Evaluation and Prediction of Latent Heat of Vaporization at Various Temperatures for Pure Components and Binary Mixtures

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by
Mohammed Jabbar Ajrash
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Jamad Al- awla **1430**
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Abstract

The prediction of latent heat of vaporization of pure compounds has at least sixteen methods to predict the latent heat of vaporization for pure compounds and three methods to predict the latent heat of vaporization for binary mixtures .All these methods has been evaluated in this work.

There are at least nine methods available in literature for prediction of latent heat of vaporization at any temperature using either vapor pressure data or the law of corresponding states .These methods predict the latent heat of vaporization at various temperatures directly. The accuracy of these methods are different. Some of these methods have accurate results when dealing with non polar compounds but not so accurate when dealing with polar compounds . Halim and Stiel is the best method among these nine methods which is directly deal with polarity of compounds by introducing what is known polarity factor of polar compounds and it gives 1.552 absolute average deviation percent compared with experimental data for 18 pure non polar compounds with 446 data points .On the other hand it gives 2.8476 AAD% compared with experimental data for 6 polar compounds with 180 data points .

The prediction of the latent heat of vaporization from normal boiling point have at least seven methods . The Riedel method at normal boiling has less absolute average deviation percent compared with experimental data .The AAD% is 1.271 for 32 pure non polar compounds while it gives 4.439 AAD% compared with experimental data for 29 polar compounds. To predict the value of latent heat of vaporization at any temperature from normal boiling point using a relation describe the change of latent heat of vaporization with temperature to give the estimated value at needed temperature ,the more accurate relation available is

Watson equation . It is found that the First Veter method has the less deviation from experimental data among these seven methods that predict the latent heat of vaporization at various temperature from normal boiling point .The AAD% is 1.344 for 18 pure non polar compounds and 446 data points. On the other hand the AAD% is 3.3426 compared with experimental data for 6 polar compounds and 180 data points.

Generally ,all methods that estimate the latent heat of vaporization at normal boiling point don't have accurate results when dealing with polar compounds. This work modified Kistiakowsky method to give accurate results with both non polar and polar compounds . These two modifications are simple and easy to use .In both modifications the compounds are classified into three groups :non polar ,alcohols and polar compounds and the values of constants are given for each group.

The first modification is the same as Kistiakowsky equation except the values of constant A are different

$$\lambda_{vap\ n.b} = (A + R \ln T_b)\ T_b$$

The AAD% obtained from this work for 34 compounds for alcohols and other polar compounds are 4.4036 and 3.38 respectively, in comparison with that of Kistiakowsky method which are 24.97 and 6.312 respectively.

The second modification of Kistiakowsky method is as follows

$$\lambda_{vap\ n.b} = R.T_b\ (a + b \ln P_c + c \ln T_b)$$

In this equation the critical pressure is included and the values of the constants a,b,c for each groupe

The overall AAD% obtained from this work for 57 compounds for non polar compounds , alcohols and other polar compounds are 1.462 , 2.278 and 2.933 respectively , in comparison with that of Kistiakowsky method the AAD% are 2.2095 , 24.97 and 6.312 respectively. It is to be noted that this work have the least deviation from experimental data from all methods that predict the latent heat of vaporization at normal boiling point for pure polar compounds. This work also are applied at various temperatures by using Watson equation, the second modification has less deviation from experimental data than the first modification . The second modification has good results for both non polar and polar compounds whereas the AAD% of 24 non polar compounds is 1.462. On the other hand the AAD% of 33 polar compounds is 2.575 and it is the least deviation form experimental data for polar compounds results from the methods that are available in literature to predict the latent heat of vaporization at normal boiling point .

For mixtures, there are three methods available in literature to predict the latent heat of vaporization of binary mixtures. The Teja method is the more accurate of them, it gives 2.261 AAD% for 4 mixtures and 46 data point .

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Nomenclature

A,B,C	Antion constant
a,b,c,d	Wagnar constant
A^+,B^+,C^+,D^+	Riedel constant of equation of equation (3-9)
dHv(λ_{vap})	latent heat of vaporization (J/mole)
F	Veter constant of equation (3-15)
K	Riedel constant of equation (2-33)
m	Grain Lyman constant
Mwt	Molecular weight
Mwt $^{/}$	Contribution molecular weight
n	Watson constant
P	Pressure (bar)
P_{br}	Reduced temperature at normal boiling point
P_c	Critical pressure (bar)
P_r	Reduced pressure
P_{vp}	Vapor pressure (bar)
R	Universal gas constant (J/mole.K)
ΔS^0 , ΔS^1 , ΔS^2	Pitzer s' parameters
T	Temperature (K)
T_b	Normal boiling temperature (K)
T_{br}	Reduced temperature at normal boiling point(K)
T_c	Critical temperature (K)
T_r	Reduced temperature
ΔU_v	Internal energy of vaporization
V_G	Saturated gas volume (cm^3/mole)
V_L	Saturated liquid volume(cm^3/mole)
ω	Acentric factor

X_i	Mole fraction of component i
χ	Polarity factor
Z_c	Critical compressibility factor
ΔZ	Compressibility factor of vaporization
$\lambda_{vap\ n.b}$	Latent heat of vaporization at normal boiling point(J/mole).
τ	$1-T_r$
α	Riedel factor
α_c	Riedel factor at critical properties

Chapter One

Introduction

The latent heat of vaporization is one of the most important thermodynamic properties of fluids , because in almost all design calculation , there is need for the values of latent heat. The analysis of phase equilibrium usually requires evaluation of change in enthalpy at saturation, thus the design of separation equipment requires enthalpy change at vaporization , which is referred to as latent heat of vaporization.

The latent heat of vaporization is the difference between the enthalpy of saturated vapor and that of the saturated liquid at the same temperature and can be explicitly defined for any system by the mathematical expression [1] :

$$\Delta H_v=\lambda_v=\Delta U_v + RT\,(Z_v-Z_L) \qquad (1\text{-}1)$$

Where

$\Delta H_v(\lambda_v)$:latent heat of vaporization

ΔU_v: internal energy of vaporization which is the work done on the vapor phase as vaporization proceeds

T: temperature of vaporization, R: constant of gases

To find the values of latent heat there are two sources of latent heat data . First , the experimental data available in literature . Second data from the accurate recommended methods for predicting the latent heat

The pure substance can be classified according to their polarity into two categories , non polar (normal) compounds and polar compounds.

Polar compounds are also classified according to bond of polarity into two categories; dipolar aprotic and polar protic .

The factors that affecting on estimation of the latent heat of vaporization are :temperature ,pressure and bounding between the atoms .

The aim of this work is to evaluate the existing methods that are available in the literature for prediction of the latent heat of vaporization at various temperatures and at normal boiling point for pure compounds and mixture . Also to specify the methods which gives high accuracy with non polar compounds and which methods give high accuracy with polar compounds . Also to indicate the limitation in each case (reduced temperature range) . Further more to study the possibility of modifying some simple methods to predict the latent heat of vaporization for non polar and polar compounds with high accuracy .

Chapter Two

Theory and literature review

2.1 Polar and non polar compounds

Non-polar compounds are compounds that have low dielectric constants and are not miscible with water. Examples include benzene (C_6H_6), carbon tetrachloride (CCl_4), and diethyl ether ($CH_3CH_2OCH_2CH_3$) [58] .

Polar compound are compounds which have unequal sharing of electrons [54]. Also have electronegativity difference about 0.5 - 1.7 .Polar compounds are classified into two types:

A . Hydrogen bounding (Polar Protic) compounds

Let's start with the meaning of the adjective protic. Protic refers to a hydrogen atom attached to an electronegative atom . For our purposes the electronegative atom is almost exclusively oxygen. In other words, polar protic compounds are compounds that can be represented by the general formula ROH. The polarity of

the polar protic compounds stems from the bond dipole of the O-H bond. The large difference in electronegativities of the oxygen and the hydrogen atom, combined with the small size of the hydrogen atom, warrant separating molecules that contain an OH group from those polar compounds that do not. Examples of polar compound are water (HOH), methanol (CH_3OH), and acetic acid (CH_3CO_2H).

B. Non hydrogen bounding(dipolar Aprotic) compounds

Aprotic describes a molecule that does not contain an O-H bond. Compounds in this class all contain a bond that has a large bond dipole. Typically this bond is a multiple bond between carbon and either oxygen or nitrogen. Most dipolar Aprotic compounds contain a C-O double bond. Examples are acetone [$(CH_3)_2C=O$] and ethyl acetate ($CH_3CO_2CH_2CH_3$).

2.2 Critical Properties

The critical temperature, T_C, of a material is the temperature above which distinct liquid and gas phases do not exist. As the critical temperature is approached, the properties of the gas and liquid phases become the same resulting in only one phase, the supercritical fluid. Above the critical temperature a liquid cannot be formed by an increase in pressure, but with enough pressure a solid may be formed for materials other than water. The critical pressure is the vapor pressure at the critical temperature. Fig. 2-1 shows the thermodynamic properties for a given substance, the point at critical temperature and critical pressure is

called the critical point of the substance. The critical molar volume is the volume of one mole of material at the critical temperature and pressure. Critical properties vary from material to material, just as is the case for the melting point and boiling point. Critical properties for many pure substances are readily available in the literature. Obtaining critical properties for mixtures is somewhat more problematic.

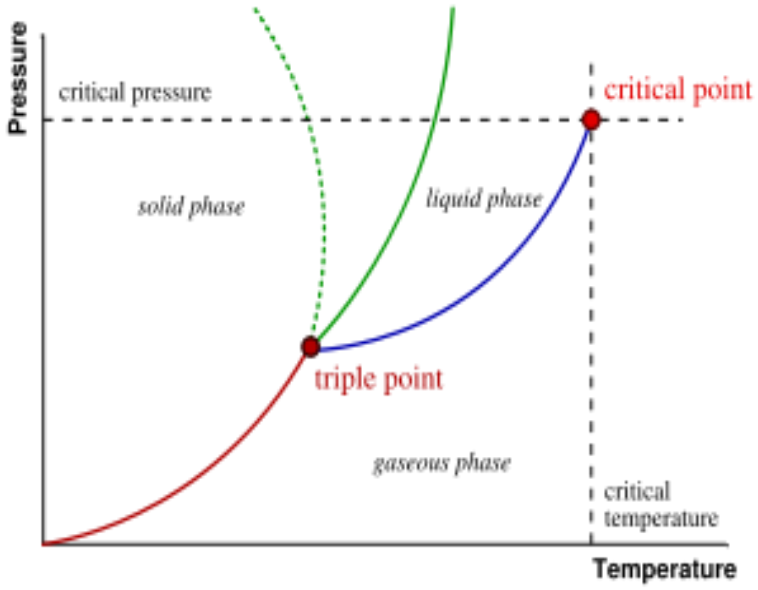


Figure 2-1 Pressure –temperature diagram

This relation can be used to evaluate two parameters for an equation of state in terms of the critical properties. Sometimes a set of reduced properties are defined in terms of the critical properties [59], i.e.:

$$T_r = T / Tc \tag{2-1}$$

$$P_r = P / P_C \tag{2-2}$$

$$V_r = V / V_C \qquad (2\text{-}3)$$

2.3 The Law of Corresponding States of three parameter :

According to the law of corresponding states of two parameter the value of the critical compressibility factor Zc (where Tr=1 , Pr=1) must be the same for all substances , however the value of Zc ranges from 0.2 to 0.3 . Lydersen et al[29] , introduced Zc as a third parameter , and the law of corresponding states becomes

$$Z= f (T_r , P_r , Zc) \qquad (2\text{-}4)$$

Pitzer [35] developed a third parameter derived from vapor pressure data .He observed that the slope of the line of plotting log Pr^{sat} versus $(1/T_r)$ for simple fluids is the same and this line passes through log Pr^{sat} = -1 at T_r = 0.7

$$\omega= -1.0 - (\log Pr^{sat})_{Tr= o.7} \qquad (2\text{-}5)$$

originally defined

$$\omega = - \log_{10} \lim_{(T/Tc)=0.7} \left[(Pvp/Pc) \right] - 1.0 \qquad (2\text{-}6)$$

So the law of corresponding state becomes

$$Z= f (T_r , P_r , \omega) \qquad (2\text{-}7)$$

With three parameters ,the principle of of corresponding states became highly accurate for non polar and slightly polar substance Riedel [40] derived factor

from vapor pressure at critical point of spherical molecular fluids which can be defined as

$$\alpha c = \left[\frac{d(\ln P)}{d(\ln T)} \right] \quad (2\text{-}8)$$

$$\alpha c = \frac{3.789K\,\psi_b + \ln((Pc/1.01325)}{K\,\psi_b - \ln T_{br}} \quad (2\text{–}9)$$

Where

$$\psi_b = -35 + 36/T_{br} + 42 \ln T_{br} - T_{br}^{6} \quad (2\text{-}10)$$

2.4 The Law of Corresponding States of four parameters [19]:

This fourth parameter is specified for polar component because it is found that the polarity that comes from the large difference in electronegativities of atoms can enter the law of corresponding states as a four parameter, so the definition of law of corresponding of four parameter become

$$Z = f(T_r, P_r, \omega, \chi) \quad (2\text{-}11)$$

Where χ is polarity factor similar to the acentric factor for normal fluids.

The vapor pressure on non polar fluids was correlated by pitzer as follows

$$\text{Log}p_r^{sat} = (\text{log}p_r^{sat})^0 + \omega\,(\text{log}p_r^{sat})^1 \quad (2\text{-}12)$$

Halm and Stiel [4] have proposed following the relation for predicting vapor pressure of a polar fluid

$$\text{Log}p\text{r}^{\text{sat}} = (\text{log}p\text{r}^{\text{sat}})^0 + \omega(\text{log}p\text{r}^{\text{sat}})^1 + \chi\,(\text{log}\,p\text{r}^{\text{sat}})^2 \qquad (2\text{-}13)$$

The factor is defined to be zero for normal fluids. The values of $(\text{log}p\text{r}^{\text{sat}})^0$, $(\text{log}p\text{r}^{\text{sat}})^1$, and $(\text{log}p\text{r}^{\text{sat}})^2$ *vs.* temperature are tabulated in original work. The value of $(\text{log}p\text{r}^0)^2$ was defined to be 1.0 at $T\text{r} = 0.7$, so that

$$\chi = \text{logPr}^{\text{sat}} - (\text{logPr}^{\text{sat}})^0 + (\text{logPr}^{\text{sat}})^1_{T\text{r}\,=\,0.7} \qquad (2\text{-}14)$$

or

$$\chi = \text{log}p\text{r}^{\text{sat}}|_{T_{\text{r}\,=\,0.7}} + 1.552 + 1.7 \qquad (2\text{-}15)$$

2.5 vapor pressure

The Clapeyron equation [57]

$$\frac{dP_{vp}}{dT} = \frac{\Delta Hv}{T\Delta U_v} = \frac{\Delta Hv}{(RT^2 / P_{vp})\,\Delta Z_v} \qquad (2.16)$$

In this equation, ΔHv and ΔZv refer to differences in the enthalpies and compressibility factors of saturated vapor and saturated liquid.

Most vapor-pressure estimation and correlation equations stem from an integration of Eq. (2-16). To integrate this equation , an assumption must be made regarding the dependence of the group $\Delta Hv / \Delta Zv$ on temperature. Also a constant of integration is obtained which must be evaluated using one vapor pressure-temperature point. The simplest approach is to assume that the group $\Delta Hv / \Delta Zv$

is constant and independent of temperature. Then, with the constant of integration denoted as *A*, integration of Eq. (2-12) leads to

$$\text{Ln Pvp} = A - B / T \qquad (2\text{-}17)$$

Where $B = Hv / R\Delta Zv$. Equation (2-16) is sometimes called the Clausius-Clapeyron equation. Surprisingly, it is a fairly good relation for approximating vapor pressure over small temperature intervals. Except near the critical point, ΔHv and ΔZv are both weak functions of temperature; since both decrease with rising temperature, they provide a compensatory effect, however, over large temperature ranges, especially when extrapolated below the normal boiling point.

2-6 latent heat of vaporization λ_v [4].

The latent heat of vaporization λ_v is sometimes referred to as the enthalpy of vaporization ΔH_V. It is the difference between the enthalpy of the saturated vapor and that of the saturated liquid at the same temperature. Because molecules in the vapor do not have the energy of attraction that those in the liquid have, energy must be supplied for vaporization to occur. This is the internal energy of vaporization ΔUv . Work is done on the vapor phase as vaporization proceeds, since the vapor volume increases if the pressure is maintained constant at *P*vp . This work is $Pvp(V_G - V_L)$. Thus

$$\Delta Hv = \Delta Uv + Pvp(V_G - V_L) \qquad (2\text{-}18)$$

$$\Delta Hv = Uv + RT(Z_G - Z_L) \qquad (2\text{-}19)$$

$$\Delta Hv = Uv + RT\Delta Z_v \qquad (2\text{-}20)$$

Many ‘‘experimental’’ values of ΔHv have been calculated from Eq. (2-16), where it was shown that ΔHv is related to the slope of the vapor pressure temperature curve. More recently, experimental techniques have been developed to the point that many experimentally determined values are available. These are often more accurate than those calculated with Eq. (2-16). Majer and Svoboda [31] compiled comprehensive and critical experimental values of ΔHv measured since 1932 for approximately 600 organic compounds. They give recommended values for ΔHv at both the normal boiling point and at 298 K by the following equation to correlate ΔHv with reduced temperature:

$$\Delta Hv = A(1- Tr)^{\beta} \exp(-\alpha Tr) \qquad (2\text{-}21)$$

In spite of the increased availability of experimental values, it is usually necessary to supplement data with results calculated or extrapolated by some methods.

2.7 The main principles methods that have been used to estimate the latent heat of vaporization (λ_v)

There are three main principle methods that have been used to estimate the latent heat of vaporization (λ_v) .They are estimation of latent heat of vaporization from vapor pressure, estimation of latent heat of vaporization from normal boiling point and estimation of the latent heat of vaporization from the law of corresponding states .

2.8 Latent heat of vaporization from vapor pressure

The vapor-pressure relations can be used to estimate enthalpies of vaporization.

$$\frac{dP}{dT} = \frac{\Delta H}{T\Delta V} \qquad (2\text{-}22)$$

The dimensionless group φ can be defined from the above equation

$$\varphi = -d\ln p_{vpr} / d(1/T_r) \qquad (2\text{-}23)$$

Differentiating the vapor-pressure equations discussed earlier, various expressions for φ can be obtained

$$\varphi = \Delta H_V / RT_C\Delta Z_C \qquad (2\text{-}24)$$

the latent heat can be expressed using vapor pressure relation as :

$$\lambda_v = \varphi \ RT_C\Delta Z_C \qquad (2\text{-}25)$$

following are the methods that uses this principle

2.8.1 Lee –kesler

Lee Kesler [26] found another form of the Pitzer equation which generally predicts the vapor pressure which can mathematically be expressed as

$$\lambda_{vap} = R\ T_c\ \Delta Z_v\ (6.09648\text{-}1.28862\ T_r + 1.016\ T_r^7 + \omega(15.6875 - 13.4721\ T_r + 2.615\ T_r^7) \qquad (2\text{-}26)$$

2.8.2 Antion equation

Antion [34] proposed a simple modification of clapeyron equation which has been widely used over limited temperature

$$\text{Log}\ P_{vp} = A - B/(T+C-273.15) \qquad (2\text{-}27)$$

Where A ,B and C are tabulated for a number of material

From vapor pressure relations

$$\lambda_{vap} / RT_C \Delta Z_{C=} \tilde{} \, d\ln p_{vpr} / d(1/T_r) \qquad (2\text{-}28)$$

Combine eq 2.28 with eq 2.27 then we have

$$\lambda_{vap} = R\, T_c\, \Delta Z_v \left(\quad T_r \ /(A - B /(T+C-273.15))^2 \right. \qquad (2\text{-}29)$$

2.8.3 Wagnar equation one

Wagner [51] used an elaborate statistical method to develop an equation for representing the vapor pressure behavior of nitrogen and argon over the entire temperature range for which experimental data were available. In this method, the actual terms as well as their coefficients were variables; i.e., a superfluity of terms was available and the most significant ones were chosen according to statistical criteria. The resulting equation is

$$\ln P_{vpr} = (a\tau + b\,\tau^{1.5} + c\tau^{3} + d\,\tau^{6})/Tr \qquad (2\text{-}30)$$

and the equation of heat of vaporization is

$$\lambda_{vap} = R\, T_c\, \Delta Z_v(-a + b\,\tau^{0.5}(.5\,\tau - 1.5) + c\tau^{2}(2\,\tau - 3) + d\,\tau^{5}(5\tau - 6))/T_r \qquad (2\text{-}31)$$

where a , b and c are constants and tabulated for a number of substance

2.8.4. Wagnar equation two .

Wagnar [52] introduced another preferred form which is

$$\ln P_{vpr} = (a\tau + b\,\tau^{1.5} + c\,\tau^{2.5} + d\,\tau^{5})/Tr \qquad (2\text{-}32)$$

for latent heat of vaporization it can expressed as

$$\lambda_{vap} = R\,T_c\,\Delta Z_v(-a+b\tau^{0.5}(.5\tau-1.5)+c\tau^{1.5}.1.5\,\tau-2.5)+d\,\tau^{5}\,(4\tau-6))/T_r \qquad (2\text{-}33)$$

2.8.5 Ambrose Walton equation

This equation is two-parameter corresponding-states equation for vapor pressure. To improve accuracy, several investigators have proposed three parameter forms. The Pitzer expansion is one of the more successful equation[2]

$$\ln P_{vpr} = f^{(0)} + \omega\, f^{(1)} + \omega^2 f^{(2)} \qquad (2\text{-}34)$$

Although a number of analytical expressions have been suggested for $f^{(0)}$, $f^{(1)}$and $f^{(2)}$ we recommend the following equations developed by Ambrose and Walton

$$f^{(0)} = (-5.97616\tau + 1.29874\tau^{1.5} - 0.60394\,\tau^{2.5} - 1.06841\,\tau^{5})/Tr \qquad (2\text{-}34A)$$

$$f^{(1)} = (-5.03365\tau + 1.11505\tau^{1.5} - 5.41217\tau^{2.5} - 7.46628\tau^{5})/Tr \qquad (2\text{-}34B)$$

$$f^{(2)} = (-0.64771\tau + 2.41539\tau^{1.5} - 4.26979\tau^{2.5} - 3.25259\tau^{5})/Tr \qquad (2\text{-}34C)$$

This set of equations where fitted to the vapor pressure behavior and they are more accurately describe this behavior than the equations of Lee and Kesler. The quantity, $f(2)$, is important only for fluids with large acentric factors and at low reduced temperatures. In fact, it is zero a Tr=0.7.

The mathematical expression of Ambrose and Walton equation for latent heat of vaporization is

$$\lambda_{vap} = R\ T_c\ \Delta Z_v = [5.97616+1.29874\ \tau^{0.5}*(.5\tau\ -1.5)-.60394\tau^{1.5}(1.5\tau\ -2.5)-1.06841\tau^4(4\tau-5) + \omega\ (5.03365+1.11505\tau^{.5})\ (.5\tau-1.5) - 5.41217\tau^{1.5}(1.5\tau-2.5)-7.46628\ \tau^4(4\tau-5)) + \omega^2(.64771+2.41539\tau^{.5})(0.5\tau-1.5)-4.26979\ \tau^{1.5}).(1.5\tau-0.5)+3.25259\ \tau^4)(4\tau-5))]$$

(2-35)

Where:

$$\tau = 1 - Tr$$

2.8.6 Riedel equation [1]

Riedel proposed a vapor pressure equation of the form

$$\ln P_{vpr} = A + B/T + C\ \ln T + DT^6 \qquad (2\text{-}36)$$

The T^6 term allows description of the inflection point of the vapor pressure curve . To determine the constants in Eq. (2.36), Riedel defined a parameter α

$$\alpha = \frac{d(\ln P)}{d(\ln T)} \qquad (2\text{-}8)$$

From a study of experimental vapor pressure data, Plank and Riedel [36] showed that

$$\frac{d(\alpha)}{d(Tr)} = 0 \quad \text{at } Tr = 0$$

Using Eq. (2-36) as a constraint on Eq. (2-38) plank an Riedel found that

$$\lambda_{vap} = R\ T_c\ \Delta Z_v\ [\ B^+ + C^+ T_r + 6D^+ T_r^7] \qquad (2\text{-}37)$$

where

$$A^+ = -35Q\ ,\ B^+ = -36Q\ ,\ C^+ = 42Q + \alpha_C\ ,\ D^+ = -\ Q\ ,$$

$$Q=K(3.758-\alpha_C)$$

where α_C is at the critical point

$$\alpha_C = \frac{3.789K\,\psi b + \ln((P_c/1.01325)}{K\,\psi_b - \ln T_{br}} \qquad (2\text{-}38)$$

$$\psi_b = -35 + 36/Tbr + 42\ln Tbr - Tbr^6 \qquad (2\text{-}39)$$

The optimized K values are linked to a well known property of the compound through generalized correlations which are valid for all the compounds that belong to the same family.

nonpolar compounds	$K = 0.066 + 0.0027H$	*(2-40A)*
acids	$K = -0.120 + 0.025H$	*(2-40B)*
alcohols	$K = 0.373 - 0.030H$	*(2-40C)*
glycos	$K = 0.106 - 0.0064H$	*(2-40D)*
other polar compounds	$K = -0.008 + 0.14$	*(2-40E)*

Where

$$H = Tb\,\frac{\ln(Pc/1.01325)}{1-Tbr} \qquad (2\text{-}41)$$

2.9 Latent heat of vaporization at normal boiling point

A pure component constant that is occasionally used in property correlations is the latent heat of vaporization at the normal boiling point λ_{vap} .The methods that are available in literature for this purpose are :

2.9.1 Calpeyron method

when the clapeyron equation is used to calculate ψ regardless Tr, ψ is equal to

$$\psi(Tr)=\psi(Tb)= T_b \quad \frac{\ln (Pc/1.01325)}{1 - Tbr} \qquad (2\text{-}42)$$

$$\lambda_{vap(n.b)} = R\, T_c\, \Delta Z_{vb}\, T_{br} \quad \frac{\ln (Pc/1.01325)}{1 - Tbr} \qquad (2\text{-}43)$$

2.9.2 Riedel method

Riedel modified eq (2-43) slightly and proposed that

$$\lambda_{vap(n.b)}= 1.093\, R\, T_c\, T_{br} \quad \frac{\ln Pc - 1.013}{0.93 - Tbr} \qquad (2\text{-}44)$$

2.9.3 Kistiakowsky method

The Kistiakowsky [39] rule is another simple equation that can be used to estimate latent heat of vaporization at normal boiling point

$$\lambda_{vap(n.b)} = (36.1+R \ln T_b)\, T_b \qquad (2\text{-}45)$$

2.9.4 Fishtine method

Fishtine [60] modified Kistiakowsky relation and expressed $\lambda_{vap\,(n.b\,)}$ as

$$\lambda_{vap\,(n.b\,)} = \frac{4.7\, Tc\, (1.0 - P_{rb})^{0.69} \log P_{rb}}{1- 1/T_{rb}} \qquad (2\text{-}46)$$

this equation was used to predict λ_{vap} for about 90 substances with an average deviation of about 1.8%. Equation (2-46) was used to predict λ_{vap} values for substances considered by Fishtine.

2.9.5 Chen method

Chen [6] used a similar expression proposed by Pitzer to correlate vapor pressures so that the acentric factor is eliminated. He obtained a relation between dHv ,Pvp and *Tr* , when applied at the normal boiling point.

$$\lambda_{vap} = \frac{3.978T_{br} - 13.9758 + 1.555 \ln P_c}{1.07 - T_{br}} \qquad (2\text{-}47)$$

2.9.6 First veter method

Veter [48, 49] proposed a relation similar to the one suggested by Chen. When applied to the normal boiling point:

$$\lambda_{vap} = RT_cT_{br} \frac{(1-T_{br})^{0.38} (\ln P_c - 0.513 + 0.5066/(P_cT^2_{br}))}{1-T_{br} + F(1-(1-T_{br})^{0.38})\ln T_{br}} \qquad (2\text{-}48)$$

F is 1.05 for alcohols and dimerizing compounds such as SO3 , NO, and NO2.. For all other compounds investigated by Veter, *F* is 1.0.

2.9.7 Second Veter method

when Tc and pc are not available Veter [47] proposed

$$\lambda_{vap} = RT_b (A + B \ln T_b + C / T_b^{1.72} / M') \quad (2\text{-}49)$$

Where A , B and C are given in table 2.1.a , M' is a fictitious molecular weight that is equal to the true molecular weight for most compounds. But for fluids that contain halogens or phosphorus, the molecular weight contributions for these atoms are those shown in table 2.1.b .

Table 2-1 a The constants of second Veter method

Groups	A	B	C
Hydrocarbons	3.298	1.015	0.00352
Alcohols	13.173	4.359	0.00151
Esters	4.814	0.890	0.00374
Other polar compounds	4.542	0.840	0.00352

Table 2.1.b The molecular weight contributions for second Veter method

Atom	Contribution
F	1
Cl	19.6
Br	60
I	60
P	24

2.10 Estimation of the latent heat of vaporization from law of corresponding states

Corresponding states methods are based on the critical temperature, critical pressure, acentric factor and other parameters . The methods are compressibility factor (Z) correlations evaluated at the critical point.

2.10.1 Pitzer equation

The Pitzer[35] equation use the acentric factor as a third parameter for the correlation of Z. The exact error is not known but the critical region is within the range of the correlation which was fitted to data within a very close deviation. It must be pointed out that, as with all of the three parameter corresponding states correlations, it is accurate only for "normal fluids". A "normal fluid" is nonpolar or only slightly polar. This means that it does not exhibit a dipole, quadrupole or higher moments, nor are there hydrogen bonding forces present. An example of a "normal fluid" would be hexane or carbon tetrachloride, polar compounds would be water or methyl chloride.

Pitzer used the Clausisus Clapeyron equation in combination with his vapor pressure and compressibility factor (volume) equations to develop a function (not requiring the direct calculation of either) for the heat of vaporization. The resulting equation has similar properties to the vapor pressure, most importantly it is limited to "normal fluids".

Pitzer equation is

$$\lambda_{VAP} / T = \Delta S^{(0)} + \omega \Delta S^{(1)} \qquad (2\text{-}50)$$

Where $\Delta S^{(0)}$ and $\Delta S^{(1)}$ are tabulated functions of T_r .Extend of pitzer parameter by Carruth and Kobayashi [55] .

The original heat of vaporization function was tabulated for reduced temperatures of 0.56 to 1.00. Carruth and Kobayashi also extended this correlation, down to a reduced temperature of 0.30 as shown in table 2.2

Table 2.2 Pitzer heat of vaporization parameters

T_r	$\Delta S^{(0)}$	$\Delta S^{(1)}$	T_r	$\Delta S^{(1)}$	$\Delta S^{(1)}$
1	0	0	0.66	14.62	20.5
0.99	2.57	2.83	0.64	15.36	21.8
0.98	3.38	3.91	0.62	16.12	23.2
0.97	4	4.72	0.6	16.92	24.6
0.96	4.52	5.39	0.58	17.74	26.2
0.95	5	5.96	0.56	18.64	27.8
0.94	5.44	6.51	0.54	19.56	29.84
0.92	6.23	7.54	0.52	20.55	32
0.9	6.95	8.53	0.5	21.6	34.22
0.88	7.58	9.39	0.48	22.7	36.48
0.86	8.19	10.3	0.46	24.05	38.8
0.84	8.79	11.2	0.44	25.5	41.14

0.82	9.37	12.1	0.42	27.05	43.5
0.8	9.97	13	0.4	28.83	46
0.78	10.57	13.9	0.38	30.7	49.2
0.76	11.2	14.9	0.36	32.8	53
0.74	11.84	16	0.34	35.1	57.4
0.72	12.49	17	0.32	37.55	63.6
0.7	13.19	18.1	0.3	40.2	71.5
0.68	13.89	19.3			

2.10.2 HALM and STIEL

The Halm and Stiel [9] method uses the acentric factor of Pitzer plus a fourth parameter, the polarity factor. This fourth parameter allowed polar forces to be described by the equation. The correlation works quite well for most polar substances, indeed much better than the three parameter correlation of Pitzer. However, the equation gave largest errors for very complex polar molecules where a simple fourth parameter is still not enough to describe the forces. Obviously the disadvantage of this method over Pitzer's is the requirement of more data, the polarity factor allowing it to predict the heat of vaporization of polar compounds.

$$\lambda_{VAP} / T = \Delta S^{(0)} + \omega \Delta S^{(1)} - \chi \Delta S^{(2)} \qquad (2\text{-}51)$$

Where :

χ is polarity factor

$\Delta S^{(0)}$,$\Delta S^{(1)}$ and,$\Delta S^{(2)}$ are Tabulated functions of T_r

New values Polarity factor [25] estimated values are shown Table 2.2.The values of *T*c, *p*c were used in this estimation.

TABLE 2.3 The values of the polarity factor of Halm Stiel

Substance	χ	Substance	χ	Substance	χ
Acetaldehyde	0.034	2,4-Dimethylphenol	0.021	3-Methyl-2-butanone	0.007
Acetone	0.007	2,5-Dimethylphenol	−0.024	Methyllbutylether	0.008
Acetonitrile	0.048	3,5-Dimethylphenol	0.016	Methylbutyrate	−0.001
Ammonia	0.003	2,3-Dimethylpyridine	−0.039	Methylformate	−0.009
Aniline	0.007	2,4-Dimethylpyridine	−0.006	o-Methylphenol	−0.004
Benzaldehyde	0.017	2,6-Dimethylpyridine	−0.003	p-Methylpheno	
Bromobenzene	0.002	3,5-Dimethylpyridine	−0.015	Methylphenylether	0.081
Bromoethane	0.035	Dimethylsulfide	0.003	Methylpropanoate	0.012
Bromomethane	0.039	Dipropylether	0.019	2-Methyl-1-propanol	−0.069
2-Butanone	0.036	1-Dodecanol	0.044	2-Methyl-2-propanol	−0.097
Butylacetate	−0.004	Dichloromethane	−0.014	Methylpropylether	0.006
Butylamine	−0.004	Ethanol	0.002	2-Methylpyridine	0.005
Butyric acide	−0.009	Ethanolamine	0.048	3-Methylpyridine	0.004
Butyronitrile	0.027	Ethylbutylether	0.03	Morpholine	0.022
Capronitrile	0.063	Ethylformate	−0.009	Nitromethane	0.038
Chlorobenzene	−0.018	Ethylenediamine	0.089	5-Nonanone	0.019
1-Chlorobutane	−0.026	Ethyleneoxide	0.012	1-Octanol	−0.083
Chloroethane	0.006	Ethylpropionate	−0.002	1-Pentanol	−0.046
Chloroethene	−0.019	Ethylpropylether	0.016	3-Pentanone	−0.010
Chloromethane	0.02	Ethylacetate	0.038	Phenol	−0.001
Cyclohexanone	0.071	Fluorbenzene	−0.001	2-Propanol	−0.054
Dibutylether	–	Fluoroethane	0.008	Propionic acid	–

Continue

To be continued…….

	0.025				0.039
m-Dichlorobenzene	0.024	Formaldehyde	– 0.015	Propionitrile	0.006
o-Dichlorobenzene	– 0.006	Hydrogenchloride	0.025	Propylacetate	– 0.004
1,2-Dichloropropane	– 0.005	Hydrogenfluoride	0.037	Pyridine	– 0.020
Diethylamine	– 0.014	Iodoethane	0.062	Sulfur dioxide	0.004
Diethylether	– 011	Isobutylamine	0.053	1,1,2,2-Tetrachloroethane	– 0.028
Diethyldisulfide	– 0.001	Methanoic acid	0.024	Thiacyclopentane	0.019
Diethylsulfide	0.008	Methanol	0.04	1,1,1-Trichloroethane	
Diisopropylamine	0.026	Methylacetate	0.004	Trichloromethane	0.013
Dimethylamine	– 0.001	Methylbenzoate	0.02	1,1,1-Trifluoroethane	0.001
Dimethylether	0.016	2-Methyl-2-butanol	– 0.090	Water	0.023

Continue

To be continued…….

2.10.3 Carruth and Kobayashi

Carruth and Kobayashi [5] made an analytical representation for pitzer correlation

$$\lambda_{vap} / RTc = 7.08 (1-Tr)^{0.358} + 10.95\ \omega(1-Tr)^{0.65} \qquad (2\text{-}52)$$

2.11 Variation latent heat of vaporization with temperature

The latent heat of vaporization decreases steadily with temperature and is zero at the critical point. There are many popular relation descript the change of latent heat with temperature

2.11.1 Sastri correlation

This is a group contribution method corrected by a temperature function such that the heat of vaporization reduces to zero at the critical point (eq 2-53).

$$dH_v = dH_{vo}(1 - T_{br})^n \qquad (2\text{-}53)$$

The exponent n depends on the reduced normal boiling point (T_{br}) and dH_{vo} is a sum of contributions for various groups. These group contributions are given in the original article.

2.11.2 Kistiakowsky correlation

The correlation relates heat of vaporization at any temperature at the normal boiling point estimated by Kistiakowsky equation and the correlation is

$$\Delta H_{V\,(T)} = \Delta H_{V(Tb)}(3\text{-}2T/T_b)^m \qquad (2\text{-}54)$$

Where m=0.19

Grain in Lyman [29] suggests

$$m = \begin{cases} 0.36 & T/T_b > 0.6 \\ 0.8 & 0.5 < T/T_b < 0.6 \\ 1.19 & T/T_b < 0.5 \end{cases}$$

2.11.3 Watson correlation

This method models the temperature variation of the heat of

vaporization, using one data point as a reference. Several authors have studied this relationship most agreeing that the power n, while it does vary somewhat, should be 0.38. Thods [45] found that for 44 substances the average value of n to be 0.378.

$$dHv = dHv_{ref} \left[\frac{1-Tr}{1-Tr_{ref}} \right]^{n} \qquad (2\text{-}55)$$

where n= .38

The expected errors will be least between the reference point and the critical point, and increasing at lower temperatures

2.12. Latent heat of vaporization for mixture

There are three methods to calculate latent heat of vaporization for mixture.

2.12.1 Pitzer equation with suitable mixing rule

Pitzer equation can be applied to calculate latent heat of vaporization for mixture after using suitable mixing rule to find mean parameter of mixture.

2.12.2. Carruth and Kobayashi with suitable mixing rule

Carruth and Kobayashi equation can also be applied to calculate latent heat of vaporization for mixture after using suitable mixing rule to find mean parameter of mixture

2.12.3 Teja

Teja [44] proposed a generalized corresponding state principle for thermodynamic properties which no longer retains the simple fluid as one of the reference equation Lee Kesler is written as

$$\frac{H^R}{RT_C}=\left(\frac{H^{ig}-H}{RT_C}\right)=\left(\frac{H^{ig}-H}{RT_C}\right)^{o}+\omega\left(\frac{H^{ig}-H}{RT_C}\right)^{'} \qquad (2\text{-}56)$$

Where tables or graphs of the values of $\left(\left(H^{ig}-H/RT_C\right)\right)'$ and $\left(\left(H^{ig}-H/RT_C\right)\right)'$ are given for specified values of $T_r = T / T_C$ and $P_r = P / P_C$. The equivalent of the two-reference approach of equation (2-56) is

$$\frac{H^R}{RT_C}(T_r,P_r,\omega)=\left(\frac{H^{ig}-H}{RT_C}\right)^{(R1)}(T_r,P_r,\omega^{(R1)})+\frac{\omega-\omega^{(R1)}}{\omega^{(R2)}-\omega^{(R1)}}$$

$$\left[\left(\frac{H^{ig}-H}{RT_C}\right)^{(R2)}(T_r,P_r,\omega^{(R2)})-\left(\frac{H^{ig}-H}{RT_C}\right)^{(R1)}(T_r,P_r,\omega^{(R1)})\right] \qquad (2\text{-}57)$$

Where the superscripts R1 and R2 refer to two reference fluids chosen so they are similar to the pure component of interest , this equation provides a method for generalizing equation of state using the known equation of two pure components

2.13 Mixing rules

For mixtures the property of Tc, Pc and ω are Lee Kesler calculated from the following equations, for a binary system which contain x_i of component i , and x_j of component j **,**

the critical volume of the mixture :

$$Vc = 1/8\ \Sigma\Sigma x_i x_j\ [V_{ci}^{1/3}+V_{cj}^{1/3}]^3 \qquad (2\text{-}58)$$

Critical temperature of the mixture :

$$Tc = 1/8Vc\ \Sigma\Sigma\ x_i x_j\ [V_{ci}^{1/3}+V_{cj}^{1/3}]^3\ \ (T_{ci}\ T_{cj})^{0.5}\ (1\text{-}K_{ij}) \qquad (2\text{-}59)$$

Critical pressure of the mixture :

$$Pc = Zc\ R\ Tc / Vc \qquad (2\text{-}60)$$

Acentric factor of the mixture:

$$\omega = \omega_i x_i + \omega_j x_j \qquad (2\text{-}61)$$

2.14 Experimental Data

It is a well known fact that the evaluation of any correlation or prediction method is done by comparison of the results with experimental dependable data. The deviation between the experimental results and the results of prediction or correlation determines the accuracy of the method. The experimental data of the latent heat of vaporization , obtained from literature for the purpose of this investigation including 18 pure non polar compounds and 6 polar compounds at various temperature are shown in table 2-4, in additional to 32 pure non polar compounds and 29 polar compounds at normal boiling point and 4 mixtures with 46 data point as shown in table 2-6 .

Table 2.4 The pure

	No of data point	Reference
Ethan	23	[34]
ethylene	20	[34]
methane	22	[34]
propane	16	[61]
iso butane	20	[10]
n octain	15	[34]
ferion 12	34	[46]
ferion 13	35	[46]
ferion 23	32	[46]
R123	37	[12]
R 134a	36	[12]
argon	16	[46]
amonia	36	[16]
nitrogen	15	[53]
benzene	24	[46]
toluene	41	[46]
butadiene	19	[46]
methlcyclopentane	20	[46]
ethylcyclopentane	21	[46]
2 -propanpl	27	[46]
1- popnanol	7	[46]
methanol	18	[46]
Water	75	[23]
ethyle astate	17	[46]

compounds latent heat of vaporization at various temperatures data

Table 2.5 The pure compounds latent heat of vaporization at normal boiling point data

Compounds	Data Ref.	Compounds	Data Ref.
ethan	[34]	trans 2 butene	[39]
ethylene	[34]	cis 2 butene	[39]
methane	[34]	1 pentanol	[46]
propane	[61]	2 pentanol	[46]
iso butane	[10]	ethanol	[46]
n octane	[62]	isobutanol	[39]
ferion 12	[46]	tert-butanol	[39]
ferion 13	[46]	butanol	[39]
ferion 23	[46]	2 butanol	[39]
R 123	[12]	2methyl2butanol	[39]
R 134a	[12]	3methyl2butanol	[39]
argon	[39]	1hexanol	[39]
nitrogen	[39]	2 hexanol	[39]
benzen	[24]	1 heptanol	[39]
aceton	[53]	1 octanol	[39]
diethylsulfide	[53]	2 octanol	[39]
anline	[53]	1 decanol	[39]
toluene	[39]	1 propnanol	[39]
butadiene	[39]	methanol	[39]
methlcyclopentane	[39]	water	[23]
ethylcyclopentane	[39]	butyl actate	[39]
1,1 dichloroethane	[39]	dimethylether	[39]
1,2 dichloroethane	[39]	chloroethane	[39]
bromoethane	[39]	methylacetate	[39]
methyl acetylen	[39]	dimethylsulfide	[39]
cyclopropane	[39]	methyl propanoate	[39]
1,2 propadiene	[39]	diethylether	[39]
propylamine	[39]	iso butylamine	[39]
methyl ethyl amine	[39]	ethyl formate	[39]
butyne	[39]		

Table 2.6 The mixtures latent heat of vaporization data

Mixtures	No of Composition	Data Ref.
Benzen - Pentane	4	[21]
Pentane-Cyclohixane	3	[17]
Benzen -Octane	2	[24]
Ethanol - Water	1	[38]

Chapter Three

Results and Evaluation of various methods for calculating latent heat of vaporization

3.1 Evaluation of various methods of predicting the latent heat of vaporization of pure compounds at various temperatures.

3.1.1 Halm and Stiel method

Table 3.1 shows that the overall absolute average deviation percent of Halm and Stiel method for 24 compounds and 626 data point is 1.876 compared with experimental data . The results indicate that it is the best method among the nine methods. This method can predict the latent heat of vaporization for both non polar and polar pure compounds with high accuracy. It can also be applied to all compounds . Since the parameters needed are available in literature or can be calculated easily. The overall absolute average deviation percent for eighteen non polar compounds and 446 data points is 1.55 as shown in table 3.2 while the absolute average deviation percent for six polar compounds and 180 data point is 2.845 as shown in table 3.3.

It is to be noted that it is the only method that deals especially with polar compounds by introducing what is known as polarity factor , The results also indicate that this method gives excellent results (least deviations from experimental data) at reduced temperature range of 0.3 to just below 0.99 .

3.1.2 Pitzer method

Table 3-1 shows that the overall absolute average deviation percent of Pitzer method for 24 compounds and 626 data point is 1.956 compared with experimental data . This method is easy to use and can be applied to all compounds and the results indicate that it is one of the best methods to predict the latent heat of vaporization of pure non polar compounds. Table 3.2 shows the overall absolute average deviation percent for 18 non polar compounds and 446 data point is 1.55% and .The overall absolute average deviation percent for 6 polar compounds and 180 data point is 3.16 as shown in table 4-3. Thus this method can be considered as an excellent method for non polar compounds but it is not so accurate for polar compounds .

Tables 1to 4 (in appendix B) indicate that this method can be applied at reduced temperature range of 0.3 to just below the critical region for non polar compounds while the reduced temperature range of 0.45 until critical region for polar compounds .

3.1.3 Carruth and Kobayashi

Table 3.1 shows that the overall absolute average deviation percent of Carruth and Kobayashi for 24 compounds and 626 data point is 2.11 compared with experimental data .This method is easy to use and can be applied to all compounds .Table 3-2 indicates that the accuracy of this method for predicting the latent heat of vaporization of non polar pure compounds is as good as Halm Stiel and Pitzer method. The overall absolute average deviation percent for 18 non polar compounds and 446 data point is 1.52 .However it is not so accurate for polar pure compounds whereas the overall absolute average deviation percent for 6 polar compounds and 180 data point is 3.52 as shown in table 3-3 . The results also indicate that Carruth and Kobayashi method works at low reduced

temperature up to reduced temperature of 0.97 where in the region from 0.97 to 1.0 has relatively high deviation from experimental latent heat of vaporization data .

3.1.4 First and Second Wagnar methods

Table 3-1 shows that the overall absolute average deviation percent for 7 pure compounds and 207 data points are 2.24 and 1.102 for first and second Wagnar methods respectively compared with experimental data .The results indicate that the second wagnar method is better than the first Wagnar method for prediction of the latent heat of vaporization of pure non polar and polar compounds. The disadvantage of these methods is the fact that they have a special constants for each compounds called Wagnar constants and these constants are not available in literature for most compounds . In case the parameters are available this equation shows high accuracy for temperature range from low temperature to near critical temperature as shown in tables B-1 to B-7.

3.1.5 Lee Keslar method

Table 3-1 shows that the overall absolute average deviation percent of Lee Keslar method for 14 compounds and 417 data point is 1.26 compared with experimental data .The disadvantage of this method is that it can not be applied to all compounds thus it can not be considered as one of the very successful methods . The results indicate that Lee Keslar method works even at low reduced temperature for non polar compounds while in polar compounds it works from reduced temperature of o.5 to just below 0.99.

3.1.6. Antion method

Table 3-1 shows that the overall absolute average deviation percent of Antion method for 14 compounds and 417 data point is 4.6474 compared with experimental data .The results indicate that this method is not very successful method to predict the latent heat of vaporization of pure non polar or polar compounds .

3.1.7 Ambrose Walton method.

Table 3-1 shows that the overall absolute average deviation percent of Ambrose Walton method for 14 compounds and 417 data point is 1.363 compared with experimental data. However it has good results to predict the latent heat of vaporization for pure non polar compounds .However it has some limitations since it is not easy to use and its parameters are not available in literature for all compounds.

3.1.8 Riedel method

Table 3-1 shows that the overall absolute average deviation percent of Riedel method for 14 compounds and 417 data point is 1.88 compared with experimental data. The results indicate that it is good method to predict the latent heat of vaporization for pure non polar compounds. It can not be considered as one of the successful methods because it is difficult to use and can not be applied to all compounds.

Table 3.1 Overall AAD% for predicting of latent heat of vaporization at various temperatures for pure non polar and polar compounds

Methods	No.of compounds	No of data point	OVER ALL AAD %
HALM STIEL	24	626	1.876
Pitzer	24	626	1.956
Carruth Kobayashi	24	626	2.112
Wagnar 1	7	207	2.24
Wagnar 2	7	207	1.103
Lee –kesler	14	417	1.261
Antion	14	417	4.047
Ambrose Walton	14	417	1.363
Riedel	14	417	1.881

Table 3.2 Overall AAD% for predicting of latent heat of vaporization at various temperatures for pure non polar compounds

Methods	No.of compounds	No.of data point	OVER ALL AAD %
HALM STIEL	18	446	1.552
Pitzer	18	446	1.552
Carruth Kobayashi	18	446	1.52
Wagnar One	5	96	2.506
Wagnar Two	5	96	0.745
Lee –kesler	12	306	1.032
Antion	12	306	4.3632
Ambrose Walton	12	306	0.5807
Riedel	12	306	0.889

Table 3.3 Overall AAD% for predicting of latent heat of vaporization at various temperatures for pure polar compounds

Methods	No.of compounds	No.of data point	Over all AAD%
HALM STIEL	6	180	2.8476
Pitzer	6	180	3.1674
Carruth Kobayashi	6	180	3.52
Wagnar 1	2	111	1.57455
Wagnar 2	2	111	1.9969
Lee –Kesler	2	111	2.635
Antion	2	111	2.15255
Ambrose Walton	2	111	6.054
Riedel	2	111	7.831

3.2 Evaluation of various methods of predicting the latent heat of vaporization at normal boiling point of pure compounds .

3.2.1 Riedel method

Table 3-4 shows the overall absolute deviation percent of Riedel method for 61 compounds is 2.767 compared with experimental data. Riedel method is easy to use and can be applied to all compounds. The results indicate that Riedel method is the best method among seven methods to predict the latent heat of vaporization at normal boiling point for pure compounds especially for non polar pure compounds whereas the overall absolute deviation percent of 32 non polar compounds is 1.271 as shown in table 3-5 .

3.2.2 Chen method

Table 3.4 shows that the overall absolute deviation percent of Chen method for 61 compounds is 2.818 compared with experimental data. This method is easy to use and can be applied to all compounds. The results indicate that Chen method can be considered as one of the best methods to predict the latent heat of vaporization at normal boiling point for pure non polar compounds. The overall absolute deviation percent of 32 non polar compounds is 1.255 as shown in table 3.5 .However the overall absolute deviation percent of 29 polar compounds is 4.471 as shown in table 3.6.

4.2.3 First Veter method

Table 3-4 shows that the overall absolute deviation percent of 61compounds using this method is 3.255 compared with experimental data. The overall absolute deviation percent of 32 non polar compounds is 1.496 as shown in table 3.5 and the overall absolute deviation percent of 29 polar compounds is 5.059 as shown in table 3.6. Thus the First Veter method has high accuracy in for non polar compounds and also it can be applied for all compounds but it is not so accurate for polar compounds .

3.2.4 Fishten method

Table 3.4 shows the overall absolute deviation percent of Fishten method of 61 compounds is 3.27 compared with experimental data . The overall absolute deviation percent of 32 non polar compounds is 2.647 as shown in table 4-5 while the overall absolute deviation percent of 29 polar compounds is 3.905as shown in table 3.6 . The results indicate that Fishten method is the best method among the seven methods to predict the latent heat of vaporization at normal boiling point for polar compounds also it can be applied for all compounds.

3.2.5 Calypyron method

Table 3.4 shows that the overall absolute deviation percent 61compounds using this method is 3.799 compared with experimental data. The overall absolute deviation percent of 32 non polar compounds is 2.327 as shown in table 3.5 while the overall absolute deviation percent of 29 polar compounds is 5.316 as shown in table 3.6. These results indicate that the Calypyron method has very good results for non polar compounds but it does not give good results when

dealing with polar compounds. The disadvantage of this method that it cannot be applied to all compounds .

3.2.6 Second Veter method

Table 3.4 shows that the overall absolute deviation percent of 61 compounds using this method is 4.75 compared with experimental data. The overall absolute deviation percent of 32 non polar pure compounds is 4.271 as shown in table 3.5 .The overall absolute average deviation percent of 29 polar pure compounds is 5.456 as shown in table 4.6.These results indicate that second Veter method is not so accurate for prediction of the latent heat of vaporization for both non polar and polar compounds .

3.2.7 Kistiakowsky method

Table 3.4 shows that the overall absolute deviation percent of 61compounds using this method is 8.375 compared with experimental data. The results indicate that it is not successful method to predict the latent heat of vaporization at normal boiling point. This high deviation from experimental data is due to the fact that this method does not work with polar pure compounds whereas the overall absolute deviation percent of 32 non polar compounds is 3.379 as shown in table 3.5 and the overall absolute deviation percent of 29 polar compounds is 13.66 as shown in table 3.6. These results also indicate that it is relatively good method to predict the latent heat of vaporization of pure non polar compounds. The method is simple method and can be applied to all compounds .

Table 3-4 Overall AD% for predicting of latent heat of vaporization at normal boiling point for pure non polar and polar compounds

	Name of method	No of compounds	Over all AD%
1	Riedel	61	2.77
2	chen	61	2.818
3	Vetere 1	61	3.255
4	Fishtine	61	3.273
5	calpeyron	61	3.799
6	Vetere 2	61	4.752
7	Kistiakowsky	61	8.375

Table 3.5 Overall AD% for predicting of latent heat of vaporization at normal boiling point for pure non polar compounds

	Name of methods	No of compounds	Over all AD%
1	Riedel	32	1.271
2	chen	32	1.255
3	Vetere 1	32	1.496
4	Fishtine	32	2.647
5	calpeyron	32	2.327
6	Vetere 2	32	4.271
7	Kistiakowsky	32	3.379

Table 3.6 Overall AD% for predicting of latent heat of vaporization at normal boiling point for pure polar compounds

	Name of method	No of compounds	Over all AD%
1	Riedel	29	4.439
2	Chen	29	4.471
3	Vetere 1	29	5.059
4	Fishtine	29	3.905
5	Calpeyron	29	5.316
6	Vetere 2	29	5.456
7	Kistiakowsky	29	13.66

3.3 Evaluation of various methods of predicting the latent heat of vaporization at any temperatures from those at normal boiling point of pure compounds

3.3.1 Riedel method at normal boiling point

Table 3.7 shows that the overall absolute average deviation percent at various temperatures from those of 24 compounds and 626 data point is 1.98 compared with experimental data .Riedel method as mentioned before is easy to use and can be applied to all compounds . Table 3.8 indicates that Riedel method has excellent agreement with experimental data for non polar compounds. The overall absolute average percent deviation for eighteen non polar compounds and 446 data points is 1.38 as shown in table 3.5. However this method is not so accurate for polar compounds whereas the overall absolute average percent deviation for six polar compounds and 180 data point is 3.81as shown in table 3.6 .Thus Riedel method can be considered as the best method to predict the latent heat of vaporization of non polar compounds among the seven methods. The results also indicate that this method works safely near the critical region but it is not so safe at reduced temperature below 0.3 specially for polar compounds .

3.3.2 Fishten method

Table 3.7 shows that the overall absolute average deviation percent of Fishten method for 23 compounds and 625 data point is 2.813 compared with experimental data. The results indicate that this method is very good to predict the latent heat of vaporization of pure non polar and polar compounds. This method as mentioned before can be applied for almost all compounds. The overall

absolute average deviation percent for 17 non polar compounds and 430 data points is 2.11 as shown in table 3.8. The overall absolute average deviation percent for 6 polar compounds and 180 data point is 3.463 as shown in table 4-9. The results also indicate that Fishten method works accurately for non polar compounds at reduced temperatures ranges from 0.25 to just below 0.99 while it works accurately for polar compounds at reduced temperatures range of 0.3 to just below 0.97 .

3.3.3 Chen method

Table 3.7 shows that the overall absolute average deviation percent of Chen method for 24 compounds and 626 data point is 2.138 compared with experimental data. This method is easy to use as mentioned before and can be applied to all compounds. The results indicate that it is very good method to predict the latent heat of vaporization of pure compounds . The overall absolute average deviation percent of 18 non polar compounds and 446 data point is 1.422 as shown in table 4-8 while the overall absolute average deviation percent of 6 polar compounds and 180 data point is 4.07 as shown in table 3.9. Thus this method is a very successful method to predict the latent heat of vaporization of pure non polar compounds . Tables B-1to B-24 indicate that this method can be applied at low reduced temperature up to just below reduced temperature of 0.99 .

3.3.4 First Veter method

Table 3.7 shows the overall absolute average deviation percent of First Veter method for 24 compounds and 626 data point is 1.84 compared with

experimental data. Thus it is one of the best method to predict the latent heat of vaporization for pure non polar and polar compounds . Table 3.8 shows the overall absolute average deviation percent for 18 non polar compounds and 446 data point is 1.34 as shown in table 4-8 while the overall absolute average deviation percent for 6 polar compounds and 180 data point is 3.34% as shown in table 3.9. These results indicate that this method is very accurate with polar compounds compares with other methods . Tables B-1 to B-24 indicate that First veter method works at wide range of reduced temperatures even when nearby the critical region for non polar compounds. While for polar compounds the deviation comparatively increases when reduced temperature becomes higher the .98 . Thus it does not give excellent prediction of latent heat of vaporization over reduce temperature of 0.9 for polar compounds .

3.3.5 Second Veter method

Table 3.7 shows that the overall absolute average deviation of Second Veter method for 24 compounds and 626 data point is 3.49 compared with experimental data. The results indicate that it is good method to predict the latent heat of vaporization of pure non polar and polar compounds .The overall absolute average deviation percent of 18 non polar compounds and 446 data point is 2.58 as shown in table 3.8 while the overall absolute average deviation percent of 6 polar compounds and 180 data point is 5.03 as shown in table 4.9 .These results indicate that the Second Veter method is very successful method to predict the latent heat of vaporization of pure non polar compounds while it is not so successful to predict the latent heat of vaporization of polar compounds . The results also indicate that this method works rather good for reduced temperature ranges from 0.4 to just below 0.96 .

3.3.6 Calpeyron method

Table 3.7 shows that the overall absolute average deviation percent of Calpeyron method for 23 compounds and 609 data point is 3.08 compared with experimental data .The results indicate that it is good method to predict the latent heat of vaporization .The overall absolute average deviation percent for 18 non polar compounds and 446 data point is 2.45 as shown in table 3-8 while the over all absolute average deviation percent for 5 polar compounds and 163 data point is 5.37 as shown in table 3-9.This indicates that the Calpeyron method is very good method to predict the latent heat of vaporization for non polar compounds while it is not so successful to predict the latent heat of vaporization of polar pure compounds. The results indicate that Calpeyron method works at reduced temperature range of 0.25 to 1.0 .

3.3.7 Kistiakowsky method

Table 3.7 shows that the overall absolute average deviation of Kistiakowsky method for 24 compounds and 626 data point is 6.528 compared with experimental data. The results indicate that the Kistiakowsky method is not so successful method to predict the latent heat of vaporization of pure compounds . The over all absolute average deviation percent of 18 non polar compounds and 446 data point is 2.7957 as shown in table 3-8 while the over all absolute average deviation percent of 6 polar compounds and 180 data point is 17.724 as shown in table 3.9. The results indicate that the Kistiakowsky method is very good to predict the latent heat of vaporization of pure non polar compounds and can be applied for all non polar compounds. Tables B-1to B-24

indicate that this method can be used safely at low temperature and near the critical region.

Table 3.7 Over all AAD% for predicting of latent heat of vaporization at various temperatures from normal boiling point for pure non polar and polar compounds

Name of methods	No of compounds	No of data point	Over all AAD%
Riedel b.p	18	446	1.381
Fishtine	17	430	2.584
chen	18	446	1.422
vetere 1	18	446	1.344
veter 2	18	446	2.5817
calpeyron	18	446	2.448
Kistiakowsky	18	446	2.796

Table 3.8 Over all AAD% for predicting of latent heat of vaporization at various temperatures from normal boiling point for pure non polar compounds

Name of methods	No of compounds	No of data point	Over all AAD%
Riedel	24	626	1.989
Fishtine	23	610	2.8134
Chen	24	626	2.138
Vetere 1	24	626	1.844
Vetere 2	24	626	3.193
Calpeyron	23	609	3.082
Kistiakowsky	24	626	6.528

Table 3.9 Over all AAD% for predicting of latent heat of vaporization at various temperatures from normal boiling point for pure polar compounds

Name of methods	No of compounds	No of data point	Over all AAD%
Riedel b.p	6	180	3.812
Fishtine	6	180	3.4634
chen	6	180	4.287
vetere 1	6	180	3.34260
veter 2	6	180	5.0252
calpeyron	5	163	5.365
Kistiakowsky	6	180	17.72

3.4 Evaluation of various methods of calculating the latent heat of vaporization of Binary mixture at any temperature

3.4.1 Teja method

Table 3.10 shows that the overall absolute deviation percent of Teja method for 10 mixtures and 46 data point is 2.2611 compared with experimental data. The results indicate that it is the best method among the three methods to predict the latent heat of vaporization for mixtures .

3.4.2. pitzer method

Table 3.10 shows that the over all absolute deviation of Pitzer for 10 mixtures and 46 data point is 7.7165 compared with experimental data, the results indicate that Pitzer method is not so accurate method to predict the latent heat of vaporization for mixtures .

4.4.3 Carruth Kobayashi method

Table 3.10 shows that the overall absolute deviation percent of Carruth Kobayashi for 10 mixtures and 46 data point is 8.16178 compared with experimental data. The results indicate that Carruth Kobayashi method is not so successful method to predict the latent heat of vaporization for mixtures .

Table 3.10 Over all AAD% for predicting of latent heat of vaporization at various temperatures for mixture

Name of method	No of data point	AAD%
Teja	46	2.261
Pitzer	46	7.7166
Carruth Kobayashi	46	8.1618

Chapter Four

Modification of Kistiakowsky method

4.1 First modification of Kistiakowsky method to predict the latent heat of vaporization at normal boiling point :

Kistiakowsky found a relation between latent heat of vaporization at normal boiling point and boiling point temperature , he used the following simple equation to estimate latent heat of vaporization at normal boiling point.

$$\lambda_{vap} = (36.1+R \ln T_b) T_b \qquad (4\text{-}1)$$

In this work the above simple equation was modified as follows

$$\lambda_{vap} = (A+ R \ln T_b) T_b \qquad (4\text{-}2)$$

where A is constant T_b boiling point temperature in degrees K, R is gas constant equals 8.314 J/mole.K .This equation was applied to more than 60 compounds and it was found that it is more convenient to classify the compounds to three groups each with it's own constants . These groups are : non polar, alcohol and other polar compounds as shown in table 4.1

Table 4.1 The values of first modification's constant of each group

Groups	**Value of A**
non polar component	36.1
alcohol	56.44
other polar component	41.36

Tables 4.2, 4.3 shows the comparison between the absolute deviation of Kistiakowsky method and this work.

Table 4.2 Comparison between the absolute deviation of Kistiakowsky method and the first modification of Kistiakowsky to predict the latent heat of vaporization at normal boiling point for alcohols

Alcohols	λexp	λ Kistiakowsky	AD%	λ calc	AD%
butanol	43.29	33.507	22.599	41.458	4.2322
1 pentanol	44.4	35.418	20.23	43.782	1.3924
2 pentanol	41.4	33.64	18.743	41.62	0.53221
ethanol	38.56	29.849	22.592	37.005	4.033
isobutanol	41.82	32.582	22.089	40.333	3.5546
tert-butanol	39.07	30.193	22.722	37.424	4.2134
2 butanol	40.75	31.797	21.971	39.378	3.368
3methyl2butanol	44.1	34.713	21.286	42.925	2.6649
1hexanol	44.5	37.243	16.308	45.999	3.368
2 hexanol	41.01	35.594	13.207	43.995	7.2795
1 heptanol	48.1	39.083	18.745	48.233	0.27721
1 octanol	46.9	40.85	12.9	50.376	7.4123
2 octanol	44.4	39.39	11.284	48.605	9.4718
1 decanol	49.8	44.293	11.059	54.55	9.538
2 propanpl	39.989	30.183	24.52	37.412	6.4421
1 popnanol	41.512	31.635	23.793	39.18	5.6165
methanol	35.932	28.537	20.582	35.406	1.4652
			24.9736		**4.4036**

Table 4.3 Comparison between the absolute deviation of Kistiakowsky method and the first modification of Kistiakowsky to predict the latent heat of vaporization at normal boiling point for other polar compounds

Other polar compounds	λexp	λ calc kistwisky	AD %	λ calc this work	AD%
ethyle astate	31.945	29.701	7.0247	31.543	1.2581
anline	42.44	39.785	6.2568	42.189	0.59061
butyl actate	36.28	34.282	5.5063	36.382	0.28025
butyl ether	21.51	20.349	5.3986	21.655	0.67352
chloroethane	24.53	23.72	3.3004	25.222	2.8199
aceton	29.1	27.751	4.6348	29.483	1.316
methylacetate	30.32	27.832	8.2063	29.568	2.4798
dimethylsulfide	27	24.117	10.679	25.641	5.0347
methyl propanoate	32.24	29.923	7.1862	31.778	1.4334
diethylether	26.52	25.754	2.8876	27.372	3.2131
iso butylamin	30.61	28.826	5.8273	30.619	0.029168
diethylsulfide	31.77	31.104	2.0971	33.025	3.9502
ethyl formate	29.91	27.589	7.7591	29.312	2.0002
3 methyl 2 butanone	32.35	31.319	3.1876	33.252	2.7886
propyacetate	33.92	29.462	13.142	31.291	7.7509
chlorobenzene	35.19	34.828	1.0284	36.958	5.024
water	40.66	31.843	21.685	33.806	16.858
			6.8122		3.38

4.2 Second modification of Kistiakowsky method to predict the latent heat of vaporization at normal boiling point :

Kistiakowsky found a relation between latent heat of vaporization at normal boiling point and boiling point temperature; he used the following simple equation to estimate latent heat of vaporization at normal boiling point

$$\lambda_{vap} = (36.1+R \ln T_b) T_b \qquad (4\text{-}1)$$

This equation was proposed when the critical pressure was not available. In this work the above simple equation was modified to include the critical pressure of compounds as follows

$$\lambda_{vap} = R.Tb (a + b\ln P_c + c \ln T_b) \qquad (4\text{-}3)$$

Where a ,b ,c are constants , T_b boiling point temperature in degrees K, Pc is critical pressure in bar and R is gas constant (8.314 J/mole.k)This equation was applied to more than 64 compounds and it was found that it is more convenient to classify the compounds in to three groups each with it's own constants . These groups are: non polar compounds, alcohol and other polar compounds as shown in table 4.4

Table 4.4 The values of second modifications' constants of each group.

Groups	a	b	c
Non polar	1.18306	0.49459	1.2634
alcohol	32.8115	0.22592	-3.48002
Other polar	6.6869	-0.72627	1.157612

Table 4.5

Comparison between the absolute deviation of Kistiakowsky method and the second modification of Kistiakowsky to predict the latent heat of vaporization at normal boiling point for non polar compounds

Compound	dh	λ calc Kistiakowsky	AD%	λ calc this work	AD%
ethan	14720.36	14668	0.3532	14897	1.1994
ethylene	13524.54	13345	1.3252	13547	0.16602
methane	8210.576	8408.5	2.4104	8396.7	2.2666
propane	18762.59	18793	0.16335	19063	1.6025
iso butane	21320.12	21528	0.97359	21738	1.9598
n octain	34583.48	34254	0.95259	34323	0.75374
ferion 12	19973.94	19910	0.31767	20195	1.1063
ferion 13	20132.69	18894	6.1542	19321	4.0338
R 123	25944.59	25131	3.1368	25477	1.8003
argon	6432.161	6393	0.60896	6359	1.137
nitrogen	5568.5	5588.7	0.36276	5421.6	2.6379
benzen	31059.97	29983	3.468	30932	0.41124
toluene	33540.22	32841	2.086	33665	0.37287
butadiene	22497.48	22189	1.3724	22611	0.50239
methlcyclopentane	29374.19	29214	0.54585	29757	1.3049
ethylcyclopentane	32361.23	32165	0.60586	32664	0.93583
1,1 dichloroethane	28850	27865	3.4135	28761	0.30978
1,2 dichloroethane	31980	30302	5.248	31412	1.776
bromoethane	27040	26114	3.4235	27175	0.49743
1,2 propadiene	20600	19489	5.3922	19994	2.9427
cyclopropane	20050	19630	2.0926	20201	0.75444
butyne	24520	23336	4.8296	23878	2.6166
trans 2- butene	23340	22681	2.8233	23064	1.1809
cis 2-butene	22720	22940	0.96759	23361	2.8209
			2.2095		**1.4621**

Table 5.6 Comparison between the absolute deviation of Kistiakowsky method and the second modification of Kistiakowsky to predict the latent heat of vaporization at normal boiling point for alcohols

Compound	λ exp	λ calc Kistiakowsky	AD%	λ calc this work	AD%
butanol	43290	33507	22.599	41964	3.0625
1 pentanol	44400	35418	20.23	43443	2.1543
2 pentanol	41400	33640	18.743	41939	1.3014
ethanol	38560	29849	22.592	39060	1.2967
isobutanol	41820	32582	22.089	41169	1.5566
tert-butanol	39070	30193	22.722	39071	0.0014128
2-butanol	40750	31797	21.971	40484	0.65351
2methyl2butanol	40000	32030	19.924	40613	1.5322
3methyl2butanol	44100	34713	21.286	42869	2.7918
1-hexanol	44500	37243	16.308	44822	0.72381
2-hexanol	41010	35594	13.207	43473	6.0061
1-heptanol	48100	39083	18.745	46174	4.0041
1-ctanol	46900	40850	12.9	47443	1.1572
2-octanol	44400	39390	11.284	46314	4.31
1-decanol	49800	44293	11.059	49824	0.047839
1-propanol	41512	31635	23.793	40437	2.59
2-propanol	399988.579	30183	24.52	39239	1.8746
methanol	35932	28537	20.582	38069	5.9465
			19.142		**2.278**

Table 4.7 Comparison between the absolute deviation of Kistiakowsky method and the second modification of Kistiakowsky to predict the latent heat of vaporization at normal boiling point for other polar compounds

Compound	λ exp	λ calc Kistiakowsky	AD%	λ calc this work	AD%
ethyle astate	31945	29701	7.026	31117	2.5932
anline	42440	39785	6.2568	41451	2.3301
butyl actate	36280	34282	5.5063	36972	1.9071
butyl ether	21510	20349	5.3986	21028	2.2394
chloroethane	24530	23720	3.3004	24586	0.22958
aceton	29100	27751	4.6348	29051	0.16733
methylacetate	30320	27832	8.2063	29141	3.8894
dimethylsulfide	27000	24117	10.679	24896	7.7943
methyl propanoate	32240	29923	7.1862	31691	1.7019
diethylether	26520	25754	2.8876	27416	3.3803
iso butylamin	30610	28826	5.8273	30510	0.32781
diethylsulfide	31770	31104	2.0971	32975	3.7913
ethyl formate	29910	27589	7.7591	28863	3.4995
3 methyl 2 butanone	32350	31319	3.1876	33404	3.2577
propyacetate	33920	29462	13.142	31584	6.8858
			6.2063		**2.933**

Table 4.5 shows that the overall absolute average deviation percent of non polar compounds for kistiakowsky equation is 2.2095 while the over all absolute deviation percent of non polar compounds for this work is 1.4620 .For alcohol

from table 5-6 the overall absolute deviation percent for Kistiakowsky equation is 19.14 and the overall absolute deviation percent of this work is 2.278 , Table 4.7 shows the overall absolute deviation percent for other polar compounds of Kistiakowsky is 6.206 and the over all absolute deviation percent of this work is 2.933. The over all absolute deviation percent of three groups using Kistiakowsky equation is 8.608 and the over all absolute deviation percent of three groups of this work is 2.106 this indicates that Kistiakowsky equation does not work with polar compounds at normal boiling point ,however Kistiakowsky equation works for non polar compounds but with relatively high deviation from experimental data at normal boiling point, and this work gives less deviations for all the three classes compounds from experimental data especially when dealing with polar compounds .

3.Application of first and second modified Kistiakowsky method at normal boiling point to various temperatures

First and second modification of Kistiakowsky method (this work) are to predict the latent heat of vaporization at normal boiling point ,also can be applied at various temperatures by using Watson equation

$$\lambda_{vap} = \lambda_{vap\,(b)} \left(\frac{1-Tr}{1-Tr_{(b)}} \right)^{n}$$

Where n = 0.38 ,λ_{vap} is the latent heat of vaporization at any temperature, $\lambda_{vap\,(b)}$ latent heat of vaporization at normal boiling point , $Tr_{(b)}$ reduced normal boiling temperature .

Tables 4.6, 4.7 show the absolute deviation percent from experimental data of First and Second modification of Kistiakowsky method at various temperatures.

Table 4.8 The absolute average deviation of first modified Kistiakowsky method to predict the latent heat of vaporization at various temperatures for twenty pure non polar and polar compounds

compound	No of data points	AAD%
1-propanol	27	4.841
2-propanol	7	6.606
methanol	18	1.4886
ethylestate	17	1.599
argon	16	2.089
benzene	24	3.8626
butadine	19	1.7195
ethane	23	1.3727
ethylecyclopentane	21	1.6081
ethylene	20	1.340
ferion 13	35	5.4941
ferion 12	34	0.5741
iso butane	20	1.30446
methane	22	1.2556
methylecyclopentane	20	1.513
n octane	15	0.63438
nitrogen	15	1.22
propane	16	0.8749

To be continued…….

Continue…..

R-123	38	2.623
toluene	41	1.834
Over all	**448**	**2.193**

Table 4.8 shows that the over all absolute average deviation percent of first modified Kistiakowsky method for 20 compounds and 448 data point is 2.193 compared with experimental data . This method is easy to use and can be applied to all compounds and the results indicate that it is one of the best methods to predict the latent heat of vaporization at various temperatures

Table 4.9 The absolute average deviation of second modified kistiakowsky method to predict the latent heat of vaporization at various temperatures for twenty pure non polar and polar compounds

Compound	No of data points	AAD%
1 propanol	27	2.88
2 propanol	7	2.301
methanol	18	6.124
ethylestate	17	1.934
argon	16	3.03
benzene	24	2.315
butadine	19	0.848
ethan	23	1.573
ethylecyclopentane	21	2.12
ethylene	20	1.0599

To be continued……

ferion 13	35	4.028
ferion 12	34	1.0418
iso butane	20	1.904
methane	22	1.964
methylecyclopentane	20	2.604
n octane	15	0.858
nitrogen	15	3.541
propane	16	1.5015
R 123	38	1.555
toluene	41	1.3073
Over all	448	2.225

Table 4.9 shows that the overall absolute average deviation percent of second modified Kistiakowsky method for 20 compounds and 448 data point is 2.225 compared with experimental data. These two methods are easy to use and can be applied to all compounds. The results indicate the these two methods in this work are among the best methods for prediction of the latent heat of vaporization especially the second modification in this work for prediction the latent heat of vaporization for alcohols and other polar compounds.

Chapter Five

Discussion

There are at least sixteen methods in literature to predict the latent heat of vaporization for pure compounds and three methods in literature to predict the latent heat of vaporization for mixtures.

It is well know that the evaluation of any correlation or prediction method is done by comparison of the values with those of experimental data .The deviation between the experimental results and those of prediction method determines the accuracy of the method. The average absolute deviation percent (which is the difference between the experimental values and the calculated values divided by experimental values), is defined as follows:

$$\mathbf{AAD\%} = [\,(\lambda_{exp} - \lambda_{calc})/\lambda_{exp}\,]\ 100 \qquad (5\text{-}1)$$

It is convenient to express the deviation of calculated latent heat of vaporization in Joules per mole.

The basis for choosing the best methods among these methods are:

1. They have least deviation from experimental data
2. They can be applied to all compounds
3. They need a few well-known parameters of pure compounds
4. They are easy to use .

5. They have an acceptable limitations of reduced temperature.

There are at least nine methods available in literature for prediction of the latent heat of vaporization for pure compounds at various temperatures using either vapor pressure data or law of corresponding states .These methods are Halm Stiel ,Pitzer ,Carruth Kobayashi , Wagnar 1, Wagnar2, Lee-Keslar, Antion ,Ambrose Walton and Riedel method .Some of these methods have accurate results when dealing with non polar compounds and not so accurate for polar compounds and some of these methods have accurate results when dealing with both non polar and polar compounds . On the basis of the five factors mentioned above it seems that Pitzer ,Halm stiel and Carruth Kobayashi methods are the best methods to predict the latent heat of vaporization for pure non polar compounds .These methods give 0.581 ,1.52 AAD% respectively for 18 non polar compounds and 446 data point .On the other hand Halim and Stiel method can be considered as best method for predicting the latent heat of vaporization at various temperatures for pure polar compounds among these nine methods which is directly deal with polarity of compounds by introducing what is known polarity factor of polar compounds and it gives 1.552 AAD% compared with experimental data for 18 pure non polar compounds and 446 data points. On the other hand it gives 2.8476 AAD% compared with experimental data for 6 polar compounds and 180 data points .

There are at least seven methods available in literature to predict the latent heat of vaporization at normal boiling point .These methods are Riedel ,Fishtine , Chen , Veter 1,Veter 2, Calpeyron and Kistiakowsky method . Riedel , Veter 1 ,Chen and Second modification methods are the best methods that predict the latent heat of vaporization at normal boiling point for pure non polar

compounds .The AAD% are 1.27,1.496,1.255 and 1.462 respectively for these four methods .On the other hand the Second modification has the least AAD% as it gives 2.575 for prediction of the latent heat of vaporization for pure polar compounds .

It is found that the First Veter and Riedel method have the least AAD% to predict the latent heat of vaporization for pure non polar compounds at various temperatures from normal boiling point .The AAD% are 1.344 ,1.381 for 626 data point and 18 non polar compounds respectively .On the other hand the AAD% are 3.343, 3.812 for 180 data point and 6 polar compounds .

Table 5.1 shows the comparison between the best methods that predict the latent heat of vaporization at various temperatures and the best methods that predict the latent heat of vaporization at various temperature from normal boiling point.

Table 5.1 Comparison between best methods for prediction of latent heat of vaporization at various temperatures

Method	No of data points	AAD%	No of data point of non polar	AAD%	No of data point of polar compounds	AAD%
HALM STIEL	626	1.876	446	1.552	180	2.848
Pitzer	626	1.956	446	1.552	180	3.167
Carruth Kobayashi	626	2.112	446	1.52	180	3.52
Riedel	626	1.989	446	1.381	180	3.812
Vetere 1	626	1.844	446	1.344	180	3.343
Chen	626	2.138	446	1.422	180	4.287

Table 5.2 shows the comparison between the best methods that predict the latent heat of vaporization at normal boiling point .Included in the table are the two modifications of Kistiakowsky equation that are done in this work

Table 5.2 Comparison between best methods for prediction of latent heat of vaporization at normal boiling point and the developed methods

Method	No of pure compoun	AAD%	No of non polar compounds	AAD%	No of polar compound	AAD%
Riedel	61	2.77	32	1.27	29	4.439
First veter	61	3.255	32	1.496	29	5.059
Chen	61	2.818	32	1.255	29	4.471
First modification	58	3.254	24	2.353	34	3.89
Second modification	57	2.106	24	1.462	33	2.575

Table 5.2 indicates clearly that the second development of Kistiakowsky method (this work) is the best method to predict the latent heat of vaporization at normal boiling point for pure polar compounds .On the

other hand Chen method is the best method to predict the latent heat of vaporization at normal boiling point for pure non polar compounds .
Table 5.3 shows the comparison between the Kistiakowsky method and the First and Second modification for latent heat of vaporization at normal boiling point.

Table 5.3 Compassion between the Kistiakowsky method and the first and second modification (this work) for latent heat of vaporization at normal boiling point.

	Non polar		Alcohols		Other polar	
	No of compounds	AAD%	No of compounds	AAD%	No of compounds	AAD %
Kistiakowsky	24	2.2095	17	24.973	17	6.3122
First modification (this work)	24	2.2095	17	4.4036	17	3.380
Second modification (this work)	24	1.462	18	2.278	15	2.933

Table 5.3 indicates that the Kistiakowsky method gives relatively good results for non polar compounds but it is not so accurate when dealing with polar compounds (alcohols and other polar compounds). The comparison indicates clearly that the first and second modifications have very

successful results even when dealing with polar compounds (alcohols and other polar compounds). The second modification has the least deviation from experimental data for polar compounds among the seven methods for predicting the latent heat of vaporization at normal boiling point.

The main features of the modified prediction method in this work for prediction the latent heat of vaporization at normal boiling point for pure compounds are

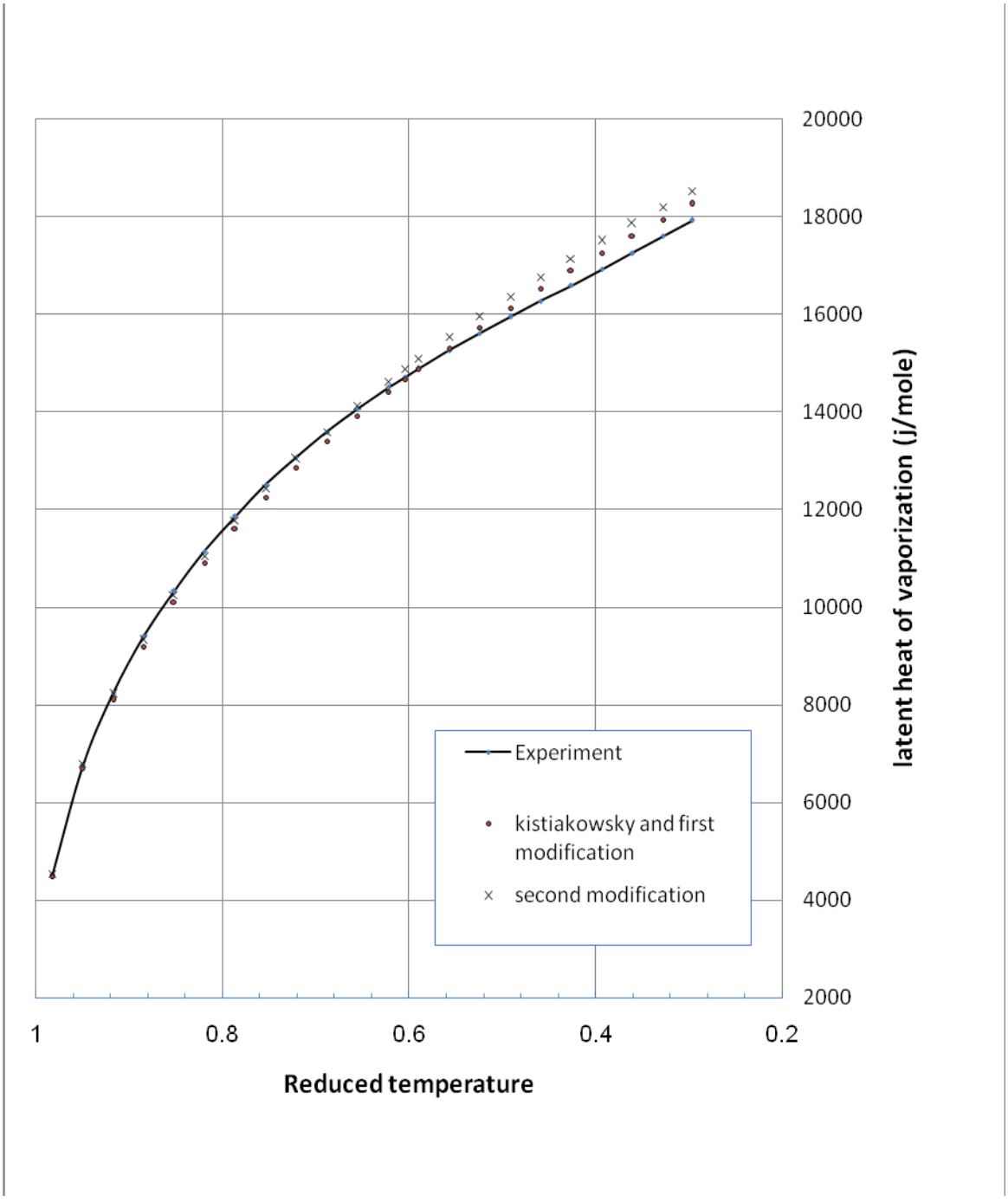
1. They are rather simple equations and easy to use
2. They need only a few well –known properties of pure compounds (T_r , P_c).
3. They can be applied to almost all compounds

As mentioned before the methods that are used to predict the latent heat of vaporization at normal boiling point can be applied at various temperatures by using Watson equation. So these two modifications can be used to predict the latent heat of vaporization not only at normal boiling point but at any temperature by using Watson equation

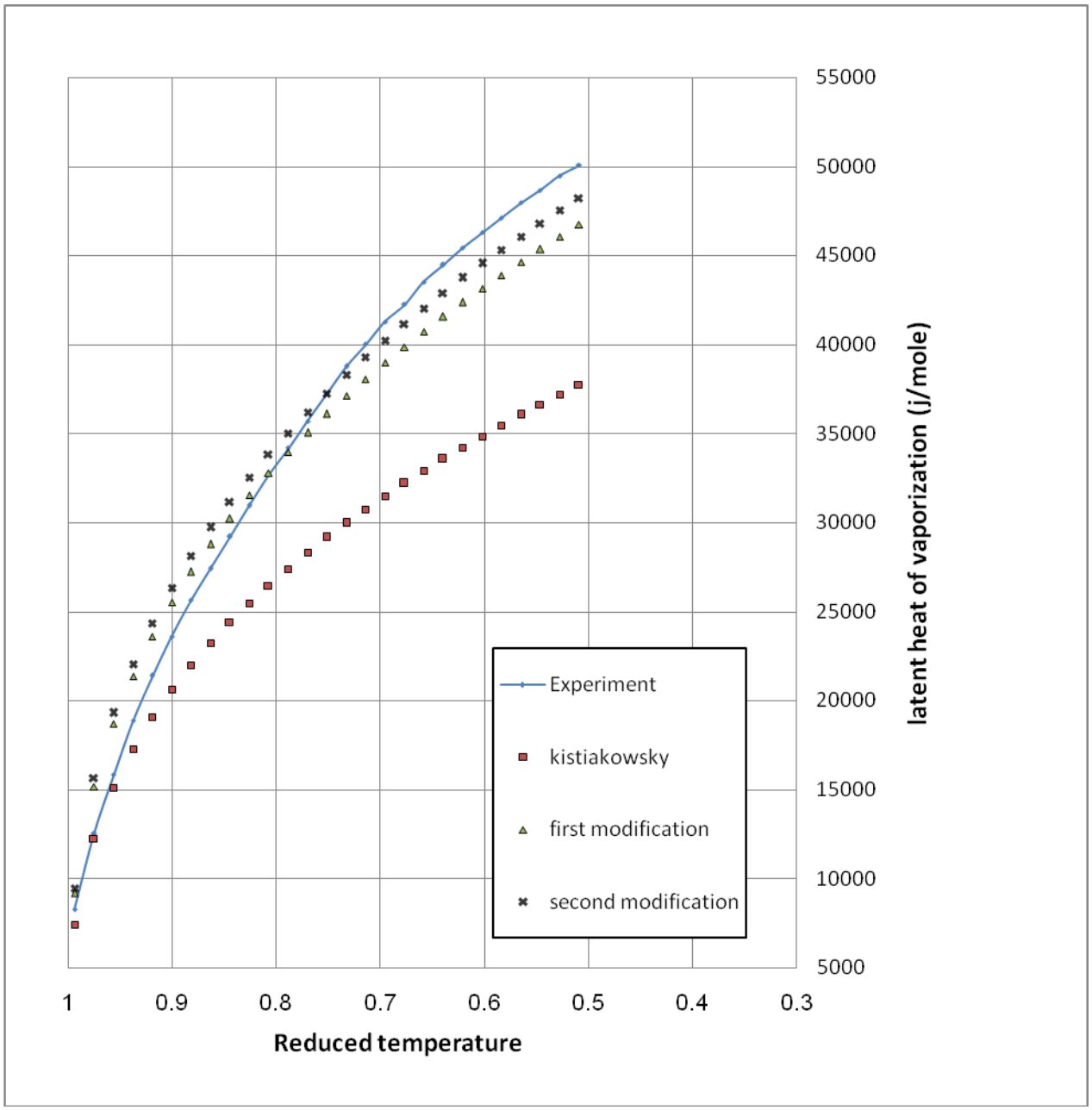
Figures 5.1 shows the relation between the values of latent heat of vaporization for ethane (which represents non polar compounds) and reduced temperatures for Kistiakowsky, First modification and the Second modification respectively .

Figures 5.2 shows the relation between the values of latent heat of vaporization for 1 propanol which represents alcohols compounds and reduced temperatures for Kistiakowsky, First modified and the Second modified respectively .This figure indicates that the modification methods have less deviation from experimental data among these three method especially the second modification(this work) .

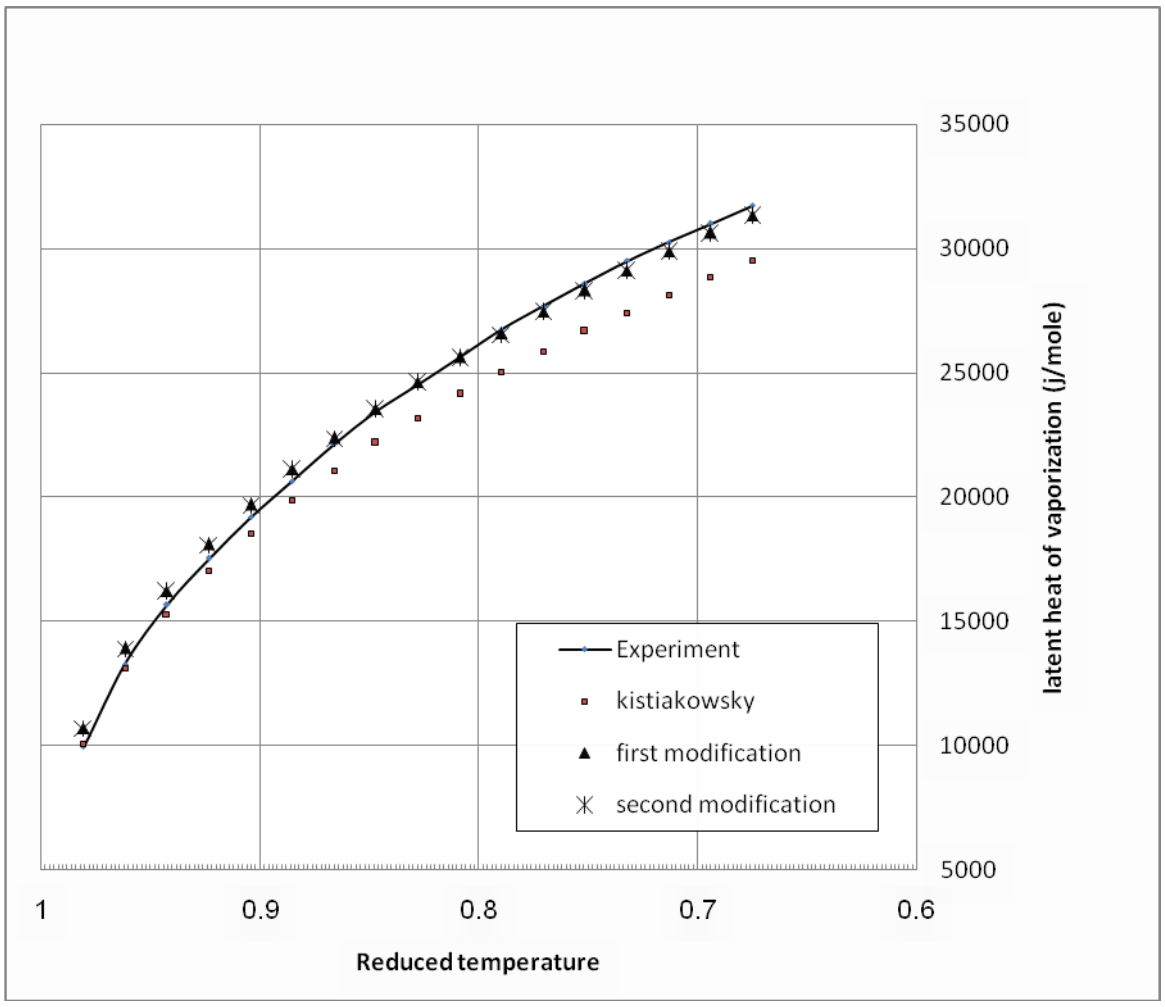
Figures 5.3 shows the relation between the values of latent heat of vaporization for ethylestate which represents other polar compounds and reduced temperatures for Kistiakowsky, First modified and theSecond modified respectively.It indicates that the modification methods have less deviation from experimental data especially the second modified.



Figures 5.1 The relation between the values of latent heat of vaporization and reduced temperature of Kistiakowsky, first modification and the second modification respectively for ethane.



Figures 5.2 The relation between the values of latent heat of vaporization and reduced temperature of Kistiakowsky, first modification and the second modification respectively for 1-propanol



Figures 5.3 shows the relation between the values of latent heat of vaporization and reduced temperature of Kistiakowsky, first modification and the second modification respectively for ethylestate

It is a well known fact that the calculations of the thermodynamic properties of the mixtures are not as easy as the calculations for pure components. This is because of finding the critical constants that represent the mixture from critical constants of pure components and this is done by using what is called mixing rules . The mixing rules are not very accurate due to difference in chemical structures of the components .Usually adjustable parameter or parameters are needed to calculate any thermodynamic property of mixture very accurately.

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Table 5.4 shows the compassion between the methods for predicting the latent heat of vaporization of mixtures at various temperatures which is summarized from table 4-10 (in chapter four).

Table 5.4 Comparison between the methods of predict the latent heat of vaporization of mixtures

Method	No of data point	AAD%
Teja	46	2.261
pitzer	46	7.7165
Carruth Kobayashi	46	8.1618

Table 5.4 indicates clearly that the Teja is the best method to predict the latent heat of vaporization for mixtures whereas the over all absolute average deviation percent for 10 mixtures and 44 data point is 2.261**.**

5.2 Sample of calculation

Calculation of the latent heat of vaporization for Toluene at 80 ^{o}C (353.15 K) by using

A. First modification of Kistiakowsky method (this work).

B. Second modification of Kistiakowsky method (this work).

The experimental value of latent heat of vaporization (λ_{vap})of Toluene at 80 ^{o}C is 35216 J/mole

A. First modification of Kistiakowsky method .

$$\lambda_{vap\ (n.b)} = (A + R \ln T_b)\, T_b$$

Data required : T_b=383.79 K

First modification constant : A=36.1 for non polar group(from table 4.1)

Applying the new equation to calculate the latent heat of vaporization at normal boiling point

$$\lambda_{vap\ (n.b)} = (36.49 + 8.314 \ln 383.79)\, 383.79$$

$$\lambda_{vap\ (n.b)} = 14004.497 \text{ J/mole} + 18985.74 \text{ J/mole}$$

$$\lambda_{vap\ (n.b)} = 32990.24 \text{ J/mole}$$

To find the value of latent heat of vaporization at needed temperature (353.15) using Watson equation as follows

$$\lambda_{vap\ (353.15\ )} = \lambda_{vap\ (383.79)} \left(\frac{1-\dot{T}r}{1-Tr_{(383.79)}} \right)^{0.38}$$

$$\lambda_{vap\ (353.15\ )} = 32990.24 \left(\frac{1-.5968}{1-.6486} \right)^{0.38}$$

$\lambda_{vap\ (353.15\ )}$ = 34759.9 J/mole

AAD%= ((35216-34759.9)/ 35216) 100%

AAD%= 1.298

B. Second modification of Kistiakowsky method .

$$\lambda_{vap\ (n.b)} = (a + b.\ln P_c + c.\ln T_b)*R.T_b$$

Data required : T_b=383.79 K ,Pc=41.08 bar

Second modification constants: a=1.18306,b=.79759,c=1.2634 for non polar group (from table 4.4)

Applying the new equation to calculate the latent heat of vaporization at normal boiling point

$\lambda_{vap\ (n.b)}$= 3774.94 J/mole +9455.906 J/mole +23986.589 J/mole

$\lambda_{vap\ (n.b)}$=33625.19 J/mole

$$\lambda_{vap\ (353.15\ )} = 33625.19 \left(\frac{1-.5968}{1-.6486} \right)^{0.38}$$

$\lambda_{vap\ (353.15)}$ = 35478.92 J/mole

AAD%= ((35216-35478.92)/ 35216)*100%

AAD%= 0.747

5.3 Conclusions

1.The latent heat of vaporization can be predicted from vapor pressure data , law of corresponding states and empirical methods .The first and second methods predict the latent heat of vaporization at any temperature while the third method predicts the latent heat of vaporization at normal boiling point.

2. There are at least nine methods available in literature for prediction of latent heat of vaporization at any temperature using either vapor pressure data or the law of corresponding states . These methods are Halm Stiel ,Pitzer ,Carruth Kobayashi , Wagnar 1, Wagnar2, Lee-Keslar, Antion ,Ambrose Walton and Riedel method .All of them are evaluated in this work .Among these methods the Pitzer ,Halm stiel and Carruth Kobayashi methods are the most accurate for non polar compounds .The AAD% for 18 non polar compounds and 446 data point are 1.552,1.552.and 1.52 respectively .

3. There are also at least seven methods available in literature for prediction of latent heat of vaporization at normal boiling point .These methods are Riedel ,Fishtine , Chen , Veter 1,Veter 2, Calpeyron and Kistiakowsky method. All of them are evaluated in this work . Among these method the Riedel and Chen methods are the most accurate for non polar compounds. The AAD% for 32 non polar compounds are 1.27 and 1.255 respectively

and the AAD% for 29 non polar compounds are 4.439 and 4.471 respectively .On the other hand Fishten method is most accurate of these methods for polar compounds which gives 3.905 %for 29 polar compounds .

These methods can be applied at various temperatures by using Watson equation .It is found that the First Veter method has less deviation from experimental data .The AAD% is 1.344 compared with experimental data for 18 pure non polar compounds and 446 data points .On the other hand it gives 3.3426 AAD% compared with experimental data for 6 polar compounds and 180 data points.

4. Two empirical modifications have been done on Kistiakowsky method in this work to predict the latent heat of vaporization at normal boiling point .These two modifications are simple and easy to use .In both modifications the compounds are classified into three groups :non polar ,alcohols(including water) and other polar compounds and the values of constants are given for each group.

The first modification is the same as Kistiakowsky equation except the values of constant A are different

$$\lambda_{vap\ n.b} = (A + R \ln T_b)\, T_b$$

Groups	Value of A
non polar component	36.1
alcohols	56.44
other polar component	41.36

The over all absolute average deviation percent obtained for this work of 34 compounds for alcohols(including water) and other polar compounds are 4.4036 and 3.38 respectively, in comparison with that of Kistiakowsky method which are 24.97 and 6.312 respectively.

5. The second modification of Kistiakowsky method is as follows

$$\lambda_{vap\ n.b} = R.T_b\ (a + b \ln P_c + c \ln T_b)$$

In this equation the critical pressure is included and the values of the constants a,b,c as follows

groups	a	b	c
Non polar	1.18306	.49459	1.2634
alcohol	32.8115	.22592	-3.48002
Other polar	6.6869	-0.72627	1.157612

The overall absolute average deviation percent obtained in this work for 57 compounds for non polar compounds , alcohols and other polar compounds are 1.462 , 2.278 and 2.933 respectively , in comparison with that of Kistiakowsky method which are 2.2095 , 24.97 and 6.312 respectively.

It is to be noted that this work has the least deviation from experimental data for all methods that predict the latent heat of vaporization at normal boiling point for pure polar compounds. This work also applied at various temperatures by using Watson equation as shown in table 6-6.

6. The prediction of latent heat of vaporization of mixtures can be done by at least three methods that available in literature and all are evaluated in this

work. It is found that the Teja method has the least absolute deviation percent to predict the latent heat of vaporization for mixtures whereas the overall absolute average deviation percent for 10 mixtures and 46 data point is 2.261.

5.4 Recommendations:

For further work, the following recommendations can be taken into considerations:

1. The modified methods may be applied also to the mixtures after developing suitable mixing rule s to give an acceptable accuracy.
2. Make an experimental work to predict the latent heat of vaporization for pure compounds .
3. Apply the proposed equation on ternary mixtures.
4. Check the effect of pressure on the proposed equation .

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Appendix A
The properties of compounds

Compounds	**Tc** K	**Tb** K	**Pc** bar	**w**

Ethan	305.32	184.55	48.72	0.099
ethylene	282.34	169.42	50.41	0.087
methane	190.56	111.66	45.99	0.011
propane	369.83	231.02	42.48	0.152
iso butane	407.85	261.34	36.4	0.186
n octain	568.7	398.82	24.9	0.399
ferion 12	385.1	243.45	41.3	0.179
ferion 13	369.28	232.14	49.86	0.221
ferion 23	298.97	191.11	48.36	0.267
r 123	456.9	300.81	36.74	0.282
r 134a	374.26	247.04	40.59	0.326
argon	150.86	87.27	48.98	0.002
amonia	405.4	239.82	113.53	0.257
nitrogen	126.2	77.35	33.98	0.037
benzen	562.05	353.24	48.95	0.21
toluene	591.75	383.79	41.08	0.264
butadiene	425	268.62	43.2	0.195
methlcyclopentane	532.79	344.98	37.84	0.227
ethylcyclopentane	569.5	376.59	33.97	0.27
1,2 dibromoethane	582.9	404.5	71.5	-
1,1 dichloroethane	523	330.45	51	-
1,2 dichloroethane	561	356.66	54	-
bromoethane	503.8	311.5	62.3	-
isoxazole	590	368.61	61	-
methyl acetylen	402.4	250.12	56.3	-
1,2 propadiene	394	238.77	52.5	-
cyclopropane	398.25	240.34	55.75	-
propylamine	497	320.38	48	-
methyl ethyl amine	471.8	304.93	45.5	-
butyne	440	281.21	46	-
trans 2 butene	428.6	274.03	41	-
cis 2 butene	435.5	276.87	42	-

butanol	563.05	390.88	44.23	0.59
1 pentanol	588.15	411.16	39.09	0.579
2 pentanol	560.3	392.3	36.75	0.561
ethanol	513.92	351.8	61.48	0.649
isobutanol	547.78	381.04	43	0.59
tert-butanol	505.21	355.49	39.74	0.613
2 butanol	536.05	372.66	41.79	0.574
2methyl2butanol	545	375.15	37.9	0.478
3methyl2butanol	579.4	403.69	39.1	0.559
1hexanol	611.3	430.44	35.1	0.573
2 hexanol	586.2	413.02	33.8	0.562
1 heptanol	631.9	449.81	31.5	0.588
1 octanol	637	468.33	28.6	0.594
2 octanol	637	453.03	28.1	0.531
1 decanol	648.4	504.25	23.7	0.661
2 propanpl	536.78	355.39	51.75	0.665
1 popnanol	508.3	370.93	47.62	0.629
methanol	512.64	337.69	80.97	0.565
Water	647.14	373.15	220.64	0.344
ethyle astate	506.8	350.21	46.9	0.361
anline	699	457.17	53.1	0.38
butyl actate	579	399.12	30.9	0.407
dimethylether	400	248.31	54	-
chloroethane	460.3	285.42	53	-
dimethylether	499	305.15	54.9	-
aceton	508.2	329.22	47	0.307
methylacetate	506.8	330.09	46.9	-
dimethylsulfide	456.4	289.75	56.3	0.276
methyl propanoate	530.6	352.6	40	0.349
diethylether	466.7	307.59	36.4	0.281
iso butylamin	528.5	340.81	40.2	0.22
diethylsulfide	557	365.25	39.6	0.295

ethyl formate	508.5	327.47	47.4	0.282
3 methyl 2 butanone	567.7	367.55	36.2	0.216
propyacetate	549.4	347.65	33.3	0.389
chlorobenzene	632.4	404.91	45.2	0.251

Appendix B

Results of AAD% of latent heat of vaporization at various temperatures for pure compounds

For water

Tr	Amros walton	Antion	Lee kesler	Riedel	Wagnar 1	Wagnar 2	Veter 1	Veter 2
0.4221	5.096	0.93747	7.3769	3.2435	0.12368	5.096	1.2512	13.898
0.42981	5.1279	0.73196	7.3368	3.2164	0.096988	5.1279	1.2123	13.855
0.43754	5.1549	0.54705	7.289	3.1889	0.068808	5.1549	1.1693	13.806
0.44527	5.1754	0.37975	7.2318	3.1612	0.037561	5.1754	1.1213	13.752
0.45299	5.2265	0.26377	7.2027	3.1331	0.038564	5.2265	1.0678	13.692
0.46072	5.2261	0.11942	7.1182	3.1047	0.0061501	5.2261	1.0095	13.627
0.46845	5.2489	0.016405	7.0541	3.0759	0.025577	5.2489	0.94563	13.555
0.47617	5.2718	0.068452	6.987	3.0468	0.041519	5.2718	0.87779	13.478
0.4839	5.2966	0.13493	6.9183	3.0173	0.0525	5.2966	0.80576	13.397
0.49162	5.3086	0.19791	6.8334	2.9875	0.072262	5.3086	0.72976	13.312
0.49935	5.3358	0.23203	6.7603	2.9573	0.07432	5.3358	0.65045	13.223
0.50708	5.3469	0.26789	6.6675	2.9267	0.088297	5.3469	0.56763	13.129
0.5148	5.368	0.28176	6.5812	2.8958	0.089479	5.368	0.48194	13.033
0.52253	5.3697	0.30225	6.4718	2.8644	0.10562	5.3697	0.39317	12.933
0.53026	5.4016	0.28331	6.3895	2.8326	0.089714	5.4016	0.30112	12.83
0.53798	5.4155	0.27135	6.2855	2.8004	0.087486	5.4155	0.20683	12.724
0.54571	5.4198	0.2592	6.1683	2.7678	0.090978	5.4198	0.1101	12.615
0.55344	5.4213	0.24111	6.0448	2.7347	0.093703	5.4213	0.010664	12.503
0.56116	5.4364	0.20214	5.9318	2.7012	0.079999	5.4364	0.090845	12.389
0.56889	5.4333	0.17311	5.7973	2.6672	0.080084	5.4333	0.19469	12.272
0.57661	5.3871	0.17832	5.6164	2.6327	0.11761	5.3871	0.30026	12.153
0.58434	5.4198	0.10256	5.5117	2.5978	0.076696	5.4198	0.40739	12.033
0.59207	5.4471	0.026462	5.3985	2.5623	0.037475	5.4471	0.51637	11.91
0.59979	5.4447	0.026509	5.253	2.5263	0.022821	5.4447	0.62618	11.787
0.60752	5.3904	0.03472	5.0532	2.4898	0.053776	5.3904	0.73757	11.661

0.61525	5.4022	0.10956	4.9171	2.4527	0.018511	5.4022	0.84954	11.535
0.62297	5.3724	0.14843	4.7374	2.4151	0.019016	5.3724	0.96196	11.409
0.6307	5.3367	0.18455	4.5501	2.3769	0.02159	5.3367	1.0752	11.281
0.63842	5.3112	0.23304	4.3715	2.3381	0.01067	5.3112	1.1878	11.155
0.64615	5.2727	0.27105	4.1786	2.2987	0.008554	5.2727	1.3007	11.028
0.65388	5.2434	0.31958	3.9941	2.2587	0.0061543	5.2434	1.4128	10.902
0.6616	5.1766	0.33347	3.7719	2.2181	0.011086	5.1766	1.5236	10.777
0.66933	5.1307	0.36792	3.57	2.1768	0.0047905	5.1307	1.6337	10.653
0.67706	5.0824	0.40046	3.366	2.1348	0.0030799	5.0824	1.7421	10.531
0.68478	5.0196	0.41909	3.1483	2.0922	0.0010415	5.0196	1.8488	10.411
0.69251	4.948	0.42859	2.9228	2.0489	0.005708	4.948	1.9529	10.294
0.70023	4.8841	0.44462	2.7065	2.0049	0.0011214	4.8841	2.0551	10.179
0.70796	4.7972	0.43706	2.4693	1.9601	0.014739	4.7972	2.1534	10.069
0.71569	4.7178	0.43494	2.242	1.9147	0.017234	4.7178	2.2491	9.9609
0.72341	4.6264	0.41901	2.0057	1.8685	0.027308	4.6264	2.3408	9.8578
0.73114	4.5387	0.40393	1.7765	1.8215	0.029927	4.5387	2.4288	9.7588
0.73887	4.445	0.37989	1.5453	1.7738	0.034413	4.445	2.5118	9.6654
0.74659	4.3465	0.34764	1.3138	1.7253	0.039554	4.3465	2.5903	9.5771
0.75432	4.241	0.30463	1.0806	1.676	0.047443	4.241	2.6635	9.4947
0.76205	4.1326	0.25434	0.8503	1.6259	0.054139	4.1326	2.731	9.4188
0.76977	4.0189	0.19378	0.62086	1.575	0.062145	4.0189	2.7922	9.3499
0.7775	3.9066	0.12916	0.39966	1.5233	0.064803	3.9066	2.8468	9.2886
0.78522	5.2093	1.4225	1.5516	1.4708	1.2988	5.2093	2.8944	9.2369
0.79295	2.2719	1.3787	1.3799	1.4175	1.4179	2.2719	2.9342	9.1902
0.80068	3.5413	0.13082	0.24493	1.3634	0.077259	3.5413	2.9663	9.1541
0.8084	3.4174	0.23425	0.44425	1.3085	0.075888	3.4174	2.9901	9.1274

0.81613	3.2995	0.34032	0.62806	1.2527	0.06508	3.2995	3.0047	9.111
0.82386	3.1812	0.45579	0.80185	1.1962	0.050981	3.1812	3.0094	9.1056
0.83158	3.0404	0.60285	0.98646	1.1388	0.055291	3.0404	3.0034	9.1124
0.83931	2.9207	0.74012	1.1394	1.0807	0.035775	2.9207	2.9868	9.131
0.84703	2.8021	0.88764	1.2792	1.0218	0.011833	2.8021	2.9583	9.1631
0.85476	2.6924	1.0389	1.3981	0.96222	0.023815	2.6924	2.9046	9.2236
0.86249	2.5291	1.2552	1.5558	0.90187	0.0101	2.5291	2.8627	9.2707
0.87021	2.3969	1.4557	1.6706	0.84083	0.029406	2.3969	2.7936	9.3483
0.87794	2.2888	1.6487	1.749	0.77913	0.074609	2.2888	2.7095	9.443
0.88567	2.1501	1.888	1.8435	0.71679	0.091997	2.1501	2.608	9.5572
0.89339	2.0035	2.1532	1.9324	0.65385	0.10335	2.0035	2.4877	9.6925
0.90112	1.8729	2.4232	1.9931	0.59036	0.13175	1.8729	2.348	9.8496
0.90885	1.7199	2.7365	2.0631	0.52636	0.13908	1.7199	2.1865	10.031
0.91657	1.6205	3.023	2.0703	0.4619	0.19946	1.6205	2	10.241
0.9243	1.4483	3.4062	2.1379	0.39704	0.18769	1.4483	1.7859	10.482
0.93202	1.3433	3.7557	2.1331	0.33183	0.24129	1.3433	1.5426	10.756
0.93975	1.165	4.2094	2.1945	0.26634	0.22044	1.165	1.2637	11.069
0.94748	0.96874	4.7197	2.2733	0.20063	0.17869	0.96874	0.94608	11.427
0.9552	0.77771	5.2718	2.3535	0.13478	0.13763	0.77771	0.58304	11.835
0.96293	0.4907	5.9704	2.5431	0.068856	0.0049992	0.4907	0.16853	12.301
0.97066	0.32116	6.6304	2.6504	0.0029401	0.038963	0.32116	0.3058	12.835
0.97838	0.12991	7.6478	3.0891	0.062887	0.3647	0.12991	0.84558	13.442
0.98611	0.61245	8.837	3.6696	0.12854	0.73761	0.61245	1.4495	14.121
0.99383	1.2939	10.484	4.6998	0.19393	1.3324	1.2939	2.114	14.869
	3.9551	1.3066	3.6572	1.8118	0.1279	3.9551	1.5905	11.2305

Tr	Chen	Clapeyron	Kistiakowsky	Fishten	Riedel n.b	Carruth	Pitzer	Hilm and Still
0.4221	5.652	3.1046	20.467	0.95334	5.0482	4.6438	5.973	0.63341
0.42981	5.6115	3.1418	20.498	0.91459	5.0079	4.5922	6.0252	1.201
0.43754	5.5666	3.183	20.532	0.87169	4.9633	4.5362	6.0628	1.7123
0.44527	5.5165	3.2289	20.569	0.82386	4.9135	4.475	6.0415	2.1692
0.45299	5.4607	3.2801	20.611	0.77053	4.858	4.408	5.981	2.5735
0.46072	5.3998	3.3359	20.657	0.71234	4.7974	4.3358	5.878	2.9218
0.46845	5.3332	3.397	20.707	0.64869	4.7312	4.2579	5.7104	3.2219
0.47617	5.2624	3.4619	20.761	0.58105	4.6608	4.1757	5.5325	3.4714
0.4839	5.1872	3.5309	20.817	0.50922	4.5861	4.0891	5.4362	3.6729
0.49162	5.1079	3.6036	20.877	0.43345	4.5072	3.9983	5.4137	3.8331
0.49935	5.0252	3.6795	20.939	0.35437	4.425	3.904	5.374	3.9498
0.50708	4.9388	3.7587	21.004	0.27179	4.339	3.8059	5.2653	4.0297
0.5148	4.8493	3.8407	21.072	0.18636	4.2501	3.7048	5.1238	4.074
0.52253	4.7567	3.9257	21.141	0.097855	4.158	3.6003	4.9548	4.0833
0.53026	4.6607	4.0138	21.214	0.0060705	4.0625	3.4923	4.7574	4.0602
0.53798	4.5623	4.104	21.288	0.087935	3.9647	3.382	4.5496	4.0174
0.54571	4.4613	4.1966	21.364	0.18439	3.8643	3.2689	4.332	3.9441
0.55344	4.3576	4.2917	21.442	0.28353	3.7612	3.153	4.1056	3.8556
0.56116	4.2517	4.3889	21.522	0.38474	3.6559	3.0347	3.9265	3.7565
0.56889	4.1433	4.4883	21.603	0.48828	3.5481	2.9139	3.8071	3.6411
0.57661	4.0332	4.5893	21.686	0.59354	3.4386	2.7913	3.7107	3.523
0.58434	3.9214	4.6918	21.77	0.70035	3.3274	2.6668	3.5994	3.3993
0.59207	3.8076	4.7961	21.856	0.80902	3.2144	2.5403	3.4737	3.2661

0.59979	3.6931	4.9012	21.942	0.9185	3.1005	2.4128	3.3619	3.1467
0.60752	3.5768	5.0078	22.03	1.0296	2.9849	2.2835	3.2618	3.0387
0.61525	3.46	5.1149	22.117	1.1412	2.8687	2.1534	3.169	2.9379
0.62297	3.3427	5.2225	22.206	1.2533	2.7521	2.0227	3.0561	2.8167
0.6307	3.2245	5.3309	22.295	1.3662	2.6346	1.891	2.9159	2.668
0.63842	3.107	5.4387	22.383	1.4785	2.5177	1.7598	2.7677	2.5111
0.64615	2.9893	5.5467	22.472	1.591	2.4007	1.6281	2.6231	2.3575
0.65388	2.8723	5.6539	22.56	1.7028	2.2844	1.497	2.471	2.1961
0.6616	2.7566	5.76	22.647	1.8133	2.1693	1.367	2.3182	2.0337
0.66933	2.6417	5.8654	22.733	1.9231	2.0551	1.2376	2.1595	1.8652
0.67706	2.5286	5.9691	22.819	2.0311	1.9427	1.1097	1.9951	1.6908
0.68478	2.4173	6.0712	22.902	2.1375	1.832	0.98336	1.8139	1.4986
0.69251	2.3086	6.1709	22.984	2.2414	1.7239	0.85939	1.6175	1.2902
0.70023	2.2021	6.2686	23.064	2.3432	1.618	0.73723	1.4176	1.081
0.70796	2.0994	6.3627	23.142	2.4412	1.5159	0.61873	1.1981	0.85472
0.71569	1.9996	6.4543	23.217	2.5366	1.4167	0.50271	0.97986	0.62954
0.72341	1.9039	6.542	23.289	2.6281	1.3216	0.39049	0.82909	0.47061
0.73114	1.8121	6.6262	23.358	2.7158	1.2303	0.2818	0.75146	0.37895
0.73887	1.7255	6.7057	23.423	2.7986	1.1441	0.17787	0.6564	0.27067
0.74659	1.6436	6.7808	23.485	2.8768	1.0627	0.078338	0.47907	0.085038
0.75432	1.5672	6.8509	23.542	2.9498	0.98671	0.016184	0.25373	0.14879
0.76205	1.4968	6.9155	23.595	3.0171	0.9167	0.10514	0.049392	0.36165
0.76977	1.4329	6.9741	23.643	3.0782	0.85317	0.18806	0.1239	0.53914
0.7775	1.3759	7.0263	23.686	3.1326	0.79655	0.26453	0.27103	0.68826
0.78522	1.3263	5.8077	22.686	3.1784	0.74718	1.0215	1.0118	0.58527
0.79295	1.2847	8.3566	24.778	3.2198	0.70583	1.7332	1.6923	2.1114

0.80068	1.2512	7.1406	23.78	3.2517	0.67259	0.45119	0.36434	0.79315
0.8084	1.2264	7.1634	23.799	3.2754	0.64793	0.4979	0.39875	0.83186
0.81613	1.2112	7.1774	23.81	3.29	0.63277	0.53576	0.4333	0.87092
0.82386	1.2062	7.1819	23.814	3.2948	0.62781	0.56411	0.43192	0.87429
0.83158	1.2126	7.1761	23.809	3.2887	0.63413	0.58193	0.3802	0.82763
0.83931	1.2298	7.1603	23.796	3.2722	0.65127	0.58972	0.33217	0.78499
0.84703	1.2596	7.133	23.774	3.2438	0.68087	0.58589	0.30367	0.76273
0.85476	1.3156	7.0816	23.732	3.1902	0.73662	0.557	0.26811	0.73384
0.86249	1.3593	7.0415	23.699	3.1484	0.78005	0.54109	0.25002	0.72026
0.87021	1.4314	6.9754	23.645	3.0796	0.8517	0.4982	0.20209	0.67206
0.87794	1.5192	6.8949	23.578	2.9957	0.93904	0.44078	0.12601	0.59389
0.88567	1.6251	6.7978	23.499	2.8945	1.0443	0.3667	0.041033	0.42635
0.89339	1.7506	6.6826	23.404	2.7745	1.1691	0.27445	0.3014	0.1659
0.90112	1.8964	6.549	23.295	2.6353	1.314	0.1636	0.45906	0.0084943
0.90885	2.0649	6.3944	23.168	2.4742	1.4816	0.031735	0.42077	0.048524
0.91657	2.2595	6.2159	23.021	2.2883	1.6751	0.12422	0.29878	0.17195
0.9243	2.4829	6.011	22.853	2.0748	1.8972	0.30681	0.20129	0.26607
0.93202	2.7369	5.7781	22.662	1.8322	2.1497	0.51759	0.15159	0.30521
0.93975	3.0278	5.5113	22.443	1.5542	2.439	0.76278	0.10647	0.34327
0.94748	3.3593	5.2073	22.193	1.2375	2.7686	1.0458	0.0030436	0.45115
0.9552	3.7381	4.8599	21.908	0.87549	3.1452	1.3732	0.062293	0.5258
0.96293	4.1706	4.4632	21.583	0.4622	3.5753	1.7517	0.073545	0.54005
0.97066	4.6656	4.0093	21.21	0.010743	4.0674	2.1909	0.064699	0.5133
0.97838	5.2288	3.4927	20.786	0.54893	4.6274	2.6999	0.20966	0.64976
0.98611	5.8589	2.9148	20.312	1.151	5.2539	3.29	0.51797	0.10287
0.99383	6.5524	2.2789	19.79	1.8136	5.9434	4.0248	13.652	13.973

	3.1773	5.374	22.3301	1.7222	2.5876	1.83812116	2.3778	1.8697

For Amonia

Tr	Ambros walton	Antion	[illegible]	[illegible]	[illegible]ar 1	Wagnar 2	Veter 1	Veter 2
0.55044	12.425	0.21328	3.8287	19.88	5.056	0.19873	0.44154	0.37092
0.56278	11.931	0.49294	3.5725	19.425	5.1659	0.010133	0.34182	0.27127
0.57511	11.603	0.61343	3.448	19.122	5.1289	0.031471	0.25724	0.18675
0.58744	11.398	0.61588	3.4161	18.925	4.9814	0.035901	0.17269	0.10226
0.59978	11.041	0.74946	3.2209	18.539	4.9592	0.035713	0.094471	0.024095
0.61211	10.783	0.79201	3.0971	18.234	4.8479	0.020153	0.029081	0.041249
0.62444	10.483	0.87252	2.9138	17.861	4.7691	0.045014	0.031832	0.10212
0.63678	10.21	0.93063	2.737	17.495	4.6632	0.047334	0.081868	0.15212
0.64911	9.9592	0.97474	2.5614	17.131	4.5367	0.033584	0.12983	0.20005
0.66145	9.6805	1.0507	2.3428	16.718	4.4323	0.048217	0.16949	0.23968
0.67378	9.4523	1.0901	2.1554	16.342	4.2827	0.020466	0.19443	0.2646
0.68611	9.1942	1.1675	1.9255	15.918	4.1584	0.02406	0.21408	0.28424
0.69845	8.9565	1.2392	1.7018	15.503	4.016	0.013283	0.23046	0.30061
0.71078	8.7146	1.3294	1.4629	15.073	3.8777	0.011218	0.22941	0.29956
0.72311	8.4824	1.4272	1.2239	14.645	3.7316	0.0052724	0.22134	0.29149
0.73545	8.2707	1.5244	0.99688	14.234	3.5685	0.014102	0.19198	0.26216
0.74778	8.0318	1.6661	0.73943	13.791	3.4312	0.0024706	0.1613	0.23149
0.76011	7.8138	1.8106	0.49854	13.372	3.2777	0.0037146	0.11563	0.18585
0.77245	7.6004	1.9745	0.26134	12.961	3.1227	0.0023752	0.049836	0.12011
0.78478	7.3961	2.1556	0.034358	12.567	2.9627	0.0021711	0.031721	0.038611
0.79711	7.1768	2.3782	0.20265	12.168	2.8202	0.019997	0.13301	0.06261

0.80945	6.9921	2.5991	0.40116	11.818	2.6507	0.018363	0.2476	0.17712
0.82178	6.7926	2.8661	0.6052	11.47	2.5	0.039835	0.38716	0.31658
0.83411	6.6205	3.1436	0.77351	11.17	2.3303	0.045603	0.56304	0.49233
0.84645	6.4603	3.449	0.91902	10.904	2.1568	0.051079	0.75372	0.68288
0.85878	6.311	3.7871	1.0413	10.674	1.9815	0.057996	0.98726	0.91626
0.87111	6.1793	4.1563	1.134	10.488	1.7997	0.061375	1.2572	1.186
0.88345	6.075	4.5533	1.188	10.357	1.6042	0.053174	1.5624	1.4909
0.89578	5.9743	5.0062	1.2273	10.254	1.4193	0.057477	1.9307	1.859
0.90812	5.9075	5.496	1.2271	10.209	1.2195	0.047523	2.3564	2.2844
0.92045	5.9	6.0111	1.1698	10.242	0.98466	0.0017884	2.8542	2.7819
0.93278	5.854	6.6529	1.1575	10.24	0.81122	0.015851	3.422	3.3492
0.94512	5.8914	7.3344	1.0938	10.312	0.5918	0.02094	4.0897	4.0165
0.95745	6.0186	8.0827	1.0034	10.43	0.32979	0.10816	4.8677	4.794
0.96978	5.9648	9.1862	1.1962	10.25	0.29545	0.020708	5.7278	5.6535
0.98212	5.9634	10.555	1.581	9.8732	0.29912	0.16723	6.3043	6.2296
	8.153	2.9985	1.6128	13.8499	3.0212	0.0387	1.1343	1.1184

Tr	Clapeyron	Kistiakowsky	Fishten	Riedel	Carruth Kobayashi	pitzer	Halim and Still
0.55044	3.706	15.797	1.1849	2.6118	1.8543	2.4183	2.3837
0.56278	3.8016	15.88	1.0844	2.5099	1.7495	2.3386	2.3193
0.57511	3.8827	15.951	0.99921	2.4235	1.66	2.2973	2.2652
0.58744	3.9637	16.022	0.91403	2.3371	1.5707	2.2636	2.2232
0.59978	4.0387	16.088	0.83524	2.2572	1.4879	2.221	2.1962

0.61211	4.1014	16.143	0.76936	2.1904	1.4181	2.2364	2.2043
0.62444	4.1598	16.194	0.708	2.1282	1.3531	2.2358	2.1888
0.63678	4.2078	16.236	0.65759	2.0771	1.2991	2.1784	2.1497
0.64911	4.2538	16.276	0.60927	2.0281	1.2474	2.1386	2.0992
0.66145	4.2918	16.309	0.56932	1.9876	1.2043	2.0965	2.0419
0.67378	4.3157	16.33	0.5442	1.9621	1.1762	2.0119	1.9706
0.68611	4.3345	16.346	0.5244	1.942	1.1537	1.9291	1.8825
0.69845	4.3502	16.36	0.5079	1.9253	1.1348	1.8258	1.7638
0.71078	4.3492	16.359	0.50896	1.9263	1.1337	1.6614	1.6135
0.72311	4.3415	16.352	0.51709	1.9346	1.1401	1.5706	1.5178
0.73545	4.3134	16.328	0.54667	1.9646	1.1683	1.6549	1.583
0.74778	4.2839	16.302	0.57758	1.9959	1.1983	1.5781	1.5296
0.76011	4.2402	16.264	0.62359	2.0426	1.2439	1.4621	1.4016
0.77245	4.1771	16.209	0.68986	2.1098	1.3104	1.4053	1.3279
0.78478	4.0989	16.14	0.77202	2.1931	1.3935	1.4232	1.3717
0.79711	4.0018	16.055	0.87406	2.2966	1.4973	1.6198	1.5487
0.80945	3.8919	15.959	0.9895	2.4137	1.6154	1.7663	1.6877
0.82178	3.7581	15.842	1.1301	2.5562	1.7598	1.9103	1.8534
0.83411	3.5895	15.695	1.3073	2.7359	1.9423	2.215	2.1451
0.84645	3.4067	15.535	1.4994	2.9307	2.1412	2.4866	2.402
0.85878	3.1828	15.339	1.7346	3.1693	2.3854	2.7128	2.6528
0.87111	2.924	15.113	2.0066	3.4451	2.6688	3.0187	2.945
0.88345	2.6315	14.857	2.314	3.7568	2.9909	3.4203	3.3307
0.89578	2.2783	14.548	2.6851	4.1331	3.3809	3.9975	3.9382
0.90812	1.8702	14.191	3.1139	4.568	3.8342	4.2986	4.2185
0.92045	1.393	13.774	3.6154	5.0766	4.3678	4.3554	4.2539
0.93278	0.84865	13.298	4.1873	5.6566	4.9828	4.424	4.3718
0.94512	0.20847	12.738	4.86	6.3388	5.715	4.5576	4.4745

0.95745	0.53742	12.086	5.6438	7.1336	6.5854	4.6514	4.5263
0.96978	1.362	11.365	6.5103	8.0123	7.5884	4.7674	4.7308
0.98212	1.9147	10.882	7.091	8.6012	8.417	4.4743	4.367
	3.3614	15.3101	1.7696	3.204769444	2.4658	2.6006	2.545605714

For Ethan

Tr	Amros walton	Antion				wagnar 2	veter 1	veter 2
0.29608	0.11882	5.8855	2.7705	4.3063	5.8855	5.8855	0.27805	3.1569
0.32753	0.22807	3.3892	2.1433	3.625	3.3892	3.3892	0.11322	3.2179
0.36028	0.19528	1.8486	1.3711	2.7956	1.8486	1.8486	0.090701	3.3011
0.39303	0.10076	0.98856	0.59012	1.9546	0.98856	0.98856	0.1332	3.2822
0.42578	0.30774	0.24021	0.18809	1.4845	0.24021	0.24021	0.1223	3.1247
0.45854	0.18556	0.098857	0.44378	0.78468	0.098857	0.098857	0.042986	2.8441
0.49129	0.11555	0.079275	0.90875	0.24662	0.079275	0.079275	0.010361	2.4731
0.52404	0.1314	0.33625	1.4275	0.34782	0.33625	0.33625	0.20536	2.0473
0.55679	0.022515	0.23361	1.4103	0.41488	0.23361	0.23361	0.026161	1.5983
0.58955	0.068257	0.23715	1.3748	0.46654	0.23715	0.23715	0.038512	1.1471
0.60461	0.092931	0.2246	1.3142	0.44742	0.2246	0.2246	0.069856	0.92801
0.6223	0.025884	0.29243	1.3105	0.49245	0.29243	0.29243	0.009059	0.70855
0.65505	0.0069454	0.26043	1.121	0.39692	0.26043	0.26043	0.00244	0.29431
0.6878	0.013066	0.11769	0.82865	0.20184	0.11769	0.11769	0.006347	0.082396
0.72056	0.028187	0.13796	0.48024	0.046532	0.13796	0.13796	0.020268	0.41328
0.75331	0.065294	0.53621	0.099092	0.32529	0.53621	0.53621	0.053409	0.72827
0.78606	0.028064	0.99886	0.17798	0.49844	0.99886	0.99886	0.010692	0.88871
0.81881	0.04064	1.6706	0.43312	0.6481	1.6706	1.6706	0.017704	1.0066

0.85157	0.074701	2.5521	0.59861	0.70725	2.5521	2.5521	0.04774	1.0266
0.88432	0.077232	3.6366	0.59456	0.59671	3.6366	3.6366	0.049673	0.87785
0.91707	0.062897	5.0173	0.44133	0.33759	5.0173	5.0173	0.040617	0.53077
0.94982	0.046545	6.7838	0.161	0.046876	6.7838	6.7838	0.053794	0.16664
0.98258	0.3316	9.3798	0.17954	0.12794	9.3798	9.3798	0.30404	1.1108
	0.103	1.9541	0.8856	0.92608	1.9541	1.9542	0.0759	1.5198

Tr	Calpeyron	Chen	kistiakowsky	Fishtine	Riedel	Carruth Kobayashi	Pitzer	Halim and Still
0.29608	1.4101	0.45191	2.2621	1.8452	5.6828	2.2821	1.6011	1.6011
0.32753	1.47	0.51122	2.3225	1.9053	5.7452	2.3424	1.721	1.721
0.36028	1.5518	0.59228	2.405	1.9875	5.8304	2.425	1.8689	1.8689
0.39303	1.5333	0.57387	2.3863	1.9689	5.8111	2.4062	1.92	1.92
0.42578	1.3785	0.42053	2.2302	1.8134	5.6497	2.2501	1.8384	1.8384
0.45854	1.1026	0.14724	1.9519	1.5363	5.3622	1.9718	1.6397	1.6397
0.49129	0.73789	0.21399	1.5842	1.1701	4.9822	1.604	1.3566	1.3566
0.52404	0.31929	0.62863	1.1621	0.74969	4.546	1.1818	1.0247	1.0247
0.55679	0.12209	1.0658	0.71699	0.30641	4.086	0.73665	0.67602	0.67602
0.58955	0.56568	1.5052	0.26968	0.13908	3.6237	0.28925	0.3324	0.3324
0.60461	0.78106	1.7186	0.052492	0.35538	3.3992	0.072021	0.16567	0.16567
0.6223	0.9968	1.9323	0.16507	0.57205	3.1744	0.14558	0.009881	0.009881
0.65505	1.404	2.3357	0.57571	0.98102	2.75	0.55631	0.27826	0.27826
0.6878	1.7744	2.7025	0.94915	1.3529	2.3641	0.92982	0.51658	0.51658
0.72056	2.0996	3.0247	1.2772	1.6796	2.0251	1.2579	0.69369	0.69369
0.75331	2.4093	3.3314	1.5894	1.9906	1.7024	1.5702	0.83513	0.83513
0.78606	2.567	3.4877	1.7485	2.149	1.538	1.7293	0.79602	0.79602
0.81881	2.6829	3.6024	1.8653	2.2654	1.4173	1.8461	0.67846	0.67846

0.85157	2.7025	3.6219	1.8851	2.2851	1.3968	1.866	0.41144	0.41144
0.88432	2.5563	3.4771	1.7377	2.1383	1.5492	1.7185	0.10465	0.10465
0.91707	2.2151	3.1391	1.3936	1.7956	1.9047	1.3744	0.95816	0.95816
0.94982	1.5295	2.46	0.70227	1.1071	2.6192	0.68289	2.4565	2.4565
0.98258	0.60137	1.5406	0.23369	0.17493	3.5865	0.25325	5.2034	5.2034
	1.5005	1.8472	1.3681	1.403	3.5107	1.3692	1.1777	1.1777

For Ethylene

Tr	Ambros	Antion	lee kslar	Riedel	Reter 1	Reter 2	Chen	Calyepron
0.36835	2.3007	2.1326	3.2126	3.4378	1.6956	1.5642	0.76908	0.88322
0.3896	2.5342	1.0169	3.0218	3.2491	1.6611	1.5977	0.7348	0.91694
0.42502	2.1307	0.42391	1.9867	2.2192	1.8487	1.4161	0.92072	0.73407
0.46044	1.6601	0.27887	0.99176	1.2292	1.9142	1.3526	0.98564	0.67022
0.49586	1.5162	0.040668	0.45486	0.69573	1.779	1.4835	0.85171	0.80195
0.53127	2.7257	1.4292	1.4321	1.6722	1.4975	1.756	0.5727	1.0764
0.56669	0.85885	0.28153	0.56161	0.31607	1.1283	2.1133	0.20693	1.4362
0.56811	5.9136	7.1247	7.4323	7.1699	3.7089	0.38449	2.7639	1.0789
0.60211	0.67953	0.28945	0.70358	0.45842	0.72141	2.5072	0.19628	1.8328
0.63753	0.52932	0.2318	0.68899	0.44649	0.31299	2.9025	0.60097	2.2308
0.67295	0.39979	0.083613	0.55095	0.314	0.070685	3.2739	0.98116	2.6048
0.70837	0.24034	0.13125	0.37429	0.14641	0.41261	3.6049	1.32	2.938
0.74378	0.13171	0.51693	0.11989	0.094339	0.69162	3.8749	1.5964	3.21
0.7792	0.035892	1.0578	0.12501	0.32003	0.88897	4.066	1.792	3.4023
0.81462	0.03147	1.795	0.32362	0.49264	0.9795	4.1536	1.8817	3.4905
0.85004	0.11545	2.7194	0.38107	0.516	0.92335	4.0992	1.826	3.4358
0.88546	0.19137	3.9104	0.28661	0.37777	0.66609	3.8502	1.5711	3.1851
0.92088	0.31927	5.4098	0.011001	0.025207	0.14017	3.3412	1.05	2.6725

0.95629	0.45553	7.483	0.31915	0.35048	0.72166	2.507	0.19603	1.8325
0.99171	0.69485	10.987	0.25904	0.14794	0.20886	3.4076	1.1181	2.7394
	1.1732	2.3672	1.1618	1.1839	1.0986	2.6628	1.0968	2.0586

Tr	kistiakowsky	Fishtine	Redel	**Carruth Kobayashi**	pitzer	Halm and still
0.36835	0.3941	4.1064	0.78053	0.004572	9.1251	9.1251
0.3896	0.42798	4.071	0.74625	0.010713	6.7362	6.7362
0.42502	0.24421	4.2631	0.93219	0.28194	3.464	3.464
0.46044	0.18005	4.3301	0.99711	0.43916	1.3692	1.3692
0.49586	0.31243	4.1918	0.86317	0.40539	0.35916	0.35916
0.53127	0.58821	3.9035	0.58413	0.23465	0.10011	0.10011
0.56669	0.94977	3.5256	0.21832	0.014144	0.15665	0.15665
0.56811	1.5777	6.1673	2.7756	2.5422	2.403	2.403
0.60211	1.3483	3.1091	0.18494	0.29047	0.03863	0.03863
0.63753	1.7483	2.691	0.58967	0.55658	0.013026	0.013026
0.67295	2.1241	2.2982	0.9699	0.78387	0.11377	0.11377
0.70837	2.459	1.9482	1.3088	0.95181	0.43967	0.43967
0.74378	2.7323	1.6625	1.5853	1.0342	0.63178	0.63178
0.7792	2.9256	1.4605	1.7808	1.0046	0.85197	0.85197
0.81462	3.0143	1.3678	1.8705	0.82599	0.61048	0.61048
0.85004	2.9593	1.4253	1.8149	0.43846	0.016736	0.016736
0.88546	2.7073	1.6887	1.5599	0.24979	0.73438	0.73438
0.92088	2.1922	2.2271	1.0388	1.3877	1.1401	1.1401
0.95629	1.3481	3.1093	0.18469	3.2789	0.60071	0.60071
0.99171	2.2595	2.1568	1.1068	5.3608	5.3078	5.3078

	1.6246	2.9852	1.0946	1.0048	1.7106	1.7106

For Methane

Tr	Ambros	Antion	Lee keslar	Riedel	Wagnar 1	Wagnar 2	Veter 1	Veter 2
0.47597	0.31684	0.11957	0.69721	3.7247	3.1784	0.096639	6.1404	2.7101
0.49853	0.24344	0.304	0.66432	3.1322	3.3334	0.1663	5.5342	2.1235
0.52477	0.16991	0.10995	0.9727	2.461	3.0848	0.053511	4.8474	1.4589
0.55101	0.10919	0.087366	1.0539	1.8006	2.9567	0.086146	4.1715	0.80489
0.57725	0.061105	0.020223	1.1426	1.1518	2.7313	0.034365	3.5076	0.16241
0.58617	0.047562	0.070011	1.0936	0.9174	2.712	0.078304	3.2678	0.069665
0.60348	0.025204	0.053361	1.1086	0.51414	2.5439	0.032228	2.8551	0.46898
0.62972	0.00078	0.10236	1.0538	0.10193	2.3083	0.013167	2.2247	1.079
0.65596	0.013125	0.24985	0.91174	0.69021	2.1025	0.025711	1.6227	1.6615
0.6822	0.017685	0.48145	0.71528	1.2455	1.9106	0.02488	1.0545	2.2114
0.70844	0.014281	0.78608	0.49515	1.7565	1.7198	0.025941	0.53158	2.7174
0.73468	0.0044713	1.1762	0.25985	2.2211	1.5403	0.020085	0.056159	3.1775
0.76092	0.010029	1.65	0.033951	2.6282	1.367	0.012886	0.36046	3.5806
0.78715	0.027358	2.2119	0.16223	2.9752	1.1998	0.004672	0.71552	3.9242
0.81339	0.045511	2.8561	0.29602	3.242	1.0255	0.008032	0.98847	4.1883
0.83963	0.062325	3.6251	0.38255	3.424	0.87708	0.011124	1.1748	4.3686
0.86587	0.075416	4.4851	0.35652	3.5001	0.70411	0.002523	1.2526	4.4439
0.89211	0.082049	5.4967	0.2495	3.4438	0.54474	0.00481	1.195	4.3882
0.91835	0.078808	6.6971	0.069671	3.2181	0.39723	0.015088	0.96405	4.1647
0.94458	0.060721	8.148	0.1455	2.7894	0.24869	0.016873	0.52537	3.7402
0.97082	0.018076	10.028	0.22123	2.1684	0.096728	0.000708	0.11004	3.1253
0.99706	0.094308	13.479	1.1424	2.4764	0.081198	0.077617	0.20511	3.4303

	0.071736	2.828974	0.601287	2.253758	1.666549	0.036891	1.968412	2.636343

Tr	Chen	Calyepron	Kistiakowsky	Fishten	Riedel	Carruth Kobayashi	pitzer	Halim and Still
0.47597	3.6481	2.9234	5.5397	8.6908	0.55185	4.0421	2.4296	2.4296
0.49853	3.0561	2.3355	4.9368	8.07	0.49529	3.5588	2.4449	2.4449
0.52477	2.3854	1.6695	4.2536	7.3664	0.77548	3.0203	2.1626	2.1626
0.55101	1.7254	1.0142	3.5821	6.6749	0.82786	2.4977	1.7942	1.7942
0.57725	1.0771	0.37037	2.9213	5.9943	0.88881	1.9952	1.518	1.518
0.58617	0.84291	0.13781	2.6827	5.7485	0.83054	1.8114	1.4572	1.4572
0.60348	0.43995	0.26234	2.2727	5.3263	0.82651	1.511	1.4788	1.4788
0.62972	0.17567	0.87365	1.6464	4.6814	0.74318	1.0569	1.3622	1.3622
0.65596	0.76351	1.4574	1.0469	4.0639	0.57479	0.64339	1.1862	1.1862
0.6822	1.3184	2.0084	0.48217	3.4823	0.35138	0.27485	0.85362	0.85362
0.70844	1.829	2.5154	0.038152	2.9465	0.10584	0.033958	0.47269	0.47269
0.73468	2.2933	2.9765	0.51084	2.4597	0.15424	0.27604	0.1107	0.1107
0.76092	2.7001	3.3804	0.92532	2.0328	0.40336	0.43696	0.11033	0.11033
0.78715	3.0468	3.7247	1.2773	1.6704	0.6226	0.50949	0.2933	0.2933
0.81339	3.3134	3.9894	1.5496	1.3899	0.77568	0.46123	0.19812	0.19812
0.83963	3.4953	4.1701	1.7337	1.2003	0.88152	0.27818	0.19271	0.19271
0.86587	3.5713	4.2455	1.8114	1.1203	0.87096	0.082436	0.54838	0.54838
0.89211	3.515	4.1897	1.7541	1.1793	0.77681	0.67782	1.2505	1.2505
0.91835	3.2895	3.9657	1.5259	1.4143	0.60506	1.6104	1.4194	1.4194
0.94458	2.8612	3.5404	1.0895	1.8638	0.39559	3.0412	1.1089	1.1089
0.97082	2.2407	2.9242	0.4576	2.5145	0.31978	5.3588	0.64876	0.64876
0.99706	2.5484	3.2298	0.77368	2.189	1.6677	11.217	40	40
	2.279	2.541	1.946	3.7309	0.6566	2.01796	1.0972	1.0972

For Propane

Tr	Ambrose	Antion	Lee keslar	Riedel	Wagnar 1	Wagnar 2	Veter 1	Veter 2
0.23119	2.3364	34.59	2.9685	7.8673	5.4688	2.3364	0.47581	0.87458
0.27039	0.39307	20.994	3.4763	5.1533	4.1815	0.39307	0.17072	0.23064
0.32447	0.43813	10.535	2.6429	3.8878	4.8872	0.43813	0.84649	0.44242
0.37855	0.42751	4.7909	1.2912	2.5935	5.3259	0.42751	1.2463	0.84058
0.43263	0.47912	1.538	0.4579	1.5132	5.6001	0.47912	1.3748	0.96858
0.48671	1.4522	0.23737	0.49173	1.6085	6.5368	1.4522	1.2551	0.84935
0.54079	0.5476	1.078	0.69897	0.15042	5.5089	0.5476	0.94044	0.53599
0.59487	0.18096	1.3238	1.187	0.431	4.84	0.18096	0.49537	0.092708
0.62488	0.20888	1.2991	1.0451	0.3818	4.6369	0.20888	0.21171	0.18982
0.64895	0.096491	1.2309	1.0693	0.41564	4.3227	0.096491	0.006259	0.40691
0.70303	0.067175	1.0345	1.1102	0.1164	3.7681	0.067175	0.49224	0.89094
0.7571	0.037357	0.98677	1.0855	0.27243	3.1387	0.037357	0.88238	1.2795
0.81118	0.049765	1.3791	0.62506	0.61437	2.4817	0.049765	1.0699	1.4663
0.86526	0.062676	2.5458	0.32842	0.68191	1.7616	0.062676	0.90097	1.298
0.91934	0.061706	4.8397	1.0262	0.36993	0.98842	0.061706	0.14426	0.54436
0.97342	0.13002	8.5734	0.16124	0.009424	0.082964	0.13002	1.1651	0.75976
	0.4356	6.061	1.2291	1.6292	3.9706	0.4356	0.7299	0.7294

Tr	**Calyepron**	**Chen**	**Kwiatkowski**	**Fishten**	**Riedel**	**Carruth Kobayashi**	**pitzer**	**Halim and Still**
0.23119	3.1367	1.0101	0.52585	2.3038	0.91696	1.7561	3.6263	3.6263
0.27039	2.5074	0.36708	0.12035	2.9684	0.2733	1.0814	0.36534	0.36534

0.32447	1.8497	0.30506	0.79578	3.663	0.39948	0.35927	0.053995	0.053995
0.37855	1.4607	0.70267	1.1953	4.074	0.79747	0.096428	0.03582	0.03582
0.43263	1.3356	0.8305	1.3238	4.2061	0.92542	0.2911	0.1337	0.1337
0.48671	1.4521	0.71143	1.2041	4.083	0.80624	0.2485	0.043272	0.043272
0.54079	1.7583	0.3985	0.88968	3.7596	0.49301	0.022915	0.11464	0.11464
0.59487	2.1915	0.044175	0.44484	3.3021	0.049917	0.31951	0.072412	0.072412
0.62488	2.4675	0.32631	0.16132	3.0105	0.23249	0.53926	0.090252	0.090252
0.64895	2.6797	0.54311	0.056543	2.7865	0.44949	0.70189	0.035417	0.035417
0.70303	3.1527	1.0265	0.54228	2.2869	0.93331	1.0466	0.45657	0.45657
0.7571	3.5324	1.4145	0.93223	1.8859	1.3217	1.2639	0.98477	0.98477
0.81118	3.7149	1.6011	1.1197	1.6931	1.5084	1.2287	1.0472	1.0472
0.86526	3.5505	1.433	0.95081	1.8668	1.3402	0.74705	0.36566	0.36566
0.91934	2.814	0.68038	0.19448	2.6446	0.58688	0.52294	0.42595	0.42595
0.97342	1.5396	0.62196	1.1142	3.9906	0.71668	3.0966	0.61953	0.61953
	2.4465	0.751	0.7232	**Iso butane**		0.8326	0.5294	

Tr	Ambrose	Antion	Lee kasler	Riedel	Wagnar 1	Wagnar 2	Veter 1	Veter 2
0.27853	2.4719	6.8385	1.3213	5.3973	3.1134	1.0412	2.0079	1.2747
0.29423	2.1946	4.953	1.1947	4.9828	3.296	1.0891	1.7467	1.0115
0.34326	1.3094	0.71896	0.80716	3.6663	3.7675	1.2295	1.1076	0.3676
0.3923	0.48118	1.6748	0.43492	2.4042	4.0793	1.3491	0.682	0.061136
0.44134	0.024318	2.5939	0.13581	1.2959	4.2318	1.4398	0.43956	0.30539
0.49038	0.057861	2.3805	0.93971	0.42137	4.237	1.496	0.35302	0.39258
0.53941	0.33544	1.6133	1.6809	0.16538	4.1146	1.5141	0.3897	0.35563
0.58845	0.44423	0.93639	1.9391	0.44296	3.8863	1.4936	0.51409	0.2303

0.63749	0.74461	0.1343	2.09	0.42804	3.5709	1.4374	0.68407	0.059052
0.64117	0.79662	0.050361	2.1198	0.41647	3.5441	1.4319	0.68772	0.05537
0.66201	0.96756	0.27994	2.1423	0.3273	3.3846	1.3977	0.77985	0.037442
0.68653	1.1981	0.64766	2.1522	0.17827	3.1804	1.3515	0.86825	0.12651
0.71105	1.3699	0.89319	2.0665	0.005501	2.9583	1.3001	0.95432	0.21322
0.73556	1.4973	1.0226	1.914	0.20827	2.7177	1.245	1.0296	0.28909
0.76008	1.6117	1.0586	1.7427	0.41238	2.4575	1.1877	1.087	0.34693
0.7846	1.6503	0.92814	1.5082	0.59879	2.1762	1.13	1.1198	0.37992
0.83364	1.5108	0.12336	0.9357	0.84046	1.5446	1.0218	1.056	0.31567
0.88268	0.82688	1.8146	0.07956	0.79657	0.81491	0.93955	0.67696	0.06621
0.93172	0.91169	5.7967	1.5561	0.45503	5.48E-05	0.91075	0.39013	1.1413
0.98075	5.2352	14.839	6.2335	0.52069	0.83366	0.99778	3.3319	4.1051
	1.282	2.4649	1.6497	1.1982	2.8954	1.2502	0.9953	0.5567

calyepron	chen	Kistiakowsky	Fishten	Riedel	Carruth Kobayashi	pitzer	Halim and Still
4.4108	2.5304	0.36925	1.0707	2.3884	2.931	1.3061	1.3061
4.1559	2.2705	0.10359	1.3402	2.1281	2.664	1.1926	1.1926
3.5325	1.6348	0.5462	1.9994	1.4915	2.0033	1.5242	1.5242
3.1174	1.2115	0.97886	2.4383	1.0676	1.5508	1.4391	1.4391
2.8809	0.97035	1.2254	2.6883	0.82613	1.2759	1.0572	1.0572
2.7965	0.88426	1.3134	2.7776	0.73992	1.1508	1.0502	1.0502
2.8323	0.92075	1.2761	2.7398	0.77646	1.1422	0.84156	0.84156

For n octane

2.9536	1.0445	1.1496	2.6115	0.90036	1.2137	0.76873	0.76873
3.1194	1.2136	0.97676	2.4362	1.0697	1.3213	0.57052	0.57052
3.123	1.2172	0.97305	2.4324	1.0733	1.3199	0.56018	0.56018
3.2128	1.3088	0.87938	2.3374	1.1651	1.3816	0.5958	0.5958
3.2991	1.3968	0.7895	2.2462	1.2532	1.4311	0.72455	0.72455
3.383	1.4824	0.70199	2.1574	1.3389	1.4741	0.97271	0.97271
3.4565	1.5573	0.62543	2.0797	1.4139	1.5014	1.054	1.054
3.5125	1.6144	0.56706	2.0205	1.4711	1.5048	1.2716	1.2716
3.5444	1.6469	0.53376	1.9868	1.5037	1.4761	1.3975	1.3975
3.4822	1.5835	0.59861	2.0525	1.4402	1.2577	0.96862	0.96862
3.1125	1.2065	0.98399	2.4435	1.0626	0.65185	0.24246	0.24246
2.0716	0.14508	2.0689	3.5441	0.000346	0.81147	0.2118	0.2118
0.79808	2.781	5.0599	6.5783	2.9307	4.9064	0.47406	0.47406
3.1397	1.431	1.086	2.499	1.3021	1.6485	0.9112	0.9112

Tr	Calpeyron	Veter 1	Veter 2	Chen	kistiakowsky	Fishten	Riedel	Carruth	pitzer	Halim and
0.4803	0.73111	1.5662	1.3008	0.9042	0.93809	2.6619	0.30923	1.8683	0.25325	0.25325
0.5155	0.25811	2.0285	1.7643	1.3696	1.4033	2.1798	0.1618	2.406	0.78652	0.78652
0.5506	0.056227	2.3356	2.0723	1.6788	1.7124	1.8595	0.47481	2.7931	1.6777	1.6777
0.5858	0.13279	2.4104	2.1473	1.7541	1.7877	1.7814	0.55105	2.9537	1.941	1.941
0.621	0.058257	2.2237	1.9601	1.5662	1.5998	1.9761	0.36081	2.8601	1.7923	1.7923
0.6561	0.39595	1.8938	1.6292	1.234	1.2677	2.3203	0.024532	2.6314	1.6589	1.6589
0.6913	0.63468	1.6605	1.3953	0.9991	1.0329	2.5636	0.2132	2.5074	1.7432	1.7432
0.7265	0.91625	1.3853	1.1194	0.7221	0.75602	2.8506	0.49359	2.352	1.9132	1.9132
0.7617	0.99317	1.3102	1.044	0.64643	0.68037	2.929	0.57019	2.4071	2.2654	2.2654
0.7968	0.912	1.3895	1.1236	0.72629	0.76021	2.8462	0.48935	2.6299	2.5825	2.5825

0.832	0.95983	1.3427	1.0767	0.67923	0.71317	2.895	0.53699	2.7478	2.5706	2.5706
0.867	1.2237	1.0849	0.8181	0.41964	0.45367	3.1639	0.79975	2.6852	2.4177	2.4177
0.902	1.6794	0.63955	0.3716	0.02868	0.0055	3.6284	1.2536	2.4797	1.8698	1.8698
0.9	2.2398	0.091967	0.177	0.57995	0.54558	4.1995	1.8116	2.2432	2.7123	2.7123
0.972	1.5788	0.73792	0.4702	0.07035	0.10449	3.5258	1.1533	3.3126	5.3104	5.3104
	0.85134	1.4734	1.2314	0.8919	0.9174	2.7587	0.6136	2.59183	2.0997	2.0997

For Freon 12

Tr	Amros walton	Antion			er 1	veter 2	chen
0.57946	0.61852	0.43704	0.89099	0.53925	0.088257	1.495	0.088257
0.59244	0.50461	0.28574	1.0085	0.35069	0.083568	1.4996	**0.083568**
0.60543	0.32211	0.066312	1.1744	0.1131	0.078137	1.505	0.078137
0.61841	0.31755	0.028354	1.1393	0.072805	0.058659	1.5241	0.058659
0.63139	0.27491	0.042444	1.1235	0.012411	0.029178	1.5531	0.029178
0.63191	4.2681	0.044874	18.772	0.010617	0.036103	1.5463	0.036103
0.64438	0.19771	0.14051	1.1247	0.065739	7.36E-05	1.5819	7.36E-05
0.65736	0.19721	0.15232	1.0314	0.051482	0.037127	1.6184	0.037127
0.67035	0.12992	0.22008	0.99073	0.090244	0.078048	1.6587	0.078048
0.68333	0.11156	0.22597	0.88736	0.067784	0.1253	1.7052	0.1253
0.69631	0.069	0.24181	0.79728	0.059354	0.18174	1.7607	0.18174
0.7093	0.079961	0.34848	0.80539	0.14929	0.23756	1.8157	0.23756
0.72228	0.054381	0.15379	0.52162	0.050032	0.29608	1.8733	0.29608
0.73526	0.066733	0.0627	0.35679	0.13058	0.36125	1.9374	0.36125
0.74825	0.057001	0.026465	0.21283	0.18981	0.41704	1.9923	0.41704
0.76123	0.063633	0.15368	0.053903	0.26345	0.48214	2.0564	0.48214

0.77421	0.092512	0.32632	0.12294	0.35458	0.54145	2.1147	0.54145
0.7872	0.11852	0.52092	0.28965	0.43534	0.59425	2.1667	0.59425
0.80018	0.096618	0.69453	0.39843	0.45807	0.6409	2.2126	0.6409
0.81317	0.14039	0.96213	0.55975	0.53323	0.66778	2.2391	0.66778
0.82615	0.15145	1.2282	0.6728	0.5602	0.68546	2.2565	0.68546
0.83913	0.19236	1.5574	0.79737	0.59894	0.67539	2.2466	0.67539
0.85212	0.17819	1.869	0.84693	0.56286	0.6452	2.2169	0.6452
0.8651	0.19277	2.2493	0.90318	0.534	0.56408	2.137	0.56408
0.87808	0.15329	2.6218	0.88302	0.42912	0.43884	2.0138	0.43884
0.89107	0.074816	3.0074	0.80171	0.26359	0.24788	1.8258	0.24788
0.90405	0.066545	3.5194	0.76954	0.14852	0.031725	1.5506	0.031725
0.91703	0.16119	3.8881	0.50327	0.20094	0.42903	1.1596	0.42903
0.93002	0.27292	4.4503	0.34442	0.44085	0.9805	0.61688	0.9805
0.943	0.60012	4.9092	0.021288	0.88766	1.7573	0.14763	1.7573
0.95599	0.91812	5.5105	0.34307	1.2884	2.8485	1.2216	2.8485
0.96897	1.3951	6.1511	0.73415	1.7569	4.4803	2.8275	4.4803
0.98195	2.4423	6.5774	1.4757	2.5772	7.154	5.459	7.154
0.99494	4.1126	7.1992	2.1334	3.3105	14.019	12.215	14.019
0.5498	0.9346	1.761	0.5498	0.5164	1.1762	2.1691	1.1762
Tr	Clapeyron eg	kistiakowsky	Fishten	Riedel b.p.	Carruth	pitzer	Halim and Still
0.57946	2.6356	0.26756	3.2708	0.27238	0.45997	0.10341	0.10341
0.59244	2.6402	0.27223	3.2659	0.26768	0.44777	0.010655	0.010655
0.60543	2.6454	0.27764	3.2603	0.26224	0.43559	0.12511	0.12511
0.61841	2.6644	0.29705	3.2402	0.24273	0.43661	0.2215	0.2215
0.63139	2.6931	0.32642	3.2098	0.21319	0.44675	0.27922	0.27922

0.63191	2.6863	0.31952	3.217	0.22013	0.43908	2.8767	2.8767
0.64438	2.7215	0.35557	3.1796	0.18389	0.45578	3.0078	3.0078
0.65736	2.7576	0.39249	3.1414	0.14677	0.47162	3.0539	3.0539
0.67035	2.7974	0.43327	3.0992	0.10577	0.49026	3.1359	3.1359
0.68333	2.8433	0.48035	3.0504	0.058435	0.51407	3.2468	3.2468
0.69631	2.8982	0.53659	2.9922	0.0018878	0.5458	3.4386	3.4386
0.7093	2.9525	0.59222	2.9346	0.05404	0.57556	3.6201	3.6201
0.72228	3.0095	0.65053	2.8742	0.11267	0.60652	3.6648	3.6648
0.73526	3.0729	0.71547	2.807	0.17796	0.64245	3.8232	3.8232
0.74825	3.1271	0.77106	2.7494	0.23385	0.6672	4.0524	4.0524
0.76123	3.1905	0.83593	2.6822	0.29907	0.69919	4.2766	4.2766
0.77421	3.2482	0.89502	2.6211	0.35848	0.7231	4.2631	4.2631
0.7872	3.2995	0.94763	2.5666	0.41138	0.7379	0.6435	0.6435
0.80018	3.3449	0.99412	2.5184	0.45811	0.74358	0.57756	0.57756
0.81317	3.3711	1.0209	2.4907	0.48505	0.72609	0.56087	0.56087
0.82615	3.3882	1.0385	2.4725	0.50276	0.6954	0.47608	0.47608
0.83913	3.3785	1.0285	2.4828	0.49267	0.63228	0.2932	0.2932
0.85212	3.3491	0.9984	2.514	0.46242	0.54343	0.18066	0.18066
0.8651	3.2702	0.91757	2.5977	0.38115	0.39683	0.030964	0.030964
0.87808	3.1483	0.79278	2.7269	0.25568	0.1977	0.19159	0.19159
0.89107	2.9626	0.6025	2.9239	0.064378	0.077794	0.61927	0.61927
0.90405	2.6906	0.32389	3.2124	0.21574	0.45578	0.97746	0.97746
0.91703	2.3041	0.072009	3.6224	0.61378	0.97004	1.0042	1.0042
0.93002	1.7676	0.62151	4.1914	1.1663	1.6644	1.1266	1.1266
0.943	1.012	1.3955	4.9929	1.9445	2.6227	1.4115	1.4115
0.95599	0.049531	2.4829	6.1188	3.0377	3.9573	1.7615	1.7615

0.96897	1.6369	4.1088	7.8024	4.6725	5.9452	2.7603	2.7603
0.98195	4.2379	6.7731	10.561	7.3511	9.2344	4.5636	4.5636
0.99494	10.916	13.614	17.644	14.229	17.869	12.176	12.176
	3.0209	1.3574	3.9128	1.1752	1.6626	2.134	2.134

For Freon 13

Tr	Amros walton	Antion	Lee kesler	Riedel on gama	Veter 1	Veter 2	Chen
0.55012	0.29347	0.39141	1.702	0.90544	0.36277	0.37265	0.95666
0.56366	0.41727	0.49983	1.8931	0.74485	0.074403	0.064567	0.5169
0.5772	0.24027	0.32001	1.7535	0.60823	0.18108	0.17125	0.40959
0.59074	0.14784	0.23357	1.6747	0.49507	0.34733	0.33752	0.24236
0.60428	0.03067	0.12744	1.5463	0.40468	0.45816	0.44836	0.13087
0.61782	0.067845	0.041718	1.4134	0.33613	0.55902	0.54923	0.029416
0.6292	0.11431	0.0051466	1.3213	0.2946	0.6456	0.63582	0.057676
0.63136	0.17087	0.049835	1.2536	0.28829	0.62526	0.61548	0.037218
0.6449	0.16269	0.034125	1.1857	0.25983	0.77065	0.76088	0.18347
0.65844	0.20455	0.075165	1.0477	0.24918	0.83365	0.82389	0.24684
0.67198	0.23758	0.11639	0.9013	0.25456	0.88081	0.87105	0.29428
0.68552	0.2866	0.18487	0.72343	0.27397	0.88279	0.87303	0.29627
0.69906	0.28108	0.21211	0.58767	0.3052	0.91415	0.90439	0.32782
0.7126	0.29131	0.2705	0.42556	0.34581	0.90555	0.8958	0.31917
0.72614	0.29964	0.34432	0.25769	0.39319	0.88022	0.87046	0.29368
0.73968	0.26699	0.39651	0.12622	0.44451	0.8787	0.86895	0.29216

0.75322	0.25109	0.48673	0.023799	0.4968	0.85093	0.84117	0.26422
0.76676	0.24929	0.61431	0.18639	0.54694	0.79292	0.78316	0.20588
0.7803	0.19997	0.72001	0.2966	0.59171	0.77492	0.76515	0.18776
0.79384	0.18165	0.8843	0.42958	0.62785	0.72952	0.71975	0.14209
0.80738	0.13044	1.0462	0.5182	0.65215	0.71143	0.70166	0.1239
0.82092	0.10592	1.2676	0.61859	0.66148	0.66977	0.66	0.081995
0.83446	0.078709	1.5226	0.69841	0.65297	0.63923	0.62945	0.051277
0.848	0.040172	1.8063	0.74638	0.62414	0.62534	0.61556	0.037304
0.86154	0.005502	2.138	0.77544	0.57311	0.61321	0.60342	0.025095
0.87508	0.070616	2.4789	0.73932	0.49891	0.65995	0.65018	0.072119
0.88862	0.10292	2.9187	0.72251	0.40191	0.66318	0.6534	0.075363
0.90216	0.093746	3.4627	0.72447	0.28439	0.63143	0.62164	0.043421
0.9157	0.031588	4.1926	0.82396	0.15159	0.63983	0.63005	0.051878
0.92924	0.18188	4.6875	0.57884	0.013321	0.62539	0.61561	0.037352
0.94278	0.094127	5.5803	0.64108	0.11287	0.42549	0.41569	0.16374
0.95632	0.17369	6.4592	0.57707	0.19508	0.27324	0.26342	0.31689
0.96986	0.034043	7.7464	0.83284	0.17013	0.33588	0.34576	0.92961
0.9834	0.16387	9.1269	1.0749	0.11565	1.3419	1.3518	1.9415
0.99694	0.86873	10.957	1.6953	1.3723	7.459	7.4696	8.0949
	0.1877	2.04	0.8719	0.4385	0.8475	0.84	0.4994

Tr	Clapeyron	Kistiakowsky	Fishten	Riedel	Carruth Kobayashi	pitzer	Halim and Still
0.55012	2.3767	5.2013	0.95334	1.2638	0.10723	0.35307	0.35307
0.56366	2.8019	5.6142	0.91459	0.8227	0.256	0.19064	0.19064

0.5772	2.9057	5.715	0.87169	0.71507	0.39785	0.10341	0.10341
0.59074	3.0674	5.872	0.82386	0.54732	0.53804	0.040349	0.040349
0.60428	3.1752	5.9767	0.77053	0.4355	0.66962	0.0049472	0.0049472
0.61782	3.2733	6.072	0.71234	0.33373	0.79392	0.042565	0.042565
0.6292	3.3575	6.1538	0.64869	0.24638	0.87967	0.084399	0.084399
0.63136	3.3377	6.1345	0.58105	0.2669	0.90816	0.10649	0.10649
0.6449	3.4791	6.2719	0.50922	0.1202	1.0096	0.18696	0.18696
0.65844	3.5404	6.3314	0.43345	0.056639	1.0956	0.26778	0.26778
0.67198	3.5863	6.3759	0.35437	0.0090531	1.1722	0.37288	0.37288
0.68552	3.5882	6.3778	0.27179	0.0070568	1.2327	0.49243	0.49243
0.69906	3.6187	6.4074	0.18636	0.024583	1.2793	0.6308	0.6308
0.7126	3.6104	6.3993	0.097855	0.01591	1.3101	0.82242	0.82242
0.72614	3.5857	6.3754	0.0060705	0.0096517	1.3281	0.90721	0.90721
0.73968	3.5842	6.3739	0.087935	0.011178	1.332	0.88397	0.88397
0.75322	3.5572	6.3477	0.18439	0.0392	1.3261	1.0191	1.0191
0.76676	3.5008	6.2929	0.28353	0.097727	1.3006	1.1499	1.1499
0.7803	3.4833	6.2759	0.38474	0.11589	1.261	1.2068	1.2068
0.79384	3.4391	6.233	0.48828	0.1617	1.2147	1.1021	1.1021
0.80738	3.4215	6.2159	0.59354	0.17995	1.1492	1.0005	1.0005
0.82092	3.381	6.1766	0.70035	0.22198	1.0695	0.90537	0.90537
0.83446	3.3513	6.1477	0.80902	0.2528	0.97781	0.69827	0.69827
0.848	3.3378	6.1346	0.9185	0.26681	0.86792	0.53015	0.53015
0.86154	3.326	6.1232	1.0296	0.27906	0.73736	0.39397	0.39397
0.87508	3.3715	6.1673	1.1412	0.23189	0.59618	0.23881	0.23881
0.88862	3.3746	6.1704	1.2533	0.22864	0.42546	0.067213	0.067213

0.90216	3.3437	6.1404	1.3662	0.26068	0.23144	0.34151	0.34151
0.9157	3.3519	6.1483	1.4785	0.25219	0.16629	0.042126	0.042126
0.92924	3.3379	6.1347	1.591	0.26676	0.28305	0.14738	0.14738
0.94278	3.1434	5.9459	1.7028	0.46846	0.63204	0.43329	0.43329
0.95632	2.9953	5.802	1.8133	0.62208	1.0987	0.86944	0.86944
0.96986	2.4028	5.2267	1.9231	1.2367	1.7758	1.0917	1.0917
0.9834	1.4243	4.2765	2.0311	2.2517	3.0524	0.86258	0.86258
0.99694	4.5259	1.5016	2.1375	8.4238	10.258	36.66	36.66
	3.2845	5.9175	0.8587	0.5927	1.221	1.55	1.55

For Freon 23

Tr	Amros walton	Antion	Lee kesler	Riedel	Veter 1	Veter 2
0.51226	2.5213	31.502	3.5406	1.3335	0.74768	3.4793
0.52898	2.114	30.546	3.3141	1.2015	0.93721	3.674
0.54571	1.9835	30.031	3.327	1.3059	1.0085	3.7472
0.56243	1.8743	29.611	3.3205	1.3934	0.98984	3.7281
0.57916	1.7288	29.199	3.2365	1.4072	0.90733	3.6433
0.59588	1.5424	28.775	3.071	1.3429	0.78435	3.517
0.6126	1.3178	28.333	2.8278	1.2043	0.63708	3.3657
0.62933	1.0802	27.892	2.5346	1.0185	0.48636	3.2109

0.63936	0.90693	27.595	2.3111	0.86089	0.38904	3.111
0.64605	0.84512	27.466	2.2099	0.80344	0.34535	3.0661
0.66278	0.69823	27.153	1.9434	0.6478	0.22328	2.9407
0.6795	0.51415	26.787	1.6117	0.4299	0.12952	2.8444
0.69622	0.39797	26.495	1.3255	0.25885	0.069121	2.7824
0.71295	0.28349	26.187	1.0224	0.073129	0.037864	2.7503
0.72967	0.24356	25.948	0.78086	0.049487	0.04434	2.7569
0.7464	0.24076	25.725	0.56869	0.14093	0.077891	2.7914
0.76312	0.27706	25.515	0.39363	0.19342	0.13033	2.8453
0.77984	0.31403	25.263	0.22342	0.23908	0.19073	2.9073
0.79657	0.37386	24.991	0.086643	0.24953	0.25466	2.9729
0.81329	0.41658	24.642	0.050098	0.25821	0.29205	3.0114
0.83002	0.47652	24.25	0.14641	0.22501	0.29699	3.0164
0.84674	0.51137	23.754	0.23879	0.18663	0.24946	2.9676
0.86346	0.50845	23.128	0.33536	0.15156	0.12718	2.842
0.88019	0.41637	22.296	0.48458	0.16889	0.088027	2.621
0.89691	0.21789	21.222	0.70436	0.25738	0.4062	2.2942
0.91364	0.036645	19.946	0.95124	0.37416	0.83918	1.8495
0.93036	0.25392	18.548	1.1485	0.44281	1.3884	1.2853
0.94708	0.72683	16.633	1.6198	0.79007	2.0302	0.62615
0.96381	0.99137	14.658	1.9763	1.0253	2.7575	0.12091
0.98053	1.152	12.285	2.5029	1.4368	3.6183	1.005
0.99726	0.55354	9.2078	3.4783	2.3081	8.4617	5.9797
	0.8232	24.3737	1.6544	0.7025	0.933731	2.830754

Tr	clapeyron e	kistiakowsky	Fishten	Riedel b.p.	Carruth Kobayashi	pitzer	Halim and Still
0.51226	2.7772	8.5152	3.4881	2.2444	1.0668	1.9706	1.9706
0.52898	2.5943	8.3431	3.6827	2.4368	1.249	2.0824	2.0824
0.54571	2.5255	8.2784	3.756	2.5091	1.3125	2.0244	2.0244
0.56243	2.5436	8.2954	3.7368	2.4902	1.2858	1.9165	1.9165
0.57916	2.6232	8.3703	3.6521	2.4064	1.1951	1.8599	1.8599
0.59588	2.7419	8.482	3.5257	2.2816	1.0638	1.8026	1.8026
0.6126	2.884	8.6157	3.3745	2.1322	0.90823	1.7454	1.7454
0.62933	3.0294	8.7525	3.2196	1.9792	0.74925	1.6487	1.6487
0.63936	3.1233	8.8409	3.1197	1.8804	0.647	1.5304	1.5304
0.64605	3.1655	8.8806	3.0748	1.8361	0.60011	1.4856	1.4856
0.66278	3.2833	8.9914	2.9494	1.7122	0.47007	1.3402	1.3402
0.6795	3.3738	9.0766	2.8531	1.6171	0.36854	1.1822	1.1822
0.69622	3.4321	9.1314	2.791	1.5558	0.30066	1.0038	1.0038
0.71295	3.4622	9.1598	2.7589	1.524	0.2622	0.77752	0.77752
0.72967	3.456	9.1539	2.7656	1.5306	0.26186	0.70157	0.70157
0.7464	3.4236	9.1235	2.8001	1.5647	0.28901	0.68892	0.68892
0.76312	3.373	9.0758	2.8539	1.6179	0.33556	0.51159	0.51159
0.77984	3.3147	9.021	2.916	1.6792	0.39068	0.42875	0.42875
0.79657	3.253	8.9629	2.9816	1.7441	0.45012	0.54947	0.54947
0.81329	3.2169	8.929	3.02	1.782	0.484	0.61264	0.61264
0.83002	3.2122	8.9245	3.0251	1.787	0.4867	0.71177	0.71177
0.84674	3.258	8.9677	2.9763	1.7388	0.43864	0.77203	0.77203
0.86346	3.376	9.0787	2.8507	1.6147	0.31815	0.63105	0.63105
0.88019	3.5837	9.2741	2.6296	1.3963	0.10797	0.46168	0.46168
0.89691	3.8908	9.563	2.3028	1.0734	0.20049	0.41856	0.41856
0.91364	4.3086	9.9562	1.858	0.63398	0.61667	0.35586	0.35586

0.93036	4.8386	10.455	1.2939	0.076576	1.1378	1.5691	1.5691
0.94708	5.4579	11.038	0.63464	0.57473	1.7314	2.9253	2.9253
0.96381	6.1598	11.698	0.11248	1.3129	2.37	4.497	4.497
0.98053	6.9905	12.48	0.99669	2.1865	3.0321	6.4703	6.4703
0.99726	11.664	16.878	5.9718	7.1017	6.892	/	/
	3.81731	9.493955	2.837794	1.871632	1.000716	1.489194	1.489194

For R 123

Tr	Amros walton	Antion	lee kesler	Riedel n.b	Veter 1	Veter 2	Chen
0.4884	0.48115	0.071586	3.8349	1.103	3.0456	2.1704	2.548
0.51029	0.13583	0.92336	2.9401	1.0611	1.8306	0.94446	1.3267
0.53217	0.14748	2.1245	1.7228	1.0175	0.34591	0.55359	0.16553
0.55406	0.36626	1.0616	2.5785	0.97183	1.0278	0.13448	0.51989
0.57595	0.51957	0.94428	2.4358	0.924	0.76356	0.13217	0.25426
0.59783	0.60808	0.43895	2.5969	0.8737	0.8744	0.020336	0.36567
0.60878	0.62875	0.14362	2.6976	0.84753	0.9745	0.080671	0.46628
0.61972	0.63427	0.18421	2.8185	0.82064	1.1107	0.21808	0.60317
0.63066	0.62525	0.34196	2.764	0.79297	1.0835	0.19065	0.57584
0.64161	0.60238	0.51774	2.7191	0.76449	1.0804	0.18751	0.57271
0.65255	0.56649	0.77073	2.7439	0.73515	1.1617	0.26953	0.65441
0.65868	0.54104	0.80995	2.6554	0.71832	1.1089	0.21625	0.60134
0.66349	0.51851	0.9315	2.6743	0.70489	1.1599	0.26772	0.65261
0.67444	0.45948	1.0711	2.5819	0.67367	1.1467	0.25439	0.63933
0.68538	0.39056	1.2748	2.5528	0.64144	1.2085	0.31682	0.70152
0.69632	0.31303	1.4081	2.4565	0.60813	1.2118	0.32015	0.70483

0.70727	0.22823	1.5613	2.3845	0.5737	1.248	0.35669	0.74124
0.71821	0.13766	1.6639	2.2691	0.53808	1.2474	0.35599	0.74054
0.72915	0.042859	1.7646	2.1611	0.50122	1.2597	0.36845	0.75295
0.7401	0.054519	1.8476	2.0473	0.46305	1.2703	0.37911	0.76357
0.75104	0.15275	1.8914	1.9088	0.42351	1.2583	0.36705	0.75156
0.76198	0.25006	1.9215	1.7738	0.38254	1.2507	0.35938	0.74392
0.77293	0.3446	1.9547	1.662	0.34007	1.2655	0.37429	0.75877
0.78387	0.4345	1.9347	1.5201	0.29606	1.2472	0.35585	0.7404
0.79481	0.5179	1.8839	1.3736	0.25043	1.2198	0.32822	0.71288
0.80576	0.5929	1.8389	1.2629	0.20314	1.2219	0.33032	0.71497
0.8167	0.65771	1.7383	1.1294	0.15412	1.1932	0.30136	0.68612
0.82764	0.71057	1.6072	1.0023	0.10333	1.1611	0.26893	0.65381
0.83859	0.74989	1.4261	0.86569	0.050722	1.1083	0.21567	0.60077
0.84953	0.77426	1.181	0.70956	0.0037425	1.0235	0.13016	0.51558
0.86047	0.78256	0.96779	0.63446	0.060096	1.006	0.1125	0.49799
0.87142	0.77408	0.69343	0.55116	0.11836	0.96626	0.072359	0.458
0.88236	0.74863	0.2919	0.39829	0.17856	0.8432	0.051816	0.33431
0.90425	0.65017	0.53787	0.25785	0.30473	0.72431	0.17177	0.21481
0.92613	0.50735	1.7634	0.013423	0.43851	0.47554	0.4228	0.035241
0.94802	0.3794	3.5766	0.47393	0.57955	0.029729	0.87263	0.48334
0.96991	0.43013	5.8724	1.0445	0.72728	0.24941	1.1543	0.7639
0.99179	1.3228	9.5143	2.4466	0.88086	0.14079	1.0447	0.65473
	0.49425	1.5908	1.8596	0.5482	1.067	0.3861	0.6492

Tr	clapeyron	kistiakowsky	Fishten	Riedel n.b	Carruth Kobayashi	pitzer	Halim and Still
0.4884	5.3785	5.0339	0.15311	1.9642	2.5848	1.7224	1.7224
0.51029	4.1927	3.8439	1.4082	0.73571	2.3678	1.3875	1.3875
0.53217	2.7438	2.3896	2.9418	0.76551	2.194	1.3309	1.3309
0.55406	3.4093	3.0576	2.2374	0.075982	2.0645	1.3905	1.3905
0.57595	3.1514	2.7987	2.5104	0.3432	1.9597	1.2588	1.2588
0.59783	3.2596	2.9073	2.3959	0.23113	1.886	1.1152	1.1152
0.60878	3.3573	3.0053	2.2925	0.12991	1.857	1.0399	1.0399
0.61972	3.4902	3.1387	2.1518	0.0077954	1.8289	0.94573	0.94573
0.63066	3.4636	3.1121	2.1799	0.019697	1.8083	0.91901	0.91901
0.64161	3.4606	3.1091	2.1831	0.022843	1.7907	0.89653	0.89653
0.65255	3.5399	3.1887	2.0991	0.059347	1.7771	0.88008	0.88008
0.65868	3.4884	3.137	2.1537	0.0059544	1.7673	0.89036	0.89036
0.66349	3.5382	3.1869	2.101	0.057535	1.7689	0.90311	0.90311
0.67444	3.5253	3.174	2.1146	0.044175	1.7616	0.92383	0.92383
0.68538	3.5857	3.2346	2.0507	0.10674	1.7567	0.99111	0.99111
0.69632	3.5889	3.2378	2.0473	0.11007	1.7496	1.062	1.062
0.70727	3.6242	3.2733	2.0099	0.14669	1.742	1.1849	1.1849
0.71821	3.6235	3.2726	2.0106	0.14599	1.742	1.3017	1.3017
0.72915	3.6356	3.2847	1.9979	0.15848	1.7331	1.3052	1.3052
0.7401	3.6459	3.295	1.987	0.16916	1.73	1.273	1.273
0.75104	3.6342	3.2833	1.9993	0.15708	1.7226	1.3873	1.3873
0.76198	3.6268	3.2759	2.0072	0.14939	1.7138	1.5434	1.5434
0.77293	3.6412	3.2904	1.9919	0.16433	1.7002	1.6356	1.6356
0.78387	3.6234	3.2725	2.0108	0.14585	1.6855	1.6742	1.6742
0.79481	3.5967	3.2457	2.0391	0.11817	1.6672	1.5807	1.5807

0.80576	3.5987	3.2477	2.0369	0.12027	1.6433	1.5328	1.5328
0.8167	3.5707	3.2196	2.0666	0.091245	1.6197	1.4939	1.4939
0.82764	3.5393	3.1881	2.0998	0.058744	1.5813	1.3854	1.3854
0.83859	3.4878	3.1364	2.1543	0.0053804	1.536	1.261	1.261
0.84953	3.4051	3.0534	2.2418	0.080318	1.4861	1.1701	1.1701
0.86047	3.388	3.0362	2.2599	0.098013	1.4201	1.1133	1.1133
0.87142	3.3492	2.9973	2.301	0.13824	1.3446	1.0218	1.0218
0.88236	3.2291	2.8767	2.4281	0.26267	1.2535	0.89714	0.89714
0.90425	3.1131	2.7603	2.5509	0.38289	1.0164	0.44884	0.44884
0.92613	2.8703	2.5166	2.8079	0.63444	0.6937	0.90755	0.90755
0.94802	2.4352	2.0799	3.2684	1.0852	0.28275	1.4862	1.4862
0.96991	2.1628	1.8065	3.5568	1.3675	0.18691	2.2821	2.2821
0.99179	2.2688	1.9129	3.44	**For R 134a**	0.25995	8.407	8.407
	3.4274	3.0758	2.2182	0.3057	1.5969	1.4197	1.4197

Tr	Clapeyron	kistiakowsky	Fishten	Riedel b.p.	Carruth Kobayashi	pitzer	Halim and Still
0.4884	3.922	8.6367	1.7093	0.55165	1.9608	3.0157	3.0157
0.51029	3.7758	8.4976	1.864	0.70466	1.084	1.9327	1.9327
0.53217	4.1117	8.817	1.5085	0.35318	0.42985	1.2585	1.2585
0.55406	3.8304	8.5495	1.8063	0.64759	0.055629	0.79656	0.79656
0.57595	3.9681	8.6805	1.6605	0.50345	0.40709	0.4775	0.4775
0.59783	3.9085	8.6238	1.7236	0.56579	0.65644	0.2744	0.2744
0.60878	3.4496	8.1874	2.2094	1.0461	0.83273	0.13904	0.13904
0.61972	3.9643	8.6769	1.6645	0.5074	0.95752	0.020959	0.020959
0.63066	3.9393	8.6531	1.691	0.53358	1.0444	0.096796	0.096796

0.64161	3.9626	8.6752	1.6664	0.50923	1.0826	0.15773	0.15773
0.65255	3.9336	8.6477	1.697	0.53955	1.1127	0.17793	0.17793
0.65868	3.9981	8.709	1.6287	0.47202	1.1638	0.29543	0.29543
0.66349	3.9945	8.7056	1.6326	0.47581	1.2045	0.44045	0.44045
0.67444	3.9743	8.6864	1.6539	0.49693	1.2421	0.59204	0.59204
0.68538	3.9749	8.6869	1.6534	0.49637	1.2799	0.80942	0.80942
0.69632	3.9682	8.6805	1.6605	0.50339	1.3117	0.83088	0.83088
0.70727	3.9561	8.6691	1.6732	0.516	1.3362	0.87912	0.87912
0.71821	3.9211	8.6357	1.7103	0.55268	1.3584	1.1212	1.1212
0.72915	3.8754	8.5923	1.7586	0.60043	1.3734	1.28	1.28
0.7401	3.8166	8.5364	1.8209	0.662	1.3821	1.3773	1.3773
0.75104	3.7254	8.4496	1.9175	0.7575	1.3701	1.2592	1.2592
0.76198	3.6392	8.3677	2.0087	0.84763	1.346	1.2247	1.2247
0.77293	3.5015	8.2368	2.1544	0.99174	1.2972	1.1578	1.1578
0.78387	3.3495	8.0922	2.3154	1.1508	1.2183	0.9474	0.9474
0.79481	3.1673	7.9189	2.5083	1.3416	1.1131	0.81905	0.81905
0.80576	2.986	7.7465	2.7002	1.5313	0.97032	0.64993	0.64993
0.8167	2.7486	7.5208	2.9515	1.7797	0.79025	0.47002	0.47002
0.82764	2.4545	7.2411	3.2629	2.0876	0.56107	0.068699	0.068699
0.83859	2.1185	6.9216	3.6185	2.4391	0.28309	0.31057	0.31057
0.84953	1.8025	6.6211	3.9531	2.7699	0.044127	0.1796	0.1796
0.86047	1.4052	6.2433	4.3737	3.1857	0.44056	0.13756	0.13756
0.87142	1.0603	5.9154	4.7388	3.5466	0.90192	0.036494	0.036494
0.88236	0.84005	5.7059	4.9719	3.7772	1.441	0.17541	0.17541
0.90425	0.15886	4.756	6.0294	4.8226	2.0849	0.16354	0.16354
0.92613	1.0994	3.8617	7.025	5.8069	2.9834	0.082309	0.082309
0.94802	6.173	0.96303	12.396	11.117	7.6632	/	/

0.99179	3.291	7.6975	2.8144	1.6442	1.2718	0.6759	0.6759

For Argon

Tr	Amros	Antion	lee kesler	Riedel	Veter 1	Veter 2	Chen
0.55548	0.79352	0.10947	0.40819	0.41638	3.2358	9.1006	0.78315
0.56344	0.79424	0.049527	0.40476	0.40096	3.0905	9.2285	0.64136
0.57868	0.75751	0.03262	0.42161	0.34811	2.8193	9.4673	0.37654
0.59658	0.63809	0.06444	0.49446	0.2333	2.4997	9.7487	0.064533
0.62972	0.45445	0.20641	0.52998	0.11931	1.9023	10.275	0.51867
0.66287	0.30713	0.45759	0.46492	0.10571	1.3022	10.803	1.1044
0.69601	0.17142	0.80688	0.34794	0.14492	0.73061	11.306	1.6625
0.72915	0.10531	1.3237	0.1495	0.26728	0.19677	11.776	2.1836
0.7623	0.030392	1.9418	0.018862	0.36279	0.26007	12.179	2.6296
0.79544	0.036573	2.6917	0.13883	0.41431	0.61905	12.495	2.9801
0.82858	0.097646	3.5901	0.17346	0.38629	0.83897	12.688	3.1948
0.86173	0.093747	4.7213	0.15226	0.30967	0.86572	12.712	3.2209
0.89487	0.12888	/	0.041103	0.069976	0.59644	12.475	2.958
0.92801	0.12692	/	0.29839	0.22292	0.20397	11.77	2.1766
0.96116	0.49256	/	0.85145	0.79884	2.2401	9.9773	0.18885
0.9943	0.89281	/	0.23655	0.19293	/	5.1348	/
	0.3701	1.333	0.3208	0.2996	1.427	10.696	1.6456

Tr	clapeyron	kistiakowsky	Fishten	Riedel n.b	Carruth	pitzer	Halim and
0.55548	0.16725	0.20977	94.897	0.9097	1.6593	0.8405	0.8405
0.56344	0.026333	0.35016	94.905	0.76774	1.5645	0.87028	0.87028
0.57868	0.23687	0.61237	94.918	0.50259	1.392	0.84714	0.84714
0.59658	0.54697	0.9213	94.934	0.19019	1.1922	0.99568	0.99568
0.62972	1.1266	1.4988	94.963	0.39375	0.82941	1.0851	1.0851
0.66287	1.7088	2.0788	94.993	0.98026	0.48306	1.039	1.039
0.69601	2.2634	2.6313	95.021	1.539	0.18817	0.76988	0.76988
0.72915	2.7814	3.1473	95.048	2.0608	0.040011	0.33778	0.33778
0.7623	3.2247	3.5889	95.07	2.5074	0.15392	0.17549	0.17549
0.79544	3.573	3.9359	95.088	2.8582	0.12004	0.15686	0.15686
0.82858	3.7864	4.1485	95.099	3.0732	0.12272	0.48282	0.48282
0.86173	3.8123	4.1744	95.1	3.0994	0.66211	1.1488	1.1488
0.89487	3.551	3.9141	95.087	2.8362	1.6644	2.2427	2.2427
0.92801	2.7744	3.1404	95.047	2.0538	3.5067	2.7194	2.7194
0.96116	0.79881	1.1722	94.947	0.063517	/	3.3748	3.3748
0.9943	/	4.1439	94.675	/	/	/	/
	2.025215533	2.4793		5890498	0.969895786	1.139082	1.139082

For Nitrogen

Tr	Amros walton	Antion	lee kesler	Riedel	wagnar 1	wagnar 2	veter 1	veter 2
0.5	1.5468	0.019907	0.45479	1.2836	3.9575	0.0075949	4.2268	6.8017
0.51506	1.4492	0.041483	0.26628	1.0632	3.9013	0.038548	3.9934	7.0105
0.55468	1.0044	0.032175	0.30653	0.40507	3.4882	0.070835	3.3877	7.552
0.59429	0.82739	0.15552	0.44924	0.17142	3.2348	0.030888	2.743	8.1286

0.61252	0.68122	0.189	0.53169	0.046567	3.0276	0.0073191	2.4773	8.3662
0.63391	0.61013	0.3473	0.49235	0.034891	2.8647	0.033919	2.0966	8.7066
0.67353	0.43876	0.67024	0.38066	0.051074	2.4848	0.030315	1.473	9.2642
0.71315	0.31303	1.1548	0.15945	0.17587	2.1157	0.027731	0.90602	9.7712
0.75277	0.20746	1.8019	0.089471	0.32881	1.7499	0.011026	0.41504	10.21
0.79239	0.10272	2.6197	0.28268	0.42791	1.3826	0.026615	0.042963	10.543
0.83201	0.064041	3.7058	0.41898	0.47338	1.0901	0.0055805	0.1813	10.743
0.87163	0.068213	4.9596	0.2832	0.25186	0.72661	0.069212	0.17969	10.742
0.91125	0.16331	6.6046	0.0098282	0.11995	0.44001	0.066433	0.16776	10.431
0.95087	0.44633	8.6562	0.55955	0.7392	0.046095	0.19025	1.144	9.5584
0.99049	0.46377	12.475	0.076282	0.15777	0.13897	0.1152	1.8947	8.8871
	0.55912	2.8955	0.3174	0.38204	2.0433	0.048765	1.6886	9.11436667

Tr	Chen	Clapeyron	Kistiakowsky	Fishten	Riedel	Carruth Kobayashi	pitzer	Halim and Still
0.5	1.3128	1.2756	2.0828	7.3049	1.2216	1.4605	0.11607	0.11607
0.51506	1.0859	1.0488	1.8542	7.0646	0.99487	1.2978	0.19571	0.19571
0.55468	0.49722	0.46025	1.261	6.4411	0.40669	0.88718	0.33938	0.33938
0.59429	0.12948	0.16622	0.62955	5.7773	0.21945	0.45363	0.39658	0.39658
0.61252	0.3878	0.42445	0.36927	5.5037	0.47754	0.29034	0.47071	0.47071
0.63391	0.75785	0.79436	0.0035946	5.1118	0.84726	0.036883	0.45883	0.45883
0.67353	1.364	1.4002	0.61431	4.4698	1.4528	0.33442	0.28058	0.28058
0.71315	1.9151	1.9512	1.1696	3.8861	2.0035	0.6207	0.17337	0.17337
0.75277	2.3924	2.4283	1.6505	3.3806	2.4803	0.79296	0.43908	0.43908
0.79239	2.754	2.7898	2.0149	2.9975	2.8416	0.79359	0.56403	0.56403
0.83201	2.972	3.0077	2.2346	2.7666	3.0594	0.56834	0.19899	0.19899

0.87163	2.9705	3.0062	2.233	2.7683	3.0579	0.0077144	0.47293	0.47293
0.91125	2.6327	2.6685	1.8927	3.126	2.7204	1.1575	1.3301	1.3301
0.95087	1.6838	1.72	0.9366	4.131	1.7724	3.4662	1.0509	1.0509
0.99049	0.95408	0.99052	0.20131	4.9039	1.0433	8.1036	0.35653	0.35653
	1.5873	1.6088	1.2765	4.642213333	1.6399	1.3514	0.45625	0.45625

Tr	Veter 1	Veter 2	Chen	Clapeyron	kistiakowsky	Fishten	Riedel	Carruth	pitzer	Halim
0.50887	8.0308	2.5068	-10.82	12.939	24.636	5.1669	1.8638	6.5297	3.9843	5.377
0.5275	8.2712	2.7616	-11.053	13.166	24.833	5.4147	2.1203	6.8547	4.6428	5.3547
0.54613	8.2128	2.6997	-10.997	13.111	24.785	5.3546	2.0581	6.879	5.1134	5.1852
0.56476	8.3046	2.797	-11.086	13.198	24.86	5.4492	2.156	7.0586	5.6413	5.306
0.58339	8.2059	2.6924	-10.99	13.104	24.779	5.3474	2.0507	7.0484	5.6554	5.3223
0.60202	8.1476	2.6306	-10.934	13.049	24.732	5.2874	1.9885	7.0828	5.8014	5.4367
0.62065	8.1355	2.6178	-10.922	13.038	24.722	5.2749	1.9756	7.1678	5.8737	5.4753
0.63927	7.928	2.3979	-10.721	12.841	24.552	5.0609	1.7542	7.0598	5.8913	5.4558
0.6579	7.7706	2.2309	-10.568	12.692	24.423	4.8986	1.5862	7.0074	5.9546	5.4794
0.67653	7.0153	1.4303	-9.8356	11.977	23.804	4.1198	0.78024	6.3583	5.4038	4.8825
0.69516	6.9705	1.3828	-9.7922	11.935	23.767	4.0736	0.73246	6.4315	5.6928	5.1228
0.71379	6.3094	0.68196	-9.1511	11.309	23.225	3.3919	0.026997	5.892	5.3896	4.7836
0.73242	5.7019	0.038005	-8.5621	10.734	22.728	2.7655	0.62121	5.4154	4.9315	4.2739
0.75105	4.5532	1.1797	-7.4482	9.6468	21.786	1.581	1.8469	4.4067	4.1153	3.4059
0.76968	3.2769	2.5326	-6.2106	8.4386	20.74	0.26498	3.2088	3.2835	3.3129	2.5633
0.78831	2.2122	3.6613	-5.1782	7.4307	19.868	0.83287	4.3449	2.3868	2.4797	1.708
0.80694	1.2368	4.6953	-4.2324	6.5073	19.069	1.8386	5.3857	1.596	1.5824	0.78405
0.82557	0.37832	6.4074	-2.6663	4.9784	17.745	3.5041	7.1091	0.18851	0.12165	0.71103
0.8442	1.8992	8.0197	-1.1915	3.5387	16.499	5.0723	8.732	1.0994	1.281	2.151
0.86283	3.4726	9.6876	0.33419	2.0492	15.21	6.6947	10.411	2.4082	2.6172	3.5261

0.88146	4.5377	10.817	1.367	1.0409	14.337	7.793	11.547	3.1763	3.4531	4.3641
0.90009	6.4368	12.83	3.2085	0.7568	12.781	9.7512	13.574	4.7177	5.433	6.3576
0.91872	8.637	15.162	5.3419	2.8396	10.978	12.02	15.922	6.4844	6.7525	7.6984
0.93735	11.567	18.268	8.1831	5.6133	8.5766	15.041	19.048	8.8597	8.6572	9.5821
0.95598	16.044	23.014	12.524	9.8511	4.9082	19.657	23.825	12.562	11.813	12.797
0.97461	18.925	26.068	15.317	12.578	2.5475	22.628	26.899	14.372	12.998	13.951
0.99324	8.9419	15.485	5.6376	3.1282	10.728	12.334	16.247	2.9523	9.6104	8.9624
										0
	7.0786	6.8406	7.936	8.9440963	18.949	6.6896	6.9561	5.7511	5.3409	5.4081

For 2 propanol

Tr	Veter 1	Veter 2	Chen	kistiakowsky	Calpeyron	Fishten	Riedel n.b	Carruth	pitzer	Halim and
0.61607	8.2055	4.5505	5.0599	25.233	8.1952	5.1317	1.6663	6.9611	5.6271	5.2397
0.63575	8.2799	4.6278	5.1368	25.294	8.2695	5.2085	1.7459	7.1496	5.9186	5.5142
0.65542	7.9019	4.2348	4.7459	24.986	7.8915	4.8179	1.341	6.886	5.7956	5.3429
0.67509	7.5768	3.8967	4.4097	24.721	7.5663	4.4819	0.99277	6.6829	5.7138	5.2076
0.69477	7.4546	3.7697	4.2833	24.622	7.4441	4.3556	0.86188	6.692	5.9549	5.3959
0.71444	6.7048	2.99	3.5078	24.011	6.6942	3.5807	0.05864	6.0772	5.5729	4.9916
0.73411	6.3097	2.5792	3.0992	23.689	6.2992	3.1725	-0.36453	5.83	5.3317	4.6923
	7.4904	3.807	4.3204	24.651			1.0044	6.6112	5.7021	5.1978

For Methanol

	Calyperon	Veter 1	Veter 2	Chen	kistiakowsky	Fishten	riedel	Carruth	pitzer	Halim and

0.65	1.5267	0.3487	3.7754	4.1929	20.443	2.3879	6.2213	2.5723	3.7388	3.3544
0.669	1.8336	0.035935	3.452	3.8682	20.691	2.0688	5.8902	2.1425	3.1919	2.7704
0.689	1.8558	0.013309	3.4286	3.8447	20.709	2.0457	5.8663	2.0038	2.8741	2.4117
0.708	1.9723	0.10535	3.3059	3.7215	20.803	1.9246	5.7407	1.7609	2.3642	1.867
0.728	1.8016	0.068579	3.4857	3.9021	20.665	2.1021	5.9248	1.809	2.2957	1.759
0.747	1.7337	0.13776	3.5573	3.9739	20.61	2.1727	5.998	1.7421	2.1394	1.559
0.767	1.8144	0.055553	3.4723	3.8886	20.676	2.0888	5.911	1.5123	1.5387	0.92108
0.786	1.8487	0.020549	3.4361	3.8522	20.703	2.0531	5.874	1.3198	1.2356	0.60631
0.806	1.6308	0.24258	3.6657	4.0828	20.527	2.2796	6.109	1.3749	1.4126	0.76278
0.825	1.4127	0.46484	3.8955	4.3135	20.351	2.5064	6.3443	1.4145	1.5091	0.84317
0.845	1.4675	0.40904	3.8378	4.2556	20.395	2.4495	6.2852	1.155	1.3732	0.68158
0.864	1.3912	0.48683	3.9183	4.3364	20.334	2.5288	6.3675	1.0075	1.2526	0.53326
0.884	1.275	0.60521	4.0407	4.4593	20.24	2.6496	6.4928	0.87148	1.1817	0.51392
0.903	1.2403	0.64053	4.0772	4.4959	20.212	2.6857	6.5302	0.61351	1.2468	0.57847
0.923	1.6102	0.26365	3.6875	4.1046	20.511	2.3011	6.1313	0.10898	0.027086	0.69236
0.942	0.85072	1.0376	4.4878	4.9082	19.897	3.0908	6.9505	0.2321	0.1886	0.82143
0.962	1.2024	3.1298	6.6515	7.0806	18.238	5.2255	9.1652	1.7254	0.71943	0.051742
0.981	3.5629	5.5352	9.139	9.5781	16.331	7.6798	11.711	3.174	1.1407	0.51749
	1.668362	0.75561	4.1841	4.6033	20.13	2.7911	6.6397	1.4744	1.635	1.1803

For Ethyle astate

Tr	veter 1	veter 2	chen	kistiawesky	Fishten	Riedel.	Carruth Kobayashi	pitzer	Halim and Still
0.67498	2.2122	0.6366	0.9373	6.9948	1.0713	0.15829	2.3285	1.4588	1.9261

0.6941	2.1561	0.6943	0.8806	6.9415	1.1292	0.21568	2.3189	1.5959	2.1134
0.7132	2.1897	0.6598	0.9146	6.9734	1.0945	0.18132	2.4008	1.9025	2.4539
0.7323	2.33	0.5153	1.0567	7.1069	0.9495	0.03761	2.5915	2.1238	2.7181
0.7514	1.9978	0.85727	0.7202	6.7909	1.2929	0.3779	2.3135	1.9936	2.6358
0.7706	1.7536	1.1086	0.4728	6.5587	1.5453	0.628	2.1264	2.0658	2.7453
0.7897	1.6591	1.2058	0.3770	6.4688	1.643	0.7248	2.092	2.0944	2.7597
0.8087	1.0813	1.8004	0.2082	5.9193	2.2401	1.3165	1.5805	1.4983	2.1871
0.8279	0.66018	2.2338	0.6349	5.5187	2.6754	1.7479	1.2298	1.0734	1.7906
0.847	0.54016	2.3573	0.756	5.4046	2.7994	1.8708	1.184	0.91349	1.6561
0.8661	0.07469	2.9901	1.3793	4.8198	3.4349	2.5006	0.65323	0.36169	1.1324
0.8852	1.1069	4.0524	2.425	3.8381	4.5018	3.5578	0.28318	0.69309	0.085736
0.9043	1.6258	4.5864	2.9506	3.3446	5.0381	4.0893	0.69978	1.3064	0.51596
0.9235	2.1981	5.1754	3.5304	2.8002	5.6297	4.6755	1.1565	1.0646	0.32808
0.9426	2.4457	5.4302	3.7812	2.5648	5.8856	4.9291	1.2753	0.49698	0.20695
0.9617	3.7001	6.7211	5.0519	1.3718	7.182	6.2138	2.3664	0.62999	0.11491
0.9808	6.3735	9.4724	7.7602	1.1709	9.9453	8.9521	4.8292	1.6423	0.93995
	2.0062	2.9704	1.9904	4.9758	3.4152	2.481	1.8488	1.3479	1.5477

For benzen

Tr	Calperon	veter 1	veter 2	chen	kistiakowsky	Fishten	Riedel b.p.	Carruth Kobayashi	pitzer	Halim and Still
0.498	1.229	0.492	0.1519	0.016	1.4225	-2.1086	0.2775	0.97272	0.5474	0.54741
0.534	1.8833	1.15	0.813	0.67833	2.0755	-1.4322	0.38682	1.6116	1.1532	1.1532
0.569	2.4242	1.696	1.3601	1.2259	2.6154	-0.87293	0.93603	2.1346	1.7163	1.7163

0.60493	2.9632	2.2392	1.905	1.7716	3.1534	-0.31569	1.4833	2.6529	2.0286	2.0286
0.64051	3.4304	2.7098	2.3773	2.2445	3.6196	0.16725	1.9576	3.0957	2.3114	2.3114
0.6761	3.8561	3.1387	2.8076	2.6754	4.0445	0.60731	2.3897	3.4926	2.7386	2.7386
0.71168	4.1004	3.3849	3.0546	2.9227	4.2883	0.85991	2.6378	3.702	3.2138	3.2138
0.72947	4.3988	3.6854	3.3562	3.2247	4.5861	1.1683	2.9407	3.981	3.5666	3.5666
0.74726	4.5637	3.8516	3.5229	3.3917	4.7507	1.3388	3.1081	4.1239	3.7471	3.7471
0.76506	4.7672	4.0566	3.7286	3.5976	4.9538	1.5492	3.3147	4.3031	4.1358	4.1358
0.78285	4.9989	4.29	3.9629	3.8322	5.185	1.7887	3.5499	4.5078	4.4515	4.4515
0.80064	5.2511	4.5442	4.2179	4.0876	5.4368	2.0495	3.8061	4.7297	4.5862	4.5862
0.81843	5.5511	4.8463	4.5211	4.3912	5.7361	2.3596	4.1105	4.9953	4.8416	4.8416
0.83622	5.9363	5.2344	4.9105	4.7811	6.1206	2.7578	4.5016	5.3415	5.0526	5.0526
0.85402	6.363	5.6644	5.3419	5.2131	6.5465	3.199	4.9349	5.7232	5.394	5.394
0.87181	6.9328	6.2384	5.9179	5.7899	7.1152	3.788	5.5134	6.2405	5.9054	5.9054
0.8896	7.6499	6.9609	6.6429	6.5158	7.8309	4.5294	6.2415	6.8954	6.416	6.416
0.90739	8.4563	7.7732	7.458	7.3321	8.6357	5.363	7.0601	7.6249	7.218	7.218
0.92518	9.4849	8.8095	8.4978	8.3733	9.6622	6.4263	8.1044	8.5563	8.8078	8.8078
0.94298	10.878	10.213	9.9064	9.7838	11.053	7.8667	9.519	9.8203	10.813	10.813
0.96077	12.799	12.148	11.848	11.728	12.97	9.8525	11.469	11.553	13.595	13.595
0.97856	16.444	15.821	15.533	15.418	16.608	13.621	15.17	14.882	18.069	18.069
0.99635	33.765	33.271	33.043	32.951	33.895	31.527	32.755	31.448	56.647	56.647
0.99991	78.648	78.489	78.416	78.386	78.69	77.927	78.323	76.85	98.489	98.489
	3.655525	2.9366	2.6049	2.4723	3.8443	1.1882	2.2323	3.2756	2.8497	2.8497

For Toluene

Tr	Calyepon	Veter 1	Veter 2	Chen	kistiakowsky	Fishten	Riedel n.b.	Carruth Kobayashi	pitzer	Halim and Still
0.30951	2.2279	2.2716	2.1787	2.8825	1.9024	5.3864	3.4218	2.1787	4.4458	4.4458
0.3264	1.7876	1.8312	1.7318	2.4395	1.4636	4.9326	2.9765	1.7318	3.3441	3.3441
0.3433	1.4184	1.4618	1.3558	2.0678	1.0955	4.552	2.6029	1.3558	2.5033	2.5033
0.3602	1.0287	1.072	0.95938	1.6757	0.70706	4.1503	2.2087	0.95938	1.9078	1.9078
0.3771	0.61761	-0.6607	0.54154	1.2619	0.29724	3.7264	1.7928	0.54154	1.268	1.268
0.394	0.29809	0.34105	0.21526	0.94036	0.021262	3.397	1.4695	0.21526	0.87879	0.87879
0.4109	0.047297	0.09015	0.042344	0.68796	0.27126	3.1385	1.2158	0.042344	0.62944	0.62944
0.4278	0.20411	0.16137	0.30055	0.43494	0.52187	2.8793	0.96146	0.30055	0.47219	0.47219
0.4447	0.38736	0.3447	0.49066	0.25052	0.70453	2.6904	0.77608	0.49066	0.40995	0.40995
0.4616	0.59611	0.55354	0.70624	0.040431	0.91262	2.4752	0.56489	0.70624	0.15049	0.15049
0.4785	0.85592	0.81346	0.97281	0.22104	1.1716	2.2074	0.30204	0.97281	0.30139	0.30139
0.4954	1.0024	0.95999	1.1262	0.36845	1.3176	2.0564	0.15387	1.1262	0.30452	0.30452
0.51229	1.082	1.0397	1.2128	0.44862	1.397	1.9742	0.073274	1.2128	0.33792	0.33792
0.52919	1.0942	1.0518	1.2319	0.46084	1.4091	1.9617	0.060991	1.2319	0.43074	0.43074
0.54609	1.2362	1.1939	1.3808	0.60377	1.5507	1.8153	0.082691	1.3808	0.70621	0.70621
0.56299	1.2892	1.247	1.4407	0.65715	1.6035	1.7606	0.13635	1.4407	0.84477	0.84477
0.57989	1.4045	1.3623	1.5627	0.77313	1.7184	1.6418	0.25293	1.5627	0.90853	0.90853
0.59679	1.4323	1.3901	1.5975	0.80116	1.7462	1.6131	0.28111	1.5975	0.87644	0.87644
0.61369	1.6071	1.565	1.7788	0.97705	1.9204	1.433	0.45793	1.7788	0.96376	0.96376
0.63059	1.7262	1.6841	1.9044	1.0969	2.0391	1.3102	0.57842	1.9044	1.0406	1.0406
0.64749	1.7638	1.7218	1.9485	1.1348	2.0766	1.2714	0.61647	1.9485	1.0788	1.0788
0.66439	1.9939	1.9519	2.1845	1.3663	2.3059	1.0343	0.84918	2.1845	1.3363	1.3363
0.68128	2.1802	2.1383	2.3768	1.5538	2.4916	0.84218	1.0377	2.3768	1.5985	1.5985
0.69818	2.2698	2.228	2.4722	1.644	2.581	0.74978	1.1284	2.4722	1.8114	1.8114
0.71508	2.4657	2.4239	2.6733	1.8411	2.7762	0.54789	1.3265	2.6733	2.2099	2.2099
0.73198	2.7521	2.7105	2.9645	2.1294	3.0618	0.25256	1.6163	2.9645	2.5196	2.5196

0.74888	2.8747	2.8331	3.0916	2.2527	3.1839	0.12623	1.7403	3.0916	2.7339	2.7339
0.76578	2.9561	2.9145	3.1771	2.3347	3.2651	0.042295	1.8227	3.1771	3.0407	3.0407
0.78268	3.0382	2.9967	3.2626	2.4173	3.3469	0.042335	1.9057	3.2626	3.2378	3.2378
0.79958	3.1052	3.0637	3.332	2.4847	3.4137	0.11139	1.9735	3.332	3.2154	3.2154
0.81648	3.1767	3.1352	3.4048	2.5567	3.485	0.18513	2.0458	3.4048	3.2773	3.2773
0.83338	3.3152	3.2738	3.5427	2.696	3.623	0.32786	2.1859	3.5427	3.3011	3.3011
0.85027	3.2394	3.1979	3.4648	2.6197	3.5475	0.24972	2.1092	3.4648	3.1534	3.1534
0.86717	3.2725	3.2311	3.4928	2.6531	3.5805	0.28387	2.1427	3.4928	3.1748	3.1748
0.88407	3.1411	3.0997	3.3527	2.5209	3.4495	0.14846	2.0099	3.3527	2.9616	2.9616
0.90097	2.9179	2.8763	3.115	2.2962	3.227	0.081679	1.784	3.115	2.5286	2.5286
0.91787	2.8358	2.7942	3.0095	2.2136	3.1452	0.16629	1.701	3.0095	2.9452	2.9452
0.93477	2.6114	2.5697	2.7473	1.9878	2.9215	0.39765	1.4739	2.7473	3.322	3.322
0.95167	2.5825	2.5407	2.6543	1.9586	2.8927	0.42747	1.4447	2.6543	4.1099	4.1099
0.96857	2.9451	2.9035	2.8969	2.3236	3.2541	0.053631	1.8115	2.8969	5.2941	5.2941
0.98547	5.0211	4.9805	4.6843	4.4129	5.3236	2.0866	3.9118	4.6843	7.7926	7.7926
	1.995161	1.9678	2.0923	1.6216	2.2128	1.5739	1.3904	2.1117	2.1309	2.1309

For Butadiene

Tr	Calyepron	Veter 1	Veter 2	Chen	kistiakowsky	Fishten	Riedel n.b.	Carruth Kobayashi	pitzer	Halim and Still
0.40741	8.3723	8.7448	7.943	8.7226	7.7206	11.816	8.9747	8.273	0.40741	0.40741
0.52506	3.6273	3.9835	3.2168	3.9622	3.0042	6.9207	4.2034	3.6131	0.52506	0.52506
0.61918	0.63872	0.29725	1.0324	0.3176	1.2362	2.5191	0.0864	0.56656	0.61918	0.61918
0.64271	0.75364	0.41257	1.1468	0.4329	1.3505	2.4005	0.2019	0.65519	0.64271	0.64271
0.66624	0.87932	0.53867	1.272	0.5589	1.4754	2.2708	0.3283	0.75208	0.66624	0.66624
0.68976	1.0801	0.74013	1.472	0.7604	1.6749	2.0637	0.5302	0.92123	0.68976	0.68976
0.71329	1.196	0.85646	1.5875	0.8767	1.7902	1.9441	0.6468	1.002	0.71329	0.71329

0.73682	1.3203	0.98114	1.7112	1.0014	1.9137	1.8158	0.7717	1.0869	0.73682	0.73682
0.76035	1.4793	1.1408	1.8697	1.1609	2.0718	1.6517	0.9317	1.2017	0.76035	0.76035
0.78388	1.5385	1.2001	1.9286	1.2203	2.1306	1.5907	0.9912	1.21	0.78388	0.78388
0.80741	1.6208	1.2827	2.0106	1.3028	2.2124	1.5058	1.0739	1.2336	0.80741	0.80741
0.83094	1.6038	1.2656	1.9936	1.2858	2.1955	1.5233	1.0568	1.1471	0.83094	0.83094
0.85447	1.7296	1.3919	2.1189	1.412	2.3205	1.3935	1.1833	1.1903	0.85447	0.85447
0.878	1.955	1.6181	2.3434	1.6381	2.5446	1.1609	1.41	1.3145	0.878	0.878
0.90153	2.084	1.7475	2.472	1.7676	2.6729	1.0278	1.5398	1.3131	0.90153	0.90153
0.92506	2.1146	1.7782	2.5025	1.7983	2.7033	0.99623	1.5705	1.1659	0.92506	0.92506
0.94859	2.8091	2.4751	3.1942	2.495	3.3936	0.27969	2.2689	1.6034	0.94859	0.94859
0.97214	0.08003	0.26336	0.4759	0.24289	0.68089	3.0955	0.4754	1.6493	0.97214	0.97214
0.97736	2.3665	2.0309	2.7533	2.0509	2.9536	0.73639	1.8238	0.50132	0.97736	0.97736
	1.960469	1.7236	2.2655	1.7372	2.4234	2.4586	1.5826	1.6	1.6342	1.6342

For Methylcycopentane

Tr	Calyperon	veter 1	veter 2	chen	kistiakowsky	Fishten	Riedel n.b	Carruth Kobayashi	pitzer	Halim and Still
0.2499	3.2126	2.9988	4.5775	3.0803	4.4459	6.2424	3.4475	1.9243	4.0133	4.0133
0.2875	2.3744	2.1624	3.7283	2.2432	3.5978	5.3796	2.6075	1.0972	3.5451	3.5451
0.3249	1.6841	1.4735	3.0288	1.5538	2.8992	4.6691	1.9156	0.41673	1.6839	1.6839
0.3625	1.4711	1.2609	2.813	1.341	2.6836	4.4498	1.702	0.20823	0.84805	0.84805
0.4000	1.0673	0.85796	2.4039	0.93777	2.275	4.0341	1.2973	0.18781	0.23002	0.23002
0.4376	0.65132	0.44284	1.9824	0.52231	1.8541	3.6059	0.88041	0.59499	0.02217	0.02217

0.4751	0.26068	0.053	1.5866	0.13217	1.4588	3.2038	0.48888	0.97603	0.5966	0.5966
0.5126	0.14354	0.35038	1.177	0.27153	1.0497	2.7877	0.08374	1.3691	0.75313	0.75313
0.5502	0.60652	0.8124	0.70791	0.73392	0.58119	2.3112	0.38029	1.8187	1.3427	1.3427
0.5878	1.1282	1.333	0.17935	1.2549	0.053299	1.7742	0.90314	2.3242	1.7604	1.7604
0.6252	1.4388	1.6429	0.13535	1.5651	0.261	1.4545	1.2144	2.6188	1.8358	1.8358
0.6628	1.899	2.1022	0.60171	2.0248	0.72677	0.98071	1.6758	3.0581	2.246	2.246
0.7004	2.0717	2.2746	0.77668	2.1972	0.90152	0.80295	1.8488	3.209	2.584	2.584
0.7379	2.3621	2.5644	1.0709	2.4873	1.1954	0.50405	2.1399	3.4707	3.0281	3.0281
0.7755	2.3646	2.5668	1.0734	2.4897	1.1979	0.50148	2.1424	3.4399	3.3738	3.3738
0.8128	2.3563	2.5585	1.065	2.4814	1.1895	0.51006	2.134	3.3867	3.2439	3.2439
0.8552	2.215	2.4176	0.92187	2.3404	1.0465	0.65545	1.9925	3.1838	2.8535	2.8535
0.8880	1.8039	2.0073	0.50535	1.9298	0.63054	1.0786	1.5804	2.6818	2.2114	2.2114
0.9256	0.29848	0.505	1.02	0.42627	0.89291	2.6283	0.071555	1.0282	1.3005	1.3005
0.9631	1.1442	0.93466	2.4817	1.0145	2.3528	4.1133	1.3744	0.75412	1.6258	1.6258
	1.527692	1.566	1.5918					1.8874	1.9549	1.9549

For Ethylcyclopentane

Tr	Calperon	veter 1	veter 2	chen	kistiakowsky	Fishten	Riedel n.b	Carruth Kobayashi	pitzer	Halim and Still
0.26892	2.5222	1.808	3.752	2.0407	3.6421	5.3032	2.5623	1.3628	4.9599	4.9599
0.30404	2.1665	1.4547	3.392	1.6867	3.2825	4.9378	2.2064	0.99463	3.5498	3.5498
0.33916	1.8366	1.1271	3.0581	1.3583	2.9489	4.599	1.8764	0.65176	1.9107	1.9107
0.37428	1.5525	0.84497	2.7706	1.0755	2.6617	4.3071	1.5921	0.35395	1.1464	1.1464
0.40939	1.0533	0.34927	2.2655	0.5787	2.1571	3.7944	1.0928	0.15653	0.55563	0.55563
0.44451	0.55425	0.1463	1.7604	0.081998	1.6526	3.2818	0.59352	0.667	0.28116	0.28116
0.47963	0.17596	0.52195	1.3776	0.29451	1.2702	2.8933	0.21509	1.0583	0.33753	0.33753

0.51475	0.19488	0.89021	1.0023	0.66361	0.89528	2.5124	0.1559	1.4423	0.53721	0.53721
0.54987	0.51805	1.2111	0.67526	0.98527	0.56858	2.1804	0.4792	1.7794	1.1146	1.1146
0.58499	0.83669	1.5275	0.35279	1.3024	0.24646	1.8532	0.79796	2.112	1.4254	1.4254
0.62011	1.2599	1.9478	0.07553	1.7237	0.18141	1.4184	1.2214	2.5478	1.6985	1.6985
0.65522	1.6485	2.3337	0.46878	2.1104	0.57424	1.0193	1.6101	2.9492	2.0841	2.0841
0.69034	1.9467	2.6298	0.7705	2.4072	0.87564	0.71307	1.9084	3.2609	2.5447	2.5447
0.72546	2.2928	2.9735	1.1208	2.7517	1.2255	0.35756	2.2546	3.6193	3.2032	3.2032
0.76058	2.4669	3.1464	1.2969	2.9249	1.4015	0.17876	2.4288	3.8066	3.6114	3.6114
0.7957	2.4789	3.1584	1.3092	2.937	1.4137	0.16635	2.4409	3.8321	3.7404	3.7404
0.83082	2.542	3.221	1.373	2.9997	1.4775	0.10156	2.504	3.9042	3.6895	3.6895
0.86594	2.1279	2.8097	0.95387	2.5875	1.0588	0.52695	2.0896	3.4985	3.1867	3.1867
0.90105	1.6432	2.3284	0.46335	2.1051	0.56881	1.0248	1.6047	3.0086	2.4207	2.4207
0.93617	0.48835	1.1816	0.70531	0.9557	0.59861	2.2109	0.44949	1.8215	2.4471	2.4471
0.97129	1.8924	1.1826	3.1147	1.4139	3.0054	4.6563	1.9322	0.71151	1.9558	1.9558
	1.533261	1.7521	1.5266	1.6659	1.5098	2.2875	1.5246	2.0733	2.2096	2.2096

Appendix C

Results of AAD% of latent heat of vaporization at various temperatures for mixtures

mixtures	Tr	Carruth kobashi	pitzer	Teja
Ethanol 96% -wate	0.9687	22.706	21.593	0.3332
Pentane19.7%-cyclohixane	0.8234	4.6009	4.4284	1.7653
Pentane19.7%-cyclohixane	0.8553	11.929	11.626	6.0701
Pentane19.7%-cyclohixane	0.9039	8.4766	7.983	3.0681
pentane35.8%-cyclohixane	0.8245	7.7695	7.5977	0.84459
pentane35.8%-cyclohixane	0.8328	8.1709	7.9585	0.85648
pentane35.8%- cyclohixan	0.8410	8.5346	8.2857	0.88922
pentane35.8%-cyclohixane	0.8492	8.8067	8.5238	0.93844
pentane35.8%-cyclohixane	0.8575	8.9345	8.6184	1.0006
pentane35.8%-cyclohixane	0.8657	8.9874	8.6408	1.1432
pentane35.8%- cyclohixan	0.8739	9.0314	8.6589	1.4002
pentane61.9%-cyclohixane	0.8303	4.5156	4.2902	4.8378
Pentane61.9%- cyclohixan	0.8621	5.2116	4.8896	3.3081
pentane61.9%-cyclohixane	0.9136	7.7509	7.5455	1.9174
benzen80.3%- octane	0.8432	2.0778	1.9659	2.2232
benzen80.3%- octane	0.8897	2.1695	2.0577	2.0887
benzen80.3%- octane	0.927	1.0814	0.96835	2.2474
benzen80.3%- octane	0.9569	2.0595	1.9476	2.8029
Benzen90.1%- Octane	0.8401	0.54202	0.86264	3.4538
Benzen90.1%- Octane	0.9222	3.301	3.1549	4.5054
Benzen90.1%- Octane	0.952	4.0735	2.3641	1.4648
benzen20.2%-pent	0.8655	3.7578	3.4353	0.38778
benzen20.2%- pentane	0.8743	3.7204	3.2936	0.35791
benzen20.2%- pentane	0.8920	3.4586	3.0347	0.32687
benzen20.2%- pentane	0.9008	3.2595	2.9184	0.32135
benzen20.2%- pentane	0.9186	2.7821	2.7139	0.32304
benzen20.2%- pentane	0.9451	1.3464	2.4665	0.73169

benzen20.2%- pentane	0.9539	0.71241	2.4005	0.94406
Benzen40.6%- pentane	0.8992	8.27	7.7109	0.58
Benzen40.6%- pentane	0.9373	7.2867	7.9794	3.8345
Benzen40.6%- pentane	0.9874	20.084	15.723	2.9608
Benzen61.9%- pentane	0.8379	7.737	7.4553	3.9628
Benzen61.9%- pentane	0.8896	9.7646	9.3018	1.3087
Benzen61.9%- pentane	0.9278	8.1118	8.4418	2.3741
Benzen 61.9%- pentane	0.9759	4.615	1.1516	2.5346
Benzen 81.6%- pentane	0.7157	13.505	14.026	1.6722
Benzen81.6%- pentane	0.74	11.901	12.032	1.6966
Benzen81.6%- pentane	0.7643	10.532	10.402	1.7722
Benzen81.6%- pentane	0.7886	9.4027	9.1161	1.9024
Benzen81.6%- pentane	0.8129	8.5197	8.1551	2.0904
Benzen81.6%- pentane	0.8372	7.889	7.4995	2.3399
Benzen81.6%- pentane	0.8615	7.5165	7.1299	2.654
Benzen81.6%- pentane	0.8834	7.4072	7.0259	2.9963
Benzen81.6%- pentane	0.9191	7.5979	7.6174	5.2726
Benzen81.6%- pentane	0.9101	7.5035	7.3875	4.5659
Benzen81.6%- pentane	0.8858	7.4077	7.0294	3.0486

الخلاصة

للتنبؤ بالحرارة الكامنة للتبخر للمركبات النقية هنالك ستة عشر طريقه مختلفة وهنالك ثلاث طرق للتنبؤ بالحراره الكامنه للتبخر للخلائط الثنائية متوفرة في الكتب و المقالات و كل هذه الطرق قد تم تقيمها في هذا العمل.

للتنبؤ بالحرارة الكامنة للتبخر للمركبات النقية في درجات الحرارة المختلفة هنالك مصدرين اما عن طريق قانون الحاله الاول عن طريق الضغط البخاري وهنالك تسعه طرق لحساب الحرارة الكامنة للتبخر عن طريق هذين المصدرين وهذه الطرق تتنبأ بالحرارة الكامنة في أي درجه حرارة مباشره , ألدقه في هذه الطرق مختلفة , البعض من هذه الطرق تكون دقيقه مع المركبات الغير قطبيه ولكن لا تكون دقيقه هي أفضل طريقه من بين التسعة طرق حيث انها Halim stiel عندما تتعامل مع المركبات القطبية . تتعامل مباشره مع القطبية للمركبات القطبية حيث قدمت كما هو معروف ب معامل القطبية للمركبات لثمانية عشر مركب نقي غير قطبي ومن جهة 1.552القطبية وكان معدل الانحراف الكلي المطلق هو % لستة مركبات قطبيه 2.8476 أخرى كان معدل الانحراف الكلي المطلق%.

للتنبؤ بالحرارة الكامنة للتبخر في درجه الغليان الطبيعية هنالك سبعه طرق متوفرة في المقالات , أعطت اقل معدل للانحراف المطلق مقارنه بالنتائج Riedel at normal boiling point طريقه معدل 4.439% و 1.271%مركب نقي غير قطبي هو 32ألمختبريه حيت إن معدل الانحراف المطلق ل مركب نقي قطبي .للتنبؤ بالحرارة الكامنة للتبخر في أي درجه حرارة عن طريق 29الانحراف المطلق ل التنبؤ بالحرارة الكامنة في نقطعه الغليان الطبيعية نستخدم معادله تصف العلاقة بين الحرارة الكامنة تعطي First Veter. ووجد ان Watsonوالتغير في درجه الحرارة وأفضل معادله متوفره هي معادله اقل معدل للانحراف المطلق للحرارة الكامنة في أي درجه حرارة عن طريق درجه الغليان الطبيعية من لثمانية عشر مركب نقي غير قطبي 1.344%بين هذه السبعة طرق حيت كان معدل الانحراف المطلق هو % لستة مركبات نقيه قطبيه.3.3426و

بصوره عامه كل الطرق التي تتنبأ بالحرارة الكامنة للتبخر في درجه الغليان الطبيعية لا تكون دقيقه عندما تتعامل مع المركبات القطبية . وفي هذا العمل تغلب على هذه المشكلة حيث طور معادله مرتان لتعطي اقل معدل للانحراف المطلق من بين الطرق المتوفرة للتنبؤ بالحرارة Kistiakowsky الكامنة للتبخر في درجه الغليان الطبيعية .في كلا التطويران قسمت المركبات إلى ثلاث مجاميع :مجموعه غير قطبيه والكحول (من ضمنها الماء) و مجوعه قطبيه .

التطوير الأول يستعمل المعادلة الأصلية نفسها ولكن يقسم الثوابت إلى الثلاث المجاميع المذكورة سابقا ولكل مجوعه ثوابتها الخاصة

$$\lambda_{vap\ n.b} = (A + R \ln T_b)\, T_b$$

Groups	Value of A
non polar component	36.1
alcohols	56.44
other polar component	41.36

4.4036مركب من الكحول والمركبات القطبية الأخرى هو 34معدل الانحراف الطلق لهذا العمل ل Kistiakowsky. على التوالي لطريقه 6.312 و24.97على التوالي , مقارنه مع 3.38و
التطوير الثاني أكثر تعقيدا من الأول وأصبحت المعادلة كما يأتي

$$\lambda_{vap\ n.b} = R.T_b\ (a + b\ ln\ P_c + c\ ln\ T_b)$$

في هذا التطوير ادخل الضغط الحرج للمركبات في المعادلة بالأضافه إلى التقسيمات الثلاثة وأصبح في المعادلة ثلاث ثوابت مختلفة لكل مجموعه وقيم الثوابت كما يأتي

Group	a	b	c
Non polar	1.18306	.49459	1.2634
alcohol	32.8115	.22592	-3.48002
Other polar	6.6869	-0.72627	1.157612

مركب غير قطبي ,الكحول والمركبات القطبية الأخرى هو 57المعدل الكلي للانحراف لهذا العمل ل التي أعطت Kistiakowsky على التوالي وبالمقارنة مع طريقه 2.933% و 2.2278و% 1.463% على التوالي . ونلاحظ ان هذا العمل يتنبأ بالحرارة الكامنة للتبخر 6.312%و 24.97 , 2.2095%% في درجه الغليان الطبيعية للمركبات القطبية بأقل معدل للانحراف المطلق . هذه العمل أبضا يطبق على التطوير الثاني يعطي اقل معدل للانحراف المطلقWatsonدرجات الحرارة المختلفة باستخدام معادله .
%مركب نقي غير قطبي هو 24من التطوير الأول , حيث ان معدل الانحراف المطلق للتطوير الثاني ل 2.575%. مركب نقي قطبي هوه 34 ومن جه اخرى أن المعدل الكلي للانحراف ف المطلق ل 1.462 وهو اقل انحراف من كل الطرق المتوفره للمركبات القطبية في درجه الغليان الطبيعية.
أما للخلاثط فهناك ثلاث طرق نستطيع ان نطبقها للتنبؤ بالحرارة الكامنة للتبخر للخلاط وأفضل هذه لستة 2.261% حيت ان معدل الانحراف الكلي المطلق لهذه الطريقه هو Tejaالطرق هي طريقه وأربعون نقطه .

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التقيم والتنبؤ من الحرارة الكامنة للتبخر في درجات الحرارة المختلفة للمركبات النقية والمخاليط الثنائية

رسالة
مقدمه إلى كليه الهندسة في جامعه النهرين وهي جزء من
متطلبات نيل درجه ماجستير علوم في الهندسة الكيمياوية

من قبل
محمد جبار عجرش
بكالوريوس علوم في الهندسة الكيمياويه 2006

جماد الأولى 1430
آيار 2009