Universal Equations for Saturation Vapor Pressure

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The Wagner equation and the modified Antoine equation are two of several that can be used to accurately estimate the vapor pressure of a saturated liquid, given the liquid's critical temperature and critical pressure. To achieve accuracy, such equations use multiple empirical constants that are unique to each liquid, but these constants are not available for all liquids. This paper presents two universal equations that provide fairly accurate vapor pressures for a variety of liquids. Each equation uses empirical constants, but a single set of constants applies to a large number of liquids. The universality of the equations suggests that they would be useful in estimating the saturation vapor pressure of a liquid whose Wagner or modified-Antoine-equation constants are unknown.

Nomenclature

T_{red} = reduced temperature
P_{red} = reduced pressure
T_{critK} = critical temperature (degrees K)
T_{critR} = critical temperature (degrees R)
P_c = critical pressure (atm or psia)

I. Introduction

One of the difficulties of estimating the vapor pressure of a saturated liquid at any given temperature is finding an appropriate equation or table that pertains specifically to the liquid of interest. Such equations and tables are readily available for common, useful liquids like water, oxygen, some refrigerants, and some hydrocarbons, but they are not available for other liquids. Furthermore, molecular-species-specific tables and equations do not completely convey the vapor-pressure traits that are shared by a large number of saturated liquids. This paper attempts to address these shortcomings by offering universal equations for the vapor pressures of saturated liquids. These universal equations employ species-specific values for critical temperature and critical pressure, but they do not rely on any other species-specific empirical constants. Instead, each universal equation uses a single set of empirical constants that apply to a variety of liquids.

II. Previous Research

Previous research on equations for estimating saturation vapor pressure is excellently and comprehensively summarized by Reid et. al.[1] Antoine[2] was among the first to suggest an empirically based saturation-vapor-pressure equation, which depends on absolute temperature and three species-specific constants. Gomez-Nieto and Thodos[3-5] offered a more complex equation that relies on reduced temperature (absolute temperature divided by critical absolute temperature), reduced pressure, and three constants. In general, these constants are not completely arbitrary for each molecular species; they depend in part on the class of the species (polar, non-polar, or hydrogen-bonded), the species critical temperature, and the reduced normal boiling temperature of the species. Nonetheless, in establishing rules for how their constants are determined, Gomez-Nieto and Thodos[3-5] recognized that helium, hydrogen and neon are outliers that require special treatment. Wagner[6] offered an empirical equation involving reduced temperature, reduced pressure, and four species-specific empirical constants. The advantage of Wagner's equation is that it is quite accurate in the upper half of the reduced-temperature range, which normally corresponds with the upper 99 % of the reduced-pressure range. McGarry[7] published Wagner-equation constants for a number of

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