Research Institute for Fundamental Physics
Kyoto University

原子力研究会. 原子力懇談会. Nov. 26, 1956

西田[illegible]氏: 動力炉.
(原子力研究所) 実験炉. (i) [illegible]
(ii) 安全性

林氏: (原子力懇談会) 融合反応の制御 Dec. 13, 1956

1938 ~ 1939: Bethe, Weizsäcker

Stellar Energy Source

⊙: $T = 1.5 \times 10^7$ °K $\rho = 100$ g/cm^3

$P = 10^{11}$ atm.

$H + H \to D + e^+ + \nu$ $H + D \to He^3$

$He^3 + He^3 \to He^4 + 2H$

$4H \to He^4 + 26$ MeV

生成率: 20 erg/g sec (極低)

10^{10} year

fusion reaction の利点

1. 燃料の供給. 海水中のD. → 10^9 year
fossil fuel → 10^2 year
U, Th → 2×10^3 year

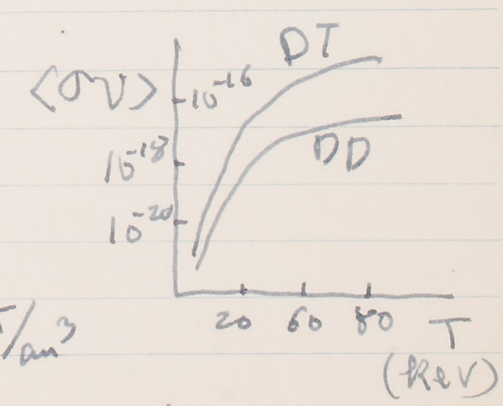
2. 灰の[illegible].
3. 安全性. 温度が下ると消える
4. 直接電気エネルギー

研究の状況

1951 Sherwood project
[illegible]

1. 融合反応

$D + D \to He^3 + n + 3$ MeV
$\quad\to T + p + 4$ MeV
$D + T \to He^4 + n + 18$ MeV



$kT = 10^9$ °K

power density $P = 10^{-27}\, n_D^2$ Watt/cm^3

100 Watt/cm^3 : $n_D = 10^{15} \sim 10^{16}$/cm^3

reaction mean free path $= 1/n_D \langle\sigma\rangle_{Av}$
$\sim 10^{10}$ cm

$\{ kT = 1$ keV, $T = 10^7$ °K

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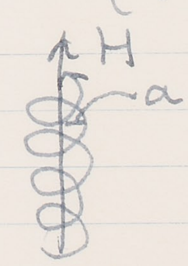
reaction time $\simeq 1/n_D \langle \sigma v \rangle_{Av} \sim 10$ sec.
ionization energy ~ 13.6 eV
plasma $\fallingdotseq$ fully ionized gas $n_i = n_e$

2. energy gain & loss.
absorption of radiation : Thomson scattering
photon mean free path $\fallingdotseq 10^{9}$ cm
creation of radiation : Bremsstrahlung
radiation loss $10^{-30} Z^2 n_i n_e T^{1/2}$ watt/cm^3
gain = loss : critical temperature
$T_c = 40$ keV D-D 4×10^{8} °K
4 keV D-T 4×10^{7} °K

3. Confinement
gas pressure $p_g = (n_i + n_e) kT$
$n_e = n_i = 10^{16}$, $T = 10^{8}$: $p_g = 100$ atm.
heat conductivity : $\sim c_v v l \sim \frac{k}{m^{1/2}} \frac{(kT)^{5/2}}{e^4} \times \frac{1}{\log \Lambda}$
electric cond. $\sim n e^2 l / m v_e \sim \frac{(kT)^{3/2}}{m^{1/2} e^2} \times \frac{1}{\log \Lambda}$
$\log \Lambda \fallingdotseq 10 \sim 20$

heat cond. $\sim 10^{7}$ $(T = 10^{8}$ °K$)$ (Cu ~ 1)
elect. cond. $\sim 10^{12}$/ohm·cm (Ag ~ 10^{6})

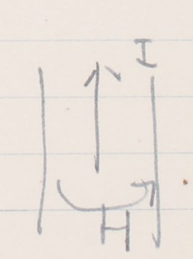
$a = \frac{m v_\perp}{eH} = 6 \times 10^{3} \frac{\sqrt{W_\perp}}{H}$ cm
$W_\perp$: keV, H : gauss



$l \gg a$

magnetic pressure $= \frac{H^2}{8\pi} = p_m$
$p_m \sim p_g$

4. pinch effect
$H = 2I/a$ $p_m = \frac{I^2}{2\pi a^2}$
$p_m = p_g$ $I^2 = 2NkT$
$N = \pi a^2 (n_i + n_e)$
(流体近似.



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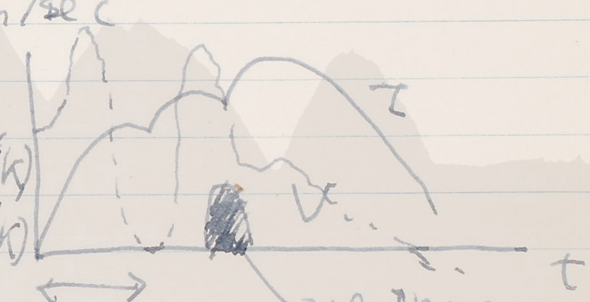
③

$T = 10^8$, $n = 10^{16}$: $H \approx 10^5$ gauss

Kurchatov: H, D, He   linear tube
A, Xe

Gas pressure 0.005 mmHg ~ 1 atm
Tube length 数cm ~ 2m
diameter 5 ~ 60 cm
V_0 = 数十keV.
peak current ~ 10^5 ~ 2×10^6 Amp.
I 10^{10} ~ 10^{12} Amp/sec



10^6K

D+D → 反応断, { 10^{-8} (10^6K), 10^{12} (10^9K) }

non-thermal neutron
(longitudinal acceleration) 3 ~ 30 microsec.

5. Necessary Conditions
$T \geq 10^8$K