

SPECIFIC HEAT CAPACITY, DENSITY OF SYSTEM TRANSFORMER OIL AND WATER OF DEPENDENCE TEMPERATURE AND PRESSURE.

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ABSTRACT.

Information on specific heat capacity, density of liquid solution is essential for designing heat exchangers, modeling natural hydrothermal processes.

The results of the experimental research on the thermodynamics properties (specific heat capacity, energy free, general energy Gibbs, energy Helmholtz, enthalpy, entropy etc.) systems transformer+water in the temperature range 293-413K, and pressure range $P = 0,101$ MPa, are presented. The heat capacity of the studied objects in the interval temperature (293-413) K was measured in the device designed and constructed by Safarov M.M. (1996). The common relative errors of measurements in specific heat capacity, density under a coefficient of confidence, α , of 0,95 are receptivity 3%, 0.1%.

INTRODUCTION.

Information about thermophysical properties (sound velocity, viscosity, heat conductivity, thermal capacity, etc.) of pure liquid mixtures at high pressure and temperature is often necessary in various fields of science and engineering. Thermodynamic properties and phase equilibria of aqueous systems are very important in biology, chemistry, physics and chemical engineering.

Thermophysical properties of transformer+water mixtures, including heat capacities, are essential input data to optimize the design of power plant equipment which use this alternative working fluid. To help meet this need, specific heat capacities at constant volume (C_V) of $\{X \text{ Tr.oil} + (1-X)\text{H}_2\text{O}\}$; ($X=0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1$) mixtures were measured with an adiabatic calorimeter.

In the present paper, we report an experimental study on the liquid phase thermodynamic properties of the transformer oils. Based on these measurements and the data which have been measured by other investigator, the thermodynamic behaviors with respect to vapor pressures and saturated and compressed liquid densities are discussed in terms of vapor pressure and saturated liquid density correlations developed and an equation of state for the

compressed liquid phase. By evaluating the behavior of the derived properties such as the specific isochoric and isobaric heat capacities, speeds of sound and Joule-Thomson coefficients, the range of validity of the developed equation of state and its physical soundness will be discussed. Modeling, simulation and design of chemical processes need accurate and reliable estimation of the mixture properties present in the process. One of the most commonly used mixture properties in process design and simulation are those related to the prediction of the phase behavior. Therefore, a library of the most common thermodynamic models used for phase equilibrium calculations have been developed so that appropriate models can be used, models for new systems can be developed /correlated, fine tuning of models for specific problems can be performed and many more. Liquid heat capacities are needed in order to calculate the energy requirements of industrial processes. The C_p° value is often estimated and calculated by means of a theoretical method with spectroscopic data. On the other hand, C_p° values can be determined from speed-of-sound measurements.

For the calculation of heat and mass exchange and the development of a mathematical model of the processes taking place in different reactors, we need data on the thermodynamic properties (specific heat capacity, Gibbs energy, Helmholtz energy, enthalpy, entropy etc.) of systems transformer+water in dependence of temperature. In this paper, we have determined the intermolecular potential (including square well, Lennard – Jones) parameters from P-T and sound speed data for liquids transformer oil, water. The experimental data used was carefully selected from many references [1-4]. After we get the intermolecular potential parameters, we used it to calculate the second virial coefficient and third virial coefficient. After processing and analysis of the experimental data on molecular heat capacity of the systems (transformer oil+water), we obtained the equation. We investigated the thermodynamic properties of the solutions (concentrations of water ranging from 0.1- 0.9 mass.%) in the temperature range (293-413)K and pressure range $P= 0,101\text{MPa}$ [5-7].

THEORY.

The molar volume of a mixture of components, v , in terms of the mole fractions X_i and partial molar volumes of the components V_i is

$$V = \sum_{i=1}^c X_i V_i \quad (1)$$

For an ideal solution, the partial molar volumes equal the molar volumes of the pure liquid components. Denoting component 1 as the main component and the impurities as $i > 1$, the volume becomes:

$$V = X_1 V_1 + \sum_{i=1}^c X_i V_i \quad (2)$$

Then using , $\rho=M/V$ (3)
 and the molar mass of the mixture :

$$M = \sum_{i=1}^c X_i M_i \quad (4)$$

and assuming that the X_i are small for $i>1$, then

$$C_p = \sum_{i=2}^c X_i C_{pi} \quad (5)$$

where X_i, C_{pi} – mass concentration and specific heat capacity of component i . The observed value of the specific heat capacity of a sample is sometimes presented as evidence of its purity.

EXPERIMENTAL.

SPECIFIC HEAT CAPACITY.

An experimental device for measuring the specific heat capacity of transformer oil+water was constructed according to the method of monotonic heating. The device consists of the measuring cell, recorder, Dewar vessel with melting ice, pressure vessel, loaded-piston manometer of type MP-2500, and electronic measuring instruments [8]. During temperature measurement we used a differential Chromel–Alumel thermocouple with a diameter of 0,15mm, the ends of which were connected to the recorder. The cold arm of the differential thermocouple was put into the Dewar vessel with melting ice, and the hot arm was touching the body of the toluene, n–hexane, and kerosene were made. The specific heat of the control patterns under atmospheric pressure was measured in the temperature range 273–373K. The results of the control measurements of the heat capacity of toluene, n – hexane, and kerosene coincide with published data, [9] within the error limit of 2%.

Specific heat capacities at constant volume (C_p) of transformer oil and water and their mixture were measured with a newly developed adiabatic calorimeter. Temperatures ranged from 293 to 413 K, and pressure ranged to 0.101 MPa. Density was determined from initial and final end points during each calorimetric experiment series. The calorimeter is a twin –cell type whose sample and reference cells (15 cm^3) and their shields are heated by electric power. The expanded relative uncertainty (with a coverage factor $K=2$ and thus a two- standard-deviation estimate) for C_v is estimated to be 1% for liquid-phase and 4% for gaseous results.

RESULTS AND DISCUSSION .

The specific heat capacity changes of aqueous solution of transformer oil for given temperature and concentration of water under atmospheric pressure are given in table 1.

Table 1. Specific heat capacity ($C_p, \text{Jkg}^{-1}\text{K}^{-1}$) of solutions of transformer oil as a function of water concentration and temperature at atmospheric pressure.

Concentration water T/K	20	25	50	75	90
293	2176	2303	2935	3567	3947
323	2319	2436	3022	3608	3959
348	2441	2551	3102	3654	3984
373	2558	2662	3184	3708	4020
383	2608	2709	3219	3728	4034

For processing and analysis of the experimental data on the specific heat capacity of the transformer oil + water solutions we used the following equation:[8]

$$C_{p,T}/C_{p,T}^* = f \{ (P/T) / [P_1/T_1] \} \quad , \quad (6)$$

where $C_{p,T}$ is the specific heat capacity of the transformer oils+water under P and T; $C_{p,T}^*$ is the specific heat capacity under P_1 and T_1 , where $P_1/\text{MPa} = 0,101$ and $T_1/\text{K} = 293$ [8].

$$C_p/C_p^* = f [T/T_1] \quad , \quad (7)$$

For generalize experimental data specific heat capacity we use following law: Where C_p^* - molecular heat capacity measurements objects at the $T_1 = 293\text{K}$. After processing and analysis of experimental data on molecular heat capacity of the measurement objects, we obtained the following empirical equation:

$$C_p = [0,1((T/T_1) + 0,9)(2,96N_{\text{H}_2\text{O}} + 2121)], \text{ J/kg}\cdot\text{K} \quad (8)$$

Equation (8) can be used for the determination of the heat capacity of measurement objects as function of temperature and concentration water..

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