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Effect of Organic and Inorganic Compounds on the Conductivity of Salt Solutions

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ABSTRACT

This study examines the effects of selected organic and inorganic compounds on the electrical conductivity of salt solutions. Organic substances (sugar, coffee, tea, and a surfactant-based cleaner) and inorganic additives (ammonium chloride in cough medicine, povidone–iodine, and carbonated beverage) were mixed with salt solutions at varying concentrations to evaluate their influence on ion availability and mobility. The results show that conductivity increases proportionally with salt concentration, confirming that ion content is the primary factor governing charge transport. Inorganic ionic additives significantly enhanced conductivity by releasing additional ions into the solution, whereas non-ionic organic compounds consistently reduced conductivity at low salt levels by diluting ionic species and hindering ion mobility. Conductivity in organic mixtures increased only when salt concentration became dominant. These findings highlight the contrasting mechanisms of organic and inorganic additives in modifying electrolyte behavior and provide useful insight for chemistry education and simple electrochemical analysis.

Keywords: Electrical conductivity, Salt solutions, Organic compounds, Inorganic compounds, Ion mobility

1. INTRODUCTION

Electrolyte solutions play a fundamental role in numerous chemical and biological processes due to their ability to conduct electrical current through the movement of ions. When ionic compounds such as sodium chloride dissolve in water, they dissociate into free cations and anions that enable electrical conduction, whereas non-electrolyte substances dissolve without producing ions and therefore contribute minimally to conductivity. The magnitude of conductivity in salt solutions is governed by ion concentration, ion mobility, and the structure of ion–solvent interactions within the aqueous medium. Recent studies emphasize that accurate conductivity behavior depends not only on the intrinsic properties of electrolytes but also on interactions that occur at the molecular level, including ion pairing and hydration structure.[1, 2]

Electrolyte solutions are characterized by their ability to conduct electrical current through the movement of dissolved ions, which originate from the dissociation of ionic compounds such as salts, acids, and bases in water. When these compounds dissolve, they release positively and negatively charged ions that serve as charge carriers, enabling the flow of electricity through the solution. The magnitude of electrical conductivity is therefore directly influenced by the concentration and mobility of ions in the solvent. National studies also confirm this fundamental relationship; for example, Parmin Lumban Toruan et al. (2023) reported that the electrical conductivity of water increases with higher concentrations of dissolved minerals and ionic species, demonstrating that a greater number of free ions enhances the solution's ability to transport electrical charge.[3] This foundational concept underscores the key role of ion dissociation and mobility in determining conductivity and provides the basis for understanding how different substances, including organic and inorganic compounds, may alter the conductive behavior of salt solutions.

Previous research on electrolyte behavior in aqueous systems has shown that conductivity is strongly influenced by the concentration and mobility of dissolved ions. Studies conducted by Maharani et al. (2022) demonstrated that salt solutions exhibit a linear increase in electrical conductivity with increasing NaCl concentration, indicating that a higher number of dissociated ions in solution enhances charge transport efficiency.[4] Similar findings were reported by Parmin et al. (2022), who observed that variations in dissolved ion content directly affect the electrical conductivity of groundwater samples, with higher ionic levels producing greater conductivity values.[5] These national studies reinforce the principle that the presence and behavior of ions are central to determining conductivity in aqueous systems. However, despite extensive work on the relationship between ion concentration and conductivity, limited attention has been given to how different types of dissolved substances particularly organic and inorganic compounds commonly encountered in daily life interact with salt solutions and modify their ionic transport properties. These findings highlight the sensitivity of electrolyte systems to the presence of additional compounds and reinforce the importance of understanding how additives influence transport properties.

Organic and inorganic compounds exhibit distinctly different behaviors when dissolved in salt solutions. Many inorganic substances, such as ammonium chloride or iodine-based compounds, readily dissociate into ions and are known to enhance the overall ionic strength of the solution, thereby increasing conductivity. In contrast, non-ionic organic substances such as sugars, beverages, and plant-derived materials typically do not ionize in water and may even decrease conductivity by diluting ionic species, increasing viscosity, or forming molecular environments that hinder ion transport. Recent reviews on electrolyte additives also show that research has historically focused on chemically controlled additives used in laboratory environments or in specialized electrochemical applications, such as aqueous battery electrolytes, rather than on household organic materials commonly encountered in daily life.[6, 7] This creates a gap in understanding how real-world organic and inorganic substances interact with salt-based electrolyte systems.

Despite growing interest in mixed-solute systems, most existing studies examine the effects of additives in isolation either focusing exclusively on inorganic ions or on specific organic molecules leaving limited comparative data between the two categories under similar conditions.[8] However, real-world applications such as food chemistry, environmental sensing, and educational demonstrations often involve complex mixtures where organic and inorganic substances coexist and jointly influence conductivity. Therefore, a systematic investigation comparing the influence of representative organic and inorganic compounds on the conductivity

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of salt solutions is needed to provide clearer empirical insight and to bridge the gap between theoretical electrolyte principles and practical mixed-solution behavior.

This study aims to systematically evaluate the effects of selected organic and inorganic compounds on the electrical conductivity of salt solutions under controlled conditions. By comparing how non-ionic organic substances and ion-dissociating inorganic additives modify ion availability, mobility, and overall conductive behavior, this research seeks to provide empirical evidence that clarifies the contrasting mechanisms through which both classes of compounds influence electrolyte performance. The findings are expected to contribute to a deeper understanding of mixed-solution electrolyte systems and to support the development of more accurate models and practical applications in chemistry education, food analysis, and low-cost electrochemical sensing.

2. EXPERIMENTAL

2.1. Materials and Tools

The materials used in this study included SANBE cough syrup containing 100 g of ammonium chloride (30 mL), table salt (100 g), sugar (5 g), coffee powder (5 g), tea powder (10 g), Wifol floor cleaner (30 mL), Sprite™ carbonated beverage (30 mL), and Betadine™ iodine solution (30 mL). The equipment utilized consisted of a custom-made electrical conductivity measurement circuit designed by the researchers and a handheld digital multimeter (DT-830D, I2041).

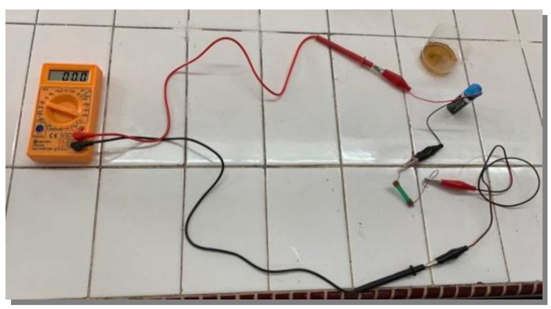

Figure 1. Measurement setup for evaluating the electrolyte properties of solutions

2.2. Research Procedure

The measurement apparatus for evaluating the electrolyte properties of the solutions was constructed using a pair of copper-wire electrodes, a multimeter, and a 9-V power source. Two copper wires (10 cm each) were coiled around a plastic dropper to form dual electrode terminals, with each coil consisting of five tight turns and approximately 5 cm of exposed wire left at one end to serve as conductive leads. Short sections of plastic straws (2.5 cm) were used as insulating spacers between the coils to maintain electrode separation.

The conductivity measurement circuit was assembled by connecting a 9-V battery equipped with a battery clip to a digital multimeter. The black test lead was inserted into the COM terminal and the red lead into the V–mA terminal. The positive terminal of the battery clip was linked to the red multimeter probe via a crocodile-clip connector, while the negative terminal was connected to one of the exposed copper-wire leads of the electrode pair. Additional crocodile clips were used to complete the circuit by connecting the remaining

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electrode lead to the black wire of the battery clip. This configuration allowed current to pass through the test solution, enabling conductivity measurements using the multimeter.

3. RESULTS AND DISCUSSION

3.1. Characterization and Conductivity Analysis

The conductivity measurements obtained in this study demonstrate clear differences in the behavior of salt solutions when mixed with various organic and inorganic compounds. As shown in Table 1, the conductivity of the control salt solution increased progressively with rising salt concentration, from 3.2 mS/cm at 5 g of salt to 10.0 mS/cm at 25 g, confirming the strong positive relationship between ion concentration and conductivity. [9, 10] This pattern reflects the fundamental principle that conductivity increases with the number of free ions available to transport electrical charge in solution.

Organic non-ionic additives including sugar, coffee, tea, and Wifol floor cleaner consistently produced lower conductivity values across all salt concentrations compared to the control salt solution. Sugar solution showed conductivity values ranging from 1.1 mS/cm (5 g salt) to 5.1 mS/cm (25 g salt), while coffee solution ranged from 0.8–6.5 mS/cm and tea from 1.6–5.0 mS/cm. This reduction occurs because these substances dissolve as neutral molecules and therefore dilute the ionic strength of the salt solution. Furthermore, the presence of organic compounds increases solution viscosity and alters ion–solvent interactions, which reduces ion mobility and consequently lowers conductivity. The same trend was observed in the Wifol solution, which recorded values between 1.2 and 7.0 mS/cm, consistent with the non-ionic nature of surfactants that do not contribute additional charge carriers.

In contrast, the cough medicine containing ammonium chloride (NH_4Cl) produced consistently higher conductivity than most organic solutions, with values ranging from 2.7 mS/cm (10 g salt) to 9.2 mS/cm (20 g salt). This occurs because ammonium chloride dissociates fully into NH_4^+ and Cl^- ions, thereby increasing the total number of free ions in solution. This finding aligns with the known behavior of strong electrolytes and supports the theoretical expectation that inorganic ionic additives enhance conductivity more effectively than organic compounds.The soda-water mixture displayed fluctuating conductivity values, ranging from 2.1 mS/cm (5 g salt) to 6.4 mS/cm (20 g salt), reflecting the unstable ionization behavior of carbonic acid and dissolved CO_2 in aqueous environments. The degassing of CO_2 during mixing likely contributed to variations in ion concentration, making conductivity values less predictable compared to stable inorganic electrolytes. Betadine®, which contains povidone–iodine, showed a moderate increase in conductivity, rising from 1.3 mS/cm (5 g salt) to 8.2 mS/cm (25 g salt). Notably, mixing Betadine with salt produced visible brown precipitates and a lighter solution color, indicating interactions between iodine species and chloride ions that may have altered iodine speciation. Despite this reaction, the presence of iodide ions still contributed to increased conductivity at higher salt concentrations.

Qualitative observations further supported these findings. Bubbling was observed around the electrodes in the salt solution and soda water, indicating either the release of dissolved gases or electrochemical reactions that occurred under certain ionic conditions. Meanwhile, iodine mixed with salt exhibited clear chemical changes, consistent with shifts in iodine chloride equilibria.

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Overall, the integrated data and observations demonstrate a strong distinction between organic and inorganic additives. Organic non-ionic compounds consistently reduced conductivity, particularly at lower salt concentrations, whereas ionic inorganic compounds increased conductivity because of their ability to contribute additional mobile ions. These results reinforce theoretical models of electrolytic behavior and align well with national research demonstrating the role of ion concentration and mobility in determining electrical conductivity in aqueous systems.

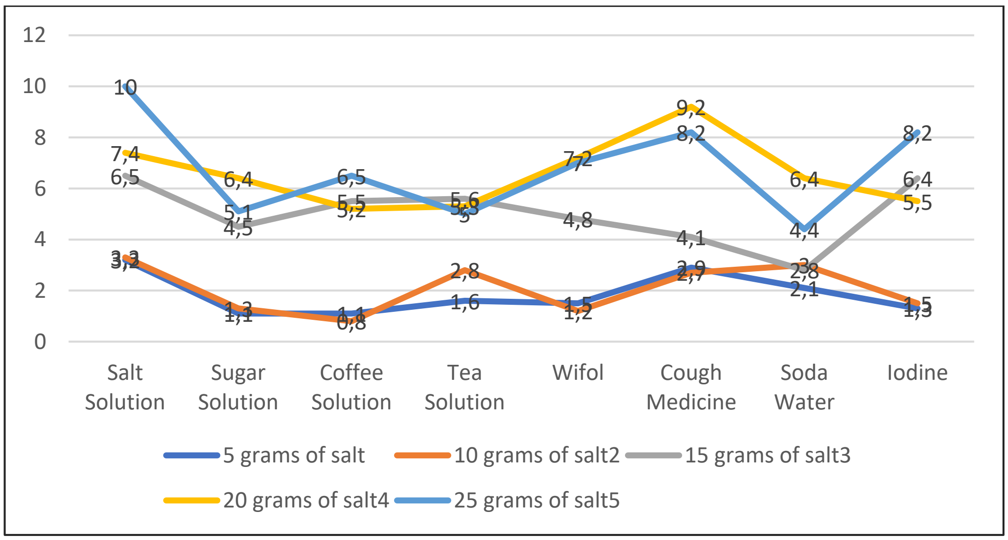

Figure 2. Conductivity profiles of various organic and inorganic solutions across increasing salt concentrations

Solution Name	Electrical Conductivity (mS/cm)				
	5 grams of salt	10 grams of salt	15 grams of salt	20 grams of salt	25 grams of salt
Salt solution	3.2	3.3	6.5	7.4	10.0
Sugar Solution	1.1	1.3	4.5	6.4	5.1
Coffee Solution	1.1	0.8	5.5	5.2	6.5
Tea Solution	1.6	2.8	5.6	5.3	5.0
Wifol	1.5	1.2	4.8	7.2	7.0
Cough medicine	2.9	2.7	4.1	9.2	8.2
Soda water	2.1	3.0	2.8	6.4	4.4
Betadine	1.3	1.5	6.4	5.5	8.2

Table 1. Conductivity of salt solutions mixed with organic and inorganic compounds

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3.2 Discussion

Based on the results of this study, the electrical conductivity of a solution is primarily determined by the number and mobility of ions present in the mixture. When salt dissolves in water, it fully dissociates into sodium (Na^+) and chloride (Cl^-) ions, which act as charge carriers that enable the flow of electrical current. An increase in salt concentration therefore results in a higher number of free ions and consequently higher conductivity, as reflected in the progressive increase observed from 3.2 mS/cm at 5 g to 10.0 mS/cm at 25 g of salt. The addition of inorganic ionic additives, such as ammonium chloride in cough medicine, further increases conductivity by contributing additional dissociated ions into the solution, producing values as high as 9.2 mS/cm at 20 g of salt. In contrast, non-ionic organic substances such as sugar, coffee, tea, and surfactant-based cleaners do not produce ions when dissolved and tend to dilute or hinder ion mobility, resulting in significantly lower conductivity values particularly at lower salt concentrations where ionic strength is still limited. [11, 12] These compounds also increase solution viscosity, which reduces ion transport efficiency, leading to conductivity values such as 1.1–1.6 mS/cm at 5 g of salt before gradually rising once salt concentration becomes dominant.

Additional observations support these conductivity trends. The carbonated beverage (Sprite) exhibited fluctuating conductivity due to the presence and release of dissolved CO_2, which forms weakly ionizing carbonic acid and escapes as gas during mixing, leading to values that rise and fall irregularly across salt concentrations. Meanwhile, the povidone-iodine solution (Betadine) showed moderate conductivity increases but also visible chemical changes, including the formation of brown clumps and a lighter solution color when combined with salt. This indicates interactions between iodine species and chloride ions that temporarily alter ion availability and speciation, producing non-linear conductivity changes such as 1.3 mS/cm at 5 g, rising sharply to 6.4 mS/cm at 15 g, and fluctuating thereafter. The appearance of bubbles around the electrodes in the salt solution and soda water further suggests gas evolution or release of dissolved gases under electrical stimulation, a phenomenon consistent with electrochemical behavior in ionic and carbonated systems. [13–15] Overall, these findings reinforce that inorganic ionic additives enhance conductivity by increasing the number of charge-carrying ions, whereas non-ionic organic compounds generally suppress conductivity by reducing ion concentration or mobility. The combined quantitative data and qualitative observations demonstrate clear mechanistic differences between organic and inorganic additives in modifying the conductive behavior of salt solutions.

4. CONCLUSION

This study demonstrates clear differences in the effects of organic and inorganic compounds on the electrical conductivity of salt solutions. Inorganic ionic additives specifically ammonium chloride and povidone–iodine (Betadine) were found to significantly increase conductivity because they release additional ions into the solution, thereby enhancing charge transport. In contrast, non-ionic organic substances such as sugar, coffee, tea, and surfactant-based cleaners consistently reduced conductivity at low salt concentrations, as these compounds do not dissociate into ions and tend to dilute or hinder ionic mobility through changes in viscosity and solvation structure. Conductivity gradually increased again at higher salt concentrations as the ionic strength of the medium became dominant. Overall, inorganic ionic compounds showed a clear enhancing

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effect on conductivity, whereas organic non-ionic compounds produced a suppressing effect, confirming that ion availability and mobility are the primary determinants of conductivity in mixed-solute salt solutions.

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