$$d + t \rightarrow \alpha + n$$

Deuterium Tritium

$E_\alpha \sim 3.5$ MeV

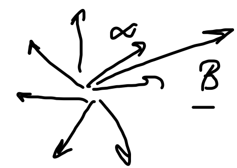
$E_n \sim 14$ MeV

$T \sim 10 \div 20$ keV

$$\frac{\partial f_T}{\partial t} = \sum_{F=i,e} \frac{q_T^2 q_F^2 \ln\Lambda}{4\pi \varepsilon_0^2 m_T} \left[-\frac{\partial}{\partial \underline{v}} \cdot \left(f_T \frac{\partial h_F}{\partial \underline{v}} \right) + \frac{1}{2} \frac{\partial}{\partial \underline{v}} \frac{\partial}{\partial \underline{v}} : \left(f_T \frac{\partial^2 g_F}{\partial \underline{v} \partial \underline{v}} \right) \right]$$

$$g_F(\underline{v}) = \int |\underline{v} - \underline{v}'| f_F(\underline{v}') \, d^3\underline{v}'$$

$$h_F(\underline{v}) = \frac{m_T}{\mu} \int \frac{f_F(\underline{v}') \, d^3\underline{v}'}{|\underline{v} - \underline{v}'|}$$



$E_\alpha = 3.5$ MeV $\rightarrow v_\alpha \approx 7 \cdot 10^6$ m/s

$T \approx 10$ keV

$v_{the} \approx 6 \cdot 10^7$ m/s

$v_{thi} \approx 10^6$ m/s

$$x = v / v_{th} < \begin{cases} x_e = v_\alpha / v_{the} \ll 1 \\ x_i = v_\alpha / v_{thi} \to 1 \end{cases}$$

$$v_{thi} < v_\alpha < v_{the}$$

$$h_F = \frac{m_T}{\mu}\frac{n_F}{v}\,\mathrm{erf}\left(\frac{v}{v_{th}}\right)$$ (assumed that $f_F(\underline{v})$ is Maxwellian)

$$\frac{\partial h_F}{\partial \underline{v}} = \frac{\partial}{\partial v} h_F \,\hat{\underline{v}}$$

$$\frac{\partial}{\partial v} h_F = \frac{m_T}{\mu} n_F \frac{\partial}{\partial v}\left(\frac{1}{v}\,\mathrm{erf}\left(\frac{v}{v_{th}}\right)\right)$$

S.L. $= \frac{d}{dx}\left(\frac{\mathrm{erf}(x)}{x}\right)$

$x = v/v_{th}$;

$$\frac{\partial}{\partial v} = \frac{\partial}{\partial x}\cdot\frac{\partial x}{\partial v} = \frac{1}{v_{th}}\frac{\partial}{\partial x}$$

$v_{th}\cdot x = v \Rightarrow \frac{1}{v} = \frac{1}{x\cdot v_{th}}$

$$\frac{1}{v} = \frac{1}{v_{th}}\cdot\frac{1}{x}$$

$$\frac{\partial}{\partial v} h_F = \frac{m_T}{\mu} n_F \frac{1}{v_{th}^2}\frac{\partial}{\partial x}\left(\frac{1}{x}\,\mathrm{erf}(x)\right)$$

$x_i >> 1$ $\qquad\qquad$ $x_e << 1$

$$\frac{d}{dx_i}\left(\frac{1}{x_i}\ln g(x_i)\right) \approx -\frac{1}{x_i^2} \qquad \frac{d}{dx_e}\left(\frac{1}{x_e}\ln g(x_e)\right) \approx -\frac{4}{3\sqrt{\pi}} x_e$$

$$\frac{\partial f_T}{\partial t} \approx \frac{Z_T^2 e^4 \ln\Lambda n_e}{4\pi\varepsilon_0^2 m_T} \frac{\partial}{\partial \underline{v}} \cdot \left[\left[\left(\frac{Z_i}{\mu_i}\frac{1}{v^2/v_{thi}^2} \cdot \frac{v^2/v_{thi}}{v^2} + \frac{4}{3\sqrt{\pi}}\frac{v}{v_{the}^3}\frac{1}{\mu_e}\right) \cdot f_T\right]\hat{\underline{v}}\right]$$

$$\frac{\partial f_T}{\partial t} \approx \frac{Z_i Z_T^2 e^4 \ln\Lambda n_e}{4\pi\varepsilon_0^2 m_T \mu_i} \frac{\partial}{\partial \underline{v}} \cdot \left[\frac{1}{v^2} f_T \left(1 + \frac{v^3}{v_{cr}^3}\right)\hat{\underline{v}}\right]$$

$$v_{cr}^3 = \frac{3\sqrt{\pi}\, Z_i\, v_{the}^3\, \mu_e}{4\, \mu_i}$$

$$\frac{\partial}{\partial \underline{v}} \cdot \left[\quad\right] \underset{\text{sph. coordinates}}{=} \frac{1}{v^2}\frac{\partial}{\partial v}\left[v^2 \left[\quad\right]\right]$$

$$\frac{\partial f_T}{\partial t} = \underbrace{\frac{n_e Z_i Z_T^2 e^4 \ln\Lambda}{4\pi\epsilon_0^2 m_T \mu_i} \frac{1}{v^2}\frac{\partial}{\partial v}\left[\left(1+\frac{v^3}{v_{cr}^3}\right) f_T\right]}_{S.D.} + S(v)$$

$d + t \to \alpha + n$

$$S(v) = \frac{S_0}{4\pi v^2}\,\delta(v - v_0) \qquad v_0 = \left(\frac{2E_0}{m_\alpha}\right)^{\frac{1}{2}}$$

$$S_0 = \frac{\#\text{ of alphas}}{\text{time} \cdot \text{volume}}$$

$$n = \int f(\underline{v})\, d^3\underline{v}$$

$$\underbrace{\frac{\partial}{\partial t}\int f_T\, d^3\underline{v}}_{\frac{\partial n}{\partial t}} = (\quad)\int d^3\underline{v}\ \frac{1}{v^2}\frac{\partial}{\partial v}\left(\left(1+\frac{v^3}{v_{cr}^3}\right) f_T\right) + \frac{S_0}{4\pi}\int d^3\underline{v}\ \frac{1}{v^2}\,\delta(v - v_0)$$

$$d^3\underline{v} = 4\pi v^2\, dv$$

$$\frac{\partial n}{\partial t} = \left(\cdot \right) \underbrace{\int dv \frac{\partial}{\partial v}\left[\left(1+\frac{v^3}{v_{cn}^3}\right)\cdot f\right]}_{\int \left(1+\frac{v^3}{v_{cn}^3}\right)\Big|_0^{+\infty}} + \frac{S_0}{4\pi}\int dv\, 4\pi\, \delta(v-v_0) = S_0$$

$$\frac{\partial n}{\partial t} = S_0$$

add a loss term
- → it acts once particles are thermalized
- → has the same strength as the source term

$$L(v) = -\frac{S_0}{4\pi v^2}\,\delta(v - v_{th})$$

$$\frac{\partial f_T}{\partial t} \simeq 0 \quad \text{(steady state)}$$

$$\frac{n_e Z_i Z_T^2 e^4 \ln\Lambda}{4\pi\varepsilon_0^2 m_T \mu_i} \frac{1}{v^2}\frac{\partial}{\partial v}\left[\left(1+\frac{v^3}{v_{cr}^3}\right) f_T\right] = \frac{S_0}{4\pi v^2}\left[\delta(v-v_{th}) - \delta(v-v_0)\right]$$

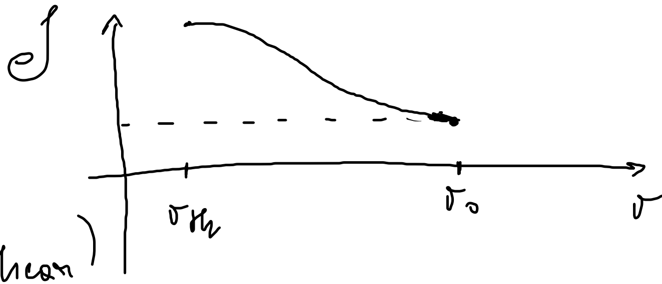
$$\int_0^v \frac{\partial}{\partial v}\left[\left(1+\frac{v^3}{v_{cr}^3}\right) f_T\right] dv = \frac{S_0}{4\pi}\int_0^v dv \left[\delta(v-v_{th}) - \delta(v-v_0)\right]$$

$\int$ $v > v_0$: 0

$\int$ $v < v_{th}$: 0

$v_{th} < v < v_0$ $\quad \int = 1$

$$\left(1+\frac{v^3}{v_{cr}^3}\right) f_T(v) = \frac{S_0}{4\pi} \Rightarrow f_T(v) \propto \frac{1}{1+\frac{v^3}{v_{cr}^3}}$$



Nuclear emission

$\alpha + {}^{9}Be \rightarrow n + {}^{12}C^{*}$ → γ

natural occurring impurity

(Shear) Alfven waves

Alpha part.

↓ excite Alfv. waves

Alfven waves

fast ion loss detector

Necessary condition: $\omega = n\omega_\phi + p\omega_b$

ω: wave frequency

ω_ϕ: toroidal precession freq.

ω_b: bounce freq.