Solvation And Interaction Analysis of a Dithiobiureto-Substituted Pyridine in Ethanol–Water Media

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doi.org/10.64643/IJIRTV12I9-195754-459

***Abstract*—Heterocyclic pyridine-based compounds continue to attract considerable attention due to their significant role in pharmaceutical and medicinal chemistry. Pyridine, a six-membered heteroaromatic system, is widely present in biologically active natural products such as vitamins and alkaloids, making its derivatives valuable scaffolds for drug design. In the present investigation, viscometric and density measurements were carried out for 1-(5-t-butyl-2,4-dithiobiureto)-2-methyl-4-methoxy-3,5-dimethylpyridine in mixed solvent systems at a fixed concentration over a range of temperatures. The experimental data were employed to analyze solute–solvent interactions and the influence of solvent composition on molecular behavior. A decrease in relative viscosity with increasing temperature was observed, suggesting enhanced solvation and reduced intermolecular resistance. These findings provide meaningful insight into the physicochemical characteristics of pyridine derivatives and contribute to a better understanding of their solution behavior, which is essential for the rational development of effective pharmaceutical formulations.**

***Index Terms*—Pyridine derivatives, Physicochemical properties, Relative viscosity, Solute–solvent interactions, Temperature effect, Viscometric study**

I. INTRODUCTION

One of the most important and fundamental areas of organic chemistry is heterocyclic chemistry. "Heteros," which means "different" in Greek, is where the word "heterocyclic" originates [1]. Nitrogen-containing heterocyclic compounds are organic molecules that have both nitrogen and carbon atoms in a cyclic ring structure. Usually, these compounds have rings with five or six members [2].
Comparing heterocyclic compounds to normal organic molecules without heteroatoms is the most effective way to understand their physical and chemical characteristics. The study of heterocyclic molecules, which make up around 65% of organic chemistry's published literature, is known as heterocyclic chemistry [3].
The organosulfur chemical dithiobiuret has the formula HN(C(S)NH2)2. Warm water and polar organic solvents dissolve this colourless solid. This planar molecule contains several C-S and C-N bonds because of its short C-S and C-N lengths [4]. Drug chemistry, pharmaceuticals, industry, and medicine all involve dithiobiuret molecules. The generated heterocycles act as intermediates in the synthesis of thiadiazols, dithiazoles, thiazines, triazines, Hector's bases, and other chemicals. Acyclic 2,4-dithiobiurets are an effective biological moiety [5]. The synthesis and biological evaluation of novel 2,4-dithiobiurets is a promising field in organic chemistry. These 2,4-dithiobiurets are a great class of organic intermediates for the synthesis of various active heterocycles [6-7]. Drugs with dithiobiureto nuclei have important applications and ramifications in the domains of biochemistry, pharmacology, industry, agriculture, and medicine [8-9].
Viscosity measurements are crucial. One essential characteristic of liquids that characterises their resistance to flow is their viscosity. It estimates a liquid's resistance to layers changing relative to one another. Internal friction that arises as the molecules in the liquid move and interact with one another is what causes this resistance [10]. Both aqueous and non-aqueous solutions include interactions between the solute and the solvent. This crucial information is obtained by measurements of viscometric properties. Measurements of a drug's viscosity and interactions with solvents in the human body will have a direct

impact on its behaviour, including absorption, transmission, and effects [11].

Mixtures of water and alcohols attract considerable scientific interest due to their intricate molecular behavior, which arises from the interplay of hydrogen bonding and hydrophobic interactions. Owing to their widespread application as solvent systems, these mixtures have been extensively explored using both experimental techniques and theoretical models. The viscosity of liquids is governed by multiple parameters, including temperature, molecular dimensions, molar mass, intermolecular forces, and the presence of trace impurities. Analysis of viscosity data offers meaningful insight into the strength and nature of molecular interactions within binary and ternary liquid mixtures, where enhanced attractive forces can lead to an increase in viscosity. Density also plays a vital role in characterizing liquid systems, as it determines the buoyancy behavior of substances; components with lower density than the surrounding liquid tend to float. In addition, density serves as a key physicochemical parameter for evaluating several acoustic and thermodynamic properties, including surface tension, molar refraction, boiling point, and dipole moment [12-18]. They have measured the viscosities of solutions at different concentrations [19-20]. Additionally, binary mixture molecular interactions are investigated [21-24]. By computing the β-coefficient, numerous studies have also examined solute-solvent interactions at various concentrations. Numerous attempts have been made to investigate the viscosities of binary liquid mixtures, but no results have been found that demonstrate optimal drug behaviour in vivo [25-28].

Pyridine derivatives have a variety of pharmacological and biochemical properties, including those of mydriatic, anaesthetising, antiviral, antibacterial, and anti-inflammatory medications, according to a review of the literature. There are many applications for the heterocyclic 2,4-dithiobiurets nucleus molecule in the fields of pharmacology, biochemistry, biotechnology, and medicine [12-13]. All things considered, this type of research improves patient outcomes by advancing the field of drug science and assisting in the development of more reliable and effective pharmaceutical products [29-32].

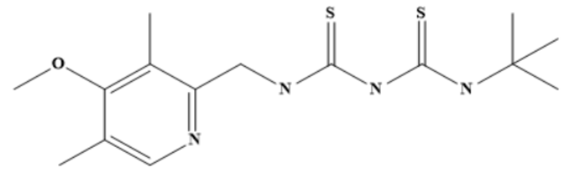

Fig. 1. 1-(5-t-butyl-2,4-dithiobiureto)- 2-methyl-4-methoxy-3,5 dimethylpyridine

II. EXPERIMENTAL DETAILS

All chemicals employed in the present work were of analytical reagent (A.R.) grade, and double-distilled water was used throughout the experiments. The masses of the compounds were determined using a high-precision Mechaniki Zakłady Precyzyjnej Gdańsk balance with an accuracy of ±0.001 g. Viscosity measurements were carried out using an Ostwald viscometer under isothermal conditions at 29 °C, maintained within ±0.1 °C using an Elite thermostatically controlled water bath. Density determinations were performed with the help of a bicapillary tube having an internal diameter of 1 mm. Prior to data collection, both the viscometer and the water bath were allowed sufficient time to attain thermal equilibrium.

For the viscometric analysis, a 60% ethanol–water mixture was used as the solvent system, and the compound 1-(5-t-butyl-2,4-dithiobiureto)- 2-methyl-4-methoxy-3,5 dimethylpyridine was studied at a concentration of 0.1 M over a range of temperatures. Freshly prepared solutions were utilized for all measurements, and the experimental procedure followed established methods reported in the literature.

III. RESULTS AND DISCUSSION

The relative viscosity (η_r) was determined using the following expression:

$\eta_r = (D_s \times t_s) / (D_w \times t_w)$,

where D and t represent the density and flow time of the solution (s) and solvent (w), respectively.

The experimental viscosity data were analyzed using the Jones–Dole equation:

$(\eta_r - 1)/\sqrt{C} = A + B\sqrt{C}$,

where A denotes the Falkenhagen coefficient, B represents the Jones–Dole coefficient, and C is the concentration of the solution. The Falkenhagen coefficient (A) was used to assess solute–solute interactions, while the Jones–Dole coefficient (B) provided insight into solute–solvent interactions. Plots of ($\eta_r - 1$)/√C versus √C were constructed for all systems, and linear relationships were observed, enabling the determination of the corresponding B-coefficient values.

IV. OBSERVATIONS AND CALCULATIONS

Based on the data obtained in the present investigation, molecular interactions were quantified in terms of the solute β-coefficient. The experimental results are summarized in Table 1. According to the Jones–Dole relationship, values of ($\eta_r - 1$)/√C were evaluated at a concentration of 0.1 M over a range of temperatures. The corresponding Falkenhagen (A) and β-coefficients calculated from this analysis are presented in Table 2.

Table No.1 Viscosities Were Measured at Constant Concentration, With Relative and Specific Viscosities Determined Across Various Temperatures At 0.1 M.

MEDIUM - 60% ETHANOL-WATER							
Conc.	Temp. (°C)	√C	Time	Density ρx103 (kg.cm -3)	ήr	ήsp=ήr-1	(ήr-1)/√C (pa-s)
0.1 M	22	0.314	62	0.9823	0.069421	-0.930579	-2.96362
	24	0.314	56	0.9763	0.058214	-0.941786	-2.99931
	26	0.314	50	0.9876	0.052143	-0.947857	-3.01779
	28	0.314	43	0.9535	0.049125	-0.950875	-3.02826

Observation table-1 reveals that temperature increases time of movement of solution decreases and density decrease. Lowest relative viscosity found at 28°C and highest relative viscosity at 22°C. Along the temperature increases from 22°C to 28°C decrease in relative viscosity and specific viscosity.

Table No.2 The A And B Values Corresponding to the 60% Concentration For 1-(5-T-Butyl-2,4-Dithiobiureto)- 2-Methyl-4-Methoxy-3,5 Dimethylpyridine Are Reported in The Referenced Literature.

W-E Mixture (%)	Temp° C	Mean “A"	β (Slope "m")
60	25	-3.00233	0.0069

V. CONCLUSION

In the present study, an increase in temperature was accompanied by a decrease in both density and relative viscosity. This behavior can be attributed to enhanced solvation resulting from stronger solute–solvent interactions at elevated temperatures. Such physicochemical insights are valuable for understanding drug behavior and have relevance to both scientific research and pharmaceutical education. The positive values of the viscosity β-coefficient indicate strong solute–solvent interactions and classify the system as a structure-forming one. The formation of hydrogen bonds within the solution may lead to either structure formation or structure disruption, depending on the nature and extent of solute–solvent interactions. These effects are reflected in changes in density and viscosity and are associated with the hydrophobic (structure-making) or hydrophilic (structure-breaking) character of the solute.

With increasing temperature, intermolecular forces weaken, allowing molecules to move more freely relative to one another, which results in a reduction in viscosity. Lower viscosity favors molecular mobility and facilitates the movement of drug molecules. This enhanced mobility supports improved diffusion and transport processes, which are critical for effective pharmacodynamic and pharmacokinetic behavior. Following metabolism, drug ions migrate toward their target sites more efficiently in lower-viscosity media, thereby promoting better diffusion and therapeutic performance.

ACKNOWLEDGMENT

I express my sincere gratitude to the Department of Chemistry, Rajarshee Shahu Science College, Chandur Railway, District Amravati, for providing the necessary laboratory facilities and a conducive research environment to carry out the present work. I am deeply thankful to the faculty members of the department for their constant encouragement, valuable guidance, and constructive suggestions throughout the course of this study. I also acknowledge the support extended by the laboratory and non-teaching staff for their assistance during experimental work. The cooperation and academic atmosphere provided by the institution played a significant role in the successful completion of this research.

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 ISSN: 2349-6002

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