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| **Instrument Number 1** | **Term 3 2024** |
| **Student Name** |  | **Handout Date** (Week Beginning) | 19/08/2024 |
| **Teacher Name** |  GILLMU, TURNGA, JORIGE | **Interim Check Date** | Ongoing |
| **Unit Number/Name** | Chemistry Preparation | **Rough Draft Date** | Ongoing |
| **Due Date** | 10/09/2024 |

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| **Assessment Technique** | Student Experiment |
| **Time/Length** | 3.5 weeks |
| **Assessment Conditions** | Summative |
| **Seen/Unseen** | Seen and unseen elements |
| Materials handed out prior to assessment? | No [ ]  | Yes [x]  | **Conditions** |
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| **Criterion** | **Marks** | **Grade** |
| Communication | /2 |  |
| Research and Planning |  /6 |  |
| Analysis of Evidence |  /6 |  |
| Interpretation and Evaluation |  /6 |  |
| **Science Understanding** | /20 |  |

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| **Differentiation: If assessment conditions have been adjusted details are provided below** |
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| **Acknowledgement of assessment responsibility** |  |
| I understand the consequences of plagiarism/cheating and confirm this is my own work. |
| **Student Signature:**  | **Date:** ……………………………… |

**Criterion: Communication -** Assessment Objective

1. communicate understandings and experimental findings, arguments and conclusions about reaction rates and collision theory

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| **The student work has the following characteristics:** | **Marks** |
| • effective communication of understandings, findings, arguments and conclusions about reaction rates and collision theory demonstrated by­ fluent and concise use of scientific language and representations­ appropriate use of genre conventions­ acknowledgement of sources of information through appropriate use of referencing conventions. | 2 |
| • adequate communication of understandings, findings, arguments and conclusions about reaction rates and collision theory demonstrated by­ competent use of scientific language and representations­ use of basic genre conventions­ use of basic referencing conventions. | 1 |
| • does not satisfy any of the descriptors above. | 0 |

**Criterion: Research and Planning -** Assessment Objectives

2. apply understanding of reaction rates and collision theory to modify experimental methodologies and process primary data

5. investigate factors that effect rates of reaction through an experiment

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| **The student work has the following characteristics** | **Marks** |
| • informed application of understanding of reaction rates and collision theory to modify experimental methodologies demonstrated by:­ a considered rationale for the experiment­ justified modifications to the methodology • effective and efficient investigation of rates of reaction demonstrated by:­ a specific and relevant research question­ a considered methodology that enables the collection of sufficient, relevant data­ considered management of risks and ethical or environmental issues. | 5–6 |
| • adequate application of understanding of reaction rates and collision theory to modify experimental methodologies demonstrated by­ a reasonable rationale for the experiment­ feasible modifications to the methodology• effective investigation of reaction rates and collision theory demonstrated by­ a relevant research question­ a methodology that enables the collection of relevant data­ management of risks and ethical or environmental issues. | 3–4 |
| • rudimentary application of reaction rates and collision theory demonstrated by­ a vague or irrelevant rationale for the experiment­ inappropriate modifications to the methodology• ineffective investigation of reaction rates and collision theory demonstrated by­ an inappropriate research question­ a methodology that causes the collection of insufficient and irrelevant data­ inadequate management of risks and ethical or environmental issues. | 1–2 |
| • does not satisfy any of the descriptors above. | 0 |

**Criterion: Analysis of Evidence -** Assessment Objectives

2. apply understanding of reaction rates and collision theory to modify experimental methodologies and process primary data

3. analyse experimental evidence about reaction rates and collision theory

5. investigate reaction rates and collision theory through an experiment

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| **The student work has the following characteristics:** | **Marks** |
| • appropriate application of algorithms, visual and graphical representations of data about reaction rates and collision theory demonstrated by­ correct and relevant processing of data• systematic and effective analysis of experimental evidence about of reaction rates and collision theory demonstrated by­ thorough identification of relevant trends, patterns or relationships­ thorough and appropriate identification of the uncertainty and limitations of the evidence• effective and efficient investigation of reaction rates and collision theory demonstrated by ­the collection of sufficient and relevant raw data. | 5–6 |
| • adequate application of algorithms, visual and graphical representations of data about reaction rates and collision theory demonstrated by­ basic processing of data• effective analysis of experimental evidence about reaction rates and collision theory demonstrated by­ identification of obvious trends, patterns or relationships­ basic identification of uncertainty and limitations of evidence• effective investigation of reaction rates and collision theory demonstrated by ­ the collection of relevant raw data. | 3–4 |
| • rudimentary application of algorithms, visual and graphical representations of data about reaction rates and collision theory demonstrated by ­ incorrect or irrelevant processing of data• ineffective analysis of evidence demonstrated by­ identification of incorrect or irrelevant trends, patterns or relationships­ incorrect or insufficient identification of uncertainty and limitations of evidence• ineffective investigation of reaction rates and collision theory demonstrated by ­ the collection of insufficient and irrelevant raw data. | 1–2 |
| • does not satisfy any of the descriptors above. | 0 |

**Criterion: Interpretation and Evaluation -** Assessment Objectives

 4. interpret experimental evidence about reaction rates and collision theory

 6. evaluate experimental processes and conclusions about reaction rates and collision theory

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| **The student work has the following characteristics:** | **Marks** |
| • insightful interpretation of experimental evidence about reaction rates and collision theory demonstrated by­ justified conclusion/s linked to the research question• critical evaluation of experimental processes about reaction rates and collision theory demonstrated by­ justified discussion of the reliability and validity of the experimental process­ suggested improvements and extensions to the experiment which are logically derived from the analysis of the evidence. | 5–6 |
| • adequate interpretation of experimental evidence about reaction rates and collision theory demonstrated by­ reasonable conclusion/s relevant to the research question• basic evaluation of experimental processes about reaction rates and collision theory demonstrated by­ reasonable description of the reliability and validity of the experimental process­ suggested improvements and extensions to the experiment which are related to the analysis of the evidence. | 3–4 |
| • invalid interpretation of experimental evidence about reaction rates and collision theory demonstrated by ­ inappropriate or irrelevant conclusion/s• superficial evaluation of experimental processes about reaction rates and collision theory demonstrated by­ cursory or simplistic statements about the reliability and validity of the experimental process­ ineffective or irrelevant suggestions. | 1–2 |
| • does not satisfy any of the descriptors above. | 0 |

**ORIGINAL EXPERIMENT**

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| **Reaction Rate between Marble Chips and Hydrochloric Acid measured through mass loss** |

Marble chips (calcium carbonate) react with dilute hydrochloric acid according to the equation:

CaCO3 (s) + 2 HCl (aq) ⎯→ CaCl2 (aq) + CO2 (g) + H2O (l)

While the reaction is proceeding, the mass of the reaction flask (with its contents) decreases as gas escapes.

By observing the loss in mass (which is the mass of carbon dioxide gas evolved), we can investigate how the reaction rate changes during the course of the reaction.

**Research Question**

To what extent does the rate of the reaction change with time for the reaction between 50mLs of 2.0 M hydrochloric acid and 2.0 g of Calcium carbonate (Marble chips).

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| **Materials** | **Chemicals** |
| * 100 mL conical flask
 | 50 mL of 2.0 mol L-1 Hydrochloric acid |
| * Cotton wool to be used as a plug
 | 2 grams Calcium carbonate chips |
| * Electronic balance
 |  |
| * Filter paper
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| * 100 mL graduated cylinder
 |  |
| * 100 mL beaker
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| * Stopwatch
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**METHOD**

1. Use a 100 mL graduated cylinder measure out 50 mL of 2.0 mol L-1 hydrochloric acid into a 100 mL conical flask.

**Figure 1:** Diagram of experiment set up

1. Record the exact volume of hydrochloric acid used \_\_\_\_\_\_\_\_\_\_\_\_\_\_ mL
2. Plug the neck of the flask loosely with cotton wool.
3. Weigh out 2.00 g of large marble chips on a filter paper on electronic balance.
4. Record the exact weight of calcium carbonate \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ g.
5. Put the flask on the pan of the balance as seen in Figure 1.
6. Record the **total mass** and record the reading in the table 1 in the results section as time zero (0).
7. Remove the cotton wool plug. Add the marble chips to the acid and quickly replace the plug. Start the stopwatch immediately. (Leave the flask with its contents and the filter paper on the balance pan.)
8. Record the total mass every 10 seconds for the first two minutes and every half-minute for the rest of the time, until two **or three consecutive constant readings have been obtained**
9. Calculate the total loss in mass for each time **Total loss in mass = mass recorded – initial mass**

**RESULTS**

Table 1: Mass of experiment vs time (seconds)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Time (s)± ……….(*est. uncert*) | Mass of Vessel (g)± ……….(*meas. uncert*) |  | Time (s)± ……….(*est. uncert*) | Mass of Vessel (g)± ……….(*meas. uncert*) |  | Time (s)± ……….(*est. uncert*) | Mass of Vessel (g)± ……….(*meas. uncert*) |
| 0 |  |  | 70 |  |  | 180 |  |
| 10 |  |  | 80 |  |  | 210 |  |
| 20 |  |  | 90 |  |  | 240 |  |
| 30 |  |  | 100 |  |  | 270 |  |
| 40 |  |  | 110 |  |  | 300 |  |
| 50 |  |  | \*120 |  |  |  |  |
| 60 |  |  | 150 |  |  |  |  |

\* = 30 sec time interval from this point

1. Plot a graph of total loss in mass (g) against time (seconds). Draw a smooth curve through as many points as possible.

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**Answer the following questions:**

1) Identify a time period at which the rate of reaction is the fastest.\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2) Identify a time period at which the rate of reaction is the slowest. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3) Determine the total mass loss of carbon dioxide \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4) Calculate the moles of calcium carbonate you used in the experiment.

5) Calculate the moles of hydrochloric acid you used in the experiment.

6) Which reagent (calcium carbonate, or Hydrochloric acid) is the limiting reagent? Show your workings

7) Calculate the theoretical yield of carbon dioxide gas.

CaCO3 (s) + 2 HCl (aq) ⎯→ CaCl2 (aq) + CO2 (g) + H2O (l)

8) Determine the average **rate of the reaction =**$ \frac{Δmoles}{Δ t}$ by following the outline shown below in the table.

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| STEP 1: Calculate the change in mass and its uncertainty for your selected time period. Time period chosen was 0 sec to ………. sec. |
| Calculation |  |
| Change in mass = mf - mi = -  = g |  |
| Caculate the measurement Uncertainty in the change in mass.Change in mass was calculated by subtracting, so use the uncertainty rule for propagating uncertainty for subtraction.**That is, add the measurement uncertainty associated with both mass values**.Meas. Uncert = ± \_\_\_\_g + ± \_\_\_\_g= ± \_\_\_\_\_ g  | What was the measurement uncertainty associated with using the electronic balance? |
| Since we only did one trial, there is no need to calculate a random uncertainty, which can only be calculated from trial results. Therefore we use the measurement uncertainty as our uncertainty. |
| Change in mass = \_\_\_\_\_\_\_\_\_ ± \_\_\_\_\_\_\_ g |
| Average moles of CO2 lost:$$Average moles of CO\_{2}= \frac{mass lost }{Molar mass(MM)}$$ |  |
| Uncertainty in moles lost:$$uncertainty= \frac{Mass lost}{MM} \pm \frac{mass lost}{MM}(\frac{uncert in mass}{Mass lost}+\frac{Uncert in MM}{MM})$$As MM is a “known value” it has zero uncert, so this formula simplifies to:$$uncertainty= \frac{Mass lost}{MM} \pm \frac{mass lost}{MM}(\frac{uncert in mass}{Mass lost})$$ |  |
| Moles of CO2 lost (n) = \_\_\_\_\_\_\_ ± \_\_\_\_\_\_\_\_ moles |

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| STEP 2: Calculate the change in time |
| Change in time*Δt* = tf - ti= \_\_\_\_\_\_- \_\_\_\_\_\_\_ |   |
| Measurement Uncertainty (primary data)Change in time was also calculated by subtracting, so use the uncertainty rule for propagating uncertainty for subtractionThat is add the measurement uncertainty associated with both time values= ± \_\_\_\_\_ s + ± \_\_\_\_\_ s | What was the measurement uncertainty associated with using the stopwatch? This would normally be taken from the digital screen, however there is additional uncert associated with you noting the time and then taking the reading. You will need to estimate a measurement uncert for this rather than simply relying in the smallest increment of the device. |
| Since we only did one trial, there is no need to calculate a random uncertainty, which can only be calculated from trial results. |
| Change in time = ± s |
| STEP 3: Calculate the rate of the reaction  |
| Rate of Reaction:$$ Rate= \frac{change in number of moles}{change in time} = \frac{∆n}{∆t}$$ = moles/s |  |
| Calculate the uncertainty in the rate of reactionRate of reaction (see left) was calculated by dividing, so use the uncertainty rule for propagating uncertainty for division.$$Uncertainty =\pm \frac{∆n}{∆t} (\frac{ uncertainty in ∆n}{ ∆n}+ \frac{ uncertainty in ∆t}{∆t})$$$Uncertainty =\pm \\_\\_\\_\\_\\_\\_\\_\\_\\_\\_ $moles/s |  |
| **Rate of reaction =** $\pm $ **moles/s** |

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| **MODIFIED EXPERIMENT (for your report)** |
| * Modify (i.e. refine, extend or redirect) the given investigation: “The rate of reaction between marble chips and hydrochloric acid **”.**
 |
| The response must be presented using an appropriate scientific genre of a scientific report and contain the following parts (use appropriate heading):* **Research question**
* **Original Experiment** (brief description – no marks for this, but it provides important context)
* **Modifications to the methodology**
* **Risk management and Environmental Issues**
* **Raw Data**
* **Data Processing** (Table)
* **Secondary Data**
* **Identifying Trends and Relationships**
* **Identifying Uncertainty and Limitations**
* **Conclusion**
* **Evaluation of the Reliability and validity**
* **Word Count**
* **Reference list**
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| **Research Question** |
| * State the research question in one sentence.
* It helps if you have clearly identified your independent variable and dependent variable because:
* The independent and dependent variable should be clearly stated in the research question. The range of variation in the independent variable should also be stated, along with any particular context the research question is based in.
* EXAMPLE - *How does changing (Independent Variable – with description of range ) in the (experiment or context) affect the (dependent Variable)?*

  |
| **Original Experiment** |
| * Brief describe the original experiment – do so in a max of 2 sentences (1 preferably). Then state the authors of the study/experiment (in this case it is Mr M. Gillis and Mr C. Turner), and main findings.
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| **Modifications to the methodology** |
| * This section is where you explain/justify how the experiment you are conducting is a modification of the original methodology of original experiment. The simplest way to do this is following the dot points below.
* Describe the change in the independent variable **if** this has changed and justify why it is occurring.
* Describe the change in the dependent variable **if** this has changed and.
* Describe the number of variations of the independent variable (and the range of the variations), and justify why you need this number of variations. *Clue - 5 variations of the independent variable is sufficient to precisely determine a trend*
* Describe the number of trials for each variation of the independent variable and justify why you need this number of trials. *Clue - a minimum of 3 trials**for each variation of the independent variable is sufficient to determine and to reduce the uncertainty of the data*.
* Describe any other changes/modifications to the methodology, such as the use of more accurate/precise equipment. Always justify why this modification was made.
 |
| **Risk Management and Environmental Issues** |
| * Use the following table structure as a guide giving 3 potential hazards/risks and strategies to handle these)

**Risk Management:**

|  |  |  |  |
| --- | --- | --- | --- |
| Source of risk | Amount of harm could it cause? (circle) | Safety precautions taken | If an incident occurred what should I do? |
|  | Minor Significant major |  |  |
|  | MinorSignificantmajor |  |  |
|  | MinorSignificantmajor |  |  |

**Environmental Issues:*** Discuss any environmental issues that arise from using or making chemicals in your experiment. This usually means discussing the disposal of your waste products. If they were safe to dispose of say so. If they needed to be retained and disposed of through a chemical disposal process say so (and explain what the danger was – Refer to MSDS)
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| **Raw data**  |
| * Quantitative (numerical) data should be in Tables; qualitative (descriptive) data can be written in sentences

Table 1: Raw data for finding mass loss when changing concentration of HCl for \_\_\_\_\_\_\_\_\_seconds.

|  |  |
| --- | --- |
| **HCl concentration****(M)** | **Mass Loss (g)** |
| **Trial 1**  | **Trial 2** | **Trial 3** | **Average** |
|  |  |  |  |  |
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 |
| **Data Processing** |
| Example: **For \_\_\_\_\_\_M HCl**

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| **Dependent variable – Rate of reaction** |
| The rate of reaction was calculated from the average mass lost, which was converted into the moles of CO2 lost, which was then converted into a rate by dividing by the time taken for this mass loss. You need to show all of these calculations along with the uncertainty associated with them. |
| Calculation formula | Example of calculation at M HCl |
|  Average mass loss:$Average Mass Loss = \frac{(Trial 1 + Trial 2 +Trial 3)}{3}$ $Average Mass Loss = $*\_\_\_\_\_\_ g* |  |
| Random Uncertainty (Uncertainty of Average):$Random uncert= \frac{range }{2} = \frac{Highest trial-lowest trial}{2}$ $= \pm \\_\\_\\_\\_\\_\\_$ *g* |  |
| Measurement Uncertainty:$Measurement uncert= \pm \\_\\_\\_\\_\\_\\_ $ *g* |  |
| Choose the greater of the two uncertainties – it is this uncertainty you will continue the rest of the calculations with. Write it down here with the average mass loss:$Average Mass Loss = \\_\\_\\_\\_\\_$ ± \_\_\_\_ *g* |
| Average moles of CO2 lost:$$Average moles of CO\_{2}= \frac{mass lost }{Molar mass(MM)}$$ |  |
| Uncertainty in moles lost:$$uncertainty= \frac{Mass lost}{MM} \pm \frac{mass lost}{MM}(\frac{uncert in mass}{Mass lost}+\frac{Uncert in MM}{MM})$$As MM is a “known value” it has zero uncert, so this formula simplifies to:$$uncertainty= \frac{Mass lost}{MM} \pm \frac{mass lost}{MM}(\frac{uncert in mass}{Mass lost})$$ |  |
| Rate of Reaction:$$ Rate= \frac{change in number of moles}{change in time} = \frac{∆n}{∆t}$$ = moles/s |  |
| Calculate the uncertainty in the rate of reaction*Note: see earlier (part 1) for your uncertainty in time value*$$Uncertainty =\pm \frac{∆n}{∆t} (\frac{ uncertainty in ∆n}{ ∆n}+ \frac{ uncertainty in ∆t}{∆t})$$$Uncertainty =\pm \\_\\_\\_\\_\\_\\_\\_\\_\\_\\_ $moles/s |  |
| Rate of reaction = \_\_\_\_\_\_\_\_ $\pm $ \_\_\_\_\_\_\_ moles/s |
| Calculate percent uncertainty in rate$$\% uncert in Rate= \frac{absolute uncert in rate x 100}{rate }$$$\% uncert in Rate= \\_\\_\\_\\_\\_\\_\\_\\_$ % |  |
| Rate of reaction = \_\_\_\_\_\_\_\_ moles/s$ \pm $ \_\_\_\_\_\_\_ % |

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| **Secondary Data**  |
| * Present your final data in a table.

 Table #:

|  |  |  |  |
| --- | --- | --- | --- |
| **HCl concentration****(M)** | **Rate****(moles/s)** | **Rate with percent Uncertainty** | **Rate with Absolute Uncertainty** |
|  |  |  |  |
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**Graphical analysis of data*** Secondary (processed) data - Graph dependent variable (average rate) versus “independent variable” (will vary depending on what you choose for your independent variable). Graph should be a scatterplot, with an appropriate scale and a trend line, with mathematical equation and R2 value displayed
 |
| **Identifying Trends and relationships** |
| * Generally speaking, trends and relationships are the same idea. Both words can be used to identify or describe how the Dependent variable (on the y axis) changes when independent variable (on the x axis) changes. However, the word relationship is more useful when talking about the maths that connects two variables. So most people use the term trend when describing the data in words, but switch to the trem relationship when describing the data using mathematics.
* For this section write a paragraph that:
* Starts with a very simple sentence identifying the trend in the data. The sentence should go along the lines of…

“As the (*independent variable*) increases, the (*dependent variable*) increases/decreases (*use which ever applies*)”.* The second part of the paragraph is a more detailed description of the trend. This can be simple, or more complex, depending on the data (shape of the trend line), and how much experience you have. Ideally you should describe the trend as linear, exponential, polynomial, power, or logarithmic; and use a mathematical relationship to identify it (excel will generate one of these, but you have to know what it means).
* The 3rd part of your paragraph will be used to quote data from the table or graph which supports the description of the trend.
* At the end of the paragraph, you can explain any specific implication of this trend. Every trend has an implication, you just have to identify it.
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| **Identifying Uncertainty and Limitations**  |
| * Do this is two parts – Uncertainty first in one paragraph, then Limitations in a second paragraph.

UNCERTAINTY* Uncertainty describes how certain you are that your data is precise.
* Start with a simple statement stating the amount of uncertainty in the data.

“There is a (*use an appropriate word*) amount of uncertainty in the data”. * The rest of the paragraph is simply justifying why you think there is this much uncertainty. You can do this three ways. Two ways look at uncertainty in the data, the third looks at the uncertainty in the trend. You need to apply all three ways. There is uncertainty in the data even if only one of these ways identifies it.
* The first way to identify uncertainty is from the data uncertainty values. Generally speaking, an uncertainty which is higher than five or ten percent (always do the percent calculation, and present this in your secondary data table) is considered to be significantly uncertain.
* The second way to identify uncertainty is to see if there was data which was not used in the final results. Scientists sometimes label them anomalies or outliers, and use an asterix and footnote underneath the raw data table to identify if there were anomalies. These anomalies were not used to calculate the averages, and therefore not used for the uncertainty calculation. Because the anomalies have been removed from the calculations, the final data set can seem to have low uncertainty. However, the fact that there are anomalies in the raw data means there is more uncertainty in the data than the uncertainty percentage suggests there is.
* The third way to identify uncertainty is by looking at the data points and the trendline on a graph. Data points which are very close to a trend line suggests that the trend line is a very precise description of the data. This means the trend has low uncertainty. If the data points are not close to the trend line, the trend line is not a good description of the data, and there is a significant amount of uncertainty in the trend. R2 is a well accepted way of judging this. R2 values which are high (>0.97), describe a trend line which… *actually just look up R squared… it’s a bit complicated and if you use it make sure you talk about it correctly!*

LIMITATIONS* Limitations are things which mean your experiment process did not necessarily measure what it was intended to. Almost all data contains limitations, you just have to identify them and explain what they are.
* Start this section with a simple statement along the lines of

“There appear to be (*use an appropriate word*) limitations in the data”. * For the rest of the paragraph, you need to justify what these limitations are by identifying them and then briefly explaining each limitation (one pr for each). There are three ways to identify the limitations. You need to apply all three ways.
* The first way to is to look at how much data was measured and the un certainty in it. If your data uncertainty was reasonably high, the data is limited in its precision. If there is a reasonable or high amount of uncertainty in the trend, then the data is limited in its ability to precisely describe a trend or relationship.
* The second way to identify limitations is to look at the value of the independent variable. Sometimes this is not a real-life value, but one the scientist used so the experiment/investigation could be completed in a shorter amount of time. Say a scientist was measuring the rate of decay in human skeletal remains – which may take many years to do in real life conditions. Scientists will often use an independent variable which is not real-life (for example - tiny bone fragments rather than whole bones) to speed things up. This is not “wrong”, and perfectly justified in science, but it can limit how well the data applies to real life conditions.
* The third way to identify limitations is by identifying any controlled variables which were not actually controlled. If the controlled variables were not actually well controlled, this limits the accuracy of any trend which has been identified.
 |
| **Conclusion** |
| * The conclusion section is usually relatively short. It is where you decide what your results mean. Initially this means an answer to the research question you have at the start, then some broader conclusions if you have them.
* The first paragraph has to be the main conclusion made from the data.
* Start the paragraph with a simple conclusion which answers your research question (one sentence).
* Follow this statement supporting evidence. Use trends to support your conclusion, not data. If you have a mathematical equation, include it here to support your simple statement. If you do not have a mathematical equation, elaborate and further explain your conclusion or the trend which supports it.
* The second paragraph (or the end of the first para), is where you broaden your conclusion to include real-life implications of the conclusion. That is, explain how this conclusion is relevant and important. Doing this generally shows you understand the significance of the conclusion.

NOTE: In the conclusion you DO NOT discuss how correct your conclusion is. This is done in the next section. |
| **Evaluation of the RELIABILITY and VALIDITY (of the experimental process)** |
| This sounds complicated, but is actually quite easy. It is easier if you discuss reliability separately from validity, so do this in two parts.* Reliability generally refers to whether your data is repeatable. That is, if anyone else was to do the investigation using the same method, would they get the same result? The uncertainty you identified earlier is very useful here. If you earlier decided that your data was uncertain (the average % uncertainty you calculated was higher than 10%), **or** that your trend was uncertain (judgement call from the line and data points, or R2), then the method is not reliable. If your uncertainty was low (average <5% uncertainty **and** low trend uncertainty), then the data is reliable. Reliability should only take one paragraph, and:
* Start the paragraph by stating if the method and resultant data is reliable, not reliable, or somewhere in between. Then justify this by explaining the uncertainty you identified earlier. Then try to identify why that uncertainty occurred by evaluating the errors that were in the method, or that you made when performing the method. This last bit is the hard part.
* Validity generally refers to whether the trends you identified, and whether the conclusions you made are valid or not. That is: are the trends real, and are the conclusions meaningful? The limitations you identified earlier can be used to argue validity, but there is also one additional way to evaluate validity. This is by comparing your conclusions to existing theory and determining if there is error in your conclusion – this is traditional error analysis. Evaluating validity should also only take one paragraph, and the sequence you should follow is outlined below.
* Start the paragraph by stating if the conclusions made in the investigation are valid, not valid, or somewhere in between. Use the limitations you identified earlier to justify your decision in the first statement. A lot of limitations, or some very important limitations may mean the conclusion is not valid at all. Explain how the limitations could have been avoided.
* If you are able to compare your main conclusion to “what you were expected to find”, this comparison should allow you calculate or judge the amount of error you have. If you have greater than 10% error (your answer is more than 10% from the expected result), then your conclusion is not valid. Note that this is nothing to do with uncertainty. This method of judging validity can only be done if you know what the “right” answer is supposed to be.
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| **Word Count** Put in a count of all the words used in your report. Do not count the raw data table, your secondary data table, or the list of references you use. Your word count should be 1000 to 1500 words |
| **Reference List** Use Harvard referencing as prescribed in your student learning journal. |