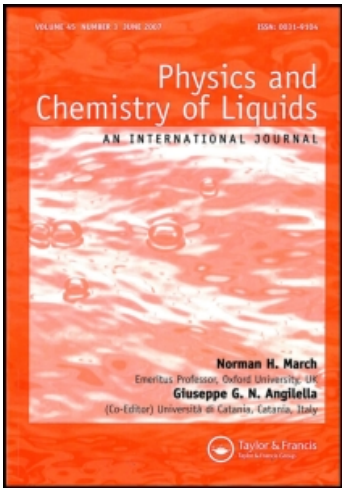

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Heat Capacity of Alkylbenzene Chloroethane Binary Mixtures*

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HEAT CAPACITY OF ALKYLBENZENE + CHLOROETHANE BINARY MIXTURES*

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Heat capacity data of the binary mixtures of: benzene + 1,2-dichloroethane, + 1,1,1-trichloroethane, + 1,1,2,2-tetrachloroethane, toluene + 1,2-dichloroethane, + 1,1,1-trichloroethane, + 1,1,2,2-tetra-chloroethane, *p*-xylene + 1,2-dichloroethane, + 1,1,1-trichloroethane, + 1,1,2,2-tetrachloroethane—measured in the range of 45–60°C using a differential heating technique are reported. The measurements are well represented by the mixture rules proposed by Jamieson and Cartwright, and Teja.

KEY WORDS: Heat capacity, mixtures, alkylbenzenes, chloroethanes.

INTRODUCTION

Heat capacity of liquids and their mixtures is an important property needed in the design and operation of chemical process. In continuation of the group's interest in a systematic study of thermophysical properties of alkylbenzene-chloroethane mixtures[1,2], this work on the heat capacity of the liquid mixtures mentioned in the abstract is undertaken.

APPARATUS AND EXPERIMENTAL

A simplified form of the differential heating/cooling apparatus described by Spear[3], shown schematically in Figure 1, is used for the measurements. It consists of two identical glass sample tubes of 2.5 cm internal diameter, fused at the bottom, enclosed by means of standard ground glass joints, into air jackets formed from 5 cm internal diameter glass tubes. The air jackets are fused into a 20 cm internal diameter glass

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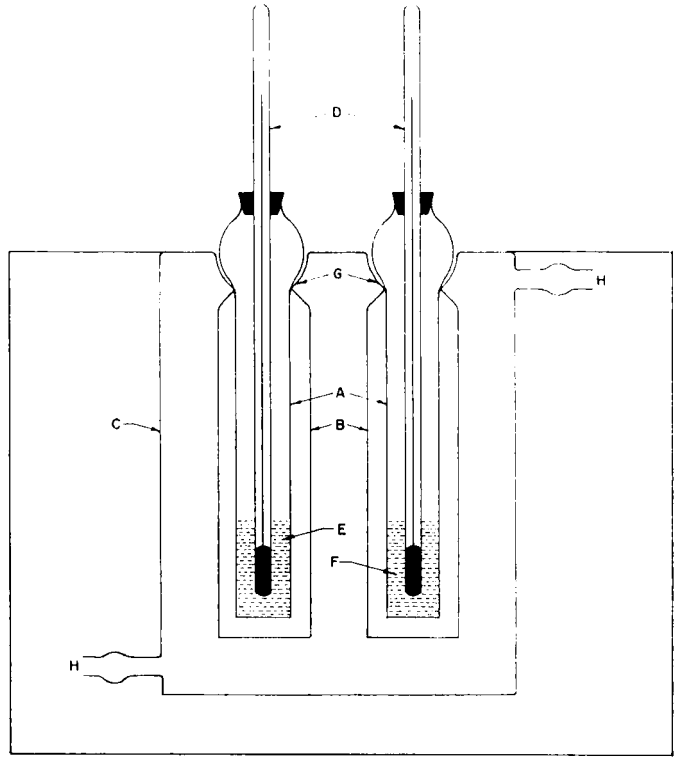

Figure 1 Schematic diagram of heat capacity apparatus.

tube. The entire assembly is kept in an electronically controlled water bath and maintained at ± 0.05°C of the desired temperature.

Sufficient time, about one and half hours is allowed for the thermostated apparatus to attain the desired equilibrium temperature of 80°C. The sample tubes are carefully cleaned, dried and weighed. Equal volumes of the test liquid and the reference liquid (of nearly the same thermal conductivity) are poured into the sample tubes and weighed. The two sample tubes are inserted into the air jackets simultaneously and the temperature rise in both the tubes is recorded every minute alternatively, till the rate of heating becomes too slow for observation. The experiment is carried out twice, with 8 ml and 5 ml samples, to eliminate the effect of evaporation terms E_T and E_R of the equation for heat capacity

$$\frac{K_T + C_{P_T} W_T}{t_T} + E_T = \frac{K_R + C_{P_R} W_R}{t_R} + E_R \tag{1}$$

where K_T and K_R are the thermal capacities of the sample tubes holding the test sample and reference liquids, C_{P_T}, W_T, C_{P_R}, W_R are the heat capacities and weights, E_T and E_R are the evaporation rates, and t_T and t_R are the times required by the test liquid and reference liquid respectively, to go through the same temperature range (with the observation temperature as the mid point). By careful calibration and checking experiments on several pure liquids—aniline, chlorobenzene, isoamyl-alcohol, toluene, etc.—the method and apparatus are found to produce heat capacity values with an average deviation of 3.0%. Prior to use in the experiments all the analar grade pure liquids are further purified employing the methods described by Weissberger[4] and Reddick and Burger[5].

RESULTS AND DISCUSSION

The physical properties of the pure liquids are compared with the literature data[6] in Table 1. The pure liquid heat capacity measurements are compared with literature values[6,7] in Table 2. The data on mixtures are presented and compared with the following estimation methods in Table 3.

Weight fraction average:

$$C_{p_m} = W_1 C_{P_1} + W_2 C_{P_2} \tag{2}$$

Jamieson and Cartwright method[8]

$$C_{P_m} = (W_1 C_{P_1} + W_2 C_{P_2})(1 + \alpha + \beta) \tag{3}$$

where

$$\alpha = (0.00141)|\Delta H_1 - \Delta H_2|^{0.88} \tag{4}$$

$$\beta = 5 \times 10^{-5}|\Delta H_1 - \Delta H_2| \sin(360 W_2) \tag{5}$$

and Teja's method[9]

$$C_{P_m}[T_R] = x_1 C_{P_1}[T_{R_1}] + x_2 C_{P_2}[T_{R_2}] \tag{6}$$

where

$$T_R = T/T_C; [T_R]_m = T/T_{c_m} \tag{7}$$

and

$$T_{c_m} = W_1 T_{C_1} + W_2 T_{C_2} \tag{8}$$

The prediction capabilities of the methods for the mixtures studied in this work are in accordance with the expectation: the Jamieson and Cartwright method requiring the latent heats of the pure liquids gives a percent average absolute deviation (PAAD) of 0.05, proving superior to the weight fraction average with a PAAD of 0.16 and Tejas' method with a PAAD of 2.0.

Table 1 Comparison of the physical properties of pure liquids with literature data[6] at 20°C.

Substance	*Density*		*Refractive-index*	
	Present work	*Literature*	*Present work*	*Literature*
Benzene	0.8825	0.885	1.4998	1.5010
Toluene	0.8669	0.867	1.4966	1.4968
p-Xylene	0.8610	0.861	1.4960	1.4958
1,2-Dichloro-ethane	1.2525	1.253	1.4446	1.4448
1,1,1-Trichloro-ethane	1.3385	1.339	1.4378	1.4379
1,1,2,2-Tetra-chloroethane	1.5947	1.595	1.4941	1.4940

Table 2 Comparison of the heat capacity of pure liquids with literature values[6,7].

Substance	*Temperature* °C	*Heat capacity, Cal/g.°C*	
		Present work	*Literature*
Benzene	45	0.423	0.434
	50	0.424	0.437
	55	0.425	0.440
	60	0.426	0.443
Toluene	45	0.428	0.425
	50	0.434	0.430
	55	0.437	0.432
	60	0.443	0.434
p-Xylene	45	0.428	0.425
	50	0.434	0.429
	55	0.441	0.432
	60	0.446	0.434
1,2-Dichloroethane	45	0.300	0.311
	50	0.301	0.313
	55	0.302	0.314
	60	0.303	0.315
1,1,1-Trichloroethane	45	0.261	0.262
	50	0.268	0.265
	55	0.275	0.279
	60	0.283	0.293
1,1,2,2-Tetrachloro-ethane	45	0.194	0.197
	50	0.196	0.198
	55	0.197	0.199
	60	0.198	0.200

Table 3 Mixture heat capacity data and comparison with estimation methods.

Temp., C	*Weight % of component (1)*	*Heat Capacity, Cal/g, °C*			
		Experimental	*Weight fraction average method*	*Jamieson & Cart Wright method*	*Teja's method*
	2	3	4	5	6
	1. *Benzene*(1) + 1,2-*dichloroethane*(2)				
45	19.13	0.326	0.323	0.324	0.328
	41.50	0.348	0.351	0.352	0.358
	62.34	0.371	0.376	0.377	0.383
	80.08	0.388	0.398	0.399	0.403
50	19.13	0.329	0.324	0.325	0.329
	41.50	0.353	0.352	0.353	0.359
	62.34	0.378	0.377	0.378	0.387
	80.08	0.394	0.400	0.401	0.404
55	19.13	0.335	0.325	0.326	0.330
	41.50	0.358	0.353	0.354	0.360
	62.34	0.384	0.378	0.379	0.385
	80.08	0.401	0.400	0.401	0.405
60	19.13	0.339	0.326	0.327	0.332
	41.50	0.362	0.354	0.355	0.362
	62.34	0.391	0.379	0.380	0.390
	80.08	0.407	0.402	0.403	0.406
	2. *Benzene*(1) + 1,1,1-*trichloroethane*(2)				
45	21.17	0.290	0.295	0.296	0.310
	40.18	0.319	0.326	0.328	0.345
	61.05	0.350	0.360	0.363	0.377
	79.19	0.376	0.389	0.392	0.400
50	21.17	0.300	0.301	0.302	0.316
	40.18	0.329	0.330	0.332	0.349
	61.05	0.361	0.363	0.366	0.379
	79.19	0.388	0.391	0.394	0.403
55	21.17	0.311	0.306	0.307	0.320
	40.18	0.340	0.335	0.337	0.353
	61.05	0.374	0.366	0.369	0.382
	79.19	0.399	0.394	0.397	0.404
60	21.17	0.320	0.313	0.314	0.326
	40.18	0.350	0.340	0.342	0.357
	61.05	0.384	0.370	0.373	0.382
	79.19	0.410	0.396	0.399	0.406
	3. *Benzene*(1) + 1,1,2,2-*tetrachloroethane*(2)				
45	19.27	0.236	0.238	0.239	0.285
	40.50	0.291	0.286	0.288	0.358
	62.55	0.342	0.337	0.340	0.387
	83.36	0.393	0.384	0.386	0.410
50	19.27	0.238	0.240	0.241	0.287
	40.50	0.293	0.288	0.290	0.361
	62.55	0.348	0.338	0.341	0.389
	83.36	0.396	0.386	0.388	0.412

(*continued*)

Table 3 (*continued*)

Temp., °C	*Weight % of component* (1)	*Heat Capacity, Cal/g, °C*			
		Experimental	*Weight fraction average method*	*Jamieson & Cart Wright method*	*Teja's method*
	2	3	4	5	6
55	19.27	0.240	0.241	0.242	0.288
	40.50	0.296	0.289	0.291	0.361
	62.55	0.352	0.339	0.342	0.390
	83.36	0.398	0.387	0.389	0.413
60	19.27	0.242	0.242	0.243	0.289
	40.50	0.299	0.290	0.292	0.362
	62.55	0.356	0.340	0.343	0.391
	83.36	0.405	0.388	0.390	0.414
	4. *Toluene*(1) + 1,2-*dichloroethane*(2)				
45	21.52	0.307	0.327	0.328	0.327
	40.67	0.344	0.352	0.353	0.353
	61.53	0.374	0.378	0.379	0.379
	79.52	0.394	0.401	0.402	0.402
50	21.52	0.320	0.329	0.330	0.330
	40.67	0.348	0.355	0.356	0.355
	61.53	0.379	0.383	0.384	0.383
	79.52	0.405	0.406	0.407	0.407
55	21.52	0.330	0.331	0.332	0.331
	40.67	0.353	0.357	0.358	0.357
	61.53	0.383	0.385	0.386	0.385
	79.52	0.407	0.409	0.410	0.410
60	21.52	0.342	0.333	0.334	0.333
	40.67	0.358	0.360	0.361	0.360
	61.53	0.388	0.389	0.390	0.390
	79.52	0.414	0.414	0.415	0.415
	5. *Toluene*(1) + 1,1,1-*trichloroethane*(2)				
45	20.60	0.288	0.295	0.296	0.294
	39.35	0.320	0.326	0.328	0.331
	60.22	0.358	0.362	0.365	0.367
	79.56	0.397	0.394	0.396	0.398
50	20.60	0.300	0.302	0.303	0.309
	39.35	0.330	0.333	0.335	0.338
	60.22	0.365	0.368	0.371	0.376
	79.56	0.400	0.400	0.402	0.406
55	20.60	0.314	0.308	0.309	0.315
	39.35	0.340	0.338	0.340	0.348
	60.22	0.372	0.373	0.376	0.382
	79.56	0.403	0.404	0.406	0.410
60	20.60	0.328	0.316	0.317	0.323
	39.35	0.349	0.345	0.347	0.355
	60.22	0.380	0.379	0.382	0.388
	79.56	0.406	0.410	0.412	0.416

Table 3 (*continued*)

Temp., °C	Weight % of component (1)	Heat Capacity, Cal/g, °C			
		Experimental	*Weight fraction average method*	*Jamieson & Cart Wright method*	*Teja's method*
	2	3	4	5	6
	6. *Toluene*(1) + 1,1,2,2-*tetrachloroethane*(2)				
45	19.89	0.241	0.240	0.241	0.274
	39.66	0.290	0.287	0.289	0.331
	61.74	0.340	0.340	0.342	0.377
	82.88	0.394	0.390	0.392	0.408
50	19.89	0.242	0.243	0.244	0.277
	39.66	0.291	0.290	0.292	0.335
	61.74	0.343	0.343	0.345	0.383
	82.88	0.396	0.393	0.395	0.414
55	19.89	0.243	0.244	0.245	0.279
	39.66	0.292	0.292	0.294	0.337
	61.74	0.342	0.346	0.348	0.384
	82.88	0.398	0.398	0.400	0.417
60	19.89	0.243	0.247	0.248	0.282
	39.66	0.292	0.295	0.297	0.342
	61.74	0.345	0.349	0.351	0.389
	82.88	0.399	0.401	0.403	0.422
	7. *p-Xylene*(1) + 1,2-*dichloroethane*(2)				
45	21.73	0.323	0.327	0.328	0.325
	40.98	0.355	0.352	0.353	0.343
	61.83	0.372	0.379	0.380	0.375
	79.73	0.396	0.402	0.403	0.404
50	21.73	0.329	0.330	0.331	0.327
	40.98	0.359	0.355	0.356	0.346
	61.83	0.374	0.383	0.383	0.379
	79.73	0.402	0.407	0.407	0.408
55	21.73	0.332	0.332	0.333	0.329
	40.98	0.363	0.358	0.359	0.349
	61.83	0.379	0.387	0.388	0.384
	79.73	0.406	0.413	0.414	0.414
60	21.73	0.337	0.334	0.335	0.331
	40.98	0.367	0.362	0.363	0.352
	61.83	0.383	0.392	0.392	0.387
	79.73	0.410	0.417	0.417	0.418
	8. *p-Xylene*(1) + 1,1,1-*trichloroethane*(2)				
45	20.82	0.291	0.295	0.296	0.298
	39.66	0.319	0.327	0.329	0.331
	60.53	0.360	0.362	0.364	0.365
	79.77	0.399	0.394	0.396	0.396
50	20.82	0.302	0.303	0.304	0.305
	39.66	0.329	0.334	0.335	0.337
	60.53	0.365	0.368	0.370	0.372
	79.73	0.401	0.400	0.402	0.402

(*continued*)

Table 3 (*continued*)

Temp., °C	*Weight % of component* (1)	*Heat Capacity, Cal/g, °C*			
		Experimental	*Weight fraction average method*	*Jamieson & Cart Wright method*	*Teja's method*
	2	3	4	5	6
55	20.82	0.313	0.309	0.310	0.312
	39.66	0.339	0.341	0.343	0.344
	60.53	0.369	0.375	0.377	0.378
	79.73	0.403	0.407	0.409	0.408
60	20.82	0.325	0.317	0.318	0.319
	39.66	0.348	0.343	0.345	0.351
	60.53	0.374	0.382	0.384	0.384
	79.73	0.405	0.413	0.415	0.415
	9. *p-Xylene*(1) + 1,1,2,2-*Tetrachloroethane*(2)				
45	20.09	0.242	0.241	0.242	0.263
	39.97	0.291	0.287	0.288	0.318
	62.04	0.342	0.339	0.341	0.366
	83.06	0.392	0.388	0.390	0.403
50	20.09	0.244	0.244	0.244	0.267
	39.37	0.292	0.291	0.292	0.323
	62.04	0.343	0.343	0.345	0.372
	83.06	0.395	0.393	0.395	0.408
55	20.09	0.245	0.246	0.247	0.269
	39.97	0.293	0.294	0.295	0.326
	62.04	0.344	0.348	0.350	0.376
	83.06	0.396	0.399	0.401	0.415
60	20.09	0.246	0.247	0.247	0.272
	39.97	0.294	0.297	0.298	0.329
	62.04	0.345	0.352	0.354	0.381
	83.06	0.398	0.404	0.406	0.419

References

1. M. V. Rao and D. S. Viswanath, Excess Enthalpies of *p*-Xylene + 1,2-Dichloroethane, +1,1,1-Trichloroethane, +1,1,2,2-Tetrachlorethane at 298.15 and 308.15 K, *J. Chem. Thermodynamics*, **15**, 89 (1983).
2. J. Prabhakar, K. Ashok Kumar, V. Narayana Swamy, M. Venkateshwara Rao and D. H. L. Prasad, Thermophysical Properties of Alkylbenzene-Chloroethane Systems—Viscosity and Surface Tension, *J. Indian Inst. Sci.*, **66**, 449 (1986).
3. N. H. Spear, Measuring Specific Heat of Liquids at High Temperatures—Small sample Apparatus, *Analytical Chemistry*, **24**(6), 938 (1952).
4. A. Weissberger, *Techniques of Chemistry, Physical Methods*, Vol. I (Interscience, New York, 1945).
5. J. A. Reddick and W. S. Bunger, *Techniques of Chemistry, Vol. II*, Organic Solvents, 3rd edn. (Wiley-Interscience, New York, 1970).
6. R. R. Dreisbach, *Physical Properties of Chemical Compounds* Vols. I–III (American Chemical Society, 1955–1961).

7. R. W. Gallant, *Physical Properties of Hydrocarbons*, Vols. 1-2 (Gulf Publishing Co., Houston, Texas, 1968).
8. D. T. Jamieson and G. Cartwright, *Properties of Binary Liquid Mixtures: Heat Capacity*, NEL Report No. 648 (NEL, East Killbridge, UK, 1978).
9. A. S. Teja, Simple Method for the calculation of Heat Capacities of Liquid Mixtures, *J. Chem. Eng. Data*, **28**, 83 (1983).