tions. As the gas constant, 1.98721 cal/mol has been used.

Plots of the experimental data are provided in Figures 1 and 2. Azeotropic behavior was not found.

As a private communication, our measurements were used by Skjold-Jørgensen et al. (*20*) for the data base of the determination of the interaction between the glycol group "DOH" and the alcohol group "OH" in the UNIFAC method.

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Glossary

A, B, C	constants of the Antoine equation
A_{ij}	parameter used in Margules, van Laar, Wilson, and UNIQUAC equations
P_i^s	vapor pressure of pure component i, mmHg
d	density, g/mL
n_D	refraction index
q_i	pure-component area parameter of component i
r_i	pure-component volume parameter of component i
t	temperature, °C
u_{ij}	interaction energy parameter in UNIQUAC equation
v_i	molar liquid volume of component i, mL/mol
x_i	liquid-phase mole fraction of component i
y_i	vapor-phase mole fraction of component i

Greek Letters

γ_i	activity coefficient of component i

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Density, Viscosity, Surface Tension, and Carbon Dioxide Solubility and Diffusivity of Methanol, Ethanol, Aqueous Propanol, and Aqueous Ethylene Glycol at 25 °C

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Density, viscosity, surface tension, and carbon dioxide solubility and diffusivity, at 25 °C, are reported for methanol, ethanol, and aqueous propanol solutions over the complete composition range and for aqueous ethylene glycol solutions for glycol mole fractions between 0 and 0.2. Where comparisons were possible, the agreement with previous data is satisfactory.

In recent studies of mass transfer in turbulent falling liquid films (*1*, 2), test liquids having a wide range of pertinent thermodynamic and transport properties were required. In particular it was desired to conveniently achieve a range of viscosity and surface tension, for which aqueous ethylene glycol and aqueous propanol solutions at 25 °C were chosen; methanol and ethanol were also utilized. The relevant properties were density, viscosity, surface tension, and carbon dioxide solubility and diffusivity, for which the data in the literature were incomplete. Thus a comprehensive set of independent measurements was obtained in our laboratory and is reported here. Useful prior work includes that of Hayduk and Malik (*3*) and Mikhail and Kimmel (*4*).

Experimental Procedures

Carbon Dioxide Solubilities. The CO_2 solubility was determined by saturating the test liquids in a gas bubbler immersed in an isothermal bath. Liquid-phase CO_2 concentrations were determined by using a standard wet chemistry technique (*1*). The partial pressures of CO_2 over the liquids were calculated by subtracting the vapor pressures of the liquids from the measured total pressures. Special care was taken to minimize the net evaporation rate from the bath, so that bubbling for an extended period of time did not cause a significant composition change of the test solution.

Molecular Diffusivity of Carbon Dioxide. The "sphere cell" method was used to measure liquid-phase diffusivities, which involved absorbing CO_2 into a laminar ripple free liquid film formed on the surface of a 3.78-cm o.d. sphere. The con-

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Table I. Liquid Properties at 25 °C

liquid	ρ, kg/m^3	$10^6\nu$, m^2/s	$10^3\sigma$, N/m	c_{sat,CO_2}, kmol/(m^3 atm)	$10^9 D_{CO_2}$, m^2/s	ν/D_{CO_2}	$10^3\nu\cdot(\rho^3 g/\sigma^3)^{1/4}$
methanol	786.6	0.695	22.2	0.159	8.37	83	3.17
ethanol	785.0	1.400	22.7	0.125	3.88	360	6.28
Aqueous Propanol Solutions							
X = 0.0	997.0	0.893	72.2	0.0346	1.95	458	2.02
0.02	987.2	1.169	41.8	0.0332	1.71	683	3.90
0.05	975.6	1.613	30.5	0.0318	1.43	1128	6.84
0.10	954.2	2.178	26.3	0.0334	1.42	1534	10.14
0.20	916.8	2.790	25.9	0.0429	1.57	1777	12.75
0.50	849.4	2.884	24.9	0.0685	1.93	1494	12.79
1.00	800.0	2.428	23.4	0.0963	2.73	889	10.79
Aqueous Ethylene Glycol Solutions							
X = 0.00	997	0.898	72	0.0346	1.96	458	2.02
0.052	1015	1.30	65	0.0302	1.58	822	3.20
0.12	1036	1.88	61	0.0279	1.22	1540	4.95
0.20	1053	2.75	57.5	0.0270	1.02	2700	7.66

struction of the cell was similar to that of Davidson and Cullen (*5*), except that an improved liquid distributor and takeoff tube were developed. The liquid flow rate was measured by using a rotameter while the gas absorption rate was obtained by using a soap film gas flow meter. The theory used for data reduction was developed in ref *5* and is based on the solution of the steady-state species conservation equation in the liquid film using a parabolic velocity distribution. The effect of solute concentration on diffusion coefficient was assumed to be negligible on the basis of the experimental study of Tang and Himmelblau (*6*).

Density, Viscosity, and Surface Tension. Densities were measured by using a 10-mL adjusted specific gravity bottle, while viscosities were measured by using a Cannon-Fenske (size 50) capillary viscometer. Surface tensions were measured by the ring method using a Du Noüy surface tensiometer. The apparent surface tension registered by the instrument was corrected by using the equation suggested by Zuidema and Walters (*7*).

Results

Table I shows the measured data, together with the dimensionless property groupings ν/D and $\nu(\rho^3 g/\sigma^3)^{1/4}$. Some pertinent comparisons with prior data follow. The solubility in ethanol agrees exactly with the value in the International Critical Tables (*8*). For aqueous ethylene glycol the density, viscosity, and CO_2 solubility agree with the data of Hayduk and Malik (*3*): the CO_2 diffusivity measured for mole fractions of glycol, X, in the range 0–0.2 by using a sphere cell extrapolate smoothly to the values measured in ref *3* by using a stationary capillary cell for X greater than 0.25. For aqueous propanol solutions the density and the viscosity agree well with the data of Mikhail and Kimmel (*4*).

Also given in Table I are the dimensionless groups Schmidt number, Sc = ν/D, for CO_2 and the capillarity-buoyancy number Cb = $\nu(\rho^3 g/\sigma^3)^{1/4}$. Both of these groups are used in the correlation of experimental data for rates of gas absorption into turbulent falling liquid films.

Glossary

c_{sat}	saturation concentration of solute at a gas-phase partial pressure of 1 atm, kmol/(m^3 atm)
D	diffusivity, m^2/s
g	gravitational acceleration, 9.81 m/s^2
X	mole fraction of glycol or propanol
ν	kinematic viscosity, m^2/s
ρ	density, kg/m^3
σ	surface tension, N/m

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Viscosities of Concentrated Aqueous Solutions of Some 1:1, 2:1, and 3:1 Nitrates at 25 °C

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The viscosities and densities of concentrated aqueous solutions of nitrates of K, Na, Cd, Cu(II), Ba, Pb, Sr, Mg, Ni, Zn, and Fe(III) have been measured at 25 °C. The relative viscosities have been fitted to an extended Jones–Dole-type equation.

Introduction

Recently there has been noticeable progress in the theory of the viscosity of electrolyte solutions at concentrations beyond the applicability of the classical Jones–Dole equation (*1a*, *2*). The equation of Breslau and Miller (*3*) is derived from the Ein-

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