SUPERCONDUCTIVITY

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INTRODUCTION

- The phenomenon of superconductivity was first discovered by Kammerlingh Onnes in 1911.
- He found that electrical resistivity of some metals, alloys and compounds drops suddenly to zero when they are cooled below a certain temperature.
- This phenomenon is known as superconductivity and the materials that exhibit this behaviour are called as superconductors.
- However, all the materials cannot superconduct even at 0 K. The temperature at which a normal material turns into a superconducting state is called critical temperature Tc. Each superconducting material has its own critical temperature.
- Kammerlingh Onnes discovered that the electrical resistance of highly purified mercury droped abruptly to zero at 4.15 K, as shown in Fig. 19.1.
- Generally good conductors like Au, Ag, Cu, Li, Na, K, etc. do not show superconductivity even at absolute zero.

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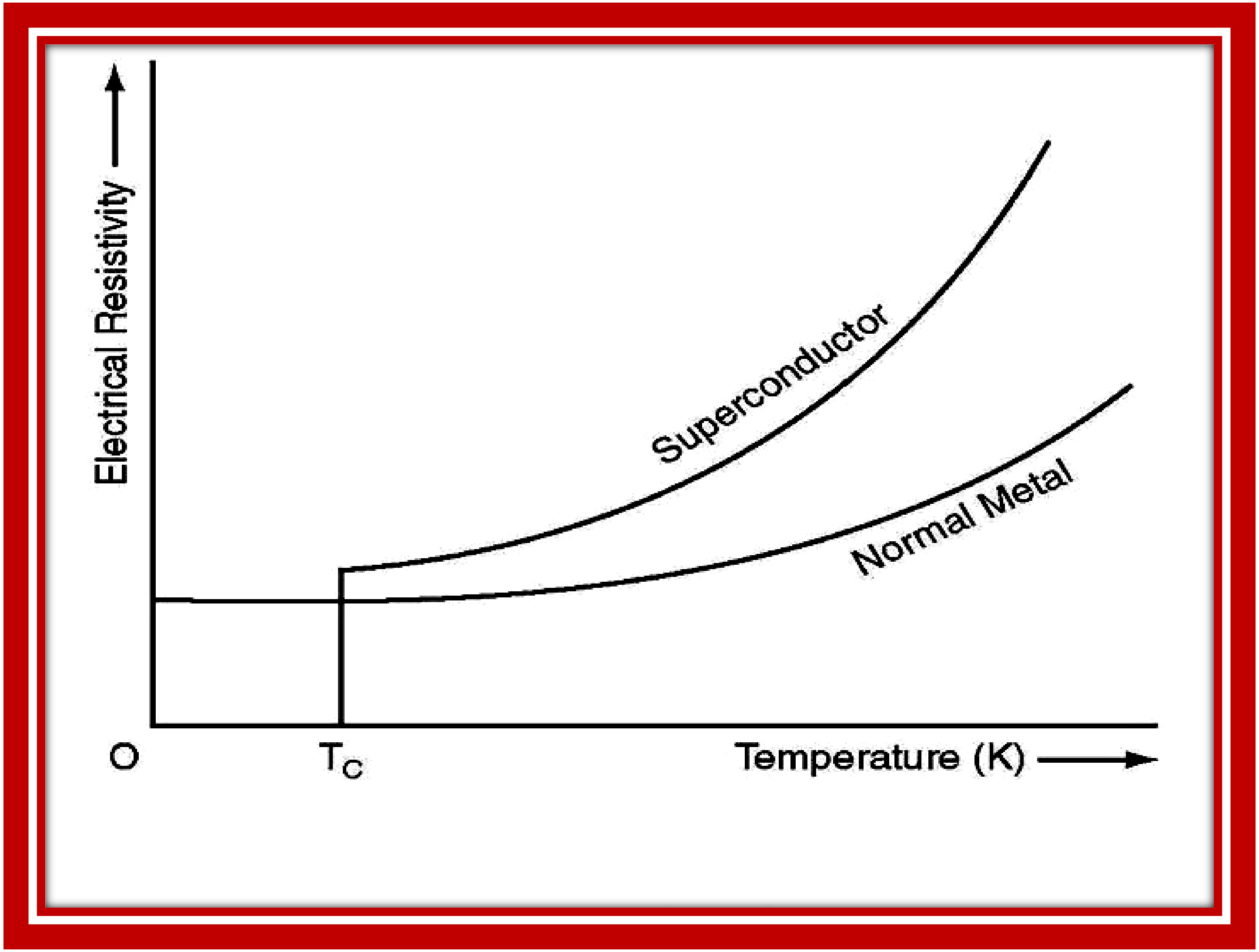

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- The interaction of electrons with one another and with the lattice ions were averaged out by the free electron theory (model) approximation.
- This could be responsible for resistance to the flow of electrons under normal conditions.
- This independent particle model was unable to explain superconductivity.The clear understanding of the phenomenon of superconductivity requires the consideration of collective behavior of electrons and ions.
- This is called many body effects in solids.

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ELECTRICAL RESISTIVITY OF SOLIDS AND PHONONS

- There are several factors that contribute to the electrical resistivity of a solid. For example, the deviations from a perfect lattice, which may be due to impurities or structural defects in crystal, can scatter the electrons.

- Moreover, the vibrations of lattice ions take place in normal modes. These vibrations constitute acoustic waves which travel through the solid.

- These waves are called phonons, which carry momentum. It is obvious that the number of photons will increase if the temperature is raised. In the presence of phonons, now there is an interaction between the electrons and phonons.

- This interaction scatters conduction electrons and hence causes more resistance. Therefore, it is clear that the electrical resistance of a solid will decrease if we cool the solid.

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Entropy

- We know that the entropy is a measure of the disorder of a system. In all superconductors, the entropy decreases significantly on cooling below the critical temperature Tc.

- Therefore, the observed decrease in entropy between the normal state and superconducting state shows that the superconducting state is more ordered than the normal state.

- For aluminium, the change in entropy was observed to be small of the order of 10^{-14} k per atom, where k is the Boltzmann constant.

- The variation of entropy of aluminium in the normal and superconducting states with temperature is shown in Fig.

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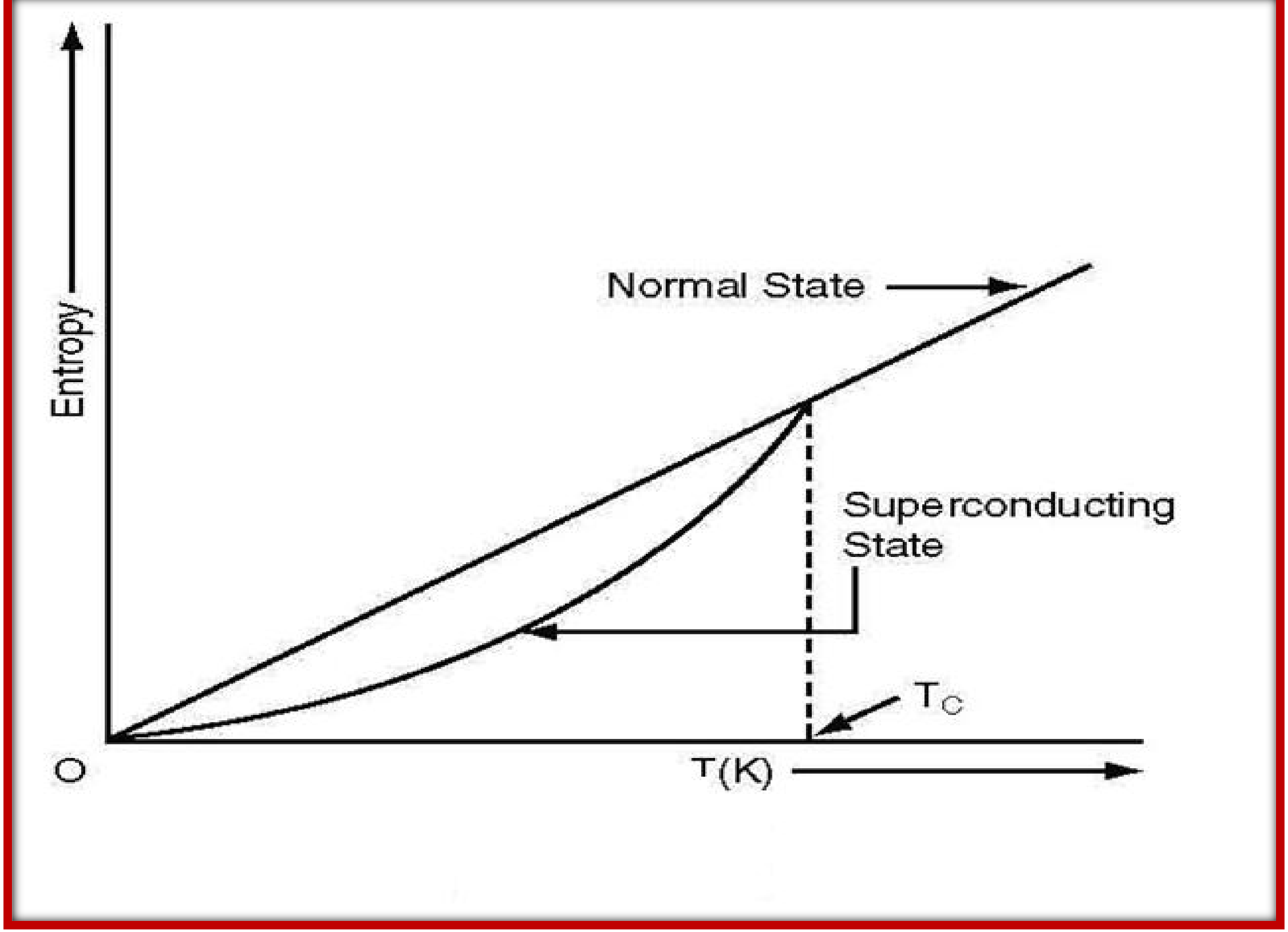

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$$C_n(T) = \gamma T + \beta T^3$$

In this relation, the first term is the specific heat of electrons in metal whereas the second term is due to the contribution of lattice vibrations at low temperature. On the other side, the specific heat of the superconductor shows a jump at T_c As we know that the superconductivity affects electrons mainly, so we may assume that the lattice vibration part remains unaffected and has the same value βT^3 in the normal and superconducting states.

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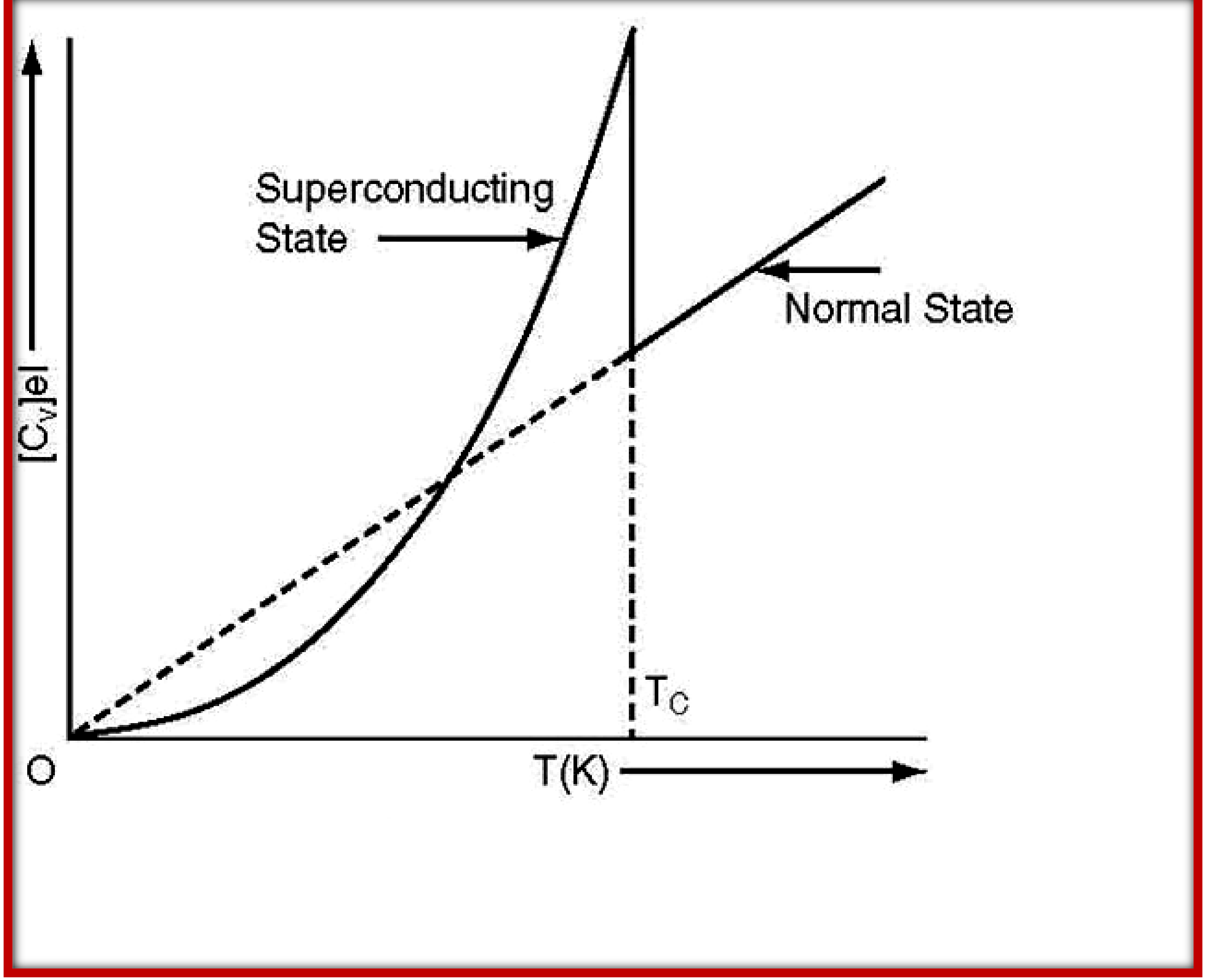

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Thermal Conductivity

- The thermal conductivity of superconductors undergoes a continuous change between the two phases. It is usually lower in the superconducting phase which shows that the electronic contribution goes down.
- This suggests that the superconducting electrons possibly play no role in the transfer of heat.