

THE EFFECTS OF TEMPERATURE AND CONCENTRATION OF SOLUTION ON THE ELECTRICAL CURRENT PASSES THROUGH A SYSTEM

EXTENDED ESSAY IN PHYSICS HL

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ABSTRACT

The purpose of this study is to investigate how the electrical resistance of saline solution changes depending on the temperature. This investigation attempts to answer the following question: “how does the temperature of the solution affect the current flowing through from the system by applying constant voltage to the solution?”. To answer this research question, an experiment was designed and performed. A solution which have been made by water and salt and same kind of metals electrods inside of solution, also in 10 different temperatures. The same solution type with tree different consantration and same kind of metals electrods was measured in 10 different solution temperatures. The mean current that passes through from system was greater than in lower temperatures, and the differences between the means were significant. This study provides a better understanding of conductivity of solutions and the principles that is effected with the conditions. Thus, with the help of the current value and voltage rating of solution which is measured under different circumstances, their electrical resistance is calculated.

In this study, the changes in the electrical resistance of three different saline solutions, concentration of which are different from each other, has experimentally observed and the results are used to construct a mathematical model in order to form a temperature-resistance relation.

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1. INTRODUCTION

When a voltage is given to a material, a current passes through this material. This current is called electrical current which is largely dependent on the voltage, chemical and physical property of material. Electric current is the rate of charge flow past a given point in electric circuit, measured in Coulombs/seconds which is named Amperes. Electrical resistivity is resistance of material against the current, measured in Ohms. It depends on chemical and physical property of material.

Therefore a current passing through electrical circuit can be changed by these factors. If the electrical circuit is established with solution, the main factors that will effect the resistivity are temperature and concentration of solution.

Temperature of solution is important because the resistivity of solution are effected from the temperature, when the temperature of solution increased, its resistivity decreases, so temperature will be important on current passing through system. Another important point is the concentration of solution because when the concentration is increased, the molecules of solution would be more close, then it would be easier for charged particles to flow and be conducted.

In this study, different temperatures of solutions and different concentrations of solutions were provided, as voltage given to system, electrical current passing through the circuit were measured. The electrical measurements have been calculated and analyzed in terms of their voltage versus current relationship to understand the effects of temperature and concentration on resistance of solution.

2. BACKGROUND INFORMATION

When we apply electrical potential (voltage) to an object it creates an electrical flow with the movement of the existing free electrons or charged ions. While the electrical current is procured by the movement of free electrons in solid objects like copper and carbon, it is procured by the electrically loaded ions in acid or saline solutions. Electric current is the rate of charge flow past a given point in electric circuit, measured in Coulombs/seconds which is named Amperes (I).

Electrical resistivity quantifies how strongly a given material resists the flow of electric current. A low resistivity indicates a material that easily allows the movement of electrons or charged ions. Electrical resistivity is measured in Ohms (Ω).

Electrical potential (voltage) is measured in Volts (V).

When the constant voltage (V) is applied on an object and the current flow in the circuit is (I); the resistance (R) of object is calculated with the formula:

$$R = V/I$$

R: Resistance of material, Ohms (Ω)

V: Voltage that applied on to material, Volt (V)

I: Electrical flow passed through the material, Amper (I)

This formula known as Ohm's Law...

By using Ohm's Law we can find the resistance of a material by measuring the voltage that we apply to the resistance and the flow through the resistance and divide the voltage to the flow.

We can also calculate the value of the resistance made from a specific material at temperature of 20° C as the following Formula :

$$R = g.L/A$$

R: Resistivity of material, Ω

g: Specific resistance of material (at 20° C) , $\Omega.mm^2/m$

A: Cross section of material, mm^2

Specific Resistance Table

Material	Specific Resistance Of Materials, r (at 20° C) $\Omega \cdot \text{mm}^2/\text{m}$
Silver	0.0167
Copper	0.0187
Aluminum	0.0278
Carbon	65.000
Constantan	0,490

Table 1: shows the specific resistance of some materials.

Let's say we have an aluminum wire, which is 100 meters long and have $0,5 \text{ mm}^2$ cross section. The resistance of this wire in 20° C is calculated as:

$$r = 0,0278 \Omega \cdot \text{mm}^2/\text{m}$$

$$L = 100 \text{ m}$$

$$A = 0.5 \text{ mm}^2$$

$$R = 0,0278 \times 100 / 0.5$$

$$R = 5,56 \Omega$$

3. THE CHANGE OF RESISTIVITY ACCORDING TO THE TEMPERATURE:

A - FOR SOLID MATERIALS

“There is a relation between the temperature of material and its resistance. It is called temperature coefficient of material. Pure metal conductors has a positive temperature coefficient of resistance, it means that their resistance increases when its temperature increases. However, some conductors like carbon and silicon has negative temperature coefficient of resistance so when the temperature of this conductor increases, resistance decreases.

Resistance values for material at any temperature other than the standard temperature (usually specified at 20° Celsius) on the specific resistance table must be determined through yet another formula:

$$R=R_{ref} [(1+\alpha(T-T_{ref}))]$$

R= Resistance of material (at T °C)

R_{ref} = Resistance of material at reference temperature (at 20°C)

α = Temperature coefficient of resistance for the material

T = Material temperature °C

T = Reference temperature (20°C)

The "alpha" (α) constant is known as the *temperature coefficient of resistance*, and symbolizes the resistance change factor per degree of temperature change. Just as all materials have a certain specific resistance (at 20° C), they also *change* resistance according to temperature by certain amounts. For pure metals, this coefficient is a positive number, meaning that resistance *increases* with increasing temperature. For the elements carbon, silicon, and germanium, this coefficient is a negative number, meaning that resistance *decreases* with increasing temperature. For some metal alloys, the temperature coefficient of resistance is very close to zero, meaning that the resistance hardly changes at all with variations in temperature. The following table gives the temperature coefficients of resistance for several common metals, both pure and alloy:

Temperature coefficients of some materials

Material α (per degree Celsius)

=====	
Nickel	0,005866
Iron	0,005671
Molybdenum	0,004579
Tungsten	0,004403
Aluminum	0,004308

Copper	0,004041
Silver	0,003819
Platinum	0,003729
Gold	0,003715
Zinc	0,003847
Carbon(graphite)	-0,000480
Germanium	-0,050000
Silicon	-0,070000”

Table 2: shows the temperature coefficients of some materials.

For example, we have a material with resistance 15 Ohms at 20° Celsius. If the temperature were to rise to 35° Celsius, we could easily determine the change of resistance for wire. Assuming the use of copper wire ($\alpha = 0,004041$) we get:

$$R=R_{ref} ((1+\alpha(T-T_{ref})))$$

$$R=15\Omega((1+0,004041(35^0-20^0)))$$

$$R=15,909 \Omega$$

The rising of temperature from 20 to 35 is also increased the resistance of copper wire from 15 to 15.909 Ohms.”(1)

If we used silicone as material instead of copper; since the α values minor ($\alpha = - 0.070000$); the resistivity of 21 °C would be less than the resistivity in 20 °C. Let’s say the resistance of a silicone wire in 20 °C is 15 Ohm. If we heat this temperature to 21 °C, we can calculate the new resistance values as:

$$R=15 [(1-0,070000(21-20))] = 15[(1-0,070000(1))] = 15(1-0,070000)=15.(0,93)=13,95 \text{ Ohm}$$

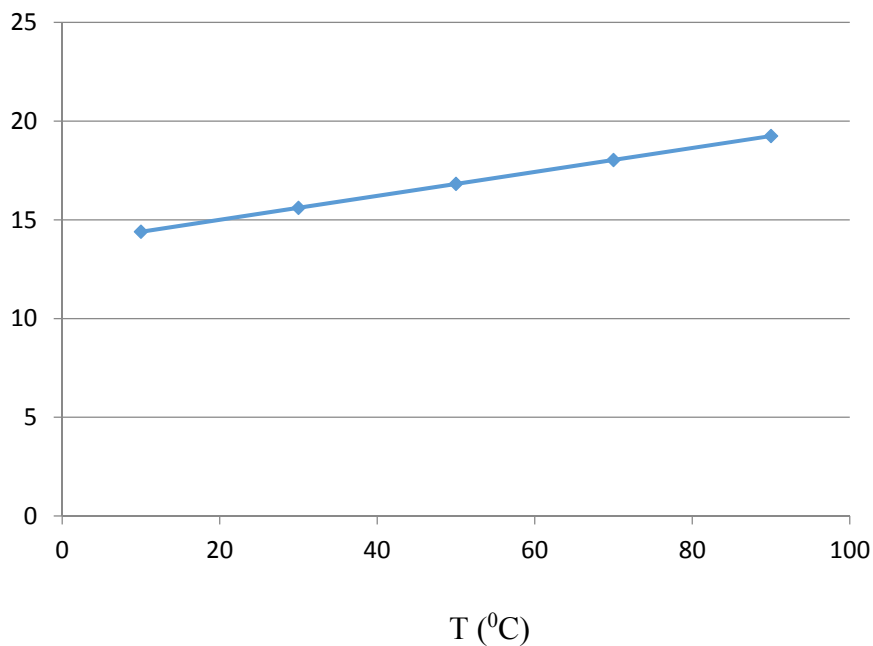
The changes in the resistivity of solid materials like metal and carbon according to the heat is linear and the inclination of it is set by constant temperature coefficient (α).

For example: Using a copper wire of which has 15 Ohm in 20 °C, let’s calculate its new resistance values for 0,10, 30, 50, 70, 90 degrees and prepare a R-T graphic.

T (°C)	R (ohms)	α (1/°C)	R (at 20 °C) Ohms
0	13,78770	0,004041	15
10	14,39385		
30	15,60615		
50	16,81845		
70	18,03075		
90	19,24305		

Table 3: shows the resistivity and constant temperature coefficient of copper wire.

R (Ohms)



Graph 1: shows the temperature vs resistivity graph of copper wire.

This graphic is expressed with an equation of $R = \alpha T + b$

In this equation lets calculate the α and b coefficients.

If $T = 0$, $R = b$. From the table above; when $T = 0$, $R = 13,78770$. So; $b = 13,78770$

Now lets find the α coefficient for $T = 10^0\text{C}$. From the table above for $T = 10^0\text{C}$, $R = 14,39385$ Ω . Coefficient b is $13,78770$.

$$14,39385 = \alpha \cdot 10 + 13,78770$$

$$\alpha = \frac{14,39385 - 13,78770}{10}$$

$$\alpha = 0,060615$$

if we put the α and b coefficient into the equation $R = \alpha T + b$; we find

$$R = 0,060615T + 13,78770$$

By using this mathematical expression the resistance can be found for this particular material for any given temperature.

B - FOR SOLUTIONS:

“Substances that give ions when dissolved in water are called electrolytes. They can be divided into acids, bases, and salts, because they all give ions when dissolved in water. These solutions conduct electricity due to the mobility of the positive and negative ions, which are called cations and anions respectively. Strong electrolytes completely ionize when dissolved, and no neutral molecules are formed in solution.

For example, NaCl,

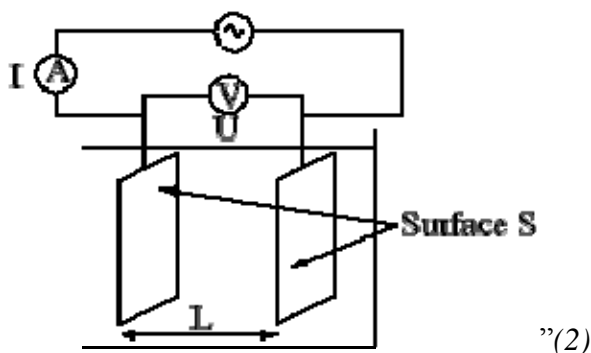


Figure 1: shows the simple example of the experiment.

When we apply voltage to this solution by using electrodes, there will be an electrical flow with the mediation of loaded ions. The amount of flow depends on;

- 1- The voltage applied,
- 2- Kind of solution (of which chemical material)
- 3- Concentration of solution (the amount of chemical material that dissolved in water)
- 4- The distance of the electrodes from each other
- 5- The area of surface of the electrodes that are in the solution,
- 6- Temperature of solution

By using Ohm's Law, we can find the resistance of a given solution in specific conditions. For this the amount of applied voltage should be divided by the amount of current flows by solution.

The variables of the resistance of solution are much more than the solid materials. Here are the variables that affects the resistivity of solution:

- 1- Kind of solution: Even if the same ratio of concentrations, the resistivity of solutions composed from different materials is different from each other.
- 2- Concentration of solution: Since the more concentrated solution means more loaded ions, it is expected that the resistivity of solution decreased as inverse proportion.
- 3- The distance between electrodes. It is expected of a direct proportion between the more distance from electrodes and increase of resistivity.
- 4- The surface area of electrodes in the solution. The more surface area for electrodes means less resistivity of solution as inverse proportion.
- 5- Temperature of solution. The more temperature of solution means the less resistivity of solution as inverse proportion.

The subject of this study is developing a mathematical model for the question "How the resistance of saline solution changes depending on temperature?"

4. AIM

The aim of this experiment is to investigate the effect of temperature on the current passing through the salt water solution by giving voltage to the solution and calculate resistance of solution.

5. RESEARCH QUESTION

How does the temperature and the concentration of salt water solution affect its resistivity?

6. HYPOTHESIS

Hypothesis 1: The resistance of the saline solution at specific temperatures shows negative correlation with the concentration of the solution.

Hypothesis 2: The resistance of the saline solution at specific concentration shows negative correlation with the temperature of the solution. Resistance-temperature relation is hyperbolic. The resistance of saline solution due to temperature is shown as a hyperbola form formulated as $y=a/x$.

7. KEY VARIABLES

INDEPENDENT VARIABLE: Temperature of the solution in celcius

DEPENDENT VARIABLE: The resistance of solition.

CONTROLLED VARIABLE:

- Amount of salt in the water (2.5 g, 5.0 g, 7.5 g)
- Volume of the water (150 ml)
- Glass container used for solution (500 ml)
- Distance between the electords(3 cm)
- The voltage given to system(5 V,7.5 V, 10.0 V)
- The length of the cables that used to complete the system(5 cm)
- The type of the electordes (steel electrodes)

8. MATERIALS

- 1500 ml tap water
- 1 big container(500 ml)
- 25 gr salt
- 2 metal electrodes(steel electrodes)
- 2 pieces of 5 cm long aluminum cable
- Power supply
- Digital multimeter
- 1 small container(250 ml)
- String stick for string solution
- Celotype
- Water bath
- Analog thermometer(± 0.5 °C)
- Digital scale(± 0.01 gr)

9. PROCEDURE

1. Take the big container and stick the two electrodes inside the container and fix them in to the container with the help of celotype.
2. Attach the endings of cables in to the “+” and “-“ parts of power supply.
3. Calibrate the power supply to the 5 V.
4. Take some 1 liter water inside of water bath.
5. And calibrate the teperature of water bath to 5 C°.
6. Wait until it comes to 5 C°.
7. After it reaches to this temperature, take 150 ml water with graduated cylinder.
8. Put 2.5 g salt in to graduated cylinder.
9. Mix the solution with stick.
10. Then quickly put the solution in to the big container which’s inside is sticked with electrodes.
11. Again quickly attach the other endings of cables to the endings of electrodes which’s ending is outside of the container.
12. Note down the first current value writes on the power supply.
13. Then disattach the cables from the endings of electrodes.
14. Make the steps 5-13 for other 5, 9, 18, 25, 34, 41, 48, 50, 61, 68, 71, 90 C° and note down the current values.
15. Then, make the steps between 1-14 for 5 gr salt and 7.5 gr salt.

10. METHODS AND DATA COLLECTION

To investigate the effect of temperature of the solution on the electrical current passing through the solution which is mixture of salt and water. The constant voltage was given to different temperatures of solution. All other factors such as the amount of salt in water and amount of water were kept constant in order to make sure that “the temperature of solution”, “voltage that used in system” and “the amount of salt in the solution” were the factor being changed during the whole experiment.

A container which is filled with 150 ml water and added 2.5 g salt was dissolved by stirring stick and the temperature of the solution was increased in each step. The copper electrode was fixed inside of the container by celotypes so the distance between the electrodes were constant. The constant voltage which was supplied from the power source, was given to the solution with help of electrodes and the current passing through the system was measured. Uncertainty was also provided along with ten current measurements for each temperature of solutions.

During data analysis, since there were only ten measurements for the each temperature of solution, it was assumed that the data was unevenly distributed.

11. DATA COLLECTION AND PRESENTATION

All the calculated parameters of the objects using the measurements and experimental results are shown in tables.

- Temperatures of water were measured. To determine the temperature of water, the water was to be heated in the water bath and the temperature need for trials to be calibrated in the water bath. For the truth value of temperature of water, temperature of water departed with digital multimeter.
- 150 ml water were departed in the graduated cylinder in order to use for salt water solution.
- The mass of salts were departed in order to make different conterated solutions.
- The current passing through the system was departed and used for calculating the resistance in the system.

11.1 CALCULATING THE RESISTIVITY OF EACH TRIALS_N (2.5 gr salt):

11.1.1 For 5 volt:

no	temperature (±0.5 C)	current (±0.1 mA)	voltage (±0.1 v)	amount of water (±0.5 ml)	amount of salt (±0.01 g)	resistivity calculated (ohm)
1	5.0	19.0	5.0	150.0	2.52	0.263
2	9.0	24.0	5.0	150.0	2.50	0.208
3	18.0	29.0	5.0	150.0	2.51	0.172
4	25.0	43.0	5.0	150.0	2.51	0.116
5	34.0	53.0	5.0	150.0	2.50	0.094
6	41.0	68.0	5.0	150.0	2.50	0.074
7	48.0	73.0	5.0	150.0	2.50	0.068
8	50.0	87.0	5.0	150.0	2.50	0.057
9	61.0	121.0	5.0	150.0	2.50	0.041
10	68.0	160.0	5.0	150.0	2.50	0.031
11	71.0	180.0	5.0	150.0	2.50	0.028
12	90.0	180.0	5.0	150.0	2.51	0.028

Table 4: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For 5C° $5/19=0.263$ ohm*
- *For 9C° $5/24=0.208$ ohm*
- *For 18C° $5/29=0.172$ ohm*
- *For 25C° $5/43=0.116$ ohm*
- *For 34C° $5/53=0.094$ ohm*
- *For 41C° $5/68=0.074$ ohm*
- *For 48C° $5/73=0.068$ ohm*
- *For 50C° $5/87=0.057$ ohm*
- *For 61C° $5/121=0.041$ ohm*
- *For 68C° $5/160=0.031$ ohm*
- *For 71C° $5/180=0.028$ ohm*
- *For 90C° $5/180=0.028$ ohm*

11.1.2 For 7.5 Volt:

no	temperature (± 0.5 C)	current (± 0.1 mA)	voltage (± 0.1 v)	amount of water (± 0.5 ml)	amount of salt (± 0.01 g)	resistivity calculated (ohm)
1	5.0	31.0	7.5	150.0	2.52	0.242
2	9.0	38.0	7.5	150.0	2.50	0.197
3	18.0	47.0	7.5	150.0	2.51	0.160
4	25.0	64.0	7.5	150.0	2.51	0.117
5	34.0	98.0	7.5	150.0	2.50	0.077
6	41.0	117.0	7.5	150.0	2.50	0.064
7	48.0	128.0	7.5	150.0	2.50	0.059
8	50.0	142.0	7.5	150.0	2.50	0.053
9	61.0	185.0	7.5	150.0	2.50	0.041
10	68.0	223.0	7.5	150.0	2.50	0.034
11	71.0	270.0	7.5	150.0	2.50	0.028
12	90.0	271.0	7.5	150.0	2.51	0.028

Table 5: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For $5C^{\circ}$ $7.5/31=0.242$ ohm*
- *For $9C^{\circ}$ $7.5/38=0.197$ ohm*
- *For $18C^{\circ}$ $7.5/47=0.160$ ohm*
- *For $25C^{\circ}$ $7.5/64=0.117$ ohm*
- *For $34C^{\circ}$ $7.5/98=0.077$ ohm*
- *For $41C^{\circ}$ $7.5/117=0.064$ ohm*
- *For $48C^{\circ}$ $7.5/128=0.059$ ohm*
- *For $50C^{\circ}$ $7.5/142=0.053$ ohm*
- *For $61C^{\circ}$ $7.5/185=0.041$ ohm*
- *For $68C^{\circ}$ $7.5/223=0.034$ ohm*
- *For $71C^{\circ}$ $7.5/270=0.028$ ohm*
- *For $90C^{\circ}$ $7.5/271=0.028$ ohm*

11.1.3 For 10 volt:

no	temperature (± 0.5 C)	current (± 0.1 mA)	voltage (± 0.1 v)	amount of water (± 0.5 ml)	amount of salt (± 0.01 g)	resistivity calculated (ohm)
1	5.0	45.0	10.0	150.0	2.52	0.222
2	9.0	51.0	10.0	150.0	2.50	0.196
3	18.0	58.0	10.0	150.0	2.51	0.172
4	25.0	79.0	10.0	150.0	2.51	0.127
5	34.0	111.0	10.0	150.0	2.50	0.090
6	41.0	137.0	10.0	150.0	2.50	0.073
7	48.0	146.0	10.0	150.0	2.50	0.068
8	50.0	174.0	10.0	150.0	2.50	0.057
9	61.0	243.0	10.0	150.0	2.50	0.041
10	68.0	312.0	10.0	150.0	2.50	0.032
11	71.0	384.0	10.0	150.0	2.50	0.026
12	90.0	385.0	10.0	150.0	2.51	0.026

Table 6: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For 5C° $10/45=0.222$ ohm*
- *For 9C° $10/51=0.196$ ohm*
- *For 18C° $10/58=0.172$ ohm*
- *For 25C° $10/79=0.127$ ohm*
- *For 34C° $10/111=0.090$ ohm*
- *For 41C° $10/137=0.073$ ohm*
- *For 48C° $10/146=0.068$ ohm*
- *For 50C° $10/174=0.057$ ohm*
- *For 61C° $10/243=0.041$ ohm*
- *For 68C° $10/312=0.032$ ohm*
- *For 71C° $10/384=0.026$ ohm*
- *For 90C° $10/385=0.026$ ohm*

Then for calculating the mean resistivity of the each trials (5, 7.5 and 10 volts), the following chart shows:

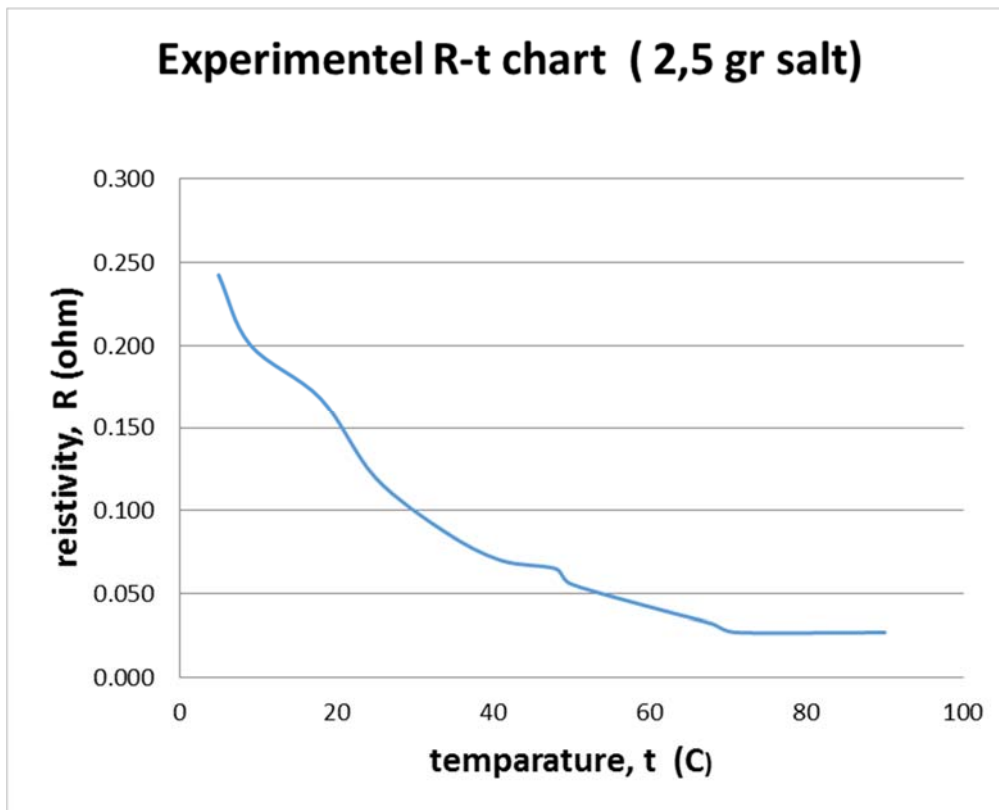
no	temperature (±0.5 C)	mean resistivity (ohm)
1	5.0	0.062
2	9.0	0.048
3	18.0	0.034
4	25.0	0.028
5	34.0	0.023
6	41.0	0.019
7	48.0	0.016
8	50.0	0.012
9	61.0	0.010
10	68.0	0.009
11	71.0	0.009
12	90.0	0.008

Table 7: shows the mean resistivities of 5, 7.5 and 10 volt trials.

Calculating the mean resistivity of the 5.0, 7.5 and 10.0 voltage solutions:

- *For 5C° $(0.263+0.242+0.222)/3=0.242$ ohm*
- *For 9C° $(0.208+0.197+0.196)/3=0.201$ ohm*
- *For 18C° $(0.172+0.160+0.172)/3=0.168$ ohm*
- *For 25C° $(0.116+0.117+0.127)/3=0.120$ ohm*
- *For 34C° $(0.094+0.077+0.090)/3=0.087$ ohm*
- *For 41C° $(0.074+0.064+0.073)/3=0.070$ ohm*
- *For 48C° $(0.068+0.059+0.068)/3=0.065$ ohm*
- *For 50C° $(0.057+0.053+0.057)/3=0.056$ ohm*
- *For 61C° $(0.041+0.041+0.041)/3=0.041$ ohm*
- *For 68C° $(0.031+0.034+0.032)/3=0.032$ ohm*
- *For 71C° $(0.028+0.028+0.026)/3=0.027$ ohm*
- *For 90C° $(0.028+0.028+0.028)/3=0.027$ ohm*

The graph of resistivity versus temperature is:



Graph 2: shows the experimental temperature vs resistivity graph of 2.5 gr salt.

The experimental graphic obtained shows quite similarities with the hyperbola form which is formulated as “ $y=a/x$ ”.

When it is considered that t is the independent variable and R is the dependent variable and when a is named as the constant resistivity, the formula of the graphic will be :

$$R=a/t$$

Now we can calculate the value of the constant resistivity (a) by using the values obtained in the experiment.

a = resistivity constant

t = temperature

R = Mean Resistivity

$$a= R/t$$

11.1.4 Calculating The Resistivity Constant

mean resistivity (ohm)	resistivity constant (ohm.C)
0.242	1.212
0.201	1.805
0.168	3.026
0.120	3.000
0.087	2.958
0.070	2.879
0.065	3.129
0.056	2.796
0.041	2.501
0.032	2.197
0.027	1.931
0.027	2.443
mean resistivity const, a (ohm.C)	2.490

Table 8: shows the resistivity constant calculated by experimental data's.

And then calculating the resistivity constant:

With using this formula $a=R*T$

- For $5C^{\circ}$ $5*0.242=1.212ohm*C^{\circ}$
- For $9C^{\circ}$ $9*0.201=1.805ohm*C^{\circ}$
- For $18C^{\circ}$ $18*0.168=3.026ohm*C^{\circ}$
- For $25C^{\circ}$ $25*0.120=3.000ohm*C^{\circ}$
- For $34C^{\circ}$ $34*0.087=2.958ohm*C^{\circ}$
- For $41C^{\circ}$ $41*0.070=2.879ohm*C^{\circ}$
- For $48C^{\circ}$ $48*0.065=3.129ohm*C^{\circ}$
- For $50C^{\circ}$ $50*0.056=2.749ohm*C^{\circ}$
- For $61C^{\circ}$ $61*0.041=2.501ohm*C^{\circ}$
- For $68C^{\circ}$ $68*0.032=2.197ohm*C^{\circ}$
- For $71C^{\circ}$ $71*0.027=1.931ohm*C^{\circ}$
- For $90C^{\circ}$ $71*0.027=1.931ohm*C^{\circ}$

The mean resistivity constant is

$$(1.212+1.805+3.026+3.000+2.958+2.879+3.129+2.749+2.501+2.197+1.931+1.931)/12=2.490 ohm*C^{\circ}$$

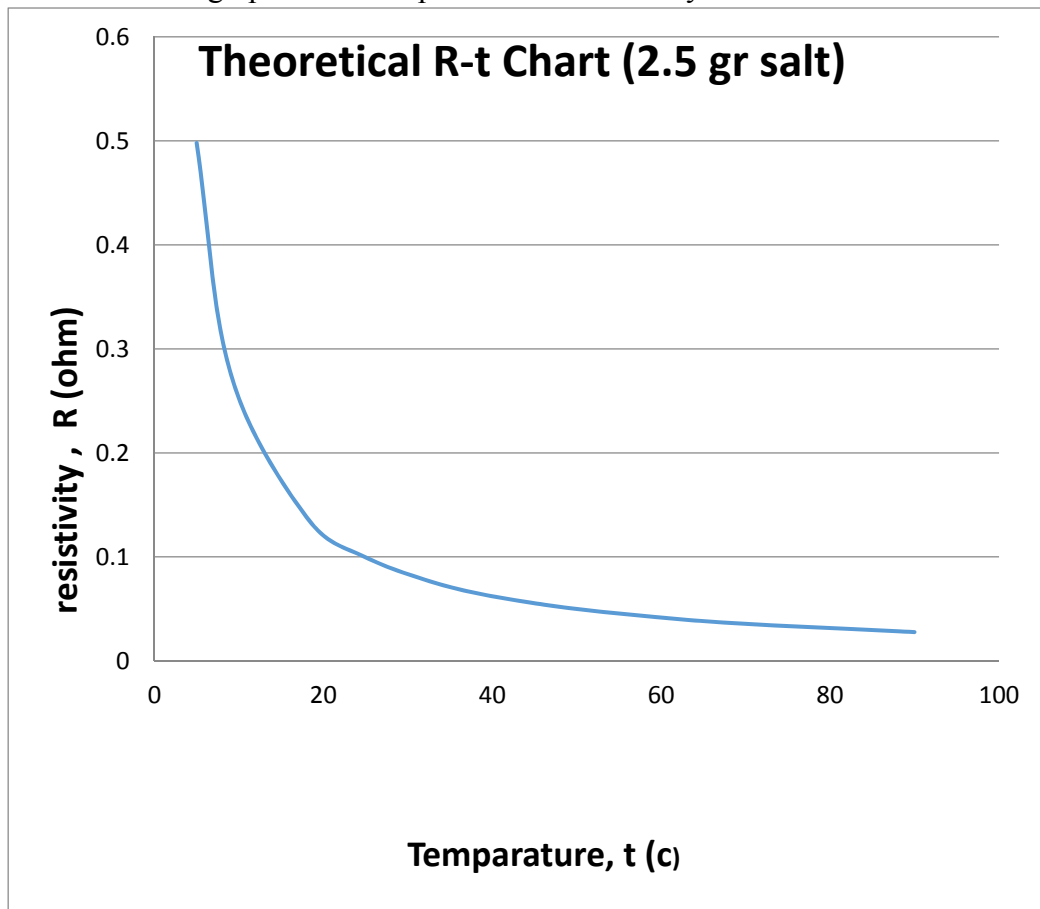
Now this “2.490 ohm* C° is our mean resistivity constant, a. For calculating the theoretical resistivity:

- For 5C° $2.49/5=0.498\text{ohm}$
- For 9C° $2.49/9=0.276\text{ohm}$
- For 18C° $2.49/18=0.138\text{ohm}$
- For 25C° $2.49/25=0.099\text{ohm}$
- For 34C° $2.49/34=0.073\text{ohm}$
- For 41C° $2.49/41=0.060\text{ohm}$
- For 48C° $2.49/48=0.051\text{ohm}$
- For 50C° $2.49/50=0.049\text{ohm}$
- For 61C° $2.49/61=0.040\text{ohm}$
- For 68C° $2.49/68=0.036\text{ohm}$
- For 71C° $2.49/71=0.035\text{ohm}$
- For 90C° $2.49/90=0.027\text{ohm}$

a	t(±0.5 C)	R
2.490	5.0	0.498
	9.0	0.277
	18.0	0.138
	25.0	0.100
	34.0	0.073
	41.0	0.061
	48.0	0.052
	50.0	0.050
	61.0	0.041
	68.0	0.037
	71.0	0.035
	90.0	0.028

Table 9: shows the theoretical resistivity constants.

The theoretical graph of the temperature vs. resistivity:



Graph 3: shows the theoretical temperature vs resistivity graph of 2.5 gr salt trial.

11.2 CALCULATING THE RESISTIVITY OF EACH TRIALS (5.0 gr salt):

11.2.1 For 5 volt:

no	temperature (± 0.5 C)	current (± 0.1 mA)	voltage (± 0.1 v)	amount of water (± 0.5 ml)	amount of salt (± 0.01 g)	resistivity calculated (ohm)
1	5.0	56.0	5.0	150.0	5.01	0.089
2	9.0	73.0	5.0	150.0	5.00	0.068
3	18.0	107.0	5.0	150.0	5.07	0.047
4	25.0	131.0	5.0	150.0	5.04	0.038
5	34.0	166.0	5.0	150.0	5.04	0.030
6	41.0	190.0	5.0	150.0	5.01	0.026
7	48.0	242.0	5.0	150.0	5.02	0.021
8	51.0	357.0	5.0	150.0	5.06	0.014
9	61.0	432.0	5.0	150.0	5.00	0.012
10	68.0	490.0	5.0	150.0	5.04	0.010
11	71.0	526.0	5.0	150.0	5.07	0.010
12	89.0	629.0	5.0	150.0	5.03	0.008

Table 10: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For 5C° $5/56=0.089$ ohm*
- *For 9C° $5/73=0.068$ ohm*
- *For 18C° $5/107=0.047$ ohm*
- *For 25C° $5/131=0.038$ ohm*
- *For 34C° $5/166=0.030$ ohm*
- *For 41C° $5/190=0.026$ ohm*
- *For 48C° $5/242=0.021$ ohm*
- *For 50C° $5/357=0.014$ ohm*
- *For 61C° $5/432=0.012$ ohm*
- *For 68C° $5/490=0.010$ ohm*
- *For 71C° $5/526=0.010$ ohm*
- *For 90C° $5/629=0.008$ ohm*

11.2.2 For 7.5 volt:

no	temperature (± 0.5 C)	current (± 0.1 mA)	voltage (± 0.1 v)	amount of water (± 0.5 ml)	amount of salt (± 0.01 g)	resistivity calculated (ohm)
1	5.0	128.0	7.5	150.0	5.01	0.059
2	9.0	175.0	7.5	150.0	5.00	0.043
3	18.0	252.0	7.5	150.0	5.07	0.030
4	25.0	298.0	7.5	150.0	5.04	0.025
5	34.0	356.0	7.5	150.0	5.04	0.021
6	41.0	402.0	7.5	150.0	5.01	0.019
7	48.0	502.0	7.5	150.0	5.02	0.015
8	50.0	596.0	7.5	150.0	5.06	0.013
9	61.0	682.0	7.5	150.0	5.00	0.011
10	68.0	789.0	7.5	150.0	5.04	0.010
11	71.0	890.0	7.5	150.0	5.07	0.008
12	90.0	920.0	7.5	150.0	5.03	0.008

Table 11: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For 5C° $7.5/128=0.059$ ohm*
- *For 9C° $7.5/175=0.043$ ohm*
- *For 18C° $7.5/252=0.030$ ohm*
- *For 25C° $7.5/298=0.025$ ohm*
- *For 34C° $7.5/356=0.021$ ohm*
- *For 41C° $7.5/402=0.019$ ohm*
- *For 48C° $7.5/502=0.015$ ohm*
- *For 50C° $7.5/596=0.013$ ohm*
- *For 61C° $7.5/482=0.011$ ohm*
- *For 68C° $7.5/789=0.010$ ohm*
- *For 71C° $7.5/890=0.008$ ohm*
- *For 90C° $7.5/920=0.008$ ohm*

11.2.3 For 10.0 volt:

no	temperature (± 0.5 C)	current (± 0.1 mA)	voltage (± 0.1 v)	amount of water (± 0.5 ml)	amount of salt (± 0.01 g)	resistivity calculated (ohm)
1	5.0	254.0	10.0	150.0	5.01	0.039
2	9.0	302.0	10.0	150.0	5.00	0.033
3	18.0	405.0	10.0	150.0	5.07	0.025
4	25.0	456.0	10.0	150.0	5.04	0.022
5	34.0	548.0	10.0	150.0	5.04	0.018
6	41.0	748.0	10.0	150.0	5.01	0.013
7	48.0	893.0	10.0	150.0	5.02	0.011
8	50.0	1140.0	10.0	150.0	5.06	0.009
9	61.0	1198.0	10.0	150.0	5.00	0.008
10	68.0	1205.0	10.0	150.0	5.04	0.008
11	71.0	1240.0	10.0	150.0	5.07	0.008
12	90.0	1350.0	10.0	150.0	5.03	0.007

Table 12: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For 5C° $10/254=0.039$ ohm*
- *For 9C° $10/302=0.033$ ohm*
- *For 18C° $10/405=0.025$ ohm*
- *For 25C° $10/456=0.022$ ohm*
- *For 34C° $10/548=0.018$ ohm*
- *For 41C° $10/748=0.013$ ohm*
- *For 48C° $10/893=0.011$ ohm*
- *For 50C° $10/1040=0.009$ ohm*
- *For 61C° $10/1098=0.008$ ohm*
- *For 68C° $10/1205=0.008$ ohm*
- *For 71C° $10/1240=0.008$ ohm*
- *For 90C° $10/1350=0.007$ ohm*

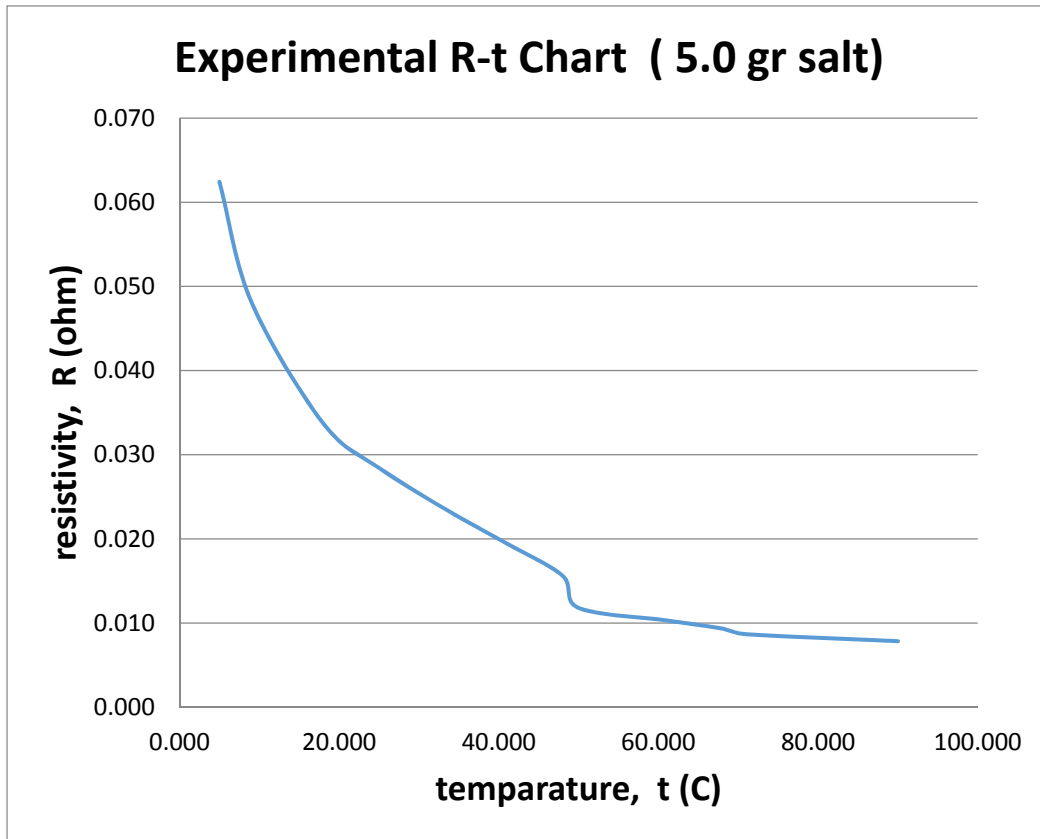
Then for calculating the mean resistivity of the each trials (5, 7.5 and 10 volts), the following chart shows:

no	temperature (±0.5 C)	mean resistivity (ohm)
1	5.0	0.062
2	9.0	0.048
3	18.0	0.034
4	25.0	0.028
5	34.0	0.023
6	41.0	0.019
7	48.0	0.016
8	50.0	0.012
9	61.0	0.010
10	68.0	0.009
11	71.0	0.009
12	90.0	0.008

Table 13: shows the mean resistivities of 5, 7.5 and 10 volt trials.

Calculating the mean resistivity of the 5.0, 7.5 and 10.0 voltage solutions:

- For 5C° $(0.089+0.059+0.039)/3=0.062$ ohm
- For 9C° $(0.068+0.043+0.033)/3=0.048$ ohm
- For 18C° $(0.047+0.030+0.025)/3=0.034$ ohm
- For 25C° $(0.038+0.025+0.022)/3=0.028$ ohm
- For 34C° $(0.030+0.021+0.018)/3=0.023$ ohm
- For 41C° $(0.026+0.019+0.013)/3=0.019$ ohm
- For 48C° $(0.021+0.015+0.011)/3=0.016$ ohm
- For 50C° $(0.014+0.013+0.009)/3=0.012$ ohm
- For 61C° $(0.012+0.011+0.008)/3=0.010$ ohm
- For 68C° $(0.010+0.010+0.008)/3=0.009$ ohm
- For 71C° $(0.010+0.008+0.008)/3=0.009$ ohm
- For 90C° $(0.008+0.008+0.007)/3=0.008$ ohm



Graph 4: shows the experimental temperature vs resistivity graph of 5 gr salt trial.

The experimental graphic obtained shows quite similarities with the hyperbola form which is formulated as “ $y=a/x$ ”.

When it is considered that t is the independent variable and R is the dependent variable and when a is named as the constant resistivity, the formula of the graphic will be :

$$R=a/t$$

Now we can calculate the value of the constant resistivity (a) by using the values obtained in the experiment.

a = resistivity constant

t = temperature

R = Mean Resistivity

$$a= R/t$$

11.2.4 Calculating The Resistivity Constant

mean resistivity (ohm)	resistivity constant (ohm.C)
0.062	0.312
0.048	0.433
0.034	0.607
0.028	0.711
0.023	0.787
0.019	0.797
0.016	0.749
0.012	0.589
0.010	0.629
0.009	0.635
0.009	0.615
0.008	0.705
mean resistivity constata, a (ohm.C)	0.631

Table 14: shows the resistivity constant calculated by experimental data's.

And then calculating the resistivity constant:

With using this formula $a=R*T$

- For $5C^{\circ}$ $5*0.062=0,312ohm*C^{\circ}$
- For $9C^{\circ}$ $9*0.048=0,433ohm*C^{\circ}$
- For $18C^{\circ}$ $18*0.034=0,607ohm*C^{\circ}$
- For $25C^{\circ}$ $25*0.028=0,711ohm*C^{\circ}$
- For $34C^{\circ}$ $34*0.023=0,787ohm*C^{\circ}$
- For $41C^{\circ}$ $41*0.019=0,797ohm*C^{\circ}$
- For $48C^{\circ}$ $48*0.016=0,749ohm*C^{\circ}$
- For $50C^{\circ}$ $50*0.012=0,589ohm*C^{\circ}$
- For $61C^{\circ}$ $61*0.010=0,629ohm*C^{\circ}$
- For $68C^{\circ}$ $68*0.009=0,635ohm*C^{\circ}$
- For $71C^{\circ}$ $71*0.009=0,615ohm*C^{\circ}$
- For $90C^{\circ}$ $71*0.008=0,705ohm*C^{\circ}$

The mean resistivity constant is

$$(0,312+0,433+0,607+0,711+0,787+0,797+0,749+0,589+0,629+0,635+0,615+0,705)/12=0,631 \text{ ohm} \cdot \text{C}^\circ$$

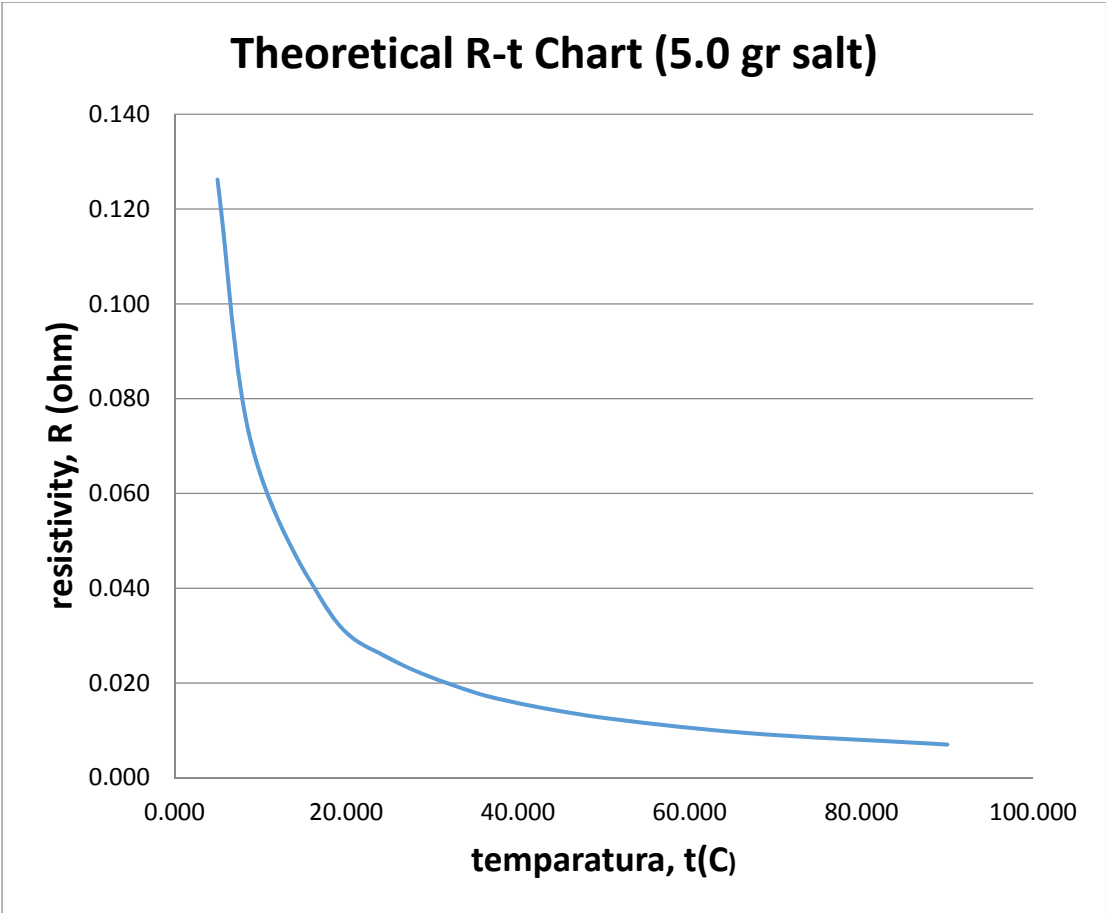
Now this “0,631 ohm · C° is our mean resistivity constant, a. For calculating the theoretical resistivity:

- For 5C° 0,631/5=0.126ohm
- For 9C° 0,631/9=0.070ohm
- For 18C° 0,631/18=0.035ohm
- For 25C° 0,631/25=0.025ohm
- For 34C° 0,631/34=0.019ohm
- For 41C° 0,631/41=0.015ohm
- For 48C° 0,631/48=0.013ohm
- For 50C° 0,631/50=0.013ohm
- For 61C° 0,631/61=0.010ohm
- For 68C° 0,631/68=0.009ohm
- For 71C° 0,631/71=0.009ohm
- For 90C° 0,631/90=0.007ohm

a	T(±0.5 C)	R
0.631	5.0	0.126
	9.0	0.070
	18.0	0.035
	25.0	0.025
	34.0	0.019
	41.0	0.015
	48.0	0.013
	50.0	0.013
	61.0	0.010
	68.0	0.009
	71.0	0.009
	90.0	0.007

Table 15: shows the theoretical resistivity constants.

The theoretical graph of the temperature vs. resistivity:



Graph 5: shows the theoretical temperature vs resistivity graph of 5 gr salt trial.

11.3 CALCULATING THE RESISTIVITY OF EACH TRIALS(7,5 gr salt):

11.3.1 For 5 volt:

no	temperature (± 0.5 C)	current (± 0.1 mA)	voltage (± 0.1 v)	amount of water (± 0.5 ml)	amount of salt (± 0.01 g)	resistivity calculated (ohm)
1	5.0	107.0	5.0	150.0	7.56	0.047
2	9.0	116.0	5.0	150.0	7.52	0.043
3	18.0	139.0	5.0	150.0	7.51	0.036
4	25.0	175.0	5.0	150.0	7.52	0.029
5	34.0	168.0	5.0	150.0	7.53	0.030
6	41.0	289.0	5.0	150.0	7.53	0.017
7	48.0	306.0	5.0	150.0	7.54	0.016
8	50.0	325.0	5.0	150.0	7.50	0.015
9	61.0	421.0	5.0	150.0	7.51	0.012
10	68.0	485.0	5.0	150.0	7.55	0.010
11	71.0	614.0	5.0	150.0	7.51	0.008
12	90.0	635.0	5.0	150.0	7.52	0.008

Table 16: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For 5C° $5/107=0.047$ ohm*
- *For 9C° $5/116=0.043$ ohm*
- *For 18C° $5/139=0.036$ ohm*
- *For 25C° $5/175=0.029$ ohm*
- *For 34C° $5/168=0.030$ ohm*
- *For 41C° $5/289=0.017$ ohm*
- *For 48C° $5/306=0.016$ ohm*
- *For 50C° $5/325=0.015$ ohm*
- *For 61C° $5/421=0.012$ ohm*
- *For 68C° $5/485=0.010$ ohm*
- *For 71C° $5/614=0.008$ ohm*
- *For 90C° $5/635=0.008$ ohm*

11.3.2 For 7.5 volt:

no	temperature (± 0.5 C)	current (± 0.1 mA)	voltage (± 0.1 v)	amount of water (± 0.5 ml)	amount of salt (± 0.01 g)	resistivity calculated (ohm)
1	5.0	248.0	7.5	150.0	7.50	0.030
2	9.0	269.0	7.5	150.0	7.51	0.028
3	18.0	351.0	7.5	150.0	7.55	0.021
4	25.0	424.0	7.5	150.0	7.51	0.018
5	34.0	465.0	7.5	150.0	7.52	0.016
6	41.0	491.0	7.5	150.0	7.56	0.015
7	48.0	645.0	7.5	150.0	7.52	0.012
8	50.0	683.0	7.5	150.0	7.51	0.011
9	61.0	921.0	7.5	150.0	7.52	0.008
10	68.0	1004.0	7.5	150.0	7.53	0.007
11	71.0	1060.0	7.5	150.0	7.53	0.007
12	90.0	1120.0	7.5	150.0	7.54	0.007

Table 17: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For 5C° $7.5/248=0.030$ ohm*
- *For 9C° $7.5/269=0.028$ ohm*
- *For 18C° $7.5/351=0.021$ ohm*
- *For 25C° $7.5/424=0.018$ ohm*
- *For 34C° $7.5/465=0.016$ ohm*
- *For 41C° $7.5/491=0.015$ ohm*
- *For 48C° $7.5/645=0.012$ ohm*
- *For 50C° $7.5/683=0.011$ ohm*
- *For 61C° $7.5/921=0.008$ ohm*
- *For 68C° $7.5/1004=0.007$ ohm*
- *For 71C° $7.5/1060=0.007$ ohm*
- *For 90C° $7.5/1120=0.007$ ohm*

11.3.3 For 10.0 volt:

no	temperature (± 0.5 C)	current (mA)	voltage (v)	amount of water (± 0.5 ml)	amount of salt (± 0.01 g)	resistivity calculated (ohm)
1	5.0	398.0	10.0	150.0	7.50	0.025
2	9.0	473.0	10.0	150.0	7.50	0.021
3	18.0	601.0	10.0	150.0	7.50	0.017
4	25.0	692.0	10.0	150.0	7.50	0.014
5	34.0	825.0	10.0	150.0	7.50	0.012
6	41.0	910.0	10.0	150.0	7.50	0.011
7	48.0	1047.0	10.0	150.0	7.50	0.010
8	50.0	1088.0	10.0	150.0	7.50	0.009
9	61.0	1290.0	10.0	150.0	7.50	0.008
10	68.0	1377.0	10.0	150.0	7.50	0.007
11	71.0	1430.0	10.0	150.0	7.50	0.007
12	90.0	1500.0	10.0	150.0	7.50	0.007

Table 18: shows the data's collected during the experiment.

Calculating the resistivity of the system:

Using $V=I \cdot R$

- *For $5C^{\circ}$ $10/398=0.025$ ohm*
- *For $9C^{\circ}$ $10/473=0.021$ ohm*
- *For $18C^{\circ}$ $10/601=0.017$ ohm*
- *For $25C^{\circ}$ $10/692=0.014$ ohm*
- *For $34C^{\circ}$ $10/825=0.012$ ohm*
- *For $41C^{\circ}$ $10/910=0.011$ ohm*
- *For $48C^{\circ}$ $10/1047=0.010$ ohm*
- *For $50C^{\circ}$ $10/1088=0.009$ ohm*
- *For $61C^{\circ}$ $10/1290=0.008$ ohm*
- *For $68C^{\circ}$ $10/1377=0.007$ ohm*
- *For $71C^{\circ}$ $10/1430=0.007$ ohm*
- *For $90C^{\circ}$ $10/1500=0.007$ ohm*

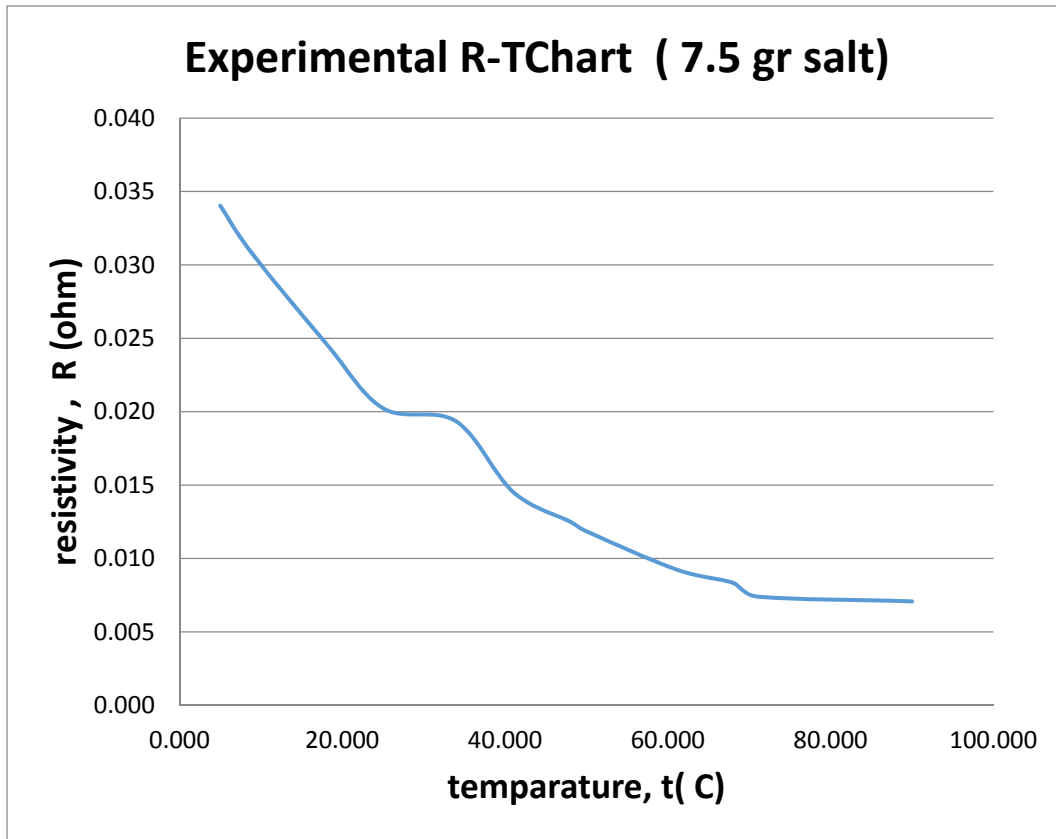
Then for calculating the mean resistivity of the each trials (5, 7.5 and 10 volts), the following chart shows:

no	temperature (±0.5 C)	mean resistivity (ohm)
1	5	0.034
2	9	0.031
3	18	0.025
4	25	0.020
5	34	0.019
6	41	0.015
7	48	0.013
8	50	0.012
9	61	0.009
10	68	0.008
11	71	0.007
12	90	0.007

Table 19: shows the mean resistivity's of 5, 7.5 and 10 volt trials.

Calculating the mean resistivity of the 5.0, 7.5 and 10.0 voltage solutions:

- For 5C° $(0.047+0.030+0.025)/3=0.034$ ohm
- For 9C° $(0.043+0.028+0.021)/3=0.031$ ohm
- For 18C° $(0.036+0.021+0.017)/3=0.025$ ohm
- For 25C° $(0.029+0.018+0.014)/3=0.020$ ohm
- For 34C° $(0.030+0.016+0.012)/3=0.019$ ohm
- For 41C° $(0.017+0.015+0.011)/3=0.015$ ohm
- For 48C° $(0.016+0.012+0.010)/3=0.013$ ohm
- For 50C° $(0.015+0.011+0.009)/3=0.012$ ohm
- For 61C° $(0.012+0.008+0.008)/3=0.009$ ohm
- For 68C° $(0.010+0.007+0.007)/3=0.008$ ohm
- For 71C° $(0.008+0.007+0.007)/3=0.007$ ohm
- For 90C° $(0.008+0.007+0.007)/3=0.007$ ohm



Graph 6: shows the experimental temperature vs resistivity graph of 7.5 gr salt trial.

The experimental graphic obtained shows quite similarities with the hyperbola form which is formulated as “ $y=a/x$ ”.

When it is considered that t is the independent variable and R is the dependent variable and when a is named as the constant resistivity, the formula of the graphic will be :

$$R=a/t$$

Now we can calculate the value of the constant resistivity (a) by using the values obtained in the experiment.

a = resistivity constant

t = temperature

R = Mean Resistivity

$$a= R/t$$

11.3.4 Calculating The Resistivity Constant

mean resistivity (ohm)	resistivity constant (ohm.C)
0.034	0.170
0.031	0.276
0.025	0.444
0.020	0.506
0.019	0.657
0.015	0.595
0.013	0.600
0.012	0.593
0.009	0.565
0.008	0.568
0.007	0.526
0.007	0.637
mean resistivity constat, a (ohm.C)	0.511

Table 20: shows the resistivity constant calculated by experimental data's.

And then calculating the resistivity constant:

With using this formula $a=R*T$

- For $5C^{\circ}$ $5*0.034=0,170ohm*C^{\circ}$
- For $9C^{\circ}$ $9*0.031=0,276ohm*C^{\circ}$
- For $18C^{\circ}$ $18*0.025=0,444ohm*C^{\circ}$
- For $25C^{\circ}$ $25*0.020=0,506ohm*C^{\circ}$
- For $34C^{\circ}$ $34*0.019=0,657ohm*C^{\circ}$
- For $41C^{\circ}$ $41*0.015=0,595ohm*C^{\circ}$
- For $48C^{\circ}$ $48*0.013=0,600ohm*C^{\circ}$
- For $50C^{\circ}$ $50*0.012=0,593ohm*C^{\circ}$
- For $61C^{\circ}$ $61*0.009=0,565ohm*C^{\circ}$
- For $68C^{\circ}$ $68*0.008=0,568ohm*C^{\circ}$
- For $71C^{\circ}$ $71*0.007=0,526ohm*C^{\circ}$
- For $90C^{\circ}$ $71*0.007=0,637ohm*C^{\circ}$

The mean resistivity constant is

$$(0,170+0,276+0,444+0,506+0,657+0,595+0,600+0,593+0,565+0,568+0,526+0,637)/12=0,511 \text{ ohm}^{\circ}\text{C}^{\circ}$$

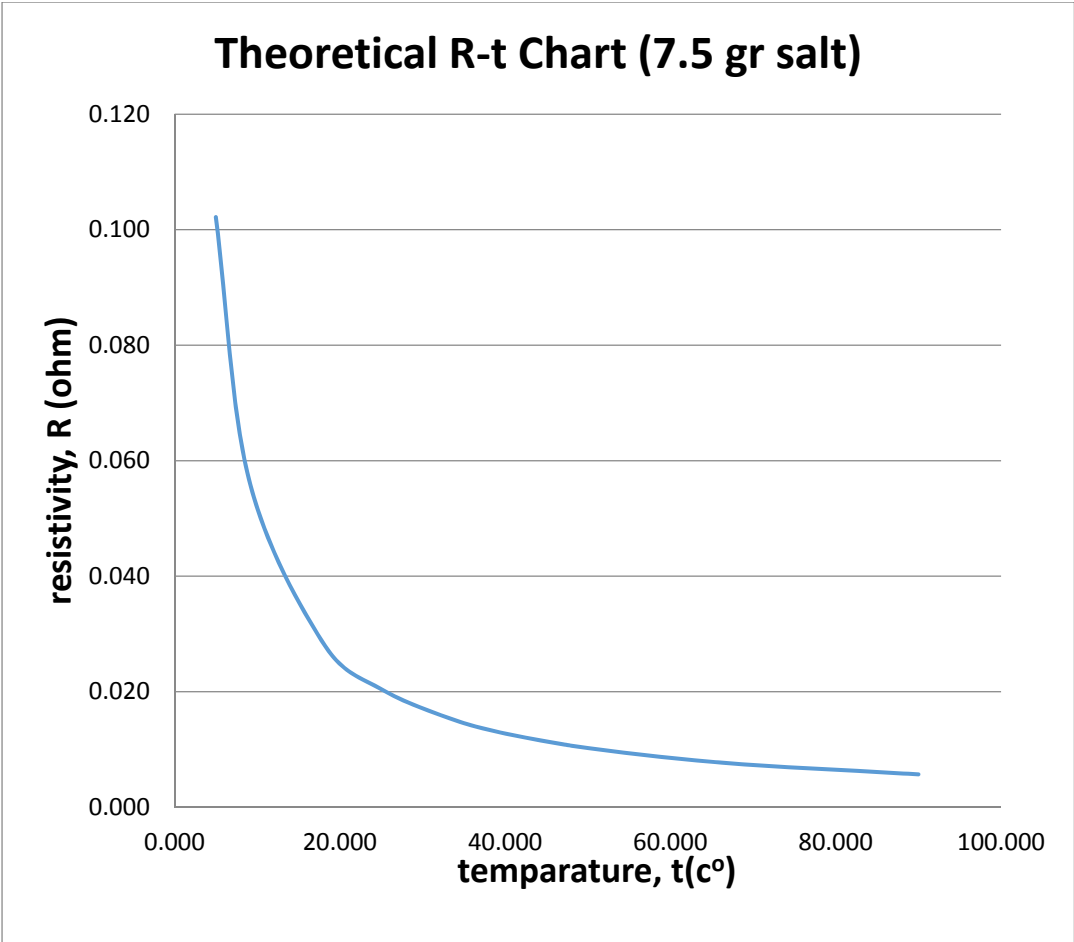
Now this “0,511 ohm* C° is our mean resistivity constant, a. For calculating the theoretical resistivity:

- For 5C° 0,511/5=0.102ohm
- For 9C° 0,511/9=0.057ohm
- For 18C° 0,511/18=0.028ohm
- For 25C° 0,511/25=0.020ohm
- For 34C° 0,511/34=0.015ohm
- For 41C° 0,511/41=0.012ohm
- For 48C° 0,511/48=0.011ohm
- For 50C° 0,511/50=0.010ohm
- For 61C° 0,511/61=0.008ohm
- For 68C° 0,511/68=0.008ohm
- For 71C° 0,511/71=0.007ohm
- For 90C° 0,511/90=0.006ohm

a	t	R
0.511	5.000	0.102
	9.000	0.057
	18.000	0.028
	25.000	0.020
	34.000	0.015
	41.000	0.012
	48.000	0.011
	50.000	0.010
	61.000	0.008
	68.000	0.008
	71.000	0.007
	90.000	0.006

Table 21: shows the theoretical resistivity constants.

The theoretical graph of the temperature vs. resistivity:



Graph 7: shows the theoretical temperature vs resistivity graph of 7.5 gr salt.

12. UNCERTAINTY CALCULATIONS:

For example for calculating the uncertainty of resistivity is like following:

Firstly we should define the uncertainty of power supply and the digital multimeter.

Power supply gives the voltage so the uncertainty of voltage is ± 0.1 V

Multimeter depends the current in the system so its uncertainty gives the uncertainty of current so the uncertainty of current is ± 0.1 A

$V = I \cdot R$ then

$R = V/I$

We should calculate the percentage uncertainty of current and voltage

For example for 2.5 gr salt, 5 volt system, calculations will be like following;

For voltage 5.000V 0.100
 100 **2.000** so percentage uncertainty is %2

For current 19.000A 0.100
 100 **0.520** so percentage uncertainty is %0.520

Then we should sum these percentage uncertainties:

$2 + 0.52 = \%2.520$

This percentage uncertainty gives the percentage uncertainty of resistivity, now we will calculate the value of uncertainty.

In the 2.5 gr salt, 5 volt, the resistivity was 0.263 ohm so

100 2.520

0.263 0.006

So resistivity is 0.263 ± 0.006 ohm

The other uncertainty calculations of other resistivity values will be same way with this one.

12.1 CALCULATING THE UNCERTANITIES OF RESISTIVITIES OF EACH TRIALS (2,5 gr salt):

12.1.1 For 5 volt:

Table 22.1.: shows the uncertainty calculations of resistivity values.

percentge uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertaninty of resistivities(\pm ohm)
0.526	2.000	2.526	0.007
0.417	2.000	2.417	0.005
0.345	2.000	2.345	0.004
0.233	2.000	2.233	0.003
0.189	2.000	2.189	0.002
0.147	2.000	2.147	0.002
0.137	2.000	2.137	0.001
0.115	2.000	2.115	0.001
0.083	2.000	2.083	0.001
0.063	2.000	2.063	0.001
0.056	2.000	2.056	0.001
0.056	2.000	2.056	0.001

12.1.2 For 7.5 volt:

Table 22.2.: shows the uncertainty calculations of resistivity values.

percentge uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertaninty of resistivities(\pm ohm)
0.323	1.333	1.656	0.004
0.263	1.333	1.596	0.003
0.213	1.333	1.546	0.002
0.156	1.333	1.490	0.002
0.102	1.333	1.435	0.001
0.085	1.333	1.419	0.001
0.078	1.333	1.411	0.001
0.070	1.333	1.404	0.001
0.054	1.333	1.387	0.001
0.045	1.333	1.378	0.000
0.037	1.333	1.370	0.000
0.037	1.333	1.370	0.000

12.1.3 For 10 volt:

Table 22.3.: shows the uncertainty calculations of resistivity values.

percentge uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertaninty of resistivities(\pm ohm)
0.222	1.000	1.222	0.003
0.196	1.000	1.196	0.002
0.172	1.000	1.172	0.002
0.127	1.000	1.127	0.001
0.090	1.000	1.090	0.001
0.073	1.000	1.073	0.001
0.068	1.000	1.068	0.001
0.057	1.000	1.057	0.001
0.041	1.000	1.041	0.000
0.032	1.000	1.032	0.000
0.026	1.000	1.026	0.000
0.026	1.000	1.026	0.000

12.2 CALCULATING THE UNCERTANITIES OF RESISTIVITIES OF EACH TRIALS (5,0 gr salt):

12.2.1 For 5 volt:

Table 23.1.: shows the uncertainty calculations of resistivity values.

percentge uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertaninty of resistivities(\pm ohm)
0.179	2.000	2.179	0.002
0.137	2.000	2.137	0.001
0.093	2.000	2.093	0.001
0.076	2.000	2.076	0.001
0.060	2.000	2.060	0.001
0.053	2.000	2.053	0.001
0.041	2.000	2.041	0.000
0.028	2.000	2.028	0.000
0.023	2.000	2.023	0.000
0.020	2.000	2.020	0.000
0.019	2.000	2.019	0.000

0.016	2.000	2.016	0.000
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12.2.2 For 7.5 volt:

Table 23.2.: shows the uncertainty calculations of resistivity values.

percentge uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertaninty of resistivities(\pm ohm)
0.078	1.333	1.411	0.001
0.057	1.333	1.390	0.001
0.040	1.333	1.373	0.000
0.034	1.333	1.367	0.000
0.028	1.333	1.361	0.000
0.025	1.333	1.358	0.000
0.020	1.333	1.353	0.000
0.017	1.333	1.350	0.000
0.015	1.333	1.348	0.000
0.013	1.333	1.346	0.000
0.011	1.333	1.345	0.000
0.011	1.333	1.344	0.000

12.2.3 For 10 volt:

Table 23.3.: shows the uncertainty calculations of resistivity values.

percentge uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertaninty of resistivities(\pm ohm)
0.039	1.000	1.039	0.000
0.033	1.000	1.033	0.000
0.025	1.000	1.025	0.000
0.022	1.000	1.022	0.000
0.018	1.000	1.018	0.000
0.013	1.000	1.013	0.000
0.011	1.000	1.011	0.000
0.009	1.000	1.009	0.000
0.008	1.000	1.008	0.000
0.008	1.000	1.008	0.000
0.008	1.000	1.008	0.000
0.007	1.000	1.007	0.000

12.3 CALCULATING THE UNCERTANITIES OF RESISTIVITIES OF EACH TRIALS (7.5 gr salt):

12.3.1 For 5 volt:

Table 24.1.: shows the uncertainty calculations of resistivity values.

percentge uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertaninty of resistivities(\pm ohm)
0.093	2.000	2.093	0.001
0.086	2.000	2.086	0.001
0.072	2.000	2.072	0.001
0.057	2.000	2.057	0.001
0.060	2.000	2.060	0.001
0.035	2.000	2.035	0.000
0.033	2.000	2.033	0.000
0.031	2.000	2.031	0.000
0.024	2.000	2.024	0.000
0.021	2.000	2.021	0.000
0.016	2.000	2.016	0.000
0.016	2.000	2.016	0.000

12.3.2 For 7.5 volt:

Table 24.2.: shows the uncertainty calculations of resistivity values.

percentge uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertaninty of resistivities(\pm ohm)
0.040	1.333	1.374	0.000
0.037	1.333	1.371	0.000
0.028	1.333	1.362	0.000
0.024	1.333	1.357	0.000
0.022	1.333	1.355	0.000
0.020	1.333	1.354	0.000
0.016	1.333	1.349	0.000
0.015	1.333	1.348	0.000
0.011	1.333	1.344	0.000
0.010	1.333	1.343	0.000
0.009	1.333	1.343	0.000
0.009	1.333	1.342	0.000

12.3.3 For 10 volt:

Table 24.3.: shows the uncertainty calculations of resistivity values.

percentage uncertainty of currents	percentage uncertainty of voltages	percentage uncertainty of resistivities	uncertainty of resistivities(\pm ohm)
0.025	1.000	1.025	0.000
0.021	1.000	1.021	0.000
0.017	1.000	1.017	0.000
0.014	1.000	1.014	0.000
0.012	1.000	1.012	0.000
0.011	1.000	1.011	0.000
0.010	1.000	1.010	0.000
0.009	1.000	1.009	0.000
0.008	1.000	1.008	0.000
0.007	1.000	1.007	0.000
0.007	1.000	1.007	0.000
0.007	1.000	1.007	0.000

So, for example one of the resistivity is (for 2.5 gr 5V);

0.263 \pm 0.007 ohm

Then for calculating the uncertainty of mean resistivity, calculation will be like following;

For calculating the mean resistivity's of 2.5 gr salt, 5,7.5 and 10 voltage:

Mean resistivity of it is: 0.242 ohm

5 volt uncertainty is ± 0.007

7.5 volt uncertainty is ± 0.004

10 volt uncertainty is ± 0.003

$$(R_{\max \text{ uncertainty}} + R_{\min \text{ uncertainty}}) / 2 = (0.007 + 0.003) / 2$$

$$= 0.005$$

Then the value is 0.242 \pm 0.005 ohm

The other uncertainty calculations of other resistivity values will be same way with this one.

For 2.5 gr salts:

For 5 gr salts:

For 10 gr salts:

uncertainty of mean resistivities(± ohm)	uncertainty of mean resistivities(± ohm)	uncertainty of mean resistivities(± ohm)
0.005	0.001	0.001
0.004	0.001	0.001
0.003	0.001	0.001
0.002	0.001	0.001
0.002	0.001	0.001
0.002	0.001	0.000
0.001	0.000	0.000
0.001	0.000	0.000
0.001	0.000	0.000
0.001	0.000	0.000
0.001	0.000	0.000
0.001	0.000	0.000
0.001	0.000	0.000

Table 25: shows the uncertainty values of mean resistivity's.

13 CONCLUSION

The aim of our studies is to observe how the resistance of saline solution changes due to the temperature and to create a mathematical model of this change.

It is predicted that the resistance of the saline solution changes in relation to the factors mentioned below:

- 1) Inversely correlated with the concentration of solution (negative correlation)
- 2) Inversely correlated with the temperature of solution(negative correlation)
- 3) Inversely correlated with parts of electrodes surface in solution (negative correlation)
- 4) Directly proportional with distance between electrodes (positive correlation)

When we were making our experiments, the distance between the electrodes and their surfaces referred to in article 3 and 4 remains constant so the effects of variables upon the experiments were disposed.

The effects of concentration upon the resistance is observed by repeating the experiments include 3 different concentrated solutions (2,5-5-7,5gr)

To observe the change of solution's resistance due to the temperature, which is our major point, we determined the temperature of solution as independent variable and the resistance of solution as dependent variable.

The resistance of solution cannot be measured directly so voltage was conducted at a certain level and current was measured. According to Ohm's law, resistance values were also calculated by using voltage and current values obtained.

In each experiments for concentration value, 12 temperature levels are chosen (5-90 °C) and by using 3 level of voltage (5-7,5-10), for each of them, the currents are measured and the resistance of solution is calculated.

The results that were confirmed after these experiments:

- 1) As it can be seen from three charts below, the resistance of solution is decreased when its concentration is increased. It is proved that there is a negative correlation between the resistance of solutions and its concentration.

For example, it is found that;

At 41°C and 2,5 gr salt concentration, the resistance of solution is 0,064 ohm.

5 gr salt concentration, the resistance of the solution is 0,019 ohm.

7,5 gr salt concentration, the resistance of the solution is 0,015 ohm.

no	temper ature (±0.5 C)	amount of salt (±0.01 g)	resistivity calculated (ohm)
1	5.0	2,52	0,242
2	9.0	2,49	0,197
3	18.0	2,51	0,160
4	25.0	2,50	0,117
5	34.0	2,50	0,077
6	41.0	2,49	0,064
7	48.0	2,50	0,059
8	50.0	2,49	0,053
9	61.0	2,50	0,041
10	68.0	2,50	0,034
11	71.0	2,49	0,028
12	90.0	2,50	0,028

amount of salt (±0.01 g)	resistivity calculated (ohm)
5,01	0,059
5,02	0,043
5,06	0,030
5,04	0,025
5,03	0,021
5,00	0,019
5,01	0,015
5,06	0,013
5,00	0,011
5,04	0,010
5,06	0,008
5,02	0,008

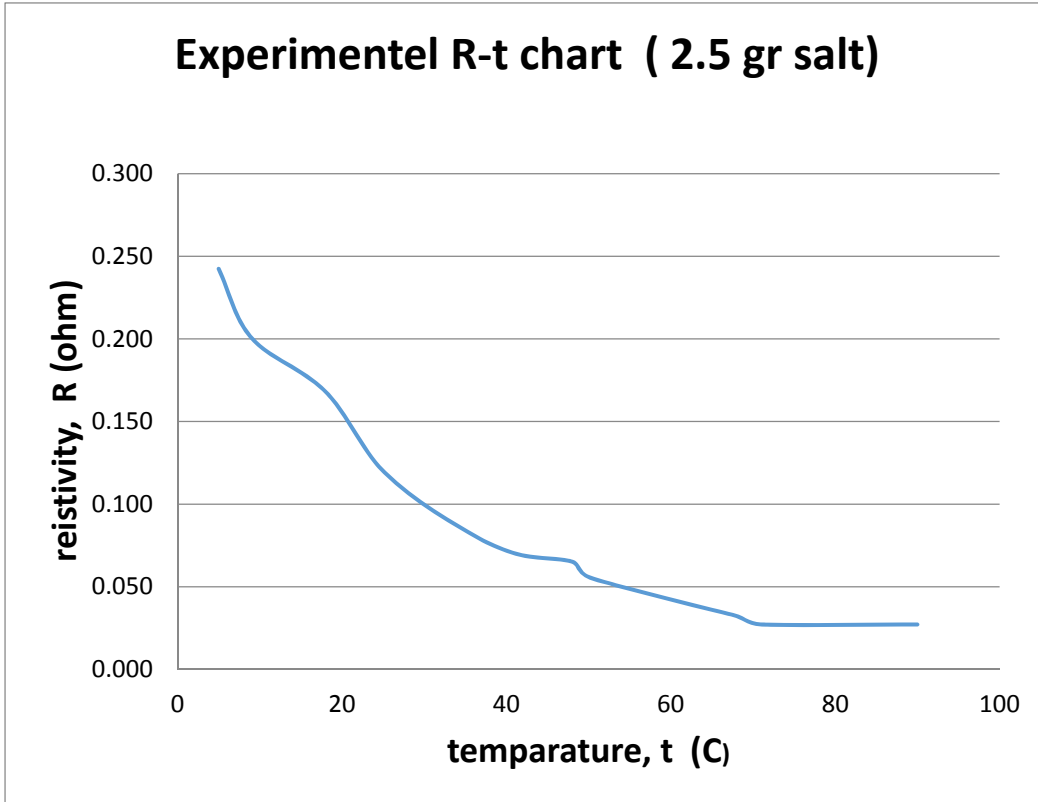
amount of salt (±0.01 g)	resistivity calculated (ohm)
7,5	0,030
7,5	0,028
7,5	0,021
7,5	0,018
7,5	0,016
7,5	0,015
7,5	0,012
7,5	0,011
7,5	0,008
7,5	0,007
7,5	0,007
7,5	0,007

Table 26: shows the data collected from the experiment and the calculated resistivity values.

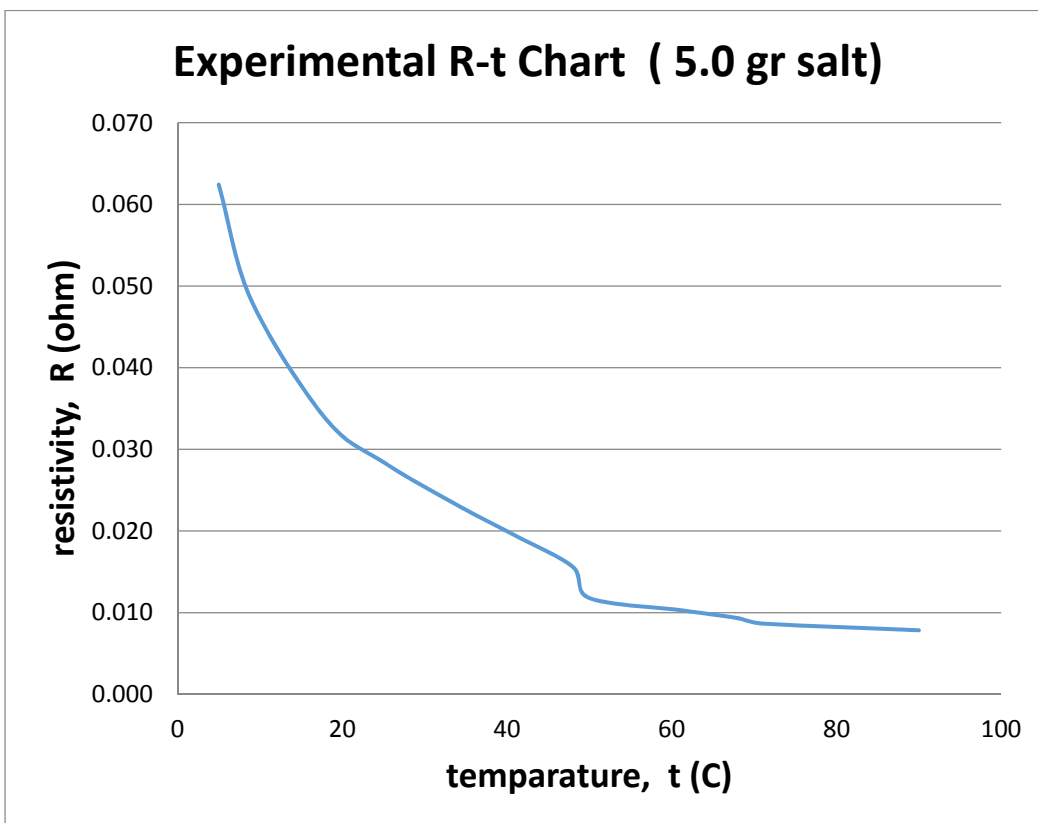
2-a) At the charts above, considering each level of concentrations, it is seen that when the temperature of the solution is increased, the resistance of solution is decreased. This results indicates that there is a negative correlation between the resistance of solutions and its temperatures.

For example; While for the concentration of 2,5 gr solutions , the resistance of solution is 0,242 ohm at 50 °C , the resistance drops to 0,028 ohm at 90 °C.

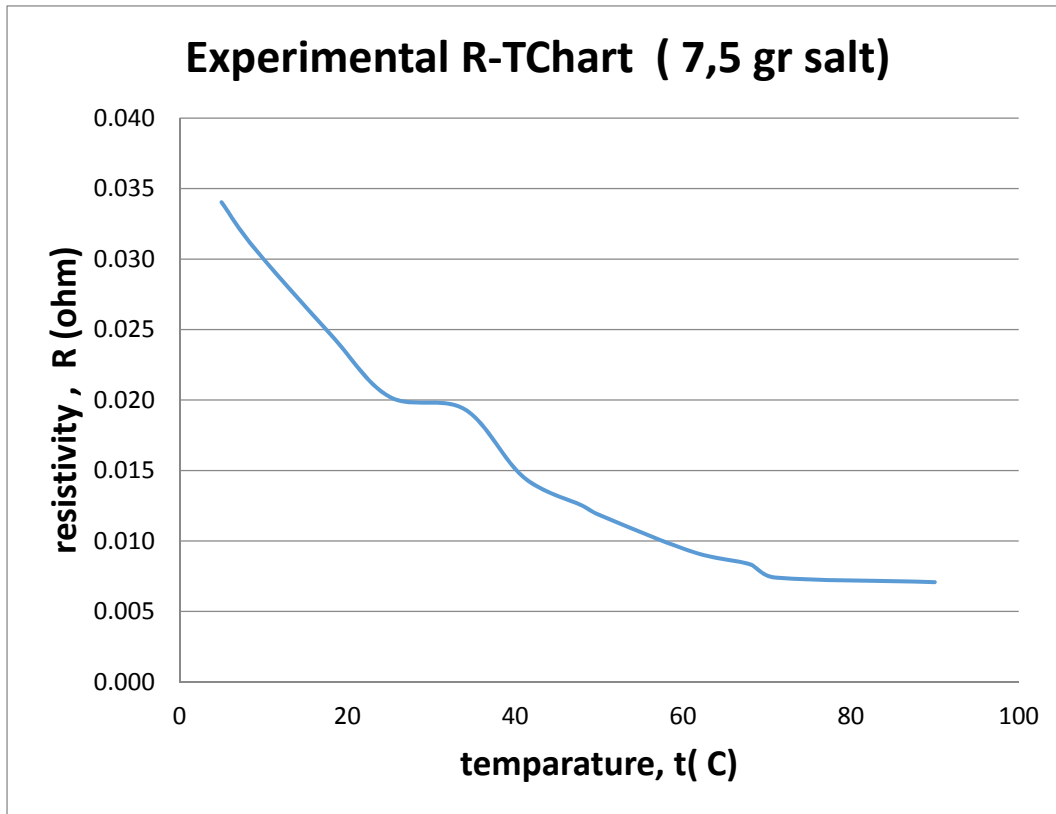
2-b) So as to increase the reliability of measurement of resistance-temperature changes, the graphs are drawn according to the values found as average and that is shown below:



Graph 8: shows the experimental temperature vs resistivity graph of 2.5 gr salt trial.

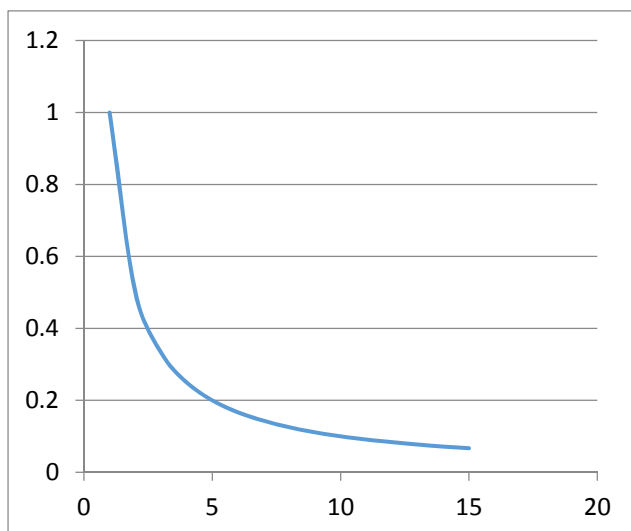


Graph 9: shows the experimental temperature vs resistivity graph of 5.0 gr salt trial.



Graph 10: shows the experimental temperature vs resistivity graph of 7.5 gr salt trial.

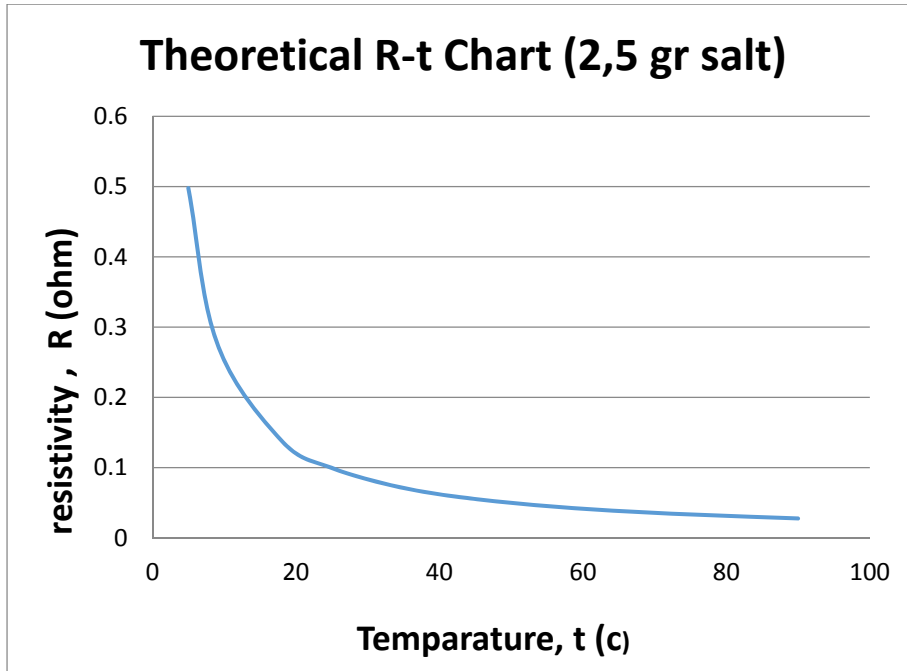
These graphics;



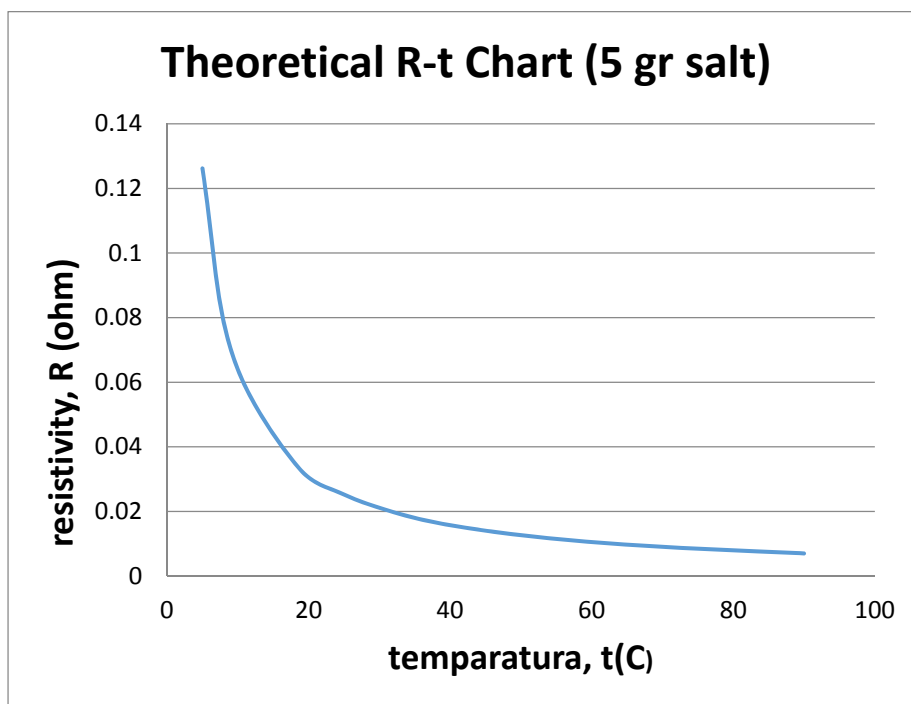
Graph 11: shows the general shape of other 2.5, 5.0 and 7.5 gr salt trial's temperature vs resistivity graphs.

It is seen that it is similar to the hyperbola form which is formulated as $y=a/x$ equation.

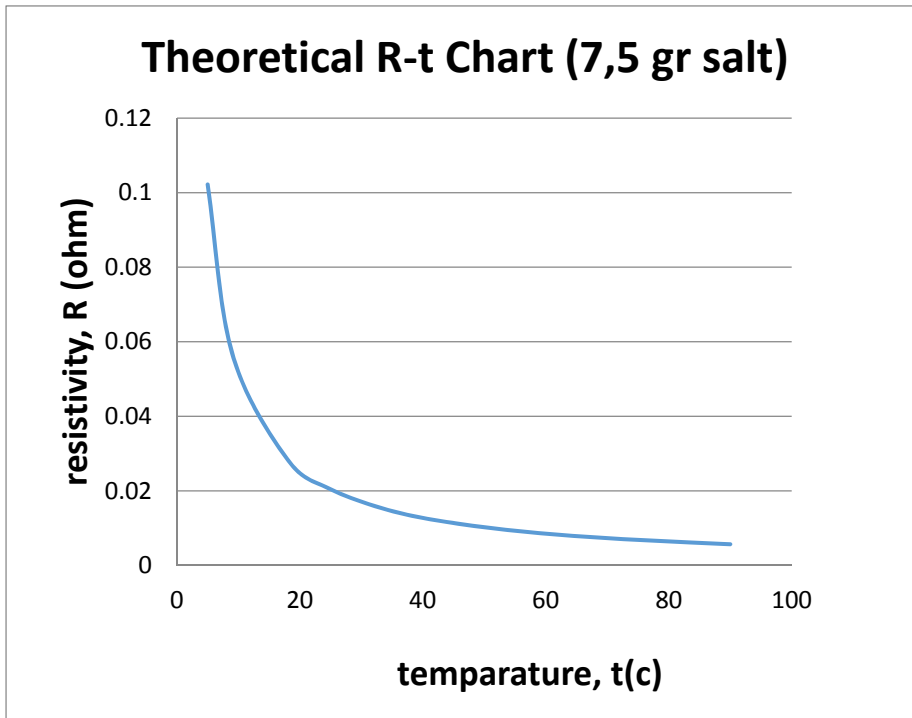
To provide a transformation from resistance-temperature changes to a hyperbolic function, $y=a/x$ equation resembled $R=a/t$ and a , the coefficient, is computed by using the averages of values that are obtained from experiments. Thus, “theoretical R-t graphs” given below are drawn for per concentration levels.



Graph12: shows the theoretical temperature vs resistivity graph of 2.5 gr salt trial.

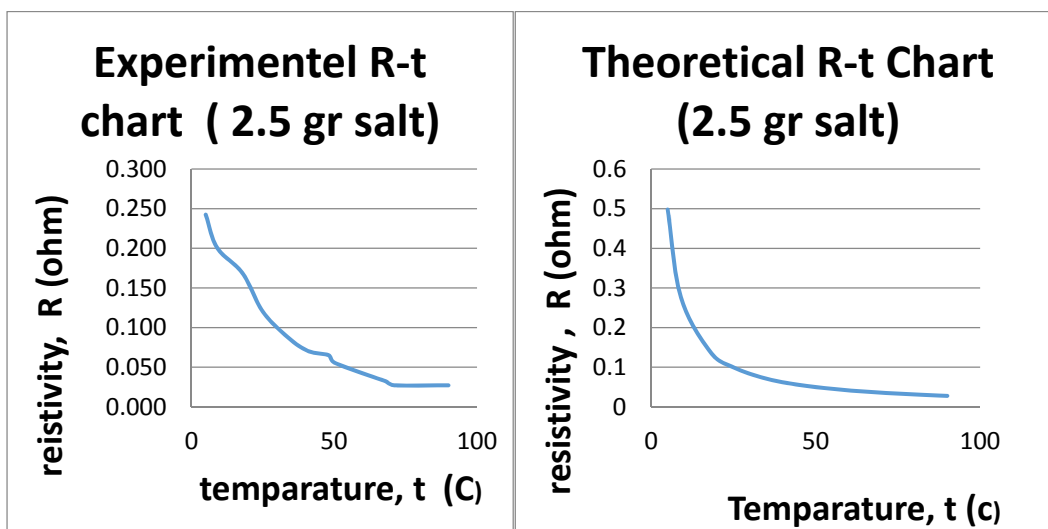


Graph13: shows the theoretical temperature vs resistivity graph of 5.0 gr salt trial.



Graph 14: shows the theoretical temperature vs resistivity graph of 7.5 gr salt trial.

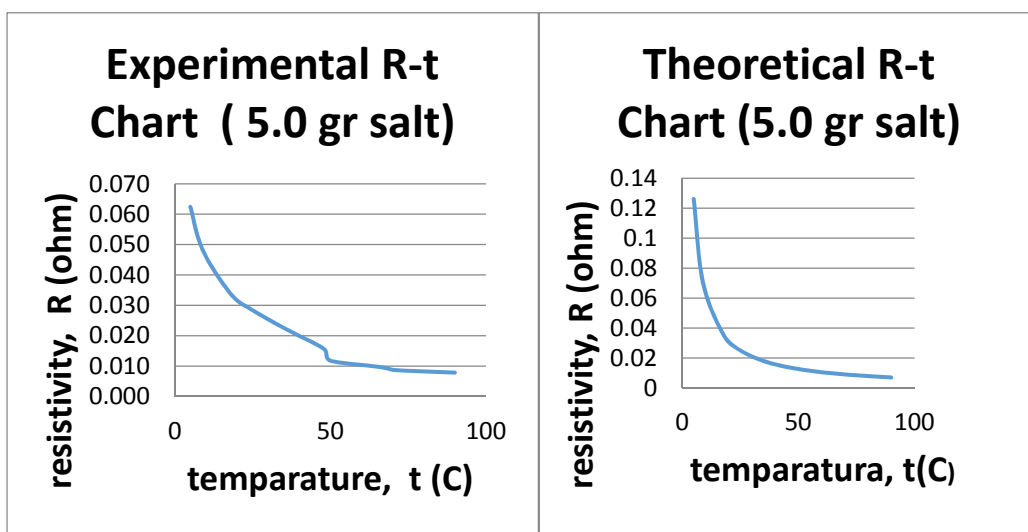
In order to make a good comparison, empirical and theoretical graphs which belong to different concentration levels and empirical and theoretical R-t charts are juxtaposed.



Graphs 15: show the comparison of the experimental and theoretical temperature vs resistivity graphs of 2.5 gr salt trial.

t	Experimentel R	Theoretical R
5	0,242	0,498
9	0,201	0,277
18	0,168	0,138
25	0,120	0,100
34	0,087	0,073
41	0,070	0,061
48	0,065	0,052
50	0,056	0,050
61	0,041	0,041
68	0,032	0,037
71	0,027	0,035
90	0,027	0,028

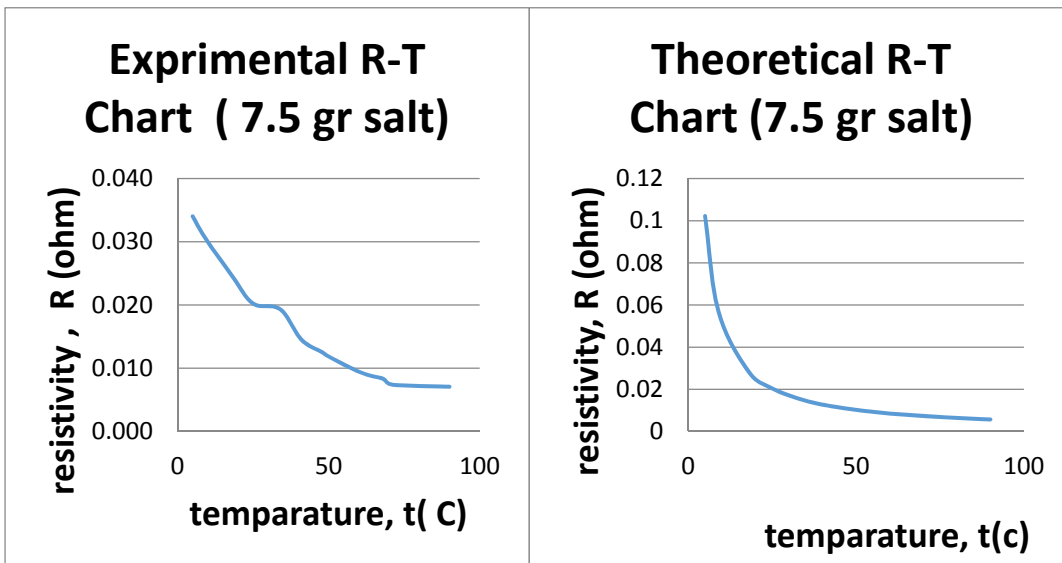
Table 27: shows the experimental and theoretical resistivity constants of 2.5 gr salt trials.



Graphs 16: show the comparison of the experimental and theoretical temperature vs resistivity graphs of 5.0 gr salt trial.

t	Experimentel R	Theoretical R
5	0,062	0,126
9	0,048	0,070
18	0,034	0,035
25	0,028	0,025
34	0,023	0,019
41	0,019	0,015
48	0,016	0,013
50	0,012	0,013
61	0,010	0,010
68	0,009	0,009
71	0,009	0,009
90	0,008	0,007

Table 28: shows the experimental and theoretical resistivity constants of 5.0 gr salt trials.



Graphs 17: show the comparison of the experimental and theoretical temperature vs resistivity graphs of 7.5 gr salt trial.

t	Experimentel R	Theoretical R
5	0,034	0,102
9	0,031	0,057
18	0,025	0,028
25	0,020	0,020
34	0,019	0,015
41	0,015	0,012
48	0,013	0,011
50	0,012	0,010
61	0,009	0,008
68	0,008	0,008
71	0,007	0,007
90	0,007	0,006

Table 29: shows the experimental and theoretical resistivity constants of 7.5 gr salt trials.

As a result of the analysis of these graphs, it is seen that empirical graphs shows similarities with theoretical graphs as a form.

In addition, when R-t values are compared, the experimental values and theoretical values jibe with each other at a great extend but 5° C and 9° C are not included.

It is not possible to compare the results because there is no specific studies about that topic both on Internet and in literature researches.

The results show that the changes of the resistance of saline solution due to the temperature is with a hyperbolic character.

14 EVALUATION

That we have to execute a voltage to the solution for measuring the resistance and passing current to the solution cause “systematic error”. The cause of this situation because of the nature of resistance measurement is tried to be explained below:

When electrical current passes through the saline solution, the chemical events occur due to electrolysis and these are mentioned below:

A half-equation shows you what happens at one of the electrodes during electrolysis. Electrons are shown as e^- . These are the half-equations:

- anode: $2Cl^- - 2e^- \rightarrow Cl_2$ (oxidation)
- cathode: $2H^+ + 2e^- \rightarrow H_2$ (reduction).

Oxidation happens at the anode because electrons are lost. Reduction happens at the cathode because electrons are gained. Oxidation Is Loss of electrons, Reduction Is Gain of electrons.

Sodium ions Na^+ and hydroxide OH^- are also present in the sodium chloride solution. They are not discharged at the electrodes. Instead, they make sodium hydroxide solution.

- chlorine gas forms at the anode (positive electrode)
- hydrogen gas forms at the cathode (negative electrode)
- a solution of sodium hydroxide forms.

These products are reactive and make some change on the materials of the electrodes and the solution.

As a result of the chemical events due to the electrolyze, hydrogen and chlorine gases which are covering the electrodes affect the conductivity of electrodes and also affect the experiment in a negative way.

Gas-bubbles cover the metal electrode and when the current value is getting more and more, it becomes visible. Gas bubbles accumulated on electrodes affect the current value by making insulation between the electrodes and the saline solution. Hence, resistance of solution can be miscalculated.

Besides, sodium hydroxide which is produced by electrolyzing changes the chemical structure of the solution by accumulation in the saline solution. It have also an aliasing effect.

During the experiments, it is observed that the colour of metal electrodes changes while measuring. The colour change incurred that compounds, that produced after chemical reactions between substances produced after electrolysis and metal electrodes, cover the surface of electrodes. That the electrodes are covered with another substance and the accumulation of these substances during the experiment are also the matters of “systematic error” which affects the results in a negative way.

To make minimize the causes above, these can be done;

- 1- During experiment, keep voltage that is applied to electrodes low because it is important to reduce the value of passing current as possible. Thus, the formation of gasses and the other chemical substances are reduced and the negative effects are reduced as well.
- 2- During experiment, use a device produces a mechanical vibration. It helps remove the gas-bubbles which accumulated over the electrodes, from the surfaces they were sticked to.
- 3- Minimize the negative effects of colour change by using new electrodes for each measurement.
- 4- Prepare a new solution for each measurement. Thus, it is possible to measure properly with reducing the chemicals produced after electrolysis.

Apart from the systematic errors mentioned above, the most cricial causes of random error which affects the test experiment is that electrodes cannot be fixed to their test tubes mechanically so they come loose and the distance among electrodes is getting destroyed.

It must be provided that the distance among electrodes stay stable by supporting them mechanically.

Due to these reasons mentioned above, during the experiment the graphs show deviations from the ideal hyperbola forms.

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