*Thermochimica Acta*, 233 (1994) 325-328
Elsevier Science B.V., Amsterdam
*SSDI* 0040-6031(93)01487-N

# Ultrasonic velocities, specific volumes, isobaric thermal expansivities, isothermal compressibilities and isochoric thermal pressure coefficients for liquid tetramethylsilane from 224.86 to 273.28 K

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(Received 30 June 1993; accepted 12 July 1993)

**Abstract**

The specific volumes of and velocities of sound in tetramethylsilane have been measured from 224.86 to 273.28 K. From the results and previously published isobaric heat capacities, the thermal expansivities, isothermal compressibilities and isochoric thermal pressure coefficients have been calculated.

## INTRODUCTION

In order to obtain values for a number of physical properties of tetramethylsilane for use in theories applied to tetramethylsilane-containing mixtures [1], we have determined the specific volumes $v$ of and velocities of ultrasound $W$ in tetramethylsilane at temperatures $T$ from 224.86 to 273.28 K. From the results and the isobaric heat capacities $C_p$ reported by Harada et al. [2], we have calculated the isothermal compressibilities $\beta_T$ and the thermal pressure coefficients $\gamma_V$.

## EXPERIMENTAL

The tetramethylsilane was Fluka AG: "puriss", "spectroscopic Grade", batch no. 87920, stated to contain not less than 99.8 mol percent of the named compound. It was dehydrated over No. 4 Grade Molecular Sieves, distilled into a Teflon-stoppered flask for storage and degassed before use.

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The ultrasonic velocities were measured using a swept-frequency acoustic resonant interferometer. The resonator, constructed from two X-cut quartz crystals, has the liquid to be examined placed between them and this forms the coupling medium whereby the elastic displacement generated in one is transmitted to the other. Application of an electrical voltage to the first crystal produces a displacement of the crystal-liquid interface relative to its unperturbed position, displacement that propagates as a plane wave and is partially reflected at the second crystal–liquid interface.

The ratio of the amount of energy transmitted to that reflected is determined by the relative magnitudes of the acoustic impedances of the two media involved. After certain conditions are satisfied with regard to displacement and impedances at the reference interfaces, namely a calibration procedure, equations for the description of the resonance conditions of the cavity as a whole can be obtained. From this point, the velocity of sound in an unknown medium $W$ may be related to that in some reference medium.

Tetramethylsilane is a fairly low absorbing liquid and, as such, the precision of the measurements of ultrasonic speeds performed with the equipment described is of the order of one part in $10^4$. Full details on the method and equipment used are available [3].

The Pyrex dilatometer used to measure the specific volumes was similar in design and method of operation to that described by Orwoll and Flory [4]. The sample was confined by mercury and changes in its volume were monitored by weighting the amount of mercury expelled from or drawn into the dilatometer. All weighings were carried out in an air-conditioned room and normal buoyancy corrections were applied; the weighings are accurate to ±30 mg. The dilatometer was placed in a thermostat which showed temperature variations of ±2 mK. The absolute temperature was measured through a platinum resistance thermometer calibrated to ±5 mK. Full details of the method of filling of the dilatometer and other manipulations are available [5].

## RESULTS

The results of the measurements are given in Table 1. From the smooth fits for the specific volumes $v$, i.e. $\ln(v/\mathrm{cm}^3\,\mathrm{g}^{-1}) = a + b(T/\mathrm{K}) + c(T/\mathrm{K})^2 + d(T/\mathrm{K})^3$, the isobaric thermal expansivities $\alpha_p$ were determined by simple differentiation. From the specific volumes and the ultrasonic velocities, the isentropic compressibilities $\beta_S$ were calculated at the temperatures $T$ via $\beta_S = v/W^2$. The isothermal compressibilities $\beta_T$ were then calculated from the relationship $\beta_T = \beta_S + TV\alpha_p^2/C_p$, where $V$ is

TABLE 1

Ultrasonic velocities $W$, isobaric specific volumes $v$ and calculated isobaric thermal expansivities $\alpha_p$, isentropic and isothermal compressibilities $\beta_S$ and $\beta_T$, isochoric thermal pressure coefficients $\gamma_V$ and isobaric heat capacities $C_p$ for tetramethylsilane as a function of temperature $T$

| $T$/K | $W$/m s$^{-1}$ | $v$/cm$^3$ g$^{-1}$ [a] | $\alpha_p$/kK$^{-1}$ | $\beta_S$/GPa$^{-1}$ [b] | $\beta_T$/GPa$^{-1}$ | $\gamma_V$/GPa kK$^{-1}$ | $C_p$/J g$^{-1}$ K$^{-1}$ [b] |
|---|---|---|---|---|---|---|---|
| 224.86 | 1158.8 | 1.4049 | 1.4549 | 1.0462 | 1.3842 | 1.0510 | 1.9784 |
| 226.70 | 1150.9 | 1.4087 | 1.4543 | 1.0635 | 1.4041 | 1.0357 | 1.9831 |
| 232.67 | 1125.2 | 1.4215 | 1.4568 | 1.1227 | 1.4739 | 0.9884 | 1.9986 |
| 235.79 | 1111.7 | 1.4274 | 1.4606 | 1.1550 | 1.5128 | 0.9655 | 2.0068 |
| 240.08 | 1093.3 | 1.4364 | 1.4689 | 1.2017 | 1.5704 | 0.9353 | 2.0181 |
| 247.55 | 1061.1 | 1.4524 | 1.4912 | 1.2900 | 1.6823 | 0.8864 | 2.0381 |
| 252.99 | 1037.7 | 1.4646 | 1.5140 | 1.3601 | 1.7738 | 0.8535 | 2.0529 |
| 254.05 | 1033.2 | 1.4665 | 1.5190 | 1.3738 | 1.7919 | 0.8477 | 2.0558 |
| 260.25 | 1006.5 | 1.4808 | 1.5527 | 1.4617 | 1.9100 | 0.8129 | 2.0729 |
| 264.71 | 987.3 | 1.4912 | 1.5813 | 1.5298 | 2.0031 | 0.7894 | 2.0853 |
| 268.61 | 970.5 | 1.5008 | 1.6093 | 1.5934 | 2.0914 | 0.7695 | 2.0963 |
| 273.28 | 950.4 | 1.5117 | 1.6465 | 1.6736 | 2.2045 | 0.7469 | 2.1095 |

[a] $\ln(v/\mathrm{cm^3\,g^{-1}}) = -0.346032 + 61.9 \times 10^{-4}(T/\mathrm{K}) - 20.82 \times 10^{-6}(T/\mathrm{K})^2 + 30.51 \times 10^{-9}(T/\mathrm{K})^3$; $\sigma = 0.5 \times 10^{-5}\,\mathrm{cm^3\,g^{-1}}$.

[b] From ref. 2.

the molar volume and $C_p$ is the molar heat capacity at constant pressure. Lastly, the thermal pressure coefficients $\gamma_V$ were calculated from $\gamma_V = \alpha_p/\beta_T$. The results of these calculations are also listed in Table 1.

## DISCUSSION

Ultrasonic velocities in tetramethylsilane have been reported by Takagi et al. [6] in the temperature range from 283 to 333 K, well above the highest temperature value of this work, so that a comparison of results was not possible. However, a graphical inspection of the two sets of measurements showed that the combined data follow one continuous line.

Saturated liquid densities of tetramethylsilane at low temperatures have been measued by Tannenbaum et al. [7] from 193 to near 300 K. More recently García-Baonza et al. [8] reported the amount-of-substance densities of tetramethylsilane together with the isothermal compressibilities and isobaric expansivities, amongst other thermodynamic quantities, in the temperature range from 198 to 298 K. They are shown in the deviation graph of Fig. 1. In general, there is clearly good agreement with the results of this work along the overlapping portion of our temperature ranges, although deviations are positive for the older reference values and systematically negative for the more recent values, both in the order of 0.24%.

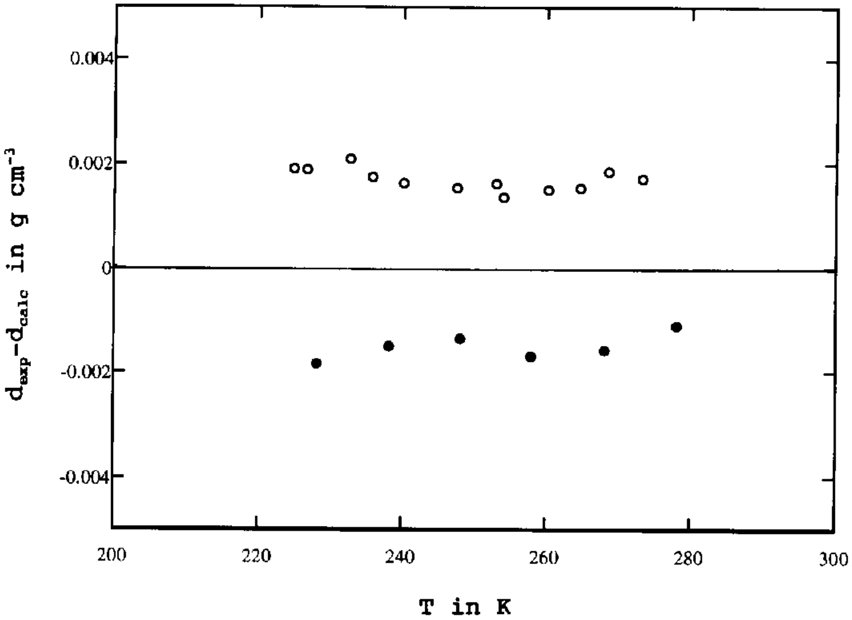

Fig. 1. Density deviation plots ($d_{exp} - d_{calc}$) as functions of temperature $T$ for tetramethylsilane with $d_{calc}$ calculated from the smoothing equation of this work. The points refer to previously published results: ○, Tannenbaum et al. [7]; ●, García Baonza et al. [8].

## ACKNOWLEDGMENTS

J.-M. B.-C. gratefully acknowledges receipt of a scholarship from the Consejo Nacional de Ciencia y Technología, and financial support from the Universidad Autónoma de Nuevo León, Monterrey, Mexico.

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