

in paraelectric phase above the transition pressure in Fig. 3(a); $g = 2.62 \times 10^7$ m/F, kbar or 1.85×10^{-5} /kbar CGSesu. The u is obtained by eq. (6); $u = -5.46 \times 10^8$ m/F or -3.85×10^{-4} CGSesu. The ξ is given by putting the value of the square of P_s which is obtained at arbitrary pressure from Fig. 3(b) and the values of g & u into eq. (9); $\xi = 1.65 \times 10^{10}$ m⁵/F² or 1.29×10^{13} cm⁴/esu² CGSesu. The calculated curve of the pressure dependence of the reciprocal relative permittivity is obtained by putting above values into eq. (11), and is expressed as a solid line in Fig. 3(a). The solid line coincides approximately with the dotted line which stands for the measured value. While the slope g of $1/\epsilon$ to p in ferroelectric phase should be twice of that in paraelectric phase by comparing eq. (11) with eq. (5), the value in measurement is 2.4 times from Fig. 3(a). The calculated curve of P_s versus p obtained by putting above values of g , u & ξ into eq. (9) is shown as a solid line in Fig. 3(b). From this figure, it is found that the measured value which is shown as the dotted line follows to eq. (9) approximately.

(ii) The electric field dependence of the permittivity; Below the transition pressure, NaNO_3 belongs to $R\bar{3}C$ in the space group, and is centrosymmetry and shows paraelectric phase. However, above the transition pressure, the crystal structure of NaNO_3 changes to $R3C$ and non-centrosymmetry and then NaNO_3 shows ferroelectric phase. Therefore, it belongs to the type I in Fig. 1(a). The pressure dependence of the reciprocal relative permittivity of NaNO_3 is shown in the paper reported by the authors^{2,3)} and is expressed as the straight line which passes through the coordinates of ($p=37$ kbar, $1/\epsilon_r=0.093$) & (45 kbar, 0.019) in paraelectric phase. The values of g & u are obtained similarly as in the case of L. H. S. from these data; $g=-8.81 \times 10^8$ m/F²·kbar, $u=4.14 \times 10^{10}$ m/F. Furthermore, the value of ξ is calculated from eq. (9) by using $P_s=2.15 \times 10^{-2}$ C/m² at $p=60$ kbar from the pressure dependence of the spontaneous polarization^{2,3)}; $\xi=2.48 \times 10^{13}$ m⁵/F²·C². Here, since the transition pressure from paraelectric phase to ferroelectric phase in the case of NaNO_3 is very high, liquid medium like in the case of L. H. S. can't be used as a pressure transmitting medium. In this case, solid medium called pyrophyllite is used as a pressure transmitting medium and then ideal hydrostatic pressure can't be strictly applied to the sample NaNO_3 . Therefore, the measured values in the case of NaNO_3 don't coincide with the calculated values

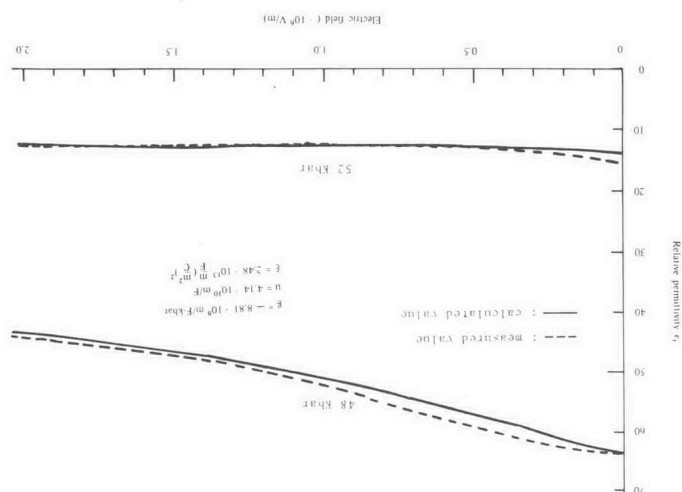


Fig. 4. Effect of external electric field on the relative permittivity of powder NaNO_3 under various pressures.

so well as in the case of L. H. S. The measured dc-electric field dependence of the relative permittivity of the sample NaNO_3 with the thickness $d=0.28$ mm is expressed as a dotted line in Fig. 4 whose curves are at $p=48$ kbar & $p=52$ kbar in ferroelectric phase^{2,3}). The calculated curve of dc-electric field $E=V/d$ dependence of the relative permittivity is obtained by putting above values of g , u & ξ into eq. (15). This curve is shown as a solid line in Fig. 4 and coincides almost with the dotted line which shows the measured value.

Subsequently, the dc-electric field dependence of the relative permittivity (ϵ_r) at $p=48$ kbar, constant g and constant u under various ξ 's, that is, ξ_1 , $10\xi_1$ & $10^2\xi_1$ etc. is shown in Fig. 5(a) from eq. (15). The decreasing rate of ϵ_r with increasing electric field E increases with increasing value of ξ , and the value of ϵ_r at constant E decreases with increasing value of ξ from Fig. 5(a).

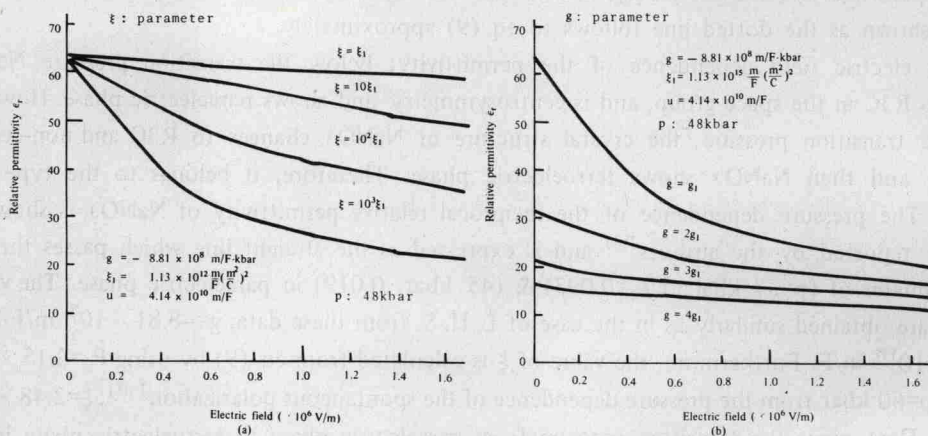


Fig. 5. Effect of external electric field on the relative permittivity under various ξ 's (a) & g 's (b).

The dc-electric field dependence of the relative permittivity (ϵ_r) at $p=48$ kbar, constant u and constant ξ under various g 's, that is, g_1 , $2g_1$ & $3g_1$ etc. is shown in Fig. 5(b) from eq. (15). The decreasing rate of ϵ_r with increasing electric field E increases with decreasing value of g , and the value of ϵ_r at constant E decreases with increasing of the value of g .

3.2 First order transition

(i) The pressure dependence of the permittivity and the spontaneous polarization; The pressure dependence of the reciprocal relative permittivity at $T=23^\circ\text{C}$, 60°C & 85°C and the pressure dependence of the spontaneous polarization at $T=23^\circ\text{C}$ & 45°C of BaTiO_3 given by G.A.Samara are shown as a dotted line in Fig. 6(a) & (b) respectively⁶). BaTiO_3 shows ferroelectric phase below the transition pressure(p_c) and paraelectric phase above p_c and then belongs to type II in Fig. 2 (b). The value of g is obtained from the curve at $T=23^\circ\text{C}$ in paraelectric phase in Fig. 6(a); $g=2.82 \times 10^6$ m/F-kbar. The value of u is calculated from eq. (6) by using the characteristic pressure $p_0=18$ kbar which is the measured value and the above value of g ; $u=-5.08 \times 10^7$ m/F. Moreover, the values of ξ & ζ are calculated by putting the value of P_s at arbitrary pressure (in this case, the value of P_s at the transition pressure) of the curve at $T=23^\circ\text{C}$ in Fig. 6(b) into eq. (19), and simultaneously putting $p_0=18$ kbar & $p=20$ kbar into eq. (20); $\xi=-1.33 \times 10^9$ m⁵/F-C² & $\zeta=5.93 \times 10^{10}$ m⁹/F-C⁴. The calculated curves of $1/\epsilon_r$ versus p & P_s versus p are obtained by putting above values of g , u , ξ & ζ into eq. (22) & eq. (21) and are shown as a solid line of $T=23^\circ\text{C}$ in Fig. 6(a) & (b) respectively.