A brief review of experimental techniques for the determination of ultrasonic velocity, density and viscosity is given in sections 3.1, 3.2 and 3.3. Experimental techniques for investigation of ultrasonic velocity, density and viscosity employed in the present investigation are described in sections 3.4, 3.5 and 3.6 respectively. These measurements are used to estimate the different elastic properties of the molecules from which the type of molecular interactions can be very well understood. For understanding the solute-solvent and solute-solute molecular interactions in solution, thermodynamic and physicochemical properties are very much useful and applicable. These measured and calculated physicochemical parameters are used to estimate the different elastic properties of the molecules from which the type of molecular interactions can be very well understood. Ultrasonic technique is regarded as being of low intensity when there no permanent change takes place in the material during propagation of ultrasonic waves. This is the uniqueness of the ultrasonic method over other diffraction methods. An ultrasonic measurement of acoustic parameters to change the number of moles gives an insight into the molecular process. Stabilization of bioactive molecules is related to various molecular interactions, further these interactions are influenced by surrounding solute and solvent molecules. Due to such molecular interaction properties of drugs such as solubility, drug activity, and alternation of solvent structure, these are affected by the presence of solutes.
3.1 MEASUREMENT OF ULTRASONIC VELOCITY (U)

3.1.1 INTRODUCTION

Various methods are used by many researchers in determining the ultrasonic velocity in given liquid or liquid mixtures to determine intermolecular interaction present in liquid mixture. Some methods used for the measurement of ultrasonic velocity are described as follows.

3.1.2 Methods of determining Velocity

3.1.2.1 Sing around Method

![Sing Around Method Diagram]

Figure 3.1: Sing Around Method

This method is used by many researchers for determining the ultrasonic velocity in liquid or liquid mixtures [1-7]. This is an automatic method for measuring ultrasonic velocity with high accuracy. It is good, but has some errors in making absolute measurement of velocity. In this, a transducer (triggered transmitter) generates mechanical waves. The received and amplified signal is used to generate a trigger signal. This initiates the new pulse from the transmitter and the loop runs continuously once initiated. The frequency of trigger signal counts per second. Sing
around system is shown in Figure 3.1. Travel time through the loop is greater than the travel time through the specimen because there are electrical delays associated with the triggering of transmitting, the rise time of the amplified pulse, generation of the trigger signal, etc. There are also acoustic delays in the two transducers and their bonds to the specimen.

### 3.1.2.2 Pulse Technique

Pulse technique was introduced by Pellam and Galt in 1946 [8]. This is widely used method to measure ultrasonic velocity in both liquids and solids. A piezoelectric transducer is used in this method. A pulse of sinusoidal voltage is applied to piezoelectric transducer. Then the transducer converts the electrical pulse into an acoustic pulse which is transmitted into the medium. When voltage amplitude ranges between a few volts to a few hundred volts, then pulse width ranges between 1 to 10 μs and the repetition rate ranges from 100 to 1000 pulses per second. 1 MHz upwards frequency is used in this method. Steaming and sample heating error was produced when pulse width is 1 μs and repetition rate is 100 per sec, and then carrier signal will exists for only 0.01% of the time. There are two types of pulse techniques available:

1) One Transducer Pulse Technique

2) Two Transducer Pulse Technique

### 3.1.2.3 Pulse Echo Overlap Method

Pulse echo overlap method is highly accurate and versatile method. Many researchers used this method for measuring ultrasonic velocity in many materials [9-12]. This method is able to handle diffraction phase corrections properly. So the absolute accuracy of the pulse echo overlap method exceeds the accuracy of most other methods. The pulse overlap method has some features than other methods. This
method operates either with the transducer bounded directly to the specimen or with a buffer rod interposed between the transducer and specimen. This method operated by broad band pulses. Advantage of broad band pulse is proper overlap can be set up with the broad band echoes unambiguously. The pulse echo overlap method can be set-up to make through transmission measurement of the travel time on a single pass between two transducers. One error of pulse echo overlap method is this method which has never been automated as its echo are overlapped by the observer in ‘scope time’ not in real time [13].

### 3.1.2.4 Optical Diffraction Method

The optical diffraction method was observed independently by R Lucas and Biquared in France and Debye and Sears in America in 1932 [14]. The phenomenon used in optical diffraction method is the diffraction of light by ultrasonic waves passing through a liquid [15, 16].

![Diffraction pattern](image)

**Figure 3.2: Optical Diffraction Method**
**Working:** Ultrasonic waves are propagated in a liquid, and then density varies from layer to layer due to periodic variations of pressure. If, under this condition monochromatic light is passed through the liquid at right angles to the waves, the liquid behaves as a diffraction grating. That grating is called as acoustic grating. This grating behaves in the same way as a ruled grating. Hence the method can be used for finding the wavelength and velocity of ultrasonic waves in liquid. The experimental arrangement is shown in Figure 3.2. Monochromatic light is used in this method. The light from such source is focused on the narrow slit by using the lens. The light from the slit now passes through another lens which turns it into a parallel beam. This parallel beam then passes through the ultrasonic cell. This cell contains a rectangular glass tank containing the liquid. The crystal is dipped into the liquid and is connected to the oscillating waves which travel through the liquid. The waves are reflected from the wall of the cell and form a stationary wave pattern which acts as an acoustic grating. The crystal is placed in the cell in such a way that the acoustical grating is formed in a perpendicular direction of the propagation of light. Now the light emerging from the cell is focused by the third lens and can be seen through a telescope. When the crystal is at rest, a single image of the slit is observed. But when ultrasonic waves are produced in the liquid by excitation of crystal, the intensity of the central image decreases and a number of diffracted images appear on either side of the centre. The angular separation $\theta$ between the direct image of the slit and the diffracted image of any order say $\eta$ is measured. Applying the theory of diffraction grating the wavelength of ultrasonic waves can be calculated. Here the grating element is the same as the wavelength of ultrasonic waves. Let it be $\lambda_c$ if $\lambda$ is the wavelength of monochromatic light used, then

$$\lambda_c \sin \theta = n \lambda.$$
\[ \lambda_c = \frac{n \lambda}{\sin \theta_n} \]  

If \( n \) be the frequency of ultrasonic oscillations, and then the velocity of ultrasonic waves in liquid can be calculated by the formula

\[ U = N \lambda_c \]

3.1.2.5 Ultrasonic Interferometer

This method is used by many researchers in determining the ultrasonic velocity in given liquid or liquid mixtures because an ultrasonic interferometer is a simple and direct device to determine the ultrasonic velocity in liquids in high degree of accuracy [17-23]. Detail information of ultrasonic interferometer is described in section 3.4.

3.2 MEASUREMENT OF DENSITY (\( \rho \))

3.2.1 Introduction

The mass of the unit volume of that liquid is nothing but its density. The unit of volume (1cm\(^3\)) is the volume occupied by 1 gm of water at the temperature of maximum density (40°C) and is symbolized as \( \rho_4^t \). The specific gravity such as relative density is the weight of a given volume of a liquid by the weight of an equal volume of water at the same temperature.

3.2.2 Methods of Determining Density

3.2.2.1 Mercury Sinker Method

The sinker as a weight of about 84.5 x 10\(^{-3}\) kg and is made by filling corning glass tube partially with mercury and then it is sealed. For weighing purposes, a digital balance with sensitivity of 0.1 x 10\(^{-6}\) kg is used. The sinker is suspended from the arm of the monopan balance with a nylon thread passing through a hole in the top of a table on which the balance is placed.
The liquid sample whose density is to be found out is taken in a glass beaker in sufficient quantity such that the sinker can be fully immersed in it. The beaker is kept in a double walled vessel of aluminum having side tubes and containing water. It is thermally insulated from the surroundings by enclosing the system in a plastic having holes to pass the tubes and a hole in the lid to pass the sinker. Water from the same thermostat mentioned earlier is circulated through the space between two walls so that the temperature of the sample in the beaker can be maintained constant. The plastic container is placed on a platform which can be raised or lowered with a jack. To obtain the density of sample free from buoyancy effect it is necessary to find the true weight of the sinker.

3.2.2.2 Pyknometer Method

![Pyknometer](image)

**Figure 3.3: Pyknometer**

Pyknometer designed by Wood and Brusic [24] could determine density up to the forth decimal place. Pyknometer method is single stem and double stems method
which is used widely due to its simplicity in design, in which temperature of the liquid
or liquid mixture can be maintained with high accuracy. Pyknometer constructed by
Methot and Desmyter [25] consists of two parallel graduated capillary tubes.
Accuracy of this device in the determination of density is up to the 5th decimal place.
U-tube shaped Pyknometer with capillary of small bore suitable for volatile liquids
was constructed by Sprengel and Ostwald [30]. In this method the mass of a given
volume of liquid is accurately determined using a pre-calibrated Pyknometer whose
volume at different temperatures and radius of the capillary of the stem are accurately
known. A review of different types of Pyknometer was given by Bauer and Lewis.

3.2.2.3 Specific Gravity Bottle

Specific gravity bottle is used by many researchers to determine density of given
liquid and liquid mixture [26]. Detail information of specific gravity bottle is
described in section 3.5.

3.3 MEASUREMENT OF VISCOSITY (η)

Definition:
“The resistance experienced by one layer of liquid in moving over another layer is
called viscosity”. In another words “Viscosity is a property by virtue of which a liquid
poses resistance to its flow”.

3.3.1 Introduction

![Figure 3.4: Flow of Liquid](image)
This tendency occurs because of the intermolecular attraction of the liquid. Viscosity of any liquid also depends on the molecular weight and nature of that liquid. Thus oil, honey, etc. is quite viscous, while liquids like ether and benzene flows readily.

Viscosity also depends on temperature. At low temperature, the viscosity of a liquid is greater because the intermolecular attractive forces simply dominate the disruptive kinetic forces. At high temperatures, the kinetic energy of the molecules increases at the expense of intermolecular forces which diminish progressively. Therefore, the molecules of a liquid at high temperature offer less resistance to the flow and hence become less viscous.

Some liquid flows more readily means they are less viscous than others. In other words, liquid molecules pose resistance to the flow or movement of one layer over another. This property of liquids which determines their flow is termed viscosity.

**Factors affecting viscosity:**

1] The intermolecular attractive forces

2] The strength of intermolecular forces

3] The molecular weight or the mass of the molecule of a liquid

4] The structure and shape of the molecules of a liquid

5] Temperature

6] Chemical composition

Liquids with large, irregularly shaped molecules are generally known to be more viscous than those with small and symmetrical molecules. Since only hard, symmetrical molecules have perfectly elastic collision, the large and irregular molecules will have less elastic collision amongst themselves. Thus the collision between large molecules involves the loss of kinetic energy and as a consequence the intermolecular forces dominating the molecules tend to stick together. This increases
the viscosity of the liquid. Viscosity also depends on temperature. An increase in temperature decreases the viscosity of liquids. As the temperature increases, the molecular motion increases at the expense of cohesive forces causing resistance to flow. Therefore, the viscosity of a liquid is found to decrease by 1 or 2 percent for each degree rise of temperature. The increase of pressure goes to strengthen the cohesive forces between molecules. That is why with the increase of pressure, the viscosity of a given liquid increases somewhat.

The best known ideal viscous body is the Newtonian fluid for which the coefficient of viscosity ‘\( \eta \)’ is a constant. The coefficient of viscosity is generally called simply viscosity and is measured in terms of poises (dynes-sec/cm\(^2\)). The so called kinematics viscosity ‘\( \nu \)’ which is directly observed in capillary tube viscometers where stress comes from the head of fluid on which the viscosity is being determined, equals the viscosity ‘\( \eta \)’ in poise divided by the density in gm/cm\(^3\). The unit of kinematic viscosity is stoke.

### 3.3.2 Methods of determining Viscosity

#### 3.3.2.1 Poiseuilles Method

The rate of flow of the liquid, under a given pressure, will obviously be less for the smaller radius of the tube, and the connection among these quantities was first derived by J. L. M. Poiseuille (1844) [27, 28]. When a liquid flows through a narrow tube, then a thin layer of liquid in contact with the walls is stationary as a result of viscosity, therefore the next layer will be slowed down to some extent, and this effect will continue, to be diminishing extent, up to the center of the tube.

\[
\eta = \frac{\pi \rho r^4 t}{8LV} \tag{3.3}
\]
where ‘V’ is volume (in cc) of a liquid of viscosity ‘η’ that flow through a capillary tube of radius ‘r’ cm and length ‘L’ cm in time ‘t’ sec under a pressure head of ρ dynes/cm².

![Figure 3.5: Poiseuilles method](image1.png)

The experimental setup for the determination of viscosity by Poiseuilles method is shown in Figure 3.5. Instead of determining η by a direct application of the Poiseuilles equation the one commonly used is the one devised by Ostwald in which the viscosity of one liquid is compared with that of liquids of known viscosity that is the viscosity of distilled water.

### 3.3.2.2 Stokes Falling Sphere Method

![Figure 3.6: Stokes Falling Method](image2.png)
Stokes' law is the basis of the falling sphere viscometer. In this method the fluid is stationary in a vertical glass tube. A sphere of known size and density is allowed to descend through the liquid. If correctly selected, it reaches terminal velocity, which can be measured by the time it takes to pass two marks on the tube. Electronic sensing can be used for opaque fluids. Knowing the terminal velocity, the size and density of the sphere, and the density of the liquid, Stokes’ law can be used to calculate the viscosity of the fluid. A series of steel ball bearings of different diameter is normally used in the classic experiment to improve the accuracy of the calculation [29, 30]. This method is especially useful for liquids having a high coefficient of viscosity.

3.3.2.3 Ostwald’s Viscometer

This method is used by many researchers in determining the viscosity in given liquid or liquid mixtures because an Ostwald viscometer is a simple and direct method to determine the viscosity in liquids in high degree of accuracy [31-33]. Detail information of Ostwald viscometer is described in section 3.6.

Experimental Techniques used for Present Investigation

3.4 ULTRASONIC VELOCITY MEASUREMENT (Interferometer Technique)

![Ultrasonic Interferometer Device]

**Figure 3.7: Ultrasonic Interferometer Device**
In the present investigation a variable path ultrasonic interferometer (Mittal enterprises, New Delhi Model F-81) is used to measure the ultrasonic velocity in liquid and liquid mixtures. It is single frequency generator that is 2 MHz as shown in Figure 3.7.

![Ultrasonic Interferometer Diagram]

**Figure 3.8: Ultrasonic Interferometer**

![Variation of current with reflector position graph]

**Figure 3.9 Variation of current with reflector position**
3.4.1 Principle

In the measurement of ultrasonic velocity the used principle is based on the accurate determination of wavelength (\( \lambda \)) in the given liquid medium. Known frequency (f) ultrasonic waves are produced by a quartz crystal. That quartz crystal is fixed at the bottom of the cell. A movable metallic plate kept parallel to the quartz crystal reflects these waves. The standing waves (acoustic resonance) are formed in the medium if the separation between these two plates is exactly equal to an integral multiple of the sound wavelength.

This acoustic resonance gives rise to an electrical reaction on the generator driving the quartz crystal and the anode current of the generator becomes maximum. The movement of the reflector by half wavelength allows the determination of the wavelength of ultrasonic waves in liquid under study. The ultrasonic velocity is calculated by the following relation.

\[
\text{Ultrasonic Velocity} \ (U) = \text{Frequency} \ (f) \times \text{Wavelength} \ (\lambda)
\]

3.4.2 Description of Equipment

1) High Frequency Generator

High frequency generator is used to excite the transducer at the required frequency (2 MHz) in the present study. Therefore, it is fixed frequency generator, the frequency of which is controlled by a quartz crystal in the power amplifier of the circuit. When RF power is drawn, the micro ammeter shows constant current, due to DC voltage applied across it.

A generator provides the voltage of about 400 volts across the crystal. R.F. generator is used to excite the X-cut quartz crystal, fitted at the bottom of the measuring cell. The oscillator assembly is provided with a micro-ammeter (0 A-50 A) to observe the changes in current.
2) Measuring Cell

Interferometer cell used is specially designed double walled cylindrical vessel made from stainless steel. It is provided with an inlet and an outlet to circulate water around the inner wall of the cell, so that temperature can be maintained at any desired temperature value. Water from a constant temperature water bath is pumped into the cell.

![Figure 3.10 Measuring Cell](image)

3) Reflector

The outer diameter of the cell is 3.96 cm and inner diameter of the cell is 0.87 cm. The height of the cell is 9.25 cm. The approximate volume of the liquid required to fill the cell is 12 ml. At the bottom of the interferometer cell gold plated x-cut quartz crystal transducer is fixed. It has an X-cut of quartz crystal of diameter 10 mm fixed at its bottom exactly at its center.

![Figure 3.11 Reflector](image)  
![Figure 3.12 Micrometer](image)
The upper surface of the crystal plate is covered with a diaphragm to prevent the liquid from coming in direct contact with the crystal surface. The pitch of the screw employed to move the reflector is 0.5 mm. The head of the screw is divided into 50 equal divisions. The least count of this setup is 0.001 cm. The bottom of the screw is coupled to the reflector rod through a steal ball which eliminates errors arising due to non-axiality between them, besides keeping the reflector free to move axially without rotating along with the screw. The reflector is loaded with spring, to avoid backlash error. The reflector can be firmly mounted on the top of the interferometer cell. The reflector is tightly coupled to the interferometer cell with the help of knurled cap.

4) Base to hold the cell

It is a heavy cylindrical metallic base. It has a space at the center equal to the outer diameter of the cell, so that it can be placed in the base. At its center, there is an electrode isolated from the base and pointed upwards to make an electrical contact with the crystal at the bottom of the cell. By using a shielded cable electrical contact of crystal is made with an oscillator from the side of the base. In addition to acting as a rigid mount for the interferometer cell, the base provides contacts to the upper and lower surfaces of the crystal transducer, so that exciting electrical signal is passed from high frequency oscillator assembly. Cell can be tightly fitted into the base with a high quality co-axial cable provided with suitable sockets.

3.4.3 Experimental Procedure

Ultrasonic velocities in liquid and liquid mixtures at different temperatures have been measured in the present investigation at a fixed frequency [2 MHz]. The interferometer cell is cleaned with acetone. The cell is filled with experimental liquid. The reflector assembly is coupled to the cell tightly by screwing the knurled cap. The cell is inserted into the base socket and clamped rigidly with the help of side screw
provided in the base. The inlet and outlet of the double walled construction are connected to a constant temperature water bath by using transparent plastic tubes. Ultrasonic interferometer with constant temperature water bath setup is shown in Figure 3.13.

![Figure 3.13: Constant Temperature Water Bath](image)

Water is pumped into the double walled cell with the help of an electrical motor provided with the constant temperature water bath. Water of constant temperature is circulated at least for 30 minutes, so that the temperature in the cell stabilizes. When required temperature is attained in the interferometer cell, then high frequency generator assembly is connected to the base of the cell using shielded co-axial cable and switched on. The reflector is gently moved towards the crystal with the help of micrometer screw. Variation of current through the crystal transducer due to the motion of the reflector is observed with the help of micro-ammeter provided with high frequency generator assembly. Readings of positions of the micrometer screw
corresponding to ten successive maxima or minima of current in the micro-ammeter are noted. Then counting maxima or minima up to 30 are noted. The difference between first and last reading is calculated. These differences should be almost equal. Otherwise, another set of fresh readings are to be taken. From this data, wavelength of ultrasonic wave is determined. The ultrasonic velocity is determined by multiplying the wavelength of ultrasonic wave with the frequency of the crystal generator (2 MHz in this investigation).

3.4.7 Calibration of the Interferometer

The instrument is calibrated by re measuring the data for ultrasonic velocity of water at different temperature and same is represented in Table 3.1

Table 3.1 Calibration of Ultrasonic Velocity at 2MHz

<table>
<thead>
<tr>
<th>Temperature (K)</th>
<th>Ultrasonic Velocity (U) (m/s)</th>
<th>Expt. Values</th>
<th>Lit. Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>303.15</td>
<td>1510.00</td>
<td>1509.55 [34]</td>
<td></td>
</tr>
<tr>
<td>308.15</td>
<td>1522.76</td>
<td>1521.90 [35]</td>
<td></td>
</tr>
<tr>
<td>313.15</td>
<td>1529.93</td>
<td>1529.76 [34]</td>
<td></td>
</tr>
<tr>
<td>318.15</td>
<td>1535.88</td>
<td>1536.40 [35]</td>
<td></td>
</tr>
</tbody>
</table>

3.5 DENSITY MEASUREMENT (Specific Gravity Bottle)

For the present investigation specific gravity bottle is used for determination of density of liquid and liquid mixture at different concentrations and at different temperatures.

3.5.1 Basic Principle

Specific gravity bottle working is based on Archimedes' principle. The principle statement is that “an object totally or partially immersed in a fluid (liquid or gas) is buoyed (lifted) up by a force equal to the weight of the fluid that is displaced”.
3.5.2 Description

Specific gravity bottle is a small glass bottle. Capacity of specific gravity bottle varies from 2 to 25 cm³. Capillary stopper either plastic or glass is fitted in its mouth.

![Specific Gravity Bottle](image)

Figure 3.14: Specific Gravity Bottle

3.5.3 Experimental Procedure

Specific gravity bottle of capacity 25 cm³ is used for determining the density of experimental liquid and liquid mixtures at different concentration and at different temperatures. The specific gravity bottle is cleaned with acetone. After cleaning the empty bottle, measure the weight of empty bottle with stopper carefully with the help of digital balance. Experimental liquid is filled in the density bottle up to the mount and the stopper is fitted tightly. Then a small amount of experimental liquid flow out the capillary and the liquid fills the bottle and the capacity right up to the upper end. For requiring a desired temperature, the density bottle is immersed in a water bath above the level of water in the water bath. After attending a required temperature, bottle is removed from the water bath and its outer surface is wiped carefully with the help of cotton. By using a digital weight balance weight of the bottle (full with
experimental liquid) is measured. Then the difference between liquid filled bottle weight and empty bottle weight gives exact weight of experimental liquid.

3.5.4 Calibration

Table 3.2 Calibration of Density at 2MHz

<table>
<thead>
<tr>
<th>Temperature (K)</th>
<th>Density (ρ) (kg/m³)</th>
<th>Experimental Values</th>
<th>Literature Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>303.15</td>
<td>995.09</td>
<td></td>
<td>995.65[47]</td>
</tr>
<tr>
<td>308.15</td>
<td>994.85</td>
<td></td>
<td>994.06 [48]</td>
</tr>
<tr>
<td>313.15</td>
<td>992.45</td>
<td></td>
<td>992.20 [48]</td>
</tr>
<tr>
<td>318.15</td>
<td>990.10</td>
<td></td>
<td>990.20 [48]</td>
</tr>
</tbody>
</table>

3.6 VISCOSITY MEASUREMENT (Ostwald’s Viscometer)

In the present investigation Ostwald viscometer method is used for determination of viscosities of liquid and liquid mixture at different concentrations and at different temperatures.

3.6.1 Basic Principle

Viscosities of two liquids or the same liquid at two different temperatures can be conveniently compared using commercially available Ostwald viscometers, without tedious measurements of the exact dimensions of viscometer. In this method the time taken by a given volume of liquid to flow through the suitable capillary tube is measured. Similarly the flow time of a reference liquid of known viscosity is also measured. The ratio of flow times is equal to the ratio of kinematic viscosities. If the densities of reference and experimental liquids are also known, then dynamic
viscosity or coefficient of viscosity of experimental liquid can be determined. This method cannot yield absolute value coefficient of viscosity.

3.6.2 Description

The Ostwald viscometer is a type of capillary viscometer. There is a U shaped tube consisting of two bulbs and two marks. The Ostwald viscometer is also known as the U tube viscometer or the capillary viscometer. This device measures the liquids viscosity using direct or reverse flow of the test liquid through a U-shaped tube. The Ostwald viscometer measurement is determined by noting the time required for the liquid to flow a certain distance through tubing of a specific diameter. Each side of an Ostwald viscometer consists of different size of tubing. Capillary is a small tube with a very small cross sectional area. For a direct flow viscometer, a bulb is located toward the top of the capillary side. On the wider diameter side, a slightly larger bulb is located toward the bottom. Two marks are placed on the tubing at a known distance apart. These marks are placed above and below the smaller bulb.

![Ostwald Viscometer](image)

**Figure 3.15: Ostwald Viscometer**
3.6.3 Experimental Procedure

A known volume of experimental liquid is introduced into bulb X of the viscometer. Gently suck the liquid into bulb Y above the mark ‘A’ and note the time say as $t_2$ which is required for the flow through the capillary from ‘A’ to ‘B’. This procedure is repeated for three times and average of three repetitions is calculated. Then viscometer is cleaned and repeats the same procedure for water of same volume. Required time for water called as $t_1$.

From Poiseuille’s equation we have

$$\eta_1 = \frac{\pi \rho_1 r_1^4 t_1}{8L}$$

For liquid

$$\eta_2 = \frac{\pi \rho_2 r_1^4 t_2}{8L}$$

$\therefore \frac{\eta_2}{\eta_1} = \frac{\rho_2 t_2}{\rho_1 t_1}$

But $\rho = \frac{\text{force}}{\text{area}} = \frac{mg}{A} = \frac{V_0 \rho}{A}$

$\therefore \frac{\eta_2}{\eta_1} = \frac{V_0 \rho_2 g / A}{V_0 \rho_1 g / A}$

$\therefore \frac{\eta_2}{\eta_1} = \frac{\rho_2 t_2}{\rho_1 t_1}$

$\therefore \eta_2 = \frac{\rho_2 t_2}{\rho_1 t_1} \eta_1$  \hspace{1cm} (3.6)

As R.H.S. quantities of above equation are known, viscosity of liquid that is $\eta_2$ can be calculated. This resultant viscosity is called absolute viscosity of experimental liquid. $\eta_2/\eta_1$ is the relative viscosity of the liquid second with respect to liquid first. If first liquid is water then it is called as specific viscosity instead of relative viscosity.
3.6.4 Calibration

Table 3.3 Calibration of Viscosity at 2MHz

<table>
<thead>
<tr>
<th>Temperature (K)</th>
<th>Viscosity (η) (kgm(^{-1})s(^{-1}) or Nsm(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental Values</td>
</tr>
<tr>
<td>303.15</td>
<td>7.988 × 10(^{-4})</td>
</tr>
<tr>
<td>308.15</td>
<td>7.225 × 10(^{-4})</td>
</tr>
<tr>
<td>313.15</td>
<td>6.539 × 10(^{-4})</td>
</tr>
<tr>
<td>318.15</td>
<td>5.955 × 10(^{-4})</td>
</tr>
</tbody>
</table>
REFERENCES


[17] J. Nath, A. Tripathi, Binary systems of 1, 1, 2, 2-tetrachloroethane with benzene, toluene, p-xylene, acetone, and cyclohexane. 1. Excess volumes, ultrasonic velocities,
and adiabatic compressibilities at 298.15 and 308.15 K, Journal of Chemical and Engineering Data, 28 (1983) 263-266.


