EFFECT OF CONCENTRATION ON THE VISCOSITY:
HYDROCHLORIC ACID- WATER SYSTEM

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ABSTRACT
The present study shows the effect of concentration 1.0 to 9.0 moldm⁻³ on the viscosities of aqueous solution of hydrochloric acid at 283.15 K. Jones-Dole and Hind viscosity equation were used. The three concentration regions in hydrochloric acid- water system have been identified on the basis of interaction between solute-solvent. The study can be applied to other solvent systems in order to find the intermolecular interactions.

Keywords: Hind viscosity equation, Hydrochloric acid, Interaction parameters, Jones-Dole equation, Solution.

I. INTRODUCTION
The molecular interaction of the solvent molecule with solute plays an important role in governing the behavior of the solution. These interactions also depend upon the nature of the polar and non-polar solute. The nature of interactions plays an important role in the mechanistic path and rate of chemical reaction in kinetic studies [1]. An ionic solute when placed in different solvent systems like non-aqueous, aqua, organic and aqueous influence the kinetic, thermodynamic, spectroscopic properties including transport properties considerably [2-7]. The variation in structure characteristics of the solvent systems takes place due to the presence of solute by induced perturbation resulting from the specific interaction and orientations of the solvent around the ions [8]. The total solvent and solute interaction energy is responsible for effects of solvent on chemical and physical phenomenon. The investigations of volumetric, viscometric and thermodynamic properties of solvents have been the important area of research for understanding the behavior of intramolecular and intermolecular interaction present in solution [9-11]. Solute-induced modification/ perturbation in the water structure have been studied by many workers [12].

Hydrochloric acid is one of the strong minerals acid. When the acid is added to water, there is an interaction between HCl and water molecules. In order to find the nature of interaction present in hydrochloric acid-water system, the study has been undertaken. Though the nature of hydrochloric acid in water at 297.65K is available [13] but very few data are available at low temperature. Hence the present study was carried out at 283.15 K. The different interaction between solute and solvent represents the behavior of the viscosity of solutions. The viscosity results were used to determine B-coefficient and Hind interaction parameters(H₁₂) in the concentration range 1.0 to 9.0moldm⁻³.
II EXPERIMENTAL

The GR grade of hydrochloric acid (E.Merck) was used for making solutions using doubly distilled water. The viscosity measurements were taken in a calibrated suspended-level viscometer (Infusil India Pvt. Ltd.). The viscometer was placed in a thermostated water bath (Tanco) having accuracy ±0.1K for constant temperature. The solution of hydrochloric acid of known concentration was taken in the viscometer and the flow time of the solution was measured with the help of a stop watch (Racer). The densities of solutions were measured using a 15 ml double arm pyknomete having accuracy ±0.00001g/ml and a single pan electronic balance (Citizen).

III RESULTS AND DISCUSSION

The viscosity of hydrochloric acid-water system is a function of concentration and the temperature of the solution. The viscosity data has been analyzed using Jones –Dole equation (1.0) [14]:

\[(\eta/\eta_0-1) c^{-0.5} = A + B c^{0.5} \ldots \ldots (1.0)\]

where \(\eta\) is the viscosity of the solution, \(\eta_0\) is the viscosity of water, concentration of acid, A is a measure of solute-solute interaction and B is a measure of solute-solvent interaction. The values of A and B- coefficient were obtained from the intercept and the slope of linear plot of \((\eta/\eta_0-1) c^{-0.5}\) versus \(c^{0.5}\) as shown in Fig. 1.

Table 1 Values of \(\rho\) (density), \(\eta/\eta_0\) (relative viscosity) of hydrochloric acid-water system at 283.15K

<table>
<thead>
<tr>
<th>(c) (moldm(^{-3}))</th>
<th>(c^{0.5}) (mol(^{1/2})dm(^{-3/2}))</th>
<th>(\rho) (g cm(^{-3}))</th>
<th>(\eta/\eta_0)</th>
<th>((\eta/\eta_0-1)c^{-0.5}) (mol(^{1/2}) dm(^{3/2}))</th>
<th>(x_1)</th>
<th>(x_2)</th>
<th>(H_{12}) (cP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.00</td>
<td>1.032</td>
<td>1.060</td>
<td>0.060</td>
<td>0.018</td>
<td>0.982</td>
<td>3.571</td>
</tr>
<tr>
<td>2.0</td>
<td>1.41</td>
<td>1.036</td>
<td>1.104</td>
<td>0.074</td>
<td>0.036</td>
<td>0.964</td>
<td>3.259</td>
</tr>
<tr>
<td>2.5</td>
<td>1.58</td>
<td>1.039</td>
<td>1.154</td>
<td>0.097</td>
<td>0.047</td>
<td>0.954</td>
<td>3.493</td>
</tr>
<tr>
<td>3.0</td>
<td>1.73</td>
<td>1.043</td>
<td>1.174</td>
<td>0.101</td>
<td>0.054</td>
<td>0.950</td>
<td>2.884</td>
</tr>
<tr>
<td>4.0</td>
<td>2.00</td>
<td>1.049</td>
<td>1.242</td>
<td>0.121</td>
<td>0.073</td>
<td>0.926</td>
<td>3.541</td>
</tr>
<tr>
<td>5.0</td>
<td>2.23</td>
<td>1.083</td>
<td>1.307</td>
<td>0.138</td>
<td>0.090</td>
<td>0.909</td>
<td>3.711</td>
</tr>
<tr>
<td>6.0</td>
<td>2.44</td>
<td>1.100</td>
<td>1.363</td>
<td>0.148</td>
<td>0.110</td>
<td>0.890</td>
<td>3.674</td>
</tr>
<tr>
<td>7.0</td>
<td>2.64</td>
<td>1.111</td>
<td>1.435</td>
<td>0.165</td>
<td>0.132</td>
<td>0.872</td>
<td>3.636</td>
</tr>
<tr>
<td>8.0</td>
<td>2.82</td>
<td>1.128</td>
<td>1.550</td>
<td>0.194</td>
<td>0.146</td>
<td>0.853</td>
<td>4.074</td>
</tr>
<tr>
<td>9.0</td>
<td>3.00</td>
<td>1.136</td>
<td>1.654</td>
<td>0.218</td>
<td>0.171</td>
<td>0.833</td>
<td>4.260</td>
</tr>
</tbody>
</table>
It is clear from Jones-Dole plot that there exists three hydrochloric acid-water systems in the concentration range 1.0 to 9.0moldm$^{-3}$. This shows the different nature of interactions between HCl and water in the concentration range 1.0 to 3.0 moldm$^{-3}$, 3.0 to 6.0 moldm$^{-3}$ and 6.0 to 9.0 moldm$^{-3}$. The value of interaction parameters are listed at the bottom of Table 1. These value shows that with increase in concentration the value of B-coefficient increases which indicate the increase in solute–solvent interaction. The same three concentration regions for HCl-water system has been reported at 297.65K [13].

In order to confirm the nature of HCl–water interaction, another viscosity equation, Hind equation (2.0) was considered [15]:

$$\eta = x_1 \eta_1 + x_2 \eta_2 + 2x_1x_2H_{12} \ldots \ldots (2.0)$$

where $x_1$ is the mole fractions of HCl, $x_2$ is the mole fraction of waterhaving viscosities $\eta_1$ and $\eta_2$ in pure state whereas $\eta$ is the viscosity of the mixed solution of two components. $H_{12}$ is a constant known as Hind’s interaction parameter. The values of Hind’s interaction parameters are given in Table 2. The variation of $H_{12}$ with concentration is given in Fig. 2 which shows inflection points in the curve. This indicates that the phase transition of the system is sharply taking place around the inflection point which confirms the presence of three hydrochloric acid-water systems in the concentration range 1.0 to 9.0moldm$^{-3}$ at 283.15K. The presence of three concentration region has also been confirmed from the reported literature [13, 16].
The calculated values of B-coefficient and $H_{12}$ which are measure of solute-solvent interaction have shown that the hydrochloric acid interacts with water and forms three systems in the different concentration range: 1.0 to 3.0moldm$^{-3}$, 3.0 to 6.0moldm$^{-3}$ and 6.0 to 9.0moldm$^{-3}$.

IV. CONCLUSIONS

It can be concluded that hydrochloric acid in water forms different species in the three different concentration regions 1.0 to 3.0moldm$^{-3}$, 3.0 to 6.0moldm$^{-3}$ and 6.0 to 9.0moldm$^{-3}$ on the basis of Jones- Dole and Hind viscosity equations. The values of B-coefficient are positive which shows that hydrochloric acid has structure making effect on water structure. The study can be used in solution chemistry for determining the nature of solute-solvent or solute-solute interaction present in the system.

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