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On the Value of the Decay Constant for Spontaneous Fission of Uranium-238 *

By

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Abstract

The fission-track method was used to determine the decay constant for spontaneous fission of uranium-238. The decay constant obtained is $7.1\times10^{-17}\,y^{-1}$.

On the other hand, for the cross checking of fission-track ages with other age determination, the same samples dated by other methods were supplied to the fission-track age determination.

Although the error limits of these results are relatively large, they support the value of $6.85\times10^{-17}\,y^{-1}$ (Fleischer and Price, 1964).

Introduction

Precise and accurate values of the decay constants for the naturally occuring radioactive isotope systems used in determining the physical ages of rocks are required in order to clarify the detailed evolution of the earth. The decay constant of spontaneous fission for uranium-238 has been obtained by several workers as shown in Table 1. These values are ranged between 5.3 to $11.9\times10^{-17}\,y^{-1}$. In these values, 6.85, 8.46 and $8.66\times10^{-17}\,y^{-1}$ were used to date by the fission-track method (Nishimura, 1972). It is to be desired that the most reliable value of decay constant for spontaneous fission of uranium-238 is obtained.

Experiment

To obtain the most reliable value of decay constant for spontaneous fission of uranium-238, two experimental methods were carried out.

1. Direct Method

The fission sources used in this experiment were prepared by the electro-deposition of natural uranium on the aluminium plate (thickness: 0.1 mm). The

* A part of this work was done by use of facilities of the Research Reactor Institute, Kyoto University and this report was read at International Meeting for Geochronology, Cosmochronology and Isotope Geology 1974, Paris.

Table 1. Values of the decay constant for spontaneous fission of ^{238}U.

Investigator	Method	Year	$\lambda_f (y^{-1})$	Ref.
Perfilov	fission chamber	1947	5.3×10^{-17}	Zh. Eksperim. i Teor. Fiz., **17**, 746.
Segré	fission chamber	1952	8.7	Phys. Rev., **86**, 21.
Kuroda *et al.*	radiochemical	1956	6.2	J. Chem. Phys., **25**, 603.
Parker and Kuroda	radiochemical	1956	8.7	J. Inorg. Nucl. Chem., **5**, 153.
Stroninger *et al.*	radiochemical	1957	8.66	Rev. Mod. Phys., **30**, 585.
Gerling *et al.*	radiochemical	1959	11.9	Radiokhimiya, **1**, 223.
Kuz'minov *et al.*	radiochemical	1960	10.7	Soviet Phys. JETP, **10**, 290
Fleischer and Price	fission track	1964	6.6	Phys. Rev., **133**, B63.
Fleischer and Price	K and Rb dating	1964	6.85	Phys. Rev., **133**, B63.
Rao and Kuroda	radiochemical	1966	7.8	Phys. Rev., **147**, 884.
Spadavecchia and Hahn	fission track	1967	8.42	Helv. Phys. Acta, **40**, 1063.
Robert *et al.*	fission track	1968	7.03	Phys. Rev., **174**, 1482.
Galliker *et al.*	fission track	1970	8.46	Helv. Phys. Acta, **43**, 577.
Leme *et al.*	fission track	1971	7.30	Nucl. Instr. Meth., **91**, 577.
Kleeman and Lovering	fission track	1971	6.8	Geochem. Cosmochem. Acta, **35**, 637.
Nishimura	fission track	1972	7.0	J. Jap. Assoc. Min. Petr. Econ. Geol., **62**, 299.

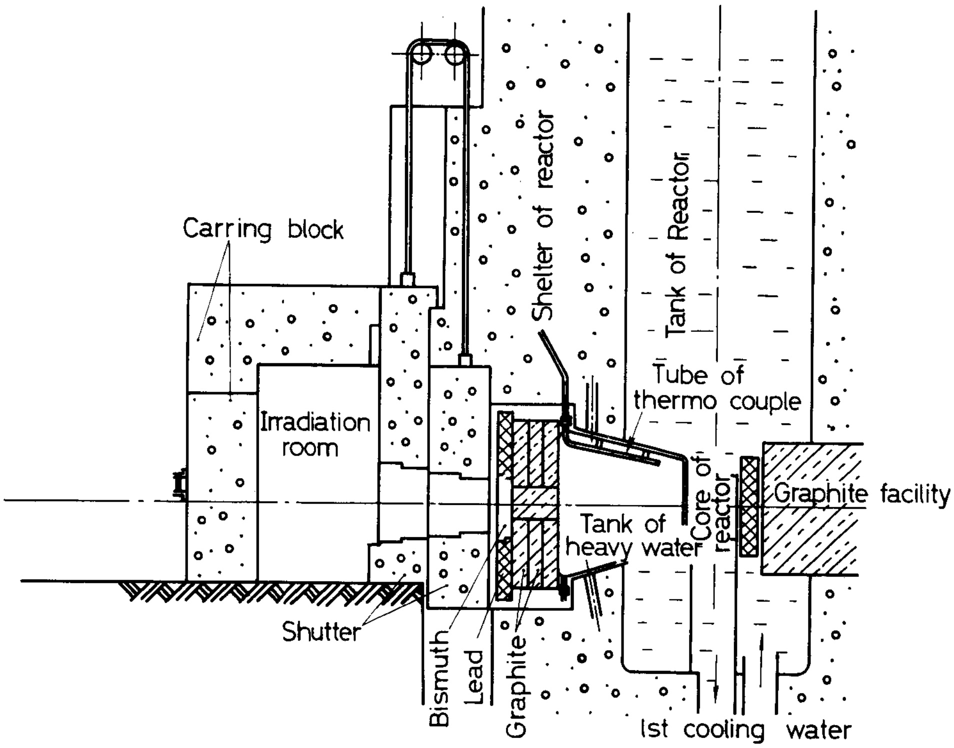

Fig. 1. Heavy Water Facility of KUR-1.

determination of the amount of fissionable material on the plate was carried out by the alpha-counting with alpha-spectrometry. The homogeneity on the distribution of fissionable material was checked by the fission-track technique.

The fission sources were divided into three parts. On these three parts, polycarbonate or muscovite sheets as the track detector were firmly kept in touch with an adhesive tape. One of these samples was followed by the neutron exposure on the reactor. The instrument of bombardment of neutron is heavy water facilitiy of KUR-1 and its flux was determined by the Au-foil and the fission-track methods. The neutron detectors were firmly touched on the turn table with a motor (60 rpm) on the front of bismuth plug. The thermal neutron flux of this experiment was obtained as $(3.9\pm0.3)\times10^{13}$ (cm^{-2}) for fission-track method and $(3.8\pm0.2)\times10^{13}$ (cm^{-2}) for Au-foil method (Hashimoto et al., 1969; Kanda, et al., 1969).

The other parts were let alone for 3.11 and 6.07 years, respectively. After the passage of these times, the polycarbonate sheets were etched. The fission-track density was calculated through the photographs from the optical microscope.

If the fission-track age, T (y), was smaller than $10^9\,y$, T can be represented by the following equation

$$T=\frac{1}{\lambda_f}\,\frac{\sigma\phi}{\eta}\,\frac{\rho_s}{\rho_i},$$

where, λ_f is the decay constant for spontaneous fission of uranium-238, ρ_s the spontaneous fission-track density (cm^{-2}), ρ_i the induced fission-track density (cm^{-2}) by bombardment with thermal neutron dose ϕ (cm^{-2}), σ the thermal neutron cross section of uranium-235 (cm^2), and η is the isotope ratio of $^{238}U/^{235}U$.

These values used in this experiment were

$\sigma=5.77\times10^{-22}$ (cm^2) (Goldman, 1965),
$\phi=(3.8\pm0.2)\times10^{13}$ (cm^{-2}),
$\eta=138$ (Lederer et al., 1967).

For $T=3.11\,y$ (from May 23, 1968 to July 3, 1971),

$\rho_s=79.5$ (cm^{-2}) (counts: 318),
$\rho_i=5.79\times10^7$ (cm^{-2}) (counts: 23148),
then, $\lambda_f=(7.0\pm0.6)\times10^{-17}\,y^{-1}$.

For $T=6.07\,y$ (from May 23, 1968 to March 10, 1974),

$\rho_s=157$ (cm^{-2}) (counts: 314),
then, $\lambda_f=(7.1\pm0.6)\times10^{-17}\,y^{-1}$.

These values are in good agreement with the values obtained by FLEISCHER and PRICE (1964); ROBERT et al. (1968); LEME et al. (1971); and KLEEMAN and LOVERING (1971).

2. Cross checking of fission-track ages with other ages

As to the cross checking of K-Ar and fission-track ages, several results were reported (e.g. FLEISCHER and PRICE, 1964; GENTNER et al., 1967; SHIMA et al.,

Table 2. Fission-track age and the other age of some minerals.

Rock type	Mineral	Fission-track age, my.	K-Ar age, my.	Rb-Sr age, my.	Pb-α age, my.	Sample source
Tai, Gneissose garnet bearing granodiorite	Zircon	400	424*	406**		
Koyama, Muscovite Schist	Zircon	310	308*** 333*** 337*** 297***	429** 454**		
Kitazaki, Granodiorite	Zircon	91	89****		115*****	Y. Karakida
Sawara, Granite	Zircon	88	82****		95*****	Y. Karakida
Rokko, Granite	Zircon Biotite	83 85		96**		
Takakumayama, Granite	Zircon Biotite	16 12	14******			
Yakushima, Granite	Biotite	12	14******			

Ref. * Kawano *et al.*, 1966, Sci. Rept., Tohoku Univ., 3 Ser. **9**, 525.
** Hayase and Ishizaka, 1967, J. Jap. Assoc. Min. Petr. Econ. Geol., **58**, 201.
*** Miller *et al.*, 1963, J. Geol. Geograph., **34**, 197.
**** Shibata *et al.*, 1965, Bull. Geol. Surv. Jap., **16**, 33.
***** Karakida *et al.*, 1965, Mem. Fac. Sci., Kyushu Univ., Ser D, **16**, 249.
****** Shibata, 1968, Rept. Geol. Surv. Jap., **227**, 7.

Table 3. Fission-track age and paleomagnetic age.

Rock type	Mineral	Fission-track age, my.	Paleomagnetic age, my.	Sample source
Toyonaka, Azuki Tuff	Hornblende	0.87	0.78*	K. Maenaka
Izumi, Komyoike Tuff	Zircon	1.1	1.0*	T. Yokoyama
Toyonaka, Shimakumayama Tuff	Zircon Hornblende	2.4 2.3	2.0–2.4*	T. Yokoyama
Kôga, Sagami Tuff	Zircon	2.9	3.0*	T. Yokoyama
Kônan, Masugi Tuff	Zircon	3.1	3.05*	T. Yokoyama

Ref. * Maenaka, 1969, J. Quater. Jap., **8**, 51.

1969; SHIMA and YABUKI, 1969; FISHER, 1969; KANEOKA and SUZUKI, 1970).

Samples used in this study are tabulated in Table 2 and in Table 3. In these tables, the fission-track ages were calculated using $\lambda_f = 6.85 \times 10^{-17}\ y^{-1}$ (FLEISCHER and PRICE, 1964). In another approach, volcanic glass of known K-Ar ages were dated and corrected for partial track loss by KANEOKA and SUZUKI (1970). The resulting λ_f-value is $7.0 \times 10^{-17}\ y^{-1}$.

From these results, it may be concluded that the fission-track ages and the K-Ar ages show good agreement in each other within their experimental errors.

Conclusions

Using the fission-track method, the decay constant for spontaneous fission for uranium-238 was obtained as $7.1 \times 10^{-17}\ y^{-1}$.

On the other hand, the cross checking between the fission-track ages and the K-Ar ages was carried out.

Although the error limits of these results are relatively large, they support the value of $6.85 \times 10^{-17}\ y^{-1}$.

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