Most of the everyday objects belong to one of the two large classes: Conductors and Dielectrics. Conductors contain unlimited supply of charges that are free to move throughout the material. In dielectrics, by contrast all charges are attached to specific atoms or molecules, but they can’t stay away from it. These materials offer a very high resistance to the passage of electric current under the action of D.C. voltage and therefore sharply differ in their basic electrical properties from conductive materials. The study of dielectric materials includes the measurement of complex permittivity as a function of frequency at a given temperature or as a function of temperature at a given frequency. The increasing use of microwaves in fields like medicine, biology, agriculture and pharmaceutical industry demands accurate data on dielectric properties of materials. By appropriate interpretation of dielectric data obtained at different frequencies and temperatures, it is possible to obtain information about the structure, molecular dynamics and relaxation behaviour of the molecules. In order to understand the interaction of dielectric material medium with electromagnetic field, it is important to know its permittivity. This information is required in many areas of industry, science and technology. Most of the organic polar liquids show fall of permittivity with frequency in microwave region of electromagnetic spectrum [1]. Therefore the dielectric property of organic liquids at these frequencies has been studied by a large community of researchers since last five decades or so. The measured values of complex permittivity at various frequencies are used to evaluate various dielectric parameters i.e. relaxation time, distribution parameter, dipole moment, thermodynamical parameters, excess permittivity, excess molar polarization. These dielectric parameters give valuable information about molecular structure, inter and intramolecular rotations, solute–solute and solute–solvent interactions. These studies are very important to predict macroscopic behaviour of substance on one hand and on the other hand they predict applications of dielectric materials in various fields like engineering, defense, medicine, pharmaceutical industry, communications etc. As far as pharmaceutical science concerned, dielectric studies can be used for understanding the molecular structures, mobility and shape of drugs [2].
Molecular interaction among the molecular species of the mixtures of polar liquids depends on many factors such as dipole moment, internal field, thermodynamical parameters, viscosity, density, dipolar interaction, temperature etc. Therefore, the interpretation of molecular interaction based on dielectric data is not unique in many cases. Many other physical methods like measurement of ultrasonic velocity, density, viscosity are also used to study molecular interaction in liquid state. If these measurements are conducted along with dielectric measurements, its results can confirm or supplement the inferences derived from dielectric studies. In present thesis, an attempt is made to study the dielectric and other physical properties of polar molecules of pharmaceutical importance. The dielectric properties show the influence of the drugs in the organic solvent which finds its applications in the pharmaceutical industries and medicinal physics. The ultrasonic studies of the drug shows the structural changes associated with them in terms of acoustic properties. A knowledge of solution behaviour is of considerable pharmaceutical importance, in terms of both formulation of medicaments and also the understanding of the distribution of drugs in tissues and membranes throughout the body [2]. This brings out modification of physico–chemical properties such as solubility, stability, photosensitivity, viscosity, density, improvement of bioavailability through modification of absorption and reduction of toxicity. Compounds used as medicines are most often mixture of organic compounds. Therefore it is important to examine the molecular interaction studies on mixture of organic liquids. Dielectric studies provide great help in the assignment of the molecular structure or configurations, particularly for organic compounds of pharmaceutical importance [3]. The dielectric constant of solvent mixtures can be related to drug solubility [4]. Drug macromolecular interactions are an important principle in physiological media such as blood, membrane, intra and extracellular fluids [5]. The ultrasonic studies of the drug show the structural changes which is associated with them in terms of acoustic properties.

**Literature survey**

Considerable work has been done on polar molecules of pharmaceutical importance through dielectric and physico–chemical methods. Molecular structural study of Ayurvedic medicine ashokarishta in ethanol at microwave frequency using TDR technique was studied by Chaudhari et al [6]. Cellulose and its derivatives are used in pharmaceutical industries for production of coated and controlled release tablets. Rachoki et al [7] studied dielectric relaxation behaviour of cellulose and its
derivatives. Dielectric relaxation studies of nicotinamide and 1-butanol at different temperatures was carried out by Jain et al [8]. In their study, they suggested the existence of both intramolecular and overall orientation in the binary mixture. They also predicted solute-solute and solute-solvent molecular interactions. Chavan et al [9] studied microwave dielectric behaviour of 1,2-propan diol and water mixtures using TDR technique. They concluded that the excess parameter and Bruggeman factor show the systematic change with change in concentration. Chaudhari et al [10] conducted dielectric studies of glycine-ethylene glycol-water solution using TDR technique. They suggested that complex permittivity spectra for aqueous glycine solutions can be well described by the Cole–Davidson expression, whereas for the ternary system, it can be well described by Havriliak–Nigami expression. Rekha Pande et al [11] studied molecular interaction in binary mixtures of diethylenetriamine with glycerine at microwave frequencies. Vyas and Rana [12] studied dielectric absorption of rigid polar molecule pyridine and its mixture with benzonitrile in benzene solution. They concluded that each component retain their characteristic dielectric behaviour in the mixture. Microwave absorption and dielectric relaxation of some rigid polar molecules pyridine, quinoline, isoquinoline and their mixtures were measured in dilute solutions of benzene by Madan et al [13]. Prathima et al [14] studied structural properties of the binary mixtures of pharmaceutical intermediates through dielectric investigations. They found the homo and hetero interaction in the binary mixtures of ethylacetate + n-butylamine, ethylacetate + cyclohexylamine and ethylacetate + diethylamine. They concluded that for all studied systems, the dielectric parameters obtained show systematic change in the molecular structure with concentration of amine in the solution. They also indicated β-multimer formation due to the presence of heterointeraction between the components of mixture. Dabrase et al [15] studied intermolecular interaction of pyridine and acetone at 313.15 K. They determined acoustical and thermodynamical parameters. They suggested presence of the intermolecular interaction between the components of molecules of the mixture. The dielectric relaxation study of binary mixtures of primary alcohols and polar solutes such as methyl acetate [16], dimethylformamide [17], dimethyl sulfoxide [18] and tetrahydrofuran [19] was conducted using TDR technique. Lokhande et al [20] reported dielectric data of pure biological samples such as Albumin and yolk of avian egg using TDR technique.
Dielectric and ultrasonic studies of the drug oxytetracycline hydrochloride in ethanol at 303 K was studied by Beena et al [21]. They calculated dielectric parameters such as static dielectric constant, microwave and optical dielectric constant and relaxation time by Higasi’s method for the drug oxytetracycline hydrochloride in ethanol for various mole fractions at 303 K. For the same system they also determined the ultrasonic velocity at 2 MHz, molar free energy of activation and viscous flow. Other acoustical parameters have also been calculated. They concluded through dielectric and ultrasonic studies that a weak interaction is taking place between the drug and ethanol molecules. Poornachandra and Nannapaneni [22] studied the dielectric behaviour of pyridine in non-polar solvents benzene and carbon tetrachloride. They reported short range intermolecular and dipole-dipole interactions of the polar molecules in liquid state.

Dielectric studies of binary mixtures of polar solute 1-chloromethylnaphthalene with non-polar solvents have been reported by Poornachandra Rao et al [23]. Dhame et al [24] studied the solute–solvent interaction through dielectric properties of allyl chloride with alcohols using TDR technique. They discussed their results to get information about molecular interaction and the dynamics of the mixture of the system. Vyas at al [25] studied the dielectric properties of mixtures of some rigid polar molecules with some primary alcohols. They reported the static dielectric constant ($\varepsilon_0$) and high frequency limit dielectric constant ($\varepsilon_c$) values of binary mixtures of rigid polar molecules bromobenzene and nitrobenzene each with three alcohols methanol, 1-propanol and 1-butanol over the entire concentration range at 28°C. They also calculated Kirkwood correlation factor and Bruggeman factor of these mixtures. They discussed their results in terms of molecular interaction between the components of the mixtures.

The polar compounds used in present work are pyridine, picolines (α- and β-picoline), amino substituted pyridines (2-amino pyridine and 4-dimethylamino pyridine), methanol and 1-propanol. Molecular structure and applications of these compounds are as follows:

**Pyridine:**

Pyridine is a heterocyclic organic compound with the chemical formula C₅H₅N. It is structurally same as benzene, with one –CH group replaced by nitrogen atom. It is used as a main precursor to pharmaceuticals and it is also known as important solvent and reagent [26].
Pyridine is present in the important vitamins niacin and pyridoxine (vitamin $B_6$) and also in highly toxic alkaloids such as nicotine. Most of pyridine and its derivatives of commercial interest find applications in market areas where bioactivity is important, as in medicinal drugs and agricultural product. Pyridine and its derivatives are mostly used in antiviral activity [27], anticancer activity [28], antichagasic activity [29], antioxidant activity [30] and antibacterial activity [31]. Chaube and Pandeya [32] studied in detail “Pyridine”: A versatile nucleuse in pharmaceutical field. In their paper very large pharmaceutical applications of pyridine and its derivatives are reported.

**Picoline:**

Picoline are known as methyl substituted pyridines which are precursor to pyridine derivatives that have wide applications in pharmaceutical and agricultural industries. $\alpha$-picoline and $\beta$-picoline is colorless liquids with formula $C_6H_7N$. The methyl group enlarges the hydrophobic part and it also affects the hydrogen bonding ability by redistribution of the electron charge in the ring. By varying the position of the methyl substituent, the strength of methyl pyridine for interaction or bonding with any solvent can be changed. The major use of $\alpha$-picoline is a precursor of 2-vinyl pyridine. It is also used as a raw material for a variety of pharmaceuticals and agrochemicals [33].
β-picoline is also used as an intermediate in the pharmaceutical industry. It is main precursor to niacin which is one of the vitamin-B families [34]. Along with its use as an essential vitamin, niacin is also a precursor of many of the compounds including cancer drugs, antibacterial agents and pesticides. Like most simple pyridine derivative, the picoline contains more nitrogen than is needed for growth of microorganisms and excess nitrogen is generally excreted to the environment as ammonium during the degradation process [35].

**Amino substituted pyridines:**

In present thesis, 2-Amino pyridine (2-AMP) and 4-Dimethyl Amino pyridine (4-DMAP) will be used as a amino substituted pyridines. 2-Amino pyridine is an organic compound with molecular formula $\text{C}_5\text{H}_6\text{N}_2$. It is one of the three isomers of amino pyridines. It is colorless solid used for the production of the pharmaceutical drugs piroxicam, sulfapyridine, tenoxicam and tripeleamine. 2-AMP is also used in the synthesis of the pharmaceuticals especially for antihistamines, antiflammatories and other drugs. 2-AMP is manufactured using the reaction of pyridine with sodium amide (Chichibabin amination). It is also used for the production of the drugs circlopiroxolamine, diphenpyramide, propiram fumarate, pyralamine, triprolidine and zomepirac [36]. On the other hand, 4-DMAP is also used as a catalyst used in the synthesis of pharmaceuticals, agrochemicals and polymers. It is also used as a catalyst in synthesis of heroin. At the global level, due to high illicit production, heroin is one of the most significant illicit drugs in terms of treatment demand, hospitalization, overdose, drug related mortality, involvement of organized crime and drug related violence [37]. 4-DMAP was also used in similar reactions yielding anampicillin derivative [38] and sulfonamides [39].
Methanol and 1-Propanol:

Among the associative liquids, alcohols are centre of interest. Methanol and 1-propanol are aliphatic molecules with flexible hydroxyl groups attached to the main carbon chain, having approximately same dipole moments. Methanol is the simplest alcohol with the formula CH₃OH. At room temperature, it is a polar liquid and used as a solvent in pharmaceutical and as a denaturant for ethanol. On the other hand, 1-propanol is a primary alcohol with formula CH₃CH₂CH₂OH. It is a colorless liquid and used as a solvent in the pharmaceutical industry mainly for resins and cellulose esters [40].

![Methanol and 1-Propanol](image)

In Chapter IV of present thesis, measured values of static permittivity ($\varepsilon_0$) and permittivity at optical frequency ($\varepsilon_{oo}$), which is taken as square of refractive index of the pyridine, 1-propanol and their binary mixtures at three different temperatures are reported. Excess permittivity ($\varepsilon_0^E$), Bruggeman factor ($f_B$) and Kirkwood correlation factor ($g_{eff}$) have been calculated from the measured parameters. Measured experimental static permittivity ($\varepsilon_0$) and refractive index ($n_0$) values of the liquid samples were compared with the theoretical values estimated using various mixing rules for static permittivity and refractive index respectively. The investigation of binary mixtures showed a systematic change in static permittivity and permittivity at optical frequency with change in concentration of pyridine in 1-propanol.

Apart from this, other physical parameters such as ultrasonic velocity ($U$), viscosity ($\eta$) and density ($\rho$) of the liquid mixtures are also reported in Chapter IV. From these measured parameters, acoustical parameters such as adiabatic compressibility ($\beta$), intermolecular free length ($L_f$), free volume ($V_f$), internal pressure ($\pi_i$) and their excess values were calculated. The results are reported in Chapter IV. The ultrasonic velocity decreases with mole fraction of 1-propanol at all studied
temperatures. The behaviour of excess viscosity reveal that weak intermolecular interaction exists in the pyridine and 1-propanol mixture which may be due to the dominance of dispersion forces and dipolar interaction between the unlike molecules.

In last two decades time domain reflectometry (TDR) has emerged as powerful technique to measure dielectric properties of liquids. In the Chapter V of present thesis, results of the investigation carried out on the dielectric relaxation of the binary mixtures of each of α-picoline (2-Methyl pyridine) and β-picoline (3-Methyl pyridine) with the lower primary alcohols methanol and 1-propanol(1-PrOH) using TDR technique, are reported. The complex permittivity of α-picoline + MeOH, β-picoline + MeOH, α-picoline + 1-PrOH and β-picoline + 1-PrOH at four different temperatures have been measured as a function of frequency between 10 MHz to 25 GHz by TDR technique. Dielectric parameters viz., static permittivity(ε₀), relaxation time(τ) and permittivity at high frequency(ε_{opt}) were obtained from complex permittivity spectra using complex non linear least square fit method using LEVMW [41] software. With these parameters excess dielectric parameters, Kirkwood correlation factor (g_{eff}) and thermodynamical parameters (ΔF_e, ΔS_e and ΔH_e) were determined. The experimentally measured values of permittivity at optical frequency, ε_{oo} of different liquid samples were also reported. Study was conducted with an aim (i) to find suitable relaxation model due to main relaxation process for each of α-picoline, β-picoline and their mixtures with the alcohols: methanol and 1-propanol, and using that model to find the relaxation parameters, (ii) to gain information about the reorientational dynamics and molecular interaction among the molecules of the binary mixture system.

Dielectric relaxation of each of 2-Amino pyridine (2-AMP) and 4-Dimethyl Amino pyridine (4-DMAP) in dilute solutions of each of three non-polar solvents benzene, carbon tetrachloride and 1,4-dioxane at single microwave frequency and different temperatures was presented in Chapter VI of the present thesis. Microwave dielectric absorption at 9.1 GHz, static permittivity (ε₀) at 2 MHz, refractive index (n₀) and density (ρ) were measured at different temperatures. Measured data have been used to evaluate the most probable relaxation time (τ), distribution parameter (α), dipole moment (μ), Kirkwood correlation factor (g), molar polarization (P) and molar volume (V_m). Some thermodynamical parameters (ΔF_e, ΔS_e and ΔH_e) were also determined. The relaxation time (τ) of these systems were determined using
Higasi [42] and Gopal Krishna’s [43] method. Results of these studies are reported in Chapter VI.

A brief review of various theories of dielectric behaviour of materials is given in Chapter II. Various experimental techniques for measurement of complex permittivity at radio and microwave frequencies using TDR (Time Domain Reflectometry) and using standard microwave bench are given in Chapter III. Experimental techniques of ultrasonic velocity measurement, density and viscosity are also presented in the same chapter. A brief description of measurement of static permittivity using LCR meter is included in the same chapter.

A summary and future scope of the present work has been presented in Chapter VII. Major results of the investigation carried out are highlighted in the same chapter.
References


