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Surface Tension of Binary Mixtures of Water + Monoethanolamine and Water + 2-Amino-2-methyl-1-propanol and Tertiary Mixtures of These Amines with Water from 25 °C to 50 °C

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The surface tension of aqueous solutions of monoethanolamine, 2-amino-2-methyl-1-propanol, and monoethanolamine + 2-amino-2-methyl-1-propanol was measured at temperatures from 25 °C to 50 °C. The concentration ranges were 0−100 mass % monoethanolamine and 2-amino-2-methyl-1-propanol, and for tertiary mixtures 50 mass % total amine concentration (the concentration range for each amine was 0−50 mass %). The experimental values were correlated with temperature and mole fraction. The maximum deviation was in both cases always less than 0.5%.

Introduction

The surface tension of mixtures is an important property for the design of contacting equipment with which some chemical processes are carried out, like gas absorption. Surface tension affects the hydrodynamics and transfer rates of such systems, particularly multiphase systems where a gas−liquid interface exits. Most commercial processes for the bulk removal of CO_2 or H_2S from industrial gaseous streams involve the use of amines, frequently amino alcohols. The common aqueous amino alcohol solutions are of monoethanolamine (MEA), diethanolamine (DEA), *N*-methyldiethanolamine (MDEA), and 2-amino-2-methyl-1-propanol (AMP). Aqueous MEA solutions are widely used due to their high reactivity, low solvent costs, ease of reclamation, and low absorption of hydrocarbons (Hagewiesche et al., 1995). However, sterically hindered amines, like 2-amino-2-methyl-1-propanol (AMP), have been proposed as commercially attractive solvents (Tontiwachwuthikul et al., 1992; Xu et al., 1996), because the formation of carbamates is inhibited.

Recently, the use of blended amines (solutions of tertiary + secondary or tertiary + primary amines) has also been proposed (Rangwala et al., 1992). The advantages in this respect include their loading capacity, faster reaction rate, and a great savings in energy requirements.

The objective of this work was to measure the surface tension of the binary aqueous solutions of MEA and of AMP, over the entire concentration range, and tertiary mixtures of MEA + AMP + water, at temperatures of 25 °C to 50 °C. The total amine concentration for the tertiary mixtures was held constant at 50 mass %, and the MEA/AMP mass % ratio was varied from 0/50 to 50/0, in 10 mass % steps.

Experimental Section

Aqueous solutions of monoethanolamine, 2-amino-2-methyl-1-propanol, and monoethanolamine + 2-amino-2-methyl-1-propanol were prepared with distilled-deionized water. Alkanolamines were Merck products of nominal purity >99% for the MEA and >98% for the AMP. All the solutions were prepared by mass with deviations of less than 0.3% from the desired nominal concentration. For all binary mixtures, the values of the mole fraction, x_A, correspond to 0−100 mass %, at 10 mass % intervals, of MEA and AMP.

Table 1. Surface Tension (σ/mN m^{-1}) of Monoethanolamine (A) + Water (B)

	t/°C					
x_A	25	30	35	40	45	50
0.000	72.01	71.21	70.42	69.52	68.84	67.92
0.015	68.45	67.66	66.86	65.99	65.32	64.40
0.032	65.97	65.17	64.41	63.50	62.83	61.92
0.049	64.09	63.29	62.51	61.63	60.96	60.05
0.069	62.63	61.84	51.06	60.17	59.49	58.59
0.112	60.41	59.61	58.84	57.94	57.27	56.36
0.164	58.74	57.94	57.15	56.27	55.58	54.67
0.228	57.31	56.52	55.74	54.84	54.16	53.25
0.307	55.99	55.20	54.43	53.52	52.84	51.93
0.407	54.66	53.86	53.07	52.18	51.49	50.58
0.541	53.18	52.37	51.58	50.69	50.00	49.09
0.726	51.38	50.57	49.77	48.88	48.18	47.27
1.000	48.95	48.14	47.34	46.43	45.73	44.81

Table 2. Surface Tension (σ/mN m^{-1}) of 2-Amino-2-methyl-1-propanol (A) + Water (B)

	t/°C					
x_A	25	30	35	40	45	50
0.000	72.01	71.21	70.42	69.52	68.84	67.92
0.011	59.74	59.13	58.58	57.93	57.30	56.63
0.022	53.44	52.87	52.30	51.72	51.12	50.48
0.034	49.53	49.00	48.44	47.85	47.22	46.58
0.048	46.87	46.30	45.75	45.17	44.52	43.94
0.063	44.95	44.36	43.77	43.19	42.58	41.95
0.080	43.41	42.85	42.26	41.66	41.05	40.43
0.119	41.22	40.63	40.02	39.40	38.76	38.17
0.168	39.58	38.98	38.37	37.76	37.14	36.50
0.232	38.25	37.63	37.01	36.41	35.76	35.11
0.320	37.00	36.37	35.74	35.12	34.48	33.85
0.447	35.63	35.01	34.41	33.78	33.15	32.50
0.645	33.94	33.30	32.75	32.14	31.54	30.85
1.000	31.37	30.80	30.20	29.64	29.04	28.44

Surface tension was determined at 5 deg intervals, between 25 °C and 50 °C, using a Traube stalagmometer and a Prolabo tensiometer, which employs the Wilhemy plate principle (Lin et al., 1990; Van der Bogaert and Joos, 1980). The detailed experimental procedure has been described elsewhere (Vázquez et al., 1995a,b). In general, each surface tension value reported was an average of 5−10 measurements, where the maximum deviations from the average value were always less than 0.4%. The precision of the temperature control in all these measurements was

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Table 3. Surface Tension (σ/mN m^{-1}) of Monoethanolamine + 2-Amino-2-methyl-1-propanol + Water

	% mass MEA/% mass AMP					
t/°C	0/50	10/40	20/30	30/20	40/10	50/0
25	39.58	42.55	44.67	47.91	51.85	57.31
30	38.98	41.95	43.98	46.96	50.75	56.52
35	38.37	41.30	43.30	45.94	49.60	55.74
40	37.76	40.73	42.55	44.89	48.46	54.84
45	37.14	40.10	41.89	43.87	47.30	54.16
50	36.50	39.49	41.10	42.88	46.15	53.25

Table 4. Surface Tension Parameters K_1 and K_2 (Eq 1) for Aqueous Alkanolamines Binary Mixtures

organic component (A)	x_A	K_1	K_2	x_A	K_1	K_2
monoethanolamine	0.000	76.0852	−0.1609	0.228	61.3633	−0.1620
	0.015	72.4767	−0.1610	0.307	60.0471	−0.1623
	0.032	70.0052	−0.1611	0.407	58.7257	−0.1627
	0.049	68.1033	−0.1612	0.541	57.2481	−0.1632
	0.069	66.6600	−0.1613	0.726	55.4724	−0.1639
	0.112	64.4414	−0.1615	1.000	53.0800	−0.1648
	0.164	62.7914	−0.1617			
2-amino-2- methyl-1-propanol	0.000	76.0852	−0.1626	0.119	44.0269	−0.1147
	0.011	62.8662	−0.1239	0.168	42.2726	−0.1133
	0.022	56.4791	−0.1209	0.232	40.8701	−0.1122
	0.034	52.5348	−0.1192	0.320	39.5805	−0.1111
	0.048	49.8429	−0.1185	0.447	38.1847	−0.1101
	0.063	47.8495	−0.1175	0.645	36.4929	−0.1085
	0.080	46.3019	−0.1164	1.000	33.9257	−0.1071

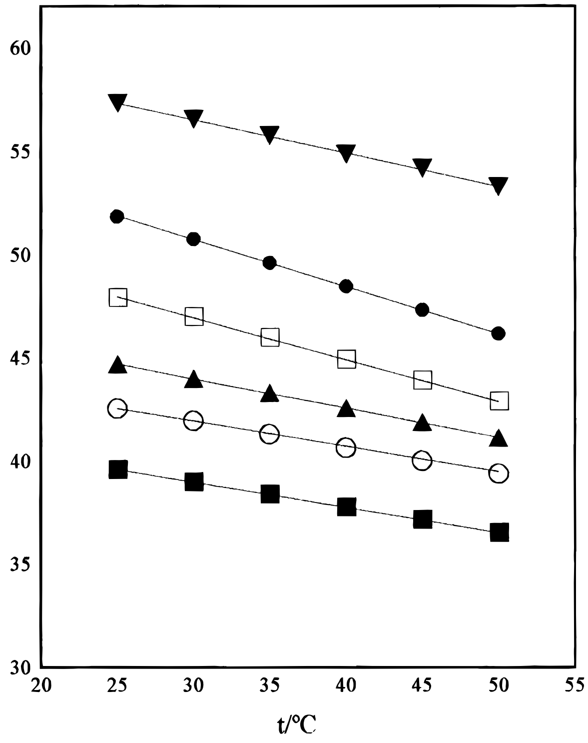

Figure 1. Surface tension of monoethanolamine + 2-amino-2-methyl-1-propanol + water as a function of temperature at different relations % mass MEA/% mass AMP: (■) 0% MEA/50% AMP; (○) 10% MEA/40% AMP; (▲) 20% MEA/30% AMP; (□) 30% MEA/20% AMP; (●) 40% MEA/10% AMP; (▼) 50% MEA/0%AMP.

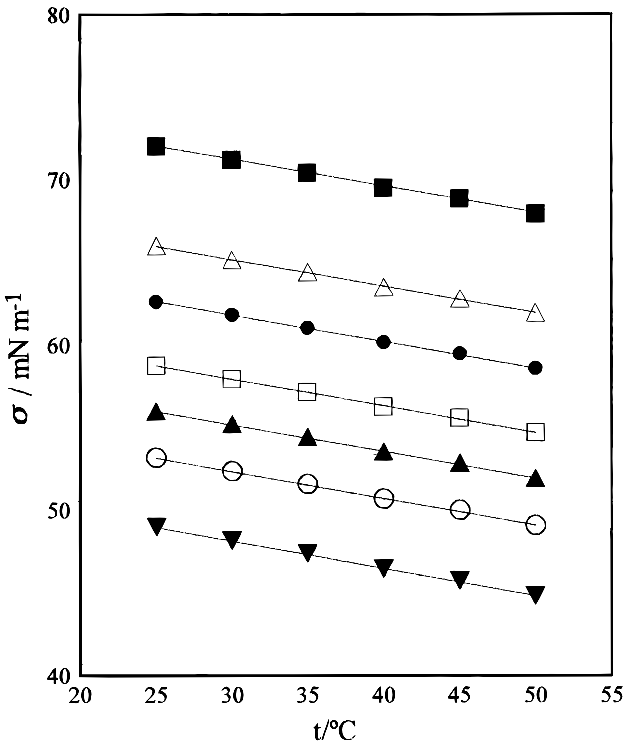

Figure 2. Surface tension of monoethanolamine (A) + water (B) as a function of temperature at different mole fractions of MEA: (■) water; (△) $x_A = 0.032$; (●) $x_A = 0.069$; (□) $x_A = 0.164$; (▲) $x_A = 0.307$; (○) $x_A = 0.541$; (▼) $x_A = 1.000$; (—) eq 1.

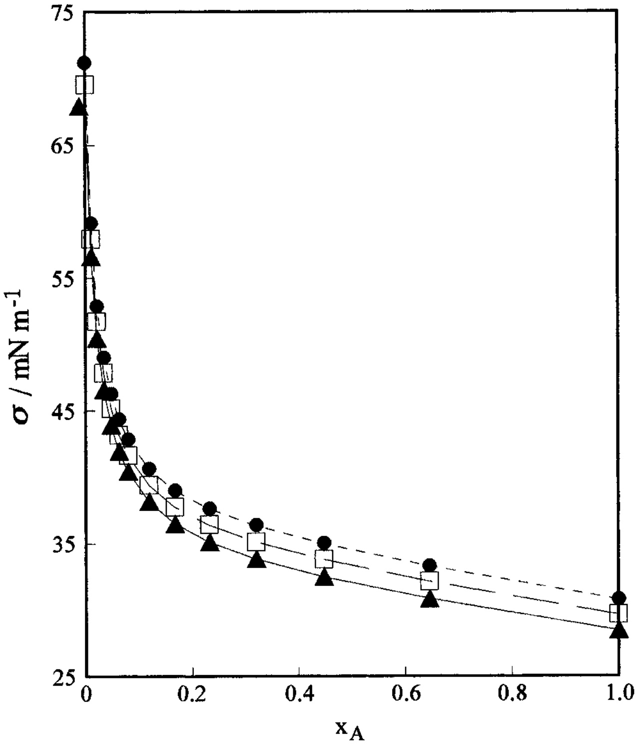

Figure 3. Surface tension of 2-amino-2-methyl-1-propanol (A) + water (B) plotted against the mole fraction of alkanolamine, x_A: (●) experimental, 30 °C; (- - -) calculated, 30 °C; (□) experimental, 40 °C; (- - -) calculated, 40 °C; (s) experimental, 50 °C; (—) calculated, 50 °C.

±0.05 deg and the accuracy of the measurements was ±0.02 mN m^{-1}.

Results and Discussion

The surface tension data for MEA, AMP, and MEA + AMP aqueous solutions are tabulated in Tables 1−3, respectively. In all systems studied surface tension decreased with increasing temperature for any given concentration or mass % ratio of amine. Figure 1 shows the variation of surface tension with the temperature for the MEA + AMP + water solutions.

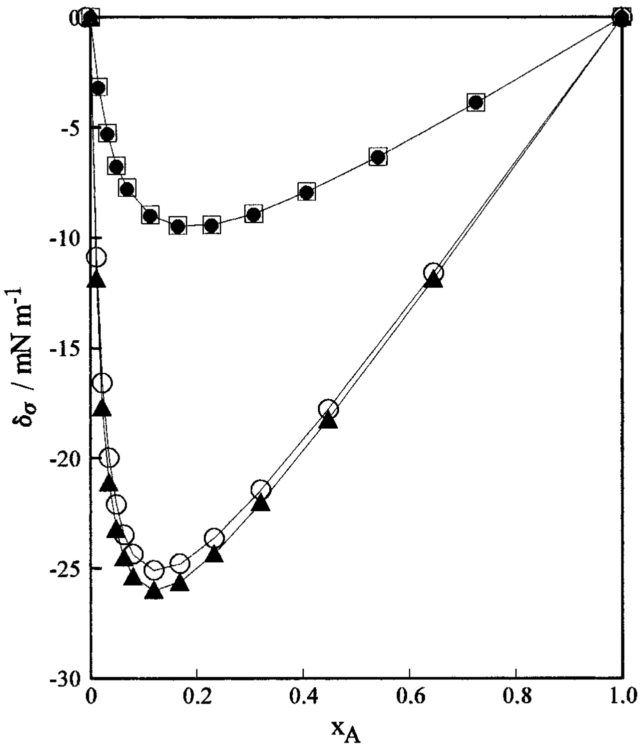

Figure 4. Surface tension deviation, δ_σ, as a function of the mole fraction of alkanolamine, x_A: (●) monoethanolamine, 25 °C; (□) monoethanolamine, 50 °C; (▲) 2-amino-2-methyl-1-propanol, 25 °C; (○) 2-amino-2-methyl-1-propanol, 50 °C; (—) calculated from eqs 2 and 3.

Table 5. Surface Tension Parameters *a* and *b* (Eq 2) for Aqueous Alkanolamine Binary Mixtures

organic component (A)	t/°C	a	b
monoethanolamine	25	0.6272	0.9465
	30	0.6264	0.9464
	35	0.6257	0.9463
	40	0.6250	0.9462
	45	0.6245	0.9461
	50	0.6239	0.9460
2-amino-2-methyl-1-propanol	25	0.8293	0.9807
	30	0.8306	0.9803
	35	0.8311	0.9799
	40	0.8325	0.9794
	45	0.8335	0.9792
	50	0.8343	0.9788

The surface tensions of binary mixtures were correlated with temperature by the following expression (Jasper, 1972), proposed for the pure components:

$$\sigma/\mathrm{mN{\cdot}m^{-1}} = K_1 - K_2 t/°\mathrm{C} \qquad (1)$$

Equation 1 also fitted the data of Tables 1 and 2 for each concentration, with deviations less than 0.5%. Figure 2 shows the results for MEA + water as an example. The fitted values of K_1 and K_2 are listed in Table 4.

For a given temperature, the surface tension of the binary mixtures decreased as the alkanolamine concentration increased. This trend is nonlinear, the change in surface tension caused by a given change in alkanolamine concentration being larger at low concentrations than at high concentrations. We fit the equation

$$\frac{\sigma_w - \sigma}{\sigma_w - \sigma_A} = \left(1 + \frac{a x_w}{1 - b x_w}\right) x_A \qquad (2)$$

to the data for each solute (where σ_w and σ_A are the surface tensions of pure water and pure alkanolamine, respectively, and x_w and x_A are the mole fractions of water and alkanolamine). The values of the fitted parameters a and b in eq 2 are listed in Table 5. The experimental and estimated surface tensions for AMP + water are compared in Figure 3. The deviations are less than 0.2% in all such plots.

The surface tension deviation is defined as the difference between the surface tension of the mixture and that expected on the basis of a mole fraction average,

$$\delta_\sigma = \sigma - (\sigma_w x_w + \sigma_A x_A) \qquad (3)$$

Plotting δ_σ against the mole fraction of the amine (Figure 4) shows that the deviation from a mole fraction average is larger for the tertiary amine than for the primary amine.

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