for titanium and thorium; titanium was found, but no thorium. The weighings showed that the residue was composed of silica and titanium in some form, and in about equal amounts in this particular case. Furthermore, analyses made on filtered and unfiltered solutions showed that a large part of the titanium residue appears in the final thorium dioxide thus giving an erroneously high value.

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[CONTRIBUTION FROM KENT CHEMICAL LABORATORY, UNIVERSITY OF CHICAGO.]

THE GAMMA RAY ACTIVITY OF THORIUM D.

BY HERBERT N. McCOY AND G. H. CARTLEDGE.

Received September 9, 1918.

Eve,[1] and McCoy and Henderson[2] have independently determined the quantity of thorium, in equilibrium with its products, which has the same γ activity as one g. radium in equilibrium. Their results were 6.9×10^6 g. and 6.85×10^6 g., respectively. Furthermore, McCoy and Henderson have determined the ratio Ms : Th, the mesothorium being expressed in terms of the weight of radium giving the same γ activity, *i. e.*, one mg. Ms means the amount of mesothorium whose activity equals that of one mg. radium one month after preparation. The value found for this ratio is given as 0.52×10^{-7}. The reciprocal ratio 19.0×10^6 is the number of grams of thorium necessary to furnish 1 g. mesothorium. Therefore, mesothorium accounts for only 6.9/19.0 or 36.3% of the total γ activity of the thorium series, although thorium D is the only other thorium product which emits a γ radiation.

It seemed, therefore, to be a matter of interest to determine independently the Th D:Th ratio in order to ascertain whether the combined mesothorium and thorium D activities would give the total γ activity.

First Procedure.—A large quantity of radiothorium was allowed to accumulate in a very active mesothorium preparation and then separated out with aluminum hydroxide, the precipitate being dissolved and reprecipitated in order to remove the mesothorium completely. The precipitate was then dissolved in hydrochloric acid and allowed to stand for over a month so as to reach equilibrium between the radiothorium and thorium X.

An aliquot of the solution was then diluted to 150 cc. in a 250 cc. Erlenmeyer flask, some barium chloride added, and then the flask closed for several days to insure the presence in the solution of the maximum amounts of thorium B, C and D; 50 mg. each of lead and mercury as chlorides were then added, the acidity reduced by neutralization to the proper point

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[1] *Am. J. Sci.*, **22**, 477 (1906).

[2] THIS JOURNAL, **40**, 1316 (1918).

for the precipitation of lead sulfide, and then hydrogen sulfide passed into the cold solution to saturation. When the precipitation was complete 20 mg. additional of lead was added in quite dilute solution and zero time was counted from this point. The mixture was rapidly filtered and washed with cold water faintly acidified and saturated with hydrogen sulfide. The precipitate was dried on the filter and its γ-activity measured under conditions identical with those described by Henderson, using 0.355 mg. radium as the standard.

Another aliquot portion of the original radiothorium solution was largely diluted in 3 stages until a convenient sample containing the equivalent of about 0.25 g. thorium was obtained. On this sample emanation determinations were made by the method described in the preceding paper, using as standards in different cases solutions of thorianite and monazite of known thorium content. By a simple calculation these measurements give the thorium X with which the thorium X would be in radioactive equilibrium.

Second Procedure.—Another scheme was used in getting the activity of the thorium D, in order to have a check on the sulfide precipitation method. A similar radiothorium precipitate was placed in a small crystallizing dish and a cover glass sealed on so that all the emanation escaping from the precipitate was held back in the dish. In order to introduce a correction for the distribution of the active deposit over the walls of the vessel the activity was noted immediately on closing it and then again several days later when equilibrium had been attained. The data showed that about 10–15% of the emanation diffused out of the precipitate, which had not been ignited. The small radium tube was then placed in an exactly similar dish and the activity measured as the tube was progressively elevated inside the dish. In this manner, by comparison, a correction could be made to compensate for the fact that a considerable portion of the activity was spread over the walls of the dish. It was impossible, however, to correct for the fact that the aluminum hydroxide was present in lumps which did not lie flat on the bottom of the dish, and for this reason it was expected that less activity would be obtained than should be.

After the activity had been determined, the precipitate was dissolved in hydrochloric acid, adding some barium chloride and filtering the solution into a graduated flask; the paper was thoroughly washed in dil. hydrochloric acid until it showed only a slight α-activity. Aliquots of this solution were abundantly diluted and emanation determinations made as before.

Table I gives at a glance the results of the determinations; Series A was made on one lot of Rt and Series B on another:

TABLE I.

	Method for Th D.	Thorium standard.	Thorium equivalent.	Th D.	Th D : Th.
		Series A.			
1......	Sulfide	Thorianite	153.4 g.	0.144×10^{-4} g.	0.94×10^{-7}
2......	Sulfide	Thorianite	844	0.824×10^{-4}	0.98×10^{-7}
		Series B.			
1......	Accumulation in $Al(OH)_3$	Monazite	5802	5.18×10^{-4}	0.89×10^{-7}
2......	Sulfide	Monazite	3868	3.81×10^{-4}	0.98×10^{-7}
				Mean (balanced)	0.956×10^{-7}

In balancing the mean, Expt. B 1 is given only half value because of the known error which would make the ratio for that experiment too low. The results of the several tests are seen to agree as well as could be expected.

Taking the reciprocal of McCoy and Henderson's[1] value for the thorium equivalent of one g. radium, 8.85×6, we get 1.46×10^{-7} g. as the weight of radium having γ-ray activity equal to one g. thorium in equilibrium. If we combine 0.52×10^{-7} (McCoy and Henderson's Ms : Th ratio) with 0.96×10^{-7} (the Th D : Th ratio here reported) we get 1.48×10^{-7} g. as the radium equivalent of the γ-products of thorium determined separately. It is clear that this figure agrees well within experimental error with that for the tatal γ-activity of the thorium minerals.

It is interesting to note that thorium D furnishes 1.81 as much γ-activity as the mesothorium in equilibrium with the same amount of thorium. Taking account of the fact that only 35% of the thorium disintegrates into thorium D, this means that *atom for atom* thorium D contributes 5.17 times as much γ-activity as mesothorium. It is not possible to pursue the discussion very far, since we know so little regarding the origin of the γ-rays; but it is very suggestive to note that for these rays there is apparently the same kind of relationship between activity and rate of decay as has been found to exist for the α-rays, and at least qualitatively also for the β-rays. It is a safe assumption that thorium D furnishes the high speed β-particles emitted from a mixture of thorium C and thorium D (velocity 0.93–0.95 that of light), and a comparison of these speeds with the fastest group from mesothorium II (0.66) may constitute an additional bit of evidence indicating a genetic, or at least a very intimate, relationship between the β- and γ-radiations.

Knowledge of the γ-activity of thorium together with the periods of mesothorium and radiothorium, allows as to calculate the rate of change with time of the total γ-ray activity of a sample of mesothorium. The immediate product of mesothorium is mesothorium II (period 6.2 hours). After 3 days new mesothorium will contain its maximum of

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[1] THIS JOURNAL, 40, 1318 (1918).

mesothorium II. If we call its γ-activity unity at this time, its activity, A, after an interval, t, is given by the equation

$$A = f_1 + 1.81 f_2,$$

where, at time t, f_1 is the fraction of the initial amount of mesothorium and f_2 is the fraction of the amount of radiothorium that would be in equilibrium with the initial amount of mesothorium in a mineral. On account of the short periods of all products intervening between radiothorium and thorium D, we may make the calculation as if radiothorium itself gave the γ-rays produced by thorium. Taking the period of mesothorium as 5.5 years[1] and that of radiothorium as 737 days,[2] we get the results shown in the following table:

TABLE II.

The Change of Gamma Ray Activity of Mesothorium with Time.

Time in years.	Ms I.	Th D.	Total.
0	1.000	0.000	1.000
1	0.881	0.489	1.370
2	0.777	0.781	1.558
3	0.685	0.935	1.620
4	0.604	1.000	1.604
5	0.532	1.007	1.538
6	0.469	0.973	1.442
7	0.413	0.921	1.334
8	0.364	0.855	1.219
9	0.321	0.786	1.107
10	0.283	0.715	0.998

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF MCGILL UNIVERSITY.]

AUTOMATIC VARIATION OF GAS PRESSURE AND ITS APPLICATION TO A VACUUM PUMP, CIRCULATION OF GASES, MAGNETIC STIRRER.

BY O. MAASS.

Received October 22, 1918.

A Geissler water suction pump can be used as a convenient source of energy for such continuous processes as the stirring of liquids, the circulation of gases and the manipulation of mercury vacuum pumps. The first apparatus about to be described may be looked upon as the control which makes the above mentioned applications practicable. By means of this device the pressure established by a Geissler, or any other suction pump, can be automatically varied between definite limits and the period of each variation can be adjusted to any desired length of time.

The apparatus is represented by Fig. 1. It is not essential that the various parts be made exactly proportional to the sizes indicated by the

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[1] McCoy and Ross, THIS JOURNAL, 29, 1709 (1907).

[2] Blanc, *Physik. Z.*, 8, 321 (1907).