

Electrical conductivity & dielectric properties of heptahydrated zinc sulphate in crystal and pellet form

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ABSTRACT

Electrical conductivity and dielectric constant variation with temperature were reported for Heptahydrate Zinc Sulphate in crystal and pellet form. The values of resistance with conductivity were noted here. Also shows the value of capacitance with Dielectric constant corresponding to temperature. Results show rising temperature tends to decrease the dielectric constant of an ionic solid by decreasing the number of ions/cm³ because of its expansion. As the temperature increases the electronic polarizing ability of individual ion increases because of the availability of larger volume causing an increase in dielectric constant.

Key words: Electrical conductivity, Dielectric constant, Heptahydrate Zinc Sulphate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$).

INTRODUCTION

Crystals are generally solids, whose atoms are arranged in a definite pattern, outwardly expressed by geometrical form with plane faces. Heating of hydrated crystals produce variety of effects, e.g. phase transition, heat of reaction, dehydration, hydrolysis, decomposition, melting, dissociation etc.

Dehydration of hydrated crystal leads to loss of water of crystallization, in definite step at definite temperatures. The process takes place without affecting the composition of other substances. The thermo gravity along with other techniques provides an effective means for the study of dehydration and the resulting lower hydrates. Several workers have worked on different crystal and pellets and established the relation between thermal and electrical properties. In this project we report the electrical and dielectric properties of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ crystals as well as pellets during the dehydration process.

EXPERIMENTAL

a) Preparation of crystals

A 250 ml coming glass beaker with about 100 ml distilled water was used to make a slightly less saturated solution of heptahydrate zinc sulphate. A glass rod of about 10 cm in length and 4 mm in diameter is used for stirrer purpose. After dissolving $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ in water, the solution appears transparent (without any colour). This beaker containing solution was covered from top with blotting paper to avoid any fall of contamination in it. Thus, beaker was kept at a constant temperature of about 28°C (at room temperature) in a dark place and free from any vibrations or any shock to beaker. After some time of about 25 days later a small pieces of about 2 mm in dimensions were observed in solution of the beaker. These pieces are called the seed. A good quality bigger in size single crystal was sorted out. A sorted seed of a crystal of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ was tied by a silk thread and was hanging under the solution. This technique of hanging helps to develop a seed effectively. Again

a period of 15 days well crystals were seen around the seed hanged under the solution. These well grown crystals by this way were collected and dried immediately with the help of dry air. A number of grown crystals of 20 were collected by the above procedure. The freshly prepared samples (crystals) were used for the study.

Preparation of Pellets

Zinc sulphate of 99% purity was obtained. They were crushed to fine powder in a pestal mortar and processed for pellet preparation in a pellet-pressing machine. The pressure applied was 5Kg. These pellets were later on used for the study.

The dimensions were of pellets measured. The thickness was measured with screw-gauge and diameter was measured with vernier calipers, and its area was calculated. The end faces of pellets were coated with a thin layer of conducting silver paste to provide good electrical contacts.

EXPERIMENTAL

Two terminal methods were applied to measure the resistance of the pellet and crystal. Digital LCR meter, which measures the resistance from 0.1Ω to $20 \text{ M}\Omega$, was used to study the temperature variations of resistivity. The pellet is placed between the two terminals of sample holder, which is placed in the electric furnace. The temperature of the furnace is increased by passing current and is controlled by adjusting the current by means of variac. Thermometer, which is placed partly inside the furnace and partly outside the furnace with the help of stand, is used to measure the temperature of the sample.

For every 2°C rise in temperature the resistance of the pellet is noted with the help of LCR meter. After determining the value of resistance and capacitance at different temperature for every 2°C rise up to 300°C . Conductivity and dielectric constant are determined respectively. The observations and calculations were tabulated as shown in table. The table shows values of resistance and conductivity corresponding to temperatures and also shows the values of capacitance and dielectric constant corresponding to temperatures.

The plot of σ versus temperature and ϵ versus temperature are plotted.

RESULTS AND DISCUSSION

The dielectric constant and Electric conductivity are studied at different temperatures for $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ sample (pellet form). The Dielectric constant (ϵ) and Electrical conductivity varies with Temperature. Also we measured the resistance and capacitance of the pellets sample.

For Electrical conductivity

The Electrical conductivity measured with resistance for different temperature. The conductivity measurements in case of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ in packed powder form shows five peaks, which corresponds to combined effect of deauration temperatures. One more peak was expected in the temperature range $160^\circ\text{C} - 200^\circ\text{C}$, but the readings were out of range of the meter. So one important peak was missed. Due to lack of time, arrangement of another measuring instrument was not possible. Group shows variation of conductivity with temperatures from $60^\circ\text{C} - 300^\circ\text{C}$; while cooling from 300°C to

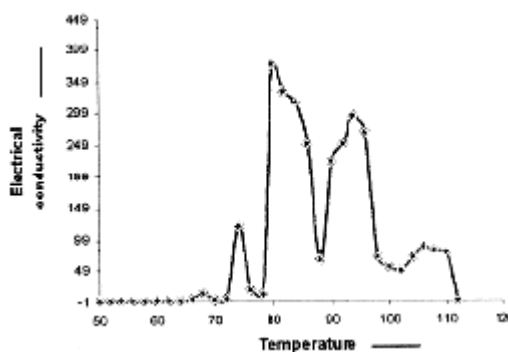


Fig. - 1: Temperature vs electrical conductivity

room temperature there was not appreciable change in the conductivity.

During deauration process a fraction of released water molecules undergoes dissociation giving H^+ or OH^- ions. The presence of large number of these free ions within the sample is responsible for the enhancements of the electrical conductivity

during the deaquation. Thus the electrical conductivity measurements also help in deciding the different deaquation steps when deaquation is followed by dissociation. The presence of peak in conductivity is due to the relatively slow movement of trapped water molecules released at the deaquation temperatures and their subsequent dissociation by the diffusion process.

Resistance (R) of the pellet sample was found by knowing the area and thickness of the pellet. Resistance is directly proportional to the thickness of the pellet. After calculating resistance (R) we can easily calculate the electrical

$\text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$ but trapped within the material and to the space charge polarization produced by the trapped +ve and -ve charges generated after the dissociation of water molecules.

It is seen from the graph that the dielectric constant shows a five peaks at 62°C, 74°C, 86°C, 116°C and 136°C, which corresponds to the combined effect of the deaquation temperatures. The dielectric constant varies from 30°C to 300°C. While cooling from 300°C to room temperature there was no appreciable change in dielectric constant. Absence of any change in dielectric constant during cooling supports the assumption of dissociation of water molecules at the respective deaquation temperatures. The dielectric constant of an ionic solid is affected by following temperature dependant factors.

- 1) Rising temperature tends to decrease the dielectric the dielectric constant of an ionic solid by decreasing the number of ions/cm³ because of its expansion.
- 2) As the temperature increases the electronic polarizing ability of individual ion increases because of the availability of larger volume causing an increase in dielectric constant.

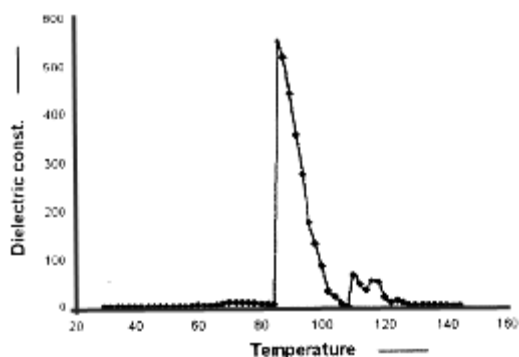


Fig. - 2: Temperature vs dielectric constant

conductivity. The fast rise and fall of conductivity indicates free charge carriers are available for conduction during dehydration.

Result of dielectric constant measurements

The dielectric constant measured with different temperatures. Graph between the dielectric constant and temperatures shows the variation of dielectric constant with temperature. This graph shows some peaks in the dielectric constant at the respective deaquation temperatures. This also indicates that $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ is transformed into $\text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$ while crushing.

The increase in dielectric constant is due to the orientation of the permanent dipole of the water molecule release from the pellet of

This indicates that the free charge carriers are available for conduction only during the deaquation process. It is therefore assumed that a very small fraction of water molecules that are detached from the structures at different deaquation temperatures get dissociated into I-t and OR ions. This increases temporarily concentration of mobile charge carriers causing the observed large increase in conductivity at the dehydration temperature.

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