#2

原子力と放射線の物理
第一歩
PHYSICS OF
NUCLEAR POWER & RADIATION
(FIRST STEP)

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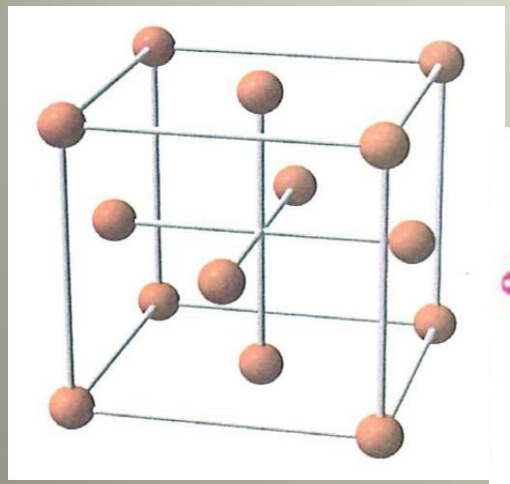
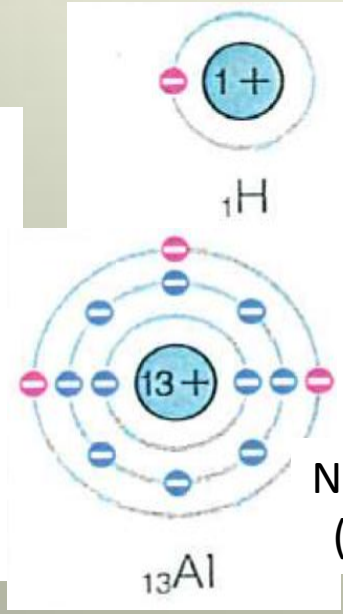
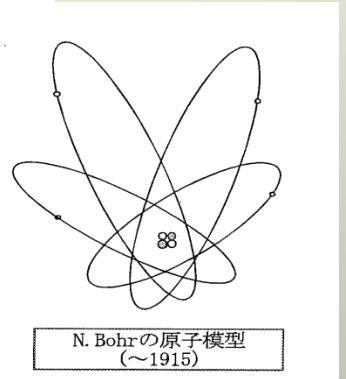
Structure of Atom &Nuclear
（原子と原子核の構造）



Crystal
(結晶）





Nuclear model by N.Bohr
(～1915)

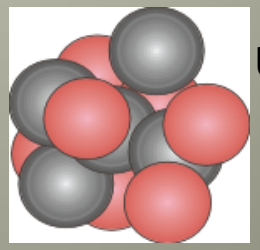
Atom(原子）

(nuclear & electron)
（原子核と電子）

proton Neutron

Hydrogen
P : 1
N: 0
(A=1)

Helium
P : 2
N : 2
(A=4)



Uranium-235
P : 92
N : 143
(A=235)

Nuclear

Weights & Dimensions(大きさと重さ)

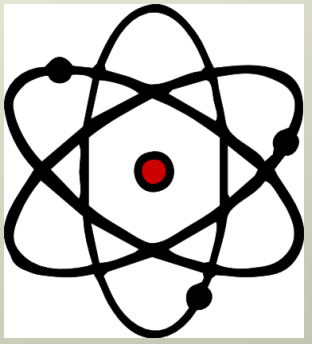
	amu (atomic mass unit)	**m_e**	**(gram)**
nuclear of carbon	12		9.1 $\times 10^{-28}$
proton	1.0073	1836.1	
neutron	1.0087	1838.6	
electron	5.49×10^{-4}	1	

Radius of Nuclear

$R = r_0 A^{1/3}$ $r_0 = 1.5 \times 10^{-13}$(cm)

Nuclear / Metal Crystal
（原子核／金属結晶）

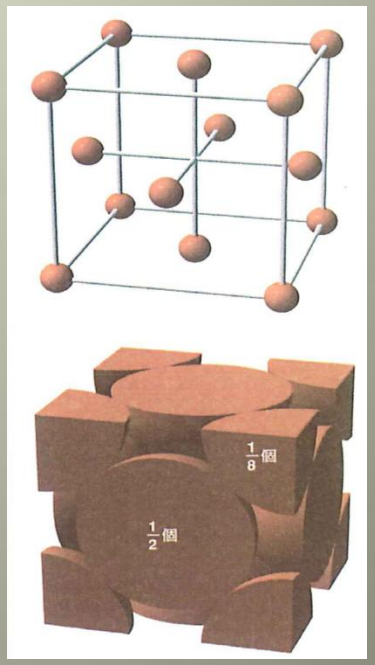
Al (aluminum)



Nuclear Radius of aluminum
（原子核の大きさ）

$R = 1.5 \times 10^{-13} \times A^{1/3}$ (cm)

$= 4.5 \times 10^{-6}$ (nm)



lattice constant of Al metal
(結晶の大きさ）
(face centered cubic lattice)

a = 0.4049 (nm)

atom size in crystal (Al)

r = 0.143 (nm)

Nuclear Reaction（核反応）

reaction of radiation with nuclear(原子核と放射線の反応）

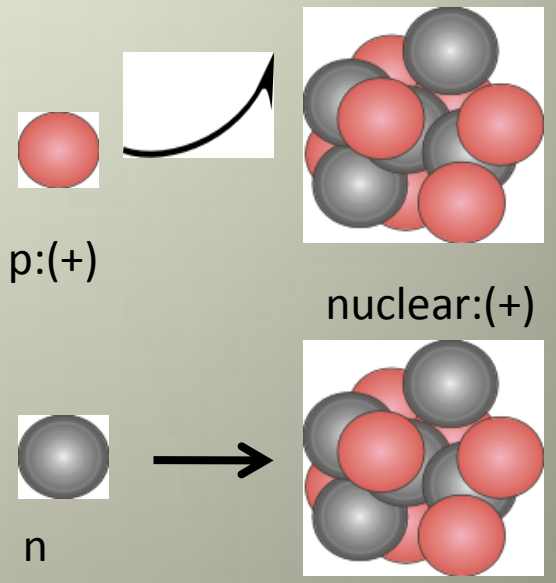
charged particle : electron, proton, alpha particle

neutron

neutron reactions(中性子の反応）

原子炉で重要

no electric charge



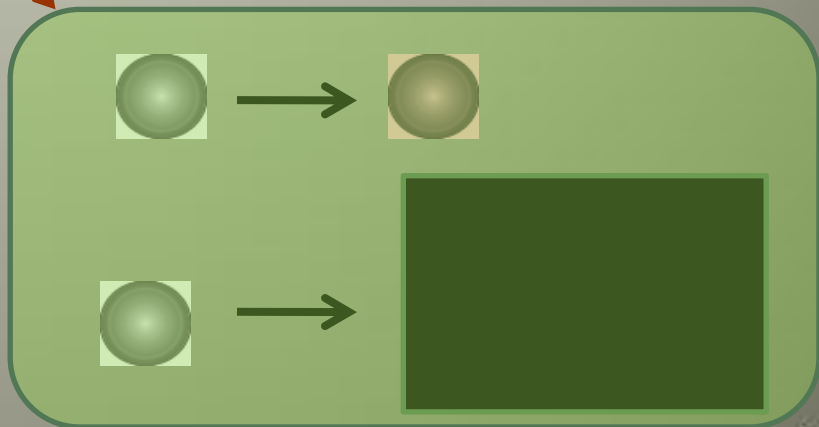
elastic scatter

in_elastic scatter

absorption capture(n,γ）

(n,α),(n,p),….

fission

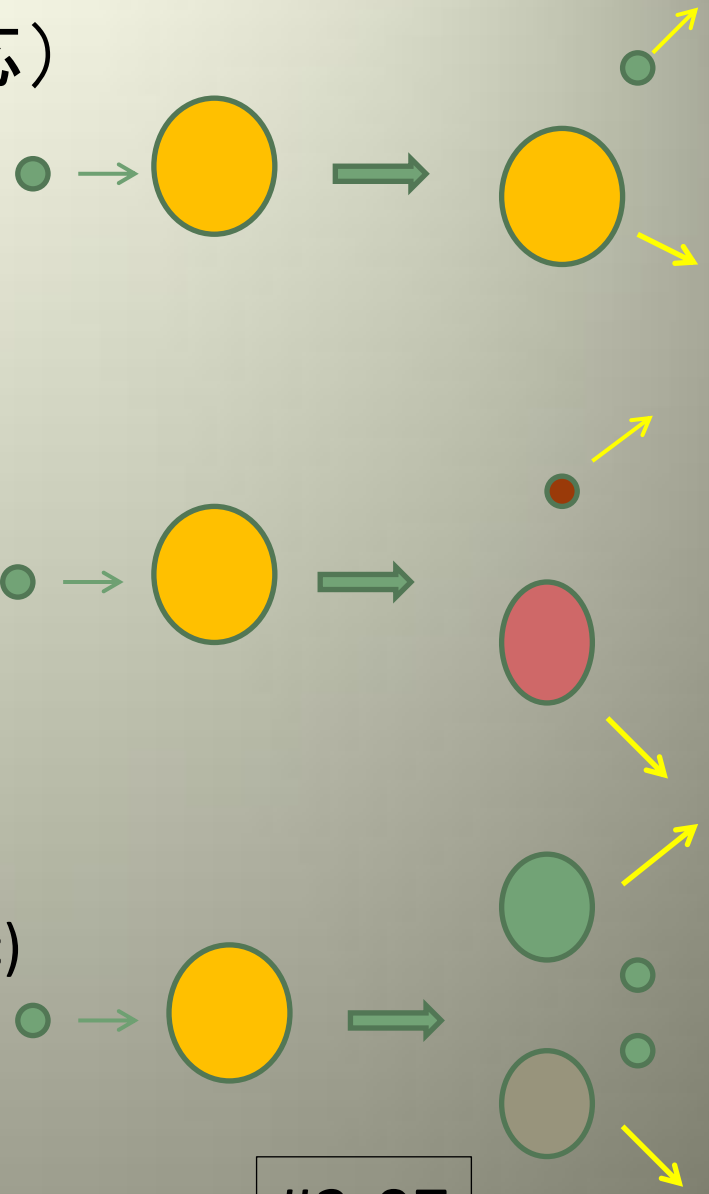


neutron reactions
（中性子の反応）

neutron emission（中性子放出）
  change of neutron energy, direction

neutron capture（中性子捕獲）
  no neutrons after reaction
  (n,γ)
(n,p),(n,α)

fission（核分裂）
  multiplication of neutrons
    neutron energy, direction(isotropic)



transport of neutron（中性子輸送）

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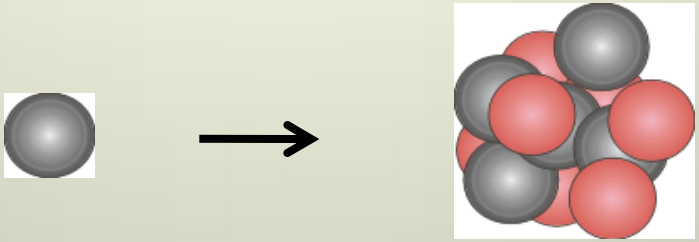
Neutron Reaction Cross Section
（中性子反応断面積）



nuclear radius(simple model by experiment)

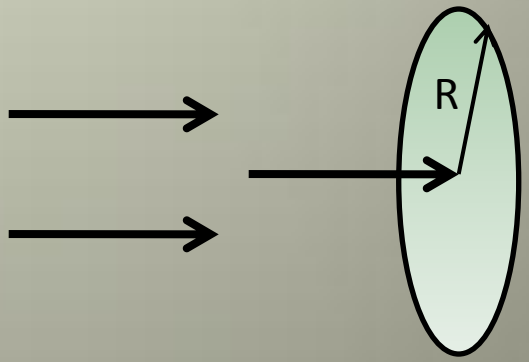
$R = 1.5 \times 10^{-15} \times A^{1/3}$ (m)

U-235

A = 235

$R \sim 9 \times 10^{-15}$ (m)

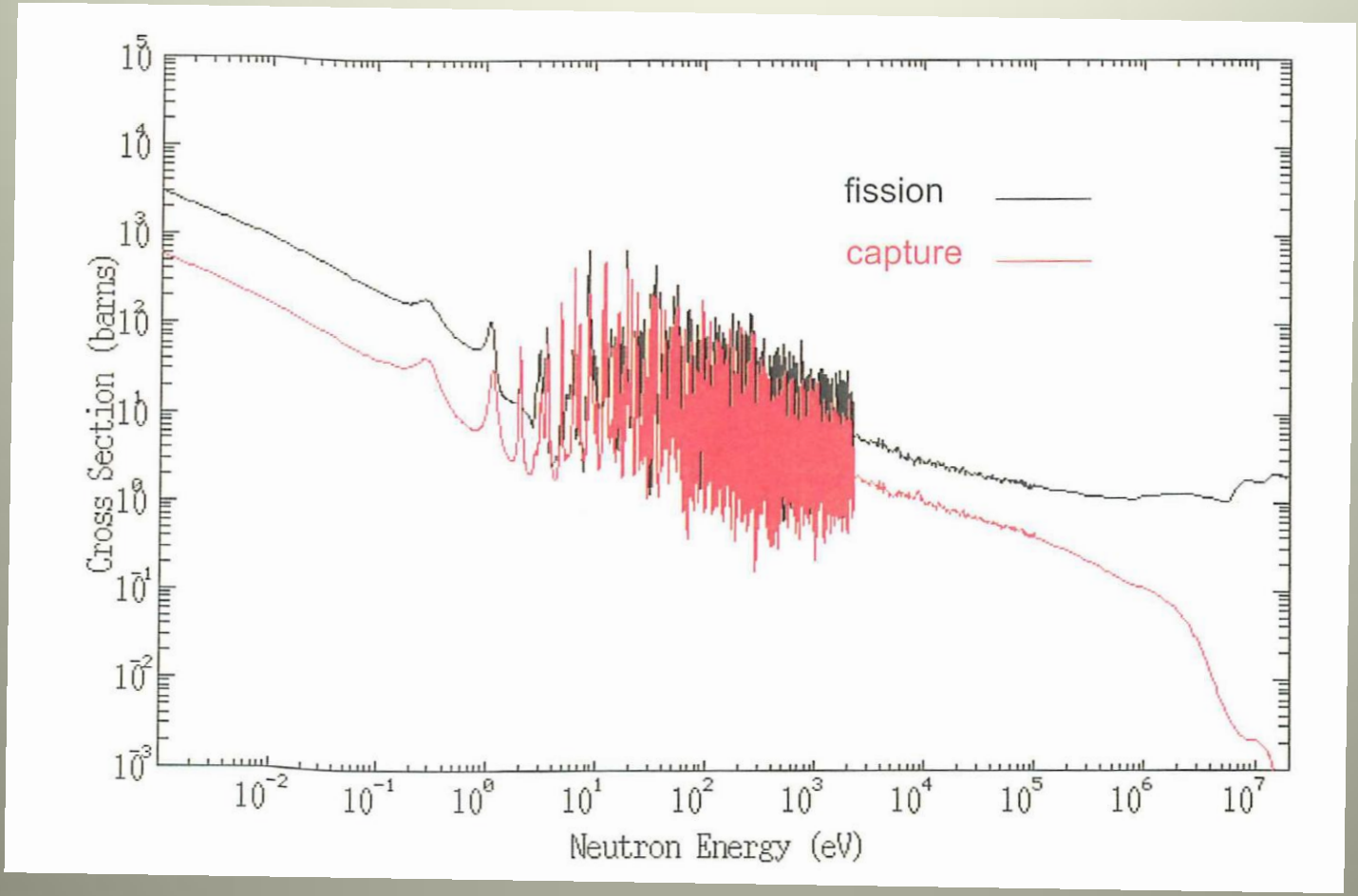
$S \sim 2.5 \times 10^{-28} (m^2)$



unit of reaction cross section

barn : 1 barn = 10^{-28} m^2

Cross Section（中性子断面積）



fission and capture cross sections for ^{235}U

Evaluated Nuclear Data File
(評価済核データファイル)

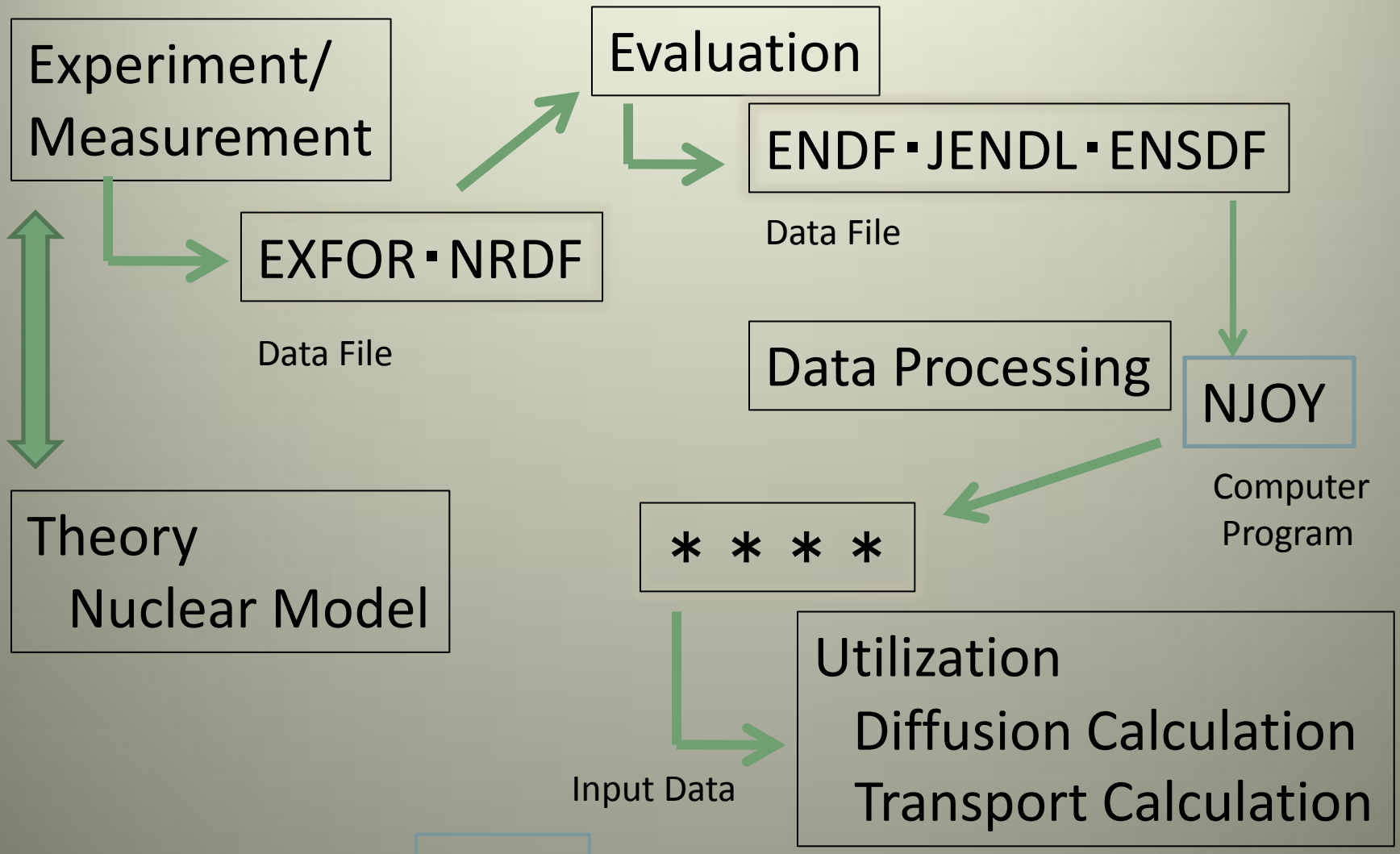
Nuclear Data（核データ）

- Nuclear Structure
- Half-Life
- Decay Scheme
- Cross-section

Use（利用）

- Industry ： Nuclear Reactor, Fusion, Nuclear Conversion
- Nuclear Medicine, Physics

From Measurement to Application
（測定データの工業利用）



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Evaluated Nuclear Data File (ENDF)

ENDF : Name of Format

: Name of U.S.A._Library

	Publish		Number of Nuclear
ENDF/B-IV.8	2001.10	U.S.A.	329
JENDL-3.3	2002.5	JAPAN	337
JEFF-3.0	2002.4	NEA	340

Data in ENDF

σ, dσ/dΩ, dσ/dE, dσ/dΩdE, Resonance Parameter

Fission Neutron, Fission Product, co_variance

ENDF
(Resonance Parameter of ^{27}Al)

```
1325 0 0 0
1.302700+4 2.675000+1 0 0 1 01325 2151 1
1.302700+4 1.000000+0 0 0 1 01325 2151 2
1.000000-5 2.100000+5 1 2 0 01325 2151 3
2.500000+0 5.098000-1 0 0 3 01325 2151 4
2.676810+1 0.000000+0 0 0 42 71325 2151 5
3.475000+4 2.000000+0 3.002300+3 3.000000+3 2.300000+0 0.000000+01325 2151 6
8.729990+4 3.000000+0 1.093110+4 1.092900+4 2.100000+0 0.000000+01325 2151 7
1.421000+5 3.000000+0 1.749510+4 1.749000+4 5.100000+0 0.000000+01325 2151 8
2.020000+5 2.000000+0 1.100600+4 1.100000+4 6.000000+0 0.000000+01325 2151 9
2.816000+5 3.000000+0 1.300270+4 1.300000+4 2.700000+0 0.000000+01325 2151 10
3.867000+5 2.000000+0 1.602900+3 1.600000+3 2.900000+0 0.000000+01325 2151 11
4.895000+5 2.000000+0 6.968700+3 6.960000+3 8.700000+0 0.000000+01325 2151 12
2.676810+1 0.000000+0 1 0 72 121325 2151 13
5.903500+3 1.000000+0 1.773000+1 1.700000+1 7.300000-1 0.000000+01325 2151 14
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3.148000+5 1.000000+0 1.100560+4 1.100000+4 5.600000+0 0.000000+01325 2151 20
3.758000+5 2.000000+0 2.503600+3 2.500000+3 3.600000+0 0.000000+01325 2151 21
4.250000+5 2.000000+0 4.104800+4 4.100000+4 4.800000+1 0.000000+01325 2151 22
5.280000+5 4.000000+0 1.000790+4 1.000000+4 7.900000+0 0.000000+01325 2151 23
5.700000+5 3.000000+0 1.971000+4 1.970000+4 1.000000+1 0.000000+01325 2151 24
5.870000+5 2.000000+0 1.903000+3 1.900000+3 3.000000+0 0.000000+01325 2151 25
2.676810+1 0.000000+0 2 0 12 21325 2151 26
3.670000+5 5.000000+0 5.004700+3 5.000000+3 4.700000+0 0.000000+01325 2151 27
4.780000+5 2.000000+0 4.965500+3 4.960000+3 5.500000+0 0.000000+01325 2151 28
1325 2 099999
```
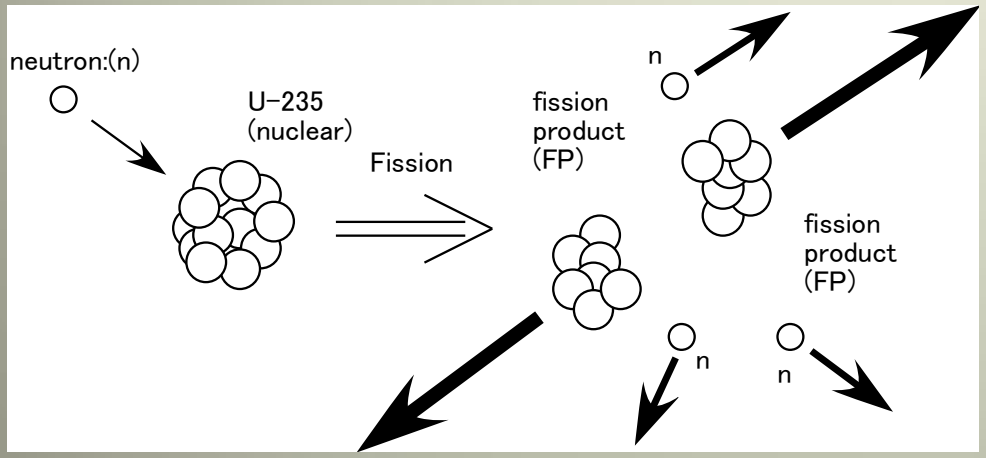

Fission
（核分裂）



Fissile Nuclear

U-235

Pu-239 ← U-238 + n

U-233 ← Th-232 + n

Production of Thermal Energy

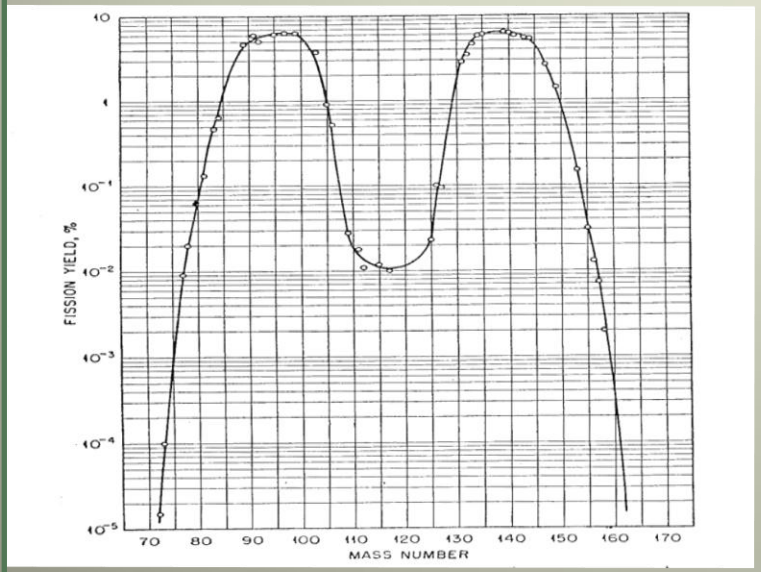
～200MeV(FP、β、γ、n)

～2MeV(/n)

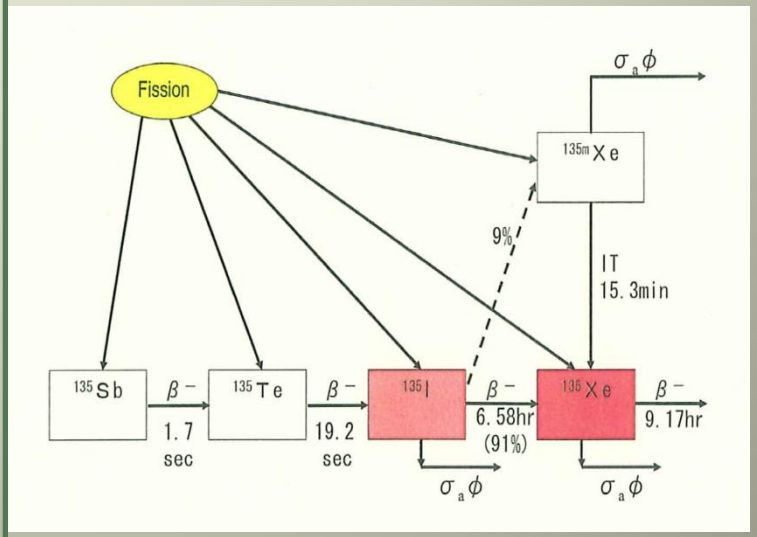
Example(statistical)

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{57}La^{147} + {}_{35}Br^{87} + 2{}_{0}n^{1}$$

Fission Products(FP) & FP Decay
（核分裂片と核分裂片の崩壊）



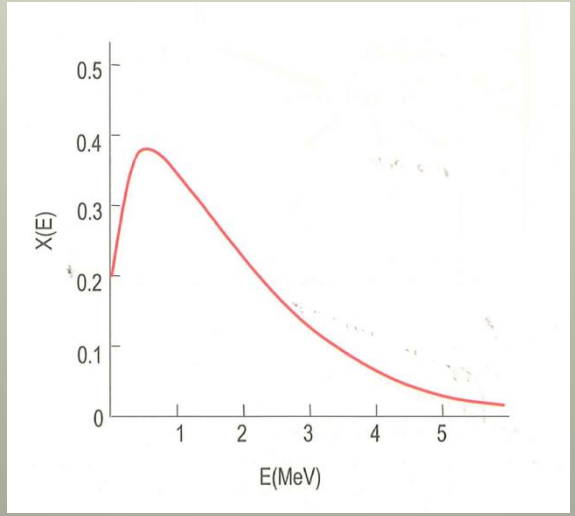
Fission Products
Mass Distribution



Fission Products Decay Chain
Including 135-Xe

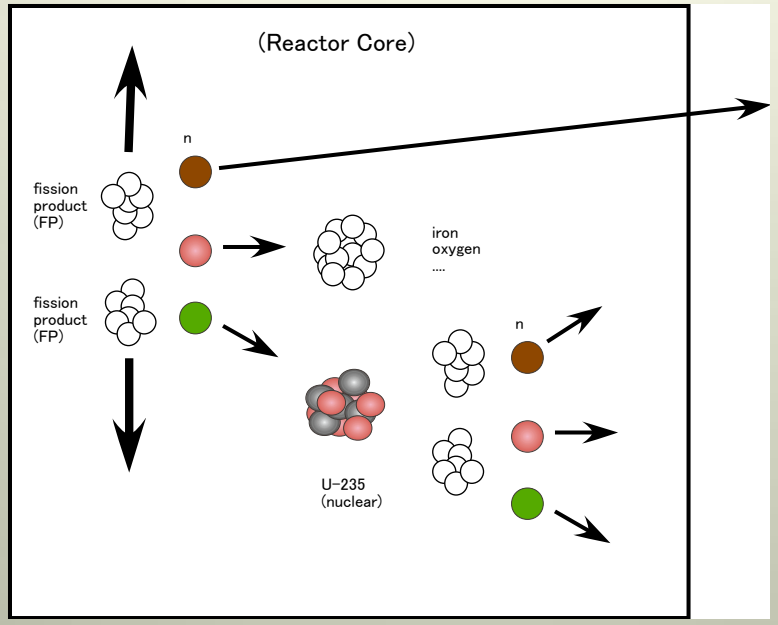
Fission　Neutron
（核分裂で発生する中性子）

Number of Fission Neutrons (ν) : 2.5 ± 0.1
（核分裂でててくる中性子の個数）
uranium-235 fission by slow neutrons



Fission Neutron
Energy Distribution

Criticality（臨界）



Chain Reaction & Criticality（連鎖反応と臨界）

mean number of neutrons（V）＝～2.5

＊　absorbed in material(iron, water, control material …)

＊　leak_out from the system

1.0　absorbed U-235 introducing next fission