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SCIENTIFIC COMMENT

Revised equation and table for determining the freezing point depression of H_2O-NaCl solutions

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SALINITIES OF H_2O-SALT inclusions are most often determined by measuring the melting temperature of ice in the inclusion and then referring this value to an equation or table describing the relationship between salinity and freezing-point depression. Generally, data for the system H_2O-NaCl are used to determine an NaCl-equivalent salinity, owing to lack of information concerning the salts (or other electrolytes) actually contributing to the freezing-point depression. The equation most often used to determine the salinity of H_2O-salt inclusions from freezing measurements is that of POTTER et al. (1978), which is based on a regression of data available in the literature at that time.

More recently, HALL et al. (1988) experimentally redetermined the ice-melting temperatures of H_2O-NaCl-KCl solutions having compositions ranging from pure water to the ternary eutectic and to each of the two binary (H_2O-NaCl and H_2O-KCl) eutectics. In the low-salinity range (less than about 10 wt%) the difference between the results of HALL et al. (1988) and previously published data for H_2O-NaCl is small, and the equations of POTTER et al. (1978) and HALL et al. (1988) agree within $\pm 0.1°C$ or ± 0.1 wt%. However, the equations of POTTER et al. (1978) and HALL et al. (1988) begin to diverge at higher salinities, and the magnitude of the difference increases with increasing salinity (Fig. 1; see also HALL et al., 1988, their Fig. 5).

Based on their new experimental data, HALL et al. (1988) presented an equation relating freezing temperature and salinity. Because HALL et al. (1988) included the NaCl/KCl ratio as a variable so that their equation could be used to calculate the ice liquidus for all compositions within the H_2O-NaCl-KCl ternary, their equation is more complex than that of POTTER et al. (1978). Moreover, the regression procedure used by HALL et al. (1988) resulted in a cubic equation with freezing-point depression as the dependent variable and salinity as the independent variable (their Eqn. 2). However, in fluid inclusion studies, the value that is measured in the laboratory is the freezing-point depression, from which we obtain the salinity of the inclusion. Recognizing this, HALL et al. (1988) solved their cubic equation to obtain an equation with ice-melting temperature as the independent variable and salinity as the dependent variable. The solution to this cubic equation is a complex expression with several fractional exponents such that the calculation requires a calculator or computer to complete and cannot be done easily with pencil and paper.

In order to facilitate and encourage use of the more accurate HALL et al. (1988) data, the original experimental results of HALL et al. (1988) for H_2O-NaCl ice-melting temperatures have been regressed using salinity as the dependent variable to provide the following simple equation:

$$\text{Salinity} = 0.00 + 1.78\theta - 0.0442\theta^2 + 0.000557\theta^3, \quad (1)$$

where θ is the depression of the freezing point in degrees Celsius. Note that Eqn. 1 has the same form as that of POTTER et al. (1978); only the regression coefficients have been changed to reflect the use of the more recent HALL et al. (1988) data in the regression. Equation 1 was generated on an Apple Macintosh IIci computer using the least-squares regression analysis procedure provided in CricketGraph v. 1.3.2. The difference between salinities predicted using Eqn. 1, based on the data of HALL et al. (1988) and those predicted by the equation of POTTER et al. (1978), are plotted as a function of freezing-point depression on Fig. 1.

Equation 1 reproduces the original experimental data of HALL et al. (1988) to better than ± 0.05 wt% NaCl at all

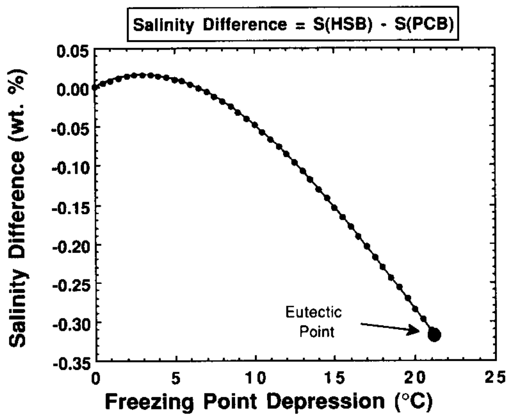

FIG. 1. Salinity difference, calculated as the salinity predicted by Eqn. 1 based on the data of HALL et al. (1988) [HSB] minus the salinity predicted by the equation of POTTER et al. (1978) [PCB], as a function of the freezing-point depression of NaCl-H_2O solutions.

Table 1. Salinities (wt.%) Corresponding to Measured Freezing Point Depressions (Degrees Celsius)

FPD	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0.	0.00	0.18	0.35	0.53	0.71	0.88	1.05	1.23	1.40	1.57
1.	1.74	1.91	2.07	2.24	2.41	2.57	2.74	2.90	3.06	3.23
2.	3.39	3.55	3.71	3.87	4.03	4.18	4.34	4.49	4.65	4.80
3.	4.96	5.11	5.26	5.41	5.56	5.71	5.86	6.01	6.16	6.30
4.	6.45	6.59	6.74	6.88	7.02	7.17	7.31	7.45	7.59	7.73
5.	7.86	8.00	8.14	8.28	8.41	8.55	8.68	8.81	8.95	9.08
6.	9.21	9.34	9.47	9.60	9.73	9.86	9.98	10.11	10.24	10.36
7.	10.49	10.61	10.73	10.86	10.98	11.10	11.22	11.34	11.46	11.58
8.	11.70	11.81	11.93	12.05	12.16	12.28	12.39	12.51	12.62	12.73
9.	12.85	12.96	13.07	13.18	13.29	13.40	13.51	13.62	13.72	13.83
10.	13.94	14.04	14.15	14.25	14.36	14.46	14.57	14.67	14.77	14.87
11.	14.97	15.07	15.17	15.27	15.37	15.47	15.57	15.67	15.76	15.86
12.	15.96	16.05	16.15	16.24	16.34	16.43	16.53	16.62	16.71	16.80
13.	16.89	16.99	17.08	17.17	17.26	17.34	17.43	17.52	17.61	17.70
14.	17.79	17.87	17.96	18.04	18.13	18.22	18.30	18.38	18.47	18.55
15.	18.63	18.72	18.80	18.88	18.96	19.05	19.13	19.21	19.29	19.37
16.	19.45	19.53	19.60	19.68	19.76	19.84	19.92	19.99	20.07	20.15
17.	20.22	20.30	20.37	20.45	20.52	20.60	20.67	20.75	20.82	20.89
18.	20.97	21.04	21.11	21.19	21.26	21.33	21.40	21.47	21.54	21.61
19.	21.68	21.75	21.82	21.89	21.96	22.03	22.10	22.17	22.24	22.31
20.	22.38	22.44	22.51	22.58	22.65	22.71	22.78	22.85	22.91	22.98
21.	23.05	23.11	23.18							

temperatures from 0.0 to −21.21°C, the eutectic temperature for H_2O-NaCl. More importantly, Eqn. 1 is sufficiently simple that it is easily solved without a computer. Alternatively, Table 1 may be used to obtain the salinity corresponding to a measured freezing temperature for any temperature between 0.0 and the eutectic temperature of −21.2°C.

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