CHAPTER –VI

Ultrasonic Velocity and Other Parameters
Abstract

Ultrasonic velocity is an important parameter, characterizing the state of the system. It can be determined experimentally by using Ultrasonic Interferometer. A brief discussion of ultrasonic interferometer and mode of determining ultrasonic velocities is given in chapter – II. The present chapter deals with the experimental determination of ultrasonic velocities and adiabatic compressibility’s of ethylene glycols and higher homologous. From the ultrasonic velocity, closely related parameters like molar sound velocity, molar compressibility, Vander Waal’s constant …etc. are evaluated. The variations in ultrasonic velocity and related parameters with degree of polymerization and a phenomenal reasoning for the same are also permuted.
CHAPTER – VI

Ultrasonic velocity and other parameters

6.1. Working principle:

Ultrasonic interferometer is a simple and direct device to determine the ultrasonic velocity of liquids with high degree of precision. The principle used in the measurement of ultrasonic velocity (U) is based on the accurate determination of wave length (λ) in the medium. Ultrasonic waves of known frequencies (f) are produced by a x-cut quartz crystal fixed at the bottom of the cell, using the piezoelectric technique. These waves were reflected by movable magnetic plate kept parallel to the quartz crystal. If the separation between these two plates is exactly an integral multiple of wave length of sound, standing waves are formed in medium. This acoustic resonance give rise to an electric impulse indicated by an anode current. The anode current becomes maximum at the antinodes when the stationary waves are formed. The distance between successive nodes or anti nodes gives (λ/2) is determined by noting down the distance travelled for 10 successive nodes and taking the average.

The glycols are directly put into the experiment without further purification as the purification process might effect the steady state condition of polymers. The glycols are obtained from M/S Precision Instruments and Chemicals PVT LTD. Guntur, AP, India.
6.2. Formulae:

**Ultrasonic velocity is** $U$.

$$U = \lambda \times f.$$  
Where $\lambda$ is the wavelength between successive current maximum.  
$f$ is the frequency of the Ultrasonic waves.

**Adiabatic Compressibility** $^{3}$ ($\beta_{ad}$).

$$\beta_{ad} = \frac{1}{\rho U^2}.$$  
Where $\rho$ is the density of the sample,  
$U$ is the ultrasonic velocity.

**Molar sound velocity** ($R_m$).

$$R_m = MV(U)^{1/3},$$  
Where $M$ is molecular weight,  
$V$ is Specific volume and  
$U$ is ultrasonic velocity of the sample.

**Molar compressibility** ($\beta$)

$$\beta = MV(\beta_{ad})^{-1/7}.$$  
Where $\beta_{ad}$ is the adiabatic compressibility,  
$M$ is molecular weight and  
$V$ is Specific volume of the sample.
Van der Waal’s Constant $^3 (b)$. 

$$b = MV \left( 1 - \frac{RT}{MU^2} \left[ \left( 1 + \frac{MU^2}{3RT} \right)^{\frac{1}{3}} - 1 \right] \right).$$

Where $R$ is universal gas constant 
$M$ is molecular weight , 
$T$ is the temperature in Kelvin 
$V$ is Specific volume and 
$U$ is ultrasonic velocity of the sample.

Inter Molecular Free length$^4 (L_f)$. 

$$L_f = C(\beta_{ad})^{1/2}$$

Where $\beta_{ad}$ is the adiabatic compressibility 
$C$ is Constant and its value is 63.

Ethylene glycols are taken in purest form and the experiment on Ultrasonic Velocity is conducted at room temperature by maintaining the temperature up to $0.01^0$ C by using adequate thermostat set up. The densities for these ethylene glycols are determined by using Archimedes principle. The values of Ultrasonic Velocity and related parameters, cited above are determined and are reported in table 6.1. The necessary parameters for evaluation of related parameters , like ‘ $R$’ universal gas constant are taken from CRC Hand Book$^1$. The variation of Ultrasonic Velocity ,Specific Volume ,Adiabatic Compressibility, Molar Sound velocity ,Molar Compressibility and other parameters is shown as a function of degree of polymerization is shown in graphs[6.1 to 6.8 ].
Table -6.1
Variation of physical parameter with molecular weight.

<table>
<thead>
<tr>
<th>S. NO</th>
<th>Name of the polymer</th>
<th>Density gm/cc</th>
<th>Ultrasonic velocity *10³ m/sec</th>
<th>Specific volume</th>
<th>Adiabatic compressibility *10⁷ N/m²</th>
<th>Molar sound velocity *10⁶ Joul/mol.Kelvin</th>
<th>Van der waals constant *10⁶ Joul m³/mol²</th>
<th>Molar compressibility *10⁶ m²/N</th>
<th>Inter molecular distance *10⁴ A⁰</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EG</td>
<td>1.09</td>
<td>1519</td>
<td>56.94</td>
<td>3.976</td>
<td>0.0406</td>
<td>0.940</td>
<td>0.774</td>
<td>39.7</td>
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<tr>
<td>2</td>
<td>DEG</td>
<td>1.121</td>
<td>1551</td>
<td>94.710</td>
<td>3.708</td>
<td>0.1162</td>
<td>1.642</td>
<td>1.365</td>
<td>38.3</td>
</tr>
<tr>
<td>3</td>
<td>PEG 200</td>
<td>1.125</td>
<td>1578</td>
<td>177.77</td>
<td>3.569</td>
<td>0.4139</td>
<td>3.152</td>
<td>2.632</td>
<td>37.6</td>
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<tr>
<td>4</td>
<td>PEG 400</td>
<td>1.141</td>
<td>1635</td>
<td>350.59</td>
<td>3.278</td>
<td>1.6519</td>
<td>6.534</td>
<td>5.520</td>
<td>36.0</td>
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<tr>
<td>5</td>
<td>PEG 600</td>
<td>1.160</td>
<td>1645</td>
<td>517.26</td>
<td>3.185</td>
<td>3.6635</td>
<td>9.862</td>
<td>8.364</td>
<td>35.5</td>
</tr>
</tbody>
</table>
Graph 6.1
Variation of Density With Degree of polymerization

Graph 6.2
Variation of Ultrasonic Velocity with Degree of polymerization
Graph 6.3
Variation of Specific Volume With Degree of polymerization

Graph 6.4
Variation of Adiabatic Compressability With Degree of polymerization
Graph 6.5
Variation of molar sound velocity With Degree of polymerization

Graph 6.6
Variation of vanderwaals constant With Degree of polymerization
Graph 6.7
Variation of Molar Compressibility With Degree of polymerization

Graph 6.8
Variation of Intermolecular Free length With Degree of polymerization
6.3 Results and Discussion:

From the tables it is observed that density is increasing with the increase in polymerization. This is expected behavior since the mass per specific volume increases with the polymerization. Similarly an increasing in Ultrasonic Velocity with polymerization is in expected lines, since the number of particles of a particular ultrasonic velocity, increase per unit volume. An increase in the Specific volume with polymerization is also understood on the basis of faster increase in molecular weight, compared to the density values. Compressibility decreases since both the Ultrasonic Velocity and density shown an increase, the reason for which are as explained above. However the Molecular Compressibility shows an increase with the rate of change of molecular weight . This is much faster than the dependence of Adiabatic Compressibility ‘β’. The molar sound velocity $R_m$ shows a prominent increase in volume with polymerization, since both molecular weight and ultrasonic velocities increases.

An expression for Van der waals constant shows that for a smaller values of $\left(\frac{MV^2}{3RT}\right)$, the expression $\left(1 + \frac{MV^2}{3RT}\right)^{1/2}$ can be approximated to $\left(1 + \frac{1}{2}\frac{MV^2}{3RT}\right)$. On substituting this value in the expression for the weight $b = \frac{2MV}{3}$, so for smaller values of $\left(\frac{MV^2}{R_T}\right)$ the Vander waals constant shows an increase with the value with the polymerization value, since both M and V increase at faster rate. The inter molecular free length decrease with an increase in polymerization because of the number of moles per unit volume in the medium increase and the probability of interaction of molecule increases there by reducing molecular free length.
References: