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PROSPECTS FOR THE USE OF THORIUM AS A NUCLEAR FUEL

Introduction

Thorium is one of the chemical elements, abundant in existence and use, symbolized by the chemical symbol "Th", its atomic number is "90" (Fig. 1), located in the periodic table within the elements of the third group and the seventh period, it follows in its classification to the elements of the actinides group.

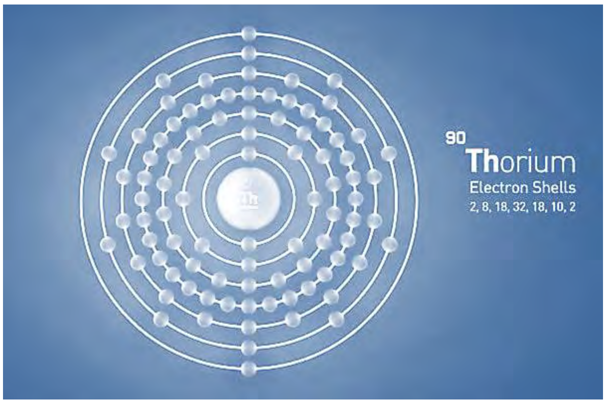

Fig.1. The atomic structure of thorium [1]

Thorium is one of the most important nuclear fuel alternatives to uranium, which is why it was given that name in honor of the Norse god of thunder, the bull. Thorium is prepared and produced by carrying out vari-ous reaction processes, where it can be prepared through the use of calcium metal, which helps in the processes of returning thorium tetrafluoride, which leads to a reaction between thorium and calcium, provided that zinc chloride is present, so that at the end of this reaction, thorium is produced in large quantities. Somewhat.

Thorium, like other elements, has been subjected to multiple isolation and separation processes, the most important of which is the ion exchange process, in addition to resorting to the process of electrolysis. In addition, many scientists resorted to a new separation process, which is mixing thori-um oxide with carbon in order to produce chloride. Thorium is capable of reacting with potassium, and as a result of this reaction, pure thorium will be obtained.

The location of thorium.

Thorium is found in many regions and countries of the world, as it is spread in Austria, Brazil and Russia, in addition to its presence in India, China and Canada, and there are percentages of this element concentrated in Africa, Australia and America [2].

In addition, quantities of this element may be found in many types of soil in addition to its presence in some types of rocks and water, and it is possible to find somewhat low percentages and levels in plants and animals.

Thorium may be found in nature associated with a group of elements and minerals, the most important of which is monazite, which contains a small percentage of the oxide of this element, in addition to its presence in each of the minerals thorite, thorianite and zircon, and it may occupy the forty-first place in terms of Its availability and presence on the surface of the earth.

In addition, thorium is often found with titanium, niobium, and tanta-lum, as thorite is one of the richest and most abundant minerals containing this element and here in the table the places or thorium all over the world (Table 1).

Table 1.

Estimates of thorium resources in the world [2]

Country	Tones	Country	Tones
India	846,000	South Africa	148,000
Brazil	623,000	China	100,000
Australia	595,000	Norway	87,000
USA	595,000	Greenland	86,000
Egypt	380,000	Finland	60,000
Turkey	374,000	Sweden	50,000
Venezuela	300,000	Kazakhstan	50,000
Canada	172,000	Other countries	1,725,000
Russia	155,000	**World total**	**6,355,000**

Thorium isotopes:

Thorium, like other elements, contains a group of radioactive iso-topes, which may number up to about 25 is a radioactive isotope, while it contains only one stable isotope, the isotope thorium 232 Which is the most stable isotope.

While the radioactive isotope thorium 230 It is one of the most widespread and abundant isotopes that has a half-life estimated at thousands of years, in addition to the fact that all radioactive thorium isotopes differ in their weight and atomic masses, in addition to their difference in their half-life.

Properties of thorium compared to uranium

1. Thorium is three to four times more abundant than uranium;
2. Thorium is more easily extracted than uranium;
3. Thorium is more abundant in nature than uranium;

4. It is fertile rather than fissile, and can only be used as a fuel in conjunction with a fissile material such as recycled plutonium;
5. Thorium fuels can breed fissile uranium-233 to be used in various kinds of nuclear reactors;
6. Molten salt reactors are well suited to thorium fuel; as normal fuel fabrication is avoided. Thorium is less radioactive than uranium.

Thorium as a nuclear fuel

Because thorium (Th-232) is not fissile, it cannot be used direct-ly in a thermal neutron reactor. It is, however, "fertile," and will transfer to uranium-233 (U-233) A, an excellent fissile fuel element B, when a neutron is absorbed. It is comparable to uranium-238 in this regard (which turns into plutonium-239). As a result, all thorium fuel concepts necessitate the irradi-ation of Th-232 in a reactor to provide the neutron dosages required to cre-ate protactinium-233. (Pa-233) can be chemically removed from the original thorium fuel and decay product U-233 and then recycled into fresh fuel, or U-233 can be used "on site" in the same fuel form, notably in molten salt re-actors (MSRs), thus thorium fuel does not require fissile material as a "mo-tor" so that the chain reaction (and hence an abundance of neutrons) can continue U-233, U-235, or Pu-239 are the only fission drivers available.

Reactors able to use thorium

1. Heavy Water Reactors (PHWRs);
2. High-Temperature Gas-Cooled Reactors (HTRs);
3. Boiling (Light) Water Reactors (BWRs);
4. Pressurized (Light) Water Reactors (PWRs);
5. Fast Neutron Reactors (FNRs);
6. Molten Salt Reactors (MSRs);
7. Accelerator Driven Reactors (ADS).

India's Plans for the Thorium Cycle

Using a three-stage model first developed at the University of Chicago in 1944, India has made the utilization of thorium for large-scale energy production a main priority in its nuclear power program. India has made the utilization of thorium for large-scale energy generation a main objective in its nuclear power program, as it possesses massive supplies of easily accessible thorium and comparatively little uranium [3].

1. Pressurized heavy water reactors (PHWRs) and light water reactors fed by natural uranium-producing plutonium is separated for use as fuel in its fast reactors and domestic advanced heavy water reactors.
2. Natural uranium-producing plutonium is removed from pressurized heavy water reactors (PHWRs) and light water reactors for use as fuel in its fast reactors and domestic advanced heavy water reactors.

3. To increase plutonium supplies, fast breeder reactors (FBRs) will use plutonium-based fuels. The blanket surrounding the core would include both uranium and thorium, resulting in the production of additional plutonium (especially plutonium-239) in addition to uranium-233.
4. Advanced Heavy Water Reactors (AHWRs) will burn thorium and plutonium fuels to produce uranium-233, which can be utilized as a self-sustaining fission lead for a fleet of breeding AHWRs in the future. This image depicted the final core of the US Shipping Port reactor.

The used fuel must be treated at each stage to recover the fissile parti-cles for recycling. India is concentrating on constructing and running a fleet of 500 megawatt sodium-cooled fast reactors to manufacture the needed plu-tonium. These reactors are critical to harnessing the energy potential of tho-rium in advanced heavy water reactors. This will take another 15-20 years, thus India will have to wait a long time to benefit from thorium's energy. The 500 MW FBR prototype was supposed to commence construction in Kalpakkam in 2014, but that timeframe has been pushed back to 2021, and India declared its determination to proceed with the project, despite the lift-ing of uranium trade restrictions.

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