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# OSMOTIC PRESSURES OF SEA WATER SOLUTIONS COMPUTED FROM EXPERIMENTAL VAPOR PRESSURE LOWERING<sup>1</sup>

BY

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## ABSTRACT

Osmotic pressures of sea water solutions for temperatures between 0 and 35°C and for chlorinities between 5 and 100 ‰ have been computed from experimental vapor pressure measurements.

The osmotic pressure,  $\pi$ , of sea water as a function of chlorinity and temperature is given in Table I. The osmotic pressure was calculated by using the equation

$$\pi = - \frac{RT \ln a_1}{\bar{V}_1 \left( 1 - \frac{\alpha \pi}{2} \right)}$$

TABLE I. SEA WATER OSMOTIC PRESSURE (ATMOSPHERES) FOR VARIOUS TEMPERATURES AND CHLORINITIES

<i>Temp</i> °C <i>Cl</i> ‰	0	5	10	15	20	25	30	35
5	5.4	5.8	5.6	6.2	6.1	5.7	5.6	6.0
10	10.9	11.8	11.3	11.4	11.5	11.5	11.7	11.6
20	21.9	23.5	22.7	23.9	24.6	24.8	24.5	24.7
30	33.1	35.5	37.1	37.6	37.9	39.5	39.6	40.4
40	47.2	47.6	50.2	51.5	52.2	53.7	55.3	56.6
50	61.6	61.9	65.0	68.9	70.7	73.0	74.5	76.6
60	76.1	78.5	83.0	86.5	90.3	94.0	96.4	99.1
70	91.0	95.4	99.9	103.4	108.7	112.7	116.9	120.2
80	109.0	114.8	120.2	126.2	130.8	136.4	139.7	143.6
90	127.5	136.8	142.5	150.8	156.8	163.7	169.8	173.6
100	152.5	159.2	166.9	174.8	181.8	190.5	196.3	203.6

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(Glasstone, 1949), where  $a_1$  is the activity of the water,  $\bar{V}_1$  its partial molal volume at atmospheric pressure, and  $\alpha$  is defined by

$$\bar{V}_p = \bar{V}_1[1 - \alpha(p - p_0)].$$

Thus  $\alpha$  is approximately the compressibility of sea water, which is about  $4 \times 10^{-5} \text{ atm}^{-1}$ ; since  $\pi \leq 200$ ,  $\alpha\pi/2$  is  $< .004$  or  $0.4\%$ ; we have therefore neglected the  $(1 - \alpha\pi/2)$  term. The activity coefficient  $a_1$  was calculated from measurements of vapor pressure lowering made by Arons and Kientzler (1954).  $\bar{V}_1$  was calculated by the equation

$$\bar{V}_1 = \frac{18}{\rho} \left[ 1 + \left( \frac{\partial \ln \rho}{\partial \ln S} \right)_{T,P} \right],$$

where  $\rho$ ,  $S$  are density and salinity respectively.  $\rho$  was assumed to vary linearly with  $S$ , using the densities of Higashi, et al. (1931) and Dorsey (1940); this probably introduces an error of about  $0.4\%$ .

It is estimated that the vapor pressure data have an error of  $2\%$  or  $0.010 \text{ mm Hg}$ , whichever is larger. The error in  $\pi$  corresponding to  $0.010 \text{ mm Hg}$  is shown in Table II.

TABLE II. ESTIMATED ERRORS IN OSMOTIC PRESSURE RESULTS

Temp. (°C)	Estimated Error (atm)	Temp. (°C)	Estimated Error (atm)
0	$\pm 2.8$	20	$\pm .7$
5	2.0	25	.6
10	1.4	30	.5
15	1.0	35	.4

In summary, a reasonable estimate of the maximum error is  $0.8\% + 2\%$ , or  $0.8\% +$  the value given in Table II, whichever is larger.

The numerical data of Table I do not lend themselves readily to empirical curve fitting. We suggest that an individual, wishing to interpolate for intermediate values, plot the data in any manner suited to his needs and draw smooth curves through the given points.

Precipitation was noticed in the samples (used for obtaining vapor pressures) when the chlorinity exceeded  $40 \text{ ‰}$ . Rough data by Thompson (1932) indicated that the amount of precipitation would not be sufficient to affect the results, compared with other errors, in the  $40\text{--}100 \text{ ‰}$  chlorinity range.

Fig. 1 compares our results with values calculated from the equation:

$$\pi = \frac{2.317 TS}{1000 - S},$$

with  $S$  in ‰ and  $\pi$  in atmospheres for 20°C. This equation is based on ideal solution theory and can be obtained from the consideration given by Sverdrup, et al. (1942:67). On the average, values calculated by this method are about 1-2 atm higher than those calculated from vapor pressure data in the 0-30 chlorinity range.

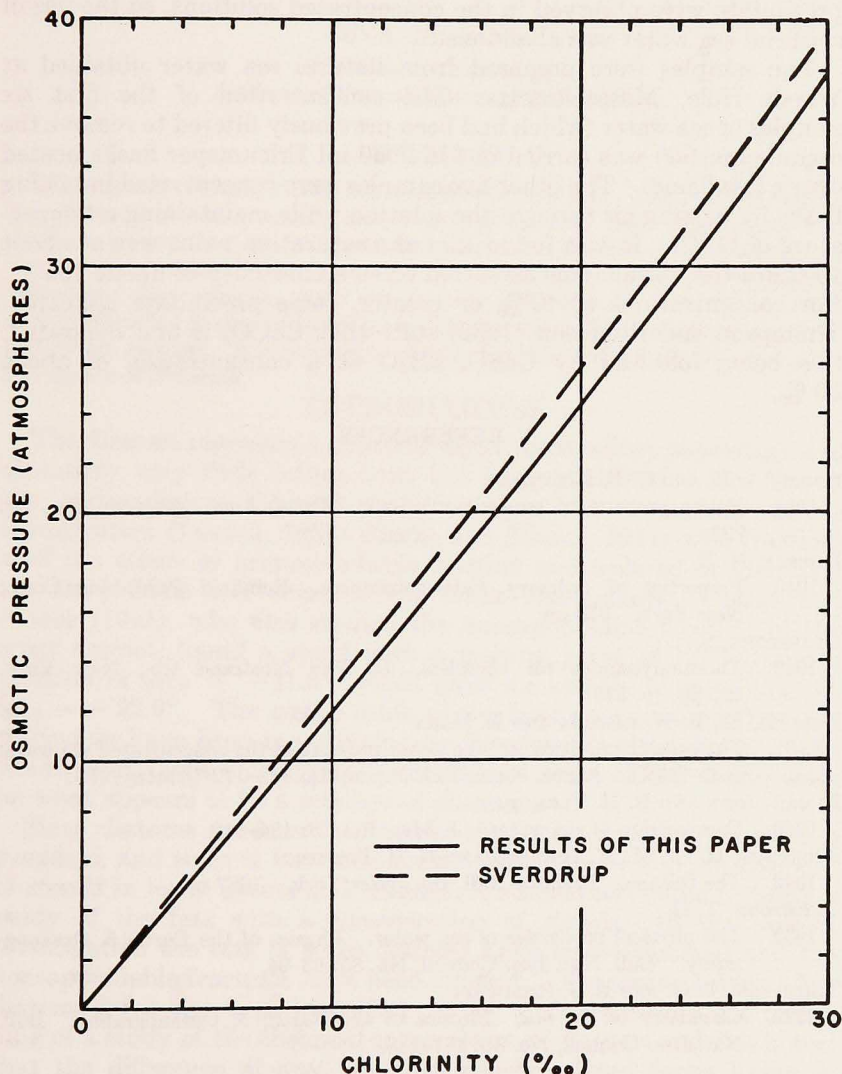


Figure 1. Comparison of the results of this work with equation based on ideal solution theory (Sverdrup, et al., 1942: 67), temperature 20°C.



The preparation of samples for the vapor pressure determinations consisted of obtaining sea salt solutions that varied in concentration from that of natural sea water to a saturated solution. Attempts were made to use a formula for artificial sea water (Lyman and Fleming, 1940) to obtain the concentrated solutions, but large amounts of precipitate were observed in the concentrated solutions, so the use of artificial sea water was abandoned.

The samples were prepared from natural sea water obtained at Woods Hole, Massachusetts. The concentration of the first six samples of sea water (which had been previously filtered to remove the organic matter) was carried out in 2000 ml Erlenmeyer flasks heated over a low flame. The other five samples were concentrated in boiling flasks by passing air through the solution while maintaining a temperature of 80°C. It was found that the saturation point was at about 10 times the normal concentration or at a chlorinity of about 155‰. For concentrations of 40‰ or greater, some precipitate appeared. Thompson and Robinson (1932) state that  $\text{CaCO}_3$  is first deposited, this being followed by  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  at a concentration of about 70‰.

#### REFERENCES

- ARONS, A. B. AND C. F. KIENZLER  
1954. Vapor pressure of sea salt solutions. *Trans. Amer. geophys. Un.*, 35: 722.
- DORSEY, N. E.  
1940. Properties of ordinary water-substances. Reinhold Publishing Corp., New York. 673 pp.
- GLASSTONE, S.  
1949. Thermodynamics for chemists. D. Van Nostrand Co., New York. 522 pp. (p. 373).
- HIGASHI, K., K. NAKAMURA AND R. HARA  
1931. The specific gravities and the vapor pressure of the concentrated sea water at 0–175°C. *J. Soc. chem. Ind. Japan*, 34: 166–172 (Abstr. 72B).
- LYMAN, JOHN AND R. H. FLEMING  
1940. Composition of sea water. *J. Mar. Res.*, 3: 134–146.
- SVERDRUP, H. U., M. W. JOHNSON AND R. H. FLEMING  
1942. *The Oceans*. Prentice-Hall, Inc., New York. 1087 pp.
- THOMPSON, T. G.  
1932. The physical properties of sea water. *Physics of the Earth*, 5, Oceanography. *Bull. Nat. Res. Council*, No. 85: 63–94.
- THOMPSON, T. G. AND R. J. ROBINSON  
1932. Chemistry of the sea. *Physics of the Earth*, 5, Oceanography. *Bull. Nat. Res. Council*, No. 85: 187–188.