Properties of liquid He →

Liquid helium (He) is one of the most unusual substances in physics. It exists in two main liquid phases — He-I and He-II — each with distinct properties.

1) Basic Physical Properties →

* Chemical formula :- He
* Atomic number :- 2
* Boiling point :- 4.2 K (-268.9°C) at 1 atm
* Freezing point :- Does not freeze at 1 atm, even at 0 K (requires pressure $\approx$ 25 atm)
* Density (at 4.2K) → $\sim 0.125\ g/cm^3$ (very low)
* Color → colorless
* Viscosity → Extremely low

Liquid helium forms when helium gas is cooled below 4.2K at atmospheric pressure.

2) Two Liquid phases of Helium
He-I (Normal liquid Helium) →

* Temperature range → 4.2K to 2.17K
* Behaves like a normal liquid
* Low viscosity
* Poor thermal conductivity
* No superfluid properties

He - II (Superfluid Helium) →

* Below 2.17 K (called the lambda point)
* Exhibits superfluidity
* zero viscosity (flows without friction)
* Extremely high thermal conductivity
* can climb container walls (Rollin film eff
* Forms quantized vortices

The transition at 2.17 K is called t lambda transition because the heat capacity curve resembles the Greek letter λ.

3) unique properties of He - II (Superfluid stat

1) Superfluidity →

* Flows without energy loss
* Passes through microscopic pores
* No measurable viscosity.

2) Fountain Effect →

* when heated, helium flows against gravity
* Demonstrates quantum mechanical behavio on a macroscopic scale.

3) High Thermal conductivity →

* Transfers heat ~1000 × better than copper

* Heat moves via "second sound" (temperature waves)

4) Zero Entropy component →

* Described by the two-fluid model
  - Normal component (with entropy)
  - Superfluid component (zero entropy)

(4) Isotopes and their behavior →

Helium-4 (^4He)

* Most common isotope
* Becomes superfluid at 2.17 K
* Bosonic behavior → Bose-Einstein condensation

Helium-3 (^3He) →

* Rare isotope
* Becomes superfluid only at extremely low temperatures (~ 0.0025 K)
* Fermionic → requires cooper pairing (similar to superconductivity)

(5) Why liquid Helium is special →

* Lowest boiling point of any element
* Remains liquid at absolute zero (at normal Pressure)
* Macroscopic quantum effects

* Essential for :-

① MRI magnets
② Superconducting research
③ Particles accelerators (e.g., CERN)
④ Space telescopes.