the flask, *H*, filling it to a mark previously determined such that the water on being boiled expanded and completely filled the flask. The gas pipette was then filled with mercury and the cock, *f*, closed and the three-way cock, *e*, turned so that connection was made between the flask and the pipette through the bent glass tube which was surrounded by the water jacket. After

opening the cock, *f*, a Bunsen flame was applied to the flask and the water heated to boiling. The boiling was continued for fifteen or twenty minutes, the steam being condensed by water flowing through the water jacket. During this time, the air left in the flask and the gas driven off from the water have been carried over into the pipette, displacing the mercury. The mercury reservoir was always placed a little lower than the pipette so that boiling took place under diminished pressure. After sufficient boiling, the mercury reservoir was lowered considerably and the water boiled vigorously so that practically all the gas was drawn into the pipette. The cock, *f*, was now closed and, after two hours from the time the water was taken from the spring (which happened to be a convenient length of time), the collected gases were introduced into the electroscope through the drying tube. This was done by partially exhausting the electroscope chamber with a filter pump to a pressure of three or four centimeters of mercury, as was shown by a manometer, *M*. The stopcock, *e*, was now turned so that the gas could be drawn through the drying tube into the electroscope. The pressure in the gas chamber was equalized by removing the bent tube and allowing the outside air to carry all the gas remaining in the connecting tubes into the electroscope. The capacity of the gas chamber was between 700 c.c. and 800 c.c. and the mixed gases had a volume of about 125 c.c.

Before introducing the gases into the electroscope the central electrode was connected to the negative pole of the battery and kept at a constant potential of -240 volts. Thus the excited activity was concentrated on the electrode, and, after three hours it had come into equilibrium with the radium emanation. After this interval, the rate of deflection of the gold-leaf was taken. The time was taken with a stop-watch and the deflection observed with a telescope fitted with a micrometer eyepiece. The rate of deflection was corrected for the natural ionization of the air. The same part of the scale was always used in taking an observation and the potential of the battery was adjusted so that the gold-leaf was deflected to the point at which the readings began. It was observed that, if the central electrode was kept charged for a considerable time to allow the charge to be evenly distributed over the insulation, the natural ionization was practically constant. Without a guard ring and without the precautions taken, the natural ionization might vary as much as two or three times any observed value.

THE RADIUM STANDARD.

In order to interpret the rate of deflection of the gold-leaf in terms of the activity of a known amount of radium, it is necessary that the elec-

troscope should be calibrated. For this purpose Professor B. B. Boltwood, of Yale University, kindly sent me a small quantity of Joachimsthal uraninite (pitchblende) which he had analyzed. The specimen contained approximately 67 per cent. uranium. Since one gram of uranium by comparison with the New International Radium Standard contains 3.2×10^{-7} grams of radium, one gram of the sample would contain 2.14×10^{-7} grams radium. Since the powdered sample loses 6 per cent. of its emanation, the amount of radium emanation secured on dissolving one gram of the sample would be equal to the amount given off by 2.0×10^{-7} grams radium. From the specimen of uraninite .0099 grams were weighed out and placed in a small flask with a side-tube and water jacket Fig. 2 (*b*). A funnel provided with a stopcock and filled with

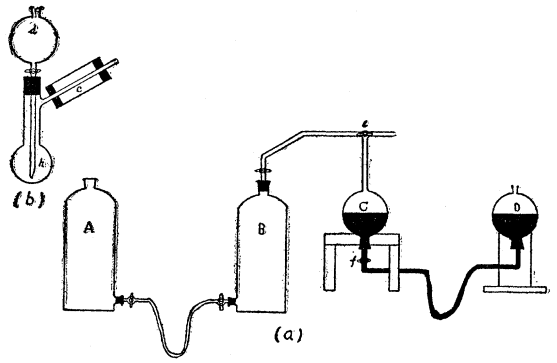

Fig. 2.

dilute nitric acid (one part acid to six parts water) was fitted with a rubber stopper into the mouth of the flask. This arrangement was now fitted to the pipette in place of the flask and its water jacket in Fig. 1. The acid was allowed to flow down into the flask to dissolve the sample. Then the flask was heated and the contents boiled and all the gases driven over into the pipette. After two hours as in the case of the water, the gases were introduced into the electroscope and the rate of deflection observed. From this observation, corrected for the natural ionization of the air, the deflection of one scale division could be estimated as that caused by the activity due to the emanation from a certain number of grams of radium. Hence, by comparison, the activity of a liter of the water could be expressed as that due to a certain number of grams of radium.

ACTIVITY OF THE GASES.

The gases were caught with a funnel which was connected to a bottle filled with water and having an outlet tube extending into the water.

As the gases accumulated, the water was displaced. When the bottle was filled it was made air-tight and taken to the laboratory, and after a period of two hours from the time of its collection, it was introduced into the electroscope. This was done by displacing the gas from *B*, Fig. 2 (*a*), with water from the bottle, *A*, into the pipette, *C*, where its volume under known conditions of temperature and pressure were ascertained. From there it was drawn into the electroscope. After standing three hours the rate of deflection was observed. Hence the activity of the gas could be computed in terms of the standard. The amount of gas used was 145 c.c. This amount of the Sand Spring gas was sufficient to give a deflection of 1.832 divisions per minute. The deflection due to the natural ionization was .007 divisions per minute.

OTHER SPRINGS TESTED.

The second spring tested is located about 200 yards below Sand Spring. It is called Wampanoag Spring. It is of much the same nature as Sand Spring. Its temperature is slightly higher and its flow much less. The activity, as seen from the table below, of both the water and gas is much greater. This might be expected from the fact that the flow is less and the amount of gas given off much smaller.

The third spring, which I will call the "Rich" Spring from the name of its owner, is about one mile distant from the other springs and on the other side of the Hoosac River. It issues from the base of Northwest Hill and is not enclosed. The flow, I should judge, is slightly greater than that of Sand Spring, though I had no ready means of making the determination. The water and gas of this spring are comparatively weak.

The other two springs are Cold Spring and Sherman Spring both of which are used as a part of the water supply for Williamstown. The water from the Sherman Spring was taken as it issued from the earth, but the water from Cold Spring was taken from the reservoir as its source was not easily accessible. For this reason, the latter had lost the greater part of its activity.

The tap-water was taken from the tap of the laboratory after letting the water run for a couple of hours.

TEST FOR DISSOLVED SALTS OF RADIUM.

Eleven liters of the water from Sand Spring were evaporated to two liters and sealed in the flask, *H*, Fig. 1. After standing sixteen days, during which time more emanation would be produced if the salts of radium were present, the water was again boiled and tested for its activity. Not a trace could be detected.

The water and gas were not tested for thorium.

TABLE OF RESULTS.

Name of Spring.	Temperature in Degrees C.		Activity per Liter of Gas, Standard Cond., in Grams Radium.	Activity of Water in Grams Radium.
	Oct.	Jan.		
Sand Spring.....	20.8	19.8	653. $\times 10^{-11}$	12.16 $\times 10^{-11}$
Wampanoag.....	21.9	21.5	729. $\times 10^{-11}$	21.6 $\times 10^{-11}$
Rich Spring.....	18.2	18.2	75.9 $\times 10^{-11}$	.897 $\times 10^{-11}$
Sherman Spring.....		5.		4.11 $\times 10^{-11}$
Cold Spring.....				1.31 $\times 10^{-11}$
Tap-water.....				.25 $\times 10^{-11}$

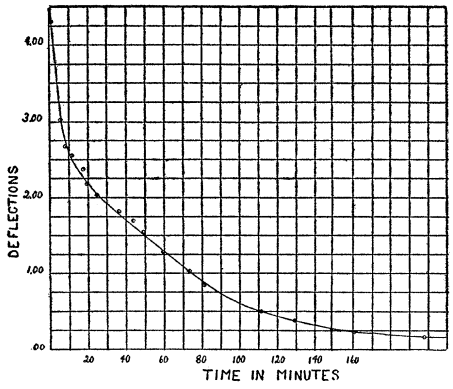

Fig. 3.

THE DECAY OF THE RADIUM EMANATION AND ITS EXCITED ACTIVITY.

Fig. 3 represents the decay of the active deposits radium *A*, *B*, and *C*, concentrated on the central electrode of the electroscope from the emanation in the Sand Spring gas. The electroscope was kept charged and the gas introduced and allowed to stand for three hours. The gas was then drawn off and the measurements of the activity taken at intervals.

Fig. 4 represents the increase of activity due to the active deposits

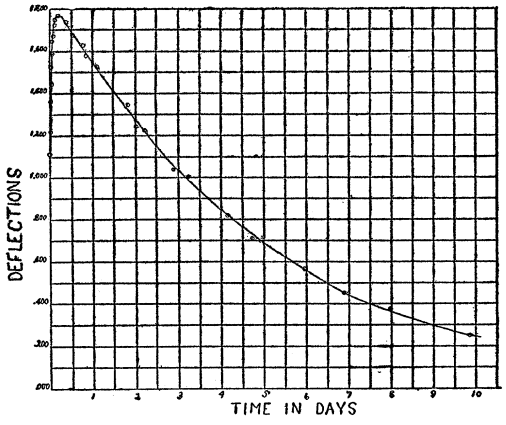

Fig. 4.

after the gas is introduced, and the decay of the radium emanation in equilibrium with its products.

Fig. 5 represents the decay of radium emanation in equilibrium with its products, plotting logarithms of deflections against time in days. The curve is a straight line showing that the gas decays according to an exponential law with a half value period practically the same as that for radium emanation, which is 3.85 days. It was difficult to make the electroscope air-tight so that correction was made for diffusion by comparison, under the same conditions, of the decay curve of the radium emanation from the sample of uraninite used for calibration.

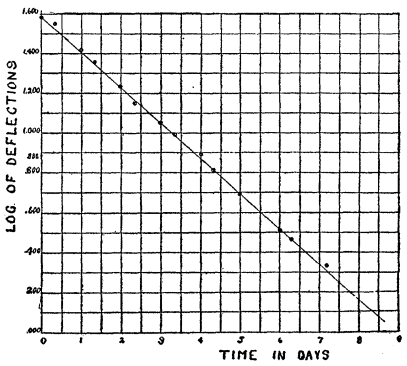

Fig. 5.

In conclusion, I wish to thank Professor B. B. Boltwood for his kindness in furnishing me with the uraninite for the calibration of my electroscope, and also Assistant Professor Brainerd Mears for the loan of apparatus from the Chemical Laboratory and for several valuable suggestions.

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