CHAPTER VI

THERMALLY STIMULATED CONDUCTIVITY

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6.1 INTRODUCTION

The measure of number of electrons in conduction band is known as conductivity of the material. The number of electrons in the conduction band can be increased by increasing the temp. full of the material. For semiconductors there are some electrons in the conduction band at room temperature. Hence they show some conductivity. However in case of insulators, band gap is large. There are no electrons in conduction band. But by increasing temperature it is possible to transfer the electrons from valence band or traps to conduction band and the resultant conductivity is called as thermally stimulated conductivity (TSC). The temp. required to transfer the electrons from valence band to conduction band depends on the band gap energy of the material. Thus from the change in resistivity with temperature it is possible to estimate the band gap energy of the material.

6.2 EXPERIMENTAL PROCEDURE

The four probe method is used to measure the resistivity of the material at different temperature. The experimental set up is described in chapter II(Section 2.4.5). The sample in the form of pellet is placed in sample holder and probes are placed so as to make good contacts. The sample was then placed in an oven and temperature was increased progressively. The current and voltage are measured at different temperatures. The resistivity of the material is calculated by using formula -

$$\rho = \frac{2\pi \, s \, V}{G7\,(W/S)\; I} \quad .. \quad (6.1)$$

where, I = current through the phosphor

V = voltage between voltage probe

S = distance between two probes

G7(W/S) = The function of thickness of sample and distance between two probes.

The value of G7(W/S) is used from the data provided by the manufacturer.

The band gap energy is given by the formula,

$$Eg = 2\,K \; \frac{\log_e \rho}{(1/T)} \quad .. \quad (6.2)$$

The value of $\left[\frac{\log_e \rho}{(1/T)} \right]$ is obtained from the slope of $\log_{10} \rho$ Vs. $1/T^{\circ}k$ graph.

6.3 RESULTS AND DISCUSSION

i) Conductivity of phosphor : It is observed that phosphor behaves as an insulator at room temperature. This shows that it has larger band gap as compared to semiconductors. As temperature increases above a certain temperature around 165°C for undoped CaS and 180°C for phosphor doped with Mn and Bi, the phosphor shows some conductivity. This conductivity is due to thermally generated electrons and holes. Thus electrons from valence band or from traps are transferred to conduction band. The values for resistivity and conductivity for typical samples (MD.39, MD 30, and MD-19) are shown in table no. 6.1 6.2, 6.3. In the present study, conductivity increases with increase in temperature.

ii) Band Gap Energy : - In Case of CaS phosphor, the reported value of band gap energy is expected around 4.5eV (1,2,4). In the present study the band gap energy is calculated by plotting the graph between

$\log_{10}\delta$ and 1/T (Fig. 6.1, 6.2, 6.3). The band gap energy thus calculated is 2.2123 eV for CaS (undoped) 1.666 eV for CaS:Bi:Tb and band gap energy for CaS:Mn:Dy is 2.1914 eV. Author would like to make clear that band gap energy estimated by four probe method does not agree with the reported value of band gap energy for CaS. Following may be probable reason for this large variation in the value of band gap energy.

To transfer sufficiently large number of electrons from valence band to conduction band, still higher temperature is required. In the present four probe set up the range of temp. of oven is limited from room temp. to 250°C. In this range of temp. electrons from intermediate traps might be getting transferred to to the conduction band instead of that from valence band. As such the calculated energy may not be a band gap energy of the material, but may be a trap depth from which electrons are transferred to the conduction band. Such an understanding requires confirmation with additional data and experimentation.

In the present study it is observed that band gap for undoped phosphor is large. In both types of phosphors of combination CaS:Bi:Tb and CaS:Mn:Dy presence of impurity (activator) is found to decrease band gap. Amongst CaS:Bi:Tb and CaS:Mn:Dy 'Eg' is small . This indicates that impurity doped CaS has smaller band gap and Bi:Tb activated calcium sulphate has the smallest value 1.666 eV. Conductivities of these phosphors are also supportive to the above mentioned results.

Table No. 6.1 : Showing the values of resitivity and Conductivity at different temperature

MD-39 (CaS undoped)

Temp. $^{\circ}k$	Resitivity $\rho\ \Omega$ cm.	Conductivity $(\Omega\ cm)^{-1}$
438	1.9255×10^{7}	5.1932×10^{-8}
448	1.9255×10^{7}	5.1934×10^{-8}
451	1.7651×10^{7}	5.6654×10^{-8}
453	1.7116×10^{7}	5.8424×10^{-8}
458	1.4671×10^{7}	6.8161×10^{-8}
463	1.2837×10^{7}	7.7899×10^{-8}
468	1.0697×10^{7}	9.3484×10^{-8}
473	1.0029×10^{7}	9.9710×10^{-8}
478	0.7432×10^{7}	13.4571×10^{-8}
483	0.6279×10^{7}	15.9261×10^{-8}
485	0.4813×10^{7}	20.7770×10^{-8}

Table No. 6.2 : Showing the values of resistivity and conductivity at different temperature.

MD-30 (CaS:Mn:Dy)

Temp. $^{\circ}k$	Resitivity Ω cm.	Conductivity $(\Omega\ cm)^{-1}$
448	0.9627×10^{7}	10.3874×10^{-8}
453	0.4279×10^{7}	23.369×10^{-8}
458	0.9627×10^{7}	10.3874×10^{-8}
463	0.8023×10^{7}	12.464×10^{-8}
468	0.6912×10^{7}	14.464×10^{-8}
473	0.6061×10^{7}	16.498×10^{-8}
478	0.4813×10^{7}	20.777×10^{-8}
483	0.4813×10^{7}	20.777×10^{-8}

Table No. 6.3 : Showing the values of resistivity & conductivity at different temperature.

MD-19 (CaS : Bi : Tb)

Temp ^{o}k	Resitivity Ω cm	Conductivity Ω cm^{-1}
453	0.3209×10^{7}	31.1623×10^{-8}
458	0.9627×10^{7}	10.3874×10^{-8}
463	0.9169×10^{7}	10.9063×10^{-8}
468	0.9927×10^{7}	10.0735×10^{-8}
473	0.8050×10^{7}	12.4223×10^{-8}
478	0.6796×10^{7}	14.7145×10^{-8}
483	0.5355×10^{7}	18.6741×10^{-8}

References

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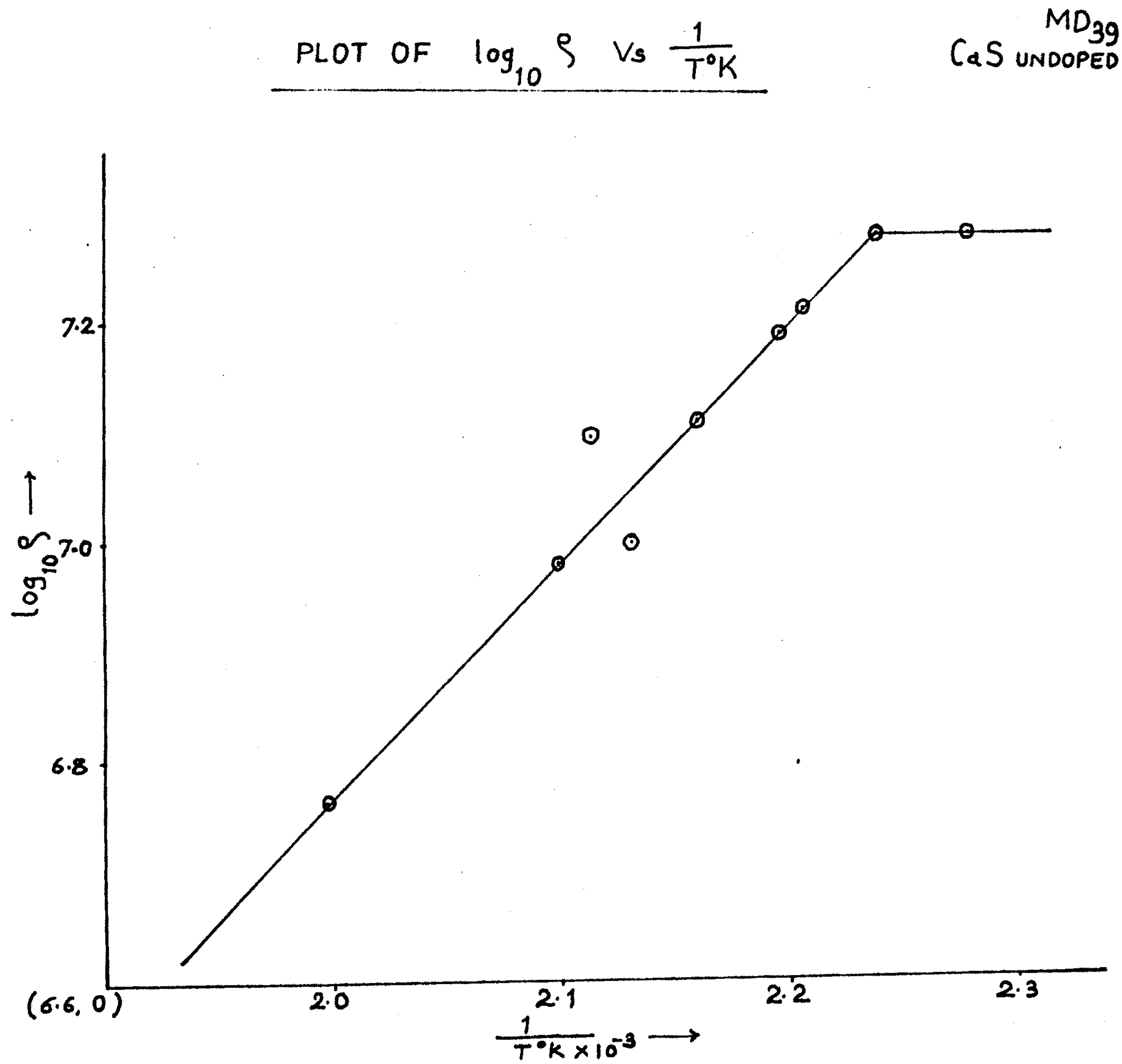

PLOT OF $\log_{10} \rho$ Vs $\frac{1}{T°K}$
MD_{39}
CaS UNDOPED
7.2
7.0
6.8
$\log_{10} \rho$ →
(6.6, 0)
2.0
2.1
2.2
2.3
$\frac{1}{T°K \times 10^{-3}}$ →

FIG. NO.: 6.1

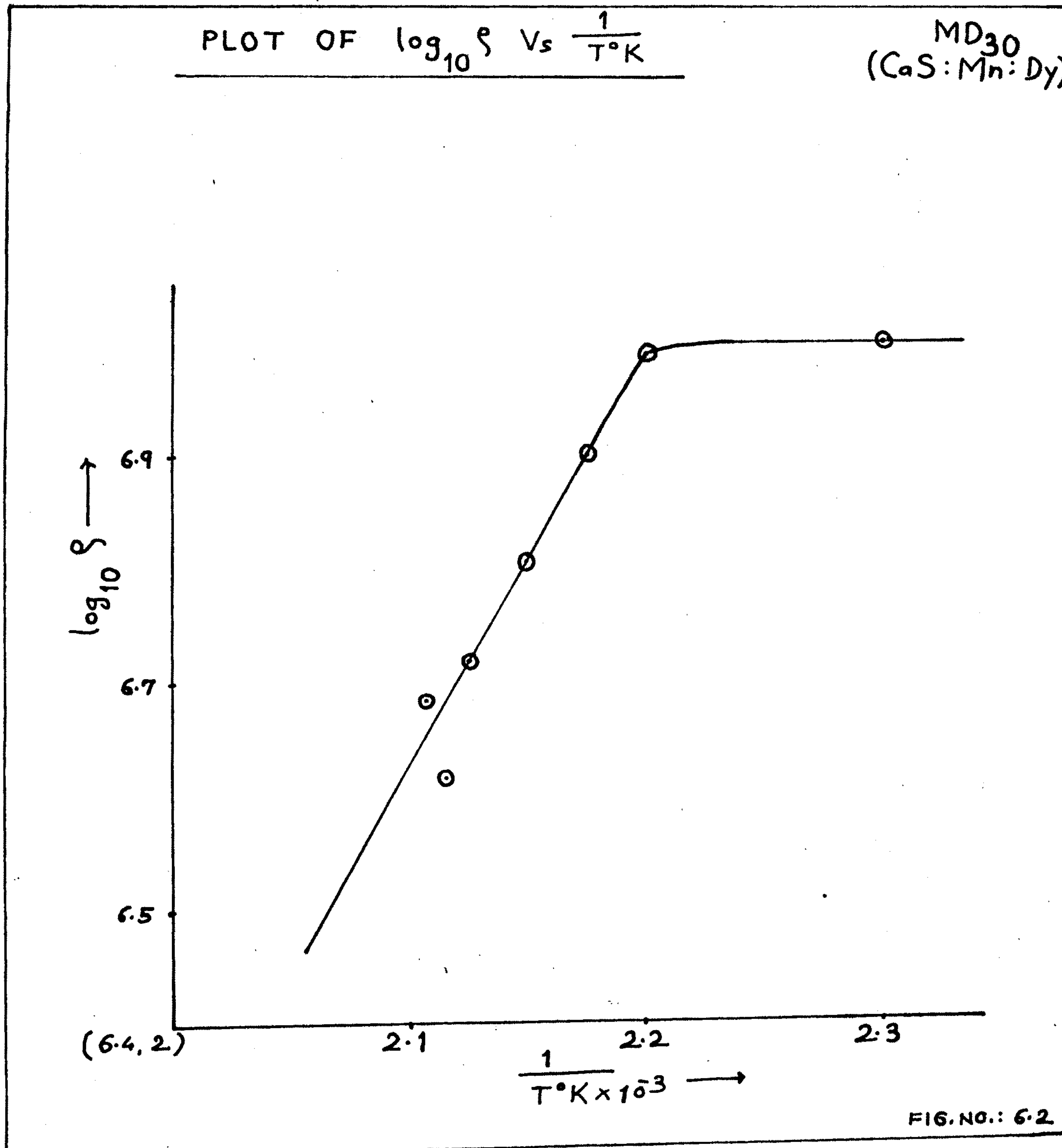

PLOT OF $\log_{10}\rho$ Vs $\frac{1}{T°K}$
MD30
(CaS : Mn : Dy)
$\log_{10}\rho$ →
6.9
6.7
6.5
(6.4, 2)
2.1
2.2
2.3
$\frac{1}{T°K \times 10^{-3}}$ →

FIG. NO.: 6.2

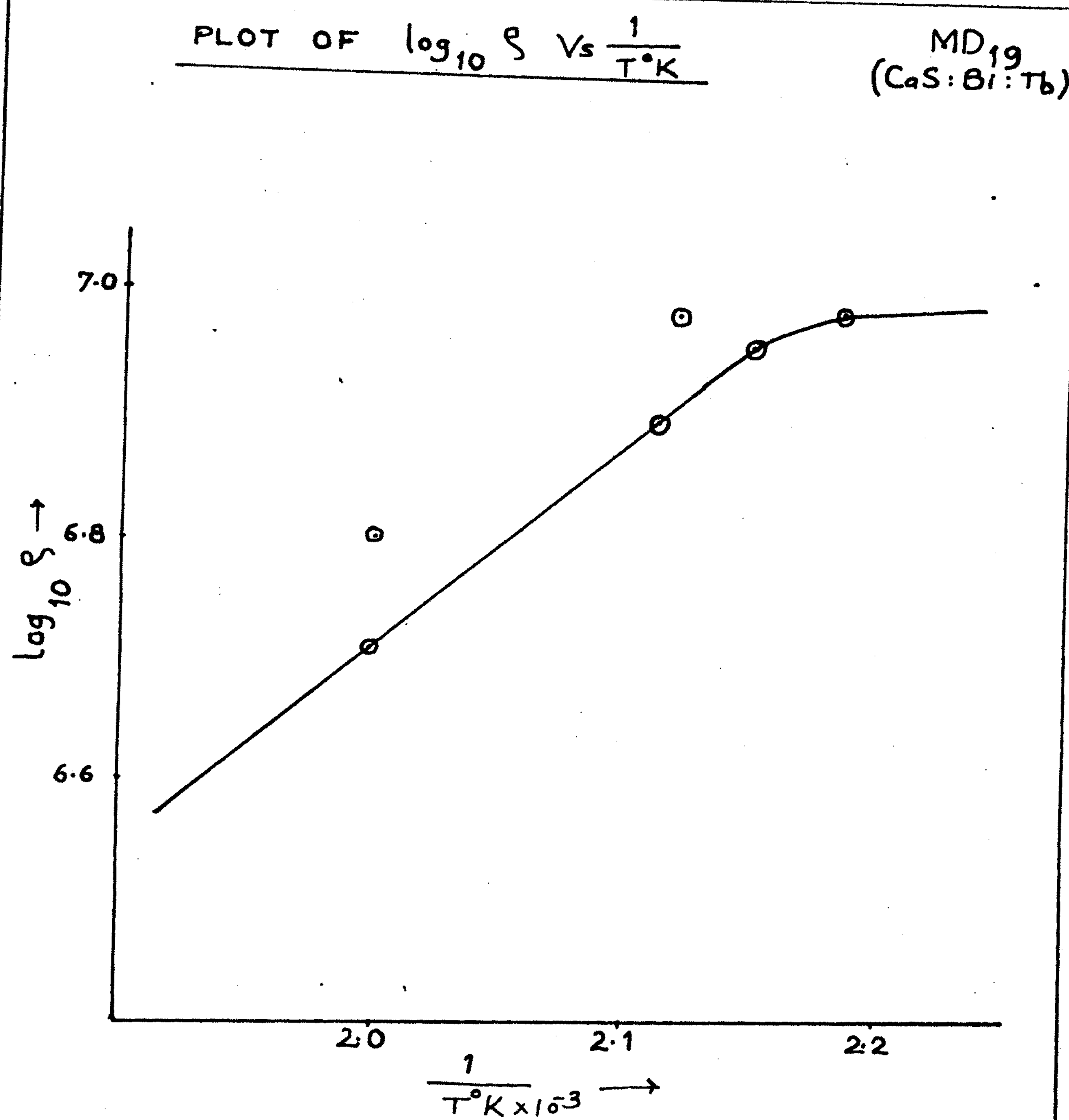
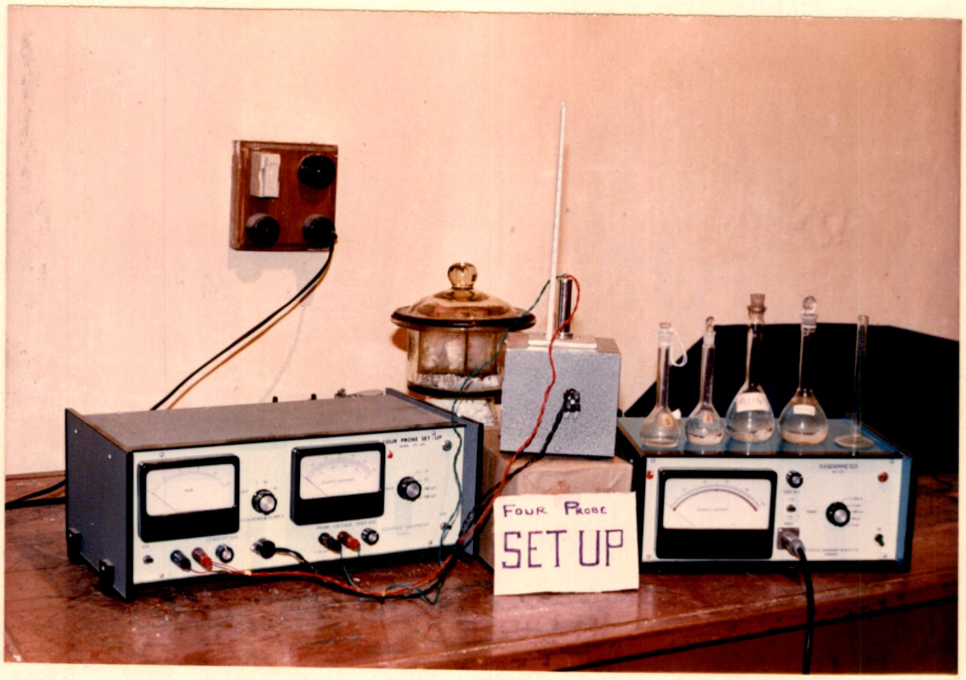

PLOT OF $\log_{10} \rho$ Vs $\frac{1}{T^\circ K}$
MD_{19} (CaS : Bi : Tb)
7.0
6.8
6.6
$\log_{10} \rho \rightarrow$
2.0
2.1
2.2
$\frac{1}{T^\circ K \times 10^{-3}} \longrightarrow$

FIG. NO.: 6.3.



FOUR PROBE SET UP

(Fig. No. 6.4)