Analysis of Temperature Dependence of Volume Expansion for Geophysical Minerals

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Abstract: In present communication, we have developed a method for estimating temperature dependence of volume thermal expansion of geophysical minerals at high pressures by modifying the formulation originally due to Anderson (1995); Stacey and Davis (2004). The values used in present work are those reported by Anderson in the form of density data. The method has been applied to the temperature dependence of thermal pressure for Mg_2SiO_4 , $MgAl_2O_4$, MnO, Fe_2SiO_4 , NaCl and KCl were carried out in our study. Computed values are compared with available experimental values. The model is extended to study the compression behavior at different temperature. A good agreement obtained between theory and experiment demonstrates the validity of the present approach.

Keywords: Volume expansion, Thermal pressure, Equation of state, Geophysical minerals, Debye temperature

I. Introduction

An adequate understanding of thermoelastic properties of geophysical minerals requires the knowledge of temperature dependence of volume thermal expansion at high pressures (Anderson 1995; Stacey and Davis 2004). A multi-step method has been developed by Anderson *et al.* (1995) for estimating the volumes of minerals at high pressures and high temperatures. The study of thermo-physical and thermo-dynamic properties of geophysical minerals is of great importance as far as the validity of high temperature and high pressure equation of state of minerals are concerned. Geophysical minerals such as MgSiO₃, MgO, Al₂O₃, CaO and Mg₂SiO₄ are the major constituents of the Earth's lower mantle and core. Thermal pressure is an important physical quantity playing the central role in the evolution of high temperature equation of states for solids. Various models for the determination of the temperature dependence of P_{th} are critically examined in the light of experimental data. We have studied several formulations for the temperature dependence of thermal pressure demonstrating the inadequacies of the models developed by the earlier researchers.

II. Temperature Dependece Of Volume At High Pressure

Equation of state for a solid describes pressure – volume – temperature relationship expressed as follows: $P(V, T) = P(V, T_0) + \Delta P_{th}$ ------(1) where P(V, T) is pressure at volume V and temperature T, $P(V, T_0)$ is the isothermal pressure - volume relationship at room temperature, T_0 = 300 K and ΔP_{th} is the difference in the values of thermal pressures at temperature T and that at room temperature i.e. $\Delta P_{th} = P_{th}(T) - P_{th}(T_0)$ ------(2)

Using Maxwell's thermodynamic relationship, equation (2) has been approximately written as $\Delta P_{th} = \alpha_0 K_0 (T-T_0)$ ------(3)

where α_0 is thermal expansivity and K_0 is the isothermal bulk modulus."₀" refers to the initial value of that parameter. However equation (3) is valid only for those solids which have their Debye temperature very close to room temperature. But some geophysical mineral used in present work have Debye temperature higher than the room temperature. Therefore equation (3) is not valid for these minerals. To investigate the temperature dependence of thermal pressure, we should know the volume dependence of isothermal bulk modulus at constant pressure. The mathematical form of the theory is: $(V/V_0) = 1 - 1/A \{n [1 + A/K_0 \{P - \alpha_0 K_0 (T - T_0)\}]$

where (V/V_0) is the relative change in volume, V_0 the initial volume, $A=(1+\delta_0T)$, δT is the Anderson-Gruneisen parameter, K the isothermal bulk modulus, P the pressure, α_0 is the thermal expansion. At P=0, eq. (4) becomes as follows: $(V/V_0) = 1 - 1/A \ln [1 - A/K_0P_{th}]$ ------(5) $P_{th} = K_0/A [1 - expA (1-V/V_0)]$ ------(6) Nand and Kumar [15] estimated the temperature dependence of thermal pressure for geophysical minerals with the help of volume expansion data, reported by Anderson [3]. They calculated P_{th} with the help of eq. (6) and found that the it is superior to other expressions. By comparing eqs. (3) and (6), it reveals that $(V/V_0) = 1 - 1/(1+\delta_0 T) \ln [1-\alpha_0 (T-T_0)/(1+\delta_0 T)]$

Using the values of input parameters from Table 1, we estimated the temperature dependence of volume expansion ratio (V/V_0) with the help of eq. (7) for various minerals. It is found that in most of the cases the predicted values from eq. (7) differ significantly from experimental data. However, for NaCl and KCl, an agreement between theory and experiment can be seen. Thus, eqs. (3) and (6) can used only for those minerals which have Debye's temperature $\theta_D \approx T_0 = 300$ K. For other minerals, these expressions cannot be used safely to determine the temperature dependence of thermal pressure. Therefore, the expression given in equation (7) for temperature dependence of thermal pressure cannot be treated as a reliable. At $T = T_0$ (Putting $P = -P_{th}$), the eq. (4) is reduced as follows

$$(V/V_0) = 1 - 1/A \ln [1 - A/K_0P_{th}]$$

-----(8)

Now, according to high pressure thermodynamics, the condition $P \rightarrow \infty$ is equivalent to $V \rightarrow 0$. This infinite pressure behavior should be followed by all equation of state (EOS). According to Stacey and Davis [10], the infinite pressure properties are simply equation of state parameters, not observable in any direct sense. However, infinite pressure parameters just as legitimate as physical entities as are zero pressure properties for high pressure materials that do not survive decompression to P = 0. It can be seen from eq. (8) that at $P \rightarrow \infty$ the volume goes to acquire negative infinite value, which has no significance. Therefore, the equation of state (EOS) used Nand and Kumar [15] does not follow the constrains made by high pressure thermodynamics. The choice between two K- prime EOS [1] and [7] is not clear-cut to the extent that there may be little reason for making a choice, other than the convenience of use. Generally, if zero pressure properties are known, then the Keane EOS [1] is easy to apply. Therefore in the present study we are applying Keane EOS to study the temperature dependence of thermal pressure. The Keane EOS is expressed as follows: $P/K_0 = K'_0 / {K'_{\infty}}^2 \{(V/V_0) - {K'_{\infty}} - 1\} + (K'_0 / {K'_{\infty}} - 1) \ln (V/V_0)$

Here K'_{∞} is the infinite pressure value of K' which is an adjustable parameter. This parameter is a material dependent and remains constant under any conditions such as isothermal, isobaric and adiabatic. At zero pressure, the resultant expression for P_{th} (T) from eq. (9) is obtained as follows (Putting P = - P_{th}) $P_{th} = K_0 [K'_0/K'_{\infty}^2 \{1 - (V/V_0) - K'_{\infty}\} - (K'_0/K'_{\infty} - 1) \ln (V/V_0)]$

We computed the temperature dependence of thermal pressure from eq.(10) for many geophysical minerals. The volume expansion data are calculated from density data, compiled by Anderson [3]. Computed values are also compared with available experimental data. Predicted values from eq. (3) and (6) are also shown in figures for the sake of comparison. It is clear from figures that the eq. (10) reproduces the experimental data very well and superior to eq. (3) and (6). It should be noted that eq. (6) is seriously wrong for those materials which have $\theta_D > T_0$. In fact, for those minerals the eq. (6) should be written as $P_{th} = \alpha * K * (T - T_0)]$

where α^* and K* are the values of α and K at T or near to the Debye temperature. To show the validity of eq. (11), we have also estimated P_{th} (T) from eq. (3) and compared with experimental data in figures. A close agreement between two sets reveals the validity of eq. (11).

Table 1 - Values of	input parameters used in	the present study	based on experimenta	al data [3]
Minerals	$\alpha_0(10^{-5}K^{-1})$	δ^0_{T}	K ₀ (G Pa)	θ _D
Mg_2SiO_4	2.72	3.98	127.3	763
$MgAl_2O_4$	2.11	7.73	207.9	862
Fe_2SiO_4	2.61	7.34	136.7	511
MnO	3.46	5.96	146.7	534
KCl	11.0	5.84	17	230
NaCl	11.8	5 56	24	304

III. Figures And Tables

Table 2 - Comparison between the values of P_{th} (G Pa) for minerals calculated from equations (3), (10) and experimental results given by Anderson [3]

KCl					
Т	V/V ₀ Cal. eq. (7)	$(\mathbf{P}_0/\mathbf{P})$ Exp.	$P_{th}(10^9)eq.(6)$	P _{th} (10 ⁹) Exp eq.(3)	$P_{th}eq.(10){3.1}$
300	1.0000	1.0000	0.0000	0.0000	0.0000
350	1.0056	1.0056	0.0931	0.0935	0.0935
400	1.0114	1.0117	0.1918	0.1870	0.1870
450	1.0175	1.0175	0.2797	0.2805	0.2804
500	1.0238	1.0243	0.3804	0.3740	0.3737
550	1.0305	1.0307	0.4705	0.4675	0.4668
600	1.0374	1.0377	0.5649	0.5610	0.5598

650	1 0447	1.0448	0.6561	0.6545	0.6524
700	1.0523	1.0526	0.7507	0.7480	0 7447
750	1.0604	1.0520	0.8418	0.8415	0.8365
800	1.0600	1.0605	0.0204	0.0350	0.0303
800	1.0090	1.0085	1.0104	1.0295	1.0192
830	1.0781	1.0772	1.0194 E- S:O4	1.0285	1.0182
			Fe ₂ SiO4	D (10) D (0)	D (10) (2.0)
1	V/V_0 Cal. eq. (7)	$(\mathbf{P}_0/\mathbf{P})$ Exp.	$P_{th}(10^{\circ})eq.(6)$	$P_{th}(10^\circ)$ Exp eq.(3)	$P_{th}eq.(10){3.2}$
300	1.0000	1.0000	0.0000	0.0000	0.0000
400	1.0026	1.0027	0.3696	0.3568	0.3568
500	1.0053	1.0057	0.7628	0.7136	0.7135
600	1.0081	1.0087	1.1486	1.0704	1.0701
700	1.0109	1.0120	1.5560	1.4271	1.4265
	MgAl ₂ O ₄				
Т	V/V ₀ Cal. eq. (7)	$(\mathbf{P}_0/\mathbf{P})$ Exp.	$P_{th}(10^9)$ eq.(6)	$P_{th}(10^9)$ Exp eq.(3)	$P_{th}eq.(10){2.8}$
300	1.0000	1.0000	0.0000	0.0000	0.0000
350	1.0011	1.0011	0.2317	0.2193	0.2193
400	1.0021	1.0022	0.4616	0.4387	0.4387
450	1.0032	1.0034	0.6898	0.6580	0.6580
500	1.0043	1.0045	0.9163	0.8773	0.8773
550	1.0054	1.0059	1.1970	1.0967	1.0965
600	1.0065	1.0070	1.4196	1.3160	1.3157
650	1.0076	1.0082	1.6405	1.5353	1.5349
700	1.0088	1.0096	1.9143	1.7547	1.7540
750	1.0099	1.0110	2.1855	1.9740	1.9731
800	1.0111	1.0125	2.4541	2.1933	2.1920
850	1.0122	1.0136	2.6670	2.4127	2.4109
900	1.0134	1.0150	2.9310	2.6320	2.6297
950	1.0146	1.0165	3.1923	2.8513	2.8483
1000	1.0158	1.0182	3.5026	3.0707	3.0669
			NaCl		
Т	V/V ₀ Cal. eq. (7)	(P ₀ /P) Exp.	$P_{th}(10^9)$ eq.(6)	$P_{th}(10^9)$ Exp eq.(3)	$P_{th}eq.(10){3.3}$
300	1.0000	1.0000	0.0000	0.0000	0.0000
				0.000	
350	1.0060	1.0061	0.1425	0.1416	0.1416
350 400	1.0060 1.0123	1.0061 1.0127	0.1425 0.2917	0.1416 0.2832	0.1416 0.2832
350 400 450	1.0060 1.0123 1.0188	1.0061 1.0127 1.0194	0.1425 0.2917 0.4363	0.1416 0.2832 0.4248	0.1416 0.2832 0.4246
350 400 450 500	1.0060 1.0123 1.0188 1.0256	1.0061 1.0127 1.0194 1.0261	0.1425 0.2917 0.4363 0.5765	0.1416 0.2832 0.4248 0.5664	0.1416 0.2832 0.4246 0.5660
350 400 450 500 550	1.0060 1.0123 1.0188 1.0256 1.0328	1.0061 1.0127 1.0194 1.0261 1.0335	0.1425 0.2917 0.4363 0.5765 0.7220	0.1416 0.2832 0.4248 0.5664 0.7080	0.1416 0.2832 0.4246 0.5660 0.7072
350 400 450 500 550 600	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481
350 400 450 500 550 600 650	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887
350 400 450 500 550 600 650 700	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289
350 400 450 550 600 650 700 750	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685
350 400 450 500 550 600 650 700 750	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653	$ \begin{array}{r} 1.0061\\ 1.0127\\ 1.0194\\ 1.0261\\ 1.0335\\ 1.0410\\ 1.0486\\ 1.0568\\ 1.0656 \end{array} $	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685
350 400 450 550 600 650 700 750 T	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7)	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp.	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6)	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3)	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 Ptheq.(10){3.1}
350 400 450 550 600 650 700 750 T 300	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 Ptheq.(10){3.1} 0.0000
350 400 450 550 600 650 700 750 T 300 400	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 P_{th}(10⁹) Exp eq.(3) 0.0000 0.3463	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463
350 400 450 550 600 650 700 750 T 300 400 500	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0025	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 P_{th}(10⁹) Exp eq.(3) 0.0000 0.3463 0.6925	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925
350 400 450 500 550 600 650 700 750 T 300 400 500 600	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 P_{th}(10⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 P_{th}(10⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 P_{th}(10⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0199	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 P _{th} (10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0059 1.0094 1.0129 1.0164 1.0199 1.0238	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0199 1.0238 1.0278	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 Ptheq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 Ptheq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300 1400	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324 1.0356	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 Ptheq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324 1.0356 1.0389	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451 1.0499	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407 5.6199	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551 4.5013	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 Ptheq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562 4.5028
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324 1.0356 1.0389 1.0422	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451 1.0499 1.0547	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407 5.6199 6.0920	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551 4.5013 4.8476	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 Pheq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562 4.5028 4.8494
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324 1.0356 1.0389 1.0422	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451 1.0499 1.0547	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407 5.6199 6.0920 MnO	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551 4.5013 4.8476	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P_{th}eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562 4.5028 4.8494
350 400 450 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1400 1500 T	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324 1.0356 1.0389 1.0422 V/V ₀ Cal. eq. (7)	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451 1.0499 1.0547 (P ₀ /P) Exp.	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407 5.6199 6.0920 MnO P _{th} (10 ⁹)eq.(6)	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551 4.5013 4.8476 Pth(10 ⁹) Exp eq.(3)	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P_{th}eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562 4.5028 4.8494 P_{th}eq.(10){3.1}
350 400 450 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1500 1500 T 300	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324 1.0356 1.0389 1.0422 V/V ₀ Cal. eq. (7) 1.0000	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451 1.0499 1.0547 (P ₀ /P) Exp. 1.0000	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407 5.6199 6.0920 MnO P _{th} (10 ⁹)eq.(6) 0.0000	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551 4.5013 4.8476 Pth(10 ⁹) Exp eq.(3) 0.0000	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P_{th}eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562 4.5028 4.8494 P_{th}eq.(10){3.1} 0.0000
350 400 450 550 600 650 700 750 T 300 400 500 600 700 600 700 800 900 1000 1100 1200 1300 1400 1500 1500 1500 1500 T 300 350	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324 1.0356 1.0389 1.0422 V/V ₀ Cal. eq. (7) 1.0000 1.0007	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451 1.0499 1.0547 (P ₀ /P) Exp. 1.0000 1.0017	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407 5.6199 6.0920 MnO P _{th} (10 ⁹)eq.(6) 0.0000 0.2445	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551 4.5013 4.8476 Pth(10 ⁹) Exp eq.(3) 0.0000 0.2538	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P_{th}eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562 4.5028 4.8494 P_{th}eq.(10){3.1} 0.0000 0.2538
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 T 300 350 400	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0324 1.0356 1.0389 1.0422 V/V ₀ Cal. eq. (7) 1.0000 1.0007 1.0000	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451 1.0499 1.0547 (P ₀ /P) Exp. 1.0000 1.0017 1.0035	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407 5.6199 6.0920 MnO P _{th} (10 ⁹)eq.(6) 0.0000 0.2445 0.5138	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551 4.5013 4.8476 Pth(10 ⁹) Exp eq.(3) 0.0000 0.2538 0.5076	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P_{th}eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562 4.5028 4.8494 P_{th}eq.(10){3.1} 0.0000 0.2538 0.5076
350 400 450 500 550 600 650 700 750 T 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 T 300 350 400 450	1.0060 1.0123 1.0188 1.0256 1.0328 1.0403 1.0482 1.0565 1.0653 V/V ₀ Cal. eq. (7) 1.0000 1.0027 1.0055 1.0083 1.0112 1.0141 1.0170 1.0200 1.0230 1.0261 1.0292 1.0356 1.0389 1.0422 V/V ₀ Cal. eq. (7) 1.0000 1.0035 1.0017 1.0035 1.0053	1.0061 1.0127 1.0194 1.0261 1.0335 1.0410 1.0486 1.0568 1.0656 (P ₀ /P) Exp. 1.0000 1.0028 1.0059 1.0094 1.0129 1.0164 1.0199 1.0238 1.0278 1.0320 1.0363 1.0407 1.0451 1.0499 1.0547 (P ₀ /P) Exp. 1.0000 1.0017 1.0035 1.0054	0.1425 0.2917 0.4363 0.5765 0.7220 0.8625 0.9982 1.1377 1.2802 Mg ₂ SiO ₄ P _{th} (10 ⁹)eq.(6) 0.0000 0.3541 0.7441 1.1689 1.5892 2.0052 2.4167 2.8607 3.2995 3.7689 4.2323 4.6895 5.1407 5.6199 6.0920 MnO P _{th} (10 ⁹)eq.(6) 0.0000 0.2445 0.5138 0.7805	0.1416 0.2832 0.4248 0.5664 0.7080 0.8496 0.9912 1.1328 1.2744 Pth(10 ⁹) Exp eq.(3) 0.0000 0.3463 0.6925 1.0388 1.3850 1.7313 2.0775 2.4238 2.7700 3.1163 3.4626 3.8088 4.1551 4.5013 4.8476 Pth(10 ⁹) Exp eq.(3) 0.0000 0.2538 0.5076 0.7614	0.1416 0.2832 0.4246 0.5660 0.7072 0.8481 0.9887 1.1289 1.2685 P _{th} eq.(10){3.1} 0.0000 0.3463 0.6925 1.0388 1.3851 1.7314 2.0777 2.4240 2.7704 3.1168 3.4632 3.8097 4.1562 4.5028 4.8494 P _{th} eq.(10){3.1} 0.0000 0.2538 0.5076 0.7613

Figure: Temperature dependence of minerals 1.2 KCI FeSiO₄ 1.6 1 1.4 0.8 1.2 1 Eq(6) 6.0 (Gba) 6.0 (Gba) 6.0 (Gba) -Eq(6) (GPa) 8.0 Exp. Eq(3) Exp. Eq(3) Э ЧН 0.6 ▲ Eq.(10){2.8} ▲ Eq.(10){3.2} 0.4 0.20.2 0 0 T (K) 450 350 650 750 850 250 450 T (K) 550 250 350 550 650 750 4 1.4 MgAl₂O₄ NaCl 3.5 1.2 3 1 2.5 0.8 × Eq(6) × Eq(6) 2 Dth (GPa) 1.5 Pth (GPa) • Exp. Eq(3) Exp. Eq(3) 0.6 ▲ Eq.(10){2.8} ▲ Eq.(10){3.3} 0.41 0.2 0.5 0 0 700 800 900 1000 550 750 300 400 600 250 650 850 ³⁵⁰ T (K) ⁴⁵⁰ 500 T(K) 1.2 Mg₂SiO₄ MnO 6 1 5 0.8 4 Eq(6) Peth (GP3) Pth (GPa) Exp. Eq(3) Exp. Eq(3) 3 ▲ Eq.(10){3.1} -Eq.(10){3.1} 2 0.2 0 🗖 0 300 400 450 500 300 500 900 1100 1300 1500 1700 350 T (K) T (K)

IV. Conclusion

From figures it is clear that our results calculated from equations (6) and (10) for geophysical minerals under study give close agreement with the experimental values of thermal pressure at different temperature. It should be emphasized that the modification considered in the present study in the form of equations (7) and (10) are of fundamental importance in the theory of thermal expansivity of solids. The present study provides the way to understand thermo-elastic property of solid by using a formulation which is valid up to extreme compression limit.

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