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THE VOLUMETRIC PROPERTIES OF VAPOR SATURATED AQUEOUS SODIUM
SULFATE SOLUTIONS FROM 0° TO 325°C BASED ON A REGRESSION
OF THE AVAILABLE LITERATURE DATA

by

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Pressure (P) - volume (V) - temperature (T) - composition (X) data for brines are required to establish optimum operating temperatures, pressures, and flow rates for the production of geothermal brine fields; to minimize scaling and corrosion; and to intelligently design turbines for production of electricity. One of the prerequisites for chemical modeling of geothermal brine systems, as well as reservoir modeling, is thermodynamic data derived from the volumetric properties of brines, e.g. partial and apparent molal volumes. The available data for the volumetric properties of brines have been summarized by Potter et al. (1975).

Prior to this, the only fairly extensive tabulation of volumetric data for aqueous, vapor-saturated sodium sulfate solutions was the International Critical Tables (1928) for 1 to 24 wt % solutions from 0° to 100°C. There are no compilations available for solutions at pressures greater than the saturation vapor pressure (Potter, 1976). The purpose of the present report is to supply a set of internally consistent density values for vapor-saturated, aqueous sodium sulfate solutions from 0° to 325°C based on currently available experimental data as summarized by Potter et al. (1975).

The density data presented in Tables 1 and 2 were obtained from a computer regression of the P-V-T-X data from the 35 references cited by Potter et al. (1975). The computer regression of the data was accomplished by using a least squares method in which the individual data points were weighted with respect to the relative uncertainty of the datum. The uncertainties used in the majority of cases were those assigned by the experimentalist; however, in those cases where uncertainties were not

stated, an estimate was supplied on the basis of the experimental method employed in the study.

The data summarized in Table 1 and 2 are for vapor-saturated solutions from 0° to 325°C. These were obtained by regressing the experimental densities at constant composition as a function of temperature and then regressing the resulting smoothed densities at constant temperature as a function of composition. Discordant data were evaluated via Chauvenet's criterion. The appropriate data were then rejected and the densities were refitted. Table 3 summarized the coefficients of the regression equations used to generate Table 1 and 2.

Attempts to obtain internally consistent density data at pressures greater than the saturation pressure were unsuccessful. Due to the lack of consistency of the data, the only method of obtaining a realistic set of internally consistent densities will be by experimental measurement.

Table 1. Densities of vapor saturated Na_2SO_4 solutions. Concentration in molality.

Temp °C	Concentration (molality)												Est. Error in Density
	.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	
0	1.0329	1.0638*	1.0933*	1.1215*	1.1486*	1.1745*	1.1994*	1.2233*	1.2462*	--	--	--	.0005
25	1.0280	1.0573	1.0854	1.1125	1.1385	1.1637	1.1880	1.2116	1.2344*	1.2564*	1.2777*	--	.0002
50	1.0181	1.0466	1.0741	1.1006	1.1262	1.1510	1.1749	--**	--**	--**	--**	--**	.0003
75	1.0045	1.0328	1.0600	1.0862	1.1116	1.1362	1.1600	--**	--**	--**	--**	--**	.0002
100	0.989	1.017	1.044	1.070	1.097	1.123	1.149	1.175	1.201	1.227	1.253	--	.003
125	0.973	1.003	1.030	1.057	1.084	1.110	1.136	1.161	1.187	1.212	1.237	--	.005
150	0.953	0.983	1.012	1.039	1.065	1.091	1.117	1.142	1.168	1.193	1.217	--	.005
175	0.933	0.964	0.992	1.019	1.045	1.070	1.095	1.119	1.143	1.166	1.189	1.212	.005
200	0.903	0.938	0.969	0.996	1.023	1.048	1.072	1.096	1.119	1.141	1.163	1.185	.005
225	0.874	0.909	0.940	0.968	0.995	1.021	1.045	1.069	1.092	1.115	1.138	1.160	.005
250	0.841	0.877	0.908	0.937	0.965	0.990	1.015	1.040	1.064	1.087	1.110	1.133	.005
275	0.804	0.840	0.873	0.902	0.931	0.958	0.984	1.010	1.035	--	--	--	.005
300	0.765	0.802	0.835	0.866	0.895	--	--	--	--	--	--	--	.005
325	0.711	0.756	0.797	--	--	--	--	--	--	--	--	--	.010

*Super-saturated solutions

**No data available

Table 2. Densities of vapor saturated Na_2SO_4 solutions. Concentration in weight percent.

Temp °C	Concentration (weight percent)															Est. Error in Density
	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	
0	1.0095	1.0287	1.0480*	1.0674*	1.0871*	1.1070*	1.1272*	1.1477*	1.1686*	1.1897*	1.2111*	1.2328*	--	--	--	.0005
25	1.0061	1.0242	1.0423	1.0608	1.0795	1.0985	1.1179	1.1377	1.1579	1.1785	1.1996	1.2211*	1.2430*	1.2654*	--	.0002
50	0.9968	1.0143	1.0320	1.0500	1.0683	1.0869	1.1060	1.1254	1.1453	1.1656	--	--	--	--	--	.0003
75	0.9835	1.0008	1.0183	1.0361	1.0542	1.0727	1.0916	1.1109	1.1306	1.1507	--	--	--	--	--	.0002
100	0.969	0.986	1.003	1.020	1.038	1.057	1.076	1.096	1.117	1.139	1.162	1.186	1.211	1.238	--	.003
125	0.949	0.969	0.988	1.006	1.024	1.043	1.063	1.083	1.104	1.125	1.148	1.172	1.196	1.222	--	.005
150	0.928	0.949	0.968	0.987	1.006	1.025	1.044	1.064	1.085	1.107	1.129	1.153	1.177	1.203	--	.005
175	0.905	0.928	0.948	0.968	0.986	1.005	1.024	1.044	1.064	1.085	1.106	1.129	1.152	1.176	1.201	.005
200	0.870	0.898	0.921	0.942	0.962	0.985	1.002	1.022	1.042	1.063	1.084	1.105	1.128	1.151	1.174	.005
225	0.840	0.869	0.892	0.913	0.934	0.954	0.974	0.994	1.015	1.036	1.057	1.079	1.101	1.125	1.149	.005
250	0.806	0.835	0.859	0.881	0.902	0.922	0.943	0.963	0.984	1.006	1.027	1.050	1.073	1.097	1.122	.005
275	0.769	0.798	0.822	0.844	0.866	0.887	0.908	0.930	0.952	0.974	0.997	1.020	1.045	--	--	.005
300	0.730	0.759	0.784	0.806	0.828	0.850	0.872	0.894	--	--	--	--	--	--	--	.005
325	0.671	0.704	0.734	0.761	--	--	--	--	--	--	--	--	--	--	--	.010

*Super-saturated solutions

Table 3. Interpolation equation coefficients for Na_2SO_4 solutions.

At 75°C and below, the available data were fit in the form of the apparent molal volume

$$\phi_v = A_0 + B_0 m^{\frac{1}{2}} + C_0 m,$$

where $d = \frac{1000d_0 + M_2 m d_0}{1000 + \phi_v m d_0}$, where d_0 is the density of water.

Temp ($^\circ\text{C}$)	A_0	B_0	C_0	d_0
0	0.6081	18.624	-1.0897	0.999840 g/cm ³
25	10.114	14.890	-1.367	0.997047 g/cm ³
50	14.096	12.381	-0.906	0.988038 g/cm ³
75	14.658	8.497	1.974	0.974844 g/cm ³

Above 75°C , the available data were fit to the equation

$$d = A + B m^{\frac{1}{2}} + C m$$

Temp ($^\circ\text{C}$)	A	B	C
100	0.9582	0.01292	0.09935
125	0.9340	0.03317	0.09012
150	0.9116	0.03999	0.08708
175	0.8839	0.06062	0.07453
200	0.8389	0.09967	0.05792
225	0.8087	0.10078	0.05893
250	0.7745	0.10190	0.06064
275	0.7387	0.09618	0.06753
300	0.6995	0.09483	0.07161
325	0.6397	0.08776	0.10900

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