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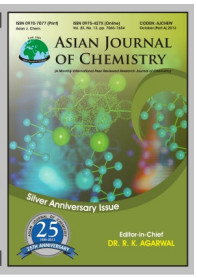

Solubility of Dilute Sulfur Dioxide in Aqueous Poly-Ethylene Glycol 1000 Solutions at 298.15 K and 123.15 kPa

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In present work, solubility data were measured for dilute sulfur dioxide in various aqueous poly-ethylene glycol 1000 (PEG) solutions at 298.15 K and 123.15 kPa and SO_2 partial pressures in the range of (0-120) Pa. Measurements were carried out by a saturation method using a glass absorption apparatus, which were controlled at constant temperature by a thermostatic circulation bath with a Beckmann thermometer. Both the gas phase was recirculated in the glass absorption apparatus by an airpump to obtain a series of solubility data. The measurement showed that the solubility of SO_2 in the aqueous poly-ethylene glycol 1000 solutions (PEGWs) system increased with the increasing PEG concentration in the whole range of mass fraction.

Key Words: Poly-ethylene glycol 1000, Pollution control, Flue gas desulfurization, Sulfur dioxide absorption, Phase equilibria.

INTRODUCTION

Coal is usually the most important consumption resource, which has been widely used in almost all the fields[1]. Sulfur dioxide, caused by the largely burning of coal with high sulfur content, is an important atmospheric pollutant. So it is necessary to eliminate the steadily increased emissions and it is severe in environmental protection. Among the many procedures employed to desulfurize exhaust gases, organic solvents have been identified as an option among the regenerative processes[2-6] because the solvents regeneration can be done by reducing pressure, by increasing temperature and by using of a carrier gas. Alcohols had shown favourable absorption and desorption capabilities[7], because of its low vapour pressure, low toxicity, high chemical stability and low melting point. Therefore, many research groups have paid great attention to the alcohol + water system for SO_2 removal[8-10].

Solubility data can explain the absorption prosperities of aqueous poly-ethylene glycol 1000 (PEGW) and provide important theoretical basis for the potential flue gas desulfurization in the technological processes. Henry's law constant (HLC), another key physical property that plays a fundamental role in understanding and predicting a compound in the environment. Compounds with different Henry's law constant values mean the solubility and stability of solute in the absorbent.

This work presents the solubility data for $SO_2 + N_2$ mixtures with various poly-ethylene glycol 1000 (PEG) + water solutions (PEGWs) at T = 298.15 K and P = 123.15 kPa in various aqueous PEG solutions. Then data were used to fit Henry's law constant as a further study. The discussion of the results will provide recommendations which estimation method should be used to receive the best results.

EXPERIMENTAL

The analytical grade PEG 1000 was purchased from Beijing Reagent Company. It was used after drying over molecular sieves (type 4A) and decompression filtration. The certified standard mixtures [SO_2 (1) + N_2 (2), $\Phi_{SO_2} = 5 \times 10^{-4}$] purchased from the Beijing Gas Company were employed to determine the solubility data for the $SO_2 + N_2$ + PEGW system. Bidistilled water was used to make the mixture solutions in this work. Solution of I_2 and $Na_2S_2O_3$ were used as standard solution. Testo 350-Pro gas analyzer (German) was used in order to determine the sulfur dioxide concentration in gas phase.

The experimental apparatus used in this work was based on a dynamic analytic method and has reported in previous work[11].

The system total pressures were inspected by a pressure gauge purchased from Fuqiang Meter Factory (Hebei province, China) with the accuracy of ± 0.1 kPa. In all cases, each experimental value was an average of at least three measurements. The solubility data were obtained with uncertainties within ± 0.1 K for temperature, ± 0.1 kPa for total pressures, ± 3 % for SO_2 concentration in the gas phase and ± 0.6 % for SO_2 concentration in the liquid phase.

RESULTS AND DISCUSSION

Solubility data for PEG + water with dilute SO_2: A series of solubility data for PEG (1) + H_2O (2) binary system were performed at T = 298.15 K and P = 123.15 kPa and the data were listed in Table-1. The absorbents in this work present the accurate factual mass fraction of PEG prepared by using an analytical balance (Sartorius BS224S) with a precision of ± 0.0001 g.

TABLE-1
SOLUBILITY DATA FOR PEG + H_2O + SO_2 + N_2 AT T = 298.15 K AND P = 123.15 kPa. w_1 DENOTES THE MASS FRACTION OF PEG IN PEG + WATER SYSTEM, Y_{SO_2} DENOTES THE VOLUME FRACTION OF SO_2 IN THE GAS PHASE, C_3 DENOTES THE MOLAR CONCENTRATION OF SULFUR (IV) COMPOSITION IN THE LIQUID PHASE AND p_3 DENOTES THE PARTIAL PRESSURE OF SO_2 IN THE GAS PHASE

100 w_1	$10^6 y_{SO_2}$	C_3 (mol m^{-3})	P_3/Pa
0.00	50	0.76	5.52
0.00	113	1.18	12.5
0.00	165	1.45	18.2
0.00	200	1.81	22.1
0.00	280	2.09	30.9
0.00	365	2.46	40.3
0.00	410	2.65	45.2
0.00	523	2.93	57.7
0.00	589	3.24	65.0
0.00	664	3.47	73.3
0.00	728	3.70	80.3
0.00	864	4.21	95.3
0.00	949	4.42	105
0.00	1017	4.73	112
20.00	30	1.32	3.69
20.00	75	1.55	9.24
20.00	159	2.31	19.6
20.00	251	2.73	30.9
20.00	373	3.51	45.9
20.00	457	4.32	56.3
20.00	552	4.74	68.0
20.00	635	5.12	78.2
20.00	720	5.67	88.7
20.00	803	6.03	98.9
20.00	914	6.17	113
20.00	1047	6.79	129
40.00	70	4.40	8.62
40.00	101	4.53	12.4
40.00	180	4.92	22.2
40.00	247	5.28	30.4
40.00	294	5.50	36.2
40.00	413	5.79	50.9
40.00	561	6.26	69.1
40.00	637	6.29	78.4
40.00	756	6.69	93.1
40.00	839	6.92	103
40.00	919	7.11	113
40.00	1047	7.80	129
60.00	38	4.54	4.68
60.00	109	4.99	13.4
60.00	188	5.44	23.2
60.00	269	5.80	33.1
60.00	307	6.31	37.8
60.00	384	6.26	47.3
60.00	468	6.95	57.6
60.00	586	7.18	72.2
60.00	724	7.55	89.2
60.00	846	8.22	104
60.00	882	8.68	109
60.00	998	8.92	123
80.00	61	6.17	7.51
80.00	156	7.11	19.2
80.00	268	7.97	33.0
80.00	359	8.38	44.2
80.00	421	8.53	51.8
80.00	503	9.43	61.9
80.00	628	10.3	77.3
80.00	717	10.8	88.3
80.00	801	11.1	98.6
80.00	897	11.6	110
80.00	1044	13.0	129

The solubility cures of PEGWs for SO_2 absorption at 298.15 K and 123.15 KPa are plotted in Fig. 1.

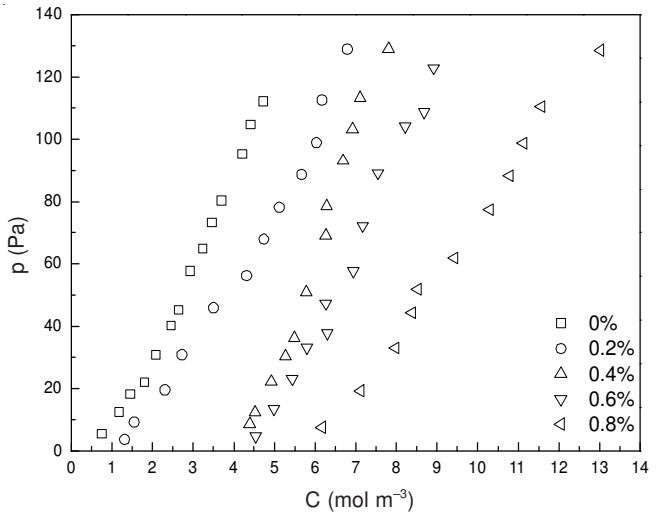

Fig. 1. Solubility curves for PEG (1) + H_2O (2) + SO_2 (3) + N_2 (4)

Fig. 1 suggested that the absorption capabilities of PEGWs increased with the increasing concentration from 0 to 80 % at the setting condition and reached the maximum at 80 %. The above results may be related to hydrogen bonding between PEG and SO_2. As high concentration of PEG can provide more hydroxyl hydrogen atoms, which interact with oxygen atoms of SO_2, so 80 % has a better solubility. As a result, the dissolving property increased extremely. Prediction can also be making that 100 % PEG has the best absorption, however, measurements do not preformed because pure PEG appears as solid.

Solubility of SO_2 in PEG + water when SO_2 volume fraction in the gas phase is designed at $\Phi_{SO_2} = 5 \times 10^{-4}$ are shown in Fig. 2. Together with Fig. 1 show that solubility of SO_2 in the system PEG (1) + water (2) increased with increasing PEG concentration in the entire composition range and 80 % presented an extreme maximum when SO_2 in the gas phase is designed at $\Phi_{SO_2} = 5 \times 10^{-4}$. The result gives us important information to optimize the composition of PEG + water for the SO_2 absorption processes.

Henry's law constant: In present work, Henry's law constant experiments were conducted at five different concentrations, which were gotten by correlating the solubility data at

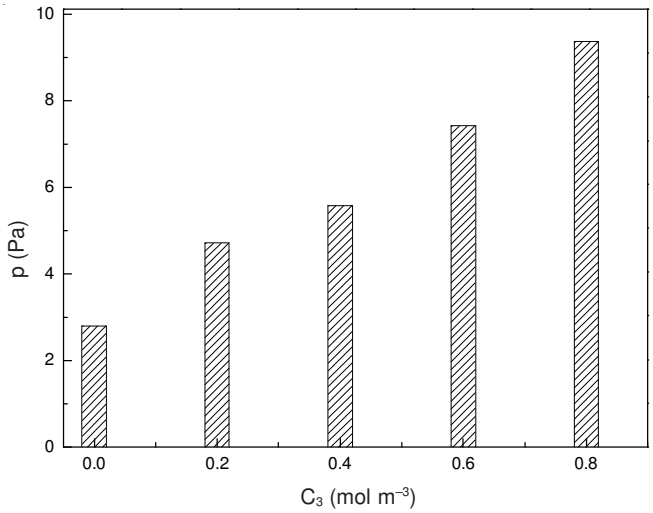

Fig. 2. Solubility of SO_2 in PEG + water when SO_2 concentration in the gas phase is designed at $\Phi_{SO_2} = 5 \times 10^{-4}$

the setting condition to provide the basic thermodynamic criterion for the further desulfurization. From the above analyze, conclusion can be drawn that concentration have great effect on the solubility (Table-2).

TABLE-2
HENRY LAW CONSTANTS (HLC) OF DIFFERENT CONCENTRATIONS AT 298.15 K

Concentration	0.80	0.60	0.40	0.20	0.00
HLC	18.6 ± 0.58	27.4 ± 1.34	38.2 ± 1.57	19.5 ± 0.65	28.1 ± 0.92

Conclusion

Fundamental experimental solubility data of various aqueous PEG solutions with SO_2, were determined as a function of concentration at T = 298.15 K and P = 123.15 kPa. The solubility data show that the solubility of SO_2 in the system PEG (1) + water (2) increased with increasing PEG concentration in the whole and the solubility of SO_2 in the system PEG (1) + water (2) presented an extreme maximum at the mass fraction of $w_1 = 80$ % when SO_2 in the gas phase is designed at $\Phi_{SO_2} = 5 \times 10^{-4}$. At the same time, Henry's law constant values were obtained by fitting the solubility data, which can provide important theoretical basis to optimize the composition of PEG + water for the SO_2 absorption processes.

REFERENCES

1. H.C. Porter, *Ind. Eng. Chem*., **15**, 335 (1923).
2. X. Esteve, A. Conesa and A. Coronas, *J. Chem. Eng. Data*, **48**, 392 (2003).
3. H.C. Ku and C.H. Tu, *J. Chem. Eng. Data*, **45**, 391 (2000).
4. A. Valtz, C. Coquelet and D. Richon, *Fluid Phase Equilib*., **220**, 77 (2004).
5. D. Nagel, R. de Kermadec, H.G. Lintz, C. Roizard and F. Lapicque, *Chem. Eng. Sci.*, **57**, 4883 (2002).
6. R. De Kermadec, F. Lapicque, D. Roizard and C. Roizard, *Ind. Chem. Eng. Res.*, **41**, 153 (2002).
7. C.N. Schubert and W.I. Echter, The Method of Polymer Ethylene Glycol for Removal Pollution from Gases, CN Patent 1364096A (2002).
8. X. Li, Y. Liu and X. Wei, *Chinese J. Chem. Eng.*, **13**, 234 (2005).
9. X. Wei, Desulfurization & Decarburization Solution Activities. CN. Patent 02130605.2 (2002).
10. X. Wei, J. Zhang, P. Zhang, L. Zhang, X. Li and M. Wan, Removal of SOx from Flue Gas by Ethylene Glycol, CN Patent 101053746 (2007).
11. J.B. Zhang, P.Y. Zhang, G.H. Chen, F. Han and X.H. Wei, *J. Chem. Eng. Data*, **53**, 1479 (2008).