2020 Basic Nuclear Engineering I　Lecture note (2)

- Nuclear Fission –

Toru Obara

Tokyo Institute of Technology

2. Nuclear Fission

2.1　Nuclear fission by neutron

・Heavy nucleus causes fission reaction by the collision with a neutron with very high speed

→ =with large mass number

→ Number of protons + neutrons

・Heavy nucleus with odd number of neutrons causes fission reaction by very slow neutrons

・Nucleus which satisfies the condition in nature is uranium 235 only

(^{235}U)

Mass number 235

U

92 Atomic number

Number of protons: 92

Number of neutrons: 235 – 92 = 143

・Example of nuclear fission of ^{235}U

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$$

Uranium235 neutron Uranium236 (unstable) Barium141 + Kripton92 + three neutrons

Various combinations

two or three neutrons emission

Mass defect in the reaction

$\simeq 3.6 \times 10^{-28}$ kg

Corresponding energy (by $E = mc^2$)

$\simeq 3.2 \times 10^{-11}$ J ($\cong$ 200 MeV)

Ref. In the chemical reaction

$C + O_2 \rightarrow CO_2$

Release energy $\simeq 7\times10^{-19}$ J

$(3.2\times10^{-11})/(7\times10^{-19}) \simeq 4.6\times10^{7}$

・Number of neutrons emitted in fission reaction ν

$\nu \simeq 2.5$ (in case of ^{235}U)

・Energy of neutrons emitted in fission reaction (fission neutron)

average 2MeV ($1eV = 1.602\times10^{-19}J$)

peak 1MeV

2.2 Actinoid

○Actinoid : element whose atomic number is from 89 to 103
Ac Lr

○Important actinoid in nuclear reactor

・Uranium (Atomic number 92)

Abundance in the earth's crust : 2×10^{-6}

Natural uranium
- uranium 235 ^{235}U 0.71%
  fissile ← easy to cause fissile by neutron
- uranium 238 ^{238}U 99.29%

・Thorium (Atomic number 90)

Abundance in the earth's crust : 7×10^{-6}

Natural thorium ・・・・ thorium 232 ^{232}Th 100%
non-fissile

^{232}Th : by neutron capture

transmuted to ^{233}U (fissile)

does not exist in nature

・Plutonium (Atomic number 94)

does not exist in nature

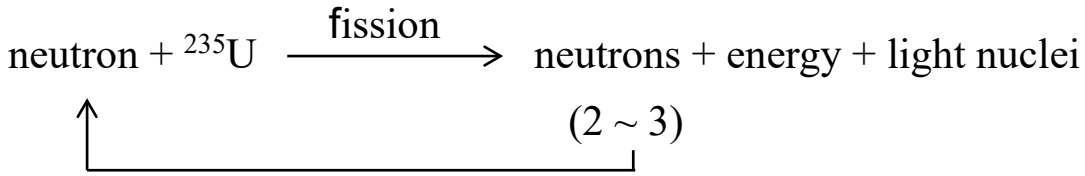
^{238}U : by neutron capture

transmuted to ^{239}Pu (fissile)

3. Nuclear fission chain reaction

3.1 Concept of nuclear fission chain reaction

By using neutrons emitted by fission reaction, causing the next fission reaction



But !!

Even if neutrons are injected to natural uranium, fission chain reaction does not occur.

(3.1. to be continued)