Helium liquids [tln33]

Helium has a small atomic mass and a weak interatomic interaction. This enhances quantum effects. Solid helium exists only at high pressure. Helium at low T and moderate p is a quantum liquid with peculiar features.

The two helium isotopes, ^{3}He and ^{4}He, are chemically similar but physically very different. The physical difference is governed by the difference in nuclear spin ($\frac{1}{2}$ versus zero).

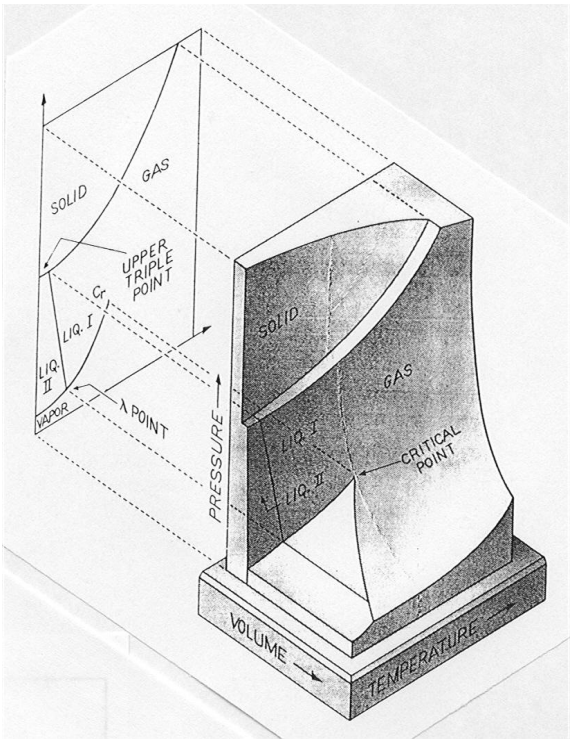
^{4}He Features

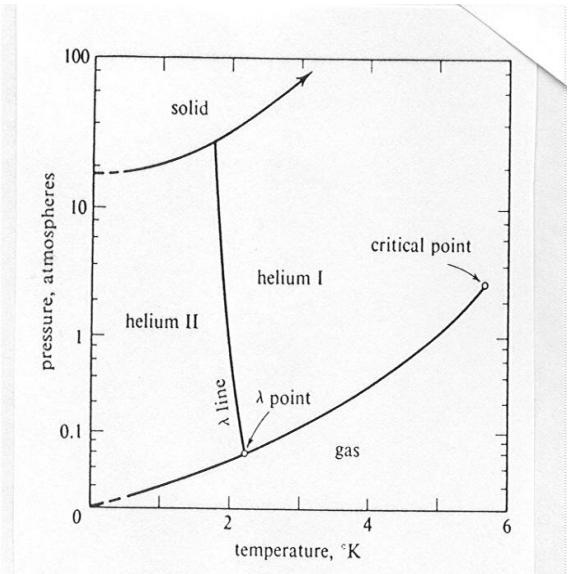
- The liquid-vapor coexistence line terminates in a critical point.
- The solid-liquid transition line is monotonic and ends at $T = 0$ and $p \simeq 25$atm with zero slope ($dp/dT = \Delta S/\Delta V = 0$).
- The λ-line separates the normal fluid (He I) from the superfluid (He II) via a continuous transition.
- Each end of the λ-line is a triple point.
- ^{4}He was first liquefied in 1908 by Kamerlingh Onnes (at 4.2K, 1atm).
- The λ-transition has been interpreted microscopically as the condensation of interacting bosons.

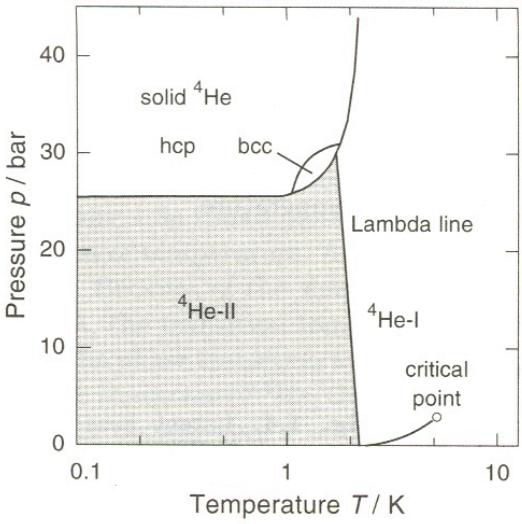
^{3}He Features

- The relative abundance of ^{3}He in natural helium is 10^{-6}.
- ^{3}He can be produced artificially from tritium (^{3}H) via β-decay.
- ^{3}He has not been available in large quantities until 1940 (Manhattan project).
- ^{3}He was first liquefied in 1948.
- A superfluid transition in ^{3}He was first observed in 1971.
- The superfluid phase in ^{3}He is akin to the superconducting phase. It is described by bound pairs of quasi-particles with spin $\frac{1}{2}$.
- The A-phase and the B-phase differ by the orientation of the bound pairs.
- The negative slope in the solid-liquid coexistence curve is attributable to an entropy effect of nuclear spins ($dp/dT = \Delta S/\Delta V < 0$).

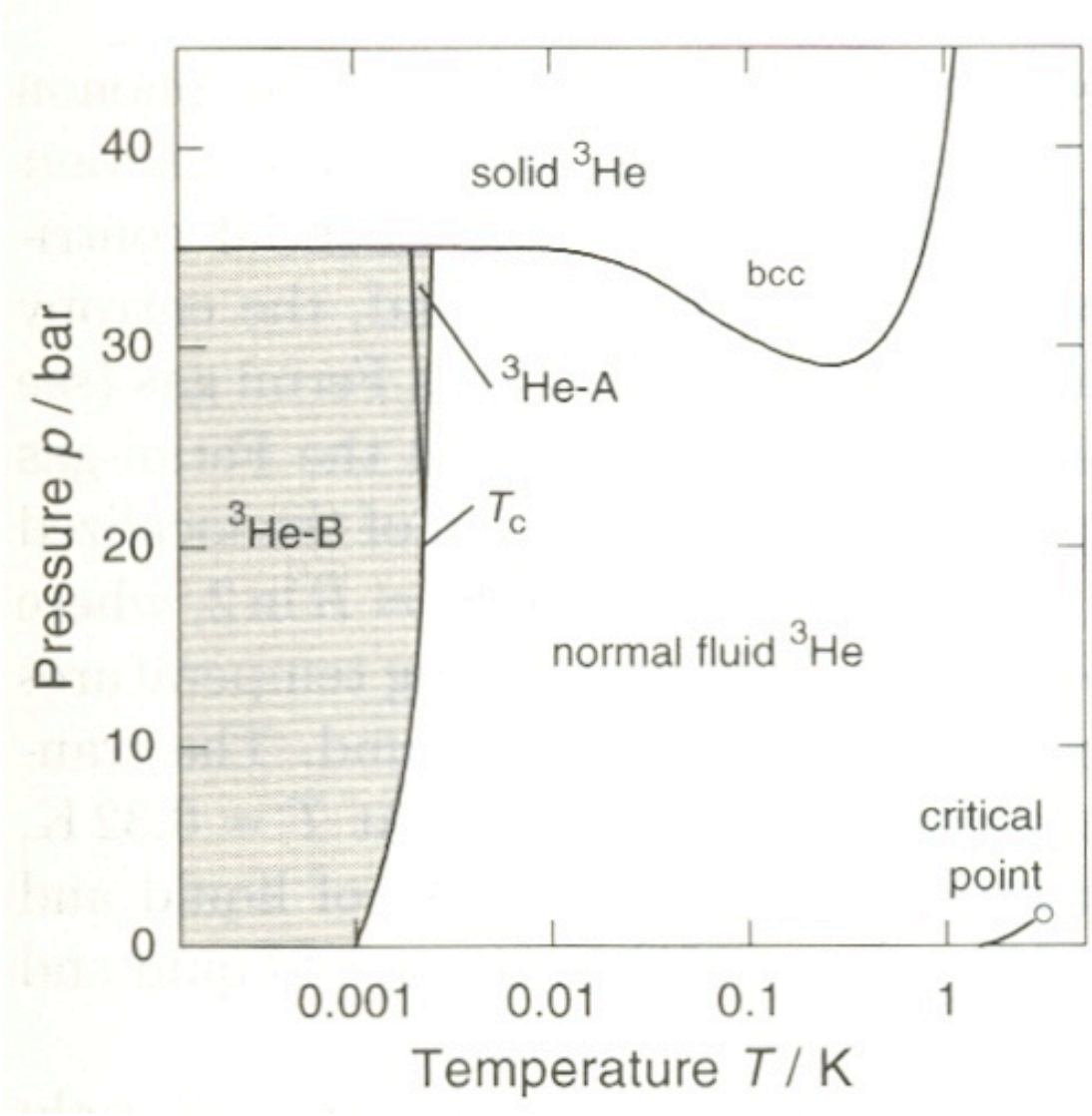
Phase diagram of ^{4}He:







Phase diagram of ^{3}He:



[from Enss and Hunklinger 2005]