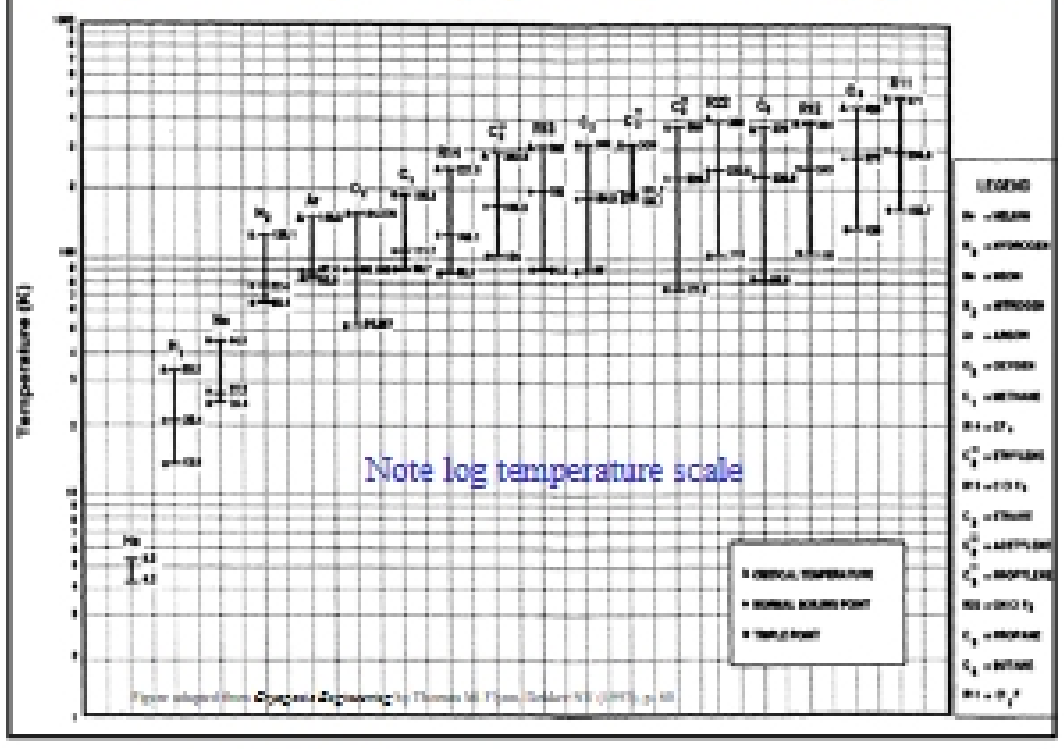
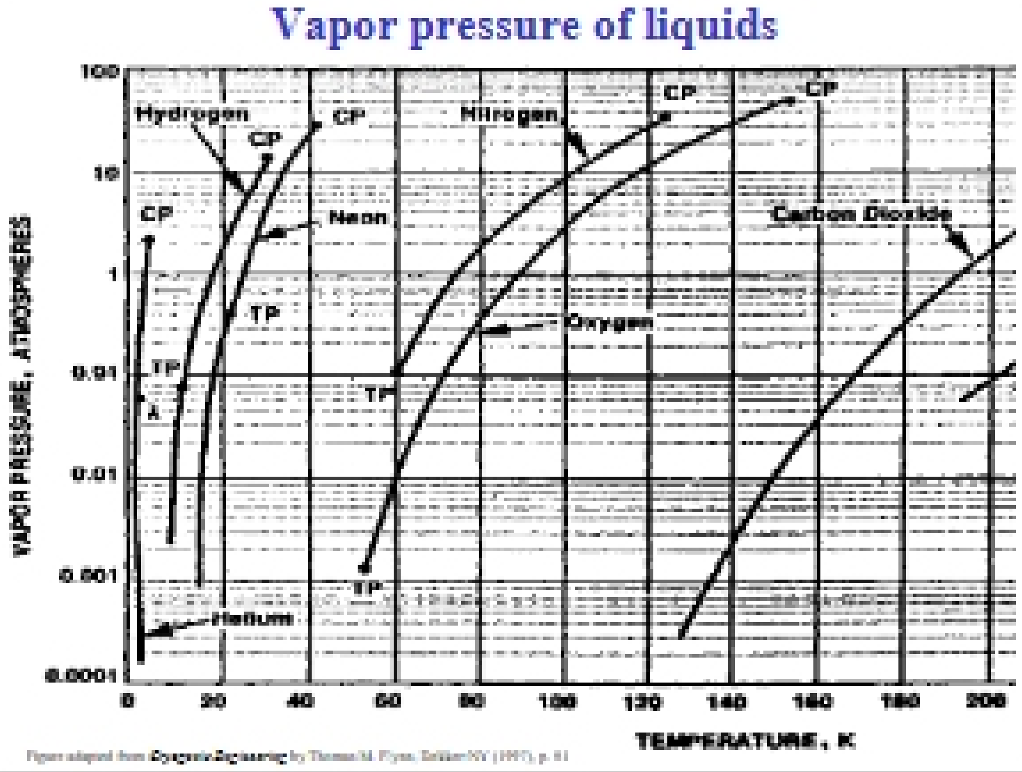
Characteristics of a cryogenic fluid

1. **Critical, normal boiling, and triple point temperatures of cryogenic fluids**
2. **Vapor pressure of liquids**
3. **Liquid Helium**
4. **Superfluids**

Critical, normal boiling, and triple point temperatures of cryogenic fluids



Vapor pressure of liquids



Helium

- Spherical shape
- Two isotropic forms: ^3He and ^4He
- Low mass
- Van der Waals forces → low critical and boiling points
- Remains a liquid even at absolute zero (unless external pressure is applied)

Spelling Bee

How do you spell the word for making a gas into a liquid?

A. liquify
B. liquefy
C. liquafy
D. liquifi
E. liquiphy

Name that man

In whose laboratory was helium first liquefied?

A. Sir James Dewar
B. Cailletet
C. Wroblewski
D. Onnes
E. Van der Waals

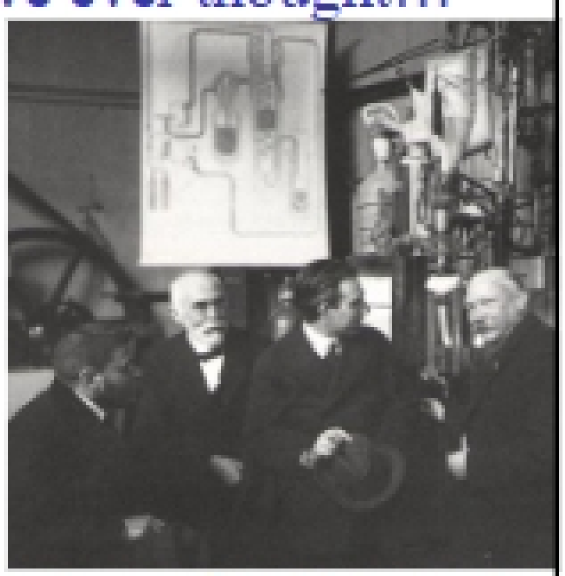
1882-Helium liquefied at Leiden University

H. Kamerlingh Onnes was one of the first professors in experimental physics at Leiden University. His lab first to liquefy helium (1908), for which he was awarded the Nobel prize in 1913, and he discovered superconductivity in 1911. He liquefied hydrogen to pre-cool the helium gas in his liquefier.

- In 1882, Onnes was appointed Professor of Experimental Physics at Leiden University. In 1895, he established Leiden Laboratory
- His researches were mainly based on the theories of J.D. van der Waals and H.A. Lorentz
- Was able to bring the temperature of helium down to 0.9 °K, justifying the saying that the coldest spot on earth was situated at Leiden.

Heike Kamerlingh Onnes (left) and Van der Waals in Leiden at the helium 'liquefactor' (1908)

Who would have ever thought…



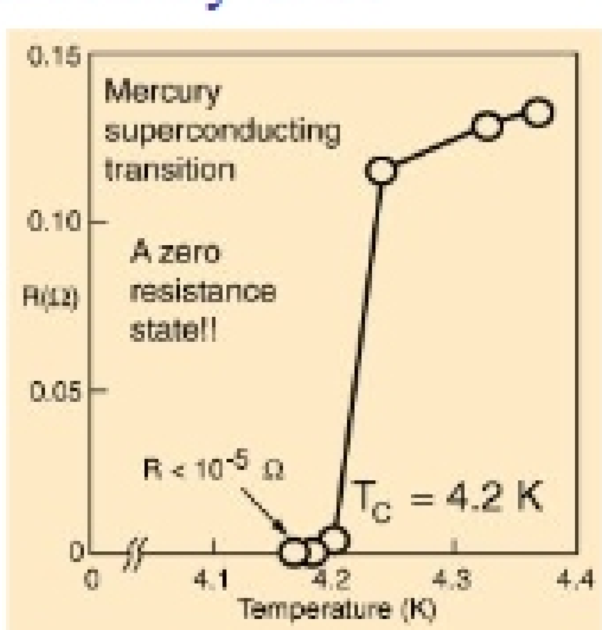
Heike Kamerlingh Onnes, his stamp, and (*right*) showing his helium liquefactor to passers-by: Niels Bohr (visiting from Kopenhagen), Hendrik Lorentz, and Paul Ehrenfest (*far left*).

Why Not A Solid?

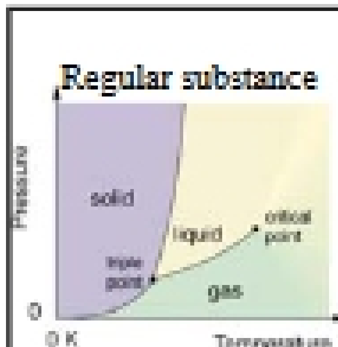
- Zero-Point Energy
- E = (3h^2)/(8mV^(2/3)) energy of a free particle in a small box
- E decreases as V increases → the effect of the Zero-Point to raise molar volume
- Kinetic energy exceeds the interaction potential energy

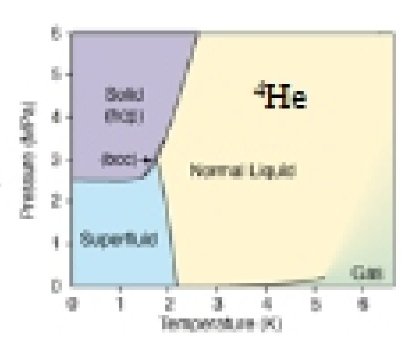
Superconductivity-1911

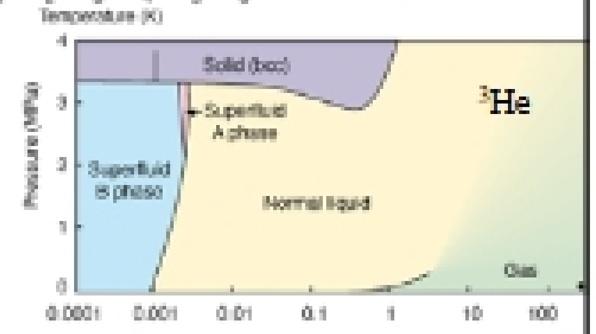
Heike Kamerlingh Onnes discovered superconductivity, the almost total lack of electrical resistance in certain materials when cooled to a temperature near absolute zero.



Phase Diagrams





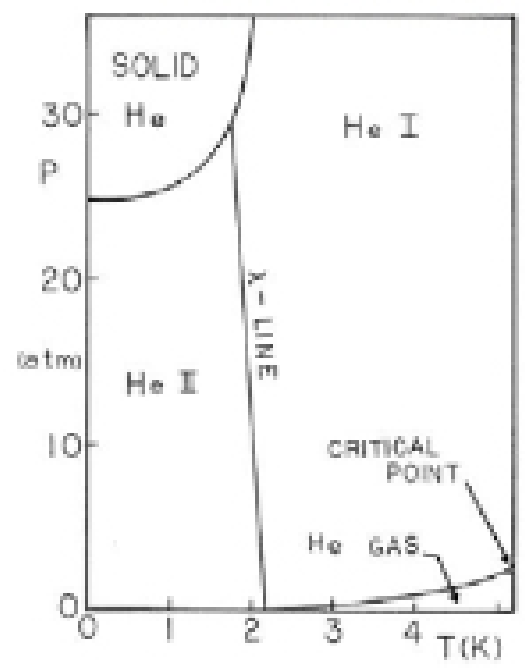


Why so low?

Superfluidity occurs in ^4He at about 4.2 K but only below about 0.002 K in ^3He. Why?

A. ^3He is rarer than ^4He in nature
B. ^3He is always in smaller containers than is ^4He
C. ^3He has different chemical properties than ^4He
D. ^4He superfluidity is an electronic process while ^3He superfluidity is a nuclear process
E. ^3He superfluidity is an electronic process while ^4He superfluidity is a nuclear process

Helium-4 Phase Diagram



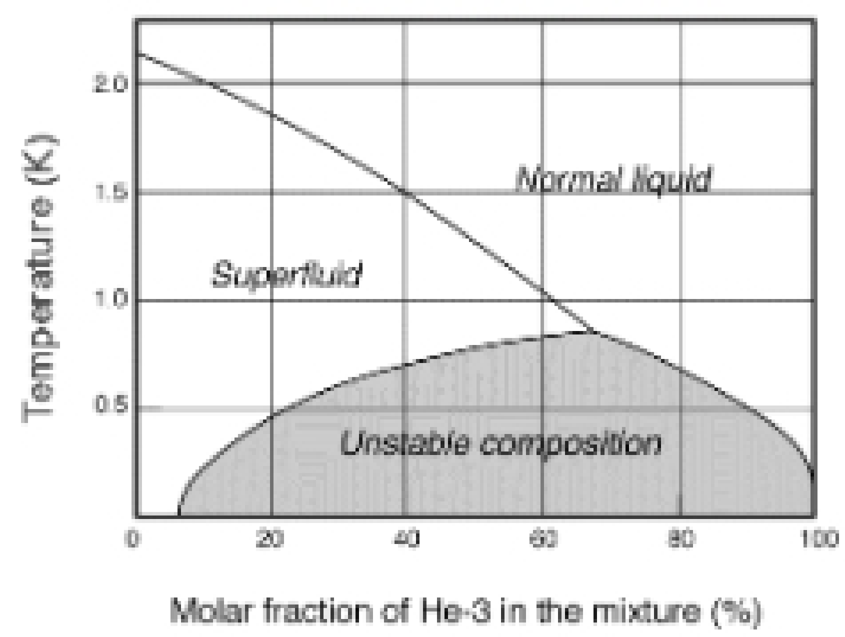
- At 2.17K ^4He undergoes a transition to the superfluid state
- The lambda line separates He I and He II
- ^3He does not become a superfluid until below 2mK

Do superfluids mix?

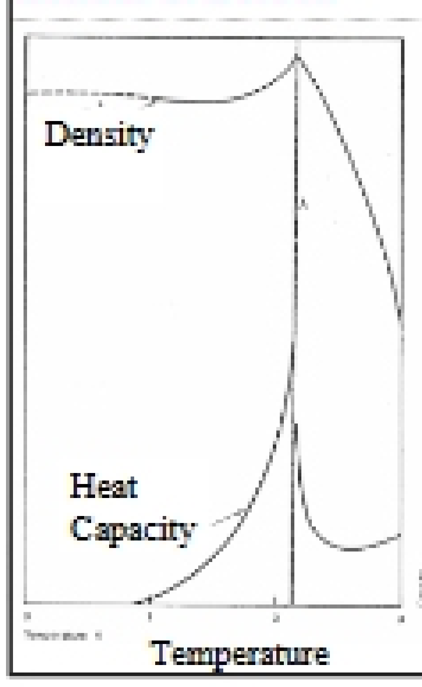
There are two isotopes of helium--under what circumstances do their liquid states mix?

A. They do not mix-it would violate thermodynamics to have a mixture at absolute zero.
B. They only mix when at absolute zero
C. ^3He can mix in ^4He but not the other way around at absolute zero

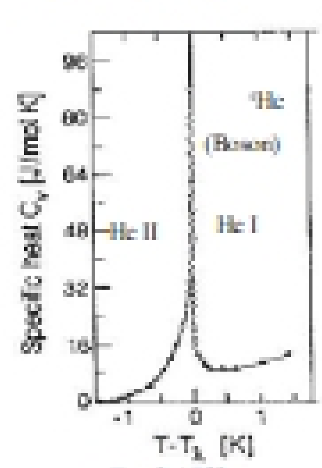
Helium Mixtures



1931: Keesom discovered lambda-specific heats in helium at Leiden



Allen and Misener and Kapitza (1939)



Superfluidity in Helium 4 in 1938

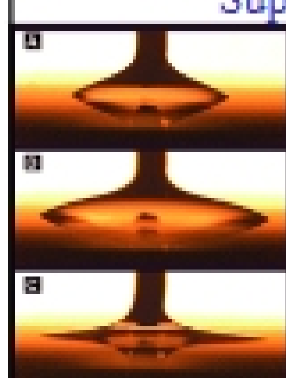


Fig. 2. (**A** through **C**) Microscope images showing an edge-on view of superfluid drops on a horizontal Cs substrate. The dark bar in the upper half of the image is the capillary tube. The pictures show the outline of the drop as well as its mirror image in the reflective substrate. As the volume of the drop increased from (A) to (B), the contact angle remained constant. When fluid was withdraw as in (C), the contact angle decreased but . the diameter remained constant

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Figure 3. Microscope image of a superfluid drop on a Cs substrate inclined at 10° to the horizontal. A drop hanging off of the capillary is also seen in the upper right. The drop on the inclined substrate is stationary. The downhill edge of the drop has the same contact angle as shown in Fig. 2B, whereas the uphill edge has a vanishing contact angle.

- Superfluidity is a dramatic visible manifestation of quantum mechanics, being the result of Bose–Einstein condensation in which a macroscopic number of ^4He atoms occupy the same, single-particle quantum state. It was discovered simultaneously by Kapitza, Allen and Misener working separately, though only Kapitza received the Nobel prize. It is also amusing to note that Allen was a "classical physicist" at heart, who didn't much care for the subatomic world. He discovered superfluidity with a pen light