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Physical Properties of Seawater Concentrates Obtained by Solar Evaporation

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ABSTRACT

Data on different physical properties of solar seawater concentrates were determined and are presented here. Vapour pressure, surface tension, refractive index, absorption of solar radiations, hydrogen ion concentration and viscosity of seawater concentrates obtained by solar evaporation were determined over density range from 1.021 to 1.377 and temperature range 30 to 100°C. Boiling points and freezing points of bittern were also determined over a density range from 1.021 to 1.377. Conventional methods have been used for their determination.

INTRODUCTION

Data of physical properties of seawater and its concentrates are often required in experimental work on desalination and recovery of chemicals by various processes. Considerable data are available on certain properties such as density, salinity and even vapour pressure of seawater within limited ranges of temperatures and concentration of solution of sea salts, and on pure binary solutions of major oceanic salts of sodium chloride, potassium chloride, magnesium chloride and magnesium sulphate. However, data on other properties of seawater are not available, particularly at high concentration. An attempt was therefore made to determine such properties.

PROCEDURE

Fresh seawater was collected and evaporated in stainless steel trays and samples of solar seawater concentrates were collected at 30°C. Vapour pressure, surface tension and densities of samples maintained at different temperatures up to 65°C in a water bath thermostat were determined. Viscosities were determined up to boiling temperatures in a paraffin oil bath thermostat maintained at different temperature within ±0.1°C. Refractive index, hydrogen ion concentration and absorption of solar radiation were determined on samples maintained at 30°C. The following methods were used for determining the physical properties as described by Findlay (1962). Viscosity by Ostwald Viscometer, surface tension by drop weight method, freezing temperature by equilibrium method, refractive index by Abbe refractometer, absorption of light by photoelectric spectrophotometer and hydrogen ion concentration by a Beckman model K-titrimeter pH meter. Boiling point was determined by Thieles tube apparatus filled with paraffin oil. A thermometer graduated to 0.1°C was used. In general, the accuracy of values presented was estimated within 0.1%.

RESULTS AND DISCUSSION

Table 1 indicates the vapour pressure and activity coefficients of water in solar seawater concentrates. Table 2 shows the variation of density and surface tension of seawater concentrates with temperatures. The refractive index and pH of seawater have been tabulated in Table 3. The variation in absorption of ultra-violet and visible radiation in seawater concentrates with wave length and density at 30°C is presented in Table 4. Table 5 gives the viscosity of seawater concentrates at different temperatures up to boiling point. Table 6 shows the boiling points of seawater concentrates of different densities.

It is evident from Table 1 that the vapour pressure of seawater concentrates decreases as the density of the seawater concentrates increases. However, the

TABLE 1

Vapour pressure and activity coefficient of solar seawater concentrates

Density of concentrates at 30°C	Vapour pressure in mm Hg at temp °C				Activity coefficient at temp °C			
	30	35	45	55	30	35	45	55
1.025	28	38.5	68.5	114.5	0.880	0.913	0.953	0.971
1.074	27	36.5	65.1	107.0	0.849	0.866	0.906	0.908
1.143	25.5	34.5	59.5	95.3	0.801	0.818	0.828	0.808
1.230	23.2	30.4	51.4	81.0	0.729	0.721	0.716	0.687
1.314	18.5	24.7	42.2	62.6	0.582	0.587	0.588	0.531
1.357	12.5	18.0	28.5	45.0	0.393	0.437	0.396	0.382
1.377	10.6	13.7	22.3	36.5	0.333	0.325	0.310	0.310
Sat. soln. of $MgCl_2.6H_2O$ Solid phase	10.1	13.4	21.8	35.2	0.317	0.318	0.303	0.299
Pure water	31.8	42.2	71.9	117.9				

TABLE 2

Variation of density and surface tension of seawater concentrates with temperature

Density (g/cc)				Surface tension (dyn/cm)			
25°C	35°C	45°C	55°C	25°C	35°C	45°C	55°C
1.021	1.017	1.014	1.011	75	73.5	72.0	70.3
1.097	1.093	1.090	1.081	76.6	75.0	72.6	70.0
1.140	1.136	1.132	1.127	79.0	76.0	73.4	70.6
1.211	1.206	1.202	1.199	85.0	81.4	77.6	73.6
1.308	1.304	1.301	1.298	101.0	98.0	94.4	90.4
1.332	1.330	1.325	1.313	113.2	111.0	110.5	104.7

TABLE 3

Variation of refractive index and pH of seawater concentrates with density at 30°C

Density (g/cc)	Refractive index	pH
1.021	1.339	8.0
1.059	1.348	7.9
1.091	1.335	7.8
1.125	1.365	7.65
1.180	1.376	7.4
1.230	1.388	7.05
1.268	1.398	6.7
1.326	1.416	5.7

TABLE 4

Variation in absorption of ultra violet and visible radiation in seawater concentrates at 30°C

Density (g/cc)	Optical density at wave lengths (Å)			
	2700	3500	5000	6500
1.025	0.015	0	0	0
1.040	0.060	0.015	0.0055	0
1.082	0.080	0.050	0.010	0
1.134	0.15	0.055	0.010	0
1.257	0.594	0.070	0.025	0
1.291	0.768	0.109	0.036	0.029
1.342	2.145	0.340	0.050	0.042

vapour pressure increases with temperature. As the temperature increases from 35 to 55°C, the vapour pressure increases from 28 to 114.5 mm Hg. Similarly, the vapour pressure decreases from 28 to 10.6 mm Hg as the density increases from 1.025 to 1.377. It can be seen from Table 2 that density and surface tension of the seawater concentrates decreases as the temperature increases. Table 3 shows that the

TABLE 5

Viscosity (in centipoise) of seawater concentrates at different temperature up to boiling point

Temp. (°C)	S.G.								
	1.095	1.120	1.145	1.182	1.219	1.247	1.257	1.287	1.293
22	1.15	1.45	1.5	1.85	2.2	3.275	3.52	5.15	5.9
50	0.70	0.80	0.875	1.05	1.25	1.80	1.87	2.65	3.30
70	0.675	0.725	0.75	0.725	0.90	1.25	1.35	1.85	2.15
90	–	0.70	0.725	0.70	0.80	0.95	1.050	1.425	1.55
100	0.62	0.63	0.64	0.65	0.70	0.80	0.85	1.250	1.40

TABLE 6.

Boiling points of seawater concentrates of different densities

Density (°Be)	Boiling point (°C)
4.1	100.5
16.5	104.0
21.3	105.8
26.0	108.0
29.0	109.6
30.0	110.4
33.5	113.5
34.8	114.2
37.0	121.0
38.0	125.0

refractive index increases as the density increases. However, the pH of the seawater concentrates decreases with the rise in density. Table 4 indicates that absorption of light in ultra-violet and visible radiation increases as the density increases. Viscosity and boiling point of seawater concentrates increases as the density of the seawater concentrates increases. However, the viscosity (Tables 5 and 6) decreases as the temperature increases.

CONCLUSION

Vapour pressure and activity coefficient of seawater concentrates is directly proportional to temperature whereas viscosity is inversely proportional to temperature i.e. $V\alpha t$, $a\alpha t$, $d\alpha(1/t)$, $\gamma\alpha(1/t)$ and $\eta\alpha(1/t)$, where V = vapour pressure, a is the activity coefficient, η is viscosity and γ is surface tension. Similarly $V\alpha(1/d)$, $a\alpha(1/d)$, $\gamma\alpha d$ and $\eta\alpha d$; where d is the density of seawater concentrates.

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