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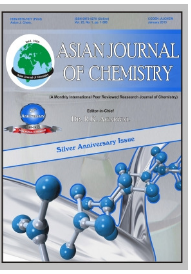

Absorption and Desorption of Sulphur Dioxide in Ethylene Glycol + Water Binary System

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In previous work, considering the industrial flue gas desulphurization (FGD) processes, Φ_1 = 80 % EGW (ethylene glycol + water) (*ca.* 0.5 molar fraction of ethylene glycol) was confirmed as the optimum composition of desulphurization solution. The present work was used to provide absorption and desorption apparatus for the flue gas desulphurization processes using simulate flue gas. The present work showed that the absorption rate of 1058 ppm SO_2/N_2 mixture was decreased into 177.2 ppm when the gas-liquid ratio is 3. In the process, the desulphurization rate arrived at 83 %. Meanwhile, in the desorption process, the concentration of SO_2 in the 80 % EGW were changed from 37.9 mg/L into 1.7 mg/L and the desorption rate arrived at 95 %.

Key Words: Desulphurization, Ethylene glycol, Sulphur dioxide.

INTRODUCTION

This paper is a continuation of the systematic program on the absorption processes of sulphur dioxide (SO_2) in the binary mixtures of ethylene glycol (EG) + water (EGW)[1,2]. Ethylene glycol is an important industrial solvent with the potential gas scrubbing. It can be used as a scrubbing liquid in the cleaning of exhaust air and gas streams from industrial production plants because of its favorable properties such as low vapour pressure, low toxicity, low viscosity, high chemical stability and low melting temperature. Ethylene glycol and its similar solvents, including diethylene glycol (DEG)[3] and poly-ethylene glycol (PEG)[4], present native hydrogen bonding sites that the potential desorption characters are presented in the regenerative processes of solutions dissolving SO_2. A number of other studies been paid great attention to alcohol + water system[5,6].

The previous results[2] show that the addition of H_2O into ethylene glycol increased the solubilities of SO_2 in ethylene glycol; meanwhile, $w_1 = 0.80$ ethylene glycol + water (volume fraction) exhibits an extreme maximum value of 778 mg/L to dissolve SO_2 when SO_2 concentration is designed at $\Phi_1 = 5 \times 10^{-4}$ (volume fraction) in the gas phase. The study of absorption processes of SO_2 in ethylene glycol + water includes the following three steps: (1) Gas-liquid equilibrium data for mixture gas of $SO_2 + N_2$ with pure EG and EG aqueous solutions, (2) density, viscosity and excess properties for EG aqueous solutions, (3) spectral properties of EG + SO_2 + H_2O interactions and (4) absorption and desorption of SO_2 in ethylene glycol + water. The previous articles cover the first three steps of this study[1,2,7]. The present work was mainly focused on investigating the absorption and desorption of SO_2 in ethylene glycol + water.

EXPERIMENTAL

The pure SO_2 gas (99.9 %) and pure N_2 gas (> 99.9 %) were purchased from the Beijing Gas Center, Peking University (China). The analytical grade EG was purchased from Beijing Reagent Company. It was used after drying over molecular sieves (type 4A) and decompression filtration before measurements. The purity of the sample was checked by density determination at 308.15 K. The density of EG at 308.15 K was found to be 1.1030 g cm^{-3}, in good agreement with the literature[8,9]. The purity of the final samples, as found by gas chromatograph, was better than 99.4 %. Bi-distilled water was used.

The apparatus used in this work was based on a dynamic analytic method and is reported. The experimental apparatus used in this work is shown in Fig. 1. SO_2 and N_2 from the gas cylinders were poured into the apparatus through switching the regulating valves and were absorbed by the ethylene glycol + water in the absorption tower (1). The gas mixtures after absoption were analyzed using an Agilent 6890N gas chromatograph (4) and an FPD detector linked to an HP6890 workstation. Absoption solutions after absorption were desorbed in the desorption tower (10). Liquid temperatures were registered on a standard thermometer (8) at different points and the temperatures do not vary more than 0.02 K. Total

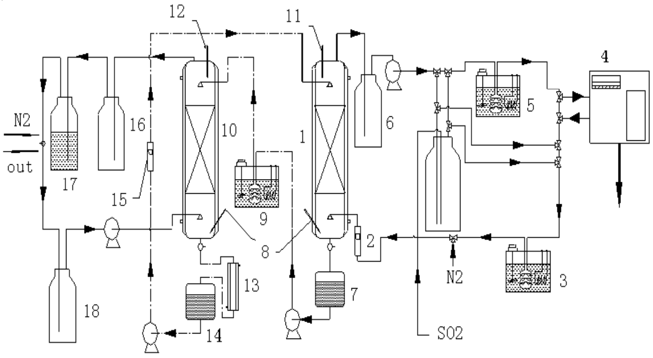

Fig. 1. Sketch of GLE experimental apparatus. 1 Absorption tower; 2, 15 Flowmeter; 3, 5, 9 Thermostatted bath; 4 GC, 6, 7, 14, 16, 17, 18 Buffer; 8, 11, 12 Thermometer; 10 Desorption tower; 13 Cooler

pressures were recorded on pressure meter. SO_2 concentrations in gas phase were determined by GC (4) FPD detector.

The concentrations of SO_2 in the gas phase were determined by a gas chromatograph (GC) on a 2 × 3.2 (m × mm) Porapak Q packed column using the Agilent 6890N gas chromatograph and an FPD detector linked to an HP6890 workstation. In all cases, the injections were repeated at least seven times and the average values were reported. To calibrate the GC FPD detector, the external standard method was used. The sulphur(IV) concentration in the liquid phase (CSO_2) was determined according to previous report[10]. The overall relative uncertainty in the determination of the sulphur(IV) concentration was estimated to be ± 0.6 %. Experiments were carried out at 298.15 K kept at a constant temperature using CS 501 thermostatted bath with a Beckmann thermometer purchased from Huanghua Meter Factory (Hebei province, China) with ± 0.02 K and inspected using an accurate thermometer with the precision of ± 0.02 K and the total pressures were inspected by a pressure gauge purchased from Fuqiang Meter Factory (Hebei province, China) with 0.133 kPa.

RESULTS AND DISCUSSION

A series of absorption and desorption experiments were carried out in the following conditions shown in Table-1. The GC FPD detector was calibrated with the standard $SO_2 + N_2$ mixture gases. And the calibrated results are shown in the Table-2.

TABLE-1
EXPERIMENTAL CONDITIONS

	Absorption tower	Desorption tower
Temperature (K)	303.15	353.15
Pressure (kPa)	123.19	≤ 80.52
Gas flow rate of gas cycle pump (L/min)	≤ 15.0	≤ 15.0
Liquid flow rate of liquid cycle pump (L/min)	≤ 2.5	≤ 2.5

Table-2 shows that GC method presented high stability in the analytical processes of SO_2 concentration, so that the method can be used in following GLE researches.

TABLE-2
CALIBRATION CURVES OF GC FOR EXPERIMENTS

Absorption condition		Calibration curve y = ax + b		
Detector way	Flux/(m^3/h)	a	b	R^2
Before	0.34	1.6235	1.1399	0.9910
	0.30	1.5986	1.2445	0.9900
	0.25	1.5987	1.1970	0.9888
	0.20	1.6380	0.9150	0.9918
	0.15	1.6615	0.6780	0.9907
	0.10	1.6681	0.4856	0.9942
After	0.35	1.5963	1.3210	0.9939
	0.30	1.5898	1.2921	0.9888
	0.25	1.6125	1.1021	0.9911
	0.20	1.6534	0.8665	0.9916
	0.15	1.6634	0.6222	0.9932
	0.10	1.6941	0.2684	0.9973

T = 303.15 K, p = 123.19 kPa.

A series of absorption and desorption experiments for the absorption (T = 303.15 K) and desorption (353.15 K) of dilute SO_2 in 80 % ethylene glycol + water were performed at various gas-liquid ratios shown in Table-1 and the data are listed in Tables 3-6 and Fig. 2. In the Tables 3-6, δ is desulphurization rate (%) and Δ is desorption rate (%) as follows.

TABLE-3
EXPERIMENTAL DATA WHEN THE GAS-LIQUID RATIO IS 20

$C_{g,\ in}$ (ppm)	$C_{g,\ out}$ (ppm)	δ (%)	C (mg/L) (s)	C (mg/L) (d)	δ (%)
146.0	121.6	16.7	44.2	0.2	99.5
274.2	201.6	26.5	81.2	0.2	99.8
443.3	322.6	27.2	101.0	1.6	98.4
547.3	286.1	47.7	126.6	0.2	99.8
765.8	480.3	37.3	150.7	7.3	95.2
1165.9	594.2	49.0	203.3	0.2	99.9
1555.6	635.5	59.1	247.3	0.2	99.9

TABLE-4
EXPERIMENTAL DATA WHEN THE GAS-LIQUID RATIO IS 10

$C_{g,\ in}$ (ppm)	$C_{g,\ out}$ (ppm)	δ (%)	C (mg/L) (s)	C (mg/L) (d)	δ (%)
226.9	80.5	64.5	18.7	1.2	93.4
515.5	185.7	64.0	43.0	2.6	94.0
868.4	271.8	68.7	51.1	1.2	97.6
962.6	286.4	70.2	63.3	2.6	95.9
1137.7	348.4	69.4	87.5	8.3	90.5

TABLE-5
EXPERIMENTAL DATA WHEN THE GAS-LIQUID RATIO IS 7.5

$C_{g,\ in}$ (ppm)	$C_{g,\ out}$ (ppm)	δ (%)	C (mg/L) (s)	C (mg/L) (d)	δ (%)
291.9	62.7	78.5	10.0	1.2	89.9
493.0	122.8	75.1	26.7	2.7	88.3
718.3	161.1	77.6	27.9	2.0	92.8
705.6	143.0	79.7	34.9	2.9	91.7
920.0	207.5	77.4	31.1	2.8	91.0
1072.6	230.5	78.5	69.7	2.0	97.1

TABLE-6
EXPERIMENTAL DATA WHEN THE GAS-LIQUID RATIO IS 3

$C_{g,\ in}$ (ppm)	$C_{g,\ out}$ (ppm)	δ (%)	C (mg/L) (s)	C (mg/L) (d)	δ (%)
284.0	55.0	80.6	18.7	0.2	98.9
316.9	69.7	78.0	20.2	0.2	99.0
525.3	105.0	80.0	28.7	0.8	97.2
888.7	162.1	81.8	31.6	1.2	96.3
1058.6	177.2	83.3	37.9	1.7	95.5
1340.3	223.4	83.3	40.1	1.8	95.5
1700.4	334.5	80.3	41.4	14.4	65.2

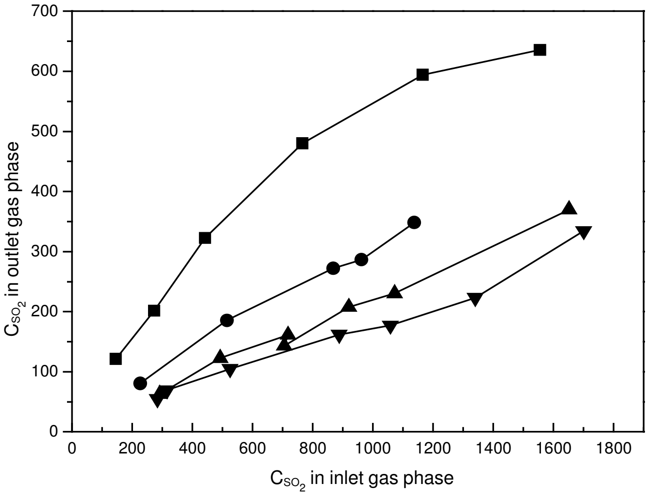

Fig. 2. SO_2 concentrate relation between inlet gas and outlet gas at various gas-liquid ratio: ■ G/L = 20 ● G/L = 10 ▲ G/L = 7.5 ▼ G/L = 3

$$\delta = \frac{(C_{g,\,in} - C_{g,\,out})}{C_{g,\,in}} \times 100\ \% \tag{1}$$

$$\Delta = \frac{(C(s) - C(d))}{C(s)} \times 100\ \% \tag{2}$$

Tables 3-6 and Fig. 2 showed that the absorption rate of 1058 ppm SO_2/N_2 mixture was decreased into 177.2 ppm when the gas-liquid ratio is 3. In the process, the desulphurization rate arrived at 83 %. Meanwhile, in the desorption process, the concentration of SO_2 in the 80 % ethylene glycol + water were changed from 37.9 mg/L into 1.7 mg/L and the desorption rate arrived at 95 %. So we thought that the 80 % ethylene glycol + water can be used in the future absorption and desorption experimental processes.

Conclusion

This paper presents the results of fundamental investigations on the absorption and desorption processes of SO_2 in 80 % ethylene glycol + water at various gas-liquid ratios. The present work showed that the absorption rate of 1058 ppm SO_2/N_2 mixture was decreased into 177.2 ppm when the gas-liquid ratio is 3. In the process, the desulphurization rate arrived at 83 %. Meanwhile, in the desorption process, the concentration of SO_2 in the 80 % ethylene glycol + water were changed from 37.9 mg/L into 1.7 mg/L and the desorption rate arrived at 95 %. So we thought that the 80 % ethylene glycol + water can be used in the future absorption and desorption experimental processes.

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