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Mini Review



# Studying the Nuclear Structure using the Naturally Occurring Radioactive Sources

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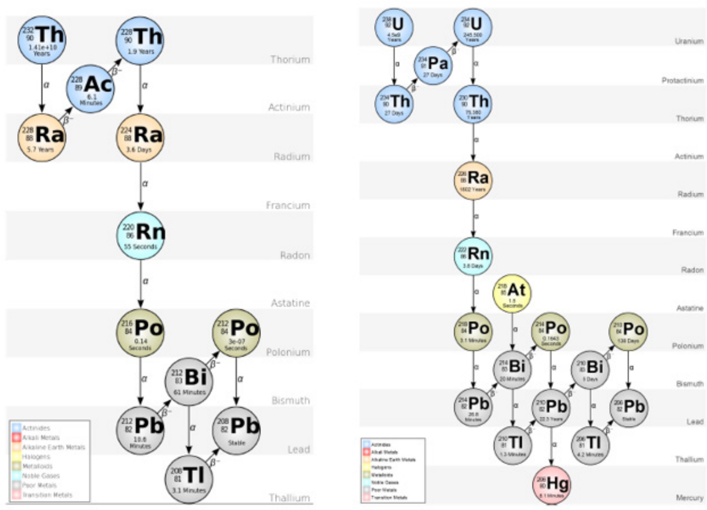
## Abstract

Scientists believe that that natural radioactive sources contains the wealth of information regarding exploring the nuclear structure as well as the search for the events during the formation of the universe and properties and existence of matter and anti-matter. Thorium and Uranium are radioactive sources and exist since the formation of earth after the Big Bang. These nuclei are found abundantly on the earth and are being been used for number different purposes including power generation, isotopes production and studying the nuclear structure at the lowest level. This short review explains that how these naturally occurring radioactive sources are being studied in the laboratories to explore nuclear structure in actinides region of nuclei and what is the scope of any potential research that can be performed. The continuously emitted alpha, beta and gamma radiations from these nuclei are an amazing source of information regarding the formation of the universe and perhaps the description of the presence of matter and anti-matter in the universe.

## Introduction




(a) 232-Th Decay chain (b) 238-U Decay chain

**Figure 1:** The decay chains of both radioactive nuclei 232-Th and 238-U shows the number of nuclei as a result of emitting α, β particles and γ radiations.

Thorium-232 and Uranium-238 are naturally occurring radioactive sources which are emitting a variety of radiations with different intensities spontaneously, a phenomenon called radioactivity. Radioactivity is described as an act of emitting radiations spontaneously where all unstable nuclei decompose and decay into more stable configuration. The half-lives of these radioactive nuclei are found to be 14 billion years and 4 billion years for 232-Th and 238-Th respectively [1,2]. A half-life is a scale in which the radioactivity of the unstable nucleus becomes half after passage of that certain period of time or it can be described as the time for half the radioactive nuclei in any sample to undergo radioactive decay. This process explains how long the intensity of the radiations will last. These two nuclei belong to the actinides regions of the nuclear chart, the nuclei in which number of neutrons exceeds the number of protons which results in emitting the radiations. These nuclei are highly radioactive and only two of these are found abundantly in the universe, Uranium and Thorium. Besides the usage of these highly radioactive nuclei in the nuclear industry for the power generation and isotopes productions in medical research industries, these nuclei provide a promising avenue for the nuclear structure research. The applications of these actinides' nuclei for the fuel production, medical isotopes production and energy productions has been vastly studied before [3,4]. However, scientists had been studying these nuclei in the state-of-the-art nuclear laboratories to study the nuclear structure of the nuclei belong to this region and to unveil the underlying mysteries in the universe. One of the beauty of these research works is that by studying the nucleus at extremely small level 10-15m, we can make a way to understand the mysteries in this vast and ever-expanding universe. As mentioned earlier, not all of them are found abundantly on the earth, but the nature is too kind to provide an opportunity to research. 232-Th and 238-U are naturally occurring radioactive sources and it is easier to study these nuclei by using the nuclear Physics data analysis tools and equipment i.e. detectors even in a small laboratory. One of the promising attributes of these nuclei from Physics point of view is their decay chains where a number of different nuclei in this region can be studied. A decay chain is described as a number of nuclei results from the different modes of decay from a heavier unstable nucleus. The decay chains of these nuclei of interest is given in Figure 1 which shows the number of nuclei is being formed on the basis of the decaying mode of radiations until the chain goes to the stability. The mode of decaying radiations depends on the nuclear structure of these nuclei. The nuclei belong to these chains are formed as a result of emitted radiations due to the internal structure by and decay modes. The mode of radiation which plays an important part in studying the nuclear structure of these nuclei is radiation which results from the emission of aforementioned modes of decay. The only things which differentiates between, and decay is the emission of particles, which does not occur in case of a decay process. The radiations, which are emitted as a result of other two decays modes and has the higher intensity also, are examined mostly to understand the structure of any nucleus. Much of the research has been done regarding studying the nuclear structures of nuclei in this region through number of experiments, however, a major breakthrough was made during studying the 224-Ra and 220-Rn nuclei [5]. The gamma rays of interest in these nuclei were studied using the state-of-the-art experimental setup at CERN [6] using the Coulomb excitation experimental technique. Coulomb excitation is a technique of exciting the nucleus of interest through inelastic collision with another nucleus through an electromagnetic interaction [7,8]. The results based on this experiment proved that those nuclei interest exhibit octupole deformation, a property adopted by the nucleus with a certain internal structural attributes which results in it having a deformed shape which resembles a pear or many scientists call it an avocado shape as well. Since the 232-Th and 238-U are naturally occurring sources and we do not have to populate the gamma-rays from these nuclei in any bigger experimental facility, these nuclei can be studied in a small laboratory by using a set of detectors. Due to the promising results from the experiment at CERN, researches at University of the West of Scotland, United Kingdom performed an experiment using the natural 232-Th source and observed the radioactive decay [9,10]. The experiment was conducted using only two fast scintillator detectors, known as LaBr3(Ce) detectors [11], the type of detector used for gamma detection and measuring the nuclear lifetimes of the excited states due to their optimal attributes necessary for doing such observations. One of the important aspects of this work was to measure the enhanced electric dipole moment in the excited states in 228-Th for the first time in actinide region [12]. These enhanced electric dipole moments are an ambiguous sign of a nuclear deformation, where a nucleus adapt a deformed shape like a pear. This shape was first observed in 224-Ra nucleus from a group of nuclear scientists mentioned above. The enhanced electric dipole moment in the nuclear excited states found due to the distribution of the charged particles, protons, in a nucleus due to its deformation [12]. This phenomenon of nuclear charge distribution happens due to moment of electron which is explained in a term called Schiff moment [13,14]. Results from the studies of 228-Th nucleus determines the presence of such a sensitive charge distribution which exhibits the shape deformation in this nucleus. The outstanding results from that experiment shows that how these sources can be utilized in a small nuclear laboratory, by using minimum resources to produce such a groundbreaking research. Another experiment was also conducted by researchers at University of the West of Scotland, where they are analyzing the radioactive decays in 238-U and gathering the results regarding the nuclear structures in nuclei belong to the decay chain in 238-U. To observe the different modes of decays as possible, a number of different detection materials are being used to study the structure of these nuclei in details. An important aspect of the above research regarding presence of a deformed or pear-like shape in the 228-Th nucleus, is the potentially an evidence of presence of anti-matter in the universe. Physics explains that fundamental particles were created after the big-bang and each particle has its anti-particle. These particle and anti-particle were created in an equal amount and the whole system described as matter and anti-matter [15]. However, only the matter has been observed in the universe where everything is believed to be made of matter. It has been a long-standing mystery in the universe. But, the presence of a pear-shaped or a deformed nucleus shape gives an argumentative proof of the existence of anti-matter in the universe. In fact, these pear-shaped nuclei provide an ideal system to look into the existence of hidden mysteries of the universe in terms of exploring the studies of dark matter and dark energy. To summarize the importance of studying these natural radioactive sources, it can be concluded that the amount of radioactivity information and nuclear data, not only related to the nuclear structure and power generation, but also regarding a step forward towards unveiling the hidden mysteries of the universe. It is a great opportunity for the students as well as researchers who can perform the simple experiments using these natural radioactive sources and equipment required to observe and analyse the radiations from these sources. By looking at the decay chains of these sources, one can reckon the amount of information that can be envisaged by analyzing the decaying radiations.

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## Conflict of Interest

No conflict of interest.

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