Limits

2 декабря 2022 г.   3:05

$$\beta_a \simeq \frac{2m^{1/2}e^6\sigma_{tr}}{M}T^{-5/2}\,.$$

$$\beta_e\,[\frac{\text{см}^6}{\text{с}}] \sim \frac{e^{10}}{\sqrt{m}T_e^{9/2}} = 5.4\cdot 10^{-27}T^{-9/2}\,[\text{эВ}]\,.$$

6

$$\frac{n_e}{n_a} > \frac{\beta_a}{\beta_e} = \frac{\frac{2\sqrt{m}}{M}e^6\frac{e^4}{T^2}T^{-5/2}}{\frac{e^{10}}{\sqrt{m}T_e^{9/2}}} = \frac{2m}{M}$$

1.) $\langle \sigma v \rangle > \beta_e n_б$ по-видимому не так?

2.) $n_б \ll n_0$ − опред. неидеальности
$\Rightarrow$ Нет возможность столкновение

Как проверить — непонятно.

3) $\beta n^2 \ll 3Hn$

$\beta n^2 \ll 3n \qquad n \ll \sqrt{\frac{3H}{\beta}}$

$$rs = r\cdot\frac{2\pi^2 g_s}{45}T^3$$

$$r \ll \sqrt{\frac{3H}{\beta}}\,T^{-3}\cdot\frac{45}{2\pi g_s}$$

$$\frac{r}{r_0} \ll \sqrt{\frac{3H}{\beta}}\,\frac{45}{2\pi g_s r_0}\,T^{-3} \qquad H = \begin{cases}\sqrt{\frac{4\pi^3 g_e}{45}}\frac{T^2}{m_{pl}}\\ \frac{2}{3t_{eq}}\left(\frac{T}{2{,}7k}\right)^{3/2}\end{cases}$$

$$\frac{r}{r_0} \ll k \sim \begin{cases}T^{-2}\\ T^{-3/4}\end{cases}$$

$$T_e \gg n\sigma\sqrt{\frac{m_a}{m_e}}\,e^2 \qquad T_e = \frac{T^2}{T_0}$$

$$T_e \gg r\cdot s\cdot\frac{e^6}{T_e^2}\sqrt{\frac{m_e}{m_б}} = \frac{r}{r_0}\cdot r_0\cdot\frac{2\pi^2 g_s}{45}\frac{T^3}{T_e^2}\sqrt{\frac{m_a}{m_б}}\,e^6$$

$$\frac{T_0^2}{T} \gg \frac{r}{r_0}\frac{T^5}{T_0^4}\frac{2\pi^2 g_s(T)}{45}\cdot r_0\sqrt{\frac{m_a}{m_б}}\cdot e^6 \qquad \boxed{\frac{T^3}{T_0^3}\cdot\left(\frac{45}{2\pi g_s(T)}\cdot\frac{1}{r_0}\cdot\frac{1}{e^6}\cdot\frac{1}{\sqrt{m_a/m_б}}\right) \gg \frac{r}{r_0}}$$

$$T \ll \sqrt{\frac{m_a}{m_б}}\,e^2\,\frac{1}{a} \qquad a \text{ – размер атома}$$

a − ? $\cancel{a = \frac{\hbar}{mc\alpha} = \frac{1}{m_a\alpha} \Rightarrow T < \sqrt{\frac{m_a}{m_б}}\,e^2\cdot m_б\alpha}$

$$a = \frac{\sqrt[3]{M/\rho}}{\sqrt[3]{N_A}} = \sqrt[3]{\frac{M}{\rho N_A}} = \sqrt[3]{\frac{m_б}{m_б n}} = n^{-\frac{1}{3}}$$

N_A − кол-во атомов в моле

M − масса 1 моля $\qquad T_e = \frac{T_0^2}{T}$

$$\frac{M}{N_a} = m_б \qquad \rho = \frac{m}{V} = \frac{m_б\cdot N_б}{V} = m_б n \qquad \boxed{\frac{m_e}{m_б} < 1}$$

$$m_a^3 \ll \frac{m_a}{m_б}$$

$$T_e \ll \sqrt{\frac{m_a}{m_б}}\,e^2\,n^{+\frac{1}{3}} \Rightarrow \frac{T_0^2}{T} \ll \sqrt{\frac{m_a}{m_б}}\,e^2 r_0^{\frac{1}{3}}\left(\frac{r}{r_0}\right)^{\frac{1}{3}}\cdot\left(\frac{2\pi^2 g_s}{45}T^3\right)^{\frac{1}{3}}$$

$$\left(\frac{r}{r_0}\right)^{\frac{1}{3}} \gg \frac{T}{T_0}\,\frac{1}{\sqrt{\frac{m_a}{m_б}}\,e^2\,r_0^{\frac{1}{3}}(\ldots)^{\frac{1}{3}}} \qquad \frac{r}{r_0} \gg \left(\frac{T_0}{T}\right)^{8}\frac{1}{\left(\sqrt{\frac{m_a}{m_б}}\right)^3 e^6\,r_0\left(\frac{2\pi^2 g_s}{45}\right)}$$

```python
def lim_3b(x):
    """
    Function that calculs limit on 3body recombination density

    x(list):    Temperature of O-fotons

    return list of density of unrecombined particles
    """
    r_pit = (Ta**2/(x**4)) / ((4*np.pi*alpha)**3 *r0*(2*np.pi**2*g_s(x)/45)*sqrt(ma/mb))
    return r_pit
```

T_e

$$\frac{r}{r_0} = \left(\frac{T_0^2}{T^4}\right)\frac{1}{r_0}\left(e^6 \cdot \left(\frac{2\pi^2 g_s}{45}\right)\sqrt{\frac{m_a}{m_b}}\right)^{-1}$$

$$r = T_e^{2-1}\left(e^6 \cdot \frac{s}{T_e^3}\sqrt{\frac{m_a}{m_b}}\right)^{-1}$$

$$n \cdot e^6 \sqrt{\frac{m_a}{m_b}} = T_e^{5\,3}$$

$$n\,3\sqrt{\frac{m_a}{m_b}} = T_e^{3\,1}$$