The Electrical Conductivity of Calcite.—By W. J. Jackson, M.A., McGregor Fellow in Physics, Dalhousie University, Halifax, N. S.

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It has been found that in crystals of calcite there is a polarisation effect due possibly to a space charge near the electrodes or throughout the crystal; the amount varying with different crystals. There is a displacement current as well as a conduction current. The relation between the current and the temperature is approximately exponential. The conductivity is directional. When the crystals are exposed to X-Rays the change in conductivity does not last for more than one or two hours.

Introduction

Experimental work on the thermo-luminescent properties of calcite and similar crystals has been carried out by Mackay* in which he found that when the crystals became luminescent the electrical conducitvity increased. The photo-electric conductivity of diamond crystals has been recently investigated by Miss Levi,† who found that the electrical resistance of diamond crystals varied with the wave-length of the exciting light. In a paper on the change in the electrical resistance which certain crystals undergo on exposure to radiation, Gudden and Pohl‡ offer an hypothesis that conduction takes place by means of negative carriers, which on becoming separated from neutral atoms leave them positively charged; the positive ions then create a space charge within the crystal.

Apparatus and Method of Measurement

Crystals of calcite were selected from a larger block of calcite which was thermo-luminescent.

Electrodes were fastened to the parallel faces by drilling the calcite and fastening in copper wires with an amalgam cement (dental). The approximate size of No. 1 crystal was (2 cm. × 5 cm. × .75 cm.) and No. 2 (2.5 cm. × 2.5 cm. × 1 cm.)

After the crystals had been carefully cleaned with alcohol and dried they were mounted as shown in the diagram.

* Proc. Roy. Soc. Canada. Vol. XV. Page No. 241; 1921.

† Proc. Roy. Soc. Canada. Vol. XVI., Page No. 95; 1922.

‡ Zeitschr. Für Physik No. 6. Page 249. No. 7. Page 65; 1921.

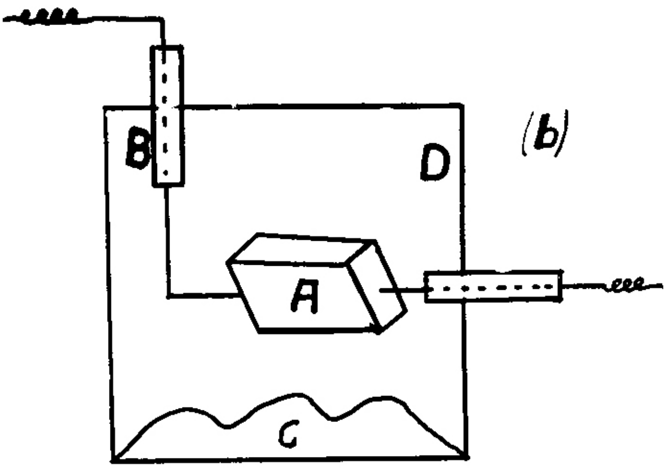


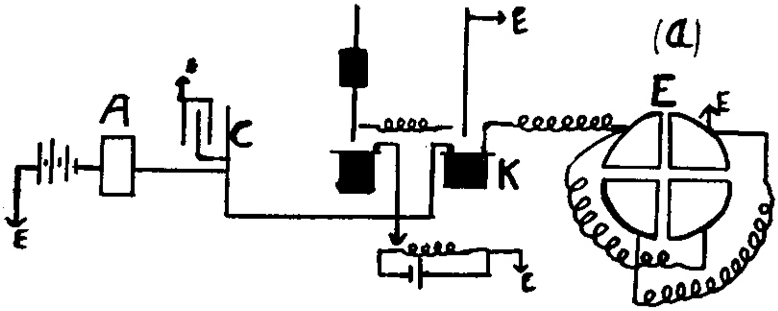
FIG. 1.

A—Cyrstal. B—Quartz Tubing. C—Cal. Chloride.
D—Tin Container.

Diagram Showing Mounting of Calcite Crystal

A guard ring was used to eliminate effects due to surface conductivity. Later it was found that this precaution was not necessary. The current through the crystals, which varied from 10^{-13} amperes to 10^{-11} amperes, was measured by means of a Dolazalek electrometer. The whole apparatus was carefully screened electrostatically and precautions were taken to keep the crystals and insulation dry. Calcium chloride was used as a drying agent.

The temperature was kept constant at any desired value by placing the crystal in a DeKhotinsky thermo-constant electrical oven. It was found that the temperature of this oven when regulated did not vary more than .5 °C. The diagram, Fig. No. 1 (A), shows the appratus assembled.



A—Crystal
C—Mica Condenser
K—Insulated Keys
P—Potentiometer
E—Dolazalek Electrometer.

FIG 2

I. Effect of Time and Temperature on the Conductivity.

A constant E. M. F. of 300 Volts obtained from storage cells, was applied to the crystal and the current was measured by the electrometer at definite intervals. Table No. 1 gives a typical set of readings, showing the decrease of current through the crystal with time, and Curve "A," Fig. No. 3, shows the data graphically.

Table No. 1

Time (Hrs.)	No. of Secs. per 100 Scale div.	Current
0	10.6 Sec.	56.9 K
2	26.7 "	22.5 K
6	32.8 "	18.2 K
10	43.7 "	15.1 K
18	52.6 "	11.4 K

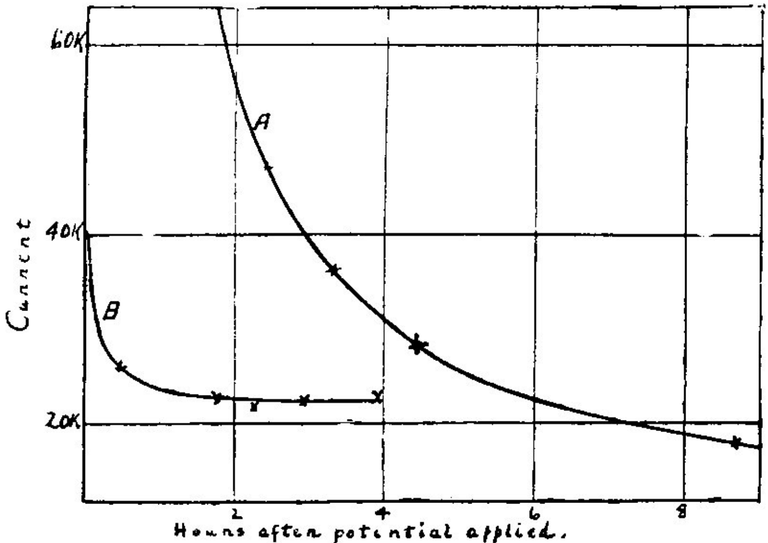


FIG. 3.

Curve "B" Fig. No. 3, is the time-current curve for crystal No. 2. The current in this case being multiplied by a factor 10 to accentuate it on the scale.

The electrical conductivity of the calcite was then measured at different temperatures at a definite time after the potential had been applied, so that the polarization effect was practically eliminated. Table No. 2 shows the effect of temperature on the conductivity and the curve in Fig. No. 4, shows that the logarithm of the current is approximately proportional to the absolute temperature.

Table No. 2

Temperature	Current
27.5°C.	8.05 K
31.0°C.	10.5 K
41.3°C.	15.3 K
45.0°C.	24.0 K
59.0°C.	65.0 K
68.5°C.	125. K

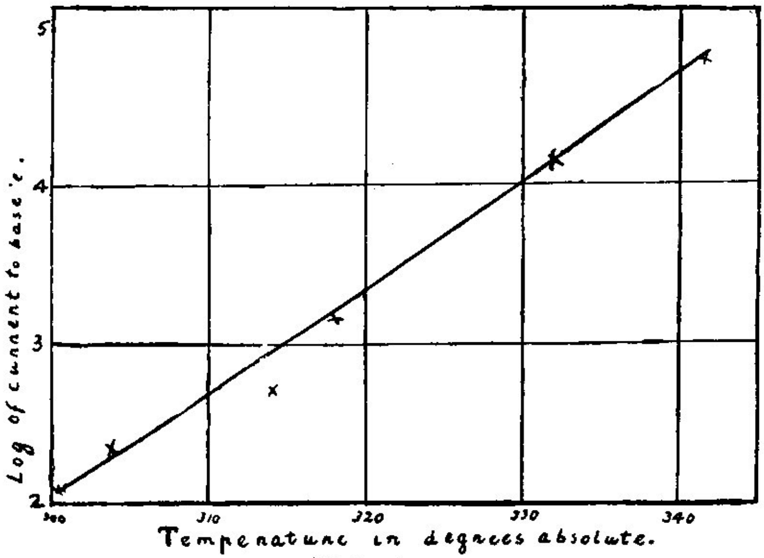


FIG. 4.

II. Polarisation and Depolarisation

The potential was applied to the crystal for 8 hours. After disconnecting the battery the crystal was earthed and the depolarization current measured by the electrometer. This current plotted against time gives what is designated here as the deplolarization curve.

Considerable light is thrown on the conduction of electricity through the calcite crystal by a study of these curves.

From the data obtained it can be said that probably a space charge exists near the elctrodes or possibly throughout the crystal. The experimental facts also give evidence of a displacement current and also a conduction current through the crystal.

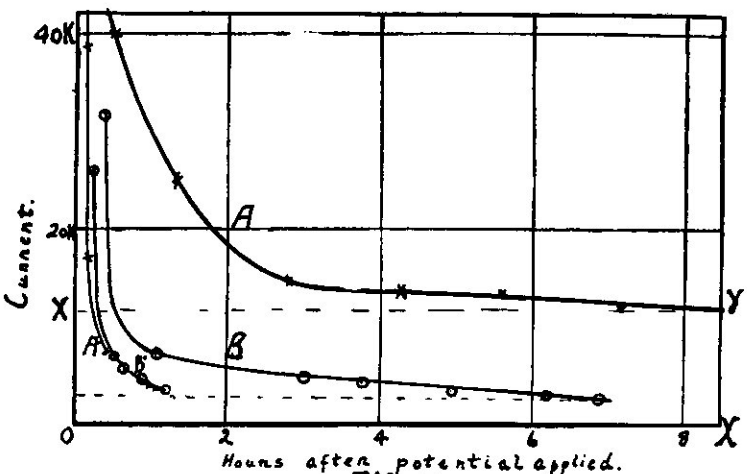


FIG. 5.

Fig. No. 5 shows a typical Current-time curve and also the corresponding depolarization curve. If a line XY is drawn as shown in the figure and the area under the curve "A" down to that line measured it is seen to be approximately equal to the area under the curve A′ (down to OX) which is the corresponding depolarization curve. Curves B and B′ also show the same phenomena. Other curves obtained, of which those in Fig. No. 5 are typical go to show that there is a displacement as well as a conduction current.

III. Directional Conductivity

In crystals No. 1 and No. 2 the conductivity in opposite directions was found to be different. Miss Levi* found similar results for diamond crystals. Curves "A" and "B," Fig. No. 5 show the relative values of the current through the crystal in opposite directions. Positive and Negative potentials were applied to both sides of the crystals alternately; the electrometer was also connected to the opposite side of the crystal.

* Proc. Roy. Soc. Canada. XVI. Page 95; 1922.

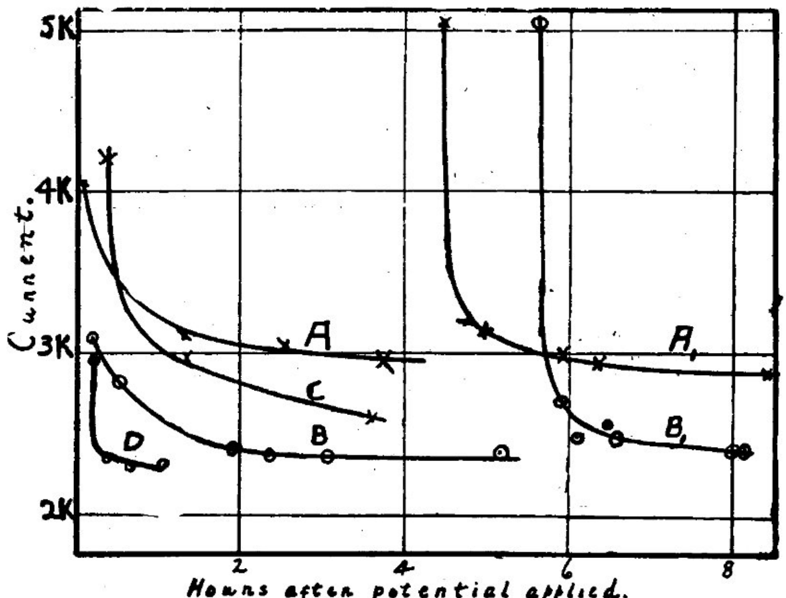


FIG. 6.

Curves A and B, Fig. 6, indicate the variation of current with time for crystal No. 2, while C and B are the corresponding curves for a direction at right angles to the first case.†

Effects of X-Rays on Polarization.

A potential of 200 volts was applied to the crystal for three or four hours before exposure to X-Rays. The results are graphically shown in Fig. 6, curves A and A′, B and B′.

† In some later work done at Princeton University using crystals sputtered with silver, the writer was unable to find any difference in conductivity in opposite directions through the crystal. It is quite possible that the earlier results on directional conductivity may have been an effect due entirely to contact.

It is noted that the current through the crystal is increased but that the X-Ray exposure has not a permanent effect on the conductivity.

Summary

1. In calcite crystals there is a polarization effect due possibly to a space charge near the electrodes or throughout the crystal.
2. There is a displacement current as well as a conduction current.
3. The relation between the current and the temperature is approximately exponential.
4. The conductivity is directional.
5. Exposure of the crystals to X-Rays increases the conductivity; returning to a normal value in one or two hours.

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