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IONIC CONDUCTIVITY AND IONIC JUMP DISTANCE OF NUCLEAR DETECTORS GROUP CR-39 AND BM-355

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التوصيل الأيوني ومسافة القفز لمجموعة الكواشف النووية

(BM-355) و (CR-39)

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البصرة - العراق

تمت دراسة الخواص الكهربائية لنموذجين من البوليمرات المعروفة باسم (CR-39) و (BM-355) وهي من ضمن مجموعة الكواشف النووية، والتي تبين بأن لها توصيلية ايونية تزداد بإرتفاع درجة الحرارة حيث يصل التيار الأول $I_1 = 9$ nA وفي الثاني $I_2 = 50$ nA عندما $V = 500$v وعند درجة حرارة الغرفة، وتزداد لتصبح $I_1 = 0.18\ \mu A$ و $I_2 = 0.24\ \mu A$ عندما $T = 90°C$ ولها مقاومة نوعية تصل إلي $\rho_1 = 1.2\times10^{10}\ \Omega.m$ و $\rho_2 = 0.3\times10^{10}\ \Omega.m$ عند درجة حرارة الغرفة، وكما تم حساب طاقة التنشيط لهما ووجد بأنها تساوي $E_{c1} = 0.28$ eV و $E_{c2} = 0.48$ eV كما حسبت مسافة القفز للأيونات والتي تتغير $a_1 = (9\text{-}14.5)$nm للـ CR-39 بتغير $T=(23\text{-}127)°C$ و $a_2 = (14\text{-}21)$nm للـ BM-355 بتغير $T = (18\text{-}112)°C$.

Key Words: Material electric properties, Nuclear detectors.

Running Title: CR-39 and BM-355 Conductivity.

ABSTRACT

Electric properties of two nuclear detectors (CR-39 and BM-355) have been investigated as a function of temperature differences. The conductivity appears to be ionic and it was increased with the temperature increase for the CR-39 the current reached I_1 = 9nA and for BM-355 I_2 = 50nA at V = 500v and at room temperature, when T = 90°C the current reached, $I_1 = 0.18\mu A$ and $I_2 = 0.24\mu A$ respectively. The specific resistivity was $\rho_1 = 1.2\times10^{10}\ \Omega.m$ and $\rho_2 = 0.3\times10^{10}\ \Omega.m$ at room temperature, with activation energy E_{c1} = 0.28eV and E_{c2} = 0.48eV. The ionic jump distance has been calculated as well, it varied between a_1 = (9-14.5nm) when T = (23-127)°C for CR-39 and a_2 = (14-21)nm when T=(18-112)°C for BM-355.

INTRODUCTION

CR-39 and BM-355 polymers were used for nuclear detectors, when many kinds of polymer nuclear detector's are shaped in sheets form and is exposed to the nuclear radiation which formed track effects. Nuclear radiation parameters can be defined from the knowledge of tracking charactrastic[1,2]. The purpose of this study is to compare between the electric properties of CR-39 and BM-355 (Super CR-39) samples, when they are exposed to a DC voltage in order to understand the bulky current and to define some parameters since they are from the same meterial chain and same kind of polymer. With the difference in the boundary conductions of polymarisoin to produce another polymer chain structure, a new charactrasitization and a better sensitivity for nuclear radiation was attained.

RESULTS AND DISCUSSION

The sample has been shaped into sheets with a thickness of 250μm for CR-39 and 447μm for BM-355. Then, those sheets were exposed to DC voltage (about 750v) when the temperature was varied in order to realise the I/V relationships and define the materials conductivity if it is ohmic or ionic from the equation of ionic current density[3]:

$$J = G \sinh (qa\, E/2KT)$$

Where G is a constant with temperature, q ion charges, (a) jump distance, E electric field values, K boltzman constant and T the temperature. Most of polymers conductivity are ionic and all of them have a high current resistivity and high insulation[4,5,6]. Many researches studied this characteristics for different kinds of polymers and calculated the ionic jump distance[7,8]. The material energy band and structure effected in the DC electric field direction, which is abatemanted in (1/2 qa E) valuse, the energy levels decreases when the electric field is increased, while (a) is not effected by the field, but it varies with temperature and decrease the energy of the level as well as the difference between the energy bands. Totally that means (a) changing the material energy band form as showing in Fig. 1[3].

Fig. 2 represent the logI/V relation for CR-39 sheet in different temperature. From the curves beahviour, which is obvious from the electric conductivity curves, it is clear that conductivity is ionic and the current response to the temperature is proporationaly increased. The same behaviour of BM-355 sheet occured as shown in Fig.3. The ionic current is increased with temperature, evidently for CR-39 as in Fig.4 and the decreasing of the current for BM. 355 with temperature when T < 54°C and the current started to increase when T > 54°C.

By calculating the specific resistivity ρ and illustrating with temp. in Fig.5, ρ decreases continuously with temp., but for BM-355 ρ increases with temp. until T < 54°C then ρ decreases when T > 54°C. Also we calculated the activation energy which is E_{c1} = 0.28ev and E_{c2} = 0.08ev, it is very high than what "Jeniges"[9] found for "Methobin" where Ec = 0.04ev, also it is less than what we found for polyacrylic acid where it was equal to Ec = 0.66ev[10]. Absolutely the ionic jump distance is varying with temperature, as clear from Fig.6. For acomparsion, it is noticed that at approximate values for the two curves, evidently the solistitial points in BM-355 curve at T = 54°C is the same temp. in Fig. 4 and Fig. 5, the behaviour was changed from increasing to decreasing and vice versa.

All figures and relations are difining some basic facts, the conductivity in CR-39 is ionic and this conductivity is increasing with temperature rise, but the specific resistivity is decreasing, to avalue $\rho = 1.2\text{x}10^{10}$ Ω.m at room temp. The jump distance for CR-39 fluctuates with temp. ranges, where a = 9nm at room temp. and a = 22nm at T = 112°C. Generally (a) increases with temp. and is increasing the distance between the energy bands as in Fig.1. On the other side the increase of (a) lowers the potential barrier by the value of (1/2 aq E) for this reason the current will be clearly increasing. In properation to BM-355 he conductivity gives a different behaviour with temp. ranges, but when T > 54°C the conductivity was ionic 100%. The resistivity $\rho_2 = 0.3\text{x}10^{10}$ Ω.m at room temperature but it is increasing with the rising of temp. at the range (18-54)°C then is decreasing at the range (54-112)°C and the reverse is correctly true for the current. Also the jump distance a = 14nm at room temp and a = 21nm at T = 122°C.

The jump distane for CR-39 change is fluctuating with the temperature range where a = 9nm at room temperature and a = 22nm at T_g = 112°C the glass transition temperature more over for BM-355, a = 14nm at room temperature and it is equal to 28.5nm at Tg = 97°C. Absolutely, the ionic jump disance is varying with termperature, as seen in Fig. 6 for two samples. Comparison, indicates that approximate values occur at evidently the solstitial points. The change in the jump distance curve is due to the fact that the polymer was inside the glass transition region which is changed (30-112)°C for CR-39 and is changed (40-97)°C for BM-355, where these two polymers are from the same kind of polymer. This difference is in fact due to the boundary the conditions of polymarisation producing another polymer chain structures.

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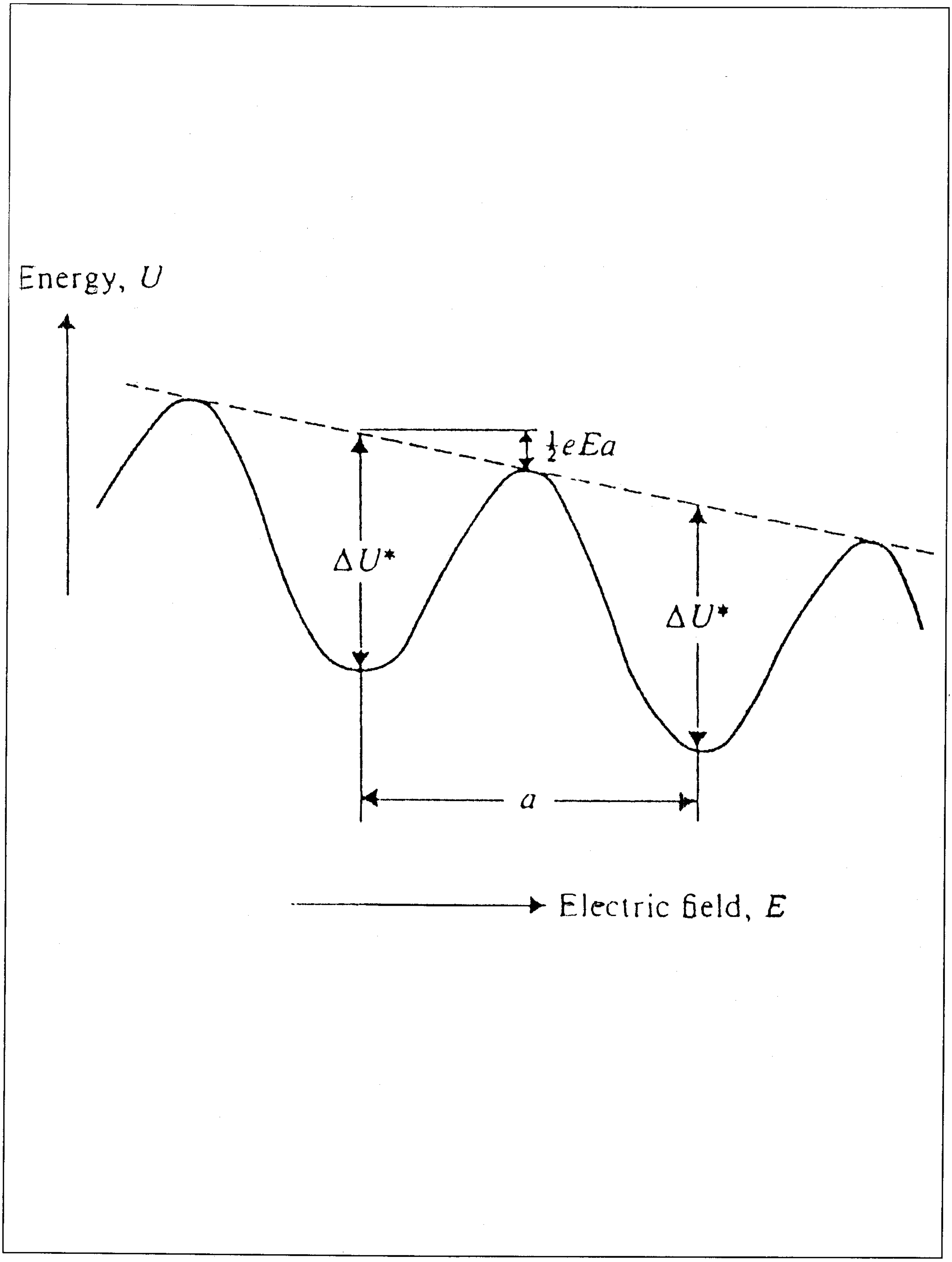

Fig. (1) : The deformation of ionic potential energy wells by an applied electric field.

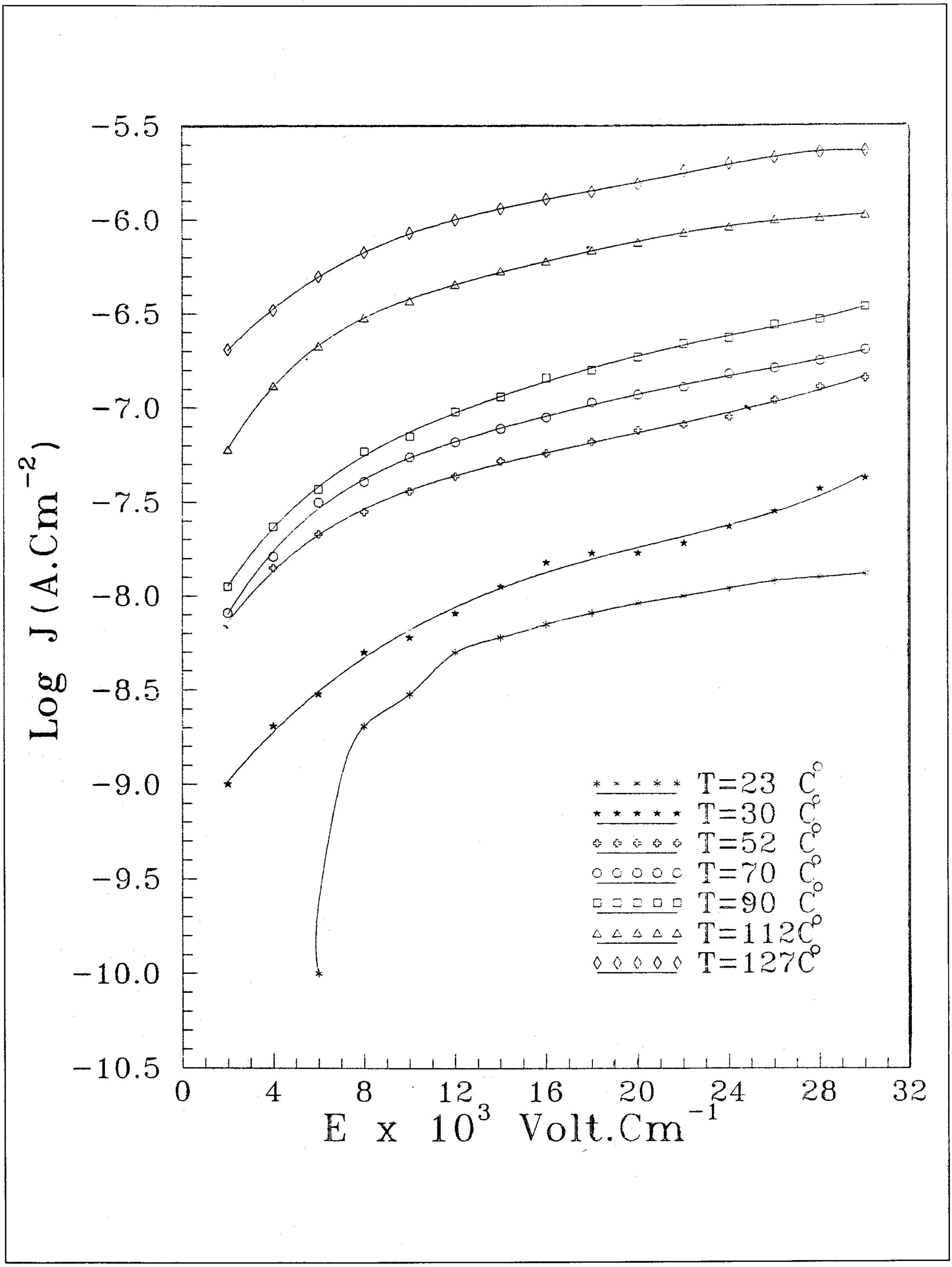

Fig. (2) : The effect of voltage (electric field) strength on conduction in CR-39 for different temperatures.

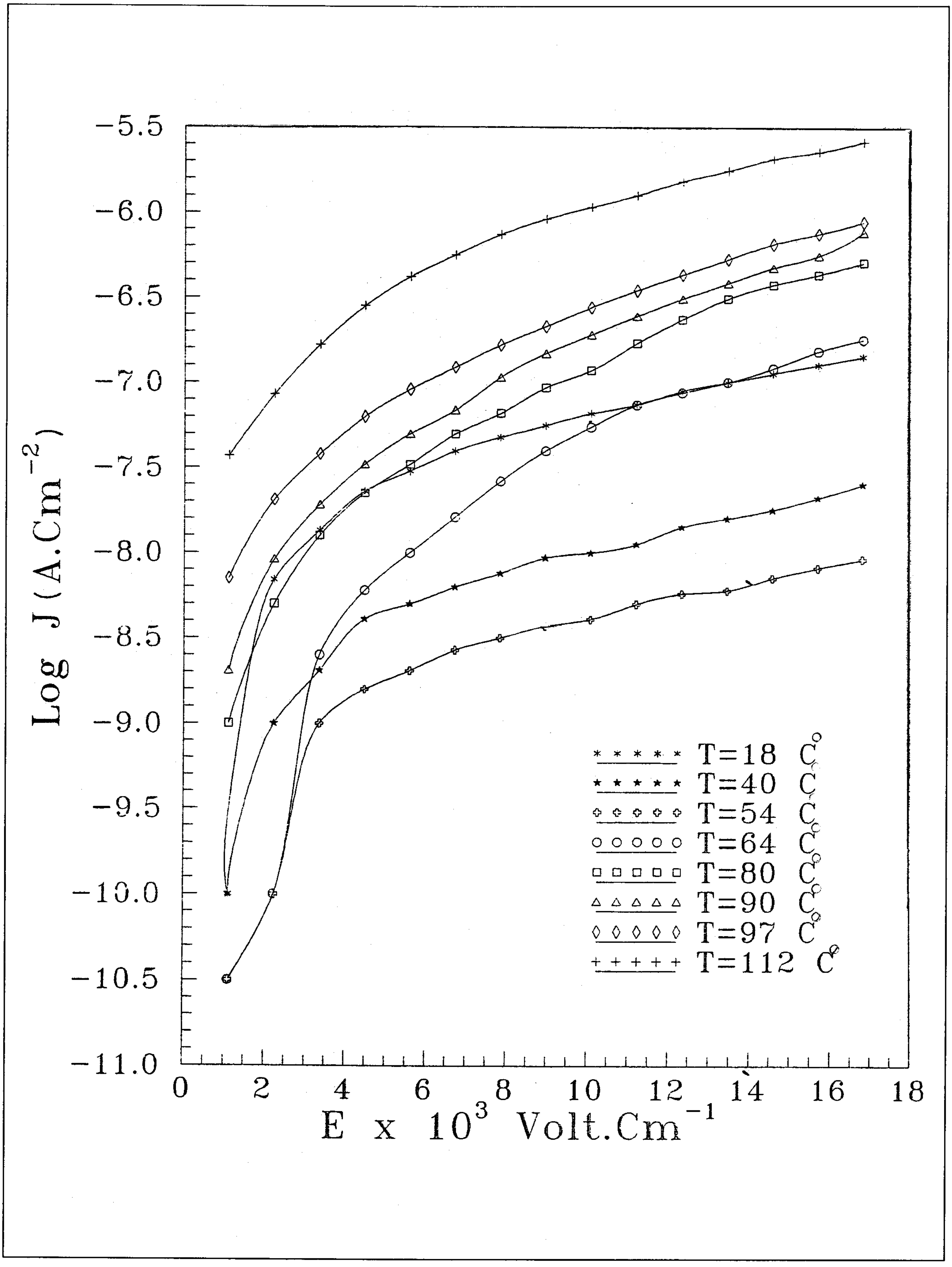

Fig. (3) : The effect of voltage (electric field) strength on conduction in BM-355 for different temperatures.

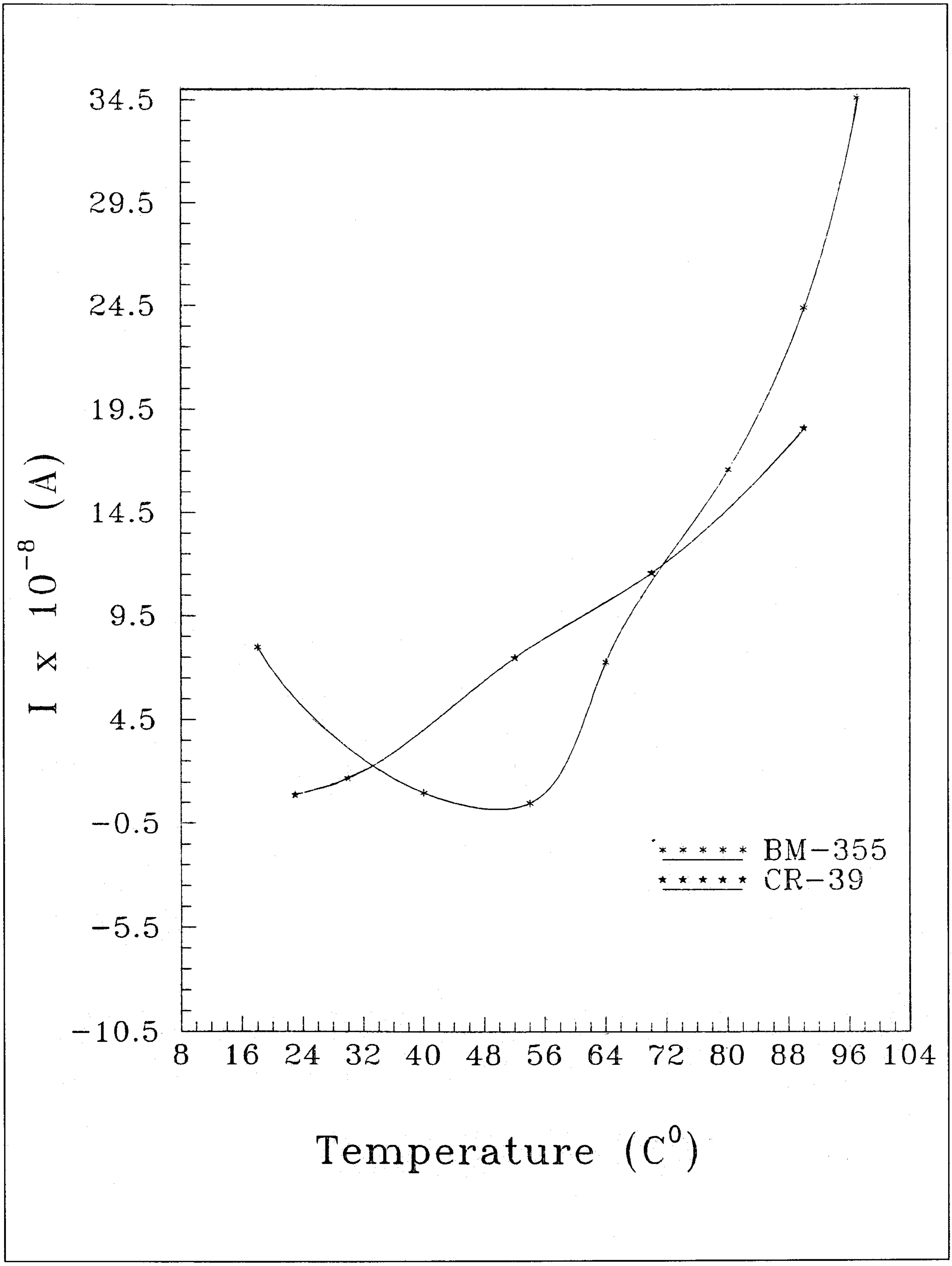

Fig. (4) : Variation of current with temperature at V=500 Volt for CR-39 and BM-355.

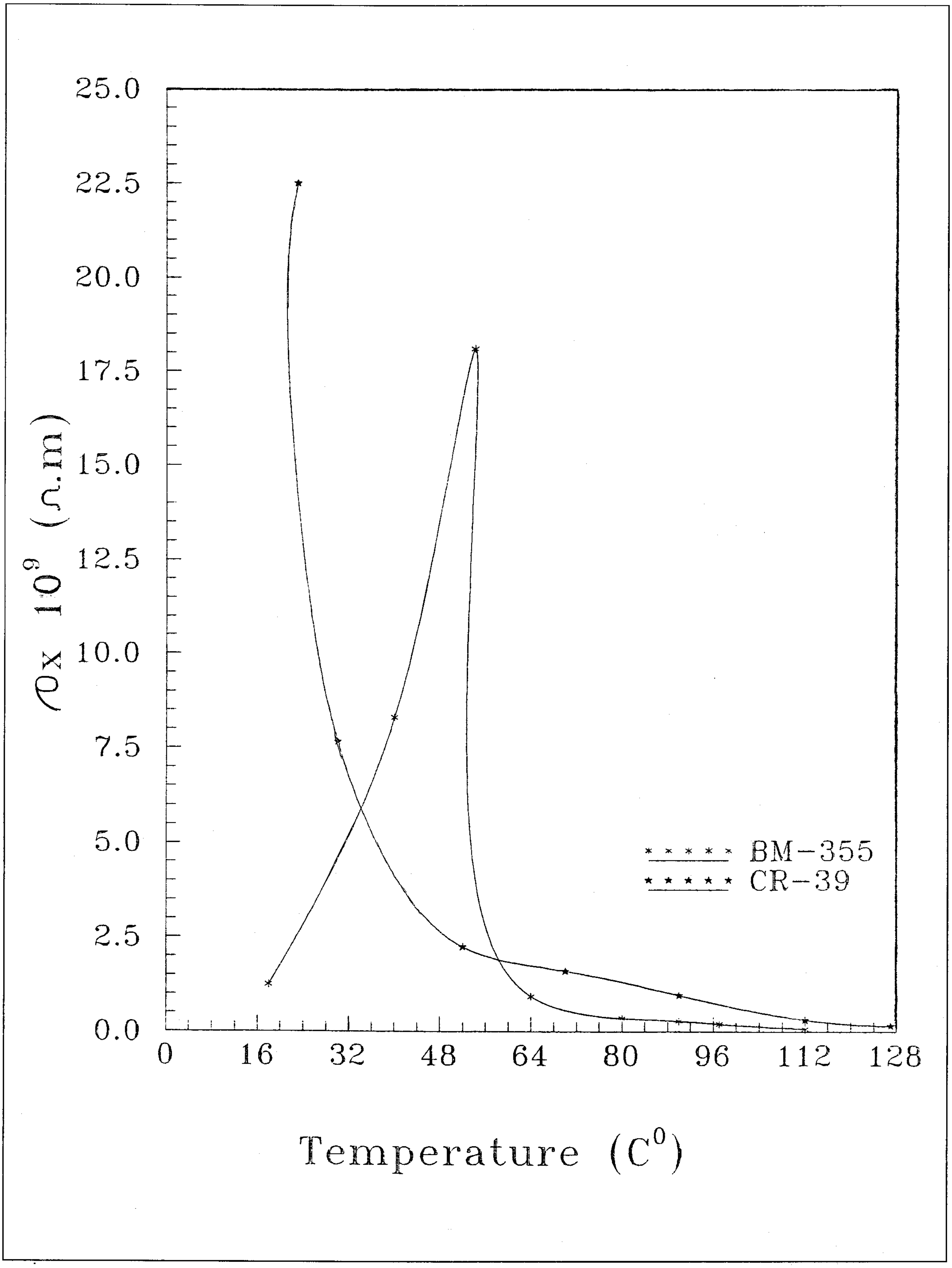

Fig. (5) : Specific resistivity vs temperature.

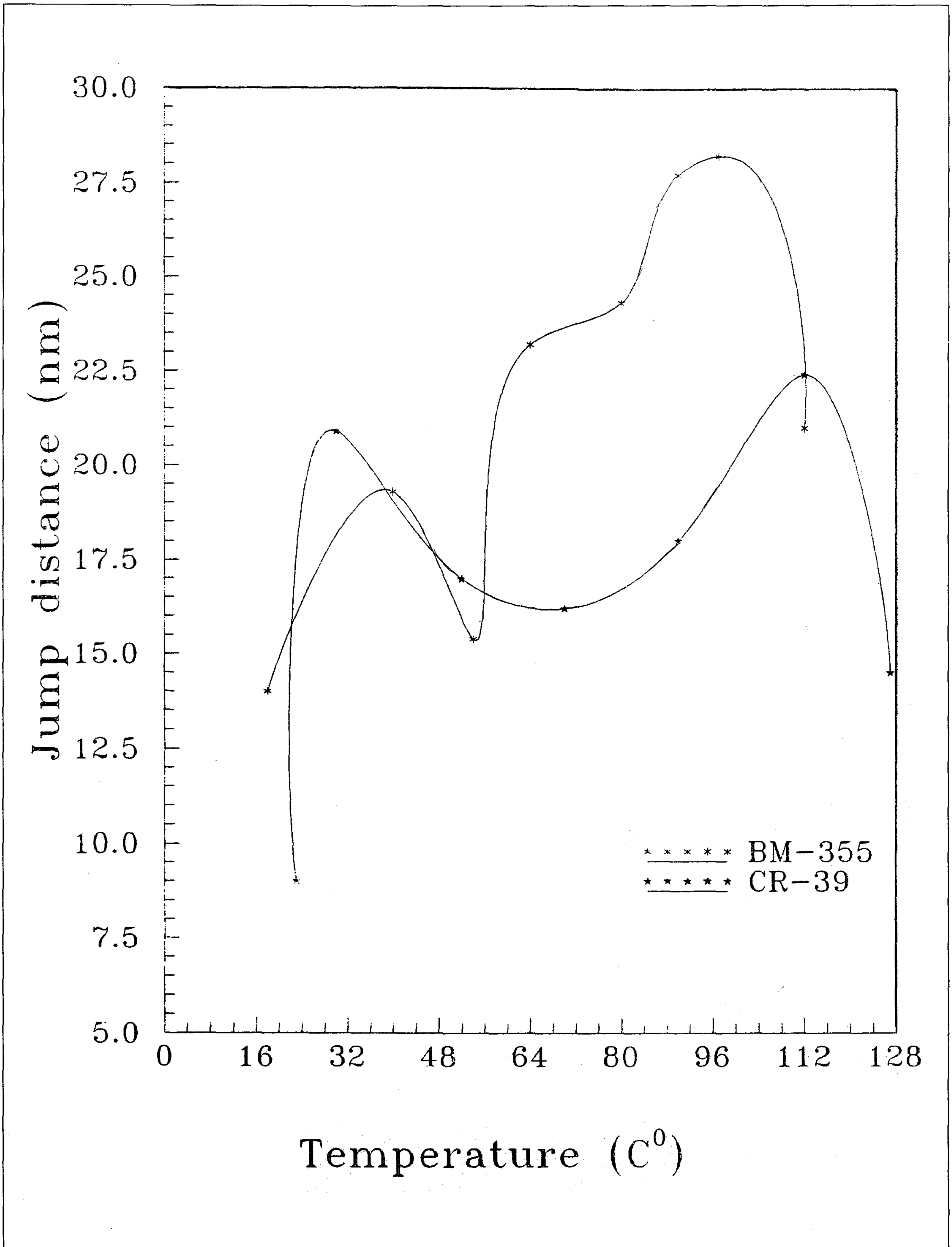

Fig. (6) : Variation of the ionic jump distance with temperature for CR-39 and BM-355.