

Activation Energy Change and Conductivity Property of Various Concentrations of Aqueous Solution of Salt and Sugar in Water at 308.15 K

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ABSTRACT

Densities and viscosity coefficients, of distilled water and salt-sugar solution were determined through a precision balance and a simple constructed capillary viscometer. The values of viscosities obtained were used to calculate the change in activation energy of the salt-sugar solution for different concentrations of salt+sugar in distilled water. It was observed that the viscosity and activation energy change increased almost linearly with increase in solute concentration in the solvent. It was also observed that the electrical conduction in the sugar-salt aqueous solution was only due to the salt ions.

Keywords: *Sugar, Salt, Solution, Distilled water, Concentration, Activation energy.*

1. Introduction

The sugar we use to sweeten coffee or tea is a molecular solid, in which the individual molecules are held together by relatively weak intermolecular forces. When sugar dissolves in water, the weak bonds between the individual sucrose molecules are broken, and these $C_{12}H_{22}O_{11}$ molecules are released into solution. It takes energy to break the bonds between the $C_{12}H_{22}O_{11}$ molecules in sucrose. It also takes energy to break the hydrogen bonds in water that must be disrupted to insert one of these sucrose molecules into solution. Sugar dissolves in water because energy is given off when the slightly polar sucrose molecules form intermolecular bonds with the polar water molecules. The weak bonds that form between the solute and the solvent

compensate for the energy needed to disrupt the structure of both the pure solute and the solvent. In the case of sugar and water, this process works so well that up to 1800 grams of sucrose can dissolve in a liter of water. Ionic solids or salts contain positive and negative ions, which are held together by the strong force of attraction between particles with opposite charges. When one of these solids dissolves in water, the ions that form the solid are released into solution, where they become associated with the polar solvent molecules.

We can generally assume that salts dissociate into their ions when they dissolve in water. Ionic compounds dissolve in water if the energy given off when the ions interact with water molecules compensates for the energy needed to break the ionic bonds in the solid and the energy required to separate the water molecules so that the ions can be inserted into solution.

All molecules possess a certain minimum amount of energy^[2]. The energy can be in the form of kinetic energy or potential energy. When molecules collide, the kinetic energy of the molecules can be used to stretch, bend, and ultimately break bonds, leading to chemical reactions. If molecules move too slowly with little kinetic energy, or collide with improper orientation, they do not react and simply bounce off each other. In laminar flow, a molecule to go ahead must squeeze past pushing aside the neighboring molecules. To achieve this, the molecule flowing ahead must acquire a definite amount of energy which may be called activation energy, E_a . Then, with Boltzmann factor, the number of molecules having such energy will be

proportional to $\exp(-E_a/k_B T)$. The rate of flow and hence fluidity would depend on this number, and the viscosity is given by

$$\mu = B \exp(E_a / k_B T)$$

(1)

where B is a constant for a given liquid, k_B is the Boltzmann constant, T is the temperature and E_a the activation energy for viscous flow. This is the energy barrier that must be surmounted in order for a molecule to squeeze by its neighbors. The activation energy of the original pure liquid should change when a solute molecule is added to it since the addition may change the bond strength of the given liquid or the solvent molecule as the solute molecule tends to occupy the neighboring positions. The change obviously will depend on the type and the concentration of the solute molecule.^[1]

From equation (1), the viscosity, μ , is expected to be affected significantly by addition of solute molecules to original solvent. The change in activation energy, ΔE_a arising from different concentrations of the solute in the mixture (solution) at constant temperature can be calculated. From equation (1), we can get the change in activation energy. If

$$\mu_1 = B \exp(E_{a1} / k_B T), \quad (1)$$

$$\mu_2 = B \exp(E_{a2} / k_B T), \text{ Then, } \Delta E_a = E_{a2} - E_{a1}, \text{ Hence,}$$

$$\Delta E_a = K_B T \ln \left(\frac{\mu_2}{\mu_1} \right), \quad (2)$$

where μ_1 , is the viscosity of distilled water, μ_2 is the viscosity of the resulting solution, T is the temperature at which μ_2 and μ_1 were determined.^[4]

2. Materials and Method

The solutes selected for the study were dry salt and sugar. Commercial distilled water was used for preparation of solution mixture. One litre of distilled water, various equal masses of salt and sugar were mixed and stirred very well to give a homogenous solution. The densities of distilled water and final solutions were measured at 308.15 K by using specific gravity bottle of 10 cm³ capacity. A precision balance with a precision of 0.05 gm was used for weighing purpose. The weighing was repeated three times

to ensure the accuracy in weights. The reproducibility of the result was close to hundred percent.

A capillary viscometer type ^{[5], [3]} was used to determine the viscosity of distilled water and that of various sugar-salt solutions. A conductivity meter was used to observe the electrical conductivity of various amount of salt added to a fixed volume of aqueous solution of sugar. Similarly, the electrical conductivity of various amount of sugar added to a fixed volume of aqueous solution of salt.

3. Results and Discussion

The experimental densities and viscosities of salt-sugar solution obtained are presented in Table 1. The value of viscosity of distilled water at 308.15 K was 7.22×10^{-4} Pa.sec

Table 1 Densities, viscosity coefficients and activation energy changes of solution mixtures of various amounts of dry salt and sugar added to 100 cc of distilled water at 308.15 K

Conc. of salt/sugar (g/cc) ±0.005	Density of the solution (g/cc) ±0.005	Viscosity of the solution (10 ⁻⁴ Pa.sec) ±0.001	ΔE_a (meV) ±0.001
1	1.056	7.401	0.727
2	1.059	7.554	0.908
3	1.063	7.586	1.015
4	1.067	7.637	1.193
5	1.071	7.694	1.403
6	1.073	7.742	1.578
7	1.079	7.801	1.751
8	1.081	7.852	1.958
9	1.083	7.903	2.128
10	1.086	7.953	2.297
11	1.091	8.051	2.537
12	1.093	8.062	2.668
13	1.096	8.115	2.836
14	1.099	8.168	2.952
15	1.151	8.222	3.198

Table 1 as well as Fig 1 show that the viscosity coefficients and change in activation energy of salt-sugar solution generally increased linearly with increase in mass per volume concentration. As the concentration increased from 1 g/cc to 15 g/cc, the viscosity coefficient of the solution mixture increased from 7.401 to 8.222 (10⁻⁴Pa.sec), at room temperature 308.15 K.

Similarly, the change in activation energy of salt-sugar, (Table 1), increased from 0.727 meV to 3.198 meV. The relationship between the changes in activation energy and salt-sugar concentration in water is linear as seen in Fig (1).

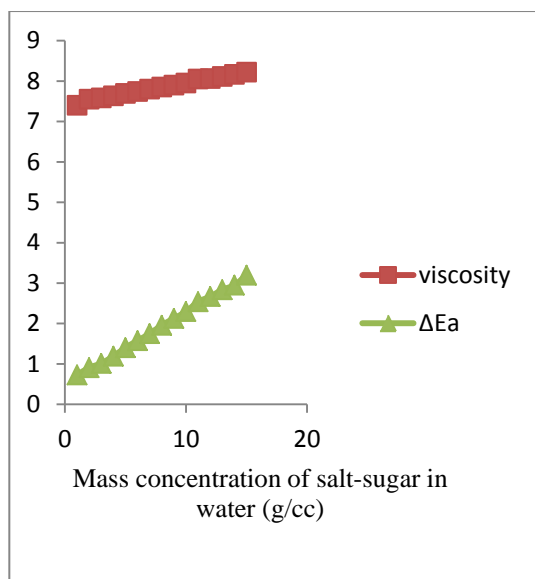


Fig 1 Variation of viscosity and activation energy change with mass concentration of salt-sugar in water

It was observed that the electrical conductivity of various amount of salt added to a fixed volume of aqueous solution of sugar was changing, while, the electrical conductivity of various amount of sugar added to a fixed volume of aqueous solution of salt did not change. Distilled water, is almost pure water and it has a negligible conductivity, i.e. it is not capable to conduct electricity. When you add salt (NaCl) to the distilled water the salt dissolves in water by splitting its molecules in ions: $\text{H}_2\text{O} + \text{NaCl} \rightarrow \text{H}_2\text{O} + (\text{Na}^+) + (\text{Cl}^-)$ The NaCl molecules react to give ions. This happens because the NaCl is a strong electrolyte. Solutions of strong electrolytes are good conductors of electricity because they contain a relatively high concentration of ions.

The H_2O molecule is electrically neutral, but the positive and negative charges are not distributed uniformly. ... The electronic (negative) charge is concentrated at the oxygen end of the molecule, owing partly to the non bonding electrons (solid blue circles), and to oxygen's high nuclear charge which exerts stronger attractions on the electrons. This charge displacement constitutes an electric dipole, Water molecules interact strongly with ions, which are electrically-charged atoms or molecules. Dissolution of ordinary salt (NaCl) in water yields a solution containing the ions Na^+ and Cl^- . Owing

to its high polarity, the H_2O molecules closest to the dissolved ion are strongly attached to it, forming what is known as the inner or primary hydration shell. Positively-charged ions such as Na^+ attract the negative (oxygen) ends of the H_2O molecules

Sugar, as a non-electrolyte substance, does not produce ions when dissolved in water. A solution of sugar contains molecules of sucrose, but no ions. The absence of ions in a sugar aqueous solution makes it a non electricity conductor fluid. When you add sugar to a salt solution: The initial solution has ions associated to water molecules and it can conduct electricity, if the solution is not saturated there are free water molecules capable of dissolve more solutes (salt sugar, acids, etc. When you add sugar the remaining free molecules of water interact with the added sugar molecules to dissolve them until saturation and no new ions are added to the final solution, so the total amount of ions remain the same and the solution is still conductive due the presence of Na^+ and Cl^- ions.

3. Conclusion

The viscosity and change in activation energy of salt-sugar solution increases almost linearly with increase in solute concentration. The electrical conduction in the sugar-salt aqueous solution was only due to the salt ions as there are no ions in sugar aqueous solution.

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