Abstract: Superfluidity in Liquid Helium

There are several isotopes of helium; most of which are unstable and decay very rapidly. The two stable, naturally-occurring isotopes are helium-3 and helium-4. Helium exists most readily as a gas and it wasn’t until 1908 that helium was first liquefied. In 1938, it was discovered that helium-4 could become superfluid—that is to say that it has zero viscosity—at 2.17K. At this triple point, Helium-4 exists as a normal liquid (helium I) and as a superfluid (helium II). Helium-4 is a boson and consequently has an integer number of spin. Using Bose-Einstein Statistics, it is possible to understand the superfluid state of this isotope. However, helium-3 is a fermion, having only one neutron and two protons which gives it a non-integer spin number. The phases of helium-3 are much more puzzling. Until the 1970’s, helium-3 was not believed to have a superfluid phase. Superconductivity theory suggests a phenomenon known as Cooper pairing. Cooper pairing proposes that fermions can pair to form bosons. As a result, helium-3 can be considered in pairs of fermions and can also be analyzed using Bose-Einstein statistics. Once helium becomes a superfluid, it exhibits a myriad of unusual properties such as the fountain effect, rotating quantized vortices, an ability to flow through tiny capillaries, and creep out of an open container unaided.
Bibliography


