

Liquid viscosities of benzene, *n*-tetradecane, and benzene + *n*-tetradecane from 313 to 393 K and pressures up to 60 MPa: Experiment and modeling

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Abstract

In this work, kinematic viscosities of benzene, *n*-tetradecane, and of the mixture benzene + *n*-tetradecane at four different compositions were measured using a rolling-ball viscometer from 313.2 to 393.2 K and pressures up to 60 MPa. Kinematic viscosities were converted to dynamic viscosities through the use of a density Tait-like equation for pure components and a single density mixing rule for the mixtures. A comparison between our measured viscosities and those reported by other authors for benzene and *n*-tetradecane was established with the correlation given by Assael et al. [M.J. Assael, J.H. Dymond, M. Papadaki, P.M. Patterson, Correlation and prediction of dense fluid transport coefficients. I. *n*-alkanes, *Int. J. Thermophys.* 13 (1992) 269–281]. The comparison showed an average absolute deviation of 1.5% for benzene and 2.7% for *n*-tetradecane. The measured mixture viscosity data were modeled with a proposed liquid viscosity model based on the Eyring's theory coupled with a cubic equation of state and using a single temperature-independent binary interaction parameter to describe the whole $\eta - T - p - x$ surface of study. Results of the modeling effort yielded an average absolute deviation of 2.0%, which is within the experimental uncertainty.

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1. Introduction

Experimental high-pressure liquid viscosities of pure hydrocarbons and their mixtures are important to simulate the behavior of petroleum fluids at oil field conditions. Also, high-pressure viscosity data over a wide range of temperature and pressure for a given composition can be used to test the capability of semi theoretical and empirical viscosity models. Unfortunately, experimental studies of viscosity for a wide range of compositions at different pressures and temperatures are costly and time consuming. An alternative to overcome this problem is to use predictive models; however, the reliability of these methods depends greatly on the accuracy and availability of the experimental data.

In order to extend the database of viscosities for pure hydrocarbon and their mixtures over a wide range of temperature and pressure, we have undertaken a systematic study of liquid viscosities of mixtures containing paraffin, aromatic, and naphthenic compounds. This study is part of a research program on viscosity measurements of hydrocarbons at oil reservoir conditions.

In this work, we report liquid viscosity measurements for the binary system benzene + *n*-tetradecane from 313.2 to 393.2 K and at pressures up to 60 MPa over the entire composition range. Kinematic viscosity data for this system were determined in a high-pressure rolling-ball viscometer (Ruska, model 1602–716). This viscosity measurement technique has been used by several authors (Barrufet et al. [1,2], Estrada-Baltazar et al. [3,4], Iglesias-Silva [5]) in the measurement of high-pressure viscosity data of pure *n*-alkanes, binary and ternary mixtures of *n*-alkanes, and CO₂ + *n*-alkanes. More recently, Pensado et al. [6] used the

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same technique for determining viscosity measurements of pure 2-3-dimethylpentane at pressures up to 60 MPa.

Dynamic viscosities were obtained through the use of a density Tait-type correlation reported by Assael et al. [7]. The measured viscosity data for pure benzene and *n*-tetradecane are compared with those values obtained from the correlation published by Assael et al. [8] while a proposed liquid viscosity model is used in the modeling of measured mixture viscosities data.

2. Experimental

2.1. Materials

Benzene and *n*-tetradecane were acquired from Aldrich (USA) with a minimum purity of 99.9 mol% and 99 mol%, respectively. Octane and dodecane, used to calibrate the apparatus, were purchased from Aldrich (USA) both with a certified purity greater than 99 mol%. All these chemicals were used without any further purification.

2.2. Apparatus

The experimental apparatus used in this work is shown schematically in Fig. 1. It is based on the high-pressure viscosity technique, which consists of a commercial rolling-ball viscometer (Ruska, model 1602–828), a pressure line, and a high-pressure cell for storing the sample at high pressure before transferring it to the viscometer.

The Ruska rolling-ball viscometer has been designed to operate in the viscosity range of 0.1–3000 mPa s. This viscometer consists of a mechanical test assembly and a control unit (Chro-

malox 2140) with a digital watch. The mechanical assembly is a stainless steel high-pressure housing fixed to a base allowing circular movements. The housing can be fixed at an angle of 23, 45, or 70° with the horizontal to carry out the measurements. Inside the housing, there is a cylindrical barrel in which a steel ball rolls on a perfectly polished surface. The upper end of the housing is closed by means of a plug that contains the barrel seal and a solenoid, while another plug that contains the bottom contact closes the lower end of the housing. When the barrel seal is closed, both ends of the barrel are closed so the sphere falls through the fluid inside the barrel.

The solenoid holds the steel sphere in the upper part of the measuring barrel, and it will not fall through the fluid until the solenoid current is interrupted in the control unit. That is, the watch in the unit control is activated when the current is interrupted and it is stopped automatically when the sphere reaches the end of its travel thus eliminating the human error when measuring the sphere roll time. Hence, repeatability of the roll time measurements is $\pm 0.1\%$. The angle at which the sphere is rolling and the sphere diameter should be selected by taking into account the viscosity of the fluid. Thus, for instance, higher angles with lower diameters should be used for high viscosities.

The viscometer is heated with an electronic heating jacket control system and the temperature can be controlled within ± 0.2 K. The temperature is measured by means of a thermocouple with a precision of ± 0.1 K over the temperature range of 303–423 K. The pressure circuit (see Fig. 1) connected to the viscometer consists a set of valves (Ruska), tubing, a high-pressure stainless steel cell, a syringe high-pressure pump (ISCO, model 100DM) with an uncertainty of ± 0.02 MPa, and a vacuum pump (Edwards).

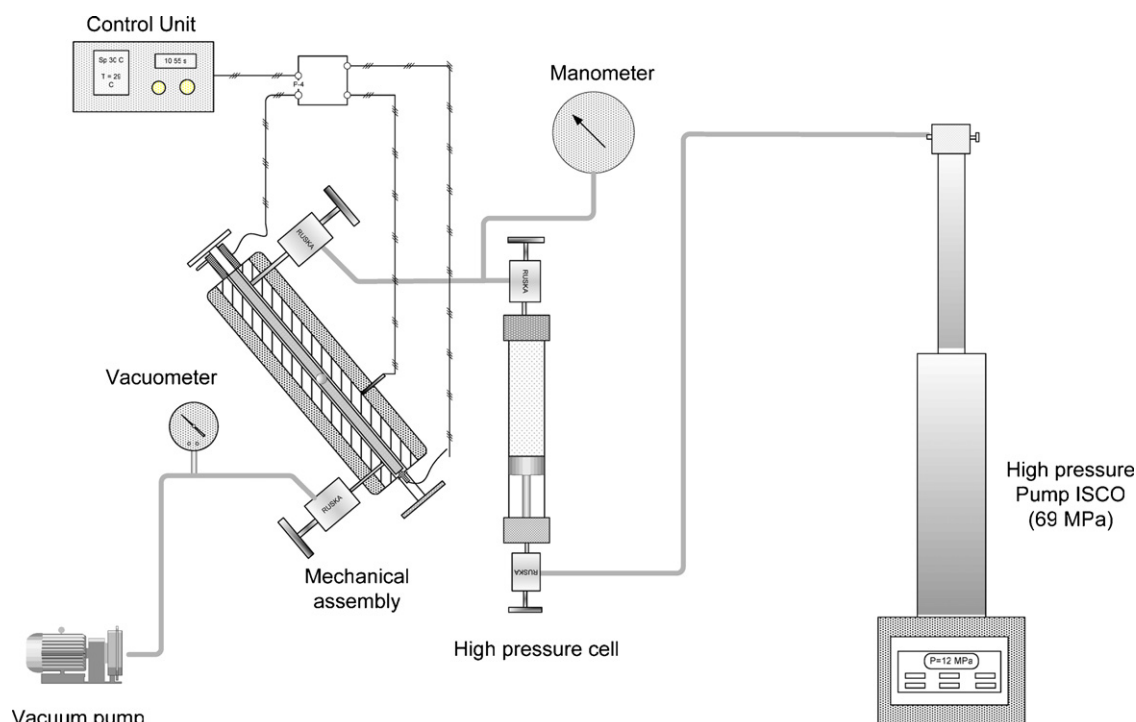


Fig. 1. Schematic diagram of the rolling-ball viscometer and the charging system.

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