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wave-length of maximum radiation at temperature T , and which is by Wien's displacement-law a universal constant, suffices and is required, in conjunction with the other recognized universal constants of nature, to establish an absolute system of fundamental units of mass, length, and time; its dimensions are therefore not expressible in terms of those of other universal constants, and it must have an independent existence of its own.

Cambridge, July 4, 1910.

XXXIII. *The Amount of Thorium in Sedimentary Rocks.*

II. *Arenaceous and Argillaceous Rocks.* By J. JOLY, F.R.S.*

IN this paper the results of thorium measurements applied to detrital sedimentary rocks are given. The method used has been described in previous papers (Phil. Mag. May and July 1909). The rock is ground to a fine powder and passed through a sieve of 100 mesh to the inch. It is then mixed with from $2\frac{1}{2}$ to $3\frac{1}{2}$ times its weight of mixed carbonates (thorium-free) and fused in a closed platinum crucible till effervescence ceases. The melt is thrown while fluid into a platinum dish, and what remains in the crucible chilled and broken out. The fragments are then ground to a coarse powder in a mortar and leached in hot water over the water-bath. After standing all night the cold supernatant liquid is removed by decantation. The residue is ground to a paste in the mortar; about 100 c.c. of water added, and finally 80 to 100 c.c. of strong HCl (thorium-free) rapidly stirred in. The final solution is seldom quite limpid. I have not found, however, that the presence of a small amount of precipitate interferes with the liberation of the emanation. Known quantities of a thorite solution added to such rock solutions, or mixed with the rock-powder before its decomposition in the crucible, produce the same effect upon the electroscope, sensibly, as do limpid aqueous solutions containing the same quantity of thorium.

The alkaline solution, which is poured off the insoluble part of the melt, contains very little thorium; in most cases none that can be detected with certainty under the conditions of the experiment, whether the solution is acidified or not. The examination of the alkaline solutions has, therefore, not been carried out in every case. The investigation is tedious and generally indecisive, many hours of

* Communicated by the Author.

observation being required (the electroscope being observed when the solution is alternately in ebullition and at rest) to detect with certainty a change amounting to a small fraction of a scale-division per hour. It may, I believe, be accepted as certain that what error may arise from confining the examination to the acid solution is very small, not more than a few per cent.

Table I. contains only arenaceous and conglomeratic rocks; mainly sandstones of various characters and ages. The greensandstone is, of course, a rock differing from the others in mode of origin. The sandstones are for the greater part constituted of residual quartz or of quartz and felspar, derived from older rocks. As the quartz is, itself, probably of very low thorium content, it is not surprising that these rocks are generally poor in thorium when contrasted with many igneous rocks. They are, however, much more radioactive than the calcareous rocks, in which, in most cases, the thorium emanation cannot be detected even when considerably larger quantities of rock are used in the experiments (Phil. Mag. July 1910).

TABLE I.

		THORIUM, grm. $\times 10^{-5}$ per gram.
1.	Greensandstone. Werl, Westphalia. Cretaceous. (15)	0.20
2.	Sandstone. Obernkirchen, Teutoburger Wald. Wealden. (15)	0.30
3.	„ Vlotho, Westphalia. Keuper. (10)	1.14
	„ „ „ „ (17)	1.02
4.	„ (red). Heidelberg, Baden. Bunter. (20)	0.12
5.	„ Remiremont, Vosges. „ (20)	0.91
6.	„ Westhofen, Westphalia. Carboniferous. (15)	0.74
7.	„ Freienohl, „ „ (15)	0.61
8.	Quartz Conglomerate. Donebate, Co. Dublin. Old Red Sandstone. (14).	0.33
9.	Grauwacke-Quartzite. Allrode, Harz. Lower Devonian. (16)	0.74
10.	Quartzite (Taunus). Schlangenbad, Nassau. Lower Devonian. (15) ...	0.34
11.	Sandstone (red). Loch Torridon, Scotland. Torridonian. (19)	0.27
12.	Quartzite-schist. Western Spessart. Archæan (?). (17)	0.32
Mean.....		<u>0.54</u>

In the above table the weight in grams of material dealt with is given in brackets.

The finer-grained detrital rocks—slates and shales—are, in contradistinction to the sandstones, derived from the more soluble and friable constituents of the primary rocks: such constituents as are reduced by denudative actions most readily to small dimensions. They are on this account precipitated furthest from the land, and represent materials

from which the more resistant grains have been sorted by gravity. As the latter are generally quartz or felspar, and hence substances which in most cases are poor in radioactive constituents, it is to be expected that the argillaceous group of detrital rocks would reveal a more considerable richness in thorium than the arenaceous. Table II. shows that this is, indeed, the case. Comparison with Table I. shows that only two of the sandstones, Nos. 3 and 5, have quantities of thorium equal to those generally prevailing in the argillites. A few surface materials of recent date are included in the table. These possess the same degree of richness in thorium.

TABLE II.

	THORIUM. grm. $\times 10^{-5}$ per gram.
1. Brick-Earth. Rosslare, Co. Wexford. Recent. (18).....	1.13
2. Clay. Friesdorf, Bonn. Recent. (15).....	0.91
3. Loess. Heidelberg. Pleistocene. (18).....	1.04
4. Bundnerschiefer (folded). Piz Ot, Ober Engadin. Jurassic. (15)	0.91
5. Schiste Lustré. Simplon Tunnel. Jurassic. (15)	1.04
6. Red Marl. Ballymurphy, Co. Antrim. Keuper. (12)	0.14
7. Roofing Slate. Wissenbach, Nassau. Upper Devonian. (15)	1.12
8. " " Caub, on the Rhine. " " (16)	1.40
9. Slate. Valentia, Co. Kerry. Devonian. (15)	1.30
10. " (dark Killas). Cornwall. " (15)	1.16
11. Grauwacke. Wipperfurth. Rhen-Prussia. Middle Devonian. (15)...	2.40
12. Clay-Slate. Mädesprung, Harz. Lower Devonian. (15).....	0.87
13. " " Weilburg, Nassau. Devonian. (14)	1.17
14. Slate (green). Kingscourt, Co. Cavan. Silurian. (15)	1.30
15. Phyllite (green). Lösnitz, Saxony. Lower Silurian (?). (15)	1.94
16. Shale (black). Moffat, Scotland. Silurian & Ordovician. (10)	1.00
17. Roofing Slate. Penrhyn, N. Wales. Cambrian. (16)	0.96
18. Slate (Oldhamia). Bray Head, Co. Wicklow. Cambrian (?). (15)	0.82
Mean.....	<u>1.14</u>

The highest result obtained, the Grauwacke No. 11, was checked by a second examination of the preparation, when the first result was almost exactly confirmed. The lowest, the Keuper Marl No. 6, refers to a material deposited under continental conditions, probably in inland waters, and is therefore of somewhat different character to the others. It contains very little calcium carbonate. Excluding this material, the general mean for the argillaceous group rises to 1.20×10^{-5} gram thorium per gram. It will be noticed that there is a remarkable sameness in the foregoing results: fifteen rocks vary between the limits 0.82 and 1.40.

The results which I have already published (Phil. Mag. July 1909), when dealing with the St. Gothard rocks, are

reproduced below. These rocks are regarded as for the greater part of sedimentary origin, although highly altered, and of Mesozoic age. Some are calcareous, some quartzose. It is, therefore, difficult to classify them with the materials grouped in the foregoing tables. The general means are, for the same reason, somewhat misleading. After subtracting from those of the Usernmulde two rocks of calcareous character, the mean for the Usernmulde (9 rocks) is 1.10×10^{-5} . The mean for the Tessinmulde exclusive of the dolomite (7 rocks) 0.53×10^{-5} . The first is in close agreement with that of Table II. : the second is too low ; but the origin of some of the more basic rocks in the Tessinmulde is sufficiently doubtful to deprive the result of much of its weight.

TABLE III.

<i>Usernmulde.</i>		THORIUM.
		gram $\times 10^{-5}$ per gram.
1.	Usern gneiss. (11.14).....	1.4
2.	Quartz-schist. (9.6)	1.1
3.	Black lustrous slate. (8.0)	0.2
4.	Grey cipolin. (9.47)	0.4
5.	Quartzitic cipolin. (11.36)	0.4
6.	Black lustrous slate. (10.66)	1.0
7.	Usern gneiss. (9.1)	1.3
8.	Sericite-schist. (8.0)	1.7
9.	Black lustrous schist (7.84).....	2.4
10.	Quartz-mica. (8.16)	<0.3
11.	Usern mica-gneiss. (8.38).....	0.5
<i>Tessinmulde.</i>		
12.	Hornblende-schist. (8.64).....	<0.3
13.	Calcareous mica-schist. (9.02)	0.5
14.	Hornblende „ „ (7.99)	0.6
15.	Amphibole garnet mica-schist. (8.38).....	1.0
16.	Quartz-schist (9.5)	<0.3
17.	Amphibole mica-schist. (9.17)	0.5
18.	Quartz „ „ (8.8)	0.5
19.	Dolomite. (8.66)	0.4

If we assume that the results on sedimentary rocks, recorded in this and the previous paper on the subject, may be accepted as approximately representative, we find that whereas the calcareous rocks show a small, almost negligible, quantity of thorium, the detrital sediments contain easily measured amounts of thorium in almost every case ; the argillaceous group having almost double the amount contained in the

arenaceous group. The former may be taken as approximating to 1.3×10^{-5} , making allowance for some small amount in the alkaline solutions; the latter to 0.6×10^{-5} gram per gram.

Accepting the estimate cited by F. W. Clarke ("A Preliminary Study of Chemical Denudation," Smithsonian Miscellaneous Collections, vol. lvi. No. 5, June 1910) that the calcareous rocks compose 5 per cent., the arenaceous 15 per cent., and the argillaceous 80 per cent. of the sedimentaries, my results on thorium measurements (assuming 0.06×10^{-5} to represent the mean for the calcareous rocks) give for the sedimentary rocks generally a thorium content of 1.16×10^{-5} gram per gram.

July 11th, 1910.

XXXIV. *The Magnetic Balance of MM. P. Curie and C. Cheneveau.* By C. CHENEVEAU, with an Appendix by A. C. JOLLEY*.

THIS apparatus is intended for the measurement of the coefficient of specific magnetization, or the susceptibility or permeability of feebly paramagnetic or diamagnetic bodies †.

Principle and Theory of the Apparatus.

The body whose magnetic properties are to be determined is suspended from one end of the arm of a torsion balance. By means of this balance the force is measured, which is experienced by the body when placed in a non-uniform magnetic field, produced by a permanent magnet whose lines of force cross the space occupied by the body. The method of calculating this force will first be briefly indicated.

Suppose that the body is placed at a point O in a field of direction Oy and of intensity H_y . The force f which tends to move the body will be normal to the direction of the field,

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† The coefficient of specific magnetization K is the ratio of the intensity of magnetization $\mathcal{I} = \frac{M}{m}$ (where M is the magnetic moment and m the mass of the body) to the magnetizing field. The magnetic susceptibility $\kappa = K\Delta$, where Δ is the density of the body, and the permeability is obtained from the susceptibility by the relation $\mu = 1 + 4\pi\kappa$.