RESEARCH ARTICLE

Physicho and electrochemical characterization of PVC incorporated ZP composite membrane and their important parameters through applying TMS equation

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Abstract: The synthetic organic-inorganic composite membranes have enormous applications in the field of filtration and purification processes. The newly synthesized PVC (polyvinyl chloride) incorporated ZP (zinc phosphate) composite membrane is used as a barrier for the transportation of some strong electrolyte solutions like KCl, NaCl and LiCl. The composite material which used to make the membrane was qualitatively synthesized by sol-gel method of material synthesis. To characterize the structural and thermal properties of membrane there are different techniques like FTIR, XRD, TGA/DTA, SEM-EDX, LCR have been used. By characterizations it is clear that the material has crystalline nature, thermally stable and no breakages or cracks are found on membrane the surface. The electrochemical observation was done by potentiometer, which shows that the membrane is cation selective. To determine the charge density of membrane Teorell-Meyer-Sievers method is used. The observed potential and charge density of the incubated membrane follows KCl<NaCl<LiCl and KCl>NaCl>LiCl order respectively. The other important parameters like transport number, mobility ratio, charge effectiveness are also calculated by observed potential values.

Keywords: PVC based ZP membrane; TMS theory; electrolyte potential; TGA/DTA analysis; Charge density of membrane.

Nomenclature

AR	Analytical reagent
C1, C2	Concentrations of electrolyte solution on either side of the membrane (mol/L)
$\overline{C}_{2+}$	Cation concentration in membrane phase 2 (mol/L)
C_i	ith ion concentration of external solution (mol/L)
$\overline{C}_i$	ith ion concentration in membrane phase (mol/L)
$\overline{D}$	Charge density in membrane (eq/L)
F	Faraday constant (C/mol)
100 Mpa	Pressure (MPa)
Q	Charge effectiveness of the membrane
R	Gas constant (J/K/mol)
SCE	Saturated calomel electrode
TMS	Teorell, Meyer and Sievers
t+	Transport number of cation
-t-	Transport number of anion

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	Mobility of cations in the membrane phase (m2/v/s)
	Mobility of anions in the membrane phase (m2/v/s)
Vk	Valency of cation
Vx	Valency of fixed-charge group
XRD	X-ray diffraction
FTIR	Fourier Transform infrared spectroscopy
PVC	Poly vinyl chloride
ZP	Zinc phosphate

Greek symbols

$\gamma_{\pm}$	Mean ionic activity coefficients
$\overline{\omega}$	Mobility ratio
$\Delta\psi_m$	Observed membrane potential (mV)
$\Delta\overline{\Psi}m$	Theoretical membrane potential (mV)
$\Delta\Psi_{Don}$	Donnan potential (mV)
$\Delta\overline{\Psi}_{diff}$	Diffusion potential (mV)

1. Introduction

The organic-inorganic composite membrane has flexible and very stable nature due to the versatile properties of used materials. Organic polymer gives much flexibility plus binding property where as inorganic material provides well mechanical stability and ion-exchange property[1–3]. So on the basis of above properties of materials the membrane broadly shows lot of applications in different important fields such as foods, drugs, dairy and beverages industries as well as pollution control, waste water treatment, fuel cells, power generation, energy saving etc. Consecutively they can also use in many other processes like electro dialysis, membrane electrolysis and electro-deionization etc[4–6].

Such types of polymer supported inorganic membranes were prepared by a simple and uniform mixing of organic and inorganic materials in a definite ratio of percentages. It is very important property of membrane that has transformed the respective electrolytes as well as heavy metal ions due to their charged, which leads to indicate the transportation of ions. The choice of polymers and inorganic materials is an important step to synthesize an innovative membrane that shows much application for scientific and industrial point of views[7–11].

In this paper we have used PVC as a binder due to their polar characteristic and economical point of views which shows very excellent mechanical stability and binding property with inorganic ZP material. In previous reported work membranes did not show such type of polymers and inorganic materials interaction as well as mechanical stability due to which this synthesized membrane shows excellent performance. The performance of such membrane is totally depends on their physical, chemical as well as morphological nature. To show good application in various fields it is very important to notice that the membrane must be unaffected through exposing into harsh or modest pH solutions. The electrochemical characterization of composite membrane that included some important physical parameters like ion exchange capacity, water content nature, transport property, thickness, thermal plus chemical stability etc[12,13]. The charge density which is very important parameter of membrane is used to identify the membrane model for application purposes. It has determined by calculating the theoretical and observed potential values of used electrolyte solutions. Related to charge density some other important parameters of membrane like transport number, mobility ratio and charge effectiveness are also calculated very easily. TMS approach has been theoretically recognized on the basis of donnan equilibrium and Nernst–Planck equation.

2. Experimental protocols

2.1. Instrumentations

Scanning electron microscopy was done by "Leo 4352" at an accelerating voltage of 20 kV. In this model the sample has mounted on a copper stub and sputter coated with gold to minimize the charging. Fourier transform infrared spectroscopy was done by "Interspec-2020" FTIR-spectrometer. The sample compartment of the model is 200 mm wide, 290 mm deep and 255 mm high, the entrance and exit beam of sample chamber is sealed with a coated KBr window and a hinged cover is used to seal from the external environment. X-ray diffraction was recorded by "Miniflex-II X-Ray diffractometer" with Cu Kα radiation. Thermogravimetric and differential thermal analysis has been done by "Shimadzu DTG-60H" under the nitrogen atmosphere by using a heating rate of 20 °C min^{-1} from 25-800 °C. The dielectric properties and impedance measurement have been carried out from 75 KHz to 5MHz frequency range by using Agilent "Model-4284A" precision LCR meter. The potentiometer "Electronic India-118" is used to observe the electrolytes potential through composite membrane[14,15].

2.2 Materials and reagents

KCl, NaCl and LiCl electrolyte solutions of different concentration are required, 200 mesh size of PVC powder, 0.2M Na_3PO_4 and $ZnCl_2$ solutions of 99.90% purity are required to make the ZP precipitate. All these reagents must be of analytical grade and double distilled water is used to prepare the above solutions.

2.3 Method

2.3.1. Sol gel method

Through sol-gel method of material preparation ZP has easily synthesized in which the mixing of 0.2 M Na_3PO_4 and $ZnCl_2$ solutions took place. A constant stirring of solution till 1-2 h has been done which result that has totally mixed with each other along by maintaining the P^H of solution. The resulting precipitate has been filtered through whatman filter paper, and the filtered material must be well washed nearly 4-5 times by deionized water to remove the free electrolytes and ions. Lastly the material has been dried by putting into an oven till 3-5 h through maintaining 100 °C temperature[16].

2.4. Designing the PVC based ZP composite membrane

To make a fine organic-inorganic composite membrane the inorganic ZP material must be homogeneously mixed with PVC in the ratio of 1:1. The mixing of both the materials has been done very carefully and cautiously through pestle and mortar until it gets totally mixed with each other. Then the material has been transferred into a special die of 2.45 cm diameter. On next step this die should be placed into a digital furnace through maintaining 100˚C temperature for 1-2 h to equilibrate the reaction mixture. Lastly it has been transferred into a pressure device of 'SL-89 UK' to apply the pressure of 5 tons which results to show the good membrane fabrication. 1:1 ratio of both the organic and inorganic materials produces very good morphological and mechanical stability. If it is exceeded or decreases the above mentioned 50-50% ratio it does not show the perfect stability and functions. Finally the stable membrane is subjected to inspect the microscopic and electrochemical observation to show the important parameters of membrane applications[9,10].

2.5. Potential observation of membrane

Through digital potentiometer 'Electronics India-118' the potential observation of electrolyte ions has been done. The solutions of KCl, NaCl and LiCl are used to obtain the ionic potential through composite membrane. It has observed by saturated calomel electrodes which kept dipped into one of the collared chamber glass cell that has unequal concentration of uni univalent electrolyte solutions. The observation has been preferred at 25–28 °C temperature. The rough diagram representation of used electrochemical setup for potential measurement is clearly

shown by Figure 1.[17,18].

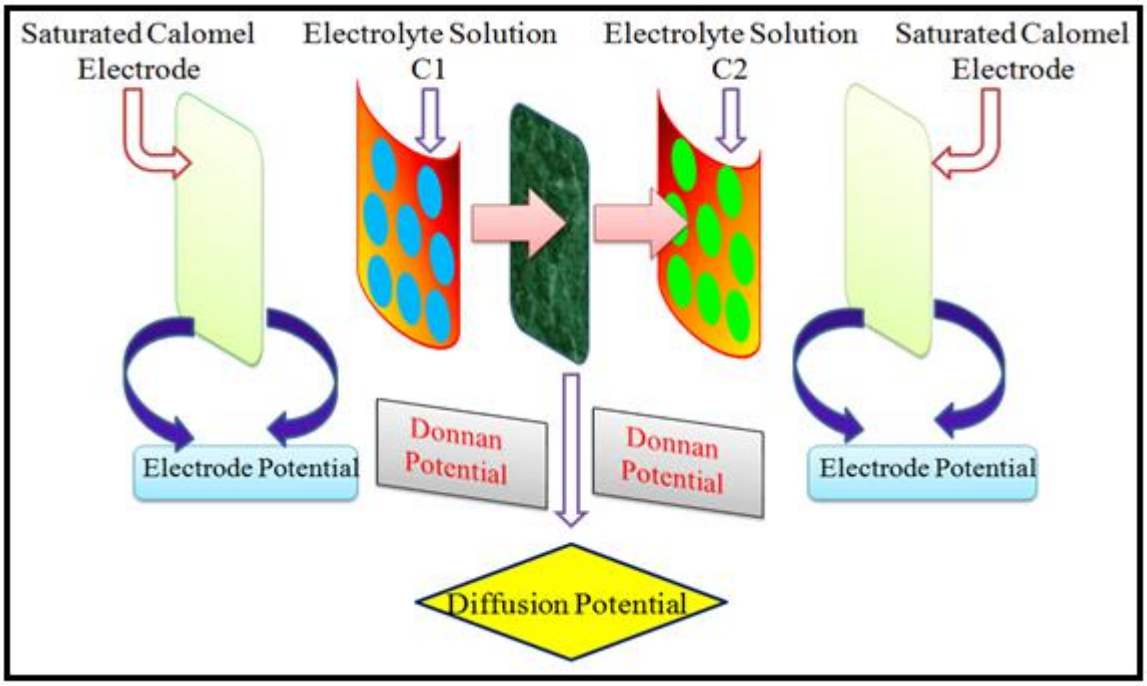

Figure 1. Electrochemical setup for ionic potential measurement

2.6. Measurement of water absorption

The water absorption or percentage of water in membrane has been calculated by the following equation.

$$\text{Water uptake (\%)} = \left(\frac{W_{wet} - W_{dry}}{W_{dry}}\right) \times 100 \quad \text{(a)}$$

Where W_{wet} is the weight of swollen membrane that is obtained by soaking into the water for 5h, and W_{dry} is the weight of dry membrane.

The porosity of membrane can also calculated very easily through the following equation.

$$\text{Porosity (\%)} = \left(\frac{Ww - Wd}{AL\rho w}\right) \times 100 \quad \text{(b)}$$

A = area of membrane, L = thickness the membrane, ρw = density of water.

2.7. Measurement of diameter, thickness and swelling.

With the help of screw gauze the diameter, thickness and swelling of membrane has been calculated through making the average thickness of 4-5th replicates. The swelling can measure by the difference between the average thickness of membrane that has equilibrated in 1 M NaCl solution and the dry membrane[19].

2.8. Dielectric properties of composite membrane

To measure the dielectric and impedance property the sample has been modified into the circular pallets and coated with silver paste on adjacent faces, thus it formed parallel plate capacitor geometry through which the values of Z, θ and C_p have been recorded. By these recorded data various dielectric parameters have calculated very easily. The dielectric loss has been calculated by the formula: tanδ =1/tanθ

Where tanδ is dielectric loss tangent which is proportional to the loss of energy from the applied field into the sample, this energy is dissipated as heat and therefore denoted as dielectric loss[14]. Real and imaginary part of impedance was calculated by using the formula: $Z' = Zcos\theta \ \ and \ \ Z'' = Zsin\theta$

2.9. Antibacterial activity of membrane

The antibacterial activity of PVC based ZP composite material was tested in vitro condition through using disc diffusion method against the two gram-positive and gram-negative bacteria Staphylococcus aureus (MSSA

22), Bacillus subtilis (ATCC 6051) and Escherichia coli (K12), Streptococcus pneumonia (ATCC,BAA-1705) respectively. The antifungal activity was also done by Candida albicans (diploid fungus). The discs of 5 mm diameter have been prepared from whatmann filter paper and sterilized by dry heat at 140 °C for 1–2 h and they were placed in nutrient agar medium. The plates have been supplied in an incubator for 24 h at 37 °C and then after it have measured. The screening was performed for 114.4 mg/ml concentration of tested composite material as well as antibiotic disc whereas the tetracycline (30 mg/disc, Hi-Media) was used to control it. The nutrient broth of logarithmiely serial took place by two fold diluted amount of tested composite material. It controls by inoculated within the range of 107–108 cfu/ml, however the highest dilution are required to capture the growth of bacteria. To spread on the agar plates each one has 0.1 ml volume diameter zone and the number of colony forming units (cfu) has counted after passing the 24 h[14–16].

3. Theories

The methods which are commonly used to evaluate the fixed charge density of composite membranes are TMS[20–22], Altug and Hair [23], Kobatake *et al.*[24,25] and the most recent one is Nagasawa and coworkers[26,27]. But for this study we applied the TMS approach which has several important points and postulations and they are illustrated as follows.

According TMS approach there must be found an equilibrium development at the all interfaces of solution and membrane which has the proper connection with Donnan equilibrium. The important postulations are described as follows:

(a) The transference of water from either side of membrane may be ignored; (b) The ionic movements as well as concentration of fixed charges are constant throughout the membrane matrix, (c) It is also independent on the salt concentration of solution. Additional assumptions are that the activity coefficient of salt is similar in both the solution as well as membrane phase. The introduction of activities for salt concentrations can only be approved through donnan potential by using Planck's or Henderson equation. The TMS graphical approach determines the important fixed charge density, transport number and cation-to-anion mobility ratio of membrane[10,12].

4. Result and discussion

SEM supported EDX is represented by Figure 2 which demonstrated the morphological structure as well as elemental percentage of composite membrane. It is illustrating that the mixing of composite material has been done very carefully which results to show that the examined membrane has homogenous and porous characteristic. There is no any visible breakage or cracks are found on the surface of composite ion exchange membrane. So it is indicating that the PVC has excellent binding nature with ZP inorganic ion exchange material[28].

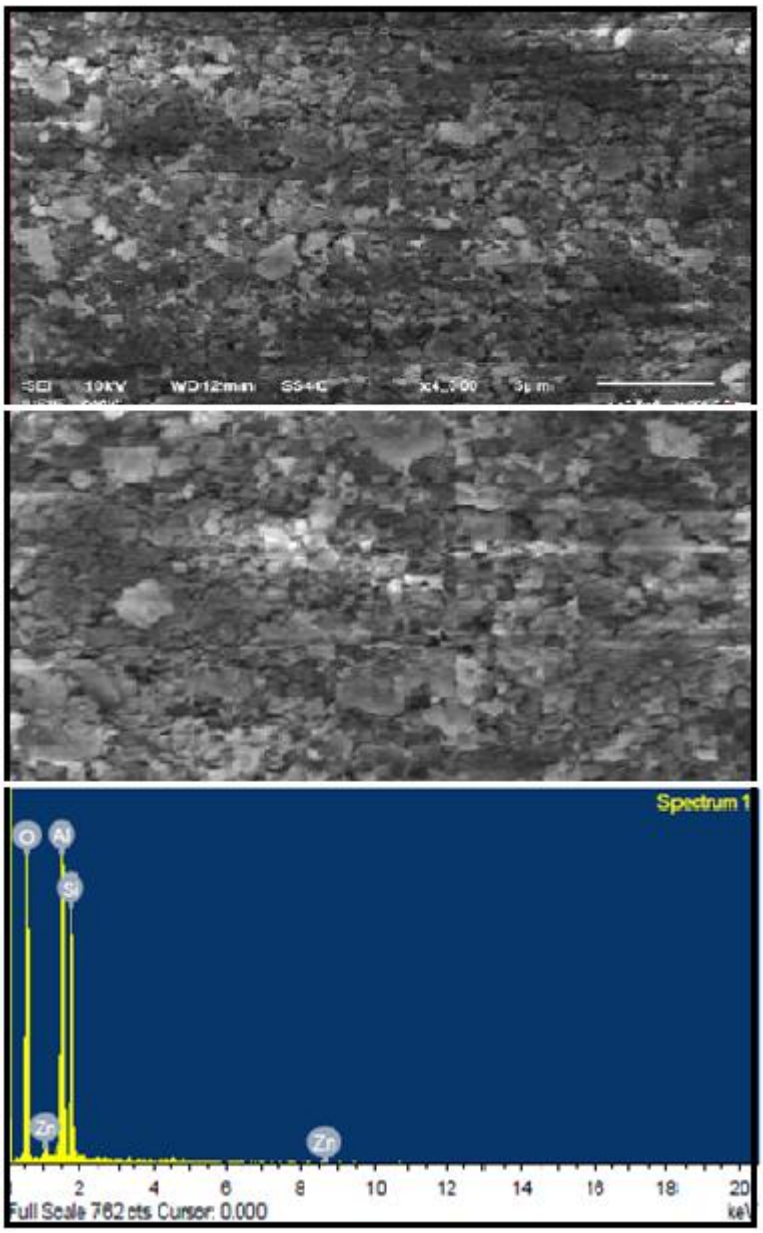

Figure 2. SEM supported EDX images of PVC based ZP composite membrane

Figure 3 illustrated the FTIR spectrum of ZP and PVC based ZP composite material, which indicated the presence of different groups at different ranges. In only ZP material there is a broad peaks near the range from 1500-1600 cm^{-1} and 3400 cm^{-1} assigned to -OH- bending and stretching vibrations respectively. A set of characteristic peaks at the ranges from 1200-500 cm^{-1} are attributed to the complex stretching and bending vibration of PO_4^{-3} group. Whereas all the peaks in PVC based ZP composite material shows rather broaden characteristic as compare to only ZP material. It shows the above difference of peak broaden due to the presence of organic PVC polymer which has double bond, CH_2 and Cl-C-H molecules[29].

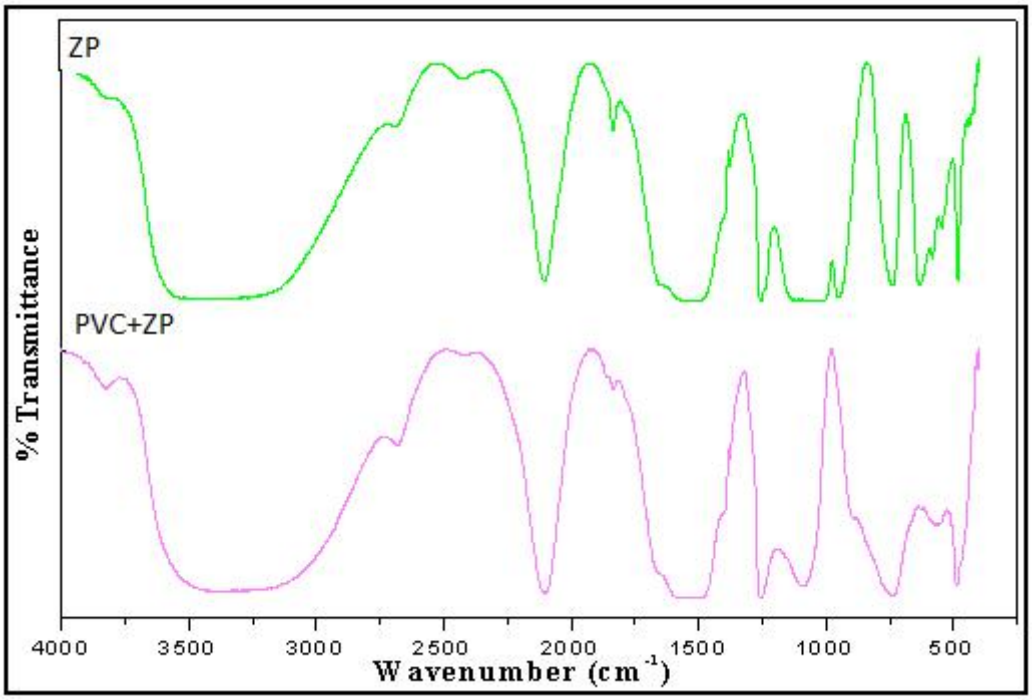

Figure 3. FTIR Spectra of only ZP and PVC based ZP composite material

XRD spectra of the sample are shows in Figure 4 which tells that the presence of sharp peaks indicated the crstallinity in nature. XRD analysis was done by using owder-x software and crystal structure observed was monoclinic with lattice parameters a =8.687, b= 9.177, c =8.264 A^0. It was observed that most intense peak present at 31.2 corresponds to (112) plane, further many other peaks are present at, 20.6 ($\bar{2}$01), 22 (021), 24.4 (210) 27.7 ($\bar{2}$12), 34.1 ($\bar{3}$12), 35 (221), 39.6 (212), 45.3 ($\bar{4}$03), 46.6 ($\bar{4}$22) 50.1 (213), 53.9 (043), 58.7 ($\bar{3}$15) and at 60.4 ($\bar{2}$44). XRD results were found to be matching with data base JCPDS No: 301489[30].

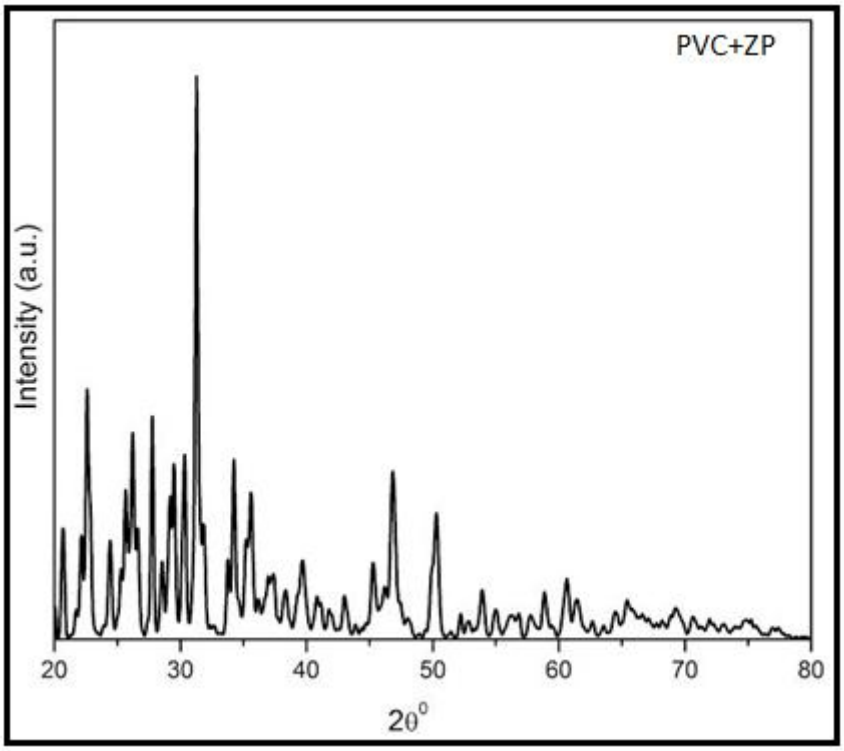

Figure 4. Xrd spectra of PVC based ZP composite material

Thermo gravimetric graphical analysis is indicated by Figure 5 which stated about the material degradation

of ZP and PVC based ZP material at different temperature ranges. The ZP and PVC based ZP material shows only one time approximately 11.38 % (5.08mg) and 19.29% (2.87mg) weight loss respectively at the range from 0-900°C. It indicated that the sample of composite membrane has endothermic nature which means that increasing the temperature leads to weight loss in material. So it is clear that the material has high hydrophilic nature which can easily absorb moisture from the surrounding atmosphere.

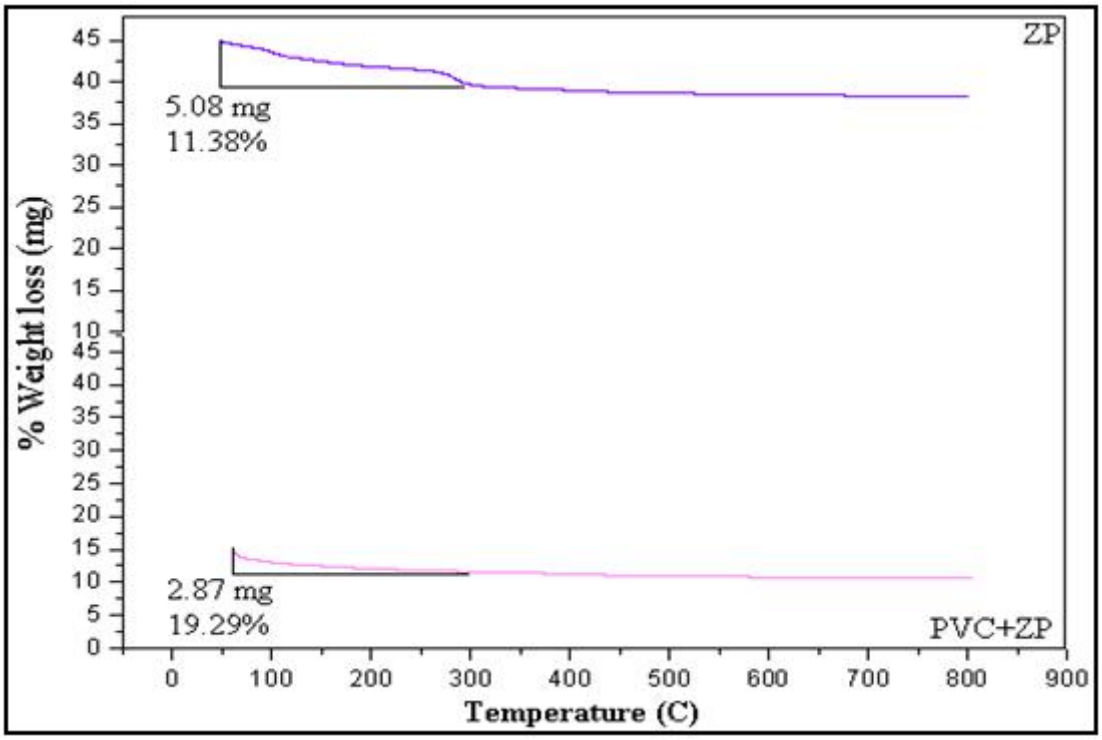

Figure 5. TGA spectral analysis of PVC based ZP composite material

By Figure 6 it is clear that the dielectric constant of PVC based ZP composite material shows variation with frequency means that it shows frequency dependent behavior. The dielectric constant is decreases by increasing frequency; firstly it has haphazardly decreases and then move to constant. Through graph the dielectric loss also shows complementary result with respect to dielectric constant which indicated that the dielectric loss is directly proportional to dielectric constant. The graph indicated that the real part of impedance also shows strong frequency dependent behavior at very low frequency and the value of $Z' = Zcos\theta$ has increasing quickly. Then after at high frequency it was frequency independent and again on higher frequency it has to showed constant behavior which has calculated by the given formula. The graph of imaginary part of impedance $Z'' = Zsin\theta$ shows the frequency dependent behavior means that increasing quickly at zero frequency or slightly more than that but again at high frequency they are behaving constant nature[31].

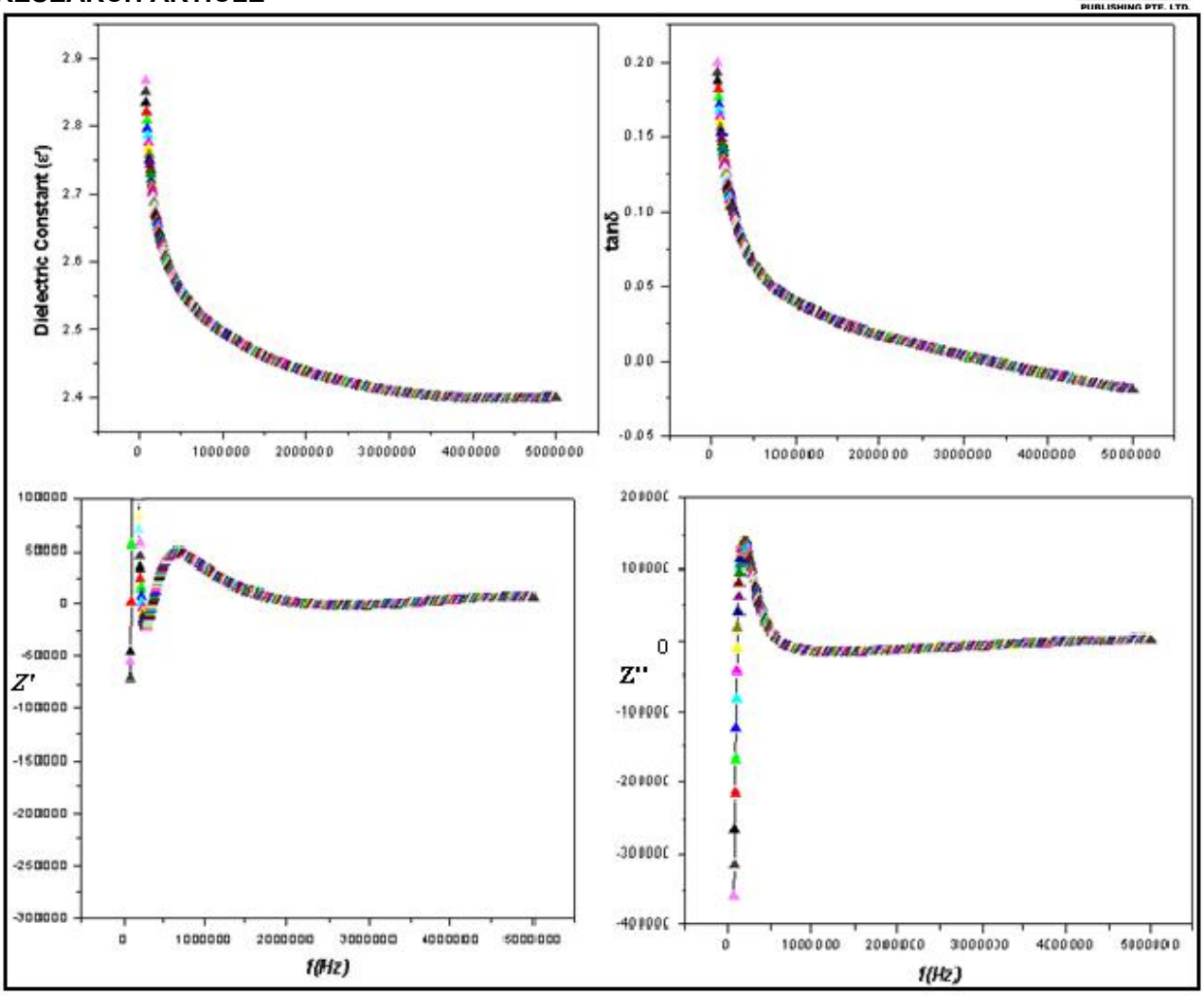

Figure 6. Dielectric nature of PVC based ZP composite membrane

The observation has been carried out to investigate the antibacterial action of composite material which is shown in Table1. The two gram-positive, two gram-negative bacteria and a diploid fungus were used to analyze the activity with the concentration range from 200 to 800 mg/ml. Tetracycline drug has been used as a standard for the comparison of bacterial results and examined data which is also present in the above table. Therefore it is clear that the newly synthesized PVC based ZP material has extraordinary inhibitory effects against the growth of the bacterial strains. The data shows that the materials of composite membrane illustrate evidences of activity against different types of used bacteria and fungus. Therefore it is clear that the above used composite material can be used as a potent antibacterial and antifungal agent.

Table: Antimicrobial activity of the test samples

Sample	Conc. (µg/ml)	*B. subtilis*	*S. aureus*	*E. coli*	*K. pneumoniae*	*C. albicans*
PVC+Zn-P	200	-	-	-	-	-
	400	11	13	11	14	13
	800	16	16	21	20	17
Tetracycline	30(µg/disc)	19	21	24	20	-

Value indicate the diameter of the zone of inhibition
-Indicates no activity

Table 1. Zone of inhibition by gram-positive and gram-negative bacteria

To show the chemical stability the membrane has been tested in different pH solutions that may be acidic, basic as well as alkaline. It is observing that the passing of time from 36-48 hrs membrane become weak due to the harsh environment of solutions which indicated that the membrane can exhaustive in such solutions and it get loses their mechanical stability. Therefore it is very exclusive feature of composite membrane that it must have high thermal and chemical stability[32].

The membrane diameter, porosity, water content percentage and swelling are designated by Table2.

Applied Pressure (Mpa)	Diameter (cm)	Thickness of membrane (cm)	Water content as % weight of wet membrane	Porosity	Swelling of % wet membrane
100	2.45	0.070	0.032	0.012	No swelling

Table2. Thickness, porocity, swelling and diameter of PVC based ZP composite membrane

The porous membrane created potential of ions due to unequal concentration of used electrolytes present in the glass cell. It has transformed the cations of electrolytes from higher to lower concentration as well as adsorb anions on the surface. It is clear through observed potential data which shows by Figure 7 that the ionic potential of electrolytes are directly increases by reducing the electrolyte concentration which suggested that the membrane has negative charge as well as cation selective. The selectivity of ions created due to charged membrane surface and this activity of ions is more flourished in high concentrated region over the dilute one. The anions do not influence the potentiometric respond so the setup shows positive potential order and follows Nernst equation[33].

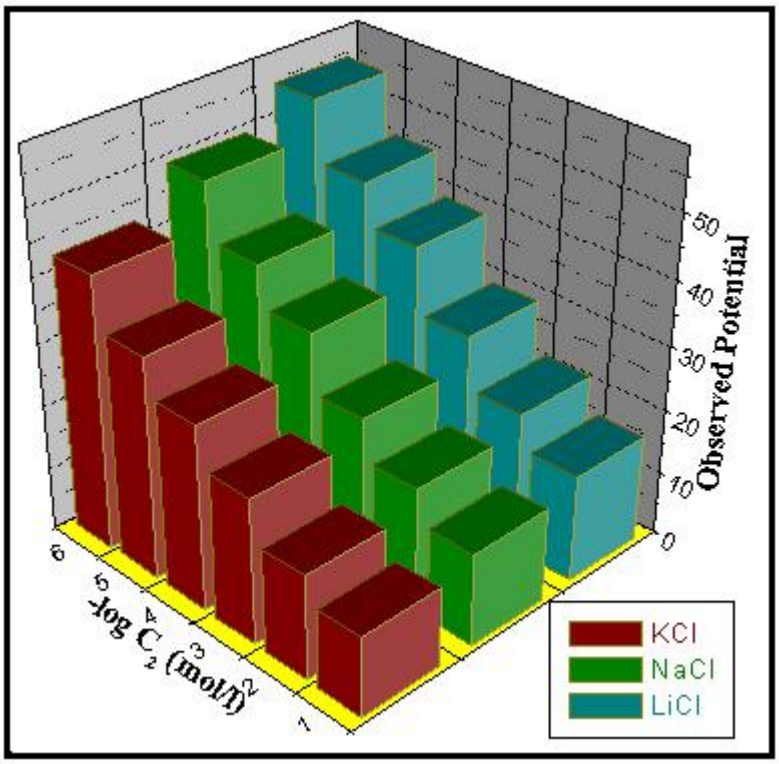

Figure 7. Plots of observed membrane potentials against logarithm of concentration for PVC based ZP composite membrane

In all types of composite membrane the most significant electrochemical property is the difference in permeability of co-ions, counter ions as well as neutral molecules. Charge on membrane is necessary to generate the good potential which is totally depends on the pore sizes of membrane. If pores are broad then a lot of charges

are required to generate good potential where as in narrow one it shows an opposite behavior. The transportation within the membrane can't be completed without evaluating the thermodynamically effective fixed charge density. It is obtained by the coinciding point which shows in the combined graphical representation of dark and broken line represented by Figure 8. The above theoretical and observed potential value shows by dark and broken line respectively and the graph were plotted as a function of –log C_2. The values of charge density always shows $\bar{D} \leqslant 1$ and it is found to depend on the initial stage of material preparation. For the above used electrolyte solutions the charge density follows KCl>NaCl>LiCl order and this order is due to the size factor of electrolytes[34,35].

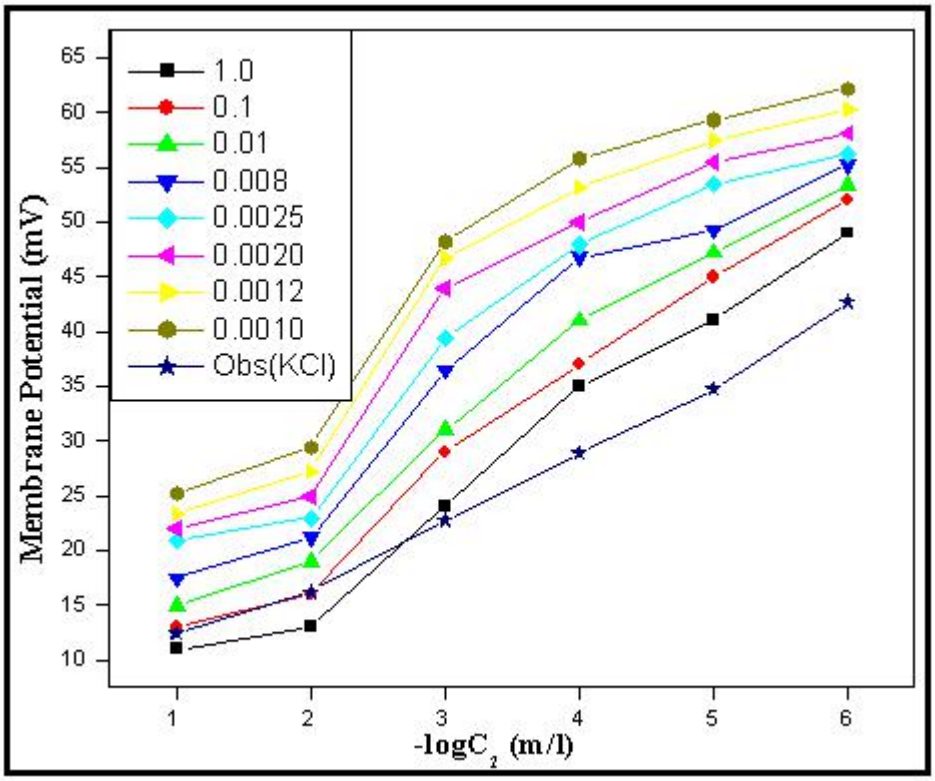

Figure 8. Plots of membrane potential (theoretical and observed) against logarithm of concentration of KCl electrolyte solution for PVC based ZP composite membrane

The electrochemical setup shows two donnan potential at the two solution membrane interfaces. The incubated membrane arise diffusion potential due to unequal electrolyte concentrations. It is resulting that there is an internal salt diffusion potential took place which represented by Henderson equation and leads to Planck expression. TMS theory always given very appropriate result on high concentration because in low concentration it shows relatively high deviation between observed and calculated potential values. There are some important theories discussed earlier which was used to determine the membranous important parameters but the applicability of TMS theory is much more in membrane technology[36,37].

TMS theory explains the membrane potential by the following Eq.1.

$$\Delta\bar{\Psi}_m = 59.2\left(\log\frac{C_2}{C_1}\frac{\sqrt{4C_1^2+\bar{D}^2}+\bar{D}}{\sqrt{4C_2^2+\bar{D}^2}+\bar{D}} + \bar{U}\log\frac{\sqrt{4C_2^2+\bar{D}^2}+\bar{D}\bar{U}}{\sqrt{4C_1^2+\bar{D}^2}+\bar{D}\bar{U}} \right) \quad (1)$$

$$\bar{U} = (\bar{u}-\bar{v})/(\bar{u}+\bar{v})$$

$C_1$and C_2 is concentration of phase1 and 2, $\bar{D}$ is charge density on membrane and $\bar{u}$ and $\bar{v}$ are the ionic mobility of cations and anions.

The Eq.1 can also be express by the sum of donnan potential ($\Delta\Psi_{Don}$) and diffusion potential ($\Delta\Psi_{Diff}$).

$$\Delta_{m;e} = \Delta\Psi_{Don} + \Delta_{diff} \quad (2)$$

$$\Delta_{Don} = -\frac{RT}{V_k F}\ln\left(\frac{\gamma_{2\pm}C_2\bar{C}_1}{\gamma_{1\pm}C_1\bar{C}_2}\right) \quad (3)$$

R, T and F have their standard meanings, $\gamma_{1\pm}$ and $\gamma_{2\pm}$ are mean ionic activity coefficients, C_{1+} and C_{2+} are the cation concentrations on phase 1 and 2

$$\bar{C}_{\pm} = \sqrt{\left(\frac{V_x\bar{D}}{2V_k}\right)^2 + \left(\frac{\gamma_{\pm}C}{q}\right)^2} - \frac{V_x\bar{D}}{2V_k} \quad (4)$$

Vk and Vx is the valency of cation and fixed-charge groups on membrane respectively and q is charge effectiveness of membrane

$$q = \sqrt{\frac{\gamma_{\pm}}{K_{\pm}}} \quad (5)$$

Where K± is distribution coefficient and it is express as:

$$K_{\pm} = \frac{\bar{C}_i}{C_i}, \bar{C}_i = C_i - \bar{D} \quad (6)$$

$\bar{C}_i$ and Ci is ith ion concentration in membrane and external solutions respectively. The diffusion potential can calculated as follows:

$$\Delta\bar{\Psi}diff = -\frac{RT}{V_k F}\frac{\bar{\omega}-1}{\bar{\omega}+1}\times\ln\left(\frac{(\bar{\omega}+1)C_{2+}+(V_x/V_k)\bar{D}}{(\bar{\omega}+1)C_{1+}+(V_x/V_k)\bar{D}}\right) \quad (7)$$

$\bar{\omega}$ = u/v is the mobility ratio of cation to anion in membrane phase. Therefore the total membrane potential can obtain by simple addition of $\Delta\Psi_{Don}$ and $\Delta\Psi_{diff}$

$$\Delta\bar{\Psi}_{m,e} = -\frac{RT}{V_k F}ln\left(\frac{\gamma_{2\pm}C_2\bar{C}_{1+}}{\gamma_{1\pm}C_1\bar{C}_{2+}}\right) - \frac{RT}{V_k F}\frac{\bar{\omega}-1}{\bar{\omega}+1}\times\ln\left(\frac{(\bar{\omega}+1)C_{2+}+(V_x/V_k)\bar{D}}{(\bar{\omega}+1)C_{1+}+(V_x/V_k)\bar{D}}\right) \quad (8)$$

$$\Delta\bar{\Psi}_m = \frac{RT}{F}(t_+ - t_-)\ln\frac{C_2}{C_1} \quad (9)$$

Where $\frac{t_+}{t_-} = \frac{\bar{u}}{\bar{v}}$ (10)

Transport number (t_+) and mobility ratio ($\bar{\omega}$) are easily calculated by Eq. (9) and (10). To show the applicability of TMS equation the diffusion and donnan potential have been easily calculated through observed potential values. The equation's parameters $\gamma_{1\pm}$, $\gamma_{2\pm}$, $\bar{C}_{1+}$, $\bar{C}_{2+}$, $\bar{\omega}$, V_x, V_k and $\gamma_{\pm}$ have the usual charted values. By the theoretical approach it is clear that the higher transport number follows high mobility ratio and it is also increases by decreasing the concentration of electrolyte solutions. It is also stating that the transport number and mobility ratio through the composite membrane follows LiCl>NaCl>KCl order which shows by Figure 9 and Figure 10 respectively[38].

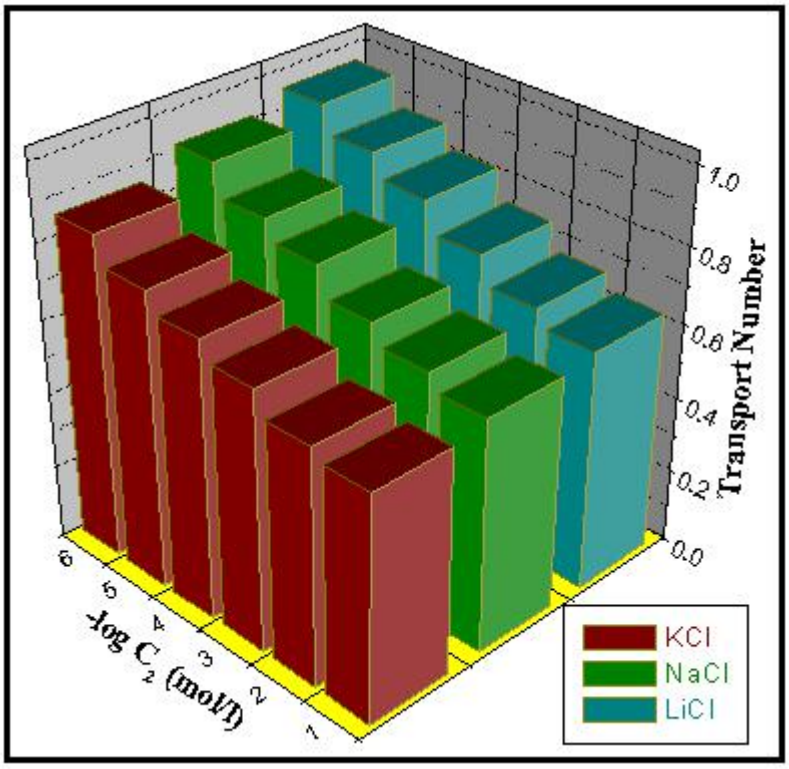

Figure 9. Plots of transport number against logarithm of concentration of PVC based ZP composite membrane

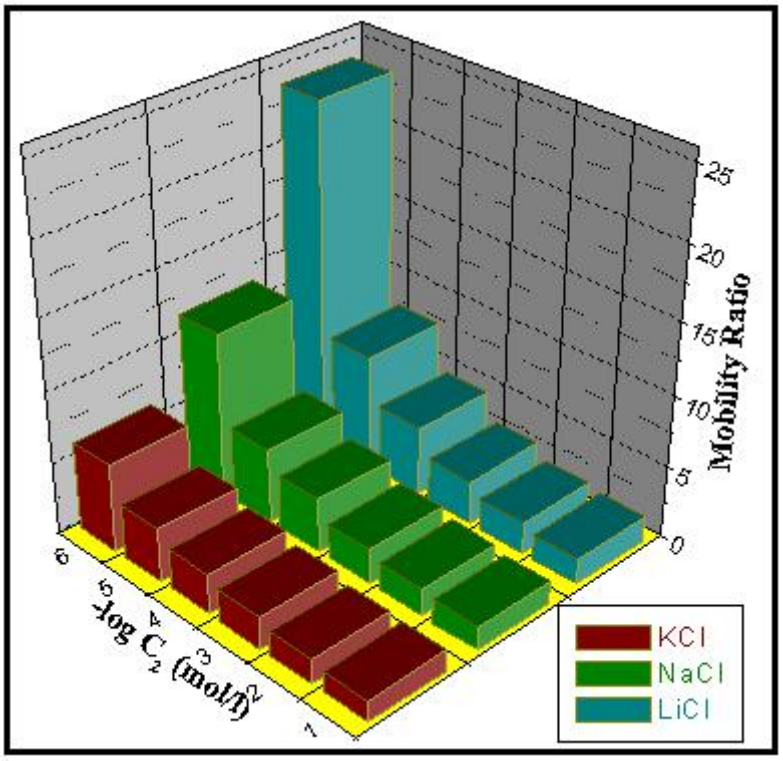

Figure 10. The plot of mobility ratio against logarithm of concentration of PVC based ZP composite membrane

The values of $U = (t_+ - t_-)$ are also represented by Figure 11.

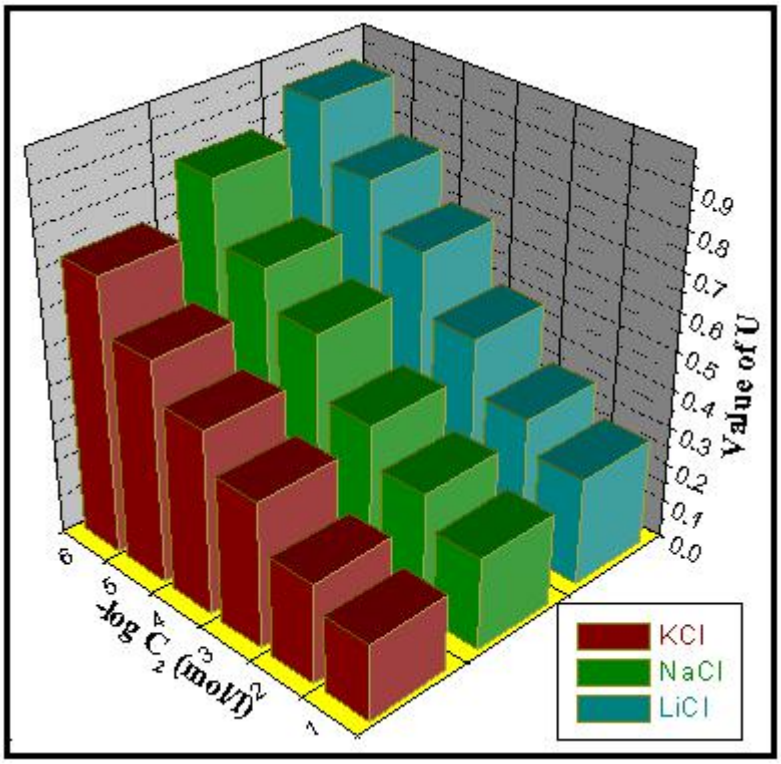

Figure 11. The plot of (U) value against logarithm of concentration of PVC based ZP composite membrane

The charge density by all the electrolytes has been calculated through the equations (3) and (7) are representing in Table3. It is also an important property of membrane that the distribution coefficients of electrolytes solution are decreases by increasing the concentration[39].

Membrane Potential Conc.	KCl	NaCl	LiCl
1.0	12.4	14.4	16.6
0.1	16.2	19.5	21.9
0.01	22.8	25.5	29.7
0.001	28.9	34.4	39.6
0.0001	34.7	40.5	45.9
0.00001	42.7	49.4	54.9
Charge Densities($Dx10^{-3}$eq/l)	2.23	1.97	1.63

Table 3. Observed membrane potential across the PVC based ZP composite membrane in contact with various 1:1 electrolytes solutions at different concentrations

Conclusions

By experimental study it is clear that the PVC based ZP composite membrane has appropriate mechanical and chemical stability due to good polymer interactions. The ZP has been successfully synthesized through sol–gel method of material synthesis. The characterization techniques stated good indication to show an idealized function of membrane according to their desired characteristic. The ion exchange capacity explaining that the composite material has cation selective nature through which the membrane shows negative charged characteristic. The membrane thickness, porosity, diameter and water incorporation has been reported very clearly through the experimental observation. TMS theoretical approach is well agreed according to experimental result which can see by getting the satisfied value of charge density. Charge density is the central parameter that governs the

transport phenomena of membrane and it is depended on feed composition and applied pressure of membrane. The membrane potential of uni-univalent electrolytes shows KCl<NaCl<LiCl order whereas the charge density follows reverse order. So the above discussed membrane model can be acceptable and withstand for upcoming works and it may be more important in the range of commercial purposes.

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