MATEC Web of Conferences 67, 02021 (2016) DOI: 10.1051/matecconf/20166702021
SMAE 2016

Frequency Dependence of Conductivity Characteristics of Seawater Ionic Solution under Magnetic Field

Shaoshuai GUO[1,a], Xueyun HAN[1,b], Yufeng PENG[1,c*] and Jiangting LI[1,d]
[1]College of Physics and Electronic Engineering, Henan Normal University, Henan Xinxiang, 453007, China
[a]984473971@qq.com[1], [b]hanxueyun126@126.com [c] yufengp@htu.cn, [d]1124703335@qq.com

Abstract. The seawater ionic relaxation processes under magnetic field (B=0.38T) reveal in the properties of conductivity. The conductivity of electrolyte solutions were measured at different concentrations, after application of magnetic field the value of conductivity changed. It was found that the frequency dependence conductivity increase at low frequency and at high frequency the conductivity decrease it is consistent with the theory of Debye-Falkenhagen and the frequency dependence of conductivity decrease with concentration increase occur at low frequency no matter with magnetic field or without it. The results also shown that the relaxation time decrease with the effect of magnetic field.

1. Introduction

The conductivity of electrolyte solution is one of the most important problems in physical chemistry. Numerous work have done on the electrolyte solution and many fundamental problems have solved. A. Chandra [1] performed molecular dynamics simulations to study frequency dependent conductivity. Amalendu and Biman [2] studied the conductivity from the frequency dependent friction and concentration dependence electrolyte friction on moving ions and electrolyte solutions and also found that the dispersion of the friction occur at a higher frequency. These theory and molecular dynamics model in line with the expression of Debye–Falkenhagen (DF) [3] in low concentration solutions. T. Yamaguchi [4] also proposed a theory on frequency dependent conductivity of electrolyte solution explained the conductivity from ion-pair dynamics and effect of hydrodynamic interaction.

It is interesting to invest the influence of external physical actions on the conductivity of electrolyte solutions. The effect of magnetic field have been extensively researched in recent years. Lucyna Holysz et al. [5] investigated the effect of magnetic field on water and electrolyte solution, it was found that the conductivity and the amount of evaporated water were influenced as the magnetic field treatment causes the hydration shells around ions changes. A. Szcześ et al. [6] performed a series of experiments and found that the conductivity of water decrease and it is inversely proportional to the flow velocity after magnetic field treatment and also found that its evaporation rate increase. Fatemeh Moosavi

* Corresponding author: 984473971@qq.com

et al. [7] examined the effect of magnetic field on the solvent properties and found that the diffusivity decreases lead to interactions increase and the strength of the hydrogen bonds enhanced under magnetic field. This is consistent with results of Chang and Weng, they suggested that the self-diffusion coefficient of the water molecules decreases and the number of hydrogen bonds increases when the magnetic field strength increased [8].

In this work, the effect of magnetic field on frequency dependence of conductivity characteristics of seawater ionic solution is investigated. The solution of NaCl, $MgSO_4$, $MgCl_2 \cdot 6H_2O$, $CaCl_2 \cdot 2H_2O$, KCl and $NaHCO_3$ with different concentrations.

2. Experimental

In experiment distilled water and inorganic salt of NaCl, $MgSO_4$, $MgCl_2 \cdot 6H_2O$, $CaCl_2 \cdot 2H_2O$, KCl, and $NaHCO_3$ were used. The purity of these salts is 99.5%, twelve samples were prepared and the range of concentration is from 0.1% to 10%.Electric conductivity is measured in the frequency range from 40 Hz to 2 MHz at 12 $^\circ C$ using an impedance analyzer (IA) (4294A, Agilent Technologies). We use parallel plate capacitor with magnet (0.38 T) in the measurement and use IA to measure G-B, still five minutes in each measurement and used computer record data.

The frequency dependence of conductivity of the sample has been calculated by using the relation

$$\sigma = \frac{dG}{A} \tag{1}$$

Where d is thickness of the capacitive plate and A is the effective surface area of capacitive plate with salt solution.

3. Results and Discussion

To better visualize, in Fig. 1-6 show the frequency dependence of conductivity of different salt aqueous solutions with various concentration compare with under magnetic field. From the plots the conductivity of salt solution increase significantly at low frequency and decrease at high frequency. This phenomenon agree with the well-known theory of Debye-Falkenhagen (DF), which could be explain as that the dynamic effect of the relation of ion atmosphere on the motion of the ion. When an ion moves in electrolyte solution, the atmosphere cannot immediately follow the motion of the central ion by external electric field. It leads to asymmetric causing a retarding effect on the motion of the ion. In oscillating electric field, the central ion oscillates and the ion atmosphere gets less time to relax and remains less asymmetric. As a result, the relaxation force reduction which leads to electron mobility rate increases and enhance the conductivity at low frequency. At high frequency, the conductivity decreases because the ions oscillate so fast that the net ionic motion along a particular direction is smaller than that in the presence of a static or low frequency field. In the numerical results we could also find that with increase of ions concentration, the value of conductivity reach peak at a lower frequency because of the effective concentration of ion increase lead to electrolyte force increase. The value of conductivity increase with increasing of ion concentration.

The effects of the magnetic field on the conductivity of salt solutions are shown in Figs.1-6 (b). In the measure range of frequency conductivity have the same trend compared with no magnetic field. With 0.38T of magnetic field applied 5min, the conductivity of salt solutions are different from no magnetized sample. It can be seen, the difference in conductivity attains magnetic field have different effects on different salts. It was found that the magnetic field increase the salt solution conductivity of NaCl, $MgCl_2 \cdot 6H_2O$, KCl, and decrease the salt solution of $MgSO_4$, $CaCl_2 \cdot 2H_2O$, $NaHCO_3$. The reason is that the changes caused by magnetic field depend on many factors, the effects can explanation from the following aspects, in the low-concentration solution relaxation and electrophoretic effects are influenced. In the high-concentration solution, the structural behavior of the solution is dominated by the ions, with the effect of magnetic field, the mobility of the ions enhanced. While the magnetic field also causes changes in the hydrating water structure around the ions.

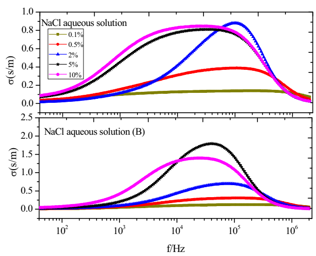


Fig. 1

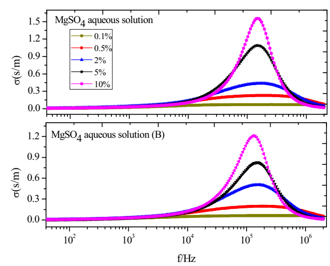


Fig. 2

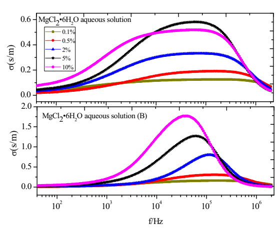


Fig. 3

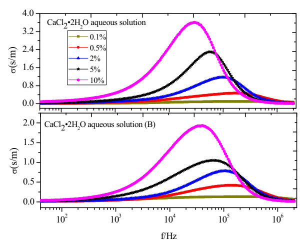


Fig.4

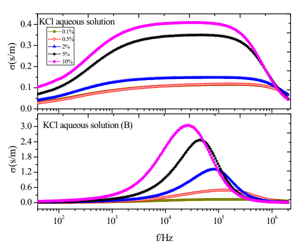


Fig.5

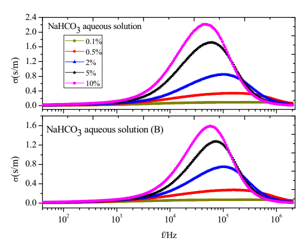


Fig. 6

Fig. 1-6. Frequency dependences of conductivity of NaCl, $MgSO_4$, $MgCl_2 \cdot 6H_2O$, $CaCl_2 \cdot 2H_2O$, KCl and $NaHCO_3$ aqueous solution with various concentrations compare with under magnetic field at $12\,^{\circ}C$.

To emphasize the effect of magnetic on the frequency dependence of the ionic conductivity, the difference of conductivity between 10KHz and 100KHz at different concentrations (at $12\,^{\circ}C$) compare with under magnetic field are plotted together in Figs. 7-12. In this paper, the relationship between conductivity and concentration is described by a new expression and this mode has been extended to higher concentrations. In Figs. 7-12, we show the example of the relationship between the plots obtained by conductivity measurement and use the curve-fitting procedure obtained the curves. In Figure 7, the change in conductivity are depicted for NaCl aqueous solution compare with under magnetic field, at low concentration the value of conductivity is higher at 100KHz than 10KHz, while in the high concentration solution the results in contrast. After application magnetic field the conductivity value increase, the differences between 10KHz and 100KHz are consistent with no magnetic field. The differences can be ascribed to ionic charge transport influenced by the concentration, frequency and magnetic field. At low concentration, the structural behavior of the salt solutions are dominated by the water molecules, at high frequency the central ion oscillates very fast and destroy molecular structure of water result in frictional force decrease. While at high concentration, the ions play a major role in the solution at high frequency the ions oscillate so fast that the net ionic motion along a particular direction is smaller and the conductivity decrease at high frequency. Since ions have their own relaxation times according frequency, the differences reflected in the frequency dispersion of the conductivity [4]. As shown in figures, the salt solutions have different results it's due to the nature of the salt solutions are determined by molten salts. Figure 8 shows the different results in $MgSO_4$ aqueous solution under the same environment, the conductivity is higher at 100KHz than 10KHz no matter with magnetic or without it. In solution of $MgSO_4$ (Figure 8), $MgCl_2{\cdot}6H_2O$ (Figure 9), $CaCl_2{\cdot}2H_2O$ (Figure 10), KCl (Figure 11) and $NaHCO_3$ (Figure 12) the conductivity difference between 10 KHz and 100 KHz is becoming bigger after magnetic field treatment. As shown in figures, magnetic treatment leads to the conductivity of NaCl, $MgCl_2{\cdot}6H_2O$, KCl solution increase, and the solution of $MgSO_4$, $CaCl_2{\cdot}2H_2O$, $NaHCO_3$ decrease. It may be expected that with the effect of magnetic field the mobility of ions enhanced in both low and high concentration solution and also influenced the electrophoretic effect of solution [9].

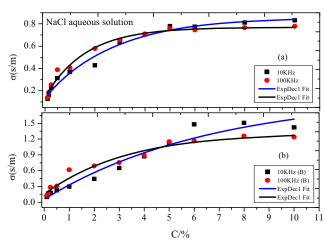


Fig. 7

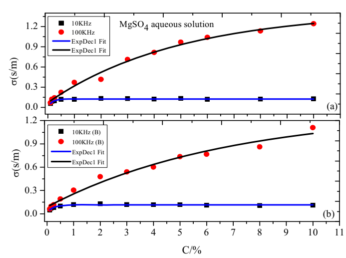


Fig.8

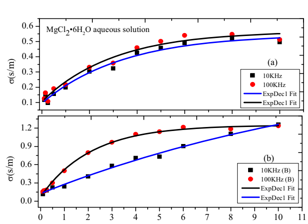


Fig.9

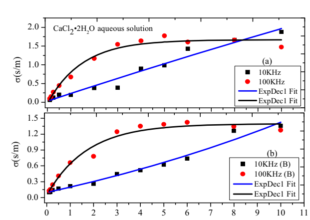
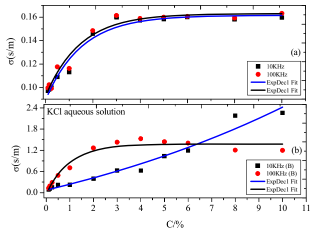


Fig. 10

DOI: 10.1051/matecconf/20166702021



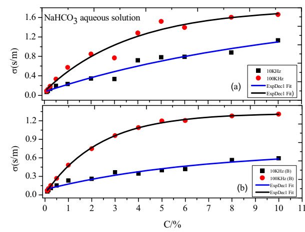


Fig. 11 Fig. 12

Fig. 7-12. Concentration dependences of conductivity of NaCl, $MgSO_4$, $MgCl_2 \cdot 6H_2O$, $CaCl_2 \cdot 2H_2O$, KCl and $NaHCO_3$ aqueous solution compare 10KHz with 100KHz. (a) without magnetic field (b) with magnetic field (at 12 $^\circ C$)

4. Conclusions

In this work we presents numerical results of the frequency dependence of conductivity for seawater ionic solutions under magnetic field (B=0.38T) of varying concentration. After application of magnetic field the value of conductivity of NaCl, $MgCl_2 \cdot 6H_2O$, KCl increase. In contrast, the solution of $MgSO_4$, $CaCl_2 \cdot 2H_2O$, $NaHCO_3$ decrease. As shown in the results, ions have their own relaxation times and the influence reflects in the frequency dependence of conductivity and with the effect of magnetic field the ionic relaxation processes is shortened. However, the changed is obvious at high concentration than at low concentration. The results suggested that the relaxation effect and electrophoretic effect are influenced by the magnetic field.

References

1. A. Chandra, D. Q. Wei, G. N. Patey, The frequency dependent conductivity of electrolyte solutions, J. The Journal of chemical physics. 99(3) (1993) 2083-2094.
2. A. Chandra, B. Bagchi, Ion conductance in electrolyte solutions, J. The Journal of chemical physics. 110(20) (1999) 10024-10034.
3. P. Debye and H. Falkenhagen, Z. Phys. 29 (1928) 121; 29 (1928) 401.
4. T. Yamaguchi, T. Matsuoka, S. Koda, A theoretical study on the frequency-dependent electric conductivity of electrolyte solutions, J. The Journal of chemical physics. 127(23) (2007) 234501.
5. L. Holysz, A. Szczes, E. Chibowski, Effects of a static magnetic field on water and electrolyte solutions, J. Journal of Colloid & Interface Science. 316(2) (2007) 996–1002.
6. A. Szcześ, E. Chibowski, L. Hołysz, et al, Effects of static magnetic field on water at kinetic condition, J. Chemical Engineering & Processing. 50(1) (2011) 124-127.
7. F. Moosavi, M. Gholizadeh. Magnetic effects on the solvent properties investigated by molecular dynamics simulation, J. Journal of Magnetism & Magnetic Materials. 354(3) (2014) 239–247.
8. K. T. Chang, C. I. Weng, The effect of an external magnetic field on the structure of liquid water using molecular dynamics simulation J. Journal of Applied physics. 100(4) (2006) 043917- 043917-6.
9. S.K. Cheng, L. Chen, N. Li, F. Cai, Experimental study of influence of magnetic field on NaCl solution conductivity, J. Chinese High Technology Letters. 10 (2010) 1091-1095.