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2ND INTERNATIONAL SCIENCE,
ENGINEERING AND TECHNOLOGY
COLLOQUIUM



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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

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ISETC 2025 Proceedings Editors

MOLAR CONDUCTIVITY AND ION TRANSPORT BEHAVIOR OF KAPPA-CARRAGEENAN (κ -CAR) - LiClO_4 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 perchlorate (LiClO_4) in aqueous medium biopolymer electrolyte system at various temperatures (25 °C–50 °C) and polymer concentration, C_{poly} (0.001–0.003 g cm⁻³) is measured for a range of salt concentration (1.000×10^{-4} – 4.702×10^{-8} mol cm⁻³) using simple AC conductivity meter that couple with its electrode. Kohlrausch's equation determines the Λ_o value of each system. It's noted that the most significant Λ_o result in this study was observed in the system with the lowest polymer concentration at the highest temperature tested. This indicates that at infinite dilution, where ion-ion interactions are minimal, ionic species exhibit maximum mobility. Λ_o is strongly influenced by both temperature and polymer concentration. As temperature increases, Λ_o increases due to enhanced ion mobility and reduced viscosity of the polymer matrix, which facilitates free movement of charge carriers. Higher temperatures also promote better salt dissociation, reducing ion-pair formation and contributing to a higher concentration of free-moving ions. Conversely, increasing polymer concentration tends to decrease Λ_o . This is because a more concentrated polymer network increases viscosity and provides more binding or coordinating sites (e.g., from sulphate groups in κ -car) that can interact with Li^+ or ClO_4^- ions. These interactions can lead to stronger ion-polymer coordination or even ion-ion association, thus limiting the number of free ions available to conduct charges. Enhanced polymer-salt interactions in the κ -car/ LiClO_4 system are expected to boost ionic conductivity and temperature response. The activation energy (E_a) of the electrolyte system is calculated after the Arrhenius equation. The findings contribute to the advancement of understanding eco-friendly electrolyte systems for more advanced applications.

Keywords: Limiting molar conductivity (Λ_o), AC conductivity meter, Kohlrausch's equation, activation energy (E_a), eco-friendly

INTRODUCTION

The objectives of this paper are to determine the Λ_o value of the electrolyte at different temperatures and κ -car concentrations. Then, to determine the Λ_o and degree of salt dissociation (α) after Kohlrausch's equation. Lastly, to calculate the activation energy, E_a for each polymer system after the Arrhenius equation. Over the years, research on eco-friendly polymer electrolytes has attracted significant attention from worldwide researchers. Utilizing bio-based polymers aligns with global initiatives to reduce the environmental impact of energy storage technologies by encouraging the use of green and renewable materials. Traditional synthetic polymers, which are derived from non-renewable resources, are expensive and non-environmentally friendly (Zainuddin & Samsudin, 2018). In contrast, a natural polymer such as κ -car offers a renewable, biodegradable, and non-toxic alternative (Ramli et al., 2024), making it highly suitable for environmentally conscious research and development. In polymer electrolyte systems, κ -car functions as a host matrix that can dissolve salts such as LiClO_4 and facilitate ion conduction. Its molecular structure contains functional groups like hydroxyl ($-\text{OH}$) and sulphate ($-\text{SO}_3^-$) groups, which interact with cations (e.g., Li^+), promoting salt dissociation and enhancing ionic conductivity. The structure of κ -car is shown below:

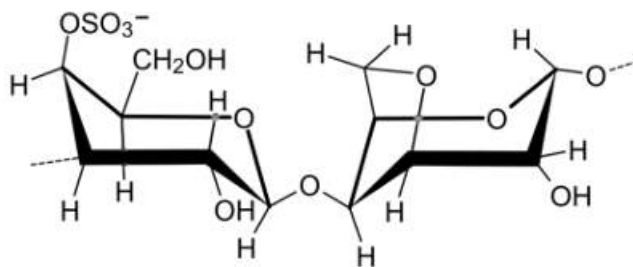


Figure 1. Structure of κ -car

The function of LiClO_4 is dissociated in the system under the thermodynamic interaction to form a large number of free-moving ions. These ions will coordinate with the backbone of the κ -car, which at the active sites ($-\text{OH}^-$ and $-\text{SO}_3^-$) under the potential difference of the ion mobility ($\mu_{\pm}$) is high. The electrolyte systems are expected to increase ionic conductivity and molar conductivity with temperature. However, when the concentration of κ -car is increases, the ionic conductivity and molar conductivity is expected to decrease.

MATERIALS AND METHODS

The material used in this research is Kappa-carrageenan (κ -car) with >99% purity ($M_w = 788.647 \text{ g mol}^{-1}$) is purchased from Sigma-Aldrich Chemical Company, USA (brand: Sigma-Aldrich CAS: 11114-20-8). Then, anhydrous lithium perchlorate, LiClO_4 ($M_w = 106.39 \text{ g mol}^{-1}$) with at least 98% of purity is obtained from Fluka (Sigma-Aldrich). Ultra-pure water is obtained from the Sartorius Water Deionizing System manufactured by Sartorius, Germany, with an electrical resistivity of $18 \text{ M}\Omega \cdot \text{cm}$ at 25°C

The experiment started by making κ -car stock solutions (C_{poly}) for different concentrations ($0.001\text{--}0.003 \text{ g cm}^{-3}$) by dissolving κ -car with ultra-pure water at 50°C and continuous stirring for two days. Next, the LPE system was prepared by dissolving the LiClO_4 in κ -car stock solutions at 50°C and with continuous stirring for two days. The salt concentration (C_{salt}) was started with $1.000 \times 10^{-4} \text{ mol cm}^{-3}$. The step was repeated for the other concentrations of κ -car stock solutions. The mixtures were cooled to room temperature. A variety of solution concentrations were prepared using a series of dilution methods, and 15-17 dilutions were made. The Ionic conductivity of all 17 mixtures was measured using a conductivity meter at temperatures of $25\text{--}50^\circ\text{C}$ with a 5°C interval. The steps were repeated for the other concentrations of κ -car stock solutions. Molar conductivity (Λ) was calculated using the formula $\Lambda = \kappa/C_{\text{salt}}$, where κ is the ionic conductivity and C_{salt} is the salt concentration. The limiting molar conductivity (Λ_o) was estimated using Kohlrausch's law, and activation energy (E_a) was determined from Arrhenius plots.

RESULT AND DISCUSSION

The temperature of an electrolyte system significantly influences the ion mobility ($\mu_{\pm}$). When the temperature increases, the viscosity of the electrolyte decreases, allowing the ions to move more freely. This is because higher thermal energy will help to overcome ion-ion and ion-polymer interaction, enhancing ionic motion (Ratner & Shriver, 1988; Gray, 1997). This behavior is consistent with Arrhenius-type conductivity, where ionic conductivity increases exponentially with temperature (Glasstone, Laidler, & Eyring, 1941).

Next, the observed trend showed that the Λ_o value decreases as the polymer concentration (C_{poly}) increases. This is because when the C_{poly} is higher, it leads to a denser polymer network, which restricts the movement of ions and increases viscosity. Furthermore, the presence of more functional groups ($-\text{OH}^-$ and $-\text{SO}_3^-$) at higher C_{poly} enhances ion-polymer interactions, which can trap lithium ions and reduce the number of free, mobile ions contributing to conductivity (Ali, Ahmad, & Mohamed, 2014; Jumaah & Arof, 2019).

Then, Λ_o is also affected by temperature. As temperatures increase, the Λ_o value also increases due to improved salt dissociation and enhanced ion mobility. This is because higher temperatures reduce the system's viscosity and weaken

ion-pair associations, allowing more charge carriers to participate in conduction (Atkins & de Paula, 2010; Bard & Faulkner, 2001).

The Λ_o value can be determined from a plot of Λ versus $C_{salt}^{1/2}$ using the extrapolation method (Hanibah et al., 2014). Lastly, the formula to calculate the Arrhenius equation is shown in Equation 1:

$$\kappa = \kappa_o \exp \left[-\frac{E_a}{kT} \right] \quad (1)$$

The result of this research is shown in tables and figures below.

Table 1. LiClO₄ - κ -car solutions (0.001 g cm⁻³)

No.	Concentrations, C_{salt} (mol cm ⁻³)	Molar conductivity, Λ S cm ² mol ⁻¹					
		25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
1.	1.000×10^{-4}	71.5	79.9	80.7	87.6	95.2	103.0
2.	6.000×10^{-5}	77.8	83.3	85.0	91.3	101.0	112.0
3.	3.600×10^{-5}	81.7	87.2	87.8	94.3	104.0	115.0
4.	2.160×10^{-5}	85.8	92.5	93.3	100.0	111.0	121.0
5.	1.296×10^{-5}	93.6	100.0	101.0	109.0	118.0	129.0
6.	7.776×10^{-6}	106.0	114.0	115.0	125.0	138.0	148.0
7.	4.666×10^{-6}	125.0	137.0	139.0	148.0	163.0	181.0
8.	2.800×10^{-6}	161.0	175.0	179.0	191.0	210.0	233.0
9.	1.680×10^{-6}	224.0	244.0	249.0	268.0	287.0	323.0
10.	1.008×10^{-6}	323.0	352.0	362.0	393.0	425.0	474.0
11.	6.048×10^{-7}	520.0	542.0	550.0	598.0	659.0	712.0
12.	3.629×10^{-7}	785.0	842.0	856.0	912.0	1020.0	1100.0
13.	2.177×10^{-7}	1300.0	1370.0	1390.0	1490.0	1610.0	1810.0
14.	1.306×10^{-7}	2450.0	2230.0	2260.0	2410.0	2630.0	2900.0
15.	7.836×10^{-8}	3570.0	3760.0	3810.0	4050.0	4410.0	4820.0
16.	4.702×10^{-8}	5830.0	6180.0	6300.0	6830.0	7440.0	8120.0
17.	2.821×10^{-8}	11000.0	10200.0	107000.0	11900.0	13100.0	14300.0

Table 2. LiClO₄ - κ -car solutions (0.002 g cm⁻³)

No.	Concentrations, C_{salt} (mol cm ⁻³)	Molar conductivity, Λ S cm ² mol ⁻¹					
		25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
1.	1.000×10^{-4}	64.6	64.5	65.3	69.9	77.0	83.6
2.	6.000×10^{-5}	71.9	72.3	73.0	78.3	85.6	92.7
3.	3.600×10^{-5}	78.2	78.2	80.1	86.3	93.9	102.0
4.	2.160×10^{-5}	89.4	89.4	91.2	97.8	107.0	118.0
5.	1.296×10^{-5}	104.0	104.0	108.0	114.0	126.0	136.0
6.	7.776×10^{-6}	129.0	129.0	133.0	145.0	157.0	171.0
7.	4.666×10^{-6}	171.0	171.0	177.0	192.0	214.0	227.0
8.	2.800×10^{-6}	239.0	239.0	247.0	277.0	296.0	326.0
9.	1.680×10^{-6}	358.0	358.0	370.0	393.0	447.0	483.0
10.	1.008×10^{-6}	547.0	547.0	566.0	601.0	683.0	751.0
11.	6.048×10^{-7}	870.0	870.0	893.0	961.0	1070.0	1170.0
12.	3.629×10^{-7}	1410.0	1410.0	1450.0	1580.0	1740.0	1900.0
13.	2.177×10^{-7}	2320.0	2320.0	2380.0	2640.0	2870.0	3100.0
14.	1.306×10^{-7}	3840.0	3840.0	3900.0	4170.0	4620.0	5110.0
15.	7.836×10^{-8}	6400.0	6400.0	6520.0	7020.0	7850.0	8760.0
16.	4.702×10^{-8}	10500.0	10500.0	10800.0	11700.0	13000.0	14600.0
17.	2.821×10^{-8}	17600.0	107600.0	18000.0	19500.0	21700.0	23800.0

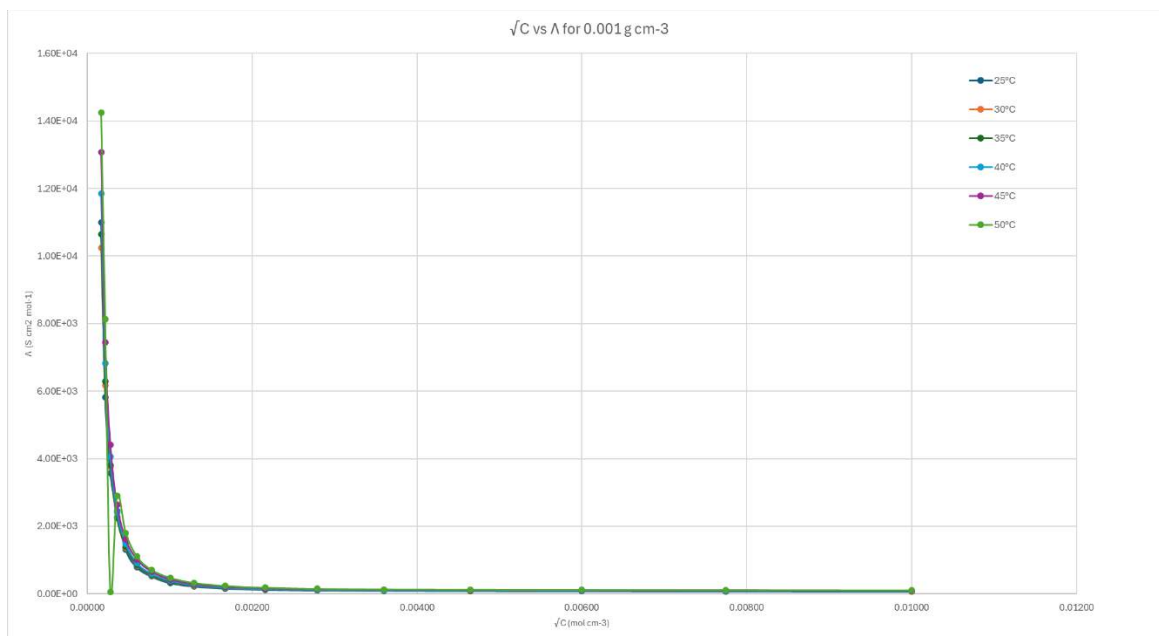


Figure 2. Λ (S cm² mol⁻¹) vs $\sqrt{C}$ (mol cm⁻³) at 0.001 g cm⁻³

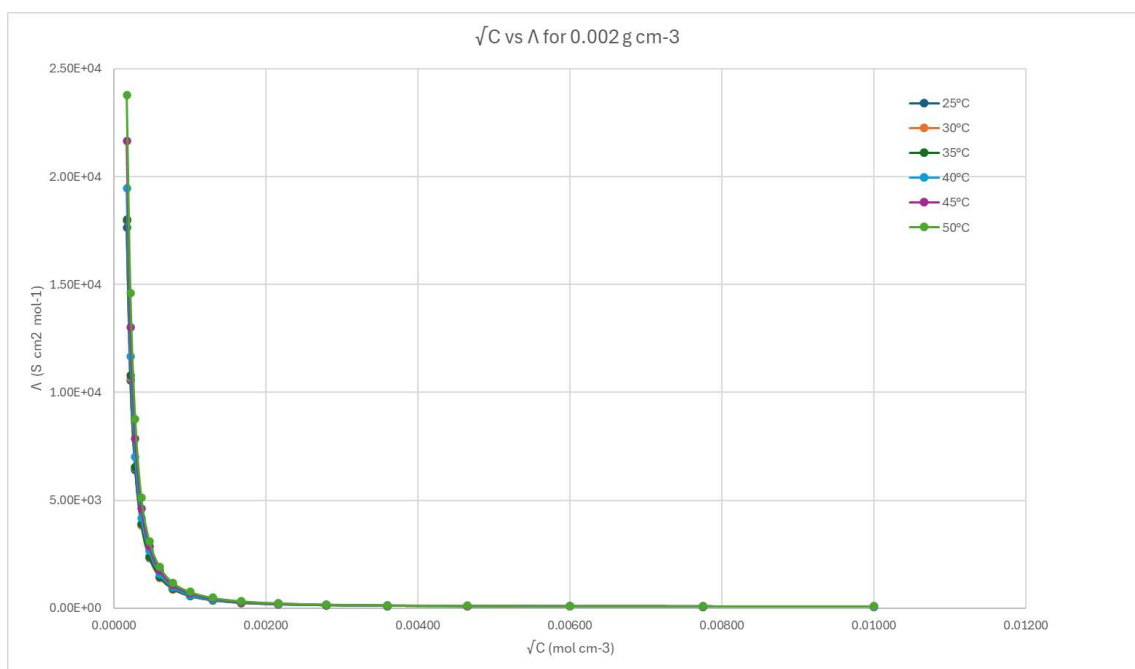


Figure 3. Λ (S cm² mol⁻¹) vs $\sqrt{C}$ (mol cm⁻³) at 0.002 g cm⁻³

CONCLUSIONS AND RECOMMENDATIONS

The limiting molar conductivity (Λ_o) of κ -car/LiClO₄-based LPE increases with temperature, owing to improved ion mobility and reduced salt-polymer binding. Bio-based κ -car offers an eco-friendly alternative for electrolyte development. Future research should focus on optimizing salt-to-polymer ratios, enhancing long-term stability, and testing electrochemical performance in actual devices.

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Prof. Madya Dr. Nur Hisham Ibrahim
Rektor
Universiti Teknologi MARA
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Kelulusan daripada pihak tuan dalam perkara ini amat dihargai.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menjalankan amanah,

Setuju.

27.1.2023

SITI BASRIYAH SHAIK BAHARUDIN
Timbalan Ketua Pustakawan

PROF. MADYA DR. NUR HISHAM IBRAHIM
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