



Critical Micelle Concentration of Nafcillin Sodium Monohydrate in Aqueous Electrolytes and Non-electrolytes Solutions

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ABSTRACT

The effect of electrolytes and non-electrolytes on the micellization of Nafcillin sodium monohydrate (NafNa)(C₂₁H₂₁N₂NaO₅S.H₂O) has been studied by conductance measurement. Conductivity of Nafcillin sodium monohydrate in aqueous electrolytes (MgCl₂, CaCl₂) and non-electrolytes (glucose, fructose) solutions were observed. From the experimental data critical micelle concentration (CMC) of Nafcillin sodium monohydrate were calculated. CMC values were found to be lower in magnitude with the increase of the concentration of MgCl₂/CaCl₂. Difference in the interaction with MgCl₂/CaCl₂ was also found. The CMC of Nafcillin reduction was found higher in CaCl₂ systems than MgCl₂ systems. On the other hand, CMC values were found to be reduced with the increase of the concentration of glucose but enhanced with the increase of concentration of fructose. In the presence of electrolytes and non-electrolytes solutions, the result provides extremely interesting information regarding the micellization of Nafcillin sodium monohydrate.

Keywords: Nafcillin sodium monohydrate, MgCl₂, CaCl₂, Glucose, Fructose, Critical micelle concentration (CMC), Conductivity.

INTRODUCTION

To evaluate the drug action and understand the action mechanism at the molecular level examine the physiochemical properties of drugs conquering great concern. Drug-body interactions reveal information about the effects of drugs on the body and the body's reactions to drugs through their physiochemical interactions with functionally significant molecules in living organisms¹⁻⁴. The majority of drug have organic moieties that have both hydrophilic and hydrophobic groups; as a result,

these compounds exhibit certain characteristics and interact with electrostatic forces. They get self- assembled into liposomes or micelles when dispersed in aqueous media in high concentration⁵⁻⁷. A chemical that has antimicrobial properties and its active against bacteria called antibiotic. The majority of disorders are specifically treated with β -lactam antibiotics. A semi-synthetic antibiotic in class of penicillin, NafNa is a β -lactam antibiotic drug (narrow spectrum). The beta-lactum ring structure of NafNa is shown in Fig. 1. It shows resistance to beta lactamase hence it is to treat infections



caused by *Staphylococcal strains* that are resistant to other penicillin, except those caused by MRSA (Methicillin Resistant *Staphylococcus aureus*). It is used as a penicillin to treat infections brought on by *Gram-positive* bacteria. Most bacteria produce a cell wall composed in part of the peptidoglycan macromolecule, which is composed of short peptides and amino sugars. In human cells peptidoglycan is not produced or do not play any vital role. The stability of β -lactam ring structure is crucial to the microbiological activity of β -lactam antibiotics⁸⁻¹². The chemical species, including electrolytes and non-electrolytes, that are present in bodily fluids have a significant impact on the stability of beta-lactam ring structures and biomolecules^{9,13}.

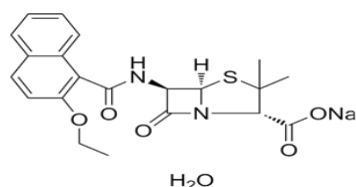


Fig. 1. Nafcillin Sodium Monohydrate (NafNa)

Carbohydrates are organic compounds found in living organisms that provide energy for working muscles, fuel for central nervous system, enable fat metabolism, serve as a preferred source of energy, and perform biological work. Glucose is an important carbohydrate for our body which is also called blood sugar. Any kind of carbohydrate we consume breaks down into glucose. This glucose then used as energy upon consumption. If there is any extra glucose in the bloodstream remains stored in liver and muscle tissue. Then that is used when any energy is needed. Fructose is a common carbohydrate in our daily life which is also called fruit sugar. It is found in fruits, vegetables, table sugar, and many processed foods. Fructose is converted into glucose in the liver to use it for energy^{8,14,15}.

Calcium chloride is very important for human body primarily for its role in maintaining proper calcium levels. Calcium is very crucial for bones, muscle functions, nerve transmissions, and blood clotting. It also helps in maintaining the balance of electrolytes in the body, preventing issues like muscle cramps and irregular heartbeats^{16,17}. Magnesium chloride is a magnesium salt needed for muscle and nerve function, regulating blood sugar and blood pressure levels, and making protein, bones, and DNA. The chemical species present in body fluids, such as electrolytes, non-electrolytes so on the stability of beta-lactam ring of NafNa in electrolytes and non-electrolytes is important to study. Other researchers studied by spectrophotometry, High performance liquid chromatography (HPLC), Conductivity, volumetric and charge transfer techniques but no report on the micellization of NafNa in aqueous glucose, fructose, $MgCl_2$ and $CaCl_2$ systems^{12,18,19}. To completely comprehend NafNa micellization in the presence of electrolytes and non-electrolytes, more research is needed. With this view, the micellization investigation of NafNa in electrolyte and non-electrolyte solutions is undertaken. And our report provides an overview of the amazing outcomes.

EXPERIMENTAL

MATERIALS AND METHODS

Analytical reagent grade ingredients were all employed in this experiment and no purification was necessary. NafNa was purchased from Med Chem Express.com. Glucose, fructose, $MgCl_2$ and $CaCl_2$ from Research-Lab Fine Chem Industries Mumbai 400 002(India). All the solutions were prepared using de-ionized water having specific conductivity less than $2 \mu S cm^{-1}$.

Table 1: Specifications of Chemicals

| Chemical name | Molar mass/kg.mol ⁻¹ | Purity declared by supplier | Origin |
|--------------------------------------|---------------------------------|-----------------------------|---|
| Nafcillin Sodium Monohydrate (NafNa) | 0.4545 | 0.970 | Med Chem Express.com |
| Calcium chloride ($CaCl_2$) | 0.1109 | 0.990 | Research-Lab Fine Chem Industries Mumbai 400 002(India) |
| Magnesium Chloride ($MgCl_2$) | 0.9521 | 0.995 | Research-Lab Fine Chem Industries Mumbai 400 002(India) |
| Glucose ($C_6H_{12}O_6$) | 0.1801 | 0.995 | Research-Lab Fine Chem Industries Mumbai 400 002(India) |
| Fructose($C_6H_{12}O_6$) | 0.1801 | 0.995 | Research-Lab Fine Chem Industries Mumbai 400 002(India) |

Preparation of Solutions

The specific conductivity and pH of NafNa+ H_2O + $MgCl_2$ / $CaCl_2$, NafNa+ H_2O +Glucose/

Fructose systems were measured through Hanna EC/TDS/Salinity Benchtop Meter-HI2550 having cell constant $1 cm^{-1}$ and the accuracy is ($\pm 0.05 \mu S$

cm⁻¹). The analytical balance FA 2204 was utilized to measure weight. Every experiment was conducted at 25°C, which was managed using the SHWB-30 shaking water bath model. The experiment was conducted in accordance with the methodology described in the literature^{20,21}.

At first 20 g solution of glucose, fructose, CaCl₂ and MgCl₂ of different concentration such as 0.1 mol/kg, 0.3 mol/Kg, 0.5 mol/Kg was prepared in de-ionized water. Then 0.03 mol/Kg solution of NafNa was prepared using glucose or Fructose solution of different concentration. Stock solution of NafNa was gradually added to glucose fructose, CaCl₂ and MgCl₂ solutions targeting a desired concentration. After adding those solution every time, it was mixed properly.

The G (conductance) values were measured using a conductivity meter on each addition. Then values of G have been plotted against the respective concentrations of NafNa in solutions. The mathematical calculation for critical micelle concentration was done by Origin pro software (Version 10.0).

RESULTS AND DISCUSSIONS

One of the mostly used methods for calculating the critical micelle concentrations (CMCs) is conductometry, it is a vulnerable method for to find out aggregation or analysis the micellar systems²². With the increasing concentrations of electrolytes solutions drastically changes observed in the curve of conductivity in the plot area of CMC as a result increase of conductivity goes down²³. This kind of change of conductivity occurs due to less micelle formation in high electrical field because of the size variation of former. The specific conductivity, G of NafNa in water, glucose+water, fructose+water, CaCl₂+water, MgCl₂+water systems are represented in the Tables 2-6 and Fig. 2, 5. In order to correctly ascertain the critical micelle concentration (CMC), the conductance, G value was fitted to the subsequent piece-wise linear model as a function of molality, c in eq. (1)

$$G = \begin{cases} A + s_1c, & m \leq CMC \\ A + s_1X + s_2(c - CMC), & m \geq CMC \end{cases} \quad (1)$$

Here s₁ and s₂ represent the slopes in the graphical data in pre and post region of CMC point, respectively and A indicates the intercepts.

If (c → 0; then G → A).

Figure 3, 4, 6, 7, 8, 9 represent the graphical data of CMC and various parameters to measure the CMC shown in the Table 7.

Critical micelle point, CMC indicates the self-assembly of ions produced from NafNa which has two parts one is hydrophilic and another one is hydrophobic. The CMC of NafNa+water system is 0.10532 mol.kg⁻¹ which is good agreement with earlier reported value¹². Conductivity of NafNa was evaluated for all systems increased with the increasing concentration of NafNa until the CMC point. After the CMC breakpoint increase rate became slower from the previous increasing rate^{12,24,25}. Addition of any kind of electrolytes and non-electrolytes such as CaCl₂, MgCl₂, glucose and fructose affect the CMC of drug and also the micellization process of counter ions produced from the drug. Water structure remain stable in the presence of neutral salts CaCl₂ and MgCl₂ due higher amount of Cl⁻ ions by complete dissociation of these electrolytes. The hydrophilic heads of NafNa feel less electrostatic repulsion in the presence of these neutral salts because they neutralize the surface charge which results micellization. Presence of neutral salts CaCl₂ and MgCl₂ stabilize the micelles formed by the counter ions produced from the NafNa. Among the both salts CaCl₂ and MgCl₂, CMC reduced more in the presence of CaCl₂ in nafcillin+water+CaCl₂ system. While in the NafNa+water+MgCl₂ system CMC reduced lesser. The CMC values are greater in presence of MgCl₂ than in presence of CaCl₂. Because the cations having higher Z/R value are more hydrated and water structure maker. As Mg²⁺ have higher Z/R value, it decreases CMC values in higher magnitude 26. Thus, the CMC value decreased with the increasing concentration of salts due to the salting effect occurred by adding neutral salts in the systems.

Glucose acts as water structure maker in low concentration. When glucose is introduced, the NafNa hydrophobic residues might cause aggregation. This promotes the creation of micelles and results in a noticeable reduction in the hydrophilic group's degree of hydration. So, the CMC values of NafNa decreases in presence of glucose. On the other hand, fructose works as water structure breaker. It increases the CMC values by interfering

with the water molecules and by enhancing the dissolution of hydrophobic species^{12,27}. Addition of fructose at low concentrations into the micellar solution of NafNa interrupt the structure of water cluster causing disruption of the micelle and CMC increases. Two important parameters related to micellization α (α) and β (β) value by which micellization of a drug can be described. The degree of dissociation of micelle describes as β and the degree of association of micelle describe as α . Less interaction of counter ions with micelle resultant stable micelle structure with higher α value.

The working mechanism, transportation and activity of NafNa can be described with α and β values²⁸. Because of low α value of antibiotics exhibit more strongly charged micelle which can interact strongly with the bacterial cell membrane, potentially enhancing the efficacy of any antibiotics. And on the other hand, β (β) value represents the CMC point at which micelle starts to form. The micelle ionization value, α was calculated from $\alpha = S_1/S_2$, where S_2 = slope after CMC, S_1 = slope before CMC. And β values can be calculated from

$\beta = 1 - \alpha$. Low α value for NafNa indicates highly charged micelle structure with less interaction with the counter ions for this study Ca^{2+} and Mg^{2+} . This effect hinders less binding and association with these counter ions because the bulky negatively charged carboxylate groups present in NafNa.

In our present study we evaluated the α values for all NafNa in glucose, fructose, CaCl_2 , MgCl_2 systems. At definite concentration α value for NafNa+ CaCl_2 +water system was lower than of NafNa+ MgCl_2 +water system which indicates the lesser interaction with Ca^{2+} ions. In the case of NafNa+glucose+water, NafNa+fructose+water systems α value was found low for NafNa+fructose+water system than that of NafNa+glucose+water system. Lower α values resultant larger micelle structure with highly negative charge. The α values were found to be low for NafNa+glucose+water, NafNa+fructose+water systems comparing to NafNa+ CaCl_2 +water, NafNa+ MgCl_2 +water systems which evaluate the larger micelle structure for NafNa+glucose+water, NafNa+fructose+water systems.

Table 2: Conductivity of NafNa in water system with different concentration of NafNa

| NafNa+Water | | | |
|--|---|--|---|
| Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) |
| 0.01250 | 0.409 | 0.16250 | 5.220 |
| 0.02500 | 0.852 | 0.17500 | 5.570 |
| 0.03750 | 1.295 | 0.18750 | 5.910 |
| 0.05000 | 1.737 | 0.20000 | 6.240 |
| 0.06250 | 2.180 | 0.21250 | 6.580 |
| 0.07500 | 2.623 | 0.22500 | 6.920 |
| 0.08750 | 3.060 | 0.23750 | 7.250 |
| 0.10000 | 3.500 | 0.25000 | 7.600 |
| 0.11250 | 3.880 | 0.26250 | 7.940 |
| 0.12500 | 4.220 | 0.27500 | 8.260 |
| 0.13750 | 4.570 | 0.28750 | 8.610 |
| 0.15000 | 4.900 | 0.30000 | 8.930 |

Table 3: Conductivity of NafNa+water+ MgCl_2 system with different concentration of electrolytes

| NafNa+water+0.05 mol/kg MgCl_2 | | NafNa +water+0.075 mol/kg MgCl_2 | | NafNa+water+0.1 mol/kg MgCl_2 | |
|---|---|--|---|--|---|
| Concentration, C of NafNa(molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) |
| 0.00000 | 7.30 | 0.00000 | 7.30 | 0.00000 | 13.81 |
| 0.00912 | 7.43 | 0.00912 | 7.43 | 0.00897 | 14.01 |
| 0.01808 | 7.57 | 0.01808 | 7.57 | 0.01793 | 14.20 |
| 0.02707 | 7.70 | 0.02707 | 7.70 | 0.02692 | 14.40 |
| 0.03605 | 7.84 | 0.03605 | 7.84 | 0.03589 | 14.58 |
| 0.04789 | 7.98 | 0.04789 | 7.98 | 0.04793 | 14.78 |

| | | | | | |
|---------|------|---------|------|---------|-------|
| 0.05688 | 8.11 | 0.05688 | 8.11 | 0.05721 | 14.99 |
| 0.06604 | 8.25 | 0.06604 | 8.25 | 0.06619 | 15.19 |
| 0.07486 | 8.39 | 0.07486 | 8.39 | 0.07507 | 15.27 |
| 0.08345 | 8.52 | 0.08345 | 8.52 | 0.08379 | 15.36 |
| 0.09205 | 8.60 | 0.09205 | 8.60 | 0.09237 | 15.44 |
| 0.10035 | 8.66 | 0.10035 | 8.66 | 0.10059 | 15.52 |
| 0.10848 | 8.73 | 0.10848 | 8.73 | 0.10873 | 15.61 |
| 0.11656 | 8.81 | 0.11656 | 8.81 | 0.11684 | 15.69 |
| 0.12450 | 8.88 | 0.12450 | 8.88 | 0.12471 | 15.77 |
| 0.13224 | 8.95 | 0.13224 | 8.95 | 0.13235 | 15.84 |
| 0.13994 | 9.03 | 0.13994 | 9.03 | 0.14007 | 15.93 |

Table 4: Conductivity of NafNa+water+CaCl₂ system with different concentration of electrolytes

| NafNa+Water+0.05 mol/Kg CaCl ₂ | | NafNa+water+0.075 mol/Kg CaCl ₂ | | NafNa+water+0.1 mol/Kg CaCl ₂ | |
|--|---|--|---|--|---|
| Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) |
| 0.00000 | 6.89 | 0.00000 | 11.56 | 0.00000 | 14.41 |
| 0.00912 | 7.02 | 0.00911 | 11.67 | 0.00913 | 14.51 |
| 0.01808 | 7.16 | 0.01801 | 11.79 | 0.01807 | 14.58 |
| 0.02706 | 7.31 | 0.02691 | 11.89 | 0.02711 | 14.64 |
| 0.03612 | 7.45 | 0.03702 | 12.01 | 0.03615 | 14.74 |
| 0.04780 | 7.61 | 0.04765 | 12.12 | 0.04767 | 14.82 |
| 0.05720 | 7.76 | 0.05683 | 12.25 | 0.05695 | 14.91 |
| 0.06632 | 7.89 | 0.06600 | 12.37 | 0.06581 | 14.94 |
| 0.07526 | 8.01 | 0.07491 | 12.43 | 0.07475 | 14.98 |
| 0.08399 | 8.07 | 0.08372 | 12.48 | 0.08339 | 15.03 |
| 0.09250 | 8.14 | 0.09235 | 12.54 | 0.09180 | 15.08 |
| 0.10093 | 8.20 | 0.10078 | 12.61 | 0.10011 | 15.11 |
| 0.10901 | 8.26 | 0.10917 | 12.68 | 0.10834 | 15.15 |
| 0.11700 | 8.33 | 0.11711 | 12.72 | 0.11639 | 15.18 |
| 0.12489 | 8.41 | 0.12493 | 12.77 | 0.12422 | 15.23 |
| 0.13253 | 8.47 | 0.13269 | 12.82 | 0.13209 | 15.26 |
| 0.14038 | 8.54 | 0.14030 | 12.89 | 0.13973 | 15.31 |

Table 5: Conductivity of NafNa+water+glucose system with different concentration of electrolytes

| NafNa+water+0.1 mol/Kg glucose | | NafNa+water+0.3 mol/Kg glucose | | NafNa+water+0.5 mol/Kg glucose | |
|--|---|--|---|--|---|
| Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) |
| 0.00978 | 0.011 | 0.00000 | 0.190 | 0.00000 | 0.190 |
| 0.01958 | 0.361 | 0.00735 | 0.473 | 0.00735 | 0.473 |
| 0.02918 | 0.701 | 0.00819 | 0.505 | 0.00819 | 0.505 |
| 0.04038 | 1.051 | 0.01635 | 0.819 | 0.01635 | 0.819 |
| 0.05337 | 1.391 | 0.02448 | 1.132 | 0.02448 | 1.132 |
| 0.06590 | 1.721 | 0.03262 | 1.445 | 0.03262 | 1.445 |
| 0.07720 | 2.071 | 0.04180 | 1.798 | 0.04180 | 1.798 |
| 0.09256 | 2.421 | 0.05135 | 2.166 | 0.05135 | 2.166 |
| 0.10637 | 2.771 | 0.06119 | 2.544 | 0.06119 | 2.544 |
| 0.12117 | 3.010 | 0.07137 | 2.936 | 0.07137 | 2.936 |
| 0.13573 | 3.240 | 0.08186 | 3.340 | 0.08186 | 3.340 |
| 0.14616 | 3.480 | 0.09346 | 3.590 | 0.09346 | 3.590 |
| 0.15858 | 3.720 | 0.10454 | 3.850 | 0.10454 | 3.850 |
| 0.16897 | 3.950 | 0.11857 | 4.090 | 0.11857 | 4.090 |
| 0.18205 | 4.190 | 0.12736 | 4.360 | 0.12736 | 4.360 |
| 0.19753 | 4.420 | 0.13840 | 4.610 | 0.13840 | 4.610 |
| 0.20826 | 4.660 | 0.16024 | 5.120 | 0.16024 | 5.120 |
| 0.22137 | 4.910 | 0.18262 | 5.620 | 0.18262 | 5.620 |
| 0.23619 | 5.140 | 0.20412 | 6.100 | 0.20412 | 6.100 |

| | | | | | |
|---------|-------|---------|-------|---------|-------|
| 0.24886 | 5.380 | 0.22344 | 6.590 | 0.22344 | 6.590 |
| 0.25922 | 5.610 | 0.24394 | 7.110 | 0.24394 | 7.110 |
| 0.00978 | 0.011 | 0.26487 | 7.610 | 0.26487 | 7.610 |
| 0.01958 | 0.361 | 0.28052 | 8.090 | 0.28052 | 8.090 |
| 0.02918 | 0.701 | 0.29997 | 8.590 | 0.29997 | 8.590 |

Table 6: Conductivity of NafNa+water+fructose system with different concentration of electrolytes

| NafNa+water+0.1 mol/kg Fructose | | NafNa+water+ 0.3 mol/kg Fructose | | NafNa+water+ 0.5 mol/kg Fructose | |
|--|---|--|---|--|---|
| Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) | Concentration of NafNa, C (molKg ⁻¹) | Specific Conductivity (mScm ⁻¹) |
| 0.00000 | 0.2701 | 0.00738 | 0.126 | 0.00770 | 0.1480 |
| 0.01599 | 0.9060 | 0.00820 | 0.168 | 0.00860 | 0.1830 |
| 0.01773 | 1.0050 | 0.01638 | 0.585 | 0.01720 | 0.5200 |
| 0.02659 | 1.2870 | 0.02451 | 0.999 | 0.02575 | 0.8550 |
| 0.03538 | 1.6290 | 0.03266 | 1.414 | 0.03435 | 1.1920 |
| 0.04503 | 1.9880 | 0.04143 | 1.861 | 0.04395 | 1.5680 |
| 0.05494 | 2.4030 | 0.05046 | 2.321 | 0.05385 | 1.9560 |
| 0.06521 | 2.7600 | 0.05968 | 2.791 | 0.06395 | 2.3520 |
| 0.07561 | 3.1300 | 0.06902 | 3.240 | 0.07432 | 2.7580 |
| 0.08621 | 3.5000 | 0.07845 | 3.700 | 0.08501 | 3.1700 |
| 0.09691 | 3.8300 | 0.08790 | 4.150 | 0.09575 | 3.5600 |
| 0.10779 | 4.1300 | 0.10964 | 5.070 | 0.10680 | 3.9700 |
| 0.11861 | 4.5500 | 0.12057 | 5.530 | 0.11768 | 4.3700 |
| 0.12935 | 4.8200 | 0.13120 | 6.000 | 0.12836 | 4.7600 |
| 0.14004 | 5.1500 | 0.14160 | 6.260 | 0.13932 | 5.1600 |
| 0.16127 | 5.7200 | 0.16246 | 6.770 | 0.16055 | 5.5800 |
| 0.18272 | 6.2400 | 0.18365 | 7.270 | 0.18173 | 5.9900 |
| 0.20351 | 6.8400 | 0.20417 | 7.790 | 0.20257 | 6.4200 |
| 0.22387 | 7.3300 | 0.22478 | 8.280 | 0.22281 | 6.8400 |
| 0.24389 | 7.7400 | 0.24413 | 8.790 | 0.24317 | 7.2400 |
| 0.26357 | 8.3200 | 0.26354 | 9.290 | 0.26265 | 7.6700 |
| 0.28244 | 8.7900 | 0.28816 | 9.780 | 0.28182 | 8.0900 |
| 0.29998 | 9.1700 | | | 0.30000 | 8.5000 |

Table 7: Critical micelle concentration, CMC of NafNa in water and in water+MgCl₂/CaCl₂/glucose/fructose solutions

| CMC of all systems | | | | |
|---|--|----------|---------|--|
| Systems | CMC NafNa in water (molKg ⁻¹) | α | β | |
| Nafcillin+water | 0.10532 | 0.763069 | 0.23693 | |
| Concentration of MgCl ₂ , C (molKg ⁻¹) | CMC of NafNa in MgCl ₂ solution | | | |
| 0.000 | 0.10532 | 0.763069 | 0.23693 | |
| 0.050 | 0.08519 | 0.62749 | 0.37250 | |
| 0.075 | 0.07529 | 0.58114 | 0.41886 | |
| 0.100 | 0.06619 | 0.49120 | 0.50880 | |
| Concentration of CaCl ₂ , C (molKg ⁻¹) | CMC of NafNa in CaCl ₂ solution | α | β | |
| 0.000 | 0.10532 | 0.763069 | 0.23693 | |
| 0.050 | 0.07039 | 0.53944 | 0.46056 | |
| 0.075 | 0.06645 | 0.57864 | 0.42136 | |
| 0.100 | 0.05598 | 0.56769 | 0.43231 | |
| Concentration of Glucose, C (molKg ⁻¹) | CMC of NafNa in Glucose solution | α | β | |
| 0.000 | 0.10532 | 0.763069 | 0.23693 | |
| 0.100 | 0.08519 | 0.62749 | 0.37251 | |
| 0.300 | 0.07681 | 0.62151 | 0.37849 | |
| 0.500 | 0.06548 | 0.70593 | 0.29407 | |
| Concentration of Fructose, C ((molKg ⁻¹) | CMC of NafNa in Fructose solution | α | β | |
| 0.000 | 0.10532 | 0.763069 | 0.23693 | |
| 0.100 | 0.11449 | 0.70613 | 0.29387 | |
| 0.300 | 0.12404 | 0.50453 | 0.49547 | |
| 0.500 | 0.13388 | 0.53964 | 0.46036 | |

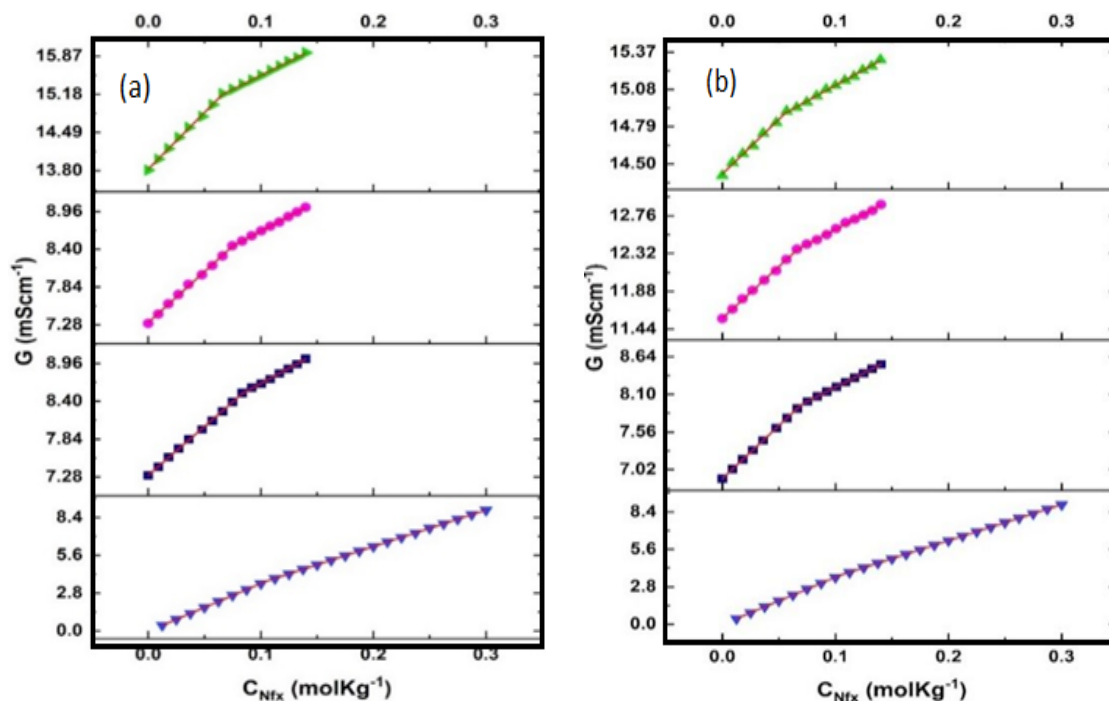


Fig. 2. Conductivity, G of (a) \blacktriangleright -NafNa+Water; \blacksquare -NafNa +Water+MgCl₂ (0.05mol/Kg); \bullet - NafNa +Water+MgCl₂ (0.075mol/Kg); \blacktriangleleft -NafNa+Water+MgCl₂ (0.1mol/Kg) and (b) \blacktriangleright -NafNa+Water; \blacksquare -NafNa+Water+CaCl₂(0.05mol/Kg); \bullet - NafNa+Water+CaCl₂ (0.075mol/Kg); \blacktriangleleft -NafNa +Water+CaCl₂ (0.1mol/Kg) systems as a function of molality, C of SDS at 295.15 K

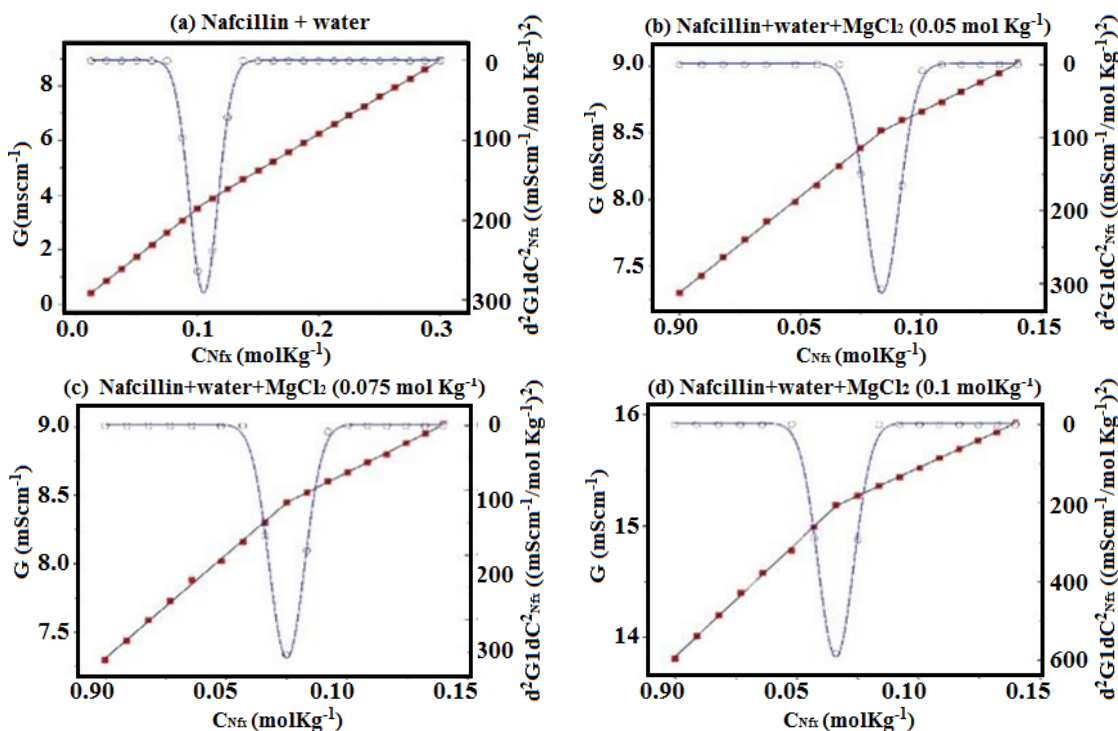


Fig. 3. Conductivities of (a) NafNa+Water, (b) NafNa+ Water+MgCl₂(0.05 mol/Kg), (c) NafNa+Water+MgCl₂ (0.075 mol/Kg) and (d) NafNa+Water+MgCl₂ (0.1 mol/Kg) (\blacksquare - represents experimental and solid line fitting data; \circ -Second erivative of fitted data; solid line fitted data to Gaussian function

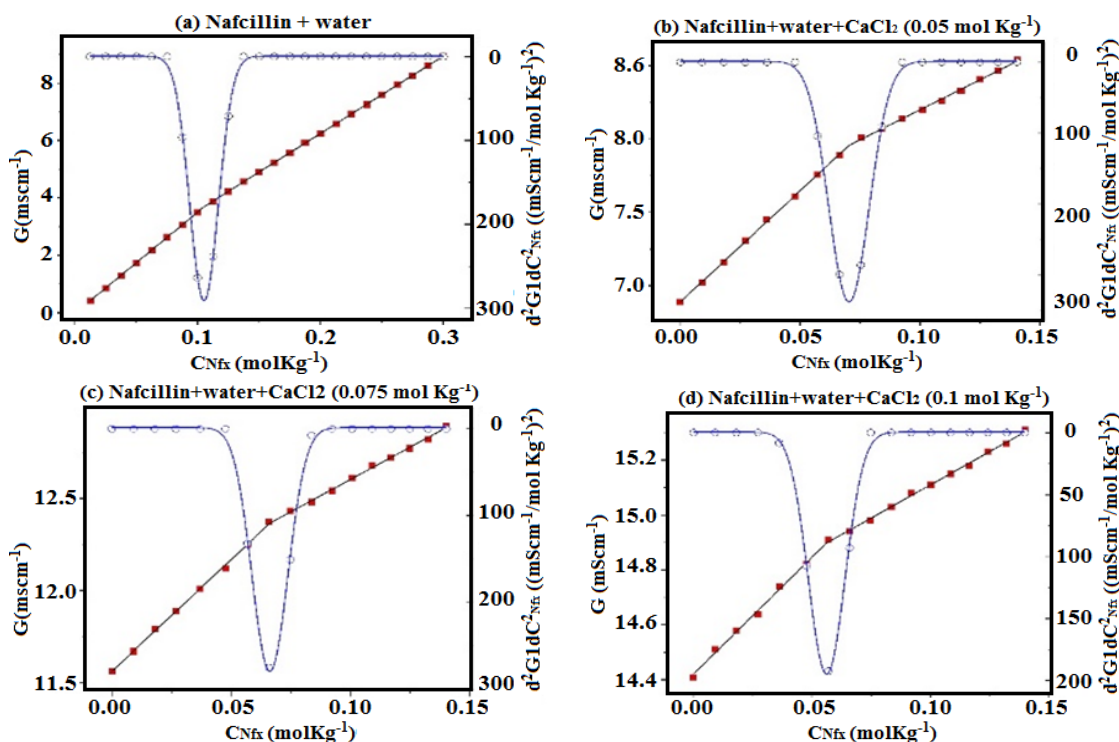


Fig. 4. Conductivities of (a) NafNa+Water, (b) NafNa+Water+CaCl₂ (0.05 mol/Kg); (c) NafNa+Water+CaCl₂ (0.075 mol/Kg), (d) NafNa+Water+CaCl₂ (0.1 mol/Kg) (■—represents experimental and solid line fitting data; o—Second derivative of fitted data; solid line fitted data to Gaussian function

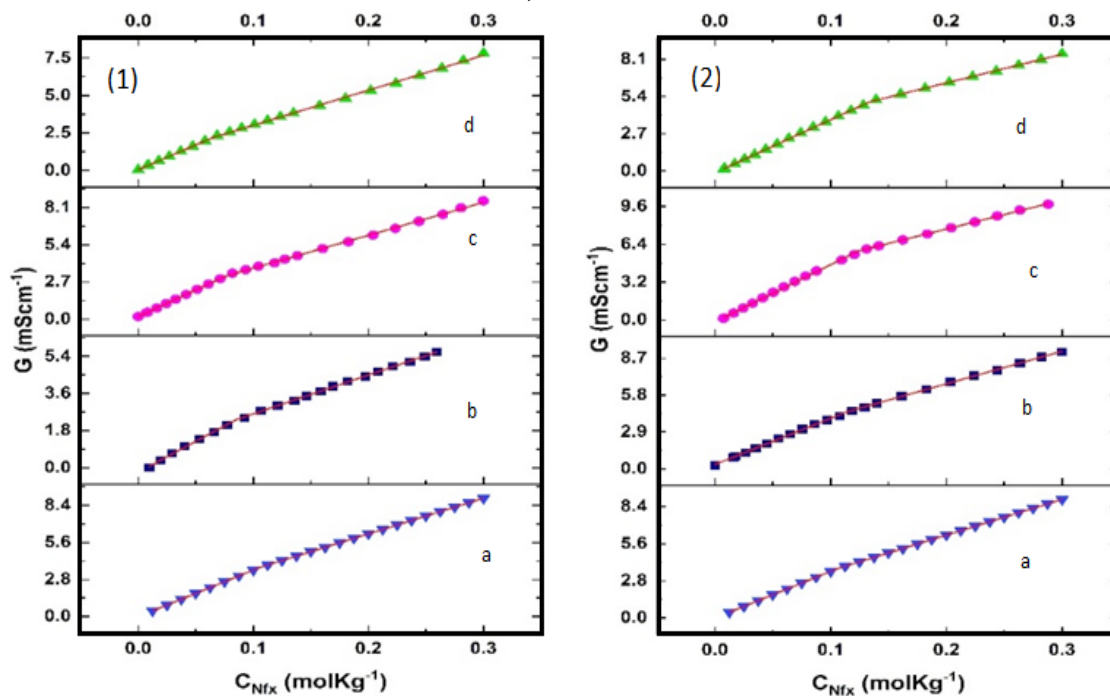


Fig. 5. Conductivity, G of (1) (a)-NafNa+Water; (b)-NafNa+Water+Glucose (0.1 mol/Kg); (c)-NafNa+Water+Glucose (0.3 mol/Kg); (d)-NafNa+Water+Glucose (0.5 mol/Kg) and (2) (a)-NafNa+Water; (b)-NafNa+Water+Fructose (0.1 mol/Kg); (c)-NafNa+Water+Fructose (0.3 mol/Kg); (d)-NafNa+Water+Fructose (0.5 mol/Kg) systems as a function of molality, m of SDS at 295.15 K

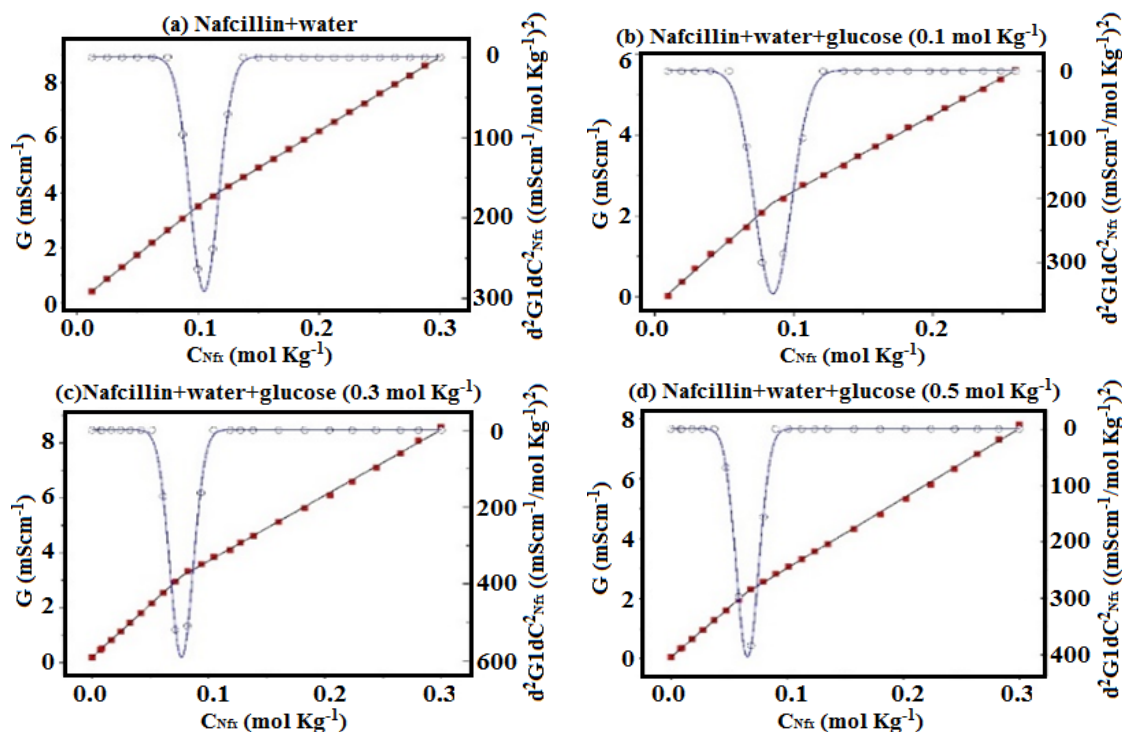


Fig. 6. Conductivities of (a) NafNa+Water, (b) NafNa+Water+Glucose (0.1 mol/Kg), (c) NafNa+Water+Glucose (0.3 mol/Kg), (d) NafNa+Water+Glucose (0.5 mol/Kg) (■—represents experimental and solid line fitting data; o - Second derivative of fitted data; solid line fitted data to Gaussian function)

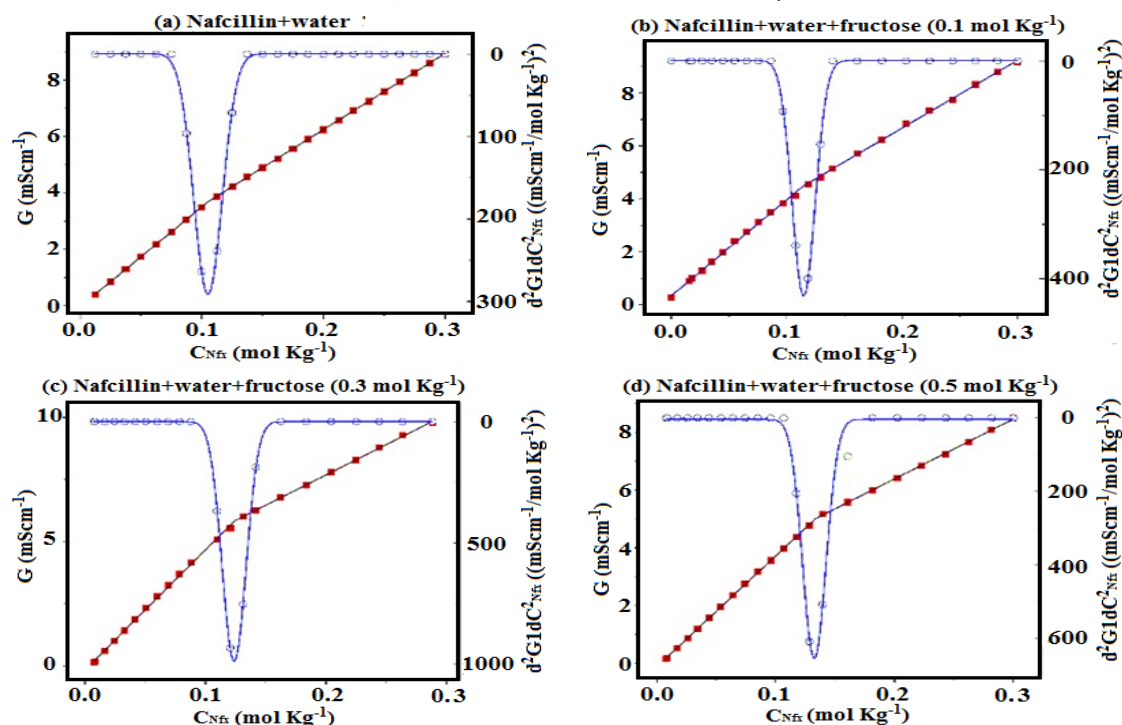


Fig. 7. Conductivities of (a) NafNa+Water, (b) NafNa+Water+Fructose (0.1 mol/Kg), (c) NafNa+Water+Fructose (0.3 mol/Kg), (d) NafNa+Water+Fructose (0.5 mol/Kg) (■—represents experimental and solid line fitting data; o - Second derivative of fitted data; solid line fitted data to Gaussian function)

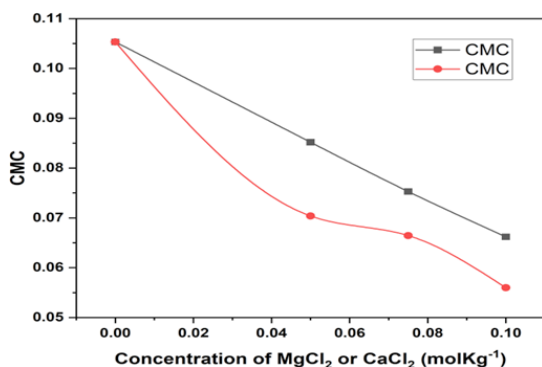


Fig. 8. CMC in NafNa+water+MgCl₂/CaCl₂ systems (■- represents CMC in presence of MgCl₂ and ●- represents CMC in presence of CaCl₂)

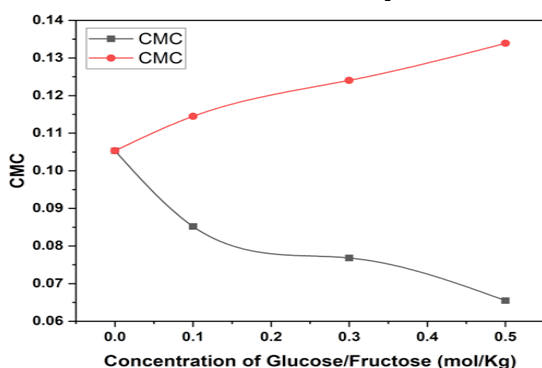


Fig. 9. CMC in NafNa+water+glucose/fructose systems (■- represents CMC in presence of Glucose and ●- represents CMC in presence of Fructose)

CONCLUSION

The Critical Micelle Concentration of Nafcillin Sodium Monohydrate in aqueous, aqueous electrolytes (CaCl₂, MgCl₂) and non-electrolytes (glucose and fructose) solutions was determined through conductometric method. CMC values

of NafNa decrease in presence of electrolytes MgCl₂ and CaCl₂ systems but comparatively higher in presence of MgCl₂ than CaCl₂. On the other hand CMC values of NafNa decrease in presence of glucose solutions but increase in presence of fructose solution. The decrease of CMC with increasing concentration of CaCl₂ and MgCl₂ is due to the minimization of electrostatic repulsion among the polar head groups of NafNa in the presence of CaCl₂ and MgCl₂. In presence of glucose, micelle formation of NafNa is facilitated and decreases the degree of hydration of the hydrophilic group. Fructose increases the CMC value of NafNa due to disruption of water cluster structure and causing the disturbance of the micelle. For the pharmacological use of medications, NafNa micellization in an aqueous environment with electrolytes and non-electrolytes present might be beneficial. The data helps us to understand the nature of the drug-electrolytes and drug-non-electrolytes interaction. It might be crucial for better drug formulation as well as medication delivery methods.

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Conflict of interest

The author declare that we have no conflict of interest.

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