<u>Osmolarity Lab</u>

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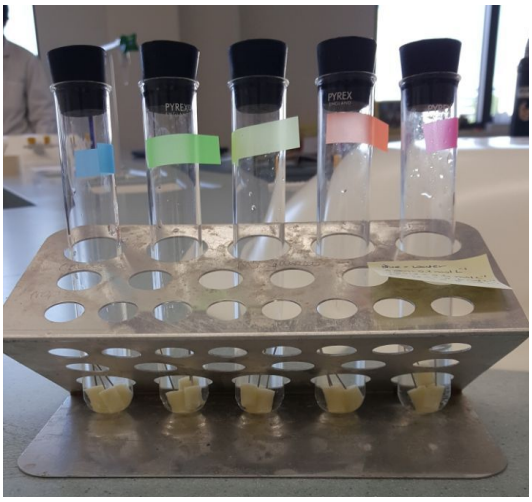
Qualitative Data

Below is two pictures, before and after leaving the potato chips in the sucrose water for approximately 72 hours. In both photos, the test tubes are colour coded for each concentration of sucrose water, and distilled water. The colour blue represented the distilled water, green was 0.20mol/L, yellow was 0.40mol/L, orange was 0.60mol/L and pink was 0.80mol/L.

Table 1. Quantitative data showing the potato chips submerged in sucrose water before and after leaving it in for 72 hours.

Data	**Observations**
Figure 1. Picture of the potato chips submerged in the sucrose water, before leaving it for 72 hours. 	Three potato chips can be seen submerged in each test tube. This is before the potatoes were left in the solution for 72 hours.
Figure 2. Picture of the potato chips submerged in the sucrose water, after leaving it for 72 hours. 	The potato chips submerged in the sucrose water after being left for 72 hours. It can be seen in the image, that the water became murky and also slightly green or translucent.

Quantitative Data

Table 2. Raw data showing mass of each potato chip (± 0.01g) before and after being placed in different concentrations of sucrose water.

	Trial 1		**Trial 2**		**Trial 3**	
Concentration (mol/L)	**Initial Mass (±0.01g)**	**Final Mass (±0.01g)**	**Initial Mass (±0.01g)**	**Final Mass (±0.01g)**	**Initial Mass (±0.01g)**	**Final Mass (±0.01g)**
0.00	0.34	0.28	0.34	0.26	0.38	0.31
0.20	0.33	0.37	0.35	0.35	0.44	0.45
0.40	0.38	0.37	0.35	0.33	0.37	0.36
0.60	0.41	0.35	0.36	0.27	0.41	0.34
0.80	0.39	0.26	0.37	0.27	0.36	0.25

*Uncertainty is ± 0.01g, as it was the smallest unit of measurement on the electric weighing scale that was used.

Processed Data

In this lab, the data was processed by calculating the percent mass change for each trial and the average, and the correlation between the average percent mass change and the concentration of the sucrose water. The average was calculated to find a single number that represents the percent mass change for each solute concentration. The correlation was calculated to test the relationship between the average percent mass change and the sucrose concentration.

Table 3. Processed data showing the percent mass change (± 0.01 %) for each potato chip in the different concentrations of sucrose water, including averages and correlation.

Concentration (mol/L)	**Percent Mass Change (±0.01%)**				**Correlation (±0.01)**
	Trial 1	**Trial 2**	**Trial 3**	**Average**	
0.00	-17.65	-23.53	-18.42	-19.87	-0.50
0.20	12.12	0.00	2.27	4.80	
0.40	-2.63	-5.71	-2.70	-3.68	
0.60	-14.63	-25.00	-17.07	-18.90	
0.80	-33.33	-27.03	-30.56	-30.31	

Sample Calculations: Microsoft excel was used to calculate the average percent mass change and correlation. The TI-Nspire CX calculator was used to calculate the percent mass change. Examples and formulas for these calculations can be seen below.

Percent Mass Change: Example of trial 1 for distilled water.

$$\begin{aligned} \textit{percent mass change} &= \frac{final - initial\ mass}{initial\ mass} \times 100 \\ &= \frac{0.28-0.34}{0.34} \times 100 \\ &= -0.176471 \times 100 \\ &= -17.6471 \\ &= -17.65 \end{aligned}$$

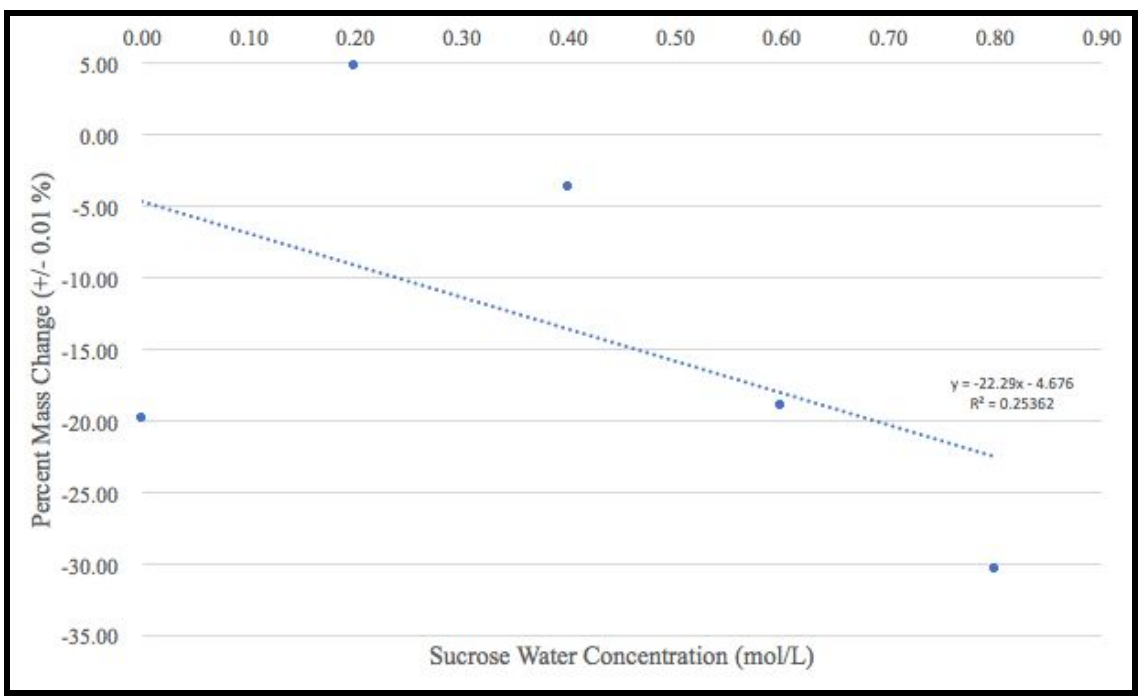
Average Percent Mass Change: $= average(data)$

Correlation: $= correl(array1,\ array2)$

Technology Used:

- Microsoft Excel
- TI-Nspire CX calculator

Figure 3. Scatter graph showing the average percent mass change (± 0.01 %) of the potato chips in the different concentrations of sucrose water, and distilled water, with correlation acting as a trendline.



The general trend that can be seen from the 0.20 concentration of sucrose water to the 0.80 concentration, is that the average percent mass change decreases, or becomes more negative. There is also a direct increase from the distilled water to the 0.20 concentration. A line of best fit is seen on the graph, representing the correlation value between the sucrose water concentration and the percent mass change of the potatoes. The correlation is negative meaning that as one variable increased, the other decreased. In this case, as the sucrose water concentration increased, the percent mass change decreased.

Additional Statistical Analysis

The additional statistical analysis that was done is the t-test, in order to test the significant difference between the changes in mass for the different sucrose concentrations.
Microsoft excel was used in order to perform the test.
H_0: There is no significant difference between the percent change in mass for the different sucrose concentrations.
H_A: There is a significant difference between the percent change in mass for the different sucrose concentrations.

Table 4. T-test showing the difference between the various sucrose concentrations and the percent change in mass.

Test	Analysis	Conclusion
Between the percent change in mass for 0.00mol/L and 0.20mol/L concentrations of sucrose water.	P = 0.004	P < 0.050 H_0 = rejected. There is a significant difference between the percent change in mass for the 0.00mol/L and the 0.20mol/L concentration of sucrose water.
Between the percent change in mass for 0.00mol/L and 0.80mol/L concentrations of sucrose water.	P = 0.016	P < 0.050 H_0 = rejected. There is a significant difference between the percent change in mass for the 0.00mol/L and the 0.80mol/L concentration of sucrose water.

*T-test results were increased to 3 decimal places in order to increase the precision, due to the small values of the numbers.

Conclusion

The purpose of this lab was to investigate the effect of sucrose concentration in water on the change in mass the potato chips. The hypothesis for this lab stated that if the concentration of the sucrose water is higher, than, the percent mass change of the potato chips would be smaller

because water moves from a lower to higher solute concentration in osmosis to dilute a solution (Allott and Mindorff, 38).

The data from the experiment supported this hypothesis, and showed that the percent mass change decreased as the concentration of the sucrose water increased. First, this is demonstrated by the qualitative data. It can be seen in figure 2, that the water is slightly more murky than figure 1. The murky water is due to the osmosis that occurred as the potato chips were submerged in the solution. More water left the potato and travelled to the sucrose water solution, or the hypertonic solution, outside the potato. This diluted the solution and created the murkiness of the water. However, because the potatoes were submerged in the solution for 72 hours, reverse osmosis occurred due to the increased vapour pressure and turgor pressure of the potato cell wall, affecting the process of osmosis as well (Silverthorn 135). Reverse osmosis is the process of osmosis in which water travels from a higher to lower solute concentration ("Osmosis"), hence skewing the data.

Furthermore, the quantitative results further supported the hypothesis. As the solute concentration of the sucrose water increased, the percent change mass decreased. The average percent mass change for the 0.20mol/L concentration was 4.80%. This decreased moving on to the next concentration, 0.40mol/L to -3.68%. The next value for the concentration, 0.60mol/L was -18.90%. The final value for the 0.80mol/L sucrose concentration was -30.31%. This data can be seen in figure 3, showing an increase in percent mass change from distilled water to 0.20mol/L concentration, following a decrease in percent mass change as the concentration continued to increase. The negative correlation value, -0.50, acted as a trend line in the graph and showed that as the concentration of sucrose water increased, the percent mass change decreased.

In addition, a t-test was performed in order to test the difference between the percent mass change for different concentrations of sucrose water. Both t-tests rejected the null hypothesis and showed a significant difference between the concentrations of sucrose water and their effect on the change in mass.

The only anomaly in this data, was the average percent mass change for the potatoes in the distilled water - with a 0.00mol/L concentration - which was, -19.87%. This is an anomaly because since the solute concentration was extremely low, water should have moved from the lower to higher solute concentration, or from the solution to the potato (Allott and Mindorff, 38). In this case the data should have shown a positive percent mass change as the mass of the potato would have increased because of the water that moved to the potato. As stated before, this anomaly was due to the error of leaving the potato chips submerged in the solution for 72 hours, resulting in reverse osmosis ("Osmosis"), which will be further discussed in the conclusion.

Despite this anomaly, the hypothesis was accepted. The results correlate with a lab done by Dee U. Silverthorn, on the osmolarity and tonicity of potatoes, turnips and pumpkins. They found that if in a hypertonic solution, water would move from the potato to the solution, and hence lose mass, and the opposite would occur, if in a hypotonic solution (Silverthorn 139-140).

Some possible extensions of this lab could be to test the effect of the different concentrations of sucrose water on the change in mass in a variety of different plants or potatoes. Also, it would be possible to test if their is a difference between sucrose water concentrations and salt water concentrations in terms of their effect on the percent mass change of the potato chips. Another possible test would be the effect of pH or temperature on osmosis.

Evaluation

Table 5. Table showing strengths of the lab.

Strength	**Explanation**
Wide range of controlled variables.	One strength of the lab was the wide range of controlled variables, such as the volume of the solution, the potato, the size of the chips, the same shape of the chips, blotting the potatoes dry before weighing the potato chips, the same time to leave the potatoes in the solution and the use of the same scales. This allowed for more accurate results, as it made the experiment more controlled.
Multiple variants of the independent variable.	Another strength of the lab was the multiple variants of the independent variable. The independent variable was the concentration of the sucrose water. In this lab, there were five variations of the concentration of the sucrose water, 0.00, 0.20, 0.40, 0.60, and 0.80mol/L. The variations of the independent variable gave more accurate results as it allowed for a more specific investigation into the difference between certain concentrations of sucrose water causing a particular change in mass.
The use of accurate measuring tool, such as a graduated (measuring) cylinder.	The use of precise measuring tools allowed for more accurate data to be drawn, and allowed for better control over the controlled variables. In this case, the control over the volume of the sucrose solution. This allowed the experimenters to gain a more accurate understanding about osmosis in potatoes.

Table 6. Table showing limitations and possible improvements for the lab.

Limitation	Explanation	Improvement	Explanation
Leaving the potato chips in the sucrose water for more than 12 hours.	Leaving the potato chips in the sucrose solution for too long affected the results because leaving them in the test tubes with a stopper added extra vapour pressure ("Osmosis"). Additionally, the hydration of the potatoes increased the turgor pressure of the cell walls, affecting the process of osmosis. This resulted in reverse osmosis, hence skewing the results as the mass change occurred because of both osmosis and reverse osmosis.	Submerge the potato chips in the sucrose solution for 10-12 hours, as stated in the method.	This will improve the data, as it will decrease the pressure in the test tubes, preventing reverse osmosis from occurring, but leaving it for enough time for osmosis to occur.
Lack of temperature control.	The science lab that the potatoes stayed over 72 hours was not temperature controlled. Due to the air conditioner turning off and on, and the amount of people that came in and left the room. This affected the rate in which the osmosis occurred, affecting the results.	Place the potatoes in a temperature controlled space, like a fridge.	This will allow the osmosis for all the potatoes to go at the same rate, allowing for more precise results.
Use of a ruler to measure the size of the potato chips.	A ruler was used to measure the size of the potato chips. This affected the results due to the lack of precision of the ruler. This caused each potato chip to have different masses or sizes causing a difference in the osmosis that would occur.	Use of a vernier caliper or a more precise measuring device.	This would allow for more specific results as the sizes and masses of the potato chips would have been more precise and consistent.

Not enough trials.	This lab only had three trials affecting the results of the experiment because if more trials were implemented, the data would have been more precise as it could have accounted for more anomalies in the data, and more detail in terms of the sucrose concentration effect on the change in mass of the potato chips.	Include at least 5 trials to the experiment.	This would allow for a deeper understanding of the lab, as more trials are there to investigate the effect of the sucrose concentration on the change in mass of the potato chips, finding further anomalies in the data and more reliable statistics.
Putting pins in the potato chips as labels.	Putting pins in the potato chips, as labels, was a source of error, because this could have affected the mass and the osmosis that occurred in the chips by poking a hole.	Put the potato chips in each test tube individually.	This would make it easier to differentiate between the separate trials for potato chips and not affect the mass and the osmosis in the process.

Bibliography

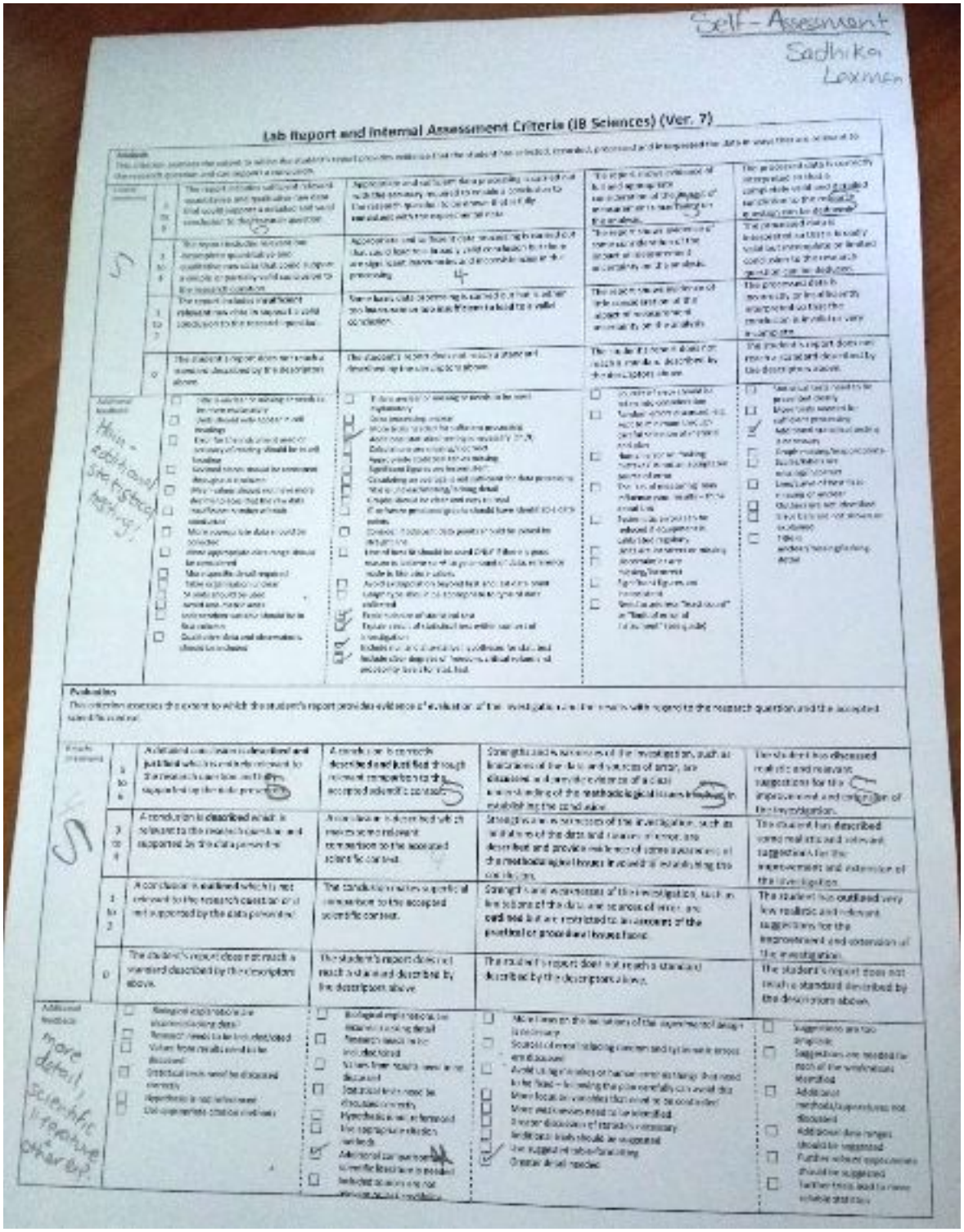
Allott, Andrew, and David Mindorff. "Membrane Transport." *IB Biology Course Companion: Oxford IB Diploma Program*, Oxford University Press, 2014, pp. 37–38.

Encyclopædia Britannica. "Osmosis." *Encyclopædia Britannica*, Encyclopædia Britannica, Inc., 25 Apr. 2017, Web. 5 Nov. 2017. <www.britannica.com/science/osmosis.>

Silverthorn, Dee U. "Osmolarity and Tonicity: An Inquiry Laboratory Using Plant Material." *Tested Studies for Laboratory Teaching*, vol. 32, 2011, pp. 135–150.

****The peer and self assessment rubrics can be seen below****

Self Assessment



Self-Assessment

Sadhika Laxman

Lab Report and Internal Assessment Criteria (IB Sciences) (Ver. 7)

Analysis	9 to 8	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and well conclusion to the research question.	Appropriate and sufficient data processing is carried out with the accuracy required to provide a conclusion to the research question. Uncertainties are calculated correctly and propagated where required.	The report includes evaluation of limitations of the data processing and its impact on the validity of the conclusion.	The processed data is correctly interpreted to lead to a complete and justified conclusion to the research question. The relevance of the results can be discussed.
	7 to 6	The report includes sufficient relevant quantitative and qualitative raw data that could support a reasonable and well conclusion to the research question.	Appropriate and sufficient data processing is carried out with the accuracy required to provide a conclusion to the research question. Uncertainties are calculated correctly.	The report includes evaluation of the limitations of the data processing and its impact on the validity of the conclusion.	The processed data is interpreted correctly to lead to a justified conclusion to the research question. The relevance of the results can be discussed.
	5 to 3	The report includes insufficient relevant raw data to support a valid conclusion to the research question.	Some basic data processing is carried out, but it is either not fully accurate or is not sufficient to lead to a valid conclusion.	The report includes some evaluation of the validity of the data processing and its impact on the validity of the conclusion.	The processed data is incorrectly, or insufficiently, interpreted so that the conclusion is invalid or very incomplete.
	0	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.

Additional feedback: Have additional sheet for analysis

Evaluation

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation in relation to the research question and the accepted scientific context.

Evaluation	9 to 8	A detailed conclusion is described and justified which is consistent with the research question and the data presented.	A conclusion is correctly described and justified through reference to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are discussed, with clear evidence of a critical understanding of the methodological issues involved in establishing the conclusion.	The student has discussed realistic and relevant suggestions for the improvement and extension of the investigation.
	7 to 6	A conclusion is described which is relevant to the research question and supported by the data presented.	A conclusion is described with reference to relevant information to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are described and provide evidence of some awareness of the methodological issues involved in establishing the conclusion.	The student has described some realistic and relevant suggestions for the improvement and extension of the investigation.
	5 to 3	A conclusion is outlined which is not relevant to the research question or is not supported by the data presented.	The conclusion makes superficial reference to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are outlined but are restricted to an awareness of the practical or procedural issues faced.	The student has outlined very few realistic and relevant suggestions for the improvement and extension of the investigation.
	0	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.

Additional feedback: more detail! scientific! creative! other up

Peer Assessment 1:

To Sathika

Lab Report and Internal Assessment Criteria (IB Sciences) (Ver. 7)

Analysis

This criterion assesses the extent to which the student's report provides evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion.

6 marks (maximum)					
	5 to 6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question.	Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data.	The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis.	The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.
	3 to 4	The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question.	Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing.	The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis.	The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.
	1 to 2	The report includes **insufficient relevant** raw data to support a valid conclusion to the research question.	Some **basic** data processing is carried out but is either too **inaccurate or too insufficient to lead to a valid** conclusion.	The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis.	The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete.
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Additional feedback:		☐ Title is unclear or missing or needs to be more explanatory ☐ Units should only appear in cell headings ☐ Error for the instrument used or accuracy of reading should be in cell heading ☐ Decimal places should be consistent throughout a column ☐ Mean values should not have more decimal places that the raw data ☐ Insufficient number of trials conducted ☐ More appropriate data should be collected ☐ More appropriate data range should be considered ☐ More specific detail required ☐ Table organization unclear ☐ SI units should be used ☐ Avoid non-metric units ☐ Independent variable should be in first column ☐ Qualitative data and observations should be included	☐ Title is unclear or missing or needs to be more explanatory ☐ Data processing unclear ☐ More trials needed for sufficient processing ☐ Additional statistical testing is necessary (chi/t) ☐ Calculations are missing/incorrect ☐ Appropriate statistical tables missing ☐ Significant figures are inconsistent ☐ Calculating an average is not sufficient for data processing ☐ Title is unclear/missing/lacking detail ☐ Graphs should be clear and easy to read ☐ IT software produced graphs should have identifiable data points ☐ Consider if adjacent data points should be joined by straight line ☐ Line of best fit should be used ONLY if there is good reason to believe so → large amount of data; reference made to literature values ☐ Avoid extrapolation beyond first and last data point ☐ Graph type should be appropriate to type of data collected ☐ Explain choice of statistical test ☐ Explain result of statistical test within context of investigation ☐ Include null and alternative hypotheses for stat. test ☐ Include clear degrees of freedom, critical values and probability levels for stat. test	☐ Sources of error should be taken into consideration ☐ Random errors discussed; e.g. kept to minimum through careful selection of material and plan ☐ Human error or 'making mistakes' is not an acceptable source of error ☐ The 'act of measuring' may influence your results – think about this ☐ Systematic errors can be reduced if equipment is calibrated regularly ☐ Units are incorrect or missing ☐ Uncertainties are missing/incorrect ☐ Significant figures are inconsistent ☐ Need to address "least count" or "limit of error of instrument" (see guide)	☐ Statistical tests need to be presented clearly ☐ More trials needed for sufficient processing ☐ Additional statistical testing is necessary ☐ Graph missing/inappropriate ☐ Scales/labels are missing/incorrect ☐ Line/curve of best fit is missing or unclear ☐ Outliers are not identified ☐ Error bars are not shown or explained ☐ Title is unclear/missing/lacking detail

Evaluation

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

6 marks (maximum)					
	5 to 6	A detailed conclusion is **described and justified** which is entirely relevant to the research question and fully supported by the data presented.	A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the **methodological issues** involved in establishing the conclusion.	The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation.
	3 to 4	A conclusion is **described** which is relevant to the research question and supported by the data presented.	A conclusion is described which makes some relevant comparison to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **described** and provide evidence of some awareness of the **methodological issues** involved in establishing the conclusion.	The student has **described** some realistic and relevant suggestions for the improvement and extension of the investigation.
	1 to 2	A conclusion is **outlined** which is not relevant to the research question or is not supported by the data presented.	The conclusion makes superficial comparison to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **outlined** but are restricted to an **account of the practical** or **procedural issues** faced.	The student has **outlined** very few realistic and relevant suggestions for the improvement and extension of the investigation.
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Additional feedback:		☐ Biological explanations are incorrect/lacking detail ☐ Research needs to be included/cited ☐ Values from results need to be discussed ☐ Statistical tests need be discussed correctly ☐ Hypothesis is not referenced ☐ Use appropriate citation methods	☐ Biological explanations are incorrect/lacking detail ☐ Research needs to be included/cited ☐ Values from results need to be discussed ☐ Statistical tests need be discussed correctly ☐ Hypothesis is not referenced ☐ Use appropriate citation methods ☐ Additional comparison to scientific literature is needed ☐ Included sources are not relevant or lack credibility	☐ More focus on the limitations of the *experimental design* is necessary ☐ Sources of error including random and systematic errors are discussed ☐ Avoid using mistakes or human error as things that need to be fixed – following the plan carefully can avoid this ☐ More focus on variables that need to be controlled ☐ More weaknesses need to be identified ☐ Greater discussion of statistics necessary ☐ Additional trials should be suggested ☐ Use suggested table-formatting ☐ Greater detail needed	☐ Suggestions are too simplistic ☐ Suggestions are needed for each of the weaknesses identified ☐ Additional methods/apparatuses not discussed ☐ Additional data ranges should be suggested ☐ Further *related* experiments should be suggested ☐ Further trials lead to more reliable statistics

Peer Assessment 2:

Lab Report and Internal Assessment Criteria (IB Sciences) (Ver. 7)

Analysis

This criterion assesses the extent to which the student's report provides evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion.

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	5 to 6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question.	Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data.	The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis.	The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.
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Additional feedback:		☐ Biological explanations are incorrect/lacking detail ☐ Research needs to be included/cited ☐ Values from results need to be discussed ☐ Statistical tests need be discussed correctly ☐ Hypothesis is not referenced ☐ Use appropriate citation methods	☐ Biological explanations are incorrect/lacking detail ☐ Research needs to be included/cited ☐ Values from results need to be discussed ☐ Statistical tests need be discussed correctly ☐ Hypothesis is not referenced ☐ Use appropriate citation methods ☐ Additional comparison to scientific literature is needed ☐ Included sources are not relevant or lack credibility	☐ More focus on the limitations of the *experimental design* is necessary ☐ Sources of error including random and systematic errors are discussed ☐ Avoid using mistakes or human error as things that need to be fixed – following the plan carefully can avoid this ☐ More focus on variables that need to be controlled ☐ More weaknesses need to be identified ☐ Greater discussion of statistics necessary ☐ Additional trials should be suggested ☐ Use suggested table-formatting ☐ Greater detail needed	☐ Suggestions are too simplistic ☐ Suggestions are needed for *each* of the weaknesses identified ☐ Additional methods/apparatuses not discussed ☐ Additional data ranges should be suggested ☐ Further *related* experiments should be suggested ☐ Further trials lead to more reliable statistics

Peer Assessment 3:

Sathika Laxman

Lab Report and Internal Assessment Criteria (IB Sciences) (Ver. 7)

Analysis

This criterion assesses the extent to which the student's report provides evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion.

6 (max)

5 to 6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question.	Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data.	The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis.	The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.
3 to 4	The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question.	Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing.	The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis.	The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.
1 to 2	The report includes **insufficient relevant** raw data to support a valid conclusion to the research question.	Some **basic** data processing is carried out but is either **too inaccurate or too insufficient to lead to a valid** conclusion.	The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis.	The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete.
0	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.

Additional feedback:

- ☐ Title is unclear or missing or needs to be more explanatory
- ☐ Units should only appear in cell headings
- ☐ Error for the instrument used or accuracy of reading should be in cell heading
- ☐ Decimal places should be consistent throughout a column
- ☐ Mean values should not have more decimal places that the raw data
- ☑ Insufficient number of trials conducted
- ☐ More appropriate data should be collected
- ☐ More appropriate data range should be considered
- ☐ More specific detail required
- ☐ Table organization unclear
- ☐ SI units should be used
- ☑ Avoid non-metric units
- ☐ Independent variable should be in first column
- ☐ Qualitative data and observations should be included

- ☐ Title is unclear or missing or needs to be more explanatory
- ☐ Data processing unclear
- ☐ More trials needed for sufficient processing
- ☐ Additional statistical testing is necessary (chi/t)
- ☐ Calculations are missing/incorrect
- ☐ Appropriate statistical tables missing
- ☐ Significant figures are inconsistent
- ☐ Calculating an average is not sufficient for data processing
- ☐ Title is unclear/missing/lacking detail
- ☐ Graphs should be clear and easy to read
- ☐ IT software produced graphs should have identifiable data points
- ☐ Consider if adjacent data points should be joined by straight line
- ☐ Line of best fit should be used ONLY if there is good reason to believe so → large amount of data; reference made to literature values
- ☐ Avoid extrapolation beyond first and last data point
- ☐ Graph type should be appropriate to type of data collected
- ☐ Explain choice of statistical test
- ☐ Explain result of statistical test within context of investigation
- ☐ Include null and alternative hypotheses for stat. test
- ☐ Include clear degrees of freedom, critical values and probability levels for stat. test

- ☐ Sources of error should be taken into consideration
- ☐ Random errors discussed, e.g. kept to minimum through careful selection of material and plan
- ☐ Human error or 'making mistakes' is not an acceptable source of error
- ☐ The 'act of measuring' may influence your results – think about this
- ☐ Systematic errors can be reduced if equipment is calibrated regularly
- ☐ Units are incorrect or missing
- ☐ Uncertainties are missing/incorrect
- ☐ Significant figures are inconsistent
- ☐ Need to address "least count" or "limit of error of instrument" (see guide)

- ☐ Statistical tests need to be presented clearly
- ☑ More trials needed for sufficient processing
- ☐ Additional statistical testing is necessary
- ☐ Graph missing/inappropriate
- ☐ Scales/labels are missing/incorrect
- ☐ Line/curve of best fit is missing or unclear
- ☐ Outliers are not identified
- ☐ Error bars are not shown or explained
- ☐ Title is unclear/missing/lacking detail

Disliked ... o. 00 mol
very well done!
L → dm³
see comment

Evaluation

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

6 (max)

5 to 6	A detailed conclusion is **described and justified** which is entirely relevant to the research question and fully supported by the data presented.	A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the **methodological issues** involved in establishing the conclusion.	The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation.
3 to 4	A conclusion is **described** which is relevant to the research question and supported by the data presented.	A conclusion is described which makes some relevant comparison to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **described** and provide evidence of some awareness of the **methodological issues** involved in establishing the conclusion.	The student has **described** some realistic and relevant suggestions for the improvement and extension of the investigation.
1 to 2	A conclusion is **outlined** which is not relevant to the research question or is not supported by the data presented.	The conclusion makes superficial comparison to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **outlined** but are restricted to an **account of the practical** or **procedural issues** faced.	The student has **outlined** very few realistic and relevant suggestions for the improvement and extension of the investigation.
0	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.

Additional feedback:

- ☐ Biological explanations are incorrect/lacking detail
- ☐ Research needs to be included/cited
- ☐ Values from results need to be discussed
- ☐ Statistical tests need be discussed correctly
- ☐ Hypothesis is not referenced
- ☐ Use appropriate citation methods

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- ☐ Values from results need to be discussed
- ☐ Statistical tests need be discussed correctly
- ☐ Hypothesis is not referenced
- ☐ Use appropriate citation methods
- ☐ Additional comparison to scientific literature is needed
- ☐ Included sources are not relevant or lack credibility

- ☐ More focus on the limitations of the experimental design is necessary
- ☐ Sources of error including random and systematic errors are discussed
- ☐ Avoid using mistakes or human error as things that need to be fixed – following the plan carefully can avoid this
- ☐ More focus on variables that need to be controlled
- ☐ More weaknesses need to be identified
- ☐ Greater discussion of statistics necessary
- ☐ Additional trials should be suggested
- ☐ Use suggested table formatting
- ☐ Greater detail needed

- ☐ Suggestions are too simplistic
- ☐ Suggestions are needed for each of the weaknesses identified
- ☐ Additional methods/operations not discussed
- ☐ Additional data ranges should be suggested
- ☐ Further related experiments should be suggested
- ☑ Further trials lead to more reliable statistics

• see comment
• Divide conclusion in paragraphs
• Specify time to subtopics chiss] improvements

Peer Assessment 4:

Sadhika

Lab Report and Internal Assessment Criteria (IB Sciences) (Ver. 7)

Analysis

This criterion assesses the extent to which the student's report provides evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion.

6 marks (maximum)					
5	5 to 6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question.	Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data.	The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis.	The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.
	3 to 4	The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question.	Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing.	The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis.	The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.
	1 to 2	The report includes **insufficient relevant** raw data to support a valid conclusion to the research question.	Some **basic** data processing is carried out but is either too **inaccurate or too insufficient to lead to a valid** conclusion.	The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis.	The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete.
	0	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.	The student's report does not reach a standard described by the descriptors above.

Additional feedback:

- ☑ Title is unclear or missing or needs to be more explanatory
- ☑ Units should only appear in cell headings
- ☑ Error for the instrument used or accuracy of reading should be in cell heading
- ☑ Decimal places should be consistent throughout a column
- ☑ Mean values should not have more decimal places that the raw data
- ☐ Insufficient number of trials conducted
- ☑ More appropriate data should be collected
- ☐ More appropriate data range should be considered
- ☐ More specific detail required
- ☑ Table organization unclear
- ☐ SI units should be used
- ☐ Avoid non-metric units
- ☐ Independent variable should be in first column
- ☑ Qualitative data and observations should be included

- ☑ Title is unclear or missing or needs to be more explanatory
- ☐ Data processing unclear
- ☐ More trials needed for sufficient processing
- ☐ Additional statistical testing is necessary (chi/t)
- ☐ Calculations are missing/incorrect
- ☐ Appropriate statistical tables missing
- ☐ Significant figures are inconsistent
- ☐ Calculating an average is not sufficient for data processing
- ☐ Title is unclear/missing/lacking detail
- ☐ Graphs should be clear and easy to read
- ☐ IT software produced graphs should have identifiable data points
- ☐ Consider if adjacent data points should be joined by straight line
- ☐ Line of best fit should be used ONLY if there is good reason to believe so → large amount of data; reference made to literature values
- ☐ Avoid extrapolation beyond first and last data point
- ☐ Graph type should be appropriate to type of data collected
- ☑ Explain choice of statistical test
- ☑ Explain result of statistical test within context of investigation
- ☑ Include null and alternative hypotheses for stat. test
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- ☑ Sources of error should be taken into consideration
- ☑ Random errors discussed; e.g. kept to minimum through careful selection of material and plan
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- ☐ Uncertainties are missing/incorrect
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- ☑ Statistical tests need to be presented clearly
- ☐ More trials needed for sufficient processing
- ☑ Additional statistical testing is necessary
- ☐ Graph missing/inappropriate
- ☐ Scales/labels are missing/incorrect
- ☐ Line/curve of best fit is missing or unclear
- ☐ Outliers are not identified
- ☐ Error bars are not shown or explained
- ☐ Title is unclear/missing/lacking detail

Evaluation

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

6 marks (maximum)					
5	5 to 6	A detailed conclusion is **described and justified** which is entirely relevant to the research question and fully supported by the data presented.	A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the **methodological issues** involved in establishing the conclusion.	The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation.
	3 to 4	A conclusion is **described** which is relevant to the research question and supported by the data presented.	A conclusion is described which makes some relevant comparison to the accepted scientific context.	Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **described** and provide evidence of some awareness of the **methodological issues** involved in establishing the conclusion.	The student has **described** some realistic and relevant suggestions for the improvement and extension of the investigation.
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Additional feedback:

- ☐ Biological explanations are incorrect/lacking detail
- ☐ Research needs to be included/cited
- ☐ Values from results need to be discussed
- ☐ Statistical tests need be discussed correctly
- ☐ Hypothesis is not referenced
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- ☐ More focus on the limitations of the *experimental design* is necessary
- ☑ Sources of error including random and systematic errors are discussed
- ☐ Avoid using mistakes or human error as things that need to be fixed – following the plan carefully can avoid this
- ☐ More focus on variables that need to be controlled
- ☐ More weaknesses need to be identified
- ☐ Greater discussion of statistics necessary
- ☐ Additional trials should be suggested
- ☐ Use suggested table-formatting
- ☐ Greater detail needed

- ☐ Suggestions are too simplistic
- ☐ Suggestions are needed for *each* of the weaknesses identified
- ☐ Additional methods/apparatuses not discussed
- ☐ Additional data ranges should be suggested
- ☐ Further *related* experiments should be suggested
- ☐ Further trials lead to more reliable statistics

• Make conclusion more concise