Thorium over uranium

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Abstract - *Now –a – days in nuclear power plants isotope of uranium is used. As there is scarcity of uranium in India, so India has to import uranium as a reactor form other countries, then it affects the economy of our country. So, to minimize the economic loss the most preferable element is thorium, as it is a radioactive element and we can use it as a fuel. This paper tells about the possibilities (like half-life period, decay reactions, etc.) of how the thorium can be used instead of uranium i.e. use of ^{235}Th instead of ^{235}U.*

***Key Words*: Radioactivity, Uranium, Thorium, Th-U cycle, Thorium as fuel.**

1. INTRODUCTION

As there is a less abundance of Uranium-235(^{235}U) in India. For the generation of electricity in nuclear power plant we use the same so we have to purchase or import the same from other countries. So, it is very economic loss of our country. So, to reduce this loss one should really think about the substitute of it. Also the Uranium-235 is isotope of uranium making up about 0.72% of natural uranium. Now we want the same efficiency the uranium as nuclear reactor gives and also want to replace it by some another element. As both the elements are radioactive in nature, so one must know radioactivity.

1.1 Radioactivity

The discovery of radioactivity took place over several years beginning with the discovery of x-rays in 1895 by Wilhelm Conrad Roentgen. Radioactivity is the property of unstable atomic nuclei to transform spontaneously, which is done by means of radioactive decay which is the process by which an unstable atomic nucleus loses energy by emitting radiation. Radioactive decay is a stochastic (i.e. random) process at the level of single atoms, this according to the quantum theory, it is impossible to predict when a particular atom will decay. When this spontaneous decay occurs the byproduct's getting from this are first one is alpha particles, secondly the gamma rays and third is the subatomic particles which are the proton, electron, and neutron. Then again the radioactive elements are bifurcated as nuclide, binuclid, etc. (which is an IUPAC reclassified names). As the first inventor of the radioactive elements was Marie curie, by examining radioactive elements she said that the real energy they emit must originate from the atom itself, perhaps through some form of decay. The second name to the radioactivity nature of elements is known as the Disintegration. In 1903 Rutherford and Soddy postulated that radioactivity is a nuclear phenomenon and all the radioactive changes taking place in the nucleus of atom. And the atomic nuclei of the radioactive elements are unstable and liable to disintegrate any moment.

2. SPECIFICATION OF URANIUM

Uranium is very much radioactive emits α-particles. As we are moving to its properties and mass as well as the main constraints as atomic mass and atomic weight. The electrons per shell are 2,8,18,32,21,9,2. As uranium atom has 92 protons and 92 electrons, of which 6 are valence electrons. The half life time of the uranium is 4.47 billion years. According to the modern periodic table the atomic mass and atomic weigh of Uranium is 92 and 238.02891amu respectively. Also the melting and boiling point of the Uranium is 1132^{o}c and 3818^{o}c respectively. But as we are very much concern about the nuclear power plant, so it is but obvious to think about nuclear reactor used in the power plant specifically of the uranium. But the Uranium atom cannot be used in the form of elementary state. So there are different isotopes of Uranium like ^{238}U, ^{235}U,etc. in that ^{235}U is used as nuclear reactor in the nuclear power plant.as we are going to discuss about the properties of these isotopes is half-life period it is for 238U is 4.47 billion years and for 235U is 704 million years. It means that about half of a sample of Uranium-238 atoms will spontaneously undergo alpha decay within *4.5 billion years* also the 235U has decay product as 231Th. The Uranium-238 is the most prevalent isotope in uranium; half the atoms in any sample will decay in that amount of time. *Uranium*-238 is the most common isotope of *uranium* found in nature, with a relative abundance of 99%. Unlike *uranium*-235, it is non-fissile, which means it cannot sustain a chain reaction. However, it is fissionable by fast neutrons, and is fertile, meaning it can be transmuted to fissile plutonium-239. As per as price is concerned comparison with oil per barrel it is at $60 a barrel, you'd need to spend $210 for oil. On the other hand, it costs around $1.43 to buy 0.24 ounces of uranium at the current price of $95 per pound. And as in this paper it is already mentioned that Uranium is less abundant in India, so we have to import it from other countries which become again more costly.

3. SPECIFICATION OF THORIUM

Thorium is a weakly radioactive metallic chemical element with symbol Th and atomic number 90.and atomic mass number is 232.038amu, the electron per shell are 2,8,18,32,18,10,2. In liquid state, thorium has a greater temperature range than any other element, with nearly 5,500 degrees Fahrenheit (3,000 degrees Celsius) between melting and boiling points, according to Chemical. Thorium dioxide has the highest melting point of all known oxides, according to Chemicool. *Thorium* metal is silvery and tarnishes black when it is exposed to air, forming the dioxide; it is moderately hard, malleable, and has a high melting point. Thorium is approximately three times as abundant as uranium in the earth's crust, reflecting the fact thorium has the longer half-life. Naturally occurring thorium has one isotope thorium-235. In D131 reactor, the initial startup fuel mix is a combination of thorium and Uranium235. The price for thorium is Rs 3000 /kilogram. Again there is different isotope of thorium such as thorium-232 which is relatively stable, with a half-life period of $1.405×10^{10}$ years. In 2013 IUPAC reclassified thorium as binuclidic, due to large amount of thorium -230 in deep sea water.

The most stable isotope of the thorium is thorium-232 which has a half-life of 14.05 billion years. More than 250spectrum shifts have been measured for the lines of the nutra thorium atom (Th1) and of the singly-ionized thorium atom (Th2) in sample of thorium containing 13% Th 230called as ionium. The observed isotope shifts between thorium-230 and thorium-232 spectrum line ranges in magnitude up to 0.94 cm^{-1} or per cm. the surface values of the Th230/Th232 ratio as a calcium carbonate concentration in Atlantic Ocean wt.% $CaCO_3$ sediments. As Thorium-231 have 141 neutrons. Ti is the decay product of Uranium-235. It is found in the small amount on the earth and has a half-life of 25.5 years. When it decays it emits beta ray and forms protactinium. It has decay energy of 0.39 Mev. It has mass of 231.0363043 gms/mole. The isotope of thorium i.e. Thorium-232 is a carcinogenic, which is any substance radionuclide or radiation that promotes carcinogens, the formation of cancer.

4. THORIUM AS A FUEL

Thorium is a basic element of nature, like Iron and Uranium. Like Uranium, its properties allow it to be used to fuel a nuclear chain reaction that can run a power plant and make electricity (among other things). Thorium itself will not split and release energy. Rather, when it is exposed to neutrons, it will undergo a series of nuclear reactions until it eventually emerges as an isotope of uranium called U-233, which will readily split and release energy next time it absorbs a neutron. Thorium is therefore called *fertile*, whereas U-233 is called fissile*.*

Reactors that use thorium are operating on what's called the Thorium-Uranium (Th-U) fuel cycle. The vast majority of existing or proposed nuclear reactors, however, use enriched uranium (U-235) or reprocessed plutonium (Pu-239) as fuel (in the Uranium-Plutonium cycle), and only a handful have used thorium. Current and exotic designs can theoretically accommodate thorium. The Th-U fuel cycle has some intriguing capabilities over the traditional U-Pu cycle. Of course, it has downsides as well. Up and coming nuclear reactor powerhouses China and India both have substantial reserves of Thorium-bearing minerals and not as much Uranium. So, expect this energy source to become a big deal in the not-too-distant future.

Thorium cycles exclusively allow thermal breeder reactors (as opposed to fast breeders). More neutrons are released per neutron absorbed in the fuel in a traditional (thermal) type of reactor. This means that if the fuel is reprocessed, reactors could be fueled without mining any additional U-235 for reactivity boosts, which means the nuclear fuel resources on Earth can be extended by 2 orders of magnitude without some of the complications of fast reactors. The Th-U fuel cycle does not irradiate Uranium-238 and therefore does not produce transuranic (bigger than uranium) atoms like Plutonium, Americium, Curium, etc. These transuranics are the major health concern of long-term nuclear waste. Thus, Th-U waste will be less toxic on the 10,000+ year time scale.

Thorium is more abundant in Earth's crust than Uranium, at a concentration of 0.0006% vs. 0.00018% for Uranium (factor of 3.3x). This is often cited as a key benefit, but if you look at the known reserves of economically extractable Thorium vs. Uranium, we'll find that they are both nearly identical. Also, substantial Uranium is found dissolved in sea-water, whereas there is 86,000x less Thorium in there. If breeding ever become mainstream, this benefit will be irrelevant because both the Th-U and the U-Pu fuel cycles will last us well into the tens of thousands of years, which is about as long as modern history.

5. DOWNSIDES OF THORIUM

Thorium fuel is a bit harder to prepare. Thorium dioxide melts at 550 degrees higher temperatures than traditional Uranium dioxide, so very high temperatures are required to produce high-quality solid fuel. Additionally, Th is quite inert, making it difficult to chemically process. Irradiated Thorium is more dangerously radioactive in the short term. The Th-U cycle invariably produces some U-232, which decays to Tl-208, which has a 2.6 MeV gamma ray decay mode. Bi-212 also causes problems. These gamma rays are very hard to shield, requiring more expensive spent fuel handling and/or reprocessing. Thorium doesn't work as well as U-Pu in a fast reactor. While U-233 an excellent fuel in the thermal spectrum, it is between U-235 and Pu-239 in the fast spectrum. So for reactors that require excellent neutron economy (such as breed-and-burn concepts), Thorium is not ideal.

Proliferation issues: - Thorium is generally accepted as proliferation resistant compared to U-Pu cycles. The problem with plutonium is that it can be chemically separated from the waste and perhaps used in bombs. It is publicly known that even reactor-grade plutonium can be made into a bomb if done carefully. By avoiding plutonium altogether, thorium cycles are superior in this regard.

6. CONCLUSION

This paper discusses about how to use thorium as fuel in nuclear power plant as a reactor instead of uranium. As all the aspects related to uranium are very much delicate such as uranium waste which is very hard to dispose but this is not the case in thorium by doing certain chemical reactions we can dispose the thorium waste. Also the half-life period of thorium is more than uranium likewise this paper discusses about different possibilities about the thorium to be used as fuel.

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