

Generation IV Nuclear Reactors: Safety and Efficiency

Vorwissenschaftliche Arbeit verfasst von

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Abstract

This is a placeholder for the abstract. It summarizes the whole thesis to give a very short overview. Usually, this the abstract is written when the whole thesis text is finished.

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1 Basic concepts of nuclear power

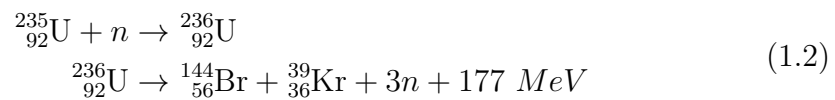
Nuclear power reactors harness the heat generated by splitting atoms of certain elements in a controlled and predictable way. This heat is used to create electrical power¹.

1.1 Fission

Nuclear fission is the spontaneous or induced reaction, by which an atom is broken up. In the case of nuclear power reactors these reactions are exothermic. Nuclear radiation such as in equation 1.1 already liberates a large amount of energy.

$${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th}, \quad P = 8 \cdot 10^{-9} \frac{W}{g} \quad (1.1)$$

This power is increased in nuclear reactors by 10 orders of magnitude. Although the effective lifespan is lowered from $4.468 \cdot 10^9$ years to a few months. Therefore fission is the main reaction through which nuclear reactors generate the majority of their power output. An example of such a reaction is given in equation 1.2.²

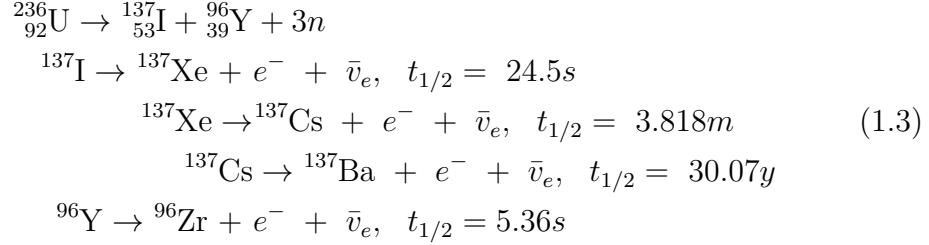


It is important to note that 1.2 is a simplification of the actual decay series of ${}_{92}^{236}\text{U}$ into stable end products. 1.2 is sufficient to understand the principle

¹World Nuclear Association, 2022.

²Basdevant, Rich, and Spiro, 2005, p. 286.

behind nuclear fission. The decay series of $^{236}_{92}\text{U}$ with no intermediates removed is given in 1.3.³



1.2 Nuclear Cross Section

Nuclear cross section describes the probability of a certain nuclear reaction to occur. This aspect needs thorough consideration in the design of nuclear reactors, as the nuclear cross section generally increases with the inverse of the velocities of the reactants⁴.

1.3 Criticality

Criticality is the operating condition of a nuclear reactor, in which the neutrons produced by fission events is sufficient to sustain a chain reaction^{5,6}.

1.4 Components of Nuclear Reactors

1.4.1 Fuel

The reactor fuel is the fissile material used in the fission reaction inside of a reactor. In most cases uranium oxide UO_2 pressed into pellets is used for this

³Basdevant, Rich, and Spiro, 2005, p. 287.

⁴Basdevant, Rich, and Spiro, 2005, p. 108.

⁵Basdevant, Rich, and Spiro, 2005, p. 308.

⁶Stacey, 2018, p. 39.

purpose. These pellets are put into tubular fuel rods. The whole fuel assembly inside the reactor consists of many such rods⁷.

1.4.1.1 Startup Neutron Source

As the fission of uranium produces three neutrons per reaction, there does not need to be a constant external influx of neutrons. However, to start this chain reaction inside a new reactor equipped with newly made fuel rods a neutron source is needed. Usually beryllium combined with an alpha emitter is used for this purpose, as the collision of an α -particle with ${}^9_4\text{Be}$ releases a neutron as part of its reaction, as can be seen in equation 1.4^{8,9}.



⁷World Nuclear Association, 2022.

⁸World Nuclear Association, 2022.

⁹Basdevant, Rich, and Spiro, 2005, p. 100.

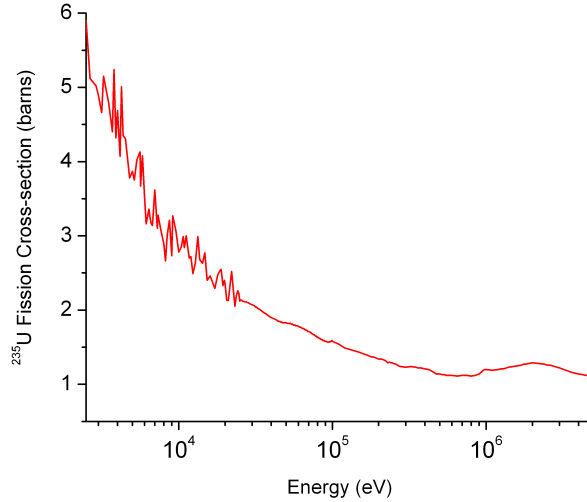


Figure 1.1: Nuclear cross section of ^{235}U in relation to neutron energy

1.4.2 Moderator

Nuclear fission events release neutrons with energies in excess of multiple MeV, or speeds higher than $10^7 \frac{m}{s}$. However at these speeds the nuclear cross section of the fission reaction is quite low as can be seen in figure 1.1.

Therefore the emitted neutrons need to be slowed down in order to be useful, they need to be slowed down. This is done using a moderator. When passing through a moderator the neutrons are slowed down through collisions with the aforementioned. Although it is important to note that the moderator should absorb as few neutrons as possible to not hinder the chain reaction. For this reason H_2O and graphite are commonly used.¹⁰

¹⁰Stacey, 2018, p. 28.

Appendix

Bibliography

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Eidesstattliche Erklärung

Ich, Elias Leitinger, erkläre hiermit eidesstattlich, dass ich diese vorwissenschaftliche Arbeit selbständig und ohne Hilfe Dritter verfasst habe. Insbesondere versichere ich, dass ich alle wörtlichen und sinngemäßen Übernahmen aus anderen Werken als Zitate kenntlich gemacht und alle verwendeten Quellen angegeben habe.

Dietach, am _____
Datum

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