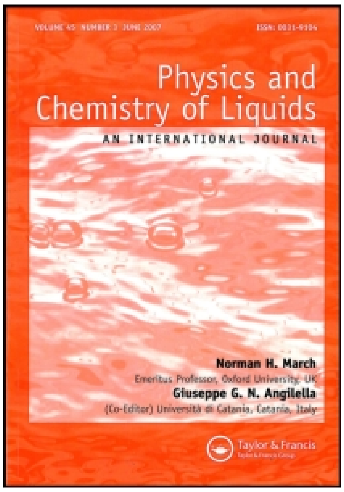

Physics and Chemistry of Liquids
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713646857

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To cite this Article Li, Hua and Hu, Guoqin(2010) 'Experiment and mechanical analysis of flue gas desulphurisation with organic solvent', Physics and Chemistry of Liquids, 48: 5, 580 — 586

To link to this Article: DOI: 10.1080/00319100903177693

URL: http://dx.doi.org/10.1080/00319100903177693

Physics and Chemistry of Liquids
Vol. 48, No. 5, October 2010, 580–586

Experiment and mechanical analysis of flue gas desulphurisation with organic solvent

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(*Received 17 June 2009; final version received 12 July 2009*)

A novel flue gas desulphurisation (FGD) technology using an organic solvent, dimethyl sulphoxide, has been studied. Process parameters studied included solvent concentration, temperature, flow rate and their role in the removal of SO_2 from flue gas. The mechanism of FGD by the organic solvent method is discussed and should be of assistance in the industrial removal of SO_2 from flue gas.

Keywords: FGD; organic solvent; mechanic analysis; SO_2

1. Introduction

Environmental pollution from flue gases is becoming more and more serious. Studies of the removal of SO_2, NO_2 and other acidic gas from flue gas comprise very important research projects around the world. In order to develop an effective desulphurisation method, various desulphurisation techniques [1–7] have been examined, such as activated carbon, molecular sieve, the electron-beam radiation technique, chemical method and physical solvents. Compared with these methods, absorption of sulphur dioxide in organic solvents offers several advantages, such as low investment, high SO_2 absorption efficiency and desorption efficiency. In this article, we examine the use of an organic absorbent, dimethyl sulphoxide (DMSO) [5] for sulphur dioxide removal and the associated mechanism of flue gas desulphurisation (FGD).

2. Experimental section

The technological process for SO_2 removal is shown in Figure 1. Sulphur dioxide of mole fraction purity $x(SO_2) \geq 0.997$ and nitrogen of purity $x(N_2) \geq 0.99999$ are both obtained from cylinders. Sulphur dioxide and nitrogen are mixed by a gas mixer with static agitation to simulate the flue gas. A flowrator is used to control the gas flow. A SO_2 analyser (type NTS 100, Nanjing, China) was used for the SO_2 analysis of the gas phase from the inlet and tail gases. The SO_2 concentration in the gas phase

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ISSN 0031–9104 print/ISSN 1029–0451 online

DOI: 10.1080/00319100903177693
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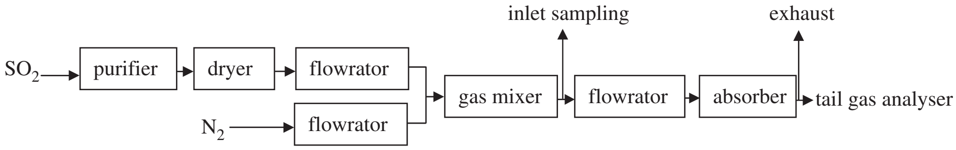

Figure 1. Technological process of SO_2 absorption.

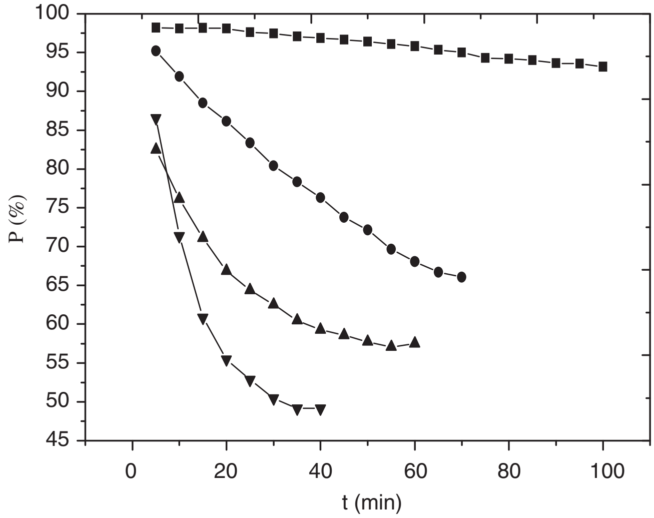

Figure 2. Influence of absorbent concentration on the removal efficiency of SO_2. ■, 100% DMSO; ●, 80% DMSO; ▲, 60% DMSO; ▼, H_2O. Experimental condition: temperature 297.15 K, gas flow: 60 ml min^{-1}, inlet SO_2 concentration: 0.1792%.

before and after absorption is analysed by SO_2 analyser, and then the purification efficiency is calculated.

The purification efficiency (P) is

$$P = \frac{C_0 - C}{C_0} \times 100\%,$$

where C_0 – the SO_2 concentration before absorption; C – the SO_2 concentration after absorption.

All the chemical reagents used are AR grade. Purified and deionised water of conductivity $< 0.06\,\mu S\,cm^{-1}$ was used in the measurements.

3. Results and discussion

3.1. *The influence of absorbent concentration on the removal efficiencies of SO_2*

The influence of absorbent concentration on the removal efficiency of SO_2 is shown in Figure 2. From Figure 2, it can be seen that the removal efficiency of SO_2 increases with the increase in DMSO concentration. SO_2 removal efficiency using DMSO-containing solvent is superior to that of water.

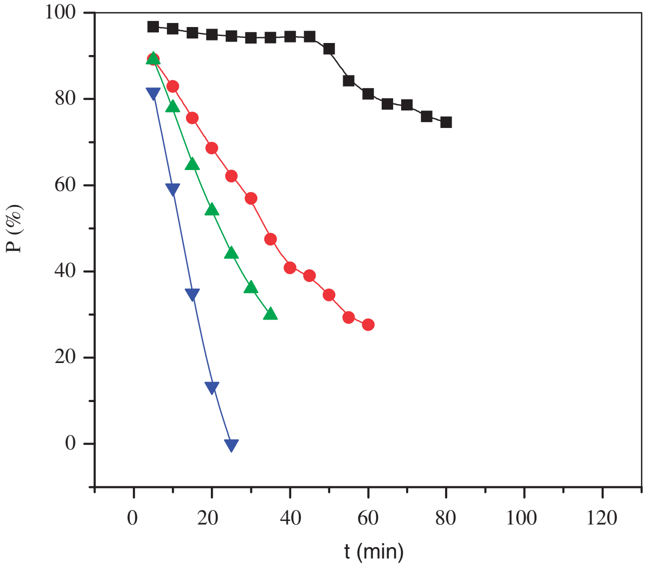

Figure 3. Influence of absorbent temperature on purification efficiency of SO_2. ■, 298.15 K; ●, 303.15 K; ▲, 313.15 K; ▼, 323.15 K. Experimental conditions: gas flow: 80 ml min^{-1}, inlet SO_2 concentration: 0.1783%.

With the same DMSO concentration, the removal efficiency of SO_2 decreases with increase in absorption time, the higher the DMSO concentration, the less the decrease of the removal efficiency of SO_2. Pure DMSO, therefore, has better purification efficiency for low SO_2-containing flue gases.

3.2. *The influence of absorbent temperature on purification efficiency of SO_2*

The role of absorbent temperature on the removal efficiency of SO_2 is shown in Figure 3. From Figure 3, it can be seen that the removal efficiency of SO_2 decreases with the increase in temperature, the higher the temperature, the less the removal efficiency of SO_2, and the results showed that SO_2 of flue gas can be effectively removed at 298.15 K, with efficiency over 94% within the absorption time of 0–30 min.

3.3. *The influence of flow rate of flue gas on purification efficiency of SO_2*

The influence of flow rate of flue gas on purification efficiency of SO_2 is shown in Figure 4. From Figure 4, it can be seen that flow rate of flue gas influences purification efficiencies, the lower the gas flow, the higher the SO_2 removal efficiency. For a gas flow rate of flue gas of 60 ml min^{-1}, the purification efficiencies exceeded 95% within the experimented time. For flow rates of flue gas higher than 60 ml min^{-1}, the SO_2 removal efficiency dropped significantly.

Therefore the optimal flow rate of flue gas is selected at 60 ml min^{-1}. If the speed is too large, gas–liquid entrainment phenomenon will occur, affecting the purification efficiencies.

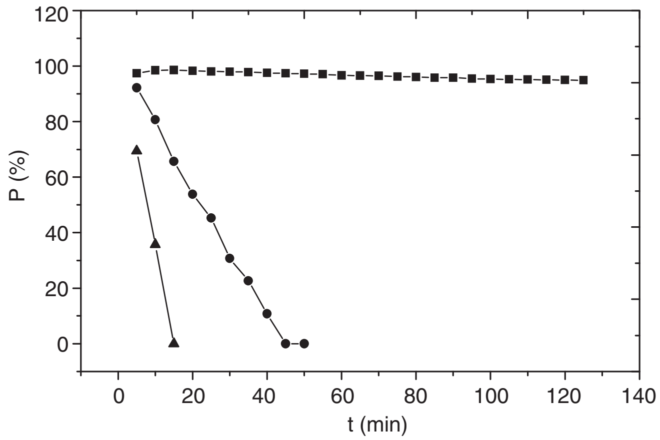

Figure 4. Influence of flow rate of flue gas on purification efficiency of SO_2. ■, 60 mL min^{-1}; ●, 100 mL min^{-1}; ▲, 200 ml min^{-1}. Experimental condition: temperature 297.15 K, inlet SO_2 concentration 0.1783%.

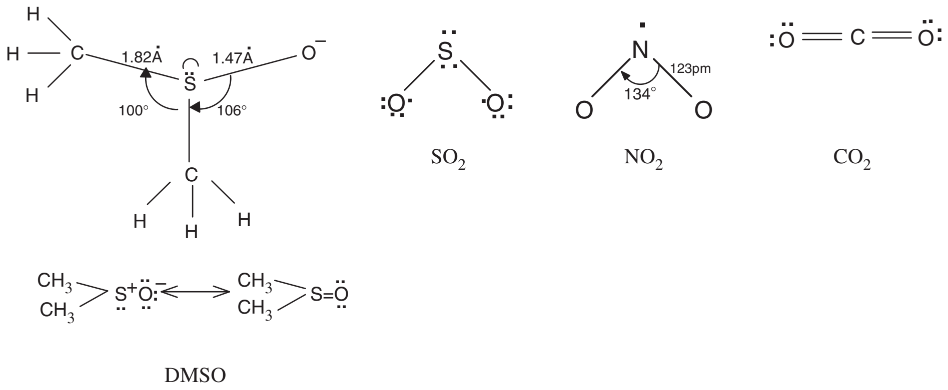

Figure 5. Molecular structure for DMSO, SO_2, NO_2 and CO_2.

4. Mechanism analysis

4.1. *FGD physical mechanism of solvent method*

DMSO is a polar aprotic organic solvent having a larger dipole moment (4.03 D). Its molecular structure is shown in Figure 5. SO_2 and NO_2 are polar gas molecules of V-type molecular configuration, also shown in Figure 5. CO_2, however, is a symmetrical linear non-polar molecule, and its molecular configuration is shown in Figure 5 as well.

DMSO is a polar organic solvent with a rather large dipole matrix, SO_2 and NO_2 are also polar gas molecules, while CO_2 is a non-polar gas molecule; therefore, DMSO has a better absorption capacity on the polarity of the sulphur dioxide and nitrogen oxides, but less absorption capacity on the non-polar carbon dioxide. It agrees with the principle that like dissolves like.

Accordingly, the absorption model of SO_2 in DMSO is shown in Figure 6 [8].

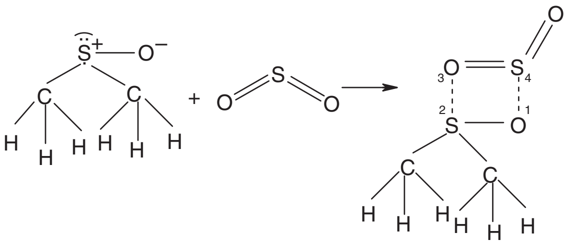

Figure 6. The absorption model of SO_2 in DMSO.

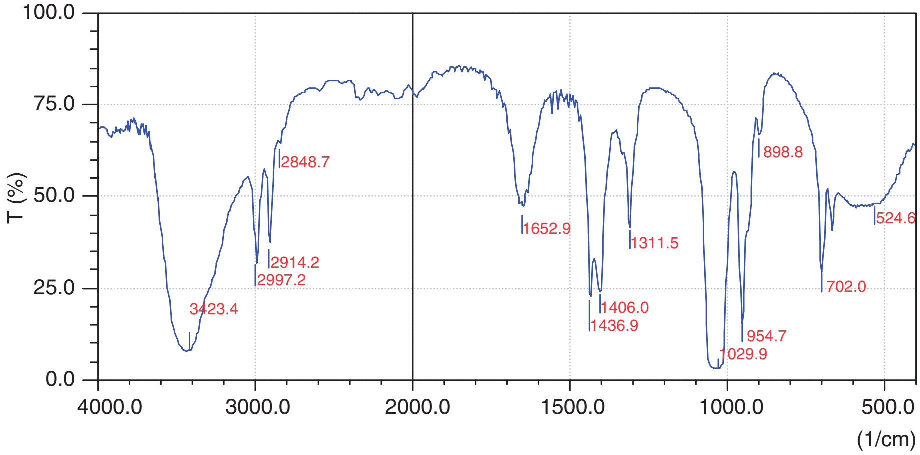

Figure 7. The infrared spectra of pure DMSO.

4.2. *The spectrum analysis of desulphurisation with DMSO solvent*

The infrared spectra of pure DMSO, of DMSO after absorption of SO_2 and of DMSO after desorption of SO_2 from the absorbing solvent are shown in Figures 7, 8 and 9, respectively. Comparison of the infrared spectra shows that the position of the absorption peak sulphoxide-based (S=O) in the saturated absorption solution is displaced from wavelength 9.7 μ to 9.76 μ, a displacement of 0.06 μ towards the low frequency. Peaks intensity becomes stronger, peak width becomes narrower, which shows that intermolecular interactions occur. From the IR spectra after regeneration, it was found that absorption peak position of the sulphoxide base (S=O) after desorption regained its original position 9.7 μ, which shows the dissolution of SO_2 by DMSO is a physical process and the absorbed sulphur dioxide can be completely desorbed from the absorbing solvent. The IR spectral characteristics of absorption–desorption of SO_2 is listed in Table 1.

5. Conclusion

A novel desulphurisation technology using an organic solvent method differs from those presently used for sulphur dioxide absorption which uses

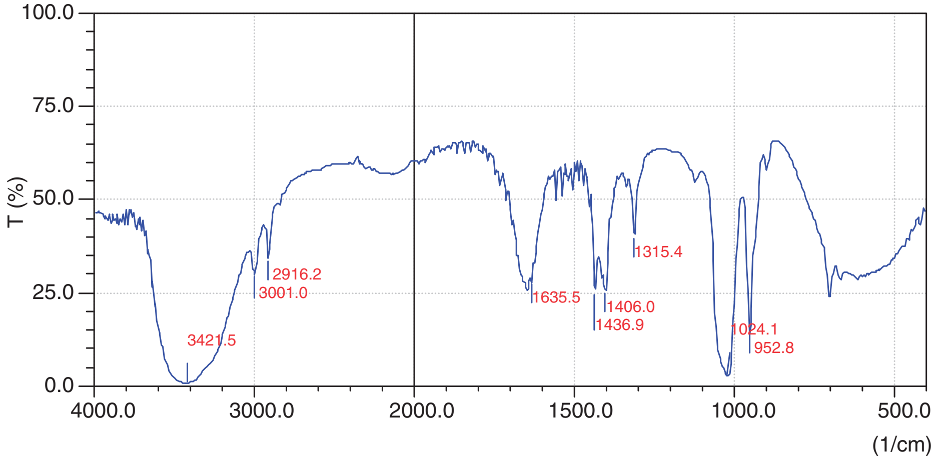

Figure 8. The infrared spectra of DMSO after absorption of sulphur dioxide.

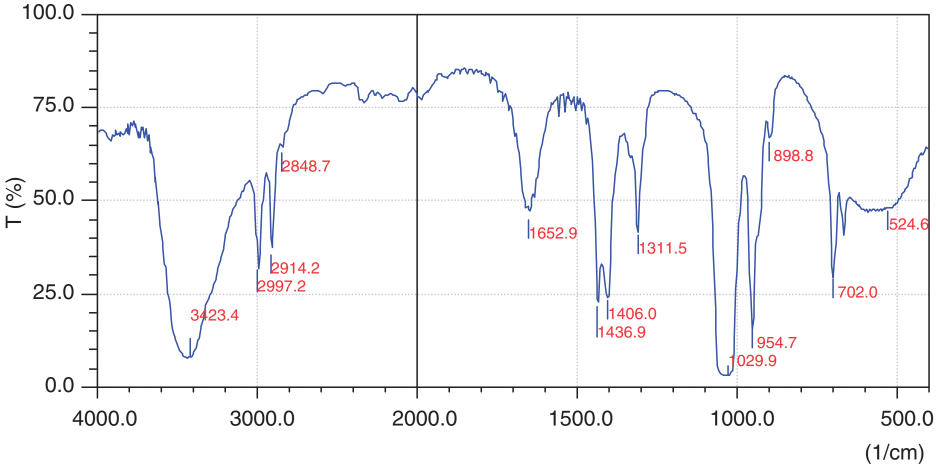

Figure 9. The infrared spectra of DMSO after regeneration.

Table 1. The IR spectral characteristics of SO_2 absorption and desorption.

Observed group	Pure DMSO	Saturable absorption solution	Regenerated solution
S=O	9.7 μ	9.76 μ, displacement 0.06 μ towards the low-frequency, peaks intensity becomes stronger, peak width becomes narrower	9.7 μ

Note: Wavelength units $\mu = 10^{-6}$ m.

inorganic compounds. The organic absorbent not only has higher removal efficiency for sulphur dioxide but is easier to regenerate and avoids problems in the use of inorganic absorbents which cannot be regenerated and recycled for further use.

From the analysis of FGD physical mechanism and infrared spectra, we can conclude that DMSO polar organic solvent has higher absorption efficiency for the polar gas molecules than for the non-polar CO_2 molecules. From a comparison of infrared spectra we find that dissolution of SO_2 by DMSO is a physical process.

DMSO has good removal and regenerative efficiency for SO_2. Therefore, it is promising for the removal of SO_2 from sulphur-containing flue gases.

Acknowledgements

Financial support for this project was provided by the Natural Science Research Project (2008B530004), Office of Education, Henan Province.

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