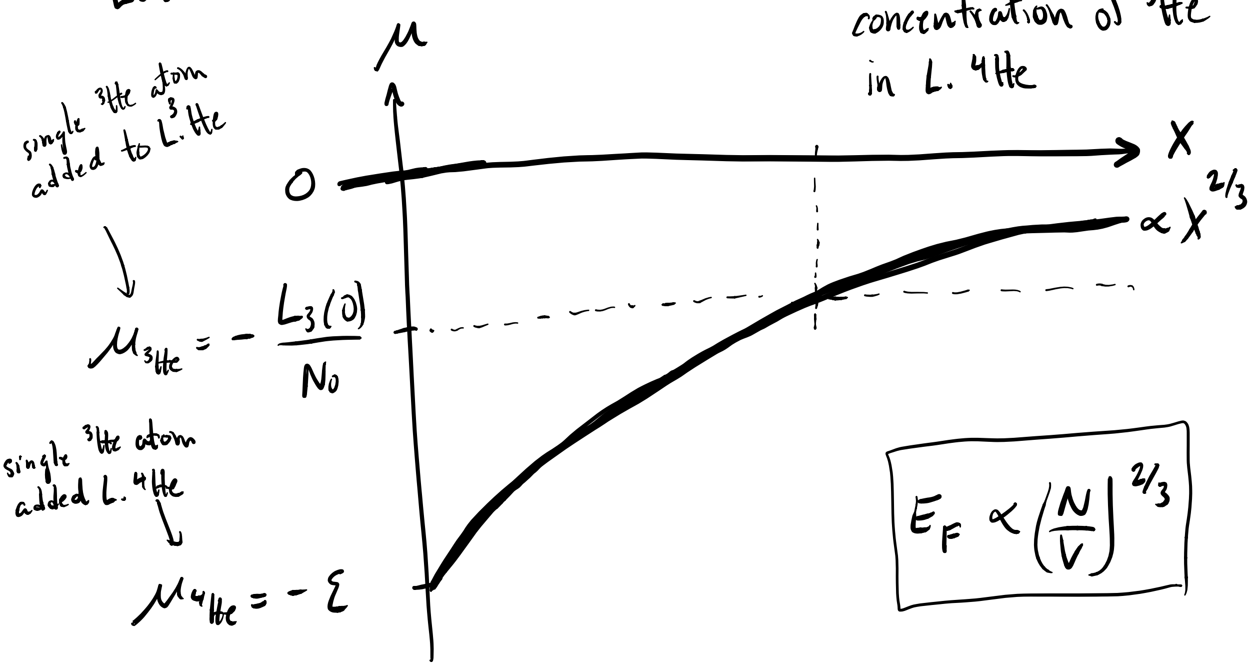
PHYS 425 - w6l2

More on energetics of ^3He-^4He mixtures.

Last Time



Large zero pt. energy of ^3He causes ^3He atom to be more strongly bound in L. ^4He than L. ^3He.

What happens if we keep adding more ^3He atoms to L. ^4He?

As more ^3He atoms added to L. ^4He of volume V, each additional atom has to go into a higher energy state. $\Rightarrow$ Pauli Exclusion principle for Fermions (at most two ^3He atoms of opposite nuclear spin can occupy the same state)

Recall $E_F = \frac{\hbar^2}{2m}\left(\frac{3\pi^2 N}{V}\right)^{2/3}$

Because energy of ^3He atoms increases, binding energy in L. ^4He decreases as particle concentration x increases.

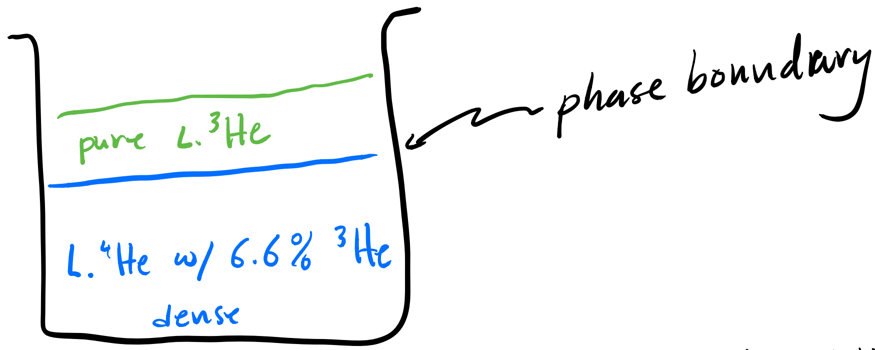
Once $-\varepsilon + E_F = -\frac{L_3(0)}{N_0}$

i.e. $\mu_{^4He}(x) = \mu_{^3He}$

the ^3He concentration in L. ^4He no longer increases $\Rightarrow$ additional ^3He atoms more strongly bound in L. ^3He.

At $T=0$ the limiting concentration of ^3He in ^3He-^4He mixtures is 6.6 %.

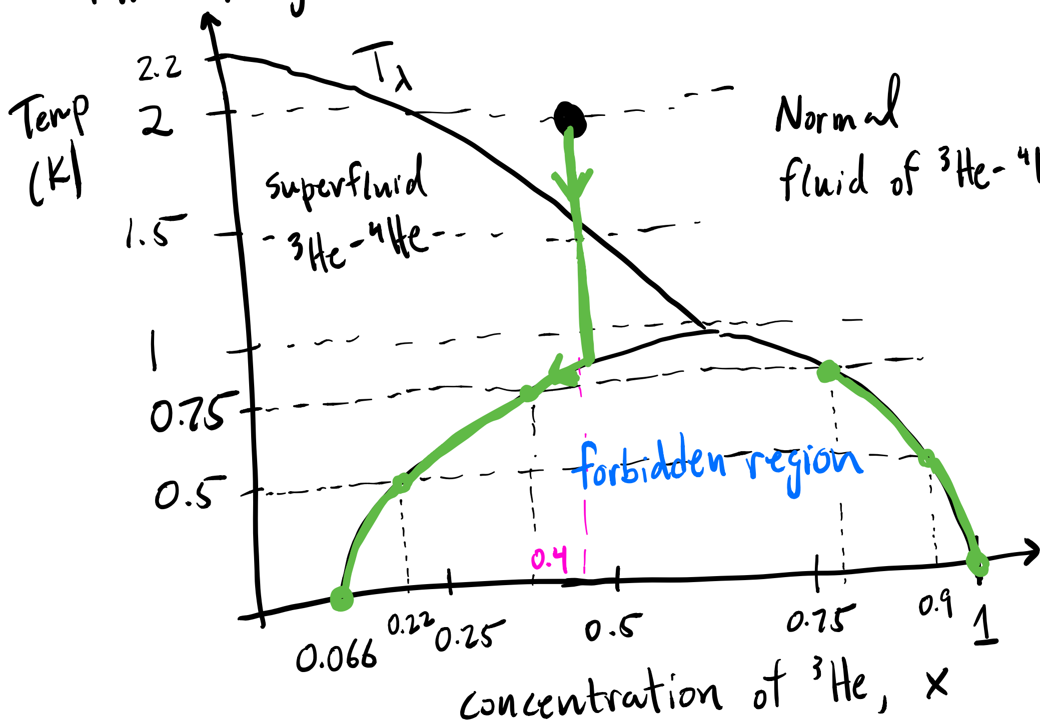
$\therefore$ ^3He - ^4He mixture @ $T=0$



What if we added ^4He atoms to L. ^3He & L. ^4He?

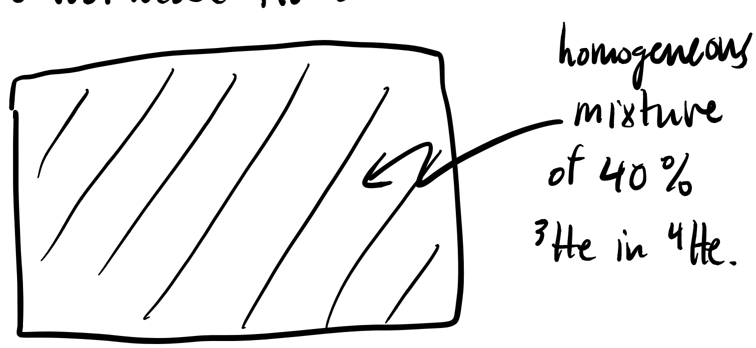
Just like ^3He, ^4He atoms more strongly bound to neighbouring atoms in L. ^4He. Since ^4He atoms are Bosons, the binding energy doesn't decrease as more ^4He atoms are added.

Phase Diagram of $^3He-^4He$ mixtures



Imagine a mixture of $^3He-^4He$ w/ $x = 0.4$ is cooled from 2 K to low temp.

1. $T = 2K$, mixture is homogeneous & behaves as a normal fluid



2. Start to cool our mixture.

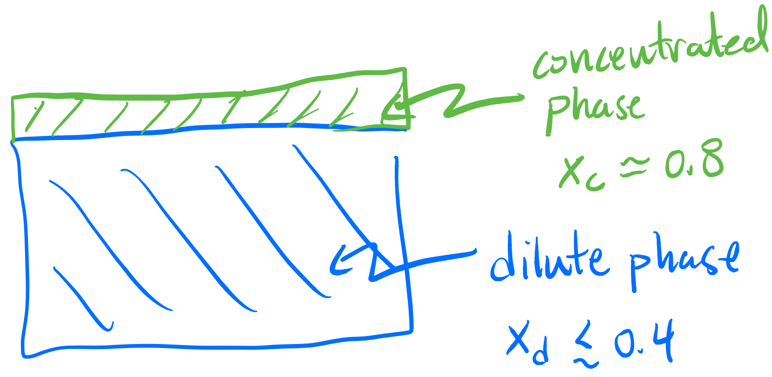
At ~ 1.5 K, the ^4He component of mixture becomes superfluid. Will discuss superfluid ^4He later in the course. Howeve, among other things, superfluid ^4He can flow through fine cappilaries w/o dissipation & it is a <u>very</u> good conductor of heat.

3. At ~750 mK mixture separates into two phases. At top of container get smaller layer which has a high concentration of ^3He. $\Rightarrow$ $X_c \simeq 80\%$.

$\uparrow$ concentrated phase (rich in ^3He)

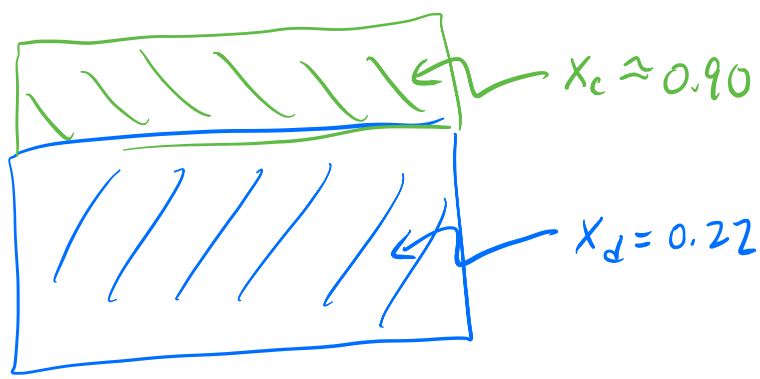
Below that we get a dilute phase (less ^3He)

$X_d \lesssim 0.4$



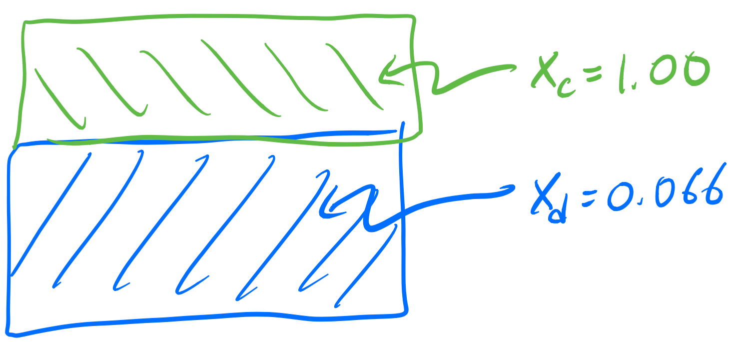
4. At 500 mK dilute phase $x_d \approx 0.22$

concentrated phase $x_c = 0.90$



5. At $T = 0$ $x_d \approx 0.066$

$x_c \approx 1.00$



We will see soon that the finite solubility of ^3He in ^4He at $T=0$ is very important for cooling by dilution refrigerators.