SASTA OLIPHANT SCIENCE AWARDS

Prize Winner

Scientific Inquiry

Year 9-10

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Australian Government Department of Defence

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SASTA South Australian Science Teachers Association

Effects of Acidification on the Surface Tension of Water

By Benita and Kyra

Oliphant Scientific Inquiry

QUESTIONING AND PREDICTING

BY BENITA WU AND KYRA HUANG

INTRODUCTION

The surface tension of liquids is frequently utilized within science and the environment. Water (H2O) has the second highest surface tension of known liquids of 72mN/m (Laurén, 2023). This high surface tension has supported ecosystems by aiding insects and raise the xylem tissues of plants within bodies of water, making surface tension of water a crucial part of the environment (Georgia Tech Biological Sciences, 2024). Due to issues with climate change and ocean acidification, the balance and properties of ocean water is altering, causing changes within the surface tension (Union of Concerned Scientists, 2019). This raised the question of how increased acidity of water affects its surface tension and modifies the impact it has on the environment. This investigation explored the affect acidification has in a body of water.

AIM

The aim of the experiment was to determine the impact of acidification on the surface tension of water in relation to ocean acidification.

HYPOTHESIS

If the acidity of the solution increases, the surface tension will decrease due to molecular interactions.

BACKGROUND INFORMATION

SURFACE TENSION

Surface tension is the chemical property of the surface of liquids and their ability to resist external force (Water Science School, 2019). The surface tension of liquids is caused by the attraction of particles on the surface layer and is determined by intermolecular forces within the fluids. The properties of liquids make it difficult to move a substance through liquid due to the strong attractive forces of the molecules near the surface, as shown in Figure 1(Laurén, 2023). Surface tension is only directly measurable for liquids (Kibron, 2022).

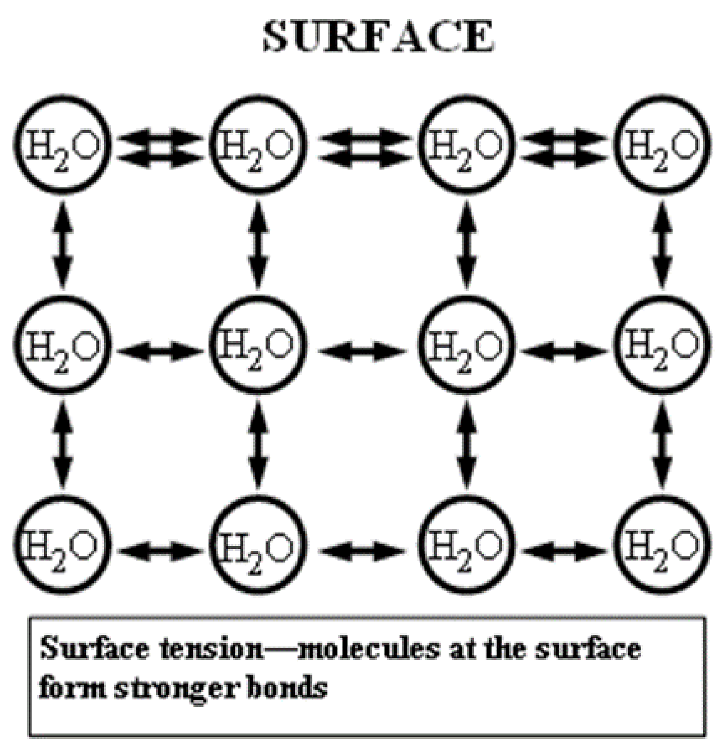

Figure 1: A diagram of the surface of liquid molecules.
Surface Tension and Water | U.S. Geological Survey (usgs.gov)

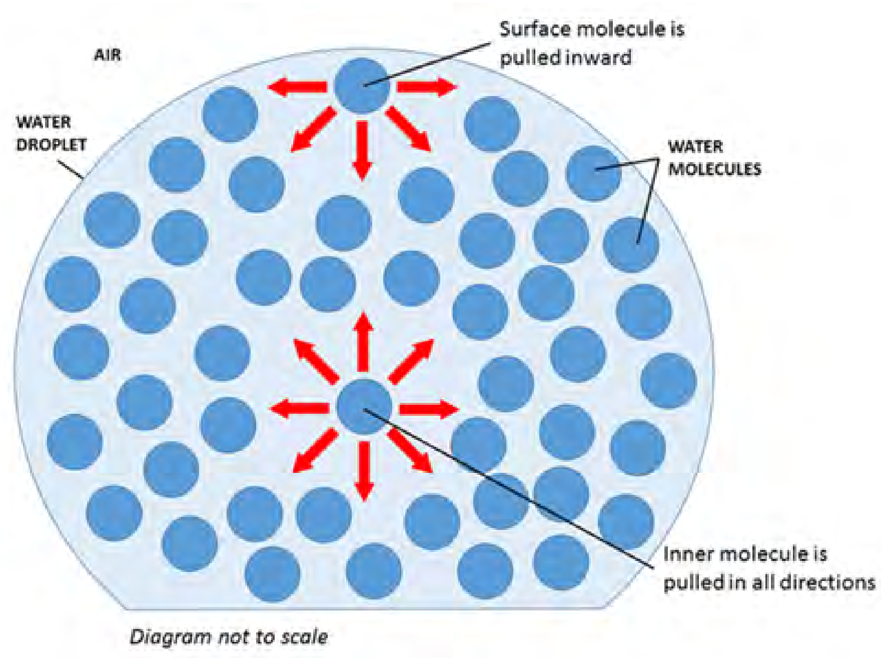

Figure 2: A diagram of the intermolecular forces a water droplet.
Measuring Surface Tension of Water with a Penny | Science Project (sciencebuddies.org)

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BACKGROUND INFORMATION

WATER AND HYDROGEN BONDING

Hydrogen bonding is an intermolecular force that forms a type of dipole-dipole attraction when a hydrogen atom is bonded to an electronegative atom. It is the strongest type of intermolecular force and generates high surface tensions (Byjus, 2022). Water is able to form 4 hydrogen bonds, causing it to have an extremely high surface tension, as seen in figure 1. On the surface of water, molecules only interact with molecules underneath them and the water molecules experience interactions in all directions, causing the net force of the molecules to face inwards, which is illustrated in figure 2 (University of Hawaii, 2024). Due to their hydrogen bonds, water molecules are attracted to each other, resulting in strong intermolecular forces in the surface causing molecules to contract and resist against being stretched or broken, as shown in figure 2 (Laurén, 2023).

ACIDS

Acids are chemical substances which contain hydrogen ions and are capable of donating a proton (Byjus, 2018). They have a lower pH and density compared to water, and exhibits 3 intermolecular forces: London dispersion forces, Dipole-Dipole forces and hydrogen bonding (Shah et al., 2022). When reacted to bases, they form salts as the cations of the base is combined with anions of the acid. Acids can be identified by observing the number of hydrogens in each substance before and after a reaction. The decrease of hydrogens indicates that the substance is an acid as it donates hydrogen ions (Byjus, 2018).

Vinegar is acetic acid which is a carboxylic acid with the chemical formula of CH_3COOH, as shown in figure 3. Acetic acid, also known as ethanoic acid has a carboxylic acid functional group which can produce hydrogen bonding and dipole-dipole interactions. Like water, it is a polar substance causing its molecules to attract with water molecules when forming a solution (Extramarks, 2022). This creates a homogenous mixture where the water molecules are dissolved into the vinegar molecules (Toppr, 2020).

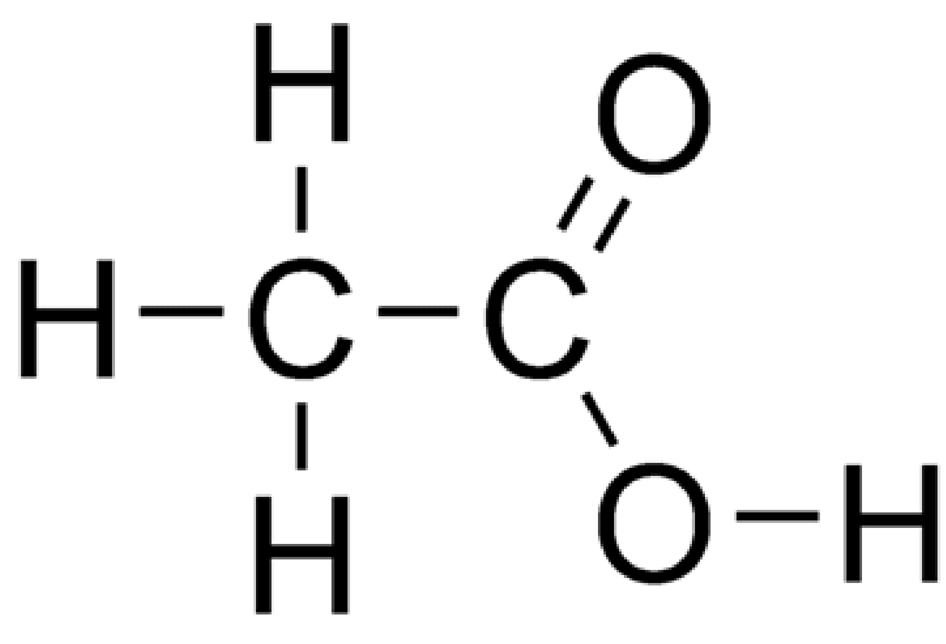

Figure 3: A diagram of the chemical composition of vinegar.
Chemical Composition of Vinegar (thoughtco.com)

Lemon juice has the chemical formula of C6H8O7, consisting of water, citric acid and carboxylic acid, as shown in figure 4 (AL-Jabri, 2018). Lemon juice has the density of approximately 1.66g/cm³. When it is added to water, the acid dissociates into charged cations and anions, forming a homogonous mixture with water (Vedantu, 2020).

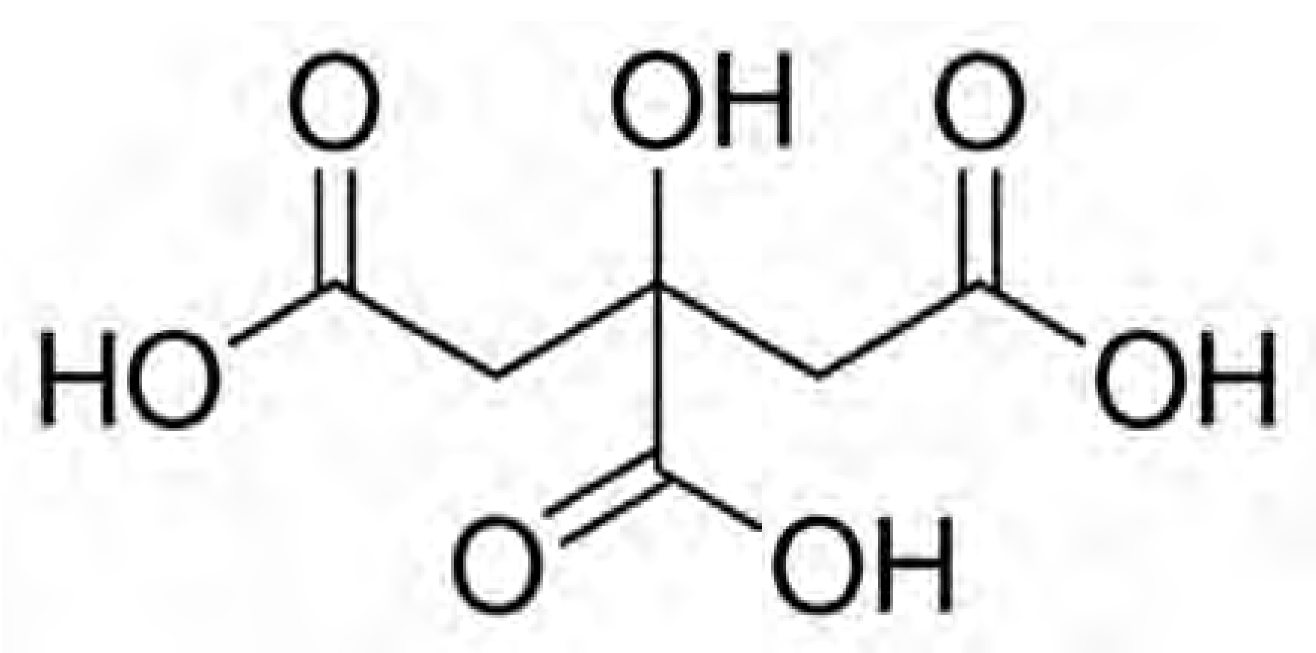

Figure 4: A diagram of the chemical composition of lemon juice.
https://www.worldofmolecules.com/acid-base-molecules/citric-acid.html

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CHOICE OF METHOD

This experiment was done in the same environment, ensuring a tighter control of variables, and is easily repeatable, which makes it easier to examine the effects of the independent variable on the dependent variable.
This investigation uses the capillary action to find the surface tension of the solutions. Capillary action utilizes adhesion and cohesive forces which create the strong forces between liquid molecules and cause liquids to stick to solid surfaces, resulting in the rise of the liquid up the straw. The height the liquid rises is used to calculate the surface tension with the formula $S = \rho hga/2$, where g stands for acceleration due to gravity, h is the height the liquid rises above water, a is the radius of the thin tube, ρ is the density of the liquid and S is the surface tension (Ruff, 2022).

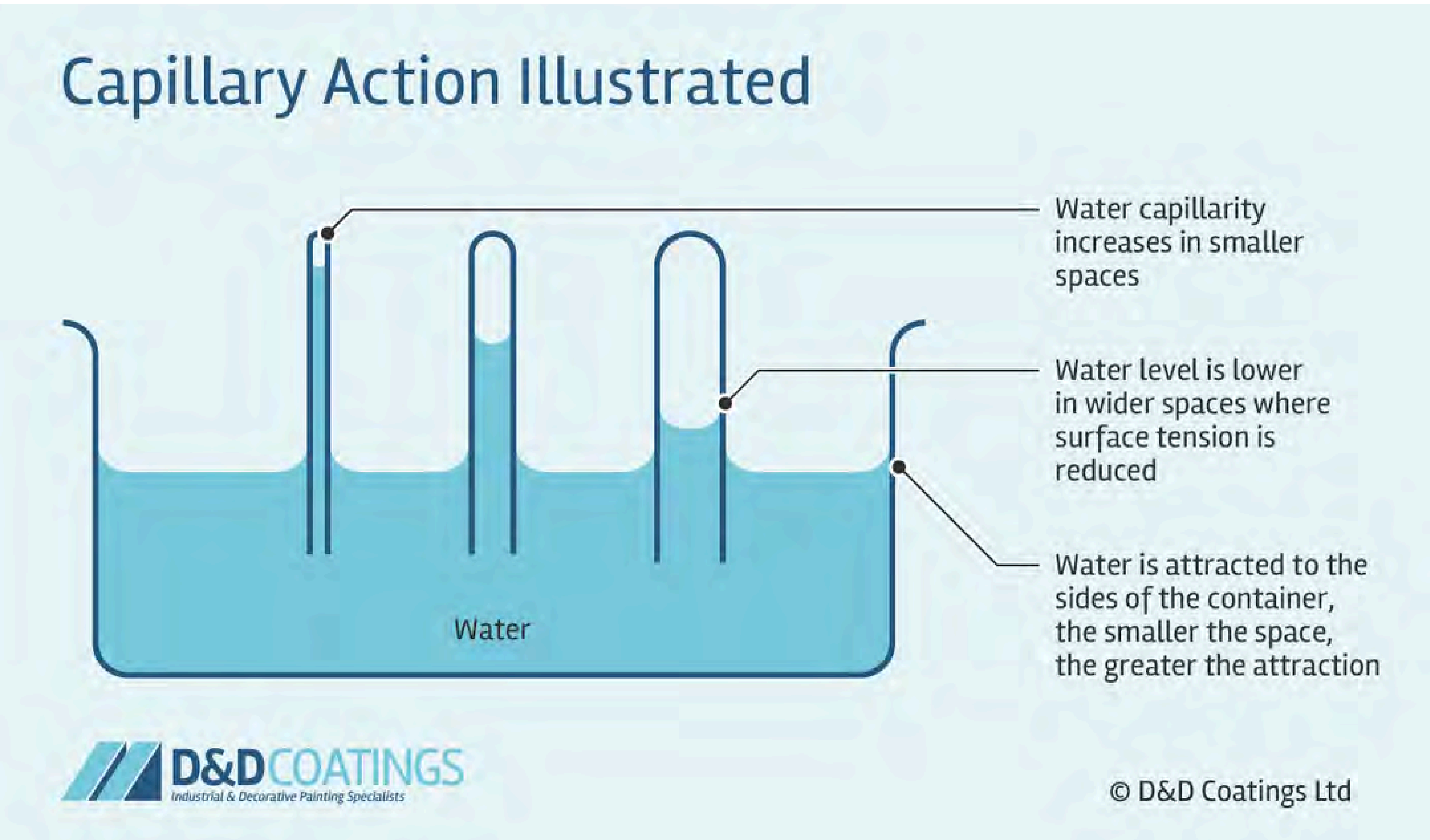

Figure 5: A diagram of Capillary Action
https://www.ddcoatings.co.uk/3213/capillary-action

WHY IS THIS A FAIR TEST?

To ensure a fair test, there must be one variable that is changed (independent variable), one that is measured (dependent variable), and all other variables kept the same (control variable), allowing the experiment to determine the affect of the independent variable on the dependent variable. The variables of this experiment are shown in Table 1. The experiment was also repeated twice, with the average measure taken, to increase the accuracy and reliability of the practical. To maintain the credibility of this experiment, potential biases (systematic and random) were avoided.

Table 1: Variables

Independent Variable	The concentration of acid in the solution (%)
Dependent Variable	Surface tension of solutions (J/m^2)
Controlled Variables	Type of Water
	Type of vinegar & citric acid
	Total amount of liquid (L)
	Temperature of liquid
	Person measuring and taking the results
	Ruler used to measure
	Environment used for experiment

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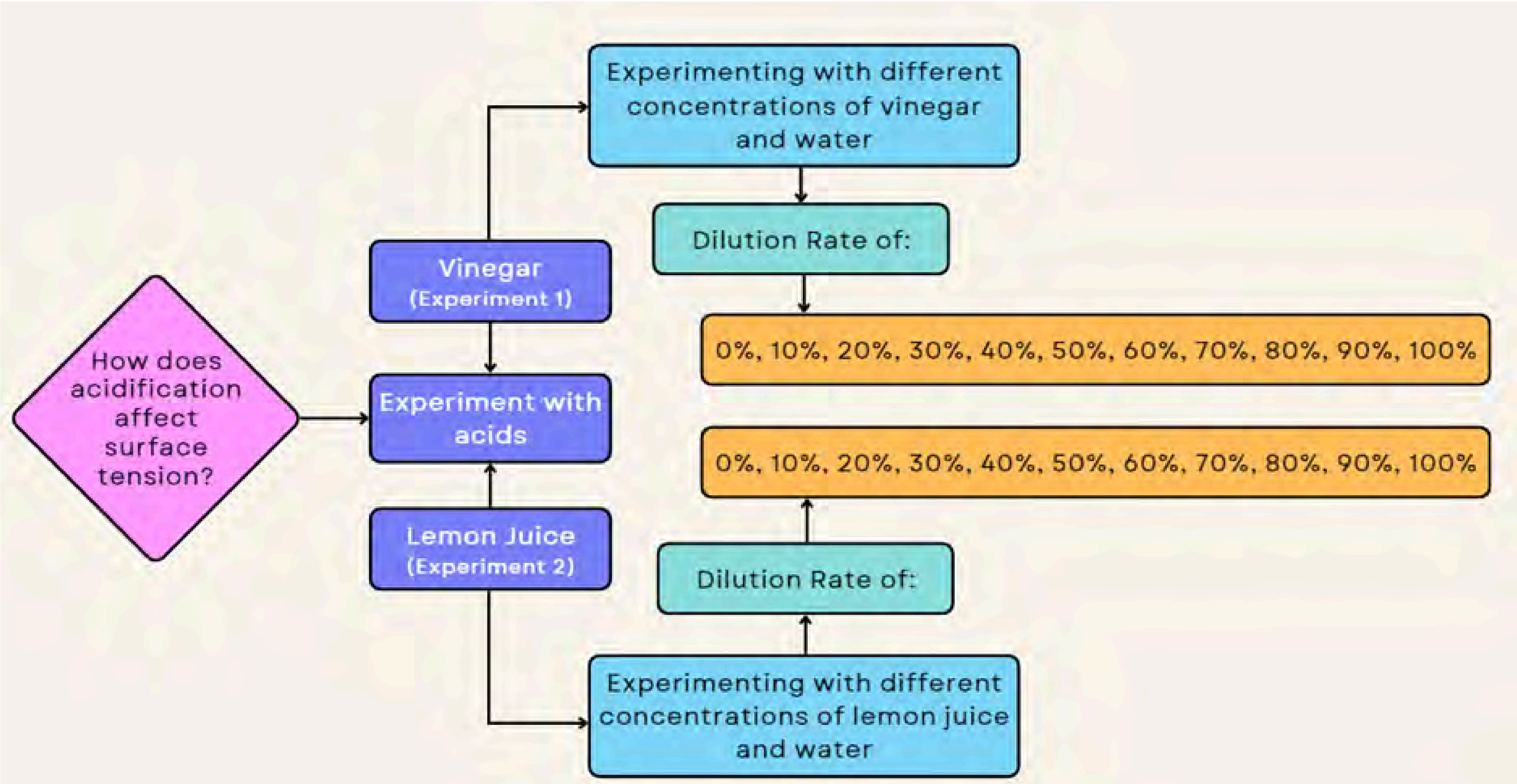
EXPERIMENT FLOWCHART



METHOD

1. 150mL of tap water was added to the cup.
2. Vinegar was added to the water according to calculations for the dilution level.
3. The plastic straw was put vertically into the centre of the cup.
4. A ruler was used to measure the height of the water raised above the surface of the glass.
5. The glass, ruler and straw were thoroughly rinsed.
6. Steps 1 to 4 were repeated for each dilution level, and the calculations below were used.
7. Steps 1 to 5 were repeated for lemon juice.

Table 2: Dilution of vinegar and lemon juice calculations

Amount of Water (mL)	Dilution Level	Calculations	Amount of Acids (mL)
150	0%	0*150	0
135	10%	0.1*150	15
120	20%	0.2*150	30
105	30%	0.3*150	45
90	40%	0.4*150	60
75	50%	0.5*150	75
60	60%	0.6*150	90
45	70%	0.7*150	105
30	80%	0.8*150	120
15	90%	0.9*150	135
0	100%	1*150	150

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EQUIPMENT AND MATERIALS

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MATERIALS

- *Vinegar x675mL*
- *Lemon Juice x675mL*
- *Water x1.35L*
- *Ruler x1*
- *Straw x1 (0.7cm in diameter)*
- *Spoon (for stirring) x1*
- *Scale (for weighing) x1*
- *Glass Cup x1*
- *Disposable Syringe x1*

Figure 6: Photos showing the materials used during the experiment.

POSSIBLE RISKS

Table 3: Risk audit

Possible Risks	Likelihood of risk	Measures of risk prevention
Reckless handling of vinegar could cause accidental inhalation or eye injuries.	Medium Risk	Measuring small amounts of vinegar at a time and making sure all bottles are labelled.
Liquid spillage could cause a tripping hazard	High Risk	Ensure all spillages are cleaned immediately.
Glass cups breaking from inattentive handling, causing glass shards scattered around experiment.	Medium Risk	Ensure all glass materials are kept within the middle of the table.
Injuries from reckless actions with materials.	Low Risk	Keeping distractions away whilst focusing on experiment and ensure the safe handling of materials.

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FORMULA

FORMULA FOR SURFACE TENSION

$$S = \frac{\rho h g a}{2}$$

ρ = density (kg/m^3)

h = height above water (m)

g = acceleration due to gravity (9.8m/s^2)

a = radius (m)

RESULTS - VINEGAR

Note: All figures are rounded to 2 decimal places other than for surface tension due to the small range of data, where is it rounded to 3 significant figures for comparison.

Table 4: Height above vinegar dilutions trial 1, trial 2, and average

Concentration of Vinegar	Height above water (mm) Trial 1	Height above water (mm) Trial 2	Average Height (mm)
0%	5.00	4.90	4.95
10%	4.50	4.20	4.35
20%	4.10	3.80	3.95
30%	3.80	3.50	3.65
40%	3.20	3.10	3.15
50%	3.00	3.00	3.00
60%	2.50	2.80	2.65
70%	2.20	2.30	2.25
80%	1.90	2.00	1.95
90%	1.40	1.30	1.35
100%	1.00	1.00	1.00

RESULTS - VINEGAR (CONTINUED)

Table 5: Average surface tension calculations for vinegar

Concentration	Density (kg/ m^3)	Height (m)	Acceleration (ms^2)	Radius (m)
0%	≈997	0.00495	9.8	0.007
10%	≈998	0.00435	9.8	0.007
20%	≈999	0.00395	9.8	0.007
30%	≈1000	0.00365	9.8	0.007
40%	≈1001	0.00315	9.8	0.007
50%	≈1002	0.003	9.8	0.007
60%	≈1003	0.00265	9.8	0.007
70%	≈1004	0.00225	9.8	0.007
80%	≈1005	0.00195	9.8	0.007
90%	≈1006	0.00135	9.8	0.007
100%	≈1007	0.001	9.8	0.007

Table 6: Finding average surface tension of solutions: rounded to 3 significant figures

Concentration	Formula	Surface tension (J/m^2)
0%	$\frac{997 \times 0.00495 \times 9.8 \times 0.007}{2}$	≈0.169
10%	$\frac{998 \times 0.00435 \times 9.8 \times 0.007}{2}$	≈0.149
20%	$\frac{999 \times 0.00395 \times 9.8 \times 0.007}{2}$	≈0.135
30%	$\frac{1000 \times 0.00365 \times 9.8 \times 0.007}{2}$	≈0.125
40%	$\frac{1001 \times 0.00315 \times 9.8 \times 0.007}{2}$	≈0.108
50%	$\frac{1002 \times 0.003 \times 9.8 \times 0.007}{2}$	≈0.103
60%	$\frac{1003 \times 0.00265 \times 9.8 \times 0.007}{2}$	≈0.091
70%	$\frac{1004 \times 0.00225 \times 9.8 \times 0.007}{2}$	≈0.077
80%	$\frac{1005 \times 0.00195 \times 9.8 \times 0.007}{2}$	≈0.067
90%	$\frac{1006 \times 0.00135 \times 9.8 \times 0.007}{2}$	≈0.047
100%	$\frac{1007 \times 0.001 \times 9.8 \times 0.007}{2}$	≈0.035

RESULTS - VINEGAR (CONTINUED)

Table 7: Trial 1 surface tension calculations for vinegar

Concentration	Formula	Surface tension (J/m²)
0%	$\frac{997\times0.005\times9.8\times0.007}{2}$	≈0.171
10%	$\frac{998\times0.0045\times9.8\times0.007}{2}$	≈0.154
20%	$\frac{999\times0.0041\times9.8\times0.007}{2}$	≈0.140
30%	$\frac{1000\times0.0038\times9.8\times0.007}{2}$	≈0.130
40%	$\frac{1001\times0.0032\times9.8\times0.007}{2}$	≈0.110
50%	$\frac{1002\times0.003\times9.8\times0.007}{2}$	≈0.103
60%	$\frac{1003\times0.0025\times9.8\times0.007}{2}$	≈0.086
70%	$\frac{1004\times0.0022\times9.8\times0.007}{2}$	≈0.076
80%	$\frac{1005\times0.0019\times9.8\times0.007}{2}$	≈0.065
90%	$\frac{1006\times0.0014\times9.8\times0.007}{2}$	≈0.048
100%	$\frac{1007\times0.001\times9.8\times0.007}{2}$	≈0.035

RESULTS - VINEGAR (CONTINUED)

Table 8: Trial 2 surface tension calculations for vinegar

Concentration	Formula	Surface tension (J/m^2)
0%	$\frac{997 \times 0.0049 \times 9.8 \times 0.007}{2}$	≈0.168
10%	$\frac{998 \times 0.0042 \times 9.8 \times 0.007}{2}$	≈0.144
20%	$\frac{999 \times 0.0038 \times 9.8 \times 0.007}{2}$	≈0.130
30%	$\frac{1000 \times 0.0035 \times 9.8 \times 0.007}{2}$	≈0.120
40%	$\frac{1001 \times 0.0031 \times 9.8 \times 0.007}{2}$	≈0.106
50%	$\frac{1002 \times 0.003 \times 9.8 \times 0.007}{2}$	≈0.103
60%	$\frac{1003 \times 0.0028 \times 9.8 \times 0.007}{2}$	≈0.096
70%	$\frac{1004 \times 0.0023 \times 9.8 \times 0.007}{2}$	≈0.079
80%	$\frac{1005 \times 0.002 \times 9.8 \times 0.007}{2}$	≈0.069
90%	$\frac{1006 \times 0.0013 \times 9.8 \times 0.007}{2}$	≈0.045
100%	$\frac{1007 \times 0.001 \times 9.8 \times 0.007}{2}$	≈0.035

Table 9: Surface tension of diluted vinegar from both trials and average

Concentration of Vinegar	Trial 1 (J/m^2)	Trial 2 (J/m^2)	Average (J/m^2)
0%	≈0.171	≈0.168	≈0.169
10%	≈0.154	≈0.144	≈0.149
20%	≈0.140	≈0.130	≈0.135
30%	≈0.130	≈0.120	≈0.125
40%	≈0.110	≈0.106	≈0.108
50%	≈0.103	≈0.103	≈0.103
60%	≈0.086	≈0.096	≈0.091
70%	≈0.076	≈0.079	≈0.077
80%	≈0.065	≈0.069	≈0.067
90%	≈0.048	≈0.045	≈0.047
100%	≈0.035	≈0.035	≈0.035

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RESULTS - LEMON JUICE

Table 10: Height above lemon juice dilutions trial 1, trial 2, and average

Concentration of Lemon Juice	Height above water (mm) Trial 1	Height above water (mm) Trial 2	Average Height (mm)
0%	5.00	5.00	5.00
10%	4.00	3.90	3.95
20%	2.50	2.30	2.40
30%	2.10	2.20	2.15
40%	2.00	2.10	2.05
50%	2.00	2.00	2.00
60%	1.90	1.90	1.90
70%	1.70	1.80	1.75
80%	1.30	1.50	1.40
90%	1.00	1.10	1.05
100%	0.75	0.50	0.63

Table 11: Average surface tension calculations for lemon juice

Concentration	Density (kg/m^3)	Height (m)	Acceleration (ms^2)	Radius (m)
0%	≈997	0.005	9.8	0.007
10%	≈1000	0.00395	9.8	0.007
20%	≈1003	0.0024	9.8	0.007
30%	≈1007	0.00215	9.8	0.007
40%	≈1010	0.00205	9.8	0.007
50%	≈1013	0.002	9.8	0.007
60%	≈1017	0.0019	9.8	0.007
70%	≈1020	0.00175	9.8	0.007
80%	≈1023	0.0014	9.8	0.007
90%	≈1027	0.00105	9.8	0.007
100%	≈1030	0.000625	9.8	0.007

RESULTS - LEMON JUICE (CONTINUED)

Table 12: Finding average surface tension of solutions: rounded to 3 significant figures

Concentration	Formula	Surface tension
0%	$\frac{997\times0.005\times9.8\times0.007}{2}$	≈0.171
10%	$\frac{1000\times0.00395\times9.8\times0.007}{2}$	≈0.135
20%	$\frac{1003\times0.0024\times9.8\times0.007}{2}$	≈0.083
30%	$\frac{1007\times0.00215\times9.8\times0.007}{2}$	≈0.074
40%	$\frac{1010\times0.00205\times9.8\times0.007}{2}$	≈0.071
50%	$\frac{1013\times0.002\times9.8\times0.007}{2}$	≈0.069
60%	$\frac{1017\times0.0019\times9.8\times0.007}{2}$	≈0.066
70%	$\frac{1020\times0.00175\times9.8\times0.007}{2}$	≈0.061
80%	$\frac{1023\times0.0014\times9.8\times0.007}{2}$	≈0.049
90%	$\frac{1027\times0.00105\times9.8\times0.007}{2}$	≈0.037
100%	$\frac{1030\times0.000625\times9.8\times0.007}{2}$	≈0.022

RESULTS - LEMON JUICE (CONTINUED)

Table 13: Trial 1 surface tension calculations for lemon juice

Concentration	Formula	Surface tension
0%	$\frac{997 \times 0.005 \times 9.8 \times 0.007}{2}$	≈0.171 J/m^2
10%	$\frac{1000 \times 0.004 \times 9.8 \times 0.007}{2}$	≈0.137 J/m^2
20%	$\frac{1003 \times 0.0025 \times 9.8 \times 0.007}{2}$	≈0.086 J/m^2
30%	$\frac{1007 \times 0.0021 \times 9.8 \times 0.007}{2}$	≈0.073 J/m^2
40%	$\frac{1010 \times 0.002 \times 9.8 \times 0.007}{2}$	≈0.069 J/m^2
50%	$\frac{1013 \times 0.002 \times 9.8 \times 0.007}{2}$	≈0.069 J/m^2
60%	$\frac{1017 \times 0.0019 \times 9.8 \times 0.007}{2}$	≈0.066 J/m^2
70%	$\frac{1020 \times 0.0017 \times 9.8 \times 0.007}{2}$	≈0.059 J/m^2
80%	$\frac{1023 \times 0.0013 \times 9.8 \times 0.007}{2}$	≈0.046 J/m^2
90%	$\frac{1027 \times 0.001 \times 9.8 \times 0.007}{2}$	≈0.035 J/m^2
100%	$\frac{1030 \times 0.00075 \times 9.8 \times 0.007}{2}$	≈0.026 J/m^2

RESULTS - LEMON JUICE (CONTINUED)

Table 14: Trial 2 surface tension calculations for lemon juice

Concentration	Formula	Surface tension (J/m²)
0%	$\frac{997\times0.005\times9.8\times0.007}{2}$	≈0.171
10%	$\frac{1000\times0.0039\times9.8\times0.007}{2}$	≈0.134
20%	$\frac{1003\times0.0023\times9.8\times0.007}{2}$	≈0.079
30%	$\frac{1007\times0.0022\times9.8\times0.007}{2}$	≈0.076
40%	$\frac{1010\times0.0021\times9.8\times0.007}{2}$	≈0.073
50%	$\frac{1013\times0.002\times9.8\times0.007}{2}$	≈0.069
60%	$\frac{1017\times0.0019\times9.8\times0.007}{2}$	≈0.066
70%	$\frac{1020\times0.0018\times9.8\times0.007}{2}$	≈0.063
80%	$\frac{1023\times0.0015\times9.8\times0.007}{2}$	≈0.053
90%	$\frac{1027\times0.0011\times9.8\times0.007}{2}$	≈0.035
100%	$\frac{1030\times0.0005\times9.8\times0.007}{2}$	≈0.018

Table 15: Surface Tension of diluted lemon juice from both trials and average

Concentration of Lemon Juice	Trial 1 (J/m²)	Trial 2 (J/m²)	Average (J/m²)
0%	≈0.171	≈0.171	≈0.171
10%	≈0.137	≈0.134	≈0.135
20%	≈0.086	≈0.079	≈0.083
30%	≈0.073	≈0.076	≈0.074
40%	≈0.069	≈0.073	≈0.071
50%	≈0.069	≈0.069	≈0.069
60%	≈0.066	≈0.066	≈0.066
70%	≈0.059	≈0.063	≈0.061
80%	≈0.046	≈0.053	≈0.049
90%	≈0.035	≈0.035	≈0.037
100%	≈0.026	≈0.018	≈0.022

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PROCESSING AND ANALYSING DATA AND INFORMATION

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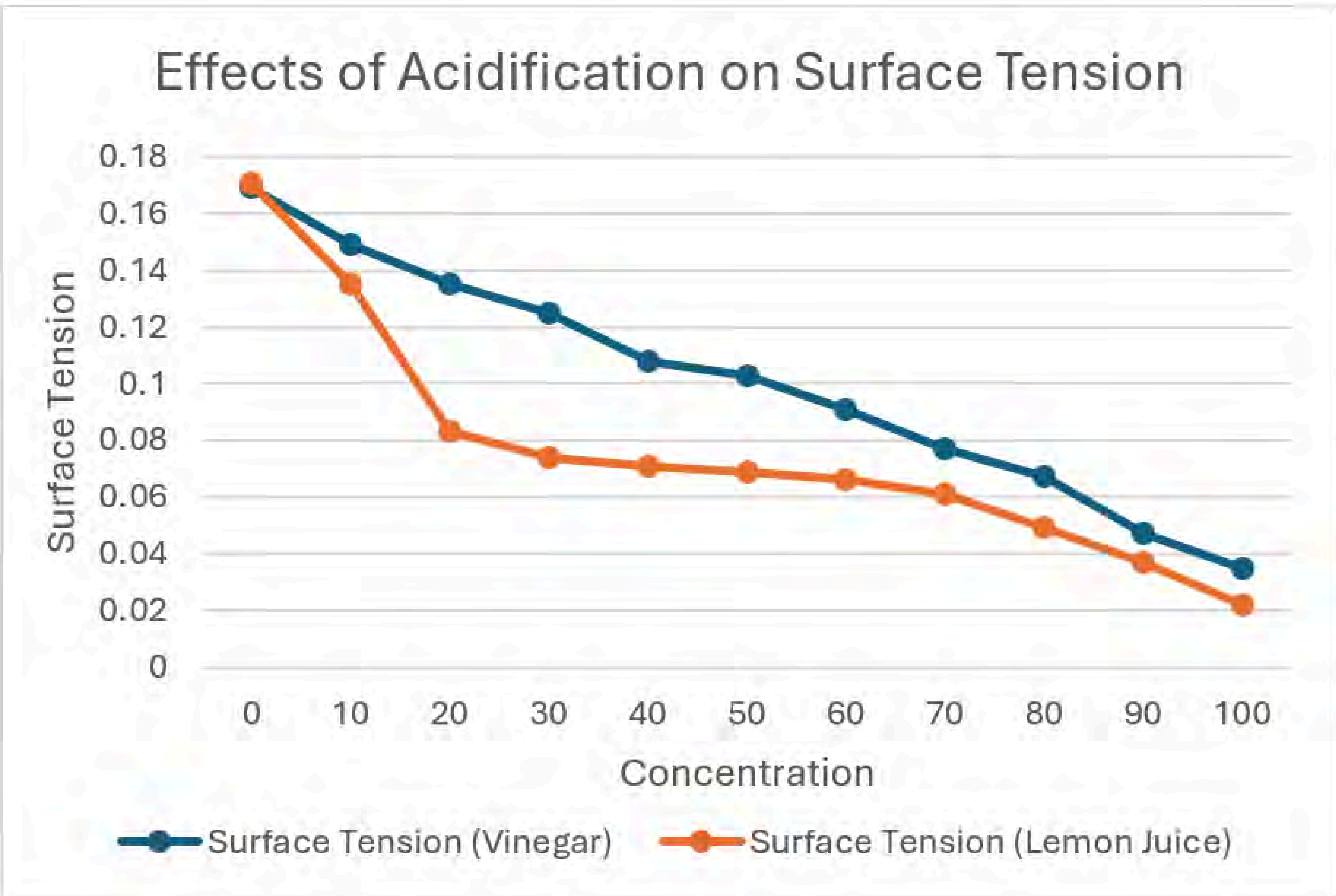
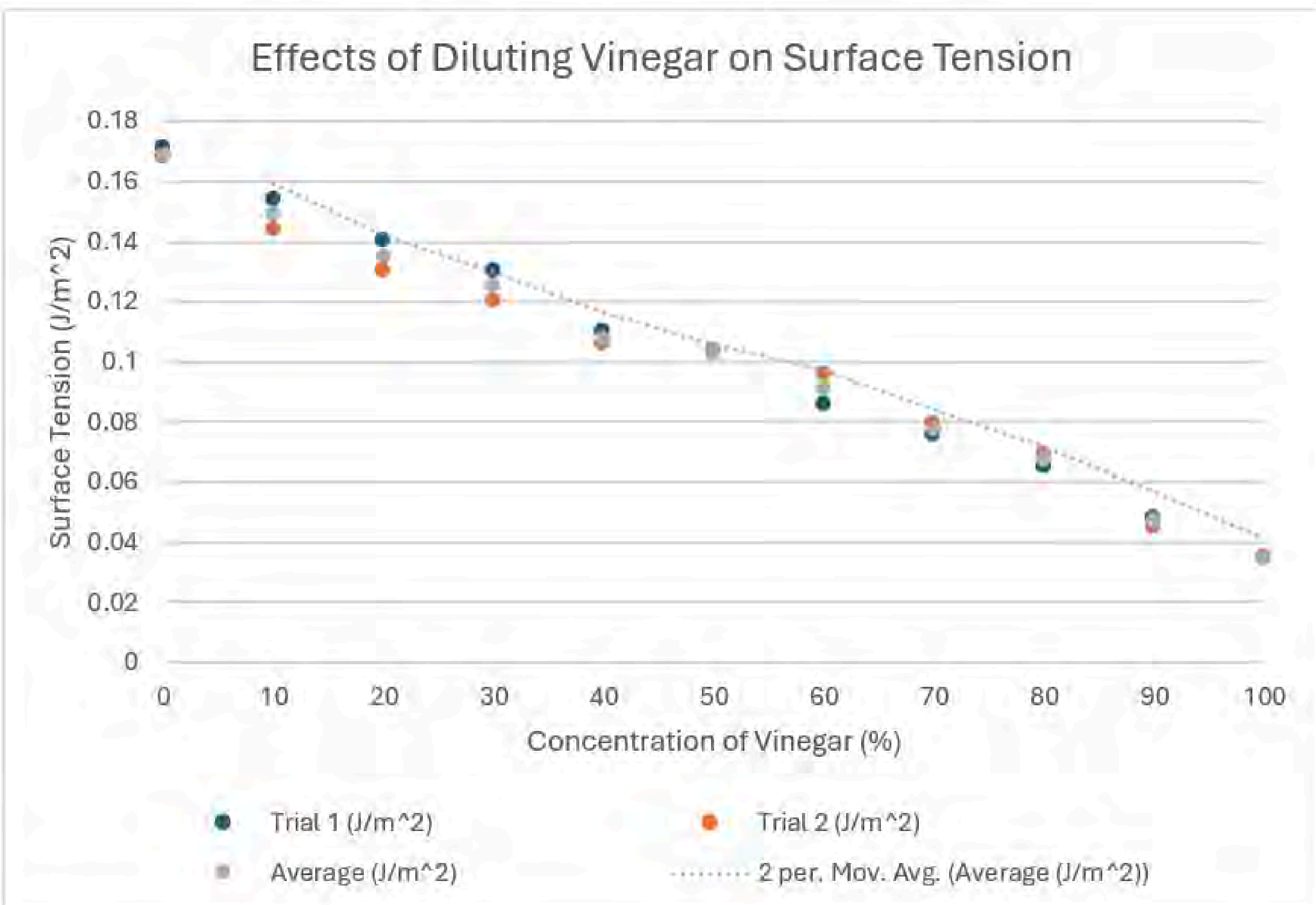
GRAPHS

Graph 1: Effects of diluting vinegar and lemon juice on surface tension of water



Graph 2: Effects of diluting vinegar on surface tension



PROCESSING AND ANALYSING DATA AND INFORMATION

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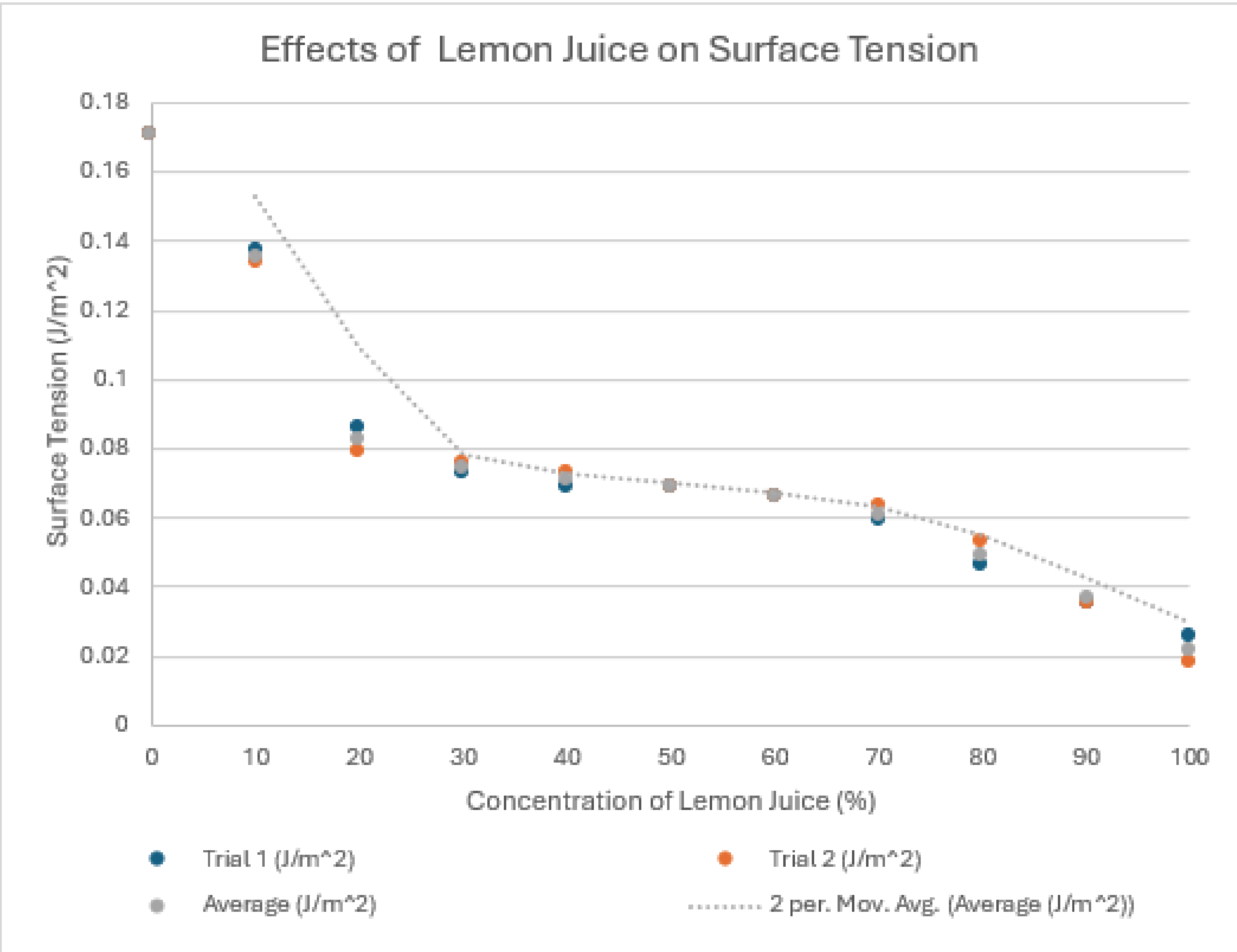
GRAPHS (CONTINUED)

Graph 3: Effects of diluting lemon juice on surface tension



DISCUSSION

Across all the graphs, a negative relationship between the concentration of the acid and surface tension was shown, proving that as the concentration of acids increased, the surface tension of the liquid decreased. Graph 2 had a relatively more consistent decreasing trend in comparison to Graph 3. As shown in Graph 1 and Graph 3, there was a very steep decrease in the surface tension between 0% and 30% of lemon juice. The slope then became more gradual until 70%, where it dropped again, replicating the steep slope on the left side of the graph. Both Graphs 2 and 3, with diluted vinegar and lemon juice, showed that as more vinegar was added to the solution, the surface tension would decrease can be drawn.

DISCUSSION (CONTINUED)

In Graph 1, the lowest point of the average surface tension for the dilution of vinegar was at 0.035 J/m^2 and the peak was at 0.169 J/m^2, while the lowest point for lemon juice was at 0.022 J/m^2 and the peak was 0.171 J/m^2, both acids at 0% to 100% concentration respectively for the lowest point and peak. This showed that as the concentration of acidic substances in the water increases, the surface tension will decrease, supported by the decreasing trend of both lines in the graph and illustrating a negative relationship between the concentration of acids and the surface tension. As more vinegar was added to the liquid until there were no remaining water molecules – reaching 100% concentration – the surface tension decreased by 0.134 J/m^2 while adding lemon juice would reduce the surface tension by 0.149 J/m^2. As the lemon juice had a slightly lower pH than the vinegar, making it more acidic, it had a vaguely bigger effect on the surface tension of the water. This was supported throughout the graph, as the surface tension of the diluted lemon juice was mostly lower than diluted vinegar. The only exception for this was at 0% concentration, being pure tap water.

In Graph 2, with vinegar diluted into the water, the surface tension from the first trial was usually stronger than in trial 2 by minor differences. When the concentration of vinegar was 0%, the result from trial 1 was higher than in trial 2 by less than 0.005 J/m^2. As the concentration of vinegar increased, there was an increase in the margin of error, with the result from trial 1 being bigger than the result from trial 2 by around 0.01 J/m^2. At 50% and 100% vinegar, the results across both trials were the same. In Graph 3, with diluted lemon juice, the strength of the surface tension across the two trials varied. However, the margin of error between the trials was smaller than vinegar, the difference generally being less than 0.01 J/m^2, as shown in Table 15. At 0%, 50%, and 60% of lemon juice, the surface tension across all trials was identical. This shows that the precision of the data was relatively high. Across the graphs, the few inconsistencies and fluctuations could have been due to potential errors in the experiment.

DISCUSSION (CONTINUED)

The decreasing surface tension when acid was added to the solution could have been due to the decrease in water molecules. Water has a naturally higher surface tension than vinegar due to its intermolecular force, polarity, and hydrogen bonding. Water has a higher polarity and stronger hydrogen bonding than vinegar, causing its intermolecular force to be high, as hydrogen bonds are the strongest intermolecular force (Toppr, 2020). Acids generally exhibit 3 intermolecular forces: Dipole Dipole, hydrogen bonding, and London dispersion (Cassandra, 2021). However, the hydrogen bonding in water is a lot stronger than those in vinegar and lemon juice, due to its molecular structure of two negative oxygen attracted with 1 positive hydrogen (Monzur, 2016). So, as more acid is added to the solution, less hydrogen bonding will be formed, decreasing its intermolecular force, which decreases the overall surface tension.

The results could have also been affected by the temperature. Acidic substances generally have a higher temperature than basic substances. An increase in the temperature could lead to a decrease in the surface tension. This is due to molecular thermal activities increasing, which causes a decrease in the intermolecular cohesive forces (Unacademy, 2022). As the temperature of water increases, more hydrogen ions are also formed due to endothermic processes, which can either enhance or weaken the hydrogen bonds, affecting their strength (LibreTexts, 2013).

Overall, the precision of this data was fairly high. The surface tension remained consistent across both trials, with a slow, downward trend of the results as the concentration of vinegar increased, which supports the hypothesis. There were a few small fluctuations which may have been caused by external factors that were not controlled or were hard to control.

Oliphant Scientific Inquiry

EVALUATION

BY BENITA WU AND KYRA HUANG

IMPROVEMENTS

A main improvement for this experiment was to use multiple different methods to measure surface tension. This would drastically improve the reliability of the results as thereoretically, different methods should still provide similar results. Another improvement was to use a thermometer to measure the starting temperatures of the liquids to ensure that there is a consistent starting temperature as surface tension is affected by temperature. This would increase the accuracy of the investigation as temperature was an uncontrolled variable.

POTENTIAL ERRORS

Table 16: Systematic Errors

Systematic Errors	Effect on Results	Improvements
Tap water was used, which means there could be varying differences in acidity and pH.	This could have altered the starting acidity of the water used as tap water could contain different amount of acidity to bottled or spring water.	Bottled water from the same brand could be used to improve the accuracy.
The straw was placed in different areas of the cup during different trials.	Whilst the cup had a flat bottom so the height would not have changed much, this still could have slightly altered the results.	To make sure the straw is placed in the same spot during every trial. To help this, the chosen spot can be marked at the bottom of the cup, so it is easier to find.

Table 17: Random Errors

Random Errors	Effect on Results	Improvements
Taking the height of water rising above the surface relied on eyesight, could have been potential human error	This would have affected the precision of the results as relying on eyesight is not completely accurate.	Setting a camera up on the same angle to capture the height.
Some inconsistent dilutions of acid and water from using measuring cups with intervals of 20mL.	This would have affected the accuracy of the results as slight differences with the concentration could have affected the overall surface tension.	By using measuring cups labelled for every 5 intervals so no measurement had to be estimated.

POTENTIAL ERRORS (CONTINUED)

Table 21: Factors not controlled/were hard to control.

Uncontrolled factors	Effect on Results	Improvements
Room temperature around the experiment.	The temperature of the water could be affected by the room temperature, therefore affecting the precision of the results as temperature alters surface tension.	By controlling the room temperature as much as possible and carrying out the experiments as quickly and efficiently as possible.
Lighting	The natural lighting could have dimmed throughout the time of the experiment, which could have changed the perception of the results, affecting the accuracy of the results.	By opening lights and closing windows to keep the environment at a similar lighting.

FURTHER INVESTIGATION

Further investigations on this topic of the effect of acidification on surface tension, would be to investigate with a variety of strong and weak acids. By observing the differences in surface tension with more acids, more conclusions can be drawn on how the difference chemical properties of each acid affect its surface tension compared to others. Basic substances can also be tested to experiment on the effect alkalines have on surface tension and how their chemical properties affect the result of the experiment.

Figure 7: Photos showing different acids and bases tested for pH that could be used for further investigation.

Oliphant Scientific Inquiry

EVALUATION

BY BENITA WU AND KYRA HUANG

CONCLUSION

The aim of this investigation was to determine the effects of acidification on the surface tension of water in relation to ocean acidification. The hypothesis that if the acidity of the solution increases, the surface tension will decrease due to molecular interactions, is supported. This is shown through the graphs, where there was a steady downward trend depicting the decrease of surface tension as the concentration of vinegar and lemon juice increases. Many improvements could be made to this experiment to avoid potential biases and increase the accuracy of this experiment.

ACKNOWLEDGEMENTS

Dr O'Halloran *(our teacher) gave us feedback on our discussions and guided us to understand the scientific concepts.*

Ms Salvi *(our teacher) helped us with getting initial ideas for the experiment and helped us understand the theories behind the experiment better.*

WORD COUNT

2198 words (headings, titles, tables, figure captions, references, and log book not included)

***There can be up to 10% tolerance of the word limit.*

Figure 8: Photos showing the procedures during the experiment.

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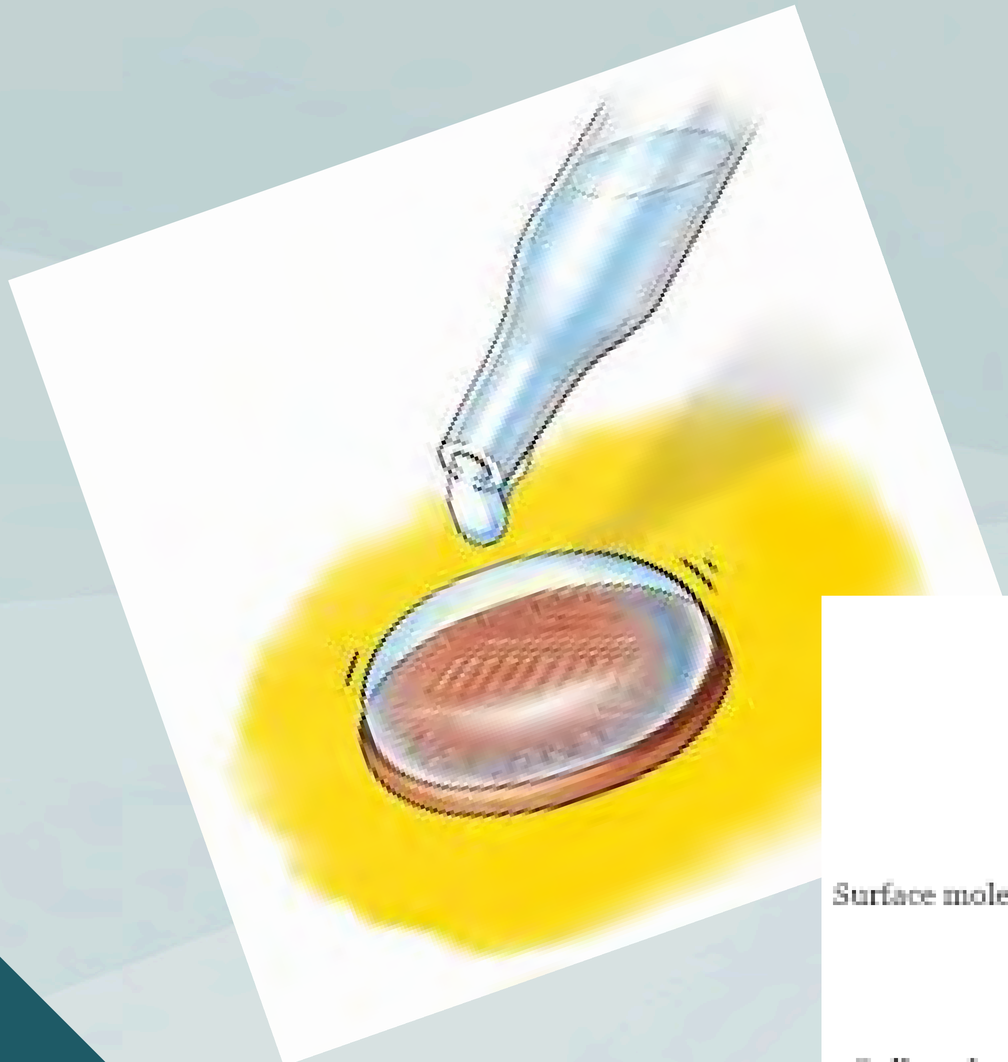
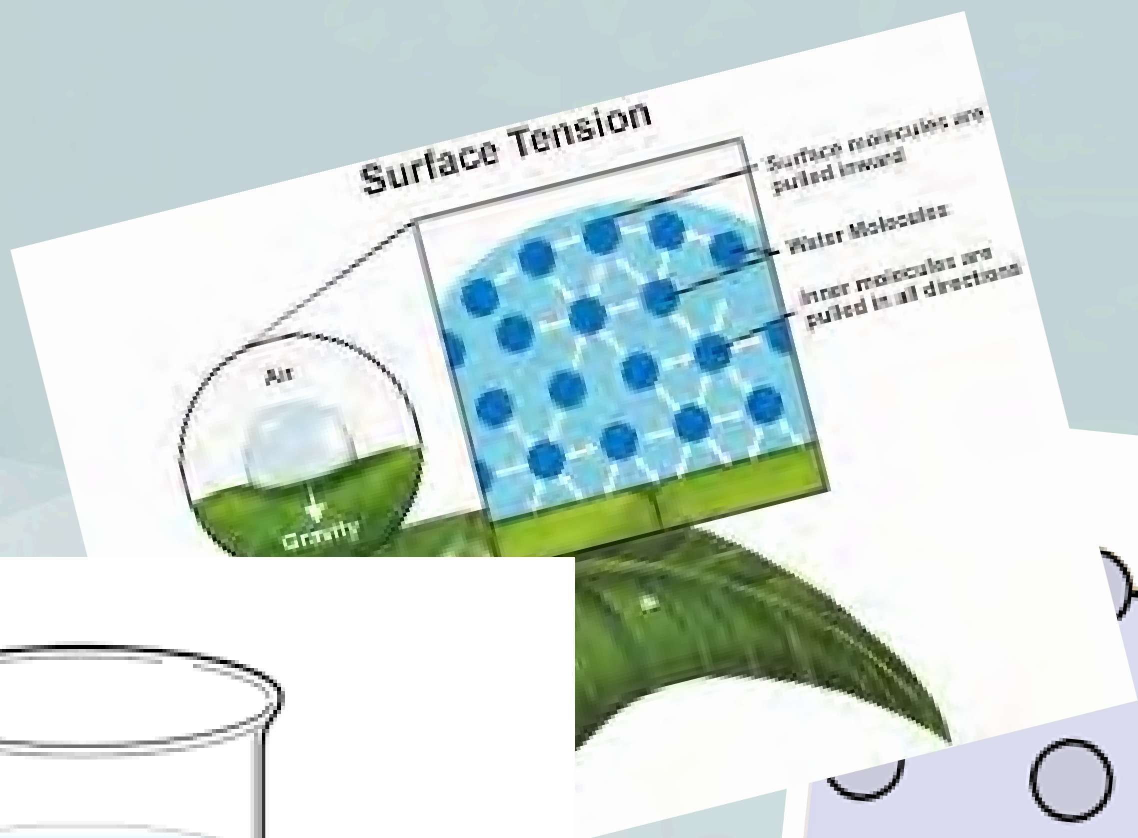
Logbook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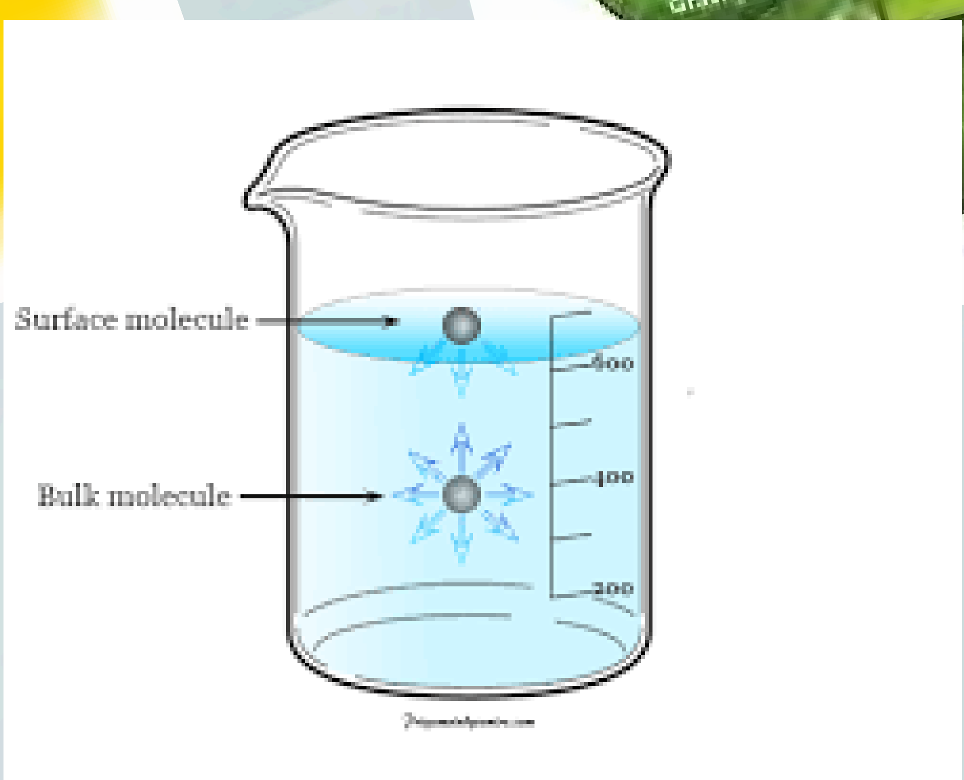
Surface molecules are pulled inward
Water Molecules
Inner molecules are pulled in all directions
Air
Gravity

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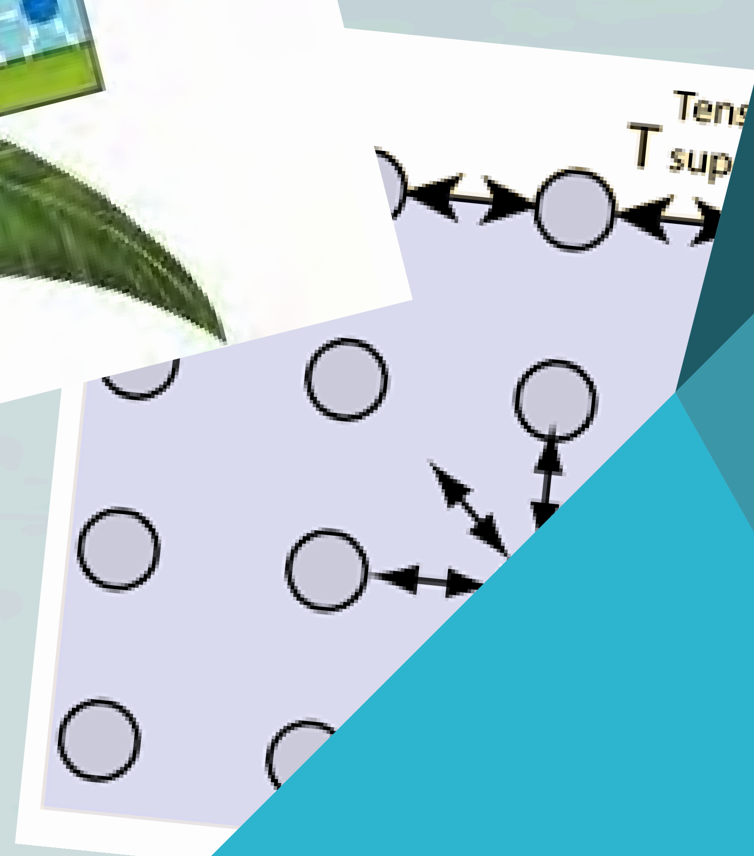
Bulk molecule


20 / 3 / 2024

Brainstorm

Chemistry

- do atoms have colour?
- why don't electrons enter the nucleus?
- why don't atoms collapse if they are mostly empty space?
- how does dissolving a salt molecule in water make atoms ionize?
- how does the pH of soil effect plant growth?
- how does climate change effect the acidification of soil?

Physics

- why are soundwaves invisible?
- Does wind speed affect the evaporation rate of water?
- How does water purity affect surface tension?

- affect of acidification on surface tension

Biology

- did cancer exist before man-made chemicals were around to create it?
- why can't there just be one cure for cancer?
- How can PCR be improved?
-

Space and earth sciences

- why is the moon so bright?
- why don't galaxies have a natural magnetic field like the earth does
- what is it about the ocean that makes it look blue when it reflects the sky?
- what makes space cold?
- How can you tell a black hole made of antimatter from a black hole made of matter?
- How do trees produce oxygen?

How different biomes affect pH

22/3/2024

* test pH of water / soil in different biomes
* climate change - increase in acidification in pH
* investigate plants and animals that live there
* most efficient pH of soil for different plants (of different biomes) - plant growth
* learn where plants grow best
  ↳ help ease climate change effects
* ocean acidification - cause of climate change
  ↳ increase of trees (that suits the pH of ocean) around banks - decrease acidification from carbon dioxide
* investigate how different plants alter pH
* pollution - water become more acidic
* get water & soil sample from different biomes

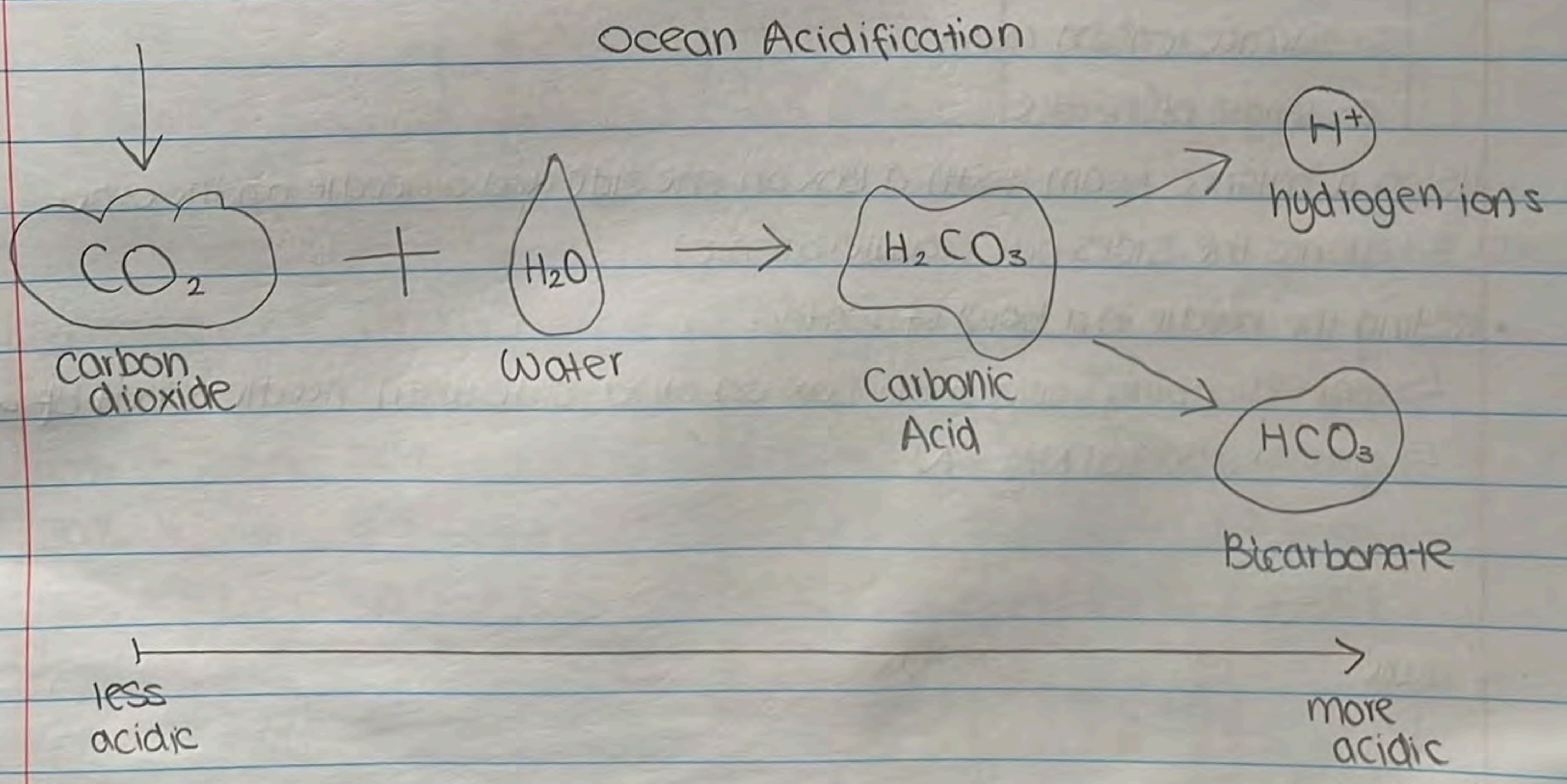
Ocean Acidification 2/4/2024

- climate change => ocean acidification
  - ↳ ocean became more acidic
  - ↳ natural => pH of 8
- plants & algae can alter pH of the ocean

Acidification problems-

- alters marine food chains and food supply to humans
- decreases storm protection from reefs
- decreases tourism opportunities
- reduces coral calcification and growth → decline in coral diversity
- increases risk of mortality in some species
  - → skeletons of corals in more acidic waters were significantly thinner
    - ↳ corals can't produce as much aragonite to thicken their skeletons
- creates conditions that eat away at the minerals used by oysters, clams, lobsters, shrimp, coral reefs

- ocean acidification reduces amount of carbonate → a key building block in seawater
  - ↳ makes it more difficult for marine organisms such as coral and plankton to form their shells and skeletons



FAILED ATTEMPT ✗ 10/4/24

- Base = baking powder
- Acid = citric acid

] finding differences between acids and bases

*results were inconsistent

→ pH target value = 3, 5, 9, 11

pH value	pH changer	Amount of added water	pH value target	Amount of pH changer
7.5	Citric powder	750mL	3	0.024g
7.5	Citric powder	750mL	5	2.379g
7.5	Baking soda	750mL	9	—
7.5	Baking soda	750mL	11	—

found through a dilution calculator

Problems =
- calculator may not have been accurate → too diluted / concentrated
- may not have been enough difference between pH values
- powders may not be strong, acid ic or alkalinic enough

GOAL - effects of pH on surface tension

12/4/24

Surface tension-

- the property of the surface of a liquid that allows it to resist external force
- water's surface tension is caused by hydrogen bonds betweens its molecules
  - ↳ has the 2nd largest surface tension
- mercury's surface tension is due to the strong metallic bonds exhibited by its molecular structure
  - ↳ has highest surface tension
- surface tension is an important parameter in many industrial applications
- surface tension of water helps creatures (mostly of the insecta class) to walk on water
- helps water move up the xylem tissue of higher plants without breaking up
- → allows certain organisms to float, move and live on the water's surface
- water's high surface tension drives the water droplet to take a shape with as little surface area possible
- if water had lower surface tension → water would evaporate faster

Measuring surface tension- (wikihow)

1. Balance beam -

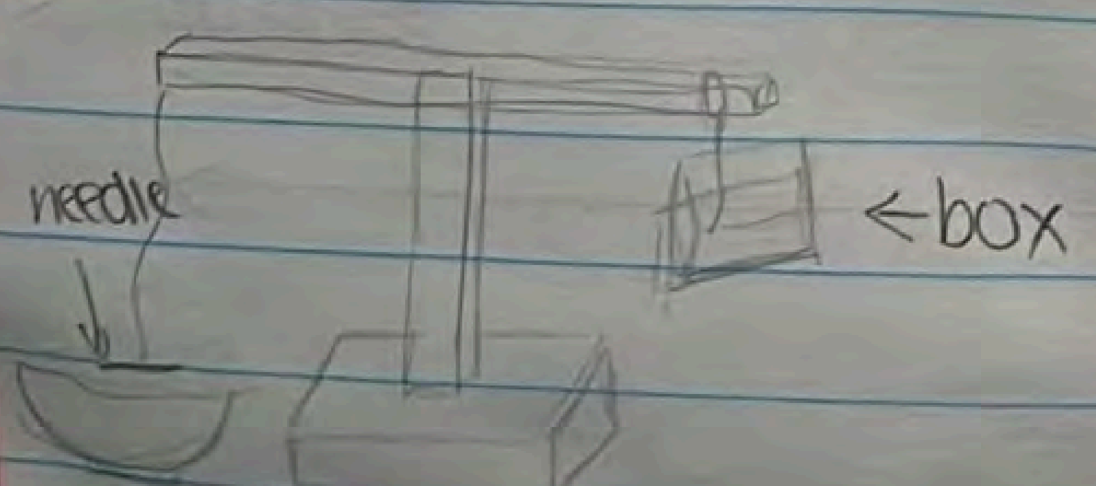
Formula: $F = 2sd$

↳ F = force (N)

s = surface tension (N/m)

d = length of needle

- using a balance beam with a box on one side and a needle on the other
  - balance the sides out (counterbalance)
- resting the needle in a bowl of water
  - ↳ start dropping weight in box on other side until needle is out of water
  - ↳ grams × 0.00981 N/g = N



2. Capillary Action-

- uses adhesion and cohesion forces → causing liquid to rise up in a tube of liquid

Formula = $S = \frac{\rho h g a}{2}$

↳ S = surface tension

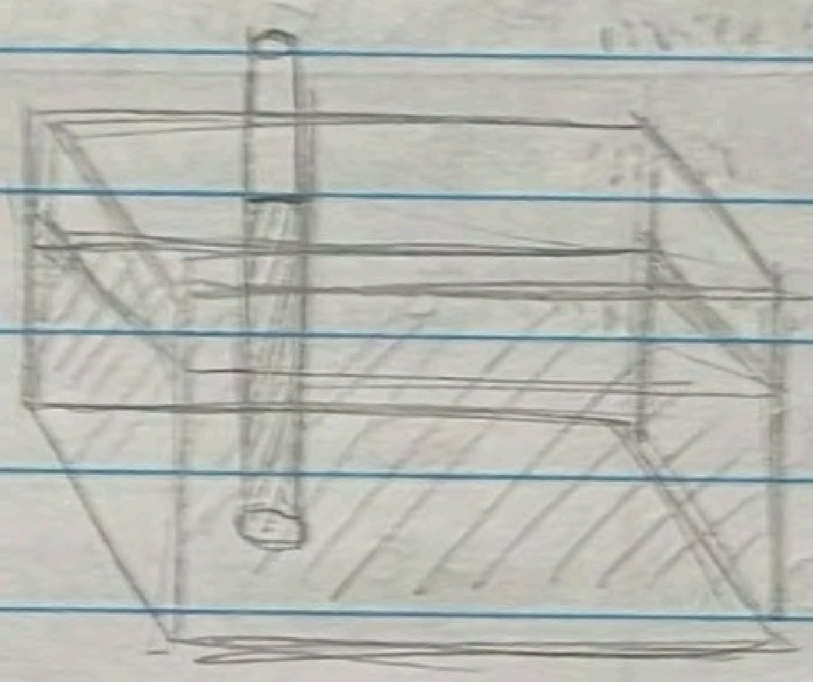
ρ = density

h = height

g = acceleration due to gravity (9.8 m/s²)

a = radius

- finding height liquid rises in a tube



3. Archi-

13/4/24

Question- The Effects of Acidification on the surface tension of water

Hypothesis- if the acidity of the solution increases, the surface tension will decrease due to molecular interactions

Experiment -

- using capillary action to measure the surface tension of various liquids-
  - lemon juice
  - vinegar

  } acidic

  - to determine effect of acidification on surface tension
- measured using dilution of acids with water-

Amount of water (mL)	Dilution level	Calculations	Amount of acid (mL)
150	0%	0×150	0
135	10%	0.1×150	15
120	20%	0.2×150	30
105	30%	0.3×150	45
90	40%	0.4×150	60
75	50%	0.5×150	75
60	60%	0.6×150	90
45	70%	0.7×150	105
30	80%	0.8×150	120
15	90%	0.9×150	135
0	100%	1×150	150

Vinegar results-

20/4/24

Concentration-

(Trial 1)		(Trial 2)	
0% = 5mm	70% = 2.2mm	0% = 4.9mm	70% = 2.3 mm
10% = 4.5mm	80% = 1.9mm	10% = 4.2mm	80% = 2 mm
20% = 4.1mm	90% = 1.4mm	20% = 3.8 mm	90% = 1.3 mm
30% = 3.8mm	100% = 1mm	30% = 3.5 mm	100% = 1 mm
40% = 3.2mm		40% = 3.1 mm	
50% = 3mm		50% = 3 mm	
60% = 2.5mm		60% = 2.8 mm	

Lemon Juice results - 25/4/24

concentration - (trial 1)	(trial 2)
0% = 5 mm	0% = 5 mm
10% = 4 mm	10% = 3.9 mm
20% = 2.5 mm	20% = 2.3 mm
30% = 2.1 mm	30% = 2.2 mm
40% = 2 mm	40% = 2.1 mm
50% = 2 mm	50% = 2 mm
60% = 1.9 mm	60% = 1.9 mm
70% = 1.7 mm	70% = 1.8 mm
80% = 1.3 mm	80% = 1.5 mm
90% = 1 mm	90% = 1.1 mm
100% = 0.75 mm	100% = 0.5mm

30/4/24

Conclusion - observations

- Acidity increases → surface tension decreases
  - could be due to intermolecular forces - hydrogen bonding
    - polarity
    - temperature

OSA RISK ASSESSMENT FORM

for all entries in (✓) ☐ Models & Inventions and ☑ Scientific Inquiry

This must be included with your report, log book or entry. One form per entry.

STUDENT(S) NAME: Kyra Huang and Benita Wu ID:

SCHOOL: Seymour College

Activity: Give a brief outline of what you are planning to do.

Finding the surface tension of various acidic liquids through the use of capillary action. This will be done by measuring the height of water and 2 acids (lemon juice and vinegar) risen through a straw in the middle of a glass cup. This will be done with various percentages of dilution for each acid.

Are there possible risks? Consider the following:

- Chemical risks: Are you using chemicals? If so, check with your teacher that any chemicals to be used are on the approved list for schools. Check the safety requirements for their use, such as eye protection and eyewash facilities, availability of running water, use of gloves, a well-ventilated area or fume cupboard.
- Thermal risks: Are you heating things? Could you be burnt?
- Biological risks: Are you working with micro-organisms such as mould and bacteria?
- Sharps risks: Are you cutting things, and is there a risk of injury from sharp objects?
- Electrical risks: Are you using mains (240 volt) electricity? How will you make sure that this is safe? Could you use a battery instead? **Only batteries can be used for Models & Inventions entries*
- Radiation risks: Does your entry use potentially harmful radiation such as UV or lasers?
- Other hazards.

Also, if you are using other people as subjects in an investigation you must get them to sign a note consenting to be part of your experiment.

Risks	How I will control/manage the risk
Glass cups being broken on accident	being careful during the experiment and keeping cups in middle of table
Vinegar or lemon juice getting in eyes	handle liquids with caution and wearing safety glasses
Shards of broken objects (if that happens) causing injuries	cleaning up any accidents immediately to prevent injuries
Spillages of liquids may cause tripping hazards.	cleaning up all spillages immediately to prevent injuries

(Attach another sheet if needed.)

Risk Assessment indicates that this activity can be safely carried out

RISK ASSESSMENT COMPLETED BY (student name(s)): Benita Wu, Kyra Huang

SIGNATURE(S): Benita Kyrae

☑ By ticking this box, I/we state that my/our project adheres to the listed criteria for this Category.

TEACHER'S NAME: C. O'Halloran

SIGNATURE: [signature] DATE: 19/05/24