k_F in terms of ρ_N^A ← nucleonic density in nucleus A

$$N = \langle F | \hat{N} | F \rangle$$

$$= \sum_{\vec{k}} \sum_{\sigma} \sum_{\tau} \langle F | \hat{n}_{\vec{k}\sigma\tau} | F \rangle$$

$$= \sum_{\vec{k}\sigma\tau} \theta(k_F - k)$$

$$= \frac{V}{(2\pi)^3} \sum_{\sigma\tau} \int d^3k \, \theta(k_F - k)$$

↑ Gives factor of 4

$$= \frac{4V}{(2\pi)^3} \int d\Omega \int_0^{k_F} dk \, k^2$$

$$= \frac{4V}{8\pi^3} \, 4\pi \, \frac{k_F^3}{3}$$

$$= \frac{2V}{3\pi^2} k_F^3$$

$$\Rightarrow \frac{N}{V} = \rho_N^A = \frac{2}{3\pi^2} k_F^3$$

$$\boxed{k_F = \left[\frac{3\pi^2}{2} \rho^A \right]^{1/3}}$$

* If I specify N, then there shouldn't be a $\sum_\tau$ sum and we would instead have

$$k_F^N = \left[3\pi^2 \rho_N^A \right]^{1/3}$$