Pitaevsky

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$$\alpha(E_{rel}) = \int \sigma(v) v f(\vec{v}, v_{rel}) d^3 \vec{v}$$

Then, calculating the integral in (10) we find the recombination coefficient

$$\alpha = \frac{32\sqrt{2\pi}}{3} \frac{m^{1/2} e^6 \sigma n}{(kT)^{5/2} M}. \qquad (19)$$

http://jetp.ras.ru/cgi-bin/dn/e_015_05_0919.pdf

requirement

the value given by (19). If our formula is to apply it is also necessary that the equilibrium over the electron coordinate system be established more rapidly than the energy equilibrium. This requirement implies that $kT \gg e^2 n\sigma\sqrt{m/M}$.

$$kT \ll \sqrt{m/M}\, e^2/a. \qquad (13)$$

$$\sigma \sim \frac{e^4}{T^2 m^2}$$

$$\alpha = \frac{32\sqrt{2\pi}}{3} \frac{\sqrt{m}\, e^6}{T_a^{5/2} M} n$$

То же, что и раньше.

Усл.: $T_a \ll e^6 n \cdot \sqrt{\frac{m}{M}}$

$$(4\pi\alpha)^3 \sqrt{\frac{m}{M}}\, n \gg T_a$$

$$n = rs = r \cdot \left(\frac{2\pi^2 g_s}{45}\right) T_R^3$$

$$(4\pi\alpha)^3 \sqrt{\frac{m}{M}}\, r \left(\frac{2\pi^2 g_s}{45}\right) \gg \frac{1}{T_a^2}$$

$$\boxed{\frac{r}{r_0} \gg \frac{1}{T_a^2} \left((4\pi\alpha)^3 r_0 \sqrt{\frac{m}{M}} \left(\frac{2\pi^2 g_s}{45}\right)\right)^{-1}}$$

$$T_\gamma = T_a \simeq \frac{T^2}{T_{eq}} \qquad T_{eq} = \frac{T_{eq}}{\sqrt{\pi}\,\varkappa^{1/3}} \qquad T_\gamma = \varkappa^{1/3} T$$

$$\boxed{\frac{r}{r_0} \gg \frac{T_{eq}^2}{T^4} \left((4\pi\alpha)^3 r_0 \sqrt{\frac{m}{M}} \left(\frac{2\pi^2 g_s}{45}\right)\right)^{-1}}$$

$$\int \frac{d\Gamma}{dE} = \int \delta\left(E - \frac{p^2}{2m} + \frac{e^2}{r}\right) d\Gamma =$$

$$= \int \delta\left(E - \frac{p^2}{2m} + \frac{e^2}{r}\right) p^2 dp\, d\Omega_p\, r^2 dr\, d\Omega_x =$$

$$= \int \delta\left(E - \frac{p^2}{2m} + \frac{e^2}{r}\right) p^2 dp\, r^2 dr \cdot (4\pi)^2 =$$

$$= \int_0^{+\infty} p^2 dp \cdot \left(\frac{2me^2}{p^2 + 2m|E|}\right)^2 \cdot (4\pi)^2 =$$

Indefinite integral

$$\int x^2 \left(\frac{1}{x^2 - a^2}\right)^2 dx = \frac{x}{2a^2 - 2x^2} - \frac{\tanh^{-1}\left(\frac{x}{a}\right)}{2a} + \text{constant}$$

Indefinite integral

$$\int x^2 \left(\frac{1}{x^2 + a^2}\right)^2 dx = \frac{1}{2}\left(\frac{\tan^{-1}\left(\frac{x}{a}\right)}{a} - \frac{x}{a^2 + x^2}\right) + \text{constant}$$

3D plot

$$p \in \left[0, \sqrt{2m|E|}\right]$$

$$-|E| = E - \frac{p^2}{2m} = -\frac{e^2}{r}$$

$$\frac{e^2}{r} - \frac{p^2}{2m} = E \qquad r = \frac{-e^2}{E - \frac{p^2}{2m}} = \frac{2me^2}{p^2 + 2m|E|}.$$

$$= (8me^2\pi)^2 \left(-\frac{p}{4m|E| + 2p^2}\Bigg|_0 + \frac{\arctan\left(\frac{p}{\sqrt{2m|E|}}\right)}{4m|E|}\Bigg|\right).$$

$$\frac{(8me^2\pi)^2}{4mE} = \frac{16\, m e^4 \pi^2}{E} \; ?$$

кол-во частиц?

$$\boxed{\frac{r}{r_0} \gg \frac{T_{eq}^2}{T^4} \left((4\pi\alpha)^3 r_0 \sqrt{\frac{m}{M}} \left(\frac{2\pi^2 g_s}{45}\right)\right)^{-1}}$$

$$n = rs$$

$$T_a < e^6 n \sqrt{\frac{m}{M}} \qquad \frac{1}{n} = \frac{V}{N} < \frac{e^6 \sqrt{\frac{m}{M}}}{T_a}$$

$$V_1 = \frac{V}{N} = \frac{1}{n} = d^3 \qquad d \leq \sqrt[3]{\frac{e^6 \sqrt{\frac{m}{M}}}{T_a}}$$