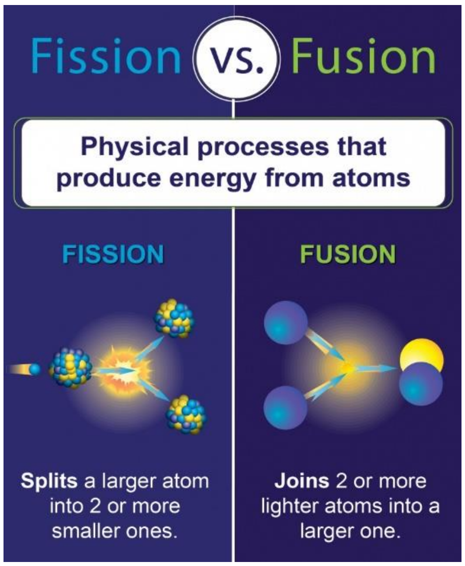
Fission versus Fusion

Introduction

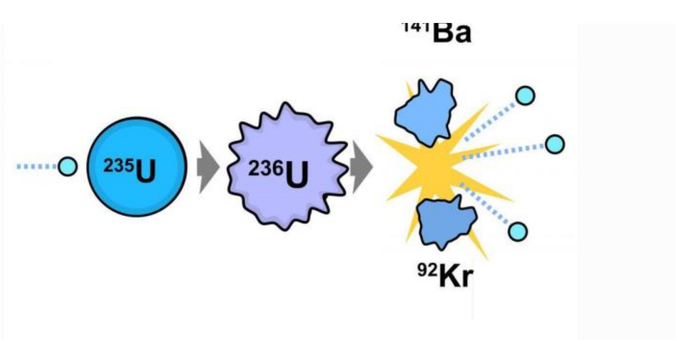
Generally, **transmutation** refers to the act of change from one **form** to another. In context to nuclear **transmutation**, it may refer to a **radioactive** process, ie. nuclear **fission,** or nuclear **fusion** where the **form** of element is changed from one to another. **Radioactive** Decay is the process by which an atomic nucleus emits elementary particles or fragments.



Nuclear fission is a nuclear reaction in which the nucleus of an atom splits into smaller parts (lighter nuclei). Nuclear fusion is a **nuclear reaction in** which two or **more atomic nuclei collide at a high energy and fuse together into a new nucleus.**

Like fission, nuclear fusion **can also transmute one element into another.** For example, **hydrogen nuclei fuse in** stars to form the element helium. Fusion is also used to force together atomic nuclei to form the newest elements on the periodic table.

In order to create a nuclear reactor today, the first ingredient we need is reactor-grade fuel. Uranium, for example, comes in two different naturally occurring isotopes: U-238 (with 146 neutrons) and U-235 (with 143 neutrons). Changing the number of neutrons does not change your element type but does change how stable your element is. For U-235 and U-238, they both decay via a radioactive chain reaction, but U-238 lives about six times as long, on average. Presently, U-235 makes up only about 0.72% of all naturally occurring Uranium, meaning it has to be enriched to at least about 3% levels in order to get a sustaining fission reaction, or a special setup (involving heavy water mediators) is required. However, 1.7 billion years ago U-235 was more than two full half-lives. Back in ancient Earth, U-235 was about 3.7% of all uranium: enough for a reaction to occur.

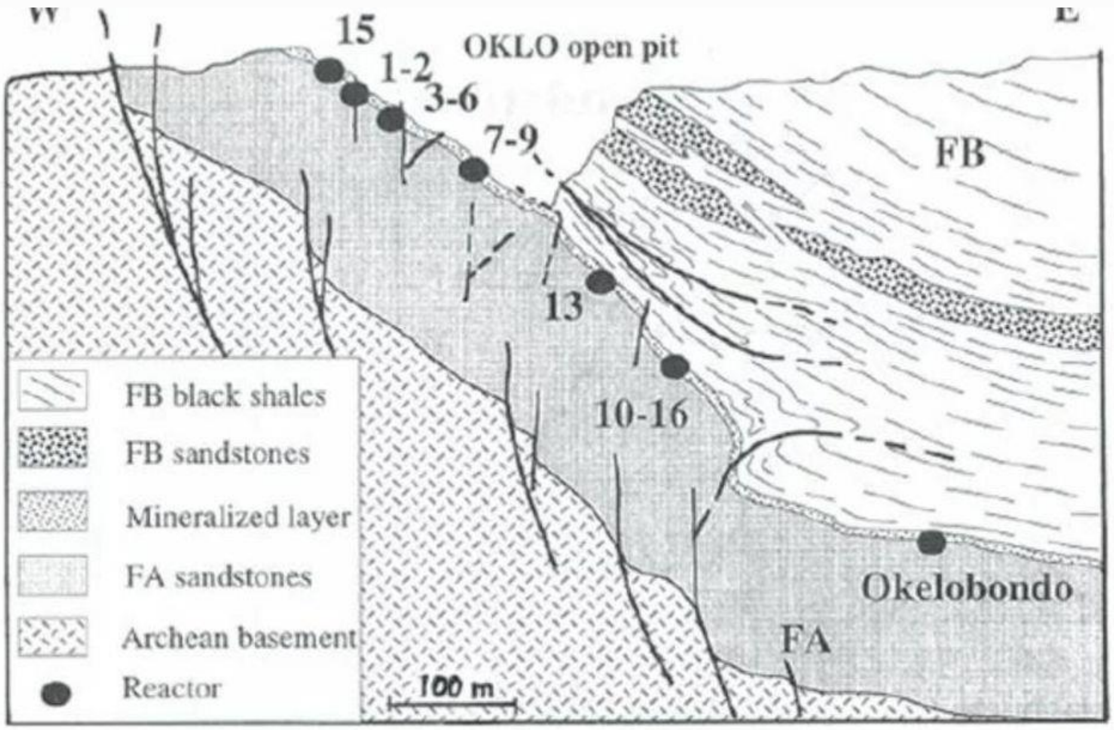


The Uranium-235 chain reaction that both leads to a nuclear fission bomb, but also generates power.

Within the Earth

In between different Earth's crust layers of stone bedrock (eg. sandstone, granite, basalt, metamorphic, etc.) you often find veins of mineral deposits, rich in a particular element. Sometimes these are extremely lucrative, ie. gold veins. However, there are rarer materials in these bedrock layers, such as uranium. In modern reactors, enriched uranium produces neutrons, and in the presence of water, which acts like a neutron moderator, a fraction of those neutrons will strike another U-235 nucleus, causing a fission reaction.

As the nucleus splits apart, it produces lighter daughter nuclei, releases energy, and also produces three additional neutrons. If the conditions are right, the reaction will trigger additional **fission** events, leading to a self-sustaining reactor.



Geologic cross-section of the Oklo and Okélobondo uranium deposits, showing the locations of the rock forms and reactors.

Two factors came together, 1.7 billion years ago, to create a natural nuclear reactor. The first is that, below and above the bedrock layers groundwater flows freely, and it is only a matter of geology and time before water flows into the uranium-rich regions. Then once uranium atoms are surrounded with water molecules, then there are conditions for a nuclear reaction. However, to get the reactor working well, in a self-sustaining fashion, the uranium atoms need to be dissolved in the water. In order for uranium to be soluble in water, oxygen must be present. Fortunately, oxygen evolved through transmutation in the Earth and was plentiful after the first mass extinction in Earth's recorded history: the great oxygenation event. With oxygen in the groundwater, dissolved uranium would be possible whenever water floods the mineral veins, then the conditions existed for uranium-rich material.

Evidence of natural nuclear reactors in the Earth

If it is assumed that the inner core is formed of crystallised Nickel Silicide instead of Iron, then it would be stable. Over time Uranium, Thorium, and other actinides due to their mass would tend to concentrate along the boundary of the inner core where they could reach a critical mass. Such a reactor could be producing about 10% of the heat within the earth and would vary over time as the actinides were gradually scavenged from the outer core and mantel. This variation over time might explain reversals of the earths geomagnetic field. The reactor would need to be a breeder to have lasted as long as it has and to have only slightly dropped in power over 4.5 billion years. The ratio of 3He/4He found in deep-mantle magma sources (Hawaiian volcanic lavas) are in excess of the current atmospheric ratio by a large factor and are consistent with those from a Deep-Earth Reactor.

In 1972, the French physicist Francis Perrin discovered a total of 17 sites spread across three ore deposits at the Oklo mines in Gabon, West Africa, that contained all four of these signatures.

This is the site of the Oklo natural nuclear reactors in Gabon, West Africa. This site was once deep inside the Earth.

The Oklo fission reactors are the only known examples of a natural nuclear reactor here on Earth, but the mechanism by which they occurred lead us to believe that these could occur in many locations and could occur elsewhere in the Universe as well. When groundwater inundates a uranium-rich mineral deposit, the fission reactions, of U-235 splitting apart, can occur.

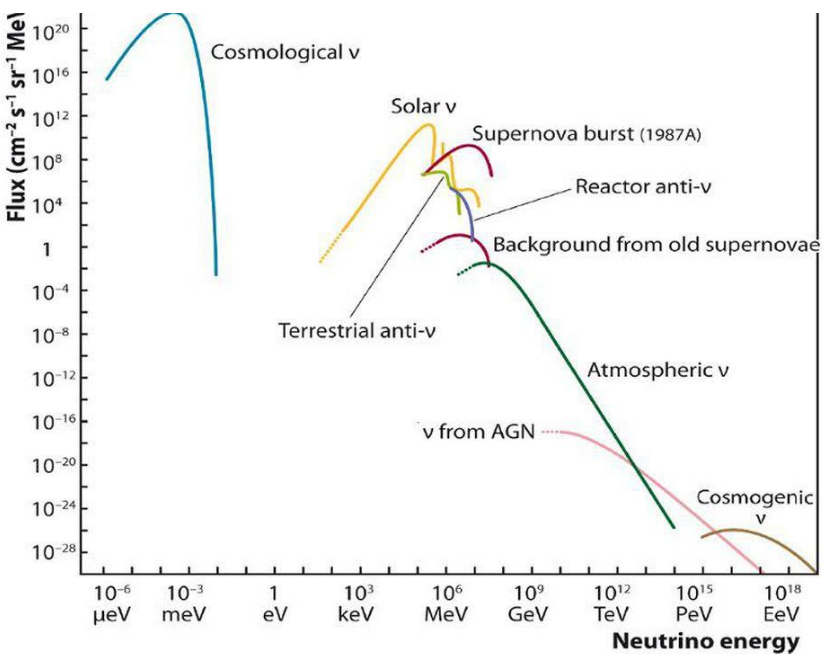
The groundwater acts as a neutron moderator, allowing (on average) more than 1 out of 3 neutrons to collide with a U-235 nucleus, continuing the chain reaction.

As the reaction goes on for only a short amount of time, the groundwater that moderates the neutrons boils away, which stops the reaction altogether. Over time, however, without fission occurring, the reactor naturally cools down, allowing groundwater back in.

The terrain surrounding the natural nuclear reactors in Oklo suggests that groundwater insertion was possible.

By examining the concentrations of xenon isotopes that become trapped in the mineral formations surrounding the uranium ore deposits, humanity, like an outstanding detective, has been able to calculate the specific timeline of the reactor. For approximately 30 minutes, the reactor would go critical, with fission proceeding until the water boils away. Over the next ~150 minutes, there would be a cooldown period, after which water would flood the mineral ore again and fission would restart.

This three-hour cycle would repeat itself for hundreds of thousands of years, until the ever-decreasing amount of U-235 reached a low-enough level, below that ~3% amount, that a chain reaction could no longer be sustained. At that point, all that both U-235 and U-238 could do is radioactively decay.



There are many natural neutrino signatures produced by stars and other processes in the Universe.

Looking at the Oklo sites today, we find natural U-235 abundances that range from 0.44% up to 0.60%: all well-below the normal value of 0.72%. Nuclear fission, in some form or another, is the only naturally-occurring explanation for this discrepancy. Combined with the xenon, the neodymium, and the ruthenium evidence, the conclusion that this was a geologically-created nuclear reactor is all but inescapable