

Alice Tasker, Tamela Maciel

Physics 353

Parthasarathy

June 2, 2008

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

- Armitage, Jonathan, and Ian Farquhar, eds. *The Helium Liquids*. New York, NY: Academic Press, 1975.
- Breon, Susan. "Introduction to Liquid Helium." Cryogenics and Fluids Branch. 9 Sep. 2004. Goddard Space Flight Center, NASA. 31 June 2008 <http://cryo.gsfc.nasa.gov/introduction/liquid_helium.html>.
- Donnelly, Russell. "Uplifting Sight at Low Temperature." *Physics World* (Mar. 1997): 26-28.
- Donnelly, Russell, ed. *High Reynolds Number Flows Using Liquid and Gaseous Helium*. New York: Springer-Verlag New York, Inc, 1991.
- Gavroglu, Kostas. "From Defiant Youth to Conformist Adulthood: The Sad Story of Liquid Helium." *Physics in Perspective* 3.2 (June 2001): 165-188.
- Halperin, W.P, and L.P. Pitaevskii, eds. *Helium Three*. Amsterdam, The Netherlands: Elsevier Science Publishers, 1990.
- "Helium Theory." Low Temperature Laboratory. 11 Jan. 2008. Helsinki University of Technology. 29 May 2008 <<http://en.wikipedia.org/wiki/Helium>>.
- Keller, William. *Helium-3 and Helium-4*. New York: Plenum Press, 1969.
- Ketterle, Wolfgang, and Yong-il Shin. "Fermi gases go with the superfluid flow." *Physics World* (June 2007): 39-43.
- Kittel, Charles, and Herbert Kroemer. *Thermal Physics*. New York: W.H. Freeman and Company, 1980.
- "Liquid Helium." *Helium*. 28 May 2008. Wikipedia. 29 May 2008 <<http://en.wikipedia.org/wiki/Helium>>.
- Sokol, Paul. "Quantum evaporation reveals Bose condensate in superfluid helium." *Physics World* (Mar. 1998): 29-30.
- Superfluid Helium. 6 May 2007. YouTube. 15 May 2008 <<http://www.youtube.com/watch?v=YKjFPpuK-Jo>>.
- Re: Superfluid Helium. 4 Aug. 2007. YouTube. 15 May 2008 <<http://www.youtube.com/watch?v=2Z6UJbwxBZI>>.

Vollhardt, Dieter, and Wolfle, Peter. The Superfluid Phases of Helium 3. London: Taylor and Francis Ltd., 1990.

Wilks, J. The Properties of Liquid and Solid Helium. Oxford: Clarendon Press, 1967.

Wilks, J., and Betts, D.S.. An Introduction to Liquid Helium. 2nd ed. New York: Oxford University Press, 1987.

Yuan, Sidney. "The Two Fluid Model of Superfluid Helium." 1 Yutopian Online. 31 May 2008
<<http://www.oslis.org/resources/cm>>.

^3He : Superfluidity of Helium. 31 May 2008.
<<http://control-theory.net/3.html>>.