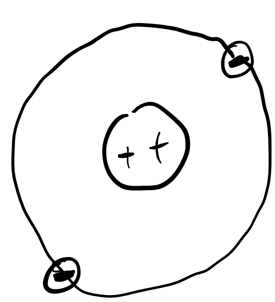
PHYS 425 - w3l1

Q: - What makes liquid helium special compared to other liquids? *

- Why does ^3He have a lower boiling temp. than ^4He? *

	^3He	^4He
Boiling temp (1 atm)	3.19 K	4.21 K
density	$0.082 \frac{g}{cm^3}$	$0.1451 \frac{g}{cm^3}$
Latent Heat	$\sim 30 \frac{J}{mol}$	$\sim 85 \frac{J}{mol}$

Note: Binding forces between helium atoms are very weak.



electron config: $1s^2$

valence shell is completely filled.

→ van der Waals force between non-polarized atoms ⇒ v. weak.

^3He & ^4He behave identically chemically b/c of same electron config.

In contrast, H_2 has large polarizibility
→ stronger attraction between atoms
→ much higher boiling temp (20.3K)

Because of weak interactions between helium atoms, liquid does not solidify at any temp except when under high pressure.

^4He solidifies at 1K when $P \simeq 25$ atm
^3He " " 1K " $P \simeq 34$ atm.

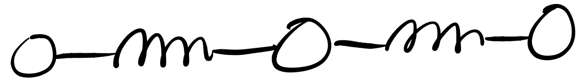
Weak interactions explains difference between helium & other liquids

What about the difference ^3He & ^4He?

clue: ^3He has lower mass than ^4He.

Zero-Pt Energy

Model interacting atoms as harmonic osc.



$$E = \frac{p^2}{2m} + \frac{1}{2}kx^2 \qquad \omega = \sqrt{\frac{k}{m}}$$

$$\therefore \underline{k = \omega^2 m}$$

by uncertainty principle

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

take min.

$$\Delta p = \left(\frac{\hbar}{2\Delta x}\right)$$

Energy of harmonic osc. must be a least:

$$\rightarrow \quad E = \frac{\hbar^2}{8m(\Delta x)^2} + \frac{1}{2}\omega^2 m(\Delta x)^2$$

minimize w.r.t. Δx

$$\frac{\partial E}{\partial(\Delta x)} = 0 = -\frac{2\hbar^2}{8m(\Delta x)^3} + \omega^2 m \Delta x$$

$$\omega^2 m \Delta x = \frac{\hbar^2}{4m(\Delta x)^3}$$

$$(\Delta x)^4 = \frac{\hbar^2}{4m^2\omega^2} \Rightarrow (\Delta x)^2 = \frac{\hbar}{2m\omega}$$

solve for ω & sub into E.

$$\omega = \frac{\hbar}{2m(\Delta x)^2}$$

$$\therefore E_0 = \frac{\hbar^2}{8m(\Delta x)^2} + \frac{1}{2}\cancel{m}\cancel{(\Delta x)^2}\frac{\hbar^2}{4m^{\cancel{2}}(\Delta x)^{\cancel{4}\,2}}$$

$$\boxed{E_0 = \frac{\hbar^2}{4m(\Delta x)^2} \quad \text{zero-pt energy}}$$

$$\Delta x = \left(\frac{V_m}{N_A}\right)^{1/3}$$ where V_m is molar volume of liquid.

$$E_0 \propto \frac{1}{m}$$

$\therefore$ ^3He has a larger zero pt energy that ^4He. $\therefore$ ^3He atoms have more K.E.

$\rightarrow$ ^3He is easier to evaporate (low boiling temp, low latent heat of vaporization) & harder to solidify (more pressure) than ^4He.