Thermal Conductivity of Liquid Diethyl Ether, Diisopropyl Ether, and Di-n-butyl Ether from (233 to 373) K at Pressures up to 30 MPa

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Thermal Conductivity of Liquid Diethyl Ether, Diisopropyl Ether, and Di-*n*-butyl Ether from (233 to 373) K at Pressures up to 30 MPa

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The thermal conductivity of diethyl ether, diisopropyl ether, and di-*n*-butyl ether in the liquid phase was reported. The measurements, covering a temperature range from (233 to 373) K and pressure up to 30 MPa, have been performed by a transient hot-wire technique with two anodized tantalum hot wires. The experimental data have been represented by polynomial functions of pressure and temperature for the purpose of interpolation. The relative uncertainty of the present thermal conductivity data was estimated to be ± 2.0 % with a coverage factor of $k = 2$.

Introduction

Alkyl ethers are important chemical materials and are regarded as good fuel additives and potential alternative fuels in the future as a result of their high oxygen content, suitable boiling point, and good solubility in diesel fuel. The thermophysical properties of these components are important to the combustion process in a diesel engine. Hence, there is an urgent need for experimental values of these potential fuel additives at high pressures.

During the last a few years, we have carried out the measurement, as accurately as possible, of the thermal properties of alternative fuels in the liquid and vapor phase. The alternative fuels considered are dimethyl ether, diethyl ether, diisopropyl ether, di-*n*-butyl ether, dimethoxymethane, and 1,2-dimethoxyethane. Especially in relation to the thermal conductivity measurements in the liquid and vapor phase, the measurements on dimethyl ether in the vapor and liquid phase,[1,2] dimethoxymethane,[3,4] and 1,2-dimethoxyethane[5] have already been reported. In this work, the results on diethyl ether, diisopropyl ether, and di-*n*-butyl ether are investigated in the liquid phase. In addition, the density and viscosity of diethyl ether, diisopropyl ether, and di-*n*-butyl ether have been measured recently.[6,7]

Experimental Section

The thermal conductivities of diethyl ether, diisopropyl ether, and di-*n*-butyl ether were measured by a transient hot-wire technique. The apparatus has been described fully in a previous publication,[5] thus only a brief introduction will be given here. The apparatus employs two anodized tantalum wires as hot wires, differing only in length, placed in a pressure vessel. A Wheatstone-type electronic bridge is used to measure the evolution of the resistance change of a finite segment of infinite wire.

The two identical wires are made out of 25 μm diameter tantalum and have lengths of 29 mm and 58 mm, respectively. They are placed one after the other and spot-welded to three 1.0 mm diameter tantalum rods which are attached to a ceramic flake. The tantalum rods act both as electrical contacts and as supports. The whole structure was anodized in situ to form a layer of insulating tantalum pentoxide on their surface.

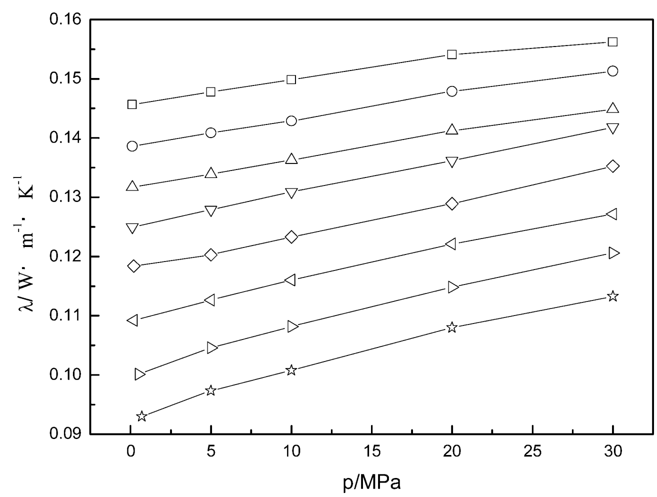

Figure 1. Pressure dependence of the thermal conductivity of diethyl ether at different temperatures: ☆, 373 K; open triangle pointing right, 353 K; open triangle pointing left, 333 K; ◇, 313 K; ▽, 293 K; △, 273 K; ○, 253 K; □, 233 K.

The two wires were supported and placed in the pressure vessel and sealed with the seal connector and nut. The apparatus and connections were all made of stainless steel (SSL 316), and the volume of the sample needed in the measurements did not exceed 30 cm^3.

The data acquisition system used in this work consists of several components: a Wheatstone bridge, Keithley 2400 Source Meter, two Keithley 2010 digital multimeters, two Agilent 34410A digital multimeters, Keithley 7001 switch systems, and an industrial computer. All the data acquisition and instrument control were performed by a computer via the IEEE-488 interfaces.

The transient hot-wire apparatus was immersed completely in a thermostatic bath (Fluke, model 7037). The temperature was measured with a platinum resistance thermometer. The total

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Table 1. Thermal Conductivity of Liquid Diethyl Ether

T_r/K	P/MPa	q/mW·m^{-1}	λ/W·m^{-1}·K	T_r/K	P/MPa	q/mW·m^{-1}	λ/W·m^{-1}·K
234.64	0.1	0.4257	0.1453	315.01	0.2	0.4448	0.1187
235.03	0.1	0.4848	0.1461	315.13	0.2	0.5062	0.1182
235.94	0.1	0.6848	0.1456	315.50	0.2	0.6058	0.1182
235.17	5.1	0.4849	0.1478	314.33	5.1	0.3087	0.1201
235.53	5.1	0.5805	0.1479	314.44	5.3	0.3874	0.1205
235.93	5.1	0.6848	0.1477	315.21	5.2	0.5063	0.1202
235.10	10.1	0.4848	0.1496	314.60	10.0	0.3874	0.1231
235.48	10.1	0.5804	0.1499	314.95	10.1	0.5063	0.1236
235.89	10.1	0.6847	0.1500	315.52	10.1	0.6059	0.1232
234.92	20.1	0.4259	0.1542	314.95	20.1	0.5064	0.1291
235.09	20.2	0.4848	0.1538	315.56	20.2	0.6059	0.1289
234.88	20.1	0.5798	0.1543	315.91	20.1	0.7146	0.1287
234.90	30.3	0.4841	0.1565	314.55	30.1	0.4449	0.1357
235.22	30.2	0.5795	0.1563	314.95	30.1	0.5064	0.1361
235.40	30.4	0.6833	0.1559	315.39	30.1	0.6059	0.1356
254.95	0.1	0.4915	0.1386	335.28	0.24	0.5064	0.1093
255.26	0.1	0.5883	0.1386	335.78	0.24	0.6059	0.1091
255.70	0.1	0.6937	0.1386	336.08	0.24	0.7146	0.1092
254.75	5.2	0.4318	0.1408	335.02	5.05	0.4449	0.1127
254.99	4.9	0.4915	0.1411	335.21	5.11	0.5064	0.1127
255.37	5.1	0.5882	0.1407	335.63	5.16	0.6059	0.1126
254.98	10.1	0.4915	0.1427	335.33	10.15	0.5064	0.1159
255.38	10.2	0.5883	0.1432	335.72	10.11	0.6060	0.1162
255.69	10.0	0.6938	0.1427	336.17	10.11	0.7146	0.1159
254.64	20.2	0.4318	0.1484	335.13	20.25	0.4450	0.1222
254.91	19.7	0.4915	0.1477	335.33	19.90	0.5065	0.1217
255.34	20.2	0.5883	0.1475	335.71	20.35	0.6061	0.1224
254.74	30.0	0.4318	0.1514	335.30	30.21	0.5065	0.1275
254.86	30.0	0.4915	0.1512	335.72	30.04	0.6061	0.1271
255.28	29.9	0.5882	0.1512	336.13	30.18	0.7147	0.1269
274.69	0.1	0.4382	0.1315	355.08	0.5	0.4450	0.1001
274.96	0.1	0.4989	0.1319	355.52	0.5	0.5065	0.1001
275.37	0.1	0.5970	0.1317	355.82	0.5	0.6061	0.1002
274.71	5.0	0.4383	0.1338	354.75	5.0	0.3876	0.1044
275.38	5.0	0.5970	0.1339	355.37	5.0	0.5066	0.1048
275.79	5.0	0.7042	0.1340	355.74	5.0	0.6062	0.1045
274.71	10.0	0.4383	0.1363	355.05	10.0	0.4451	0.1084
274.97	10.0	0.4989	0.1362	355.32	10.1	0.5066	0.1082
275.56	10.1	0.7042	0.1364	355.80	10.0	0.6062	0.1079
274.70	20.1	0.4383	0.1409	355.18	20.0	0.5067	0.1150
274.93	20.0	0.4989	0.1409	355.52	20.0	0.6063	0.1148
275.70	20.0	0.7043	0.1407	356.03	20.0	0.7150	0.1147
274.92	30.0	0.4989	0.1447	354.59	30.0	0.3877	0.1208
275.21	30.0	0.5970	0.1450	355.05	30.0	0.5066	0.1206
275.64	30.0	0.7041	0.1450	355.39	30.0	0.6062	0.1204
295.31	0.1	0.5052	0.1248	375.72	0.7	0.5059	0.0926
295.60	0.1	0.6045	0.1252	376.18	0.7	0.6053	0.0925
296.02	0.1	0.7129	0.1250	376.80	0.7	0.7139	0.0923
294.81	5.1	0.4436	0.1280	374.70	5.2	0.3870	0.0974
295.04	5.0	0.5050	0.1280	375.25	5.1	0.4443	0.0973
295.43	5.1	0.6042	0.1277	375.40	5.0	0.5057	0.0973
294.79	10.1	0.4436	0.1311	374.62	10.0	0.3870	0.1004
295.06	10.1	0.5048	0.1309	375.06	10.0	0.4443	0.1011
295.26	10.0	0.6041	0.1308	375.46	10.0	0.5057	0.1008
294.61	20.2	0.4435	0.1366	375.22	20.0	0.5056	0.1081
294.93	20.0	0.5049	0.1366	375.62	20.0	0.6050	0.1082
295.25	20.0	0.6042	0.1365	376.28	20.0	0.7134	0.1076
294.83	29.9	0.5048	0.1419	374.92	30.0	0.3869	0.1132
295.08	29.7	0.6040	0.1416	375.01	29.7	0.4443	0.1131
295.53	29.9	0.7124	0.1419	375.51	29.8	0.6049	0.1135

uncertainty of the temperature for the thermal conductivity measurements was less than ± 10 mK.

The pressure of liquids in the cell was achieved by an HPLC pump (Beijing Satellite manufactory, model 2PB05C)

Table 2. Thermal Conductivity of Liquid Diisopropyl Ether

T_r	P	q	λ	T_r	P	q	λ
K	MPa	$mW \cdot m^{-1}$	$W \cdot m^{-1} \cdot K$	K	MPa	$mW \cdot m^{-1}$	$W \cdot m^{-1} \cdot K$
235.54	0.1	0.4262	0.1258	315.13	0.1	0.4450	0.0993
235.46	0.1	0.4852	0.1259	315.48	0.1	0.5065	0.0996
236.06	0.1	0.5810	0.1259	315.88	0.1	0.6061	0.0994
236.25	5.0	0.3774	0.1280	315.03	5.0	0.4450	0.1027
236.33	5.0	0.4334	0.1275	315.39	5.0	0.5064	0.1023
236.67	5.0	0.4934	0.1277	315.73	5.1	0.6061	0.1027
236.29	10.1	0.4334	0.1300	315.35	10.0	0.5064	0.1050
237.15	10.2	0.3775	0.1302	315.71	10.0	0.6060	0.1054
236.70	10.2	0.5907	0.1305	316.26	10.0	0.7146	0.1050
236.45	20.3	0.4334	0.1337	315.07	20.0	0.4449	0.1105
236.44	20.2	0.4933	0.1331	315.26	20.0	0.5064	0.1099
236.80	20.3	0.5906	0.1337	315.76	20.0	0.6061	0.1104
236.15	30.6	0.4334	0.1369	314.96	30.0	0.4449	0.1145
236.53	29.9	0.4934	0.1364	315.24	30.0	0.5063	0.1144
236.92	30.0	0.5906	0.1363	315.98	30.0	0.7146	0.1144
254.73	0.1	0.3818	0.1201	335.23	0.1	0.4457	0.0935
255.08	0.1	0.4385	0.1205	335.46	0.1	0.5072	0.0932
255.26	0.1	0.4991	0.1199	335.94	0.1	0.6070	0.0931
254.66	5.1	0.3817	0.1220	335.01	5.4	0.4455	0.0959
254.89	5.3	0.4383	0.1223	335.84	5.0	0.6069	0.0960
255.14	5.1	0.4989	0.1221	336.37	5.2	0.7157	0.0959
254.74	10.0	0.3816	0.1238	334.99	10.1	0.4456	0.0998
254.86	10.2	0.4382	0.1241	335.32	10.1	0.5071	0.0995
255.13	10.1	0.4988	0.1236	335.84	10.1	0.6069	0.0995
254.40	20.4	0.3815	0.1276	335.11	20.0	0.5071	0.1038
254.90	20.1	0.4986	0.1280	335.68	19.7	0.6068	0.1043
255.61	19.9	0.5969	0.1285	336.31	20.1	0.7156	0.1042
254.47	30.4	0.4379	0.1314	335.29	29.9	0.4456	0.1093
254.76	29.5	0.4985	0.1312	335.51	30.2	0.6068	0.1094
255.58	30.1	0.7038	0.1315	335.72	30.0	0.7154	0.1096
275.00	0.1	0.4415	0.1129	355.29	0.3	0.4452	0.0865
275.30	0.1	0.5027	0.1135	355.66	0.3	0.5067	0.0869
275.91	0.1	0.6016	0.1131	356.04	0.3	0.6063	0.0866
274.95	5.1	0.4415	0.1154	355.45	5.0	0.4452	0.0916
275.19	5.0	0.5025	0.1150	355.56	5.0	0.5066	0.0910
275.60	5.0	0.6015	0.1152	354.97	5.0	0.3877	0.0913
274.72	10.1	0.3844	0.1177	355.23	10.1	0.4452	0.0944
275.02	10.0	0.4414	0.1178	355.33	10.1	0.5067	0.0944
275.25	10.0	0.5025	0.1175	355.87	10.0	0.6063	0.0940
274.89	20.0	0.4413	0.1220	354.85	19.7	0.3879	0.1006
275.51	20.1	0.6013	0.1218	354.97	19.8	0.4453	0.1000
276.04	20.1	0.7093	0.1219	355.47	20.1	0.5069	0.1001
274.60	30.0	0.3844	0.1274	354.72	29.9	0.4452	0.1060
274.86	29.9	0.4414	0.1269	354.72	29.9	0.6063	0.1051
275.17	30.1	0.5024	0.1271	356.04	29.9	0.7149	0.1056
294.58	0.1	0.3864	0.1073	375.24	0.4	0.3869	0.0813
295.03	0.1	0.5049	0.1071	375.47	0.4	0.4442	0.0812
295.70	0.1	0.6043	0.1066	375.87	0.4	0.5056	0.0816
294.95	5.0	0.4436	0.1089	375.40	5.1	0.4442	0.0858
295.35	5.0	0.5049	0.1085	375.75	5.1	0.5055	0.0853
295.82	5.0	0.6043	0.1087	376.26	5.1	0.6049	0.0854
294.65	10.0	0.3862	0.1118	375.25	10.0	0.4441	0.0893
294.98	10.0	0.4435	0.1115	375.61	10.0	0.5055	0.0889
295.32	10.1	0.5049	0.1111	376.23	10.0	0.6049	0.0890
295.13	20.1	0.5050	0.1161	375.12	20.0	0.4442	0.0959
295.60	20.1	0.6042	0.1160	375.57	20.0	0.5056	0.0957
296.18	20.1	0.7127	0.1159	376.05	20.0	0.6050	0.0955
294.64	30.1	0.4436	0.1197	374.95	29.8	0.3869	0.1021
295.14	30.1	0.6043	0.1199	375.55	30.3	0.5057	0.1026
295.27	30.0	0.7172	0.1198	374.75	30.0	0.4442	0.1021

with the pressure readings acquired. The pressure was measured with a resistance pressure transducer (Micro Sensor Co. Ltd., model MPM480) from (0 to 40) MPa with an uncertainty of 0.1 MPa.

Table 3. Thermal Conductivity of Liquid Dibutyl Ether

T_r / K	P / MPa	q / mW·m^{-1}	λ / W·m^{-1}·K	T_r / K	P / MPa	q / mW·m^{-1}	λ / W·m^{-1}·K
236.22	0.2	0.4294	0.1403	314.87	0.2	0.4441	0.1201
236.62	0.2	0.4889	0.1406	315.21	0.2	0.5055	0.1203
236.95	0.2	0.5850	0.1402	315.55	0.2	0.6048	0.1200
236.56	5.1	0.4887	0.1418	315.10	5.0	0.5051	0.1219
236.96	5.0	0.5850	0.1414	315.63	5.05	0.6044	0.1223
237.10	5.0	0.6902	0.1419	315.97	5.03	0.7128	0.1218
236.17	10.1	0.4293	0.1432	315.16	10.1	0.5051	0.1246
236.58	10.0	0.4888	0.1432	315.55	10.0	0.6045	0.1245
236.87	10.1	0.5850	0.1432	315.95	10.0	0.7129	0.1250
236.06	20.0	0.4293	0.1463	314.68	20.0	0.4438	0.1286
236.40	20.1	0.4887	0.1462	315.00	20.0	0.5051	0.1285
236.55	20.1	0.5849	0.1464	315.32	20.0	0.6044	0.1289
235.96	30.0	0.4289	0.1494	315.16	30.1	0.4438	0.1326
236.88	30.1	0.5845	0.1491	314.97	30.1	0.5051	0.1326
237.29	30.0	0.6896	0.1488	315.45	30.0	0.6044	0.1327
255.11	0.2	0.4345	0.1368	334.91	0.2	0.4448	0.1145
255.06	0.2	0.4945	0.1367	335.18	0.2	0.5063	0.1142
255.45	0.2	0.5918	0.1364	335.59	0.2	0.6058	0.1147
254.73	5.1	0.4343	0.1379	335.29	5.0	0.5063	0.1168
255.01	5.1	0.4944	0.1384	335.69	5.0	0.6059	0.1173
255.36	5.1	0.5917	0.1379	336.14	5.1	0.7146	0.1174
254.65	10.0	0.4342	0.1394	335.00	9.9	0.4448	0.1191
254.85	10.0	0.4944	0.1400	335.31	10.1	0.5064	0.1197
255.03	10.0	0.5917	0.1402	335.74	10.1	0.6059	0.1191
254.96	20.0	0.4943	0.1429	334.94	2.0	0.4449	0.1240
255.11	20.0	0.5916	0.1431	335.28	20.0	0.5064	0.1241
255.78	20.0	0.6979	0.1430	335.74	20.0	0.6060	0.1245
254.45	30.1	0.4341	0.1455	335.41	30.0	0.5064	0.1280
254.84	30.0	0.4942	0.1460	335.64	30.1	0.6059	0.1286
255.35	30.0	0.5916	0.1456	335.74	30.0	0.7146	0.1288
274.66	0.2	0.3824	0.1316	355.04	0.2	0.5062	0.1083
274.84	0.2	0.4999	0.1310	355.63	0.2	0.6056	0.1081
275.44	0.2	0.5983	0.1312	356.48	0.2	0.7143	0.1087
274.92	5.0	0.4385	0.1323	355.09	5.2	0.4448	0.1114
275.08	5.2	0.4991	0.1330	355.34	5.3	0.5062	0.1118
275.56	5.1	0.5974	0.1324	355.69	5.2	0.6057	0.1113
274.78	10.1	0.4385	0.1352	355.19	10.3	0.4448	0.1145
275.06	10.2	0.4992	0.1352	355.28	10.2	0.5062	0.1142
275.50	10.0	0.5974	0.1346	355.73	10.1	0.6058	0.1147
275.27	20.3	0.4992	0.1384	354.90	20.1	0.4450	0.1196
275.31	20.0	0.5974	0.1384	355.04	20.0	0.5064	0.1195
275.87	20.1	0.7046	0.1380	355.56	20.0	0.6059	0.1190
274.96	30.4	0.4387	0.1413	355.24	30.0	0.4450	0.1229
275.12	30.1	0.4993	0.1413	354.98	30.0	0.5065	0.1232
275.38	30.2	0.5975	0.1414	355.47	30.0	0.6060	0.1231
295.17	0.2	0.5034	0.1260	374.72	0.2	0.3867	0.1025
295.56	0.2	0.6025	0.1266	375.00	0.2	0.4440	0.1024
295.95	0.2	0.7106	0.1262	375.25	0.2	0.5054	0.1024
295.17	5.0	0.4423	0.1276	374.98	5.0	0.4440	0.1054
295.03	5.1	0.5035	0.1281	375.25	5.0	0.5054	0.1049
295.13	5.2	0.5035	0.1284	375.70	5.0	0.6046	0.1055
294.81	10.2	0.4424	0.1306	375.26	10.0	0.5054	0.1088
295.07	10.0	0.5035	0.1299	375.58	10.0	0.6046	0.1082
295.37	10.0	0.6026	0.1302	376.07	10.0	0.7131	0.1085
294.81	20.0	0.4424	0.1344	375.15	20.0	0.5053	0.1134
295.29	20.0	0.5036	0.1351	375.52	20.0	0.6046	0.1128
295.78	20.0	0.7108	0.1347	375.97	20.0	0.7131	0.1141
294.96	30.0	0.4424	0.1383	374.99	30.0	0.4441	0.1183
295.02	30.1	0.5035	0.1378	374.90	30.0	0.5055	0.1186
295.55	30.0	0.6026	0.1384	375.95	30.0	0.6049	0.1198

Measurements. The sample of diethyl ether was provided by Tianjin FuYu Chemical Co. Ltd., China, at a nominal mass purity specification of 99.5 %. Diisopropyl ether and di-*n*-butyl ether used in this work were purchased from Alfa Aesar, USA.

Table 4. Coefficients Employed in Equation 1

	diethyl ether		diisopropyl ether		dibutyl ether	
a_{ij}	value	uncertainty	value	uncertainty	value	uncertainty
a_{00}	$2.0733 \cdot 10^{-1}$	$2.5271 \cdot 10^{-6}$	$7.4932 \cdot 10^{-2}$	$1.8424 \cdot 10^{-6}$	$2.0953 \cdot 10^{-1}$	$4.3043 \cdot 10^{-6}$
a_{01}	$5.4173 \cdot 10^{-3}$	$3.0546 \cdot 10^{-5}$	$3.0705 \cdot 10^{-2}$	$2.2099 \cdot 10^{-5}$	$2.0294 \cdot 10^{-3}$	$5.1353 \cdot 10^{-5}$
a_{02}	$-1.9599 \cdot 10^{-4}$	$3.1771 \cdot 10^{-4}$	$-2.0834 \cdot 10^{-3}$	$2.2852 \cdot 10^{-4}$	$-3.4940 \cdot 10^{-4}$	$5.2870 \cdot 10^{-4}$
a_{03}	$3.4767 \cdot 10^{-8}$	$1.1201 \cdot 10^{-5}$	$3.3238 \cdot 10^{-5}$	$8.0507 \cdot 10^{-6}$	$1.1603 \cdot 10^{-5}$	$1.8589 \cdot 10^{-5}$
a_{10}	$-2.4029 \cdot 10^{-4}$	$2.1301 \cdot 10^{-5}$	$9.8720 \cdot 10^{-4}$	$1.4370 \cdot 10^{-5}$	$-4.3343 \cdot 10^{-4}$	$3.3451 \cdot 10^{-5}$
a_{11}	$-4.6690 \cdot 10^{-5}$	$7.2112 \cdot 10^{-6}$	$-2.9655 \cdot 10^{-4}$	$4.8976 \cdot 10^{-6}$	$2.5957 \cdot 10^{-5}$	$1.1436 \cdot 10^{-5}$
a_{12}	$1.9321 \cdot 10^{-6}$	$3.2528 \cdot 10^{-6}$	$2.0327 \cdot 10^{-5}$	$2.3313 \cdot 10^{-6}$	$3.2495 \cdot 10^{-6}$	$5.4108 \cdot 10^{-6}$
a_{13}	$-8.9776 \cdot 10^{-9}$	$1.1349 \cdot 10^{-7}$	$-3.2257 \cdot 10^{-7}$	$8.1284 \cdot 10^{-8}$	$-1.1152 \cdot 10^{-7}$	$1.8808 \cdot 10^{-7}$
a_{20}	$3.9446 \cdot 10^{-8}$	$1.3977 \cdot 10^{-7}$	$4.4316 \cdot 10^{-6}$	$9.3977 \cdot 10^{-8}$	$9.5206 \cdot 10^{-7}$	$2.1824 \cdot 10^{-7}$
a_{21}	$1.3284 \cdot 10^{-7}$	$4.7286 \cdot 10^{-8}$	$9.4437 \cdot 10^{-7}$	$3.2004 \cdot 10^{-8}$	$-1.0139 \cdot 10^{-7}$	$7.4572 \cdot 10^{-8}$
a_{22}	$-5.7985 \cdot 10^{-9}$	$1.1276 \cdot 10^{-8}$	$-6.4771 \cdot 10^{-8}$	$8.0363 \cdot 10^{-9}$	$-9.4893 \cdot 10^{-9}$	$1.8712 \cdot 10^{-8}$
a_{23}	$4.8297 \cdot 10^{-11}$	$3.8252 \cdot 10^{-10}$	$1.0197 \cdot 10^{-9}$	$2.7290 \cdot 10^{-10}$	$3.4336 \cdot 10^{-10}$	$6.3300 \cdot 10^{-10}$
a_{30}	$-5.8266 \cdot 10^{-10}$	$2.2573 \cdot 10^{-10}$	$4.9152 \cdot 10^{-9}$	$1.5124 \cdot 10^{-10}$	$-1.4925 \cdot 10^{-9}$	$3.5037 \cdot 10^{-10}$
a_{31}	$-1.0617 \cdot 10^{-10}$	$7.6349 \cdot 10^{-11}$	$-9.7295 \cdot 10^{-10}$	$5.1481 \cdot 10^{-11}$	$1.3823 \cdot 10^{-10}$	$1.1965 \cdot 10^{-10}$
a_{32}	$5.2504 \cdot 10^{-12}$	$1.3120 \cdot 10^{-11}$	$6.7308 \cdot 10^{-11}$	$9.2876 \cdot 10^{-12}$	$8.6152 \cdot 10^{-12}$	$2.1672 \cdot 10^{-11}$
a_{33}	$-6.5319 \cdot 10^{-14}$	$4.2833 \cdot 10^{-13}$	$-1.0492 \cdot 10^{-12}$	$3.0426 \cdot 10^{-13}$	$-3.3954 \cdot 10^{-13}$	$7.0722 \cdot 10^{-13}$

The purities of diisopropyl ether and di-*n*-butyl ether as reported by Alfa Aesar are better than 98 % and 99 %, respectively. No additional purification was performed.

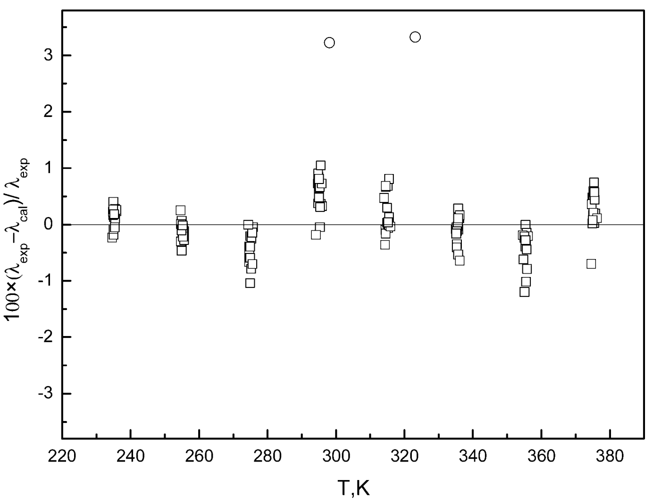

Figure 2. Relative deviations of calculated values by eq 1 from experimental data for pure diethyl ether: □, this work; ○, ref 9.

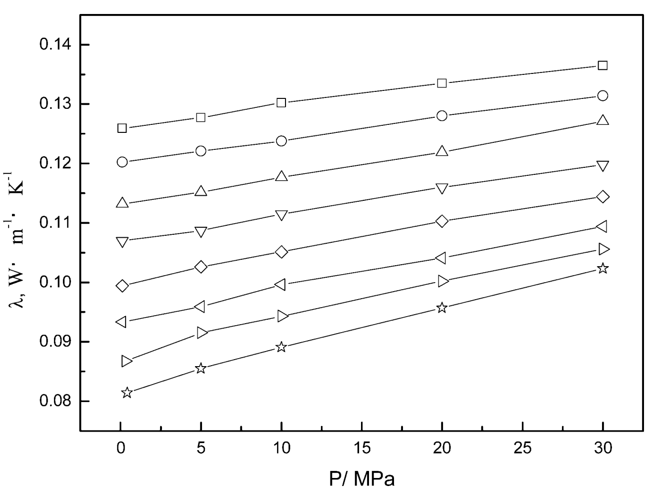

Figure 3. Pressure dependence of the thermal conductivity of diisopropyl ether at different temperatures: ☆, 373 K; open triangle pointing right, 353 K; open triangle pointing left, 333 K; ◇, 313 K; ▽, 293 K; △, 273 K; ○, 253 K; □, 233 K.

All measurements were performed from just above the saturation pressure, up to 30 MPa from (233.15 to 373.15) K, spacing 20 K. The thermal conductivity of toluene was measured before each liquid, to ensure the continuing good

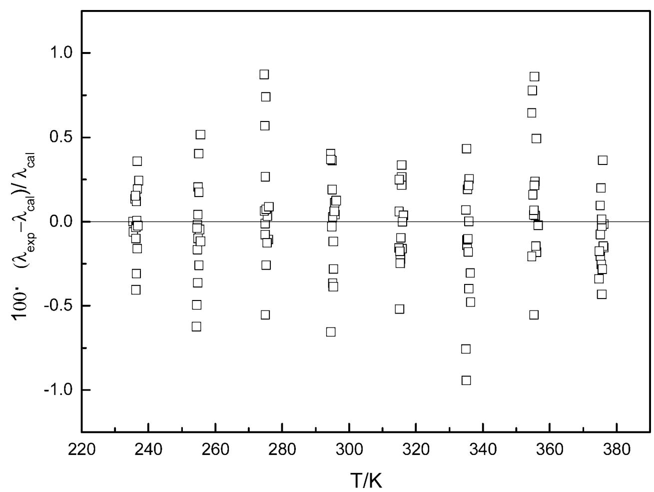

Figure 4. Relative deviations of calculated values by eq 1 from experimental data for pure diisopropyl ether: □, this work.

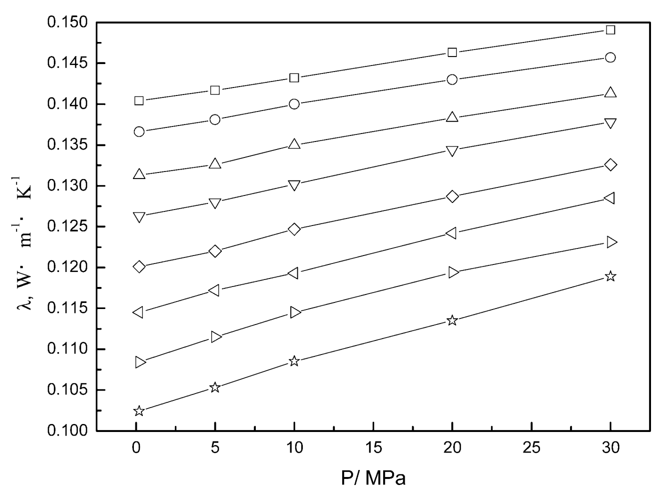

Figure 5. Pressure dependence of the thermal conductivity of dibutyl ether at different temperatures: ☆, 373 K; open triangle pointing right, 353 K; open triangle pointing left, 333 K; ◇, 313 K; ▽, 293 K; △, 273 K; ○, 253 K; □, 233 K.

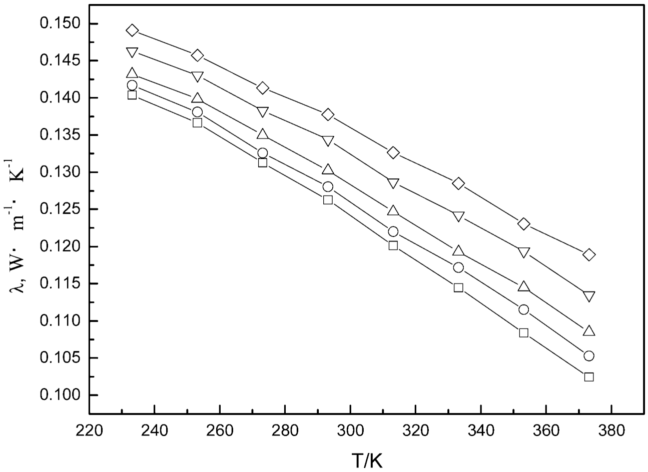

Figure 6. Temperature dependence of the thermal conductivity of dibutyl ether at different temperatures: ◇, 30 MPa; ▽, 20 MPa; △, 10 MPa; ○, 5 MPa; □, 0.2 MPa.

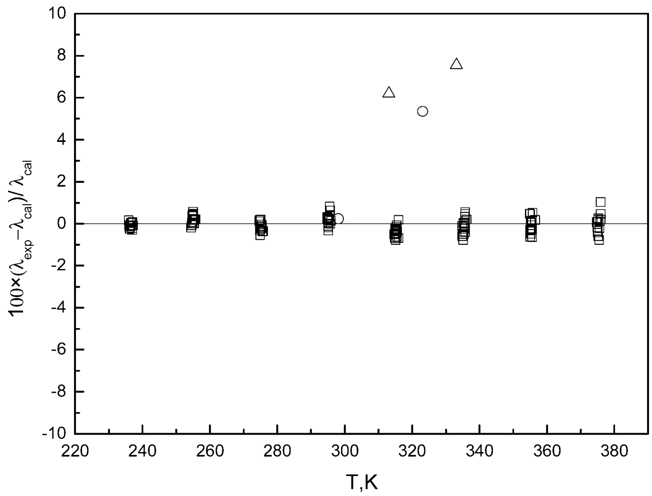

Figure 7. Relative deviations of calculated values by eq 1 from experimental data for pure dibutyl ether: □, this work; ○, ref 9; △, ref 10.

operation of the instrument. Agreement with the recommended values[8] is within a maximum deviation of 0.51 % and an average absolute deviation of 0.23 %, respectively. Tables 1, 2, and 3 show the present experimental measurements for the thermal conductivity of diethyl ether, diisopropyl ether, and di-*n*-butyl ether, respectively. All thermal conductivity data of each alkyl ether have been correlated as a function of the temperature and pressure, for the purpose of interpolation only, by an equation of the form

$$\lambda/\mathrm{W\cdot m^{-1}\cdot K^{-1}} = \sum_{i=0}^{3}\sum_{j=0}^{3} a_{ij}(T/\mathrm{K})^i(P/\mathrm{MPa})^j \qquad (1)$$

The value of all the coefficients is shown in Table 4.

Accounting for all of the random errors of measurement, and following our previous discussion, it is estimated that the tabulated thermal conductivity data have a relative uncertainty of better than ± 2.0 % with a coverage factor of $k = 2$. The temperature dependence of the thermal conductivity of diethyl ether, diisopropyl ether, and di-*n*-butyl ether at different pressures is shown in Figures 1, 3 and 5, respectively. The pressure dependence of the thermal conductivity of di-n-butyl ether at different temperatures is shown in Figure 6.

The average relative deviations of experimental data of diethyl ether, diisopropyl ether, and di-*n*-butyl ether from those calculated by the equation were 0.33 %, 0.23 %, and 0.28 %, and the relative deviations were 1.2 %, 0.94 %, and 1.0 % as shown in Figure 2, 4, and 7, respectively. As shown in Figure 2, the deviation of two data points at (298.15 and 323.15) K reported by Baroncini[9] was 3.2 % and 3.3 %. To the best of our knowledge, there are no comprehensive experimental data of the liquid thermal conductivity of diisopropyl ether reported in the published literature. Hence, no comparisons were made in Figure 4. For di-*n*-butyl ether, a comparison with the measurements of other investigators[9,10] is also presented in Figure 7. A good agreement (0.23 %) was found with the result of Baroncini[9] at 298.15 K. However, the data exhibit deviations as much as 5.3 % at 323.15 K. The deviations calculated from Sakiadis[10] and this work were from 6.1 % to 9.1 % as shown in Figure 7.

Conclusion

Measurements of the thermal conductivity of diethyl ether, diisopropyl ether, and di-*n*-butyl ether in this work were performed in a transient hot-wire instrument employing for the heat source two electrical insulated tantalum wires, over the temperature range (233 to 373) K at pressures up to 30 MPa. The overall relative uncertainty in the reported data is ± 2.0 %. The experimental data were correlated as a function of pressure and temperature. The average relative deviation of experimental data from those calculated by the equation were 0.33 %, 0.23 %, and 0.28 %, and the relative deviations were 1.2 %, 0.94 %, and 1.0 %, respectively.

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