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| **EXTENDED EXPERIMENTAL INVESTIGATION – EXEMPLAR WITH SCAFFOLDING AND ANNOTATIONS** |
| SCAFFOLDING | REPORT | ANNOTATIONS |
| **Title** **Investigation Question** | **Acid rain and Calcium carbonate structures****What effect does contact with acids have on structures made from calcium carbonate?** |  |
| **Introduction**The introduction has **three main parts**. **1st Part**This part of the introduction provides the context for the investigation. This part is usually 2 paragraphs.The 1st paragraph introduces the topic covered by the experiment. It explains why this topic is important in a “big picture” sense.The 2nd paragraph explains some of the real life implications of the topic, or provides further explanation.**2nd Part**Provides an explanation of all of the theory you will use in your investigation. It describes the science behind the topic which is relevant to this experiment.This part also explains any scientific laws or mathematical formulas which apply to the experiment.**3rd Part**This should be a general description of how you will do your investigation – that is describe what you will do. Do not list steps (we do this in the method), just summarize the process of completing the investigation.**/ ?** | **INTRODUCTION**Acid rain is a term used to describe rain (or other precipitation) which is acidic. Rain which has a pH less than or equal to 5.5 is considered to be acidic. When power stations, [factories](http://www.ecoca.ro/meteo/tutorial/Acid_Rain/Younger/Industry.html), houses and [cars](http://www.ecoca.ro/meteo/tutorial/Acid_Rain/Younger/Cars.html) emit pollution into the air, it contains chemicals known as sulphur dioxide and nitrogen oxides. These chemicals may mix with water in the air to form acids which can be transported long distances by the wind before being deposited in rain (*Manchester Metropolitan University1)*. Acid rain can therefore be a significant and widespread problem where industrial and car pollution is not controlled.Diagram 1*http://archive.thedailystar.net/beta2/news/sustainer-of-life-or-angel-of-death/*Acid rain can have harmful [impacts](http://www.ecoca.ro/meteo/tutorial/Acid_Rain/Younger/Impacts.html) on the environment in many ways. It affects [freshwater lakes](http://www.ecoca.ro/meteo/tutorial/Acid_Rain/Younger/Freshwater.html) and the [wildlife](http://www.ecoca.ro/meteo/tutorial/Acid_Rain/Younger/Wildlife.html) that depend upon them. It also affects [trees](http://www.ecoca.ro/meteo/tutorial/Acid_Rain/Younger/Trees.html) by harming leaves and soil, and it damages [buildings](http://www.ecoca.ro/meteo/tutorial/Acid_Rain/Younger/Buildings.html) and outdoor statues made of limestone and marble *(Singh, A. and Agrawal, M. 20082).* The damage caused to buildings and statues is the most commonly noticed example of the damage caused by Acid rain (see diagram 1).Marble and Limestone are both forms of Calcium Carbonate - CaCO3. These two chemicals are hard rock like substances but they can be sculpted and shaped into statues and buildings. Both chemicals react with acid in the rain according to the following chemical equation. In the equation below the acid is Sulphuric acid (H2SO4), the most common form of acid found in acid rain. CaCO3 + H2SO4 → CaSO4 + H2O + CO2 (g) Marble Sulphuric Acid Calcium Sulphate Water Carbon DioxideThe only product of the reaction which is a solid - calcium sulphate - is more like a powder than a rock. Therefore, acid rain causes marble and limestone to gradually crumble and erode away. This reaction is very slow in natural conditions but the damage accumulates over many years and is irreversible. This investigation will measure the effect of changing the concentration of sulphuric acid on the rate of the reaction with marble. The acid used will be Sulphuric acid, and the building or a statue will be represented by marble chips. Marble chips will be placed in Sulphuric acid on an electronic balance. The mass of the mixture will be measured for three minutes. The greater the mass lost by the marble and sulphuric acid mixture, the faster the reaction is between the marble and the acid. Mass is lost because the reaction between marble chips (CaCO3) and Sulphuric Acid (HCl) releases Carbon Dioxide (CO2) gas. The Carbon Dioxide gas bubbles to the surface of the acid and leaves the reaction beaker, causing a loss in mass. The more mass that is lost in the three minutes the greater the rate of reaction. | *Topic sentence**Elaborate/Explain**Topic sentence describes the experiment. The rest of the paragraph explains the key parts in the method, but is not a list of steps.* *No link as this is the end of the introduction**Topic sentence**Elaborate**Explain/Evidence**This paragraph introduces some real life implications and starts to narrow the focus from “big-issue” to our area of study – the reaction between acid and marble.**Link**Topic sentence**Elaborate/Explain**Explain/Evidence**This paragraph explains what Acid Rain is and why it is a big issue**Topic sentence**Elaborate/Explain**Explain/Evidence**This paragraph introduces the chemical equations and describes it. It also uses this theory to further explain some real-life implications of acid rain.* |
| **Aim**The aim is one sentence which links the independent and dependant variables. A basic format is…To investigate if varying the **(independant variable)** changes the (dependant variable)**/?** | **AIM:**To investigate if varying the concentration of Sulphuric acid changes the rate of reaction between the acid and marble chips (Calcium carbonate). | *Independent variable (one we are deliberately changing) is the concentration of Sulphuric acid. The dependent variable (one we will measure) is the rate of the reaction – although in this case we will use mass loss as a measure of rate.* |
| **Hypothesis**A hypothesis has **two** sentences – the first is what you expect to happen, the second is why you think it will happen.**/?** | **HYPOTHESIS:**The rate of the reaction between Sulphuric acid and marble should increase as the concentration of the acid increases. This should occur because at higher concentrations of acid there are more acid molecules to react with the marble. | *The key “thing” expected to happen**The theory explaining why this is expected to happen* |
| **Method**A Method has 2 parts – the Materials (a list of equipment), a Diagram, and a Procedure (a list of steps to do the experiment)Materials - List the materials you will use in your experiment. Use a bullet list style. Read the procedure (next page) to ensure you have all you needDiagram - draw a neat and reasonably accurate diagram and label all the main parts. Procedure - What were the steps in the investigation? Write a numbered list of steps. Each step describes something you did in the experimentDo not start with something like “Collect the equipment”Use the term “Repeat steps… “ to avoid having to write steps which are being repeated.At the end of the procedure list the relevant variables for your investigationIndependent Variable – this is the one which you are making changes to deliberately.Dependent Variable – this is the one you are expecting to change as a result – you are measuring this one.Controlled Variables – these are ones you want to keep the same each and every time.**/?** | **METHOD:**Materials:* 1 x 100 mL beaker
* 1 x electronic scales
* Container of marble chips
* Sulphuric acid (1.0M)
* 1 x 25 mL Measuring Cylinder
* Distilled water
* Watch or timer

Beaker (50mL Acid)Marble ChipsElectronic BalanceDIAGRAM 1Procedure:1. Measure 50 mL of sulphuric acid (1.0M) and pour into the Beaker

*At the start you could say “assemble the apparatus as shown in diagram 1” if it is appropriate.**Write your method for a fellow student to follow. Assume that student is capable, but not a mind-reader*1. Place the beaker on the electronic scales as shown in Diagram 1
2. On the electronic scales, beside the beaker add exactly 4 grams of marble chips.
3. Tare (zero) the scales so that the reading is 0.00 g
4. Pick up the Marble chips and add them (all together to the beaker of Acid). Start the timer at this point. (The mass of the beaker will reduce so a negative mass will show on the electronic balance – this is the mass lost)
5. At the three-minute mark record the loss in mass of the acid and Marble Chip mixture.
6. Discard this mixture into the waste beaker at the front of the room and rinse and dry the beaker. You should wash the marble chips thoroughly with water and dry them for reuse.
7. Repeat steps 1-7 but using different concentrations of Acid - 0.8M, 0.6M, 0.5M, and 0.4M.

Independent Variable – Concentration of Sulphuric AcidDependent Variable – Mass loss in three minutesControlled Variables – Volume of Sulphuric acid Temperature of Sulphuric Acid Mass of Marble Chips Size and Shape of the Beaker Time (3 minutes) | *Methods do not usually contain explanations – but here the fact that the electronic balance is recording mass loss as a negative number is explained.**List one variable – the one you deliberately changed**List one variable – the one you measured**List all the variables you are trying to control (keep the same) for the experiment* |
| **Risk assessment** **Fill in the table** for the things in your experiment which may be a source of harm. Check with your teacher for some if you are not sure**/?** |

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

**Risk assessment:** Table 1 – Possible risks in experiment |  |
| **Results**Draw a table to collect your data (or use the one already drawn)A table will have a heading such as:*Table 1: Description of the data in the table*In your table…The **first column** will be your independent variable, so use this for a heading in this column (along with units) The second Column will be your dependent variable, so use this for a heading in this column (along with units).You may need more than two columns if you are collecting other data OR if you are doing more than one trial (RECOMMENDED you do this) Your table should have at least 5 rows to collect 5 variations of your independent variableRemember – if you do 3 or more trials, you need to calculate an average result. When calculating the average you may not have to use all 3 trials, two may be enough. If any of the trials is “too different” or “looks wrong” you can ignore it as it is likely to be an error.**/?** | **RESULTS:**The table below records the mass lost from the reaction between Sulphuric acid and the Marble chips after a time period of three minutes.Table 2: Mass loss after three minutes – Marble chips in Acid

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| **Concentration of Sulphuric Acid (M)** | **Mass loss after 3 minutes (g)** |
| **Trial 1** | **Trial 2** | **Trial 3** | **Average** |
| 1 | 0.56 | 0.53 | 0.58 | 0.56 |
| 0.8 | 0.36 | 0.37 | 0.41 | 0.38 |
| 0.6 | 0.25 | 0.11\* | 0.21 | 0.23 |
| 0.5 | 0.18 | 0.19 | 0.18 | 0.18 |
| 0.4 | 0.19 | 0.2 | 0.19 | 0.19 |

\**this result was not used to calculate an average for this concentration*These results from table 1 are graphically represented in a trend line scatter graph shown below in Graph 1 | *If your table is complicated, you may need to introduce it so the reader “gets” what the data is**Data – notice no units in the cells. Units belong in the headings.**Always use a table number in the title AND a very brief descriptor.**Tables are very visual – they rely on appearance, so be tidy and do not make your table too small. See the use of a footnote (\*) to describe one piece of data**Headings. Always include the units in the column headings**Introduce the graph which follows the table. This is not always necessary, especially if the graph is immediately after the table. It is necessary if you have several tables and each graph is not directly after the table it relates to.* |
| **Graph**Draw a **scatter graph** (crosses for each data point) of your independent variable (on the x axis) versus your dependant variable (on the y axis)Each data point should be a small cross of circle. You should have at least 5 data points (crosses) on your graphLach axis with the variable name and units, put a title, use a key if you have more than one set of data. Look at all the data points carefully. What pattern or “trend” do they make? **Draw the trend line** where you think the “trend” or “pattern” of the points is. The trend line may be a straight line, or it may be a curve. If it is a curve draw it with a smooth curve. The trend line does not have to go through all, or even any of the points.**/ ?** | **Graph 1:** Plot of Concentration of acid and its effect on the mass loss of Marble chips | *Always use a graph number in the title AND a very brief descriptor.**Show the data clearly visible as crosses or small dark dots. The trend line MUST be a straight line or a smooth curve**Note the scale on each axis is consistent. Each jump along the axis represents the same amount of value.**Note that each axis has a heading along with the units – get both of these from the table. The horizontal axis is the independent variable, while the vertical axis is the dependent variable.* |
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| **Analysis** Have a careful look at your results. There are 2 main parts to an analysis. The 1st part is about what you can decide from your results while the 2nd part is about the error you may have.**1St Part - conclusions**Write a sentence describing the main conclusion (decision) you can make from your results. Now describe or list the data which supports your conclusion (refer to tables or graphs). Use the trend line to describe the relationship between your independent and dependent variable. If you have a computer generated trend line, identify and explain the equation to the trend line. Explain the theory behind this conclusion if you can. You should be using the theory you included in the 2nd part of your introduction. Lots to do here so you may need more than one paragraph.**If there are other conclusions you could make then repeat this process for each conclusion you make.** **2nd Part - errors****1st Paragraph -** Write a sentence about how much error there is in the results. Then you have to explain why you think this (rest of the paragraph). Judge the error using at least 1 of the 3 methods described in the appendix. **2nd Paragraph -** State how the error occurred (what caused it). Then make suggestion about how this could have been avoided. **3rd Paragraph -** State if the conclusion you made earlier are valid. This will depend on how much error you believe you have. Use the amount of error you have to justify your decision.**/?** | **ANALYSIS:***Topic sentence - This is the main conclusion – stated quite simply and directly.* *Topic sentence**This elaboration is clarifying the type of “affect” stated in the topic sentence**This “2nd” conclusion is really just another way of interpreting data supporting the main conclusion. The writer is trying to show there are a couple of ways to interpret the data* *Evidence to support the main conclusion**The conclusion is explained or analysed using the theory from the 2nd part of the introduction**The conclusion is explained or analysed using the theory from the 2nd part of the introduction**Elaboration**Evidence**The equation to a trend line is a very precise mathematical way of describing the relationship between your independent and dependent variables. Equations to the trend line are very useful if you understand them.* The concentration of the Sulphuric acid does affect the mass loss of the marble chip and acid mixture. As the concentration of the acid increases so does the loss in mass. At an acid concentration of 0.4M, the mass loss was 0.19g. At double this concentration (0.8M) the mass loss was 0.38g. As the concentration of acid doubled, so did the mass lost by the marble. This suggests a simple, directly proportional relationship between acid concentration and the rate of reaction between the acid and marble. This type of relationship seems consistent with the simple reaction process between Calcium carbonate and sulphuric acid (see equation for this reaction in the introduction, p1).However the trend line in graph 1 indicates a complex relationship between Acid concentration and Mass loss. The trend line is curved upwards - meaning at high concentrations of acid the mass loss was higher than would be expected from a simple directly proportional relationship (a straight trend line). The trend shows that at a concentration of 0.5M a mass loss of just less than 0.2g is predicted. At double this concentration (1.0M), the trend line predicts a mass loss of well over 0.5g - considerably more than double the mass loss predicted at 0.5M concentration. This indicates that the mathematical relationship between acid concentration and mass loss is not directly proportional and may be exponential. The equation to the trend line is  $y=0.9x^{2}-0.6x+0.3$ Or $mass loss=0.9\left(conc of acid^{2}\right)-0.6\left(conc of acid\right)+0.3$A second order polynomial relationship such as the one above would suggest that at high concentrations of acid rain there is a much larger than expected increase in the rate of erosion of calcium carbonate structures. Conversely however, it also suggests that decreasing the concentration of acid rain (by reducing pollution) may have greater than expected benefits in reducing the erosion of such structures.There is significant error in the results. Generally speaking, the closer the data points are to the trend line the more consistent the pattern (trend) is in the data, and the lower the error. There are several points in graph 1 which are not close to the trend line. The data points at 0.6M and 1.0M are close to the trend line; however the data points at 0.4M and 0.5M are not. The data points also indicate that a concentration of 0.5M would cause less mass loss (0.18g) than the lower concentration of 0.4M (0.19g). This result is not logical and contradicts other data points. Therefore the data points do not form a consistent pattern and contain significant error. This type of error is referred to as episodic (individual episodes of error). Graph 1 indicates that error was made in the 0.4M and 0.5M experiments as these data points are furthest from the trend line.This is supported by the R2 value shown in Graph 1. The R2 value of 0.85 also indicates there is too much error for this data to be considered accurate. The reason for this was poor laboratory technique by the person(s) doing the experiment. The error is likely to be either not mixing the concentration of the acid accurately, or not measuring the mass of the Marble chips at exactly three minutes. | *Explanation – but not of the topic sentence itself. This explains how the error was judged – see appendix 3**This paragraph is poorly structured as It starts with evidence and not a proper topic sentence.**This paragraph is poorly structured as it starts with evidence. A proper topic sentence would have been…”Some of the data appears contradictory”.* *Evidence**Topic sentence – clearly simply states the amount of error* |
| **Conclusion*** **1St Paragraph**

Re-read your aim - write a sentence that **explains what your results show in light of what the aim says**. This sentence is your **main conclusion**.State whether this is consistent with the theory (what you expected to happen). Explain how the theory (you wrote about this in your introduction) explains your results.* **2nd Paragraph**

Write a sentence about the amount of error in your investigation (you decided this in the analysis). Explain how this error occurred. Provide suggestions to improve the experiment so these errors could be avoided. * **3rd Paragraph**

Sum up your conclusion by again stating * your main conclusion,
* how this conclusion relates to the global issue outlined in Part 1 of the introduction.
* If your conclusions are valid or not. Your conclusion will not be valid if you have too much error.

**/ ?** | **CONCLUSION***Topic sentence of conclusion should reflect the original aim of the investigation.**Summary of key point(s) raised in the first part of the analysis**Explanation of topic sentence* Varying the concentration of sulphuric acid changes the rate of reaction between the acid and the marble. Higher concentrations of acid cause greater mass loss when it reacts with marble. The relationship between acid concentration and mass loss is not directly proportional and may be quite complex as higher concentrations of acid have a greater than expected effect on the marble. The exact relationship between acid concentration and the mass loss of the marble was $mass loss=0.9\left(conc of acid^{2}\right)-0.6\left(conc of acid\right)+0.3$*Topic sentence on error**Summary of key point(s) about the error*The results appear to contain significant error. The data points appear to contradict each other and several are not close to the trend line - indicating that the pattern formed by the data is not consistent. It is recommended that the investigation be repeated with more attention to mixing concentration of the acid and controlling all variables. Another recommendation would be to perform more experiments - at concentrations of 0.2M, 0.7M, and 0.9M. This would mean there are more data points to determine the trend line, and the trend line should therefore be more accurate.*Recommendations to improve the investigation are not general things - but are specific to the type and amount of error pointed out in the analysis.**Topic sentence relates to investigation question and/or aim. Note that the use of the word PROVED is incorrect. Investigation “show” or “demonstrate” – proof only occurs after repeated investigations.*This investigation proved that an increased concentration of acid rain will cause an increased rate of reaction (and therefore greater mass loss) when reacting with Calcium Carbonate structures. The exact relationship was complex and indicated that higher concentrations of Acid have a greater than expected effect on the Marble. This finding is significant as increases in pollution may have greater than expected effects on Calcium carbonate structures such as statues and buildings. There was significant error in the investigation and the error appeared to be caused by poor laboratory techniques. It is logical that higher concentrations of Acid would cause a higher mass loss. However, given the degree of error in the investigation this conclusion is not necessarily accurate and further repeated investigation, is recommended. |  |
|  | **References**1. Manchester Metropolitan University. 1999. *Acid Rain*. [ONLINE] Available at: <https://chemlinks.beloit.edu/Rain/copy/mmu/03uk.html>. [Accessed 12 January 2016].
2. Singh, A., & Agrawal, M. (2008). Acid rain and its ecological consequences. Journal of Environmental Biology, 29(1), p.15-24
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| **APPENDIX 1 – general scientific report wring genre*** General advice – do not use “you”, “us”, “we”, “they” or other personal pronouns. A passive voice is used. For example, instead of “we measured the depth of…”, use “the depth of …. was measured”
* You should stick to one tense, either past tense or present tense and not swap between them.
* Use in text referencing for any of your references. Harvard style is preferred. Your school diary explains how to do this and there are several sites which will automate this process for you.
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| **APPENDIX 2 –**  **Using the TEEL structure for each paragraph** **T** – Topic sentence which is short and simple.**E** – Elaborate or Explain any complex ideas or complex words you have in your topic sentence**E** – provide Evidence to support your topic sentence**L** – if possible Link your topic to the topic in the next paragraph. |
| **APPENDIX 3 –**  **Evaluating errors (3 methods)** **You can judge error using three simple processes. Which process you use generally depends on the type of data you have. You can judge your error using all three processes.** **1st** **–** If you have qualitative data (not numbers, but judgements), ask yourself the question…Do the results make sense? Are they logical? You have to make the call here…if your data seems weird, it is likely you have significant error.**2nd –** If you have quantitative data (numbers) then you should have drawn a trend line graph. (scatter gram). Ask yourself the question…do the points on your graph make a consistent trend (are the points close to the trend line or a little “scattered”?).The closer the points to the trend line the less error you have.**3rd –** If you have done trials in your experiment, look at the trials and compare them to each other. Did the trials give similar results? If the results for the trials are close to each other, this would indicate consistency and accuracy in your results. If the trials vary from each other there is a lack of consistency, and possible error.**In addition:** Sometimes things can get a little strange. For example it is possible that your data points are very consistent and all are very close to the trend line – but the trend itself does not appear right. In other words your data appears to be accurate, but your answer appears to be wrong! You have to explain this! |