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2 ND INTERNATIONAL SCIENCE, ENGINEERING AND TECHNOLOGY COLLOQUIUM



THE POWER OF SCIENTIFIC INNOVATION

INTELLIGENT SOLUTIONS FOR A SUSTAINABLE WORLD

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PREFACE

Welcome to the 2nd International Science, Engineering and Technology Colloquium 2025 (ISETC 2025)!

It is with great pleasure that we present this year's colloquium, a distinguished gathering of scholars, researchers, and professionals dedicated to the advancement of applied sciences. Held virtually on 9th July 2025, ISETC 2025 serves as a platform to highlight cutting-edge research, foster meaningful networking, encourage collaborations, and explore innovative solutions to global challenges.

This year's theme, "The Power of Scientific Innovation: Intelligent Solutions for a Sustainable World" highlights our shared goal to solve global challenges through applied science. It celebrates innovation as a key to building a more sustainable and resilient future. We're proud to feature keynote speakers and presenters who bring fresh insights, bold ideas, and breakthroughs shaping tomorrow's world.

We would like to extend our heartfelt appreciation to the Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, for their outstanding support and assistance throughout the planning and execution of the event. Their dedication has been instrumental to the success of this colloquium. We would like to sincerely thank all participants and researchers for their valuable contributions. We also appreciate the reviewers for their careful evaluations and helpful feedback. Your hard work and support mean a lot to us.

As editors, we are proud to present this collection of proceedings. It is an honour to bring together the interesting and meaningful work of our speakers and authors. We hope the ideas shared will lead to new discoveries, encourage more research, and help solve global challenges through science and innovation.

Warm regards,

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
Ms. Nurul Nazwa Mohammad
Ms. Rozaina Saleh

ISETC 2025 Proceedings Editors

MOLAR CONDUCTIVITY AND ION TRANSPORT BEHAVIOUR OF KAPPA CARRAGENAAN (κ-CAR)-LiCl BIOPOLYMER ELECTROLYTES AT VARYING TEMPERATURES

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Abstract: The limiting molar conductivity (Λ^o) and ion transport behavior of a kappa-carrageenan (κ-car) and lithium chloride (LiCl) in aqueous medium biopolymer electrolyte system at various temperatures 25 °C-50 °C and polymer concentrations (Cpoly) of $1.0x10^{-3}$ 1g/cm³ - $3.0x10^{-3}$ g/cm³ are measured for a range of salt concentration of $1.00x10^{-4}$ to $2.821x10^{-8}$ mol/cm^3 using a simple AC conductivity meter connected with its electrode. The Λ^o for each system is determined after the Kohlrausch equation. The results show that the Λ^o increases with temperature, indicating ion pairing happened, decreases salt dissociation (α), and increase ion-ion association. As the polymer concentration increases, a decreasing trend in conductivity is observed due to the restriction of ion movement and stronger ion-polymer interactions. Enhanced interactions between polymer and salt in the κ-car/LiCl system contribute to better ionic conductivity response with temperature. The activation energy (Ea) of the system is calculated using the Arrhenius equation, supporting the temperature-dependent conductivity behavior. These findings contribute to the advancement of eco-friendly biopolymer electrolyte systems for potential applications in green electrochemical devices.

Keywords: *Limiting molar conductivity (Λ_o), AC conductivity meter, Kohlrausch equation, activation energy (Ea), eco-friendly*

INTRODUCTION

Over the years, research on eco-friendly polymer electrolytes has attracted significant attention from researchers worldwide due to the increasing demand for sustainable, non-toxic, and biodegradable alternatives in energy storage systems (Barbosa et al., 2022). Traditional liquid electrolytes, which often involve flammable and environmentally harmful solvents, pose safety risks and ecological concerns. This has led to growing interest in solid and gel polymer electrolytes derived from natural materials, particularly those that can offer both safety and high ionic conductivity (Bertaglia et al., 2024).

Kappa-carrageenan (κ-car), a natural polysaccharide extracted from red seaweed, is a promising candidate as a polymer host matrix due to its excellent film-forming ability, biodegradability, and abundance of functional groups such as sulfate and hydroxyl groups (Cheng et al., 2022). These groups can actively participate in ionic coordination, thus enhancing ion transport within the matrix. Its hydrophilic nature and ability to form stable, flexible films make it suitable for application in biopolymer electrolyte systems (Huang et al., 2019). Moreover, the eco-friendly nature of κ-car aligns with the development goals for green and sustainable energy materials (Barbosa et al., 2022).

In this system, lithium chloride (LiCl) is incorporated as the lithium-ion source. LiCl dissociates in the aqueous medium under thermodynamic interaction, producing a high concentration of free-moving Li^+ ions. These ions coordinate with the active sites along the κ-car polymer backbone, particularly the negatively charged sulfate groups (Chattopadhyay et al., 2023). This ion–polymer coordination is essential for establishing ion conduction pathways within the biopolymer matrix. Under an applied potential difference, the mobility of the Li^+ ions increases, facilitating efficient ionic conductivity.

As the concentration of κ-car increases, the polymer network becomes denser, which may enhance ion–polymer interactions due to the availability of more active sites. However, excessive polymer content could also increase viscosity and hinder ion mobility, thus potentially reducing the overall conductivity (Zakaria et al., 2023). Therefore, understanding the balance between ion coordination and ion mobility is crucial in optimizing the performance of κ-car-based biopolymer electrolytes.

MATERIALS AND METHODS

The experiment was initiated by preparing κ-carrageenan (κ-car) stock solutions at concentrations of $1.0x10^{-3}$ 1g/cm³ - $3.0x10^{-3}$ g/cm³. Each solution was prepared by dissolving κ-car in ultra-pure water at 50 °C under continuous stirring for 48 hours. Subsequently, lithium chloride (LiCl) was added to each κ-car stock solution, and the mixtures were stirred at 50 °C for another 48 hours to form the liquid polymer electrolyte (LPE) systems.

After cooling to room temperature, the solutions were subjected to serial dilution to produce approximately 15–17 different concentrations for each κ-car system. The ionic conductivity of each diluted solution was measured using an AC conductivity meter across a temperature range of 25 °C to 50 °C, with measurements taken at 5 °C intervals.

The molar conductivity (Λ) for each sample was calculated using the equation $\Lambda = \kappa / C_{salt}$, where κ represents the measured ionic conductivity and C_{salt} is the salt concentration. The limiting molar conductivity (Λ_0) was determined based on Kohlrausch's Law, and the activation energy (Ea) for each system was obtained from Arrhenius plots constructed from the temperature-dependent molar conductivity data.

RESULTS AND DISCUSSION

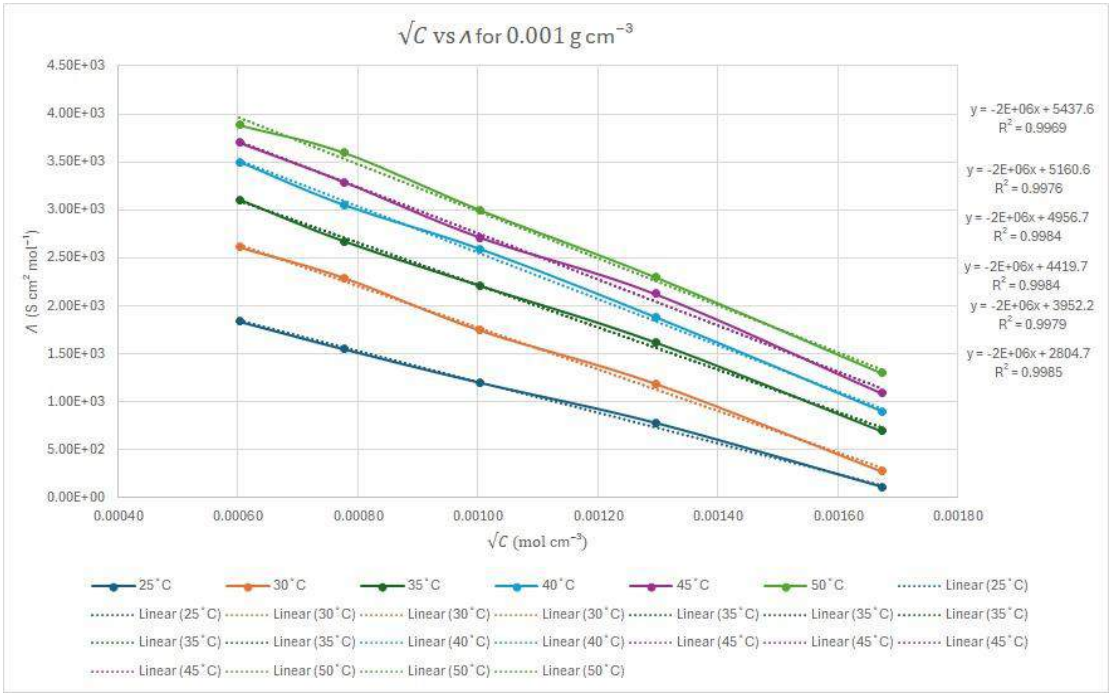


Figure 1. LiCl k-car solution (0.001 gcm^{-3})

Table 1. LiCl k-car solution

No	Concentration, mol/cm	25˚C	30˚C	35˚C	40˚C	45˚C	50˚C
1	$1.00x10^{-4}$	8080	41350	41650	30350	24450	24450
2	$6.00x10^{-5}$	5040	25700	25900	28000	30600	30600
3	$3.60x10^{-5}$	3160	16155	16200	17845	19355	19355
4	$2.16x10^{-5}$	2020	10350	10405	11365	12600	12600
5	$1.30x10^{-5}$	1311.5	6650	6780	7490	8325	8325
6	$7.78x10^{-5}$	886	4535	4360	5170	5640	5640
7	$4.67x10^{-6}$	639.5	3295	3320	3760	4040	4040
8	$2.80x10^{-6}$	483	2495	2505	2820	3055	3055
9	$1.68x10^{-6}$	393	2040	2070	2340	2560	2560
10	$1.01x10^{-6}$	339	1757.5	1789	2035	2020	2020
11	$6.05x10^{-7}$	303	1587.5	1613.5	1843.5	1990	1990
12	$3.63x10^{-7}$	284	1475	1500	1740.5	1900	1900
13	$2.18x10^{-7}$	274	1425	1460.5	1680	1850	1850
14	$1.31x10^{-7}$	265	1370	1460.5	1613	1746.5	1746.5
15	$7.84x10^{-7}$	264	1486.5	1408.5	1628	1771.5	1771.5
16	$4.70x10^{-7}$	262	1508	1423	1665.5	1797.5	1797.5
17	$2.82x10^{-7}$	256	1427.5	1399	1667.5	1835.5	1835.5

Conductivity data show that the molar conductivity Λ ($S \cdot cm^2 \cdot mol^{-1}$) of LiCl in κ-carrageenan solution increases with temperature at both polymer concentrations. This behavior indicates that ion mobility grows as temperature rises – higher thermal energy reduces solution viscosity and accelerates ion diffusion. Such thermally-activated conduction is well established: conductivity typically follows an Arrhenius relation (σ or $\Lambda \propto \exp(-Ea/RT)$). For example, Li et al. (2023) report that polymer electrolyte conductivities fit an Arrhenius plot, yielding low activation energies and faster ion transport at higher T. Similarly, Saeed and Abdullah (2020) observed that the impedance semicircles shrink with increasing temperature, "denoting the increase in conductivity value with increasing temperature". In our data the $\ln(\Lambda)$ vs 1/T plots were linear, and the slope (–Ea/R) gives the activation energy Ea.

Comparing the two κ-carrageenan concentrations, we find that higher polymer concentration yields lower Λ (at any given temperature). In other words, adding more κ-carrageenan depresses molar conductivity. This trend is consistent with the increased solution viscosity and stronger ion–polymer interactions at higher polymer loading. A more viscous medium slows ionic motion (Walden's rule: $\Lambda\eta \approx$ constant), so increasing κ-carrageenan (which raises η) lowers Λ. Thus, the 0.002 g/cm^3 κ-car samples always showed smaller Λ values than the 0.001 g/cm^3 samples, reflecting reduced mobility of Li^+ and Cl^- in the denser polymer matrix.

Limiting molar conductivity (Λ_0) – the value at infinite dilution – was obtained by extrapolating Λ vs $\sqrt{C}$ to zero concentration. According to Kohlrausch's law, a plot of Λ against $\sqrt{c}$ is linear at low c (for a strong electrolyte), and the intercept gives Λ_0. We found that Λ_0 increases with temperature, as expected from reduced viscosity at high T. (Walden's rule predicts $\Lambda_0 \propto 1/\eta$, so as η falls with T, Λ_0 rises.) From the Arrhenius behavior of Λ_0 vs T we calculated the activation energy for ionic conduction Ea: using $\ln(\Lambda_0)$ versus 1/T, the slope = –Ea/R. The extracted Ea values were on the order of a few kJ/mol, comparable to literature reports for aqueous electrolytes. Key formulas used were Kohlrausch's Law**:** $\Lambda = \Lambda_0 - K\sqrt{c}$. The intercept Λ_0 (as $c \to 0$) is the limiting molar conductivity and Arrhenius relation: σ (or Λ) $= \sigma_0 \exp(-Ea/RT)$. These relationships and observations agree with recent studies of electrolyte conductivity: higher temperature and lower viscosity always promote ion mobility, while added polymeric drag reduces conductivity.

CONCLUSIONS

The study confirms that molar conductivity increases with temperature due to enhanced ion mobility and thermal activation, consistent with the Arrhenius model. At 0.001 g/cm³ polymer concentration, the highest limiting molar conductivity (Λ_0) was observed at 50 °C, indicating improved ionic dissociation at higher temperatures. In contrast, increasing polymer concentration to 0.002 g/cm³ resulted in a decrease in Λ, likely due to increased viscosity and restricted ion movement. The activation energy (Ea) values obtained support the thermal dependence of ion transport. These findings highlight κ-carrageenan's potential as an eco-friendly electrolyte matrix for green energy applications.

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