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Faculty of Graduate Studies

**Modification of the Fixman's Analytic Function
in Binary Liquid Mixtures**

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III

Dedication

This thesis is dedicated to my father and mother, to my wife, as well as, to my brothers and sisters.

With respect and love.

Acknowledgement

I would like to express my greatest thanks and gratitude to my supervisor, Prof. Dr. Issam Rashid Abdelraziq for his helpful efforts.

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الإقرار

أنا الموقع ادناه مقدم الرسالة التي تحمل العنوان:

Modification of the Fixman's Analytic Function in Binary Liquid Mixtures

أقر بأن ما اشتملت عليه الرسالة إنما هو نتاج شخصي، باستثناء ما تمت الإشارة إليه أينما ورد، وأن هذه الرسالة ككل أو جزء منها لم يقدم من قبل لنيل أي درجة أو بحث علمي أو بحث لدى مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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VI
Table of Contents

No.	Contents	Page
	Dedication	III
	Acknowledgement	IV
	Declaration	V
	Table of Contents	VI
	List of Tables	VI
	List of Figures	X
	List of Abbreviations	XI
	Abstract	XII
	Chapter One: Introduction	1
1.1	Introduction	2
1.2	Literature Survey	4
1.3	Research Objective	11
1.4	Organization of The Thesis	11
	Chapter Two: Theory	12
2.1	Dynamic Renormalization Group Theory	13
2.2	Dynamic Scaling Theory	14
2.3	Mode-Coupling Theories	16
	Chapter Three: Results and Discussion	20
3.1	Results and Discussion	21
3.1.1	Fixman's analytic function and scaling function	21
3.1.2	Modification of Fixman's analytic function	24
3.1.3	modification of Fixman's scaling function	27
3.2 3	Methylpentane+Nitrothane	30
3.3	Nitrobenzene+n Hexane	35
	Chapter Four: Conclusion	4
	References	46
	Appendix A	57
	Appendix B	63
	Appendix C	69
	الملخص	F

List of Tables

No.	Table	Page
Table (3.1)	Numerical values of Fixman's scaling function $I_F(\omega^*)$ using Fixman's analytic function $K_F(x) = x^2(1 + x^2)$.	22
Table (3.2)	Scaling function $I_{m'F}(\omega^*)$ using our modification analytic function with form $K_m(x) = 2x^2(1 + 10x^2 + 8x^3 + 6x^4)$.	25
Table (3.3)	Numerical values of our modification of Fixman's scaling function $I_{mF}(\omega^*) = (\frac{\gamma_0}{\gamma_0-1} + 2.30) \int \left[\frac{x^2 dx}{\{1+x^2\}^2} \right] \left[\frac{\omega^* K_m(x)}{\{K_m^2(x) + \omega^{*2}\}} \right]$ as a function of reduced frequencies.	28
Table (3.4)	The necessary data which are needed to calculate $A_F(T)$ for 3Methylpentane+Nitrothane.	31
Table (3.5)	The values of reduced frequency, sound velocity, and critical amplitude of binary liquid mixture 3Methylpentane+ Nitroethane at $f = 1\text{MHz}$, where $\omega_0 = 1.23 \times 10^{11}$.	32
Table (3.6)	Measured absorption per wavelength α_λ of a critical mixture of 3methylpentane+nitroethane as a function of temperature at different frequencies. Data are taken from Garland and Sanchez paper (Garland and Sanchez, 1983). All values of α_λ are given in units of 10^{-4} Np.	33
Table (3.7)	The necessary data which are needed to calculate $A_F(T)$ for Nitrobenzene+n Hexane.	36
Table (3.8)	The values of reduced frequency, sound velocity, and critical amplitude of binary liquid mixture Nitrobenzene+n Hexane.	37
Table (3.9)	Absorption data for the critical mixture Nitrobenzene+n Hexane.	38
Table (3.10)	Absorption per wavelength data for the critical mixture Nitrobenzene+n Hexane.	40
Table (4.1)	The analytic and scaling functions of Fixman and our modification of the analytic and scaling functions.	45
Table (a1)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 1$ MHz for 3Methylpentane+Nitroethane, and $\omega_0 = 1.23 \times 10^{11}$ Hz.	57

VIII

Table (a2)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 3$ MHz for 3Methylpentane+Nitreothane, and $\omega_0 = 1.23 \times 10^{11}$ Hz.	58
Table (a3)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 7$ MHz for 3Methylpentane+Nitreothane, and $\omega_0 = 1.23 \times 10^{11}$ Hz.	59
Table (a4)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 9$ MHz for 3Methylpentane+Nitreothane, and $\omega_0 = 1.23 \times 10^{11}$ Hz.	60
Table (a5)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 11$ MHz for 3Methylpentane+Nitreothane, and $\omega_0 = 1.23 \times 10^{11}$ Hz.	61
Table (a6)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 17$ MHz for 3Methylpentane+Nitreothane, and $\omega_0 = 1.23 \times 10^{11}$ Hz.	62
Table (b1)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 5$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz.	63
Table (b2)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 7$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz.	64
Table (b3)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 10$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz.	65
Table (b4)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 15$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz.	66

Table (b5)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 21$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz.	67
Table (b6)	Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 25$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz.	68
Table (c1)	Numerical values of Fixman's scaling function $I_F(\omega^*)$ using Fixman's analytic function $K_{m1}(x) = x^2(1 + x^2 + x^3)$.	70
Table (c2)	Numerical values of Fixman's scaling function $I_F(\omega^*)$ using Fixman's analytic function $K_{m1}(x) = x^2(1 + x^2 + \frac{1}{x})$.	72

List of Figures

No.	Figure Caption	Page
Fig.1.	Fixman's scaling $I_F(\omega^*)$ function using Fixman's analytic function $K_F(x) = x^2(1 + x^2)$	23
Fig.2.	Scaling function $I_{m'F}(\omega^*)$ using our modification of Fixman's analytic function $K_m(x) = 2x^2(1 + 10x^2 + 8x^3 + 6x^4)$.	26
Fig.3.	Fixman's scaling function using Fixman's analytic function in solid line, and scaling function using our modification analytic function in dashed line.	26
Fig.4.	Our modification of Fixman's scaling function $I_{mF}(\omega^*)$.	29
Fig.5.	Fixman's and our modification of Fixman's scaling function as a function of reduced frequency.	30
Fig.6.	Experimental absorption values $(\frac{\alpha_\lambda}{\pi u^2 A_F(T)})$ versus reduced frequency ω^* for 3Methylpentane+Nitrothane according to Fixman theory along with the theoretical scaling integral $I_F(\omega^*)$.	34
Fig.7.	Experimental absorption values $(\frac{\alpha_\lambda}{\pi u^2 A_F(T)})$ versus reduced frequency (ω^*) for 3Methylpentane+Nitrothane according to modification Fixman theory along with the theoretical scaling integral in solid line.	35
Fig.8.	Temperature dependence of absorption for the critical binary mixture of Nitrobenzene+n Hexane above T_c (Abdelraziq <i>et al</i> , 1990).	39
Fig.9.	The experimental value $(\frac{\alpha_\lambda}{\pi u^2 A_F(T)})$ versus reduced frequency ω^* for Nitrobenzene+n Hexane according to Fixman theory along with the theoretical scaling function $I_F(\omega^*)$ shown in solid line.	41
Fig.10.	The experimental value $(\frac{\alpha_\lambda}{\pi u^2 A_F(T)})$ versus reduced frequency ω^* for Nitrobenzene+n Hexane according to modification Fixman's theory along with the modified theoretical scaling function $I_{mF}(\omega^*)$ shown in solid line.	42
Fig.c1.	Fixman's scaling function using Fixman's analytic function in solid line, and Fixman's scaling function using first modification analytic function in dashed line.	71
Fig.c2.	Fixman's scaling function using Fixman's analytic function in solid line, and Fixman's scaling function using second modification analytic function in dashed line.	73

List of Abbreviations

T_c	Critical temperature
C_p	Heat capacity at constant pressure
C_{pb}	Background heat capacity at constant pressure
C_{pc}	Classical specific heat at constant pressure
D_0	Diffusion coefficient
χ	Critical concentration
γ_0	Ratio of heat capacities at constant pressure and volume
μ_0	Viscosity
ξ	Correlation length
$\text{\AA}$	Angstrom
cP	Centipoise
FB	Ferrel-Bhattacharjee
Fig.	Figure
MCT	Mode-Coupling Theories
Vs.	Versus
ρ	Mass Density
K	Kelvin
$I_F(\omega^*)$	Fixman's scaling function using Fixman's analytic function
$I_{m'F}(\omega^*)$	Fixman's scaling function using our modification of Fixman's analytic function
$I_{mF}(\omega^*)$	Our modification of Fixman's theory

Modification of the Fixman's Analytic Function in Binary Liquid Mixtures**By****Diya Aldeen Adnan Abu Arra****Supervisor****Prof. Issam Rashid Abdelraziq****Abstract**

The mode-coupling theory of Fixman failed to explain the experimental behavior of the binary liquid mixtures at critical concentration and above critical temperature. The analytic function of Fixman's theory was modified in order to get an agreement with the experimental behavior of the binary liquid mixtures at critical concentration and above the critical temperature. Ultrasonic absorption and velocity of some binary liquid mixtures were used to test the validity of the Modified-Fixman's theory. It is found that the ratio of heat capacities $\gamma_0 = \frac{c_p}{c_v}$ (at constant pressure and volume) of the binary liquid mixtures is the term which plays the role to modify the Fixman's theory to get a good agreement with the experimental behavior.

Chapter One

Introduction

1.1: Introduction

Pure substances are substances that have a uniform thermodynamic properties and invariable composition, such as, water, helium, carbon dioxide, and nitrogen, which pure substance exist in three principle phase, solid, liquid, and gas (Kendig *et al.*, 1964). Pure substances not only contains single element, but it contains two or more substance if it's homogenous, such as, ice and water, water and steam (Fenner, 1981).

Binary mixture is a system contains two systems that not have a homogenous composition, which occurs of phase separation of that component when there is temperature under critical point; but at temperature highest than critical temperature there is a homogenous phase and form a single (Wheeler, 1975).

Critical point of binary mixture is a point at which binary system behaves the same homogenous phase under the same condition pressure, specific heat, viscosity, and thermal conductivity (Rice, 1949).

The theoretical understanding of liquid-liquid mixture is very important. The knowledge of physicochemical properties of these mixtures are important for many chemical process industries. Petroleum and petrochemical are some examples to be mentioned. These types of mixtures are commonly used in industries where physicochemical processes are involved to handle the mixtures of hydrocarbons, alcohols, aldehydes and ketones. Importantly, for accurate designing equipment, it is necessary to know the interaction between the components of mixtures (Rice, 1949; Wheeler and Griffiths, 1970; Hildebrand, 1975, D'Espagnat, 1999).

The theories describing critical absorption of the binary mixture based on the mode-coupling theories so that it is taken only the effect of two heat-mode states. These theories are based on the view that understanding the fluctuations that occur in those binary mixture rather than focus on microscopic aspects (Botchand and Fixman, 1965), which made it a viable theories to give important information about how to act on the binary liquid mixture when it reaches the critical points (Fuchs *et al.*, 1998).

The first theory of mode coupling theories has been developed by Fixman to describe the absorption and dispersion of sound near critical point of binary mixture, it predicts the large absorption of sound near critical point (Fixman 1962, Gutschickt *et al.*, 1971).

The simple fluid systems can be studied by using the ultrasonic pressure amplitude attenuation per wavelength $\alpha_\lambda(\omega)$ or absorption coefficient and the sound velocity $u(\omega)$, mainly when absorption coefficient of ultrasound near critical point is being observed. It was found that there is an increase in this absorption and loss of energy from the sound wave to the fluctuations near the critical point (Mistura, 1972; Shiwa, 1977; Garland and Sanchez, 1983).

The thermal conductivity of binary mixture is non-divergent, and it only becomes divergent at an azeotropic critical point where the Onsager kinetic coefficient for diffusion should be non-divergent (Mistura, 1972).

The anomalous viscosity observed experimentally near the critical region in binary mixture, this behavior was found as a function of temperature and

concentration (Sengers, 1972; D'Arrigo *et al.*, 1977; Nieuwoudt and Sengers, 1989; Abdelraziq *et al.*, 1992, Abdelraziq *et al.*, 1996).

The order parameter decay slowly in time near the critical point, which cause the phenomenon known as the critical slowing down of fluctuations (Oxtoby and Gelbart, 1974; Arcovito *et al.*, 1969)

The isothermal compressibility and the specific heat at constant pressure in the critical gases become anomalously large when it's approached the critical point (Fukuyama, 1968; Abdelraziq, 2003).

The developed theories described the ultrasonic absorption near critical point of binary mixture are named Renormalization-Group Theory and Dynamic Scaling Theory. It was found that its more suitable to describe the ultrasonic absorption than mode-coupling theories (Kroll and Ruhland, 1981; Ferrel and Battcharjee, 1981, 1985; Onuki, 1997).

1.2: Literature Survey

Fixman in his theory of Mode-Coupling theories, focused in the anomalous heat capacity has been made for the basis of a theory of ultrasonic attenuation (Fixman 1962).

Mode-Coupling theory was developed by Kawasaki in terms of critical behavior of bulk viscosity. He studied theoretically the sound attenuation and dispersion using the extended mode-mode coupling theory (Kawasaki, 1970; Shiwa and Kawasaki, 1981).

Fukuyama in his paper discussed the sound absorption coefficient in the critical gases theoretically by using the time-correlation function (Fkuyama, 1967). Vincent and Pings studied the re-derivation and the analysis of

Fixman's theory of excess sound absorption near fluid critical points (Vincent and Pings, 1971).

Mistura in his theory, focused on the critical behavior of complex specific heat, the sound absorption and dispersion near critical point in multicomponent system was studied. He found that, when the number of component increase, the absorption and dispersion should decrease (Mistura, 1972).

Calmettes analyzed the data of shear viscosity of pure liquid and binary liquid, which led him to consider its critical transport properties of pure and binary mixture (Calmettes, 1977).

Kroll and Ruhland described the propagation of acoustic wave in the vicinity of critical point using the renormalization group theory to determine the bulk viscosity (Kroll and Ruhland, 1981).

Ferrel and Bhattacharjee developed the dynamic scaling theory for the critical ultrasonic attenuation in a binary liquid mixture (Ferrel and Bhattacharjee, 1981, 1985). Tanaka and Wada showed that the form of critical amplitude in Kroll-Ruhland is the same as in the case of Ferrel and Bhattacharjee dynamic scaling theory (Tanaka and Wada, 1985). Hornowski and his group developed the modified version of the mode-coupling theory for the acoustic anomaly based on the critical behavior of a relaxing complex heat capacity (Hornowski and Labowski, 1990).

Researchers have been studied vapor-liquid and liquid-liquid phase equilibrium of binary mixtures containing helium by comparing the experimental results with predictions of MCT theory using equation of

state. They studied the critical absorption and dispersion of sound in fluids and mixtures (Kendig *et al.*, 1964; Wei and Sadus, 1996; Folk and Moser, 1999).

Bains and Breazeale have been measured the velocity and ultrasonic attenuation at the critical point of a binary mixture of β,β' -dichloroethyl ether+ Hexane at the frequencies of 1, 3, 5, 7, and 9 MHz (Bains and Breazeale, 1974)

Abdelraziq applied the modified mode-coupling theory by Hornowski (Hornowski and Labowski, 1990) to describe the critical attenuation of the binary system of Aniline + Cyclohexane. He found that there is poor agreement between this modification and experimental data above 10 MHz of reduced frequency (Abdelraziq, 2001). The ultrasonic absorption of binary mixtures Benzene + Coconut oil and β,β' -dichloroethyl ether+Hexane at 5, 7, 10, 15, 21, and 25 MHz, and binary mixture Nitrobenzene + n Hexane above critical point at homogeneous phase were measured by using dynamic scaling theory of Ferrel and Bhattacharjee (FB), and binary mixture Poly(ethylene glycol) +Water (Abdelraziq *et al.*, 1990, Esquivel-Sirvent *et al.*, 1993; Abdelraziq, 1996; Abdelraziq, 2005).

Volumetric behavior of binary mixtures at a temperature of 303.15K was studied by Wahab (Wahab *et al.*, 2002). However, Jiang and Prausnitz discussed the critical temperatures and pressures for hydrocarbon mixtures from an equation of state using renormalization-group theory correction (Jiang and Prausnitz, 2000).

The attenuation of sound in a critical mixture of 3Methylpentane + Nitroethane over the frequency range 1-17 MHz, Triethylamine + Water over the frequency range 1-27.3 MHz, and the binary mixture Cyclohexane+ Nitroethane over the range of frequency 3-27 MHz were measured by Garland and Sanchez, Garland and Nan Lai. (Garland and Sanchez, 1983; Sanchez and Garland, 1983; Sanchez *et al.*, 1983; Garland and Nan Lai, 1978).

The binary system Triethylamine + Water was studied by Behrends and his group over the range of frequency 100 KHz-500 MHz and have measured the diffusion coefficient, shear viscosities and heat capacity at various temperature of this binary mixture (Thoen *et al.*, 1978; Flewelling *et al.*, 1996; Behrends *et al.*, 2002).

The binary mixture Nitrobenzene + Isooctane was studied by Anancaraman at temperatures of 30.5, 34.8 and 44.8 °C for five frequencies between 4.5 and 16.5 MHz (Anantaraman *et al.*, 1966). Nitrobenzene + n Hexane mixture was studied by measuring ultrasonic absorption and velocity near the critical region over wide range of temperatures and frequencies (D'Arrigo and D. Sette, 1968; Abdelraziq *et al.*, 1990).

Ultrasonic absorption and velocity in Triethelymine + Water was measured by Yun at (3, 5, 10 and 15 MHz), he identified the critical temperature of solution through the Pulse-Echo method (Yun, 1970). The ultrasonic absorption of Aniline + Cyclohexane, Triethylamine + Water, and Nitrbenzene + Isooctane binary liquid mixtures were discussed by Bains

and Breazeale, and also Tanaka and his group (Bains and Breazeale, 1975, Tanaka *et al.*, 1982).

The thermal expansion coefficient of different binary mixtures near of their critical point, and universality of critical amplitudes of specific heat were measured by Klien and Woermann (Klien and Woermann, 1976).

Zlaeser and Beysens measured the refractive index, density, and turbidity for the binary mixture Triethylamine + Water (Zalczer and Beysens, 1990).

Pepin and his group measured the refractive-index behavior of binary mixture Triethylamine + Water in its homogeneous phase, they concluded that with existing density, there is an intrinsic effect opposite in sign to the density contribution (Pepin *et al.*, 1988).

The refractive index of binary mixture Nitroethane + Isooctane was measured by Bysens. He concluded that the refractive index depends on the density and local field effect (Bysens and Wesfried, 1979). Bloemen and other measured the anomaly specific heat of the binary system Triethylamine + Heavy water by constant heating rate method (Bloemen *et al.*, 1980).

Greer and Hocken measured the density as a function of temperature in one-phase region near critical point in binary mixture 3Methylpentane + Nitroethane (Greer and Hocken, 1975).

Fast and Yun compared between the experimental values of the slope of $\frac{\alpha}{f^2}$ versus $f^{-1.06}$ to the calculated values of the ultrasonic attenuation of the binary system Triethylamine + Water using the Dynamic Scaling Theory (Fast and Yun, 1985).

Experiments conducted on several binary mixture in terms of the ultrasonic spectrometry, dynamic light scattering, shear viscosity, and the specific heat, near its conslute point, these are, Nitroethane + n Pentanol, Methanol + Hexane, Nitroethane + Cyclohexane, 2,6-Dimethylpyridine +Water, and Carbontetrachloride+Coconut Oil(Abdelraziq, 1992; Iwanowski *et al.*, 2004; Iwanowski *et al.*, 2006, Behrends, 2004, Mirzaev, 2006).

The shear viscosity of 3Methylpentane+Nitroethane was measured by some researchers using different techniques, Iwanowski and his group discussed the dynamic light scattering measurements, and ultrasonic spectrometry for 3Methylpentane+Nitroethane, (Leister *et al.*, 1969; Tsai *et al.*, 1973; Clerke *et al.*, (1983) ; Harada *et al.*, 1980; Abdelraziq, 2002; Iwanowski *et al.*, 2006).

Using dynamic scaling theory, Abdelraziq analyzed the results of ultrasonic absorption and velocity measurements of binary mixture Perfluoromethyl cyclohexane+Carbon tetrachloride. The viscosity of the mixture was measured over the range of frequency 5, 7, 10, 21, and 25 MHz, above the critical point (Abdelraziq, 2000).

A study was performed in the binary mixture Perfluoromethylcyclohexane + Carbon tetrachloride in terms of the ultrasonic attenuation, specific heats at constant pressure, static and dynamic light scattering as well as shear viscosity (Mirzaev *et al*, 2007)

Harda and his group studied theortically the sound absorption and dispersion near critical point of binary liquid mixture using Kawaski mode-coupling theory. They showed that the existence of MCT approach

dropped down over a wide range of frequency and temperatures (Harda *et al.*, 1980).

The sound absorption and velocity of binary mixture 2, 2, 4-Trimethylpentane + Nitrobenzene was measured in range of temperature interval of (7mK to 30 K) from the critical value in the range of frequency (1 to 91 MHz) (Fenner, 1981).

The ultrasonic attenuation in the critical composition of Nitrobenzene+n Hexane was measured and analyzed in the range of frequency (50 KHz and 1GHz) by Mirzaev and Katze, the scaling function of this binary mixture was analyzed by predictions of F-B theory. (Mirzaev and Katze, 2012).

The diffusivity of liquid of binary mixture Nitrobenzene+n Hexane was measured by using Taylor dispersion method at critical composition at various temperatures by Lopes and his group, which the results agreed with theoretically predicted at critical point (Lopes *et al.*, 1992).

Ultrasonic attenuation, shear viscosity, and dynamic light scattering data were evaluated for Ethanol+Dodecane and Methanol+Cyclohexane binary mixtures using Ferrell-Bhattacharjee dynamic scaling theory as well as the Folk-Moser and the Onuki scaling functions (Behrends and Kaatz, 2004).

Near critical point, Bhattacharjee and his group discussed the origin of sound absorption. They analyzed the concept of theoretical approach which describes the critical contributions to the propagation of sound (Bhattacharjee *et al.*, 2010).

1.3: Research Objective:

The main goal of this work is to modify the Fixman's theory which is related to the analytic function and scaling function, which is failed to describe the critical behavior of binary liquid mixtures above critical temperature and at critical composition, in order to explain the trend of the experimental data. The suitable modification terms will be found by using Matlab program.

1.4: Organization of the thesis:

Subsequent chapters offer the following:

Chapter two is talking about the theories of sound absorption and sound velocity above the critical point, which include three basic theories, the first one is renormalization-group theory, the second theory is dynamic scaling theory, and the third theory is mode-coupling theories.

Chapter three displays the results and discussion of our results of Fixman's and our modification of Fixman's theory. Also, in this chapter the results are tested on the two binary liquid mixtures 3Methylpentane+Nitreothane and Nitrobenzene+n Hexane, to insure the validity of our modification Fixman's theory. Finally, chapter four is talking about conclusion, which gives the summary of this work.

Chapter Two

Theory

Theory

2.1: Dynamic Renormalization Group Theory

Kroll and Ruhland used renormalization group theory in order to explain the critical behavior of binary mixture. The basis of this theory is to describe the behavior of ultrasonic propagation in the existence of consolute point to calculate the bulk viscosity. The only significant contribution to the bulk viscosity comes directly from order-parameter fluctuations, and renormalization-group theory. The expression of the critical attenuation per wavelength α_λ can be written in a following form (Kroll and Ruhland, 1981):

$$\frac{\alpha_\lambda(\text{crit})}{u^2(\omega)} = \pi H \text{Im } f(\bar{\omega}) \quad (1)$$

where $u(\omega)$ is the velocity of sound wave, $f(\bar{\omega})$ is the scaling function, H is the critical amplitude, and $\bar{\omega} = \frac{\omega}{\omega_c}$ is reduced frequency, such that

$\omega_c = \frac{\omega_D}{2}$ is the characteristic frequency of order parameter fluctuations.

Since thermal energy fluctuations are proportional to the square of order-parameter fluctuations, on the other hand $\bar{\omega} = 2\omega^*$.

where

$$\omega^* = \frac{\omega}{\omega_D} = \frac{2\pi f}{\omega_D t^{z\nu}} \quad (2)$$

Such that ω_D is the characteristic frequency, which is given by (Garland and Sanchez, 1983).

$$\omega_D = \frac{k_B T}{3\pi\mu\xi^3} = \frac{k_B T}{3\pi\mu_0\xi_0^3} t^{(3+\chi_\mu)\nu} = \omega_0 t^{z\nu} = 2D_0\xi_0^{-2} t^{z\nu} \quad (3)$$

where ξ_0 is the correlation length at critical point, μ_0 is shear viscosity at critical point, and ω_0 is the frequency at critical temperature.

The critical amplitude factor H appearing in Eq. (1) is given by

$$H = \frac{c'_1 c'_3}{|g(t, \omega^*)|^2} t^{\frac{\bar{\alpha}}{\nu}} \quad (4)$$

Where $g(t, \omega^*) = c'_2 + c'_3 t^{\frac{\bar{\alpha}}{\nu}} f(\omega^*)$ and c'_1, c'_2, c'_3 are non-universal quantities that are approximately constant, $t = \frac{T - T_c}{T_c}$ is the reduced temperature, T_c is the critical temperature of the binary mixture, $\nu = 0.61$, and $\bar{\alpha} = 0.11$ are critical exponents.

2.2: Dynamic Scaling Theory

Ferrell and Bhattacharjee (Ferrel and Bhattacharjee, 1981) have developed a theory for the critical sound attenuation in a binary mixture that is based on temperature fluctuations associated from sound attenuation in critical region of binary mixture. This theory shows that the heat capacity C depends on complex frequency. They introduced adiabatic coupling constant g which is a thermodynamic relation connected between complex sound velocity with complex heat capacity. Their theory predicts linear relation between $\frac{\alpha}{f^2}$ and $f^{-1.06}$ above the critical point. The predicted result at $T = T_c$ is

$$\frac{\alpha(T_c)}{f^2} = \left[\frac{\pi^2 \bar{\alpha} g^2 u c_{pc}}{2 z \nu T_c c_{pb}} \left(\frac{\omega_0}{2\pi} \right)^{\frac{\bar{\alpha}}{z\nu}} \right] f^{-\left(1 + \frac{\bar{\alpha}}{z\nu}\right)} + \frac{\alpha_b}{f^2} \quad (5)$$

$$\frac{\alpha(T_c)}{f^2} = S f^{-1.06} + b \quad (6)$$

where $\frac{\alpha(T_c)}{f^2}$ describes the critical absorption at critical temperature and critical concentration, $b = \frac{\alpha_b}{f^2}$ describes the classical absorption

(background absorption), u is the sound velocity, and c_{pc} and c_{pb} indicates the critical and background part of specific heats at constant pressure, respectively.

$\bar{\alpha}$ is the critical exponent = 0.11, $1 + \frac{\bar{\alpha}}{zv} = 1.06$, and the quantity S corresponds to term brackets in Equation (5).

Ferrell and Bhattacharjee express the critical term of the attenuation $\alpha(crit)$ as a function of the reduced frequency ω^* . The result is given in the form (Garland and Sanchez, 1983)

$$\frac{\alpha}{\alpha_c} = \frac{\alpha(crit, \omega, T)}{\alpha(crit, \omega, T_c)} = F(\omega^*) \quad (7)$$

where $\frac{\alpha}{\alpha_c}$ is the critical attenuation ratio, $\alpha(crit, \omega, T)$ is the critical term at critical concentration and temperature T , and $\alpha(crit, \omega, T_c)$ is the critical term at critical concentration and critical temperature T_c .

The scaling function $F(\omega^*)$ has the following form:

$$F(\omega^*) = \left(1 + \omega^{*- \frac{1}{2}}\right)^{-2} \quad (8)$$

where

$$\omega^* = \frac{\omega}{\omega_D} = \frac{2\pi f}{\omega_0 t^{zv}} \quad (9)$$

where

ω_D is the characteristic frequency given by (Garland and Sanchez, 1983).

$$\omega_D = \frac{k_B T}{3\pi\mu\xi^3} = \frac{k_B T}{3\pi\mu_0\xi_0^3} t^{(3+\chi_\mu)\nu} = \omega_0 t^{zv} = 2D_0\xi_0^{-2} t^{zv} \quad (10)$$

The critical attenuation per wavelength in dynamic scaling theory is given in the form (Garland and Sanchez, 1983).

$$\frac{\alpha_\lambda(crit)}{u^2(\omega)} = \pi A_{FB}(T) G(\omega^*) \quad (11)$$

where $G(\omega^*)$ is the approximate form of scaling function, given by:

$$G(\omega^*) = (\omega^*)^{-\frac{\bar{\alpha}}{zv}} F(\omega^*) \quad (12)$$

$A_{FB}(T)$ is the critical amplitude in dynamic scaling theory has the following form (Hornowski and Madej, 2001)

$$A_{FB}(T) = \frac{\pi \bar{\alpha} g^2 u^2 C_{pc} t^{-\bar{\alpha}}}{2zv T_c C_{pb}^2} \quad (13)$$

The adiabatic coupling constant, g is given in the form (Garland and Sanchez, 1983)

$$g = \rho_c C_p \left[\left(\frac{dT_c}{dp} \right) - \left(\frac{T \alpha_p}{\rho C_p} \right) \right] \quad (14)$$

where ρ_c is the density at critical temperature and concentration, α_p is the isobaric thermal expansion coefficient, and $\frac{dT_c}{dP}$ is the slope of the critical line of consolute points as a function of pressure.

2.3: Mode-Coupling Theories

The mode-coupling theories lead to the general expression for the attenuation per wavelength α_λ at critical concentration (Kawasaki, 1970; Shiwa and Kawasaki, 1981) which is:

$$\frac{\alpha_\lambda}{u^2(\omega)} = \pi A(T) I(\omega^*) \quad (15)$$

where $u(\omega)$ is the velocity of sound, $A(T)$ is the critical amplitude, and $I(\omega^*)$ is the scaling function.

The scaling function is generalized relaxation function, which is given by (Fixman, 1962; Kawasaki, 1970; Mistura, 1972; Shiwa and Kawasaki, 1981):

$$I(\omega^*) = \int_0^\infty \left[\frac{x^2 dx}{\{1+x^2\}^2} \right] \left[\frac{\omega^* K(x)}{\{K^2(x) + \omega^{*2}\}} \right] \quad (16)$$

Where

$K(x)$ is the analytic function, and $x = q\xi$, and ξ is correlation length, and q is wave number.

The analytic function $K(x)$ of Kawasaki, Mistura, and Chaban is given by (Shimakawa, 1961; Kawasaky, 1970; Mistura, 1972; Garland and Sanchez, 1983)

$$K(x) = \frac{3}{4} \left[1 + x^2 + \left(x^3 - \frac{1}{x} \right) \arctan(x) \right] \quad (17)$$

While the Fixman's analytic function $K(x)$ is given by (Fixman, 1962; Mistura, 1972)

$$K(x) = x^2(1 + x \quad (18)$$

$$\omega^*: \text{is reduced frequency} = \frac{\omega}{\omega_D} = \frac{2\pi f}{\omega_0 t^{z\nu}} \quad (19)$$

where ω_D is the characteristic frequency given by (Garland and Sanchez, 1983).

$$\omega_D = \frac{k_B T}{3\pi\mu\xi^3} = \frac{k_B T}{3\pi\mu_0\xi_0^3} t^{(3+\chi_\mu)\nu} = \omega_0 t^{z\nu} = 2D_0\xi_0^{-2} t^{z\nu} \quad (20)$$

where k_B is the boltzmann's constant, D_0 is the diffusion coefficient at critical point (Mistura, 1972; Ferrell and Bhattacharjee, 1981), ξ_0 is the correlation length at critical point, and μ_0 is shear viscosity at critical point. The correlation length and shear viscosity are given by formula (Calmettes, 1977)

$$\xi = \xi_0 t^{-\nu} \quad (21)$$

$$\mu = \mu_0 t^{-\nu\chi_\mu} \quad (22)$$

Where $t = \frac{T-T_c}{T_c}$ is the reduced temperature, which determines the distance from the critical point on temperature scale, $z = 3 + \chi_\mu = 3.06$, $\nu = 0.61$ and $\chi_\mu = 0.06$ are critical exponents with ($z\nu = 1.93$).

The expressions for the critical amplitudes $A(T)$ of the binary mixture in the mode-coupling theories are given as follows:

Fixman's and Kawasaki's critical amplitudes $A_F(T)$ and $A_K(T)$ are given by (Fixman, 1962; Kawasaki, 1970; Garland and Sanchez, 1983; Roe and Meyer, 1978):

$$A_F(T) = \left[\frac{K_B(\gamma_0-1)\nu^2}{\pi \rho u c_{pb} \xi_0^3} \right] t^{-\bar{\alpha}} \quad (23)$$

Mistura's form of the critical amplitude is given by (Mistura, 1972; Garland and Sanchez, 1983; Shimakawa, 1961).

$$A_M(T) = A_F(T)[\gamma_0 - 1]^{-2}[1 - 0.5\eta]^2 \quad (24)$$

$$A_M(T) = 96 \times 10^{-4} [A_F(T)[\gamma_0 - 1]^{-2}] \quad (25)$$

Chaban's form $A_C(T)$ is given by (Fuchs *et al.*, 1998)

$$A_C(T) = A_F(T) \left[1 - \left(\frac{\rho c_{pb}}{\alpha_{pb}} \right) \left(\frac{dT_c}{dP} \right) \right]^2 \quad (26)$$

where ρ is the density of the mixture, c_{pb} is background heat capacity at constant pressure, $\gamma_0 = \frac{c_p}{c_v}$ is the ratio of heat capacities, α_{pb} is the background amplitude of the thermal expansion, ξ_0 is the correlation length at critical point, $\frac{dT_c}{dP}$ is the slope of the critical line of consolute points as a function of pressure, and $\eta = 0.04$, $\nu = 0.61$, and $\bar{\alpha} = 0.11$ are critical exponents

Hornowski's modification is based on the critical behavior of a relaxing

complex heat capacity. The general expression for the critical amplitude $A_H(T)$ has been derived in terms of the dimensionless parameter d (Hornowski and Labowski, 1990)

The critical Hornowski's amplitude $A_H(T)$ is given by (Hornowski and Labowski, 1990):

$$A_H(T) = 96 \times 10^{-4} [A_F(T) f(d)] \quad (27)$$

Where the function

$$f(d) = [(\gamma_0 - 1)^2 - 2d \gamma_0 [d - (\gamma_0 - 1)^{-1}]] \quad (28)$$

where $\gamma_0 = \frac{C_p}{C_v}$

d is the dimensionless parameter, which is given by:-

$$d = \left[\frac{C_{vb} \rho}{T \alpha_{pb}} \right] \left[\frac{dT_c}{dP} \right] \quad (29)$$

where C_{vb} is the back ground specific heat capacity coefficient at constant volume.

Chapter Three

Results and Discussion

3.1: Results and discussion

Fixman's theory was used in previous study that related to study of critical behavior of binary liquid mixtures, and the theory did not show agreement between experimental results and theoretical predictions (Abdelraziq, 2001). To illustrate this theory, we will study Fixman's theory which is related to analytic function and scaling function.

3.1.1: Fixman's analytic function and scaling function:

Fixman's analytic function is given by the relation (Fixman, 1962).

$K_F(x) = x^2(1 + x^2)$. In addition, Fixman's scaling function is given by the relation:

$$I_F(\omega^*) = \int_0^\infty \left[\frac{x^2 dx}{\{1+x^2\}^2} \right] \left[\frac{\omega^* K(x)}{\{K^2(x) + \omega^{*2}\}} \right].$$

The values of reduced frequencies ω^* , which are needed to calculate $I_F(\omega^*)$, are listed in Table (3.1)

Table (3.1): Numerical values of Fixman's scaling function $I_F(\omega^*)$ **using Fixman's analytic function $K_F(x) = x^2(1 + x^2)$**

ω^*	$I_F(\omega^*)$
500000.00	0.0159
8993.09	0.0424
1844.05	0.0611
647.44	0.0765
329.69	0.0875
103.83	0.1068
50.65	0.1179
30.05	0.1244
19.93	0.1283
14.21	0.1303
10.66	0.1311
8.30	0.1309
6.65	0.1301
5.45	0.1287
3.86	0.1251
2.88	0.1207
2.23	0.1158
1.78	0.1109
1.46	0.1060
1.03	0.0965
0.76	0.0878
0.59	0.0799
0.47	0.0729
0.38	0.0666
0.25	0.0537
0.18	0.0440
0.05	0.0176
2.00×10^{-3}	0.0011
7.63×10^{-4}	0.0004

The scaling function of Fixman, which is calculated as a function of reduced frequency ω^* in table (3.1) is plotted in Figure (1). This shows the relation between Fixman's scaling function versus reduced frequency.

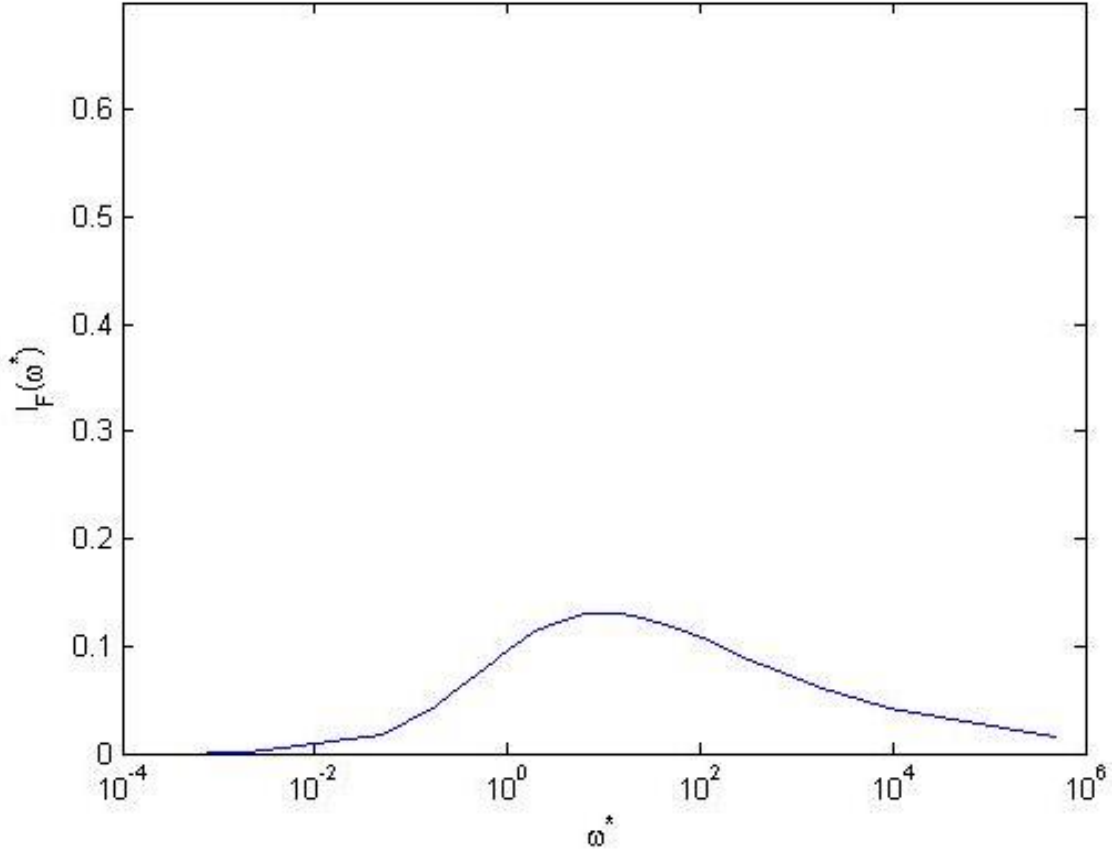


Fig. 1 Fixman's scaling function $I_F(\omega^*)$ using Fixman's analytic function $K_F(x) = x^2(1 + x^2)$

Previous study indicated that Fixman's theory does not fit with experimental data (Abdelraziq, 2001). Modification of Fixman's theory was made into two phases. The first phase concerns with the analytic function which deals with correlation length. The second phase has to do with the scaling function by adding a term that depends on one of the order parameters such as heat capacity.

Modification of Fixman's analytic function and modification of Fixman's scaling function will be discussed in section (3.1.2 and 3.1.3).

3.1.2 Modification of Fixman's analytic function.

Analytic function affects in the form of the scaling function. Modification of the analytic function depends on the correlation length (ξ).

The final modified form which has been adopted after many attempts (as given in appendix C) to reach to the proper form of analytic function is given by the relation:-

$$K_m(x) = 2x^2(1 + 10x^2 + 8x^3 + 6x^4) \quad (30)$$

Where

$K_m(x)$: is our modification of Fixman's analytic function, and $x = q\xi$

ξ is correlation length, and q is wave number.

Our modification of Fixman's analytic function is replaced in Fixman's scaling function. However, the numerical values of Fixman's scaling function using our modification analytic function is given in Table (3.2).

Table (3.2): Scaling function $I_{m'F}(\omega^*)$ using our modification analytic function with form $K_m(x) = 2x^2(1 + 10x^2 + 8x^3 + 6x^4)$

ω^*	$I_{m'F}(\omega^*)$
500000.00	0.0467
8993.09	0.0802
1844.05	0.0906
647.44	0.0933
329.69	0.0925
103.83	0.0858
50.65	0.0784
30.05	0.0718
19.93	0.0660
14.21	0.0610
10.66	0.0567
8.30	0.0529
6.65	0.0495
5.45	0.0465
3.86	0.0414
2.88	0.0373
2.23	0.0338
1.78	0.0309
1.46	0.0284
1.03	0.0244
0.76	0.0212
0.59	0.0187
0.47	0.0166
0.38	0.0149
0.25	0.0117
0.18	0.0095
0.05	0.0039
2.00×10^{-3}	5.2×10^{-12}
7.60×10^{-4}	1.9×10^{-12}

where $I_{m'F}(\omega^*)$ is scaling function using our modification of Fixman's analytic function.

Scaling function $I_{m'F}(\omega^*)$ as a function of reduced frequency at each temperature is shown in Figure (2).

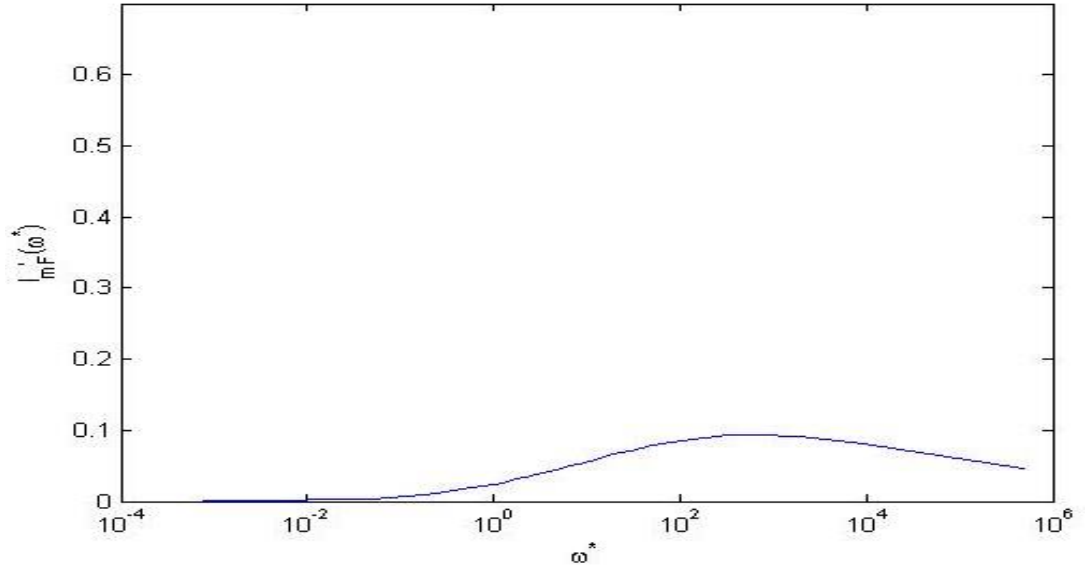


Fig. 2 Scaling function $I_{m'F}(\omega^*)$ using our modification of Fixman's analytic function $K_m(x) = 2x^2(1 + 10x^2 + 8x^3 + 6x^4)$

Significant difference between two scaling functions Figure (1) and Figure (2) as illustrated in Figure (3). However, our modification of analytic function causes a change in the scaling function.

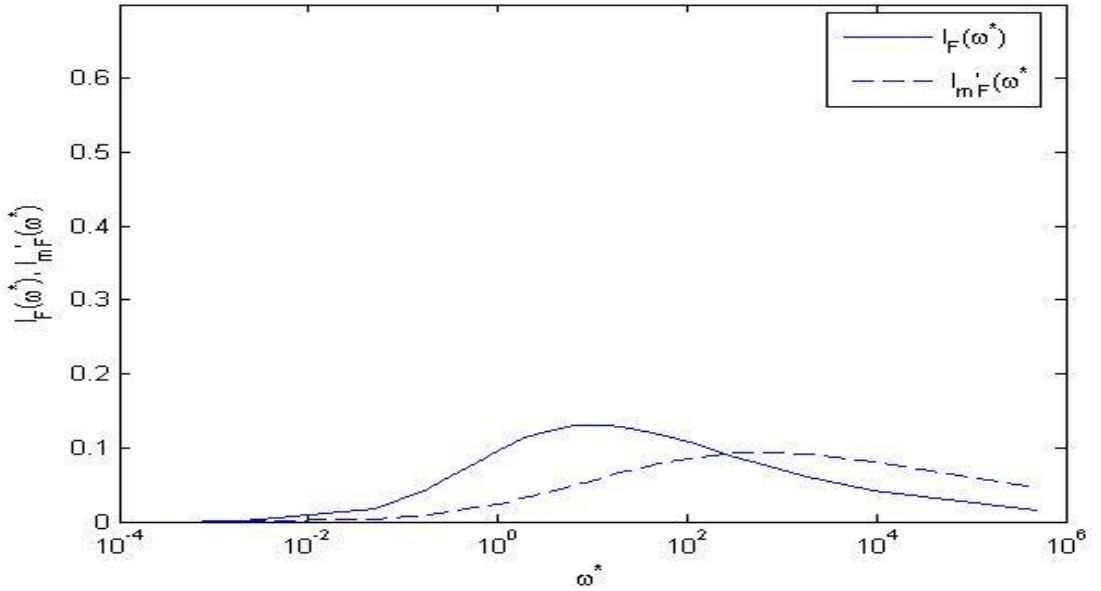


Fig. 3 Fixman's scaling function using Fixman's analytic function in solid line, and scaling function using our modification analytic function in dashed line

The experimental results show discrepancy with scaling function using our modification analytic function as will be discussed later in section (3.2). It seems that not only the correlation length need to be modified but the scaling function need to be modified, too.

3.1.3 Modification of Fixman's scaling function

The order parameters of binary mixtures such as the heat capacity behave anomalously near critical point. Thus, after many attempts had be done, modification term is added to the scaling function which depends on the heat capacity at constant pressure (C_p) and volume (C_v).

The term equals to $(\frac{\gamma_0}{\gamma_0-1} + 2.30)$, where $\gamma_0 = \frac{C_p}{C_v}$. This term is unitless, which serves the dependence on the heat capacities ratio.

The modification of Fixman's scaling function is given by the relation:

$$I_{mF}(\omega^*) = (\frac{\gamma_0}{\gamma_0-1} + 2.30) \int \left[\frac{x^2 dx}{\{1+x^2\}^2} \right] \left[\frac{\omega^* K_m(x)}{\{K_m^2(x) + \omega^{*2}\}} \right] \quad (31)$$

Where $I_{mF}(\omega^*)$ is our modification of Fixman's scaling function.

Our modification of Fixman's scaling function can be used in the range of γ_0 between (1.1— 2.0).

Numerical values of our Modificaion of Fixman's scaling function $I_{mF}(\omega^*)$ are given in table (3.3)

Table (3.3): Numerical values of our modification of Fixman's scaling function $I_{mF}(\omega^*) = (\frac{\gamma_0}{\gamma_0-1} + 2.30) \int \left[\frac{x^2 dx}{\{1+x^2\}^2} \right] \left[\frac{\omega^* K_m(x)}{\{K_m^2(x) + \omega^{*2}\}} \right]$ as a function of reduced frequencies

ω^*	$I_{mF}(\omega^*)$
500000.00	0.3596
8993.09	0.6175
1844.05	0.6976
647.44	0.7184
329.69	0.7122
103.83	0.6606
50.65	0.6036
30.05	0.5528
19.93	0.5082
14.21	0.4697
10.66	0.4365
8.30	0.4073
6.65	0.3811
5.45	0.3580
3.86	0.3187
2.88	0.2872
2.23	0.2602
1.78	0.2379
1.46	0.2186
1.03	0.1878
0.76	0.1632
0.59	0.1439
0.47	0.1278
0.38	0.1147
0.25	0.0901
0.18	0.0731
0.05	0.0300
2.00×10^{-3}	40×10^{-11}
7.63×10^{-4}	15×10^{-12}

Our modification of Fixman's scaling function $I_{mF}(\omega^*)$ is plotted as a function of reduced frequency (ω^*) as shown in Figure (4).

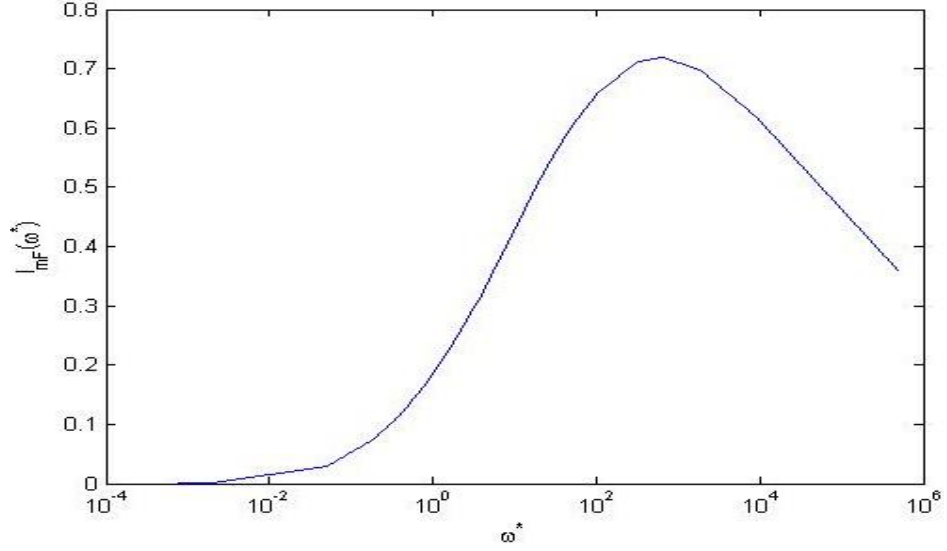


Fig. 4 Our modification of Fixman's scaling function $I_{mF}(\omega^*)$ as a function of reduced frequency

Fixman's and our modification of Fixman's scaling function illustrated in Figure (5).

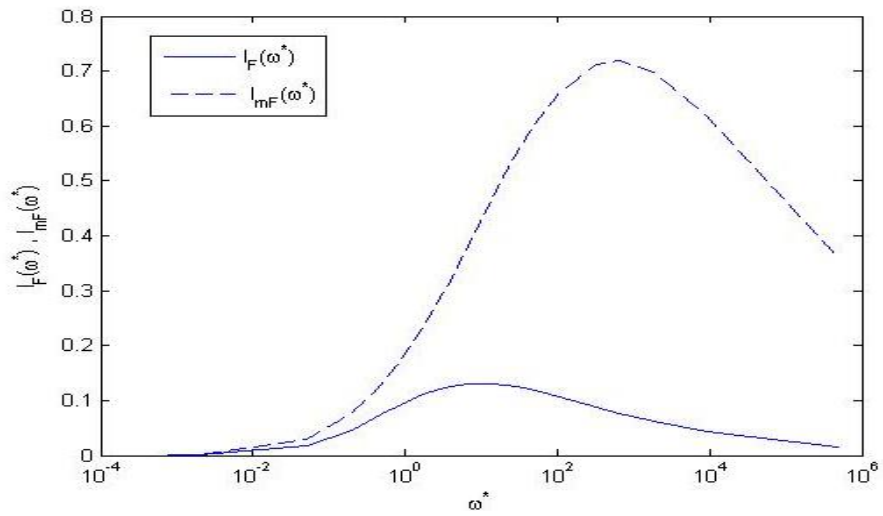


Fig. 5 Fixman's and our modification of Fixman's scaling function as a function of reduced frequency

Figure (5) shows that there is large discrepancy between our modification $I_{mF}(\omega^*)$ and Fixman's scaling function $I_F(\omega^*)$.

The validity of the modification of Fixman's theory can be checked by using the experimental data (which can be obtained from literature) for two binary liquid mixtures 3Methylpentane+Nitreothane at frequencies 1, 3, 7, 9, 11, and 17 MHz, and Nitrobenzene+n Hexane at frequencies 5, 7, 10, 15, 21, and 25 MHz.

3.2. 3 Methylpentane+Nitreothane

3Methylpentane+Nitrothane system has a chemical form of $C_6H_{14} - C_2H_5NO_2$, and has critical temperature 299.6 K, the critical concentration is 0.500 mole fraction by weight of Nitroethane (Garland and Sanchez, 1983).

The measured sound velocity in the binary mixture 3Methylpentane + Nitrothane at all frequencies is given by the following linear relation (Garland and Sanchez, 1983).

$$u = 1097.7 - 3.98(T - T_c) \frac{m}{s} \quad (32)$$

The colletral data needed to find the value of critical amplitude $A_F(T)$ of binary mixture 3Methylpentane+Nitrothane are given in table (3.4).

Table (3.4): The necessary data which are needed to calculate **$A_F(T)$ of 3Methylpentane+Nitrothane**

Quantity	Value	References
$T_c(K)$	299.6	(Leister <i>et al.</i> , 1969)
C_{pb} (erg/gK)	1.94×10^7	(Greer and Hocken, 1975)
$\xi_0(\text{\AA})$	2.16	(Tsai <i>et al.</i> , 1973)
$D_0(\text{cm}^2/\text{s})$	3.28×10^{-5}	(Greer and Hocken, 1975)
ρ (g/cm ³)	0.791	(Tsai <i>et al.</i> , 1973)
$\omega_0(\text{Hz})$	1.23×10^{11}	(Garland, 1983)
$\mu_0(\text{cP})$	0.35	(Greer and Hocken, 1975)
γ_0	1.28	(Garland, 1983)

$\omega^* = \frac{\omega}{\omega_D} = \frac{2\pi f}{\omega_0 t^{2\nu}} = \frac{2\pi f}{\omega_0 t^{1.93}}$ is used to calculate the reduced frequency at different temperatures.

The value of ω_0 is 1.23×10^{11} Hz for 3Methylpentane+Nitreothane binary mixture. (Garland and Sanchez, 1983), where $t = \frac{T-T_c}{T_c} = \frac{\Delta T}{T_c}$

The values of Fixman's critical amplitude $A_F(T) = \left[\frac{K_B(\gamma_0-1)\nu^2}{\pi \rho u C_{pb} \xi_0^3} \right] t^{-\bar{\alpha}}$ was calculated and are given in table (3.5).

The values of reduced frequency ω^* at frequency 1 MHz, sound velocity, and critical amplitude $A_F(T)$, are listed in table (3.5) at each temperature. Other values of reduced frequencies ω^* at 3, 7, 9, 11, and 17 MHz are given in appendix A.

Table (3.5): The values of reduced frequency, sound velocity, and critical amplitude of binary liquid mixture 3Methylpentane+Nitrethane at $f = 1\text{MHz}$, where $\omega_0 = 1.23 \times 10^{11}$

$\Delta T(K)$	$u(T)$ (m/s)	$t = \frac{\Delta T}{T_c}$	$t^{1.93}$	$\omega_0 t^{1.93} \times 10^8$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1.93}}$	$\pi A_F(T) \times 10^{-12}$
0.004	1097.68	0.00001	0.0000000004	0.0000005	130558.20	2.92
0.040	1097.54	0.00013	0.0000000330	0.0000409	1533.92	2.62
0.091	1097.33	0.00030	0.0000001620	0.0002000	313.93	2.07
0.159	1097.06	0.00053	0.0000004770	0.0005873	106.92	1.95
0.197	1096.91	0.00066	0.0000007220	0.0008881	70.71	1.90
0.219	1096.82	0.00073	0.0000008850	0.0010895	57.63	1.88
0.295	1096.52	0.00098	0.0000015740	0.0019361	32.43	1.82
0.391	1096.14	0.00130	0.0000027110	0.0033348	18.83	1.76
0.495	1095.72	0.00165	0.0000042740	0.0052573	11.95	1.72
0.644	1095.13	0.00215	0.0000071020	0.0087363	7.19	1.67
0.851	1094.31	0.00284	0.0000121620	0.0149604	4.19	1.62
1.167	1093.05	0.00389	0.0000223720	0.0275185	2.28	1.56
1.176	1093.02	0.00392	0.0000227070	0.0279296	2.25	1.55
1.708	1090.90	0.00570	0.0000466630	0.0573959	1.09	1.50
2.410	1088.11	0.00804	0.0000906910	0.1115507	0.56	1.44
3.538	1083.61	0.01181	0.0001902720	0.2340356	0.26	1.38
4.807	1078.56	0.01604	0.0003437880	0.4228598	0.14	1.33
5.676	1075.10	0.01894	0.0004737790	0.5827485	0.10	1.31
6.770	1070.75	0.02259	0.0006657480	0.8188711	0.08	1.28
7.952	1066.05	0.02654	0.0009082250	1.1171174	0.06	1.26
8.948	1062.08	0.02986	0.0011405260	1.4028477	0.04	1.25
10.012	1057.85	0.03341	0.0014167050	1.7425475	0.03	1.23
11.064	1053.66	0.03693	0.0017180060	2.1131479	0.02	1.22
13.434	1044.23	0.04484	0.0024986790	3.0733762	0.02	1.19

The experimental values of absorption of sound per wavelength α_λ of the binary system 3Methylpentane+Nitrethane at frequencies 1, 3, 7, 9, 11, and 17 MHz, are taken from Garland and Sanchez paper and listed in table (3.6) (Garland and Sanchez, 1983).

Table (3.6): Measured absorption per wavelength α_λ of a critical mixture of 3methylpentane+nitroethane as a function of temperature at different frequencies. Data are taken from Garland and Sanchez paper (Garland and Sanchez, 1983). All values of α_λ are given in units of 10^{-4} Np

$\Delta T(K)$	α_λ	α_λ	α_λ	α_λ	α_λ	α_λ
	<u>1MHz</u>	<u>3MHz</u>	<u>7MHz</u>	<u>9MHz</u>	<u>11MHz</u>	<u>17MHz</u>
0.004	140	135	131	132	132	134
0.040	138	131	130	131	131	133
0.091	130	128	124	127	128	132
0.159	126	120	120	124	126	131
0.197	120	119	118	122	124	130
0.219	117	119	118	121	125	130
0.295	111	117	116	119	122	128
0.391	102	112	113	118	120	126
0.495	97	109	112	116	120	125
0.644	87	101	109	114	117	123
0.851	77	95	106	111	114	121
1.167	65	84	100	105	109	119
1.176	65	82	97	103	105	118
1.708	53	75	91	96	102	112
2.410	43	60	80	88	91	104
3.538	32	47	68	76	80	94
4.807	-----	35	58	65	71	85
5.676	-----	31	51	60	65	78
6.770	-----	22	48	52	59	70
7.952	-----	20	41	46	50	65
8.948	-----	16	37	43	47	60
10.012	-----	15	32	39	43	55
11.064	-----	13	29	35	39	52
13.434	-----	11	22	30	33	45

The relation of $\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$ along with the scaling function of Fixman $I_F(\omega^*)$

are shown in Figure (6), where $I_F(\omega^*)$ is the Fixman scaling function.

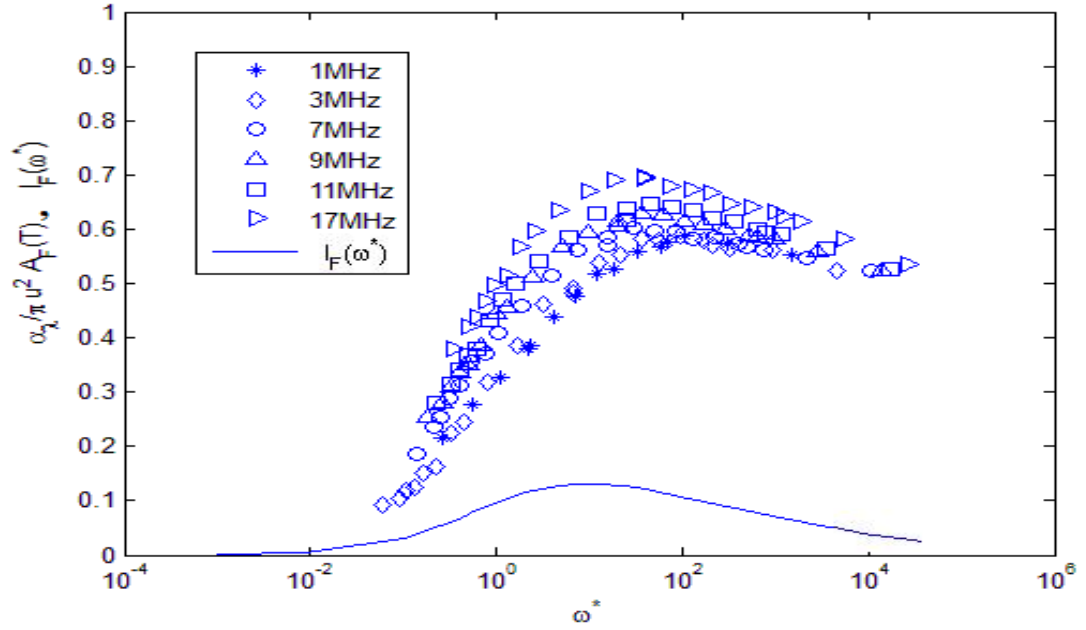


Fig. 6 Experimental absorption values $(\frac{\alpha_\lambda}{\pi u^2 A_F(T)})$ versus reduced frequency ω^* for 3Methylpentane+ Nitrothane according to Fixman theory along with the theoretical scaling integral $I_F(\omega^*)$

Large discrepancies are shown between the experimental values $\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$ and the scaling function $I_F(\omega^*)$. However, the higher the reduced frequency the larger discrepancy between the scaling function and the experimental values, as shown in figure (6).

Our modification of Fixman's scaling function and analytic function is applied to the binary mixture 3Methylpentane+Nitreothane and shown in Figure (7).

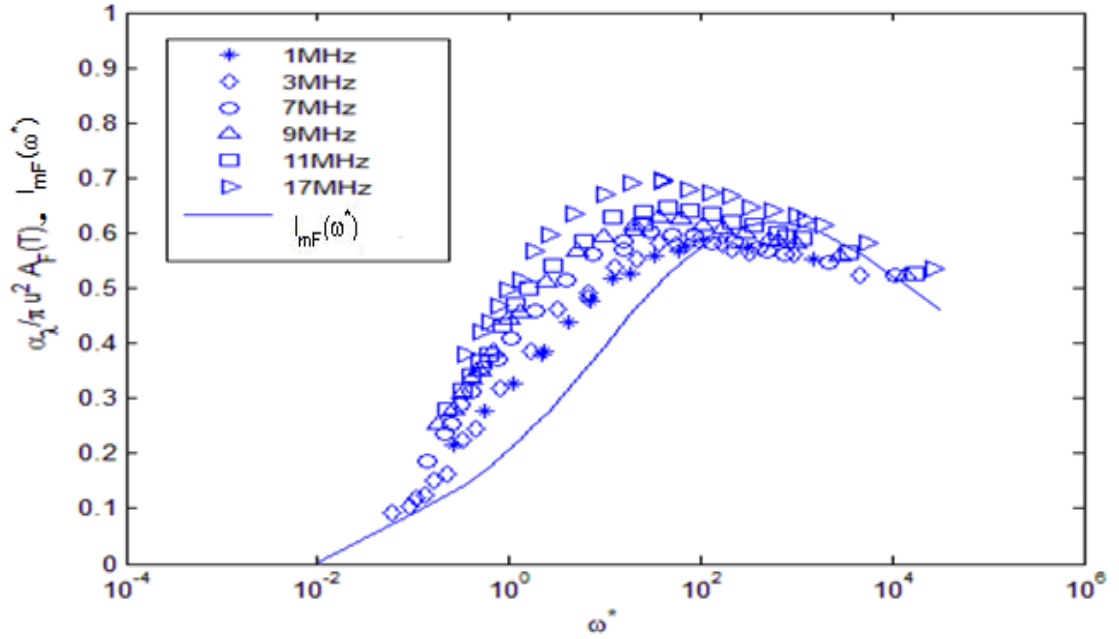


Fig. 7 Experimental absorption values $(\frac{\alpha_\lambda}{\pi u^2 A_F(T)})$ versus reduced frequency ω^* for 3Methylpentane+Nitrothane according to our modification of Fixman's theory along with $I_{mF}(\omega^*)$

Figure (7) shows a good agreement for large reduced frequency (ω^*) between experimental values and theoretical predictions. This is because our modification depends on correlation length (ξ) and the ratio of heat capacities which increases the sound absorption near the critical point.

3.3: Nitrobenzene+n Hexane:-

Nitrobenzene+n Hexane system has a chemical form of $C_6H_5NO_2 - C_6H_{14}$, and has critical temperature 293.25 K. The concentration is 0.33 mole fraction by weight of nitrobenzene (D'Arrigo and Sette, 1968).

The velocities of sound at 5 MHz, and 15 MHz in binary mixture Nitrobenzene+n Hexane can be described by the linear temperature relations (Abdelraziq *et al.*, 1990).

$$u = 1209.2 - 3.58(T - T_c) \text{ m/s} \quad \text{at 5 MHz} \quad (33)$$

$$u = 1206.1 - 3.59(T - T_c) \text{ m/s} \quad \text{at 15 MHz} \quad (34)$$

The colletral data needed to find the value of critical amplitude $A_F(T)$ are given in table(3.7).

Table (3.7): The necessary data which are needed to calculate $A_F(T)$ of Nitrobenzene +n Hexane.

Quantity	Value	References
$T_c(K)$	293.25	(D'Arrigo and Sette, 1968)
C_{pb} (erg/gK)	1.90×10^7	(Greer and Hocken, 1975)
$\xi_0(\text{\AA})$	2.03	(D'Arrigo and Sette, 1968)
$D_0(\text{cm}^2/\text{s})$	3.28×10^{-5}	(Greer and Hocken, 1975)
ρ (g/cm ³)	0.8432	(Abdelraziq <i>et al.</i> , 1990)
$\omega_0(\text{Hz})$	2×10^{10}	(Abdelraziq <i>et al.</i> , 1990)
μ_0 (cP)	0.563	(Abdelraziq <i>et al.</i> , 1990)
γ_0	1.24	(Abdelraziq <i>et al.</i> , 1990)

$\omega^* = \frac{\omega}{\omega_D} = \frac{2\pi f}{\omega_0 t^{2\nu}} = \frac{2\pi f}{\omega_0 t^{1.93}}$ is used to calculate the reduced frequency at different temperatures.

The value of ω_0 is 2×10^{10} Hz for Nitrobenzene+n Hexane binary mixture (Abdelraziq *et al.*, 1990).

The values of reduced frequency ω^* at frequency 5 MHz, sound velocity, and

critical amplitude $A_F(T)$, are listed in table (3.8) at different temperatures, other values of reduced frequencies at frequencies 5, 7, 10, 15, 21, and 25MHz are given in Appendix B.

Table (3.8): The values of reduced frequency, sound velocity, and critical amplitude for binary mixture Nitrobenzene+n hexane.

$T(K)$	$\Delta T(K)$ $= T - T_c$	$u(T)$ at 5MHz (m/s)	$u(T)$ at 15MHz (m/s)	$\pi A_F(T) \times 10^{-}$	$t = \frac{\Delta T}{T_c}$	ω^*
293.26	0.01	1209.16	1206.06	2.50	0.000034	657156.80
293.36	0.11	1208.80	1205.70	1.90	0.000375	6423.60
293.50	0.25	1208.30	1205.20	1.76	0.000852	13171.70
293.68	0.43	1207.60	1204.55	1.66	0.001460	462.40
293.86	0.61	1207.01	1203.91	1.59	0.002080	235.40
294.36	1.11	1205.22	1202.11	1.49	0.003780	74.16
294.86	1.61	1203.42	1200.32	1.43	0.005490	36.18
295.36	2.11	1201.62	1198.52	1.39	0.007190	21.46
295.86	2.61	1199.83	1196.73	1.36	0.008900	14.24
296.36	3.11	1198.03	1194.93	1.33	0.010600	10.15
296.86	3.61	1196.24	1193.14	1.31	0.012300	7.61
297.36	4.11	1194.44	1191.34	1.29	0.014000	5.92
297.86	4.61	1192.65	1189.55	1.28	0.015700	4.75
298.36	5.11	1190.85	1187.75	1.26	0.017400	3.89
299.36	6.11	1187.26	1184.16	1.24	0.020800	2.75
300.36	7.11	1183.67	1180.57	1.22	0.024200	2.05
301.36	8.11	1180.08	1176.98	1.20	0.027600	1.59
302.36	9.11	1176.49	1173.39	1.19	0.031000	1.27
303.36	10.11	1172.90	1169.80	1.17	0.034400	1.04
305.36	12.11	1165.72	1162.62	1.15	0.041200	0.73
307.36	14.11	1158.54	1155.44	1.13	0.048100	0.55
309.36	16.11	1151.36	1148.26	1.12	0.054900	0.42
311.36	18.11	1144.18	1141.08	1.10	0.061700	0.34
313.36	20.11	1137.00	1133.90	1.08	0.068500	0.28
318.36	25.11	1119.05	1115.95	1.06	0.085000	0.18
323.36	30.11	1101.10	1098.01	1.04	0.102000	0.13

The experimental data of $\frac{\alpha}{f^2}$ is taken from Abdelraziq and his group at frequencies 5, 7, 10, 15, 21, and 25 MHz (Abdelraziq *et al.*, 1990), which are given in table (3.9), and illustrated in Figure (8).

Table (3.9): Absorption data for the critical mixture Nitrobenzene+n**Hexane**

Absorption $\frac{\alpha}{f^2} (10^{-17} S^2 cm^{-1})$							
$T(K)$	$\Delta T(K) = T - T_c$	5 MHz	7MHz	10MHz	15MHz	21MHz	25MHz
293.26	0.01	3535.4	2471.3	1795.1	1460.1	1084.0	857.0
293.36	0.11	3354.1	2306.2	1650.0	1378.0	1033.0	802.0
293.50	0.25	3172.8	2210.7	1541.4	1328.0	997.0	752.0
293.68	0.43	2990.2	2126.0	1482.9	1278.0	979.0	703.0
293.86	0.61	2690.2	1956.9	1403.2	1227.0	961.0	661.0
294.36	1.11	2419.6	1789.3	1286.7	1107.0	900.0	580.5
294.86	1.61	2251.8	1621.1	1196.0	989.0	844.0	508.0
295.36	2.11	2096.3	1412.4	1106.0	890.0	795.0	445.0
295.86	2.61	1975.6	1252.2	1021.0	795.0	749.0	397.0
296.36	3.11	1825.0	1102.7	954.0	726.0	707.0	370.0
296.86	3.61	1708.4	998.8	899.0	657.0	664.0	343.0
297.36	4.11	1605.7	905.4	845.0	617.0	625.0	321.7
297.86	4.61	1429.8	826.0	805.0	587.0	590.0	299.7
298.36	5.11	1341.1	774.2	755.0	559.0	520.0	287.1
299.36	6.11	1153.8	673.0	644.0	503.0	455.0	276.4
300.36	7.11	982.5	581.8	574.0	451.0	401.0	251.8
301.36	8.11	806.5	501.0	499.0	405.0	361.0	233.7
302.36	9.11	652.2	431.0	429.0	364.0	342.0	222.5
303.36	10.11	539.2	380.0	371.0	328.0	305.0	207.6
305.36	12.11	423.3	311.0	301.0	296.0	284.0	178.3
307.36	14.11	317.3	254.0	248.0	245.0	232.0	160.4
309.36	16.11	272.0	201.0	198.0	186.0	198.0	141.0
311.36	18.11	241.7	161.0	153.0	149.0	162.0	123.1
313.36	20.11	200.6	136.0	129.0	124.0	137.0	104.9
318.36	25.11	180.9	101.2	94.5	89.0	76.2	74.8
323.36	30.11	142.0	70.4	61.0	54.0	37.4	34.3

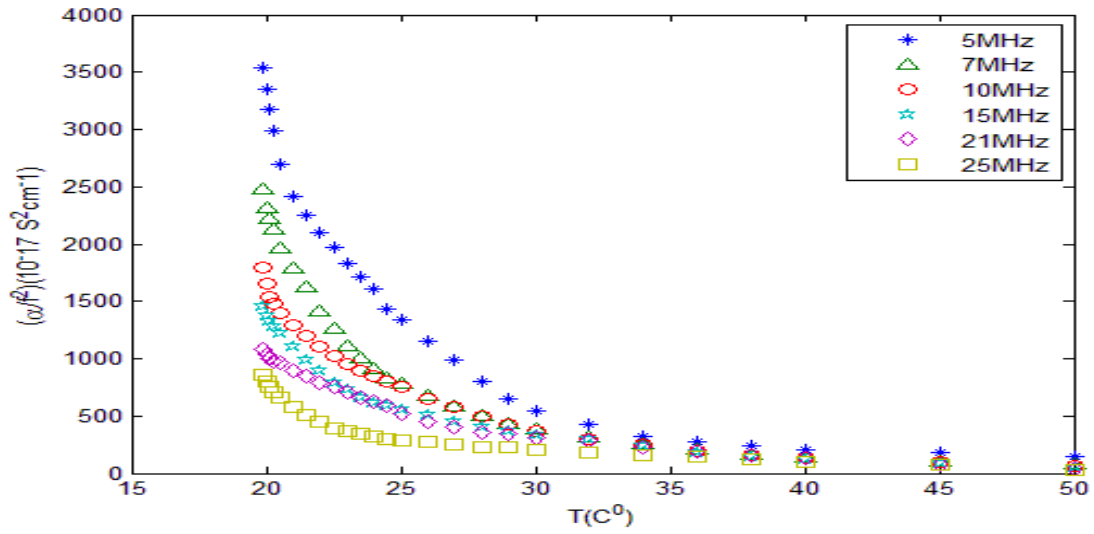


Fig. 8 Temperature dependence of absorption for the critical binary mixture of Nitrobenzene + n Hexane above T_c (Abdelraziq *et al*, 1990)

The absorption versus temperature of the critical binary mixture of Nitrobenzene+n Hexane above the critical temperature, are used to calculate the absorption per wavelength α_λ .

The calculated α_λ are given in Table (3.10), and the collateral data in Table (3.7) are used to calculate the critical amplitude of Fixman $A_F(T)$.

Table (3.10): Absorption per wavelength data for the critical mixture**Nitrobenzene+n Hexane**

Absorption per wavelength α_λ (Np)							
$T(K)$	$\Delta T(K) = T - T_c$	<u>5 MHz</u>	<u>7MHz</u>	<u>10MHz</u>	<u>15MHz</u>	<u>21MHz</u>	<u>25MHz</u>
293.26	0.01	0.0214	0.0209	0.0217	0.0264	0.0275	0.0258
293.36	0.11	0.0203	0.0195	0.0199	0.0249	0.0262	0.0242
293.50	0.25	0.0192	0.0187	0.0186	0.0240	0.0252	0.0227
293.68	0.43	0.0181	0.0180	0.0179	0.0231	0.0248	0.0212
293.86	0.61	0.0162	0.0165	0.0169	0.0222	0.0243	0.0199
294.36	1.11	0.0146	0.0151	0.0155	0.0200	0.0227	0.0174
294.86	1.61	0.0135	0.0136	0.0144	0.0178	0.0213	0.0152
295.36	2.11	0.0126	0.0119	0.0133	0.0160	0.0200	0.0133
295.86	2.61	0.0119	0.0105	0.0122	0.0143	0.0188	0.0119
296.36	3.11	0.0109	0.0092	0.0114	0.0130	0.0177	0.0111
296.86	3.61	0.0102	0.0084	0.0107	0.0118	0.0166	0.0102
297.36	4.11	0.0096	0.0076	0.0101	0.0110	0.0156	0.0096
297.86	4.61	0.0085	0.0069	0.0096	0.0105	0.0147	0.0089
298.36	5.11	0.0080	0.0064	0.0090	0.0100	0.0130	0.0085
299.36	6.11	0.0068	0.0056	0.0076	0.0089	0.0113	0.0082
300.36	7.11	0.0058	0.0048	0.0068	0.0080	0.0099	0.0074
301.36	8.11	0.0048	0.0041	0.0059	0.0072	0.0089	0.0069
302.36	9.11	0.0038	0.0035	0.0050	0.0064	0.0084	0.0065
303.36	10.11	0.0032	0.0031	0.0043	0.0058	0.0075	0.0061
305.36	12.11	0.0025	0.0025	0.0035	0.0052	0.0069	0.0052
307.36	14.11	0.0018	0.0021	0.0029	0.0042	0.0056	0.0046
309.36	16.11	0.0016	0.0016	0.0023	0.0032	0.0048	0.0040
311.36	18.11	0.0014	0.0013	0.0017	0.0026	0.0039	0.0035
313.36	20.11	0.0011	0.0011	0.0015	0.0021	0.0033	0.0030
318.36	25.11	0.0010	0.0008	0.0011	0.0015	0.0018	0.0021
323.36	30.11	0.0008	0.0005	0.0007	0.0009	0.0009	0.0009

The experimental values of $\frac{a_\lambda}{u^2(\omega)\pi A_F(T)}$ of binary mixture Nitrobenzene+n

Hexane according to Fixman's theory along with scaling function $I_F(\omega^*)$ with Fixman's analytic function of this mixture as a function of reduced frequency ω^* , is presented in figure (9).

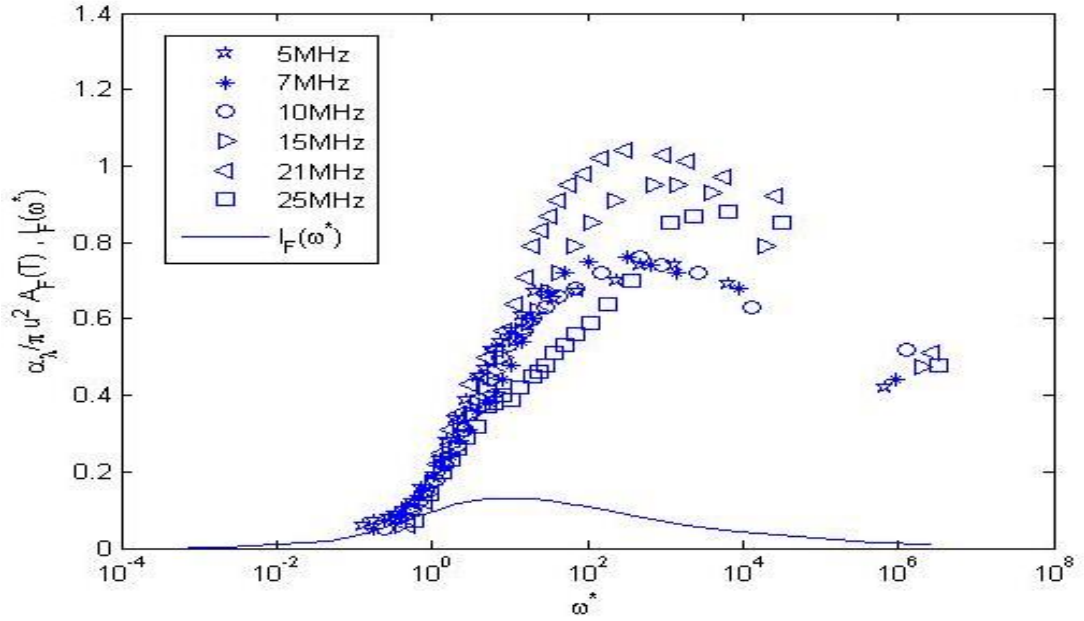


Fig. 9 The experimental value $\left(\frac{\alpha_\lambda}{\pi u^2 A_F(T)}\right)$ versus reduced frequency ω^* for Nitrobenzene + n Hexane according to Fixman theory along with the theoretical scaling function $I_F(\omega^*)$ shown in solid line

As seen in Figure (9), the scaling function of Fixman's theory $I_F(\omega^*)$ doesn't agree with experimental values, especially at high reduced frequencies.

Our modification of Fixamn's scaling function using our modification of analytic function is plotted along with the experimental values $\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$ for Nitrobenzene+n Hexane. The relation of $\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$ along with our modification of scaling function $I_{mF}(\omega^*)$ are shown in Figure (10).

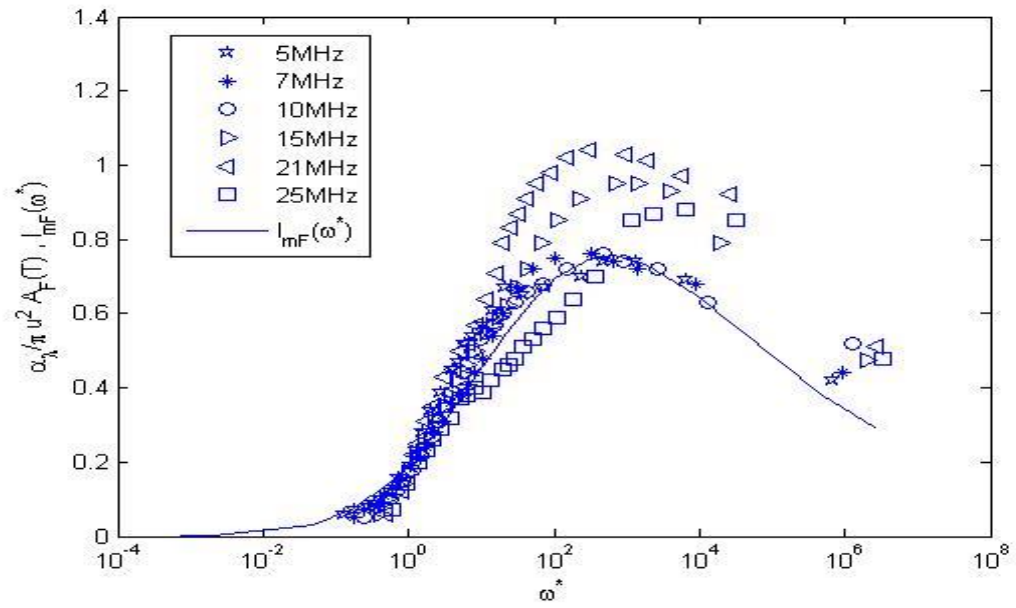


Fig. 10 The experimental values $(\frac{\alpha_\lambda}{\pi u^2 A_F(T)})$ versus reduced frequency ω^* for Nitrobenzene + n Hexane along with our modification of scaling function $I_{mF}(\omega^*)$ shown in solid line

Good agreement between the experimental values and our modification scaling function using our modification analytic function have been found. The final relation of our modification of Fixman's theory depends on γ_0 , that causes the agreement between experimental values and our theoretical predictions.

Chapter Four

Conclusion

Conclusion:

Binary liquid mixtures have phase separation before critical point. The thermodynamic fluctuations of certain macroscopic variables increase enormously near the critical point (T_c, X_c) and tend to become in order above critical point.

Mode-Coupling theory of Fixman was used to describe the critical behavior of binary liquid mixtures above critical point (T_c, X_c) . The analytic function of Fixman's theory is not proper to yield suitable scaling function in order to get an agreement with experimental values. The analytic function of Fixman's theory relates to the correlation length. Modification of Fixman's analytic function depends on the correlation length, which is affected in the form of scaling function. The scaling function is still poor for describing the critical behavior of a binary mixture above the critical point.

Fixman's theory depends on the heat capacity in order to describe the origin of sound absorption in binary liquid mixtures. Our modification of Fixman's scaling function depends on the ratio of heat capacities at constant pressure and volume γ_0 , which equals $\frac{\gamma_0}{\gamma_0-1} + 2.30$.

Our modification of Fixman's theory was applied to 3Methylpentane+ Nitroethane at frequencies 1, 3, 7, 9, 11, and 17 MHz, and Nitrobenzene+n Hexane at frequencies 5, 7, 10, 15, 21, and 25 MHz. It was found out that there is a good agreement between the experimental values and our theoretical predictions.

The entire work can be summarized in Table (4.1), which shows the comparison between Fixman's theory and our Modification of Fixman's theory.

Table (4.1): The analytic and scaling functions of Fixman and our modification of the analytic and scaling functions

	Fixman's Theory	Our Modification of of Fixman's Theory
Analytic function	$K(x) = x^2 [1 + x^2]$	$K_m(x) = 2x^2(1 + 10x^2 + 8x^3 + 6x^4)$
Scaling function	$I(\omega^*) = \int \left[\frac{x^2 dx}{\{1 + x^2\}^2} \right] \left[\frac{\omega^* K(x)}{\{K^2(x) + \omega^{*2}\}} \right]$	$I_m(\omega^*) = w \int \left[\frac{x^2 dx}{\{1 + x^2\}^2} \right] \left[\frac{\omega^* K_m(x)}{\{K_m^2(x) + \omega^{*2}\}} \right]$
	Where; $x = q\xi$, ξ is Correlation length, q is the wave number, and $w = \frac{\gamma_0}{\gamma_0 - 1} + 2.30$	

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Appendix A

The data of α_λ for 3Methylpentane+Nitreothane is given from the work of Garland and Sanchez (Garland and Sanchez, 1983). The values of $\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$ at different temperature and reduced frequency are listed in tables (a1-a6) at frequencies 1, 3, 7, 9, 11, and 17 MHz.

Table (a1): Reduced frequencies (ω^*) and experimental absorption values $\left(\frac{\alpha_\lambda}{\pi u^2 A_F(T)}\right)$ at different temperatures at $f = 1$ MHz for 3Methylpentane+Nitreothane, and $\omega_0 = 1.23 \times 10^{11}$ Hz

$\Delta T(K)$ $= T - T_c$	$t = \frac{\Delta T}{T_c}$	$t^{1.93}$	$\omega_0 t^{1.93} \times 10^8$	ω^* $= \frac{2\pi f}{\omega_0 t^{1.93}}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
0.004	0.00001	0.0000000004	0.00000005	130558.20	0.39
0.040	0.00013	0.0000000330	0.0000409	1533.90	0.50
0.091	0.00030	0.0000001620	0.0002000	313.90	0.52
0.159	0.00053	0.0000004770	0.0005873	106.90	0.52
0.197	0.00066	0.0000007220	0.0008881	70.70	0.52
0.219	0.00073	0.0000008850	0.0010895	57.60	0.51
0.295	0.00098	0.0000015740	0.0019361	32.40	0.50
0.391	0.00130	0.0000027110	0.0033348	18.80	0.48
0.495	0.00165	0.0000042740	0.0052573	11.90	0.47
0.644	0.00215	0.0000071020	0.0087363	7.19	0.43
0.851	0.00284	0.0000121620	0.0149604	4.19	0.40
1.167	0.00389	0.0000223720	0.0275185	2.28	0.35
1.760	0.00392	0.0000227070	0.0279296	2.25	0.35
1.708	0.00570	0.0000466630	0.0573959	1.09	0.29
2.410	0.00804	0.0000906910	0.1115507	0.56	0.23
3.538	0.01181	0.0001902720	0.2340356	0.26	0.19
4.807	0.01604	0.0003437880	0.4228598	0.14	
5.676	0.01894	0.0004737790	0.5827485	0.11	
6.770	0.02259	0.0006657480	0.8188711	0.07	
7.952	0.02654	0.0009082250	1.1171174	0.06	

Table (a2): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 3$ MHz for 3Methylpentane+Nitrethane, and $\omega_0 = 1.23 \times 10^{11}$ Hz

$\Delta T(K)$ $= T - T_c$	$t = \frac{\Delta T}{T_c}$	$t^{1.93}$	$\omega_0 t^{1.93} \times 10^8$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1.93}}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
0.004	0.00001	0.0000000004	0.00000005	391674.00	0.38
0.040	0.00013	0.0000000330	0.0000409	4601.17	0.48
0.091	0.00030	0.0000001620	0.0002000	941.70	0.51
0.159	0.00053	0.0000004770	0.0005873	320.77	0.51
0.197	0.00066	0.0000007220	0.0008881	212.00	0.52
0.219	0.00073	0.0000008850	0.0010895	172.92	0.53
0.295	0.00098	0.0000015740	0.0019361	97.31	0.53
0.391	0.00130	0.0000027110	0.0033348	56.49	0.53
0.495	0.00165	0.0000042740	0.0052573	35.83	0.52
0.644	0.00215	0.0000071020	0.0087363	21.56	0.50
0.851	0.00284	0.0000121620	0.0149604	12.50	0.49
1.167	0.00389	0.0000223720	0.0275185	6.84	0.45
1.760	0.00392	0.0000227070	0.0279296	6.74	0.43
1.708	0.00570	0.0000466630	0.0573959	3.28	0.42
2.410	0.00804	0.0000906910	0.1115507	1.68	0.35
3.538	0.01181	0.0001902720	0.2340356	0.81	0.29
4.807	0.01604	0.0003437880	0.4228598	0.44	0.22
5.676	0.01894	0.0004737790	0.5827485	0.32	0.20
6.770	0.02259	0.0006657480	0.8188711	0.23	0.15
7.952	0.02654	0.0009082250	1.1171174	0.17	0.14
8.948	0.02986	0.0011405260	1.4028477	0.13	0.11
10.012	0.03341	0.0014167050	1.7425475	0.11	0.11
11.064	0.03693	0.0017180060	2.1131479	0.09	0.09
13.484	0.04484	0.0024986790	3.0733762	0.06	0.08

Table (a3): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 7$ MHz for 3Methylpentane+Nitrethane, and $\omega_0 = 1.23 \times 10^{11}$ Hz

$\Delta T(K)$ $= T - T_c$	$t = \frac{\Delta T}{T_c}$	$t^{1.93}$	$\omega_0 t^{1.93} \times 10^8$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1.93}}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
0.004	0.00001	0.0000000004	0.0000005	913908.00	0.37
0.040	0.00013	0.0000000330	0.0000409	10737.40	0.47
0.091	0.00030	0.0000001620	0.0002000	2197.40	0.49
0.159	0.00053	0.0000004770	0.0005873	748.40	0.50
0.197	0.00066	0.0000007220	0.0008881	494.90	0.51
0.219	0.00073	0.0000008850	0.0010895	403.47	0.52
0.295	0.00098	0.0000015740	0.0019361	227.05	0.53
0.391	0.00130	0.0000027110	0.0033348	131.80	0.53
0.495	0.00165	0.0000042740	0.0052573	83.61	0.54
0.644	0.00215	0.0000071020	0.0087363	50.31	0.54
0.851	0.00284	0.0000121620	0.0149604	29.38	0.55
1.167	0.00389	0.0000223720	0.0275185	15.97	0.53
1.760	0.00392	0.0000227070	0.0279296	15.73	0.52
1.708	0.00570	0.0000466630	0.0573959	7.659	0.51
2.410	0.00804	0.0000906910	0.1115507	3.94	0.47
3.538	0.01181	0.0001902720	0.2340356	1.88	0.42
4.807	0.01604	0.0003437880	0.4228598	1.04	0.37
5.676	0.01894	0.0004737790	0.5827485	0.75	0.34
6.770	0.02259	0.0006657480	0.8188711	0.54	0.33
7.952	0.02654	0.0009082250	1.1171174	0.39	0.29
8.948	0.02986	0.0011405260	1.4028477	0.31	0.26
10.012	0.03341	0.0014167050	1.7425475	0.25	0.23
11.064	0.03693	0.0017180060	2.1131479	0.21	0.21
13.484	0.04484	0.0024986790	3.0733762	0.14	0.17

Table (a4): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 9$ MHz for

3Methylpentane+Nitrethane, and $\omega_0 = 1.23 \times 10^{11}$ Hz

$\Delta T(K)$ $= T - T_c$	$t = \frac{\Delta T}{T_c}$	$t^{1.93}$	$\omega_0 t^{1.93} \times 10^8$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1.93}}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
0.004	0.00001	0.0000000004	0.0000005	1175024.00	0.36
0.040	0.00013	0.0000000330	0.0000409	13805.00	0.47
0.091	0.00030	0.0000001620	0.0002000	2825.00	0.51
0.159	0.00053	0.0000004770	0.0005873	962.00	0.52
0.197	0.00066	0.0000007220	0.0008881	636.00	0.53
0.219	0.00073	0.0000008850	0.0010895	518.00	0.53
0.295	0.00098	0.0000015740	0.0019361	291.00	0.54
0.391	0.00130	0.0000027110	0.0033348	169.00	0.55
0.495	0.00165	0.0000042740	0.0052573	107.00	0.56
0.644	0.00215	0.0000071020	0.0087363	64.00	0.57
0.851	0.00284	0.0000121620	0.0149604	37.00	0.57
1.167	0.00389	0.0000223720	0.0275185	20.50	0.56
1.760	0.00392	0.0000227070	0.0279296	20.20	0.55
1.708	0.00570	0.0000466630	0.0573959	9.80	0.54
2.410	0.00804	0.0000906910	0.1115507	5.06	0.52
3.538	0.01181	0.0001902720	0.2340356	2.41	0.47
4.807	0.01604	0.0003437880	0.4228598	1.33	0.42
5.676	0.01894	0.0004737790	0.5827485	0.97	0.40
6.770	0.02259	0.0006657480	0.8188711	0.69	0.35
7.952	0.02654	0.0009082250	1.1171174	0.51	0.32
8.948	0.02986	0.0011405260	1.4028477	0.40	0.30
10.012	0.03341	0.0014167050	1.7425475	0.32	0.28
11.064	0.03693	0.0017180060	2.1131479	0.27	0.26
13.484	0.04484	0.0024986790	3.0733762	0.18	0.23

Table (a5): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 11$ MHz for 3Methylpentane+Nitrethane, and $\omega_0 = 1.23 \times 10^{11}$ Hz

$\Delta T(K)$ $= T - T_c$	$t = \frac{\Delta T}{T_c}$	$t^{1.93}$	$\omega_0 t^{1.93} \times 10^8$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1.93}}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
0.004	0.00001	0.0000000004	0.0000005	1436141.10	0.37
0.040	0.00013	0.0000000330	0.0000409	16873.10	0.48
0.091	0.00030	0.0000001620	0.0002000	3453.20	0.51
0.159	0.00053	0.0000004770	0.0005873	1176.20	0.52
0.197	0.00066	0.0000007220	0.0008881	777.70	0.54
0.219	0.00073	0.0000008850	0.0010895	634.00	0.55
0.295	0.00098	0.0000015740	0.0019361	346.70	0.56
0.391	0.00130	0.0000027110	0.0033348	207.10	0.57
0.495	0.00165	0.0000042740	0.0052573	131.40	0.58
0.644	0.00215	0.0000071020	0.0087363	79.00	0.58
0.851	0.00284	0.0000121620	0.0149604	46.20	0.59
1.167	0.00389	0.0000223720	0.0275185	25.10	0.58
1.760	0.00392	0.0000227070	0.0279296	24.70	0.57
1.708	0.00570	0.0000466630	0.0573959	12.00	0.57
2.410	0.00804	0.0000906910	0.1115507	6.20	0.53
3.538	0.01181	0.0001902720	0.2340356	2.90	0.49
4.807	0.01604	0.0003437880	0.4228598	1.60	0.46
5.676	0.01894	0.0004737790	0.5827485	1.20	0.43
6.770	0.02259	0.0006657480	0.8188711	0.80	0.39
7.952	0.02654	0.0009082250	1.1171174	0.60	0.35
8.948	0.02986	0.0011405260	1.4028477	0.50	0.33
10.012	0.03341	0.0014167050	1.7425475	0.40	0.27
11.064	0.03693	0.0017180060	2.1131479	0.30	0.29
13.484	0.04484	0.0024986790	3.0733762	0.20	0.27

Table (a6): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) at different temperatures at $f = 17$ MHz for 3Methylpentane+Nitrethane, and $\omega_0 = 1.23 \times 10^{11}$ Hz

$\Delta T(K)$ $= T - T_c$	$t = \frac{\Delta T}{T_c}$	$t^{1.93}$	$\omega_0 t^{1.93} \times 10^8$	ω^* $= \frac{2\pi f}{\omega_0 t^{1.93}}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
0.004	0.00001	0.0000000004	0.0000005	2219460.80	0.37
0.040	0.00013	0.0000000330	0.0000409	26076.70	0.49
0.091	0.00030	0.0000001620	0.0002000	5336.80	0.53
0.159	0.00053	0.0000004770	0.0005873	1817.70	0.54
0.197	0.00066	0.0000007220	0.0008881	1202.00	0.57
0.219	0.00073	0.0000008850	0.0010895	979.90	0.57
0.295	0.00098	0.0000015740	0.0019361	551.40	0.58
0.391	0.00130	0.0000027110	0.0033348	320.10	0.59
0.495	0.00165	0.0000042740	0.0052573	203.00	0.60
0.644	0.00215	0.0000071020	0.0087363	122.20	0.61
0.851	0.00284	0.0000121620	0.0149604	71.40	0.62
1.167	0.00389	0.0000223720	0.0275185	38.80	0.64
1.760	0.00392	0.0000227070	0.0279296	38.20	0.63
1.708	0.00570	0.0000466630	0.0573959	18.60	0.62
2.410	0.00804	0.0000906910	0.1115507	9.60	0.61
3.538	0.01181	0.0001902720	0.2340356	4.60	0.58
4.807	0.01604	0.0003437880	0.4228598	2.50	0.55
5.676	0.01894	0.0004737790	0.5827485	1.80	0.52
6.770	0.02259	0.0006657480	0.8188711	1.30	0.47
7.952	0.02654	0.0009082250	1.1171174	0.90	0.45
8.948	0.02986	0.0011405260	1.4028477	0.80	0.43
10.012	0.03341	0.0014167050	1.7425475	0.60	0.39
11.064	0.03693	0.0017180060	2.1131479	0.50	0.38
13.484	0.04484	0.0024986790	3.0733762	0.30	0.35

Appendix B

The data of $\frac{\alpha}{f^2}$ for Nitrobenzene+n Hexane is taken from the work of Abdelraziq and his group (Abdelraziq *et al.*, 1990). The values of $\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$ at different temperature and reduced frequency are listed in tables (b1-b6) at frequencies 5, 7, 10, 15, 21, and 25 MHz.

Table (b1): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 5$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz

$T(K)$	$T_c(K)$	$\Delta T(K) = T - T_c$	$\omega_0 t^{1,93} \times 10^{12}$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1,93}}$	$u(T) \frac{m}{s}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
293.26	293.25	0.01	0.000003	657156.80	1209.2	0.45
293.36	293.25	0.11	0.000300	6423.00	1208.8	0.69
293.50	293.25	0.25	0.001400	1317.00	1208.3	0.74
293.68	293.25	0.43	0.003900	462.46	1207.6	0.74
293.86	293.25	0.61	0.007700	235.00	1207.0	0.70
294.36	293.25	1.11	0.024500	74.16	1205.2	0.67
294.86	293.25	1.61	0.050100	36.18	1203.4	0.65
295.36	293.25	2.11	0.084500	21.46	1201.6	0.67
295.86	293.25	2.61	0.127400	14.24	1199.8	0.61
296.36	293.25	3.11	0.178700	10.15	1198.0	0.57
296.86	293.25	3.61	0.238200	7.61	1196.2	0.54
297.36	293.25	4.11	0.306000	5.92	1194.4	0.52
297.86	293.25	4.61	0.381900	4.75	1192.6	0.47
298.36	293.25	5.11	0.465900	3.89	1190.8	0.45
299.36	293.25	6.11	0.657800	2.75	1187.2	0.39
300.36	293.25	7.11	0.881300	2.05	1183.7	0.34
301.36	293.25	8.11	1.136200	1.59	1180.1	0.28
302.36	293.25	9.11	1.422000	1.27	1176.5	0.23
303.36	293.25	10.11	1.738600	1.04	1172.9	0.19
305.36	293.25	12.11	2.463200	0.73	1165.7	0.16
307.36	293.25	14.11	3.308400	0.55	1158.5	0.12
309.36	293.25	16.11	4.272900	0.42	1151.3	0.10
311.36	293.25	18.11	5.355700	0.34	1144.2	0.09
313.36	293.25	20.11	6.556000	0.28	1137.0	0.08
318.36	293.25	25.11	10.06300	0.18	1119.1	0.07
323.36	293.25	30.11	14.28700	0.13	1101.1	0.06

Table (b2): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 7 \text{ MHz}$, and $\omega_0 = 2 \times 10^{10} \text{ Hz}$

$T(K)$	$T_c(K)$	$\Delta T(K) = T - T_c$	$\omega_0 t^{1,93} \times 10^{12}$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1,93}}$	$u(T) \frac{m}{s}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
293.26	293.25	0.01	0.000003	920019.50	1208.4	0.46
293.36	293.25	0.11	0.000300	8993.09	1208.1	0.68
293.50	293.25	0.25	0.001400	1440.50	1207.5	0.72
293.68	293.25	0.43	0.003900	647.44	1206.9	0.74
293.86	293.25	0.61	0.007700	329.69	1206.2	0.76
294.36	293.25	1.11	0.024500	103.83	1204.4	0.75
294.86	293.25	1.61	0.050100	50.65	1202.2	0.72
295.36	293.25	2.11	0.084500	30.05	1200.8	0.67
295.86	293.25	2.61	0.127400	19.93	1199.0	0.60
296.36	293.25	3.11	0.178700	14.21	1197.2	0.54
296.86	293.25	3.61	0.238200	10.66	1195.4	0.48
297.36	293.25	4.11	0.306000	8.30	1193.6	0.44
297.86	293.25	4.61	0.381900	6.65	1191.9	0.41
298.36	293.25	5.11	0.465900	5.45	1190.1	0.38
299.36	293.25	6.11	0.657800	3.86	1186.5	0.36
300.36	293.25	7.11	0.881300	2.88	1182.9	0.31
301.36	293.25	8.11	1.136200	2.23	1179.3	0.28
302.36	293.25	9.11	1.422000	1.78	1175.7	0.24
303.36	293.25	10.11	1.738600	1.46	1172.1	0.21
305.36	293.25	12.11	2.463200	1.03	1164.9	0.19
307.36	293.25	14.11	3.308400	0.77	1157.7	0.15
309.36	293.25	16.11	4.272900	0.59	1150.6	0.13
311.36	293.25	18.11	5.355700	0.47	1143.3	0.11
313.36	293.25	20.11	6.556000	0.39	1136.2	0.08
318.36	293.25	25.11	10.06300	0.25	1118.3	0.07
323.36	293.25	30.11	14.28700	0.18	1100.3	0.05

Table (b3): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 10$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz

$T(K)$	$T_c(K)$	$\Delta T(K) = T - T_c$	$\omega_0 t^{1,93} \times 10^{12}$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1,93}}$	$u(T) \frac{m}{s}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
293.26	293.25	0.01	0.000003	1314314.00	1207.7	0.48
293.36	293.25	0.11	0.000300	12847.20	1207.3	0.63
293.50	293.25	0.25	0.001400	2634.35	1206.8	0.72
293.68	293.25	0.43	0.003900	924.90	1206.2	0.74
293.86	293.25	0.61	0.007700	470.90	1205.5	0.76
294.36	293.25	1.11	0.024500	148.32	1203.7	0.72
294.86	293.25	1.61	0.050100	72.36	1201.9	0.68
295.36	293.25	2.11	0.084500	42.93	1200.1	0.66
295.86	293.25	2.61	0.127400	28.48	1198.4	0.63
296.36	293.25	3.11	0.178700	20.30	1196.6	0.60
296.86	293.25	3.61	0.238200	15.23	1194.8	0.57
297.36	293.25	4.11	0.306000	11.85	1192.9	0.55
297.86	293.25	4.61	0.381900	9.50	1191.2	0.53
298.36	293.25	5.11	0.465900	7.78	1189.4	0.50
299.36	293.25	6.11	0.657800	5.51	1185.8	0.44
300.36	293.25	7.11	0.881300	4.11	1182.2	0.39
301.36	293.25	8.11	1.136200	3.19	1178.7	0.35
302.36	293.25	9.11	1.422000	2.55	1175.1	0.31
303.36	293.25	10.11	1.738600	2.08	1171.5	0.27
305.36	293.25	12.11	2.463200	1.47	1164.34	0.22
307.36	293.25	14.11	3.308400	1.09	1157.2	0.18
309.36	293.25	16.11	4.272900	0.84	1150.0	0.15
311.36	293.25	18.11	5.355700	0.67	1142.7	0.12
313.36	293.25	20.11	6.556000	0.55	1135.7	0.10
318.36	293.25	25.11	10.06300	0.36	1117.8	0.08
323.36	293.25	30.11	14.28700	0.25	1099.9	0.05

Table (b4): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 15$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz

$T(K)$	$T_c(K)$	$\Delta T(K) = T - T_c$	$\omega_0 t^{1,93} \times 10^{12}$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1,93}}$	$u(T) \frac{m}{s}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
293.26	293.25	0.01	0.000003	1971470.00	1206.1	0.54
293.36	293.25	0.11	0.000300	19270.00	1205.7	0.79
293.50	293.25	0.25	0.001400	3951.50	1205.2	0.93
293.68	293.25	0.43	0.003900	1387.30	1204.6	0.95
293.86	293.25	0.61	0.007700	706.40	1203.9	0.95
294.36	293.25	1.11	0.024500	222.40	1202.1	0.91
294.86	293.25	1.61	0.050100	108.50	1200.3	0.85
295.36	293.25	2.11	0.084500	64.40	1198.5	0.79
295.86	293.25	2.61	0.127400	42.70	1196.7	0.72
296.36	293.25	3.11	0.178700	30.40	1194.9	0.67
296.86	293.25	3.61	0.238200	22.80	1193.1	0.62
297.36	293.25	4.11	0.306000	17.70	1191.3	0.59
297.86	293.25	4.61	0.381900	14.20	1189.6	0.57
298.36	293.25	5.11	0.465900	11.60	1187.8	0.55
299.36	293.25	6.11	0.657800	8.30	1184.2	0.50
300.36	293.25	7.11	0.881300	6.20	1180.6	0.46
301.36	293.25	8.11	1.136200	4.80	1176.9	0.42
302.36	293.25	9.11	1.422000	3.80	1173.4	0.38
303.36	293.25	10.11	1.738600	3.13	1169.8	0.35
305.36	293.25	12.11	2.463200	2.20	1162.6	0.32
307.36	293.25	14.11	3.308400	1.60	1155.4	0.27
309.36	293.25	16.11	4.272900	1.30	1148.3	0.21
311.36	293.25	18.11	5.355700	1.00	1141.1	0.17
313.36	293.25	20.11	6.556000	0.80	1133.9	0.14
318.36	293.25	25.11	10.06300	0.50	1115.9	0.10
323.36	293.25	30.11	14.28700	0.40	1098.0	0.06

Table (b5): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 21$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz

$T(K)$	$T_c(K)$	$\Delta T(K) = T - T_c$	$\omega_0 t^{1,93} \times 10^{12}$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1,93}}$	$u(T) \frac{m}{s}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
293.26	293.25	0.01	0.000003	2760058.00	1206.1	0.58
293.36	293.25	0.11	0.000300	26979.00	1205.7	0.92
293.50	293.25	0.25	0.001400	5532.00	1205.2	0.97
293.68	293.25	0.43	0.003900	1942.30	1204.6	1.01
293.86	293.25	0.61	0.007700	989.08	1203.9	1.03
294.36	293.25	1.11	0.024500	311.50	1202.1	1.04
294.86	293.25	1.61	0.050100	151.90	1200.3	1.02
295.36	293.25	2.11	0.084500	90.10	1198.5	0.98
295.86	293.25	2.61	0.127400	59.80	1196.7	0.95
296.36	293.25	3.11	0.178700	42.60	1194.9	0.91
296.86	293.25	3.61	0.238200	31.90	1193.1	0.87
297.36	293.25	4.11	0.306000	24.90	1191.3	0.83
297.86	293.25	4.61	0.381900	19.90	1189.6	0.79
298.36	293.25	5.11	0.465900	16.30	1187.8	0.71
299.36	293.25	6.11	0.657800	11.60	1184.2	0.64
300.36	293.25	7.11	0.881300	8.60	1180.6	0.57
301.36	293.25	8.11	1.136200	6.70	1176.9	0.52
302.36	293.25	9.11	1.422000	5.30	1173.4	0.50
303.36	293.25	10.11	1.738600	4.40	1169.8	0.45
305.36	293.25	12.11	2.463200	3.10	1162.6	0.43
307.36	293.25	14.11	3.308400	2.30	1155.4	0.35
309.36	293.25	16.11	4.272900	1.80	1148.3	0.31
311.36	293.25	18.11	5.355700	1.40	1141.1	0.25
313.36	293.25	20.11	6.556000	1.20	1133.9	0.22
318.36	293.25	25.11	10.06300	0.80	1115.9	0.12
323.36	293.25	30.11	14.28700	0.50	1098.0	0.06

Table (b6): Reduced frequencies (ω^*) and experimental absorption values ($\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$) for Nitrobenzene+n Hexane at different temperatures at $f = 25$ MHz, and $\omega_0 = 2 \times 10^{10}$ Hz

$T(K)$	$T_c(K)$	$\Delta T(K) = T - T_c$	$\omega_0 t^{1,93} \times 10^{12}$	$\omega^* = \frac{2\pi f}{\omega_0 t^{1,93}}$	$u(T) \frac{m}{s}$	$\frac{\alpha_\lambda}{\pi u^2 A_F(T)}$
293.26	293.25	0.01	0.000003	3285784.00	1206.1	0.54
293.36	293.25	0.11	0.000300	32118.20	1205.7	0.85
293.50	293.25	0.25	0.001400	6585.90	1205.2	0.88
293.68	293.25	0.43	0.003900	2312.30	1204.6	0.87
293.86	293.25	0.61	0.007700	1177.40	1203.9	0.85
294.36	293.25	1.11	0.024500	370.80	1202.1	0.70
294.86	293.25	1.61	0.050100	180.90	1200.3	0.64
295.36	293.25	2.11	0.084500	107.30	1198.5	0.59
295.86	293.25	2.61	0.127400	71.20	1196.7	0.56
296.36	293.25	3.11	0.178700	50.80	1194.9	0.53
296.86	293.25	3.61	0.238200	38.10	1193.1	0.51
297.36	293.25	4.11	0.306000	29.60	1191.3	0.48
297.86	293.25	4.61	0.381900	23.70	1189.6	0.46
298.36	293.25	5.11	0.465900	19.50	1187.8	0.45
299.36	293.25	6.11	0.657800	13.80	1184.2	0.42
300.36	293.25	7.11	0.881300	10.30	1180.6	0.39
301.36	293.25	8.11	1.136200	7.90	1176.9	0.40
302.36	293.25	9.11	1.422000	6.30	1173.4	0.38
303.36	293.25	10.11	1.738600	5.20	1169.8	0.37
305.36	293.25	12.11	2.463200	3.70	1162.6	0.32
307.36	293.25	14.11	3.308400	2.70	1155.4	0.29
309.36	293.25	16.11	4.272900	2.10	1148.3	0.26
311.36	293.25	18.11	5.355700	1.70	1141.1	0.23
313.36	293.25	20.11	6.556000	1.40	1133.9	0.20
318.36	293.25	25.11	10.06300	0.90	1115.9	0.14
323.36	293.25	30.11	14.28700	0.60	1098.0	0.07

Appendix C

Many attempts have been made to get a proper form of analytic function to make sure the experimental data agree with theoretical predictions. Some attempts will be displayed and compared with Fixman's analytic function

The values of reduced frequencies ω^* , which are needed to calculate $I_{m1F}(\omega^*)$, are listed in Table (c1)

where

$I_{m1F}(\omega^*)$ is Fixman's scaling function using First modification of scaling function, which gives in the form $K_{m1}(x) = x^2(1 + x^2 + x^3)$.

The final result of attempts is our modification of Fixman's analytic function.

Table (c1): Numerical values of Fixman's scaling function $I_F(\omega^*)$ using Fixman's analytic function $K_{m1}(x) = x^2(1 + x^2 + x^3)$

ω^*	$I_F(\omega^*)$
500000.00	0.0243
8993.09	0.0529
1844.05	0.0697
647.44	0.0818
329.69	0.0896
103.83	0.1015
50.65	0.1069
30.05	0.1092
19.93	0.1099
14.21	0.1096
10.66	0.1087
8.30	0.1073
6.65	0.1057
5.45	0.1039
3.86	0.0999
2.88	0.0958
2.23	0.0916
1.78	0.0875
1.46	0.0837
0.76	0.0695
0.59	0.0636
0.47	0.0583
0.38	0.0533
0.25	0.0438
0.18	0.0368
0.05	0.0160
2.00×10^{-3}	9.7053×10^{-04}
7.63×10^{-4}	3.8451×10^{-04}

Scaling function $I_{m1F}(\omega^*)$ and scaling function $I_F(\omega^*)$ as a function of reduced frequency at each temperature is shown in Figure (c1).

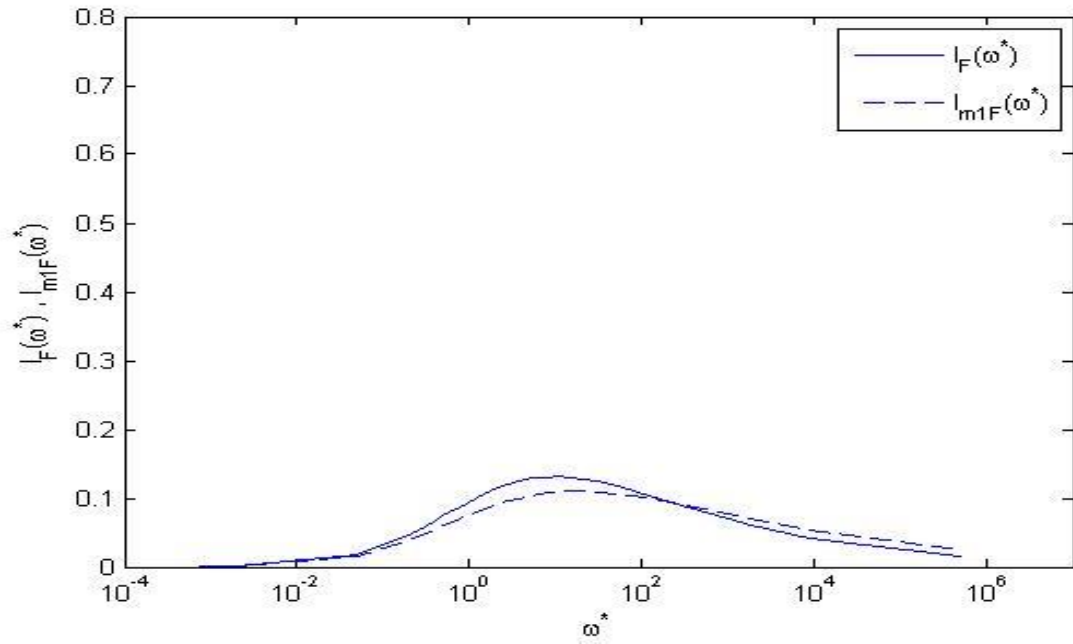


Fig .c1 Fixman's scaling function using Fixman's analytic function in solid line, and Fixman's scaling function using first modification analytic function in dashed line

The second modification of Fixamn's analytic function $K_{m2}(\omega^*)$ depends on adding term equal $(\frac{1}{x})$. However, the numerical values of Fixman's scaling function with second modification of Fixamn's analytic function are given in Table (c2).

Table (c2): Numerical values of Fixman's scaling function $I_F(\omega^*)$ using Fixman's analytic function $K_{m1}(x) = x^2(1 + x^2 + \frac{1}{x})$

ω^*	$I_F(\omega^*)$
500000.00	0.0159
8993.09	0.0417
1844.05	0.0592
647.44	0.0730
329.69	0.0824
103.83	0.0979
50.65	0.1057
30.05	0.1096
19.93	0.1112
14.21	0.1113
10.66	0.1104
8.30	0.1088
6.65	0.1068
5.45	0.1044
3.86	0.0990
2.88	0.0931
2.23	0.0872
1.78	0.0813
1.46	0.0759
0.76	0.0563
0.59	0.0488
0.47	0.0423
0.38	0.0367
0.25	0.0268
0.18	0.0205
0.05	0.0064
2.00×10^{-3}	2.6075×10^{-04}
7.63×10^{-4}	9.9487×10^{-05}

Scaling function $I_{m2F}(\omega^*)$ and scaling function $I_F(\omega^*)$ as a function of reduced frequency at each temperature is shown in Figure (c2).

where $I_{m2F}(\omega^*)$ is Fixman's scaling function by using second modification of scaling function, which is given in the form of

$$K_{m2}(x) = x^2(1 + x^2 + \frac{1}{x}).$$

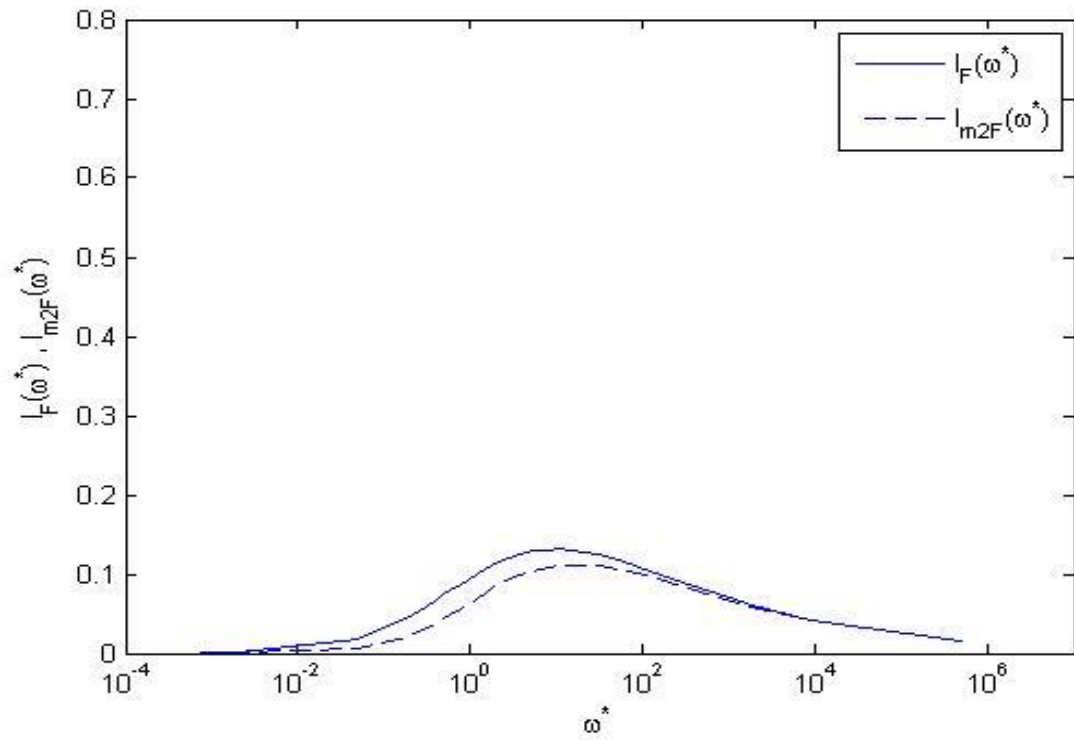


Fig .c2 Fixman's scaling function using Fixman's analytic function in solid line, and Fixman's scaling function using second modification analytic function in dashed line

Comparing Figure (c1) and Figure (c2), one can find that with the addition term (x^3) to the analytic function contributes to increase the band of scaling function this can be applied to all terms which may be added to the Fixman's analytic function. However, when the term $\left(\frac{1}{x}\right)$ is added to the analytic function it leads to decrease the band of the scaling function.

جامعة النجاح الوطنية

كلية الدراسات العليا

تعديل الاقتران التحليلي لنظرية فيكسمان في مخاليط السوائل الثنائية

إعداد

ضياء الدين عدنان عبد اللطيف قاسم

إشراف

أ.د. عصام راشد عبد الرازق

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في الفيزياء بكلية

الدراسات العليا في جامعة النجاح الوطنية في نابلس - فلسطين

2014

ب
تعديل الاقتران التحليلي لنظرية فيكسمان في مخاليط السوائل الثنائية
إعداد
ضياء الدين عدنان عبد اللطيف قاسم
إشراف
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الملخص

تم دراسة نظرية فيكسمان التي تختص بالسوائل ثنائية المخاليط ودرستها بعد النقطة الحرجة، التي لم تعمل على وصف السلوك الحرج بالشكل الدقيق خاصة عند الترددات العالية. تم تعديل الاقتران التحليلي لنظرية فيكسمان باضافة حدود جديدة تعتمد على طول الارتباط (correlation length)، وهذا التعديل أسهم في تغيير شكل الاقتران الاتزاني، مع بقاء الاقتران الاتزاني غير موافق للنتائج التجريبية. لذلك تم تعديل الاقتران الاتزاني لنظرية فيكسمان باضافة حد جديد يعتمد على النسبة بين السعة الحرارية بثبوت الضغط و السعة الحرارية بثبوت الحجم وهو $(2.30 + \frac{\gamma_0}{\gamma_{0-1}})$. لقد تم اخذ نتائج تجريبية من مراجع على معامل امتصاص الصوت وسرعته في المركبات الثنائية نيتروبنزين+ ن هيكسان و 3ميثيلبنتان+ نيتروايثان وتم مقارنة النتائج التجريبية مع النظرية التي تم تعديلها لنظرية فيكسمان، ووجد أن هناك توافق جيد بين النتائج التجريبية والنتائج النظرية، بسبب وجود الحد الذي يعتمد على γ_0 المضاف الى الاقتران الاتزاني والذي يلعب دور رئيسي في مطابقة النتائج التجريبية مع النتائج النظرية.