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Measurement of Densities and Partial Molar Volume of Paracetamol in different media

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Abstract

The partial molar volume of Paracetamol (4-acetamidophenol) in water, 0.1 M HCl solution and 0.9% NaCl solution at 298.15K, 303.15 K, 308.15 K and 310.15 K have been evaluated with the help of vibrating tube densitimeter Anton Paar (DMA 48). The effect of 0.1 M HCl solution whose pH is comparable with the pH of stomach and 0.9% NaCl solution is comparable with the isotonic solution of human fluid were checked. The results were fitted by the regression to equation that describe the plot (V_ϕ, T, m). At infinite dilution, partial molar volumes were obtained over the range of temperature by extrapolating these plots to m = 0 mol/kg.

Key Words: Densities, Apparent Molar Volume, Partial Molar Volume, Paracetamol, Solute-Solute Interaction and Solute-Solvent Interaction.

Introduction

Paracetamol is used as nonsteriodal anti-inflammatory drugs (NSAID). It is an important drug used extensively to cure the inflammation (initial rupture of tissue injury) [1]. However not much informations are available regarding the thermodynamic properties of its aqueous solution as function of temperature [2]. The aim of this work is to determine the apparent molar volume and partial molar volume of the paracetamol in different solvents (like body fluids) at different temperature comparable to body fluid.

Experimental

Paracetamol used in the study was supplied by Merck (purity 99-99.98%) with molecular weight of 151.17 g/mol, with melting point of 169-172°C. Hydrochloric acid (37%) and sodium chloride (99.5-100%) was also of analytical grade. Doubly distilled water was used to prepare all solutions. The densities of the paracetamol solutions of different concentrations were determined using a vibrating tube densitimeter (Anton Paar, DMA 48), which was thermostated with a temperature controller circulator. The period of vibration, the temperature of solution and densities were recorded for at least 800 s while the period was stable [3]. The pressure inside the densitimeter was maintained and the temperature was controlled to ± 0.1K.

Density was calculated by the following formula.

$$d = A \cdot T^2 - B \qquad [1]$$

Constants A and B are the spring constant of the oscillator respectively (The mass of the empty tube and the volume of the sample involved). A and B are therefore, device constants for each individual oscillator. They can be derived from two period measurements when oscillator has been filled with substance of the known density (normally air and water).

The proportional relationship between density difference and the difference of the squares of the corresponding periods can be solved to an accuracy of $\pm\ 1.10^{-4}$ g/cm^3 for the densitimeter. This means an accuracy of ± 1×10^{-4} for a measurement range of 0.5-1.5 g/cm^3 if the constants were determined using air and water.

Results and Discussion

Apparent molar volumes ($\phi_{v,}$ $cm^3.mol^{-1}$) were calculated by the following equation

$$V_{\phi} = M/d_s - \frac{1000\left(d_S - d_O\right)}{m\ d_S\ d_O} \qquad [2]$$

Where M is the molar mass of paracetamol and d_o, d_s and m were the density of solvent, solution and molality of the solution respectively.

ϕ_v data obtained form eq.[2] were fitted to the following equation using a weighted least-squares fit program.

$$V_{\phi} = V_{\phi}^{\circ}{}^{\circ} + S_v\, m \qquad [3]$$

Values of V_{ϕ} i.e. the apparent molal volume were taken at 25°C/298.15K, 30°C/303.15K, 35°C/308.15 and 37.5°/310.65K) for water , 0.1M HCl and 0.5 % NaCl solution as shown in Table 1, 2 and 3 respectively. Values of partial molar volume ($V_{\phi}^{\circ}{}^{\circ}$) were taken at 25°C/298.15K, 30°C/303.15K, 35°C/308.15 and 37.5°/310.65K for water, 0.1 M HCl and 0.5 % NaCl solution as shown in Table 4 along with the values of coefficient S_v, the pair interaction parameter, indicative of solute-solute interactions. Different concentrations of pararcetamol at various temperatures and in different solutions were plotted and are shown in Fig. (1-3).

Table 1: Apparent molar volume V_{ϕ} for aqueous solution Paracetamol. The ± uncertainties are standard deviations from multiple measurements taken during a 800s interval while the period of vibration was stable.

Solvent Water	Molality mol. kg^{-1}	$V\phi$ $cm^3.\ mol^{-1}$ T = 298.15K	$V\phi$ $cm^3.\ mol^{-1}$ T=303.15K	$V\phi$ $cm^3.\ mol^{-1}$ T=308.15K	$V\phi$ $cm^3.\ mol^{-1}$ T=310.65K
	0.003010	184.6355±0.003	184.6566±0.005	184.7044±0.002	184.8393±0.008
	0.006022	184.6119±0.002	184.6330±0.003	184.6808±0.004	184.8156±0.006
	0.009037	184.5883±0.004	184.6094±0.003	184.6571±0.003	184.7920±0.007
	0.012053	184.5647±0.003	184.5858±0.007	184.6335±0.002	184.7683±0.004
	0.015072	184.5411±0.004	184.5622±0.004	184.6099±0.005	184.7446±0.006
	0.018093	184.5175±0.002	184.5386±0.003	184.5863±0.003	184.7210±0.005
	0.021116	184.4939±0.005	184.5149±0.004	184.5627±0.004	184.6973±0.006
	0.024141	184.4703±0.006	184.4913±0.003	184.5390±0.003	184.6737±0.008
	0.027168	184.4467±0.004	184.4677±0.004	184.5154±0.003	184.6500±0.003
	0.030197	184.4231±0.002	184.4441±0.002	184.4918±0.006	184.6264±0.002

[a] **Average experimental values of d_s can be obtained with equation (1) and with d_w given in the reference14.**

Table 2: **Apparent molar volume V_ϕ for aqueous 0.1M HCl solution of Paracetamol. The ± uncertainties are standard deviations from multiple measurements taken during a 800s interval while the period of vibration was stable.**

Solvent 0.1M HCl	Molality mol. kg^{-1}	$V\phi$ $cm^3. mol^{-1}$	$V\phi$ $cm^3. mol^{-1}$	$V\phi$ $cm^3. mol^{-1}$	$V\phi$ $cm^3. mol^{-1}$
	0.003010	184.5415 ±0.008	184.5623 ±0.008	184.6145 ±0.003	184.7418 ±0.006
	0.006022	184.5179 ±0.009	184.5387 ±0.009	184.5909 ±0.006	184.7182 ±0.004
	0.009037	184.4944 ±0.006	184.5151 ±0.007	184.5673 ±0.004	184.6946 ±0.003
	0.012053	184.4708 ±0.005	184.4915 ±0.004	184.5437 ±0.002	184.6709 ±0.006
	0.015072	184.4472 ±0.002	184.4679 ±0.002	184.5201 ±0.005	184.6473 ±0.007
	0.018093	184.4236 ±0.004	184.4443 ±0.004	184.4965 ±0.003	184.6237 ±0.008
	0.021116	184.4000 ±0.006	184.4207 ±0.005	184.4729 ±0.006	184.6000 ±0.009
	0.024141	184.3765 ±0.003	184.3972 ±0.009	184.4493 ±0.002	184.5764 ±0.007
	0.027168	184.3529 ±0.005	184.3736 ±0.011	184.4257 ±0.005	184.5528 ±0.006
	0.030197	184.3293 ±0.002	184.3500 ±0.005	184.4021 ±0.003	184.5292 ±0.005

[a] **Average experimental values of d_s can be obtained with equation (1) and with d_w given in the reference14.**

Table 3: **Apparent molar volume V_ϕ for aqueous 0.9% NaCl solution of Paracetamol. The ± uncertainties are standard deviations from multiple measurements taken during a 800s interval while the period of vibration was stable.**

Solvent 0.9% NaCl	Molality mol. kg^{-1}	$V\phi$ $cm^3. mol^{-1}$ T= 298.15K	$V\phi$ $cm^3. mol^{-1}$ T= 303.15K	$V\phi$ $cm^3. mol^{-1}$ T= 308.15K	$V\phi$ $cm^3. mol^{-1}$ T= 310.65K
	0.003010	184.2792 ±0.006	184.3087 ±0.004	184.3634 ±0.006	184.4798 ±0.006
	0.006022	184.2556 ±0.008	184.2852 ±0.006	184.3399 ±0.004	184.4562 ±0.005
	0.009037	184.2321 ±0.004	184.2617 ±0.007	184.3164 ±0.008	184.4326 ±0.004
	0.012053	184.2086 ±0.003	184.2382 ±0.006	184.2928 ±0.005	184.4091 ±0.003
	0.015072	184.1851 ±0.003	184.2146 ±0.007	184.2693 ±0.006	184.3855 ±0.004
	0.018093	184.1616 ±0.004	184.1911 ±0.004	184.2458 ±0.003	184.3619 ±0.006
	0.021116	184.1381 ±0.005	184.1676 ±0.006	184.2222 ±0.004	184.3384 ±0.005
	0.024141	184.1146 ±0.002	184.1441 ±0.006	184.1987 ±0.008	184.3148 ±0.003
	0.027168	184.0911 ±0.006	184.1206 ±0.004	184.1752 ±0.006	184.2913 ±0.008
	0.030197	184.0675 ±0.008	184.0971 ±0.006	184.1516 ±0.004	184.2677 ±0.007

[a] **Average experimental values of d_s can be obtained with equation (1) and with d_w given in the reference14.**

Table 4: **Partial molar volume V_ϕ° for aqueous solution, 0.1M HCl and 0.9% NaCl solution of Paracetamol.**

Temperature (K)	Water		0.1 M HCl as solvent		0.9% NaCl solution	
	V_ϕ°	S_V	V_ϕ°	S_V	V_ϕ°	S_V
298.15	184.66	-7.78124	184.56	-7.805	184.3	-7.7831
303.15	184.68	-7.8173	184.59	-7.8082	184.33	-7.7842
308.15	184.73	-7.8199	184.64	-7.8124	184.39	-7.7902
310.15	184.86	-7.8313	184.77	-7.8215	184.52	-7.8002

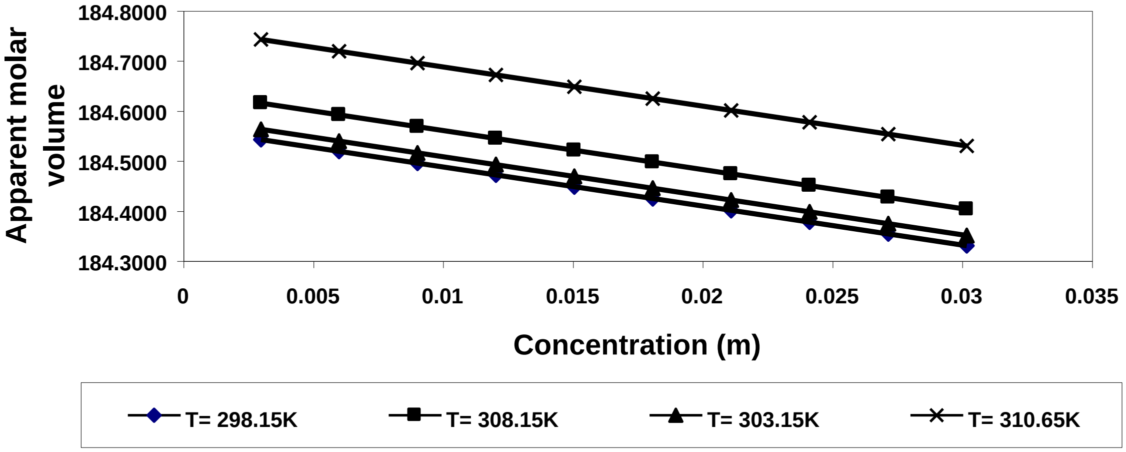

Figure 1 Graph of apparent molar volume verses concentration of paracetamol in water at different temperatures

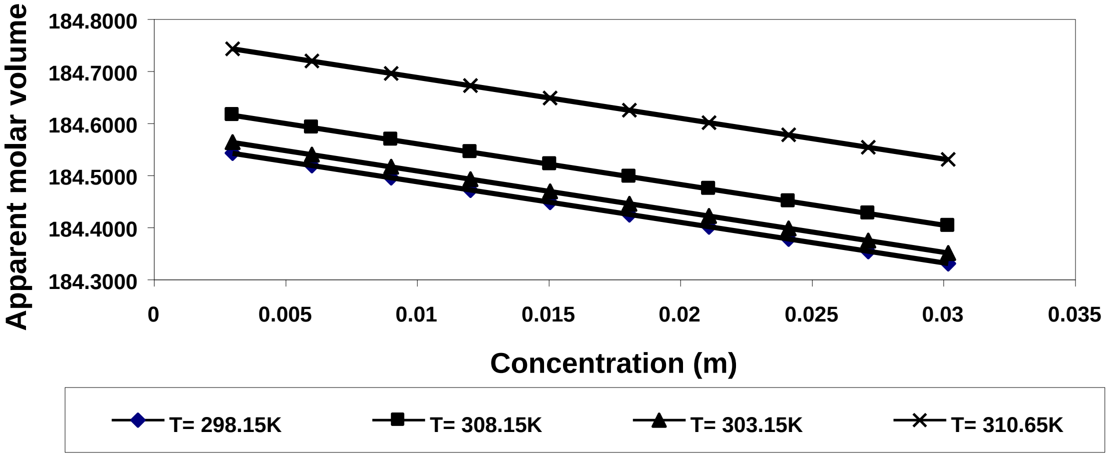

Figure 2 Graph of apparent molar volume verses concentration of paracetamol in 0.1M HCl at different temperatures

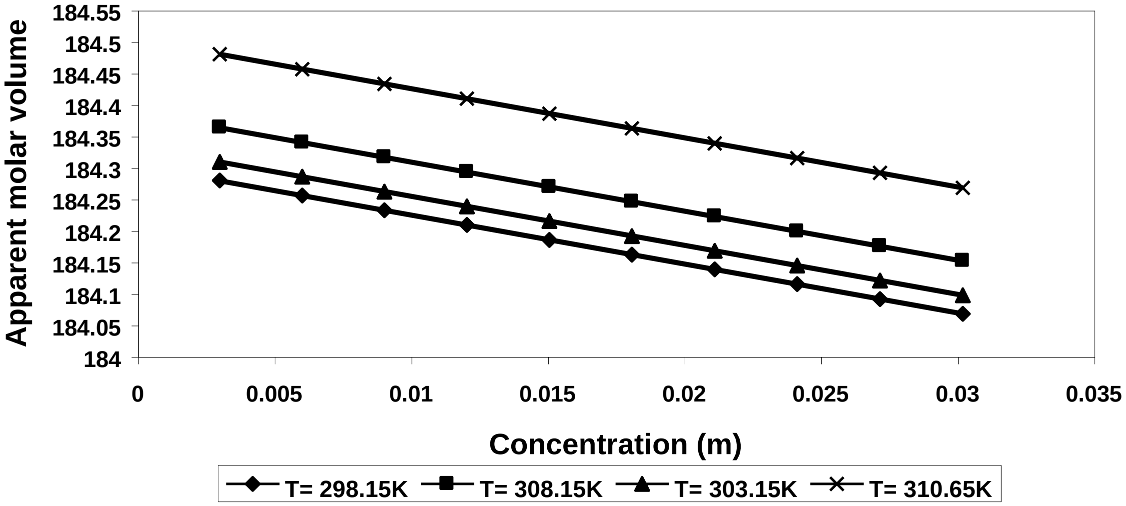

Figure 3 Graph of apparent molar volume verses concentration of paracetamol in 0.9% NaCl at different temperatures

Solute-solvent interactions

Studies on dipolar ions have shown that in aqueous system, these types of solutes represent hydration characteristics which can be described briefly as follows:

(i) Paracetamol molecule is hydrated in an electrostrictive manner while the intervening backbone is hydrated in accordance with its character, which may be hydrophilie, hydrophobic, amphiphilic, or that involving hydrogen bonding , etc. (4-11).
(ii) The change in volume occuring is believed to be due to the net result of two opposing effects (12): (a) an increase in $V_{\phi}^{\circ o\circ}$ due to the reduction in electrostriction at the terminal; (b) a decrease in $V_{\phi}^{\circ o\circ}$ due to the disruption of side-group hydration by that of the charged end.
(iii) As a consequence of (i) the increase in $V_{\phi}^{\circ o\circ}$ with the increase in temperature was observed but as consequence of (ii) $V_{\phi}^{\circ o}$ decrease with the increase in concentration at the same temperature.

For instance, a comparison between the $V_{\phi}^{\circ o}$ values of two different temperatures show effects rather more conspicuously.

Solute-solute interactions

Studies conducted on a variety of hydrophilic, hydrobhobic, and amphiphilic solutes in the past have shown that positive S_v values are generally associated with soluted showing an overall hydrophilic character while negative values are found to be associated with hydrophobic solutes.

Amphiphilic solutes are found to shown little or no concentration dependence of V_{ϕ}° data.

In the context of solute-solute interactions, the Cosphere overlap model proposed by Gurney (16) is also a frequent reference used and is often employed in interpreting S_v data. Using this model and the generalizations obtained from the study of a variety of model compounds, it appear that paracetamol exhibit hydrophobic character in aqueous environments. Gurney's model describes the overlapping of hydrated solutes using spherical shapes for hydrated species. In the case of solutes having nonspherical shapes (oblong, cylindrical, red shaped. Etc.), e.g. the peptides under study, the spherical manner.

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