# 2020 Basic Nuclear Engineering 1 Lecture note (1)

## - Nuclear Energy –

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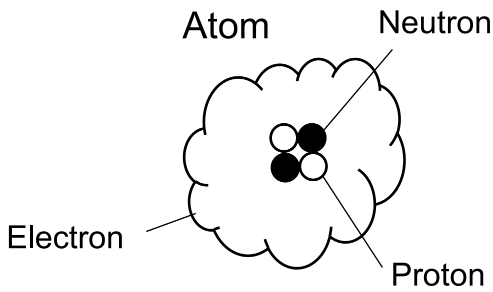



## 1. Nuclear Energy

### 1.1 Origin of nuclear energy

・Structure of atom

Atom ── Nucleus ── Proton (+)
 │ │
 └── Electron (-) └── Neutron (no charge)

・Relation between energy and mass

$$E = m c^2$$

E : energy

m : mass

c : the speed of light ( $=3\times10^8$ 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　　　　　　　　　　　　　Ms

Mc　<　Total mass of protons and neutrons (Ms)

$\Delta M = Ms - Mc$

Mass defect

$\Delta E = \Delta M c^2$

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

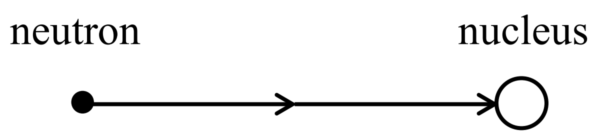
→ Energy release

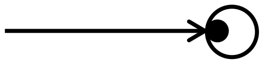
Kinetic energy of the $\alpha$ - particle or the electron

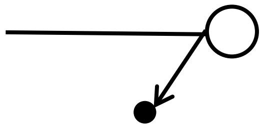
Energy of photon ( $\gamma$ -ray)

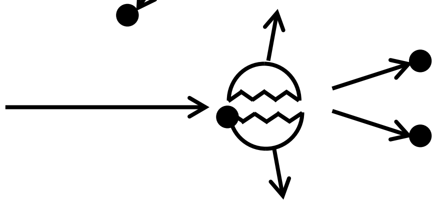
## 1.3 Nuclear reaction with neutrons

・Nuclear reactions



・Capture 

・Scattering 

・Fission 

・Nuclear cross section

Index of probability of nuclear reaction

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

・Capture cross section $\sigma_c$

・Scattering cross section $\sigma_s$

・Fission cross section $\sigma_f$

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

・Nuclear cross sections of $^{235}U$ and $^{238}U$ (Fig of cross sections)

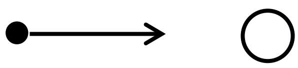
$^{235}U$ 0.7% in natural uranium

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

・Fission cross section $\sigma_f$

$^{235}U$ ・・・・ large in <u>low neutron energy</u> (<1eV)

slow speed



about 1b if E > 1MeV

(high energy = high neutron speed)

$^{238}U$・・・・almost 0 in low energy

about 1b if E > 1MeV

・Capture cross section $\sigma_c$

$^{238}U$・・・・many large peaks between 5eV ~ 500eV (Resonance peaks)