2019 Basic Nuclear Engineering I　Lecture note (3)

- Nuclear fission chain reaction–

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3.1 Concept of nuclear fission chain reaction (continued)

The reason　　Nat. U ^{235}U…0.7%

^{238}U…99.3%

	Energy	
① Fission neutrons	2MeV	slowing down of neutrons
② Large neutron capture cross section of ^{238}U	5~ 500eV	neutrons are captured
③ Large fission cross section of ^{235}U	below 0.1eV	neutrons are captured

By making neutron capture (②) small, and nuclear fission (③) large, it may be possible to continue fission chain reaction.

(Concept of <u>thermal reactor)</u>

The measures for it

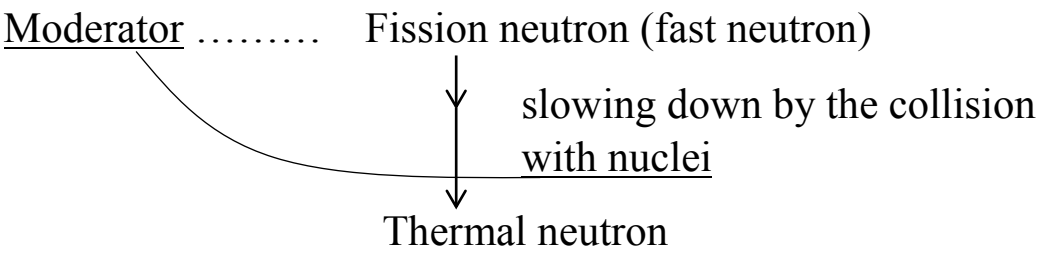
1. Use of moderator
2. Heterogeneous structure of uranium and moderator
3. Enrichment of uranium

3.2 Moderator

Thermal neutron … Energy < 1eV

equilibrium with thermal motion of nuclei in material

Thermal reactor … Fission chain reaction by using thermal neutrons



・Properties needed in moderator

1. Small mass number

→ The neutron energy is decreased a lot by a collision.
(speed low)

2. Large scattering cross section

→ The probability of scattering can be large.

3. Small capture cross section

→ The loss of neutrons can be small.

・Examples of good moderator
- Heavy water (D_2O)
- Graphite (C)
- Beryllium (Be)

Light water is not so good. Capture cross section is a little large.

3.3 Hetrogeneous structure of Uranium and Moderator

Without mixing uranium and moderator,

setting the uranium and moderator with a structure

→ The neutron capture probability by ^{238}U can be reduced remarkably.

- Heavy water moderator or Graphite moderator

+

- (Very well designed) heterogeneous structure of uranium and moderator

⇒ It is possible to cause fission reaction chain by using natural uranium.

- The world's first nuclear reactor (1942) Chicago Pile-1 (CP-1)

The pieces of natural uranium were set in graphite block.

The size of pile: 6m cubic (very large)

3.4 Enrichment of uranium

Natural U $\left\{\begin{array}{l} {}^{235}\mathrm{U}\ldots 0.7\% \\ {}^{238}\mathrm{U}\ldots 99.3\% \end{array}\right.$ $\Rightarrow$ increase the ratio artificially (enrichment of uranium)

⇩

The neutrons captured by ^{238}U can be small.

⇩

Easy to cause fission chain reaction.

Fuel	Ratio of ^{235}U	Possible nuclear reactor
Natural uranium	0.7%	Nuclear reactor with heavy water or graphite as the moderator
3% enriched uranium	3%	Nuclear reactor with light water as the moderator (Current popular power reactor)
10% enriched uranium	10%	Nuclear reactor without the moderator (Fast reactor) The fission chain reaction is possible without moderator. It can be achieved with mixture of ^{239}Pu and ^{238}U as well.