Effect of SO_2 on the Viscosity of Tetrabutylammonium Bromide Aqueous Solution

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Abstract **-Tetrabutylammonium bromide (TBAB) aqueous solution could effectively absorb SO2. To well know effect of sulfur dioxide on the properties of TBAB mixtures, the viscosity of the tetrabutylammonium bromide aqueous solution and the mixtures containing SO2 and TBAB aqueous solution were measured. The results show that the viscosity of TBAB aqueous solution decreases with the increase of temperature and decrease of concentration. When the TBAB aqueous solution absorbs SO2, the solution is divided into two layers, supernatant and lower course. The supernatant solution viscosity remains stable along with the temperature changing. However the lower course viscosity sharply increases with the temperature and concentration incremental.**

Keywords-tetrabutylammonium bromide; SO_2; viscosity

I INTRODUCTION

Sulfur dioxide(SO2)，a common greenhouse gas and sulfide, is harmful for human beings, causes to acid rain which corrodes construction, harms environment and affects the growth of plants and animals[1-3]. Flue gas desulfurization(FGD) used to treat SO2 emissions in industry of effective desulfurization. SO2 was gathered at low efficiency in this process, causing to secondary pollution, non-recyclable and other disadvantages. Ionic liquids as green solvents has no secondary pollution, can be recycled many times and has a high absorption efficiency. Because of these properties it has higher prospect of industrial application in terms of desulfurization.

The preparation method of quaternary ammonium salt type of functional ionic liquid is simple and the materials are cheap. Asa solvent, it is almost no losses when recycled[4-5]. The research group founded that CPL-TBAB ionic liquid has stable nature, low melting point and absorbedhighly in SO2 in the early time. Further study founded TBAB aqueous solution has rather absorption rate to SO2 and appears stratified phenomenon after SO2 was absorbed in. A variety of physical properties are characterized to study the absorption mechanism of the TBAB aqueous solution. Viscosity, one of the most important physical properties of the material, internal friction and hydrogen bond are showed by the viscosity is bad for the process of dissolution and filtration. Besides, transmission efficiency and segregation rate are reduced by the viscosity. High viscosity brings about high energy consumption and causes problems to production in the chemical industry. The viscosity of imidazole ionic liquid decreases with temperature increasing[6-7] and more sensitive than density at the same temperature and concentration[8-10]. Guo[11] found the viscosity values of the binary mixtures of themethylbenzene and imidazole ionic liquid ([Bmim][BF4] and [Bmim][PF6]), decreased with the increase of temperature and the mole fraction of methylbenzene.

In the manuscript, the viscosity of SO2 absorbed by TBAB aqueous solution was measured and correlated with Vogel-Fulcher-Tammann (VFT) equation.

II EXPERIMENTAL

A *Materials*

Tetrabutylammoniumbromide (A.R., Jintan Huadong Chemical Research Institute), SO2 (99.99%, Special north oxygen gas research institute Co., LTD), NaOH(A.R., Continental chemical reagent factory in Tianjin).

B *Measurement of viscosity*

A certain amount of TBAB and water were measured by analytical balance (EL204, Mettler Toledo instrument (Shanghai) co., LTD, ±0.0001). SO2 and TBAB

aqueoussolution reacts for 30 and stand it for 30 minutes, whose temperature is controlled by thermostat water bath (HH-2, Changzhou city, Jiangsu province maple of instrument co., LTD, ±0.1). At last viscosity is measurued by viscometer(DV-Ⅱ+, BROOKFIELD.US, ±0.01).

III RESULTS AND DISCUSSION

The viscosity of TBAB aqueous solutions and TBAB aqueous solutions and SO2 were determined with respect to temperature. These data were fit to an equation, which was first proposed by Vogel-Fulcher-Tammann (VFT) equation and subsequently used by other researchers (Eq. (1)) [12]. The fitted data are shown in Fig. 1 and Fig. 2.

$$\eta/\mathrm{mPas} = A \cdot \exp\{B/[(T/\mathrm{K}) - T_0]\} \quad (1)$$

In this equation, ηrepresents the viscosity value; $T$is the absolute temperature; and A, $B$and T_0 refer to the fit coefficients. The values of the parameters A, B, T_0 and R-square (R^2) are listed in Table 2.

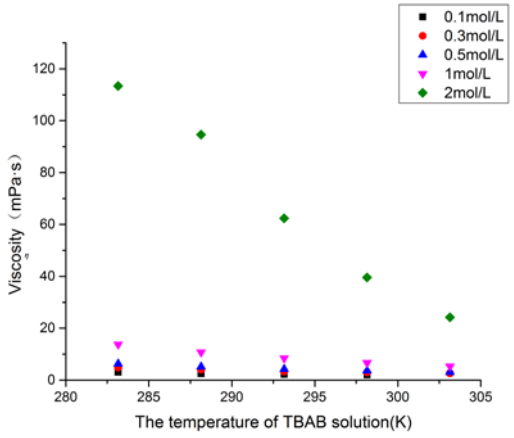

FIGURE I. VISCOSITY (H) OF THE TBAB AQUEOUS SOLUTIONS AS A FUNCTION OF TEMPERATURE

TABLE I. PARAMETERS FOR EQ. (1)AND R-SQUARE VALUES FOR THE VISCOSITY MEASUREMENTS OF DIFFERENT CONCENTRATIONS OF TBAB AQUEOUS SOLUTIONS WITH RESPECT TO TEMPERATURE

Concentration(mol/L)	*A*	*B*	T_0	R^2
0.1	0.97248	28.850	257.84	0.99998
0.3	0.36155	164.84	219.71	0.99704
0.5	0.028800	690.38	155.03	0.99972
1	7.0699E-7	5608.8	-51.049	0.99991
2	2.7186E-41	13956	-1138.2	0.93064

The viscosity reduces with the temperature increasing and the viscosity increases with the concentration reducing. Because that with the temperature increasing the combining capacity of solution intermolecular hydrogen bond reduces, which causes to the viscosity of solution reducing and is in line with the previous experimental results that the higher the temperature, the larger the absorbed .

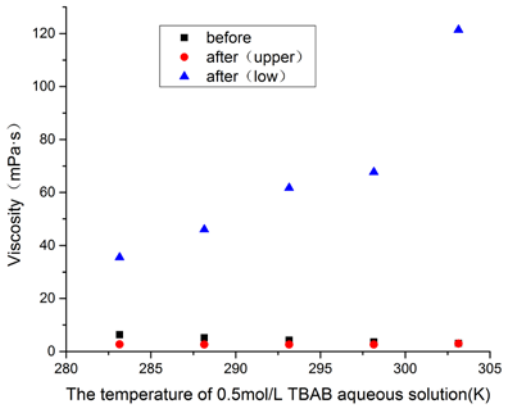

FIGURE II. VISCOSITY (H) OF THE TBAB AQUEOUS SOLUTIONS AS A FUNCTION OF TEMPERATURE

TABLE II.PARAMETERS FOR EQ. (1)AND R-SQUARE VALUES FOR THE VISCOSITY MEASUREMENTS OF DIFFERENT CONCENTRATIONS OF TBAB AQUEOUS SOLUTIONS WITH RESPECT TO TEMPERATURE

Entry	*A*	*B*	T_0	R^2
After(low)	7.4512E28	-59465	-659.94	0.8585
Before	0.028800	690.38	155.02	0.9997
After(upper)	5.1522E7	-724870	-4032.0	-0.4335

The viscosity of superstratum solution after absorbing SO_2 is almost stable, because the superstratum is almost water. The viscosity of substratum solution after absorbing SO_2 increases with the temperature rising. The reaction of SO_2 and TBAB aqueous solution may reduce the hydrogen bond of TBAB aqueous solution. The solubility of SO_2 in TBAB aqueous solution reduces when the temperature rises. So the viscosity of substratum solution increases with the temperature rising.

IV CONCLUSION

Through the study we can get the following conclusions:

1) The solution viscosity of the TBAB aqueous solution before absorbing reduces with the increase of temperature. What's more, the solution viscosity increases along with the solution concentration increasing.

2) The superstratum solution after absorbing is almost water, which leads to the viscosity reducing compared with the TBAB aqueous solution and the viscosity remains unchanged.

3) The viscosity of substratum solution after absorbing gradually increases with the temperature rising.

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REFERENCES

[1] S. Nazari n, O. Shahhoseini, A.vSohrabi-Kashani, S. Davari, H. Sahabi,

A. Rezaeian, SO_2 pollution of heavy oil-fired steam power plants in Iran[M], *Energy Policy* , April 2012, Volume 43, Pages 456–465.

[2] Shaodong Xie, Li Qi, Ding Zhou,Investigation of the effects of acid rain on the deterioration of cement concrete using accelerated tests established in laboratory[J], *Atmospheric Environment*, September 2004, Volume 38,Issue 27, Pages 4457–4466.

[3] Yu-Kai Huang, Munkh-Erdene Luvsan, Enkhjargal Gombojavc, Chimedsuren Ochir, Jargal Bulgan, Chang-Chuan Chan，Land use patterns and SO_2 and NO_2 pollution in Ulaanbaatar, Mongolia, *Environmental Research*, July 2013, Volume 124, Pages 1–6.

[4] Huang, J. Riisager, A. Berg, R W Fehrmann R. Tuning ionic liquids for high gas solubility and reversible gas sorption[J], *Journal of Molecular Catalysis a-Chemical*, 2008, 279 (2): 170-176.

[5] Bonhote P, Dias A P, Pnicholas. Hydrophobic, Highly Conductive Ambient-TemPeratureMotlen Salts. *Inorg. Chem*. 1996, 35(5): 1168-1178.

[6] Luís C. Branco, João N. Rosa, Joaquim J. Moura Ramos Prof. andCarlos A. M. Afonso Prof., Preparation and Characterization of New Room Temperature Ionic Liqui, *Chemistry - A European Journal*[J], August 16, 2002,Volume 8, Issue 16, pages 3671-3677.

[7] Welton, Thomas, Room-Temperature Ionic Liquids. Solvents for Synthesis and Catalysis.[J] *Chemical Reviews*, 8 (1999): 2071-2084.

[8] Elena Gómez , Begoña González , Ángeles Domínguez , Emilia Tojo ,and José Tojo, Dynamic Viscosities of a Series of 1-Alkyl-3-methylimidazolium Chloride Ionic Liquids and Their Binary Mixtures with Water at Several temperatures[J], *Journal of chemical & engineering data*, 2006, 51 (2), pp 696-701.

[9] N. Mac Dowell, F. Llovell, N. Sun, J. P. Hallett, A. George, P. A. Hunt, T. Welton ,B. A. Simmons, and L. F. Vega J. Phys. Chem. B, New Experimental Density Data and Soft-SAFT Models of Alkylimidazolium([CnC1im]+) Chloride (Cl–), Methylsulfate ([MeSO4]−), and Dimethylphosphate([Me2PO4]−) Based Ionic Liquids [J], *American Chemical Society*, 2014, 118 (23), pp 6206–6221.

[10] Elise A. Cade , David R. Saeva , and Markus M. Hoffmann, Comparing Composition and Temperature-Dependent Excess Molar Volumes of Binary Systems Involving Ionic Liquids, *J. Chem. Eng. Data*, 2014, *59* (6), pp 1892–1914

[11] Bin Guo, Yu Song, Weizhao Liang, Dandan Zhang, Wei Han, and Wei Song, Viscosity of methylbenzene in [Bmim][BF_4] and [Bmim][PF_6] ionic liquids, *Advanced Materials Research*, Vols. 864-867 (2014) pp 125-130.

[12] ErhongDuan, Bin Guo, Miaomiao Zhang, Yanan Guan, Hua Sun, Han Jing, Efficient capture of SO_2 by a binary mixture of caprolactamtetrabutylammoniumbromide ionic liquid and water, *Journal of Hazardous Materials*, 194(2011)48-52.