

**OPTIMIZATION
OF HYDROGEN PRODUCTION
WITH ASSISTED ENERGY SOURCES**

By
Mike Chrzanowski
Damen Haughey
Chris Meyers
Alex T. Poterack – Team Leader

Fountain Hills High School
16100 Palisades Blvd
Fountain Hills, AZ 85268

Sponsored by
Dr. Paul McElligott
Science Chair
Fountain Hills High School

April 2006

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Introduction

Goal

The ultimate goal of this project is to develop a green energy system harnessing energy from the sun by photo-panels and using it to electrolyze water. An optimized process of electrolysis to produce hydrogen gas would be installed and powered by the sun. The hydrogen would be compressed by a special pump and stored in a low carbon steel tank. The hydrogen would be used at will by the service group of the Fountain Hills Unified School District by directing the hydrogen into a fuel cell that would require hydrogen and air to produce electricity and water as products.

Phases of the Project

This project is the first phase of a four-phase project to occur over three years. This project has been evolving as more grant money and donations have been collected toward the project. The original scope was to evaluate fuel cells and hydrogen optimization in order to use less expensive energy to run district equipment. The energy would be captured and stored in the form of hydrogen gas. The gas would then be sent at will through developed fuel cells in order to produce electrical power and water.

The current project became reality with a generous educational donation from ASU-PTL of four solar panels. We have now reconfigured the program to be a four phase process. The overall scope has not changed but with the advent of the solar panels, effort was diverted from fuel cell development to mainly hydrogen production optimization using a totally environmentally friendly energy source, solar energy. Part of this year's resources have been devoted to experimenting with the solar panels in order to understand how much power can be relied on during different weather conditions. The fuel cell research will continue in year two with new students and solar power studies will be carried out this summer 2006.

Fall 2005 -- Spring 2006

The first phase involves the investigation of basic optimization of hydrogen gas by various techniques and materials. In addition to the optimization, a literature search was done on fuel cells during this phase. The DOE (Department of Energy) has a very specific web site that addresses most of our concerns and interest in cell efficiencies.

Spring 2006 -- Fall 2006

The second phase involves a long-term study using two and four solar panels. The purpose of the study is to calculate the average energy the fuel cells will generate per hour during the day. The cells will also be examined during the months of the four seasons. Energy generated by the panels will be translated into volumes of hydrogen produced and waste materials produced. A Cost Benefit Analysis will result from the study.

Fall 2006 -- Spring 2007

Phase three involves the study of a small number of fuel cells and the analysis of the long term generation of power possible with the quality of the hydrogen from the phase one electrolysis process. Power comes from the mix of air and hydrogen into several catalytic stacks of cells that create energy and water as products.

Spring 2007 -- Spring 2008

Phase four involves the matching of tools and their power needs with the output potential of the fuel cells as well as an efficiency study. Tools and their requirements will be matched up with the power capability of the fuel cells so a profile of equipment that the service group uses can be matched up with the green energy production. Finally, a number of studies will be carried out. The efficiency of the system will be monitored. The possible energy storage capacity for the system will be predicted. The financial savings of the system over using conventional power will be calculated.

Literature Discussion

As demand for environmental protection becomes more of a priority, researchers, companies and government incentives build to look at alternate fuels, and resources as methods of both reducing our dependency on fossil fuels and improve our environment at the same time. Recently the president of the United States has expounded on the needs to look at alternative fuels and directly mentioned hydrogen as one of those fuels whose time has come.

Hydrogen production has long been explored by electrolysis. It is well documented and understood. The methods of optimization of hydrogen have been examined in the literature. A number of catalytic and chemical methods exist to stimulate the production of hydrogen but the most recent areas of interest are those that use other energies to stimulate hydrogen production during electrolysis. The areas uncovered that appear to help reactions and physical processes proceed include laser, ultrasonic, and microwave stimulation.

Direct electrolysis of a number of processes is becoming more recognized as a viable method of production that is environmentally safe (1). It was more recently seen that co-stimulation of electrolysis with microwaves can accelerate chemical reactions. This has been demonstrated in both organic and inorganic synthesis (2,3), mineral digestion (5), and even extraction (6). In one case, the hydrothermal production of ceramic powders was achieved with kinetic acceleration of one to two orders of magnitude (7). Microwave assisted chloride leaching (8) of copper minerals at reflux temperatures has shown three times the production enhancement.

Stimulation of chemical reactions has been the focus of many papers involving both UV and IR radiation of metal and oxide surfaces. In particular UV radiation has been

observed in the stimulation of water electrolysis on a platinum electrode using titanium oxide as a single crystal electrode (9). Here the paper focused on the enhancement of gas production with mixed metal and metal oxide surfaces being needed. The process was not efficient above a low voltage.

Infrared was also found to stimulate some gas production on a metal surface during electrolysis (10). The study used IR lasers to help stimulate the metal surface and studied the problems of gas evolution at the metal surface as well as voltage problems.

Several articles on hydrogen production were also found using UV and IR stimulation of platinum and palladium in the presence of titanium oxide catalysts (11-13). Kraeutler and Bard, as far back as 1978 (14), observed hydrogen and carbon dioxide production from acetic acid. These reactions were carried out in small photochemical cells as a means to look for an efficient manufacture of methane. This was done during the synthetic-fuels funding of the government during the 1970-80's.

The third form of stimulation used to produce hydrogen gas was ultrasonic waves. These studies mainly focused on the unusual effects that ultrasonic waves played in the reduction of the common over voltage that would occur at the electrodes (15). It was reported that ultrasonic waves could produce ac/dc changes in the electrodes during hydrogen production. It was also reported that the atomic formation of hydrogen is responsible for the over voltage at the electrodes and that this could be reduced by the effects of ultrasonic waves (15). The effect was found to depend on the formation of gas bubbles at the electrode.

This type of co-radiation was found to be helpful in several other papers. The hydrogenation of coal was found to be helped by a combination of ultrasonic waves and electrolysis (16). The generation of hydrogen peroxide was found to be very favorable in the electrolysis of water with ultrasonic waves as long as caustic soda was administered (17).

It is with these literature concepts that a program was assembled to examine the optimization of hydrogen by electrolysis using various types of energies that might help stimulate the production of mainly hydrogen gas. The literature was not very clear at how the various types of energies could compare. Even though the use of lasers, ultrasonic waves, microwaves, and electrolysis are all used in industrial processes, the use of them in combination was very difficult to find. There are some publications in the mining industry using ultrasonic waves in leaching and in hydrogenation. Until recently lasers were not used in hydrogen production. One company has a reported process using lasers to produce high efficiency hydrogen production but no patent is pending yet (18).

Materials and Methods

Materials

Hydrogen production was carried out in a 500 ml beaker as a holding base with a single glass calibrated closed end gas tube inverted into the electrochemical solution. The positive electrode was placed in the beaker. It consisted of a coated 18 gauge copper wire stripped clean to expose 5 centimeters. The negative electrode consisted of another 18 gauge copper electrode also stripped bare to 5 centimeters. This electrode was placed inside the bottom the gas tube for hydrogen generation.

Power was applied most of the time from an Extech #3822313 DC power supply capable of delivering 35 volts potential and 5 amps of current. The power supply was on occasion substituted with four roof-mounted 1000 watt-meter squared panels from the Solarex Corporation and donated by Arizona State University –Photovoltaic Labs under an educational grant. The panels are rated up to 120 watts, 50 volts and 5 amps each. The panels were connected in parallel.

Class IIIa lasers red, green and blue were used in stimulation studies. The lasers purchased were 5 mW (laser pointers) up to 500 mW lasers. The lasers were used behind aluminum foil screening.

Ultrasonics were carried out with a 35 watt Rio Grande CD –2800 ultrasonic cleaning bath. It is one typical of jewelry cleaning.

Microwaves were focused from a 0.5GH horn rated between 5-10 watts of power. The horn was set up and used at Grand Canyon University. The apparatus was placed behind a special microwave absorbing shield for protection.

Isothermal heating was carried out in a five-gallon isothermal temperature bath by Precision Scientific.

Methods

A standard reaction condition and monitoring system was the first order of priority. We measured the voltage and current from the applied readings on the power source. The gas was measured in real time by the calibrations on the glass tube and later adjusted to STP conditions. The timing was done by hand held stopwatches.

The standard reaction of choice was selected after extensive testing. The safety of researchers was considered in this choice. It was decided that the method to measure the

relative optimizations using external energy sources, was by a salt solution consisting of sodium chloride. The rationalization for this choice was as follows:

- a. We needed a simple low cost but safe method that the students could see and measure reliably;
- b. The chlorine electro-potentials of chlorine gas production versus a harmless salt production demonstrated that the chance of forming chlorine gas was minimal;
- c. Chlorine was tested in the water by two methods sensitive to 5 ppm. These are pool chemical kits that are available in pool houses. As a back-up, the quantitative measure of copper oxidation was compared to the amount of bright orange-yellow copper (I) chloride that is made. The results demonstrated that the reaction was quantitative;
- d. The appearance of the non-toxic salt is bright, obvious and a wonderful indicator of cathode production versus the colorless hydrogen;
- e. The standard use of caustic or acid solutions generates hydrogen as well as oxygen gas. There is real potential for explosive gas mixtures if a mistake or accident should occur.

All materials were properly disposed of in chemical waste bottles.

Key Reactions

1. Control Electrolysis Reactions

The power supply was hooked up through two 18 gauge copper leads stripped at the ends to 5 cm. The anode is inserted inside an open end glass tube filled with room temperature (25C) DI water saturated with sodium chloride. This is a tube closed ended at one side and calibrated to establish the gas produced. The cathode is inserted in a 400 ml beaker half filled with saturated room temperature water. The tube is inverted into the beaker to keep all or most of the solution in the tube. The tube is then supported by a clamp and ring stand. An electronic thermometer is used to measure any variations in temperature during the reaction. Typically this reaction would experience only a 2-5 C increase during the electrolysis.

2. Laser Induction With Electrolysis

The standard reaction was set up and reproduced a few times. On the third run four lasers were used. Two class III red lasers emitting light at 720nm were aimed at the bare copper anode wire. The first run was with a 5 mW laser and the second trial was with a borrowed 500 mW. Both lasers were held at an angle and the beam was emitted through the glass calibration tube.

The green lasers, both class III 0.5 mW and 500 mW, were set up the same way. The electrolysis condition picked was the room temperature saturated solution.

3. Ultrasonic Bath Trials

A series of reactions were carried out in a 100 ml beaker using the same gas tube. The base electrolytic solution was used at the start. The beaker was placed inside the ultrasonic cleaning bath (prior to filling with the salt solution). The anode was placed such that it would be totally within the ultrasonic zone.

The ultrasonic bath was turned on for 5 seconds prior to the electrolysis run. The solutions were quickly warmed and volumes of hydrogen gas had to be readjusted back to STP.

The ultrasonic runs were done under a number of conditions:

- a. Various temperature runs were carried out. Preheating the salt solutions and the ultrasonic bath water was done and the apparatus was reassembled. Temperatures were conducted between 4C and 90C;
- b. Various metal electrodes were tested under standard temperature conditions;
- c. Different sized copper electrodes were also tested. We did this to see what effect the size of the electrode would have on the rate. In order to activate the proper reaction, the electrode was wrapped in a spiral. In this way the electrode would fit in the glass calibrated tube and the electrode would be inside the ultrasonic zone.

4. Variable Effects on Hydrogen Production

a. Temperature

The rate of hydrogen production was examined by using saturated room temperature solutions of sodium chloride in DI water. These solutions were prepared by adding slight excesses of sodium chloride into the water and boiling for 30 minutes. The solutions were cooled for 1-2 hours at room temperature and the density was checked each time.

The filtered solutions were then tested in a large 10-gallon isothermal bath. The bath was large enough to keep the water in the beaker and the lower gas tube at a constant temperature just before the start of the runs. The temperature was maintained in the bath during production and the internal temperature of the gas tube near the electrode was monitored by an electric thermocouple attached to a thermometer.

b. Salt Concentration

Salt concentrations were changed in the electrolytic solutions by adjusting the weight percent of salt in each solution. Higher temperature solutions were created in the isothermal baths at the appropriate temperatures of the run. We found that 50C was a reasonable temperature to run these studies because of the limitations of the bath and useful high production data that came from the runs.

c. Water Gas Bubbles

This was a difficult experiment to conduct. The premise from the literature is that water gas production may possibly be one key to increasing hydrogen production. Several runs were done from 50C to 104C using 25C saturated salt solutions and 50C saturated salt solutions. The bubble formation was watched closely at each temperature and when the degree of water gas bubble formation appeared to be a constant, the electrolysis was run.

d. Microwave

These runs were done courtesy of Mr. Hal Easton, a professor at Grand Canyon University. The university had a 0.5 GHz microwave horn rated at 5-10 watts of power. The horn was aimed at the electrodes and placed on 1-second pulses. The reactions were run with saturated room temperature salt solutions. The horn was approximately 10 centimeters from the electrode placed in the gas tube. The angle of the horn was to be down at a 45-degree angle facing into the salt bath and centered on the anode.

Results

Control Electrolysis Reactions

1. The control run for these studies is a room temperature 25C sodium chloride saturated solution. The literature value (CRC) is 26 weight percent of sodium chloride. At this saturation we see an average rate of 14 milliliters of hydrogen gas evolving per minute. The average power was derived from a stable 1.7 amps of current and 31.4 volts of potential. This is equivalent to 53.38 watts of power. The total accumulated energy consumed was 5,972 joules per 100 mls of hydrogen or 24,754 kj/mole at STP.
2. A second base run was done at 50C under saturated salt conditions for 50C. We ran the reaction in an iso-temp bath and also on a hot plate and have received similar results since the heat source is near the electrodes. At these conditions we monitored the density of the salt to verify the weight percent of sodium chloride.

We observed 30.2 mls per minute hydrogen production. The average current of 3.4 amps and potential of 29.8 volts gave us a power rating of 101.32 watts. The total power consumed during 100 mls of production was 15,210 joules or 3,382 kj/mole at STP.

Laser Induction with Electrolysis

Red lasers, both 5 mW and 500 mW, were used on a 25 C saturated sodium chloride solution. In both cases the lasers were aimed at the anode down through the glass gas tube. The lasers were also aimed at the cathode through the water in the beaker.

The red lasers gave on average 14.5 mls/minute hydrogen production using 31.5 volts at 1.65 amps. This gave the power of the electrolysis through the solution at 51.97 watts. The average energy consumed at the electrodes was 5,910 joules per 100 mls of hydrogen produced.

The green lasers, both 5 mW and 500 mW, were used on a 25 C saturated sodium chloride solution. In both cases the lasers were aimed at the anode down through the glass gas tube. The lasers were also aimed at the cathode through the water in the beaker.

The green lasers gave on average 13.25 mls/minute hydrogen production using 31.5 volts at 1.55 amps. This gave the power of the electrolysis through the solution at 48.82 watts. The average energy consumed at the electrodes was 5,845 joules per 100 mls of hydrogen produced.

Ultrasonic Bath Trials

1. Room temperature run compared to the control electrolysis.

Run at Room temperature sodium chloride saturation (26% by wt.) with the electrodes both within the sonic range of the ultrasonic bath. The achieved rate of hydrogen production was on average 28.8 mls /min. This was achieved with the voltage of 25 volts and 1.2 amps. This is a power usage of 30 watts. The power to produce hydrogen gas was 1,778 joules on average per 100 ml of gas or nearly a 1/3 reduction in power required.

2. A series of runs done off center of the ultrasonic bath waves.

These runs were done with the electrodes 2.5 centimeters above the water level. The observed run produced an average of 14 mls / minute of hydrogen. It required 30 volts of potential and 3.2 amps of current. The power requirements were 96 watts on average and absorbed 24,221 joules of energy for 100 mls of hydrogen gas.

3. Mid temperature range

Room temperature saturated (26% by wt) sodium chloride solutions were warmed on hot plates to the temperature of 50 C and 60C.

- a. The 50 C run with ultrasonic run produced a hydrogen production rate of 36.1 mls per minute. This was done with a current of 3.5 and 21 volts of potential. This required 73.5 watts of energy and an accumulated 18,192 joules of energy absorbed for 100 mls of gas.
- b. The 60 C run produced a volume of hydrogen gas rate of 42.2 mls of gas per minute. This required 3.5 amps and 23 volts of potential. The average power required was 80.5 watts. The accumulated energy used was 23,104 joules per 100 mls of gas.

4. Various metal anodes were tested under standard 50C temperature conditions.

Roughly 0.5 cm square centimeter electrodes were compared under saturated salt conditions at 60C temperature. The results were as follows:

Metal	Volume per minute of hydrogen
Carbon	22 ml
Aluminum	22.8 ml
Zinc	29 ml
Copper	30 ml
Silver	33 ml

Clearly silver, which will eventually corrode, is the best. Zinc and copper are about equal in their production rates while carbon and aluminum were lowest in production.

5. Different sized copper electrodes

Tests were carried out using identical saturated salt solutions at room temperature. Copper strips were tested in a range from 3 centimeter square strips to 15 centimeter square strips. The longer strips were wrapped into a spiral arrangement in order to fit in the glass gas tube and still be in the ultrasonic bath range.

3 and 5 centimeter square copper produced 15 mls/minute hydrogen rates.
 7 and 10 centimeter square copper electrodes produced 18 and 20 mls/minute.
 12 and 15 centimeter square produced around 22 -24 mls/minute.

Variable Effects on Hydrogen Production

1. Temperature

Several runs were conducted using solutions of 1% salt to 28 % salt starting from 50 C to 104 C. In each case, the production of hydrogen was linear (98 percent correlation). The data shows that the highest hydrogen production is at 104C each time. At 28% salt the time to produce 100 mls of gas is 2.5 minutes.

Table A

Salt Concentration (%)	Temperature (°C)	Time to Produce 5mls of Hydrogen Gas (sec)	Slope. (°C/sec)
1	50	84	0.3
	60	78	0.3
	70	72	0.3
	80	66	0.3
	90	62	0.3
	100	50	0.3
5	50	72	0.78
	60	60	0.78
	70	56	0.78
	80	40	0.78
	90	27	0.78
	100	20	0.78

Table A (Cont.)

Salt Concentration (%)	Temperature (°C)	Time to Produce 5mls of Hydrogen Gas (sec)	Slope. (°C/sec)
10	50	50	1.15
	60	48	1.15
	70	43	1.15
	80	29	1.15
	90	21	1.15
	100	15	1.15
20	50	28	3.12
	60	23	3.12
	70	18	3.12
	80	16	3.12
	90	14	3.12
	100	12.3	3.12
30	50	17	4.09
	60	15	4.09
	70	13	4.09
	80	10.5	4.09
	90	7	4.09
	100	5	4.09

2. Salt Concentration

When one does a plot of concentration versus hydrogen production at any temperature a curve occurs. This curve reflects the dominance of salt concentration by the square of the concentration. This influence is magnified over the simple thermal linear plots because of the complexity of how the ions transport ions and the resistance built up from gaseous water pockets and hydrogen pockets at the electrodes.

The data was taken from *Table A*.

3. Water Gas Bubbles

A plot of gaseous steam bubbles on the electrodes versus hydrogen production was found to have no correlation from 50 C to boiling at 104C.

4. Microwave

Three runs were conducted at room temperature sodium chloride saturation (26% by wt.) with the electrodes both within the 0.5 GHz microwave horn range of 10 centimeters. The achieved rate of hydrogen production averaged 24.6 mls/min. This was achieved with the voltage of 20 volts and 1.1 amps. This is a power usage of 22 watts or a reduction of almost 60%. The power to produce hydrogen gas was 1,270 joules on average per 100 ml of gas or nearly a 50% reduction in power required.

Discussion

Control Runs

The control runs were used as a comparison for many cases. These runs were repeated several times for their accuracy. The runs reflect the results of saturated sodium chloride solutions at room temperature and an elevated temperature. It appeared in the first run that the main reason for the elevation in gas production was an increase in salt concentration. On checking on the solubility of this salt, it only increased in solubility by less than 1 percent by weight. As a result the increase appears to be more temperature related.

Laser Induction with Electrolysis

Several tests were carried out using four separate lasers. The red and green lasers were low and medium power in the red and green spectrum range. The tests were carried out in two ways to check for any influence. First, the standard runs were done with and without the lasers. Second a run was done without a laser and roughly half way through the runs the laser was turned on. In both types of trials there was no appreciable difference in hydrogen production rates. Although there are a few companies claiming to have proprietary laser induced hydrogen methods, there must be a specific wave length and intensity that improves hydrogen production. We saw no effect using lasers.

Ultrasonic Bath Trials

1. Room Temperature

The comparison of this run with the control shows that double the production can be achieved through ultrasonic wave addition. The reduction in power by almost one-third appears to be attributable to slightly more of a current drop than a voltage drop. The voltage dropped 19 % as compared to the current drop of 29%.

2. Mid—Range Temperature

The 50C run in the ultrasonic bath demonstrated that at elevated temperatures the improvements appear to moderate. The power drop was 27.8% which is all due to voltage. There was little current drop observable. The rise in hydrogen production was a healthy 16.3% over the control.

The 60C run revealed that the power requirements are continuing to rise. The hydrogen production is above other 60C saturated runs we have done by 20.2 percent and the power was lower by 20.5 %. The power drop is from both current and voltage almost equally.

3. Metal Anodes (50C)

There was some interest in seeing if we should consider different types of metal as anodes for hydrogen production. It appears from the preliminary data that this should be further investigated. From our first runs it appears that silver electrodes will produce some additional hydrogen but the replacement cost may not warrant their use. The copper and zinc in a couple of trials appear to be second choice. Both electrodes came within 4 percent of the other in production. The least effective appears to be carbon and aluminum.

4. Copper Electrodes

When we first tried to run these reactions we were finding no significance in electrode size. We realized that when we wrapped the electrode as a spiral the diffusion was cut down dramatically by the metal configuration. The metal was then bent into a long v-shaped pattern. This would not do for ultrasonic waves since it would stick outside the ultrasonic beam but was fine for normal thermal runs.

We did find reasonable increase in production with the added area of the electrode surface. It did not match proportionally. The results tend to point out the need for further research but with a fruitful outcome.

Variable Effects on Hydrogen Production

1. Temperature

Table A shows a number of effects. In this section we will examine the direct effects of temperature on each salt solution at elevated temperatures. The effects reflect purely temperature, since all salt solutions were prepared at 26% by weight.

The slope is given in units of degrees per second of each concentration. All plots were found to be linear from 96% to 98% by least squares methods. The correlation improves with high salt concentration from 96% to 99% correlation. The temperature effects are very pronounced and act in linear fashion with a known salt concentration.

In a lower temperature study the effects of saturated salt solutions were made based on saturations at those lower temperatures, rather than from room temperature 26% salt saturation. The solutions were examined from 20C to 60C. Here we see that a dramatic effect occurs when you saturate solutions at high temperatures. The study suggests that the power and total energy requirements of the solutions drop when the high temperature solutions are run. It is not clear if the electric power drop is made up by the power input by the isothermal bath solution. Early calculations show that this only makes up for part of the energy loss but not all of it.

2. Salt Concentration

If one examines the increase in salt concentration with the slope of the hydrogen production per degree, we see that the effect of the salt concentration on hydrogen production is a curve that slopes up with each addition of salt up through the saturation point. This curve reflects the strong salt influence on hydrogen production.

3. Water Gas Bubbles

One popular theory that has yet to be proven is the possibility that steam pockets forming on the electrodes could in fact contribute to jumps in hydrogen production that salt concentration and heat cannot do individually. Studies examining solutions from 50C through boiling reveal linearity in hydrogen production while keeping salt concentration constant. Plots of hydrogen production versus concentration show modest gains in gas production. These results do not account for all of the increase in gas production. Additional studies were done qualitatively looking at the volume of gas bubbles and the hydrogen production and there was not match or predictability in any of the data.

4. Microwave

The results of four microwave runs confirm again that when a reasonable frequency radiation is mingled with electrolysis, improvements are seen of up to 60% in gas production rates with a drop in power of 48%.

Conclusion

Comparison of Effects on Hydrogen Production

When one examines the individual effects of concentration versus temperature, it is clear that both contribute, but the effects of salt concentration far outweigh the mere temperature effects. The salt only increases by no more than 2 weight percent by all known standards of salt solutions and yet it magnifies and curves the production rate up with each modest increase in weight percent. It is quite clear the last couple percent make all the difference. Solutions with the highest ionic strength therefore will be the top priority.

Temperature is also an added factor to improve solubility. Since all plots reveal the temperature to be very reproducible and linear, the effects are seen to be a secondary additive effect to ionic strength.

Comparison of Merged Energies with Electrolysis

A number of additional energy sources were examined. Laser, microwave and ultrasonic waves were examined based on literature leads. The highest hydrogen production was accomplished with ultrasonic waves, but the highest power drop was experienced with microwaves. It appears, unless we are fortunate, the leads of laser induction of electrolysis will be difficult to produce. Several companies claim such advancements in their products but the technology is all unpublished proprietary data. From a practical standpoint the ultrasonic bath presents an element of reliability and lower risks to the human condition with reasonable safe guards. Microwaves are dangerous to humans if uncontrolled leakage occurs.

Effects of Gaseous Water Bubbles

This is one area we are just about to examine. It appears that under normal conditions, steam does not contribute to added production rates. However, if steam is produced while under ultrasonic wave or microwave conditions, added effects could result. It is the opinion of this group that a number of possibilities could force added benefits, and steam generation in coordination with other energies could just be that avenue.

Graphs and Charts

Control Runs

7C

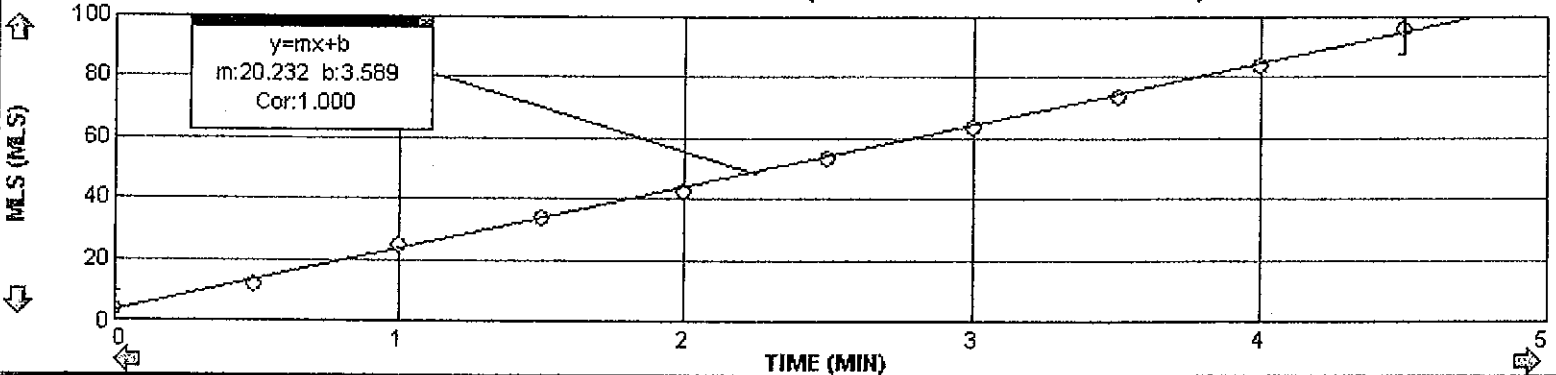
20C

30C

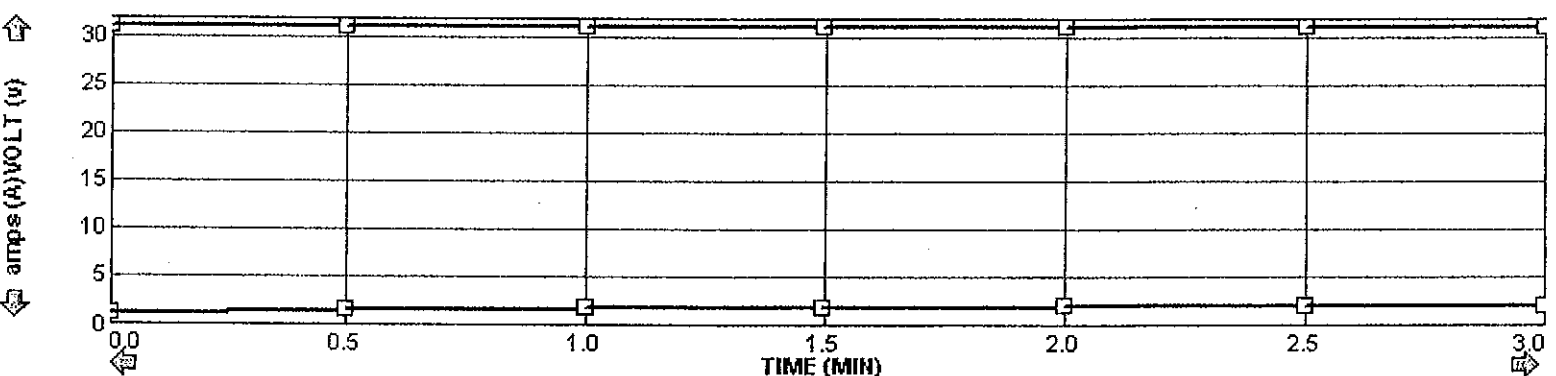
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50C

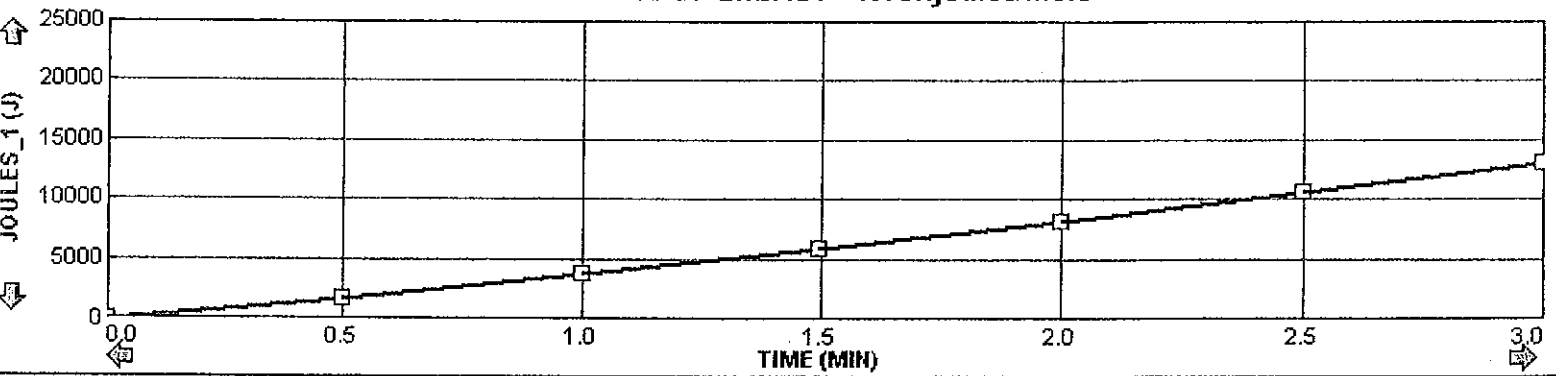
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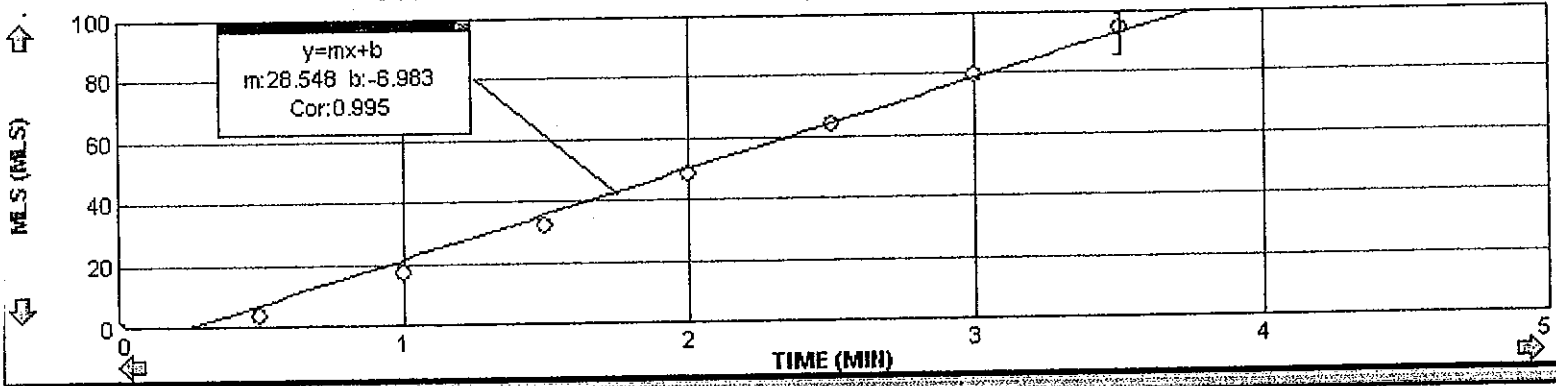
COMPARISON OF AMPS AND VOLTS



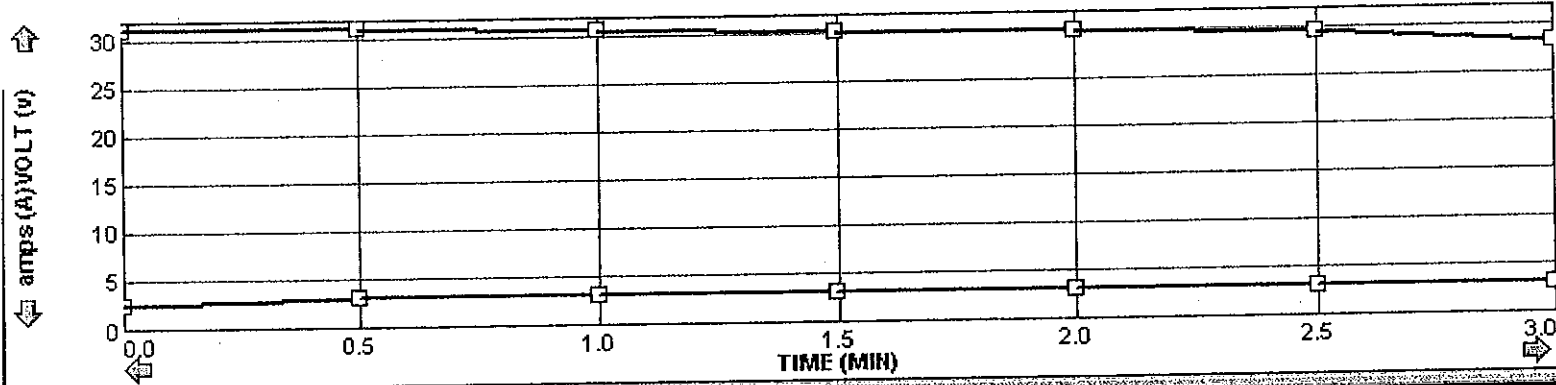
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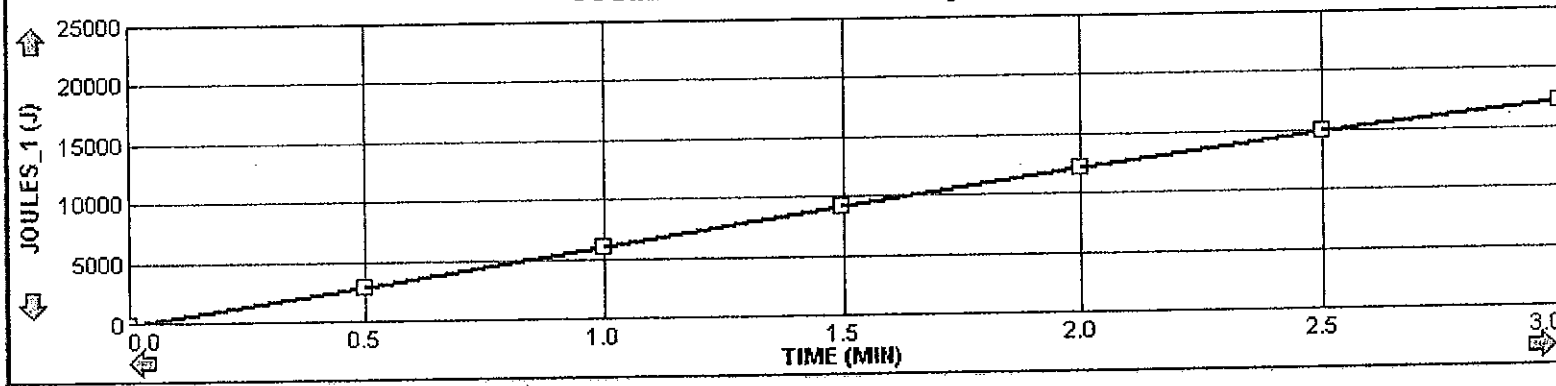
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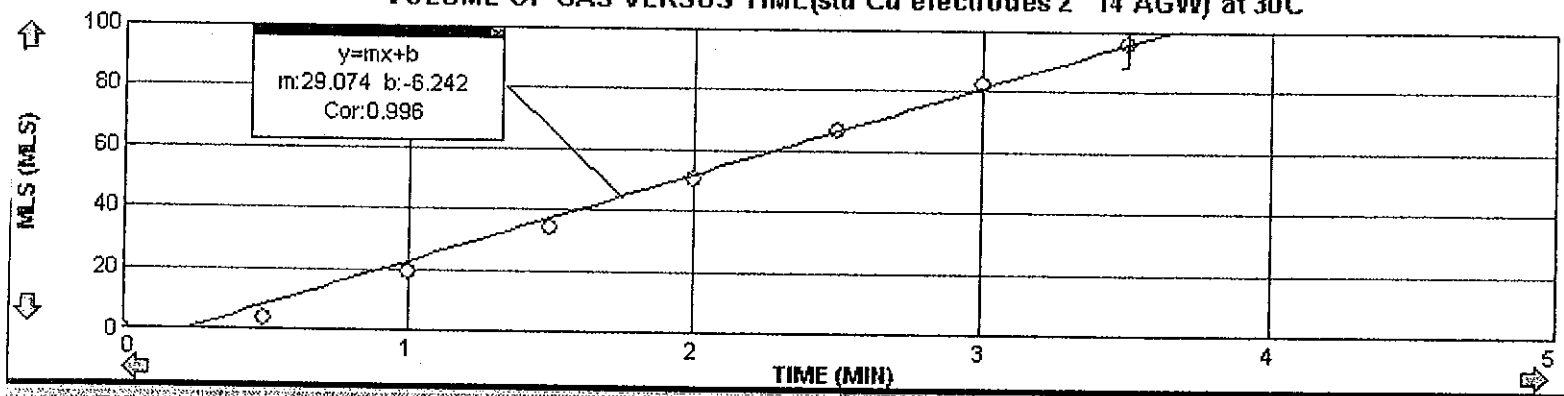
COMPARISON OF AMPS AND VOLTS



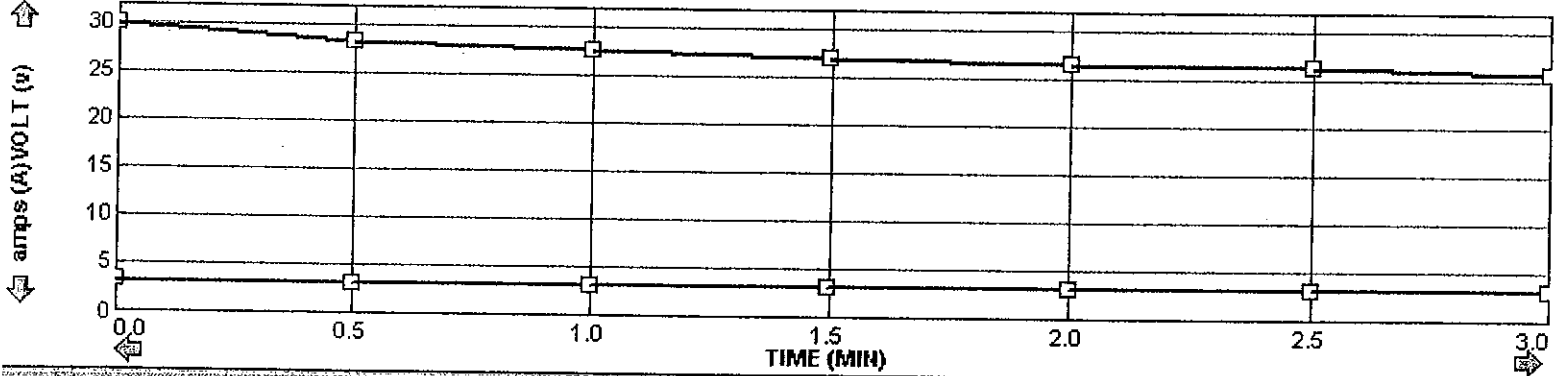
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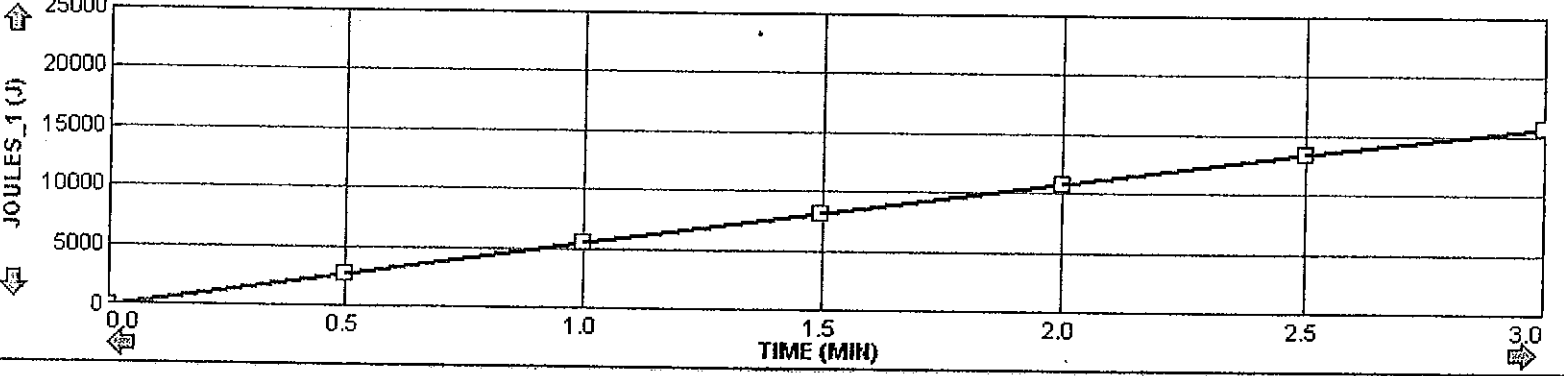
VOLUME OF GAS VERSUS TIME (std Cu electrodes 2" 14 AGW) at 30C



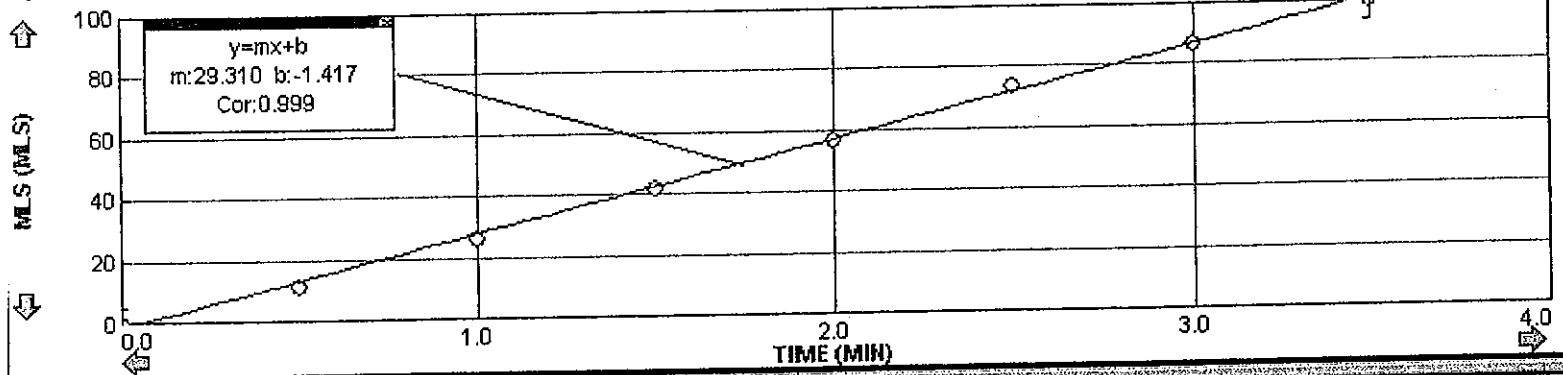
COMPARISON OF AMPS AND VOLTS



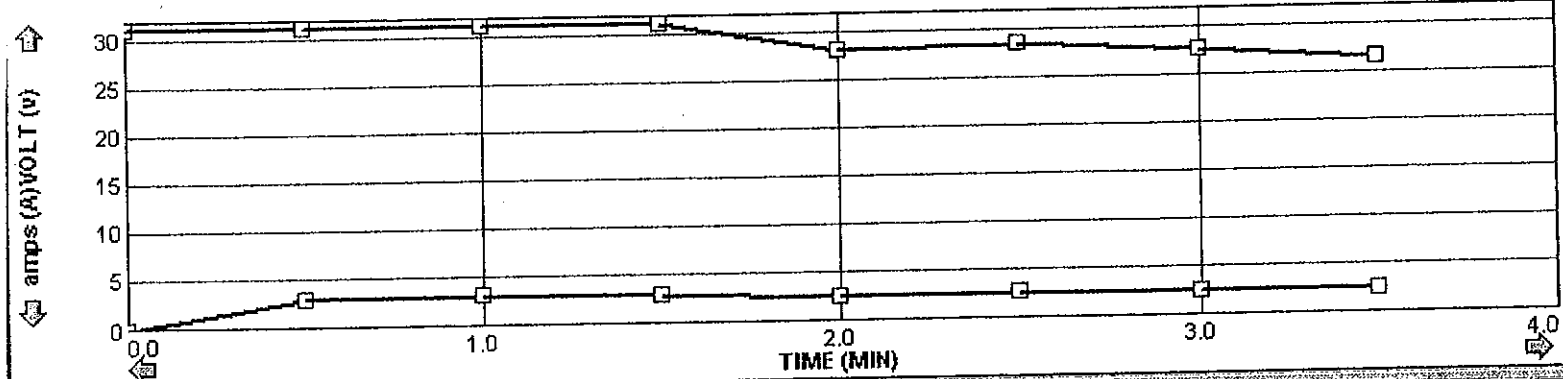
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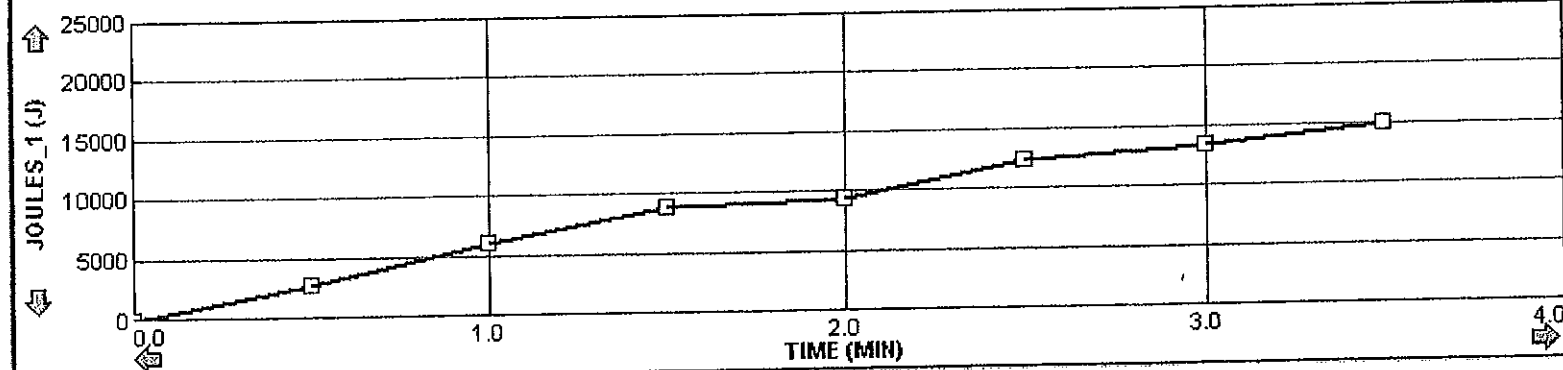
VOLUME OF GAS VERSUS TIME (std Cu electrodes 2" 14 AGW) at 40C -II

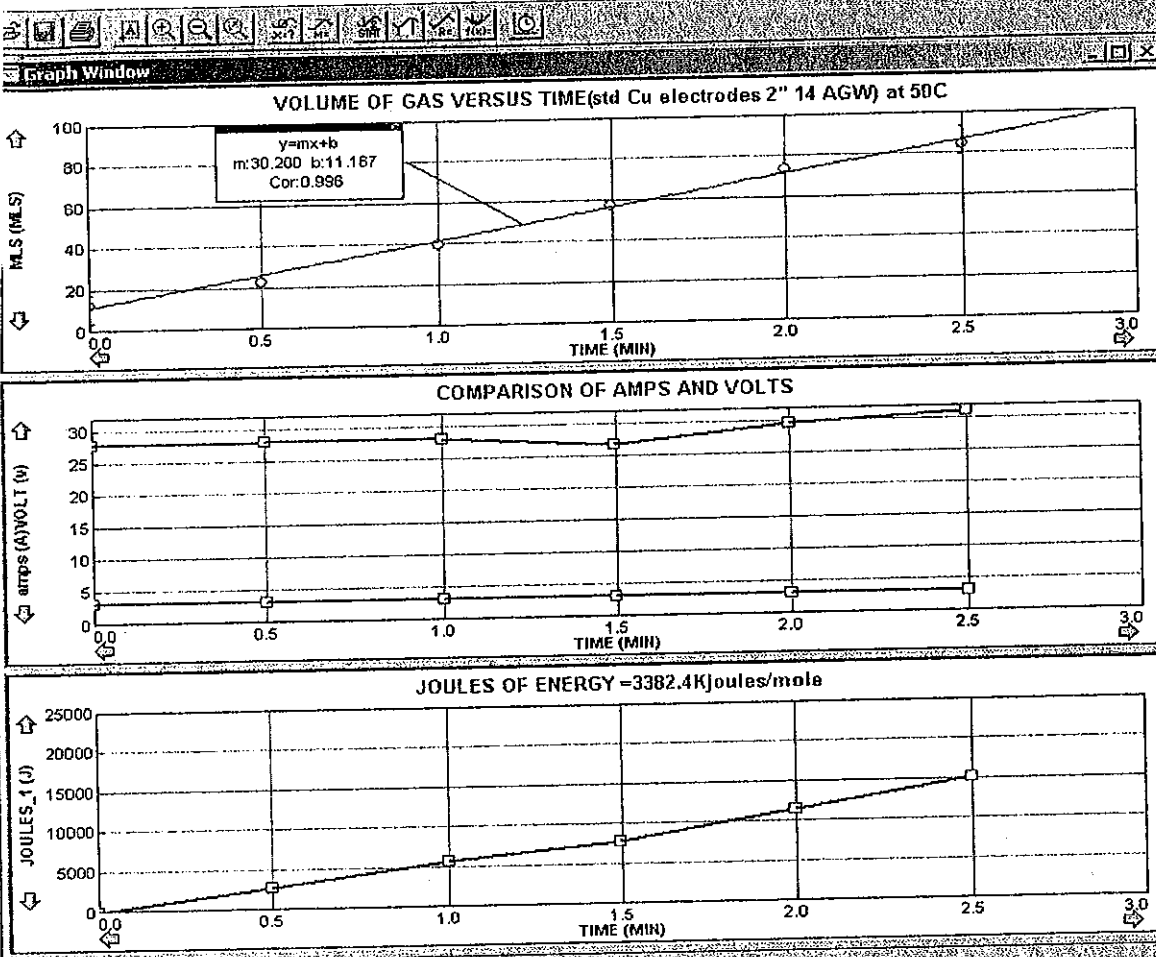


COMPARISON OF AMPS AND VOLTS



JOULES OF ENERGY = 3298Kjoules/mole



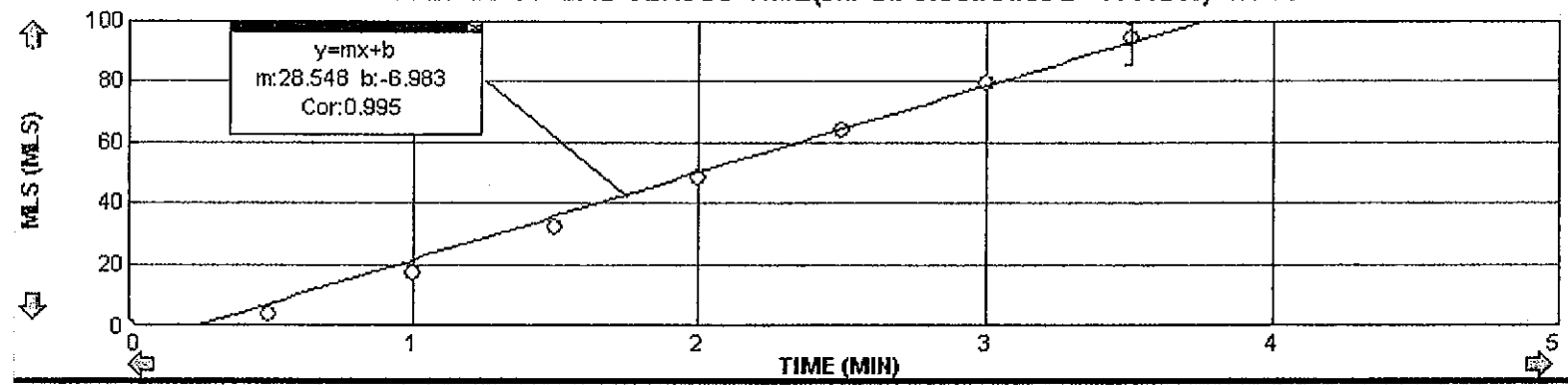


TIME (MIN)	current (A)	MLS (MLS)
0.000	3.40000	13.500
0.500	3.40000	23.000
1.000	3.40000	40.000
1.500	3.30000	58.000
2.000	3.25000	74.000
2.500	3.25000	85.000

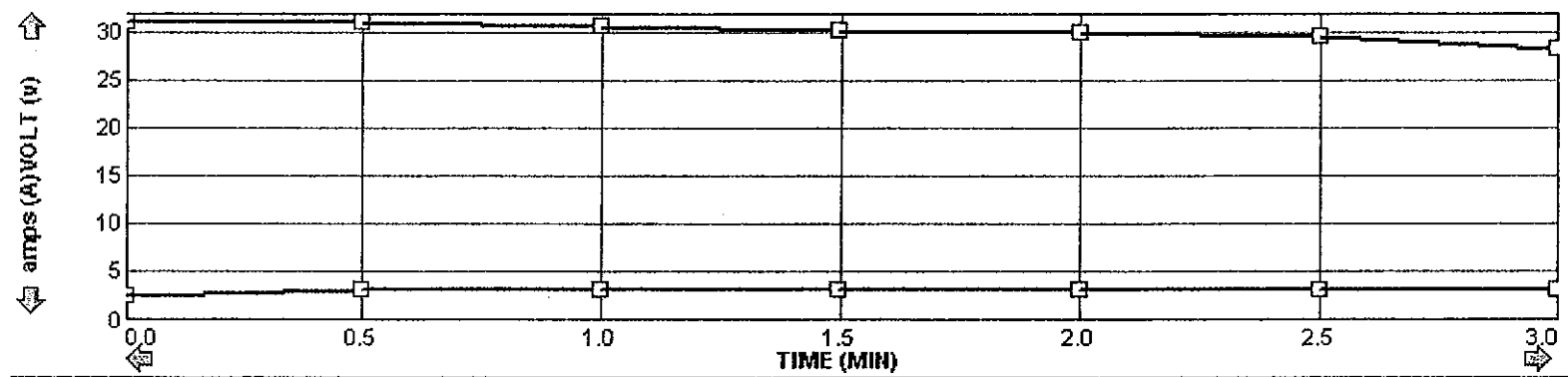
For Help, press F1

Ultrasonic Runs

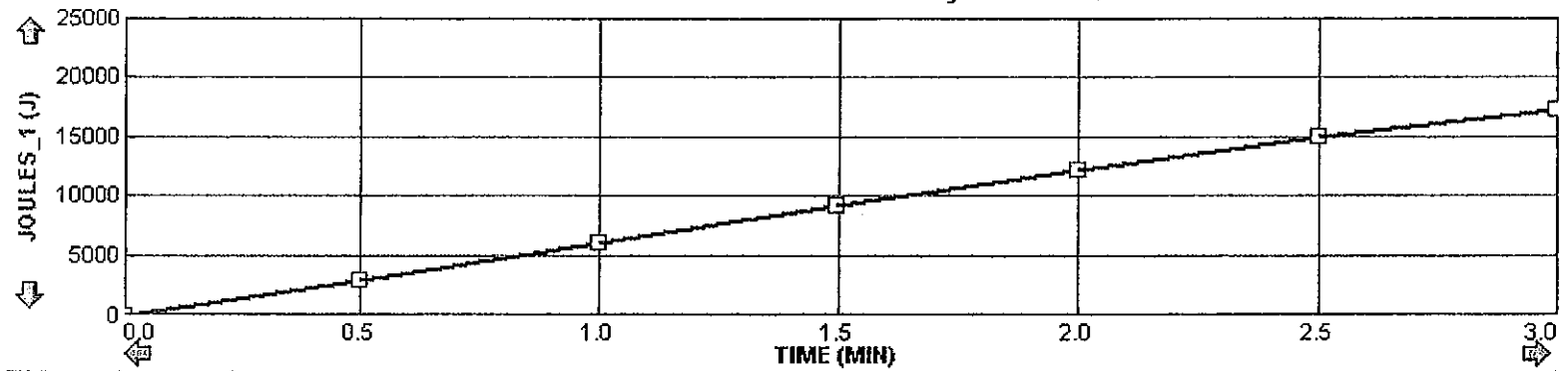
VOLUME OF GAS VERSUS TIME (std Cu electrodes 2" 14 AGW) at 20C



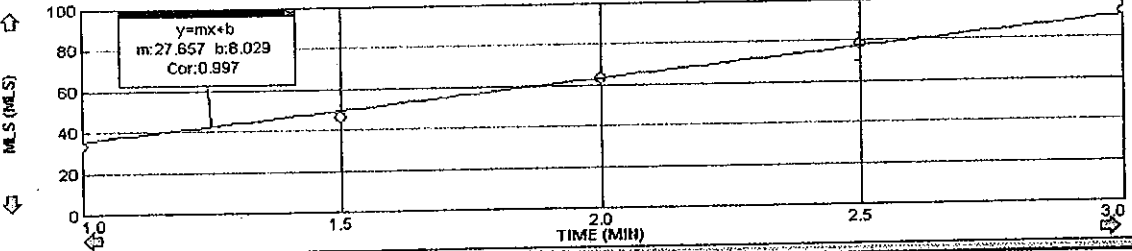
COMPARISON OF AMPS AND VOLTS



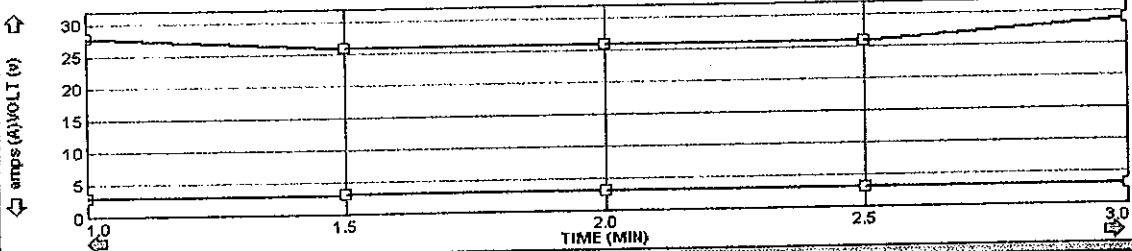
JOULES OF ENERGY = 4763Kjoules/mole



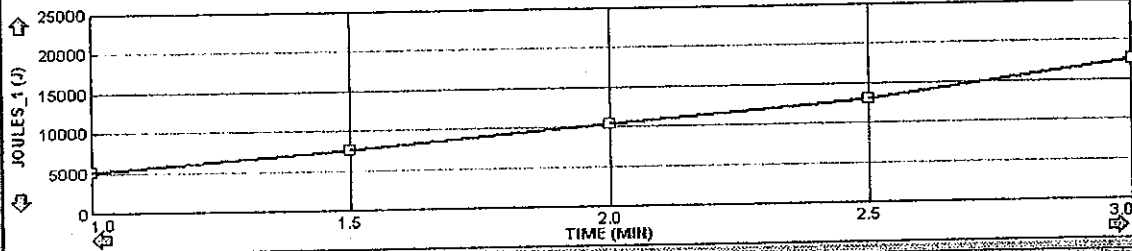
VOLUME OF GAS VERSUS TIME (note electrode is centered in the ultrasonic ran)



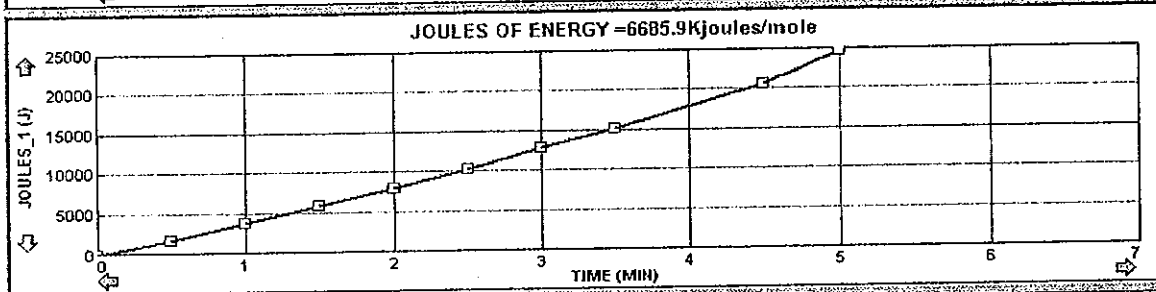
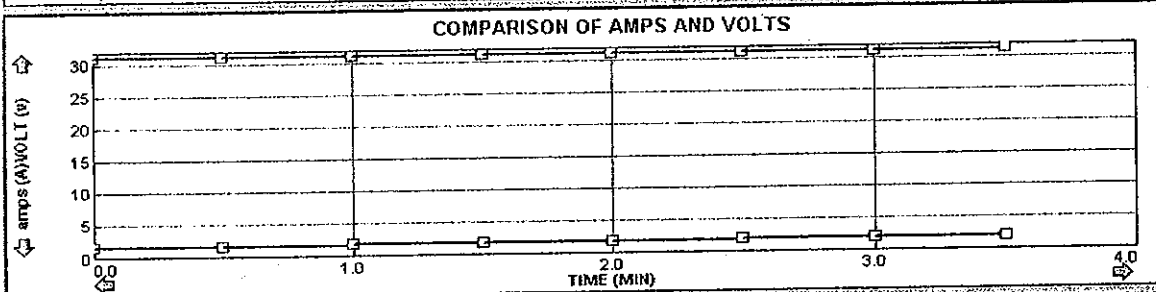
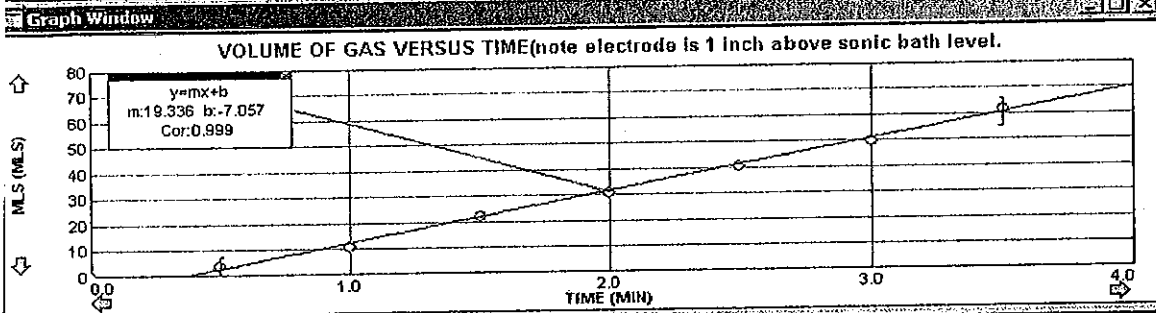
COMPARISON OF AMPS AND VOLTS



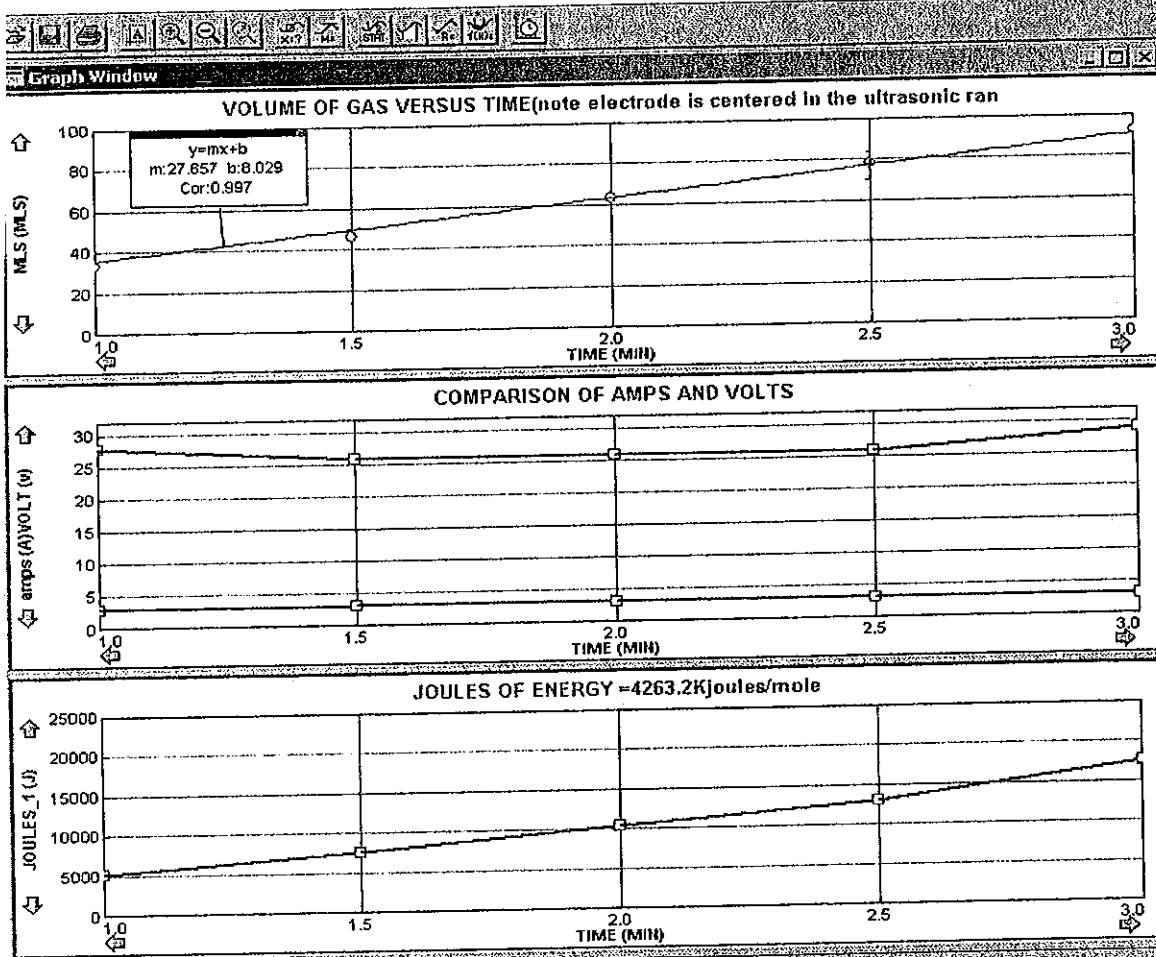
JOULES OF ENERGY = 4263.2Kjoules/mole



TIME (MIN)	Current (A)	MLS (MLS)
0.000	3.42000	10.600
0.500	2.40000	21.000
1.000	3.20000	34.000
1.500	3.30000	47.000
2.000	3.40000	64.000
2.500	3.40000	79.000
3.000	3.40000	93.000



TIME (MIN)	current (A)	MLS (MLS)
0.000	1.75000	0.000
0.500	1.88000	4.000
1.000	2.08000	11.000
1.500	2.16000	22.300
2.000	2.15000	31.000
2.500	2.23000	41.000
3.000	2.30000	50.000
3.500	2.31000	62.000
4.500	2.45000	72.000
5.000	2.63000	83.000



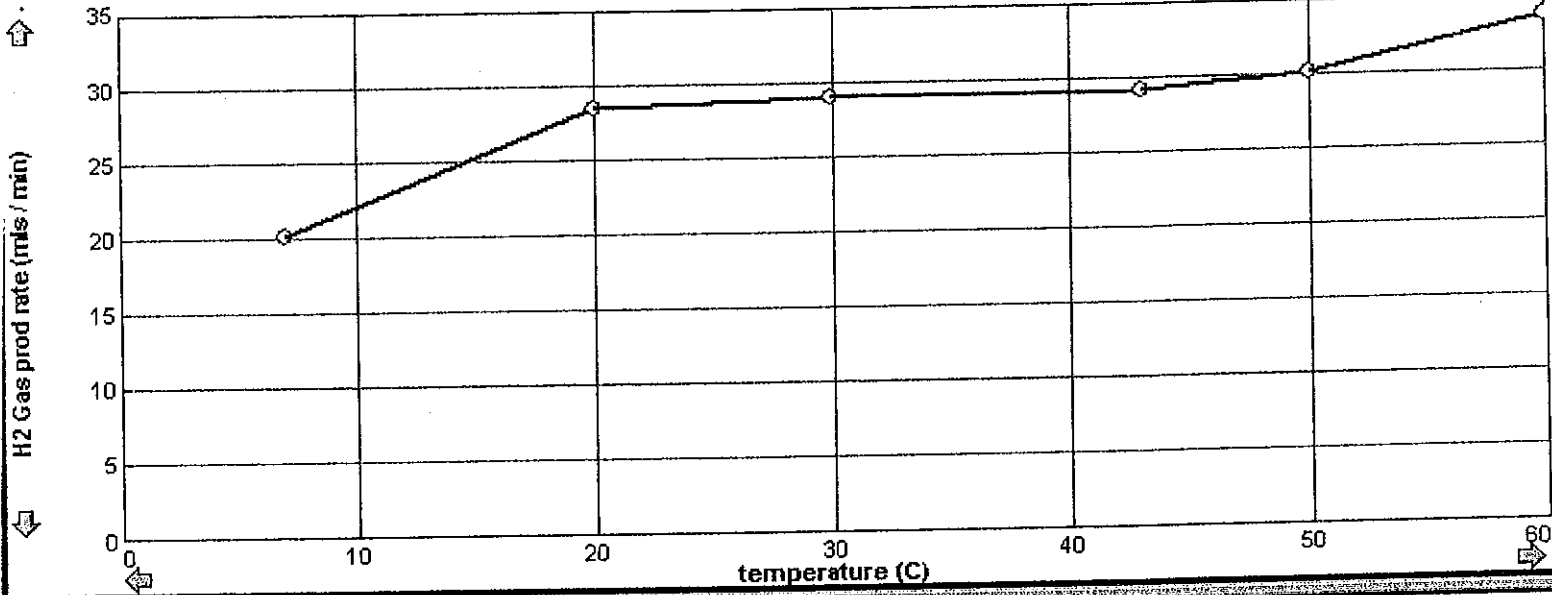
All	TIME (MIN)	current (A)	MLS (MLS)
1	0.000	3.42000	10.600
2	0.600	2.40000	21.000
3	1.000	3.20000	34.000
4	1.500	3.30000	47.000
5	2.000	3.40000	64.000
6	2.500	3.40000	79.000
7	3.000	3.40000	93.000
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For Help, press F1

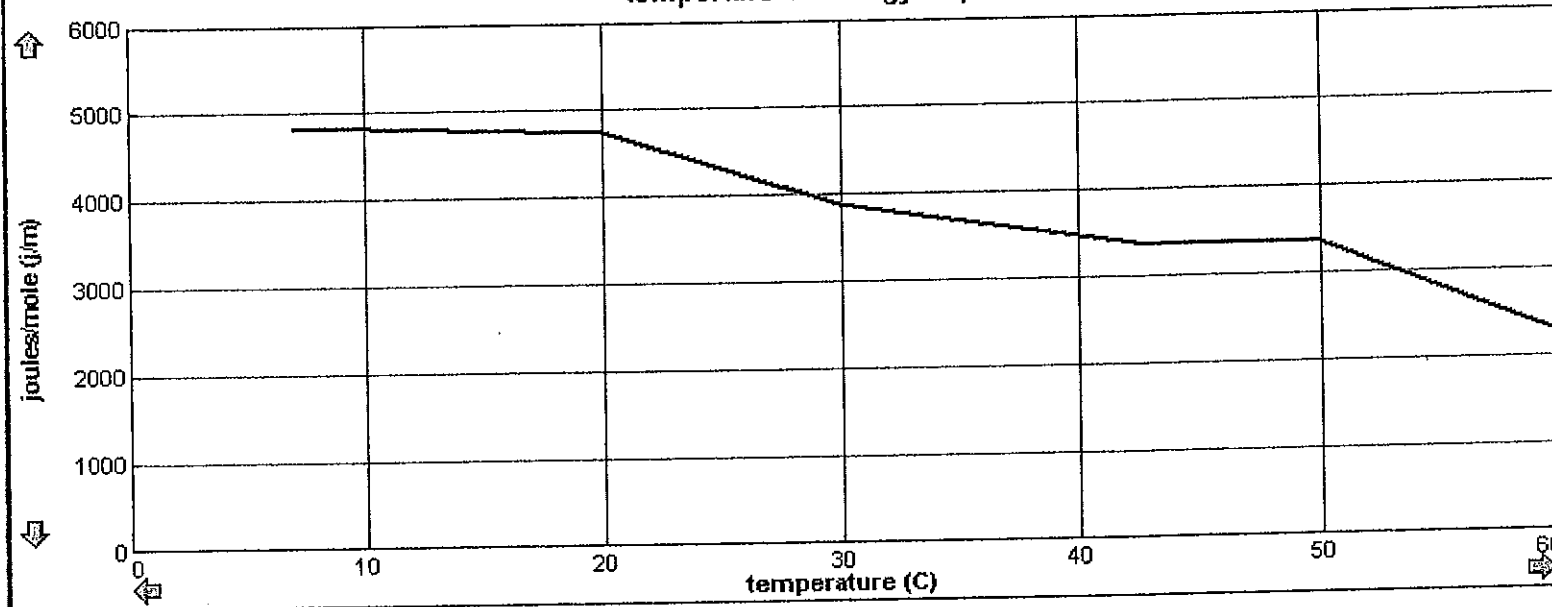
Lower Temperature Runs

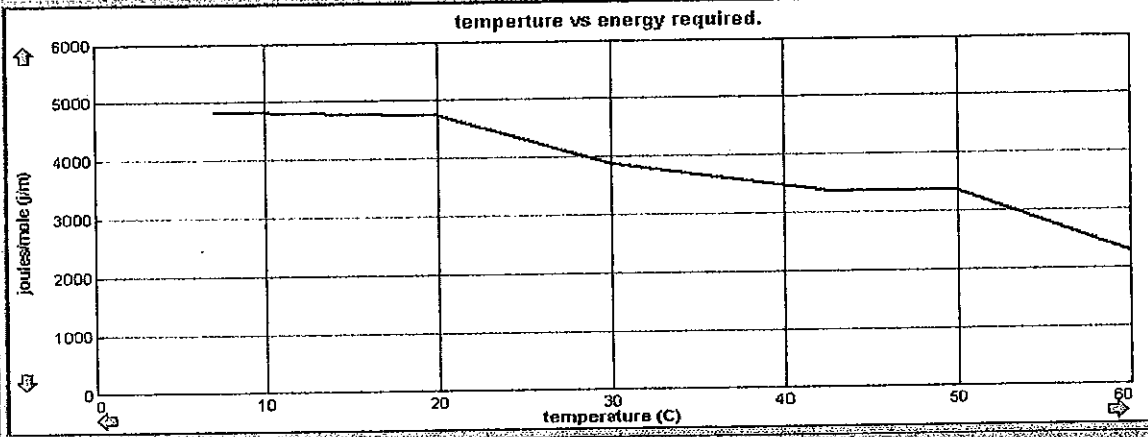
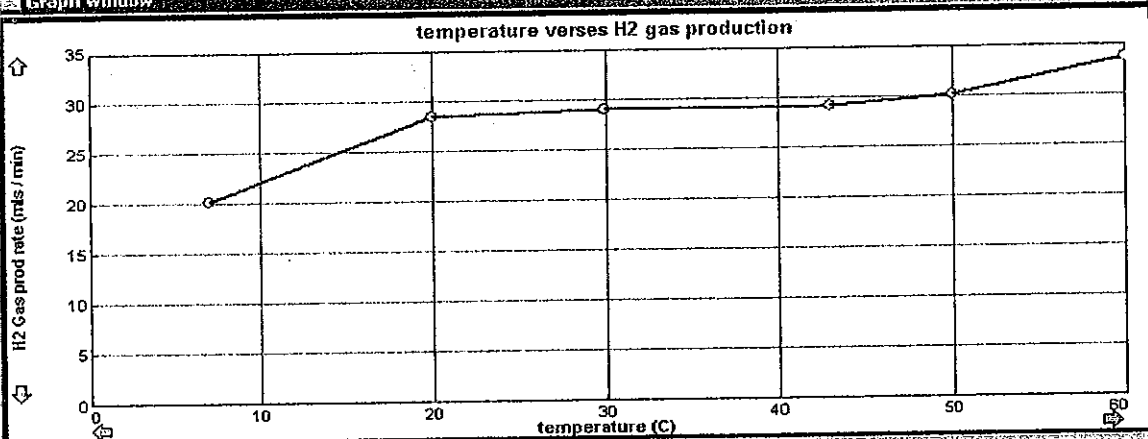
25C – 60C

temperature verses H2 gas production



temperture vs energy required.





	Latest		
All	C (C)	m/min (mls / min)	j/m (j/m)
1	7.000	20.200	4873.000
2	20.000	28.540	4763.000
3	30.000	29.070	3920.000
4	43.000	29.300	3390.000
5	50.000	30.200	3382.000
6	60.000	33.770	2303.000
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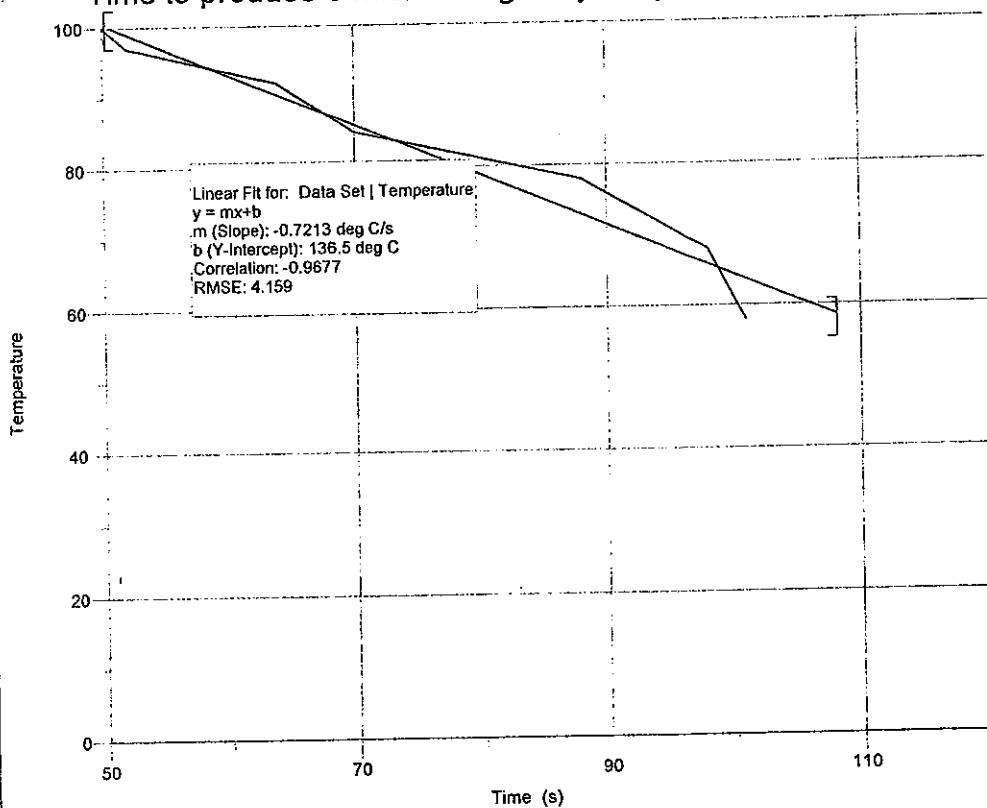
For Help, press F1

Higher Temperature Runs

50C – 100C

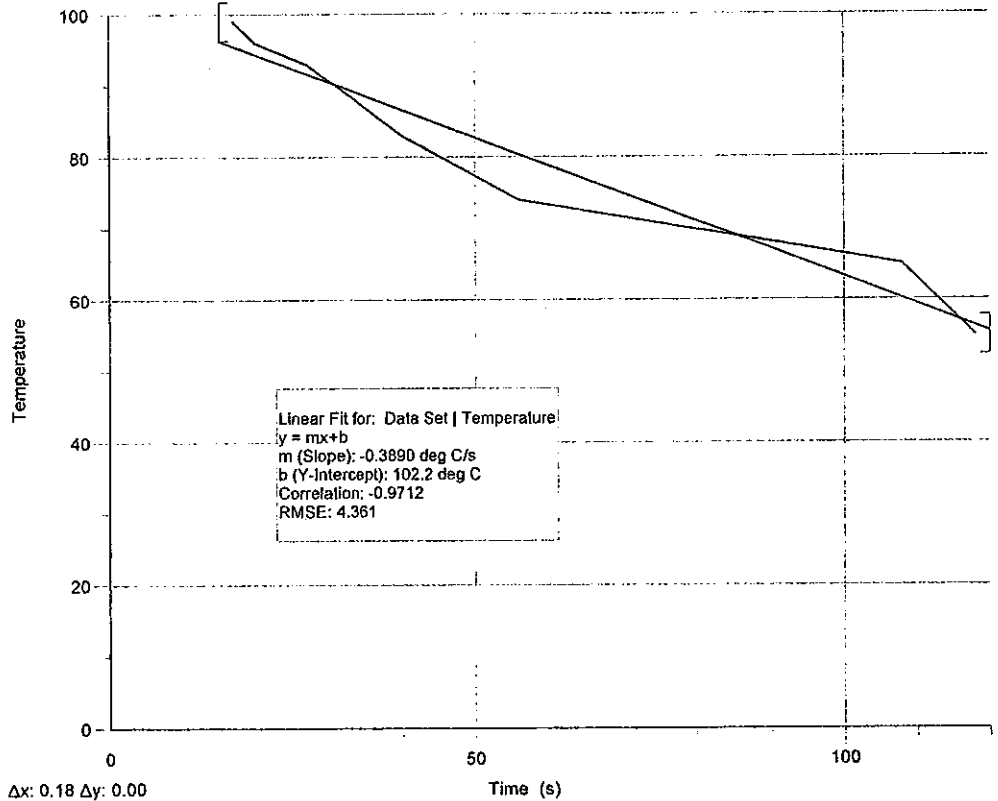
Data Set		
	Time (s)	Temperature (deg C)
1	101	58
2	98	68
3	88	78
4	70	85
5	64	92
6	52	97
7	50	100
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Time to produce 5 mls of H2 gas by temperature at 1% salt



Data Set		
	Time (s)	Temperature (deg C)
1	118	55
2	108	65
3	56	74
4	40	83
5	27	93
6	20	96
7	17	99
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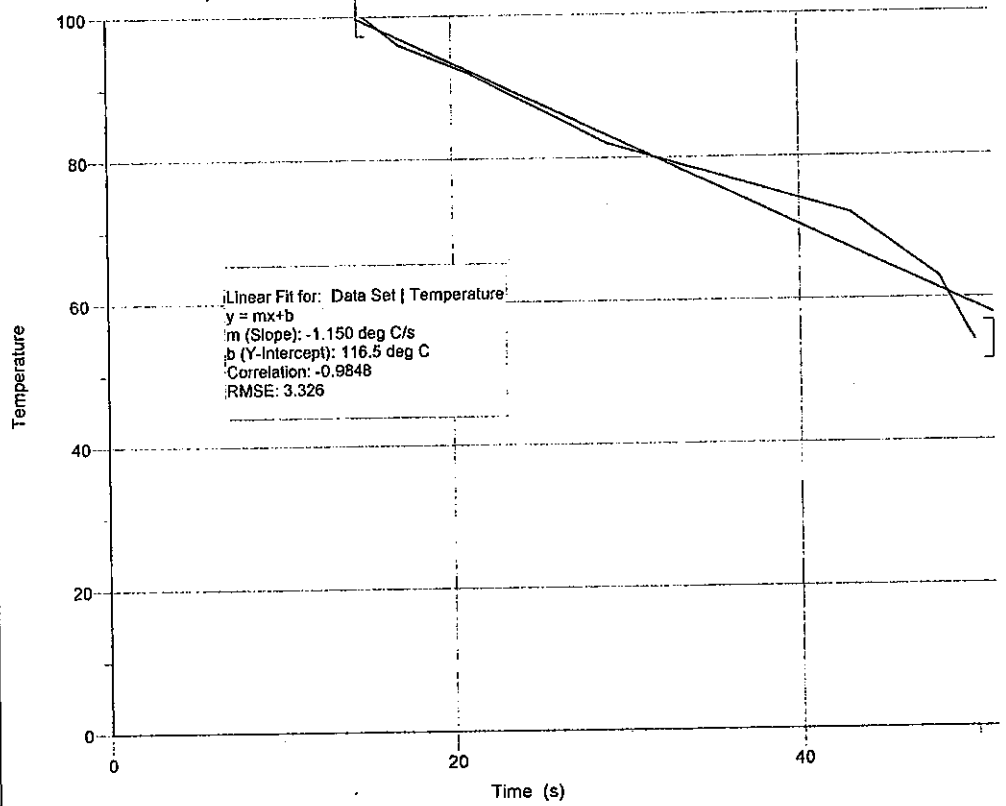
Time to produce 5 mls of H2 gas by temperature at 10% salt



Δx: 0.18 Δy: 0.00

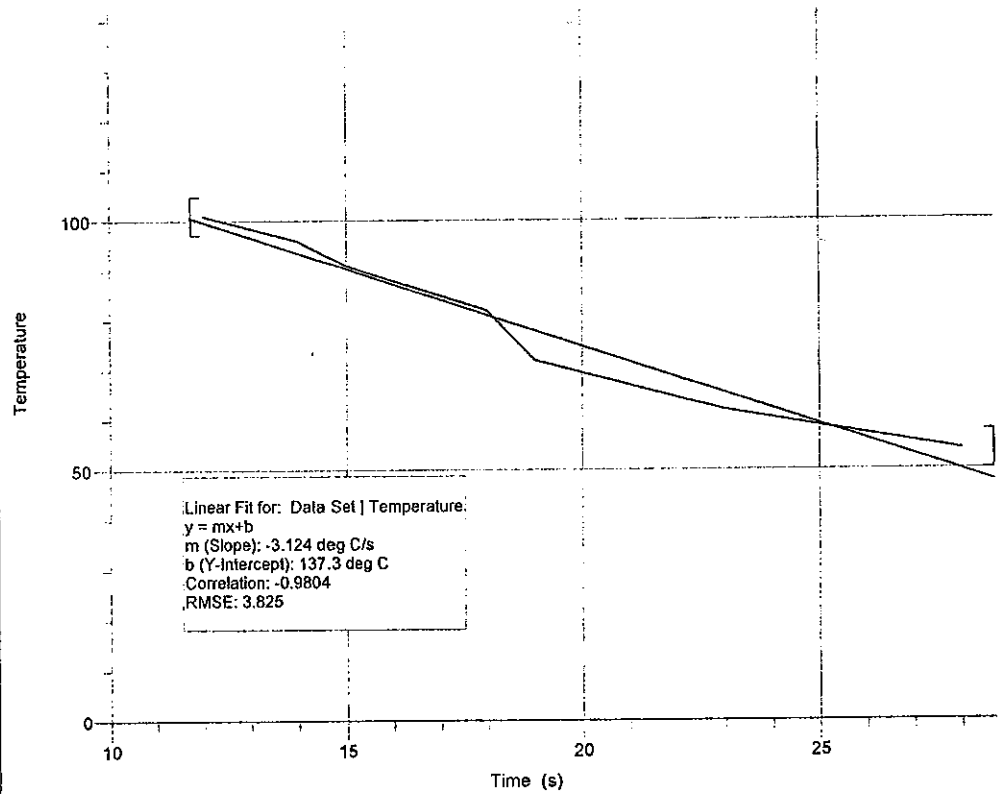
Data Set		
	Time (s)	Temperature (deg C)
1	50	54
2	48	63
3	43	72
4	29	82
5	21	92
6	17	96
7	15	100
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Time to produce 5 mls of H2 gas by temperature at 5% salt



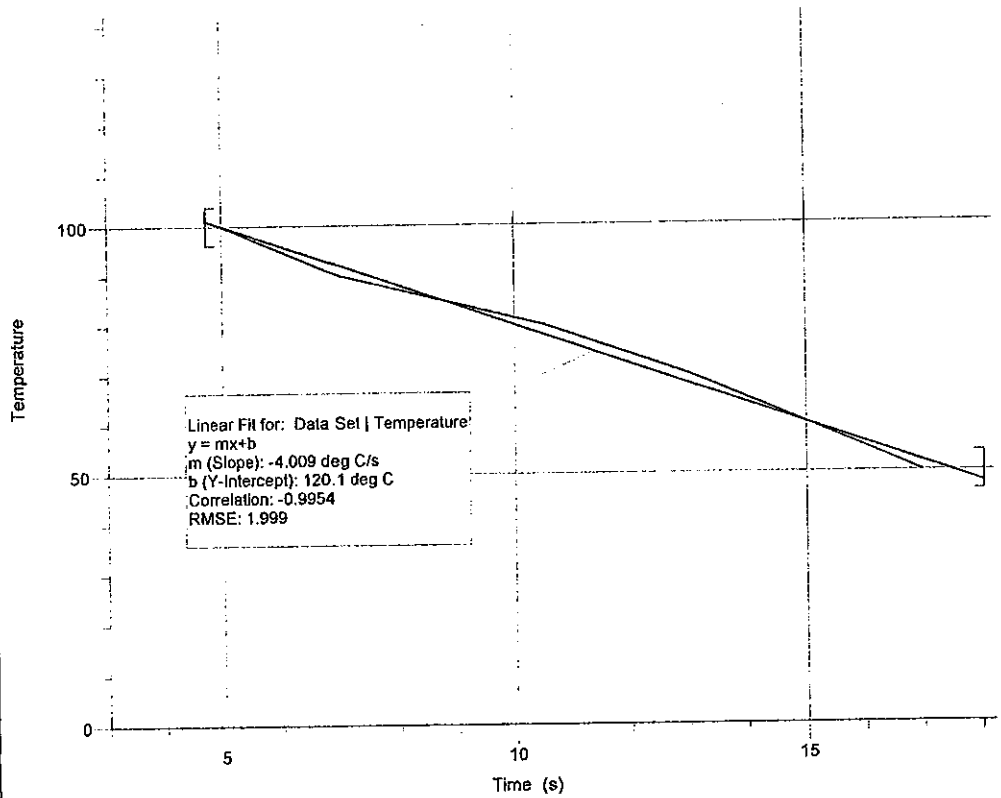
Data Set		
	Time (s)	Temperature (deg C)
1	28	54
2	23	62
3	19	72
4	18	82
5	15	91
6	14	96
7	12	101
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Time to produce 5 mls of H2 gas by temperature at 20% salt



Data Set		
	Time (s)	Temperature (deg C)
1	17.0	50
2	15.0	60
3	13.0	70
4	10.5	80
5	7.0	90
6	5.0	100
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Time to produce 5 mls of H2 gas by temperature at 30% salt

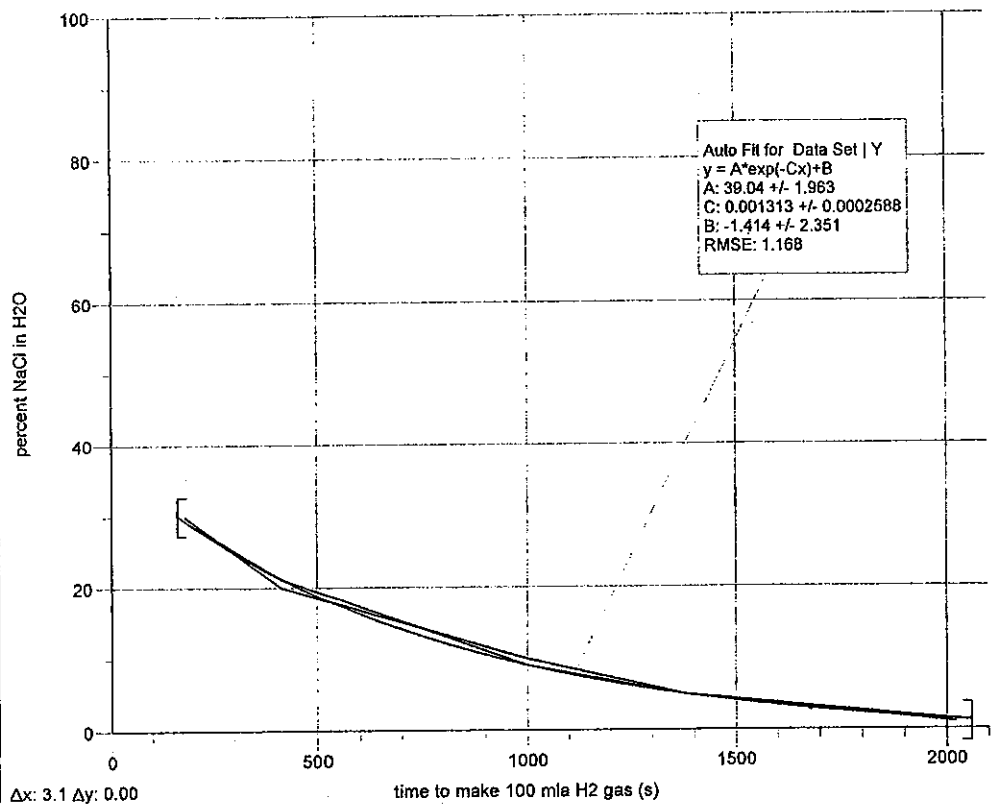


Salt Concentration Runs

At 50C

Data Set		
	Y	CC
1	1	1.339
2	5	4.965
3	10	9.090
4	20	21.197
5	30	29.409
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Curve of Hydrogen production at 50C versus % salt



Acknowledgements

The authors of this paper would like to recognize the SRP Enviro-Tech grant for direct support of this work.

We would like to also thank the Arizona State University Photovoltaic Labs for their generous donation of four solar panels for the latter part of this work.

Finally, we would like to thank Fountain Hills Unified School District without whose support none of this would be possible.

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