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Study on Thorium and Uranium Decay Series in Nuclear Emulsion

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Abstract

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စာတမ်းအကျဉ်း

သဘာဝအလျောက်တွေ့ရသော အယ်လ်ဖာယိုယွင်းမှုဖြစ်စဉ် လေးမျိုးရှိပါသည်။ ၎င်းတို့အနက် နျူကလိယာအမားလ်ရှင်းထဲတွင် သိုရီရမ်နှင့် ယူရေနီယမ်ယိုယွင်းမှုဖြစ်စဉ်များကို အမှတ်တခုမှဖြာထွက်လာသော လမ်းကြောင်း၅ကြောင်းနှင လမ်းကြောင်း၄ကြောင်း ပါဝငသော 'အယ်လ်ဖာကြယ်' များအဖြစ်တွေ့ရှိရပါသည်။ နျူကလိယအီမားလ်ရှင်း ဆိုသည်မှာ မိုက်ခရမီတာလောက်ထိ ခွဲခြားနိုင်စွမ်းရှိသော ဓာတ်ပုံဖလင်အမျိုးအစား ဖြစ်ပါသည်။ အီမားလ်ရှင်းဖလင်ပြားများက ဓာတ်ဆေးပြီးသည့်အခါ မိုက်ခရိုစကုတ် ကိုအသုံးပြု၍ အမှုန်များ၏လမ်းကြောင်းများကိုမြင်နိုင်ပါသည်။ ဤစာတမ်းတွင် သိုရီရမနှင့်ယူရေနီယမ်ယိုယွင်းမှုဖြစ်စဉ်ပုံစံဓာတ်ပုံများကိုဖော်ပြထားပြီး၎င်းတို့၏သွင်ပြင လက္ခဏာ များနှင့် ပတ်သက်၍ဆွေးနွေးတင်ပြထားပါသည။ ဤစာတမ်းသည် နျူကလီယာ ရူပဗေဒကို လေ့လာနေကြသော ကျောင်းသားကျောင်းသူများအား နျူကလီယာအီမားလ်ရှင်းထဲရှိ အယ်လ်ဖာယိုယွင်းမှုလမ်းကြောင်းများကိုလက်တွေ့တိုင်းတာဆုံးဖြတ်ခြင်းအားဖြင့်အယ်လ်ဖာ ယိုယွင်းမှုဖြစ်စဉ်နှငပတ်သက်သောအသိပညာများကိုရရှိစေရန်ရည်ရွယ်ပါသည်။

သော့ချက်စကားလုံးများ။ သိုရီယမ်ယိုယွင်းမှုဖြစ်စဉ်၊ ယူရေနီယမ်ယိုယွင်းမှုဖြစ်စဉ်၊ နျူကလီယာအီမားလ်ရှင်း

Introduction

In Nuclear Science, the decay series refers to the radioactive decay of different discrete radioactive decay products as a chained series of transformations. They are also known as "radioactive cascades". Most radioisotopes do not decay directly to a stable state, but rather undergo a series of decays until eventually a stable isotope is reached. Stable isotopes have ratios of neutrons to protons in their nucleus that start out at 1 in stable helium-4 and smoothly rise to ~1.5 for lead. All nuclides having atomic number Z greater than 83 are unstable and disintegrate with the emission of either an alpha (α), which reduces the mass number of a nucleus by 4, or a beta (β) particle, which does not change the mass number.

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Most of the radioactive nuclides found in nature are members of four radioactive series. The first member of the series is called the parent, the intermediate members are called daughters and the final stable member is called the end-product. These series are Thorium series, Neptunium series, Uranium (or Radium) series and Actinium series. The mass number of every isotope in these series can be represented as A= 4n, A= 4n+1, 4n+2 and 4n+3, respectively.

In this paper, the characteristics of naturally occurring Thorium and Uranium series in nuclear emulsion of KEK-PS E373 experiment will be presented.

1. Nuclear Emulsion

Nuclear emulsion plates are fabricated by drying after pouring emulsion on both sides of polystyrene film (base). The main component of emulsion is gelatin. It contains silver halide microcrystals (AgX) with their size of 0.2μm. The base film is used for support to avoid separation of the emulsion during photographic development.

Nuclear Emulsion is the best three-dimension detector. It is used to detect charged particles, and measures the energies of particles more accurately than other detecting devices. The masses of several elementary particles have been measured in emulsion immediately after their discovery. It is also possible to measure the true rectified range of the particle and to determine the magnitude and direction of its velocity, the product of its velocity and momentum. On the other hand, the ranges and lifetime of short lived particles such as hyper-fragments are easily measured. Moreover, it can be used in radiation monitoring for the protection of people who work with radioactive material, X ray generators, and high-energy accelerators.

2. Thorium and Uranium series

The decay chain of Thorium and Uranium series are shown in Fig. 1 and Fig.2, respectively. In those figures, τ represent the life time, the value with % indicate the percent branching and the value in keV unit express the kinetic energy of emitted alpha particles for corresponding nucleus.

Thorium and Uranium series in Nuclear Emulsion

Since, the time for pouring and development of nuclear emulsion plates took a year for E373 experiment, the five alpha decays from ^{228}Th were observed in the decay chain of thorium series in both sides of emulsion plates. In nuclear emulsion, a member of an alpha-active series as several tracks (Range = 20μm~ 50μm) may be found emerging from a common point. This event can occur if the successive nuclides found are of short life. Five alpha tracks are emitted from ^{228}Th, ^{224}Ra, ^{220}Rn, ^{216}Po and ^{212}Po nuclides. Some sample of thorium decay series and their schematic drawing are shown in Fig.3. On the other hand, a 4-prong star of alpha decays (from ^{226}Ra, ^{222}Rn, ^{218}Po and ^{214}Po) can be observed from the decay chain of uranium series. Samples of Uranium series in nuclear emulsion are presented in Fig.4.

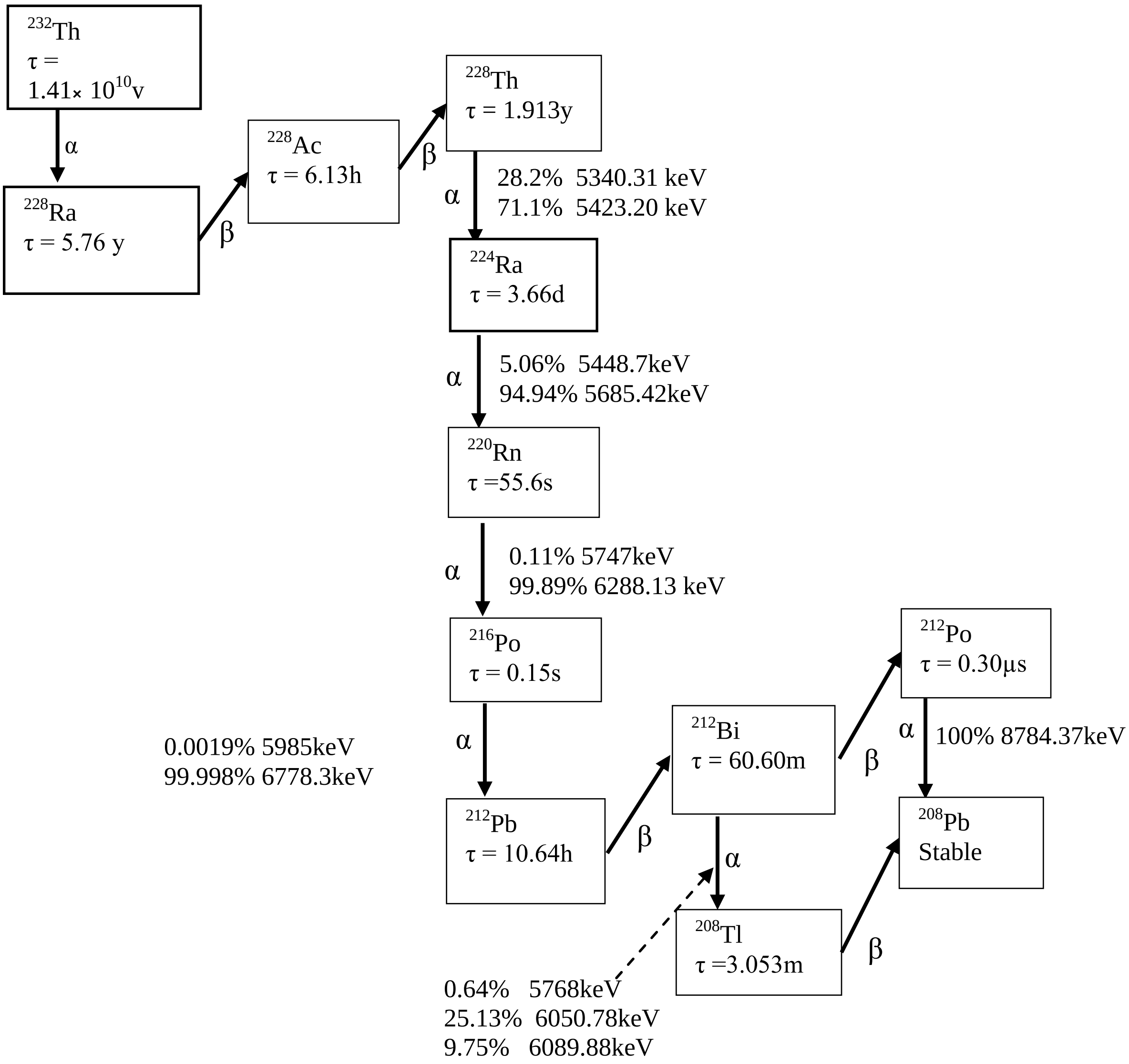

Fig. 1. Decay chain of Thorium series

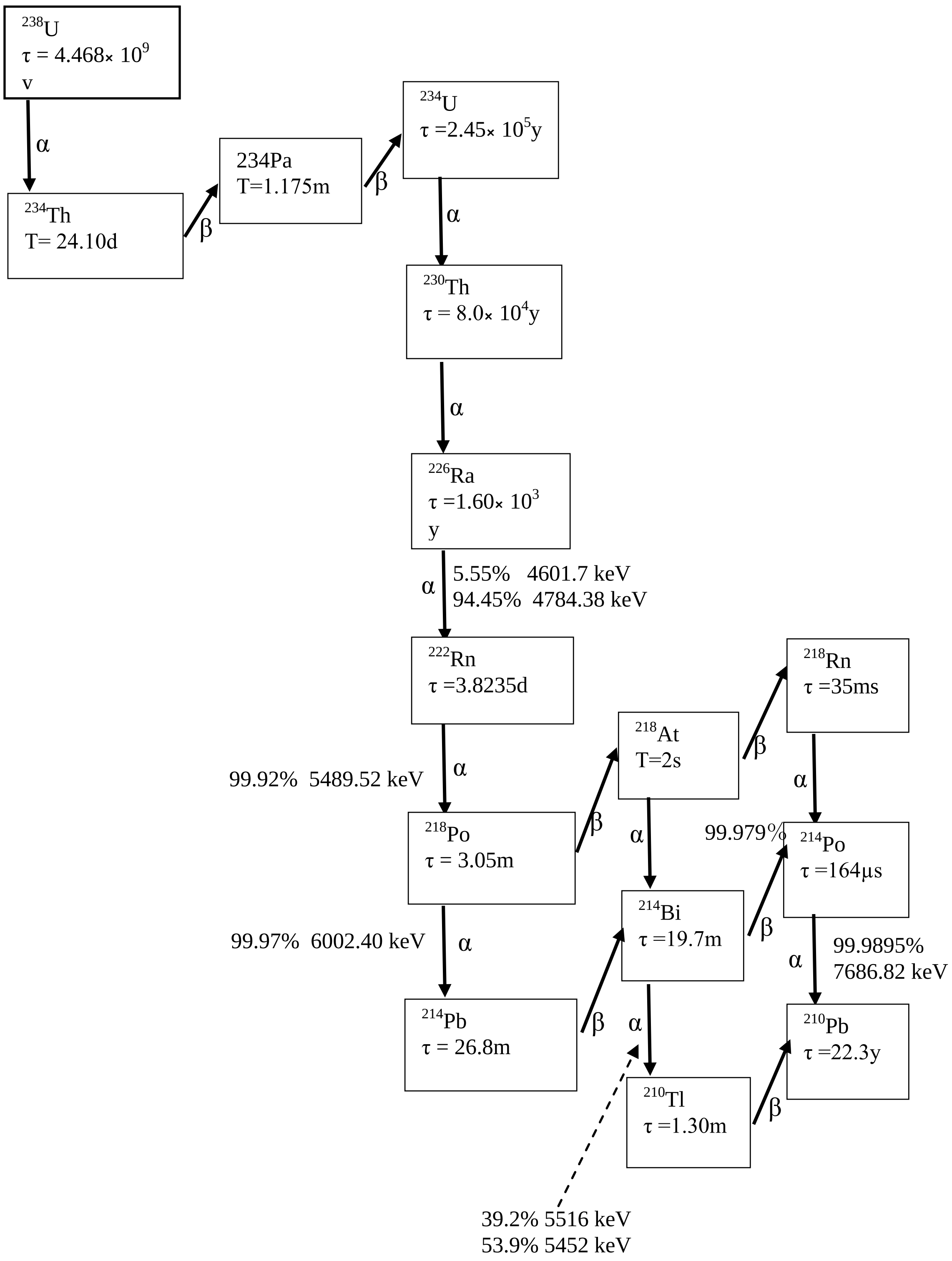

Fig. 2 Decay chain of Uranium series

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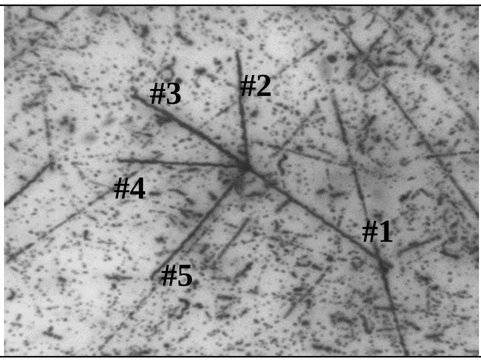
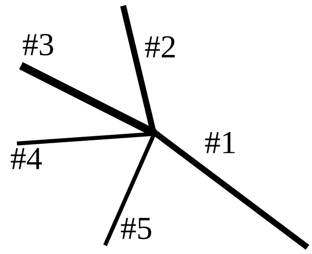
<tr><td>
</td><td>
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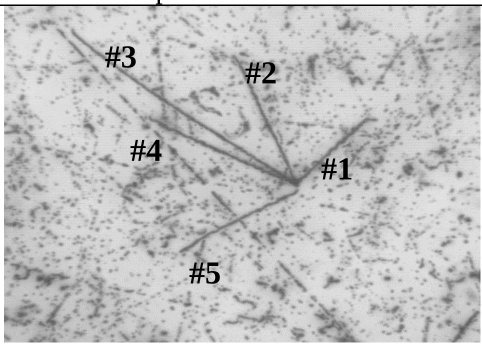
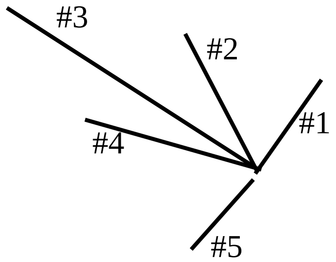
<tr><td>(A) 5 alpha tracks emerging from a common point</td><td>Schematic Drawing of (A)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>(B) 4 alpha tracks emitted from a point and one isolated track which is track #5</td><td>Schematic Drawing of (B)</td></tr>
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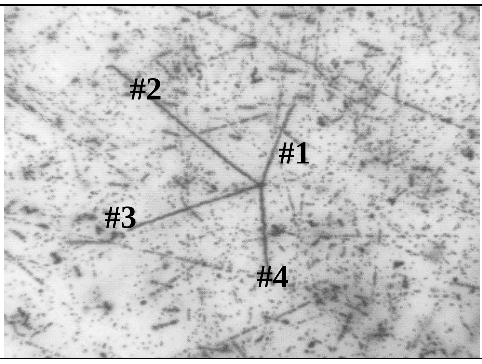
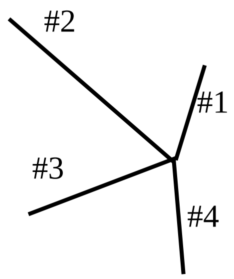
Fig. 3. Some sample of Thorium series in nuclear emulsion

<table>
<tr><td>
</td><td>
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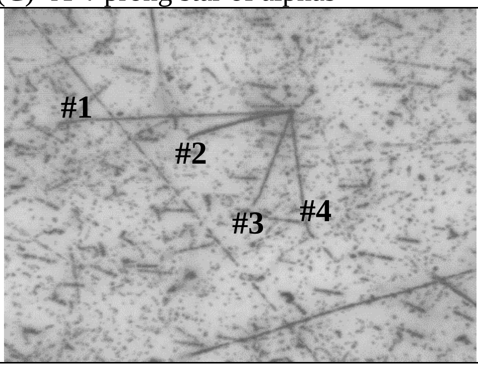
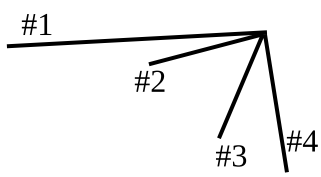
<tr><td>(C) A 4-prong star of alphas</td><td>Schematic Drawing of (C)</td></tr>
<tr><td>
</td><td>
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<tr><td>(D) Four alpha tracks emitted from a</td><td>Schematic Drawing of (D)</td></tr>
</table>

point	

Fig. 4. Some sample of Uranium series in nuclear emulsion

Identification of Radioactive Isotope from the Alpha Particles Ranges

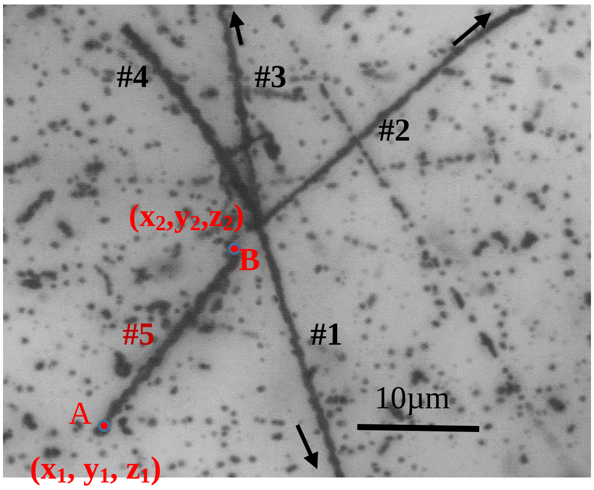
The identification of the radioactive isotopes is possible, in principle, from the alpha particle ranges. The concept of the residual range is one that is quite important in emulsion analysis. The residual range, R, is the average distance that a particle with a given velocity has to go before coming to rest. It is a track variable that rises with the velocity, momentum and energy. The residual range is an ideal distance or it is the expectation value of the path length required to bring the particle to rest. Since the present emulsion is mounted pellicles, we need to consider shrinkage factor only in z axis (S_z = S) which means ($S_x \approx S_y \approx 1$). When the emulsion shrinks only in the z direction, the range is obtained from the following formula

$$R=\sum_{i=1}^{n}\left[(x_i-x_{i-1})^2+(y_i-y_{i-1})^2+S^2(z_i-z_{i-1})^2\right]^{1/2} \qquad (1)$$

Range of alpha particles can be measured by using the microscope system. The measured point on a track and microscope system are shown in Fig. 5. If we know the coordinates at point A (x_1, y_1, z_1), and point B (x_2, y_2. z_2), range of track #5 can be obtained by using Equation (2). Range of other alpha particle tracks in Thorium and Uranium series are measured with the same manner as explained in above.

$$R=\left[(x_2-x_1)^2+(y_2-y_1)^2+S^2(z_2-z_1)^2\right]^{1/2} \qquad (2)$$

In above equations S express the Shrinkage factor which is the thickness ratio of emulsion at the time of beam exposure to the present time.



(i) A Photograph of Thorium series in two dimensional view

(ii) Microscope system for measurement of range of particle tracks

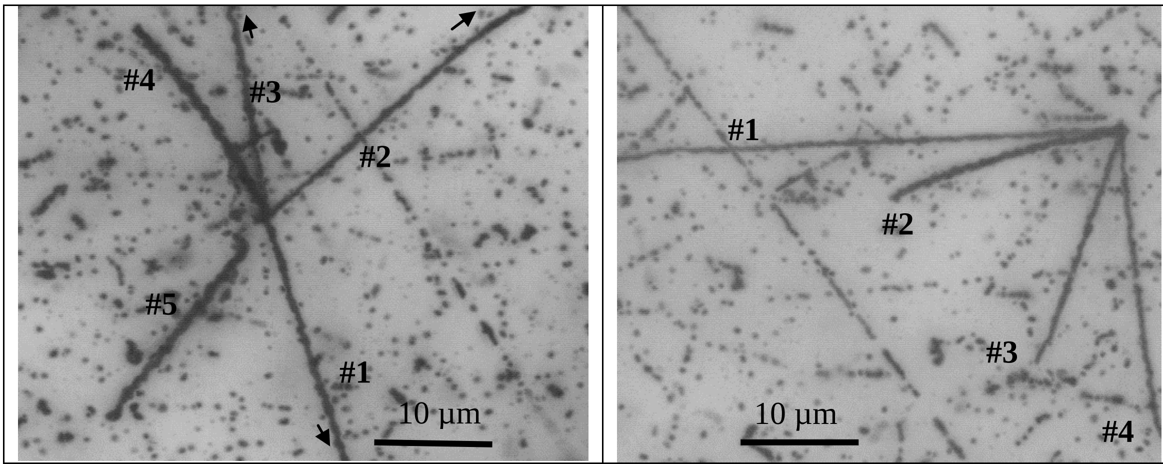
Fig. 5. The photograph of a Thorium series in nuclear emulsion and microscope system

Result and Discussion

The appearance of Thorium and Uranium series in nuclear emulsion as a chain of disintegrations from a point is somewhat the same as that of a disintegration star called "alpha stars". Some samples of the decay chains of thorium and uranium series are shown in Fig.3 and Fig.4, respectively. Since the time between the pouring and the development of the emulsion was in the range from several months to a year, five alpha decays from ^{228}Th were observed in the decay chain of thorium series as shown in Fig. 3(A). Among the five α particles, the α-particle from ^{212}Po has a separately higher energy (~8MeV in decay chain) than the others. Therefore it has a longer range. The α-particle from ^{228}Th is observed in a little distance from the others, because ^{224}Ra may move thermally in its life time of 3.66 days as shown in Fig.3 (B). On the other hand, a 4-prong star can be observed from the decay chain of uranium series, as presented in Fig.4 (C). Among the four tracks of α-particles, an α-track from ^{214}Po is longer than the others because of its relatively high energy as shown in Fig.4 (D).

Ranges of α-tracks in decay chain as shown in Fig.6 were measured and identified the radioactive isotope by comparing the range of α-tracks obtained by W.H. Barkas. The results are shown in Table (1). The first column in Table (1) represents the Thorium and Uranium Series, Fig.6 (i) and Fig.6 (ii) respectively. The second column represents the tracks numbers in figures. Measured ranges of alphas in each series are presented in third column. Ranges of alpha particles (radioactive isotope or alpha emitters) in standard emulsion by Barkas are expressed in fourth column. The identified radioactive isotopes for each track in decay chains of Fig. 6 are expressed in the last column.

The measured range of alphas in each decay chain in nuclear emulsion plate of E373 is a litter longer than the range in standard emulsion because the values of the density of emulsion plates are different, The more density is higher the more range is shorter. Therefore, our measured range values are comparable with the range in standard emulsion.



(i) A Photograph of Thorium Series | (ii) A Photograph of Uranium Series

Fig. 6. The photographs of Thorium and Uranium Series

Table. (1) Identification of Radioactive Isotopes in Thorium and Uranium Series

Name of Series	Track#	Range of alpha tracks (μm) our result ($\rho = 3.6\ gcm^{-3}$)	Range of alpha tracks in standard emulsion(μm) [Ref: 2] ($\rho = 3.815\ gcm^{-3}$)	Identified Radioactive Isotope for Fig. (6)
Thorium Series Fig. 6 (a)	#1	49.2	48.2 (^{212}Po)	^{212}Po
	#2	28.9	28.8 (^{220}Rn)	^{220}Rn
	#3	32.8	32.2 (^{216}Po)	^{216}Po
	#4	26.5	25.0 (^{224}Ra)	^{224}Ra
	#5	23.7	23.5 (^{228}Th)	^{228}Th
Uranium Series Fig. 6 (b)	#1	39.2	38.8 (^{214}Po)	^{214}Po
	#2	27.4	26.9 (^{218}Po)	^{218}Po
	#3	19.8	19.7 (^{226}Ra)	^{226}Ra
	#4	24.5	23.8 (^{222}Rn)	^{222}Rn

Conclusion

In nuclear emulsion, Thorium series and Uranium series can be seen as 5-prong star and 4-prong star, respectively in which one track is longer than the others. The photographs of some sample of Thorium and Uranium Series are shown in Fig.3 and Fig. 4, respectively. In decay chain events, we found that an event such as all alpha tracks are emitted from a point and another event with some tracks are emitted from one point and others are emitted as an isolated track. The measured ranges of alpha particles in the decay chain events are comparable with the ranges in standard emulsion. Form the measured range of alphas; the types of radioactive isotopes are also identified. Now, we are developing image processing for measurement of range of particles not only using microscope system but also using only computer from slice pictures.

Acknowledgement

I would like to express my special thanks to Dr Ko Ko Myint, Principal of Myingyan Degree College for his permission and encouragement to perform this research. I would also like to express my deepest appreciation to Dr Kyi Kyi Thein, Professor, Head of Department of Physics, Myingyan Degree College and Dr. K. Nakazawa, Professor, Department of Physics, Gifu University, Japan, for their continuous encouragement.

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