International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 06 | June 2019 www.irjet.net p-ISSN: 2395-0072

Determination of the Ultrasonic Velocities in Binary Liquid Mixture by using Ultrasonic Interferometer

Sana Rajgoli[1], Ashish Patil[2]

[1]*Assistant Professor, Dept. of Physics, Shaikh College of Enginerring & Technology, Karnataka, India*
[2]*Head of Department, Dept. of Science, Jain Heritage School, Karnataka, India*

Abstract - Ultrasonic methods find extensive applications for characterizing aspects of physicochemical behavior such as nature of molecular interactions in pure liquids as well as liquid mixtures. Experimental technique employed in the present for the measurement of ultrasonic velocity and working principle of ultrasonic interferometer have been discussed in this paper. In addition to that the present paper also include a brief discussion on experimental setup, different parts, procedure of ultrasonic interferometer and various thermodynamics parameters like adiabatic compressibility ,free length etc.

In this paper an attempt to investigate the ultrasonic studies of Benzene, Methanol, Ethanol, Propanol, Butanol, Dimethyl sulfoxide, Acetonitrile binary liquid mixture systems. We have measured density (ρ), ultrasonic velocity (u), viscosity (Ƞ) of mixtures of these liquids .From this data acoustical parameters like adiabatic compressibility, free length (L_f), free volume (V_f), and their excess values are computed

Key Words: Ultrasonic methods, ultrasonic interferometer, binary liquid mixture systems

1. INTRODUCTION

Ultrasonic interferometer is a simple and direct device which yields accurate and consistent data, from which one can determine the velocity of ultrasonic sound in a liquid medium. The operating generator has been used to measure the ultrasonic velocity.

Ultrasonic sound refers to sound pressure with a frequency greater than the human audible range (20 Hz to 20 KHz) .When an ultrasonic wave propagates through a medium , the molecule in that medium vibrate over very short distance in a direction parallel to the longitudinal wave. During this vibration, momentum is transferred among molecules. This causes the wave to pass through the medium.

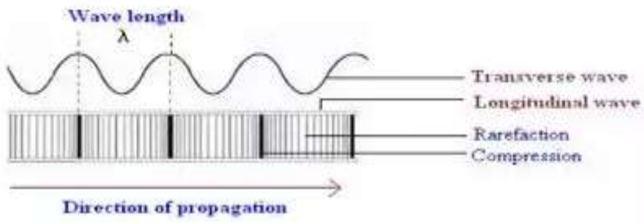

Fig.1.1 Transverse and Longitudinal wave

1.1 Generation Of Ultrasound

Ultrasound can be produced by different methods. The most common methods include

1. Mechanical method - In this ultrasonic frequencies up to 100 KHz are produced. But this method is rarely used due to its limited frequency range.
2. Piezoelectric method- When crystals like quartz or tourmaline are stressed along any pair of opposite faces, electric charges of opposite polarity are induced in the opposite faces perpendicular to the stress as shown in fig. 1.2. This is known as Piezoelectric effect.

Fig.1.2 Generation of ultrasound using piezoelectric method

This is the most common method used for the production of ultrasound. Piezoelectric effects are exhibited by certain crystals which lack centre of symmetry. In a piezoelectric crystal positive and negative electrical charges are separated. But symmetrically distributed, so that the crystal over all is electrically neutral, each of these sides forms an electric dipole and dipoles near each other tend to be aligned in region called Weiss domains. The domains are usually randomly oriented, but can be aligned during poling, a process by which a strong electric field is applied approx the material, usually at elevated temperatures.

When a mechanical stress is applied, this symmetry is distributed and the charge symmetry generates a voltage across the material

For example: One cm cube of quartz with 2KN (500/bf)of correctly applied force can produce a voltage of 12500 volt. Piezoelectric materials also show the opposite effect called inverse (converse) piezoelectric effect. Where the application of the electric field creates mechanical deformation in the crystal.

When an alternating electromagnetic field is applied opposite faces of a quartz are tourmaline crystal. It undergoes contraction and expansion alternatively in the perpendicular direction ,this is known as inverse piezoelectric effect. This is made use of in the piezoelectric generator.

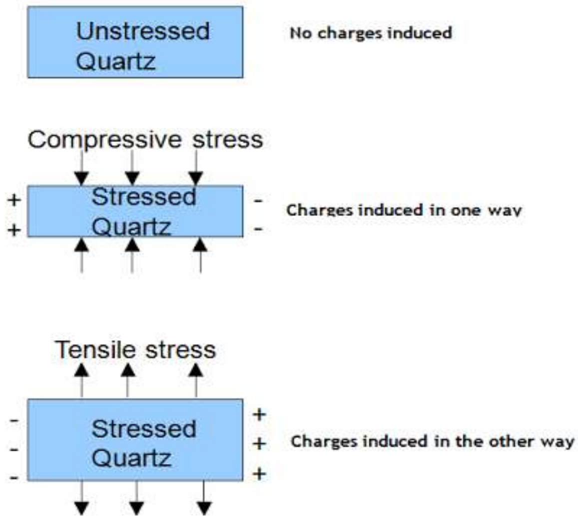

Fig. 1.3 Illustration of charges induced in piezoelectric material

1.2 Piezoelectric generator

A slab of piezoelectric crystal is taken and using this a parallel plate capacitor is made . Then with other electronic components an electronic oscillator is designed to produce electrical oscillations greater than 20 kHz. Generally one can generate ultrasonic waves of order of MHz. Using piezoelectric generator quartz slabs are prepared because it posses rare physical and chemical properties.

A tank circuit has a variable capacitor 'C', and an inductor 'L' which describes the frequency of the electrical oscillations. When the circuit is closed current rushes through the tank circuit and the capacitor is charged, after fully charged no current passes through the same.

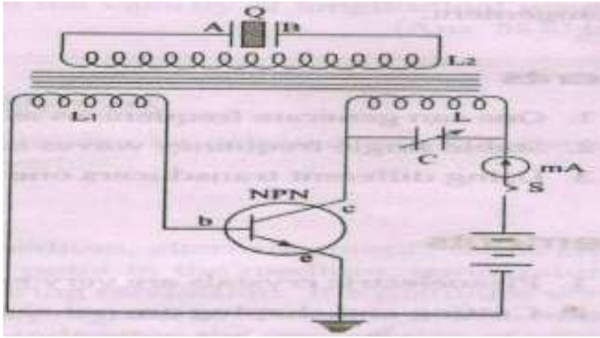

Fig.1.4 Circuit diagram of piezoelectric generator

Then the capacitor starts discharging through the inductor and hence the electrical energy is in the form of electric and magnetic field associated with the capacitor and the inductor respectively. Thus we get electrical oscillations in the tank circuit with the help of other electronic components including a transistor, electrical oscillations are produced continuously. This is fed to the secondary circuit and th piezoelectric crystal vibrates as it is continuously subjected to varying (alternating) electric field, and it produces sound waves, when the frequency of an electrical oscillations is in the ultrasonic range then ultrasonic waves are generated. When the frequency of oscillation is matched with the natural frequency of piezoelectric slab then it will vibrate with maximum amplitude. The frequency generated is given as follows.

$$F = pE$$

Where p is density of piezoelectric material and E is Young's modulus of piezoelectric material.

1.3 Ultrasonic Interferometer

The schematic diagram of an ultrasonic interferometer is shown in the fig. 1.4.

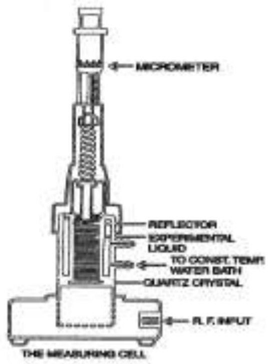

Fig.1.5 Diagram of ultrasonic interferometer

In an ultrasonic interferometer, the ultrasonic waves are produced by the piezoelectric method. In a fixed frequency variable path interferometer, the wavelength of the sound in an experimental liquid medium is measured and from this one can calculate its velocity through that medium. The apparatus consist of an ultrasonic cell , which is a double walled brass cell with chromium plated surfaces having a capacity of 10 ml .The double wall allows water circulation around the experimental medium to maintain it at a known constant temperature.

The micrometer scale is marked in units of 0.01mm and has an overall length of 25mm. Ultrasonic waves of known frequency are produced by quartz crystal which is fixed at the bottom of the cell. There is a movable metallic plate parallel to the quartz plate, which reflects the waves. The waves interfere with their reflections, and if the separation between the plates is exactly an integer multiple of half wavelength of sound, standing waves are produced in the liquid medium. Under these circumstances, acoustic resonance occurs. The resonant waves are maximum in amplitude causing corresponding maximum in the anode current of the piezoelectric generator.

The ultrasonic interferometer consist of mainly two parts

1) The high frequency generator-
The high frequency generator is designed to excite the quartz crystal fixed at the bottom of the measuring cell at it resonance frequency to generate ultrasonic waves in experimental liquid filled in the "Measuring cell". A micrometer is provided to observe the changes in current and to control for the purpose of sensitivity regulation and initial adjustment of the micrometer are provided on the panel of the high frequency generator.

2) The measuring cell
The measuring cell is specially designed double walled cell for maintaining the temperatures of the liquid constant during the experiment. A fine micrometer screw has been provided at the top, which can lower or raise the reflector plate in the liquid in the cell through a known distance. It has a quartz crystal fixed at its bottom.

In ultrasonic interferometer dual frequency, frequency selector knob should be positioned at desired frequency and the corresponding cell should be connected to the generator. For initial adjustment two knobs are provided on high frequency generator, one is marked with "ADJ" to adjust the position of the needle on the ammeter and the knob marked "GAIN" is used to increase the sensitivity of the instrument for greater deflection if desired. The ammeter is used to notice the number of maximum deflections while micrometer is moved up and down liquid.

1.3.1 Properties of ultrasonic waves

• Ultrasonic waves are having frequencies higher than 20 KHz and hence they are highly energetic and their wavelength is small.
• Due to their small wavelengths, the diffraction is negligible. Hence, they can be transmitted over a long distances without any appreciable loss of energy.
• When they are passing through a medium, at discontinuities, they are partially reflected and this property is used in Non-Destructive Technique (NDT).
• When the ultrasonic wave is absorbed by a medium, it generates heat.
• They are able to drill and cut thin metals.
• At room temperature, ultrasonic welding is possible.
• They mix molten meals of widely different densities to produce alloys of uniform composition.
• Using ultrasonic wave, Acoustic grating can be formed in a liquid.
They undergo reflection and refraction.
• They produce heating effect, mechanical effect and chemical effect.
• They produce biological effect. Animals such as frogs and rats are killed when subjected to ultrasonic waves.
• Produce stationary wave pattern in liquids of suitable dimensions and behave as an acoustical grating.

1.3.2 Applications

Ultrasonication is used in many applications such as Homogenizing, Disintegration, Sonochemistry, Degassing or Cleaning.

1) Ultrasonic Homogenizing
Ultrasonic processors are used as homogenizers, to reduce small particles in a liquid to improve uniformity and stability. These particles can be either solids or liquids. Ultrasonic homogenizing is very efficient for the reduction of soft and hard particles. Laboratory ultrasonic devices can be used for volumes from 1.5 ml to 2 l. Ultrasonic industrial devices are used for the process development and production batches from 0.5 to 2000 l are flow rates from 0.1 l to 20 m3 per hour.

2) Dispersing and deagglomeration
Dispersing and deagglomeration of solids into liquids is an important application of ultrasonic devices. Ultrasonic cavitations generate high shear forces that break particles agglomerates into single dispersed particles. The mixing powders into liquids is a common step in the formulation of various products , such as paint, ink, shampoo, beverages or polishing media. The attraction forces must be overcome by vanderwaal forces on order to deagglomerate and disperse the particles into liquid media. For this high intensity ultrasonication is an interesting alterative to high pressure

3) Ultrasonic Emulsifying
A wide range of intermediate and consumer products, such as cosmetics and skin lotions, pharmaceutical ointments, varnishes, pints and lubricants and fuels are based wholly or in part os emulsions. Emulsions are dispersions of two are more immiscible liquids.

4) Ultrasonic wet-milling and grinding
Ultrasonic is an efficient means for the wet milling and micro-grinding of particles in particular further manufacturing of superfine size slurries, ultrasonic has many

advantages, when compared with common size reduction equipment ,such as colloid mills(e.g.ball mills,bead mills)

5) Cell Disintegration
Ultrasonic treatment can disintegrate fibrous, cellulosic material into fine particles and breaks the walls of the cell structure. Such that cell wall material is being broken into small debris.

6) Ultrasonic cell extraction
The extraction of enzymes and proteins stored in cell and sub cellular particles is an effective application high intensity ultrasound, has the extraction of organic compounds contained within the body of plants and seeds by a solvent a significantly improved.

7) Sonochemical application of ultrasonics
Sonochemistry is the application of ultrasound to chemical reactions and processes. The mechanism causing sonochemical effects in liquids is the phenomenon of acoustic cavitation. This includes increase in reaction speed and more efficient energy usage.

8) Trannsesterification(Biodiesel)
Ultrasnication increases the chemical reaction speed and yield of the transesterification of vegitable oils and animal fats into biodiesel.

9) Ultrasonic degassing of liquids
Degassing of liquids is an interesting application of ultrasonic devices. in this case the ultrasound removes from small suspended gas bubbles from the liquids and reduces the level of dissolved gas.

10) Leak detection (bottles and cans)
Ultrasound is being used in bottling and filling machines to check cans and bottles for leaks. The instantaneous release of carbon di oxide is tha decisive effect of ultrasonic leakage test of containers.

11) Cable and strip
Ultrasonic cleaning is an environmentally friendly alternative for the cleaning of continuous materials, such as wire and cable, tape or tubes.

2. EXPERIMENTAL TECHNIQUE

Source Used: Benzene, Methanol, Ethanol, Propanol, Butanol, DMSO, Acetonitrile
Frequency used : 2 MHz
Least Count of the micrometer: 0.01 mm

2.1 Procedure

Ultrasonic interferometer is used to determine the ultrasonic waves in liquids. It consists of a high frequency generator and measuring cell.

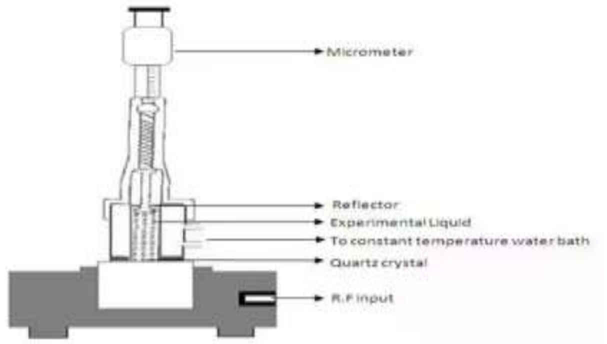

Fig.2.1 Experimental set-up

1) Insert the Quartz crystal in the socket at the base and clamp it tightly with a help of a screw provided on one side of the instrument.
2) Weigh the empty specific gravity (W_o) and weight the specific gravity bottle with water (W_1) and weight the specific gravity bottle with solution (W_2)
3) Calculate the density by using formula

$$= \frac{W2 - Wo}{W1 - Wo}$$

4) Calculate weight fraction by using the formula,
Solute/Solute + Solvent i.e. X / (X+15)
5) repeat the above two steps for different liquid.
6) Unscrew the knurled cap of cell and lift it away from double walled concentration of the cell. In the middle portion of it pour experimental liquid and screw the knurled cap wipe out excess liquid overflowing from the cell.
7) Connect the high frequency generator with all by coaxial cable provided with the instrument.
8) Select the desire frequency using the frequency selector knob
9) There are two knobs on the instrument "ADJ" and "GAIN" with "ADJ" position of the needle on the ammeter is adjusted and the knob "GAIN" is used to increase the sensitivity of the instrument.
10) Move micrometer slowly in either clockwise direction or anticlockwise direction till the anode current on the ammeter on high frequency generator shows a max or min.
11) Note down the micrometer reading corresponding to the maximum or minimum in the micro ammeter.
12) Continue to increase the micrometer setting noting the reading at each maximum. Count any number of maxima and subtract the reading at first maxima from the reading at the next maximum. This will make the measurement accurate. We take this measurement as difference

$$d = \lambda/2$$

Take average of all the differences ($\lambda/2$)
13) Once the wavelength (λ) is known the velocity (V) in the liquid can be calculated with the help of the relation

$$V = \lambda f$$

3. RESULT AND DISCUSSION

The binary mixture system taken up for the present study are : Benzene + Methanol, Ethanol, Propanol , Butanol, Dimthyl sulfoxide, Acetonitrile. The values of solvent paprameter are given in table I. The experimentally determined values of velocity, density and along with the calculated values of adiabatic compressibility (β), Intermolecular Free length (Lf), Acoustic impedance (Z) and free volume (V_f) all are reported in table II.

TABLE I- Solvent Parameters

Solvent Parameters		
Liquids	**Molecular weight in g/mol**	**Viscosity η in mPa**
Benzene	78.11	0.603
Methanol	32.04	0.54
Ethanol	46.068	1.07
Propanol	60.095	2.04
Butanol	74.122	2.54
DMSO	78.13	0.92
Acetonitrile	41.05	0.334

Sample Calculation
1) For Benzene
Weight of specific gravity bottle (Wo) = 18.178 gm
Weight of specific gravity bottle + Water (W1) = 29.588 gm
Weight of specific gravity bottle + Benzene (W2) = 28.058 gm

$$\rho = \frac{W2 - Wo}{W1 - Wo} = 0.865$$

We have, d = λ/2
0.31 = λ/2
λ = 2 x 0.31
= 0.62 m
Velocity = f λ
= 2 x 0.62
= 1240 m/s

TABLE II- Results

Liquids	Concentration	Velocity U m\s	Wavelength λ	Density ρ	Weight fraction
Benzene	1	1240	0.62	0.864	0.0625
Methanol	1	1259	0.629	0.863	0.0625
	1.5	1261.3	0.630	0.865	0.0909
	2	1224	0.612	0.865	0.1176
Ethanol	1	1273.3	0.636	0.867	0.0625
	1.5	1239.6	0.619	0.870	0.0909
	2	1244	0.622	0.860	0.1176
Propanol	1	1219	0.609	0.861	0.0625
	1.5	1245.7	0.622	0.863	0.0909
	2	1244	0.622	0.855	0.1176
Butanol	1	1275	0.637	0.835	0.0625
	1.5	1238	0.619	0.883	0.0909
	2	1235	0.617	0.977	0.1176
DMSO	1	1305.3	0.652	0.753	0.625
	1.5	1283.5	0.641	0.883	0.0909
	2	1304	0.652	0.886	0.1176
Acetonitrile	1	1272.8	0.636	0.867	0.0625
	1.5	1269.7	0.634	0.862	0.0909
	2	1311.1	0.655	0.863	0.1176

Acoustic parameter such as Adiabatic compressibility (β), Intermolecular Free length (Lf), Acoustic impedance (Z) and Free volume (Vf) were determined using the following relations.

Adiabaticn Compressibility $B = \frac{1}{u^2\rho}$

Intermolecular Free length $L_f = K_T\beta$

Free volume $V_f = \frac{Mu^{3/2}}{k\eta}$

Acoustic impedance Z= uρ
Where K_T is the temperature dependent having a value of 199.53x10^{-8} in MKS system is temperature independent constant whose value is 4.28x10^{9} in MKS system, ρ is density in Kg/m^3 and M is molecular weight.

Values of ultrasonic velocity(u) m/s, density()kg/m^3, adiabatic compressibility() m^2/N , intermolecular free length(Lf) m, acoustic impendence (Z) kg/m^2s and free volume(Vf) m^3/mol of binary systems as a function of molar concentration of components are below table III.

TABLE III- Results

Conc.	u m/s	ρ	β x 10^{-7}	L_f x10^{-15}	Z m/s	V_f
Methanol + Benzene						
0	1240	0.865	7.1518	1500.18	1072.6	7.270
1	1259	0.864	7.3018	1456.92	1086.7	2.305
1.5	1261.3	0.865	7.2668	1449.9	1091.02	2.312
2	1224	0.865	7.7165	1539.67	1058.76	2.210
Ethanol + Benzene						
0	1240	0.865	7.1518	1500.18	1072.6	7.270
1	1273.3	0.867	7.140	1419.45	1103.95	1.449
1.5	1239.6	0.870	7.4802	1492.52	1078.45	1.391
2	1244	0.860	7.5138	1499.22	1069.84	1.399
Propanol + Benzene						
0	1240	0.865	7.151	1500.18	1072.6	7.270
1	1219	0.861	7.8160	1559.52	1049.55	7.68
1.5	1245.7	0.863	7.4672	1489.93	1075.0	7.939
2	1244	0.855	7.5577	1507.98	1063.62	7.922
Butanol + Benzene						
0	1240	0.865	7.1518	1500.18	1072.6	7.270

1	1275	0.835	7.377	1469.9	1087.05	8.105
1.5	1238	0.883	7.3892	1474.3	1093.15	7.755
2	1235	0.977	6.7107	1338.98	1206.59	7.726
DMSO +Benzene						
0	1240	0.865	7.1518	1500.18	1072.6	7.270
1	1305.3	0.753	7.7944	1555.2	982.89	4.723
1.5	1283.5	0.883	6.8746	1371.68	1133.3	4.072
2	1304	0.886	6.6376	1324.40	1155.3	4.1261
Acetonitrile + Benzene						
0	1240	0.865	7.1518	1500.18	1072.6	7.270
1	1272.8	0.636	7.2452	1448.63	1103.51	6.987
1.5	1269.7	0.634	7.1559	1435.7	1100.82	6.962
2	1311.1	0.655	6.7408	1344.99	1131.47	7.305

4. CONCLUSIONS

I have performed the experiment by using the Ultrasonic Interferometer. I have calculated Ultrasonic velocities in the binary mixtures of polar and non polar solvents. I have also calculated adiabatic compressibility, Intermolecular free length and Acoustic Impedance.

The calculated values suggest that, the presence of strong interaction in all the binary mixtures which may be due to hydrogen bind, dipole moment, hyper conjugation and charge transfer. It is found that intermolecular interaction is very strong in alcohol + non polar solvents and this strong interaction is due to negative inductive effect dominant over the resonance effect in the mixture.

REFERENCES

[1] K.A.Kashinath, 1980 "Ultrasonic behaviour of binary liquid mixtures of butyl amine with aromatic hydrocarbon" Acta chimi academic Scientiaram hungaricae tomus 104 (4), pp 43-47.

[2] A.K. Chottopadhay, 1982 " Studies on the Salvation of amino acid in ethanol and water mixtures", electochimica acta Vol 27, No. 2, pp 269-272.

[3] K.Bebek, 2005 "SPEED OF SOUND AND THERMODYNAMIC PROPERTIES OF 1-BUTANOL IN BINARY LIQUID MIXTURES AT 293.15 K" J. molecular and Quantum Acoustics, Vol.26, pp 15-20.

[4] Ktzysztof BEBEK, 2006 "Acoustic and Thermodynamic Properties of Binary Liquid Mixtures of 2-methyl-1-propanol on Hexane and Cyclohexane at 293.15 K" J. molecular and Quantum Acoustics, Vol.27, pp 337-342.

[5] S.K. Kushare, 2008 "Volumetric and Compressibility Properties of liquid water as a solute in glycolic, propylene carbonate and tetramethylurea solutions at T=298.15 K J. of Chem. Thermodynamics, Vol. 40, pp 78-83.

BIOGRAPHIES

Sana Rajgoli has a rich experience in teaching physics for engineering students. Has secured 2nd rank at her PG course.

Ashish Patil presently working as HOD of science has a vast experience in teaching Mechanical subjects