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Manufacture of an Electrical Conductor Cell of Chromium 316 and its Analytical Applications

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Abstract This research studied the manufacture of a cell for measuring electrical conductivity that consists of two electrodes made of chromium 316 with dimensions of (1 × 4) cm, and a thickness (0.5mm) each, and installed on a glass cell with a fixed dimension separated by (1cm).
Each electrode in the solution must be (1 × 1) cm to obtain a technical cell constant ($1cm^{-}$).
The manufactured cell is linked with the Wheatstone Bridge, which is made of 3 resistors (two resistors with a value of 5 KΩ and one variable resistance) and the bridge was linked with an alternating current transformer, then the transformer was linked to the Galvano scale, then the optimal conditions for the operation of this cell were studied on a standard solution of potassium chloride (KCl) with a concentration of (0.01M) which has an electrical conductivity (1413 /s / cm) at 25 ℃.
The best wave is found to be a sine wave at (1000Hz) frequency with a potential difference (3V) and an alternating current using the temperature coefficient given by the following equation: $K_{Tref} = \frac{100 \times K_T}{100 + \theta(T - T_{ref})}$ to have electrical conductivity measurements at a reference temperature of 25 ℃ .
The manufactured cell was applied in direct measurements of different samples and in indirect measurements of adjustments and deposition titrations for analytical and environmental testing

Keywords Electrical conductivity Cell Manufacture, Electrical conductivity Solution, Cell Constant, Temperature Coefficient, Chromium 316.Wheatstone Bridge

1. Introduction

There is increasing interest worldwide in the use of fast and less expensive analytical methods as an alternative to the more complex and costly ones, one of the most important is the electrical conductivity of solutions Due to its analytical, environmental and applied importance in the food and pharmaceutical industries. Where the electrical conductivity is used to monitor the ion content of (fruit solutions _ juices _ carbonated drinks _ dialysis liquids) in addition to water (drinking water _ sewage _ treated water), the term electrical conductivity is related to resistance of the electric current according to the relationship $K_c = \frac{K_{cell}}{R_s}$

K_c : Conductivity of the solution, K_{cell} : cell constant , R_s : electrical resistance of the solution [1].

For many years, measuring instruments (resistance, conductivity) have been used as reliable indicators to measure the ionic quality of water, particularly high purity water [2].

Electrical conductivity is also an easy, fast and essential method used to monitor the performance of demineralization and other processes in water treatment and to detect ion pollution in boiler and water used in pharmaceutical industries [3].

The electrical conductivity device consists of a conductivity cell and an electrical conductivity meter, the cell consists of two electrodes (platinum plates) fixed at a fixed distance from each other. They were connected by cables to the meter, which in turn consisted of the Wheatstone Bridge circuit.

Alternating current was used to avoid apparent change and resistance over time due to chemical reactions (polarization effect on electrodes) [4].

In designing electrical conductivity cells, the following points should be considered:

1- Electrodes should be made of a good conductive material, chemically inert and thermally stable.

2- Electrodes must have the same measurement and do not stir or mix the solution when taking electrical conductivity results [5].

Dual electrode conductivity cells are easy to conserve, economical. They are used in viscous solutions or contain suspensions, The conductivity meter also depends mainly on the resistance of the components of the solution. The solution is supplied with alternating current and the resistance of the solution is obtained by using one of the methods (generator or oscilloscope, amplifier, resistance measuring device) [6].

2. Methods and Materials

2.1. Equipment used in the installation of a conductivity meters

Frequency generator FUNKTIONSGENERA, Galvanometer, Avo device PEAKTECH 3340 DMM, AC to DC converter GBJ 2510, Wheatstone Bridge: It was installed from two fixed resistors on the bridge each 5 kΩ, Three variable resistors (removable): First resistance [0-1]KΩ, Second resistance[0-5]KΩ, Third resistance [0-20]KΩ, Electrical wirings.

2.2. Tools used in the manufacture of electric conductivity cell

Round glass plate, flask (round-bottom), two electrodes made of chrome metal 316, Teflon and chemical adhesives, 2 wires for connecting.

2.3. Different instruments and laboratory equipment

Beakers, Burette, Falsk (conical), Flask (volumetric), Measuring cylinder, All made of glass.

EC Meter: EC-METER GLP 31+, Crison.

2.4. Chemicals used in this research

Standard solutions were used to measure electrical conductivity (KCl) Production Company Crison, Sodium chloride (pure solid), Chloric Acid 35% and Sodium hydroxide 99.0% -solid, ($AgNO_3$) Pure Solid.

3. Manufacture of electrical conductivity cell measurement and calculation of technical cell constant

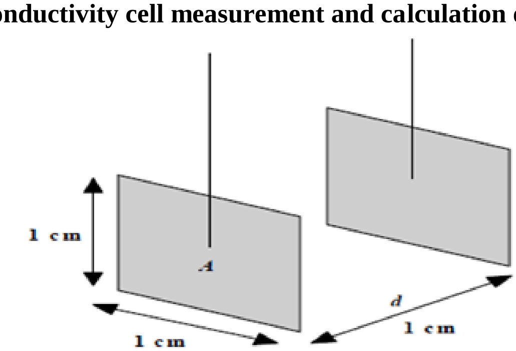

Figure 1: Electrode dimensions and the distance between them

The conductivity cell is made of chromium 316, the cell consists of two electrodes rectangular with dimensions (1 x 4) cm, and thickness 0.5mm, Fixed using Teflon material on a glass panel installed in turn within Laboratory glass cell It was drilled from below by a variable dimensional glass drill, Chemical labels were used inside to stabilize the two electrodes so that the distance between them is fixed (1cm). The immersed part of the solution from each electrode is a square nominally (1 × 1)cm. In order to obtain the technical cell constant with the value (1 cm^{-1}). This is an application of the relationship: $K_{cell} = {}^{L}/_{A}$; K_{cell}: Technical cell constant, L: The distance between the two electrodes.

A: Surface area of the electrode [2]. Polishing and softening of the electrode was carried out after cutting, washed with alcohol and then drip-distilled water to obtain a clean, effective surface area.

4- Installation of electrical conductivity meter (Wheatstone Bridge):

The manufactured conductivity cell was connected to the Wheatstone Bridge by electric wires. The bridge, in turn, consists of four resistors (Resistors R1, R2 have constant values (5KΩ), R3 variable resistance with a specific range, R4, resistance of the studied solution).

The following relationship was applied: $\frac{R2}{R1} = \frac{R_{solution}}{R3}$;

$\frac{R3*R2}{R1} = R_{solution}$ [8-7].

And because (R1=R2=5kΩ) the previous relationship is as follows: $R_3 = R_{solution}$.

Calculating the value of the variable resistance by the AVO device is obtained by the value of the resistance of the solution, including the conductivity of the solution.

Figure (2) shows the general method used to link the electrical conductivity cell with the Wheatstone Bridge [9].

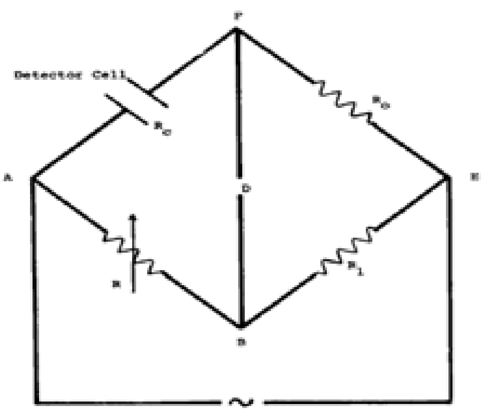

Figure 2: Linking the Wheatstone Bridge with the manufactured cell to measure electrical conductivity

5. Temperature correction coefficients

In order to obtain the electrical conductivity values of aqueous solutions at reference temperature (25)℃ Two coefficients were used to correct the temperature.

The first is given by the following equation: $K_{Tref} = \frac{100 \times K_T}{100 + \theta(T - T_{ref})}$ [10].

K_{Tref}: Electrical conductivity at reference temperature(25℃), K_T: Electrical conductivity at the temperature of the solution, T_{ref}: Reference temperature (25℃), T: the temperature of the solution, θ: Temperature coefficient.

Table (1) shows temperature coefficients for some chemicals [11].

Table 1: Temperature coefficients for some chemicals

Chemical	Temperature coefficient θ (%/℃)
Acids	1.0-1.6
Foundations	1.8-2.2
Salts	2.2-3.0
Drinking water	2.0
Distilled water	5.2

The second coefficient is given by the following: $K_{Tref} = \frac{K_T}{1+0.0191(T-25)}$

K_{Tref} : Electrical conductivity at reference temperature(25℃), K_T : Electrical conductivity at the temperature of the solution, T_{ref} : Reference temperature (25℃), T: the temperature of the solution [12-13].

6. Results and Discussion

6.1. Test cell conductivity manufactured using standard solutions

After the selection of the conditions of work of the cell were tested for validity and accuracy on three standard solutions of potassium chloride at different concentrations the three solutions have specific values for electrical conductivity [14].

Table 2: Measurements of Electrical Conductivity Cell Manufactured on Standard Solutions

KCl 0.1 M	KCl 0.01 M	KCl 0.001 M	Standard Solution
12880	1413	147	Theoretical value of conductivity K(μs/cm)
14180	1568	157	The electrical conductivity value of
14355	1565	161	the manufactured cell
14290	1581	168	K(μs/cm)(30℃)
14275	1571	162	Average K(μs/cm)
12689	1396	441	$K_{Tref} = \frac{100 \times K_T}{100 + \theta(T - T_{ref})}$
98.51	98.79	97.95	Retrospective %
88.46	8.5	5.56	SD
0.69	0.61	3.86	RSD%
2.94	3.46	0.93	t_{ex}
13031	1434	148	$K_{Tref} = \frac{K_T}{1 + 0.0191(T - 25)}$
101.17	101.48	100.68	Retrospective %
88.46	8.5	5.56	SD
0.67	8.37	3.75	RSD%
2.95	4.27	0.31	t_{ex}

By comparing all measurements of the conductivity of the manufactured cell to the reference tables at a confidence level (95%) It was noted that they gave a correct result from a statistical point of view.

The experiment was conducted at 30 ° C and compensated (θ =2.5) for the first temperature coefficient.

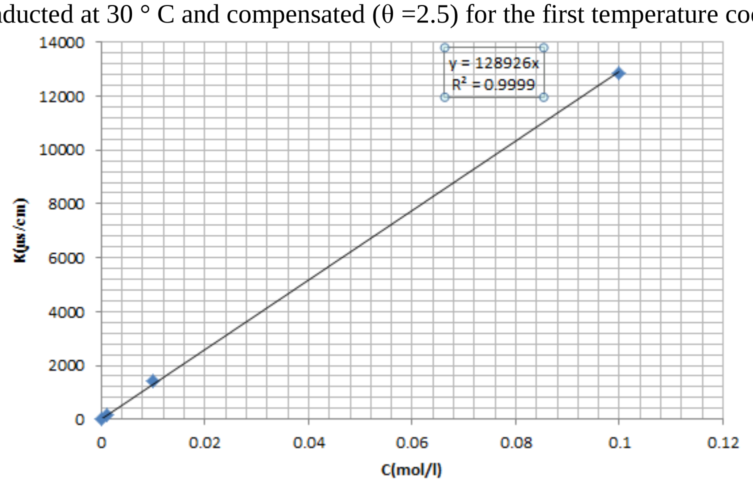

Figure 3: Electrical curved conductivity with standard solutions

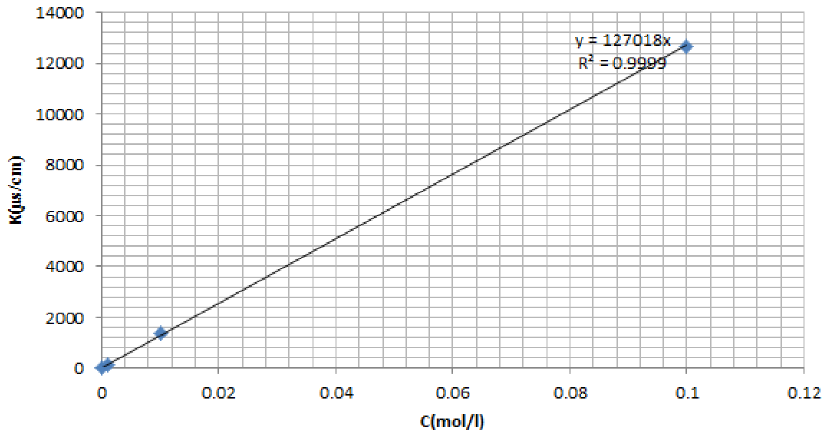

Figure 4: Electrical conductivity bended with calibrated solutions of the manufactured cell and the first temperature coefficient

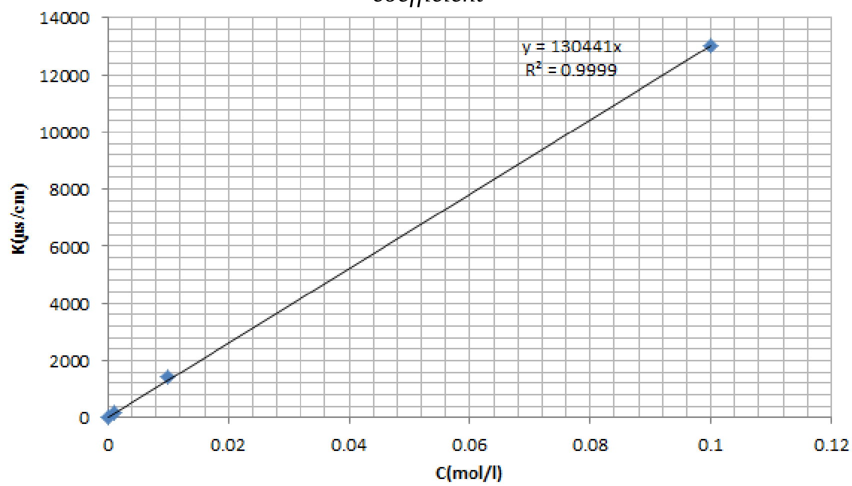

Figure 5: Electrical conductivity curve with standard solutions of the manufactured cell and the second temperature coefficient

6.2. Measuring an unknown concentration of a solution by a prepared series of sodium chloride solution

The manufactured conductivity was used to measure the electrical conductivity of a standard series of NaCl solution and a value was determined Anonymous focus C_x for a sample of this series and Table 3 shows the results obtained:

Table 3: Electrical Conductivity Measurements for Sodium Chloride Solution

$(\boldsymbol{NaCl})_{aq}$ **0.01M**	$(\boldsymbol{NaCl})_{aq}$ $\boldsymbol{C_x}$	$(\boldsymbol{NaCl})_{aq}$ **0.005M**	$(\boldsymbol{NaCl})_{aq}$ **0.004M**	$(\boldsymbol{NaCl})_{aq}$ **0.001M**	**The sample 30℃**
1180	829	583	469	127	Conductivity value of the systemic cell K(µs/cm)
1330	925	639	527	146	The electrical conductivity value of the manufactured cell K(µs/cm)
1326	927	634	521	147	
1341	949	660	533	153	
1182	822	568	468	130	$K_{Tref} = \frac{100 \times K_T}{100 + \theta(T - T_{ref})}$
1179	824	566	463	131	
1192	844	587	473	136	
1184	830	574	468	132	Average K(µs/cm)

100.33	100.12	98.45	99.78	103.93	Retrospective%
6.80	12.16	11.59	5	3.21	SD
0.57	1.46	2.01	1.08	2.43	RSD%
0.51	0.14	1.49	0.34	2.69	t_{ex}
1214	844	583	481	133	$K_{Tref} = \frac{K_T}{1 + 0.0191(T - 25)}$
1210	846	579	476	134	
1224	866	602	487	140	
1216	852	588	481	136	Average K(µs/cm)
103.05	102.77	100.85	102.55	107.08	Retrospective%
7.21	12.16	12.28	5.50	3.79	SD
0.59	1.42	2.08	1.14	2.78	RSD%
8.64	3.23	0.70	4.09	4.12	t_{ex}

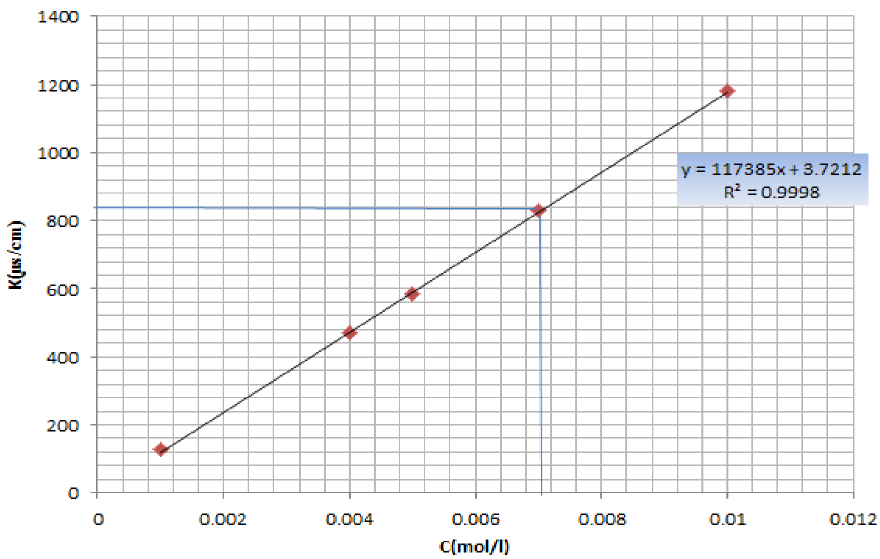

Figure 6: Direct curve measurement of a series of sodium chloride using a systemic cell

Figure (6) found that the concentration of the unknown sample is 0.071 moll / l.

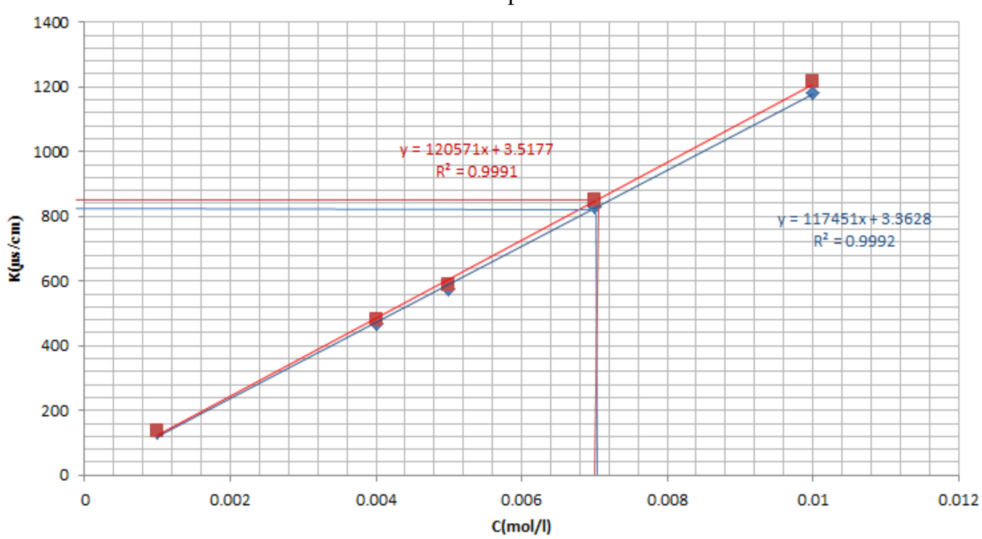

Figure 7: Direct measurement curve of a series of sodium chloride for the manufactured cell

From Figure (7) the concentration of the unknown sample is 0.071 moll / l.

6.3. Titration of strong acid with strong basis

A strong acid titration experiment was performed (chlorine acid is of unknown concentration. The volume of the solution is 50ml) with a strong base of sodium hydroxide (0.1M).

Table 4: Electrical Conductivity Measurements for titration of HCl Acid Based on NaOH

3.5	**3**	**2.5**	**2**	**1.5**	**1**	**0.5**	**0**	**(NaOH) 0.1M/ ml**
1512	1277	1025	737	439	870	1235	1480	Conductivity value of the systemic cell K(μs/cm)
1672	1421	1138	819	480	937	1330	1592	The electrical conductivity value of the manufactured cell K(μs/cm) 30 ℃
1666	1410	1130	821	473	945	1349	1602	
1670	1410	1142	834	486	934	1337	1611	
1520	1292	1034	745	451	880	1249	1495	$\frac{100\times K_T}{100+\theta(T-T_{ref})}=K_{Tref}$
1514	1282	1027	746	444	887	1267	1504	
1518	1282	1038	758	456	877	1255	1513	
1517	1285	1033	750	450	881	1257	1504	Average K(μs/cm)
100.33	100.62	100.78	101.76	102.50	101.26	101.78	101.62	Retrospective%
3.05	5.77	5.56	7.23	6.02	5.13	9.16	9	SD
0.20	0.44	0.53	0.96	1.33	0.58	0.72	0.59	RSD%
1.43	2.4	2.49	3.11	3.16	3.71	4.15	4.61	t_{ex}
1526	1297	1039	748	438	855	1214	1453	$\frac{K_T}{1+0.0191(T-25)}=K_{Tref}$
1521	1287	1031	749	432	863	1231	1462	
1524	1287	1042	761	444	853	1220	1471	
1524	1290	1037	753	438	857	1222	1462	Average K (μs/cm)
100.79	101.01	101.17	102.17	99.77	98.50	98.94	98.78	Retrospective%
2.51	5.77	5.68	7.23	6	5.29	8.62	9	SD
0.16	0.44	0.54	0.96	1.36	0.61	0.70	0.61	RSD%
8.28	3.9	3.65	3.83	0.28	4.25	2.61	3.46	t_{ex}

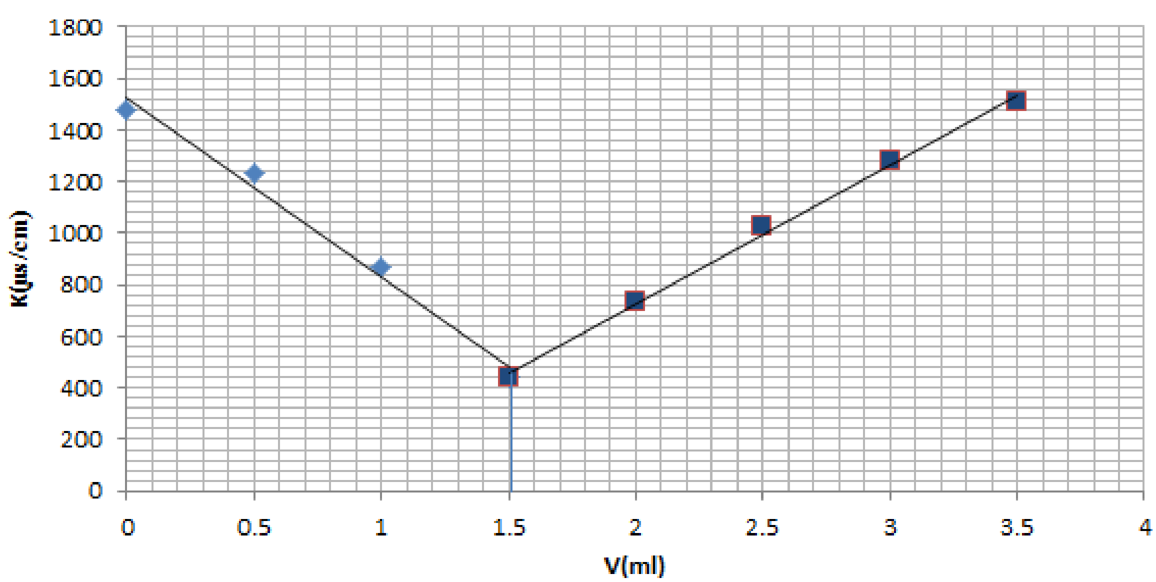

Figure 8: Electrical conductivity curve of the systemic apparatus to titration a strong acid with a strong base

Figure (8) found that the volume of sodium hydroxide needed for the titration of chlorine acid (1.5) ml.

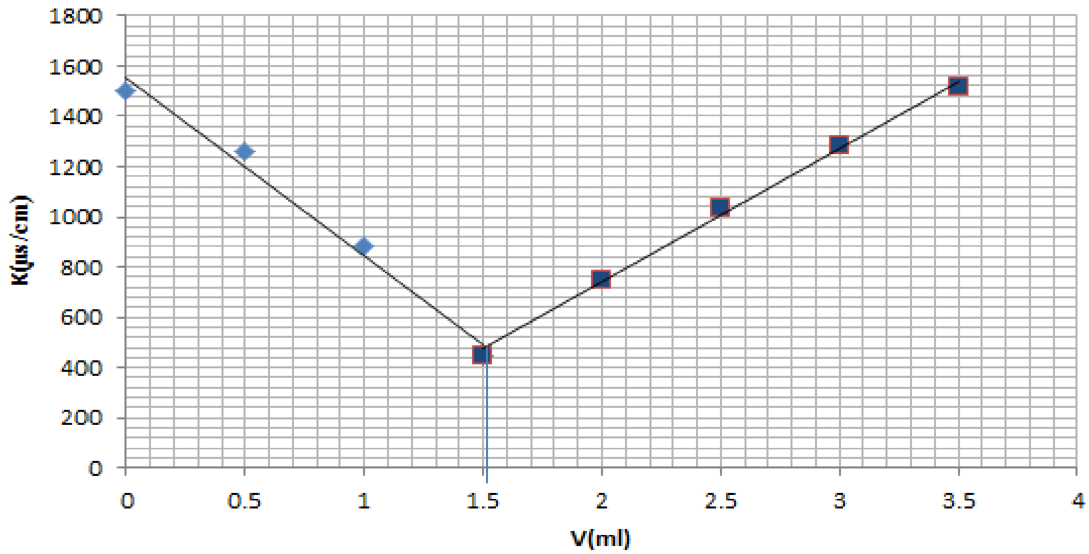

Figure 9: The electric conductivity curve of the manufactured cell is to titrate a strong acid with a strong basis by compensating for the first temperature coefficient

It is observed from Figure (9) that the necessary volume of sodium hydroxide for the titration of chloric acid is (1.51) ml

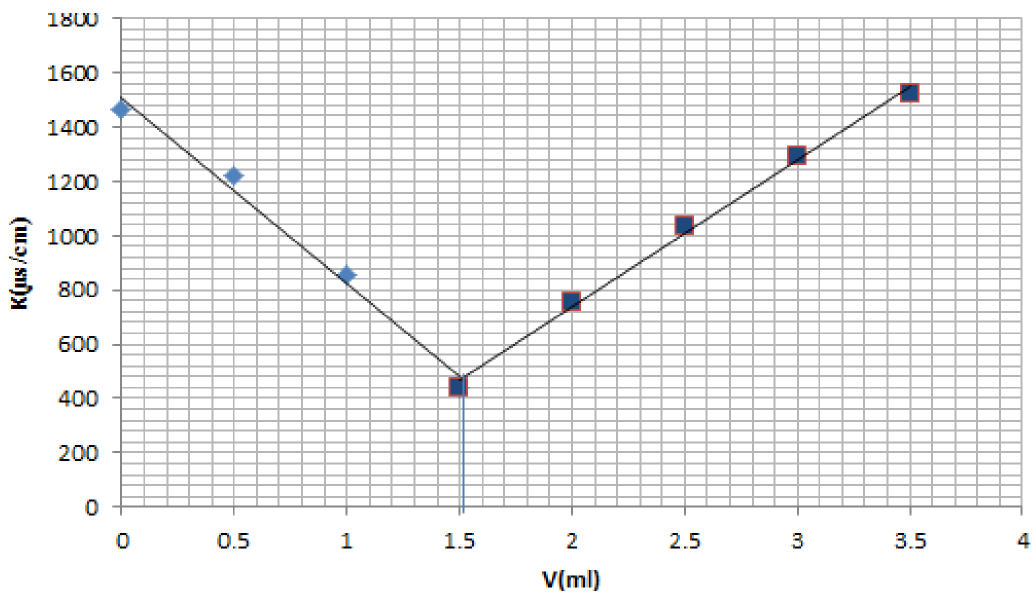

Figure 10: The electric conductivity curve of the manufactured cell to titrate a strong acid with a strong basis by compensating for the second coefficient of temperature

From Figure (10) the necessary volume of sodium hydroxide to calibrate the chlorine acid is (1.51) ml.

The form of a strong acid-titration curve with a strong base using the manufactured cell corresponds to the curves in the reference studies [15].

6.4. Titration of Silver Nitrate Deposition with Sodium Chloride

Titration of silver nitrate (unknown concentration, solution volume 50ml) with potassium chloride (0.1M) was performed as follows:

Table 5: Electrical Conductivity Measurements for $AgNO_3$ Calibration with KCl

6	**5**	**4**	**3**	**2**	**1**	**0**	**KCl 0.1 M ml**
2010	1781	1527	1254	1168	1165	1162	Conductivity value of the systemic cell K(µs/cm)
2320	2040	1780	1449	1355	1344	1355	The electrical conductivity value of the manufactured cell K(µs/cm) 30℃
2329	2029	1765	1438	1349	1350	1340	
2310	2048	1772	1440	1337	1359	1360	
2017	1774	1547	1260	1178	1169	1178	$K_{Tref} = \frac{100 \times K_T}{100 + \theta(T - T_{ref})}$
2025	1764	1535	1250	1173	1174	1165	
2009	1781	1541	1250	1163	1181	1183	
2017	1773	1541	1253	1171	1175	1175	Average K(µs/cm)
100.34	99.55	100.91	99.92	100.25	99.14	101.11	Retrospective%
8	8.54	6	5.77	7.63	6.02	9.29	SD
0.39	0.48	0.38	0.46	0.65	0.51	0.79	RSD%
1.51	1.62	4.04	0.30	0.68	2.87	2.42	t_{ex}
2081	1830	1597	1300	1215	1206	1216	$K_{Tref} = \frac{K_T}{1 + 0.0191(T - 25)}$
2090	1820	1584	1290	1210	1211	1202	
2072	1837	1590	1292	1199	1219	1220	
2081	1829	1590	1294	1208	1212	1212	Average K(µs/cm)
103.53	102.69	104.12	103.18	103.42	104.03	104.30	Retrospective%
9	8.54	6.50	5.29	8.18	6.55	9.45	SD
0.43	0.466	0.41	0.40	0.67	0.54	0.77	RSD%
13.66	9.73	16.78	13	8.46	12.42	9.34	t_{ex}

Titration was performed at 30 ℃ and compensated by θ=2.5.

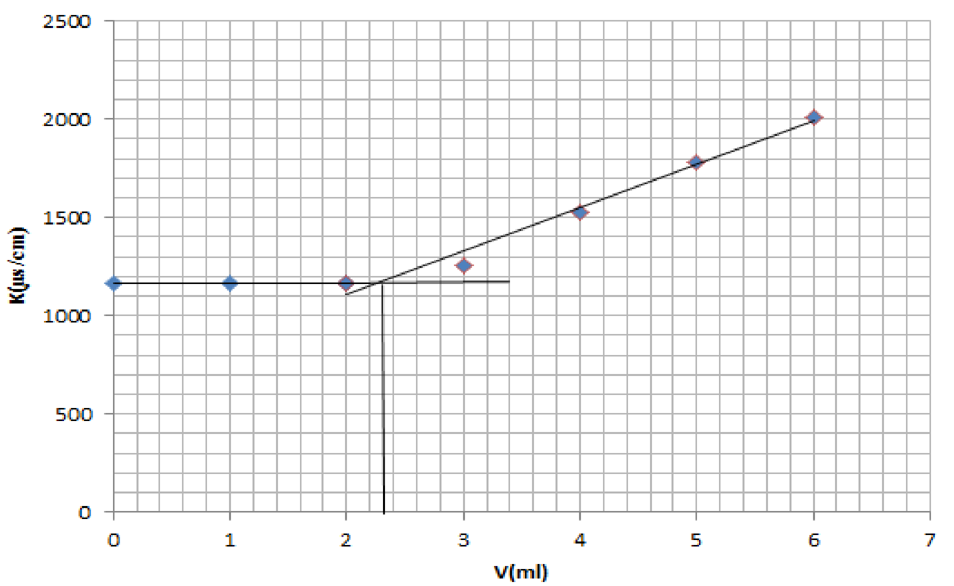

Figure 11: Electrical conductivity curve of the systemic apparatus for the titration of silver nitrate with potassium chloride

Figure (11) shows that the required volume of potassium chloride to titrate silver nitrate is (2.32) ml.

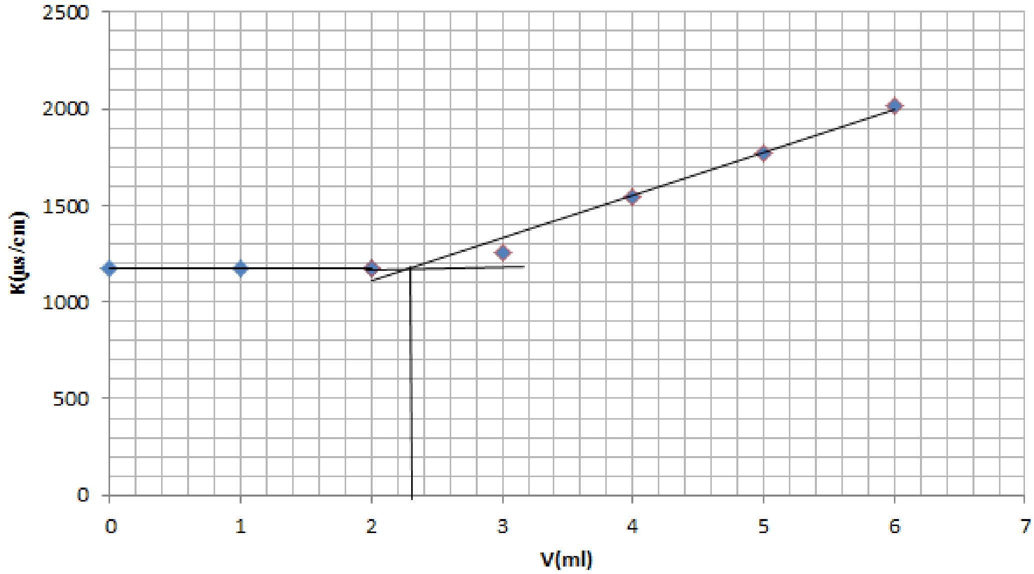

Figure 12: The electric conductivity curve of the manufactured cell to titrate silver nitrate with potassium chloride by compensating for the first temperature coefficient

Figure (12) shows that the volume of potassium chloride needed to titrate silver nitrate is (2.3) ml.

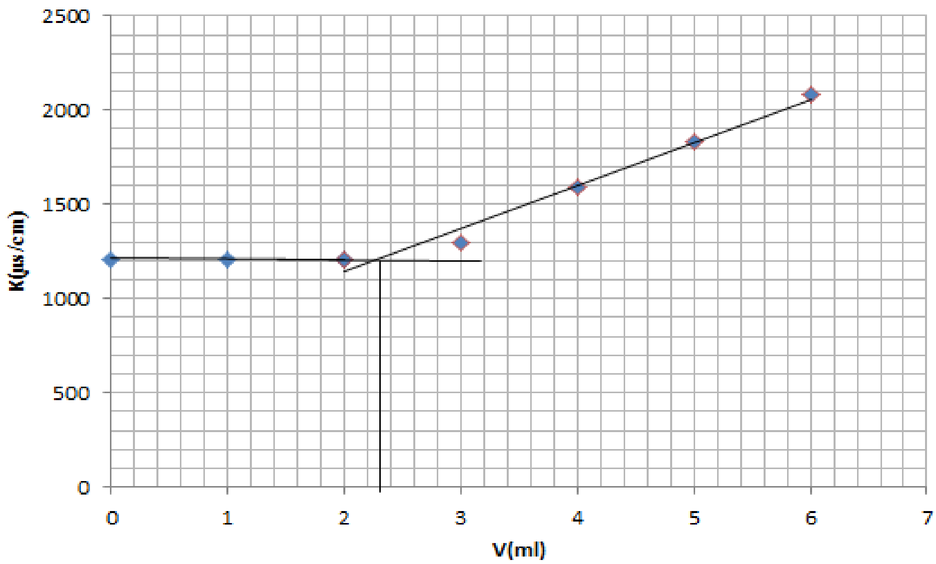

Figure 13: Electrical conductivity curve of the manufactured cell for calibration of silver nitrate with potassium chloride the heat by compensating for the second temperature coefficient

Figure (13) shows that the required volume of potassium chloride for titration of silver nitrate is (2.3) ml.

7 Conclusions

- The study showed that chromium 316 can be used in making two electrodes with suitable cell dimensions to measure the electrical conductivity of solutions**.**
- In this study, using the manufactured conductivity cell, the electrical conductivity values were obtained at the actual temperature of the solution and also at the reference temperature.

- Electrical conductivity values can be obtained at temperature (25 ℃) using the temperature adjustment coefficient given by the following relation: $K_{Tref} = \frac{100\times K_T}{100+\theta(T-T_{ref})}$ and other coefficient: $K_{Tref} = \frac{K_T}{1+0.0191(T-25)}$.
- The manufactured cell was used in direct and indirect analytical measurements, noting that the results showed validity and regression compared with the results of the comparative device.

References

[1]. Shreiner, R.H. Stability of standard electrolytic conductivity solutions in glass containers. Journal of Research of the National Institute of Standards and Technology, US.A Vol. 107, N˚.5, 2002.

[2]. Bevilacqua, A. C. Ultrapure water–the standard for resistivity measurements. Membrane Technology, U.S.A, Vol. 1998, N˚.100, 1998.

[3]. Ferraris, F.; Durbiano, F. Traceability of electrolytic conductivity measurements for ultra pure water. Dottorato in Metrology: Measuring Science and Technique, Porto, 2014.

[4]. Sawyer, C.N; Mccarty, P.L; Parkin, C.F; DHV Consultants BV. Understanding electrical conductivity. Hydrology Project World Bank & Government of The Netherlands funded, New Delhi – 110016 India, 1999.

[5]. Minear, R.A. Water analysis Inorganic Species, Part 1. Elsevier Science, Saint Louis, 1982, Page 137**.**

[6]. Shreiner, R.H; Pratt, K.W. Standard Reference Materials: Primary Standards and Standard Reference Materials for Electrolytic Conductivity. NIST Special Publication 260-142, USA, 2004.

[7]. Morzinski, K.; Azucena, O.; Downs, C.; Favaloro, T.; Park, J.; U, V. Circuit Design: An Inquiry Lab Activity at Maui Community College .Astronomical Society of the Pacific. Maui, v. 436, 2010.

[8]. Purkait, P. Electrical and electronics measurements and instrumentation. McGraw Hill Education (India) New Delhi, 2013, 651.

[9]. Scott, R.P. Chapter 4 The Electrical Conductivity Detector. Liquid Chromatography Detectors, USA, Volume 11, 1977, Pages 79-90.

[10]. Mantynen, M; Senllman, M; Vira, J. Temperature correction coefficients of electrical conductivity and of density measurements for saline groundwater, Working Report2001-15, Helsinki, Finland, 2001.

[11]. Natural Water temperature correction (ISO/DIN 7888), Bibliography: Wagner, R. Temperaturkorrekturfaktorenfür die elektrischeLeitfähigkeit von Wässern. Z. Wasser - Abwasserforsch. (2) 1980"

[12]. Asha Devi1 and K. Malakondaiah. Embedded based System for the measurement of conductivity and monitoring through web, I J E S C E © RESEARCH SCIENCE PRESS, India, Vol. 3, No. 2, July-December 2011.

[13]. Ronald L. Miller, Wesley L. Bradford, and Norman E. Peters. Specific Conductance: Theoretical Considerations and Application to Analytical Quality Control, U.S. Geological Survey Water-Supply Paper 2311, 1988.

[14]. Clesceri, L.S; Eaton, A.D. Standard methods for examination of water and waste water. American Public Health Association, DC20005, Washington, 1992.

[15]. Laguna, N.R; Hernades, A.R; Silva, M.R; Garcia, L.H; Romo, M.R. An Exact Method to Determine the Conductivity of Aqueous Solutions in Acid-Base Titrations. Journal of Chemistry, hindwai, Volume 2015, Article ID 540368.