**Investigating the factors that affect the conductance of different solutions**

**Introduction**

Just as metallic conductors have a resistance when a current is passed through them so do ionic solutions. However, when dealing with solution it is more convenient to look at its conductance, G, rather than its resistance and is simply the reciprocal of the resistance, R. The unit of measurement is siemens,$\Omega$-1 G=1/R. We can also work the conductance from knowing the current and the voltage G=I/V.
The ability of a solution to conduce electricity is due to the dissociation of the compounds presence into its constituent ions. Theses ions play the same role, in solutions, as electrons do in metallic conductors, they transport the electric charge from one electrode to the other.

**Aim**

To investigate how certain factors affect the conductance of a solution.

The factors I have considered investigating, that may have an affect on the conductances of a solution are:
- different concentrations of the solution (0.5M, 1M, 1.5M, 2M, 2.5M & 3M)
- the temperature of the solution (ranging between 20°C to 90°C)
- different solutions (Sodium Chloride& Sulphuric Acid)
- different electrodes (Carbon & Copper)

**Summary**

In this investigation I analysed certain factors that I thought might affect the conductance of a solution i.e. concentration, temperature, different solutions, different electrodes. Before carrying out my actual experiment I carried out a trial to see whether they're any areas for improvement. After inputting the improvements I carried the actual experiment. Once the results were obtained I used graphical techniques to present the data.

My results for all the factors showed a definite trend, which were easy to provide simple superficial explanations for. However underneath lay a much more complex relationship between the individual factors and conductance, which were far more intricate then I had imagined at the on set of the investigation

At the end of the investigation I felt that this was a very worthwhile and extremely interesting topic. Before conducting this investigation I knew very little about this field of physics but after doing the research and carrying out the experiments I have learned a much greater insight to the workings of conductance.

## Method

**Different concentrations**

To begin with it was essential that all concentrations of solutions used in the experiment were uncontaminated since this would immediately make the results of the experiment invalid. First collect the required apparatus and set it up as shown in diagram 1. Then measure 50ml of 0.5M sodium chloride solutions in a beaker using a measuring cylinder. Then place the graphite electrodes into the solution and connect it up to the circuit using crocodile clips. After that switch the power pack on and take the readings from the ammeter and the voltmeter. Repeat the process three times in order to take an average reading. Then carry out the experiment for the different concentrations i.e. 1M, 1.5M, 2M, 2.5M & 3M. Once you finish the experiment with carbon electrodes, and then repeat the experiments again but this time alter the electrode and use copper electrode instead of carbon electrode.

Now do the experiment again but this time with sulphuric acid. Making sure all the process is repeated.

**Modifications to experimental method following trial.**

In my trial I used a d.c current. This altered my experiment results because I found that using a d.c. Current caused chlorine gas to be given off, identifiable from the smell. This happened because the electrodes were producing their own voltage, so electrolysis was taking place. This also meant the concentration of the solution would have changed. These could have caused a large inaccuracy in my results.

**Improvement**- Instead of using d.c use a.c current. By using an a.c current electrolysis is avoided because the ions are constantly flowing in alternating directions so do not get time to form at either electrode.

Before carrying out the actual experiment I improved my method by altering the problems found during the trial.

## Temperature

Again make sure that all concentrations of solutions used in the experiment are uncontaminated since this would immediately make the results of the experiment invalid. Then set up the apparatus as shown on diagram 2. Then measure 50 ml of sodium chloride into the beaker. Place the digital thermometer into the solution then Heat the solution using the Bunsen burner. Remove the heat and place the electrodes into the solution. Afterwards switch the power pack on and take the readings of the ammeter and voltmeter. Then heat the solution for till the solution reach the next desired temperature and carry out the same process. Repeat the experiments for all the temperatures. Carry out the same experiment again but this time change the electrode and use copper electrode.

Replicate the experiment again but this time with sulphuric acid. Making sure all the process is repeated.

**Modifications to experimental method following trial.**

In my I found that it was very hard to heat the solution to a certain temperature because during heating the temperature rise was very rapid and did not allow enough time to take accurate readings.

**Improvement**- Instead of heating the solution to one temperature after the other, I found that by heating the solution to the maximum temperature and leaving it cool to the necessary temperature was more effective.

The maximum temperature I went up to was 83 °c because my preliminary work showed that solution started to boil above this temperature, so I knew if that happened my experiment would not have been fair.

Before carrying out the actual experiment I improved my method by altering the problems found during the trial.

In my final experiment I only tested one concentration of both solutions because all concentrations should show the same effect in conducting the current when the temperature is increased.

**Apparatus List**

Voltmeter
Ammeter
Digital thermometer
50 ml beakers
Graphite & Copper electrodes
Power Pack
Connection leads

- Clamps & Clamp stands
- Bunsen burner
- Crocodile clips

## Setting of the apparatus

Diagram 1 (Concentration)

Diagram 2 (Temperature)

**Hypothesis: What effect does different concentrations of the solution (0.5M, 1M, 1.5M, 2M, 2.5M & 3M) have on the conductance of a solution?**

I hypothesise that as I concentration of the solution is increased the conductance of the solution will also increase.  I predict the rate of the conductance is directly proportional to the concentration. This is because in solutions, the process of electrolysis conducts electricity, which is when the compound dissociates into its constituent ions. These ions then carry the charge from one electrode to the other. So going back to concentration we can see if the concentration is increased there will be more ions and charge carriers present in the solutions, causing an increase in the conductance.

I hypothesise when I plot a graph for concentration against conductance I will expect to get a similar graph to the one below:

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νχε
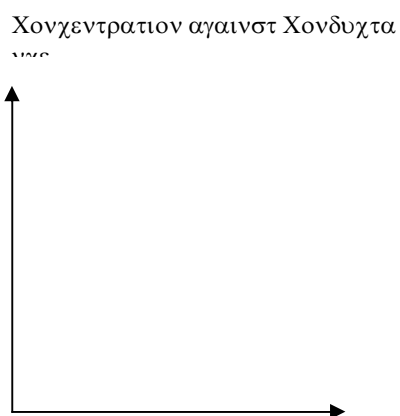
I predict the graph will have the following shape because when the concentration increases the conductunce is also incraesing at the same time.

**Hypothesis: What effect does different temperatures of the solution (ranging between 20°C to 90°C) have on the conductance of a solution?**

I hypothesise as I increase the temperature of the solution the conductance of the solution will also increase. This happens because when we heat the solutions, the in the ions in the solution get a bigger kinetic energy from the heat. The extra kinetic energy makes the ions move vibrate faster. This leads to rush in the electricity transfer between ions to ions and it leads to the increase in conductance.

I hypothesise when I plot a graph for concentration against conductance I will expect to get a similar graph to the one below:
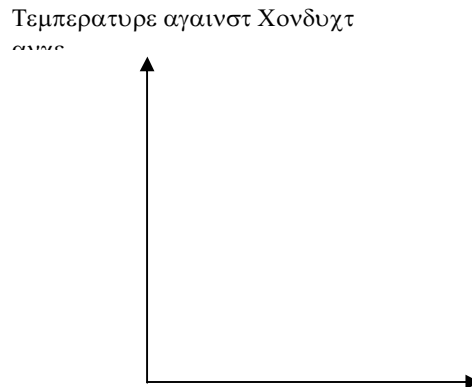
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I predict the graph will have the following shape because when the concentration increases the conductunce is also incraesing at the same time.

**Hypothesis: What effect does different solutions (Sodium Chloride& Sulphuric Acid) have on the conductance rate of a solution?**

I hypothesise out of the two solutions Sulphuric acid will conduct the solution better than sodium chloride. I think this will happen because in sulphuric acid there are more positively charged ions to carry the electric charge than there is sodium chloride. In sulphuric acid there are 2H+ ions where there is only one Na+. So more positively charged ions the better the conductance will be.

**Hypothesis: What effect does different electrodes (Carbon & Copper) have on the conductance rate of a solution?**

I hypothesise Carbon will have better conductance rate than some Copper because it's a better conductor of electricity than copper. So better conductor means the higher conductance.

## Results

## Concentration

### Sodium Chloride (Carbon electrode)

| Concentration (M) | Voltage (Volts) | Average Voltage | Current (Amps) | Average Current (3d.p) | Conductance (S) (3s.f) |
|---|---|---|---|---|---|
| 0.5M | 2.1 | 2.1 | 0.226 | 0.228 | 0.109 |
| | 2.1 | | 0.228 | | |
| | 2.1 | | 0.229 | | |
| 1M | 2 | 2.0 | 0.285 | 0.286 | 0.143 |
| | 2 | | 0.287 | | |
| | 2 | | 0. 285 | | |
| 1.5M | 1.9 | 1.9 | 0.311 | 0.311 | 0.164 |
| | 1.9 | | 0.312 | | |
| | 1.9 | | 0.311 | | |
| 2M | 1.9 | 1.9 | 0.387 | 0.389 | 0.205 |
| | 1.9 | | 0.388 | | |
| | 1.9 | | 0.391 | | |
| 2.5M | 1.9 | 1.9 | 0.415 | 0.418 | 0.220 |
| | 1.9 | | 0.420 | | |
| | 1.9 | | 0.418 | | |
| 3M | 1.9 | 1.9 | 0.468 | 0.471 | 0.248 |
| | 1.9 | | 0.472 | | |
| | 1.9 | | 0.473 | | |

### Sulphuric acid (Carbon electrode)

| Concentration (M) | Voltage (Volts) | Average Voltage | Current (Amps) | Average Current (3d.p) | Conductance (S) (3s.f) |
|---|---|---|---|---|---|
| 0.5M | 1.8 | 1.8 | 0.513 | 0.521 | 0.289 |
| | 1.8 | | 0.505 | | |
| | 1.8 | | 0.546 | | |
| 1M | 1.8 | 1.8 | 0.570 | 0.526 | 0.292 |
| | 1.8 | | 0.505 | | |
| | 1.8 | | 0.504 | | |
| 1.5M | 1.8 | 1.8 | 0.550 | 0.555 | 0.308 |
| | 1.8 | | 0.555 | | |
| | 1.8 | | 0.559 | | |
| 2M | 1.8 | 1.8 | 0.564 | 0.587 | 0.326 |
| | 1.8 | | 0.606 | | |
| | 1.8 | | 0.590 | | |
| 2.5M | 1.7 | 1.7 | 0.635 | 0.639 | 0.376 |
| | 1.7 | | 0.638 | | |
| | 1.7 | | 0.644 | | |
| 3M | 1.7 | 1.7 | 0.649 | 0.652 | 0.383 |
| | 1.7 | | 0.651 | | |
| | 1.7 | | 0.655 | | |

**Sodium Chloride (Copper electrode)**

| Concentration (M) | Voltage (Volts) | Average Voltage | Current (Amps) | Average Current (3d.p) | Conductance (S) (3s.f) |
|---|---|---|---|---|---|
| 0.5M | 2.2 | 2.2 | 0.195 | 0.196 | 0.089 |
| | 2.2 | | 0.198 | | |
| | 2.2 | | 0.196 | | |
| 1M | 2.2 | 2.2 | 0.245 | 0.236 | 0.107 |
| | 2.2 | | 0.227 | | |
| | 2.2 | | 0.235 | | |
| 1.5M | 2.1 | 2.1 | 0.285 | 0.287 | 0.137 |
| | 2.1 | | 0.288 | | |
| | 2.1 | | 0.288 | | |
| 2M | 2.1 | 2.1 | 0.305 | 0.322 | 0.153 |
| | 2.1 | | 0.329 | | |
| | 2.1 | | 0.331 | | |
| 2.5M | 2.1 | 2.1 | 0.338 | 0.340 | 0.162 |
| | 2 | | 0.345 | | |
| | 2.1 | | 0.336 | | |
| 3M | 2 | 2 | 0.354 | 0.361 | 0.181 |
| | 2 | | 0.365 | | |
| | 2 | | 0.365 | | |

**Sulphuric acid (Copper electrode)**

| Concentration (M) | Voltage (Volts) | Average Voltage | Current (Amps) | Average Current (3d.p) | Conductance (S) (3s.f) |
|---|---|---|---|---|---|
| 0.5M | 2.1 | 2.1 | 0.258 | 0.255 | 0.121 |
| | 2.1 | | 0.247 | | |
| | 2.1 | | 0.259 | | |
| 1M | 2.1 | 2.1 | 0.361 | 0.365 | 0.174 |
| | 2.1 | | 0.370 | | |
| | 2.0 | | 0.365 | | |
| 1.5M | 1.7 | 1.7 | 0.629 | 0.628 | 0.370 |
| | 1.7 | | 0.622 | | |
| | 1.7 | | 0.634 | | |
| 2M | 1.5 | 1.5 | 1.034 | 1.048 | 0.699 |
| | 1.5 | | 1.050 | | |
| | 1.5 | | 1.059 | | |
| 2.5M | 1.5 | 1.4 | 1.105 | 1.109 | 0.792 |
| | 1.4 | | 1.111 | | |
| | 1.4 | | 1.111 | | |
| 3M | 1.4 | 1.3 | 1.200 | 1.205 | 0.927 |
| | 1.3 | | 1.214 | | |
| | 1.3 | | 1.200 | | |

**Temperature**

**1 M Sodium Chloride (Carbon electrode)**

| Temperature °C | Voltage (Volts) | Average Voltage | Current (Amps) | Average Current (3d.p) | Conductance (S) (3s.f) |
|---|---|---|---|---|---|
| 21.9 | 2.1 | 2.1 | 0.199 | 0.198 | 0.094 |
| | 2.1 | | 0.195 | | |
| | 2.1 | | 0.199 | | |
| 33.3 | 2.1 | 2.1 | 0.208 | 0.208 | 0.099 |
| | 2.1 | | 0.209 | | |
| | 2.1 | | 0.207 | | |
| 43.1 | 2.1 | 2.1 | 0.229 | 0.227 | 0.108 |
| | 2.1 | | 0.226 | | |
| | 2.1 | | 0.227 | | |
| 53.8 | 1.9 | 1.9 | 0.269 | 0.269 | 0.142 |
| | 1.9 | | 0.268 | | |
| | 1.9 | | 0.269 | | |
| 63.6 | 1.9 | 1.9 | 0.431 | 0.433 | 0.228 |
| | 1.9 | | 0.435 | | |
| | 1.9 | | 0.433 | | |
| 73.9 | 1.9 | 1.9 | 0.466 | 0.466 | 0.245 |
| | 1.9 | | 0.466 | | |
| | 1.9 | | 0.466 | | |
| 83.7 | 1.8 | 1.8 | 0.512 | 0.513 | 0.285 |
| | 1.8 | | 0.513 | | |
| | 1.8 | | 0.515 | | |

**1 M Sulphuric acid (Carbon electrode)**

| Temperature °C | Voltage (Volts) | Average Voltage | Current (Amps) | Average Current (3d.p) | Conductance (S) (3s.f) |
|---|---|---|---|---|---|
| 21.9 | 1.7 | 1.7 | 0.697 | 0.697 | 0.410 |
| | 1.7 | | 0.697 | | |
| | 1.7 | | 0.698 | | |
| 33.3 | 1.7 | 1.7 | 0.745 | 0.745 | 0.438 |
| | 1.7 | | 0.747 | | |
| | 1.7 | | 0.744 | | |
| 43.1 | 1.7 | 1.7 | 0.793 | 0.794 | 0.467 |
| | 1.7 | | 0.793 | | |
| | 1.7 | | 0.795 | | |
| 53.8 | 1.7 | 1.7 | 0.841 | 0.842 | 0.495 |
| | 1.7 | | 0.843 | | |
| | 1.7 | | 0.843 | | |
| 63.6 | 1.7 | 1.7 | 0.877 | 0.880 | 0.518 |
| | 1.7 | | 0.879 | | |
| | 1.7 | | 0.883 | | |
| 73.9 | 1.6 | 1.6 | 0.909 | 0.909 | 0.568 |
| | 1.6 | | 0.909 | | |
| | 1.6 | | 0.909 | | |
| 83.4 | 1.6 | 1.6 | 0.932 | 0.934 | 0.584 |
| | 1.6 | | 0.935 | | |
| | 1.6 | | 0.934 | | |

**1 M Sodium Chloride (Copper electrode)**

| Temperature °C | Voltage (Volts) | Average Voltage | Current (Amps) | Average Current (3d.p) | Conductance (S) (3s.f) |
|---|---|---|---|---|---|
| 23.4 | 2.0 | 2.0 | 0.457 | 0.457 | 0.229 |
| | 2.0 | | 0.457 | | |
| | 2.0 | | 0.458 | | |
| 33.3 | 1.9 | 1.9 | 0.552 | 0.552 | 0.291 |
| | 1.9 | | 0.552 | | |
| | 1.9 | | 0.552 | | |
| 43.9 | 1.9 | 1.9 | 0.618 | 0.621 | 0.327 |
| | 1.9 | | 0.622 | | |
| | 1.9 | | 0.623 | | |
| 53.6 | 1.9 | 1.9 | 0.698 | 0.698 | 0.367 |
| | 1.9 | | 0.698 | | |
| | 1.9 | | 0.699 | | |
| 63.6 | 1.8 | 1.8 | 0.765 | 0.767 | 0.426 |
| | 1.8 | | 0.768 | | |
| | 1.8 | | 0.768 | | |
| 73.9 | 1.8 | 1.8 | 0.782 | 0.782 | 0.434 |
| | 1.8 | | 0.783 | | |
| | 1.8 | | 0.782 | | |
| 83.2 | 1.8 | 1.8 | 0.798 | 0.801 | 0.445 |
| | 1.8 | | 0.801 | | |
| | 1.8 | | 0.805 | | |

**1 M Sulphuric Acid (Copper electrode)**

| Temperature °C | Voltage (Volts) | Average Voltage | Current (Amps) | Average Current (3d.p) | Conductance (S) (3s.f) |
|---|---|---|---|---|---|
| 24.2 | 1.6 | 1.6 | 0.862 | 0.864 | 0.540 |
| | 1.6 | | 0.865 | | |
| | 1.6 | | 0.866 | | |
| 33.3 | 1.5 | 1.5 | 1.112 | 1.113 | 0.742 |
| | 1.5 | | 1.112 | | |
| | 1.5 | | 1.115 | | |
| 43.5 | 1.4 | 1.4 | 1.169 | 1.169 | 0.835 |
| | 1.4 | | 1.170 | | |
| | 1.4 | | 1.168 | | |
| 53.8 | 1.4 | 1.4 | 1.297 | 1.297 | 0.926 |
| | 1.4 | | 1.299 | | |
| | 1.4 | | 1.295 | | |
| 63.6 | 1.3 | 1.3 | 1.335 | 1.335 | 1.027 |
| | 1.3 | | 1.335 | | |
| | 1.3 | | 1.336 | | |
| 73.9 | 1.3 | 1.3 | 1.387 | 1.386 | 1.066 |
| | 1.3 | | 1.388 | | |
| | 1.3 | | 1.384 | | |
| 83.2 | 1.3 | 1.3 | 1.414 | 1.416 | 1.089 |
| | 1.3 | | 1.419 | | |
| | 1.3 | | 1.414 | | |

The results above were averaged out and in some cases they are rounded up to certain degree of accuracy.

I used the following formula to calculate the results:

If: $G=1/R$ and $R=V/I$

Therefore: $G = \dfrac{1}{(V/I)}$ $\Rightarrow$ **$G = I / V$**

**Working out Error bars and Error box**

When we take the reading of any apparatus such as voltmeter, ammeter or thermometer there is always going to be an error. This error will have an effect on the graph we plot so we also need to plot the error points on the graph in order to find the actual line. If we were plotting error points for any other experiments, we will only have to plot $\pm$ a certain value. But in this certain case we have to work out the $G_{max}$ and $G_{min}$ to plot in the graph because conductance is worked out from two points. Also due to the restrictions in Microsoft excel we have to work the average of these max and min results and subtract them away from the actual reading to find the Error$_{max}$ and Error $_{min.}$

Absolute errors:
Voltage (v)- 0.05 volts      current (i)-0.0005amps      temperature- (t) 0.05

$$G = I / V$$

$$G_{max} = \frac{I_{max}}{V_{min}} \qquad = \frac{I + \Delta I}{V - \Delta v} \qquad \mathbf{E_{max}} = \frac{I + \Delta I}{V - \Delta v} \quad - I / V$$

When I = 0.311      V= 1.9      G=0.164

E.g. -: $G_{max} = \dfrac{0.3115}{1.85} = 0.168$ (3.d.p)

finally      E $_{max}$ = 0.168 –0.164= 0.004

Also      $G_{min} = \dfrac{I_{min}}{V_{max}} \qquad = \dfrac{I - \Delta i}{V + \Delta v}$

$G_{min} = \dfrac{0.3105}{1.95} = 0.159$ (3.d.p)

finally      E $_{min}$ = 0.159 – 0.164 = - 0.005

**Sodium Chloride (Carbon electrode)**

| Concentration (M) | $G_{min}$ (3d.p) | $G_{max}$(3d.p) |
|---|---|---|
| 0.5M | -0.003 | 0.002 |
| 1M | -0.029 | 0.003 |
| 1.5M | -0.005 | 0.004 |
| 2M | -0.006 | 0.006 |
| 2.5M | -0.006 | 0.006 |
| 3M | -0.007 | 0.007 |
| | $E_{min}$ = **-0.009** | $E_{max}$ = **0.005** |

**Sulphuric acid (Carbon electrode)**

| Concentration (M) | $G_{min}$(3d.p) | $G_{max}$(3d.p) |
|---|---|---|
| 0.5M | -0.008 | 0.009 |
| 1M | -0.008 | 0.009 |
| 1.5M | -0.008 | 0.009 |
| 2M | -0.009 | 0.010 |
| 2.5M | -0.009 | 0.012 |
| 3M | -0.011 | 0.012 |
| | $E_{min}$ = **-0.009** | $E_{max}$ = **0.010** |

**Sodium Chloride (Copper electrode)**

| Concentration (M) | $G_{min}$(3d.p) | $G_{max}$(3d.p) |
|---|---|---|
| 0.5M | -0.002 | 0.002 |
| 1M | -0.002 | 0.003 |
| 1.5M | -0.004 | 0.003 |
| 2M | -0.004 | 0.004 |
| 2.5M | -0.004 | 0.004 |
| 3M | -0.005 | 0.004 |
| | $E_{min}$ = **-0.004** | $E_{max}$ = **0.003** |

**Sulphuric acid (Copper electrode)**

| Concentration (M) | $G_{min}$(3d.p) | $G_{max}$(3d.p) |
|---|---|---|
| 0.5M | -0.003 | 0.003 |
| 1M | -0.005 | 0.004 |
| 1.5M | -0.011 | 0.011 |
| 2M | -0.023 | 0.024 |
| 2.5M | -0.028 | 0.030 |
| 3M | -0.035 | 0.037 |
| | $E_{min}$ = **-0.018** | $E_{max}$ = **0.018** |

**Temperature**

For the temperature the error is going to be constant $\pm0.05$. However for we have to work out the $E_{min}$ and $E_{max}$. .

**1 M Sodium Chloride (Carbon electrode)**

| Temperature °C | $G_{min}(3d.p)$ | $G_{max}(3d.p)$ |
|---|---|---|
| 21.9 | -0.002 | 0.003 |
| 33.3 | -0.003 | 0.003 |
| 43.1 | -0.003 | 0.003 |
| 53.8 | -0.004 | 0.004 |
| 63.6 | -0.006 | 0.006 |
| 73.9 | -0.006 | 0.007 |
| 83.7 | -0.007 | 0.008 |
| | $E_{min} = \mathbf{-0.004}$ | $E_{max} = 0.005$ |

**1 M Sulphuric acid (Carbon electrode)**

| Temperature °C | $G_{min}(3d.p)$ | $G_{max}(3d.p)$ |
|---|---|---|
| 21.9 | -0.012 | 0.013 |
| 33.3 | -0.013 | 0.014 |
| 43.1 | -0.014 | 0.015 |
| 53.8 | -0.014 | 0.016 |
| 63.6 | -0.015 | 0.016 |
| 73.9 | -0.017 | 0.019 |
| 83.4 | -0.018 | 0.019 |
| | $E_{min} = \mathbf{-0.015}$ | $E_{max} = 0.016$ |

**1 M Sodium Chloride (Copper electrode)**

| Temperature °C | $G_{min}(3d.p)$ | $G_{max}(3d.p)$ |
|---|---|---|
| 23.4 | -0.006 | 0.006 |
| 33.3 | -0.008 | 0.008 |
| 43.9 | -0.009 | 0.009 |
| 53.6 | -0.009 | 0.011 |
| 63.6 | -0.012 | 0.013 |
| 73.9 | -0.012 | 0.013 |
| 83.2 | -0.012 | 0.013 |
| | $E_{min} = \mathbf{-\ 0.010}$ | $E_{max} = \mathbf{0.010}$ |

**1 M Sulphuric Acid (Copper electrode)**

| Temperature °C | $G_{min}(3d.p)$ | $G_{max}(3d.p)$ |
|---|---|---|
| 24.2 | -0.017 | 0.018 |
| 33.3 | -0.024 | 0.026 |
| 43.5 | -0.029 | 0.031 |
| 53.8 | -0.032 | 0.035 |
| 63.6 | -0.038 | 0.041 |
| 73.9 | -0.040 | 0.043 |
| 83.2 | -0.044 | 0.044 |
| | $E_{min} = \mathbf{-0.032}$ | $E_{max} = \mathbf{0.034}$ |

## Analysis

What effect does different concentrations of the solution (0.5M, 1M, 1.5M, 2M, 2.5M & 3M) have on the conductance of a solution?

Graphs 1 – 4 illustrate the relationship between of conductance against different concentration. All four graphs are upwards sloping curves, which all show that as the concentration increases; the value of conductance increases in magnitude illustrating a direct relationship.

Graphs 5-8 illustrate the relationship between of conductance against different temperatures. Again all four graphs are upwards sloping curves, which all show that as the concentration increases; the value of conductance increases in magnitude illustrating a direct relationship.

**Graph One (Sodium Chloride (Carbon electrode))**

From this graph I can see that as the concentration of the sodium chloride increases by every 0.5M the conductance also increases by a by a value. In between 0-1 M the line of best fit is almost a straight line. From 1-3M the line steadily slopes up wards.

**Graph Two (Sodium Chloride (Copper electrode))**

The graph shows a steady increase. The slope is constantly increasing all the way and most of the points fell into the line of bet fit.

**Graph Three (Sulphuric acid (Carbon electrode))**

This graph is very similar to the first one. At the start the gradient is almost constant and it's almost a straight line. The from about 1M the slopes upwards and increases the gradient.

**Graph Four (Sulphuric acid (Copper electrode))**

Unlike the other graph this graph has a different line. Unlike the other slopes this one increases straight from the start. It has steeper gradient, which shows that it has a faster rate.

**Temperatures**

**Graph Five (1 M Sodium Chloride (Carbon electrode))**

This graph again has a similar slope. As the temperature increases the conductance is also increasing. In the graph until about 40°c we get a straight line with a very straight gradient. After that the line increases monotonically with an upward slope. I think the reason we get a curve like this is because the conductance   readings are very close together.

**Graph Six, Seven and eight**
The shape of curves these graphs are similar. As the concentration increases the conductance also increases. They are all increasing at a steady rate. They also have an upward slope.

**Conclusion:**

**What effect does different concentrations of the solution (0.5M, 1M, 1.5M, 2M, 2.5M & 3M) have on the conductance of a solution?**

Φορ μψ ηψποτηεσισ Ι πρεδιχτεδ τηατ ασ τηε χονχεντρατιον οφ τηε σολυτιον ισ ινχρεασεδ φρ ομ 0.5Μ το 3.0Μ, τηε ρατε οφ χονδυχτανχε ωουλδ αλσο ινχρεασε. Ιτ ισ χλεαρ φρομ ταβλεσ 1 το 4 ασ ωελλ ασ γραπησ 1–4 τηατ ασ τηε χονχεντρατιον οφ σολυτιονσ ινχρεασεδ, τηε ρατε ο φ χονδυχτανχε αλσο ινχρεασεδ. Τηισ προωεδ μψ ηψποτηεσισ χορρεχτ σινχε:

- Φρομ τηε δατα αναλψσισ ωε χαν σεε τηατ ασ τηε ρατε ινχρεασινγ.
- Φρομ τηε γραπη ωε γετ αν υπωαρδ σλοπινγ ατ α στεαδψ ρατε.
- Φρομ τηε ρεσυλτ ταβλε ωε χαν σεε τηε χονδυχτανχε ισ ινχρεασινγ ασ ωε γο δοων φρ ομ 0.5–3Μ.

Αλλ τηισ ηαππενεδ βεχαυσε ασ τηε χονχεντρατιον ινχρεασεσ τηερε ισ αν ινχρεασε ιν τηε νυ μβερ ιονσ πρεσεντ ιν τηε σολυτιον περ υνιτ ϖολυμε. Τηερεφορε βψ ινχρεασινγ τηε αμουντ οφ ιονσ μορε χηαργε χαν βε χαρριεδ, ωηιχη μεανσ τηε ρατε χονδυχτανχε αλσο ρισεσ.

Ωηατ εφφεχτ δοεσ διφφερεντ τεμπερατυρεσ οφ τηε σολυτιον (ρανγινγ βετωεεν 20°Χ το 90°Χ) η αϖε ον τηε χονδυχτανχε οφ α σολυτιον?

Ιν μψ ηψποτηεσισ Ι πρεδιχτεδ τηατ ασ τηε τεμπερατυρε ισ ινχρεασεδ τηε χονδυχτανχε ωουλδ αλσο ινχρεασε. Τηερε ωερε α νυμβερ οφ νοταβλε διφφερενχεσ ασ τηε τεμπερατυρε ινχρεασεδ . Α νοτε οφ τηεσε ωερε μαδε:

- ασ τηε τεμπερατυρε ωασ ινχρεασεδ τηερε ωασ χονσιδεραβλε ρισε ιν τηε ρατε οφ χον δυχτανχε ιν σομε σολυτιονσ
- ασ τηε τεμπερατυρε ωασ ινχρεασεδ τηερε ωασ χονσιδεραβλε ρισε ιν τηε ρατε οφ χον δυχτανχε ιν σομε σολυτιονσ ωιτη α χερταιν ελεχτροδεσ

Ιτ ισ χλεαρ φρομ ταβλεσ 5 το 8 ασ ωελλ ασ γραπη 5 το 8 τηατ ασ τηε τεμπερατυρε ινχρεασεδ τηε χονδυχτανχε αλσο ινχρεασεδ. Τηυσ, προϖινγ τηατ μψ ηψποτηεσισ ωασ χορρεχτ σινχε:

- Φρομ ατ τηε ρεσυλτ ταβλε οφ 1 Μ Σοδιυμ Χηλοριδε (Χαρβον ελεχτροδε) Ι χαν σεε ωη εν τηε τεμπερατυρε ωασ ατ $21.9^0Χ$ τηε χονδυχτανχε ωασ 0.094Σ βυτ ωηεν τηε τεμπερ ατυρε ωασ ατ $83.7^0Χ$ τηε χονδυχτανχε ωασ 0.285Σ, σο τηερε ισ α ρισε οφ 0.191 Σ ιν α βουτ $60^0Χ$ ρανγε. Αλσο ιφ ωε λοοκ ατ 1 Μ Συλπηυριχ αχιδ (Χοππερ ελεχτροδε) ταβλε ιτ ισ χλεαρ τηατ τηερε ισ α ρισε οφ 0.549Σ ιν ουρ $60^0Χ$ ρανγε.
- Τηε γραπησ αλσο σηοω α χλεαρ εϖιδενχε οφ ινχρεασε ιν τεμπερατυρε βεχαυσε τηεψ αλλ σηοω τηε λινε ινχρεασινγ εξπονεντιαλλψ.

Αλλ τηισ ηαππενσ βεχαυσε ωηεν τηε τεμπερατυρε ισ ινχρεασεδ τηε σολυτιονσ ϖισχοσιτψ δε χρεασεσ. Ονε φαχτορ τηατ χοντριβυτεσ λαργελψ το ηισ φαλλ ιν ϖισχοσιτψ ωιτη τεμπερατυρ ε ισ τηε δεχρεασε ιν δενσιτψ οφ τηε σολυτιον ασ τηε τεμπερατυρε ρισεσ. Τηισ ρεδυχτιον ιν δε νσιτψ ισ δυε το τηε παρτιχλεσ ιν τηε λιθυιδ γαινινγ κινετιχ ενεργψ ανδ φορχινγ εαχη οτηερ φ υρτηερ απαρτ, σο τηισ χαυσεσ τηεμ το σπρεαδ ουτ ωηιχη δεχρεασεσ τηε ϖισχοσιτψ.

Ασ τηε ϖισχοσιτψ δεχρεασεσ τηε ιον μοβιλιτψ ινχρεασεσ. Τηισ ισ βεχαυσε τηε ιονσ μοϖε μο ρε φρεελψ τηρουγη ουτ τηε λιθυιδ χαυσινγ τηεμ το φλοω ωιτη α γρεατερ ϖελοχιτψ.

Φιναλλψ αν ινχρεασε ιν ιον μοβιλιτψ ρελατεσ το αν ινχρεασε ιν χονδυχτανχε βεχαυσε ιφ ιο νσ μοϖε ωιτη α γρεατερ ϖελοχιτψ τηε ρατε χυρρεντ ωιλλ αλσο ινχρεασε.
Ωηατ εφφεχτ δοεσ διφφερεντ σολυτιονσ (Σοδιυμ Χηλοριδε& Συλπηυριχ Αχιδ) ηαϖε ον τηε χο νδυχτανχε ρατε οφ α σολυτιον?

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Τηερε ισ χλεαρ εϖιδενχε φρομ τηε ρεσυλτσ τηατ συλπηυριχ αχιδ ηασ α βιγγερ χονδυχτανχε τηαν σοδιυμ χηλοριδε. Τηισ προϖεσ μψ Ηψποτηεσισ, ωηιχη στατεδ τηε σαμε αργυμεντ.

Τηισ ηαππενσ δυε το τηε ρατιο2: 1 οφ χονδυχτινγ ιονσ. Σο μορε χονδυχτινγ τηερε ισ βεττερ τ ηε χονδυχτανχε ρατε ωιλλ βε.

Ωηατ εφφεχτ δοεσ διφφερεντ ελεχτροδεσ (Χαρβον & Χοππερ) ηαϖε ον τηε χονδυχτανχε ρατε οφ α σολυτιον?

Υνλικε οτηερσ τηισ προβλεμ διδν□τ ηαϖε α διρεχτ σολυτιον. Υνλικε Ι ηψποτηεσισεδ χαρβον ελεχτροδε διδν□τ ηαϖε τηε βεττερ χονδυχτανχε ρατε. Ιν φαχτ χαρβον ηαδ βεττερ χονδυχτανχ ε ιν σομε σολυτιονσ ανδ χοππερ ηαδ βεττερ χονδυχτανχε ιν οτηερσ. Φρομ τηισ ιτ ισ χλεαρ τ ηειρ χονδυχτανχε ρατε ϖαριεδ φρομ σολυτιον το σολυτιον.

Εϖαλυατιον

Ι τηινκ τηισ ωασ α συχχεσσφυλ εξπεριμεντ. Ι συχχεσσφυλλψ μαναγεδ το ηψποτηεσισ. Βοτη σ ετσ οφ εξπεριμεντσ ωερε χαρριεδ ουτ ιν ϖερψ σιμιλαρ φασηιον, ανδ μανψ μεασυρεσ ωερε τα κεν το χαρρψ τηεμ φαιρλψ.

Ηοωεϖερ σεϖεραλ στεπσ χουλδ βε τακεν φορ ανψ φυτυρε ινϖεστιγατιονσ το ιμπροϖε τηε ρε λιαβιλιτψ οφ ανψ ρεσυλτσ ανδ ψιελδ μορε ϖαλιδ ανδ μορε αππλιχαβλε δατα:

- διφφερεντ φαχτορσ χαν βε τεστεδ ε.γ. ιμπυριτιεσ
- διφφερεντ σολυτιονσ χαν βε τεστεδ ε.γ. συγαρ σολυτιον, ωατερ.
- διφφερεντ τεμπερατυρεσ χαν βε τεστεδ συχη ασ χολδ τεμπερατυρεσ

Τιμε Πλαν

We started this coursework towards the start of July. I spent the first week doing research and gathering information that could help me with my coursework. I used the next few I lessons to write up my plan and decide what apparatus will needed. After that I spent the next week carrying out a trial experiment for all the variables concerned. It took me between 6-7 lessons. I spent the following two lessons to input my modifications and to alter my plan.

Once everything was finalised I spent the about 6-10 lessons carrying out the actual experiment. Finally I spent the rest of the time writing up the results.

Βιβλιογραπηψ

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Ωεβσιτεσ

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