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THE DESIGN OF A SIMPLE URANIUM-THORIUM DISCRIMINATOR FOR WEAKLY ACTIVE ORES CONTAINING LESS THAN 1% U_3O_8 EQUIVALENT

Part II.—Design, Use and Testing of Discriminator

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1. Basis of the Design

In Part I of this communication,[1] a critical analysis was made of the measurements of beta and gamma activity from various thicknesses of samples containing around 0.1% of the metals uranium and thorium in approximate equilibrium with their decay products. This analysis indicated the feasibility of using the following ratios (cf. Fig. 1) for good discrimination between uranium and thorium:

(1) $\frac{1}{R_4}$,

where $R_4 = \dfrac{\text{Near saturation gamma ray counts from (8 g/cm.}^2\text{)}}{\text{Saturation beta counts}}$

(2) $\frac{1}{R_3}$,

where $R_3 = \dfrac{\text{Gamma slope at 4 g./cm.}^2}{\text{Origin (beta + gamma) slope}} \times 100$

Of these two ratios, the second one gives the better discrimination, but this is offset by the fact that the first ratio can be obtained from one measurement only of the beta and gamma counts respectively whereas the second requires at least three measurements of comparatively higher accuracy, each with a different sample thickness. It is therefore preferable to use the first ratio as the basis of the design of a simple discriminator. On

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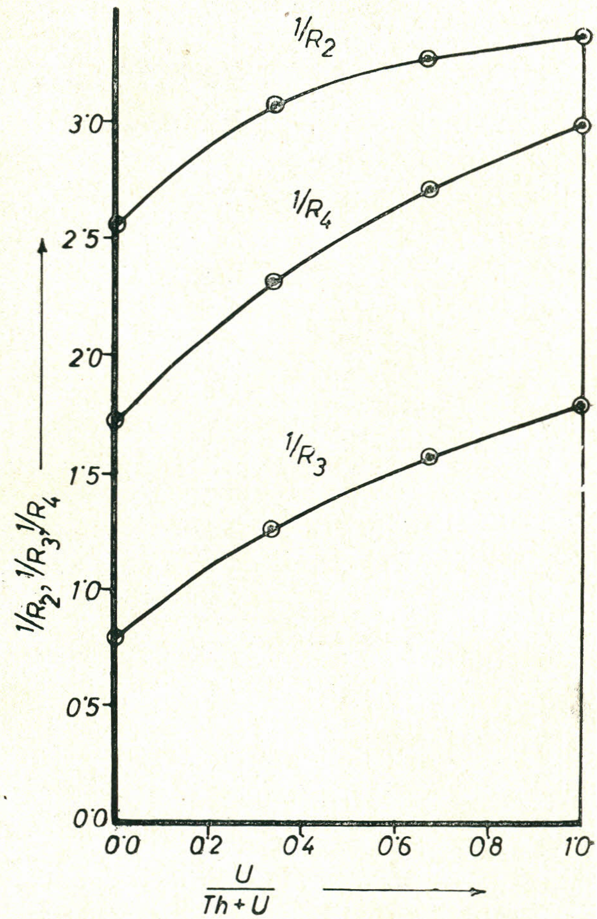

Fig. 1.—Previously reported graphs for the values of 0.1/R2, 1/R3 and 1/R4, for different ratios of uranium/(uranium + thorium).

this basis, we require a sample thickness corresponding to about 8 g./cm.^{2}, which would correspond to a thickness of a little over 5 cms. for a mineral sample with an apperant density of 1.5 g./ml. in the powdered state (approximately 2.5 as solid rock).

2. The Dimensions of the Sample Container

In the measurements described in Part I, the counter was placed above a slab of the sample under test, and this method is desirable when the effect of varying sample thickness is being studied. However, this is not the most efficient arrangement in respect of counts/g. of material, because only a small fraction of the total solid angle (4π) is utilized. The use of a simple double-walled cylindrical container as shown in Fig. 2 is a convenient way of increasing the efficiency very considerably.

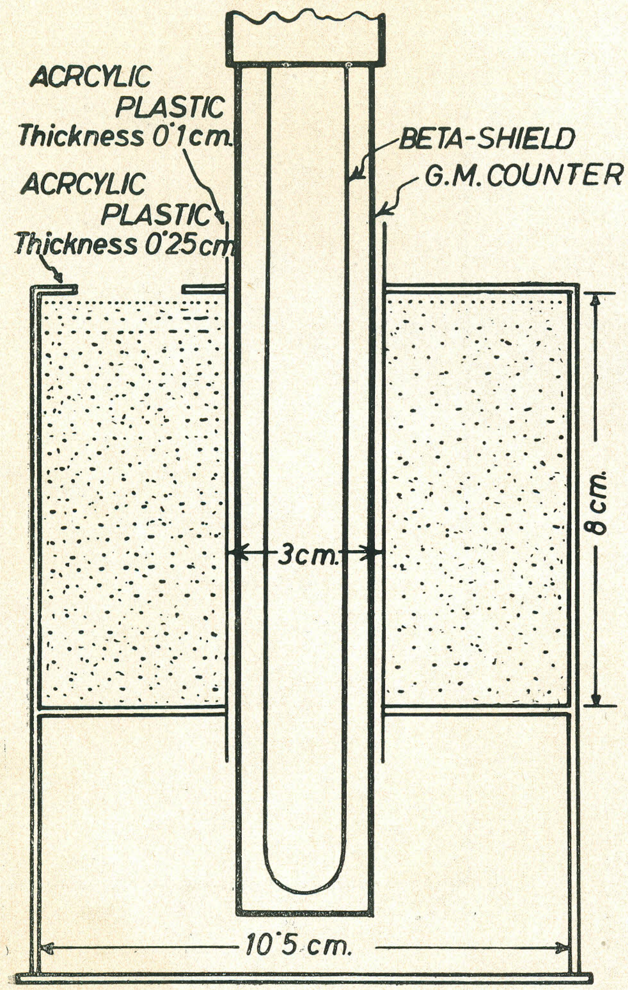

Fig. 2.—Cylindrical discriminator: diagrammatic sketch.

Now $1/R_4$ is the ratio of the saturation beta counts to the gamma counts from a sample of thickness of the order of 8 g./cm^2. Both these quantities can be obtained if we use an annular cylindrical container with an inner radius R_i just greater than that of the tube counter (with beta-shield), and outer radius R_o of 6 to 8 cms., which will give a sample thickness of about 5 cms. corresponding to about 8 g./cm^2.

Two different counting systems were tried out, one with a scaler unit in conjunction with a probe unit and H.T. power supply, and the other with a ratemeter circuit. Two slightly different cylindrical containers were made out of transparent acrylic plastic 2.5 mm. thick for use with the two counters. The dimensions of one of them are shown in the sketch of Fig. 2, from which it is seen that the counter tube collects radiations from a solid angle somewhere around 2π i.e. one half of the maximum possible. Of course there will be a relative bias against the gammas coming from near the circumference of the container, because of the smaller solid angle subtended at the counter. This will tend to give larger values for $1/R_4$ than with the flat samples.

3. Use of Discriminator

After noting the background counts, the (extra) counts obtained when the unshielded counter tube is inserted in the central hole will correspond essentially to the saturation beta counts from the layer within 1 cm. of the inner wall, because (a) the contribution from the gamma counts is small, and (b) the small thickness of the inner wall of the container is equivalent to about 0.05 g./cm.^{2}, which is considerably smaller than the thickness (0.3 g./cm^2.) required to produce a reduction of $1/e$ in the beta counting rate from various samples containing uranium and thorium. When the beta-shield tube is inserted between the counter tube and the cylindrical hole in the sample container, only the gamma counts from the whole mass of the sample are recorded. Thus two measurements, with and without the beta shield tube, give estimates of the saturation beta counts and the gamma counts from a thickness of about 8 g./cm.^{2}, and their ratio directly gives the quantity corresponding to $1/R_4$. It will differ from the $1/R._4$ as determined from a flat sample (cf. Part I) be cause while the beta effective part of the annular sa mple is only slightly separated from the counter, g iving a large effective solid angle for the beta c ounts, this solid angle will be considerably smaller for the gamma counts.

This cylindrical type of discriminator was first tested with two standard preparations containing

0.5% thorium nitrate and 0.5% uranyl acetate, respectively, in calcium carbonate. The mixing was done by successive dilutions in solid phase and the weight of the sample in both cases was about 500 g. The actual counts obtained with a G.M. Counter-FHZ 69 and scaler are given in Table 1, and are seen to be 2 to 3 times those previously obtained with the flat sample. The value of R_4 is found to be 0.31 for thorium and only 0.01 in case of uranium, more or less as expected.

Since it is known that natural radio-active materials are very nearly in equilibrium, whereas our standards may be in equilibrium with only the first two or three decay products, samples containing 10% and 1% low-grade pitchblende (having 7% uranium) were next tested. The value of R_4 was also determined for a mixture containing thorium (0.05% thorium mixture) and uranium (0.05% uranium from pitchblende) in equal proportions. These results are also shown in Table 1.

TABLE 1.

Sample	Excess gamma counts/min. (a)	Excess beta counts/min. (b)	$R_4 = (a)/(b)$	$1/R_4 = (b)/(a)$
0.5% Thorium nitrate ..	25.2 ± 0.2	82 ± 2	0.31	3.2
0.5% Uranyl acetate ..	4.5 ± 0.8	540 ± 8	0.01	120
10% Low grade pitchblende (i.e. 0.7% uranium)	200 ± 3	1500 ± 15	0.13	7.5
1% Pitchblende (i.e. 0.07% uranium) ..	19.1 ± 1	147 ± 5	0.13	7.7
50-50 mixture of 0.05% thorium with 0.05% uranium from pitchblende ..	22.0 ± 1.3	118 ± 3	0.18	5.4

TABLE 2.

Sample	Excess gamma counts/min. (a)	Excess beta counts/min. (b)	$R_4 = (a)/(b)$	$1/R_4 = (b)/(a)$
0.5% Thorium nitrate	61.0 ± 3	122 ± 10	0.50	2.0
,, ,, ,, ..	53.7 ± 3	169 ± 10	0.32	3.1
,, ,, ,, ..	49.8 ± 3	156 ± 10	0.32	3.1
Mean	54.8 ± 6	149 ± 10	0.37	2.7
0.5% Uranyl nitrate	18.9 ± 1	1610 ± 20	0.012	85
,, ,, ,, ..	19.5 ± 1	1709 ± 20	0.011	85
Mean ..	19.2 ± 2	1660 ± 50	0.012	85

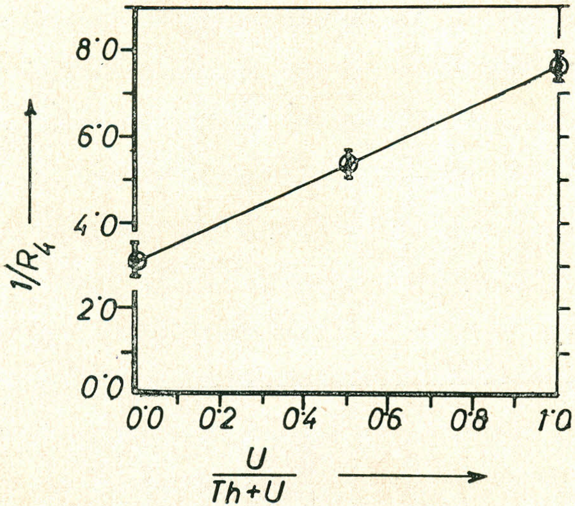

Fig. 3.—Graph showing the value of $1/R_4$ for different ratios of uranium/(uranium + thorium) obtained with the cylindrical discriminator of Fig. 2.

Another series of observations was taken using a G. M. counter in conjunction with a Labgear Laboratory Ratemeter type D.4101, the inner and outer radii of the discriminator made for this work being 3.8 cms. and 13 cms. respectively. For each measurement, the readings of the ratemeter were recorded every half minute for about 5 to 10 minutes and then the mean of these readings was obtained. Table 2 shows the actual counts. The value of R_4 in this case is found to be 0.37 for thorium and 0.012 for uranium. These values are slightly higher than those from the previous set of readings, cf. Table 1.

4. Discussion

Figure 3 shows the graph between $1/R_4$ and the ratio uranium to (uranium + thorium) in a mixture of uranium (in equilibrium) and thorium. The graph is nearly linear. Comparing the observations for pitchblende with chemically separated uranium, it is noted that while the beta counts are not greatly influenced by the equilibrium products, the gamma counts are increased manifold. Thus, any considerable lack of equilibrium will tend to increase the value of $1/R_4$ and therefore lead to an underestimate of thorium in relation to uranium.

Reference

1. K. Husain, M. Azeem N. Ahmed and M. M. Qurashi, Pakistan J. Sci. Ind. Research, **1**, 273 (1958).