Transport Properties of Water-Air Mixture System

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Abstract: Transport properties of the water-air mixture systems were calculated by assuming the thermal equilibrium conditions. The calculated thermal conductivities of the pure water and pure air systems were in good agreement with the previous studies. Moreover, it was found that Wilke's mixing rule underestimates the thermal conductivity in water-air mixture systems.

1. Introduction

Water plasma jets are known to be able to decompose persistent substances such as polychlorinated biphenyls and chlorofluorocarbons. However, the detailed decomposition process has not yet been elucidated, and unsteady numerical simulations are required to elucidate it. Water plasma jets ejected into the atmosphere can change their transport properties by mixing with air. Therefore, it is necessary to calculate the transport properties of water-air mixture systems accurately.

In this study, we aim to calculate the transport properties of water-air mixture systems and to compare the calculated results with those obtained using the well-known Wilke's mixing rule [1].

2. Methods

2.1 Equilibrium Composition

The equilibrium compositions of water-air mixture systems were calculated using the commercial software FactSage 8.2 by assuming the systems were in local thermal equilibrium states. Here, the pressure was fixed to be 101,325 Pa and the target temperature ranged from 400 K to 6,000 K. In this range, the chemical species to be considered are H_2O, H_2, N_2, O_2, OH, NO, H, N, and O.

2.2 Transport Properties

The thermal conductivity is calculated as the sum of the translational, internal, and reactive thermal conductivities. The translational thermal conductivity was calculated based on the first-order Chapman-Enskog approximation using Eq. (30) in Ref. [2]. The internal and reactive thermal conductivities were calculated using Eq. (39) in Ref. [3] and Eq. (3) in Ref. [4], respectively.

3. Results and Discussion

Figure 1 shows the calculated thermal conductivities of water-air mixture systems for different mixing ratios. The dashed and dotted lines show the results in the previous studies [5, 6]. This figure shows that the calculated results for pure water and pure air are in good agreement with the results in the previous studies. In the pure water system, the thermal conductivity has a local maximum at 3,700 K. This is mainly caused by the dissociation of H_2O, and the maximum decreased as the percentage of the air increased. Figure 2 provides a comparison of the thermal conductivity of the mixture of water 80% + air 20% between the present result and the result by Wilke's mixing rule [1]. The thermal conductivity calculated using Wilke's mixing rule underestimates the maximum value by a factor of 0.49.

4. Conclusion

In this study, the transport properties of the water-air mixture systems were calculated under the assumption of thermal equilibrium conditions. The calculated results of the pure water and pure air systems were in good agreement with the previous studies. Moreover, it was found that Wilke's mixing rule underestimates the thermal conductivity in water-air mixture systems.

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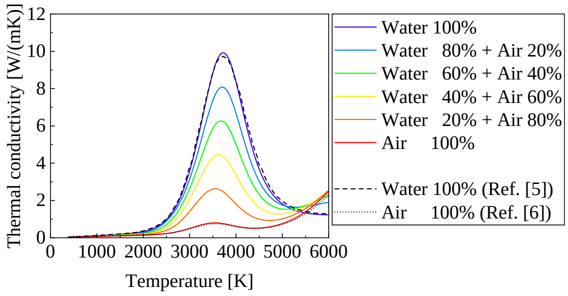

Fig. 1. Calculated thermal conductivities of water-air mixture systems for different mixing ratios.

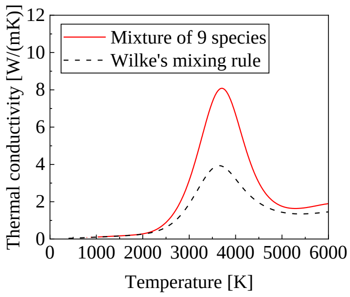

Fig. 2. Comparison of thermal conductivities calculated using the present method and Wilke's mixing rule [1] for the mixture of water 80% + air 20%.