iJRASET

International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: IX Month of publication: September 2020

DOI: <https://doi.org/10.22214/ijraset.2020.31609>

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Study of Static Dielectric Constant and Relaxation Time of Brucine-Chloroform Solution using Time Domain Reflectometry

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Abstract: The complex permittivity, static dielectric constant and relaxation time of Brucine – Chloroform solution for different concentration have been studied using time domain Reflectometry at temperature 298°K, in frequency range 10 MHz to 30 GHz. The effect of Brucine concentration in non-polar solvent chloroform on static dielectric constant (ϵ_0) and relaxation time (τ) was studied. The static dielectric constant slightly decreases and relaxation time increases with concentration of Brucine.

Index Terms: Brucine; Dielectric constant; Relaxation time; TDR.

I. INTRODUCTION

Brucine was discovered in 1819 by Pelletier and Caventou in the bark of Strychnos nux vomica tree. It comes under the Indole- II group of alkaloid [1]. It is a natural alkaloid. It was closely related to Strychine [2]. Brucine is large chiral molecule, it is used in chiral solution. It is also called 2-3 Dimethoxystrychnine. Brucine is used for medical use. It has anti-tumor properties [3]. It is poisonous alkaloid, hence it is also used as a pesticide. [4, 5] . Molecular formula is $C_{23}H_{26}N_2O_4$. It dissolves in alcohol and chloroform. It's molecular mass is 394.46 gm/Mole. As per use in medical and agricultural field, it is necessary to study in depth. In this paper, I present effect of Brucine concentration on static dielectric constant and relaxation time at temperature 298°K using time domain Reflectometry. .

II. EXPERIMENTAL

A. Material

Brucine (2-3 Dimethoxystrychnine) was obtained from OTTO Chemie India. Considering the molecular mass and solubility of Brucine in chloroform, molar solutions 0M, 0.06M, 0.12M, 0.18M, 0.24M, 0.3M were prepared. Chloroform is non-polar solvent.

B. Experimental Setup

Digital serial Analyser sampling oscilloscope DSA-8200 (Tektronics), sampling TDR module 80E08 with step generator was used. Bandwidth of DSA-8200 is 50 GHz [6,7]. To maintain temperature 298°K, temperature control system was used. The Fig. 1 shows block diagram of TDR.

Fig. 1 Experimental setup of TDR

C. Experimental Procedure

By maintaining temperature 298°K constant, the reflected pulse without sample $R_1(t)$ and with sample $R_x(t)$ were recorded in time window 5 ns and Considering the digitized in 2000 points for Brucine-chloroform solution of different concentration using TDR technique between frequency range 10 MHz to 30 GHz.

III. RESULT AND DISCUSSION

The complex coefficient $\rho^*(\omega)$ over frequency range 10MHz to 30GHz determined as

$$\rho^*(\omega) = \frac{p(\omega)}{j\omega d q(\omega)} \quad \text{-- (1)}$$

Where, $p(\omega)$ and $q(\omega)$ are Fourier Transform of time domain $p(t)$ and $q(t)$. If The reflected pulse without sample is $R_1(t)$ and with sample is $R_x(t)$. Then,

$$p(t) = [R_1(t) - R_x(t)] \quad \text{-- (2)}$$

$$q(t) = [R_1(t) + R_x(t)] \quad \text{-- (3)}$$

$p(\omega)$ and $q(\omega)$ in equation (1), obtained by summation and Samulon method [7, 8]

$$p(\omega) = T \sum_{n=0}^N \exp(-i\omega nT) p(nT) \quad \text{-- (3)}$$

$$q(\omega) = \frac{T}{1 - \exp(-j\omega T)} [\sum_{n=0}^N (q(nT) - q(n-1)T) \exp(-j\omega nT)] \quad \text{-- (4)}$$

The complex permittivity spectra $\epsilon^*(\omega)$ is obtained from reflection coefficient spectra $\rho^*(\omega)$ by using Bilinear calibration method suggested by Cole [10-12].

Due to brucine concentration to the dielectric polarization, the dielectric spectra for brucine- chloroform solution are more complicated. The dielectric relaxation for Brucin-Chloroform solution is described by Harilliak and Negami equation [13].

$$\epsilon^*(\omega) = \epsilon_\infty + (\epsilon_0 - \epsilon_\infty) / [1 + (j\omega\tau)^{1-\alpha}]^\beta \quad \text{--(5)}$$

Where, ϵ_0 is static dielectric constant, ϵ_∞ is dielectric constant at high frequency, τ is relaxation time, α and β are distribution parameter.

Brucine chloroform solution for all concentration could fit Debye type dispersion [14]. Therefore $\alpha = 0$, $\beta = 1$ and experimental values $\epsilon^*(\omega)$ were fitted to Debye equation as

$$\epsilon^*(\omega) = \epsilon_\infty + \frac{(\epsilon_0 - \epsilon_\infty)}{(1 + j\omega\tau)} \quad \text{---(6)}$$

By using, nonlinear square fir method, static dielectric constant ϵ_0 an relaxation time τ for different concentration at 298°K are determined which is as shown in Table 1.

Table 1: Dielectric relaxation parameters for solution of Brucine – chloroform at different concentration at temperature 298°K

298°K			
Concentration of Brucine in Molar (M)	ϵ_∞	ϵ_0	$\tau(\text{ps})$
0	2 (1)	4.82 (1)	6.87 (4)
0.06	2.30 (3)	4.41 (3)	9.12 (7)
0.12	2.04 (5)	4.43 (4)	10.08 (9)
0.18	2.03 (3)	4.36(3)	11.04 (7)
0.24	2.04 (7)	4.34 (8)	12.28 (15)
0.3	2.62 (1)	4.31 (3)	13.52 (29)

(Note – The number in bracket indicate error, for e.g. 6.87(4) means $6.87 \pm (0.04)$)

Variation of static dielectric constant with molar concentration of Brucine at temperature 298° K is as shown in Fig. 2

Fig.2 Variation of static dielectric constant with molar concentration of Brucine at temperature 298° K

Similarly, variation of relaxation time with molar concentration of Brucine in chloroform at 298° K is as shown in Fig.3

Fig.2 Variation of relaxation time with molar concentration of Brucine in chloroform at 298° K

IV. CONCLUSION

The Dielectric constant is mainly dependent on dipole moment and number of molecules per unit volume. Static dielectric constant (ϵ_0) decreases with increase in concentration of Brucine. The relaxation time increases with increase in concentration of Brucine.

V. ACKNOWLEDGEMENT

Author A. R. Lathi thanks to Dr. S.K.Popalghat (J.E.S. College, Jalana) and Dr. A.C. Kumbharkhane (school of Physical Sciences Swami Ramanand Teerth, Marathwada University, Nanded).

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