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Thermodynamics of High Temperature Brines

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ABSTRACT

Osmotic and activity coefficient data and enthalpy and heat capacity data for NaCl solutions at saturation pressure of water from 0-300°C and to saturation composition have been simultaneously fit to a 30 parameter equation. The data are reproduced by the equation, in most cases, to within experimental error. Calculated values of the osmotic coefficient, the activity of water, the activity of NaCl, and the heat capacity, enthalpy and entropy of the solution are given in Tables in 25°C intervals from 0-300°C and concentrations from 0.25 - 25 wt% NaCl.

KEY WORDS

Brines, Aqueous Solutions, Thermodynamic Properties, High Temperatures, Enthalpy, Entropy, Activity, Sodium Chloride.

Introduction

There is increasing interest in aqueous electrolytes at high temperatures and pressures for a wide range of industrial and geochemical systems. Sodium chloride solutions have been far more widely investigated than those of any other salt. Also sodium chloride is usually the dominant salt in geochemical brines as in sea water, and it is often most important in industrial brines. Hence it is desirable to have equations for the various thermodynamic properties of aqueous sodium chloride which cover a wide range of conditions as accurately as possible. The principal contribution in the present paper is such an equation for aqueous sodium chloride under saturation pressure and from 0 to 300°C. From appropriate derivatives of the basic equation for the Gibbs energy, equations based on the same parameters yield the activity and osmotic coefficients, the enthalpy, the entropy, and the heat capacity.

A system of equations appropriate for representation of these properties and a preliminary fit to the then available data for aqueous sodium chloride were presented by Pitzer[1] and by Silvester and Pitzer,[2] respectively. For that work only osmotic coefficient data were employed above 200°C. Subsequently, enthalpy and heat capacity measurements have become available extending to 300°C from the work of Borodenko and Galinker,[3] of Cobble,[4] and of Puchkov, et al.[5] It is now possible to evaluate various properties much more accurately in the 200-300°C range. Also we have been able to improve the representation of heat capacities in the 0-25°C range and the composition dependence of various properties above 200°C.

In preparation for this revision of the equation for saturation pressure and more particularly for work in progress for above-saturation pressures, a new equation[6] was developed for the dielectric constant of water and the related Debye-Hückel parameters have been calculated for the range 0 - 350°C and 0 - 1000 bar.

A few comments are added concerning similar work in progress for aqueous potassium chloride and for mixed solutions of sodium and potassium chlorides.

Equations

The general form of the equations is the same as was used previously[1,2] but there were several changes which will be discussed below. The equations for the various functions are as follows:

$$\phi-1 = -|z_M z_X| A_\phi \left(\frac{I^{1/2}}{1+bI^{1/2}}\right) + m\,\frac{2\nu_M\nu_X}{\nu}\left(\beta_{MX}^{(0)} + \beta_{MX}^{(1)}\,e^{-\alpha_1 I^{1/2}} + \beta_{MX}^{(2)}\,e^{-\alpha_2 I^{1/2}}\right) + m^2\,\frac{2(\nu_M\nu_X)^{3/2}}{\nu}\,C_{MX}^{\phi} \quad (1)$$

$$\ln\gamma_\pm = -|z_M z_X| A_\phi\left[\frac{I^{1/2}}{(1+bI^{1/2})} + \frac{2}{b}\ln(1+bI^{1/2})\right] + m\,\frac{2\nu_M\nu_X}{\nu}\left[2\beta_{MX}^{(0)} + \frac{2\beta_{MX}^{(1)}}{\alpha_1^2 I}\left(1-\left(1+\alpha_1 I^{1/2} - \frac{\alpha_1^2 I}{2}\right)e^{-\alpha_1 I^{1/2}}\right) + \frac{2\beta_{MX}^{(2)}}{\alpha_2^2 I}\left(1-\left(1+\alpha_2 I^{1/2} - \frac{\alpha_2^2 I}{2}\right)e^{-\alpha_2 I^{1/2}}\right)\right] + \frac{3m^2}{2}\left(\frac{2(\nu_M\nu_X)^{3/2}}{\nu}\right)C_{MX}^{\phi} \quad (2)$$

$$C_p = \frac{1}{(1000 + mM_2)} \Bigg(m\,\bar{C}^{\circ}_{p,2} + m|z_M z_X| \frac{A_J}{b} \ln (1+bI^{1/2})$$

$$- 2\, m^2 \nu_M \nu_X\, RT^2\, [\beta^{(0)''}_{MX} + \frac{2\beta^{(1)''}_{MX}}{\alpha_1{}^2 I} (1-(1+\alpha_1 I^{1/2})\, e^{-\alpha_1 I^{1/2}})$$

$$+ \frac{2\beta^{(2)''}_{MX}}{\alpha_2{}^2 I} (1-(1+\alpha_2 I^{1/2})\, e^{-\alpha_2 I^{1/2}})] - (\nu_M \nu_X)^{3/2}\, RT^2\, m^3\, C^{\phi''}_{MX}$$

$$+ 1000\; C^{\circ}_{p1} \Bigg) \tag{3}$$

$$\Delta\bar{H}_{sol} = \Delta\bar{H}^{\circ}_{sol} + |z_M z_X| \frac{A_H}{b} \ln (1+bI^{1/2})$$

$$- 2\, m\nu_M \nu_X\, RT^2 [\beta^{(0)'}_{MX} + \frac{2\beta^{(1)'}_{MX}}{\alpha_1{}^2 I} (1-(1+\alpha_1 I^{1/2})\, e^{-\alpha_1 I^{1/2}})$$

$$+ \frac{2\beta^{(2)'}_{MX}}{\alpha_2{}^2 I} (1-(1+\alpha_2 I^{1/2})\, e^{-\alpha_2 I^{1/2}})] - (\nu_M \nu_X)^{3/2}\, RT^2\, m^2\, C^{\phi'}_{MX} \tag{4}$$

Where $b = 1.2$, $\alpha_1 = 2.0$ and $\alpha_2 = 1.0$. Also for a 1-1 electrolyte such as NaCl, $\nu_M = \nu_X = 1$ and $\nu = 2$; also A_ϕ, A_H and A_J are Debye-Hückel parameters as defined by Bradley and Pitzer.[6] M_2 is the molecular weight of the solute.

The heat of dilution is given by

$$\Delta\bar{H}_D = \Delta\bar{H}_{sol}\,(m_F) - \Delta\bar{H}_{sol}\,(m_I) \tag{5}$$

also

$$\bar{C}^{\circ}_{p2} = (\frac{\partial\Delta\bar{H}_{sol}}{\partial T})_p + \bar{C}^{\circ}_{p2}(S) \tag{6}$$

where $C_{p,2}(S)$ is the heat capacity of the solid.

$$\beta_{MX}^{(0)'} = \left(\frac{\partial \beta_{MX}^{(0)}}{\partial T}\right)_p \tag{7}$$

$$\beta_{MX}^{(0)''} = \left(\frac{\partial^2 \beta^{(0)}}{\partial T^2}\right)_p + \frac{2}{T}\left(\frac{\partial \beta^{(0)}}{\partial T}\right)_p \tag{8}$$

The other primed quantities are defined in a manner analogous to $\beta^{(0)'}$ and $\beta^{(0)''}$.

In other investigations[1,7] it was found that data for a very wide range of solutes were consistent with fixed values of b and α_1. The value b = 1.2 was adopted for all solutes and the value $\alpha_1 = 2.0$ for all electrolytes with one univalent ion at room temperature. For 2-2 and higher valence types it was necessary to include the term in α_2 and $\beta^{(2)}$. Only the linear parameters $\beta^{(0)}$, $\beta^{(1)}$, $\beta^{(2)}$ (if included) and C^ϕ are adjusted for each substance. There is no fundamental reason why the parameters b, α_1 and α_2 should not be temperature dependent, but it is a great convenience if they can be held constant, and this was done by Silvester and Pitzer (who did not use the term in α_2 and $\beta^{(2)}$). We found no difficulty in holding b constant but analysis of isothermal data sets indicated that the optimum value for a single α shifted from 2.0 at room temperature to about 1.0 near 300°C. Rather than provide a temperature dependence of α_1 however, it proved to be more convenient to introduce the term in α_2 and $\beta^{(2)}$, with $\alpha_2 = 1.0$, and to place the temperature dependence in the linear parameters $\beta^{(1)}$ and $\beta^{(2)}$.

It should be noted that this paper follows the definitions of Bradley and Pitzer,[6] for the Debye-Hückel parameters A_H and A_J which are smaller by the factor 2/3 than those used earlier.[2]

Some rather complex functions were required to describe the temperature dependence of some of the parameters. In particular functions of temperature differences near the freezing point, such as (T-255) (with T in Kelvins), or near the critical point, such as (643-T), were essential in representing the rapid changes near the ends of the temperature range. No special significance should be attributed to the values 255, 200 or 643 K. These values were chosen by a trial and error method. The fit was found to be relatively insensitive to the actual values chosen. The particular equations are as follows:

$$\beta^{(0)} = U(1) + U(2)\,T + U(3)\,T^2 + U(4)\,T^3 + U(5)\,\ell n\,T + U(6)\,(T\,\ell nT - T) + U(7)\,\ell n\,(T-255) \quad (9)$$

$$\beta^{(1)} = U(8) + U(9)\,T + U(10)\,T^2 + U(11)\,T^3 + U(12)\,\ell n\,T \quad (10)$$

$$\beta^{(2)} = U(13) + U(14)\,T^2 \quad (11)$$

$$C^{\phi} = U(15) + U(16)\,T + U(17)\,T^2 + U(18)\,T^3 + U(19)\,\ell n\,T + U(20)\,(T\,\ell nT - T) + U(21)\,\ell n\,(T-255) \quad (12)$$

$$\Delta\bar{H}^{\circ}_{sol} = U(22) + U(23)\,T + U(24)\,T^2 + U(25)\,T^3 + U(26)/(643-T) + U(27)/(643-T)^2 + U(28)\,\ell n\,(643-T) + U(29)\,\ell n\,(T-255) + U(30)\,\ell n\,(T-200) \quad (13)$$

The behavior of $\beta^{(0)}$ and C^{ϕ} is shown in figures 1 and 2. Table 2 shows the values of U(1) through U(30).

Application to Aqueous NaCl

The experimental data employed in this application are listed in Table I. This array differs from that used earlier primarily in the addition of the three sets[3,4,5] mentioned earlier together with the recently published heat capacity measurements from 5 to 85°C by Tanner and Lamb.[25] However, as indicated above, our more complex equations allowed a much better fit of the heat capacity from 0 to 25°C as well as in the high-temperature region. In general we believe the fit is within or very near to experimental uncertainty, however, there are a few regions where different sets of experimental data disagree by more than the presumed uncertainty.

In fitting this large array of data (974 data points), obtaining a proper set of weighting factors was critical. In general the weight given any particular data point was proportional to $1/\sigma^2$ where σ is the estimated uncertainty of the data. As a result,weighting was primarily a function of the type of data and the temperature at which it was measured and not a function of molality.

Discussion

Osmotic and Activity Coefficient Data

At temperatures above 100°C the data comprise primarily the apparently excellent results of Lindsay and Liu[17,18] but also include those of Gardner et al.[21] At concentrations greater than 1 M the fit to the data was better than $\pm$ 0.005 being approximately $\pm$ 0.001 both above 200°C and below 100°C. The low molality data however was not fit as well. This was primarily due to inconsistencies in the data. It appears that the experimental error at 1 M and 0.1 M, and temperatures above 100°C, are approximately ± 0.008 and 0.012 respectively. This type of increase in uncertainty would be expected from vapor pressure measurements as ΔP decreases. The osmotic coefficient behavior is shown in figure 3.

Mashovets,et al;[19] vapor pressure data at 300 and 350°C were incorporated into the final fit,but weighted low,in order to determine the feasibility of extending our equation to higher temperatures. Their results were found to agree with those of Lindsay and Liu at 300°C to within 10% below 3 m and 3% above 3 m. At 350°C the discrepancy between our extrapolated results and Mashovets,et al,data increased to approximately 15% at 1 molal and 8% at higher concentrations. This seems to indicate that at high molality fairly reasonable extrapolations for the osmotic coefficient can be made up to 350°C.

Enthalpy Data

The low molality heat of solution data of Cobble and co-workers[4,20,21] have in all cases been fit to within their stated experimental error. The largest difference between experimental and calculated values occurs at 300°C where we differ by approximately 5 kJ/mole. This is due primarily to the disagreement between Cobble's results and those of Borodenko and Galinker[3]. The latter authors' heat of solution results yield ΔH^{o}_{sol} (300°C) = -98.7 kJ/mole while Cobble obtained -107 kJ/mole. Our result of -102 kJ/mole splits the difference.

The values obtained for the total relative molal enthalpy (ϕ_L) agree with those obtained by Ensor and Anderson[23] and Messikomer and Wood[22] to within ± 60 J/mole up to 75°C,however, at 100°C the deviation increases to approximately 250 J/mole at 5 molal. This is well outside the stated experimental uncertainties in the enthalpy results and is the result of an incompatibility between the various types of data. This is a matter that should be investigated further.

Heat Capacity Data

The heat capacity data below 100°C has been fit to better than 0.004 J/gm-deg except for deviations as large as 0.01 J/gm-deg at high molalities at 318 and 338 K. This misfit is probably associated with the structural changes that are occurring in water at these temperatures and give rise to the maximum in the apparent molal heat capacity at infinite dilution (C°_{p2}). At temperatures up to 250°C the data of Puchkov et al.[5] were fit to better than ± 0.03 J/mole-deg at concentrations below 5 m. The deviation at 6 m above 100°C is approximately 0.04 J/mole-deg. At 275°C the deviation from experiment increases to a fairly constant 0.05 J/mole-deg. Above 275°C the fit deteriorates rapidly. The largest residual at 300°C is 0.17 J/mole-deg. A comparison of our results with the heat capacity data are shown in figure 4.

To obtain an estimate of the behavior of our equation for temperatures above 300°C the data of Puchkov, et al,[5] at 325 and 350°C were included in the final fit. The deviations at 325°C and 350°C average 0.56 J/mole-deg and 16 J/mole-deg, respectively. This is undoubtedly due to our lack of guidance on the exact behavior of C°_{p2} at these temperatures and indicates that an extrapolation of the heat capacity and enthalpy results reported here will probably lead to erroneous results. A better technique to determine high temperature enthalpies would be to use the 300°C results reported here and then use Puchkov's results above 300°C to calculate a correction term. As shown in figure 5, at temperatures below 100°C our calculated values for C^{o}_{p2} deviate by as much as 10 J/mole-deg from the values obtained by extrapolating individual data sets at constant temperature. Considering that the data below 1 molal were in general fit to ± 0.02 J/mole-deg (which is approximately the level of agreement between authors) suggests the possibility that our temperature dependent fit of the data leads to a more accurate value of C^{o}_{p2}. It should also be noted that the value of C^{o}_{p2} is also strongly influenced by the ΔH^{o}_{sol} data which were fit extremely well in this region.

Table 3 lists properties for the solute in the infinitely dilute standard state.

Resulting Thermodynamic Properties

Tables 4-9 contain calculated values for the osmotic coefficient, activity of water, activity of NaCl, C_p, and the enthalpy and entropy of the solution relative to the triple point of water 0.01°C. The concentration of NaCl is expressed in weight percent and the enthalpy, entropy, and heat capacity expressed on a unit weight basis. All data on the solvent were taken from Keenan et al[30] except values of C^{o}_{p1} which below 100°C were taken from Stimson.[31]

KCl and Mixtures of KCl and NaCl

Although the experimental data for KCl are much less extensive than for NaCl, enough is known to justify the development of a general equation analogous to that presented here for NaCl. This work is now in progress. In the meantime, we can present only interim comments concerning KCl and mixtures.

Holmes, Baes, and Mesmer,[32,33] have made isopiestic measurements, referenced to NaCl, for KCl-NaCl mixtures in addition to those for pure KCl. Their results were interpreted in terms of the same form of equation as used in our work and, for the mixtures, the form of Pitzer and Kim.[34] The properties of mixtures are given by the properties of the pure components together with a small, often negligible, mixing term. The expression of Holmes, et al,[33] for the primary mixing parameter, $\theta = -6.726/T + 0.00399$ will allow the calculation of various properties of the mixtures as soon as the full equation for pure KCl is available. In the meantime we suggest use of the parameters found from isopiestic measurements by Holmes, et al; their values for $\beta^{(0)}$ are about two-thirds of those for NaCl whereas their values for C^{ϕ} are almost the same as those for NaCl. For $\beta^{(1)}$ the situation is more complex since we have introduced an additional term in $\beta^{(2)}$ for NaCl; however, the KCl values are essentially the same as those for NaCl in the earlier treatment[2] when the $\beta^{(2)}$ term was not included. In general the properties of aqueous of KCl are, not unexpectedly, very similar to those NaCl but with slightly smaller virial-coefficient corrections to the "Debye-Hückel" behavior.

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TABLE I. Data on Aqueous NaCl Solutions

Reference	Data Type	Method	T Range °C	m
8	ϕ	isop	0	.1-4.0
9	ϕ	isop	15	.1-4.0
10	$\gamma_{\pm}$	emf	15	0.002-0.1
11	$\gamma_{\pm}$	emf	15-50	0.01-1.0
12	ϕ	vp	20-30	2.0-4.0
13	ϕ	vp	25-100	1.0-6.1
14	ϕ	bp	60-100	0.05-1.0
15	ϕ	bp	60-100	1.0-4.0
16	ϕ	vp	125-250	0.5-3.0
17	ϕ	vp	75-300	4.8-sat
18	ϕ	vp	125-300	0.1-3.5
19	ϕ	vp	150-350	1.2-5.6
20	$\Delta\bar{H}_S$	cal	0-100	0.001-0.03
21	$\Delta\bar{H}_S$	cal	100-200	0.007-0.04
3	$\Delta\bar{H}_S$	cal	200-300	2.0-sat
4	$\Delta\bar{H}_S$	cal	300	0.003-0.018
22	$\Delta\bar{H}_D$	fcal	25-100	0.04-5.0
23	$\Delta\bar{H}_D$	cal	40-80	0.005-6.0
24	C_p	fcal	1.5-45	0.01-3.0
25	C_p	cal	5-85	0.04-6.0
26	C_p	fcal	24.15	0.001-2.0
27	C_p	fcal	25.0	0.01-3.0
28	C_p	cal	25.0	0.04-2.3
29	C_p	cal	80-200	0.35-2.1
5	C_p	cal	150-350	0.43-6.0

TABLE II. Coefficients for the Equations

U(1) = -4.305640E1	U(16) = -1.363795E-2
U(2) = -5.533834E-1	U(17) = -1.421663E-6
U(3) = -1.323959E-4	U(18) = 8.084562E-12
U(4) = 3.888219E-8	U(19) = 4.184027E-1
U(5) = 1.351532E1	U(20) = 2.291733E-3
U(6) = 1.012506E-1	U(21) = -2.818197E-3
U(7) = 1.399931E-2	U(22) = -5.151215E3
U(8) = -8.139942E1	U(23) = 2.152020E2
U(9) = -1.533972E-1	U(24) = -4.469652E-1
U(10) = 1.965331E-4	U(25) = 3.548016E-4
U(11) = -1.108085E-7	U(26) = -2.581373E6
U(12) = 1.981514E1	U(27) = 3.177029E6
U(13) = -9.033620E-2	U(28) = -1.532433E2
U(14) = 7.223543E-7	U(29) = -6.826872E2
U(15) = -1.390067	U(30) = -3.672874E3

TABLE III. Calculated Values for the Standard State Heat Capacity and Entropy of NaCl (aq) and the Enthalpy of Solution of NaCl

T/°C	$C^{\circ}_{p_2}$ (J mol^{-1}deg^{-1})	$(S^{\circ}_2(T)-S^{\circ}_2(.01))$ (J mol^{-1}deg^{-1})	ΔH°_{sol} (kJ mol^{-1})
0	-186.2	.007	7.975
10	-121.9	-5.389	6.012
20	- 91.88	-9.063	4.489
25	- 82.84	-10.54	3.818
30	- 76.32	-11.87	3.186
40	- 68.49	-14.23	1.995
50	- 65.44	-16.34	0.857
60	- 65.61	-18.36	-0.268
70	- 68.12	-20.35	-1.407
80	- 72.47	-22.39	-2.582
90	- 78.24	-24.52	-3.807
100	- 85.40	-26.77	-5.096
125	-108.8	-33.10	-8.690
150	-141.7	-40.78	-12.97
175	-189.0	-50.33	-18.24
200	-260.7	-62.59	-24.96
225	-377.3	-79.04	-33.95
250	-582.8	-102.5	-46.82
275	-986.6	-139.0	-66.86
300	-1920.0	-202.5	-102.4

Table 4. Osmotic Coefficient for NaCl (aq).

WT. PERCENT	T(C) 0.00	25.00	50.00	75.00	100.00	125.00	150.00
.25	.9465	.9461	.9441	.9410	.9371	.932	.927
.50	.9340	.9347	.9327	.9291	.9242	.918	.911
.75	.9269	.9286	.9269	.9231	.9177	.911	.903
1.00	.9221	.9250	.9236	.9197	.9140	.907	.898
1.25	.9188	.9227	.9217	.9178	.9119	.904	.895
1.50	.9163	.9213	.9207	.9169	.9107	.903	.893
1.75	.9144	.9204	.9203	.9166	.9103	.902	.892
2.00	.9131	.9201	.9204	.9167	.9104	.902	.891
2.25	.9120	.9200	.9208	.9173	.9109	.902	.891
2.50	.9113	.9203	.9215	.9181	.9116	.903	.891
2.75	.9109	.9208	.9224	.9191	.9126	.903	.892
3.00	.9106	.9214	.9234	.9204	.9138	.904	.892
3.25	.9105	.9223	.9247	.9218	.9152	.906	.893
3.50	.9106	.9233	.9261	.9233	.9167	.907	.894
3.75	.9109	.9244	.9276	.9249	.9183	.908	.896
4.00	.9112	.9256	.9292	.9267	.9200	.910	.897
4.25	.9117	.9269	.9309	.9286	.9219	.912	.898
4.50	.9123	.9283	.9327	.9305	.9238	.914	.900
4.75	.9131	.9299	.9346	.9325	.9258	.915	.902
5.00	.9139	.9315	.9366	.9346	.9279	.917	.903
6.00	.9181	.9387	.9452	.9437	.9368	.926	.910
7.00	.9237	.9470	.9547	.9536	.9465	.935	.919
8.00	.9306	.9564	.9651	.9644	.9570	.944	.927
9.00	.9386	.9666	.9764	.9758	.9681	.955	.937
10.00	.9477	.9778	.9883	.9878	.9797	.966	.946
11.00	.9579	.9898	1.0010	1.0004	.9918	.977	.956
12.00	.9693	1.0027	1.0143	1.0136	1.0043	.988	.967
13.00	.9818	1.0164	1.0283	1.0273	1.0173	1.000	.977
14.00	.9953	1.0309	1.0430	1.0415	1.0307	1.013	.988
15.00	1.0101	1.0463	1.0582	1.0562	1.0444	1.025	.999
16.00	1.0259	1.0624	1.0741	1.0713	1.0584	1.038	1.011
17.00	1.0430	1.0794	1.0906	1.0868	1.0728	1.051	1.022
18.00	1.0612	1.0972	1.1076	1.1028	1.0874	1.064	1.033
19.00	1.0807	1.1159	1.1253	1.1191	1.1022	1.077	1.045
20.00	1.1016	1.1354	1.1435	1.1358	1.1173	1.091	1.057
21.00	1.1237	1.1558	1.1623	1.1529	1.1326	1.104	1.068
22.00	1.1472	1.1771	1.1817	1.1703	1.1481	1.118	1.080
23.00	1.1722	1.1993	1.2016	1.1881	1.1637	1.131	1.092
24.00	1.1987	1.2225	1.2222	1.2062	1.1794	1.145	1.103
25.00	1.2268	1.2466	1.2433	1.2245	1.1952	1.158	1.114

Table 4. Osmotic Coefficient for NaCl (aq).

WT. PERCENT	175.00	200.00	225.00 T(C)	250.00	275.00	300.00
.25	.920	.912	.902	.891	.875	.855
.50	.903	.892	.880	.864	.844	.817
.75	.893	.881	.867	.849	.825	.794
1.00	.887	.874	.858	.838	.812	.777
1.25	.883	.869	.852	.831	.803	.765
1.50	.881	.866	.848	.825	.795	.755
1.75	.879	.864	.845	.820	.789	.747
2.00	.878	.862	.842	.817	.784	.740
2.25	.877	.861	.840	.814	.780	.735
2.50	.877	.860	.839	.812	.777	.730
2.75	.877	.860	.837	.810	.774	.725
3.00	.878	.859	.837	.808	.771	.722
3.25	.878	.859	.836	.807	.769	.719
3.50	.879	.860	.836	.806	.767	.716
3.75	.880	.860	.836	.805	.766	.713
4.00	.881	.860	.836	.804	.764	.711
4.25	.882	.861	.836	.804	.763	.709
4.50	.883	.862	.836	.804	.762	.707
4.75	.884	.863	.836	.803	.761	.706
5.00	.885	.864	.837	.803	.761	.704
6.00	.891	.868	.839	.804	.759	.700
7.00	.898	.873	.843	.805	.759	.698
8.00	.906	.879	.847	.807	.759	.697
9.00	.913	.885	.851	.810	.760	.696
10.00	.922	.892	.856	.814	.762	.697
11.00	.930	.899	.862	.818	.765	.698
12.00	.939	.906	.867	.822	.767	.699
13.00	.948	.914	.873	.826	.770	.701
14.00	.958	.922	.880	.831	.773	.703
15.00	.967	.930	.886	.835	.777	.706
16.00	.977	.938	.892	.840	.781	.709
17.00	.987	.946	.899	.845	.784	.711
18.00	.997	.954	.905	.851	.788	.714
19.00	1.007	.962	.912	.856	.792	.718
20.00	1.017	.970	.919	.861	.796	.721
21.00	1.026	.979	.925	.866	.800	.724
22.00	1.036	.987	.932	.871	.804	.728
23.00	1.046	.995	.938	.876	.808	.731
24.00	1.055	1.002	.944	.881	.812	.734
25.00	1.065	1.010	.950	.885	.816	.738

Table 5. Activity of Water in NaCl (aq).

WT. PERCENT	T(C) 0.00	25.00	50.00	75.00	100.00	125.00	150.00
.25	.9985	.9985	.9985	.9985	.9986	.999	.999
.50	.9971	.9971	.9971	.9971	.9971	.997	.997
.75	.9957	.9957	.9957	.9957	.9957	.996	.996
1.00	.9943	.9943	.9943	.9943	.9943	.994	.994
1.25	.9929	.9928	.9928	.9929	.9929	.993	.993
1.50	.9914	.9914	.9914	.9914	.9915	.992	.992
1.75	.9900	.9899	.9899	.9900	.9901	.990	.990
2.00	.9886	.9885	.9885	.9885	.9886	.989	.989
2.25	.9871	.9870	.9870	.9871	.9872	.987	.987
2.50	.9857	.9856	.9855	.9856	.9857	.986	.986
2.75	.9842	.9841	.9840	.9841	.9842	.984	.985
3.00	.9828	.9826	.9825	.9826	.9827	.983	.983
3.25	.9813	.9811	.9810	.9811	.9812	.981	.982
3.50	.9798	.9796	.9795	.9796	.9797	.980	.980
3.75	.9784	.9780	.9780	.9780	.9782	.978	.979
4.00	.9769	.9765	.9764	.9765	.9766	.977	.977
4.25	.9754	.9750	.9748	.9749	.9751	.975	.976
4.50	.9738	.9734	.9733	.9733	.9735	.974	.974
4.75	.9723	.9718	.9717	.9717	.9719	.972	.973
5.00	.9708	.9702	.9701	.9701	.9703	.971	.971
6.00	.9645	.9637	.9635	.9635	.9638	.964	.965
7.00	.9580	.9570	.9567	.9567	.9570	.958	.958
8.00	.9513	.9500	.9496	.9496	.9500	.951	.952
9.00	.9444	.9428	.9422	.9422	.9427	.943	.944
10.00	.9371	.9352	.9345	.9346	.9351	.936	.937
11.00	.9296	.9274	.9266	.9266	.9272	.928	.930
12.00	.9217	.9192	.9183	.9183	.9190	.920	.922
13.00	.9135	.9106	.9096	.9097	.9105	.912	.914
14.00	.9049	.9017	.9006	.9008	.9017	.903	.906
15.00	.8959	.8924	.8912	.8915	.8926	.894	.897
16.0C	.8865	.8827	.8815	.8818	.8831	.885	.888
17.00	.8766	.8726	.8714	.8718	.8733	.876	.879
18.00	.8662	.8620	.8608	.8614	.8632	.866	.869
19.00	.8553	.8510	.8498	.8506	.8527	.856	.860
20.00	.8439	.8395	.8384	.8394	.8418	.845	.850
21.00	.8318	.8274	.8266	.8278	.8306	.834	.839
22.00	.8191	.8149	.8143	.8159	.8190	.823	.829
23.00	.8058	.8018	.8015	.8035	.8071	.812	.818
24.00	.7919	.7882	.7882	.7907	.7948	.800	.807
25.00	.7771	.7740	.7745	.7775	.7822	.788	.795

Table 5. Activity of Water in NaCl (aq).

	T(C)					
WT. PERCENT	175.00	200.00	225.00	250.00	275.00	300.00
.25	.999	.999	.999	.999	.999	.999
.50	.997	.997	.997	.997	.997	.997
.75	.996	.996	.996	.996	.996	.996
1.00	.994	.995	.995	.995	.995	.995
1.25	.993	.993	.993	.994	.994	.994
1.50	.992	.992	.992	.992	.993	.993
1.75	.990	.991	.991	.991	.991	.992
2.00	.989	.989	.989	.990	.990	.991
2.25	.988	.988	.988	.989	.989	.990
2.50	.986	.986	.987	.987	.988	.989
2.75	.985	.985	.986	.986	.987	.987
3.00	.983	.984	.984	.985	.985	.986
3.25	.982	.982	.983	.983	.984	.985
3.50	.981	.981	.981	.982	.983	.984
3.75	.979	.980	.980	.981	.982	.983
4.00	.978	.978	.979	.980	.981	.982
4.25	.976	.977	.977	.978	.979	.981
4.50	.975	.975	.976	.977	.978	.980
4.75	.973	.974	.975	.976	.977	.979
5.00	.972	.972	.973	.974	.976	.977
6.00	.966	.966	.968	.969	.971	.973
7.00	.959	.960	.962	.963	.965	.968
8.00	.953	.954	.956	.958	.960	.963
9.00	.946	.947	.949	.952	.955	.958
10.00	.939	.941	.943	.946	.949	.953
11.00	.932	.934	.936	.940	.943	.948
12.00	.924	.927	.930	.933	.938	.943
13.00	.916	.919	.923	.927	.932	.937
14.00	.908	.912	.916	.920	.925	.932
15.00	.900	.904	.908	.913	.919	.926
16.00	.892	.896	.901	.906	.912	.920
17.00	.883	.887	.893	.899	.906	.914
18.00	.874	.879	.885	.891	.899	.908
19.00	.865	.870	.876	.884	.892	.901
20.00	.855	.861	.868	.876	.885	.895
21.00	.845	.852	.859	.868	.877	.888
22.00	.835	.842	.850	.859	.869	.881
23.00	.825	.833	.841	.851	.862	.874
24.00	.814	.823	.832	.842	.854	.867
25.00	.803	.813	.823	.834	.846	.859

Table 6. Activity of Sodium Chloride in NaCl (aq).

WT. PERCENT	T(C) 0.00	25.00	50.00	75.00	100.00	125.00	150.00
.25	.0013	.0013	.0012	.0012	.0012	.001	.001
.50	.0046	.0046	.0045	.0044	.0042	.004	.004
.75	.0097	.0097	.0095	.0092	.0088	.008	.008
1.00	.0164	.0165	.0161	.0156	.0149	.014	.013
1.25	.0247	.0248	.0244	.0235	.0225	.021	.020
1.50	.0345	.0348	.0342	.0330	.0314	.030	.027
1.75	.0458	.0464	.0456	.0439	.0417	.039	.036
2.00	.0586	.0596	.0586	.0564	.0534	.050	.046
2.25	.0729	.0744	.0732	.0704	.0666	.062	.057
2.50	.0886	.0907	.0894	.0860	.0812	.076	.069
2.75	.1058	.1088	.1073	.1031	.0973	.090	.082
3.00	.1244	.1284	.1268	.1219	.1148	.106	.097
3.25	.1446	.1498	.1481	.1423	.1339	.124	.112
3.50	.1663	.1729	.1712	.1644	.1546	.143	.129
3.75	.1896	.1978	.1960	.1883	.1769	.163	.147
4.00	.2144	.2245	.2228	.2140	.2008	.185	.167
4.25	.2409	.2531	.2515	.2415	.2264	.208	.187
4.50	.2689	.2836	.2821	.2710	.2538	.233	.209
4.75	.2987	.3161	.3148	.3024	.2830	.259	.232
5.00	.3302	.3506	.3496	.3358	.3140	.287	.257
6.00	.4741	.5101	.5112	.4912	.4580	.417	.370
7.00	.6495	.7078	.7127	.6851	.6370	.576	.508
8.00	.8604	.9490	.9601	.9232	.8562	.771	.675
9.00	1.1120	1.2408	1.2606	1.2124	1.1214	1.005	.874
10.00	1.4106	1.5910	1.6228	1.5608	1.4398	1.284	1.109
11.00	1.7637	2.0095	2.0571	1.9781	1.8196	1.615	1.385
12.00	2.1805	2.5080	2.5756	2.4755	2.2704	2.005	1.709
13.00	2.6722	3.1005	3.1928	3.0664	2.8033	2.463	2.085
14.00	3.2525	3.8036	3.9259	3.7663	3.4313	2.999	2.522
15.00	3.9378	4.6377	4.7953	4.5935	4.1694	3.624	3.027
16.00	4.7485	5.6270	5.8252	5.5696	5.0351	4.352	3.610
17.00	5.7093	6.8008	7.0446	6.7199	6.0487	5.197	4.280
18.00	6.8509	8.1946	8.4879	8.0740	7.2335	6.177	5.050
19.00	8.2110	9.8514	10.1965	9.6671	8.6167	7.312	5.933
20.00	9.8366	11.8237	12.2197	11.5403	10.2297	8.622	6.943
21.00	11.7864	14.1753	14.6166	13.7421	12.1090	10.135	8.097
22.00	14.1339	16.9849	17.4584	16.3297	14.2964	11.877	9.413
23.00	16.9723	20.3489	20.8308	19.3707	16.8406	13.883	10.910
24.00	20.4193	24.3864	24.8371	22.9445	19.7976	16.187	12.612
25.00	24.6259	29.2452	29.6023	27.1452	23.2318	18.832	14.541

Table 6. Activity of Sodium Chloride in NaCl (aq).

WT. PERCENT	T(C) 175.00	200.00	225.00	250.00	275.00	300.00
.25	.001	.001	.001	.001	.001	.001
.50	.004	.003	.003	.003	.002	.002
.75	.007	.007	.006	.005	.005	.004
1.00	.012	.011	.010	.009	.007	.006
1.25	.018	.016	.015	.013	.010	.008
1.50	.025	.023	.020	.017	.014	.010
1.75	.033	.029	.026	.022	.017	.013
2.00	.042	.037	.032	.027	.021	.016
2.25	.052	.046	.039	.033	.026	.019
2.50	.062	.055	.047	.039	.030	.021
2.75	.074	.065	.055	.045	.035	.025
3.00	.087	.076	.064	.052	.040	.028
3.25	.100	.087	.073	.059	.045	.031
3.50	.115	.099	.083	.067	.050	.035
3.75	.130	.112	.094	.075	.056	.038
4.00	.147	.126	.105	.083	.062	.042
4.25	.165	.141	.117	.092	.068	.045
4.50	.184	.157	.129	.101	.074	.049
4.75	.203	.173	.142	.111	.081	.053
5.00	.224	.190	.156	.121	.088	.057
6.00	.320	.268	.216	.165	.117	.074
7.00	.435	.361	.287	.216	.151	.093
8.00	.573	.470	.369	.274	.188	.114
9.00	.736	.597	.463	.339	.229	.136
10.00	.926	.744	.571	.413	.274	.160
11.00	1.148	.914	.693	.495	.324	.186
12.00	1.404	1.107	.831	.586	.379	.214
13.00	1.700	1.328	.986	.687	.439	.244
14.00	2.039	1.578	1.160	.799	.504	.277
15.00	2.428	1.862	1.355	.923	.575	.312
16.00	2.872	2.182	1.572	1.060	.652	.349
17.00	3.377	2.543	1.814	1.210	.736	.389
18.00	3.952	2.949	2.083	1.374	.827	.432
19.00	4.604	3.404	2.381	1.555	.926	.478
20.00	5.343	3.914	2.711	1.753	1.033	.528
21.00	6.177	4.484	3.075	1.969	1.149	.580
22.00	7.118	5.119	3.478	2.204	1.273	.637
23.00	8.177	5.827	3.920	2.461	1.408	.697
24.00	9.367	6.612	4.407	2.740	1.552	.761
25.00	10.702	7.484	4.940	3.043	1.708	.830

Table 7. Total Specific Heat Capacity of NaCl (aq), $C_p/JK^{-1}\ g^{-1}$.

WT. PERCENT	T(C) 0.00	25.00	50.00	75.00	100.00	125.00	150.00
.25	4.1991	4.1654	4.1672	4.1791	4.2015	4.240	4.296
.50	4.1813	4.1519	4.1544	4.1661	4.1879	4.225	4.281
.75	4.1638	4.1386	4.1418	4.1533	4.1745	4.211	4.265
1.00	4.1468	4.1255	4.1294	4.1407	4.1614	4.197	4.250
1.25	4.1300	4.1126	4.1172	4.1283	4.1484	4.183	4.235
1.50	4.1136	4.0998	4.1051	4.1160	4.1356	4.169	4.220
1.75	4.0975	4.0872	4.0931	4.1039	4.1229	4.156	4.206
2.00	4.0817	4.0748	4.0813	4.0918	4.1103	4.143	4.192
2.25	4.0661	4.0625	4.0695	4.0799	4.0978	4.129	4.178
2.50	4.0509	4.0503	4.0579	4.0681	4.0855	4.116	4.164
2.75	4.0359	4.0382	4.0464	4.0564	4.0733	4.104	4.150
3.00	4.0211	4.0263	4.0350	4.0447	4.0612	4.091	4.137
3.25	4.0066	4.0145	4.0237	4.0332	4.0492	4.078	4.123
3.50	3.9924	4.0028	4.0124	4.0218	4.0372	4.066	4.110
3.75	3.9784	3.9912	4.0013	4.0104	4.0254	4.053	4.097
4.00	3.9647	3.9797	3.9903	3.9992	4.0137	4.041	4.084
4.25	3.9511	3.9683	3.9793	3.9880	4.0020	4.029	4.071
4.50	3.9379	3.9570	3.9684	3.9769	3.9905	4.016	4.058
4.75	3.9248	3.9458	3.9577	3.9659	3.9790	4.004	4.045
5.00	3.9120	3.9348	3.9469	3.9550	3.9676	3.992	4.032
6.00	3.8629	3.8914	3.9049	3.9120	3.9229	3.946	3.983
7.00	3.8172	3.8496	3.8641	3.8702	3.8795	3.900	3.936
8.00	3.7747	3.8091	3.8244	3.8296	3.8372	3.856	3.890
9.00	3.7352	3.7700	3.7859	3.7900	3.7961	3.813	3.845
10.00	3.6987	3.7322	3.7484	3.7515	3.7560	3.772	3.802
11.00	3.6648	3.6957	3.7120	3.7140	3.7171	3.731	3.760
12.00	3.6335	3.6604	3.6767	3.6775	3.6793	3.692	3.720
13.00	3.6045	3.6264	3.6423	3.6420	3.6424	3.654	3.680
14.00	3.5775	3.5935	3.6090	3.6074	3.6066	3.617	3.642
15.00	3.5525	3.5617	3.5766	3.5738	3.5718	3.581	3.606
16.00	3.5291	3.5310	3.5452	3.5412	3.5380	3.547	3.570
17.00	3.5070	3.5015	3.5148	3.5095	3.5051	3.513	3.536
18.00	3.4860	3.4729	3.4853	3.4787	3.4732	3.480	3.502
19.00	3.4657	3.4454	3.4567	3.4488	3.4422	3.448	3.470
20.00	3.4457	3.4188	3.4291	3.4197	3.4121	3.418	3.439
21.00	3.4257	3.3932	3.4023	3.3916	3.3828	3.388	3.409
22.00	3.4051	3.3684	3.3764	3.3642	3.3545	3.359	3.380
23.00	3.3836	3.3444	3.3514	3.3377	3.3269	3.331	3.351
24.00	3.3606	3.3211	3.3272	3.3120	3.3002	3.304	3.324
25.00	3.3354	3.2985	3.3038	3.2871	3.2742	3.277	3.298

Table 7. Total Specific Heat Capacity of NaCl (aq), $C_p/JK^{-1}\ g^{-1}$.

WT. PERCENT	T(C) 175.00	200.00	225.00	250.00	275.00	300.00
.25	4.371	4.472	4.614	4.819	5.138	5.672
.50	4.353	4.452	4.590	4.788	5.093	5.597
.75	4.336	4.432	4.566	4.758	5.051	5.526
1.00	4.319	4.414	4.544	4.729	5.010	5.460
1.25	4.303	4.395	4.522	4.702	4.972	5.398
1.50	4.287	4.377	4.501	4.675	4.935	5.338
1.75	4.271	4.360	4.480	4.649	4.899	5.281
2.00	4.256	4.342	4.460	4.624	4.865	5.227
2.25	4.240	4.325	4.440	4.600	4.831	5.174
2.50	4.225	4.309	4.421	4.576	4.799	5.124
2.75	4.211	4.292	4.402	4.553	4.768	5.075
3.00	4.196	4.276	4.384	4.530	4.737	5.028
3.25	4.181	4.260	4.365	4.507	4.707	4.982
3.50	4.167	4.244	4.347	4.486	4.678	4.938
3.75	4.153	4.229	4.330	4.464	4.650	4.895
4.00	4.139	4.214	4.312	4.443	4.622	4.853
4.25	4.125	4.199	4.295	4.423	4.595	4.813
4.50	4.112	4.184	4.278	4.402	4.568	4.774
4.75	4.098	4.169	4.262	4.382	4.542	4.736
5.00	4.085	4.155	4.245	4.363	4.517	4.699
6.00	4.032	4.098	4.182	4.288	4.420	4.560
7.00	3.982	4.044	4.122	4.217	4.331	4.436
8.00	3.934	3.992	4.065	4.150	4.247	4.324
9.00	3.887	3.943	4.010	4.087	4.169	4.222
10.00	3.842	3.895	3.957	4.026	4.096	4.131
11.00	3.799	3.849	3.907	3.969	4.028	4.048
12.00	3.757	3.804	3.859	3.914	3.963	3.973
13.00	3.716	3.762	3.812	3.862	3.902	3.906
14.00	3.677	3.721	3.768	3.811	3.845	3.846
15.00	3.639	3.681	3.725	3.763	3.790	3.792
16.00	3.603	3.643	3.684	3.717	3.739	3.745
17.00	3.567	3.606	3.644	3.673	3.690	3.703
18.00	3.533	3.571	3.606	3.630	3.644	3.666
19.00	3.500	3.536	3.569	3.589	3.600	3.635
20.00	3.469	3.503	3.533	3.550	3.559	3.608
21.00	3.438	3.472	3.499	3.512	3.520	3.586
22.00	3.409	3.441	3.466	3.475	3.482	3.569
23.00	3.380	3.411	3.433	3.440	3.447	3.555
24.00	3.353	3.383	3.402	3.406	3.413	3.546
25.00	3.326	3.355	3.372	3.373	3.381	3.540

Table 8. Total Enthalpy of NaCl (aq), H/Jg^{-1}, referenced to the Triple Point of Water.

	T(C)						
WT. PERCENT	0.00	25.00	50.00	75.00	100.00	125.00	150.00
.25	-.02	104.52	208.63	312.91	417.69	523.3	630.1
.50	-.02	104.15	207.94	311.91	416.37	521.6	628.1
.75	-.03	103.78	207.26	310.92	415.07	520.0	626.1
1.00	-.04	103.40	206.58	309.94	413.77	518.4	624.1
1.25	-.06	103.03	205.90	308.96	412.49	516.8	622.2
1.50	-.09	102.65	205.23	307.99	411.21	515.2	620.2
1.75	-.13	102.28	204.55	307.02	409.93	513.6	618.3
2.00	-.17	101.90	203.87	306.05	408.66	512.0	616.4
2.25	-.22	101.51	203.20	305.09	407.40	510.4	614.5
2.50	-.28	101.13	202.52	304.12	406.14	508.8	612.6
2.75	-.34	100.74	201.84	303.16	404.88	507.3	610.7
3.00	-.41	100.35	201.17	302.20	403.63	505.7	608.8
3.25	-.48	99.95	200.49	301.24	402.38	504.2	606.9
3.50	-.56	99.56	199.81	300.28	401.13	502.6	605.0
3.75	-.65	99.16	199.13	299.32	399.89	501.1	603.2
4.00	-.75	98.75	198.45	298.37	398.65	499.5	601.3
4.25	-.85	98.35	197.77	297.41	397.41	498.0	599.5
4.50	-.95	97.94	197.09	296.46	396.18	496.5	597.6
4.75	-1.07	97.53	196.41	295.51	394.94	494.9	595.8
5.00	-1.19	97.12	195.72	294.55	393.71	493.4	594.0
6.00	-1.72	95.43	192.98	290.75	388.81	487.4	586.7
7.00	-2.34	93.71	190.23	286.96	383.95	481.4	579.5
8.00	-3.05	91.94	187.46	283.18	379.11	475.4	572.5
9.00	-3.85	90.14	184.67	279.41	374.32	469.6	565.5
10.00	-4.72	88.29	181.88	275.65	369.55	463.8	558.6
11.00	-5.67	86.41	179.07	271.90	364.82	458.0	551.7
12.00	-6.70	84.50	176.26	268.16	360.13	452.3	545.0
13.00	-7.79	82.56	173.44	264.45	355.47	446.7	538.4
14.00	-8.94	80.59	170.62	260.75	350.85	441.1	531.8
15.00	-10.15	78.59	167.80	257.07	346.28	435.6	525.3
16.00	-11.41	76.58	164.98	253.41	341.75	430.2	519.0
17.00	-12.72	74.54	162.17	249.79	337.27	424.8	512.7
18.00	-14.06	72.50	159.36	246.19	332.85	419.5	506.5
19.00	-15.44	70.44	156.58	242.63	328.48	414.3	500.4
20.00	-16.83	68.39	153.81	239.11	324.17	409.2	494.4
21.00	-18.24	66.33	151.06	235.64	319.92	404.1	488.6
22.00	-19.65	64.29	148.35	232.21	315.74	399.2	482.8
23.00	-21.05	62.26	145.67	228.84	311.64	394.3	477.2
24.00	-22.43	60.26	143.04	225.54	307.62	389.5	471.7
25.00	-23.78	58.29	140.46	222.31	303.69	384.9	466.3

Table 8. Total Enthalpy of NaCl (aq), H/Jg^{-1}, referenced to the Triple Point of Water.

WT. PERCENT	T(C) 175.00	200.00	225.00	250.00	275.00	300.00
.25	738.7	849.5	963.2	1081.1	1204.8	1337.1
.50	736.3	846.6	959.8	1077.0	1199.8	1330.7
.75	733.9	843.8	956.5	1073.0	1194.9	1324.5
1.00	731.5	841.0	953.2	1069.1	1190.2	1318.4
1.25	729.2	838.2	950.0	1065.3	1185.6	1312.5
1.50	726.9	835.5	946.8	1061.5	1181.0	1306.8
1.75	724.6	832.8	943.6	1057.8	1176.5	1301.1
2.00	722.3	830.1	940.4	1054.1	1172.1	1295.6
2.25	720.0	827.4	937.3	1050.4	1167.7	1290.1
2.50	717.7	824.8	934.2	1046.8	1163.4	1284.7
2.75	715.5	822.2	931.2	1043.2	1159.1	1279.4
3.00	713.3	819.6	928.1	1039.6	1154.9	1274.2
3.25	711.0	817.0	925.1	1036.1	1150.7	1269.0
3.50	708.8	814.4	922.1	1032.6	1146.5	1263.9
3.75	706.6	811.8	919.1	1029.2	1142.4	1258.9
4.00	704.4	809.3	916.2	1025.7	1138.4	1253.9
4.25	702.3	806.7	913.2	1022.3	1134.3	1249.0
4.50	700.1	804.2	910.3	1018.9	1130.3	1244.1
4.75	697.9	801.7	907.4	1015.5	1126.4	1239.3
5.00	695.8	799.2	904.5	1012.2	1122.4	1234.5
6.00	687.2	789.2	893.1	999.0	1107.0	1215.8
7.00	678.8	779.5	881.9	986.1	1092.0	1197.8
8.00	670.5	769.9	870.9	973.5	1077.3	1180.3
9.00	662.4	760.5	860.1	961.2	1063.1	1163.3
10.00	654.3	751.3	849.6	949.1	1049.1	1146.9
11.00	646.4	742.2	839.2	937.2	1035.5	1130.9
12.00	638.6	733.2	829.0	925.7	1022.2	1115.3
13.00	630.9	724.4	819.0	914.3	1009.2	1100.1
14.00	623.3	715.8	809.2	903.2	996.5	1085.2
15.00	615.8	707.3	799.5	892.2	984.0	1070.8
16.00	608.5	698.9	790.1	881.5	971.8	1056.7
17.00	601.3	690.7	780.8	871.1	959.9	1042.9
18.00	594.2	682.6	771.7	860.8	948.2	1029.5
19.00	587.2	674.7	762.8	850.7	936.8	1016.4
20.00	580.4	667.0	754.1	840.9	925.6	1003.6
21.00	573.6	659.4	745.5	831.3	914.7	991.1
22.00	567.1	652.0	737.2	821.8	904.0	978.9
23.00	560.6	644.7	729.0	812.6	893.6	967.0
24.00	554.3	637.6	721.0	803.6	883.4	955.4
25.00	548.2	630.6	713.2	794.9	873.4	944.1

Table 9. Total Entropy of NaCl (aq), S/JK^{-1} g^{-1}, referenced to the Triple Point of Water.

WT. PERCENT	T(C) 0.00	25.00	50.00	75.00	100.00	125.00	150.00
.25	2.96	369.12	704.45	1015.19	1305.66	1579.1	1838.7
.50	5.06	369.91	704.21	1014.00	1303.57	1576.2	1834.8
.75	6.80	370.37	703.64	1012.51	1301.18	1572.9	1830.7
1.00	8.29	370.59	702.86	1010.80	1298.59	1569.4	1826.3
1.25	9.59	370.64	701.91	1008.94	1295.87	1565.8	1821.9
1.50	10.73	370.55	700.83	1006.97	1293.02	1562.1	1817.3
1.75	11.74	370.33	699.64	1004.88	1290.08	1558.4	1812.7
2.00	12.62	370.02	698.36	1002.71	1287.06	1554.5	1808.0
2.25	13.39	369.61	696.98	1000.46	1283.97	1550.6	1803.2
2.50	14.07	369.11	695.53	998.14	1280.81	1546.6	1798.4
2.75	14.65	368.53	694.02	995.76	1277.59	1542.6	1793.6
3.00	15.15	367.89	692.43	993.31	1274.32	1538.5	1788.7
3.25	15.57	367.17	690.78	990.81	1271.00	1534.3	1783.8
3.50	15.91	366.39	689.08	988.26	1267.63	1530.2	1778.8
3.75	16.17	365.55	687.33	985.66	1264.22	1526.0	1773.8
4.00	16.37	364.65	685.52	983.02	1260.77	1521.7	1768.8
4.25	16.50	363.70	683.66	980.33	1257.28	1517.4	1763.7
4.50	16.57	362.69	681.76	977.60	1253.75	1513.1	1758.6
4.75	16.57	361.64	679.81	974.83	1250.19	1508.8	1753.5
5.00	16.52	360.53	677.82	972.02	1246.59	1504.4	1748.4
6.00	15.73	355.65	669.47	960.44	1231.90	1486.7	1727.6
7.00	14.09	350.10	660.53	948.36	1216.77	1468.6	1706.6
8.00	11.69	343.93	651.07	935.82	1201.26	1450.2	1685.3
9.00	8.56	337.20	641.13	922.87	1185.40	1431.4	1663.8
10.00	4.76	329.94	630.75	909.54	1169.22	1412.5	1642.1
11.00	.31	322.18	619.95	895.86	1152.76	1393.3	1620.2
12.00	-4.75	313.95	608.75	881.86	1136.02	1373.9	1598.2
13.00	-10.39	305.26	597.18	867.54	1119.04	1354.3	1576.1
14.00	-16.59	296.13	585.25	852.94	1101.83	1334.6	1553.9
15.00	-23.32	286.60	572.99	838.06	1084.41	1314.7	1531.5
16.00	-30.55	276.66	560.41	822.93	1066.79	1294.6	1509.1
17.00	-38.26	266.35	547.52	807.55	1048.98	1274.4	1486.7
18.00	-46.43	255.67	534.34	791.94	1031.00	1254.2	1464.1
19.00	-55.02	244.64	520.89	776.12	1012.87	1233.8	1441.6
20.00	-64.01	233.28	507.17	760.11	994.59	1213.3	1418.9
21.00	-73.37	221.61	493.22	743.91	976.18	1192.7	1396.3
22.00	-83.05	209.65	479.03	727.54	957.66	1172.1	1373.7
23.00	-93.04	197.41	464.64	711.02	939.04	1151.4	1351.0
24.00	-103.28	184.93	450.06	694.37	920.34	1130.7	1328.4
25.00	-113.74	172.21	435.30	677.60	901.58	1110.0	1305.8

Table 9. Total Entropy of NaCl (aq), $S/JK^{-1}\ g^{-1}$, referenced to the Triple Point of Water.

	T(C)					
WT. PERCENT	175.00	200.00	225.00	250.00	275.00	300.00
.25	2086.8	2325.8	2557.6	2784.9	3011.1	3240.7
.50	2082.0	2319.9	2550.6	2776.6	3001.0	3228.0
.75	2076.9	2313.9	2543.5	2768.2	2990.9	3215.3
1.00	2071.7	2307.7	2536.2	2759.7	2980.8	3202.8
1.25	2066.3	2301.4	2528.9	2751.2	2970.7	3190.4
1.50	2060.9	2295.1	2521.6	2742.7	2960.7	3178.1
1.75	2055.4	2288.7	2514.2	2734.2	2950.7	3166.0
2.00	2049.9	2282.3	2506.8	2725.6	2940.7	3153.9
2.25	2044.3	2275.8	2499.4	2717.1	2930.8	3141.9
2.50	2038.6	2269.3	2491.9	2708.6	2920.9	3130.1
2.75	2033.0	2262.7	2484.5	2700.1	2911.1	3118.3
3.00	2027.3	2256.2	2477.0	2691.5	2901.2	3106.5
3.25	2021.5	2249.6	2469.5	2683.0	2891.5	3094.9
3.50	2015.7	2243.0	2462.1	2674.5	2881.7	3083.3
3.75	2009.9	2236.4	2454.6	2666.1	2872.0	3071.8
4.00	2004.1	2229.7	2447.1	2657.6	2862.3	3060.3
4.25	1998.3	2223.1	2439.6	2649.1	2852.6	3049.0
4.50	1992.4	2216.4	2432.0	2640.6	2842.9	3037.6
4.75	1986.5	2209.8	2424.5	2632.2	2833.3	3026.4
5.00	1980.6	2203.1	2417.0	2623.7	2823.7	3015.2
6.00	1956.9	2176.2	2387.0	2590.1	2785.6	2970.8
7.00	1932.9	2149.3	2356.9	2556.5	2747.9	2927.2
8.00	1908.7	2122.3	2326.9	2523.2	2710.5	2884.3
9.00	1884.5	2095.2	2296.9	2490.0	2673.4	2842.0
10.00	1860.1	2068.1	2267.0	2457.0	2636.7	2800.3
11.00	1835.6	2041.0	2237.1	2424.1	2600.3	2759.1
12.00	1811.0	2013.8	2207.4	2391.4	2564.1	2718.4
13.00	1786.4	1986.7	2177.7	2358.9	2528.3	2678.2
14.00	1761.7	1959.6	2148.1	2326.6	2492.7	2638.4
15.00	1737.0	1932.6	2118.6	2294.4	2457.5	2599.1
16.00	1712.3	1905.6	2089.2	2262.5	2422.4	2560.2
17.00	1687.6	1878.6	2060.0	2230.7	2387.7	2521.7
18.00	1662.9	1851.7	2030.8	2199.1	2353.2	2483.6
19.00	1638.2	1824.9	2001.8	2167.7	2319.0	2445.9
20.00	1613.5	1798.2	1973.0	2136.5	2285.0	2408.5
21.00	1588.8	1771.5	1944.2	2105.4	2251.3	2371.5
22.00	1564.2	1744.9	1915.6	2074.6	2217.9	2334.9
23.00	1539.7	1718.5	1887.2	2044.0	2184.7	2298.6
24.00	1515.2	1692.1	1858.9	2013.6	2151.7	2262.7
25.00	1490.8	1665.9	1830.8	1983.3	2119.0	2227.1

Figure Captions

Fig. 1. a) $\beta^{(0)}$ as function of temperature; note the rapid decrease from 50 to 0°C and the apparent up turn above 300°C.

b) $\beta^{(0)''}$ (the term linear in molality for the apparent molal heat capacity) as a function of temperature; note the rapid change at low temperatures and the relatively constant behavior over a broad range of temperature.

Fig. 2. a) C^{ϕ} as a function of temperature; as with $\beta^{(0)}$ a rapid change in behavior is associated with low temperatures.

b) $C^{\phi''}$ (the quadratic term in molality in the apparent molal heat capacity equation); again there is a rapid change at low temperatures and then a relatively constant value.

Fig. 3. The osmotic coefficient as a function of temperature and molality. The most significant changes in ϕ as the temperature increases are that its minimum value shifts to higher molality and its molality dependence, at high molality, decreases. Note that some of the data at low molality are not self-consistent. This is not unexpected as the error in ϕ should increase as the molality and hence ΔP decreases.

Fig. 4. Total specific heat capacity of aqueous NaCl solution as a function of temperature and molality. Note that the quality of the fit has deteriorated significantly at 300°C.

Fig. 5. The partial molal heat capacity at infinite dilution, $\bar{C}^{\circ}_{p,2}$. As with $\beta^{(0)}$ and C^{ϕ}, $\bar{C}^{\circ}_{p,2}$ changes very abruptly below 50°C. It changes more between 0°C and 50°C than between 50°C and 175°C.

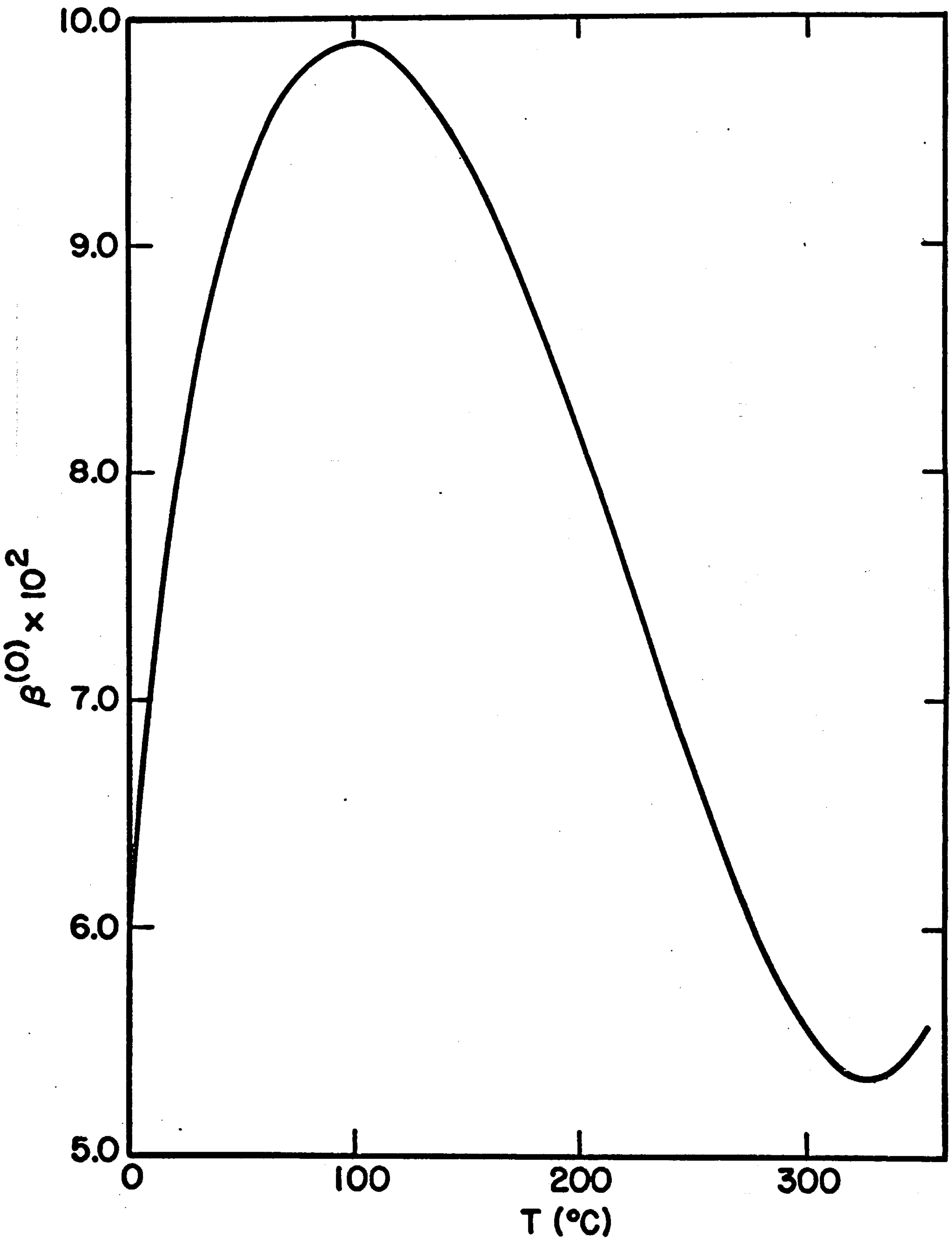


Fig. 1a

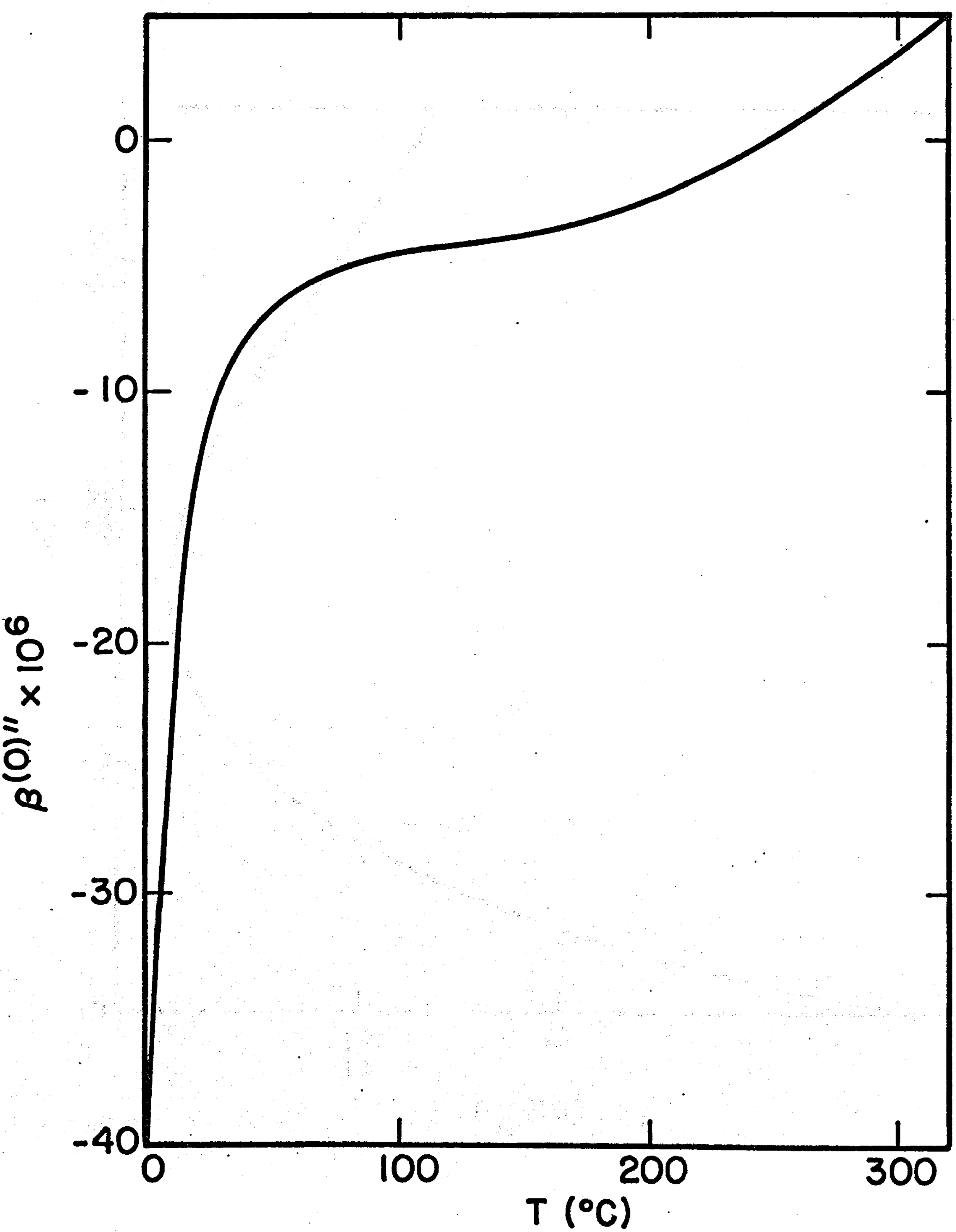


Fig. 1b

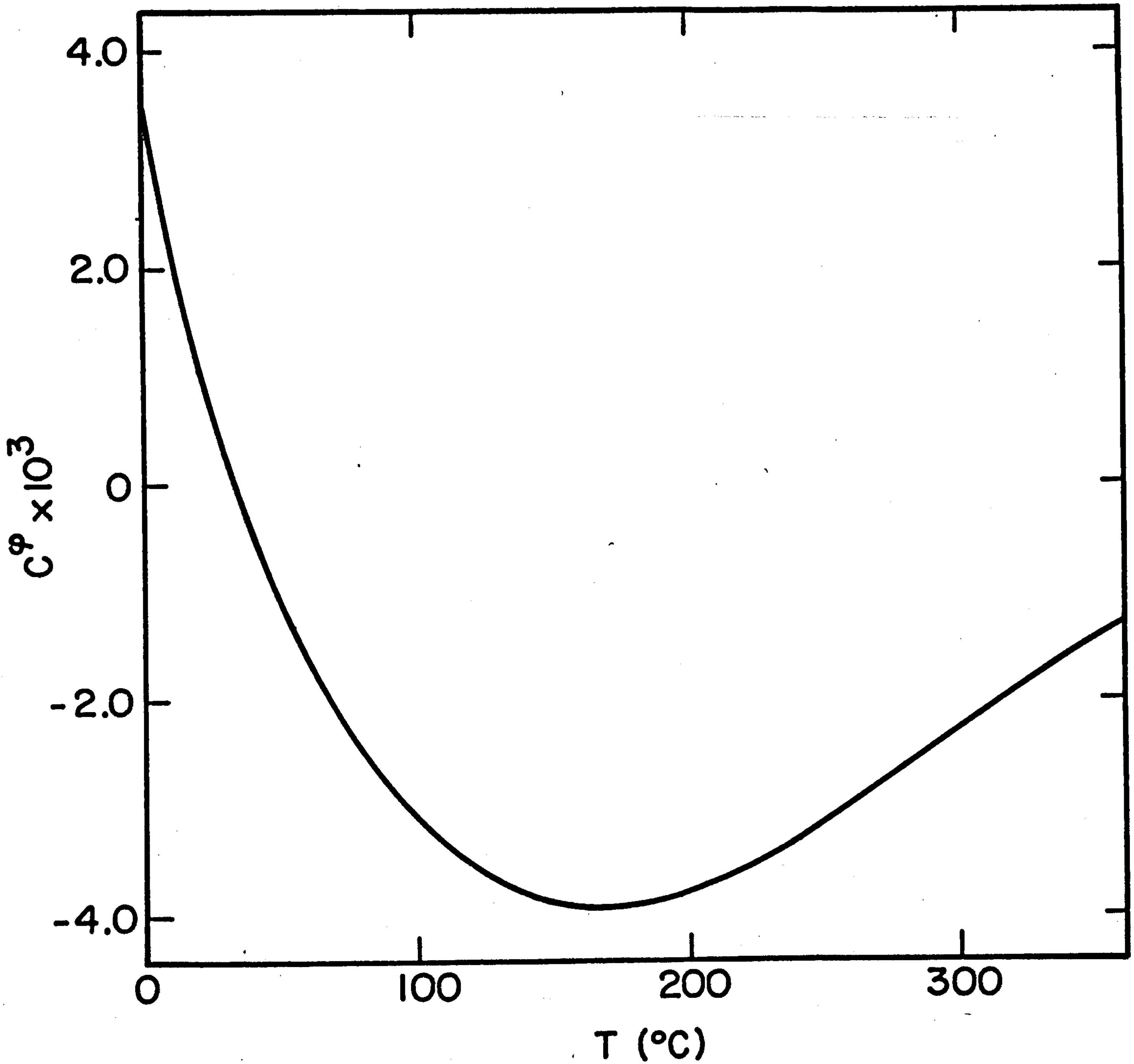
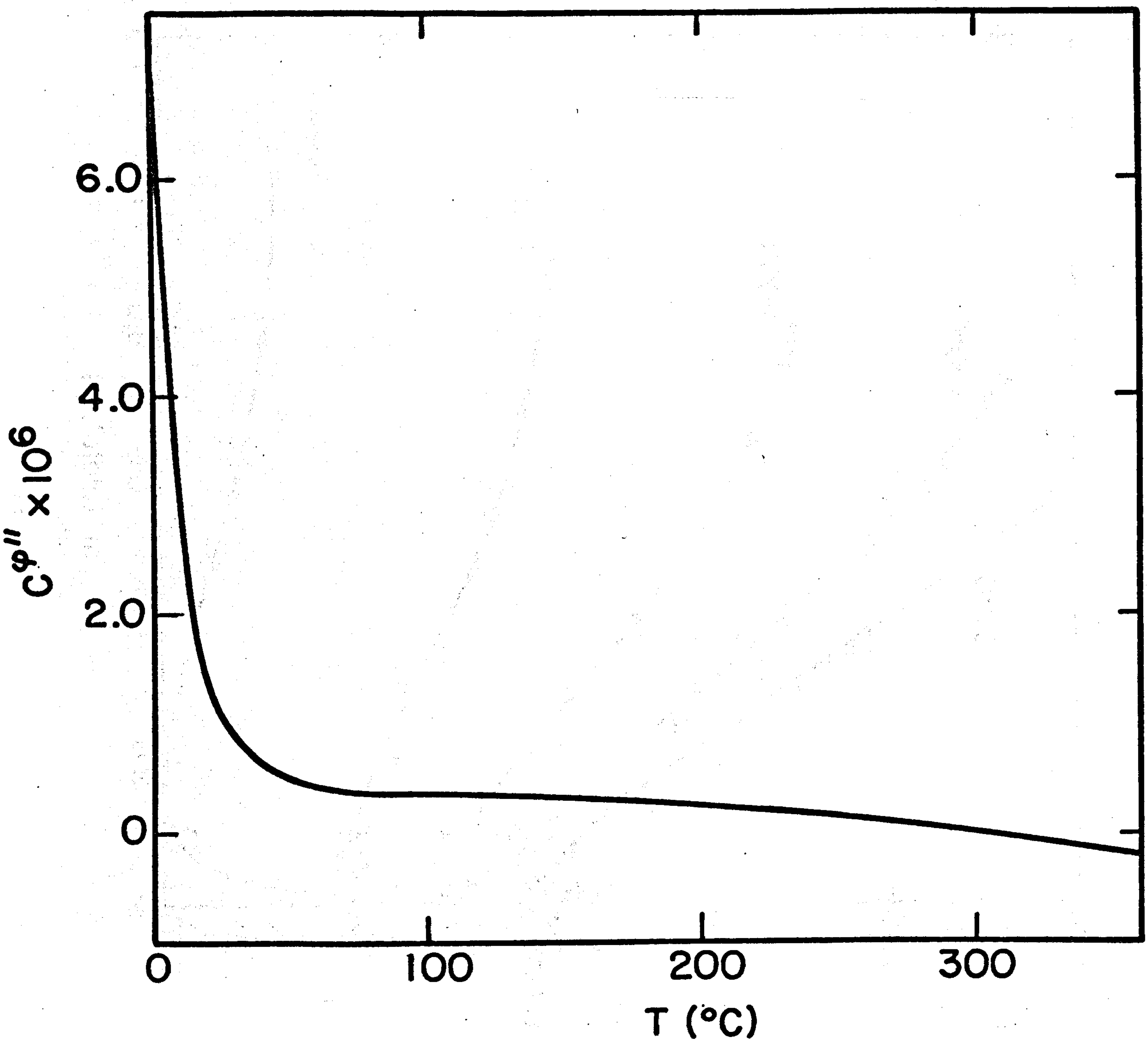


Fig. 2a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$C^{\varphi''} \times 10^6$
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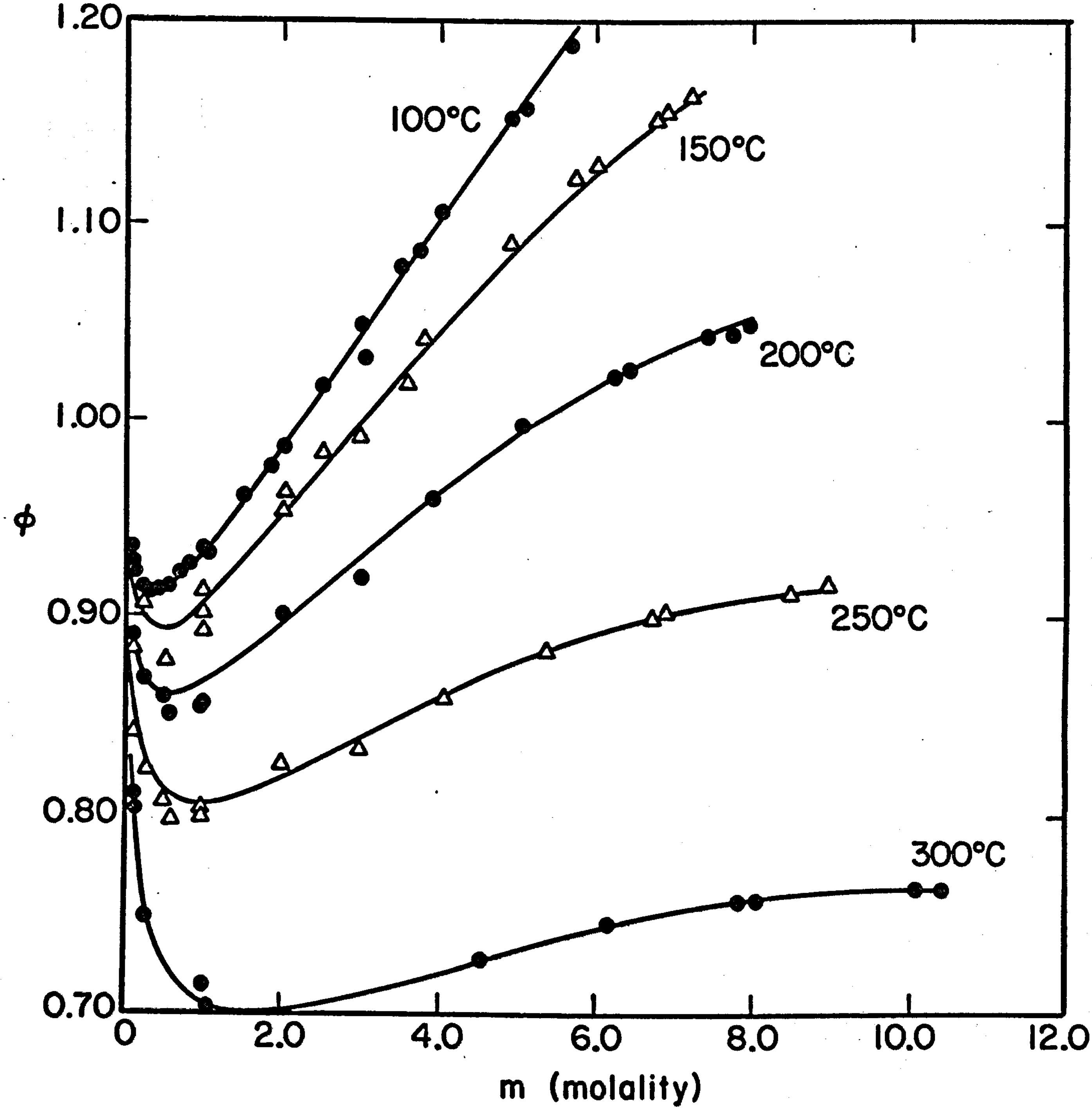
T (°C)



1.20
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250°C
300°C
0
2.0
4.0
6.0
8.0
10.0
12.0
m (molality)

Fig. 3

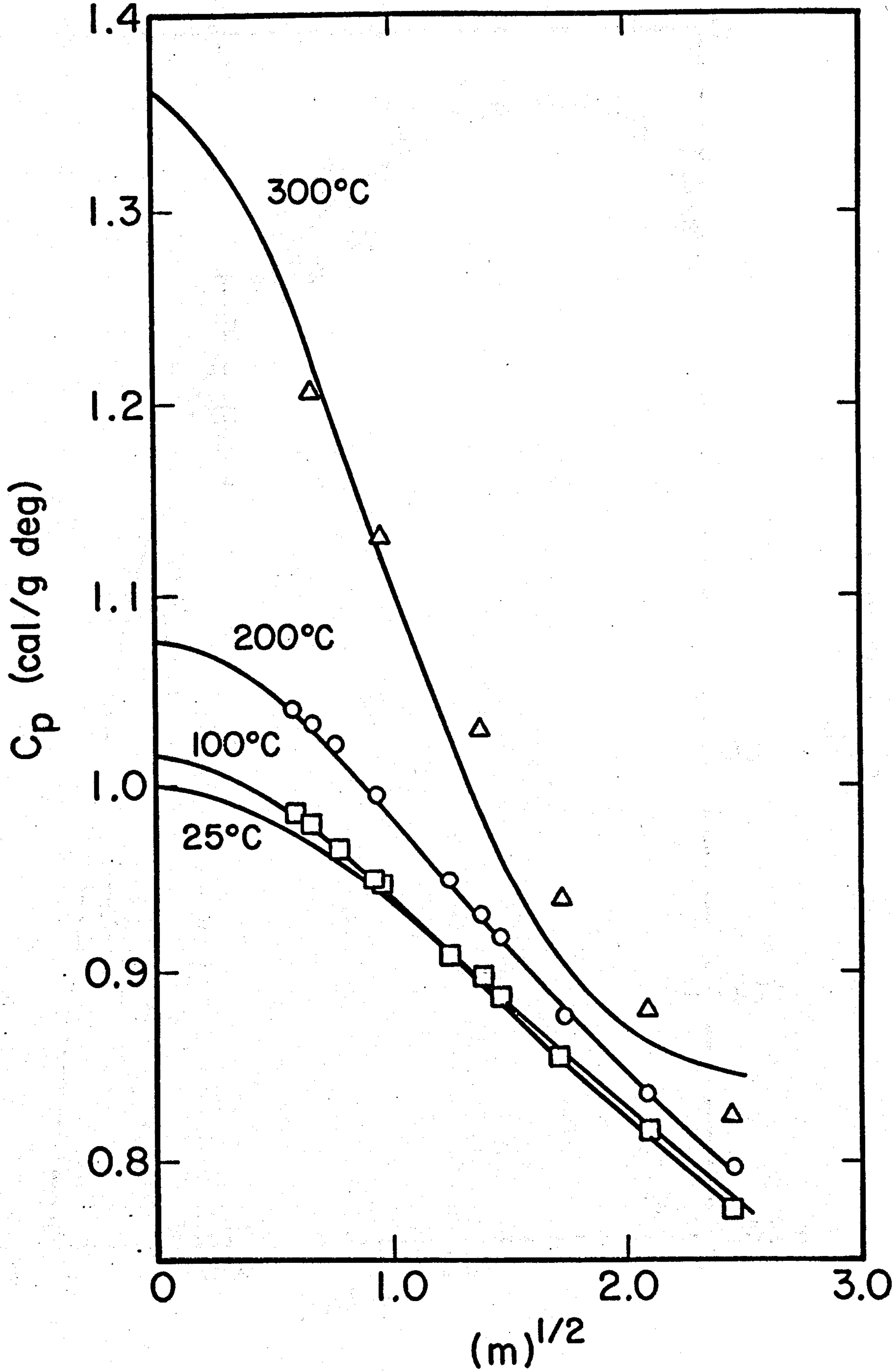

Fig. 4

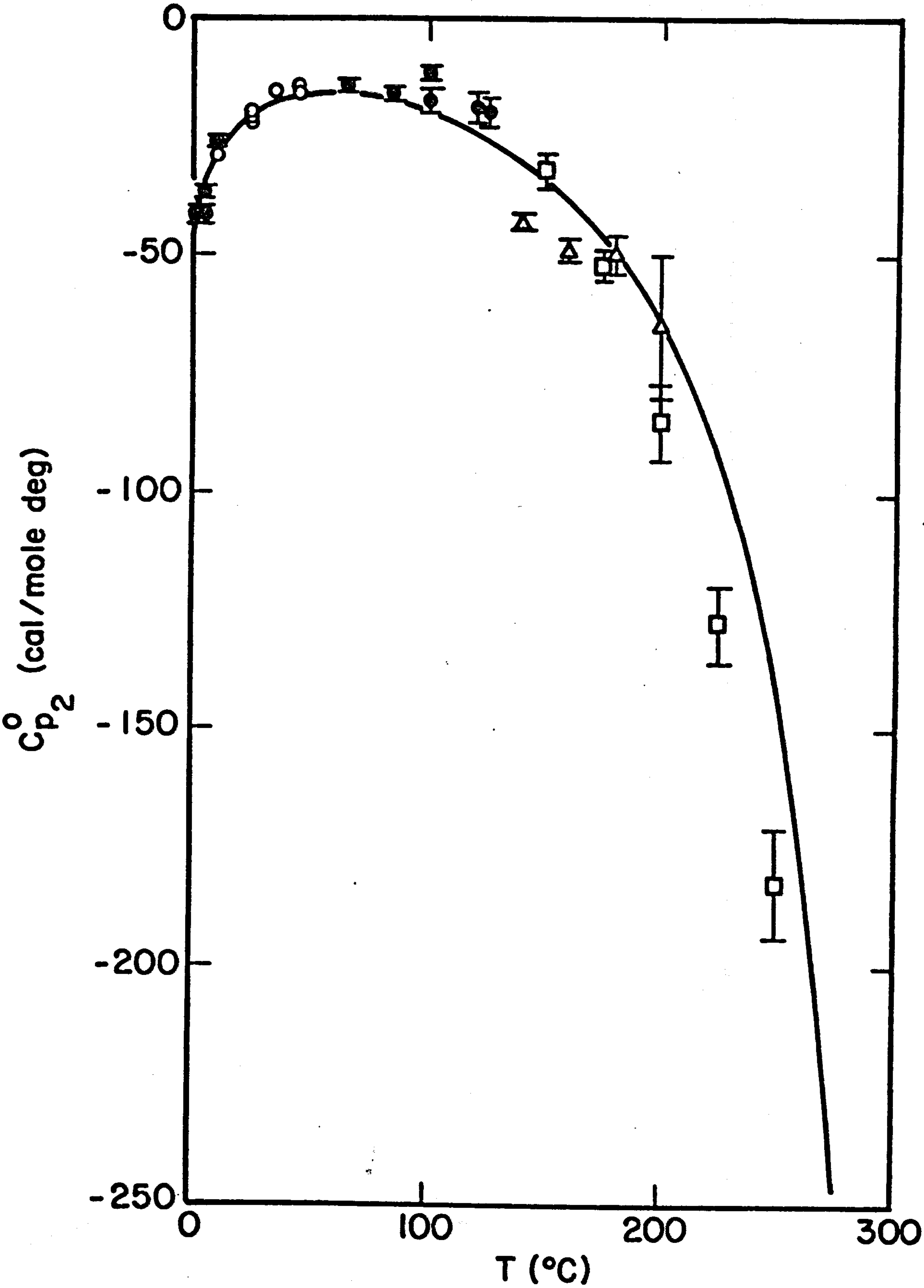

Fig. 5