



INTERNATIONAL RESEARCH JOURNAL OF HUMANITIES AND INTERDISCIPLINARY STUDIES

(Peer-reviewed, Refereed, Indexed & Open Access Journal)

DOI : 03.2021-11278686

ISSN : 2582-8568

IMPACT FACTOR : 5.71 (SJIF 2021)

Binary Solution of Hydrochloric acid and Water at 283.15K: Masson's Equation

Renu Loshali

Assistant Professor,
Department of Chemistry,
Shri Ram Singh Dhoni
Government Degree College,
Jainti (Almora),
(Uttarakhand, India)

Kailash Tamta

Assistant Professor,
Department of Chemistry,
Government Degree College,
Kanda, Bageshwar,
(Uttarakhand, India)

Narain Datt Kandpal

Professor,
Physical Chemistry Laboratory,
Department of Chemistry,
S.S.J. University, Almora,
(Uttarakhand, India)

DOI No. **03.2021-11278686** DOI Link :: <http://doi-ds.org/doi/10.2021-64255734/IRJHIS2105024>

Abstract:

Densities (ρ) and apparent molar volumes (Φ_v) of aqueous solution of hydrochloric acid in the concentration range of 1.0 mol dm^{-3} to 9.0 mol dm^{-3} were measured at 283.15K. Masson's equation was used in order to study the nature of solute-solute and solute-solvent interactions taking place in hydrochloric acid + water system. The presence of strong solute-solvent interaction has been proposed in the study which was confirmed by the large positive value of limiting apparent molar volume (Φ_v^0).

Keywords: Hydrochloric acid; Solute-solvent interactions; Masson's equation, Apparent molar volume, Density.

Introduction:

A solution that comprises of two components is called binary solution. Here one component is known as solute and the other component is known as solvent. The concept of solubility is quite complex as it involves principles of electrolytic, dissociation, diffusion, thermodynamics, kinetics involving Raoult's and Henry's Law [1]. The way in which solute molecule interact with solvent attains the attention of several workers in the field of solution chemistry in order to understand intermolecular or intramolecular interactions [2-8]. There are several reports available in which the structure of solvent changes due to the presence of solute [9-13]. In case the solute is ionic in nature, both ions (cations and anions) has a tendency to influence the structure of the solvent. In case of

water which is a neutral amphiprotic solvent, those ions which increase water structure are called kosmotropes or structure- maker while those ions which decreases the water structure are called chaotropes or structure- breaker [14]. The molecular interactions that occur in a solution (solute-solute, solute-solvent, solvent- solvent) is related to the apparent molar volume (Φ_v) [15-17]. The apparent molar volume of amino acids [18, 19], oxalic acid [20], polymers [21, 22], synthetic polyelectrolytes [23] were reported. Hydrochloric acid is one of the mineral acid which dissociates to form hydrated chloride and hydronium ion in dilute solution [24, 25]. The apparent molar volume which is a measure of solute- solvent interaction of binary solution of hydrochloric acid and water at 283.15K is still a subject of investigation.

Objectives:

The present study deals with the below mentioned objectives:

- To measure the densities of aqueous solution of hydrochloric acid in the concentration range of 1.0 mol dm^{-3} to 9.0 mol dm^{-3} at 283.15K.
- To determine the apparent molar volumes of aqueous solution of hydrochloric acid in the concentration range of 1.0 mol dm^{-3} to 9.0 mol dm^{-3} at 283.15K.
- To understand the nature of interactions (solute-solute, solute-solvent) present in the hydrochloric acid + water system, Masson's equation have been taken into consideration.

Methodology:

- **Materials:** The chemicals used in this study are hydrochloric acid (GR), sodium hydroxide (GR) and oxalic acid (GR). Their supplying agency were E.Merck, Sarabhai M. Chemicals and Sarabhai M. Chemicals respectively. All these chemicals were used without any further treatment.
- **Preparation of Solutions:** For the preparation of solutions of required concentration 1.0 mol dm^{-3} to 9.0 mol dm^{-3} , double distilled water was used having specific conductance of the order of $2 \times 10^{-6} \Omega^{-1} \text{ cm}^{-1}$. For measuring the weight of an oxalic acid, an electronic digital single pan balance having an accuracy of $\pm 0.0001 \text{ g}$ of citizen. was used. Firstly, the standard solution of oxalic acid was prepared from which the concentration of sodium hydroxide was calculated by using law of Equivalence. Then the concentration of aqueous solution of hydrochloric acid (prepared by dilution obtained from source) was determined by acid-base titration method using standard sodium hydroxide solution where phenolphthalein was used as an indicator. The stock solution of desired concentration of hydrochloric acid were prepared by adding calculated volume of distilled water.
- **Measurement of the densities:** The densities of different concentrated solution of hydrochloric acid were measured by using pycnometer at 283.15K. The pycnometer used

was calibrated with double distilled water and Tanco make thermostat working at 220 volts AC mains was used in this study.

Result and Discussion:

By using expression (1), the values of apparent molar volumes (Φ_v) at 283.15K were calculated for aqueous solution of hydrochloric acid having the concentration varying from 1.0 moldm⁻³ to 9.0 moldm⁻³.

$$\Phi_v = \frac{M}{d_0} + \frac{1000(d_0 - d)}{cd_0} \dots \dots \dots (1)$$

Where d_0 represents the density of the water, d represents the density of the solution, c represents the concentration of solution and M represents the molecular weight of hydrochloric acid. Table 1 contains the value of apparent molar volumes (Φ_v) at different concentration at 283.15K.

Table 1. Densities and apparent molar volumes of hydrochloric acid – water system at 283.15K

Concentration (c); (moldm ⁻³)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
\sqrt{c} (mol ^{1/2} dm ^{-3/2})	1.0	1.4142	1.7320	2.0	2.2360	2.4494	2.6457	2.8284	3.0
Density (gcm ⁻³)	1.0321	1.0366	1.0435	1.0494	1.0833	1.1003	1.1119	1.1287	1.1362
Apparent molar volume; Φ_v (cm ³ mol ⁻¹)	4.062	18.0154	21.8665	24.0422	19.7459	19.6992	20.4375	20.3411	21.2997

All the values of apparent molar volumes are positive and fairly large which shows that there occur strong solute- solvent interaction in hydrochloric acid- water system. The positive values obtained is in agreement with the available literature [13, 26]. In addition to apparent molar volume, limiting apparent molar volume (Φ_v^0) of solution also play an important role in governing the behavior of interaction present in the solution [27, 28]. Using Masson's equation (2), the value of limiting apparent molar volume (Φ_v^0) was obtained by plotting the values of apparent molar volume (Φ_v) against the square root of the concentration (c).

$$\Phi_v = \Phi_v^0 + S_v c^{1/2} \dots \dots \dots (2)$$

The slope and intercept of the plot gives the value of S_v which is a measure of solute- solute interaction and Φ_v^0 which is a measure of solute- solvent interaction respectively. The value of Φ_v^0 obtained for hydrochloric acid at 283.15K is 6.99 which shows that there is strong interaction between solute and solvent. The value of S_v is found to be 5.52 which shows the presence of solute- solute interaction. Finally it is concluded that in hydrochloric acid- water system at 283.15K, in addition to strong solute- solvent interaction there exist solute- solute interaction but to less extent which has been justified by the different types of interaction that occurs in the three concentration region 1.0 mol dm^{-3} to 3.0 mol dm^{-3} , 3.0 mol dm^{-3} to 6.0 mol dm^{-3} and 6.0 mol dm^{-3} to 9.0 mol dm^{-3} within the concentration range 1.0 mol dm^{-3} to 9.0 mol dm^{-3} for aqueous solution of hydrochloric acid [13, 26].

Conclusion:

The positive and large value of limiting apparent molar volume (Φ_v^0) and S_v justifies that in aqueous hydrochloric acid solution having concentration 1.0 mol dm^{-3} to 9.0 mol dm^{-3} at 283.15K, there exist different types of interactions including solute-solute and solute- solvent. This confirms the presence of three concentration region: 1.0 mol dm^{-3} to 3.0 mol dm^{-3} , 3.0 mol dm^{-3} to 6.0 mol dm^{-3} and 6.0 mol dm^{-3} to 9.0 mol dm^{-3} and structure making nature of hydrochloric acid in water. The study is helpful in order to understand the concept of interactions that takes place in case of binary solution.

References:

1. G. G. Hawley, The condensed Chemical Dictionary, Van Nostrand Reinhold Company, New York (1977).
2. A. K. Mandal and S. C. Lahiri, Bull. Chem. Soc. Jpn., 48 (1976) 1829.
3. S. Das, D. K. Hazra and S. C. Lahiri, Z. Physik. Chem. (NF), 138 (1983) 185.
4. A. K. Bhattacharyya, A. Pal and S. C. Lahiri, Z. Physik. Chem. (Leipzig), 271 (1990) 397.
5. O. Popovych and R. P. T. Tomkins, Non Aqueous Solution Chemistry, A Wiley Interscience Publication, New York (1981).
6. A. K. Couington and P. Jones (eds), Hydrogen Bonded Solvent Systems, Taylor and Francis, London (1968).
7. S. Thirumaran and A. N. Kannappan, Global J. Mol. Sci., 4 (2009) 160.
8. D. S. Wankhede, N. N. Wankhede, M. K. Lande and B. R. Arbad, J. Sol. Chem., 34 (2005) 233.
9. R. Bhattacharyya and S. C. Lahiri, J. Indian Chem Soc., 85 (2008) 1249.

10. R. Loshali and N. D. Kandpal, Indian J. Chem., 55A (2016) 1080.
11. R. Loshali and N. D. Kandpal, Int. J. Innov. Res. Sci. Eng., 2(7) (2016) 58.
12. R. Loshali and N. D. Kandpal, J. Chil. Chem. Soc., 62(1) (2017) 3386.
13. R. Loshali, B. Chandra, NeetiSah and N. D. Kandpal, Int. J. Chem. Sci., 12 (2014) 1439.
14. R. Zangi, J. Phys. Chem. B, 114 (2010) 643.
15. F. J. Millero, Chem. Rev., 71(2) (1971) 147.
16. F. J. Millero, Water and Aqueous Solutions, Structure, Thermodynamics and Transport properties, Chapter 13, R.A. Home, Ed., Wiley Interscience, New York (1972).
17. R. Perkins, T. Andersen, J. O. M. Bockris and B. E. Conway, Modern Aspects of Electrochemistry, Kluwer Academic Publishers, Norwell, MA, USA (1969).
18. X. Ren, Y. Ni and R. Lin, Acta Phys. Chem. Sin., 16 (2000) 166.
19. A. Pal and S. Kumar, J. Indian Chem. Soc., 79 (2002) 866.
20. R. R. Gupta and M. Singh, Indian J. Chem., 46A (2007) 455.
21. N. Ise and T. Okubo, J. Am. Chem. Soc., 90 (1968) 4527.
22. J. Skerjanc, J. Phys. Chem., 77 (1973) 2225.
23. H. Inagaki and A. Teramoto, Makromol, Chem., 47 (1961) 185.
24. K. E. Laaronen and M. L. Klein, J. Phys. Chem. A, 101 (1997) 98.
25. D.W. Oxtoby and N. H. Nachtrieb, Modern Chemistry, Saunders, New York, (1990).
26. R. Loshali and N. D. Kandpal, Int. J. Innov. Res. Sci. Eng, 2(8) (2016) 187.
27. Q. M. Omar, J. N. Jaubert and J. A. Auan, int. J. Chem. Eng., (2018) 1.
28. K. Kandpal, B. K. Joshi, S. K. Joshi and N.D. Kandpal, E- J. Chem., 4(4) (2007) 574.