2.7 Super Fluidity in Helium-3 : Concept of Nobel Prize in Physics for the year 1996

2.7.1. Introduction

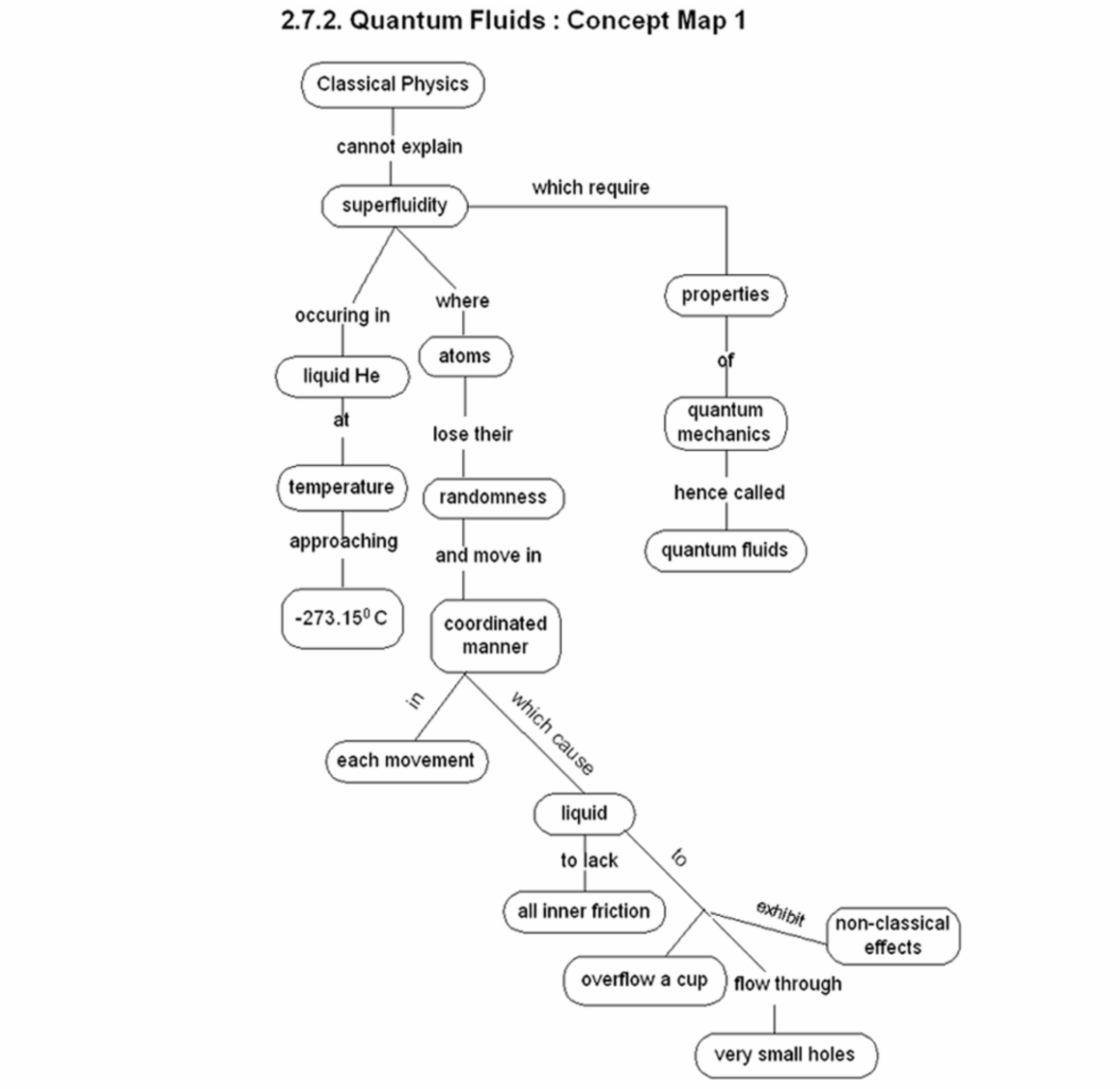
The **Nobel Prize** in **Physics** for **1996** was awarded to Professor **David M.Lee**, Cornell University USA, Professor **Douglas D.Osharoff**, Stanford University USA, and Professor **Robert C.Richardson**, Cornell University USA, for their discovery of **superfluidity** in **helium-3**.

Nine Concept Maps illustrate the Quantum Fluid, Isotopes of Helium and their Properties, Phase Transition in Helium-3, Superfluidity in Helium-3, Properties and Applications of Superfluidity.

By studying the phenomenon of superfluidity in helium-3 the scientists have paved way for better understanding of matter at low temperatures.

2.7.2. Quantum Fluids

Classical physics cannot explain superfluidity occurring in liquid helium when temperature approaches absolute zero (-273.15^0 C), since atoms lose their randomness and move in co-ordinated manner in each movement. This behaviour would cause liquid to lack all inner friction. Hence it would make liquid to over flow a cup, flow through very small holes and exhibit non-classical effects. Hence the behaviour of superfluidity can be explained on the basis of quantum mechanics.



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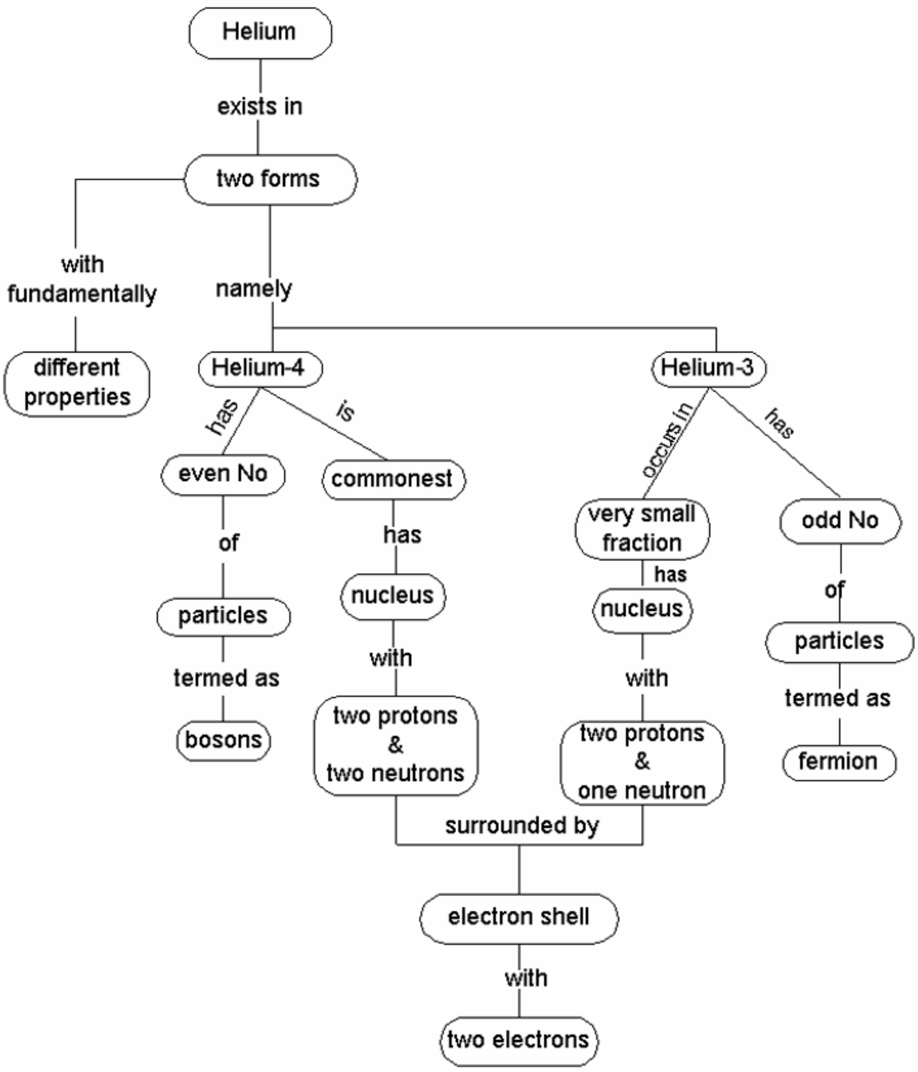
2.7.3. Isotopes of Helium

Helium exists in two forms with fundamentally different properties. They are Helium-4 and Helium-3. Helium-4 has even number of particles and hence termed as bosons. It is commonest and its nucleus has 2 protons and 2 neutrons surrounded by electron shell with 2 electrons.

Helium-3 occurs in very small fraction and its nucleus has 2 protons and 1 neutron. Since it has odd number of particles it is termed as fermion. The nucleus of Helium-3 is also surrounded by electron shell with 2 electrons.

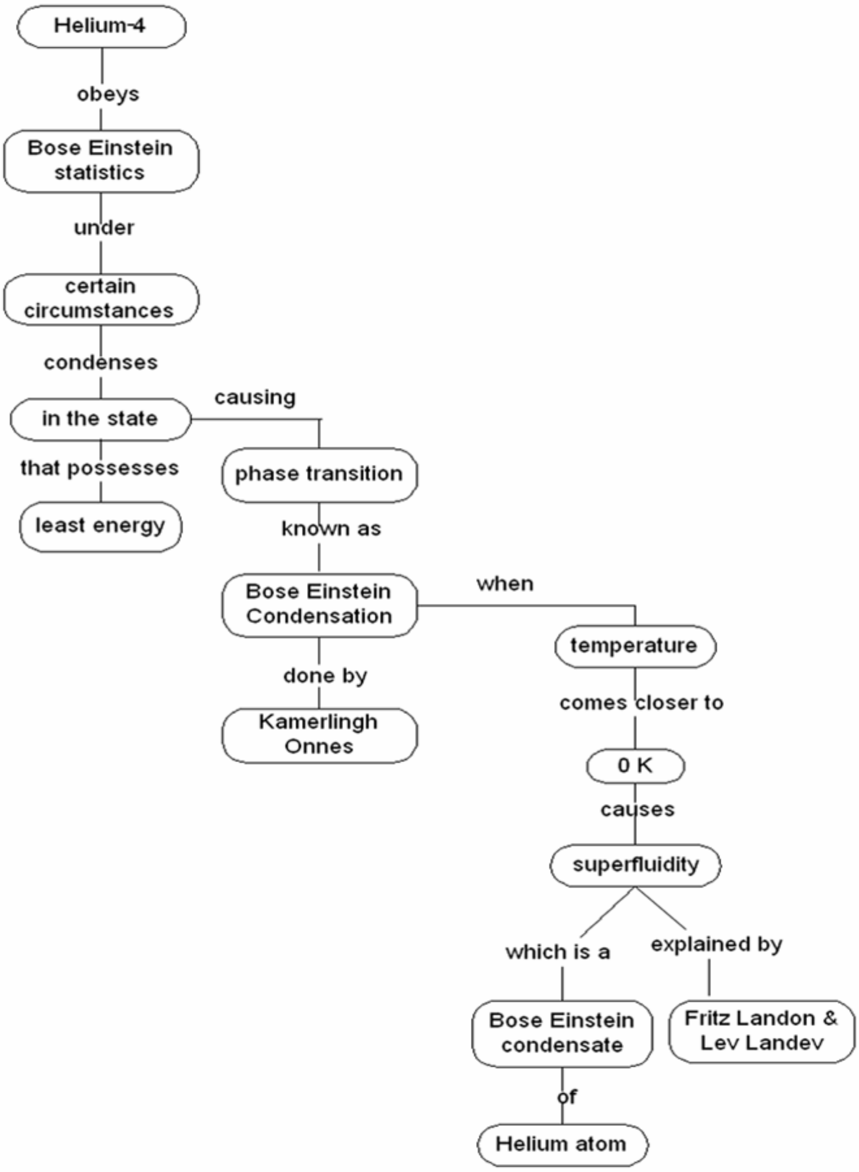
2.7.3. Isotopes of Helium : Concept Map 2



2.7.4. Properties of Helium-4

Helium-4 obeys Bose Einstein statistics. Under certain circumstances it condenses in the state that possesses least energy, causing phase transition known as Bose Einstein condensation. When temperature comes closer to 0 K, it causes superfluidity, which is a Bose Einstein Condensate of Helium atom and is explained by Fritz London and Lev Landau.

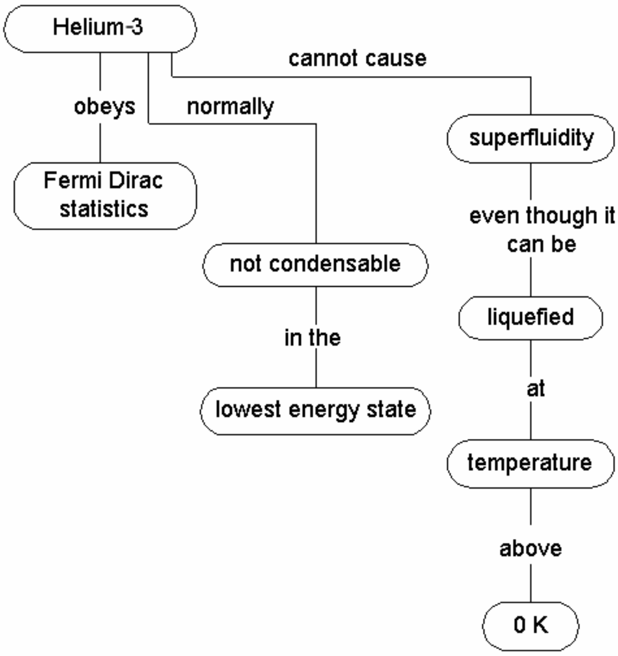
2.7.4. Properties of Helium-4 : Concept Map 3



2.7.5. Properties of Helium-3 : Under Normal Conditions

Helium-3 obeys Fermi Dirac statistics. It is not normally condensable in the lowest energy state. It cannot cause superfluidity even though it can be liquefied at temperature above 0 K.

2.7.5. Properties of Helium-3 : Under Normal Conditions :Concept Map 4

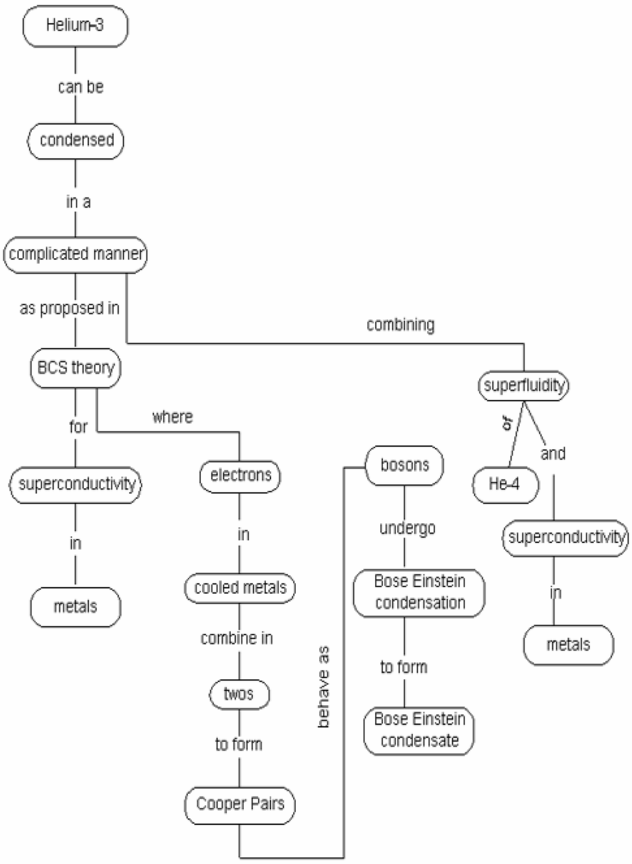


2.7.6. Properties of Helium-3 : Under Special Conditions

Helium-3 can be condensed in a complicated manner as proposed in BCS theory for superconductivity in metals. The electrons in cooled metals combine in twos to form Cooper Pairs and behave as bosons undergoing Bose Einstein condensation to form Bose Einstein Condensate.

Thus Helium-3 can be condensed in a complicated manner combining superfluidity of Helium-4 and superconductivity in metals.

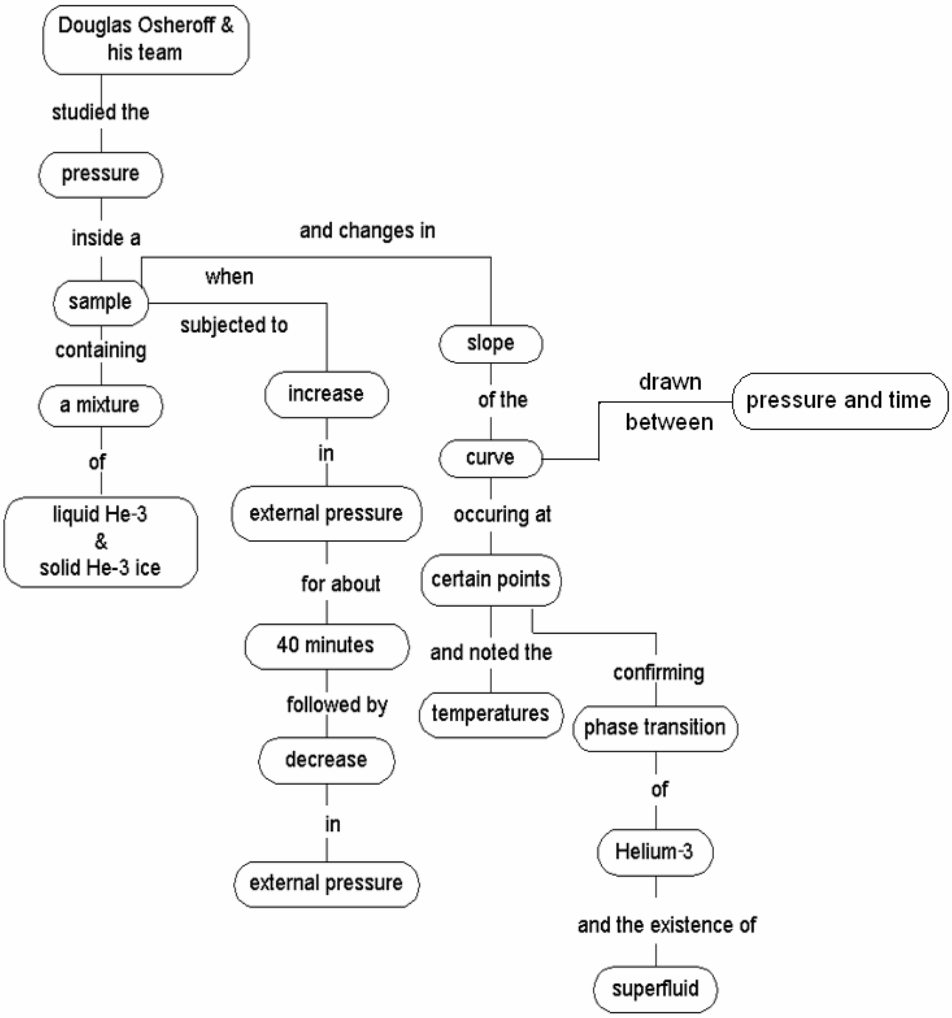
2.7.6. Properties of Helium-3 : Under Special Conditions : Concept Map 5



2.7.7. Phase Transition in Helium-3

Douglas Osheroff studied the pressure inside a sample containing a mixture of liquid Helium-3 and solid Helium-3 ice. The sample was subjected to increase in external pressure for about 40 minutes followed by decrease in external pressure. He observed the changes in slope of the curve (drawn between pressure and time) and noted the temperatures confirming phase transition of Helium-3 and the existence of superfluid.

2.7.7. Phase Transition in Helium-3 : Concept Map 6



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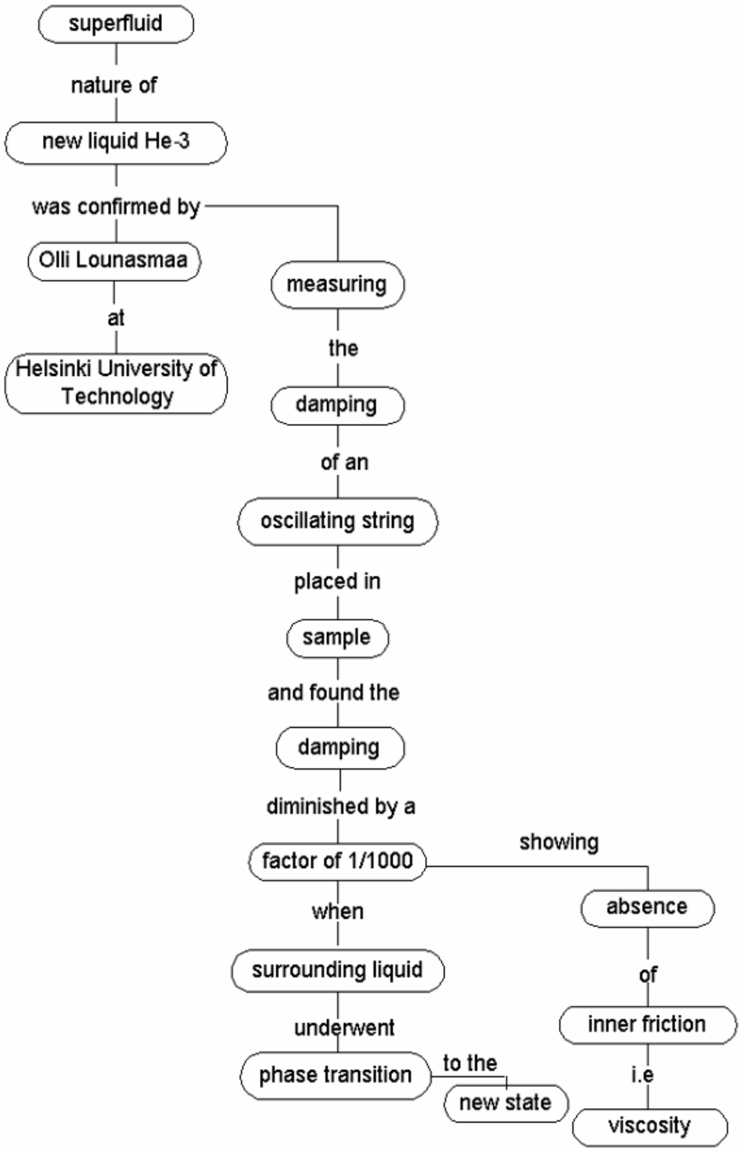
2.7.8. Superfluidity in Helium-3

Olli Lounasmaa of Helsinki University of Technology confirmed the superfluid nature of new liquid Helium-3. He confirmed the superfluid nature by measuring the damping of an oscillating string placed in sample and found the damping diminished by a factor of 1/1000 when the surrounding liquid underwent phase transition to the new state. This phenomenon showed the absence of inner friction i.e. viscosity.

2.7.8. Superfluidity in Helium-3 : Concept Map 7



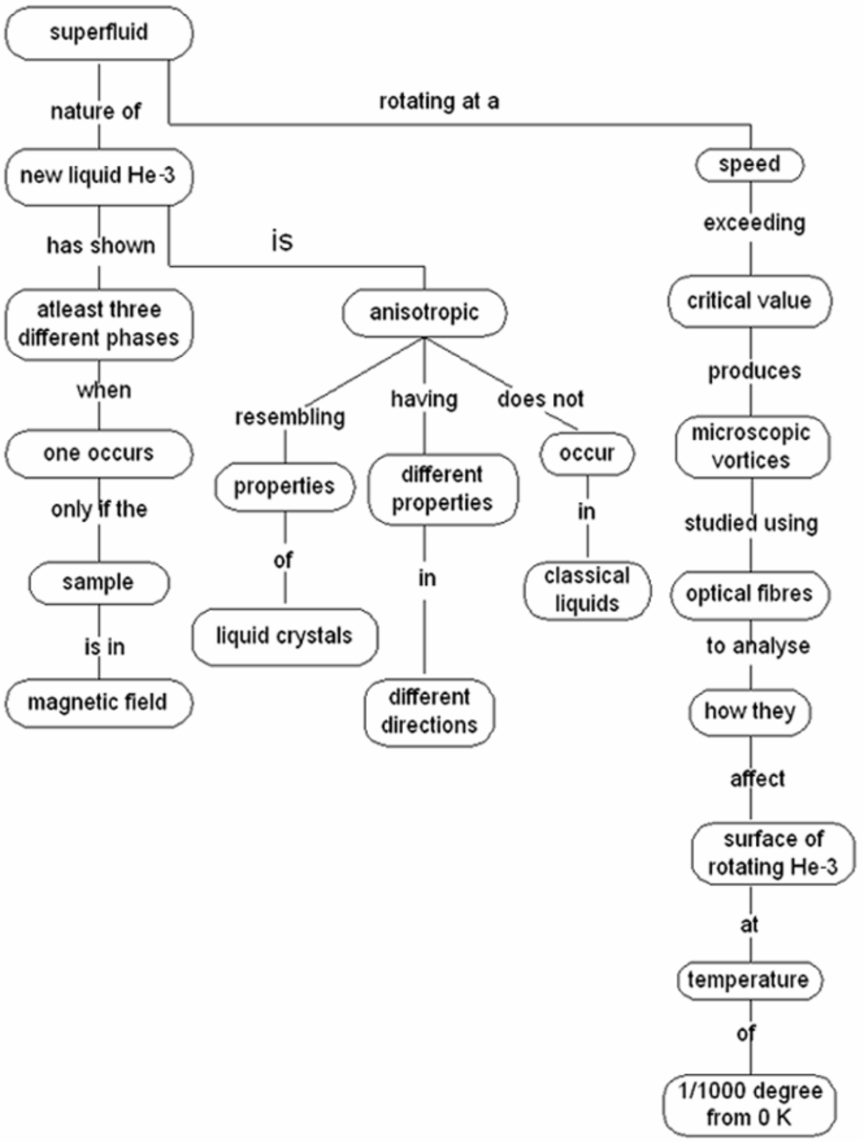
2.7.9 Properties of Superfluidity in Helium-3

The superfluid nature of new liquid Helium-3 was found to exhibit atleast three different phases, where one of them occurs only if the sample is placed in magnetic field.

It is found that the superfluid nature of new liquid Helium-3 is anisotropic. It resembles properties of liquid crystals, has different properties in different spatial directions, which does not occur in Classical Physics.

The superfluid rotating at a speed exceeding critical value produces microscopic vortices. They were studied using optic fibres to observe how they affect surface of rotating Helium-3 at temperature of 1/1000 degree from 0 K.

2.7.9. Properties of Superfluidity in Helium-3 : Concept Map 8



2.7.10. Applications of Superfluidity in Helium-3

Superfluidity in Helium-3 where phase transition occurs have been studied to test cosmic strings formed in the universe. The cosmic strings might have arisen due to rapid phase transition occurred within fraction of a second after big bang. Neutrino induced nuclear reactions were performed to heat superfluid Helium-3 which when cooled formed balls of vortices which are prescribed to correspond to the cosmic strings.

2.7.10. Application of Superfluidity in Helium-3 : Concept Map 9