Properties of liquid helium

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Properties of Liquid helium

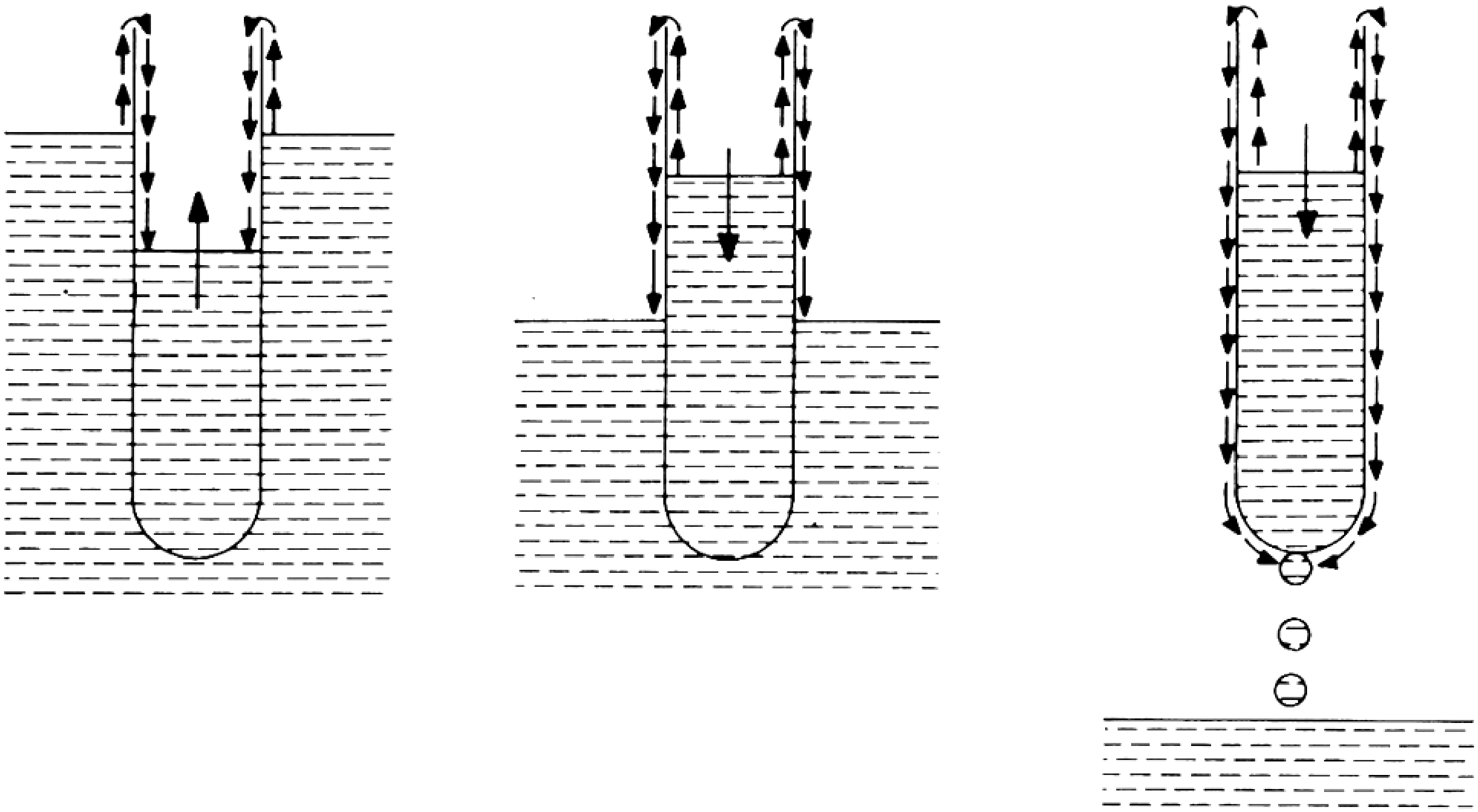
- Keeson in 1932 got success in lowering its temperature upto 0.71K
- Liquid helium has many unusual physical properties
- Commonly, density of a material increases with decreasing temperature but Helium has maximum density (0.1462 g/cc) at 2.2K.
- On further lowering of the temperature its density decreases and after 1.5K it attains a constant value.
- After detailed study it has been observed that liquid He under goes a transition at 2.186K. This temperature is defined as λ-point.
- Liquid He behaves differently before and after λ-point transition

- To acknowledge the difference in the properties on two sides of λ-point helium is called He-I above λ-point and He-II below λ-point.
- He-II has extraordinary thermal conductivity (810 cgs units) at 1.8K
- Unusual low viscosity
- Liquid He-II creeps rapidly along the surface of pot
- He-II looses its special properties below 1K.

Superfluidity of He-II

- Viscosity of He-I is around 2×10^{-5} poise but below λ-point its viscosity sharply and suddenly drops upto ~10^{-10} poise which is almost equal to zero.
- At this state it can flow through thinnest capillary
- Laws which describe flow of normal liquid fails when applied to He-II
- As per Poiseuille's law rate of flow, through a capillary, increases with increasing pressure difference (ΔP) between two ends and it decreases if the length of the capillary decreases.
- But in case of He-II both these parameters do not show any effect.
- If the radius of capillary increases the flow rate of He-II decreases which is again contrary to other liquids.
- Explaining these behavior using normal laws is not possible. Only quantum mechanics can explain its behavior

Thin Moving Film of liquid He-II



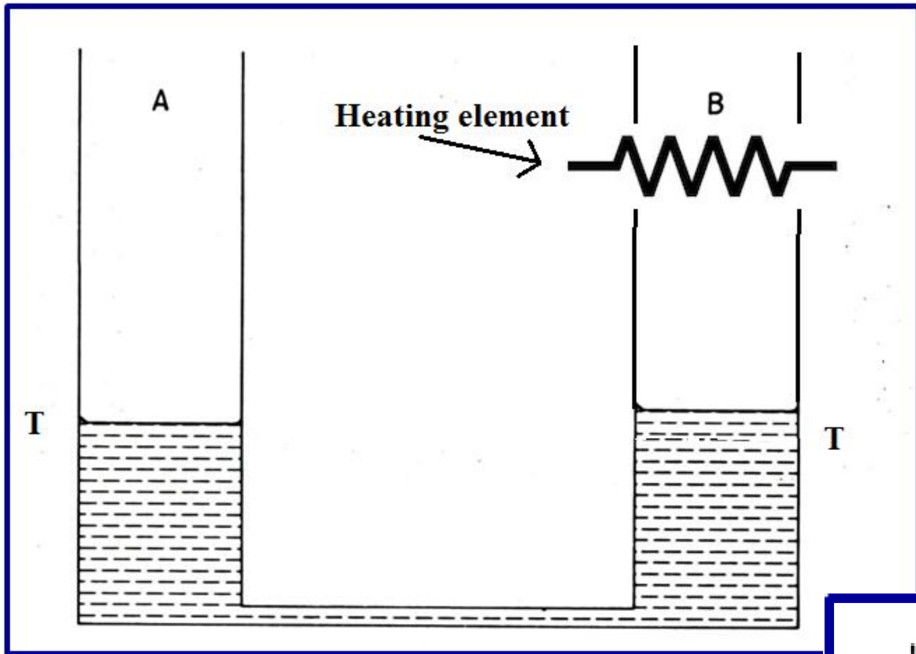
- Liquid Helium-II forms a thin moving film on the surface of contact.
- The unusual flow properties of He II result in the covering of the exposed surface of a partially immersed object being covered with a film about 30 nm (or 100 atomic layers) thick, near the surface.
- The temperature is same throughout the system, and the superfluid acts as a siphon, flowing through the film to equalize the levels in the two bulk liquids.
- By observing the rate at which the beaker level changes, the superfluid velocity has been found to be about 20 cm/s.

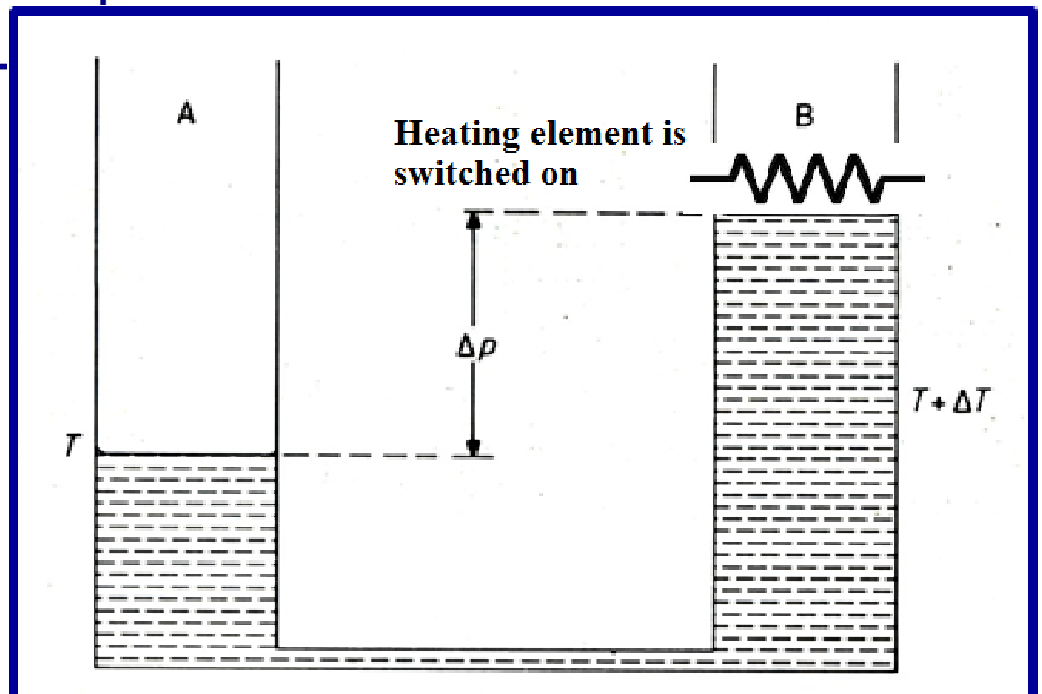
Thermomechanical Effect

Normal liquid flows from source to sink

But

Liquid He-II flows from sink to source

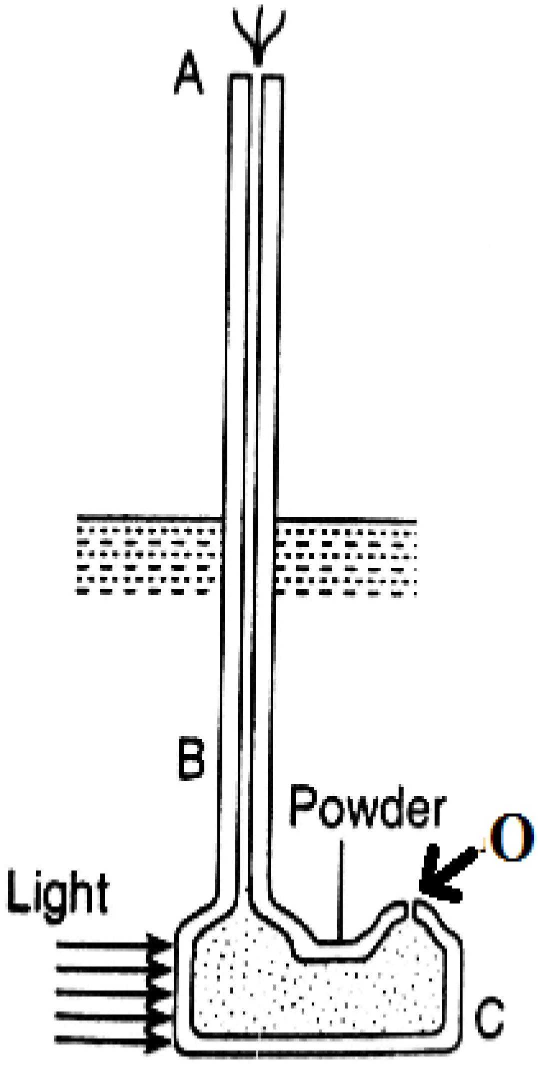




- Let us design a chamber which has two parts (A and B) connected via superleak (means an opening small enough so that only superliquid can flow through.
- Chamber B has a heating element which is initially switched off and in that case liwuid level in both the chambers is same
- Now when the heating element is switched on so that a temperature gradient is set up between two chambers the superfluid flows to the higher temperature side, in order to reduce the temperature gradient.
- This is an example of the thermomechanical effect. It shows that heat transfer and mass transfer cannot be separated in He II.

Fountain Effect

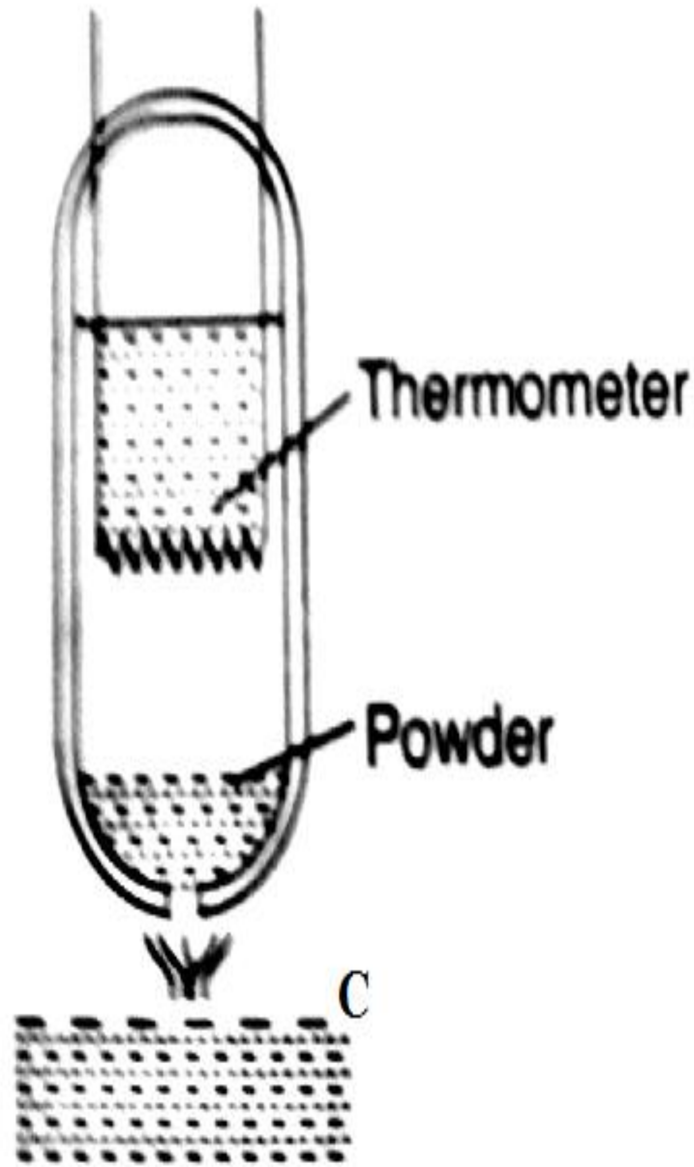
- Fountain Effect is also based on Thermomechanical phenomenon.
- It is a specially designed chamber so that when He-II gets heated it rises in capillary
- The lower portion (C)of chamber if filled with dark powder (emery). It has a small opening 'O' and other end of chamber 'C' has an fine capillary 'AB'
- The whole set up (except upper portion of capillary) is submersed in liquid He-II.



- When light (Infra red) falls on it, heat is produced.
- Hence liquid He-II comes from opening 'O' from the outer chamber filled with He-II (which is at low temperature) and reaches to the point where light is falling (where temperature is higher)
- Pressure at the heating end increases and hence the liquid He-II rises in capillary.
- Since the upper end of capillary is open so it comes out from there and looks like fountain.
- It has been observed that He-II can be lifted upto 30cm using this technique

Mechano-caloric Effect

- It is a phenomenon opposite to Thermomechanical Effect.
- Here if liquid He-II is filled in a container having a thermometer arrangement then it is observed that flow of liquid He-II produces a heat flux, opposite to mass flow.
- A chamber having superleak at bottom and filled with black powder is used to demonstrate the phenomenon.
- This chamber has thermocouple fitted in it.



- When such chamber is dipped liquid He-II chamber (Lets call it 'C') the liquid rises through superleak point and fills the chamber
- When the chamber is lifted above 'C' then liquid flows out through the point at bottom.
- At this moment it has been observed that thermocouple reading increases indicating a temperature rise.

Interesting video regarding extraordinary behavior of Helium

https://youtu.be/S30-5KTYq6o?list=PL442F47F12D99C4D2

https://youtu.be/uMK6ZDPjPYM?list=PL442F47F12D99C4D2

https://youtu.be/3I95-cW23y4?list=PL442F47F12D99C4D2

https://youtu.be/XgmmHCrhkZQ?list=PL442F47F12D99C4D2

https://youtu.be/rCUWwadYtDI?list=PL442F47F12D99C4D2

https://youtu.be/MIlpuPdxINk?list=PL442F47F12D99C4D2

https://youtu.be/2Z6UJbwxBZI