

# 2019 Basic Nuclear Engineering 1    Lecture note (1)

## - Nuclear Energy -

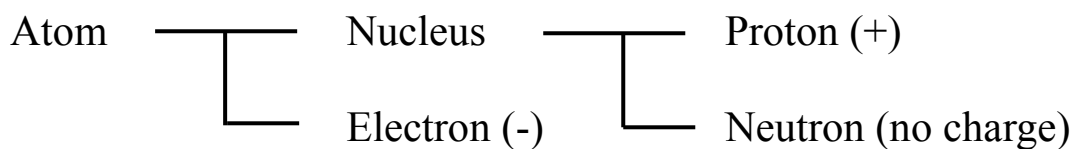
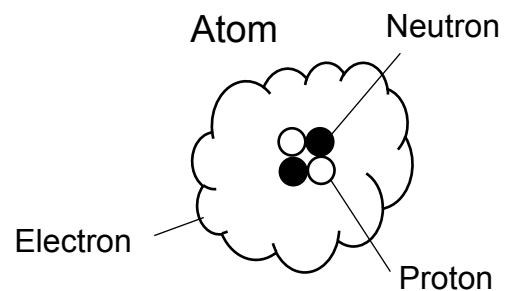
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### 1. Nuclear Energy

#### 1.1 Origin of nuclear energy

##### • Structure of atom



##### • Relation between energy and mass

$$E = m c^2$$

$E$  : energy

$m$  : mass

$c$  : the speed of light ( $=3 \times 10^8$  m/s)

##### • Chemical energy and nuclear energy

Chemical energy (Combustion of coal, oil, etc.)

Change of chemical binding

→ small reduction of mass

→ energy release

Nuclear energy (Nuclear reactor, Sun)

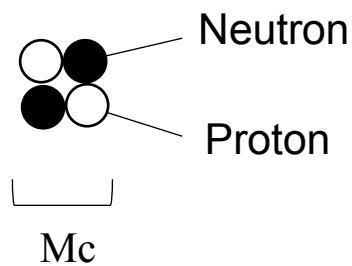
Change of nuclear binding

→ change of mass

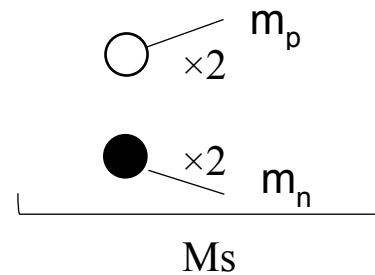
→ energy release

• Mass defect and binding energy

Nucleus



Protons and neutrons



$Mc < \text{Total mass of protons and neutrons (Ms)}$

$$\Delta M = Ms - Mc$$

Mass defect

$$\Delta E = \Delta Mc^2$$

Binding energy

• Binding energy per nuclear

(Figure) Fig of Binding energy

Composition (or fusion) of light nuclei

→ Energy release (Fusion reactor, Sun)

Splitting (or fission) of heavy nuclei

→ Energy release (Nuclear reactor)

## 1.2 Radioactivity

The process that nucleus changes the number of protons and neutrons spontaneously

- $\alpha$  -decay: An alpha-particle (two protons + two neutrons) is emitted

Atomic number -2, Mass number -4

- $\beta$  -decay: A neutron in the nucleus is transformed into a proton.

An electron is emitted. (  $\beta$  -ray)

Atomic number +1, Mass number unchanged

The decay process → Mass defect

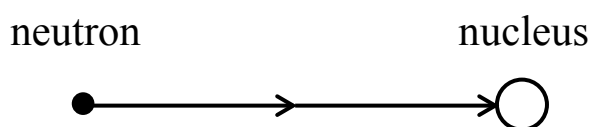
→ Energy release

Kinetic energy of the  $\alpha$  - particle or the electron

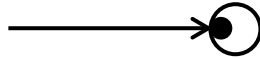
Energy of photon (  $\gamma$  -ray)

## 1.3 Nuclear reaction with neutrons

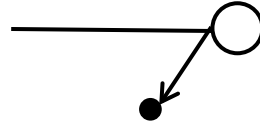
- Nuclear reactions



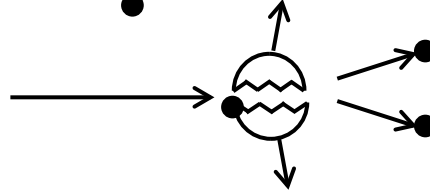
- Capture



- Scattering



- Fission



- Nuclear cross section

Index of probability of nuclear reaction

$$\text{unit } b (\text{barn}) = 10^{-24} \text{ cm}^2$$

- Capture cross section  $\sigma_c$

- Scattering cross section  $\sigma_s$

- Fission cross section  $\sigma_f$

(unit of energy  $1\text{eV} = 1.602 \times 10^{-19} \text{ J}$ )

- Nuclear cross sections of  $^{235}\text{U}$  and  $^{238}\text{U}$  (Fig of cross sections)

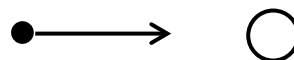
$^{235}\text{U}$  0.7% in natural uranium

$^{238}\text{U}$  99.3% in natural uranium

- Fission cross section  $\sigma_f$

$^{235}\text{U}$  . . . . large in low neutron energy ( $<1\text{eV}$ )

slow speed



about 1b      if  $E > 1\text{MeV}$   
(high energy = high neutron speed)

$^{238}\text{U}$  . . . . almost 0 in low energy

about 1b      if  $E > 1\text{MeV}$

• Capture cross section  $\sigma_c$

$^{238}\text{U}$  . . . . many large peaks between  $5\text{eV} \sim 500\text{eV}$  (Resonance peaks)