Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

DETERMINING THE ACTIVITY COEFFICIENT AND IONIC ATMOSPHERE THICKNESS USING ELECTROCHEMICAL METHODS TO ASSESS THE IMPACT OF SALTS ON GALLICONE

Mahmoud Yahya Saleh Aboud Al-Shahrani[1]**
Israa Hamed Mohammed Dawood Al-Samarrai[2]**
Marwa Taha Abdul Karim Jasim Al-Samarrai[3*]**
Marwan Taha Abdul Karim Jasim Al-Samarrai[4**]**
1Department of Chemistry, College of Science, University of Tikrit
2,3,4Department of Applied Chemistry, College of Applied Sciences, University of Samarra.
Email: mahmoud.alshaharly@gmail.com* , **esraahamid180@gmail.com
***alsamrayytmrwt28@gmail.com ****ma20180770912546@gmail.com

Abstract:
In this research, the relationship between electrical conductivity (Λ) for strong electrolytes and ionic strength was explored using monovalent and trivalent strong electrolytes, such as Potassium Chloride (KCl) and Chromium(III) Chloride (CrCl3), in various ratios ranging from 0.1:0.2 to 0.1:0.6. The impact of these electrolytes on unsaturated aromatic compounds (gallicones), prepared from the reaction of 4-aminoacetophenone with 4-nitrobenzene, was observed, and their electrical conductivity was measured. It was inferred that conductivity increases incrementally with the use of KCl, whereas with CrCl3, the increase was consistent. From the measurements, ionic strength was calculated based on the relationship between ionic strength and electrical conductivity (Λ*I=F). Additionally, the activity coefficient was determined along with the thickness of the ionic atmosphere for the reaction. This relationship allows for the direct calculation of ionic strength by measuring the conductivity of any unknown sample and provides more accurate, straightforward, and less complex results.
Furthermore, the order of the reaction was calculated and found to be second-order, from which the reaction rate constant was computed at each concentration. ZAZB was calculated using the Bronsted-Bjerrum relationship, indicating a negative value which suggests that the reaction progresses with an increase in the negative direction.
Keywords: Electrolytes, Electrical Conductivity, Ionic Strength, Gallicones, Reaction Kinetics

Introduction:

Various theories on the conductivity of electrolytes have been extensively reviewed by numerous researchers. The modern theory of electrolyte conductivity was developed by Debye-Hückel and later refined by Onsager through studies on the behavior of ions in electrolytic solutions. It has been deduced that due to the electrical attraction between positive and negative ions in an electrolytic solution, ions cluster around a central ion as if located at the center of a sphere surrounded from all sides at varying distances. The ion at the center of this sphere is known as the central ion, and the ions and solvent molecules within the surrounding shell form what is known as the ionic atmosphere. The net charge within the ionic atmosphere is equal in magnitude but opposite in sign to that of the central ion. Under normal conditions, without an applied electric field, this ionic atmosphere remains uniformly spherical.

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

The activity coefficient of an ion decreases with increasing ionic strength of the solution, with a more significant decrease observed for ions carrying multiple charges. This rule applies to dilute solutions, but as the concentration of the electrolytic solution exceeds 0.1M, where the radius of the ionic atmosphere becomes comparable to that of the central ion, Debye-Hückel introduced modifications to the equation. The sum of electrostatic interactions between ions plays a crucial role in determining the thermodynamic conductivities of strong electrolyte solutions, which is termed the activity coefficient.
All solutions contain ions and charged particles that deviate from ideal behavior, and the degree of deviation is proportional to the electrical charge resulting from the ions and charged particles.
The activity coefficient of an electrolyte clearly depends on the concentration. In dilute solutions, the intermolecular forces are simple Coulombic attractions and repulsions, where the ions are sufficiently spaced apart to prevent any significant attraction between them, and the activity coefficient approaches one. This effect is more pronounced for ions with higher charges and solvents with low electrochemical constants, where the electrostatic environmental effects are stronger. A study was conducted to explore the relationship between conductivity and ionic strength for electrolyte solutions (KCl, $CrCl_3$) with different ratios ranging from 0.1:0.2 to 0.1:0.6.

Research Objective:

- To monitor the reaction process between monovalent and trivalent salts and their effect on unsaturated compounds (gallicones) using an electrochemical method.
- To determine the reaction order and calculate the reaction rate constant.
- To calculate the ionic strength (I) and the activity coefficient (F) for the reaction.
- To compute the thickness of the ionic atmosphere (d).

Literature Review:

In 2009, researcher Iqbal Salman studied the relationship between the electrical conductivity of strong electrolytes and ionic strength using divalent strong electrolytes (sodium carbonate, sodium sulfate) at concentrations ranging from 0.01M to 0.1M. The activity coefficient (F) was also calculated, showcasing a method that directly calculates ionic strength by measuring the conductivity of any unknown sample, providing more accurate results simply and with less effort.
In the same year, Amer Dawood studied the relationship between electrical conductivity (Cond) and ionic strength (I) in aqueous solutions of the following electrolytes: (NaCl, $NaCO_3$, $NaNO_3$, Na_2SO_4, K_2SO_4, $CuSO_4$, $MgSO_4.7H_2O$) at concentrations ranging from 0.1 to 1 molar at 25 degrees Celsius. Ionic strength was calculated from electrical conductivity measurements, showing that conductivity increases with ionic strength in the following order:
$K_2SO_4 > MgSO_4 > CuSO_4 > Na_2SO_4 > Na_2CO_3 > NaCl > NaNO_3$
A mathematical relationship was also developed in this research to calculate the thickness of the ionic atmosphere (d) from the electrical conductivity measurements of electrolyte solutions:
$d = 4.3 \times [2(F \cdot Cond)]^{(-1/2)}$

Electrolyte Solutions:

Electrolyte solutions are those substances whose solutions have the ability to conduct electric current. Examples include solutions of acids, bases, and salts. The ability of electrolytes to conduct electricity is due to their dissociation into ions in solution, where these ions are capable of moving and transferring electricity throughout the solution. Electrolytes are divided into two types: weak electrolytes and strong electrolytes.

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

Weak Electrolytes are those substances that partially dissociate into their ions in solution, resulting in weak electrical conductivity due to the low number of ions produced from their dissociation. Examples include carbonic acid (H2CO3) and acetic acid (CH3COOH).

Strong Electrolytes are substances that almost completely dissociate into ions in their solutions, resulting in very high electrical conductivity. This category includes strong acids, strong bases, and their salts. Strong acids completely dissociate to produce a very large number of hydrogen ions, such as:

1. **Potassium Chloride (KCl)** is a chemical compound with the formula KCl. It is odorless in its pure state. Its crystals are white or colorless and glassy. Its crystal structure easily cleaves in three directions. Potassium chloride dissolves well in water, approximately 34g per 100 ml of water at 20°C. In contrast, potassium chloride is practically insoluble in most organic solvents. Its molecular weight is 74.551 g/mol and its melting point is 790°C.
2. **Chromium(III) Chloride (CrCl3)** is a chemical compound in the form of a crystalline powder that is violet (anhydrous) or dark green. The oxidation state of chromium in this compound is +3. The anhydrous form of chromium chloride has low solubility in water, but in the presence of traces of chromium(II), a rapid and exothermic dissolution process occurs and the green hydrate form of chromium(III) chloride forms, involving six water molecules linked to the central chromium atom in its crystal structure.

The **Bronsted-Hjerrum hypothesis** includes the effect of salt addition on the rate of reaction. According to this hypothesis, reactions between ions proceed through the formation of complex intermediate compounds (Intermediate Complex), which then dissociate into the reaction products. The reaction between ions A and B, which have charge factors ZA and ZB respectively, can be represented by the following equation:

AZA + BZB ----------- XZA + ZB (Intermediate Complex) ------ (Product)

Bronsted and Hjerrum also found a secondary relationship based on the Debye-Huckel equation:

logK = logK^o + AΔZ^2 √μ, pK = pK^o - AZ^2 √μ

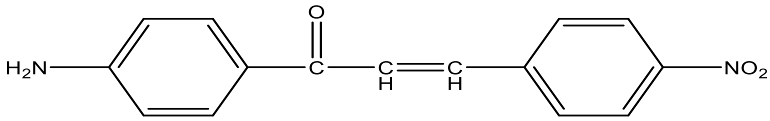
Here, K is the reaction rate constant, C is a constant concentration, and μ is the ionic strength within the reaction environment. This mathematical relationship illustrates that adding a neutral salt to a specific reaction accelerates the reaction between ions carrying similar charges. The product of ZAZB will have a positive value and slows the reaction if the ions carry different charges and does not affect the reaction rate if one of the reactant ions is uncharged.

Chalcones: Chalcones are α, β-unsaturated carbonyl compounds, with chalcone itself being (1,3-diphenyl-2-propen-1-one). Other names for it include benzalacetone or phenyl styryl ketone. It is a ketonic compound containing two benzene rings connected by a carbonyl group linked with a double bond at the α, β position. In addition to the term chalcone, these compounds contain substituted groups on the benzene ring in various positions (o, m, p). The presence of two aromatic rings at the ends of the chalcone shows the planarity of the rings with the (C=C-C=O) system, which reduces the effect of substituent groups, whether they are electron-withdrawing or electron-donating.

The name chalcone was first used by researchers Tambor and Kostaneck for the purpose of preparing colored compounds. Both researchers managed to prepare yellow crystalline compounds that are insoluble in water but soluble in organic solvents. Chalcones are important for their varied uses as a material of special importance in many reactions that produce

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

important medical and industrial products, and the structure below illustrates the chalcone used in this study.



Chemical Formula: $C_{15}H_{12}N_2O_3$
Molecular Weight: 268.27
Elemental Analysis: C, 67.16; H, 4.51; N, 10.44; O, 17.89
M.P : 207 C°

Practical Section:
Prepared Standard Solutions:

1. **Chalcone Solution (0.001M):** Prepared by dissolving 0.0127g of yellow chalcone powder in a quantity of high-purity ethanol (99.9%), then diluting to the mark in a 50 ml volumetric flask.
2. **Potassium Chloride (KCl) Solution (0.001M):** Prepared by dissolving 0.0037g of crystalline KCl powder in a quantity of high-purity ethanol (99.9%). The solution was heated slightly to aid the dissolution of KCl in the organic solvent, as KCl is poorly soluble in organic solvents. The volume was then adjusted to the mark in a 50 ml volumetric flask.
3. **Chromium(III) Chloride (CrCl3) Solution:** Prepared by dissolving 0.008g of green crystalline CrCl3 powder in a quantity of high-purity ethanol (99.9%) and diluting to the mark in a 50 ml volumetric flask.

Methodology:
First: Measurement of Conductivity and Calculation of Ionic Strength, Activity Coefficient, and Ionic Atmosphere Thickness for KCl:

- A mixture of 0.1 ml of chalcone with various volumes of KCl (0.6, 0.5, 0.4, 0.3, 0.2 ml) was prepared. Conductivity was measured over a period, and ionic strength, activity coefficient, and ionic atmosphere thickness were calculated using the following equations:
  - I=12∑cZ2I = \frac{1}{2} \sum cZ^2I=21∑cZ2
  - I=F·AI = F \cdot AI=F·A
  - d=4.3×[2(F·Cond)]−12d = 4.3 \times \left[2(F \cdot \text{Cond}) \right]^{-\frac{1}{2}}d=4.3×[2(F·Cond)]−21

The results are shown in the tables and figures below:

Table 3: Conductivity Values for KCl-Chalcone Mixture (2:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)	Ionic Strength I(M)I (M)I(M)	Molar Conductivity ΛΛΛ (µS)	Conductivity (µS)
6.799	2.778	0.2	7200	7200
6.799	2.614	0.2	7650	7650

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

6.799	2.532	0.2	7900	7900
6.799	2.525	0.2	7922	7922
6.799	2.469	0.2	8100	8100
6.799	2.454	0.2	8150	8150
6.799	2.424	0.2	8250	8250
6.799	2.367	0.2	8450	8450
6.799	2.299	0.2	8700	8700
6.799	2.281	0.2	8770	8770

Table 4: Conductivity Values for KCl-Chalcone Mixture (3:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)	Ionic Strength I(M)I (M)I(M)	Molar Conductivity ΛΛΛ (µS)	Conductivity (µS)
5.551	4.792	0.3	6260	6260
5.551	4.129	0.3	7266	7266
5.551	3.879	0.3	7733	7733
5.551	3.689	0.3	8133	8133
5.551	3.629	0.3	8266	8266
5.551	3.521	0.3	8521	8521
5.551	3.409	0.3	8800	8800
5.551	3.403	0.3	8816	8816
5.551	3.238	0.3	9266	9266
5.551	3.183	0.3	9426	9426

Table 5: Conductivity Values for KCl-Chalcone Mixture (4:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)	Ionic Strength I(M)I (M)I(M)	Molar Conductivity ΛΛΛ (µS)	Conductivity (µS)
4.807	8.556	0.4	4675	4675
4.807	7.111	0.4	5625	5625
4.807	7.097	0.4	5636	5636
4.807	7.048	0.4	5675	5675
4.807	6.957	0.4	5750	5750
4.807	6.867	0.4	5825	5825
4.807	6.695	0.4	5975	5975
4.807	6.691	0.4	5978	5978
4.807	6.679	0.4	5989	5989
4.807	6.668	0.4	5999	5999

Table 6: Conductivity Values for KCl-Chalcone Mixture (5:1 Ratio)

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)	Ionic Strength I(M)I (M)I(M)	Molar Conductivity ΛΛΛ (µS)	Conductivity (µS)
4.3	13.441	0.5	3720	3720
4.3	12.69	0.5	3940	3940
4.3	12.563	0.5	3980	3980
4.3	12.438	0.5	4020	4020
4.3	12.376	0.5	4040	4040
4.3	12.315	0.5	4060	4060
4.3	11.874	0.5	4211	4211
4.3	10.994	0.5	4548	4548
4.3	10.922	0.5	4578	4578
4.3	10.841	0.5	4612	4612

Table 7: Conductivity Values for KCl-Chalcone Mixture (6:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	**Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)**	**Ionic Strength I(M)I (M)I(M)**	**Molar Conductivity ΛΛΛ (µS)**	**Conductivity (µS)**
3.925	13.384	0.6	4483	4483
3.925	12.723	0.6	4716	4716
3.925	12.33	0.6	4866	4866
3.925	11.146	0.6	5383	5383
3.925	10.73	0.6	5592	5592
3.925	10.313	0.6	5818	5818
3.925	10.263	0.6	5846	5846
3.925	10.206	0.6	5879	5879
3.925	10.084	0.6	5950	5950
3.925	9.756	0.6	6150	6150

Second: Measurement of Conductivity and Calculation of Ionic Strength, Activity Coefficient, and Ionic Atmosphere Thickness for CrCl3:

- A mixture of 0.1 ml of chalcone with various volumes of CrCl3 (0.6, 0.5, 0.4, 0.3, 0.2 ml) was prepared. Conductivity was measured over a period, and ionic strength, activity coefficient, and ionic atmosphere thickness were calculated. The results are shown in the tables and figures below:

Table 8: Conductivity Values for CrCl3-Chalcone Mixture (2:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	**Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)**	**Ionic Strength I(M)I (M)I(M)**	**Molar Conductivity ΛΛΛ (µS)**	**Conductivity (µS)**

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

3.04	9.804	1	10200	10200
3.04	7.491	1	13350	13350
3.04	6.579	1	15200	15200
3.04	6.192	1	16150	16150
3.04	5.9	1	16950	16950
3.04	5.714	1	17500	17500
3.04	5.362	1	18650	18650
3.04	5.076	1	19700	19700
3.04	4.619	1	21650	21650
3.04	4.264	1	23450	23450

Table 9: Conductivity Values for CrCl3-Chalcone Mixture (3:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)	Ionic Strength I(M)I (M)I(M)	Molar Conductivity ΛΛΛ (µS)	Conductivity (µS)
2.482	12.858	1.5	11666	11666
2.482	10.87	1.5	13800	13800
2.482	10.714	1.5	14000	14000
2.482	9.934	1.5	15100	15100
2.482	8.876	1.5	16900	16900
2.482	8.638	1.5	17366	17366
2.482	8.123	1.5	18466	18466
2.482	7.692	1.5	19500	19500
2.482	7.258	1.5	20666	20666
2.482	7.053	1.5	21266	21266

Table 10: Conductivity Values for CrCl3-Chalcone Mixture (4:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)	Ionic Strength I(M)I (M)I(M)	Molar Conductivity ΛΛΛ (µS)	Conductivity (µS)
2.15	20.101	2	9950	9950
2.15	17.167	2	11650	11650
2.15	15.936	2	12550	12550
2.15	15.238	2	13125	13125
2.15	14.363	2	13925	13925
2.15	13.536	2	14775	14775
2.15	12.658	2	15800	15800
2.15	12.384	2	16150	16150
2.15	12.066	2	16575	16575
2.15	11.628	2	17200	17200

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

Table 11: Conductivity Values for CrCl3-Chalcone Mixture (5:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)	Ionic Strength I(M)I (M)I(M)	Molar Conductivity ΛΛΛ (μS)	Conductivity (μS)
1.923	26.539	2.5	9420	9420
1.923	24.606	2.5	10160	10160
1.923	23.234	2.5	10760	10760
1.923	22.242	2.5	11240	11240
1.923	21.222	2.5	11780	11780
1.923	20.695	2.5	12080	12080
1.923	20.096	2.5	12440	12440
1.923	19.41	2.5	12880	12880
1.923	18.491	2.5	13520	13520
1.923	17.832	2.5	14020	14020

Table 12: Conductivity Values for CrCl3-Chalcone Mixture (6:1 Ratio)

Ionic Atmosphere Thickness d(Ao)d(A^o)d(Ao)	Activity Coefficient F(×10−5)F (×10^{-5})F(×10−5)	Ionic Strength I(M)I (M)I(M)	Molar Conductivity ΛΛΛ (μS)	Conductivity (μS)
1.755	44.444	3	6750	6750
1.755	34.156	3	8783	8783
1.755	32.432	3	9250	9250
1.755	30.354	3	9883	9883
1.755	29.126	3	10300	10300
1.755	28.037	3	10700	10700
1.755	26.588	3	11283	11283
1.755	25.751	3	11650	11650
1.755	25.751	3	11650	11650
1.755	25.316	3	11850	11850

Discussion and Interpretation of Results:

The molar conductivity of high concentrations of both salts is less than expected despite the presence of a large number of charged ions. This is because increasing the concentration leads to the ions coming closer together, causing the positive ion (+) to approach the negative ion (-) and form what is known as an ion pair, represented as (M+A-). Continuous exchange occurs between the ions of different pairs, with each ion pair having a specific lifetime. The ion pair behaves as an undissociated molecule and does not contribute to carrying the electric current within the solution. As the concentration of ion pairs in the solution increases, the molar

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

conductivity decreases because part of the electrolyte concentration is bound in ionic clusters incapable of carrying the electric current. The concentration of ion pairs in the electrolyte solution increases as the ion size decreases and its charge increases, and also as the dielectric constant of the medium increases. It refers not to the bare ion size but to its size when associated with solvent molecules, which is usually larger than the bare ion size (20)(21). In the case of chromium chloride, two types of ion pairs can form at high concentrations of these electrolytes: one with the CrCl3 ion and the solvent, and the other with the positive electrolyte ion in the solution. The presence of these pairs causes the ion to move slowly and creates an effect. Conductivity may increase again with increasing concentration due to the formation of ion triplets in addition to the effect of the ionic atmosphere. These ion pairs and triplets (e.g., M+A-M+ or A-M+A-) appear as if they carry a single positive or negative charge, respectively, and can conduct electric current in the electrolyte solution (5).
For the CrCl3 Electrolyte Solution: Trivalent electrolyte solutions at different concentrations have higher conductivity than monovalent electrolytes (KCl) due to the increased charges contributing to conductivity. Conductivity increases with increasing ionic strength but decreases significantly at high concentrations due to internal forces.

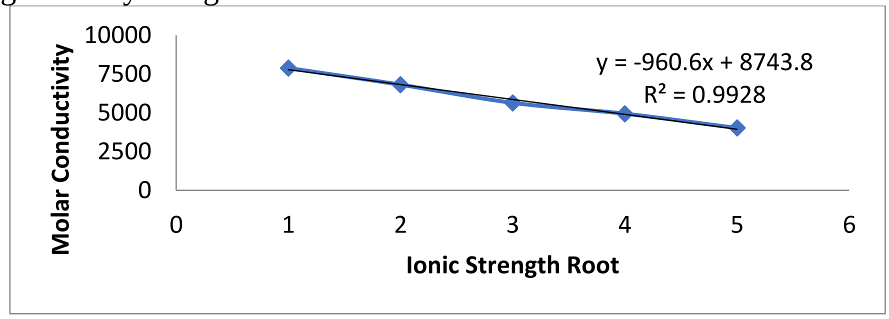


Figure (11): Relationship between Ionic Strength Root and Molar Conductivity for CrCl3 Salt with Chalcone For CrCl3, this relationship and the above plot indicate a negative slope, suggesting that an increase in ionic strength leads to a decrease in molar conductivity and, consequently, a decrease in reaction rate. This occurs in the case of ions with different charges, resulting in a negative slope. The slope value indicates the type of valence ions involved in the reaction, suggesting that one reactant is monovalent and the other divalent, as shown in the following figure.

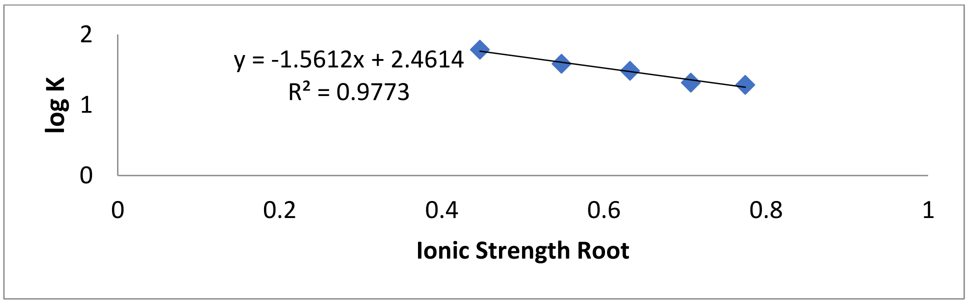


Figure (12): Relationship between Ionic Strength Root and log K for CrCl3 Salt with Chalcone For KCl salt, as shown in the figure below, the slope value is negative and monovalent, indicating that both reacting ions (chalcone and salt) are monovalent.

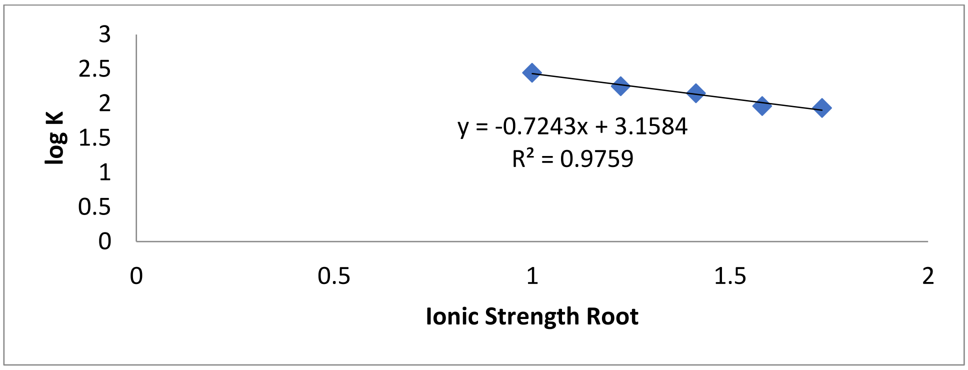


Figure (13): Relationship between Ionic Strength Root and log K for KCl Salt with Chalcone

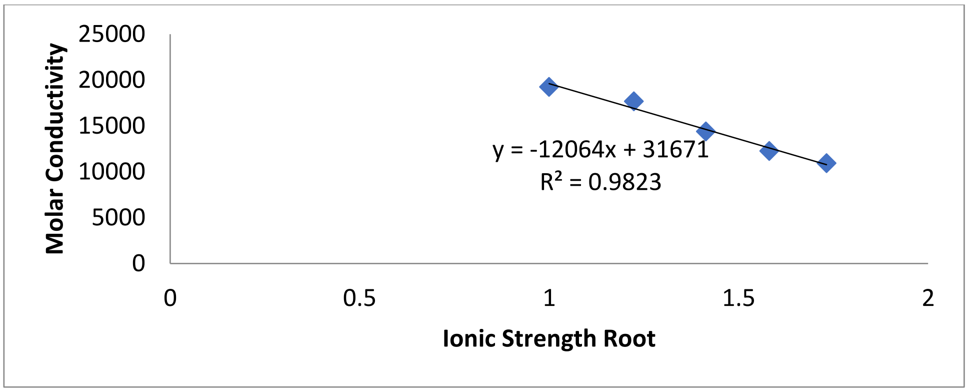


Figure (14): Relationship between Ionic Strength Root and Molar Conductivity for KCl Salt with Chalcone

Conclusions:

- The electrical conductivity (Λ) increases with increasing ionic strength (I) in the order CrCl3 > KCl, indicating that trivalent positive ions contribute more to conductivity due to the increased number of current-carrying ions at a given concentration.
- The electrical conductivity (Λ) of the trivalent electrolyte CrCl3 is higher than that of the monovalent electrolyte KCl due to the increased charges contributing to conductivity, which increases with ionic strength and decreases significantly at high concentrations due to internal forces.
- Activity coefficients (F) for different concentrations were derived from the relationship (I = F.Cond), which can be used to determine ionic strength through direct and easy measurement of electrical conductivity.
- The thickness of the ionic atmosphere was calculated by measuring the electrical conductivity of CrCl3 and KCl salt solutions in this study using the ionic atmosphere thickness relationship: d=4.3×[2(F·Cond)]−12d = 4.3 \times \left[2(F \cdot \text{Cond}) \right]^{-\frac{1}{2}}d=4.3×[2(F·Cond)]−21

References:

1. P. Debye and E. Huckel, Z. Bid, 24, 305, (2001).
2. V. J. Ram, A. S. Saxena, S. Srivastave and S. Chander, "Bioorg Med. Chem. Lett.", 10, 2159, (2009).
3. Chandrika Akilan, N. Ohman, Chem, Physchem, Vol.7, Issn:11, 2319-2330, (2006).

4. J.M. Salah, Electrical chemistry, Baghdad University, (1992).
5. J.J.M. Bockris and A.N. Reddy, Modern Electrochemistry, Vol.1, Plenum Press, (1970). 10-Bockris, J. Modern Electrochemistry 1, 2A and 2B, 2nd ed, 215-218, (2007).
6. Kith J. Indler and John H. Meiser, Physical Chemistry, New York 303, (1999).
7. K.S. Pitzer, Activity, Coefficients in Electrolyte Solution. 2nd ed., London CRC Press, Baca. Raton, 237, (2011).
8. J.M.J. Barthal, K. Krienke and W. Kanz, J. Physical Chemistry of Electrolyte Solution. New York, 356, (2008).
9. Iqbal Salman Mohammed, "The Relationship Between Electrical Conductivity and Ionic Strength in Divalent Electrolytes", Diyala Journal, Issue 39, 2009.
10. C.P. Atkins and J.D. Scanttelaury, Journal of Corrosion Science and Engineering, 1, 2, (1995).
11. C.L. Paye, P. Vassic, Materials and Structures, 243, (1998).
12. Amer Fadel Daoud, "Estimation of Ionic Strength and Development of Ionic Atmosphere Thickness Equation in Aqueous Solutions by Electrical Conductivity Method for Some Electrolytes", Diyala Journal, Issue 39, 2009.
13. C.L. Paye, P. Vassic, Materials and Structures, 243, (1998).
14. Taschenbuch Chemische Substanzen, Willmes, Verlag Harri Deutsch, ISBN 3-8171-1662-4.
15. Hefter, Glenn, Ting, Journal of Physical Chemistry B, ISSN: 1520-6106, (1999).
16. Sigma Material Safety Data Sheet – Potassium, Section, Sigma Chemical Company, valid 11/7/2001.
17. Taschenbuch Chemische Substanzen, Willmes, Verlag Harri Deutsch, ISBN 3-8171-1662-4.
18. C. S. Marrel, L. E. Coleman and G.P. Scott, “J. Organic Chemistry”, 20, PP. (1785-1792), (2006).
19. D.N. Dhar, "The Chemistry of Chalcones and Related Compounds", John Wiley and Sons, Inc., 54-57, (1981).
20. R.G. Hammond, "Elements of Organic Chemistry", 2nd ed., McGraw-Hill, Inc. (1979).
21. A. Vogel, "Text-Book of Practical Organic Chemistry", 4th ed., Longman, London (1978).
22. Kadham, S. M., Mustafa, M. A., Abbass, N. K., & Karupusamy, S. (2024). IoT and artificial intelligence–based fuzzy-integral N-transform for sustainable groundwater management. Applied Geomatics, 16(1), 1-8.
23. Ali, S. H., Armeet, H. S., Mustafa, M. A., & Ahmed, M. T. (2022, November). Complete blood count for COVID-19 patients based on age and gender. In AIP Conference Proceedings (Vol. 2394, No. 1). AIP Publishing.
24. Shakir, O. M., Abdulla, K. K., Mustafa, A. A., & Mustafa, M. A. (2019). Investigation of the presence of parasites that contaminate some fruits and vegetables in the Samarra City in Iraq. Plant Arch, 19, 1184-1190.
25. Abdulqader, A. T., Al-Sammarie, A. M. Y., & Mustafa, M. A. (2022, May). A comparative environmental study of aqueous extracts of ginger and grapes to protect hepatocytes in Albino rabbits and a comparison of extracts in preserving Awassi lamb meat from oxidation. In IOP Conference Series: Earth and Environmental Science (Vol. 1029, No. 1, p. 012001). IOP Publishing.

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

26. Kadham, S. M., Mustafa, M. A., Abbass, N. K., & Karupusamy, S. (2023). Comparison between of fuzzy partial H-transform and fuzzy partial Laplace transform in x-ray images processing of acute interstitial pneumonia. International Journal of System Assurance Engineering and Management, 1-9.
27. Meri, M. A., Ibrahim, M. D., Al-Hakeem, A. H., & Mustafa, M. A. (2023). Procalcitonin and NLR Measurements in COVID-19 Patients. Latin American Journal of Pharmacy, 220-223.
28. Mustafa, M. A., Raja, S., Asadi, L. A. A., Jamadon, N. H., Rajeswari, N., & Kumar, A. P. (2023). A Decision-Making Carbon Reinforced Material Selection Model for Composite Polymers in Pipeline Applications. Advances in Polymer Technology, 2023(1), 6344193.
29. Valluru, D., Mustafa, M. A., Jasim, H. Y., Srikanth, K., RajaRao, M. V. L. N., & Sreedhar, P. S. S. (2023, March). An Efficient Class Room Teaching Learning Method Using Augmented Reality. In 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS) (Vol. 1, pp. 300-303). IEEE.
30. Mustafa, M. A., Kadham, S. M., Abbass, N. K., Karupusamy, S., Jasim, H. Y., Alreda, B. A., ... & Ahmed, M. T. (2024). A novel fuzzy M-transform technique for sustainable ground water level prediction. Applied Geomatics, 16(1), 9-15.
31. Hsu, C. Y., Mustafa, M. A., Yadav, A., Batoo, K. M., Kaur, M., Hussain, S., ... & Nai, L. (2024). N2 reduction to NH3 on surfaces of Co-Al18P18, Ni-Al21N21, Fe-B24N24, Mn-B27P27, Ti-C60 and Cu-Si72 catalysts. Journal of Molecular Modeling, 30(3), 1-11.
32. Yaseen, A. H., Khalaf, A. T., & Mustafa, M. A. (2023). Lung cancer data analysis for finding gene expression. Afr. J. Biol. Sci, 5(3), 119-130.
33. Lu, Z. F., Hsu, C. Y., Younis, N. K., Mustafa, M. A., Matveeva, E. A., Al-Juboory, Y. H. O., ... & Abdulraheem, M. N. (2024). Exploring the significance of microbiota metabolites in rheumatoid arthritis: uncovering their contribution from disease development to biomarker potential. APMIS.
34. Saadh, M. J., Avecilla, F. R. B., Mustafa, M. A., Kumar, A., Kaur, I., Alawayde, Y. M., ... & Elmasry, Y. (2024). The promising role of doped h-BANDs for solar cells application: A DFT study. Journal of Photochemistry and Photobiology A: Chemistry, 451, 115499.
35. Mahmoud, Z. H., Ajaj, Y., Hussein, A. M., Al-Salman, H. N. K., Mustafa, M. A., Kadhum, E. H., ... & Kianfar, E. (2024). CdIn2Se4@ chitosan heterojunction nanocomposite with ultrahigh photocatalytic activity under sunlight driven photodegradation of organic pollutants. International Journal of Biological Macromolecules, 267, 131465.
36. Saadh, M. J., Mustafa, M. A., Hussein, N. M., Bansal, P., Kaur, H., Alubiady, M. H. S., ... & Margarian, S. (2024). Investigating the ability of BC2N nanotube to removal Eriochrome blue black from wastewater: A computational approach. Inorganic Chemistry Communications, 163, 112311.
37. Espín, C. G. S., Morocho, W. M. B., Cordero, A. Á. S., Chandra, S., Bansal, P., Kaur, H., ... & Lasisi, A. (2024). Theoretical and experimental study of flower-like NiMoS/NiO/NF with interface layer as a novel highly efficient bifunctional-electrode toward supercapacitor and HER. Journal of Electroanalytical Chemistry, 960, 118163.

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

38. Saadh, M. J., Mustafa, M. A., Batoo, K. M., Chandra, S., Kaur, M., Hussain, S., ... & Su, G. (2024). Performances of nanotubes and nanocages as anodes in Na-ion battery, K-ion battery, and Mg-ion battery. Ionics, 1-8.
39. Kumar, A., Mustafa, M. A., Fouly, A., Bains, P. S., Sharma, R., Bisht, Y. S., ... & Singh, P. (2024). NiO x/PANI nanocomposite doped carbon paste as electrode for long-term stable and highly efficient perovskite solar cells. RSC advances, 14(19), 13374-13383.
40. Hadi, E. F., Baharuddin, M. Z. B., Zuhdi, A. W. M., Ghadir, G. K., Al-Tmimi, H. M., & Mustafa, M. A. (2024). Enhancing Remaining Useful Life Predictions in Predictive Maintenance of MOSFETs: The Efficacy of Integrated Particle Filter-Gaussian Process Regression Models. International Journal of Safety & Security Engineering, 14(2.(
41. Hsu, C. Y., Mustafa, M. A., Kumar, A., Pramanik, A., Sharma, R., Mohammed, F., ... & Abosaoda, M. K. (2024). Exploiting the immune system in hepatic tumor targeting: unleashing the potential of drugs, natural products, and nanoparticles. Pathology-Research and Practice, 155266.
42. Saadh, M. J., Morocho, W. M. B., Ajaj, Y., Yadav, A., Cabezas, N. T. M., Bansal, P., ... & Muzammil, K. (2024). Direct CO2 disassociation and HA activation mechanisms on Fe-doped graphdiyne for enhanced catalyst design. Sustainable Chemistry and Pharmacy, 38, 101487.
43. Behmagham, F., Mustafa, M. A., Saraswat, S. K., Khalaf, K. A., Kaur, M., Ghildiyal, P., & Vessally, E. (2024). Recent investigations into deborylative (thio-/seleno-) cyanation of aryl boronic acids. RSC advances, 14(13), 9184-9199.
44. Ortiz, D. T. C., Ghadir, G. K., Mustafa, M. A., Chandra, S., Kaur, I., Saadh, M. J., ... & Elmasry, Y. (2024). Exploring the photovoltaic performance of boron carbide quantum dots doped with heteroatoms: A DFT analysis. Diamond and Related Materials, 110933.
45. Valverde, V., Ortiz, D. T. C., Mustafa, M. A., Kumar, A., Kaur, I., Karim, M. M., ... & Lasisi, A. (2024). Design gas sensor based on transition metal doped graphene like nanosheets: A quantum chemical study. Diamond and Related Materials, 110895.
46. CHOWDHARY, H., CHAUDHARY, D. N. K., HARAHSHEH, F. A. H., MUSTAFA, M. A., RAJAK, D. M., & TOMAR, R. K. (2024). TECHNICAL ANALYSIS OF INTERNET SHUTDOWNS: ECONOMIC AND CYBERSECURITY DIMENSIONS IN INDIA AND INTERNATIONAL CONTEXT. Journal of Theoretical and Applied Information Technology, 102(4.(
47. Saadh, M. J., Lagum, A. A., Ajaj, Y., Saraswat, S. K., Dawood, A. A. A. S., Mustafa, M. A., ... & Elmasry, Y. (2024). Adsorption behavior of Rh-doped graphdiyne monolayer towards various gases: A quantum mechanical analysis. Inorganic Chemistry Communications, 160, 111928.
48. Jameel, M. K., Mustafa, M. A., Ahmed, H. S., jassim Mohammed, A., Ghazy, H., Shakir, M. N., ... & Kianfar, E. (2024). Biogas: Production, properties, applications, economic and challenges: A review. Results in Chemistry, 101549.
49. Saadh, M. J., Ajaj, Y., Mustafa, M. A., Kattab, N. O., Osman, S. M., Ahmad, H., ... & Elawady, A. (2024). Iridium (Ir) decorated silicon Carbide (SiC) nanosheet as a promising sensitive material for detection of γ-Hydroxybutyric acid drug based on the DFT approach. Molecular Physics, e2356754.
50. Laylani, L. A. A. S. S., Al-Dolaimy, F., Altharawi, A., Sulaman, G. M., Mustafa, M. A., Alkhafaji, A. T., & Alkhatami, A. G. (2024). Electrochemical DNA-nano biosensor

for the detection of Goserelin as anticancer drug using modified pencil graphite electrode. Frontiers in Oncology, 14.
51. Mahmoud, Z. H., Ghadir, G. K., Al-Tmimi, H. M., Al-Shuwaili, S. J., Ami, A. A., Radi, U. K., ... & Mustafa, M. A. (2024). Polyaniline/TiO2 nanocomposite for high performance supercapacitor. Bulletin of the Chemical Society of Ethiopia, 38(4), 1177-1188.
52. Saadh, M. J., Mustafa, M. A., Kumar, S., Gupta, P., Pramanik, A., Rizaev, J. A., ... & Alzubaidi, L. H. (2024). Advancing therapeutic efficacy: nanovesicular delivery systems for medicinal plant-based therapeutics. Naunyn-Schmiedeberg's Archives of Pharmacology, 1-26.
53. Mejía, N., Mustafa, M. A., Kumar, A., Kumar, A., Ghildiyal, P., Malik, A., ... & Wei, Q. (2024). Potential of Nanocages as Effective Catalysts for Oxygen Reduction Reaction. Silicon, 1-8.
54. Santos, D. K. C., Mustafa, M. A., Bansal, P., Kaur, H., Deorari, M., Altalbawy, F. M., ... & Zhang, L. (2024). Investigation of ORR and OER Mechanisms by Co-and Fe-doped Silicon Nanocages (Si48 and Si60) and Co-and Fe-doped Silicon Nanotubes (SiNT (5, 0) and SiNT (6, 0)) as Acceptable Catalysts. Silicon, 1-13.
55. Hsu, C. Y., Mutee, A. F., Porras, S., Pineda, I., Mustafa, M. A., Saadh, M. J., & Adil, M. (2023). Amphiregulin in infectious diseases: Role, mechanism, and potential therapeutic targets. Microbial Pathogenesis, 106463.
56. Saadh, M. J., Singh, D., Mayorga, D., Kumar, A., Albuja, M., Saber, A. I., ... & Sun, N. (2024). The potential of 2D carbon nitride monolayer as an efficient adsorbent for capturing mercury: A DFT study. Diamond and Related Materials, 141, 110566.
57. Alabbasy, R. H., Azeez, A. K., Meri, M. A., & Mustafa, M. A. (2023, December). Histological study of the effect of some oncology drugs on heart muscle. In AIP Conference Proceedings (Vol. 2977, No. 1). AIP Publishing.
58. Khaleel, Z. I., Saab, N. G., Meri, M. A., & Mustafa, M. A. (2023, December). The role of microbial pathogens in infection of lung organs and spleen of laboratory albino rats. In AIP Conference Proceedings (Vol. 2977, No. 1). AIP Publishing.
59. Taha, W. A., Shakir, O. M., Meri, M. A., & Mustafa, M. A. (2023, December). Study of some biochemical indicators levels in the people infected by Toxoplasma gondii. In AIP Conference Proceedings (Vol. 2977, No. 1). AIP Publishing.
60. Mustafa, M. A., Mustafa, H. A., Ahmed, M. T., & Meri, M. A. (2023). Virulence factors of proteus mirabilis isolated from urinary tract infection patients. Lat. Am. J. Pharm, 42, 418-421.
61. Mustafa, M. A., Rahman, M. A. A., & Almahdawi, Z. M. M. (2023). Male infertility treatment unveiled: exploring new horizons with Q-Well 10-results from a pioneering medical study.
62. Alamiry, S. N. J., Kadham, S. M., Mustafa, M. A., & Abbass, N. K. Encryption and enhance medical image using hybrid transform (Ã-module and partial fuzzy Ȟ-transform.(
63. Kadham, S. M., & Mustafa, M. A. Medical applications of the new-transform.
64. Kadham, S. M., & Mustafa, M. A. Fuzzy SHmath. Mbio-transform generalization and application to skin cancer imaging (distributed diseases.(

Western European Journal of Medicine and Medical Science
Volume 2, Issue 8, August, 2024
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

65. Khudhair, M. A., & Mustafa, M. A. Investigating the Relationship between Hyperprolactinemia, Menstrual Disorders, and Infertility in Women of Reproductive Age.
66. Abdulazeez, M. I., Hamdi, A. Q., Mohammed, H. Y., & Mustafa, M. A. (2020). Dental trauma of permanent incisor teeth in children/Kirkuk city. Systematic Reviews in Pharmacy, 11(12).