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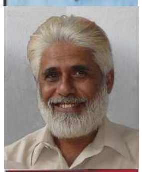
Dielectric Properties of Medicinal Compounds Using Microwave

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Abstract

Dielectric properties of materials are of interest to scientists and engineers, this includes properties like permittivity, permeability and conductivity. We studied the dielectric properties of selected medicinal compounds such as menthol and thymol in varying concentration of their solution in Acetone. We used microwave reflectromety technique for the measurement of dielectric properties at microwave frequency of 9.8 GHz at constant temperature of 293 K. The advantage of this approach is that using a reflectrometry measurement setup of liquids, the dielectric properties of solids can be estimated from their solutions. Dielectric constant, dielectric loss and tangent loss is measured for the solutions of the two medicinal compounds in different concentration in acetone and details discussed.

Keywords: Microwave, Plunger cell, Dielectric Properties, Constant temperature Bath etc.

Subject Classification: Physical Chemistry

1. Introduction

In relation to dielectric properties, the electromagnetic properties of material of interest to scientists and engineers include the permittivity, permeability and conductivity. For dielectric materials both for lossy and lossless, the most identifying parameter is the dielectric constant or permittivity. Dielectric properties are intrinsic characteristics of the materials explaining the behavior and degree of the wave-mater interaction when exposed to microwave field. . These properties are very important in microwave heating, microwave sensing, process design and application. For example, there are many researchers who have used dielectric properties to measured moisture content of material and agro-food. A number of methods for measuring the microwave dielectric constant and dielectric loss of liquids have been proposed by different research groups and the classic paper on the method of measurement is that of Heston and

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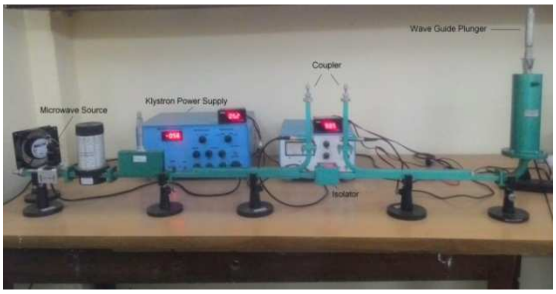
Smyth Method for low loss liquids[6]. The measurement of dielectric properties of liquid materials at microwave frequencies can be used to determine some physical properties and evaluation of biological effects in biological molecules.

2. Experimental

The present work relates to the permittivity of some medicinal powder (Thymol and Menthol) in Acetone have been measured at 9.8 GHz for mode TE_{10} and temperature of 27°C by using waveguide plunger technique. An X-band microwave bench was used to measure the guide wavelength, wavelength in dielectric, and a standing wave ratio. Photograph of the experimental set up is shown in Fig. 1. In the present work we used two directional couplers with isolator for the measurement of the incident and reflected microwave in terms of current form the detector. This incident and reflected intensity of microwave was used for calculation of VSWR using the relation:

$$VSWR = S = \frac{I_f + I_r + 2\sqrt{I_f I_r}}{I_f - I_r}$$

Fig 1 Photograph of experimental setup showing details of various components used like waveguide plunger and the two couplers along with the rest of the system.



When microwave is travelling through medium 1 (air) and strikes normally to the surface of medium 2 (dielectric material), which one part of the energy is reflected, another part is transmitted through the surface and the rest of it is absorbed. The proportions of energy which fall into these three categories have been defined in term of the dielectric properties. The complex relative permittivity **ε** of the material is expressed as

$$\varepsilon = \varepsilon' - j\,\varepsilon'' \qquad (1)$$

Where,

ε' is the dielectric constant

ε'' is the dielectric loss

The dielectric constant ε' and dielectric loss ε'' are given by equation (1).

$$\varepsilon' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \qquad (2)$$

$$\varepsilon'' = \frac{2}{\pi}\left(\frac{\lambda_0}{\lambda_d}\right)^2 \left(\frac{\lambda_g}{\lambda_d}\right)\left(\frac{d\rho_{mean}}{dn}\right) \qquad (3)$$

Where λ_0 is free space wavelength, λ_d is wavelength in dielectric, λ_c is cut off wavelength = 2a. Here a is the width of the cell and λ_g is guide wavelength. To eliminate later losses, a graph is plotted between several mean values of ρ_n versus n, Here ρ_n is an inverse of V.S.W.R . The slope of this graph is equal to the value of $\frac{d\rho_{mean}}{dn}$.

Other important dielectric properties i.e. Tangent loss (tan δ) is calculated using

$$\text{Loss tangent} = \quad Tan\delta = \frac{\varepsilon''}{\varepsilon} \qquad (4)$$

3. Materials and method

A microwave X- bench Band were used to measure the dielectric properties Dielectric constant (ε'), Dielectric loss (ε'') and tangent loss (Tan δ) of powder–solvent mixtures. All properties were measured by using Surber's technique of reflectometry at room temperature 20^0C.

Dielectric measurements of the powders (Menthol and Thymol) and all mixtures were carried out in the Acetone content fixed and changes the wt fraction of powder in the range 0–1.0 kg kg^{-1} (0.2 kg kg^{-1} intervals). The sample (of given moisture content) was prepared by mixing the required weight (±0.01 g) of powder with the required weight (±0.1 g)

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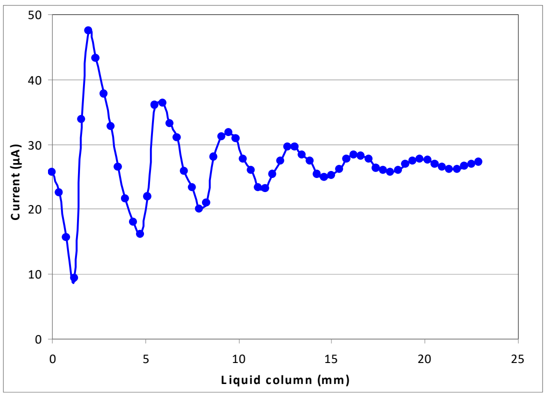
of solvent. The dielectric properties of the solvents were also measured.

For each experiment, a powder dissolved in solvent using Magnetic Stirrer and directly used for further analysis. Dielectric measurements were made at standard frequency of 9.8 GHz was used to investigate with various Powder - Solvent concentration. Each experiment was performed in triplicate.

4. Result and Discussion:

The measurement of Dielectric constant ε', dielectric loss and tangent loss for solutions of the two medicinal compounds menthol and thymol is presented. The experimental setup is shown in Fig. 1 and the microwave bench operating at microwave frequency of 9.8 GHz was used. Accurate quantities of solid sample (medicinal compound) were weighed and were dissolved in calculated amount of acetone to obtain solution in desired concentration (w/w). The experiment was carried out by gradually changing the thickness of liquid column and recording the signal strength in terms of current in the detector. A graph is then plotted using the thickness of the liquid column on the x – axis and the signal strength (μA) on the axis of y. The resulting plot is in the form of a damped oscillation as shown in Fig. 2 for acetone.

Fig. 2 Plot of microwave signal strength versus the liquid column of acetone at 293K.



Summary of results obtained for menthol in different concentration with acetone is tabulated in Table – 1. Table – 1 lists the values of dielectric constant ε', dielectric loss ε'' and tangent loss for solution of menthol in acetone in different concentrations.

Table- 1 Dielectric Constant, Dielectric Loss and Tangent loss of Menthol in Acetone at different Concentration

Sr. No.	Weight concentration Kg/Kg	ε'	ε''	Tan δ
1	1:0	21.4259	9.5967	0.4479
2	1:0.2	16.7784	6.9138	0.4121
3	1:0.4	13.8013	5.4445	0.3945
4	1:0.6	13.2013	4.8822	0.3698
5	1:0.8	13.0166	4.7901	0.3680
6	1:1	11.6247	4.1511	0.3571

Fig.3 Dielectric Constant of Menthol in Acetone at different Kg/Kg concentration

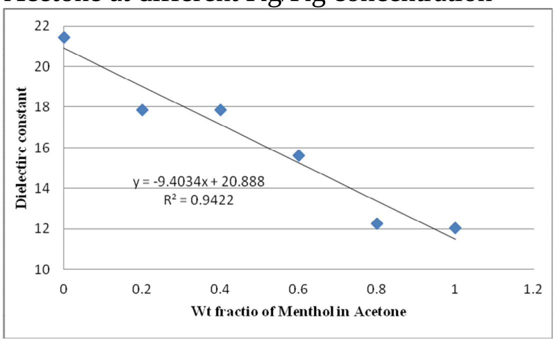


Fig.4 Dielectric loss of Menthol in Acetone at different Kg/Kg concentration

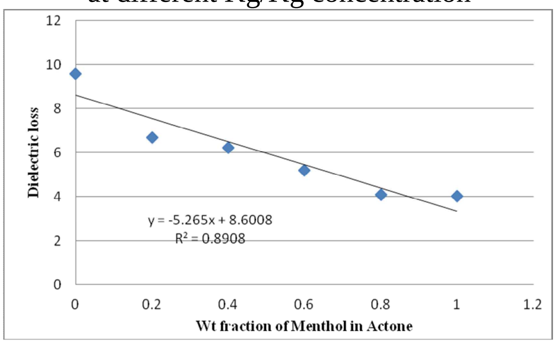


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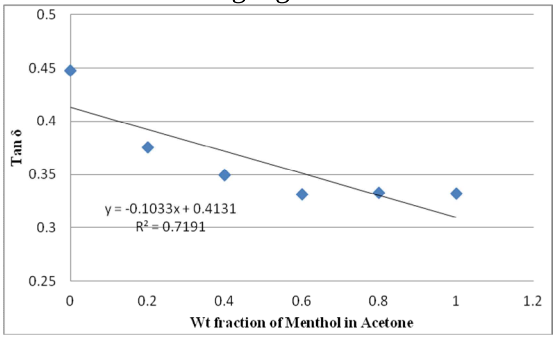
Fig.5 Tan d of Menthol in Acetone at different Kg/Kg concentration



shown graphically in Fig. 1. It is seen that as the amount of menthol is increasing in the solution, this results in the decrease in the net value of dielectric constant of the solution. This is in accordance with the expectation as the dielectric constant of acetone is much high as compared to that of the medicinal compound menthol. This is also visible from the value of dielectric constant of the solution when both solute and solvent are in equal proportion.

Similarly the values of dielectric loss ε" and the value of Tan δ are found to change with concentration of solute (menthol) in the solvent acetone. The relationship is more or less similar such that an increase in concentration of the solute menthol results in a decrease in dielectric loss and loss tangent Tan δ as is seen in Fig. 2 and 3 respectively.

Summary of results obtained for thymol in different concentration with acetone is tabulated in Table – 2. Table – 2 lists the values of dielectric constant ε', dielectric loss ε" and tangent loss for solution of menthol in acetone in different concentrations.

Table- 2 Dielectric Constant, Dielectric Loss and Tangent loss of Thymol in Acetone at different Concentration

Sr. No.	Weight concentration Kg/Kg	ε'	ε"	Tan δ
1	1:0	5.7638	3.4254	0.5942
2	1:0.2	5.2501	2.6548	0.5056
3	1:0.4	4.9440	2.4302	0.4915
4	1:0.6	4.7148	2.2155	0.4699
5	1:0.8	4.5030	2.0639	0.4583
6	1:1	4.3074	1.9219	0.4461

Fig.6 Dielectric Constant of Thymol in Acetone at different Kg/Kg concentration

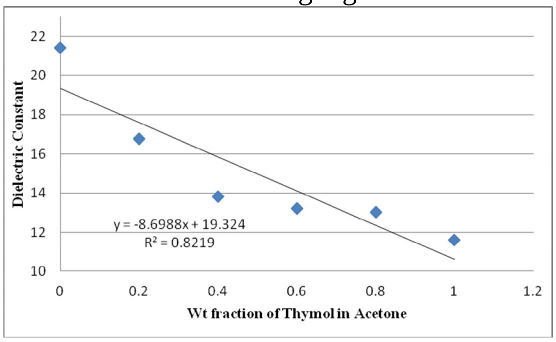


Fig.7 Dielectric loss of Thymol in Acetone at different Kg/Kg concentration

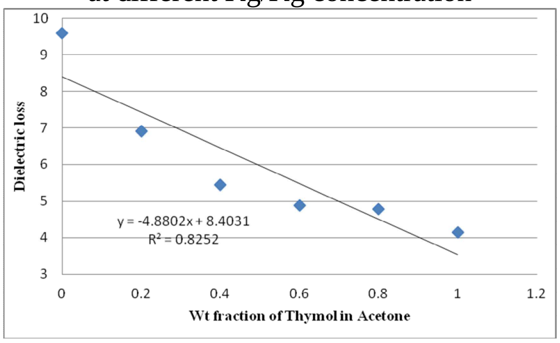


Fig.8 Tan δ of Thymol in Acetone at different Kg/Kg concentration

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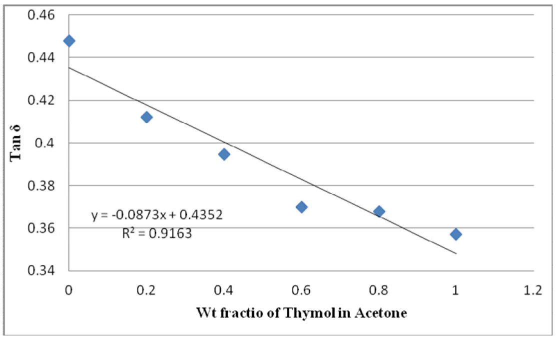

The effect of change in concentration of thymol in acetone on the dielectric constant ε' is shown graphically in Fig. 1. It is seen that as the amount of menthol is increasing in the solution, this results in the decrease in the net value of dielectric constant of the solution. This is in accordance with the expectation as the dielectric constant of acetone is much high as compared to that of the medicinal compound menthol. This is also visible from the value of dielectric constant of the solution when both solute and solvent are in equal proportion.

Similarly the values of dielectric loss ε" and the value of Tan δ are found to change with concentration of solute (menthol) in the solvent acetone. The relationship is more or less similar such that an increase in concentration of the solute menthol results in a decrease in dielectric loss and loss tangent Tan δ as is seen in Fig. 4 and 5 respectively. In Fig. 7 - 8 the points plotted represent actual data from measurements and the straight line joining these points is the best fitting straight line to this data whose equation is also shown in the inset.

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