

of 5000 grams of the "Residue." The solids were determined and analyzed with the results given below:

Fraction	Volume Cc.	Wt. of solids in fractions	Per cent of anthracene in solids
1.....	250	None	...
2.....	260	None	...
3.....	250	None	...
4.....	260	1.2	58.20
5.....	250	5.8	47.26
6.....	260	11.0	46.83
7.....	250	15.2	40.52
8.....	250	14.4	43.76
9.....	250	12.1	39.19
10.....	250	5.4	21.73
11.....	260	None	...
12.....	250	None	...

In the steam distillation, therefore, 0.517 per cent of anthracene was recovered from the "Residue" above 250°, equivalent to 0.383 per cent of the original tar. There was clearly less decomposition when steam was used, since the pitch contained but 5.6 per cent of free carbon, whereas that from the dry distillation averaged 57 per cent. Practically all of the anthracene comes over under 360° in the dry distillation, and at that temperature little cracking has taken place, the pitch containing but 6.0 per cent free carbon. Above 360° an orange-colored, viscous, semi-solid material appears in the distillate and seems to be indicative of marked decomposition.

Fairly pure anthracene was prepared from the expressed solids by washing with gasoline, and subliming the residue. This anthracene melted at 207°–211° C. and when mixed with a sample of Kahlbaum's anthracene, the mixture melted at 208°–211°.

As a further test of the quality of the solids pressed from the high boiling distillates of water gas tar, 50 grams of these solids recovered from the distillate between 289° and 361° were oxidized with bichromate and sulfuric acid. The anthraquinone after purification was sublimed giving 18.2 grams of crystalline anthraquinone. Anthraquinone prepared in this way was converted into the sodium anthraquinone-mono-sulfonate which in turn was converted into alizarine. A beautiful orange-red crystalline preparation of alizarine was obtained on subliming the product. Under laboratory conditions the transformation of anthraquinone into alizarine is difficult, and the yields obtained correspondingly low. From about 20 grams of anthraquinone only about 7 grams of alizarine were obtained.

#### SUMMARY

A systematic fractional distillation of water gas tar shows that it possesses a general resemblance to coal tar in its hydrocarbon content although, of course, the bases, phenols, and free carbon of the latter are absent or nearly so. The small amounts of material in the distillates resisting the action of sulfuric acid indicate an absence of paraffin and naphthene hydrocarbons, and the marked variation in the capacity for halogen addition points to variable amounts of unsaturated linkings outside the benzene ring.

Benzene, toluene, the xylenes, mesitylene, naphthalene, and anthracene were shown to be present in sub-

stantial amounts. The preparation of the pure hydrocarbons and of commercial products could be effected by methods similar to those employed with coal tar, and without encountering special difficulties.

It would appear probable that water gas tar may offer a commercial source of supply for the various grades of benzol and solvent naphtha. Naphthalene could readily be produced, but there is no adequate demand, and it is likely that the present trade conditions would not warrant the production of anthracene.

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#### THE RADIOACTIVITY OF SOME TYPE SOILS OF THE UNITED STATES

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Received March 6, 1914

Strutt<sup>1</sup> first called attention to the radioactivity of igneous and sedimentary rocks. The average of his results on igneous rocks showed a radium content of  $3.3 \times 10^{-12}$  grams of radium per gram of rock. The radium content of the sedimentaries was somewhat less. Joly<sup>2</sup> has examined a large number of rocks for radium and thorium. His radium values are somewhat larger than those of Strutt and other workers. The average of a number of his thorium determinations indicates the presence of  $1.58 \times 10^{-5}$  grams of thorium per gram of rock. Fletcher,<sup>3</sup> working primarily with secondary rocks, has confirmed Joly's results and at the same time pointed out that, with the exception of the calcareous rocks, those of the same types have always very nearly the same radium content.

Although a considerable amount of work has been done on the radioactivity of rocks and minerals, very little has been attempted along this line with soils. A knowledge that the atmosphere was radioactive was naturally followed by an investigation of the activity of the underground air. Elster and Geitel, Bumstead, Blanc, Gadourian, Wilson, Ebert, Eve, Sanders, Satterly and others have contributed to our knowledge of this subject. Whereas a study of the underground air indicates very plainly that the soil is radioactive, it does not give any absolute values for the activity of the soil itself, as the activity of the underground air depends as much upon the emanating power of the radioactive matter in the soil as it does upon the amount of that material actually present. Some rough minimum determinations have been attempted. Wilson states that there is probably seven times as much thorium as uranium in the surface soils at Manchester. Blanc, on the other hand, estimates that from 5 per cent to 70 per cent of the activity of the Roman soil is due to thorium; while Sanderson's<sup>4</sup> work indicates that 1 cc. of soil at New Haven produces radium emanation in equilibrium with  $8.9 \times 10^{-14}$  grams of radium, and thorium emanation in equilibrium with  $1.35 \times 10^{-6}$  grams of thorium. Fletcher<sup>5</sup> gives the radium content

<sup>1</sup> *Proc. Roy. Soc., (A)* **77** (1906), 472.

<sup>2</sup> *Phil. Mag.*, **17** (1909), 760; **18** (1909), 140; **23** (1912), 201.

<sup>3</sup> *Ibid.*, **23** (1912), 279.

<sup>4</sup> *Am. Jour. Sci.*, **32** (1911), 169.

<sup>5</sup> *Phil. Mag.*, **23** (1912), 279.

of two Dublin soils passing a 50-mesh sieve as  $5.2 \times 10^{-12}$  grams and  $2.8 \times 10^{-12}$  grams per gram of soil.

Strutt<sup>1</sup> states that the radium content of the Cambridge Gault is  $1 \times 10^{-12}$  grams per gram of material.

Satterly<sup>2</sup> measured the amount of radium emanation in the air of different soils at different intervals extending over a year. For depths of from 100–150 cm. in gravelly soil the amount of emanation is on the average  $200 \times 10^{-12}$  curies per liter. This is about 2,000 times as much as is usually in the atmosphere. He found that a liter of soil air was in association with 1200 grams of dry or 1400 grams of damp soil, and calculated from this that the apparent radium content of the soil is  $1.7 \times 10^{-14}$  grams per gram of dry soil. As the actual radium content of the soil is certainly very much larger than this, it follows that only a small portion of the emanation generated in the soil escapes under normal conditions from the soil particles into the air surrounding them.

Satterly also measured the proportion of radium emanation to thorium emanation in soil air at various depths. He found that the ratio increased from 1600 near the surface to 26,000 at a depth of 400 cm. At 150 cm. it is 8,600 and taking the radium content of the soil at  $1.1 \times 10^{-12}$  grams per gram of soil, he calculated that the thorium content would be  $1.4 \times 10^{-5}$  grams per gram of soil.

Apparently no systematic attempt has yet been made to correlate the radioactivity of soils with their other properties. Recently an elaborate study of the chemical composition of a number of type soils of the United States has been undertaken by G. H. Failyer and W. O. Robinson, of the U. S. Bureau of Soils. A mineralogical examination has been made of the same soils by Professor W. J. McCaughey. The author has these unpublished results at his disposal and has examined the soils for their radium content. The present paper constitutes a report on the results obtained.

Since radium is found in varying amounts in all rocks, spring waters, and even in underground waters, it is not surprising that botanists have tried the effects of the radium rays on the germination of seeds and the growth of plants. Since radioactivity is a factor of plant environment, it is possibly an agent in plant growth. Not only must the direct effect of the rays themselves be considered, but the chemical action induced by these rays, slight rises of temperature, etc., must be taken into account. The emanation, or gas, given off by radium salts diffuses through the soil, is dissolved by the soil solution, and comes in intimate contact with the plant roots even though the radium itself is in the soil as an insoluble sulfate or silicate. It is therefore more probable that if the presence of radium in the soil does affect the growth of plants appreciably, this effect will be more directly due to the influence of the emanation than to the radium. Some experimenters have not taken this fact into account and the influence of the  $\beta$  and  $\gamma$  rays on plants has in many cases been tested rather than bringing the roots in contact with the diluted emanation.

A far more serious objection to the experimental work with plants is that much greater amounts of radium have been employed than are ever present in the soil naturally, or likely to be added in actual agricultural or greenhouse practice. The amount normally present in soils is sensibly the same, namely, about 3 milligrams per acre foot. To increase this content one milligram per acre foot in the form of ground ore would cost about 20 dollars, and as pure radium salt about 120 dollars. The experimental work so far done indicates that at least several milligrams per acre would have to be added to produce an appreciable effect on the crop. Nevertheless, it seems well to call specific attention to some of the more important investigations in this direction.

Danyisz<sup>1</sup> found that the rays from radium and the emanation hindered all species of bacteria in their development, some varieties being more sensitive than others.

Dixon<sup>2</sup> stated that the growth of cress seedlings was retarded by the  $\beta$  and  $\gamma$  rays from radium salts. Dixon and Wigham also found that  $\beta$  rays exercised an inhibitory action on the growth of certain bacilli.

Germination of the spores of *Aspergillus niger*<sup>3</sup> was found by Koernicke to be inhibited by exposure to the  $\beta$  and  $\gamma$  rays. Generally speaking, he found that roots were more sensitive than shoots.

Hussakof,<sup>4</sup> in a review published in 1907, showed that up to the time of his publication there was a general agreement on the following conclusions:

- (1) The rays from radium affect the life processes of plants as well as animals. The Roentgen rays have a similar effect.

- (2) Different species of plants are affected differently in degree.

- (3) Younger tissues are more sensitive than older ones.

- (4) The general effect is to retard all activity. There are a few exceptions.

- (5) The growth and activity of enzymes are affected by the rays from radium.

Gager<sup>5</sup> found that in general the germination of both dry and wet seeds was retarded by the radium rays. Timothy grass seeds exposed to radium of weak activity showed an initial slowing up and then after five days an increased metabolism over the control culture. A similar result was obtained with bean seeds.

On the other hand, when unsoaked oat grains were planted at distances of 7, 22, and 45 mm. from a sealed glass tube containing 10 mg. radium bromide of 1,500,000 activity inserted in the soil, germination and subsequent growth were accelerated. The seeds farthest from the radium were accelerated most; those nearest, least. When timothy grass was grown in an atmosphere containing radium emanation, the result was dependent upon the amount of emanation used, the height above the soil at which the emanation was delivered, etc. Gager sums up by stating that "the

<sup>1</sup> *Compt. Rend. Acad. Sci. Paris*, **136** (1903), 461.

<sup>2</sup> *Nature*, **69** (1903), 5.

<sup>3</sup> *Ber. deut. Bot. Ges.*, **22** (1904), 155.

<sup>4</sup> *Med. Record*, **72**, July 20, 1907.

<sup>5</sup> *Memoirs New York Botanical Gardens*, **4** (1908).

<sup>1</sup> *Proc. Roy. Soc., (A)* **78** (1906–07).

<sup>2</sup> *Proc. Camb. Phil. Soc.*, **16**, p. 6.

rays of radium act as a stimulus to protoplasm. Retardation of growth following an exposure to the rays is an expression of overstimulation. Acceleration of growth indicates stimulation between a minimum and an optimum point."

Fabre<sup>1</sup> also studied the effect of radium emanation in the air on the germination of seeds and the growth of plants. The spores of *Sterigmatocystis nigra* on gelatin showed a retarded growth when exposed to strong doses of the emanation, the retardation being very largely proportionate to the amount of emanation. With *Linum catharticum* the germination of the seeds and the development of the plants were increased by increasing doses up to 1.5 microcuries per two liters of air. Above this, growth was retarded. It required a larger amount of emanation to retard germination. There seemed to be, however, an appreciable increase in the number of leaves developed on plants subjected to radium rays.

Acqua<sup>2</sup> gives the results of the effect of radium rays on the germination of seeds, development of seedlings, growth of pollen tubes and movements of protoplasm in several green plants. Great differences in reaction to the rays existed between different species and even between different organs of the same species. The root system generally responded when a more or less complete arrest of development was shown, although there were many exceptions. The aerial parts proved highly resistant, showing no general response either in stems or foliage. The pollen gave diverse results, some not growing at all, while others gave no reaction to the rays. Protoplasmic movements seem to be totally unaffected.

#### RADIUM CONTENT OF THE SOILS

All samples of soil used in this investigation were obtained by putting through a sieve of six meshes to the linear inch and grinding to an impalpable powder. Strutt's<sup>3</sup> method of getting the material in solution was used. The soil was fused with four times its weight of mixed alkali carbonates, treated with water, filtered, the residue washed with sodium carbonate solution to prevent hydrolysis, and then dissolved in hydrochloric acid. After standing a month, the combined emanation from the alkaline and acid solutions was introduced into the electroscope, which was of the C. T. R. Wilson type, modified by Boltwood.<sup>4</sup>

The standard used is that suggested by Boltwood.<sup>5</sup> It depends upon the fact that in old uranium minerals, the radium present bears a constant ratio to the uranium content of the mineral. Expressed in figures, 1 gram of uranium is in radioactive equilibrium with  $3.3 \times 10^{-7}$  grams of radium. Therefore, if the percentage of uranium in such a mineral is known, the amount of radium present is also known, and the emanation obtained from this radium can be used for standardizing the electroscope providing a correction is made for the amount of emanation which naturally

escapes at ordinary temperatures from the particular sample of mineral used. This must be determined for every sample of uranium mineral used for standardization.

McCoy<sup>1</sup> and Boltwood<sup>2</sup> showed that the ratio of radium to uranium in primary minerals, such as pitchblende, was constant. Their results were confirmed by Marckwald and Russell.<sup>3</sup> Mlle. Gleditsch,<sup>4</sup> however, obtained different ratios for different samples of pitchblende and following this there was a tendency to use dilute solutions of a pure radium salt as a standard. From such solutions, however, a portion of the radium nearly always precipitates sooner or later even though barium chloride is added. Heimann and Marckwald<sup>5</sup> have recently taken the matter up again and obtained the same ratio of radium to uranium in eight samples of pitchblende from different parts of the world, the average error being less than 0.5 per cent. It seems to be preferable, therefore, to use an analyzed pitchblende as a standard rather than a solution containing a radium salt.

The apparatus used for boiling off the emanation from the pitchblende for standardizing, and from the solutions obtained from the soils, was that designed by Schlundt and Moore.<sup>6</sup> All of the well known designs of apparatus for this purpose have been tested and compared by Randall,<sup>7</sup> who finds that the two forms of apparatus used by Schlundt and Moore give the highest ionization currents and the more uniform results.

Joly<sup>8</sup> has criticized the radioactive results obtained by the present method of getting rocks and minerals in solution. He claims that it is almost impossible to get solutions perfectly limpid and the precipitated silica carries down with it some of the radium. Although this is true to some extent, fairly concordant results can be obtained in the case of rocks and minerals by its use. Much more difficulty is experienced with soils than with rocks. Hydrolysis nearly always takes place and the filtering process is both long and tedious. On standing a short time silica invariably separated from the solutions. This was filtered off and fused again with alkali carbonates, and the process repeated until clear solutions were obtained. Even with the greatest care, some of the solutions became turbid before the emanation was boiled off. In order to lessen the difficulty with the silica, some of the soils were first treated with hydrofluoric and a little sulfuric acid. After evaporation and ignition, they were fused with fusion mixture in the ordinary way. The addition of the sulfuric acid at first sight would seem to be inadvisable, but as the solutions obtained by this method remained more limpid, and as practically all soils contain both sulfates and barium, it was thought that the advantages would outweigh the disadvantages. The

<sup>1</sup> Ber. der deut. chem. Gesell., **36** (1903), 3093; Jour. Am. Chem. Soc., **27** (1905), 391.

<sup>2</sup> Phil. Mag., **9** (1905), 599.

<sup>3</sup> Ber. der deut. chem. Gesell., **44** (1911), 771.

<sup>4</sup> Le Radium, **8** (1911), 256.

<sup>5</sup> Jahrb. Rad. u. Elektron., **10** (1913), 299; Phys. Zeit., **14** (1913), 303.

<sup>6</sup> Jour. Phys. Chem., **9** (1905), 320.

<sup>7</sup> Trans. Am. Electrochem. Soc., **21** (1912).

<sup>8</sup> Phil. Mag., **22** (1911), 134.

<sup>1</sup> Compt. Rend. Soc. Biol., **70**, 187; **69**, 523; **70**, 419.

<sup>2</sup> Ann. Bot. Rome, [2] **8** (1910), 223-238.

<sup>3</sup> Proc. Roy. Soc., (A) **77** (1906), 472.

<sup>4</sup> Am. Jour. Sci., 4th Ser., **18** (1904), 97.

<sup>5</sup> Ibid., **18** (1904), 381.

results obtained, however, seemed to be low, so duplicate samples of the soils treated in this manner were fused in the ordinary way and a comparison of the results is given in Table I. In column B the results are given when the soil was treated with hydrofluoric and sulfuric acids previous to fusion. Column A gives the results when these acids were not used.

TABLE I

NO.	DEPTH	RADIUM (Gram $\times 10^{-12}$ per gram of soil)	
		A	B
1	Volusa silt loam, Naples, N. Y. ....	0"-8" 0.93	3.76
2	Volusa silt loam, Naples, N. Y. ....	8"-36" 1.10	..
3	Cecil clay, Charlotte, N. C. ....	0"-6" 1.94	0.54
4	Cecil clay, Charlotte, N. C. ....	6"-36" 0.78	..
5	Cecil sandy loam, Charlotte, N. C. ....	0"-8" 1.26	0.28
6	Cecil sandy loam, Charlotte, N. C. ....	8"-36" 1.95	1.33
7	Durham sandy loam, Ancher, N. C. ....	0"-10" 1.73	0.45
8	Durham sandy loam, Ancher, N. C. ....	10"-36" 1.66	..
9	Norfolk sandy loam, Laurinburg, N. C. ....	0"-14" 2.56	..
10	Norfolk sandy loam, Laurinburg, N. C. ....	14"-36" 2.80	..
11	Decatur clay loam, Hollywood, Ala. ....	0"-4" 2.78	..
12	Decatur clay loam, Hollywood, Ala. ....	4"-36" 1.52	1.27
13	Hagerstown loam. ....	0"-8" 2.57	1.21
14	Hagerstown loam. ....	8"-36" 0.83	1.13

When the activity was determined both with the use of sulfuric and hydrofluoric acids, and without, the results in six of the eight cases were uniformly lower when sulfuric acid was used. In the case of the Volusa silt loam soil, which is an exception, the results are so much at variance with the others that a suspicion as to the reliability of the figure  $3.76 \times 10^{-12}$  at once arose. An examination of the records showed the possibility, though not the certainty, of a contamination of this solution owing to an accident. This possibility of contamination, however, should cause the above figure to be rejected. In the case of the Hagerstown loam the two values are close, but there is no explanation for the discrepancy with the other results. A preliminary report on this work<sup>1</sup> was made before the two methods were used on the same samples. This preliminary report, therefore, does not show the variations in the results obtained.

In four cases, as shown in Table II, the soil is more active than the subsoil; in three, the reverse is true. The average activity of the soils is  $1.97 \times 10^{-12}$ , and that of the subsoils is  $1.52 \times 10^{-12}$ .

There seems to be a fairly definite relationship between the activity and the combined amounts of barium and strontium. In the majority of cases the soil or subsoil which has the highest activity also has the largest amount of barium plus strontium. The Hagerstown loam and Decatur clay loam are exceptions, the soil of the latter having a considerably larger activity than the subsoil, but carries a little less barium and strontium. The same reaction holds fairly well with the amount of sulfur present. In the Cecil clay and Durham sandy loam the amount of sulfur in the soil and subsoil in each case is the same, although the activity of the soil is greater. In only one case, however, the Decatur clay loam again, are the figures actually reversed.

This relationship between the activity of the soil

and the amount of barium, strontium and sulfur present is not surprising. Since radium has an insoluble sulfate, which precipitates with the sulfates of barium and strontium, the above results seem to indicate that radium in the soil is very largely, if not entirely, in the form of sulfate.

The number of samples tested does not justify any attempt to correlate the activities of the different soils with their productivity. Such figures would be reliable only when a much larger number of results are available.

The amount of rare earths present in the soils as determined by Failyer and Robinson<sup>1</sup> was so small that no conclusion can be drawn by a comparison of the rare earth content with the amount of activity.

TABLE II

SOIL	ACTIVITY					
	Gram $\times 10^{-12}$ per gram of material		BaO(a) and SrO(a)		SULFUR(a)	
	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil
Cecil clay. ....	1.94	0.78	0.10	0.05	0.07	0.07
Durham sandy loam. ....	1.73	1.66	0.16	0.14	0.06	0.06
Decatur clay loam. ....	2.78	1.52	0.06	0.07	0.13	0.19
Hagerstown loam. ....	2.57	0.83	0.17	0.17	0.39	0.14
Volusa silt loam. ....	0.93	1.10	0.08	0.10	0.09	0.10
Cecil sandy loam. ....	1.26	1.95	0.05	0.05	0.04	0.09
Norfolk sandy loam. ....	2.56	2.80	0.02	0.03	0.07	0.13
	13.77	10.64	0.64	0.61	0.85	0.78
Average. ....	1.97	1.52	0.09	0.09	0.12	0.11

(a) Unpublished determinations by Failyer and Robinson.

Since the activity of at least secondary rocks of the same type is fairly constant, it would seem that there ought to be more connection between the mineralogical composition of a soil and its activity. Unfortunately, the mineralogical data at my disposal are not sufficiently complete to draw any such connection. Only the potash feldspars and micas were determined quantitatively—the others qualitatively, and as most rock-forming minerals occur in all soils, the qualitative results showed no significance. Monazite occurs in some soils, but was not specially looked for in the twelve samples examined and was not listed among the minerals in any of them.

#### THORIUM CONTENT OF THE SOILS

After experimenting with other methods,<sup>2</sup> that used by Joly for determining the thorium of rocks and minerals was finally decided on. Fig. 1 shows the apparatus. *A* is the flask containing the solution of the material to be tested. In this case it contained either the acid or alkaline solution obtained from fusion of the soil with fusion mixture. *B* is a drying tube containing at one end calcium chloride and at the other, phosphorus pentoxide, the two separated by a plug of glass wool. *C* is a tube of small diameter, with a bulb at the top and dipping at the bottom into a fairly heavy oil. *D* is the electroscope and at *E* there is a needle valve (not shown).

The flask *A* is first disconnected from the apparatus and the solution boiled vigorously for ten minutes. This is to get rid of the radium emanation. Thorium emanation is boiled off, of course, at the same time,

<sup>1</sup> Private communication.

<sup>2</sup> I desire to thank Mr. W. O. Robinson of the Bureau of Soils for valuable assistance in this part of the work.

but as the half-life period of the radium emanation is 4.8 days and that of the thorium emanation 54 seconds, the latter is very rapidly and the former very slowly reformed. Hence any active gas which is found in the solution after the ten minutes' boiling and during the progress of the experiment can be considered as thorium and not radium emanation.

The flask *A* is now connected with *B* and gently boiled while a constant current of air is drawn through the whole apparatus in the direction of the electroscope. This current can be controlled by the needle valve. *C* assists in regulating the pressure in the apparatus. If the boiling is steady the leaf does not vibrate and readings are readily made.

If the air is pulled too rapidly through the apparatus, the emanation is too much diluted; if too slowly, a considerable portion of the emanation decays before it reaches the electroscope. A maximum effect can therefore only be obtained by trial.

The activity of any given soil is, of course, the sum of the activities of the acid and alkaline solutions obtained from that soil.

The natural leak of the electroscope under the experimental conditions is obtained by substituting for *A*, a similar flask containing distilled water and boiling as already described. It was noted that if air was

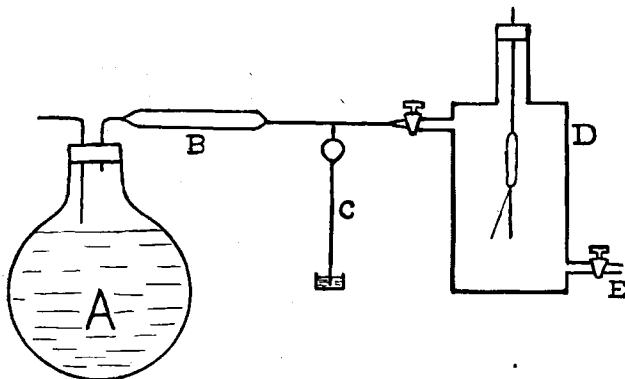


FIG. I

passed over calcium chloride and phosphorus pentoxide and then through the electroscope, the leak was smaller than when no air was passed. Also, if the leaf was steady and air was then passed, the leaf slowly rose during a period of ten minutes and usually over about five small scale divisions. This result is probably closely connected with the observations made by Schlundt and Moore<sup>1</sup> in a somewhat similar case, and discussed by Randall<sup>2</sup> in a later paper. Readings were made only after the maximum point was reached.

The electroscope was standardized by using an acid solution of a thorium mineral in which the disintegration products are in equilibrium. In the present case an analyzed specimen of thorianite was used. A flask containing distilled water, to which a certain volume of the standard thorianite solution was added, was substituted for *A* after first boiling to get rid of the radium emanation. The effect on the electroscope of the emanation from a known quantity of thorium

could therefore be observed and compared with the results obtained from the soil solutions under similar conditions after the leak was deducted in each case.

In order to test the accuracy of the method, different thorianite solutions of known strength were used and the results compared. For example, 10 cc. containing 0.0021 gram thorium metal gave (leak deducted) a drop of twelve divisions per hour. 40 cc. of the same solutions gave a drop of 47.8 divisions per hour.

The results obtained are shown in Table III.

TABLE III

	Depth	Thorium gram $\times 10^{-5}$ per gram of soil
Durham sandy loam.....	10"-36"	5.4
Norfolk sandy loam.....	0"-14"	3.3
Decatur clay loam.....	4"-36"	5.6
Hagerstown loam.....	8"-36"	4.02
York silt loam.....	0"-8"	4.37

The results are not numerous enough to justify any conclusions as regards the relative amounts of thorium in the soils and subsoils. Comparing them with Joly's results on rocks, they seem to indicate that soils contain more thorium than most rocks, the average of the above results being much higher than the average of Joly's results, *viz.*,  $1.58 \times 10^{-5}$  gram per gram of rock. The figures are also higher than those obtained by Blanc for Roman soils.<sup>1</sup>

Strutt<sup>2</sup> has shown that the amount of radium in the earth's crust is more than sufficient to account for its internal heat. He did not take into account the thorium present. Averaging the amount of radium in the soils and subsoils and reducing this back to the uranium content, it can readily be seen that the amount of uranium present is about 10 per cent that of the thorium. While it is difficult to state just to what extent the thorium assists in maintaining the earth's internal heat, the effect must at least be appreciable.

The small variation in the amount of thorium in the five samples tested is noteworthy.

My thanks are due to Dr. Frank K. Cameron, Chief of the Division of Physical and Chemical Investigations, Bureau of Soils, for many courtesies extended during the progress of this investigation.

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## PARTIAL AND INTERMITTENT COMBUSTION OF GAS

By E. E. SOMERMEIER

Received November 21, 1913

### COMBUSTIBLE, INFLAMMABLE AND EXPLOSIVE MIXTURES

A *combustible mixture* is usually defined as a mixture of a composition such that if any part of it is raised to its ignition temperature a reaction between the components will become self-sustaining and will extend to all parts of the mixture; an *inflammable mixture* as a mixture of a composition such that if it is ignited at any point a visible flame will spread throughout the entire mixture; an *explosive mixture* as a mixture of a composition such that if a portion of it is raised to its ignition temperature an explosive reaction will

<sup>1</sup> Trans. Am. Electrochem. Soc., 8 (1905), 292.

<sup>2</sup> Ibid., 21 (1912), 463.

<sup>1</sup> Phil. Mag., 18 (1909), 146-148.

<sup>2</sup> Proc. Roy. Soc., (A) 77 (1906), 472-485.