

## 2020 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  $^{235}\text{U}$ ...0.7%

$^{238}\text{U}$ ...99.3%

① Fission neutrons

Energy

2MeV

slowing down of neutrons

② Large neutron capture  
cross section of  $^{238}\text{U}$

5~

neutrons are captured

500eV

③ Large fission cross  
section of  $^{235}\text{U}$

below

neutrons are captured

0.1eV

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

(Concept of thermal reactor)

The measures for it

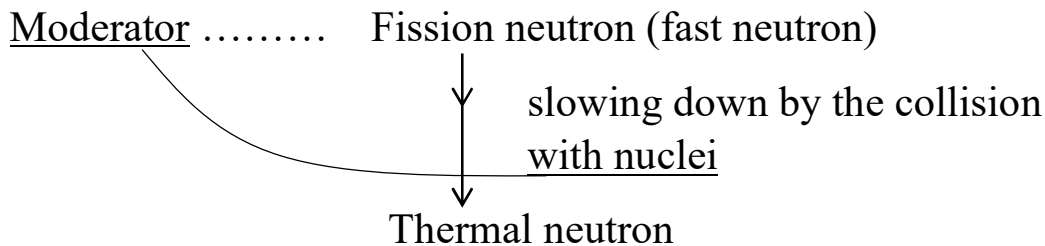
1. Use of moderator
2. Heterogeneous structure of uranium and moderator
3. Enrichment of uranium

### 3.2 Moderator

Thermal neutron ... Energy  $< 1\text{eV}$

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 ( $\text{D}_2\text{O}$ )
	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  $^{238}\text{U}$  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  $\left\{ \begin{array}{l} {}^{235}\text{U} \dots 0.7\% \\ {}^{238}\text{U} \dots 99.3\% \end{array} \right. \Rightarrow \text{increase the ratio artificially}$   
 (enrichment of uranium)



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



Easy to cause fission chain reaction.

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Fuel	Ratio of ${}^{235}\text{U}$	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 ${}^{239}\text{Pu}$ and ${}^{238}\text{U}$ as well.

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