2019 Basic Nuclear Engineering I Lecture note (2)

- Nuclear Fission -

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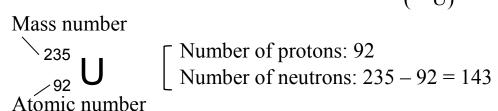
2. Nuclear Fission

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 (235U)



•Example of nuclear fission of ²³⁵U

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

Uranium235 neutron

Uranium236 (unstable)

Barium141 + Kripton92

+ three neutrons

Various combination

two or three neutrons emission

Mass defect in the reaction

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

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

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

Ref. In the chemical reaction

$$C + O_2 \rightarrow CO_2$$

Release energy $\simeq 7 \times 10^{-19} \text{ J}$

$$(3.2 \times 10^{-11}) / (7 \times 10^{-19}) \simeq 4.6 \times 10^7$$

• Number of neutrons emitted in fission reaction v

$$v \simeq 2.5$$
 (in case of ²³⁵U)

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

average
$$2 \text{MeV}$$
 $(1 \text{eV} = 1.602 \times 10^{-19} \text{J})$

peak 1MeV

2.2 Actinoid

OActinoid: 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 235 235 U 0.71% fissile \leftarrow 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 232Th 100% non-fissile

²³²Th: by neutron capture

transmuted to ²³³U (fissile)

does not exist in nature

·Plutonium (Atomic number 94)

does not exist in nature

²³⁸U : by neutron capture

transmuted to ²³⁹Pu (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

neutron +
$$^{235}U$$
 $\xrightarrow{\text{fission}}$ neutrons + energy + light nuclei $(2 \sim 3)$ But !!

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

(3.1. to be continued)