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.

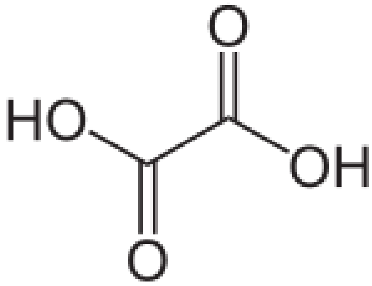


Figure 1: 2D chemic structure of the organic compound, Oxalic acid

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

Independent Variable	*Dependent Variable*
Temperature of Solution	Total Dissolved Solids
Alcohol Type	-

Controled Variable	*Reason for Control*	*Method of Control*
Alcohol concentration	Variation in the alcohol concentartion 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 inconsistant amount of alcohols would result in inacurate data readings	20 ml of Alcohol is used per trial
Amount of Oxalic Acid used	Using an inconsistant amount of oxalic acid would result in inacurate 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 primary, secondary or tertiary. For the purpose of this investigation, we shall only use primary alcohols.

4.4 Procedure

Step 1: Measure (using Pippetette) 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

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

Table 1: Processed Data from the experiment

7 Analysis

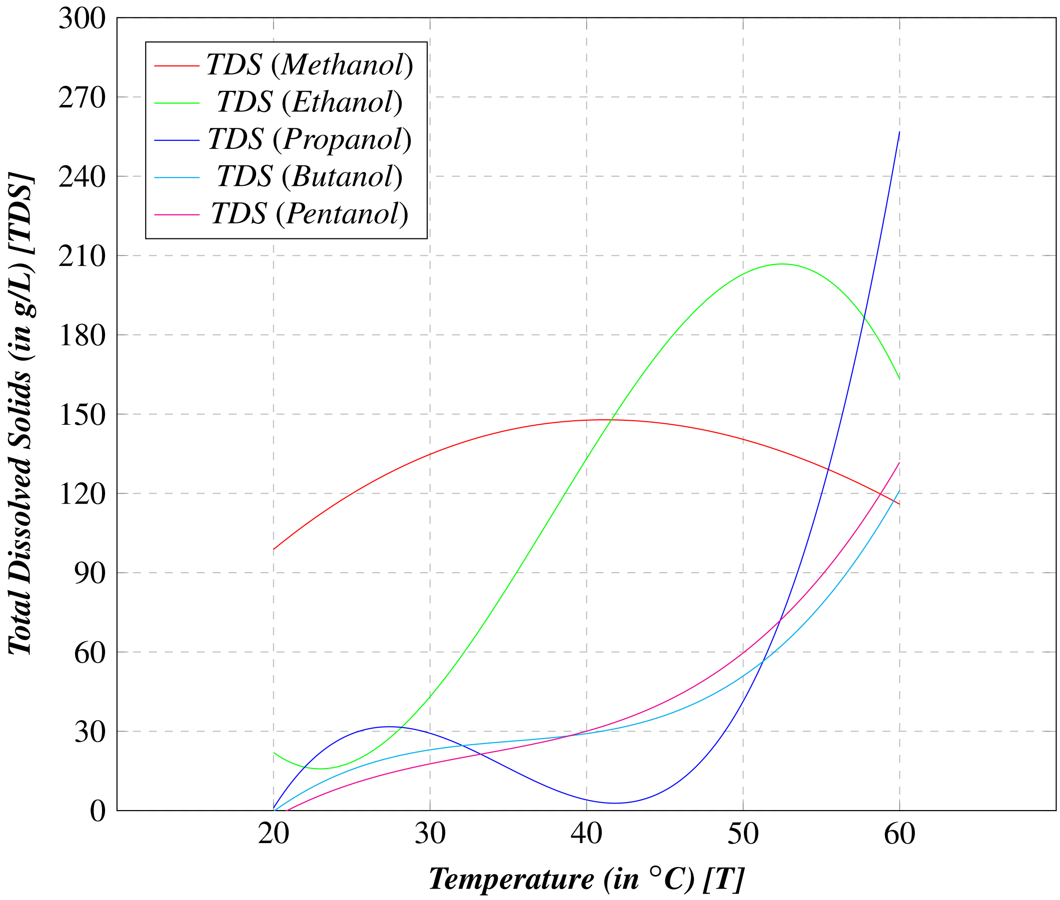


Figure 2: *Graph in relation to the* ***regression line*** *of* ***TDS*** *versus* ***temperature***

The above graph is the **cubic regression** of all **data points** within the **data set** of **experimentally collected values**. A **cubic regression** was utilized to plot the **line of best fit**, because a regression creates an **accurate model** of the system according to the data points and is a **mathematical function of each and every data point**. This was used rather than plotting an simple line between the range of the **maximum and minimum** values of the data points, as it would be 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 $^\circ$ C to 60 $^\circ$ 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 all),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 $\left|1 - \overline{TDS_{error}}\right| \cdot 100\% = \mathbf{0.1368\%} \approx \mathbf{0.14\%}$

9 Limitations of Study

There are various limitations in this study/investigation as we have placed forth, certain strict conditions that make this system so constrained and disables us to expand our researching capability of this chaotic 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 Safety Measures that were taken during the experimentation as as follows:

- 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
- Any and all lab equipment was thoroughly examined for any defects that could potentially lead to safety hazards, before initiating experimentation
- It was made sure the experiment shall not be performed to highly flammable materials that would result in combustion from the frictional force onto the alcohols

11 Sources of Error

There are various ways through which errors might have crept into our raw and ordered data, some of the possible sources of errors are:

1. Raw experimental data presented here in the investigation report is collected through lab experimentation, and there are chances that the data collected may have slight discrepancy in it
2. Insignificant random human errors by the observer, ie. parallax errors
3. Uncertainties that cannot be minimized due to lack of highly sophisticated equipment and materials used in the experiments in this investigation
4. Assumptions and certain conditions put forth on the the system to model its chaotic 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

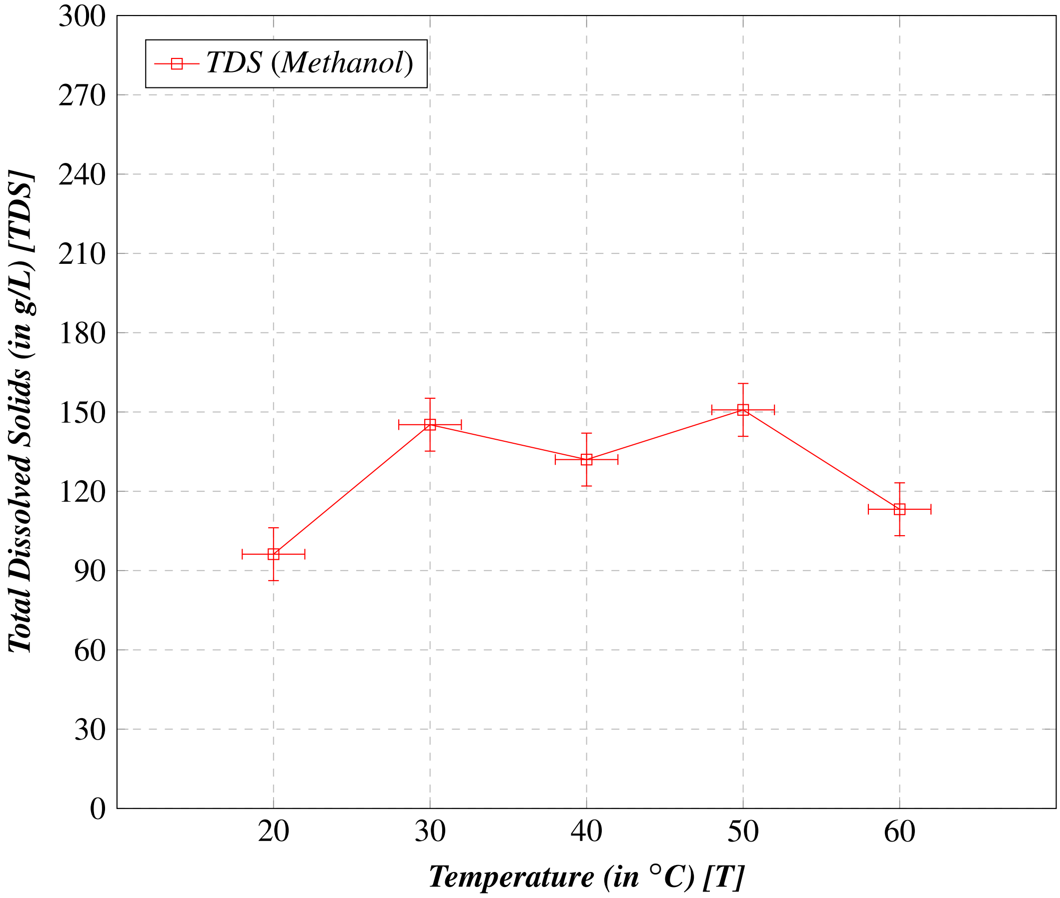
[1] National Center for Biotechnology Information. ”PubChem Compound Summary for CID 971, Oxalic acid” *PubChem*, `https://pubchem.ncbi.nlm.nih.gov/compound/Oxalic-acid`. Accessed 3 December, 2021.

[2] “Oxalic Acid — Formula, Uses, Facts.” *Encyclopedia Britannica*, PubChem, `www.britannica.com/science/oxalic-acid`. Accessed 3 Dec. 2021.

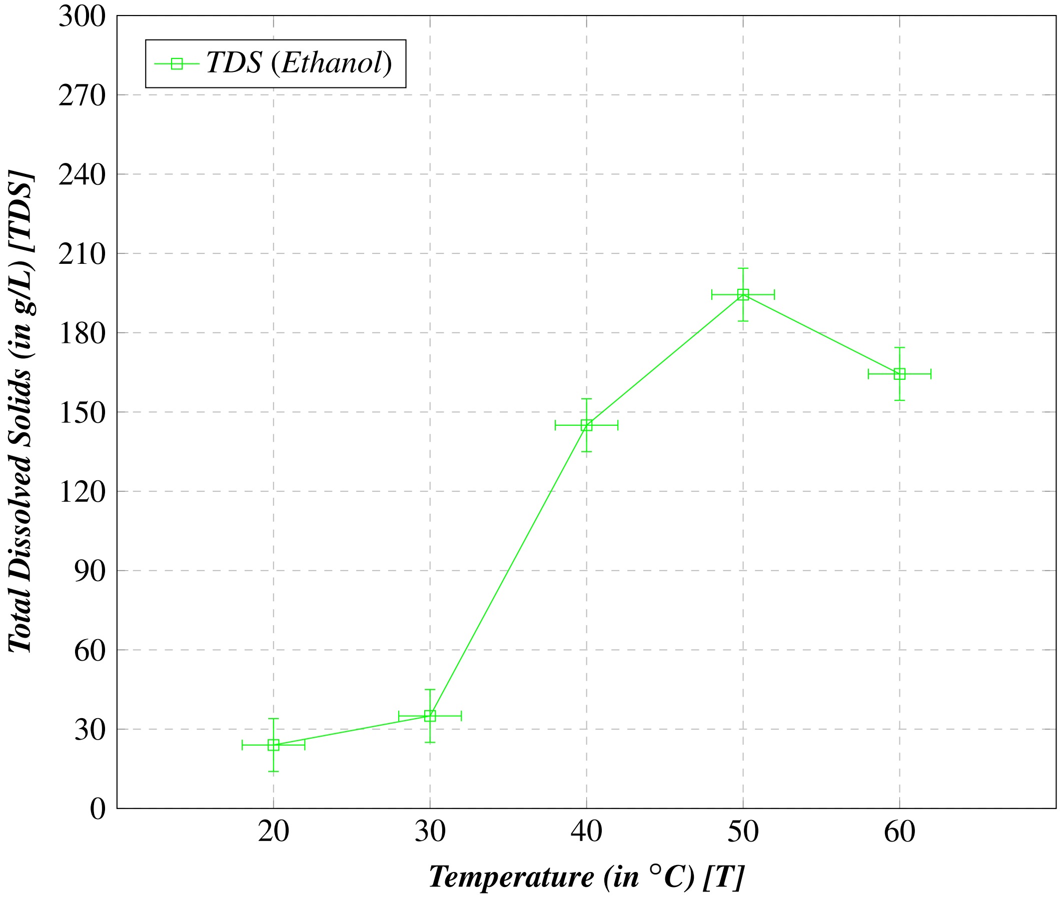
[3] Syed Tasleem Hussain, Gul Abad Khan, Muhammad Shabeer, ”Solubility of Oxalic Acid”. *Asian J. Research Chem*. 5(11): Nov., 2012; Page 1323-1330.

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

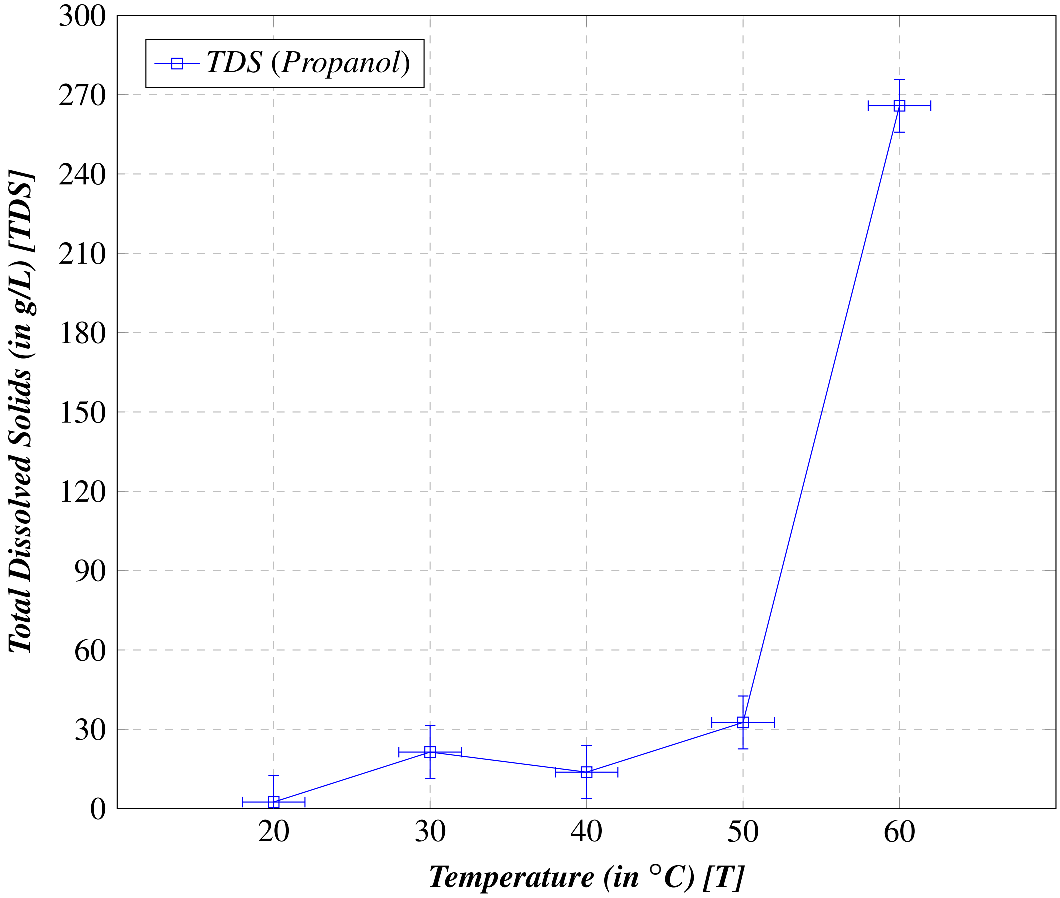

TDS (Methanol)
Total Dissolved Solids (in g/L) [TDS]
Temperature (in °C) [T]
0
30
60
90
120
150
180
210
240
270
300
20
30
40
50
60

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

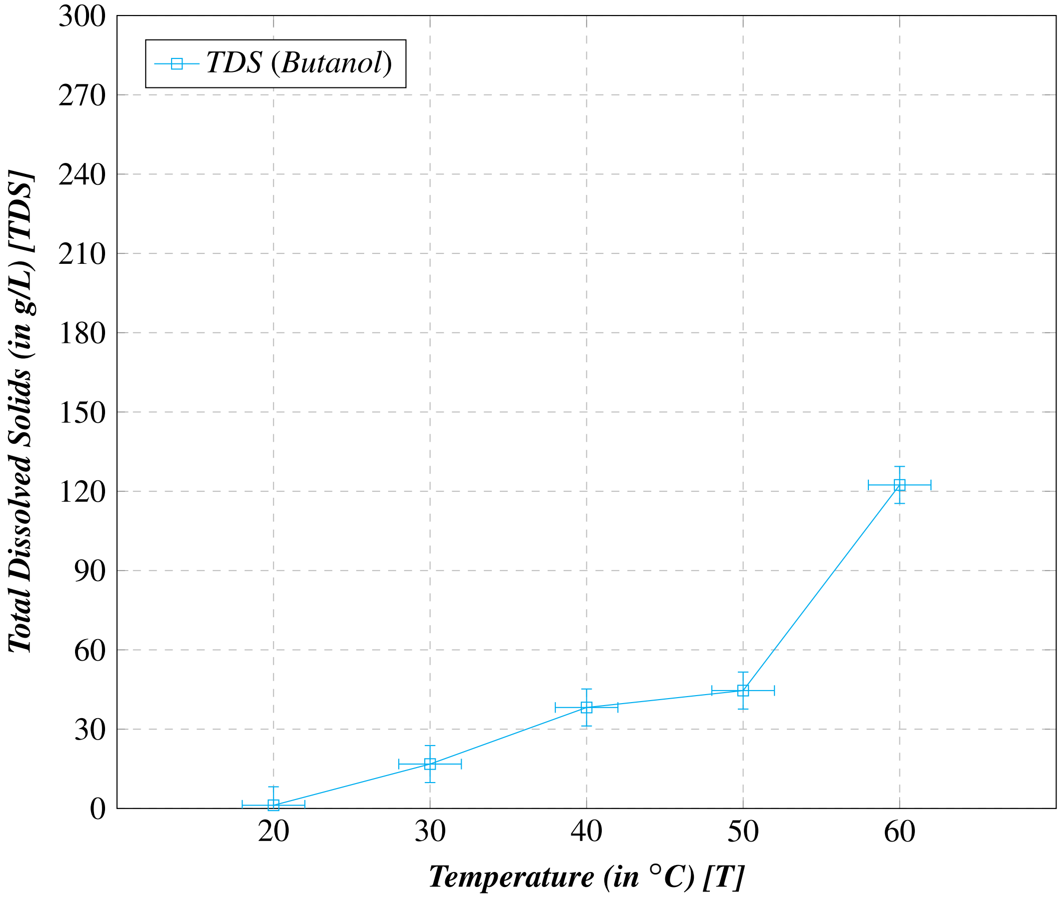


TDS (Ethanol)
300
270
240
210
180
150
120
90
60
30
0
Total Dissolved Solids (in g/L) [TDS]
20
30
40
50
60
Temperature (in °C) [T]

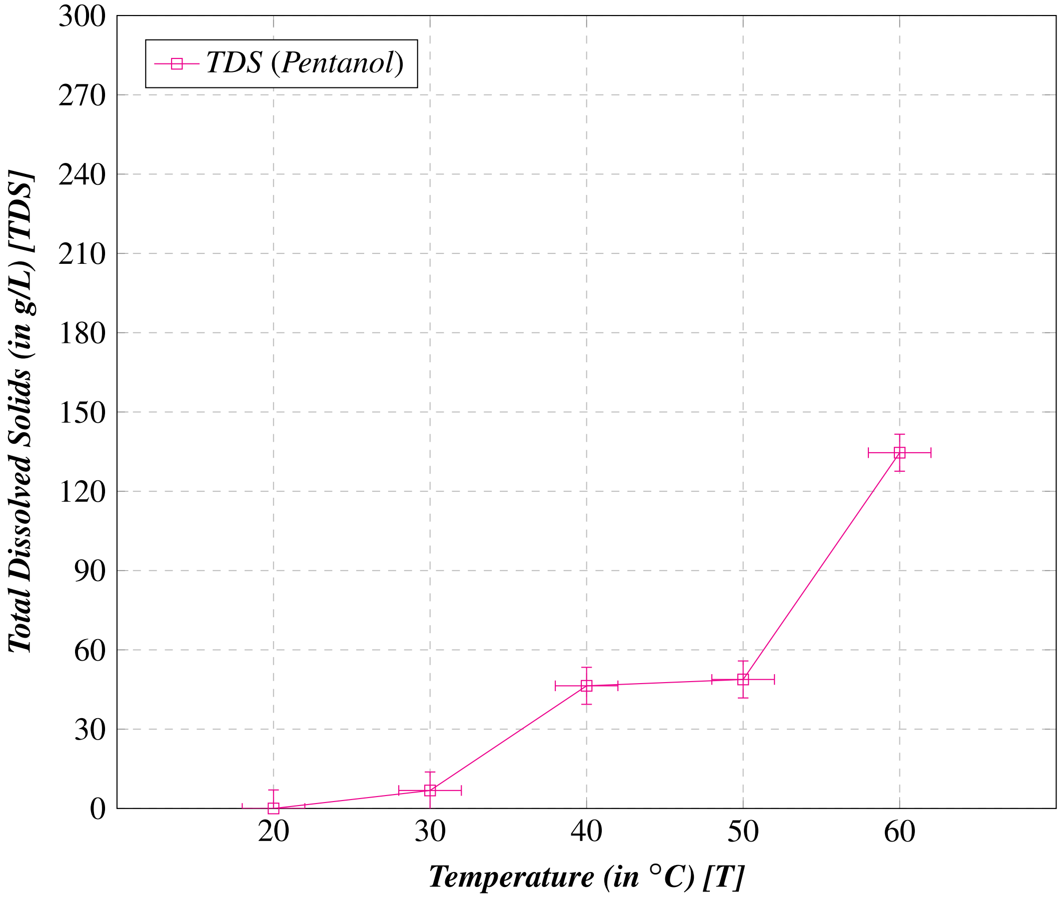
Propanol		
Temperature (°C)	Trials	TDS Reading (g/L)
20	1	2.5
	2	2.2
	3	2.6
	4	2.8
	5	2.4
30	1	29
	2	21
	3	20
	4	18
	5	19
40	1	14
	2	15
	3	13
	4	14
	5	13
50	1	33
	2	31
	3	32
	4	34
	5	33
60	1	266
	2	265
	3	267
	4	266
	5	265


TDS (Propanol)
Total Dissolved Solids (in g/L) [TDS]
Temperature (in °C) [T]
0
30
60
90
120
150
180
210
240
270
300
20
30
40
50
60

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


TDS (Butanol)
300
270
240
210
180
150
120
90
60
30
0
20
30
40
50
60
Total Dissolved Solids (in g/L) [TDS]
Temperature (in °C) [T]

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



TDS (Pentanol)
Total Dissolved Solids (in g/L) [TDS]
300
270
240
210
180
150
120
90
60
30
0
20
30
40
50
60
Temperature (in °C) [T]