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Thermodynamic and acoustic properties of binary liquid mixture under uncertainty

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Abstract

Speeds of sound in liquid n-heptane, n-octane and their binary mixtures were measured at the tem-peratures T = 293.15 to 523.15 K and pressures up to 60 MPa. The pulse-echo method with a fre-quency of 8 MHz and uncertainty of ±0.08% was used. Measured values was fitted to a poly-nomial equation as functions of temperature and pressure described by interval numbers, and the reliability of the present results were compared with the literature data.

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Keywords: Speed of sound; liquid; method puls-echo.

1. Introduction

If low frequency and low power acoustic wave existing in the sample is propagated isentropically, then the speed of sound W has a close relation to the following derivative.

$$\left(\frac{\partial p}{\partial \rho}\right)_s = W^2,$$

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where ρ is density, p is pressure, and s is entropy. This equation is extremely important in obtaining isentropic compressibility $k_s = 1/(\rho W^2)$ directly. Compared to the other thermodynamic properties, such as: the thermal expansion coefficient and the specific heat capacity, the speed of sound in fluid can be measured accurately in wide range of temperatures and pressures. Consequently, the speed of sound of n-heptane and n-octane has been reported at atmospheric and higher pressure (Papaioannou et al. (1991), Kiyohara and Benson (1979), Junquera and Tardajos (1988), Dzida and Ernst (2003), Takagi and Teranishi (1985), Muringer and Trappeniers (1985), Zak et al. (2000), TRC (1998), Treszczanowicz and Benson (1977), Aicart et al. (1990), Dominguez et al. (2004), Daridon et al.(1998), Orge et al. (1999), Dominguez et al. (2002), Bolotnikov et al. (2005), Boelhouwer (1967), Hasanov et al. (2004)). The literature also contains measurements of the viscosity, speed of sound, heat capacity and density for mixtures of alcohols with hydrocarbon (see, for example, the works of Papaioannou et. al. (1991), Takagi and Teranishi (1985), Treszczanowicz and Benson (1977), Aicart et al. (1990), Ding et al. (1997), Aleksandrov and Larkin (1976)). However, measurements of the liquid phase speed of sound of n-heptane - n-octane mixtures can no be found in the literature.

During previous years experimental techniques for the measurements of the speed of sound were developed in the wide range of temperatures and pressures. However, the mechanical determination of the acoustic path length, $l_{p,t}$ is required to obtain the speed of sound: $W = 2Fl_{p,t} - \Delta W_{\text{dif}}$, where $l_{p,t} = l_{20}(1+\alpha(t-20))[1-(1-2\mu)(p/E)]$ is the path length, taking into account the factor of linear expansion α, E - the modulus of elasticity and the Poisson ratio for a tube μ. F is the frequency of the impulses, send into the fluid sample, ΔW_{dif} is the correction for diffraction (Ding et al. (1997)).

In this work the speed of sound data in the liquid mixture n-heptane - n-octane at the temperatures T = 293.15 to 523.15 K and pressures up to 60 MPa estimated as interval are reported. A large number of experimental studies on the sound speed for these compounds have been reported in the literature, but there are no correlated and evaluated latest experimental results, especially those in the compressed liquid. A confirmation of the reliability for the new experimental values with the selected reference data will contribute to improve the experimental results in this field.

2. Experiments

The speed of sound was determined with the pulse-echo method, that has been described in detail in, with an uncertainty of ±0.08% as interval number. Only the important features are described here.

Main part of installation is the acoustic sensor, which implements the technique of the echo impulse measurement (Fig. 1).

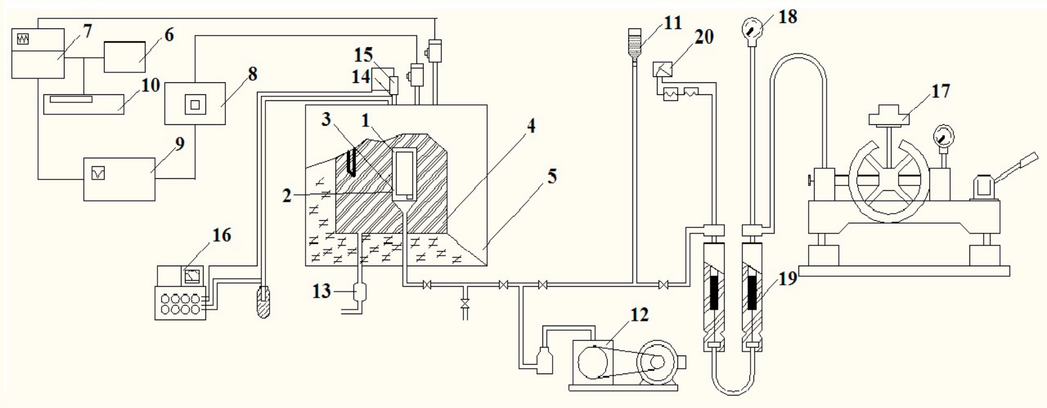

Fig. 1. Acoustic sensor

The experimental setup for measuring of the speed of sound in liquids at hidh pressures and temperatures: *1, 2* - piezoelements; *3* – acoustic dividing tube; *4* - autoclave (Br.M5); *5,13 – 17* - systems for creating, maintaining and measuring the temperature and pressure; *6* - generator G3-118; *7* - generator G5-27A; *8* - wide amplifier DUK-66; *9* - oscilloscope S1-70; *10* - frequency meter F5041; *11* - system theme for the installation of a liquid filling; *12* - vacuum pump; *18* – exemplary manometer; *19* - mercury manometer; *20* – the device for the control the a level of mercury.