**Interaction**

We can represent the 4He interaction as a simple kinetic energy + potential H:



where we use the Leonard Jones potential to describe the interaction between the neutral He atoms.



ε ~ 10kB is the maximum well depth, and σ is the hard core radius, where the well has its minimum. Note that the potential is repulsive in the short range and attractive in the long range. The r-6 term comes from Van der Waals forces. This is the typical force of attraction between noble gases, an instantaneous dipole-dipole interaction which exists because even though the electric dipole moment of each He atom time averages to zero (full shell), the attraction between the instantaneous dipole moments doesn’t. The repulsive part of the potential is probably not r-12 and this approximation was chosen for mathematical convenience. The typical form of the potential is shown below, with Ne-Ne interaction for comparison.

Diagram

Description automatically generated

**General Comments**

4He is a bosonic liquid (because full s-orbital means no net S, but 4 nucleons makes it integer spin). It shows a phase transition at T = 2.172 to a superfluid state which is similar to Bose-Einstein condensation, although vastly modified by the strong inter-particle interactions.