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Časopis pro pěstování matematiky a fysiky, Vol. 66 (1937), No. 1, 63--66

Persistent URL: http://dml.cz/dmlcz/122898

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The Disintegration Constant of Thorium and the Branching Ratio of Thorium C.

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(Received July 7, 1936.)

In calculating the age of radioactive minerals there have been used two values of the disintegration constant of thorium. One of these values is the original determination by Geiger and Rutherford[1]) while the second value was deduced by Kirsch[2]) from data by Hönigschmidt in the chemical analysis of a certain specimen of Ceylon thorianite whose lead content had the atomic weight nearly the same as that of ordinary lead. These two values of the constant differ by 30 percent. Geiger and Rutherford counted scintillations produced by the α-particles from specimens of thorium oxide prepared from the mineral thorite. Kirsch's determination is based on the fact that if the lead in Hönigschmidt's thorianite is considered as a mixture of radium G and thorium D (and perhaps of some ordinary lead) the ratio $\lambda_{th} : \lambda_u$ is very approximately equal to the ratio of the mass of thorium lead per gram of thorium in the mineral to the mass uranium lead per gram of uranium. Thus λ_{th} can be calculated in terms of λ_u. Other values of the constant obtained by various methods have also been reported and these lie between the above two values. Most recent value was obtained by Fesefeldt[3]) using thorium oxide from monazite sand and this was found to check Geiger-Rutherford's value.

A critique of the values of the constant has been given by one of us in the Age of the Earth.[4]) Suffice it to say here that the Ceylon thorianites, being found in geological river beds, have all the appearances of having been acted on by external agents and it is very doubtful that they can be considered as unaltered primary mine-

[1]) Geiger H.-Rutherford E., Phil. Mag. (6) **20** (1910), 691—698.
[2]) Kirsch G., Akad. Wiss. Wien. Ber. **131**, IIa (1922), 551—568.
[3]) Fesefeldt H., Zeitschr. f. Phys. **86** (1933), 605—610.
[4]) Knopf et al., Age of the Earth, N. R. C. Bulletin No. **80**.

rals. For these and other reasons Kirsch's value seems questionable. It is to be added that ionium correction has not been made in the various determinations of the constant and in some cases the history of the oxide used was not known.

In the case of Geiger-Rutherford's determination the oxide was prepared from the thorite and its history was known completely except for the ionium, the correction being neglected because the amount of uranium present in the mineral was found to be very small. Their method was direct and indicates that the result should be fairly accurate except for the ionium correction and the relatively small number of counts made. In our experiments we have also chosen the thorite and the analysis of the mineral and preparation of the oxide was made by Dr. Mme. Cornet-Henri of Brussels in 1930 during her stay at New Haven. Thorium content was found to be 42,21 percent, uranium 0,52 percent of the mineral. Mesothorium and radium were completely removed and saved for the determination of the radium content of the mineral which was ultimately done by the emanation method and was found to give the ionium α-ray activity equal to 3,25 percent of the thorium activity. The thorium oxide, therefore, initially contained thorium and radiothorium in equilibrium and ionium. Tables of values of the relative amounts of radiothorium (and its products in transient equilibrium) for various periods of time after the preparation of the material, were made. In these calculations the accepted values of the disintegration constants of mesothorium and radiothorium of Meitner[5]) were used. Our experiments made it possible to check the calculated values and the agreement was found satisfactory, showing that no serious errors are involved in the values of Meitner's constants.

This preliminary report gives the value of the disintegration constant of thorium obtained by counting α-particles from the thorium oxide from thorite and is nearly in agreement with Geiger and Rutherford's value. Other experiments involving other sources are still in progress. The experimental procedure made it also possible to make a determination of the branching ratio of thorium C' to thorium C and this was found in good agreement with Meitner and Freitag's[6]) determination.

Method and Procedure.

The method employed to obtain the rate of disintegration of the atoms for a given amount of thorium and its products was

[5]) Meitner L., Phys. Zeitschr. 19 (1918), 257—263.
[6]) Meitner L.-Freitag K., Zeitschr. f. Phys. 37 (1926), 481—517.

similar to that used in the determination of the uranium disintegration constant.[7]) The α-particles from the source were restricted geometrically by channels and those emerging entered an ionization field whose effect was amplified so that it could be automatically registered by a mechanical device. In the present experiments no relays were used, the circuits being adapted to the use of thyratrons. Specimens of thorium oxide ranging in surface density from 0,885 to 2,66 mg ThO_2 per cm^2 were used. The oxide was deposited from suspension in chloroform on an aluminium plate and was covered by varnished films of celluloid impounding the thoron but having, usually, a stopping power of about 3 to 5 mms, air equivalent, for α-rays of 3 cms. Special technique had to be devised to produce such films. The grid with channels for the α-particles was the same as in the uranium experiments. If the emerging number of α-particles is N and the source per square millimeter emits N_0 α-particles, then for the channels used[7])

$$N = N_0 \,.\, 0{,}36067.$$

The procedure of counting was to obtain per unit of time:

A. Counts of α-particles from all the α-rays emitting substances in the source.

B. Counts of α-particles from all the substances excepting thorium and ionium. This necessitates the plotting of a curve giving counts for different absorbing screens placed over the grid. The difference in the range of the thorium (and ionium) α-particles and those of the next higher order is sufficiently great so that a horizontal step in the „counts-range" curve is obtained.

C. Counts of α-particles of the normal 8,6 cm range. In this case the horizontal step in the curve is quite long.

D. Counts for the naturals or background effect.

The following deductions can then be made:

1. The difference A—B gives the thorium plus ionium α-particles per second emerging through the channels. This, when corrected for the ionium, gives the rate of disintegration of thorium alone.

2. The ratio of the net count B to the net count A (corrected also for ionium) gives the check on the tabulated values referred to above.

3. The net count C gives the rate of disintegration of thorium C'.

4. Since radiothorium, thorium X, thoron, thorium A, and thorium $(C + C')$ are in transient equilibrium and their total

[7]) Kovarik Alois F.-Adams Norman I. Jr., Phys. Rev. (2), 40 (1932), 718—730.

α-particle emission is given by net B count, it is evident that the branching ratio $ThC' : ThC$ can be obtained.

The net counts referred to are the actual counts corrected for the background effect D.

The Results.

1. The disintegration constant obtained is

$$\lambda = 1{,}638 \cdot 10^{-18}\ \text{sec}^{-1} = 5{,}17 \cdot 10^{-11}\ \text{year}^{-1}.$$

Corresponding to the half-value period

$$T = 1{,}34 \cdot 10^{10}\ \text{years}.$$

2. The $ThC' : ThC$ branching ratio obtained is 0,660.

*

Rozpadová konstanta thoria a poměr rozvětvení thoria C.

(Obsah předešlého článku.)

Při počítání stáří radioaktivních minerálů se užívá dvou hodnot pro rozpadovou konstantu thoria. Jednu stanovili Geiger a Rutherford počítáním scintilací vzbuzených paprsky α, druhou odvodil Kirsch z dat, která dostal Hönigschmidt chemickou analysí jistého druhu ceylonského thorianitu. Obě tyto hodnoty se liší o 30 proc. Proto autoři určili rozpadovou konstantu thoria znova, a to počítáním scintilací. Výchozí látkou byl minerál thorit, z něhož byl připraven oxyd thoria; ten obsahoval thorium a radiothorium v radioaktivní rovnováze, dále něco ionia. Experimentální uspořádání bylo stejné jako to, jehož autoři užili k stanovení rozpadové konstanty uranu. Pro rozpadovou konstantu thoria dostali

$$\lambda = 1{,}638 \cdot 10^{-18}\ \text{sec}^{-1} = 5{,}17 \cdot 10^{-11}\ \text{rok}^{-1},$$

čemuž odpovídá poločas

$$T = 1{,}34 \cdot 10^{10}\ \text{roků}.$$

To souhlasí dobře s hodnotou Geigerovou-Rutherfordovou.

Z měření bylo možno určiti také poměr rozvětvení thoriové řady u thoria C; je $ThC' : ThC = 0{,}660$. I to je v souhlasu s číslem, které nalezli Meitnerová a Freitag.