

# *Solubility in Alcohols*

## **1 Research Question**

How does Temperature of an Alcohol affect the solubility of Oxalic acid in different types of primary Alcohols

## **2 Introduction**

I have chosen this research question as I was highly interested in Medicinal Chemistry and Medicine, in general. I very well wanted to investigate something that had its application in the medical sciences. I had initially thought of investigating the solubility of Asprin in Alcohol when the alcohol is completely miscible in blood.

Preliminary research and data collection have shown me that this is not a feasible topic of study. Observing the solubility of Asprin in Alcohol when the alcohol is completely miscible in blood on the microscopic level is excruciatingly challenging due to the lab constraints at a high-school level. I then decided to study the **Temperature dependence of the Solubility of Oxalic Acid in various Alcohols** as I had previously researched and studied a lot on the solubility of Alcohols. I chose to Oxalic Acid as my chosen solute as it was easily soluble in alcohols.

## **3 Background Research**

### **3.1 Oxalic Acid**

Oxalic Acid is an odorless, colorless white granular solid. It is synthesized from Acetic acid and is an organic compound belonging to the family of carboxylic acids. It is also a polar compound and is soluble in all polar solvents; Therefore it is an ideal solute to study the changes in the solubility in Alcohols with respect to temperature.

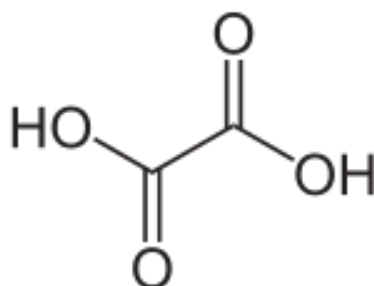


Figure 1: 2D chemic structure of the organic compound, Oxalic acid

### 3.2 Solubility in Alcohols

Alcohols are a class of polar compounds, therefore are perfectly soluble with polar solutes and solvents. As Oxalic Acid is polar, it is expected that all types of Alcohols would be perfect solvents for it.

The property of Oxalic acid being polar makes it hydrophilic for Alcohol; and as a result it is also hypothesized that as the length of the alkyl chain increases, the non-polar part of the compound increases thus making the higher members of the Alcohol less polar, therefore decreasing its solubility with Oxalic Acid.

## 4 Methodology

### 4.1 Variables

<i>Independent Variable</i>	<i>Dependent Variable</i>
Temperature of Solution	Total Dissolved Solids
Alcohol Type	-

<i>Controlled Variable</i>	<i>Reason for Control</i>	<i>Method of Control</i>
Alcohol concentration	Variation in the alcohol concentration amongst various alcohols might affect our ability to evaluate data accurately	All Alcohol used are of 98% Concentrations
Environment Temperature	This could affect the precision in our readings	Experimentation is performed in a lab which maintains constant temperature
Amount of Alcohol used	Using an inconsistent amount of alcohols would result in inaccurate data readings	20 ml of Alcohol is used per trial
Amount of Oxalic Acid used	Using an inconsistent amount of oxalic acid would result in inaccurate data readings	20 g of Oxalic Acid is used per trial

## 4.2 Apparatus Required

- Pasco Conductivity & Dissolved Solids Sensor ( $\pm 0.5$  g/L)
- Digital Thermometer ( $\pm 0.01$  °C)
- Pipette & Pipette Filler ( $\pm 0.05$  ml)
- 25, 100 ml Beakers ( $\pm 10$  ml)
- Water Bath
- Petri Dish
- Weighing Machine  $\pm 1$  g

## 4.3 Materials Required

- 100 ml of Methanol
- 100 ml of Ethanol
- 100 ml of 1-Propanol
- 100 ml of 1-Butanol
- 100 ml of 1-Pentanol

- 500 g of Oxalic Acid (solid)

**Note:** In theory, the alcohols used in this exploration could be primary, secondary or tertiary. For the purpose of this investigation, we shall only use primary alcohols.

## 4.4 Procedure

**Step 1:** Measure (using Pipette) and Pour 20 ml of a type of alcohol into a 100 ml beaker

**Step 2:** Measure (using Weighing Machine) 20 g of Oxalic Acid in a Petri Dish

**Step 3:** Add the 20 g of Oxalic Acid into the 100 ml beaker with the 20 ml alcohol

**Step 4:** Using a glass rod, mix and dissolve the Oxalic acid at room temperature until saturation point at room temperature (20° Celsius/293.16 K)

**Step 5:** Measure the TDS reading using the Pasco Conductivity Dissolved Solids Sensor at 20° Celsius/293.16 K.

**Step 6:** Immerse the beaker in a water bath set at 100° Celsius.

**Step 7:** Immerse a digital thermometer in the solution (beaker) and measure the TDS reading at various temperature values (for our experiment, temperature data points are at 20°, 30°, 40°, 50° and 60° Celsius)

**Step 8:** Repeat the above experiment for a total of 5 trials

**Step 9:** Repeat the above experiment for all alcohol types

## 5 Hypothesis

The solubility of Oxalic acid in various alcohols (in the order of the hierarchy of the homologous series of alcohols), generally **decreases** with increase in temperature, ie. **The solubility in alcohols generally decreases with respect to temperature as the length of the hydrocarbon chain increases.**

## 6 Data

<i>Alcohol Type</i>	<i>Temperature (°C) <math>\pm 0.2</math></i>	<i>TDS Reading (g/L) <math>\pm 0.5</math></i>
<i>Methanol</i>	20	96.2
	30	145.2
	40	132
	50	150.8
	60	113.2
<i>Ethanol</i>	20	24
	30	35
	40	145
	50	194.4
	60	164.4
<i>Propanol</i>	20	2.5
	30	21.4
	40	13.8
	50	32.6
	60	265.8
<i>Butanol</i>	20	1.2
	30	16.8
	40	38.2
	50	44.6
	60	122.4
<i>Pentanol</i>	20	0
	30	6.8
	40	46.4
	50	48.8
	60	134.6

Table 1: Processed Data from the experiment

## 7 Analysis

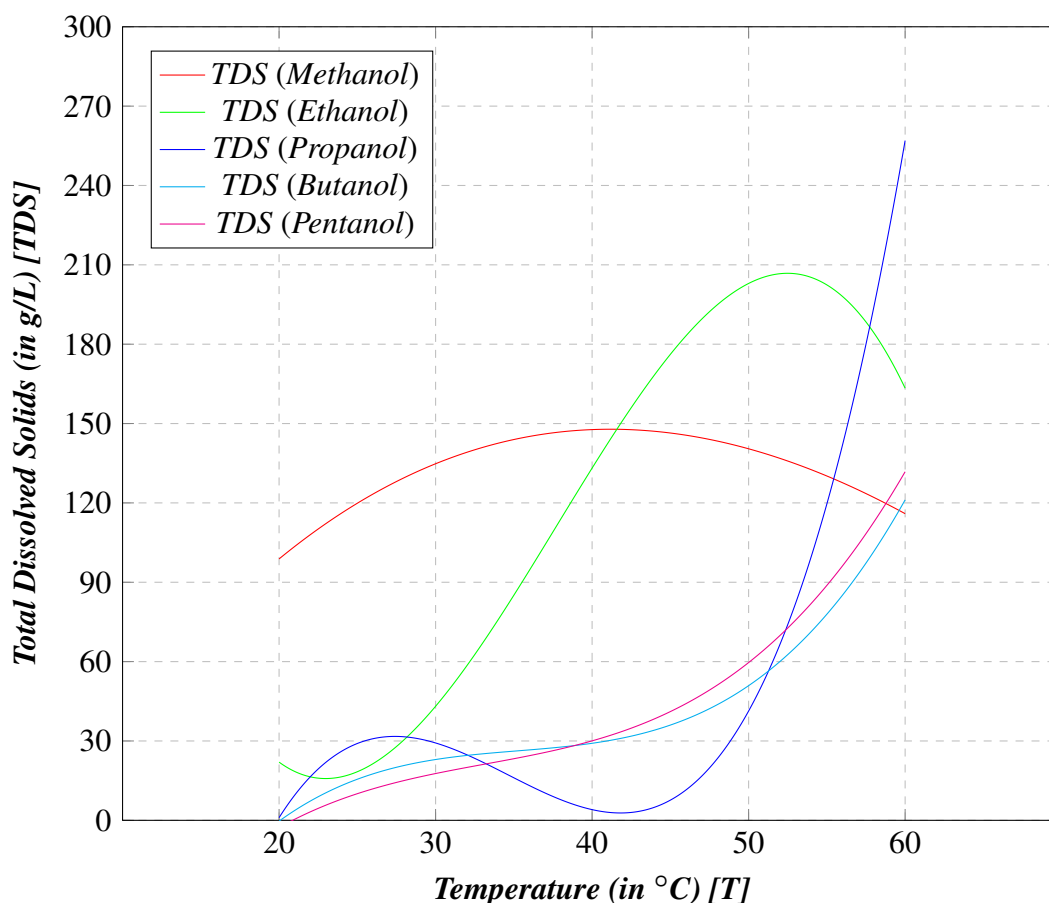


Figure 2: Graph in relation to the **regression line** of **TDS** versus **temperature**

The **cubic regression** of all **data points** within the given **data set** of **experimentally collected values** is depicted in the graph above. Because a regression generates an appropriate model of the system based on the data points and is a **mathematical function** of each and every data point, a cubic regression was used to depict the **line of best fit**. This was employed instead of showing a simple line between the range of the data point's **maximum and minimum** values because it would have been similar to guesswork.

**Note:** The **cubic regression** was plotted to only **study the trends** (gradation) of the **changes in the solubility of Oxalic acid in various alcohols with changes in temperature**. The cubic regression model does **not** accurately model the

**behavior of the phenomenon** of the solubility in alcohol's, though it can **predict the trends** at a given **temperature range** (domain of temperature in the study).

**Note:** Due to constraints of resources (small data set), a **cubic regression model** was utilized instead of a **quintic** or a **higher order regression model**, but the part of the model that we are to analyze exhibits **accurately similar behavior** over temperature to a higher order regression model when restricted in the domain from 20 ° C to 60 ° C.

On effectively studying and analyzing the above graph (regression graph) with scrutiny, we observe that,

- The solubility of all alcohols generally **increases** with **increase in temperature**, till a cutoff point which is the point at which the **trend of the model reverses**
- The cutoff point generally increases with increase in temperature over the hierarchy of the homologous series of alcohols, ie. **The cutoff point in alcohols generally increases with respect to temperature as the length of the hydrocarbon chain increases**
- Alcohols that are **odd** in the hierarchy of the homologous series of alcohols, first tend to **increase** and then **decrease** (this pattern may sequentially continue), this pattern can be evident by studying the trends of **Methanol, Propanol** and **Pentanol**
- Alcohols that are **even** in the hierarchy of the homologous series of alcohols, first tend to **decrease** and then **increase** (this pattern may sequentially continue), this pattern can be evident by studying the trends of **Ethanol** and **Butanol**
- The solubility of Oxalic acid in various alcohols (in the order of the hierarchy of the homologous series of alcohols), generally **decreases**, ie. **The solubility in alcohols generally decreases as the length of the hydrocarbon chain increases**
- The solubility of Oxalic acid in a particular alcohol, generally **increases** with increase in temperature
- The solubility of Oxalic acid in various alcohols (in the order of the hierarchy of the homologous series of alcohols), generally **decreases** with increase in temperature, ie. **The solubility in alcohols generally decreases with respect to temperature as the length of the hydrocarbon chain increases**

## 8 Evaluation

When comparing our readings and data from (Syed T. Hussain, Gul A. Khan, et al), we see that if we are to define,  $TDS_{expt}$  as the experimentally found TDS for all cases and  $TDS_{art}$  as the TDS readings from the research article then we find that our error in the collected data is

$$\overline{TDS_{error}} = \frac{\sum_{n=1}^n \frac{TDS_{exp}}{TDS_{art}}}{n} = \frac{\frac{TDS_{exp}}{TDS_{art}} + \frac{TDS_{exp}}{TDS_{art}} + \frac{TDS_{exp}}{TDS_{art}} + \frac{TDS_{exp}}{TDS_{art}} + \frac{TDS_{exp}}{TDS_{art}}}{5}$$

Therefore we have,

$$\overline{TDS_{error}} = \pm 1.368 g/L$$

We see that the value of  $\overline{TDS_{error}}$  that, we have found is not equal to 1, but is relatively very close to it, so we can say that we have some errors in calculating the **Total Dissolved Solids in the Alcohol solutions**.

**Percentage uncertainty** in measurement of **Total Dissolved Solids in the Alcohol solutions** is  $|1 - \overline{TDS_{error}}| \cdot 100\% = 0.1368\% \approx 0.14\%$

## 9 Limitations of Study

As we have stated before, there are certain restrictions to this study/investigation, as well as certain strict conditions that restrain this system and prevent us from expanding our research capabilities into this phenomenon. Conditions such as,

- Restricting the value of temperature domain from 20°Celsius to 60°Celsius
- Restricting the study to only incorporate the first five alcohols from the homologous series of alcohols
- Using an cubic regression model instead of an higher order regression model

## 10 Safety Measures

The following are the safety precautions that were implemented during the experiment:

- Proper Laboratory equipment was utilized to conduct and collect data
- All Laboratory equipment was used in the presence of Lab instructors and Lab personnel



- The experiment was performed at a distance from the observer so as to, limit or eliminate the chances of any possible physical harm to the observer
- Before beginning experiments, all lab equipment was rigorously evaluated for any faults that could result in a safety hazard

## 11 Sources of Error

Errors may have crept into our raw and ordered data in various ways. A few probable causes of errors are:

1. The raw experimental data included in this investigation report was gathered through laboratory experimentation, and there are possible chances that the data acquired may have minor discrepancies in it
2. Random human errors made by the observer, such as parallax errors, which are insignificant.
3. Due to the lack of advanced equipment and the materials employed in the experiment, there are uncertainties that cannot be minimized in this investigation
4. Assumptions and conditions are applied to the system to analyze its dynamic behavior

## 12 Conclusion

In this paper, I have shown the effects of changes in the **temperature** on the **solubility** of Oxalic acid on various **alcohol solutions** by collecting raw data relating to the above parameters, under certain controlled conditions as so to completely study the **temperature dependence of solubility of Oxalic acid in various Alcohols with respect to a gradation on the homologous series**.

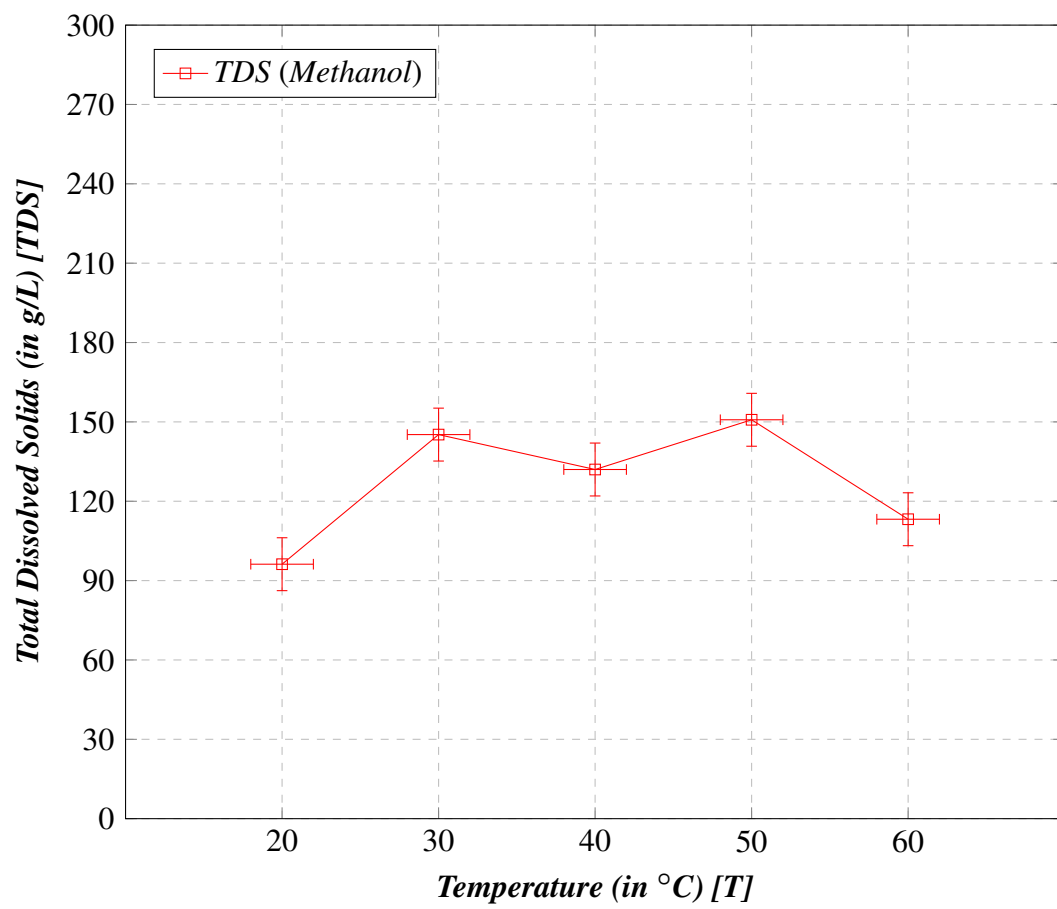
## Works Cited

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- [3] Syed Tasleem Hussain, Gul Abad Khan, Muhammad Shabeer, "Solubility of Oxalic Acid". *Asian J. Research Chem.* 5(11): Nov., 2012; Page 1323-1330.

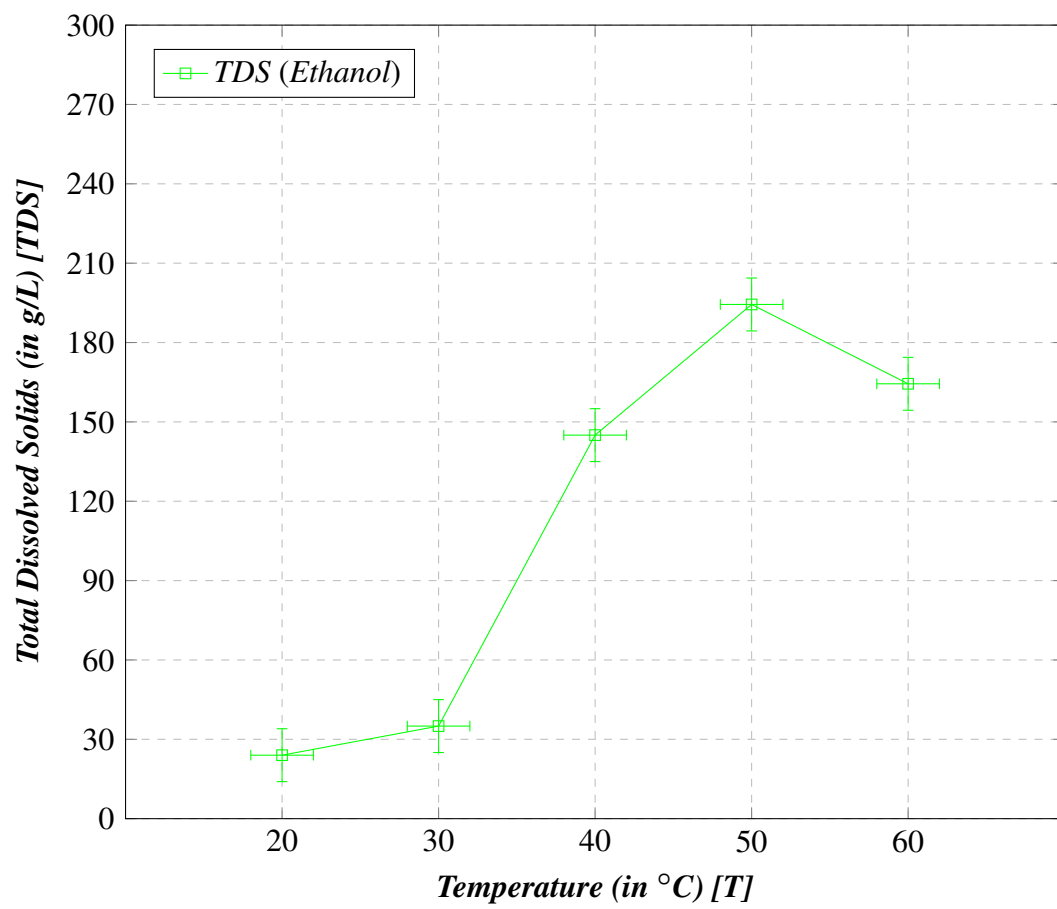


## A Appendix: Raw Data

Methanol		
Temperature (°C)	Trials	TDS Reading (g/L)
20	1	96
	2	97
	3	95
	4	97
	5	96
30	1	146
	2	145
	3	144
	4	145
	5	146
40	1	134
	2	132
	3	131
	4	133
	5	130
50	1	151
	2	148
	3	152
	4	154
	5	149
60	1	116
	2	112
	3	113
	4	115
	5	110

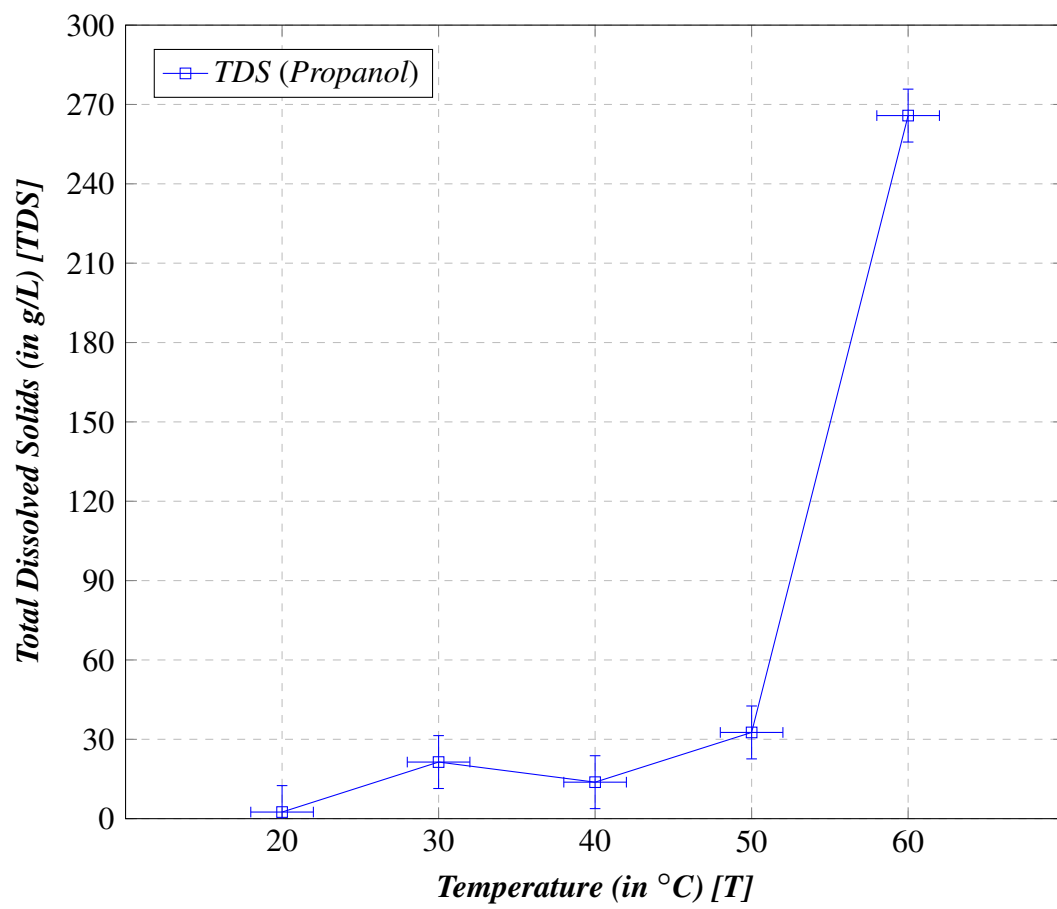


Ethanol		
Temperature (°C)	Trials	TDS Reading (g/L)
20	1	25
	2	22
	3	23
	4	26
	5	24
30	1	34
	2	36
	3	35
	4	36
	5	34
40	1	145
	2	146
	3	144
	4	144
	5	146
50	1	196
	2	194
	3	195
	4	192
	5	195
60	1	164
	2	165
	3	162
	4	166
	5	165

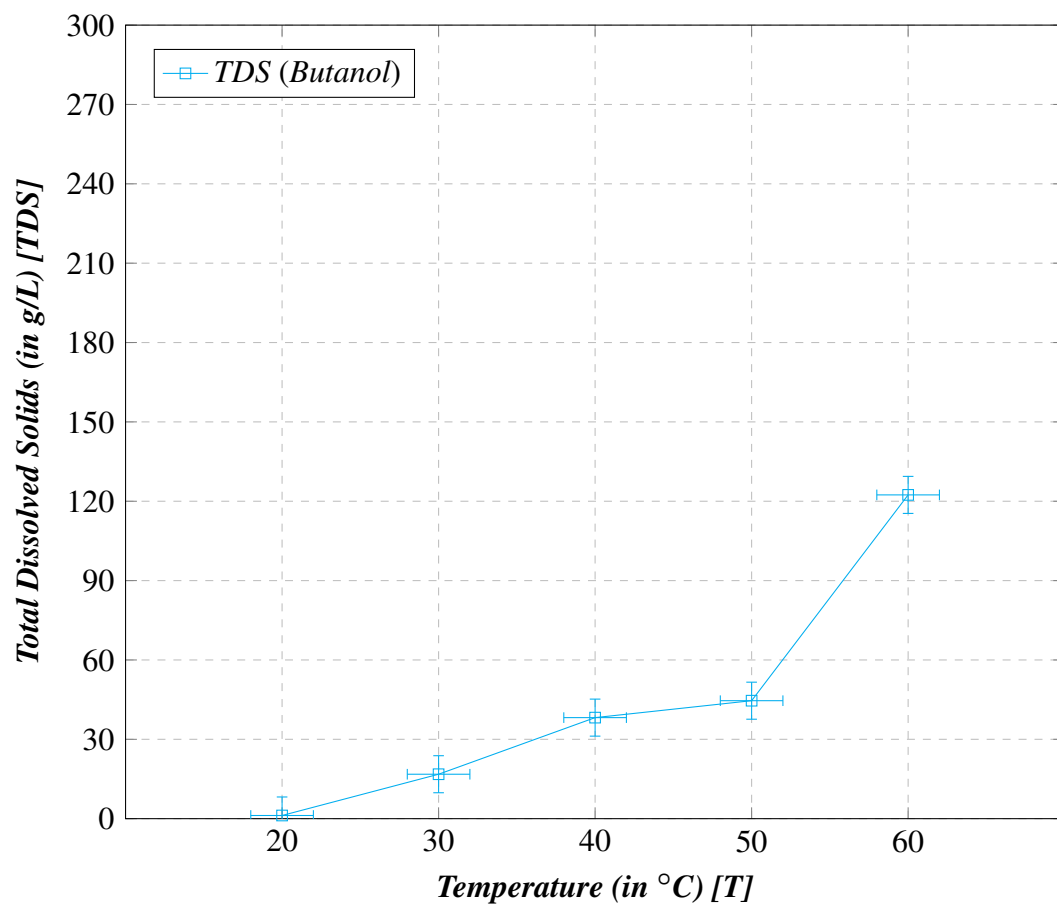


Propanol		
Temperature (°C)	Trials	TDS Reading (g/L)
20	1	2.5
	2	2.2
	3	2.6
	4	2.8
	5	2.4
30	1	29
	2	21
	3	20
	4	18
	5	19
40	1	14
	2	15
	3	13
	4	14
	5	13
50	1	33
	2	31
	3	32
	4	34
	5	33
60	1	266
	2	265
	3	267
	4	266
	5	265





Butanol		
Temperature (°C)	Trials	TDS Reading (g/L)
20	1	2.5
	2	2.2
	3	2.6
	4	2.8
	5	2.4
30	1	29
	2	21
	3	20
	4	18
	5	19
40	1	14
	2	15
	3	13
	4	14
	5	13
50	1	33
	2	31
	3	32
	4	34
	5	33
60	1	266
	2	265
	3	267
	4	266
	5	265



Pentanol		
Temperature (°C)	Trials	TDS Reading (g/L)
20	1	2.5
	2	0
	3	0
	4	0
	5	0
30	1	29
	2	6
	3	8
	4	7
	5	5.6
40	1	14
	2	15
	3	13
	4	14
	5	13
50	1	33
	2	31
	3	32
	4	34
	5	33
60	1	266
	2	265
	3	267
	4	266
	5	265

