Chapter II

*Experimental And Theoretical*
2.1 Introduction

This chapter deals with the materials and different methods used in the present study. The details of experimental techniques used for the measurement of density, ultrasonic velocity, refractive index and viscosity of antidiabetic and antacid drugs in different media are given in this chapter. The details of calculation of each experimental property are discussed. A representative data showing determination of ultrasonic velocity of water at three temperatures is presented. Mathematical formulae used for the calculation of different volumetric, acoustical, optical and transfer properties of drug solutions are discussed. The extrathermodynamic relations for concentration dependence of apparent molar volumes and apparent molar isentropic compressibilities of drug solutions also covered in this chapter.

2.2 Materials

Deionized distilled water (HPLC grade, pH=6.91) obtained from Millipore prefiltration kit (Direct-Q™ system series) was used. Methanol (Merck, minimum assay 99.0 %), ethanol (SD fine, minimum assay by volume 99.9%) and 2-propanol (SD fine, minimum assay 99.0 %) were used.

Water and alcohols used in present work are protic solvents, and are hydrogen bond donors (HBD) strongly polar molecules. They are good anion solvators. Of these water belongs to hydrogen bonding strongly associated (HBSA) and methanol, ethanol and 2-propanol belongs to hydrogen bonding (HB). Other details of chemicals used in present investigation are given in Table 2.1-2.3.

2.3 Experimental

2.3.1 Glassware calibration and cleaning

All glassware used in the present investigation were cleaned and dried before and after use. All the glassware’s were of Borosil make and calibrated before use. Volumetric flasks and other glassware were cleaned by freshly prepared chromic acid, followed by distilled water and then rinsed with acetone and dried.
Table 2.1. Name, formula, molar mass, polarity, electron pair donicity, hydrogen bond donicity and thermodynamic properties (at 25 °C) of solvents [1] used in present work along with their nature

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Formula</th>
<th>Molar mass, M/kg·mol⁻¹</th>
<th>Polarity</th>
<th>Electron Pair Donicity</th>
<th>Hydrogen Bond Donicity</th>
<th>Refractive index, ( n )</th>
<th>Dipole moment, ( \mu/D )</th>
<th>Polarizability, ( 10^{30} \alpha/m^3 )</th>
<th>Surface tension, ( \sigma/m\cdot Nm^{-1} )</th>
<th>Density, ( \rho/\text{kg} \cdot \text{m}^{-3} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>H₂O</td>
<td>0.0180</td>
<td>1.00</td>
<td>18.0</td>
<td>54.8</td>
<td>1.3325</td>
<td>1.834</td>
<td>1.456</td>
<td>71.96</td>
<td>997.04</td>
</tr>
<tr>
<td>Methanol</td>
<td>CH₄O</td>
<td>0.0320</td>
<td>0.762</td>
<td>30.0</td>
<td>41.5</td>
<td>1.3265</td>
<td>2.870</td>
<td>3.300</td>
<td>22.30</td>
<td>787.20</td>
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<tr>
<td>Ethanol</td>
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<td>0.0461</td>
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<td>37.1</td>
<td>1.3594</td>
<td>1.660</td>
<td>5.100</td>
<td>21.90</td>
<td>784.80</td>
</tr>
<tr>
<td>i-Propanol</td>
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<td>36.0</td>
<td>33.5</td>
<td>1.3752</td>
<td>1.660</td>
<td>7.000</td>
<td>21.20</td>
<td>781.50</td>
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</table>

Table 2.2. Name, molar mass and category of the co-solutes used in present work

<table>
<thead>
<tr>
<th>Chemical used</th>
<th>Formula</th>
<th>Molar mass, M/kg·mol⁻¹</th>
<th>Nature</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium chloride</td>
<td>NaCl</td>
<td>0.0584</td>
<td>Electrolyte</td>
<td>Fisher scientific</td>
</tr>
<tr>
<td>Sucrose</td>
<td>C₁₂H₂₂O₁₁</td>
<td>0.3423</td>
<td>Non-electrolyte</td>
<td>Sd fine</td>
</tr>
<tr>
<td>Chemical structure</td>
<td>Name</td>
<td>Molecular formula</td>
<td>Category</td>
<td>Molar mass, M/kg·mol(^{-1})</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------</td>
<td>-------------------</td>
<td>----------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td><img src="image1" alt="Chemical structure" /></td>
<td>Metformin hydrochloride</td>
<td>C(<em>4)H(</em>{12})ClN(_5)</td>
<td>Antidiabetic</td>
<td>0.16562</td>
</tr>
<tr>
<td><img src="image2" alt="Chemical structure" /></td>
<td>Sitagliptin hydrochloride</td>
<td>C(<em>{16})H(</em>{15})FrN(_3)O HCl</td>
<td>Antidiabetic</td>
<td>0.44377</td>
</tr>
<tr>
<td><img src="image3" alt="Chemical structure" /></td>
<td>Ranitidine hydrochloride</td>
<td>C(<em>{13})H(</em>{23})ClN(_4)O(_3)S</td>
<td>Antacid</td>
<td>0.35086</td>
</tr>
<tr>
<td><img src="image4" alt="Chemical structure" /></td>
<td>Pantoprazole sodium</td>
<td>C(<em>{16})H(</em>{14})F(_2)N(_3)NaO(_4)S</td>
<td>Antacid</td>
<td>0.40535</td>
</tr>
</tbody>
</table>
2.3.2 Preparation of alcohol-water volume mixtures (% v/v)

All the binary solvent mixtures were prepared by volume. Different solvent mixtures were prepared as discussed below. The volume percent (v/v) solutions of methanol-water, ethanol-water and 2-propanol-water were prepared by using following formula:

\[
\% v / v = \frac{V_{\text{solute}}}{V_{\text{solution}}} \times 100
\]

(1)

Where, \(V_{\text{solute}}\) = Volume of solute (mL) and \(V_{\text{solution}}\) = Volume of solution (mL).

For example, for the preparation of 30%v/v methanol-water mixture, 300 mL methanol was taken in the 1 L standard volumetric flask and double distilled water was added to make the total volume 1L. The aqueous-alcoholic mixtures were shaken thoroughly and kept overnight to release air bubbles.

2.3.3 Preparation of drug solutions

The drugs received were recrystallized before use. Solutions of different drugs were prepared in pure and mixed solvents in standard volumetric flasks (50 mL) by dissolving accurate amounts of drug in respective solvent or solvent mixture. The measurement of experimental thermodynamic properties of these drug solutions was carried out at experimental temperatures and atmospheric pressure.

2.3.4 Density determination

Pycnometric measurement of density is simple and inexpensive method [2]. It involves the accurate determination of mass of the solution of known volume. The density of different drug solutions was measured using high precision single capillary pycnometer (Borosil 1624, capacity tolerance=±0.3 ml) of 10 cm\(^3\) capacity. The pycnometer was calibrated using triply distilled water at different temperatures. Single pan, electronic balance (± 0.0001 g) was used for weighing. The weighing scoop was used for weighing the drug on balance. Pycnometer along with experimental solution was kept in constant temperature water bath to attain thermal equilibrium for 15 minutes each tie and then removed, dried and weighed. It was found that accuracy of density measurement was within 0.1%. Averages of the three weights were considered for the density calculation.

The precautions taken during density measurements are listed below:

i. The level of liquid/solution in the pycnometer was checked each time carefully.
ii. During filling of the pycnometer with liquid/solution, air bubbles are checked and not allowed to form.

iii. When liquid level crossed mark, the excess of liquid was removed using the filter paper.

iv. When liquid/solution level was below mark, a small drop of liquid/solution was added with glass rod

v. After every weighing the pycnometer was rinsed with solvent and dried properly with hot air drier.

vi. After filling the solution in pycnometer, outer wall of the pycnometer was cleaned and dried.

vii. Temperature of water bath was checked from time to time and it was maintained constant for the liquid/solution.

From mass of water, liquid and density of water at given temperature, density was calculated. The balance used and its details are shown in Figure 2.1.

![Digital electronic balance with technical details](image)

<table>
<thead>
<tr>
<th>Company</th>
<th>Contech Instrument Ltd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
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</tr>
<tr>
<td>Readability</td>
<td>0.0001</td>
</tr>
<tr>
<td>Repeatability (+/-)</td>
<td>0.2 mg</td>
</tr>
<tr>
<td>Linearity (+/-)</td>
<td>0.3 mg</td>
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<tr>
<td>Pan size</td>
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</table>

**Fig. 2.1.** Digital electronic balance with technical details

### 2.3.5 Ultrasonic velocity measurements

Ultrasonic velocity/speed of sound \((u)\) was measured using thermostatically controlled ultrasonic interferometer (Model-F05, Mittal, 2 ± 0.0001 MHz). From the plot of distance travelled by micrometer (0.001mm) versus current in ammeter \((I, \mu A)\), the wavelength \((\lambda, \text{mm})\) of sound wave travelling through solution was determined. For each solution average of 20 micrometer readings was considered. The distance traveled by
micrometer screw to get one maxima in ammeter “d” expressed in mm is related to the wavelength $\lambda$ as:

$$d = \frac{\lambda}{2}$$  \hspace{1cm} (2)

Speed of sound was calculated from wavelength and frequency ($f=2$MHz) of the interferometer using following relation.

$$u = \lambda \times f \times 10^3$$  \hspace{1cm} (3)

Where, $u= $ velocity in m/sec. Figure 2.3 and Table 2.4 presents the distance travelled by micrometer ($d$, mm), average value of ($d_{av}$, mm) and calculated ultrasonic velocity ($u$, m/sec) in double distilled water at 30, 35 and 40 °C. Set up for the measurement of ultrasonic velocity is shown in Figure 2.2.

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**Fig. 2.2. Ultrasonic interferrometer and its measuring cell showing different parts**

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**Fig. 2.3. Graph showing variation in the distance traveled by micrometer for each measurement at different temperatures**
Table 2.4. Distance travelled by micrometer \((d, \text{ mm})\), average value of \(d_{av}\) and ultrasonic velocity \((u, \text{ m/sec})\) in double distilled water at 30, 35 and 40 °C

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>(d)</th>
<th>(d_{av})</th>
<th>(u=\lambda \times f)</th>
<th>(d)</th>
<th>(d_{av})</th>
<th>(u=\lambda \times f)</th>
<th>(d)</th>
<th>(d_{av})</th>
<th>(u=\lambda \times f)</th>
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<tr>
<td></td>
<td></td>
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<td>(30^\circ\text{C})</td>
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<td>(35^\circ\text{C})</td>
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<td>(40^\circ\text{C})</td>
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</tr>
</tbody>
</table>

Note: The values in parenthesis indicate ultrasonic velocity of water reported by V.A. del Grosso, C.W. Mader [3].

2.3.6 Refractive index measurements

Refractive index \((n)\) represents the ratio of velocity of light in vacuum to velocity of light in medium. It is most important properties of liquid which can be measured easily with a high degree of accuracy.
In the present investigation, Cyber LAB-Cyber Abbe Refractometer (*Amkette Analytics*, ±0.0002, 1.3000 to 1.7000) was used for the refractive indices measurements of different drug solutions. Refractometer was calibrated time to time with liquids like water, ethanol and acetone at experimental temperature. Refractive index was adjusted by standard specimen (*n*=1.5167) supplied. Constant temperature of liquid was maintained using water circulation system surrounding prism box of refractometer. To read temperature of experimental liquid in refractometer, digital thermometer (±0.1 °C) attached to refractometer was used.

Precautions taken during refractive index measurements are:

- To prevent optical part, refractometer was kept in a dry and well ventilated room.
- Refractometer was always kept clean.
- To prevent from corrosive damage, refractometer was cleaned in time.
- After use refractometer was kept into a box.
- Instrument was protected against drastic vibration and impacts to prevent optical parts from being damaged.
- Optical parts were cleaned rubbing lightly by absorbent cotton.
- Rough (incident prism) and polished surface (refracting prism) of refractometer was cleaned with liquid mixture of 1:1 absolute alcohol and ether mixture.

Different parts and technical specifications of refractometer used are shown in Figure 2.4.

![Abbe refractometer showing different parts and technical specifications](image-url)

*Fig. 2.4. The Abbe refractometer showing different parts and technical specifications*
2.3.7 Viscosity measurements

The viscosity measurements were carried out for systems containing \{\text{drug + aqueous-NaCl/sucrose}\} at 30°C. Viscosity of stock solutions of aqueous-NaCl/sucrose and experimental solutions of \{\text{drug + aqueous-NaCl/sucrose}\} at 30°C were measured by flow time method using suspended level Ostwald’s type viscometer (Figure 2.5) and atmospheric pressure.

![Viscometer used for the present study](image)

Viscometer was kept in the constant temperature water bath for 15 min to attain the thermal equilibrium [4-5]. Reference liquid and experimental solutions were allowed to flow from upper mark to lower mark. Flow time was recorded for reference liquid of known viscosity and each solution. Flow times were measured by electronic digital stop watch (±0.01s) and average of three flow times were considered for calculation of viscosity of solution [6]. From flow times and viscosity of reference liquid and flow times of experimental solutions, viscosity of experimental solutions was calculated. After taking the flow time reading for each solution, the viscometer was washed and dried. Viscosities were calculated for solutions of different concentrations. Primary reference liquid for viscosity is water. Values of viscosity and density of pure water were taken from literature [7].

At least three readings of the flow times of solvent and solutions were recorded and used for the further calculations.
The experimental arrangement for the measurement of ultrasonic velocity and refractive index of drug solutions is shown in Figure 2.5. The ultrasonic velocities of pure solvents viz. water and methanol and solvent mixtures are measured every time when the drug solution measurements were performed in each system. Therefore, the ultrasonic velocities of these solvent/solvent mixtures show slight variations which are under the considerations of experimental conditions such as temperature etc. Also the solvent mixtures were prepared fresh every time for each drug and therefore there is a chance of slight variation in the ultrasonic velocities of these solvent mixtures. Similar is the case of densities and refractive indices of solvents and solvent mixtures. For the purpose of the calculation of the derived properties where the densities, ultrasonic velocities and refractive indices of solvents and solvent mixtures are needed, the respective values of the properties obtained during measurements of individual drug have been used. The densities, ultrasonic velocities and refractive indices measured for given solvent system showed good agreement.
2.4 Theoretical

Introduction
This part of the chapter contains mathematical equations involved in calculation of different physical properties of drug solutions. Derived volumetric, acoustical and optical properties of antidiabetic (MFH and SGH) and antacid drugs (RTH and PPS) are calculated from experimental density, ultrasonic velocity and refractive index data in water, methanol, ethanol and 2-propanol and in solvent mixtures of variable composition (vol%) at different temperatures. These properties are also calculated for the drugs in aqueous solutions of sodium chloride and sucrose. The mathematical formulae used for the calculation of various physical properties of drug solutions are discussed below.

2.4.1 Volumetric Properties

Density
Density measurements are carried out by using single capillary calibrated pycnometer. Equation (4) or (5) is used for the calculation of the density of drug solutions.

\[ \rho = \frac{w_s}{w_w} \times \rho_w \]  \hspace{1cm} (4)

\[ \rho = \frac{m_s}{V_w} \]  \hspace{1cm} (5)

Where, \( \rho \) = density of drug solution, \( w_s \) = weight of solution (g) at given temperature, \( w_w \) = weight of water (g) at given temperature, \( \rho_w \) = density of water (g·cm\(^{-3}\)) at given temperature and \( V_w \) = volume of water filling pycnometer at given temperature.

Apparent molar volume
Apparent molar volume \( (V_{2,\rho}) \) is a function of composition of solution at given \( T \) and \( P \) and at infinite dilution it represents partial molar volume \( (V_{2,\rho}^o) \). It is important thermodynamic property which gives idea about physicochemical behavior and intermolecular forces in solution.

For the solution containing \( n_1 \) and \( n_2 \) moles of component 1 and 2, we can write:

\[ \overline{V}_1 = \left( \frac{\delta V}{\delta n_1} \right)_{T,P,n_2} \]  \hspace{1cm} (6)

Change in volume of solution on addition of one of component at constant \( T \) and \( P \) is:
Apparent molal volume is given by:

\[ V_{2,\phi} = \frac{V - n_1 V_1^0}{n_2} \]  (8)

Where, \( V_1^0 = \) Volume of one mole of pure solvent at constant T and P. Rearranging Equation (8):

\[ V = n_2 V_{2,\phi} + n_1 V_1^0 \]  (9)

Differentiate Equation (9) with respect to \( n_2 \), we get

\[ \bar{V}_2 = \left( \frac{\delta V}{\delta n_2} \right)_{T, P, n_i} = V_{2,\phi} + n_2 \left( \frac{\delta V_{2,\phi}}{\delta n_2} \right)_{T, P, n_i} \]  (10)

From Equation (7):

\[ \bar{V}_i = \frac{V - n_2 \bar{V}_2}{n_1} \]  (11)

Combining Equations (9)-(11) we get

\[ \bar{V}_i = \frac{1}{n_1} \left[ n_1 V_{2,\phi} + n_1 V_1^0 - n_2 V_{2,\phi} - n_2 \left( \frac{\delta V_{2,\phi}}{\delta n_2} \right)_{T, P, n_i} \right] \]  (12)

Now, If \( M_1 \) and \( M_2 \) are molar masses of component 1 and 2 and \( \rho \) is experimental density of solution, then

\[ V = \frac{n_1 M_1 + n_2 M_2}{\rho} \]  (13)

Adding (13) in (8):

\[ V_{2,\phi} = \frac{1}{n_2} \left[ n_1 M_1 + n_2 M_2 \rho - n_1 V_1^0 \right] \]  (14)

In terms of molal concentration scale, \( n_2 = m_2 \) and \( n_1 = 1000 / m_1 \). Then,

\[ V_{2,\phi} = \frac{1}{m} \left[ \frac{1000 + m M_2}{\rho} V_1^0 \right] \]  (15)

Also, \( M_1 / \bar{V}_1^0 = \rho_0 \) = density of pure solvent at given T and P. Therefore, we write:

\[ V_{2,\phi} = \frac{M_2}{\rho} + \frac{1000}{m \rho \rho_0} (\rho_0 - \rho) \]  (16)

Where, \( V_{2,\phi} = \) apparent molar volume, \( \rho_0 = \) density of solvent in which solutions are prepared (g·cm\(^{-3}\)), \( \rho = \) density of experimental solution (g·cm\(^{-3}\)), \( M_2 = \) molar mass of solute (drug) and \( c = \) molar concentration of solution (mol·dm\(^{-3}\)). The apparent molar volume was calculated [8] using Equation (16).
Partial molar volume

Partial molar volume is an important thermodynamic property which gives an idea regarding volume changes with concentration of drug and solute-solvent interactions. It has applications in different fields of the science such as biochemistry, pharmaceutical sciences, oceanography, aquatic environmental science etc. The drugs used in the present investigation are electrolytes. In order to extract the coefficients related to solvation and different interactions, extrathermodynamic equation for dependence of apparent molar volume on drug concentration is fitted to Massons Equation [9-11]:

\[ V_{2,\phi} = V_{2,\phi}^{o} + S_m^{1/2} \]  

(17)

Where, \( m \) = molal concentration of drug solution, \( V_{2,\phi}^{o} \) = limiting infinite dilution apparent molal volume and \( S_m \) = experimental slope which represents solute-solute interactions.

Apparent molar expansibility at infinite dilution

The apparent molar expansibility at infinite dilution (\( \phi_E^0 \)) is obtained by differentiating the \( V_{2,\phi}^{o} \) with respect to temperature at constant pressure [12].

\[ \phi_E^0 = \left( \frac{\delta V_{2,\phi}^{o}}{\delta T} \right)_P \]  

(18)

Isobaric thermal expansion coefficient

Isobaric thermal expansion coefficient (\( \alpha_2 \)) at infinite dilution is calculated [12] using Equation (19).

\[ \alpha_2 = \frac{1}{V_{\phi}^{o}} \left( \frac{\delta V_{2,\phi}^{o}}{\delta T} \right)_P = \frac{\phi_E^0}{V_{2,\phi}^{o}} \]  

(19)

Transfer volume

Partial molar volume of transfer (standard transfer volume of drug, \( \Delta V_{2,\phi}^{o} \)) which gives information regarding solute-co-solute is calculated [13-14] using Equation (20):

\[ \Delta V_{2,\phi}^{o} = V_{2,\phi}^{o} (aq. solution) - V_{2,\phi}^{o} (water) \]  

(20)

Where, \( \Delta V_{2,\phi}^{o} \) = Partial molar volume of transfer, \( V_{2,\phi}^{o} (aq. solution) \) = Partial molar volume in aqueous-alcoholic solution and \( V_{2,\phi}^{o} (H_2O) \) = Partial molar volume in water.
2.4.2 Acoustical Properties

From measured density and ultrasonic velocity of solutions, following acoustical parameters of all drug solutions in different media has been calculated [15-17].

Change in ultrasonic velocity

Change in ultrasonic velocity i.e. ultrasonic velocity of drug solution minus ultrasonic velocity of solvent/solvent mixture has been determined from Equation (21).

\[ du = u - u_o \]  

(21)

This gives an idea about effect of drug addition in solvent system on ultrasonic velocity.

Isentropic compressibility (\( \kappa_s \))

Isentropic compressibility (\( \kappa_s \)) is calculated using Equation (22).

\[ \kappa_s = \frac{1}{u_s^2} \rho \]  

(22)

For solvent and solvent mixture, the isentropic compressibility is

\[ \kappa_0 = \frac{1}{u_0^2} \rho_0 \]  

(23)

This compressibility is adiabatic and not isothermal. When ultrasound passes through solution, the compressions that occur are very rapid and they do not escape from heat produced.

Apparent molar isentropic compressibility (\( \kappa_{s,2,\phi} \))

Apparent molar isentropic compressibility (\( \kappa_{s,2,\phi} \)) is calculated using Equation (24).

\[ \kappa_{s,2,\phi} = \frac{1000(\kappa_s \rho_o - \kappa_0 \rho)}{m \rho_o \rho} + \frac{M \times \kappa_s}{\rho} \]  

(24)

Partial molar isentropic compressibility (\( \kappa_{s,2,\phi}^0 \))

The limiting apparent isentropic compressibility \( \kappa_{s,2,\phi}^0 \) is obtained by extrapolating the plots of \( \kappa_{s,2,\phi} \) versus the \( \sqrt{m} \) by least-square method [18-19] using Equation (25).

\[ \kappa_{s,2,\phi} = \kappa_{s,2,\phi}^0 + S_4 m^{1/2} \]  

(25)
Limiting apparent molar isentropic compressibility, $\kappa_{S,2,\phi}^0$, and the experimental slope $S_k$ can be interpreted in terms of solute-solvent and solute-solute interactions respectively.

**Transfer partial molar isentropic compressibility ($\Delta \kappa_{S,2,\phi}^0$)**

Again, the transfer partial molar isentropic compressibility $\Delta \kappa_{S,2,\phi}^0$ of drug solutions was obtained [20] from following Equation (26).

$$\Delta \kappa_{S,2,\phi}^0 = \kappa_{S,\phi}^0 (aq.solutions) - \kappa_{S,\phi}^0 (water)$$

(26)

**Specific acoustic impedance ($Z$)**

Specific acoustic impedance ($Z$) of drug solutions is calculated using Equation (27).

$$Z = u \rho$$

(27)

**Intermolecular free length ($L_f$)**

Intermolecular free length ($L_f$) of drug solutions is calculated using Equation (28).

$$L_f = K (\kappa_f)^{1/2}$$

(28)

**Relative association ($R_A$)**

Relative association ($R_A$) of drug solutions is calculated using Equation (29).

$$R_A = \frac{\rho}{\rho_0} \left( \frac{u_0}{u} \right)^{1/3}$$

(29)

Where, $u=$ultrasonic velocity of drug solution, $u_0=$ultrasonic velocity of solvent/solvent mixture, $m=$ molality of solution, $\rho_0 =$ density of solvent/solvent mixture, $\rho =$ density of solution and $K=$Jacobson’s temperature-dependent constant ($=93.875 + 0.375T \times 10^{-8}$).

**Molar sound number ($U$)**

$$U = \frac{u - u_0}{u_0 m}$$

(30)

**Relaxation strength ($r$)**

$$r = 1 - \left( \frac{u}{u_\infty} \right)^2$$

(31)

Where, $u_\infty =$1600 m·s⁻¹.
2.4.3 Optical Properties

The index of refraction or refractive index is the ratio of speed of light in a vacuum to speed of light in another substance. Optical data (refractive index) of drug solutions provide interesting information related to molecular interactions and structure of the solutions, as well as complementary data on practical procedures, such as concentration measurement or estimation of other properties.

Refractive index-concentration relation

The refractive index-concentration relation is studied [21] by following Equation (32).

\[ n = n^0 + Kc \]  

(32)

Where, \( n^0 \) = refractive index at infinite dilution and \( K \) = constant depend on chemical and physical properties of drug. Graphical values of \( n^0 \) and \( K \) along with \( r^2 \) values of linearity of the plots are reported.

Atomic polarization

Atomic polarization which contributes to the molar refraction of studied solutions was calculated [22-23] using Equation (33).

\[ P_a = 1.05 \times n^2 \]  

(33)

2.4.4 Transfer Properties

Viscosity and relative viscosity

In chapter V, measurements of viscosity along with density, ultrasonic velocity and refractive index of drug solutions containing aqueous-NaCl/sucrose are carried out. The theoretical details of these systems are given below.

Viscosity (\( \eta \)) of solutions was calculated [24] using following fundamental relationship:

\[ \eta = \frac{t \times \rho}{t_o \times \rho_o} \times \eta_o \]  

(34)

The relative viscosity (\( \eta_r \)) of drug solution was calculated using following Equation (35).

\[ \eta_r = \frac{\eta}{\eta_o} = \frac{t \times \rho}{t_o \times \rho_o} \]  

(35)
Where, \( \eta \) = viscosity of drug solution, \( \eta_o \) = viscosity of pure solvent, \( t \) = flow times of drug solution, \( t_o \) = flow time of pure solvent, \( \rho \) = density of drug solution and \( \rho_o \) = density of pure solvent. The values of density and viscosity of pure water come from literature.

**Jones-Dole Equation and viscosity coefficients**

Relative viscosity data is fitted to Jones-Dole Equation and viscosity coefficients were determined graphically as an intercept and slope of plots between \( \eta_r -1/\sqrt{c} \) vs. \( \sqrt{c} \) [25-26].

\[
\eta_r = 1 + A\sqrt{c} + Bc  \quad (36)
\]

\[
\frac{\eta_r - 1}{\sqrt{c}} = A + B\sqrt{c}  \quad (37)
\]

Where, \( c \) = Concentration of drug solution, \( A \) = Viscosity coefficient representing solute-solute interactions and \( B \) = Viscosity coefficient representing solute-solvent interactions. These coefficients are interpreted in terms of solute-solvent and solute-solute interactions. The experimental and derived physical properties of antidiabetic and antacid drugs are reported in the respective chapters. These properties are discussed in terms of different interactions and structural fittings of studied solutions.

**Viscosity B-coefficients of Transfer**

The viscosity \( B \)-coefficients of transfer of drug in aqueous co-solutes solutions are calculated from the following equation.

\[
\Delta B = B_{(aq.\;solution)} - B_{(water)}  \quad (20)
\]

The viscosity \( B \)-coefficients of transfer of drug solutions obtained from the Jones-Dole relation are useful for the interpretation of the structure making/breaking ability of the drug solute.
References