Surface Tension of Helium–Oxygen and Helium–Ethane Solutions

V. G. Baidakov1,2 and I. I. Sulla1

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The capillary constant has been measured, and the surface tension of gas-saturated solutions of He–O₂ and He–C₂H₆ has been calculated in the temperature range from the solidification temperature to approximately 0.9Tₑ, where Tₑ is the critical temperature of the solvent. Measurements have been carried out along isotherms at pressures from the saturation pressure of the pure solvent to 5 MPa. Equations approximating the baric dependence of the capillary constant and the concentration dependence of the surface tension are proposed. Adsorption is determined. The data obtained are discussed within the framework of the method of a finite-thickness layer. It is shown that for the investigated solutions the approximation of a monomolecular surface layer is not justified even at temperatures lower than the normal boiling point.

KEY WORDS: adsorption; capillary constant; ethane; gas-saturated solution; helium; oxygen; surface tension.

1. INTRODUCTION

Of interest are investigations of the properties of solutions with molecules that have sharply different intermolecular interaction parameters. Such solutions include solutions of helium in simple classical liquids. The linear molecular dimensions here differ by approximately a factor of 1.4–1.5, the depth of the potential differs by an order of magnitude, and differences in the molecular masses are just as large. These systems are characterized by a very small solubility of the helium in the liquid phase, while the vapor phase at sufficiently low temperatures is practically fully represented by this very component. Such concentrations variations in bulk phases affect the

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1 Institute of Thermophysics, Urals Division of Russian Academy of Sciences, Pervomaiskaja str. 91, GSP-828, Ekaterinburg 620219, Russia.
2 To whom correspondence should be addressed.
surface tension, the effective thickness of the surface layer, and the distribution of the concentration and the density of the surface layer. A study of the entire spectrum of properties of the solution interphase boundary requires the use of sophisticated physical methods of investigation. However, significant results may already be obtained by measuring the concentration and temperature dependences of the surface tension of these solutions and their analysis in terms of molecular theories of capillarity. Such an approach is especially important at temperatures that are far below the critical temperature, where the surface layer has a thickness of molecular size, and optical methods can be used to investigate its properties.

This paper presents the results of experimental investigations of the capillary constant and surface tension of two gas-saturated solutions: helium–oxygen and helium–ethane. The system He–C₂H₆ is characterized by a stronger molecular interaction than the system He–O₂. This results in differences in the character of the temperature dependence of the critical curves in the vicinity of the critical point of a solvent. In the classification of Van Konynenbyrg and Scott [1], we see that the He–C₂H₆ solution, with a positive slope of the critical-temperature curve, is of the III-d type, and the He–O₂ solution, for which the line of critical curves with increasing pressure shifts into the region of low temperatures, is of the III-c type. Solutions of helium in H₂, CC₁₄, and C₆H₆ also belong to type III-d; solutions of helium in cryogenic liquids (He–Ar, He–N₂) belong to type III-c.

The effect of small amounts of helium on the properties of the interphase boundary of liquids at higher temperatures has been discussed in the literature (see, for instance, Refs. 2 and 3). For solutions of cryogenic liquids (He–H₂, He–Ar, He–O₂) experimental investigations of the surface tension were carried out in 1965–1968 by Blagoy [4] at temperatures close to the triple point of the solvent. A strong effect of small amounts of helium on the surface tension of a liquid caused mainly by the adsorption of the surface-active component was discovered.

The paper is organized as follows. Section 2 describes the experimental equipment and technique. Section 3 gives the results of the measurements of the capillary constant and the surface tension of the two gas-saturated solutions. In Section 4 the data are analyzed in terms of the thermodynamics of surface phenomena. The results are summarized in the conclusion.

2. EXPERIMENTS

To determine the surface tension of the liquid–vapor interface of gas-saturated solutions, use was made of a differential capillary-rise method