Fusion

Hans Bethe (1967, Nobel)

Proton-proton chain:

$$^{1}H + {}^{1}H \rightarrow {}^{2}H + \beta^{+} + \nu$$

$$^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma$$

$$^{3}He + {}^{3}He \rightarrow {}^{4}He + {}^{1}H + {}^{1}H$$

Carbon or CNO cycle:

$$^{1}H + {}^{12}C \rightarrow {}^{13}N + \gamma$$

$$^{13}N \rightarrow {}^{13}C + \beta^{+} + \nu \qquad T_{1/2} = 9.96\,min$$

$$^{1}H + {}^{13}C \rightarrow {}^{14}N + \gamma$$

$$^{1}H + {}^{14}N \rightarrow {}^{15}O + \gamma$$

$$^{15}O \rightarrow {}^{15}N + \beta^{+} + \nu \qquad T_{1/2} = 2.04\,min$$

$$^{1}H + {}^{15}N \rightarrow {}^{12}C + {}^{4}He$$

On Earth: H-bomb, Tokamak, National Ignition Facility, Z-pinch

Special application

Medicine : - diagnostics
- cancer treatment
- tomography (CT, PET)

Geology, archeology :

$$n + {}^{14}N \rightarrow {}^{14}C + p$$

$${}^{14}C \rightarrow {}^{14}N + \beta^- + \bar{\nu} \qquad T_{1/2} = 5730\,y$$

$$\frac{{}^{14}C}{{}^{12}C} = R_0 = 1.2 \cdot 10^{-12}$$ for living creatures

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Four radioactive series:		$T_{1/2}(y)$
4m Thorium	${}^{232}_{90}Th \rightarrow {}^{208}_{82}Pb$	$1.4 \cdot 10^{10}$
4m+1 Neptunium	${}^{237}_{93}Np \rightarrow {}^{209}_{83}Bi$	$2.14 \cdot 10^{6}$
4m+2 Uranium	${}^{238}_{92}U \rightarrow {}^{206}_{82}Pb$	$4.47 \cdot 10^{9}$
4m+3 Actinium	${}^{235}_{92}U \rightarrow {}^{207}_{82}Pb$	$7.04 \cdot 10^{8}$

Neutron activation : (n, γ)

neutron source: PuBe

Radioisotope generators:

Plutonium and thermocouples

Nuclear reactions

Notation: $^{14}N(\alpha, p)^{17}O$

$$^{14}_{7}N + \alpha \rightarrow p + ^{17}_{8}O$$

target → $^{14}_{7}N$; projectile → α ; detected particle → p ; residual n. → $^{17}_{8}O$

This was the reaction by Rutherford in 1919

Generally:

$X(x, y)Y$ $\quad x, y: p, n, d, t, \alpha, \beta^{\pm}, \gamma$

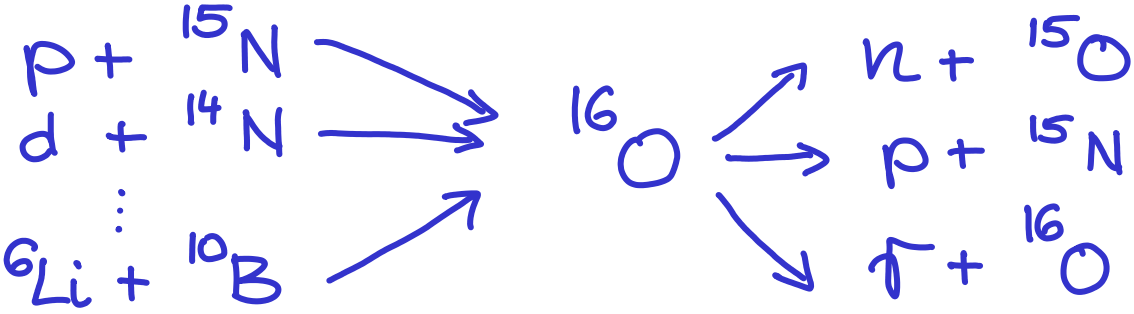
Reactions:

→ elastic scattering: $\alpha + Au \rightarrow \alpha + Au$

→ inelastic scattering: $\alpha + ^{20}Ne \rightarrow \alpha + ^{20}Ne^{*}$

If $E < 10$ MeV, then the interaction is mainly Coulomb.

→ compound nucleus (Bohr, 1936)



entrance channels exit channels

→ direct reactions (10–100 MeV)