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The impact of thermophysical properties on eflornithine drug solute in acetone and ethyl acetate solvent interactions at varying concentrations and temperatures

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Abstract

The study was conducted on the impact of thermophysical properties on eflornithine drug solute–solvent interactions in aqueous ethyl acetate and acetone at different concentrations and temperatures. The aim of this study is to enhance the understanding of eflornithine's behavior in different solvents, which is crucial for its effective use in pharmaceutical applications. The density, molar volume, viscometric, and conductometric characteristics of the eflornithine drug solutions (0.025, 0.05, 0.075, 0.1, and 0.125 mol/kg) in acetone and 25% (v/v) aqueous ethyl acetate were measured within a temperature range of 298.15 K–318.15 K. Based on the determined density parameters, the following parameters were assessed: viscosity (η), equivalent molar conductance, limiting apparent molar volume ($V^0\varphi$), apparent molar volume of transfer ($V^0\varphi_{tr}$), and apparent molar volume (Vφ). The Masson empirical relationship and the viscosity-to-Jones-Dole (JD) equation were used to evaluate the partial molar volume (Vφ), experimental slope (S_V), viscosity, and density data. Temperature and concentration were used to determine each parameter. For each set of dilutions, conductometric studies were conducted in both study solvents. The gathered data was analyzed in order to evaluate the ion–solvent interactions. The Walden product $\Lambda^o{}_m\eta_o$'s positive temperature coefficient values indicate that the drug eflornithine functions as a structural modifier in acetone and aqueous acetyl acetate systems. The structure-making and breaking characteristics of the polar solvents acetone and ethyl acetate were identified.

Keywords Molar volume, Density, Eflornithine drug, Thermal conductance, Viscosity

Introduction

Drugs have been used for a very long time as important chemicals that help identify, reduce, and predict diseases in living organisms. Due to its complex structure, it is hard to probe how drugs interact with large biomolecules such as sugars, proteins, and carbohydrates [1]. However, the solute–solvent interactions in mixed aqueous solutions can be understood through thermodynamic and thermophysical properties. The presence of hydrophilic and hydrophobic groups in the drug molecules causes them to interact with other molecules differently in the solution. Density (ρ), volumetric, acoustic, and conductance data are some parameters derived from which useful information concerning the structural features and properties of solutions can be obtained. Nevertheless, volumetric and acoustic characteristics offer insights into the kind of interaction existing between solute and solvent [2].

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Understanding biological processes is significant for applications in the pharmaceutical research and laboratory industries. This can be achieved by studying the thermophysical properties of organic compounds in aqueous mixed solvents [3]. Important properties in the characterization of solute–solvent interactions are density, conductance, and viscosity. Eflornithine is an oral ornithine decarboxylase inhibitor that treats adults and children at high-risk of neuroblastoma [31–33]. A solution's thermophysical behavior is the culmination of all potential interactions between solute particles and the solvent, as well as other systemic manifestations [4]. Important insights into solute–solvent interactions can be gained from the thermophysical characteristics of the drug eflornithine in acetone and aqueous ethyl acetate solutions. The nature of the solute and solvent, as well as whether the solute alters or distorts the solvent's structure, are well understood from solute–solvent interactions [5–7]. Inferences about these interactions are derived from conductance molar volume and viscosity studies in mixed solvents are particularly interesting because unusual results are obtained in the majority of solvent systems [8].

The several articles provide a detailed understanding of the interaction between solute and solvent using properties such as conductance, density, and viscosity [9–13]. The components of solvent mixtures hold ions that constitute the eflornithine drug or its components, which affect its solubility in acetone and ethyl acetate solutions. Apart from the disintegration process of the solute molecules, some particular consequences resulting from various types of particle solvation are very important. For grasping the general features of any solution, different crystal solvents can be very problematic in both research laboratories and chemical industries. Solvent mixtures have an essential role to play; they are useful where they enhance chemical reactivity by enhancing reactant dissolution or product separation, for example, mixed solvents [14].

Different methods can be used to analyze the effects of mixed solvent and temperature on solute–solvent interactions [15–17]. Ion–solvent interactions in acetone and certain organic solvents have been investigated, but their effects in solvent mixtures have received less attention [18]. When it comes to revealing the different kinds of interactions taking place in solutions, volumetric properties are crucial. These are also useful in explaining the nature of the solute in the solvent, intermolecular interactions, and the solvent's ability to create or disrupt structures [19–24]. Determining density and then evaluating apparent molar volume, limiting apparent molar volume, and calculating the intrinsic coefficient or experimental slope are the best ways to gain insight into volumetric properties. The viscous flow of organic compounds between adjacent liquid layers is measured by viscosity, which is an important physical property of liquids [25]. From a pharmaceutical perspective, viscosity is associated with how well a drug enters the body and proceeds through physiological and metabolic processes across biological membranes.

Conductivity is the material's capacity to conduct power and is connected with the ionic items in the solution. Conductivity estimations are the most modest and dependable approach to estimating ionic items in solutions to compute the boundary of thermophysical properties. The goal of this work is to determine how the eflornithine drug solute is impacted by solvent interactions among $(CH_3)_2CO$ and ethyl acetate derivation at various concentrations and temperatures. The viscosity, conductance, and consistency of eflornithine in fluid ethyl acetate and $(CH_3)_2CO$ dissolvable at various temperatures in the range of 298.15 K and 318.15 K must likewise be estimated by experimental evidence [26–28]. Molar composition going from 0.00 to 0.125 kg^{-1}.mol, volumetric, viscometric, and conductometric concentrations as a component of dissolvablity and temperature were utilized in light of their importance. Particle-solvent interactions were utilized to decide how these boundaries relied upon temperature and concentrations [29, 30]. Generally, Understanding eflornithine's behavior in different solvents is crucial for designing effective and stable drug formulations, optimizing solubility and stability, developing accurate models, and improving energy-efficient manufacturing processes, ultimately enhancing the overall effectiveness and efficiency of eflornithine as a pharmaceutical product.

Materials and methods

Chemicals

Chemicals were employed along with molar mass, provenance, mass fraction purity, chemical abstract service numbers, and purification method for the investigation of the effects of the drug eflornithine concentration in different concentrations of aqueous acetone and aqueous ethyl acetate solutions at different temperatures. The all chemicals used in this study were greater than 99%. Aqueous acetone and aqueous ethyl acetate (mass fraction purity > 0.99) were acquired from Dambi Dollo University's Chemistry Laboratory, while eflornithine (mass fraction purity > 0.99) was purchased from Sigma Aldrich and used as such. Aqueous ethyl acetate and acetone were used to prepare each solution. Analytical reagent grade was prepared using eflornithine drug, acetone, aqueous ethyl acetate ($CH_3COOC_2H_5$), and acetone + 25% (v/v) aqueous ethyl acetate. Throughout the work, flasks, measuring cylinders, beakers, specific gravity, and conductivity cells were cleaned using distilled water and potassium

permanganate. Moreover, KCl was utilized to standardize the conductometric cell [5].

Instrumentation

The densities of the solutions were estimated utilizing a solitary, slim, explicit gravity made of borosilicate glass with a bulb limit of approximately 50 ml. The particular gravity was fixed for around 30 min in a thermostatic water bath to diminish warm uncertainties. In viscosity, all through the trial measures, a conductance of 1.414 cm^{-1} was ready, and the marks were adjusted utilizing refined water at different temperatures. An electronic balance would be utilized to quantify the mass. The eflornithine drug solutions were made utilizing weight and molality, which were then changed over completely to molarities utilizing standard lapses. The vibroviscometer, which initially aligns with refined water, would be utilized to measure viscosity. To lessen warm variance, the vibro viscometer wouldn't allow remaining in a water bath with indoor regulator control. Standard conductive cells were utilized to quantify conductivity. A standard of 0.01 m potassium chloride (KCl) was made for the conductivity cell. Prior to being utilized in the experiment, the materials were cleaned and dried in a drying boiler at 100 °C for one hour. A thermometer was likewise used to gauge the temperature; all measurements except for viscosity were made in a water bath utilizing an indoor air regulator that vacillated in temperature.

Methods

Preparation of solutions

Solutions were arranged utilizing triple-refined deionized water with a particular conductance of under 10^{-6} $S.cm^{-1}$. A molality premise was utilized to set up the arrangements for the readiness of the eflornithine drug in $(CH_3)_2CO$ and 25% v/v ethyl acetate ($CH_3COOC_2H_5$). 98% v/v (0.00–0.125 kg^{-1}.mol) accurate amounts of eflornithine would be prepared in $(CH_3)_2CO$ and ($CH_3COOC_2H_5$) at different temperature ranges from 2981.5 K–318.15 K. Furthermore, 0.01 m of potassium chloride (KCl) was utilized as an alignment standard for the conductivity cell, and utilizing refined water, it was an adjustment of specific gravity.

Measurement of density

Specific gravity method Specific gravity was utilized to compute densities with the utilization of dry air and water [9]. The particular gravity was estimated using a gravity bottle and an overall estimation technique. The density (ρ) was found with an exactness of 1×10^{-4} g/cm^3. The temperature was consequently kept at that level. For the predefined molality values, by dissolving the proper sum in acetone and ethyl acetate and mixing dissolvable separately at various temperatures ranges from 298.15 to 318.15 K. Each weight of eflornithine drug in $(CH_3)_2CO$ and 25% ethyl acetate ($CH_3COOC_2H_5$) was added to determine gravity. The mass of the solutions was then estimated at every conc. and temperature, at long last, specific gravity was utilized. To ascertain the densities of solutions, all in all, the particular gravity volume is separated by the mass of the arrangement in unambiguous gravity less the mass of the unfilled specific gravity.

Measurement of conductance

Standard conductive cells were utilized to gauge conductivity. An adjustment standard of 0.01 m potassium chloride (KCl) was made for the conductivity cell. Set up the $(CH_3)_2CO$ and 25% ethyl acetate ($CH_3COOC_2H_5$) 0.00–0.125 $mol.kg^{-1}$ solution of the eflornithine drug and measure the outcomes at different temperatures, going from 298.15 to 318.15 K, to peruse the conductivity at every temperature. An experiment was conducted with ± 0.01 °C temperature accuracy. Every arrangement was blended for 30 s utilizing an attractive stirrer and afterward permitted to represent one moment. Each conductivity estimation was performed threefold or until a recurrent value was acquired. For a conductivity cell with a known cell arrangement and for every temperature, wash the cell each time with.

Determination of Walden's rule

Walden's standard was expressed as the result of the same conductance or restricting molar conductance [15]. At boundless dilutions of an electrolyte in a given dissolvable, the viscosity of that dissolvable is a constant. Furthermore, it utilizes structure-making and structure-breaking, as determined. First, set up the solutions of the eflornithine drug in $(CH_3)_2CO$ and 25% ethyl acetate ($CH_3COOC_2H_5$) 0.00–0.125 $mol.kg^{-1}$ at various temperatures ranging from 298.15–318.15 K, ready to peruse the conductivity at every temperature. The restricting molar conductance and viscosity of dissolvables at infinite dilutions of every solution utilizes conductivity cell and a vibro viscometer inside a known cell constant.

Measurement of viscosity

One significant physical quantity is viscosity [18]. In this study, a vibro viscometer was employed. In the current study, viscosity was assessed at a temperature range of 298.15–318.15 K while thermostatic conditions were in place. A mixture of acetone, 25% (v/v) aqueous ethyl acetate, and 98% (v/v) (0.00–0.125 $mol.kg^{-1}$) of eflornithine drug was produced by dissolving the appropriate amount in distilled water at varying temperatures, ranging from 298.15 to 318.15 K. Viscosity values at each temperature were measured after each solution was stirred for 30 s

using a magnetic stirrer and then allowed to stand for one minute. Every viscosity measurement was performed three times or until a repeat value was obtained. Then for each solution and each temperature was measured.

Results and discussion

Volumetric studies

Density measurement

Density measurements were made to acquire comprehension of volumetric qualities, which are helpful in recognizing the kinds of intermolecular interactions [13]. The density data for all dilutions of the eflornithine drug in $(CH_3)_2CO$ and 25% ethyl aceticate ($CH_3COOC_2H_5$) is depicted below (Table 1). In a watery solution of $(CH_3)_2CO$ and 25% ethyl acetate ($CH_3COOC_2H_5$), the exploratory upsides of arrangement density for the eflornithine drug (0.00–0.125 mol.kg^{-1}) were estimated at different temperatures T = (298.15, 303.15, 308.15, 313.15, 318.15) K. Table 3 records the density upsides of the multitude of arrangements at different temperatures. It is seen that, for arrangements containing explicit groupings of $(CH_3)_2CO$ and ethyl acetate, the viscosity of the solutions increases as the concentration of the eflornithine rises and marginally diminishes as the temperature increases. In view of the volume extension acquired by decreasing the intermolecular forces between the particles of the dissolvable and the eflornithine, the value of thickness diminished as temperature rose.

Experimental values of density for aqueous solutions $(CH_3)_2CO$ and ethyl acetate at various temperatures are in great agreement with literature value [29]. The experimental densities for the combination show a similar pattern, as revealed in the table below (Table 2). Temperature-subordinate varieties in density values occur in a successive way, implying that density values decline as temperatures rise in solutions of liquid $(CH_3)_2CO$ and ethyl acetate as solvents. The experimental upsides of densities (ρ) the obvious molar volume the restricting clear molar volume, and the evident molar exchange of the eflornithine drug are recorded in (Tables 1, 2, 3, 4 and 5) separately listed below.

The densities of aqueous solutions of solutes have been computed using the following equation:

$$\rho = \frac{W - Ws}{Vs} \tag{1}$$

where, W is the weight of solution, *V*s is the volume of the specific gravity bottle, W_s is the weight of specific gravity bottle.

Apparent molar volume

Apparent molar volume is a useful concept for understanding solute–solvent interactions in a solution. It represents the change in volume when a solute is added to a solvent, accounting for the interactions between the solute and solvent molecules [25]. The apparent molar volumes (V_ϕ) of Eflornithine drug solutions in acetone and aqueous ethyl acetate (v/v) have been calculated from the density values of the solvent and solution by using the relation.

Table 1 Origin and quality of the examined chemical samples:

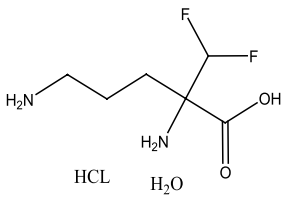
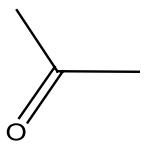
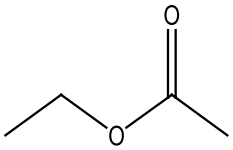
Chemical Name	Molar mass (g.mol^{-1})	Provenance	Mass fraction Purity	Structure	Chemical Abstract Service number
Eflornithine (2,5-diamino-2-(difluoromethyl) pentanoic acid hydrate)	236.65	Sigma Aldrich	> 0.99		70,052-12-9
Acetone	46	DaDU Chem lab	> 0.99		67-64-1
Ethyl acetate	88	DaDU Chem lab	> 0.99		141-78-6

Table 2 Densities of solutions of Eflornithine drug in acetone and 25% (v/v) aqueous $CH_3COOC_2H_5$ at different temperatures and concentrations of solvents as functions of the molality (*m*) of Eflornithine drug and temperature

Concentration (*m* (kg^{-1}.mol)) Temperature (K)					
	298.15	**303.15**	**308.15**	**313.15**	**318.15**
Eflornithine drug + acetone ρ($kg.m^{-3}$) × 10^{-3}					
0.000	0.9871	0.9857	0.9841	0.9822	0.9802
0.025	0.9887	0.9869	0.9854	0.9841	0.9823
0.050	1.0001	0.9981	0.9969	0.9956	0.9941
0.075	1.0011	0.9994	0.9981	0.9967	0.9954
0.100	1.0019	1.0003	0.9991	0.9979	0.9967
0.125	1.0028	1.0015	1.0001	0.9991	0.9982
Eflornithine drug + 25% (v/v) aqueous ethyl acetate ρ($kg.m^{-3}$) × 10^{-3}					
0.000	0.9071	0.9047	0.9015	0.8979	0.8955
0.025	0.8989	0.8959	0.8929	0.8892	0.8871
0.050	0.9001	0.8973	0.8948	0.8913	0.8891
0.075	0.9021	0.8991	0.8962	0.8931	0.8911
0.100	0.9041	0.9012	0.8983	0.8953	0.8931
0.125	0.9063	0.9041	0.9011	0.8981	0.8958

Standard uncertainty of T = ± 0.01 K, ρ = 0.01 kg/m^3

Table 3 Apparent molar volume (V_φ)

Concentration (m(kg^{-1}.mol)) T(K)					
	298.15	**303.15**	**308.15**	**313.15**	**318.15**
Eflornithine drug + acetone *Vφ* (cm^3.mol^{-1}) × 10^{-4}					
0.000	83.628	84.59	85.529	86.0789	86.845
0.025	83.141	84.024	84.868	85.421	86.159
0.050	82.754	83.521	84.391	84.891	85.593
0.075	82.414	83.161	83.931	84.461	85.094
0.100	82.198	82.849	83.551	84.029	84.671
0.125	82.016	82.598	83.191	83.661	84.246
Eflornithine drug + 25% (v/v) aqueous ethyl acetate *Vφ* (cm^3.mol^{-1}) × 10^{-4}					
0.000	93.058	93.686	94.114	94.432	94.956
0.025	92.425	92.981	93.421	93.808	94.303
0.050	91.885	92.341	92.781	93.261	93.689
0.075	91.274	91.726	92.191	92.641	93.065
0.100	90.651	91.178	91.671	92.107	92.509
0.125	90.051	90.591	91.187	91.551	91.871

Standard uncertainty of T = ± 0.01 K, V = 0.02L

$$V\varphi = \frac{M_2}{\rho} + \frac{(\rho_o - \rho)}{m\rho\rho_o} \quad (2)$$

where, $V\phi$ represents the molar volume of the electrolyte, ρ is the density of the solution, ρ_0 is the density of the solvent, m is the molality of the solution, and M_2 is the molecular weight of the eflornithine drug. The density (ρ) molar volume of the arrangements of different concentrations for various frameworks was accompanying. The clear molar volume information of the multitude of preparations of eflornithine drug in both solvents of study at all working temperatures is obtained from the below determined data (Table 3). It is acquired that the value free from molar volume lessened with an increase in concentration and increased with an the increase in temperature. The diminished

Table 4 Limiting molar volume ($V^0\varphi$) and experimental slope, (Sv)

Eflornithine drug in acetone										
$V^0\varphi$ ($10^{-4} \times cm^3.mol^{-1}$)						S_v ($\frac{cm^3.mol^{-1}}{\sqrt{mol.Kg^{-1}}}$)				
Concentration (m (kg^{-1}.mol)	298.15	303.15	308.15	313.15	318.15	298.15	303.15	308.15	313.15	318.15
0.000	82.48	83.49	84.53	85.54	86.25	0.00	0.00	0.00	0.00	0.00
0.025	81.95	82.99	84.03	84.99	85.71	− 21.2	− 20.00	− 20.00	− 22.0	− 21.60
0.050	81.61	82.56	83.65	84.55	85.25	− 13.6	− 17.20	− 15.20	− 17.6	− 18.4
0.075	81.41	82.26	83.29	84.06	84.86	− 8.00	− 12.00	− 14.40	− 19.6	− 15.6
0.100	81.14	81.98	82.96	83.69	84.48	− 10.8	− 11.20	− 13.20	− 14.8	− 15.20
0.125	80.93	81.71	82.62	83.41	84.11	− 8.40	− 10.80	− 13.60	− 11.2	− 14.80
Eflornithine drug in 25% (v/v) aqueous ethyl acetate										
0.000	92.86	93.39	93.99	94.43	94.96	0.00	0.00	0.00	0.00	0.00
0.025	92.33	92.85	93.38	93.88	94.35	− 21.20	− 21.60	− 24.40	− 22.00	− 24.40
0.050	91.82	92.31	92.77	93.26	93.77	− 20.40	− 21.60	− 41.20	− 24.80	− 23.20
0.075	91.31	91.79	92.19	92.66	93.15	− 20.40	− 20.80	− 23.20	− 24.00	− 24.80
0.100	90.84	91.26	91.66	92.12	92.49	− 18.80	− 21.20	− 21.20	− 21.60	− 26.40
0.125	90.42	90.75	91.09	91.55	91.91	− 16.80	− 20.40	− 22.80	− 22.80	− 23.20

Standard uncertainty of T = ± 0.01 K, V = 0.02L

Table 5 the transfer volume, $V^0\varphi_{tr}$ values for Eflornithine drug from acetone to aqueous ethyl acetate solutions

$V^0\varphi_{tr}$ (10^{-4} cm^3. mol^{-1})					
Eflornithine drug from acetone to aqueous ethyl acetate (v/v) solutions					
Concentration (m (kg^{-1}.mol))	**298.15**	**303.15**	**308.15**	**313.15**	**318.15**
0.000	10.38	9.91	9.46	8.89	8.71
0.025	10.36	9.86	9.35	8.89	8.64
0.050	10.21	9.75	9.12	8.71	8.52
0.075	9.91	9.53	8.91	8.61	8.29
0.100	9.28	9.28	8.71	8.43	8.01
0.125	9.49	8.71	8.47	8.14	7.81

Standard uncertainty of T = ± 0.01 K, V = 0.02L, ρ = 0.01 kg/m^3

value with concentration is related to the compression in volume due to the change in mean distance and solvophobic hydration between the eflornithine drug polar groups and solvent. The weaker intermolecular interactions cause a decrease in apparent molar volume, which increases with temperature. Furthermore, the ethyl group in ethyl acetate causes steric hindrance in the way of electrostriction, which causes a change in volume. This is related to the gradually increasing apparent molar volume in ethyl acetate as compared to acetone. Conversely, ethyl acetates apparent molar volumes in solution are greater than those of acetones.

The apparent molar volume values in double mixtures decline as the eflornithine concentration rises as the proportion of ethyl acetate in combinations increases. The apparent molar volume values increased too suggesting a strengthening of the solute–solute interactions in mixtures. The addition of the solute brings about a bigger change in the apparent molar volume in light of the solvents feeble way to deal with the solute particles. These volumes are moved in $(CH_3)_2CO$ ethyl acetate rather than acetone. This shows the strong and variable associates between solutes and solvent. The clear molar volume likewise followed a similar example increasing with temperature across all frameworks and demonstrating the presence of a weak particle dissolvable collaboration at higher concentrations as needs be the value V of the eflornithine drug in the $(CH_3)_2CO$ and ethyl acetate are positive solutions implying that the medication goes about as a design creator in the fluid $(CH_3)_2CO$ and ethyl acetate. The molar volume esteems graphically (Fig. 1). The apparent molar volume of eflornithine drug solutions in $(CH_3)_2CO$ and ethyl acetate fluid at different temperatures and concentrations is displayed in Fig. 1. Plots of eflornithine drug solutions in fluid $(CH_3)_2CO$ (Fig. 1A) and eflornithine drug solutions in ethyl acetate (Fig. 1B) at 298.15 K–318.15 K were drawn. It was found that the clear molar volumes differed directly with the molality thus the information was fitted to the straight condition utilizing the least-squares method.

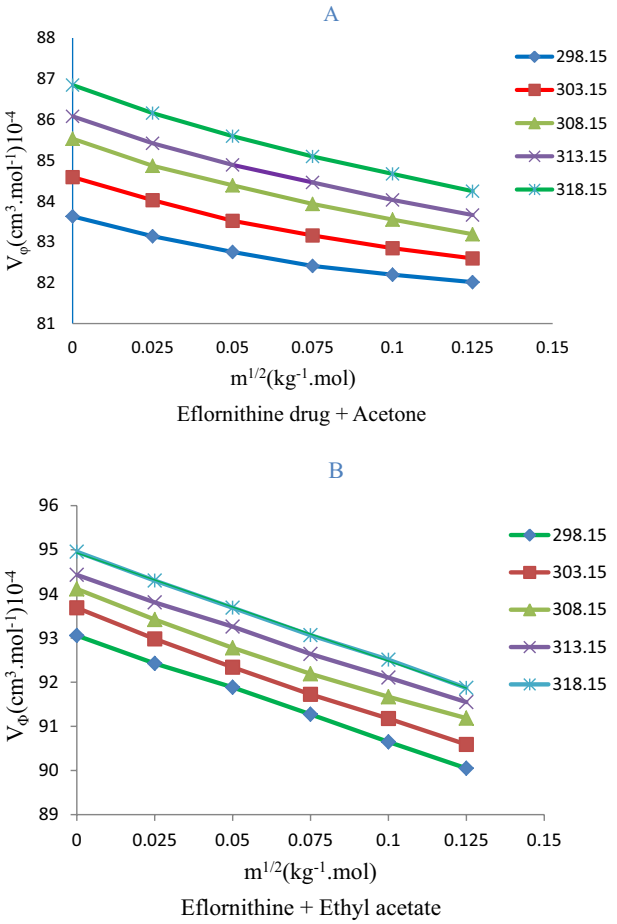


Fig. 1 Experimental values of apparent molar volume versus concentrations of Eflornithine drug in acetone (**A**) and aqueous ethyl acetate (**B**) at different temperature and concentrations

Limiting apparent molar volume

The values of limiting partial molar volume, $V^0\phi$ and the slope, S_v, have been obtained using method of linear regression of V_ϕ versus molality of Eflornithine drug in acetone and aqueous ethyl acetate (v/v) solvents from the following relation [25].

$$V\varphi = V^0\varphi + Sv\sqrt{m} \quad (3)$$

where, $V^0\phi$ is the limiting apparent molar volume (equal to infinite dilution partial molar volume). It gives the measure of ion–solvent interactions present in solution. The S_v is an experimental slope and given a measure of ion-ion interactions present in the solution. The negative Sv values show that the strong electrostatic ion–solvent interactions which cause ionic association and weaken ion-ion interactions. From the data already available in the literature for different solvents including water, can be concluded that, in general, (i) the value of slope more smaller is favored if the dielectric constant of the medium is high whether the solvent is hydrogen bonded or non-hydrogen bonded [37, 38] and (ii) the electrostatic ion-ion interaction is weak due to the large ionic size or due to the very high dielectric constant. Strong electrostatic solvation (primary solvation) is responsible for the decrease of $[dV^0\phi/dT]$ values. Similarly, weak electrostatic solvation is responsible for the increase of $[dV^0\phi/dT]$ values [39–41].

If the calculated values of $V^0\phi$ and S_V for Eflornithine drug solutions in acetone and aqueous ethyl acetate are summarized in Table 4. The value of limiting molar volume is found to be positive and increased in linear manner with temperature indicating strong solute–solvent interactions. This must be explained by the organic compound's solvation and hydration behavior, the decrease in electrostriction, and the volume change brought on by the solvent migrating from the second layer surrounding the drug Eflornithine to the bulk solvent. The experimental slope value was found to be negative, suggesting poor solute–solute interactions and the drug Eflornithine's hydrophobic nature, which results in insufficient counter-ion binding with solute molecules and decreases with concentration. The drug Eflornithine's dissociation pattern in solution is thought to have decreased as indicated by the decreased or negative value of S_V with temperature.

The positive value of $V^0\phi$ indicates strong solute–solvent interactions. The volume behavior of a solute at infinite dilution is satisfactorily represented by $V^0\phi$ which is independent of solute–solute interactions and provides information concerning solute–solvent interactions. As demonstrated in Table 4 the $V^0\phi$ are large positive for all the mixtures at all the investigated temperatures, suggesting the presence of strong solute–solvent interactions and weak solute–solute interactions in these systems. The increase in $V^0\phi$ values with increase in temperature for Eflornithine drug solutions in acetone and aqueous ethyl acetate can be explained by considering the size of primary and secondary solvation layers (Fig. 2). At higher temperatures, the solvent from the secondary solvation layer of Eflornithine drug is released into the bulk of the solvent, resulting in the expansion of the solution, as inferred from large $V^0\phi$ values at higher temperatures. The values of $V^0\phi$ increase with increase in concentration of ethyl acetate indicating that solute–solvent interactions are increasing with the concentration of co-solute. In the present systems, the $V^0\phi$ values increase with increasing temperature suggesting the increase of solute–solvent interactions with temperature. An increase in temperature reduces the electrostriction and hence $V^0\phi$ increases. The values of experimental slopes (S_V) which are indicative of solute–solute interactions are

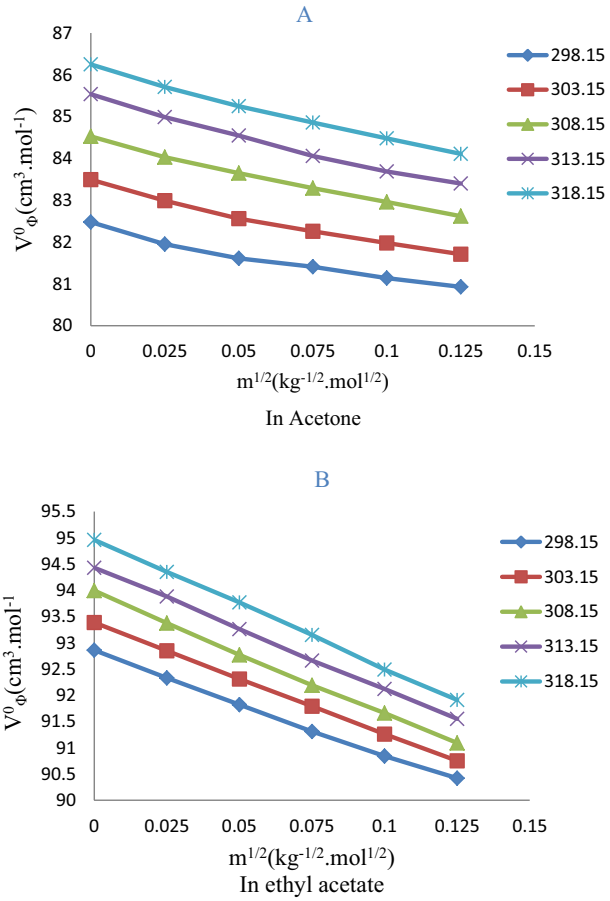


Fig. 2 Experimental values of limiting molar volume versus concentrations of Eflornithine drug in acetone (**A**) and aqueous ethyl acetate (**B**) at different temperature and concentrations

found to be positive as well as negative but smaller than $V^0\phi$ values, suggesting that solute–solute interactions are weaker than solute–solvent interactions in the systems under study. The below Table 4 depicted that the limiting molar volume and the values of experimental slopes (S_V) of studied systems. The S_V values are always smaller than the V^0_ϕ values for all the studied solutions and this fact indicates that the ion–solvent interactions play a dominant role over the ion-ion interactions in characterizing the volumetric properties.

In the study of solute–solvent interactions in aqueous solutions, limiting the apparent molar volumes of solutes at infinite dilution offers a useful tool. Limiting apparent molar volume data in aqueous solutions are available for a variety of electrolytes and non-electrolytes. Molar volumes of electrolytes have been studied extensively in both aqueous and non-aqueous solvents [26–30]. The interactions (i.e., ion-ion, ion–solvent, and solvent–solvent) that occur in solutions can be better understood by utilizing the apparent molar volume and limiting apparent molar volumes of electrolyte solutions [34–36]. The limiting apparent molar volume of electrolytes at infinite dilution are useful to study ion–solvent and solvent–solvent interactions, while its dependence on the concentration can be used to study ion-ion interaction. So, the values of $V^0\varphi$ eflornithine drug in acetone and 25% (v/v) aqueous ethyl acetate solutions are positive indicates that Eflornithine drug in acetone behaves as structure making in acetone and 25% (v/v) aqueous ethyl acetate.

Transfer volume

The transfer volume is a concept used to describe the change in volume when a solute is transferred from one solvent to another. This parameter is particularly useful in understanding solute–solvent interactions and the solvation process [42, 43]. Limiting apparent molar properties of transfer volume $V^0\phi_{tr}$ provide qualitative as well as quantitative information regarding solute–solvent interactions without taking into account the effects of solute–solute interactions. The transfer volumes, $V^0_{\phi tr}$ of Eflornithine drug from acetone and aqueous ethyl acetate solutions were calculated by using the relation.

$$V^0\varphi_{tr} = V^0\varphi_{\text{aqueous ethyl acetate}} - V^0\varphi_{\text{acetone}} \quad (4)$$

where $V^0\Phi_{\text{acetone}}$ is the limiting apparent molar volume of Eflornithine drug in acetone$V^0\phi_{\text{aqueous ethyl acetate}}$ is the limiting apparent molar volume of Eflornithine drug in aqueous ethyl acetate.

The $V^0\phi_{tr}$ values for Eflornithine drug from acetone to aqueous ethyl acetate solutions are depicted (Table 5). Data in Table 5 indicates that $V^0\phi$ of Eflornithine drug are more than those in acetone, i.e. $V^0\phi_{tr}$ values are positive. The $V^0\phi_{tr}$ are all positive and increase with an increase in the concentration of aqueous ethyl acetate for each Eflornithine drug, which implies a larger dehydration effect on Eflornithine drug. Observed positive values of $V^0\phi_{tr}$ suggest strong ion–solvent interactions of aqueous ethyl acetate with Eflornithine drug. Because the structural moiety of the drug eflornithine and aqueous ethyl acetate both contain polar groups that cause interactions, the solute's ability to form structures in the solution is enhanced. Additionally, the solutes' solvophobic solvation and the structural interaction between two co-spheres, as predicted by the co-sphere overlap model, are responsible for the observed positive transfer volume values, which also point to the solutes' structure-promoting/maker nature. Because of the small contribution from solute–solute interactions in the context of the co-sphere overlap model with respect to $V^0\phi$tr, they offer insights into solute–solvent interactions. The possibility of various interactions that occur between

Eflornithine drug and aquose ethyl acetate molecules could be.

(i) ion-hydrophilic interactions (between zwitterionic centers of Eflornithine drug and polar groups of aqueous ethyl acetate)
(ii) hydrophilic-hydrophilic interactions (between polar groups of Eflornithine drug and polar groups of aqueous ethyl acetate)
(iii) ion-hydrophobic interactions (between zwitterionic centers of Eflornithine drug and non-polar groups of ethyl acetate) and
(iv) Hydrophobic-hydrophobic interactions (between non-polar groups of Eflornithine drug and non-polar groups of ethyl acetate).

According to co-sphere overlap model, ion-hydrophobic interactions and hydrophobic-hydrophobic interactions contribute negatively whereas ion-hydrophilic and hydrophilic-hydrophilic interactions contribute positively to the $V^0\phi_{tr}$ values. This would lead to positive volume transfer or in other words it could say that there is an increase in electrostriction.

At higher percentages of ethyl acetate, hydrophilic interactions predominate over hydrophobic interactions in the ethyl acetate-acetone system of the drug eflornithine. The behavior of both positive and negative transfer volumes is comparable to the first study. so, the positive value $V^0\phi_{tr}$ Eflornithine drug in acetone and 25% (v/v) aqueous ethyl acetate solutions indicates that Eflornithine drug behaves structure in case of making 25% (v/v) aqueous ethyl acetate.

Conductance measurement

Electrical conductivity is a reliable indicator of the intermolecular interactions and plays a significant role in defining the nature of solutions [44]. The following Table 6 and Fig. 3 show that the value of electrical conductivity in the current study increased with concentration as well as temperature. This is explained by the fact that temperature and concentration both increase the number of charge carriers and their mobility. There is a correlation between the two factors and higher electrical conductivity values. Additionally, the increased conductivity values do not increase as temperature and concentration rise, most likely because of intermolecular interactions that provide steric hindrance to charge carrier mobility. The two solvents under investigation both followed this pattern. In acetone and aqueous ethyl acetate systems, the conductivities were utilized to compute the molar conductance for the drug eflornithine at various temperatures and electrolyte concentrations. When an electrolyte solution is diluted, its molar conductance rises and eventually approaches a limiting value. This value is called molar conductance at infinite dilution (Λ^o_m). Molar conductance at infinite dilution has been determined by the relation, as shown in Eq. 5 by the huckle-Onsager's (HO) equation as:

Table 6 The experimental values of equivalent conductance solutions of Eflornithine drug in acetone and aqueous 25% (v/v) ethyl acetate at different temperatures and concentrations

Eflornithine drug + acetone: Equivalent conductivity (λ_m(Sm^2mol^{-1}))					
T(K)					
Concentration(m(kg^{-1}.mol))	**298.15**	**303.15**	**308.15**	**313.15**	**318.15**
0.000	127.03	128.99	130.59	131.65	132.50
0.025	126.25	128.13	129.75	130.84	131.65
0.050	125.59	127.39	129.01	130.14	131.01
0.075	124.88	126.77	128.19	129.29	130.09
0.100	123.99	125.89	127.22	128.22	129.13
0.125	122.99	124.92	126.19	127.09	127.99
Eflornithine drug + 25% (v/v) ethyl acetate: Equivalent conductivity (λ_m(Sm^2mol^{-1}))					
0.000	105.98	117.25	127.25	132.99	140.12
0.025	103.23	116.15	125.98	132.12	138.91
0.050	102.12	113.25	124.15	130.91	137.65
0.075	100.12	110.98	120.25	127.45	133.98
0.100	95.680	105.86	115.91	122.67	129.56
0.125	90.820	101.23	110.25	116.65	123.45

Standard uncertainty of T = ± 0.01 K, V = 0.02L, ρ = 0.01 kg/m^3, Λ = 0.01 Sm^2mol^{-1}

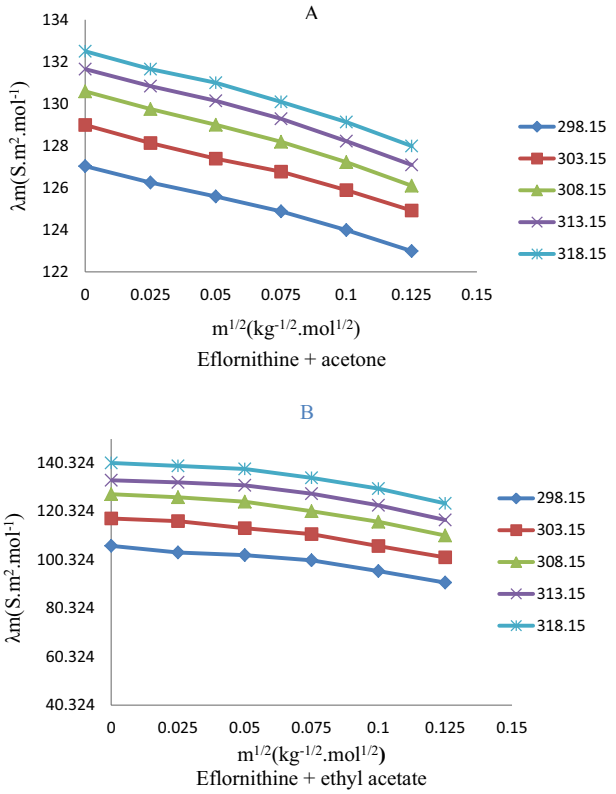


Fig. 3 Experimental values of equivalent molar conductance versus concentrations of Eflornithine drug in acetone (**A**) and aqueous 25% (v/v) ethyl acetate (**B**) at different temperature and at different concentrations

$$\Lambda_m = \Lambda o_m - (A + B\Lambda 0_m)\sqrt{m} \quad (5)$$

where, Λ^o_m is the molar conductance at infinite dilution, A and B are the constant for an electrolyte of a given valence type in each particular solution. At the point when the concentration of electrolytes in $(CH_3)_2CO$ and ethyl acetate solvents increased the molar conductance diminished also. This exhibits that when solute conc. increments more particles are created which dials back particle development and brings down molar conductance. When solute conc. is weakened, particles become free and show high qualities. the way of behaving of electrolytes in mixture dissolvable framework is impacted by the natural solvents $(CH_3)_2CO$ and ethyl acetate which are pretty much aprotic and in this manner different properties like dielectric constant fascination powers and ionic connections can be concentrated by physiochemical properties of electrolytes in blended dissolvable frameworks molar conductance at boundless weakening expanded with the expansion in temperature while diminished with the increment of watery 25% (v/v) ethyl acetate derivation. Subsequently, solute-dissolvable interactions have been diminished the restricting molar conductance's for eflornithine drug in $(CH_3)_2CO$ and ethyl acetate solutions were acquired by extrapolating the direct plots of molar conductance versus to zero conc. The plot of molar conductance versus $\sqrt{m}$ for eflornithine drug in $(CH_3)_2CO$ and ethyl acetate is displayed in (Fig. 3). The restricting molar conductance for eflornithine drug in arrangements at 298.15, 303.15, 308.15, 313.15 and 318.15 K temperatures are kept in. Table 6 shows that restricting molar conductance increments with expansion in temperature which might be because of expansion in ionic versatility of particles at boundless dilution.

Determination of Walden's rule

The outcome showed that the restricting molar conductance (λ_0) increment as the temperature increment yet decline as the convergences of the Eflornithine drug in the dissolvable combinations increments [45]. This pattern in restricting molar conductance can be all around depicted by the consistency conduct of the dissolvable media. Overall consistency improvement was found to prevail over restricting molar conductance decrement and thus Walden item ($\Lambda_m \times \eta_0$) increment as the groupings of the Eflornithine drug in the dissolvable blends increase. Nonetheless, the rising pattern of Walden item ($\Lambda_m \times \eta_0$) with expanding temperature can be credited to the warm extension of the dissolvable sheath because of the initiations of the dissolvable atoms. Changes in Walden item with fixations are normal and they can ascribe to changes in particle dissolvable connections. The Walden item information ($\Lambda_m \times \eta_0$) has been records in Fig. 4. The designs making/breaking nature of solute still up in the air from temperatures coefficient of Walden item for example [$d(\lambda_m \times \eta_0)/dT$]. The positive temperatures coefficient of Walden item for Eflornithine drug in $(CH_3)_2CO$ and 25% ethyl acetate solutions shows that Eflornithine drug acts as design making in $(CH_3)_2CO$ and ethyl acetate. Figure 4 show that the plot of $\Lambda_m \times \eta_0$ versus T for Eflornithine drug in $(CH_3)_2CO$ and ethyl acetate.

Viscosity measurement

Viscosity coefficients are crucial in understanding solute–solvent interactions. They provide insights into how solutes affect the viscosity of a solution, which in turn reflects the nature of interactions between solute and solvent molecules [46]. The solute-dissolvable particle dissolvable cooperation's can likewise be examined as far as the progressions in property like viscosity and conductivity from the beneath arranged Table 7. Information it is obvious that worth of consistency got expanded with the conc. of solutions. Because of the advancement of solute and solute-dissolvable

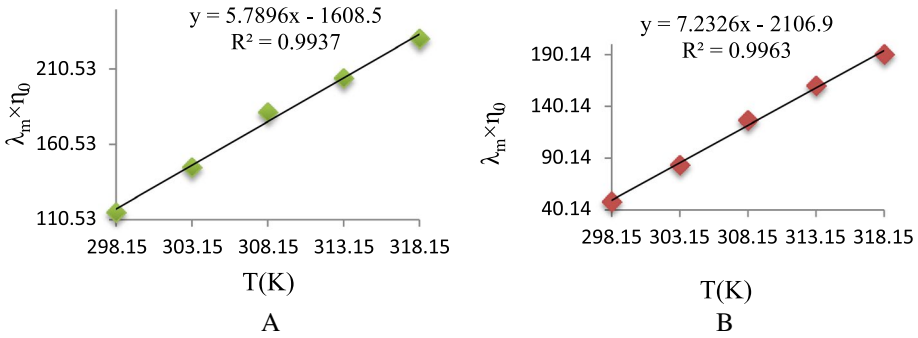


Fig. 4 Walden Product versus concentrations for Eflornithine drug at different concentrations in Acetone (**A**) and 25% (v/v) aqueous ethyl acetate (**B**) solutions at different temperatures

Table 7 The experimental values of viscosity and relative viscosity solutions of Eflornithine drug in acetone and aqueous 25% (v/v) ethyl acetate at different temperatures and at different concentrations

$\frac{\eta}{\eta 0} - 1/\sqrt{m}$(specific—viscosity) Concentration(m(kg^{-1}.mol)) Eflornithine drug + acetone										
	298.15	**303.15**	**308.15**	**313.15**	**318.15**	**298.15**	**303.15**	**308.15**	**313.15**	**318.15**
0.000	0.8902	0.797	0.698	0.6826	0.676	0.00	0.00	0.00	0.00	0.00
0.025	0.90	0.891	0.87	0.86	0.85	0.696	0.743	1.5584	2.009	3.971
0.050	0.95	0.92	0.90	0.89	0.88	0.33	0.688	1.294	1.359	1.349
0.075	0.97	0.95	0.93	0.923	0.914	0.327	0.669	1.214	1.286	1.334
0.100	0.99	0.96	0.94	0.93	0.923	0.324	0.645	1.096	1.146	1.155
0.125	1.02	0.98	0.96	0.95	0.94	0.312	0.638	1.061	1.108	1.104
Eflornithine drug + 25% (v/v) aqueous ethyl acetate										
0.000	0.44	0.39	0.37	0.35	0.33	0.00	0.00	0.00	0.00	0.00
0.025	0.77	0.75	0.74	0.72	0.70	4.743	5.838	6.324	6.686	7.091
0.050	0.82	0.78	0.77	0.76	0.74	3.862	4.472	4.834	5.239	5.556
0.075	0.85	0.82	0.79	0.77	0.75	3.402	4.025	4.644	4.782	4.947
0.100	0.97	0.95	0.912	0.874	0.85	3.351	3.84	4.372	4.442	4.682
0.125	1.05	0.97	0.95	0.93	0.90	3.218	3.206	4.152	4.244	4.462

Standard uncertainty of T = ± 0.01 K, V = 0.02L, viscosity = 0.04%

interactions the obstruction in the progression of particles of solution creates. The viscosity of the eflornithine drug solutions in $(CH_3)_2CO$ and ethyl acetate diminished because of the breakdown of dissolvable and natural particles associated through hydrogen bonds because of the fulfillment of exorbitant dynamic energy prompting diminished strength of intermolecular strength. From Table 7 the density of eflornithine drug solutions under concentration decline especially as temperature is raised. As the temperature expanded more atoms can escape from the potential wells given by their neighbors thus the arrangement turns out to be more liquid. The noticed worth of consistency expanded with expanding eflornithine drug focus because of the increment of the intermolecular powers which cause to oppose in stream process.

Effects of density on solute–solvent interactions

The effects of density on solute–solvent interaction are directly proportional to density. i.e., as the solute–solvent interactions increase, the densities also increase, but the temperature is vice versa. When the temperature increased, the density of the solution was decrease as seen in the above equations for density relationships. Partial molar volume is one such property, and these volumes of electrolytes in mixed solvents have proven useful in ascertaining the solute–solvent interaction.

Effects of conductance on solute–solvent interactions

Temperature increases cause an equal increase in an arrangement's conductance, which suggests that either the particles of the arrangement free move at that

condition and conductivity increases or the solute dissolvable collaboration of intermolecular power declines.

Effects of viscosity on solute–solvent interactions

The impacts of solute-dissolvable collaborations on the arrangement viscosity can be derived from the B-coefficient. The viscosity temperature steadiness was explored by contrasting it's first at various temperatures. The viscosity decline implies a solute dissolvable association. It declines when temperature increases in solutions, so the arrangement moves free and the viscosity of the arrangement diminishes the cooperation among solvent and solute particles, causing an inhomogeneous viscosity conveyance of dissolvable particles around a solute. The inhomogeneous viscosity dispersion brought about by the dissolvable solute interaction acts the motions of a solution.

Conclusion

The aim of this study is to enhance the understanding of eflornithine's behavior in different solvents, which is crucial for its effective use in pharmaceutical applications. The information of densities, conductometry, and viscosity variations as well as the capability of concentrations and temperature were studied in this study. Because of the values of the obvious molar volume restricting evident molar volume thickness and Walden, different boundaries demonstrate the presence of solid solute-dissolvable interactions and weak solute cooperation with expanding eflornithine drug concentrations in $(CH_3)_2CO$ while showing the shortfall of solid solute-dissolvable interactions and the presence of solid solute associations. For the eflornithine drug in nearly $(CH_3)_2CO$ and ethyl acetate solute-dissolvable collaborations diminish the expansion in the level of ethyl acetate in its fluid solutions and prevail at higher temperatures for water, though the solute connection escalates at higher temperatures for the nearly $(CH_3)_2CO$ and ethyl acetate mixture. These realities could be ascribed to the transcendence of particle hydrophilic and hydrophilic gathering transportations over particle hydrophobic hydrophobic and hydrophilic-hydrophobic connections. It is seen that eflornithine drug goes about as a design producer in these watery ethyl acetate solvents, thus the $V^0\phi$, Walden products are positive. However, the dB/dt the value was negative in arrangements involving the eflornithine drug in ethyl acetate and acetone, demonstrating that the eflornithine drug acts as design making in $(CH_3)_2CO$ and ethyl acetate.

Abbreviations

DaDU	Dambi Dollo University
HO	Huckle-Onsager's
JD	Jones-Dole
S_V	Molar volume slopes

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Author contributions
Dereje Fedasa contributed to the information collection, concept and layout and drafted the manuscript, and Shuma Fayera contributed to the revision of the manuscript for essential highbrow.

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Availability of data and materials
The data sets used and analyzed during the current study are available from the corresponding author on reasonable request. We have presented all data in the form of Tables and Figures in the manuscript.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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