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Surface tension of diethyl carbonate, 1,2-dimethoxyethane and diethyl adipate

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ABSTRACT

The surface tension was investigated with a differential capillary rise method in the temperature range from 273 to 373 K for diethyl carbonate, 278 to 373 K for 1,2-dimethoxyethane, and 293 to 373 K for diethyl adipate, respectively. The uncertainties of the temperature and surface tension were estimated to be within ±10 mK and ±0.2 mN m^{-1}, respectively. A surface tension correlation was developed as a function of temperature with the experimental data, and the average absolute deviations were 0.04, 0.07 and 0.09 mN m^{-1} for diethyl carbonate, 1,2-dimethoxyethane and diethyl adipate, respectively.

1. Introduction

Oxygenated additives [1–3], such as diethyl carbonate, 1,2-dimethoxyethane and diethyl adipate, are thought to be potential alternative fuels and good fuel additives for their excellent combustion characteristic. The thermophysical properties are indispensable for the increased applications of oxygenated additives. In our previous work, the liquid density, viscosity and thermal conductivity of diethyl carbonate, 1,2-dimethoxyethane were measured [4–6]. Surface tension, as an important property influencing the heat transfer, flow and phase change characteristic, is useful for the calculation of combustion. Though Sugden [7], Vogel [8], Deng et al. [9] and Ren et al. [10] have measured the surface tension of diethyl carbonate; Karosi and Kovlts [11], Kumar et al. [12] and Deng et al. [9] have measured the surface tension of 1,2-dimethoxyethane; and Vogel [8,13] and Mumford and Phillips [14] have measured the surface tension of diethyl adipate, unfortunately only a few data points were obtained. In this work, the surface tension was investigated in the temperature range from 273 to 373 K for diethyl carbonate, 278 to 373 K for 1,2-dimethoxyethane, and 293 to 373 K for diethyl adipate, respectively. The experimental data was used to develop a surface tension correlation for diethyl carbonate, 1,2-dimethoxyethane and diethyl adipate.

2. Experimental

2.1. Materials

Diethyl carbonate was provided by Chaoyang Chemical Co., Ltd, China (minimum mass purity of 99.7%). 1,2-Dimethoxyethane was provided by Jixi Sanming Industry of Fine Chemicals Co., Ltd, China (nominal mass purity specification of 99.9%). Diethyl adipate was provided by National Medicine and Chemistry Co., Ltd, China (minimum mass purity specification of 99.0%). The fluid samples were used without any further treatment.

2.2. Measurements

The differential capillary rise method was used for the surface tension measurement. The same experimental apparatus and procedure has been used to measure the surface tensions of some oxygenated fuels in our previous work [15–17].

During the experiment, the capillary rise difference Δh_0 was measured, and the surface tension can be calculated using the following expression as:

$$\sigma = \frac{(\rho_L - \rho_g)g}{2(1/r_1 - 1/r_2)}(\Delta h_0 + r_1/3 - r_2/3) \quad (1)$$

where σ is the surface tension, g is the local gravitational acceleration (this work, $g = 9.7965\ \mathrm{m\,s^{-2}}$), ρ_L and ρ_g are the densities of saturated liquid and vapor, respectively. Δh_0 is the height difference of the meniscus bottom of the two capillaries. r_1 and r_2 are the radii of two different capillaries used in the experiment, respectively.

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Table 1
Surface tension of diethyl carbonate, 1,2-dimethoxyethane and diethyl adipate.

Sample	T (K)	ρ_L (kg m^{-3})	ρ_g (kg m^{-3})	Δh_0 (mm)	a^2 (mm^2)	σ (mN m^{-1})
Diethyl carbonate	273.18	998.2	0.036	14.56	5.96	29.2
	278.18	992.7	0.040	14.38	5.89	28.6
	283.18	987.1	0.046	14.18	5.80	28.1
	288.18	981.4	0.051	13.96	5.71	27.5
	293.16	975.7	0.057	13.70	5.61	26.8
	298.10	970.0	0.063	13.50	5.53	26.3
	303.17	964.2	0.070	13.26	5.43	25.6
	308.11	958.4	0.077	13.08	5.35	25.1
	313.19	952.5	0.085	12.82	5.25	24.5
	318.16	946.6	0.093	12.66	5.18	24.0
	323.16	940.8	0.102	12.44	5.09	23.5
	328.13	935.0	0.111	12.26	5.02	23.0
	333.18	929.1	0.121	12.00	4.91	22.4
	338.17	923.4	0.131	11.78	4.82	21.8
	343.17	917.6	0.142	11.54	4.72	21.2
	348.17	911.9	0.153	11.32	4.63	20.7
	353.19	906.3	0.164	11.10	4.54	20.2
	358.18	900.8	0.176	10.88	4.45	19.6
	363.16	895.3	0.189	10.66	4.36	19.1
	368.18	889.9	0.202	10.48	4.29	18.7
	373.17	884.7	0.216	10.16	4.16	18.0
1,2-Dimethoxyethane	278.17	882.5	0.121	14.98	6.13	26.5
	283.17	877.1	0.159	14.76	6.04	26.0
	288.18	871.7	0.206	14.46	5.92	25.3
	293.17	866.3	0.265	14.20	5.81	24.7
	298.03	861.0	0.335	13.87	5.68	23.9
	303.15	855.3	0.424	13.66	5.59	23.4
	308.12	849.8	0.528	13.41	5.49	22.8
	313.16	844.2	0.654	13.15	5.38	22.3
	318.17	838.6	0.802	12.83	5.25	21.6
	323.18	832.9	0.977	12.60	5.16	21.0
	328.17	827.2	1.179	12.32	5.04	20.4
	333.17	821.4	1.414	12.06	4.94	19.8
	338.17	815.6	1.686	11.82	4.84	19.3
	343.17	809.7	1.997	11.57	4.73	18.7
	348.17	803.7	2.353	11.28	4.62	18.1
	353.18	797.6	2.758	11.04	4.52	17.6
	358.17	791.5	3.213	10.70	4.38	16.9
	363.17	785.3	3.727	10.44	4.27	16.4
	368.17	779.0	4.303	10.14	4.15	15.7
	373.17	772.6	4.947	9.90	4.05	15.2
Diethyl adipate	293.16	1006.5	0.001	28.10	6.64	32.7
	298.09	1001.9	0.001	27.72	6.55	32.2
	303.17	997.1	0.001	27.40	6.47	31.6
	308.11	992.5	0.002	27.00	6.38	31.0
	313.18	987.7	0.003	26.52	6.26	30.3
	318.15	983.1	0.004	26.14	6.17	29.7
	323.17	978.3	0.005	25.78	6.09	29.2
	328.12	973.7	0.006	25.45	6.01	28.7
	333.16	968.9	0.008	25.24	5.96	28.3
	338.16	964.2	0.010	24.84	5.87	27.7
	343.15	959.4	0.012	24.48	5.78	27.2
	348.13	954.7	0.014	24.12	5.70	26.6
	353.16	949.9	0.016	23.87	5.64	26.2
	358.13	945.2	0.019	23.59	5.57	25.8
	363.13	940.4	0.022	23.24	5.49	25.3
	368.15	935.6	0.026	22.92	5.41	24.8
	373.14	930.9	0.029	22.56	5.33	24.3

In general, the capillary constant a^2 is defined in order to learn the accuracy of the apparatus itself.

$$a^2 = \frac{\Delta h_0 + r_1/3 - r_2/3}{1/r_1 - 1/r_2} \quad (2)$$

For the diethyl carbonate and 1,2-dimethoxyethane, bore radii of two capillaries are $r_1 = 0.1490 \pm 0.0001$ mm and $r_2 = 0.2340 \pm 0.0001$ mm. For the diethyl adipate, bore radii of two capillaries are $r_1 = 0.1556 \pm 0.0001$ mm and $r_2 = 0.4528 \pm 0.0001$ mm. Their radii were determined by partially filling the capillaries with plugs of mercury. The plugs were weighed and their lengths were measured with a traveling microscope. The procedure was repeated at least six times for each capillary with different plugs of mercury.

The capillaries were placed in a small pressure cell with observation windows, and the pressure cell was placed in a thermostatic bath in which the temperature stability was within ±10 mK in 2 h. The silicon oil was chosen as the working fluid. The temperature measurement system consisted of an Agilent 3458A and two 25 Ω standard platinum resistance thermometers. One thermometer (no. 68033) was used from 83.81 to 273.16 K, and another (no. 68115) was used from 273.15 to 933.47 K. The thermometers were calibrated on ITS-90 at the National Institute of Metrology of China. The total uncertainty of temperature for surface tension was less