International Journal of Thermophysics, Vol. 13, No. 5, 1992

Experimental Determination of the Thermal Diffusivity of Molten Alkali Halides by the Forced Rayleigh Scattering Method. III. Molten NaI, KI, RbI, and CsI

N. Nakazawa,[1] Y. Nagasaka,[1] and A. Nagashima[1]

Received February 24, 1992

This paper is an addendum to two previous papers which contained data on the thermal diffusivity of molten alkali metal chlorides and bromides. The present salts are alkali metal iodides: NaI, KI, RbI, and CsI. The measurements were performed utilizing the forced Rayleigh scattering method at temperatures up to 1234 K. The accuracy of the reported data is estimated to be ± 5 to $\pm 10\%$. It is again found that our data show one of the smallest values and weakly negative temperature dependencies.

KEY WORDS: alkali halides; forced Rayleigh scattering method; molten salts; thermal conductivity; thermal diffusivity.

1. INTRODUCTION

In continuation of our investigation of the thermal diffusivity of molten alkali halides [1, 2], we report here the results of measurements on four molten alkali metal iodides: NaI, KI, RbI, and CsI. The temperature ranges covered were 961–1099 K for NaI, 965–1234 K for KI, 963–1226 K for RbI, and 937–1227 K for CsI. The accuracy is estimated to be ± 5 to $\pm 10\%$, depending on the measured samples.

The methodology remained exactly the same as in the earlier papers. This permits us to restrict this account to results only.

[1] Department of Mechanical Engineering, Keio University, 3-14-1 Hiyoshi, Yokohama 223, Japan.

0195-928X/92/0900-0763$06.50/0 411 1992 Plenum Publishing Corporation

2. EXPERIMENTAL

The measurements have been performed in our forced Rayleigh scattering instrument, adequately described in earlier publications [3–6]. The experimental procedure and the method used for the evaluation of the data remained the same as in our earlier works [1, 2]. Each sample used had a nominal purity of better than 99%. $K_2Cr_2O_7$, 1 wt%, was mixed in order to color the transparent molten salt samples.

3. RESULTS AND DISCUSSION

In Tables I to IV the present measurements of the thermal diffusivity of KaI, KI, RbI, and CsI as a function of temperature are presented together with the derived values of the thermal conductivity. The accuracy of the measured data is estimated to be $\pm 7\%$ for NaI, $\pm 5\%$ for KI, $\pm 6\%$ for RbI, and $\pm 10\%$ for CsI. For the same reason as in our previous papers, we calculated the thermal conductivity using density and specific heat capacity. The density data were obtained from Yaffe and Van Artsdalen [7], with an uncertainty of less than $\pm 0.5\%$, while the specific heat capacity data used were temperature-independent values of Murgulescu and Telea [8], with uncertainties of ± 3 to $\pm 4\%$ for NaI, ± 4 to $\pm 5\%$ for KI, ± 7 to $\pm 9\%$ for RbI, and ± 9 to $\pm 10\%$ for CsI.

Table I. Experimental Results for Thermal Diffusivity and Derived Thermal Conductivity of Molten NaI

T (K)	a $[(m^2 \cdot s^{-1}) \times 10^{-7}]$	λ $(W \cdot m^{-1} \cdot K^{-1})$ [a]
961	1.73	0.206
961	1.70	0.202
961	1.73	0.206
962	1.73	0.206
962	1.74	0.207
1049	1.78	0.205
1049	1.67	0.192
1096	1.96	0.221
1097	1.86	0.211
1097	1.87	0.212
1098	1.77	0.200
1099	1.77	0.200

[a] For λ calculation, ρ $(kg \cdot m^{-3}) = 3627.5 - 0.9491T$ (K) [7] and C_p $(J \cdot kg^{-1} \cdot K^{-1}) = 437.6$ [8].

Table II. Experimental Results for Thermal Diffusivity and Derived Thermal Conductivity of Molten KI

T (K)	a $[(m^2 \cdot s^{-1}) \times 10^{-7}]$	λ $(W \cdot m^{-1} \cdot K^{-1})$ [a]
965	1.47	0.147
966	1.45	0.145
966	1.50	0.150
966	1.45	0.145
966	1.45	0.146
1023	1.42	0.139
1023	1.46	0.143
1024	1.44	0.141
1024	1.42	0.139
1024	1.49	0.145
1081	1.50	0.144
1081	1.46	0.140
1082	1.46	0.140
1082	1.45	0.139
1082	1.54	0.147
1143	1.42	0.133
1144	1.35	0.126
1144	1.45	0.135
1146	1.42	0.133
1146	1.39	0.129
1195	1.45	0.133
1195	1.43	0.130
1195	1.39	0.127
1195	1.37	0.125
1196	1.38	0.126
1233	1.36	0.122
1233	1.38	0.124
1234	1.35	0.121

[a] For λ calculation, ρ $(kg \cdot m^{-3}) = 3359.5 - 0.9557T$ (K) [7] and C_p $(J \cdot kg^{-1} \cdot K^{-1}) = 411.3$ [8].

3.1. NaI

Figure 1 shows the present thermal conductivity results for molten NaI together with those from earlier studies. The results of Harada [10] are about 15% larger than the present data (with an estimated accuracy of $\pm 11\%$), but the temperature dependence is the same. This agreement seems reasonable since Harada's modified laser flash method [11, 12] is

Table III. Experimental Results for Thermal Diffusivity and Derived Thermal Conductivity of Molten RbI

T (K)	a [$(m^2 \cdot s^{-1}) \times 10^{-7}$]	λ ($W \cdot m^{-1} \cdot K^{-1}$)[a]
963	1.24	0.120
973	1.33	0.128
973	1.37	0.132
973	1.38	0.133
973	1.32	0.127
974	1.37	0.132
974	1.34	0.129
974	1.39	0.134
974	1.35	0.130
975	1.35	0.130
975	1.34	0.129
1030	1.40	0.132
1031	1.35	0.127
1031	1.29	0.121
1031	1.31	0.123
1033	1.33	0.125
1083	1.33	0.122
1083	1.39	0.128
1084	1.31	0.120
1084	1.31	0.120
1085	1.29	0.119
1142	1.35	0.121
1142	1.30	0.117
1143	1.31	0.117
1143	1.30	0.117
1143	1.37	0.123
1221	1.28	0.111
1224	1.25	0.108
1225	1.23	0.106
1226	1.22	0.106
1226	1.29	0.111

[a] For λ calculation, ρ ($kg \cdot m^{-3}$) $= 3950.0 - 1.1435T$ (K) [7] and C_p ($J \cdot kg^{-1} \cdot K^{-1}$) $= 339.6$ [8].

capable of eliminating the effect of radiation heat losses, which become significant at high temperatures. The deviations of the data by McDonald and Davis [9] from our results reach almost 40%. This difference is considerably large, in contrast to the rather food agreement in the case of chlorides and bromides [1, 2].

Table IV. Experimental Results for Thermal Diffusivity and Derived Thermal Conductivity of Molten CsI

T (K)	a [$(m^2 \cdot s^{-1}) \times 10^{-7}$]	λ ($W \cdot m^{-1} \cdot K^{-1}$)[a]
937	1.35	0.121
937	1.31	0.118
937	1.32	0.118
937	1.33	0.119
937	1.31	0.117
956	1.12	0.100
958	1.16	0.103
1013	1.25	0.109
1111	1.17	0.0977
1174	1.17	0.0952
1210	1.14	0.0916
1227	1.15	0.0915

[a] For λ calculation, ρ ($kg \cdot m^{-3}$) $= 4241.1 - 1.1834T$ (K) [7] and C_p ($J \cdot kg^{-1} \cdot K^{-1}$) $= 286.1$ [8].

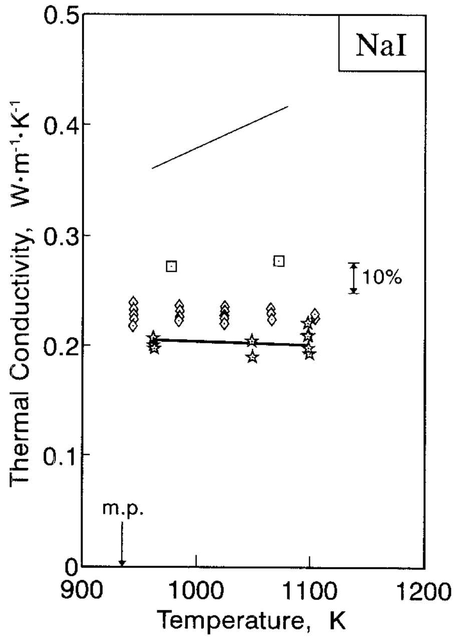

Fig. 1. Thermal conductivity of molten NaI: (□) McDonald and David [9]; (◇) Harada [10]; (——) Smirnov et al. [13]; (☆) present work. The present thermal diffusivity data were used to obtain thermal conductivity.

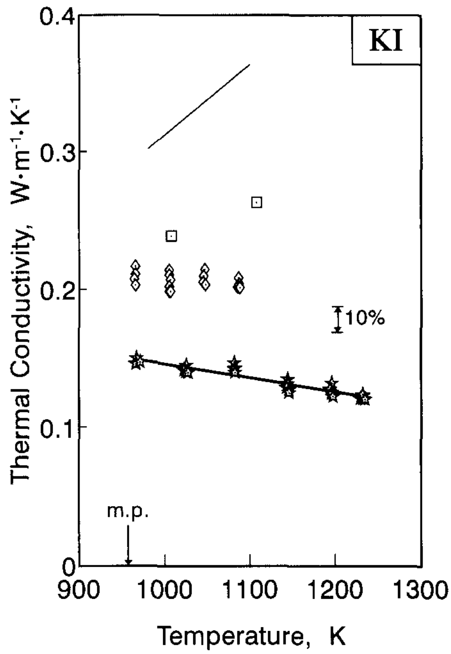

Fig. 2. Thermal conductivity opf molten KI: (⊡) McDonald and Davis [9]; (◇) Harada [10]; (——) Smirnov et al [13]; (☆) present work. The present thermal diffusivity data were used to obtain thermal conductivity.

3.2. KI

The present thermal conductivity results for molten KI are compared with those of previous works in Fig. 2. The accuracy of the converted thermal conductivity of molten KI is estimated to be $\pm 9\%$. In this case, the agreement between three previous studies, Harada [10], McDonald and Davis [9], and Smirnov et al. [13], and the present results are poor. Moreover, the data of Smirnov et al. [13] and those of McDonald and Davis [9] show a positive temperature dependence, in contrast to our weakly negative dependence.

3.3. RbI

Figure 3 displays the present results for molten RbI including comparison with earlier experimental studies. The overall accuracy of the

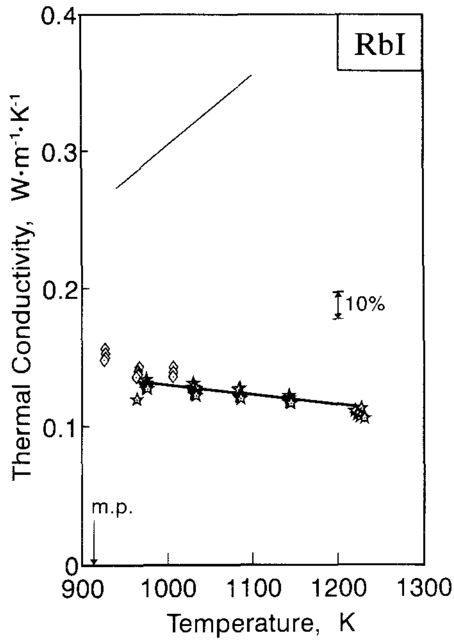

Fig. 3. Thermal conductivity of molten RbI: (◇) Harada [10]; (——) Smirnov et al. [13]; (☆) present work. The present thermal diffusivity data were used to obtain thermal conductivity.

converted thermal conductivity is estimated to be $\pm 15\%$. Harada's [10] data, which are very close to the melting temperature, nearby coincide with our present results. Again, Smirnov's [13] results are almost 200 to 300% higher than ours and show a very strong positive temperature dependence.

3.4. CsI

The present results for molten CsI are shown in Fig. 4, in addition to the results of the earlier study by Smirnov et al. [13]. Because of slightly strong scattering light of probing laser in the detected light signals, which is a measurement condition similar to that in the case of molten LiCl [1], the overall uncertainty is estimated to be $\pm 20\%$. Even with this relatively low accuracy, however, we believe that Smirnov and co-workers' results contain significant positive systematic errors owing to the radiative and convective heat losses which are inevitable when using conventional steady-state methods at high temperatures.

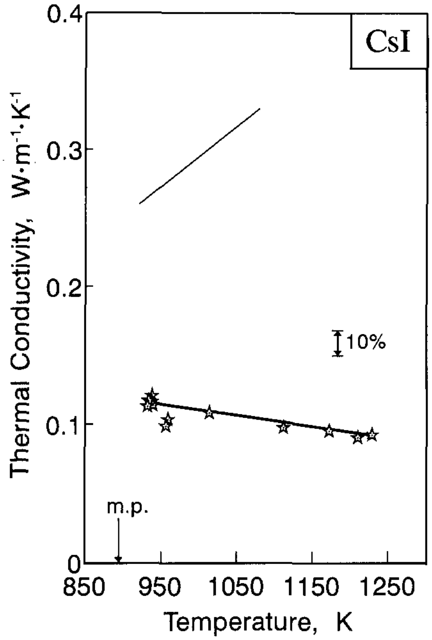

Fig. 4. Thermal conductivity of molten CsI: (——) Smirnov et al. [13]; (☆) present work. The present thermal diffusivity data were used to obtain thermal conductivity.

3.5. Summary of the Thermal Conductivity of Molten Alkali Metal Iodides

The thermal conductivities of molten alkali metal iodides studied in this paper vary with temperature according to the following empirical linear equation:

$$\lambda = \lambda_m + b(T - T_m) \tag{1}$$

Table V. Optimum Values of the Coefficients in Eq. (1)

	λ_m $(W \cdot m^{-1} \cdot K^{-1})$	b $(W \cdot m^{-1} \cdot K^{-2}) \times 10^{-4}$	T_m (K)	Temperature range (K)
NaI	0.206	−0.3	935	961–1099
KI	0.150	−1.0	958	965–1234
RbI	0.136	−0.7	913	963–1226
CsI	0.119	−0.8	894	937–1277

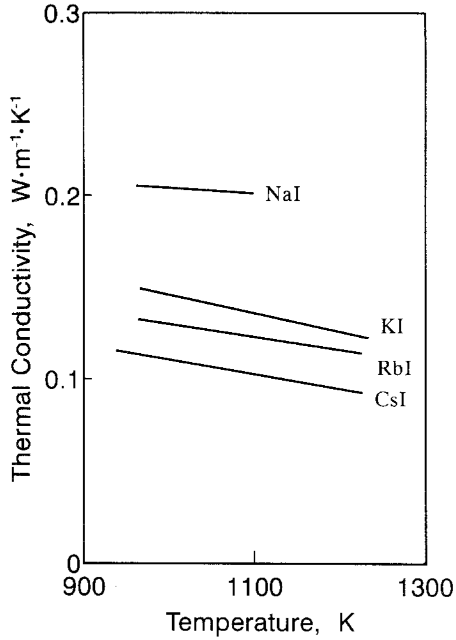

Fig. 5. Thermal conductivity of molten alkali metal iodides calculated by Eq. (1).

The values of λ_m and b calculated from the present experimental data by least-squares fitting are given in Tale V. Figure 5 displays these correlated results.

Since we have obtained the thermal conductivity of 13 kinds of molten alkali halides in a wide temperature range through systematically performed forced Rayleigh scattering experiments, it is possible to apply the corresponding-states correlation to the measured results. The preliminary study on this correlation is described in Ref. 14, and a further study is currently under way.

ACKNOWLEDGMENTS

The authors would like to thank M. Nose, who helped with the measurements and calculations. Professor T. Yamamura of Tohoku University is gratefully acknowledged for his preparation of purified salt samples.

REFERENCES

1. Y. Nagasaka, N. Nakazawa, and A. Nagashima, *Int. J. Thermophys.* **13**:555 (1992).
2. N. Nakazawa, Y. Nagasaka, and A. Nagashima, *Int. J. Thermophys.* **13**:753 (1992).

3. T. Hatakeyama, K. Kadoya, M. Okuda, Y. Nagasaka, and A. Nagashima, *Trans. JSME.* **B53**:1590 (1987).
4. Y. Nagasaka, T. Hatakeyama, M. Okuda, and A. Nagashima, *Rev. Sci. Instrum.* **59**:1156 (1988).
5. Y. Nagasaka and A. Nagashima, *Int. J. Thermophys.* **9**:923 (1988).
6. W. A. Wakeham, A. Nagashima, and J. V. Sengers (eds.), in *Experimental Thermodynamics, Vol. III* (Blackwell Scientific, Oxford, 1991), pp. 213–225.
7. I. S. Yaffe and E. R. Van Artsdalen, *J. Phys. Chem.* **60**:1125 (1956).
8. I. G. Murgulescu and C. R. Telea, *Rev. Roum. Chim.* **22**:683 (1977).
9. J. McDonald and H. T. Davis, *Phys. Chem. Liq.* **2**:119 (1971).
10. M. Harada, Personal communication.
11. Y. Tada, M. Harada, M. Tanigaki, and W. Eguchi, *Rev. Sci. Instrum.* **49**:1305 (1978).
12. A. Shioi, T. Miura, and M. Harada, *Proc. 11th Jap. Symp. Thermophys. Prop.*, 1990, p. 259.
13. M. V. Smirnov, V. A. Khokholov, and E. S. Filatov, *Electrochim. Acta* **32**:1019 (1987).
14. Y. Nagasaka and A. Nagashima, *Proc. 11th Japan. Symp. Thermophys. Prop.*, 1990, p. 275.