Lindemann ("disorder") parameter for a nucleus

3/01/14 (3)

Making use of the harmonic oscillator approximation for the single-particle potential (cf. Fig. 2-22 Bohr and Mottelson, 1969), one can write (cf. Eq. (2-130) of the above reference),

$$\sum_{k=1}^{A} \langle r_k^2 \rangle = \frac{\hbar}{M\omega_0} \sum_{k=1}^{A} \left(N_k + \frac{3}{2}\right) = \frac{3}{5} A R^2,$$

where $A = N + Z$ is the nuclear mass number, while the nuclear radius $R = r_0 A^{1/3}$, with $r_0 = 1.2\,fm$, It is of notice ~~that~~ N_k is the oscillator principal quantum number associated with the stat k (cf. Fig. 2-23 Bohr and Mottelson, 1969).

The average internucleon distance can be determined from the relation (Brink and Broglia, 2005, App. C)

$$a' = \left(\frac{V}{A}\right)^{1/3} = \left(\frac{\frac{4\pi}{3}R^3}{A}\right)^{1/3} = \left(\frac{4\pi}{3}\right)^{1/3} \times 1.2\,fm.$$

$$\approx 2\,fm$$

Thus,

$$\Delta_L = \frac{\sqrt{\frac{3}{5}}\,R}{2\,fm} \approx 2.3, \quad (A \approx 120).$$

While it is difficult to compare crystal, aperiodic finite crystal and atomic nuclei, arguably, the above value indicates ~~that~~ a nucleus is liquid-like. More precisely, it is made out of a non-Newtonian fluid, which reacts elastically to sudden sollicitations, and plastically to strain. In any case, one expects from $\Delta_L = 2.3$ that the nucleon mean free path is long, larger than nuclear dimensions.