Effects of liquid height/volume and dissolved gas on sonochemical oxidation activity

Seongeun Lee[1,2†], Iseul Na[1,2], Younggyu Son[1,2]
([1]Department of Environmental Engineering, Kumoh National Institute of Technology
[2]Department of Energy Engineering Convergence, Kumoh National Institute of Technology)

1. Introduction

The effect of dissolved gas on cavitational activity such as sonochemical oxidation activity has been investigated over decades. Rooze et al. reported that Ar resulted in better sonochemical acitvity than air at 20 kHz while air showed better performance than Ar at higher frequency conditions for KI dosimetry.[1)] It was also found that no significant sonochemical activity was obtained for He, N_2, and CO_2.[2)] Buckett and Hua reported that the mixture of Ar/O_2 (75:25) resulted in the highest sonochemical oxidation activity and the highest sonoluminesence (SL) intensity was detected for 100% Ar.[3)]

Recently, some researchers focused on the geometric effect on cavitational activity and found that slight change in the geometric factors such as liquid height could result in remarkable differences of sonochemical acitivity. Asakura et al. investigated the effect of liquid hight on sonochemial oxdiation activity for various frequency conditions.[4)] Son suggested optimal height ranges as 5λ to 15λ for 291 kHz and 448 kHz in bath-type sonoreactors.[5)]

In this study, the effect of dissolved gas on sonochemical oxidation activity was investigated for various liquid height/volume conditions in a 28 kHz cylindrical sonoreactor as one of basic steps for the design of industrial sonoreactors.

yson@kumoh.ac.kr

2. Materials and Methods

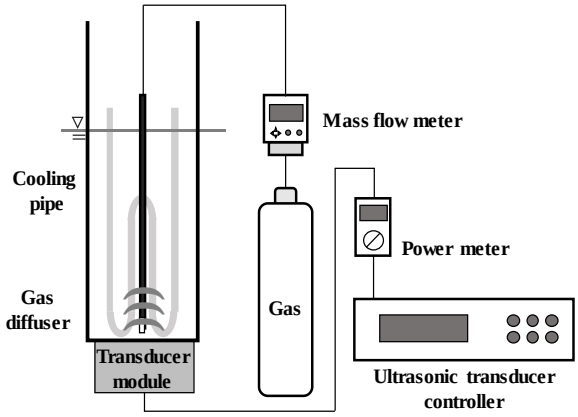
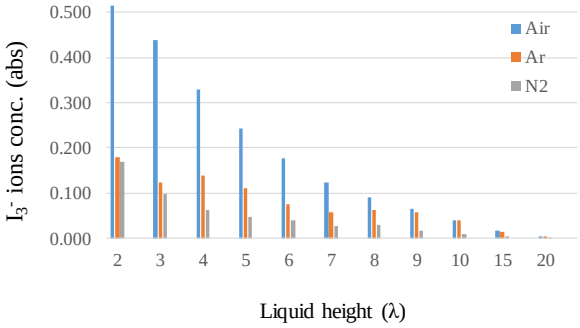


Fig. 1 A schematic of 300 kHz ultrasonic system and gas supply system in this study.

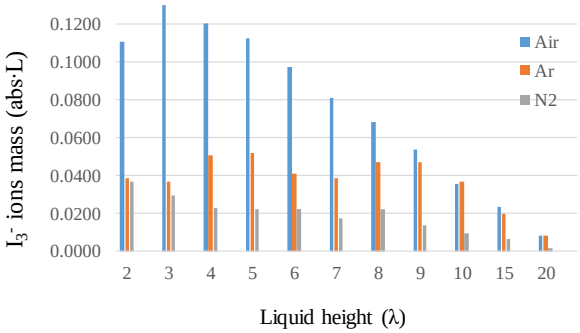
Fig. 1 shows the ultrasonic system used in this study. It consisted of a cylindical sonoreactor equipped with a 300 kHz transducer module (Mirae Ultrasonic Tech.)at the bottom, a gas diffuser connected to gas cylinders (Air, Ar, O_2, and N_2) and mass flow meters, and a cooling system. The applied liquid height/volumes were calculated based on the applied frequency and wave length and the liquih height/volume range was 2λ (215 mL) to 20λ (1,770 mL). To quantify sonochemical oxidation activity, KI dosimetry (KI conc.: 10 g/L) was used for each liquid height/volume condition. Considering the change of liquid volume, sonochemical activity was compared using not the concentration of generated I_3^- ions but the mass of I_3^- ions in this study.[5,6)] To quantify the degree of gas saturation, dissolved gas (DO) concentration was measured using a DO meter (ProODO; YSI

Inc.)

3. Results and Discussions



(a) Concentration of I_3^- ions



(b) Mass of I_3^- ions

Fig. 2 Variations of sonochemically generated I_3^- ions concentration and mass for Air, Ar, and N_2 under various liquid height conditions.

Sonochemial oxidation activity using KI dosimetry was investigated for various dissoved gas and liquid height/volume conditions as shown in Fig. 2. As the liquid volume increased, the concentration of I_3^- ions decrased drastically due to the increase in the liquid volume under the same input power condition.[7,8] Thus, the highest concentrations were observed at the lowest liquid height condition, 2λ. However, the mass of I_3^- ions did not decrease drastically and the highest value was observed not at 2λ but at higher height conditions. This might be due to the enhancement of cavitation events for higher liquid height/volumes and the optimal condition could be suggested depending on the applied gas conditioin. In this study the optimal liquid height was 3λ, 5λ, and 2λ for air, Ar, and N_2, respectively. The DO concentration was maintained less than 1 mg/L for both Ar and N_2 during the tests.

The reason why air resulted in higher sonochemical activity than Ar and N_2 was that the presence of oxygen in air could generate oxidizing radicals such as OH radicals more easily. It was reported that lower sonochemical activity was observed for 100% Ar condition even though the highest cavitational activity was obtained.

Acknowledgment

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References

1. J. Rooze, E. Rebrov, J. Schouten and J. Keurentjes: Ultrason. Sonochem. **20** (2013) 1.
2. J. Rooze, E. Rebrov, J. Schouten and J. Keurentjes: Ultrason. Sonochem. **18** (2011) 209.
3. M. A. Beckett and I. Hua: J. Phys. Chem. A **105** (2001), 3796.
4. Y. Asakura, Y. Nishida, T. Matsuoka, and S. Koda: Ultrason. Sonochem. **15** (2008) 244.
5. Y. Son: Chem. Eng. J. **328** (2017) 654.
6. Y. Son, Y. No, and J. Kum: Ultrason. Sonochem. **65** (2020) 105065.
7. Y. Son, M. Lim, M. Ashokkumar, and J. Khim: J. Phys. Chem. C **115** (2011) 4096.
8. J. Choi, J. Khim, B. Neppolian, and Y. Son: Ultrason. Sonochem. **51** (2019) 412.