Physical, Thermodynamic, and Transport Properties for Carbon Dioxide and Nitrous Oxide in Solutions of Diethanolamine or Di-2-propanolamine in Polyethylene Glycol

Richard A. Davis, Ronald E. Menéndez, and Orville C. Sandall*

Department of Chemical and Nuclear Engineering, University of California, Santa Barbara,
Santa Barbara, California 93106

Several properties important for the absorption of carbon dioxide and nitrous oxide in solutions of diethanolamine (DEA) or di-2-propanolamine (DIPA) and polyethylene glycol (PEG 400, average molecular weight 400) were determined experimentally. These properties include the density and viscosity of the amine–PEG 400 solutions, the physical solubility and diffusivity of CO_2 in PEG 400, and the physical solubility and diffusivity of N_2O in DEA–PEG 400 and DIPA–PEG 400 solutions. The results were obtained for 0–30 wt % amine in PEG 400 over the temperature range of 20–40 °C. The results were correlated for temperature and composition dependence.

The polar organic solvent polyethylene glycol (PEG 400) is of interest for gas absorption processes because of its large capacity to absorb carbon dioxide. The addition of amines enhances the solvent's capacity and selectivity for CO_2 absorption. The two secondary alkanolamines diethanolamine (DEA) and di-2-propanolamine (DIPA) are among the most commonly used amines for acid gas treating because of their thermal stability and favorable reaction kinetics with CO_2. These amines are also miscible with PEG 400. In this work several properties of the CO_2–amine–PEG 400 gas–liquid system were determined experimentally. These properties are the density and viscosity of the amine–PEG 400 solvents, the solubility and diffusivity of CO_2 and N_2O in PEG 400, and the solubility and diffusivity of N_2O in solutions of PEG 400 with DEA or DIPA. The solubility and diffusivity of CO_2 in the amine–PEG 400 solutions could not be determined directly due to the reaction of CO_2 with the amine. Thus, the similarity between the CO_2 and N_2O molecules can be exploited to approximate the behavior of CO_2 in reactive solvents where N_2O is inert.

N_2O Analogy

The N_2O molecule is similar to the CO_2 molecule in configuration, molecular weight, electronic structure, and molar volume. Good estimates of solubility have been generated by equating the ratio of the solubilities of N_2O and CO_2 in nonreacting solvents to their ratio in reacting solvents. The solubility ratio in terms of Henry's constants can be written as follows:

$$H_{CO_2}/H^\circ{}_{CO_2} \cong H_{N_2O}/H^\circ{}_{N_2O} \qquad (1)$$

where H° is Henry's constant of the gas in a nonreacting solvent (PEG 400 for this work). Laddha et al. (*1*) showed that this approximation is valid for a variety of aqueous solutions of organic solvents similar in structure to DEA and that the ratio of the solubility of CO_2 to N_2O in these cases is relatively constant and equal to 1.37 ± 0.04. The N_2O analogy can also be used to estimate the diffusivity of CO_2 in the reacting amine solutions according to the following relationship (*2, 3*):

$$D_{CO_2}/D^\circ{}_{CO_2} \cong D_{N_2O}/D^\circ{}_{N_2O} \qquad (2)$$

where D° indicates the diffusivity of the solvated species in a nonreactive solvent.

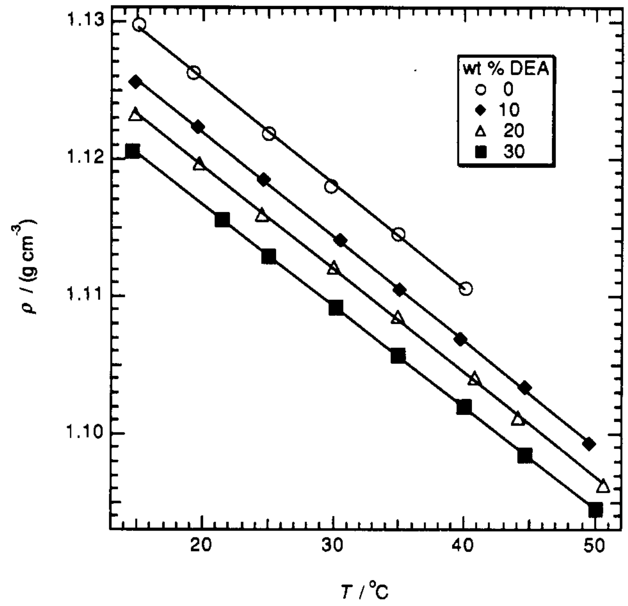

Figure 1. Density vs temperature for DEA–PEG 400 solutions.

Table I. Experimental Results for the Density of 0–30 wt % DEA in PEG 400

	ρ/(g cm^{-3})			
T/°C	0 wt %	10 wt %	20 wt %	30 wt %
15	1.1298	1.1256	1.1232	1.1206
20	1.1262	1.1223	1.1196	1.1155
25	1.1218	1.1185	1.1159	1.1129
30	1.1180	1.1140	1.1121	1.1091
35	1.1145	1.1104	1.1084	1.1057
40	1.1106	1.1068	1.1040	1.1019
45		1.1033	1.1011	1.0985
50		1.0993	1.0963	1.0945

Solvent Preparation

The DEA and PEG 400 were obtained from Fisher Scientific. The DIPA was obtained from the Eastman Kodak Co. The amines were >99% pure. The PEG 400 consisted of a mixture of polyethylene glycols with an average molecular weight of 400. The amine–PEG 400 samples were degassed by heating while being stirred under vacuum. Care was taken not to overheat the PEG 400 because it is thermally unstable

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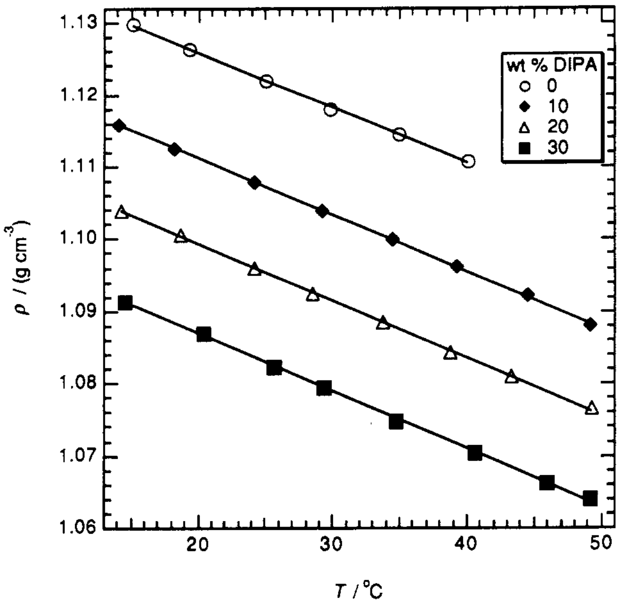

Figure 2. Density vs temperature for DIPA-PEG 400 solutions.

Table II. Experimental Results for the Density of 0–30 wt % DIPA in PEG 400

	ρ/(g cm^{-3})			
T/°C	0 wt %	10 wt %	20 wt %	30 wt %
15	1.1298	1.1158	1.1038	1.0913
20	1.1262	1.1123	1.1006	1.0869
25	1.1218	1.1077	1.0960	1.0823
30	1.1180	1.1039	1.0923	1.0794
35	1.1145	1.0999	1.0884	1.0749
40	1.1106	1.0960	1.0843	1.0703
45		1.0921	1.0809	1.0661
50		1.0879	1.0764	1.0639

Table III. Constants for Use in Equation 4 for the Density of DEA–PEG 400 Solutions (Equation Predicts Density Data to within ±0.011%)

i	a_i	b_i	c_i	unit
1	1.1410	-3.312×10^{-4}	0	g cm^{-3}
2	-7.622×10^{-4}	-2.651×10^{-7}	3.997×10^{-8}	g cm^{-3} K^{-1}

Table IV. Constants for Use in Equation 4 for the Density of DIPA–PEG 400 Solutions (Equation Predicts Density Data to within ±0.020%)

i	a_i	b_i	c_i	unit
1	1.1410	-1.289×10^{-3}	0	g cm^{-3}
2	-7.622×10^{-4}	-3.601×10^{-6}	8.881×10^{-8}	g cm^{-3} K^{-1}

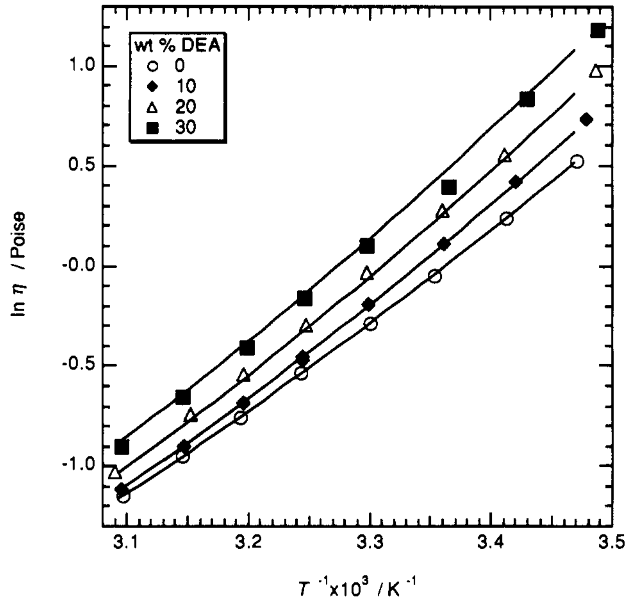

Figure 3. Dynamic viscosity vs temperature for DEA–PEG 400 solutions.

Table V. Experimental Results for the Kinematic Viscosity of 0–30 wt % DEA in PEG 400

	ν/St			
T/°C	0 wt %	10 wt %	20 wt %	30 wt %
15	1.4930	1.8417	2.3671	2.9068
20	1.1260	1.3485	1.5561	2.0548
25	0.8492	0.9934	1.1808	1.3342
30	0.6672	0.7374	0.8693	0.9985
35	0.5253	0.5639	0.6703	0.7691
40	0.4208	0.4550	0.5265	0.6036
45	0.3479	0.3679	0.4321	0.4707
50	0.2865	0.2979	0.3264	0.3704

Table VI. Experimental Results for the Kinematic Viscosity of 0–30 wt % DIPA in PEG 400

	ν/St			
T/°C	0 wt %	10 wt %	20 wt %	30 wt %
15	1.4930	1.8530	2.2637	2.9181
20	1.1260	1.2373	1.5587	1.9631
25	0.8492	0.9385	1.0954	1.3432
30	0.6672	0.7144	0.7860	0.9977
35	0.5253	0.5420	0.6270	0.7107
40	0.4208	0.4365	0.4411	0.5228
45	0.3479	0.3444	0.3662	0.4054
50	0.2865	0.2695	0.3021	0.3529

at high temperatures. This is evidenced by a change in the color of the normally clear, colorless PEG 400 to brown. The amine concentrations in the samples were determined to ±0.05 wt % by titration with 0.1 N HCl to a pH 4.5 end point.

Density

The density of the liquid solutions was determined with a 49.4390 cm^3 pycnometer of the Gay-Lussac type. The procedure for determining the density consisted of charging the pycnometer with a liquid sample and immersing the device in a constant-temperature bath until the liquid sample temperature was the same as the bath temperature. The bath temperature was maintained within ±0.05 °C of the desired set point. The temperature was measured with a mercury-filled glass thermometer. Liquid sample was added or removed from the pycnometer in order to keep the volume of the sample the same as the volume of the pycnometer. At the desired temperature, the device was weighed with and without the sample and the sample weight was determined by difference. The density was calculated as the ratio of the sample weight to the pycnometer volume. The measurements were done at 5 °C temperature intervals for the temperature range of 15–50 °C and a concentration range of 0–30 wt % amine in PEG 400.

The results for the density were correlated for temperature and amine concentration dependence by the following empirical equation:

$$\rho/(\text{g cm}^{-3}) = r_1 + r_2(T/°\text{C}) \tag{3}$$

where

$$r_i = a_i + b_i w + c_i w^2 \tag{4}$$

T is the liquid temperature, and w is the weight percent of the amine in PEG 400. The density results for DEA and DIPA in PEG 400 are listed in Tables I and II. Müller and Rasmussen (*4*) recently reported values for the density of PEG 400 at 24.90 and 34.90 °C to be 1.122 30 and 1.113 72

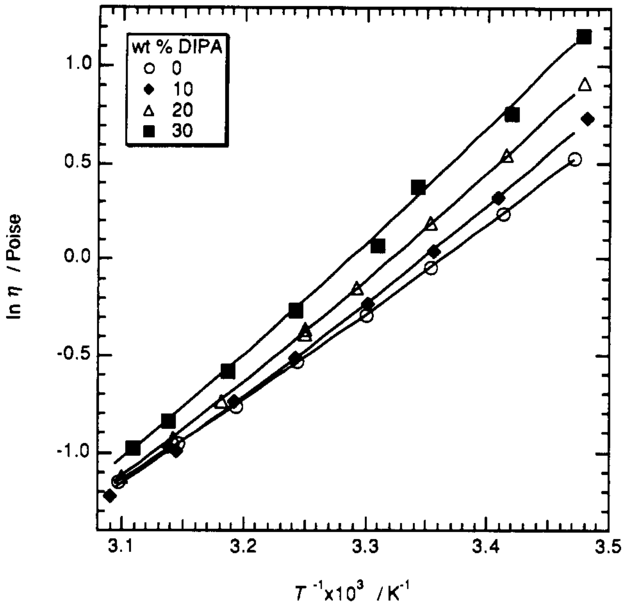

Figure 4. Dynamic viscosity vs temperature for DIPA-PEG 400 solutions.

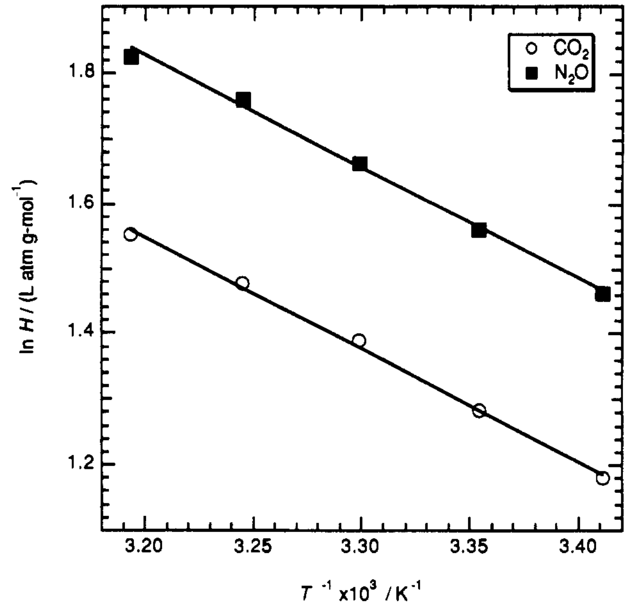

Figure 5. Clausius–Clapeyron-type correlation of Henry's constant for the solubility of CO_2 and N_2O in PEG 400.

Table VII. Constants for Use in Equation 7 for the Dynamic Viscosity of DEA–PEG 400 Solutions (Equation Predicts Viscosity Data to within 1.6%)

i	a_i	b_i	c_i	unit
1	-45.14	-0.9828	0.020 40	
2	9061	167.9	-3.219	K
3	0.049 34	0.001 437	-3.143×10^{-5}	K^{-1}

Table VIII. Constants for Use in Equation 7 for the Dynamic Viscosity of DIPA–PEG 400 Solutions (Equation Predicts Viscosity Data to within 1.3%)

i	a_i	b_i	c_i	unit
1	-45.14	-1.243	0.028 79	
2	9061	210.3	-4.280	K
3	0.049 34	0.001 819	-4.727×10^{-5}	K^{-1}

Table IX. Experimental Results for Henry's Constant for CO_2 and N_2O Solubility in PEG 400

T/°C	H_{CO_2}/ (L atm mol^{-1})	H_{N_2O}/ (L atm mol^{-1})	T/°C	H_{CO_2}/ (L atm mol^{-1})	H_{N_2O}/ (L atm mol^{-1})
20.0	3.26	4.32	35.0	4.38	5.82
25.0	3.61	4.76	40.0	4.72	6.20
30.0	4.01	5.27			

Table X. Constants for Use in Equation 10 for Henry's Constant for CO_2 in PEG 400 (Equation Predicts Solubility Data to within ±2.6%)

i	a_i	unit
1	7.036	
2	-14 260	J mol^{-1}

Table XI. Experimental Results for Henry's Constant for the Solubility of N_2O in 0–30 wt % DEA in PEG 400

	H_{N_2O}/(L atm mol^{-1})			
T/°C	0 wt %	10 wt %	20 wt %	30 wt %
20.0	4.32	4.49	8.68	11.8
25.0	4.76	5.28	9.24	13.2
30.0	5.27	6.00	11.8	15.3
35.0	5.82	6.46	12.5	16.6
40.0	6.20	6.84	13.4	16.5

g cm^{-3}, respectively. The results from this work are in agreement with their values within ±0.07%.

The linear temperature dependence of the density of DEA–PEG 400 and DIPA–PEG 400 is illustrated in Figures 1 and 2. The results for density have been correlated for temperature and concentration dependence according to eq 3 by a linear least-squares fit of the results. The correlation parameters are given in Tables III and IV. The correlations are plotted along with the data in Figures 1 and 2 for comparison. The density correlations for DEA–PEG 400 and DIPA–PEG 400 solutions fit the density results with mean deviations of ±0.011% and ±0.020%, respectively.

Viscosity

The kinematic viscosity was measured with Cannon-Fenske routine viscometers for transparent liquids. The procedure for measuring viscosity consisted of charging the viscometer with a degassed liquid sample and immersing the device in a constant-temperature bath until the sample temperature was at the desired set point. The bath temperature was maintained at the set point within ±0.05 °C. The temperature was measured with a mercury-filled glass thermometer. The liquid was drawn into the upper reservoir with a vacuum. The flow times were measured with a hand-held stopwatch. The measurements were repeated three times at 5 °C temperature intervals for the temperature range of 15–50 °C over a concentration range of 0–30 wt % amine in PEG 400.

The dynamic viscosity, η, is calculated as the product of the liquid density, ρ, and kinematic viscosity, ν, as follows:

$$\eta = \rho\nu \qquad (5)$$

The temperature and concentration dependencies were correlated by a linearized form of the modified Andrade equation (*5*):

$$\ln(\eta/\mathrm{P}) = n_1 + n_2/(T/\mathrm{K}) + n_3(T/\mathrm{K}) \qquad (6)$$

where the density was determined from the correlations of the previous section. The concentration dependence is in the coefficients, n_i:

$$n_i = a_i + b_i w + c_i w^2 \qquad (7)$$

The averaged results for the kinematic viscosity of DEA–PEG 400 and DIPA–PEG 400 solutions are listed in Tables V and VI. The temperature dependence in the form of eq 6 is shown in Figures 3 and 4. Jerome et al. (*6*) reported a value for the dynamic viscosity of PEG 400 at 25 °C as 0.9901 P. The value reported here agrees with their result within 4%. The results of a linear least-squares fit of the data to eq 6 are

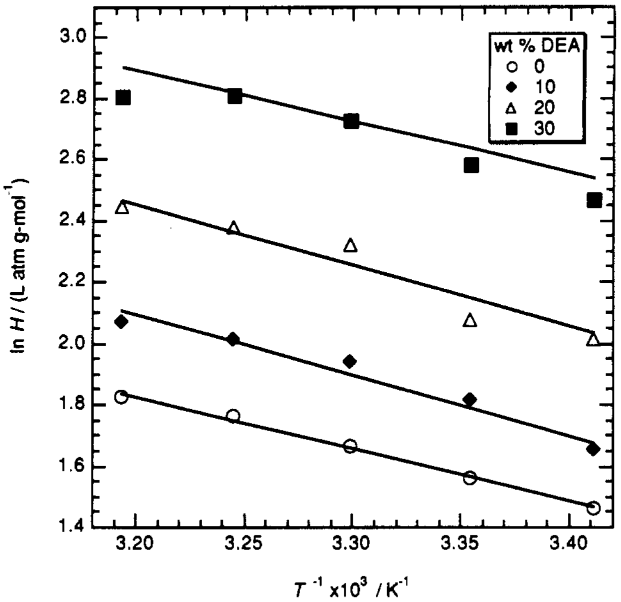

Figure 6. Clausius–Clapeyron-type correlation of Henry's constant for the solubility of N_2O in DEA–PEG 400.

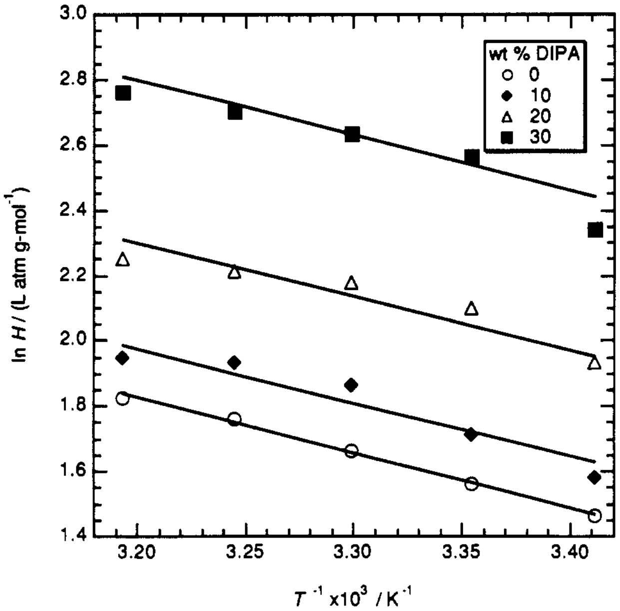

Figure 7. Clausius–Clapeyron-type correlation of Henry's constant for the solubility of N_2O in DIPA–PEG 400.

Table XII. Experimental Results for Henry's Constant for the Solubility of N_2O in 0–30 wt % DIPA in PEG 400

	H_{N_2O}/(L atm mol^{-1})			
T/°C	0 wt %	10 wt %	20 wt %	30 wt %
20.0	4.32	4.39	7.65	10.4
25.0	4.76	5.01	9.02	13.0
30.0	5.27	5.84	9.75	13.9
35.0	5.82	6.24	10.1	14.9
40.0	6.20	6.34	10.5	15.8

also plotted in Figures 3 and 4. The correlation coefficients for eq 7 are listed in Tables VII and VIII. The correlations fit the dynamic viscosity results with mean deviations of ±1.6% and ±1.3% for solutions of DEA–PEG 400 and DIPA–PEG 400, respectively.

Gas Solubility

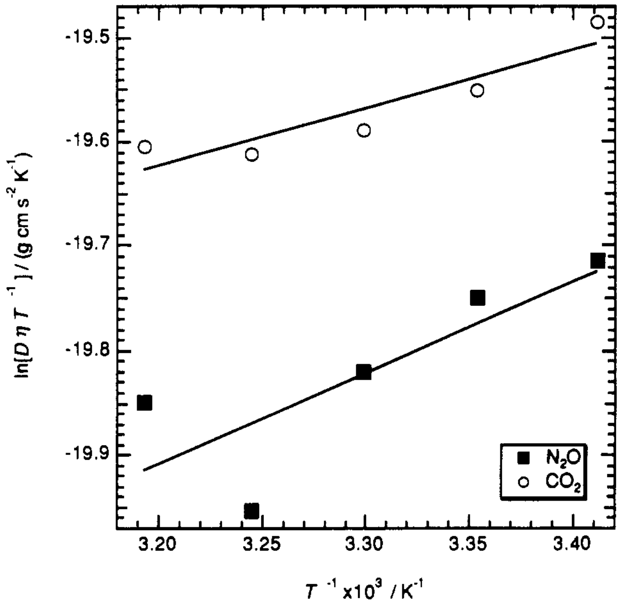

Figure 8. Diffusion coefficients for CO_2 and N_2O in PEG 400.

Table XIII. Constants for Use in Equation 10 for Henry's Constant for N_2O in DEA–PEG 400 (Equation Predicts Solubility Data to within ±9.8%)

i	a_i	b_i	c_i	unit
1	7.277	0.1633	−0.004 365	
2	−14 160	−365.5	12.46	J mol^{-1}

Table XIV. Constants for Use in Equation 10 for Henry's Constant for N_2O in DIPA–PEG 400 (Equation Predicts Solubility Data to within ±7.8%)

i	a_i	b_i	c_i	unit
1	7.277	−0.019 81	0.001 686	
2	−14 160	67.22	−2.095	J mol^{-1}

Table XV. Diffusion Coefficients for CO_2 and N_2O in PEG 400

T/°C	$D_{CO_2}\times 10^7$/(cm^2 s^{-1})	$D_{N_2O}\times 10^7$/(cm^2 s^{-1})	T/°C	$D_{CO_2}\times 10^7$/(cm^2 s^{-1})	$D_{N_2O}\times 10^7$/(cm^2 s^{-1})
20.0	8.02	6.37	35.0	16.0	11.3
25.0	10.0	8.21	40.0	20.4	16.0
30.0	12.7	10.0			

The solubility of CO_2 and N_2O in the amine–PEG 400 solutions was measured directly in the gas solubility apparatus described in detail by Haimour and Sandall (*2*) and Al-Ghawas et al. (*3*). The principle idea of this device is to bring a known quantity of liquid into contact with the dissolving gas at constant temperature and pressure. The gas and liquid samples are allowed to equilibrate, and the amount of gas dissolved is measured volumetrically. The results were interpreted in terms of Henry's law as follows:

$$H = P/C \tag{8}$$

where H is Henry's constant for N_2O or CO_2 in the liquid solvents, C is the concentration of CO_2 or N_2O in the liquid sample, and P is the partial pressure of CO_2 or N_2O in the gas phase. The experimental results are best represented by the following integrated form of the Clausius–Clapeyron equation:

$$\ln\,(H/(\text{L atm mol}^{-1})) = h_1 + h_2/R(T/\text{K}) \tag{9}$$

where R = 8.314 J mol^{-1} K^{-1} is the ideal gas constant, h_1 is an integration constant, and h_2 is the heat of absorption. The concentration dependence is described in terms of h_i as

$$h_i = a_i + b_i w + c_i w^2 \tag{10}$$

The form of eq 10 is strictly empirical.

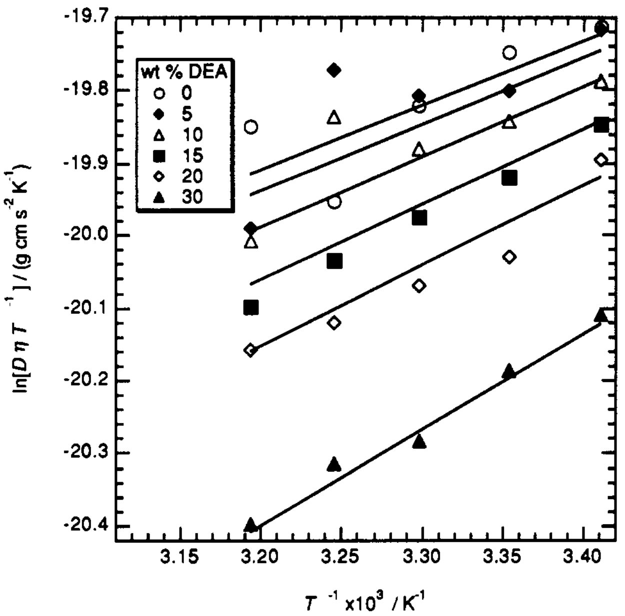

Figure 9. Diffusion coefficients for N_2O in DEA–PEG 400.

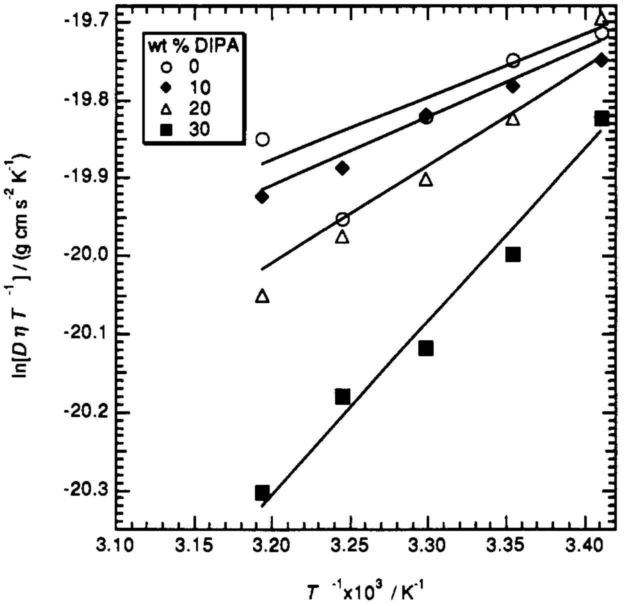

Figure 10. Diffusion coefficients for N_2O in DIPA–PEG 400.

Table XVI. Constants for Use in Equation 14 for the Diffusivity of CO_2 in PEG 400 (Equation Predicts Diffusivity Data to within ±3.8%)

i	a_i	unit
1	−21.40	
2	4618	J mol^{-1}

Solubility experiments were performed for the systems of CO_2 and N_2O in pure PEG 400 and N_2O in solutions of DEA and DIPA in PEG 400. The measurements were repeated three times at atmospheric pressure and at 5 °C temperature intervals for the temperature range of 20–40 °C over a concentration range of 0–30 wt % amine in PEG 400. The vapor pressure of the liquid samples was assumed to be negligible. The vapor pressure of ethylene glycol was calculated from Antoine's equation to be $\sim 2 \times 10^{-4}$ atm at 25 °C (*5*). Amine–PEG 400 solutions consist of much larger molecules and should have a lower vapor pressure. Thus, the partial pressure of the absorbing gas was approximated as the total pressure in the equilibrium chamber.

Table XVII. Diffusion Coefficients for N_2O in 0–30 wt % DEA in PEG 400

	$D_{N_2O} \times 10^7/(cm^2\ s^{-1})$					
T/°C	0 wt %	5 wt %	10 wt %	15 wt %	20 wt %	30 wt %
20.0	6.37	5.97	5.18	4.50	3.91	2.55
25.0	8.21	7.42	6.68	5.75	4.74	3.30
30.0	10.0	9.40	8.61	7.34	6.17	4.11
35.0	11.3	13.1	11.8	9.13	7.81	5.35
40.0	16.0	13.0	12.8	11.1	9.80	6.49

Table XVIII. Diffusion Coefficients for N_2O in 0–30 wt % DIPA in PEG 400

	$D_{N_2O} \times 10^7/(cm^2\ s^{-1})$			
T/°C	0 wt %	10 wt %	20 wt %	30 wt %
20.0	6.37	5.51	4.87	3.37
25.0	8.21	7.33	6.06	4.09
30.0	10.0	9.50	7.73	5.13
35.0	11.3	14.3	9.69	6.68
40.0	16.0	14.6	11.9	8.03

The averaged results for CO_2 and N_2O in PEG 400 are reported in Table IX. The solubility of CO_2 was found to be greater than that for N_2O in agreement with results for aqueous systems (*1*). However, the ratio of CO_2/N_2O solubilities is 1.32 ± 0.01 compared with 1.37 reported by Laddha et al. (*1*) for aqueous systems. In the case of pure PEG 400, the mole fraction of CO_2 in the solution exceeds 0.01 for a CO_2 partial pressure of 1 atm. Thus, according to the criterion suggested by Carroll (*7*), it is not recommended that these results be used for CO_2 partial pressures much larger than 1 atm. The results are plotted in Figure 5 in the form of eq 9. A linear least-squares correlation of the solubility results for CO_2 in PEG 400 to eq 9 is given in Table X. The correlation fits the solubility results in terms of Henry's constants with a mean deviation of ±2.6%.

The solubility of N_2O in solutions of DEA–PEG 400 and DIPA–PEG 400 was measured to apply the N_2O analogy for CO_2 in reactive amine systems. The averaged results are reported in Tables XI and XII. The results are plotted in Figures 6 and 7 in the form of eq 9. Correlations of the experimental results for solubility to eq 9 are given in Tables XIII and XIV. The correlation fits the solubility results in terms of H for N_2O in solutions of DEA–PEG 400 and DIPA–PEG 400 with mean deviations of ±9.8% and ±7.8%, respectively.

The form of eq 9 is convenient for approximating the solubility of CO_2 in DEA–PEG 400 or DIPA–PEG 400 using the N_2O analogy in eq 1. Upon substitution of the appropriate correlations for CO_2 and N_2O into eq 1, a predictive equation for H_{CO_2} based on eqs 9 and 10 is obtained by simply replacing the constants for a_i in Tables XIII and XIV with the corresponding values for a_i from Table X for CO_2. For example, in the case of CO_2 solubility in DEA–PEG 400 solutions, the composition-dependent terms in eq 10 become

$$h_1 = 7.036 + 0.1633w - 0.004365w^2 \qquad (11)$$

$$h_2 = -14260 - 365.5w + 12.46w^2 \qquad (12)$$

where the correlation constants a_i are from Table X for CO_2 while the constants b_i and c_i are from Table XIII for N_2O.

Diffusivity

The diffusion coefficients of CO_2 and N_2O in the solvent–amine solutions were determined from dynamic gas absorption experiments in a wetted sphere gas–liquid contacting device. The wetted sphere apparatus is commonly employed for gas absorption experiments where small to intermediate contact times are required. The operation is similar to a wetted wall column; however, the geometry of the sphere reduces the end effects in the liquid film. The apparatus and procedure are

Table XIX. Constants for Use in Equation 14 for the Diffusivity of N_2O in DEA–PEG 400 (Equation Predicts Diffusivity Data to within 3.4%)

i	a_i	b_i	c_i	unit
1	−22.71	−0.019 83	−0.001 453	
2	7276	41.92	2.676	J mol^{-1}

Table XX. Constants for Use in Equation 14 for the Diffusivity of N_2O in DIPA–PEG 400 (Equation Predicts Diffusivity Data to within 3.6%)

i	a_i	b_i	c_i	unit
1	−22.71	0.1200	−0.009 203	
2	7276	−281.7	21.76	J mol^{-1}

described in detail by Al-Ghawas et al. (*3*). The analysis of Olbrich and Wilde (*8*) was used to determine values for the diffusivity from experimental measurements of the gas absorption rate into a liquid film in laminar flow over the surface of the sphere. The experiments were done for the temperature range of 20–40 °C at 5 °C intervals and a concentration range of 0–30 wt % amine in PEG 400.

The diffusion coefficients, D, were correlated for temperature and amine concentration dependence according to the following functional form proposed by Akgerman and Gainer (*9*) for a system of small solute molecules diffusing in a medium of much larger solvent molecules where the Stokes–Einstein equation breaks down:

$$\ln\left[\frac{(D/(\mathrm{cm}^2\ \mathrm{s}^{-1}))(\eta/\mathrm{P})}{T/\mathrm{K}}\right] = d_1 + \frac{d_2}{R(T/\mathrm{K})} \qquad (13)$$

The parameter d_2 can be considered an activation energy for solute molecules jumping past solvent molecules. The correlation parameters are functions of the amine concentration in the form of the empirical eq 14.

$$d_i = a_i + b_i w + c_i w^2 \qquad (14)$$

The experimental results for the diffusion coefficients of CO_2 and N_2O in PEG 400 are listed in Table XV. The temperature dependence for the diffusion coefficients in the form of eq 13 is shown in Figure 8. The results for CO_2 diffusivity were correlated to eq 13 by a linear least-squares method. The dynamic viscosity was obtained from the correlation in Table III. The fitted constants are found in Table XVI. The correlation represents the experimental results for the diffusivity with a mean deviation of ±3.8%.

The experimental results for the diffusivity of N_2O in DEA–PEG 400 and DIPA–PEG 400 solutions are given in Tables XVII and XVIII. The diffusion coefficients are shown to follow the temperature dependence of eq 13 in Figures 9 and 10. The experimental results were correlated to eq 13 by a linear least-squares technique. The dynamic viscosity was determined by the predictive correlations in Tables III and IV. The fitted constants are listed in Tables XIX and XX. The correlations predict the diffusivity results with mean deviations of ±3.4% and ±3.6% for N_2O in solutions of DEA–PEG 400 and DIPA–PEG 400, respectively. As with the solubility results, the diffusivity of CO_2 in these solutions can be approximated according to the N_2O analogy of eq 2 by substituting the CO_2 correlation parameters a_i from Table XVI into the N_2O correlations found in Tables XIX and XX.

Glossary

a_i,b_i,c_i	property correlation constants in eqs 4, 7, 10, and 14
C	concentration of CO_2 or N_2O in amine–PEG 400, mol L^{-1}
d_i	diffusivity composition correlation function defined in eq 14
D	diffusion coefficient of CO_2 or N_2O in amine–PEG 400, cm^2 s^{-1}
$D°$	diffusion coefficient in nonreactive solvent, cm^2 s^{-1}
h_i	Henry's constant composition correlation function defined in eq 10
H	Henry's law constant for CO_2 or N_2O in amine–PEG 400, L atm mol^{-1}
$H°$	Henry's law constant in nonreactive solvent, L atm mol^{-1}
n	liquid dynamic viscosity composition correlation parameter defined in eq 7
P	partial pressure of CO_2 or N_2O, atm
r_i	liquid density composition correlation parameter defined in eq 4
R	ideal gas constant, 8.314 J mol^{-1} K^{-1}
T	temperature, K
w	weight percent DEA or DIPA in PEG 400

Greek Letters

η	dynamic viscosity, P
ν	kinematic viscosity, St
ρ	density, g cm^{-3}

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