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| **SCAFFOLDING**  **Title**  **Research Question**  **Rationale**  1st Part  This part of the introduction provides the context for the investigation. It introduces the topic covered by the experiment and positions the topic is in a “big picture” sense. It should describe at least one real life implications of the topic.  2nd Part  Provides an explanation of all of the theory you need to interpret your data or understand its meaning. It describes the science within the topic which is relevant to this experiment. This part also details any scientific laws or mathematical formulas which apply to the experiment.  3rd Part  This should provide a justification of the investigation. This usually involves a couple of sentences explaining how the investigation will provide a better or more detailed understanding of “the concept” being investigated.  **Research Q**  Short and sharp, be as specific as possible, relate independent to dependent variable.  **Methodology**  1st Part  The introductory paragraph describes the method you will modify. It provides a very brief background to the intent or findings (if you know them) of that investigation. It explains the reason for choosing your research question. This section is not marked, but can help teachers decide on the “justification” of your modifiactions  Modifications  This explains how you are modifying the original experiment. It is not a list of steps. It explains every change to the original method and provides the reason (justifies) for it. If possible, where different equipment is suggested indicate the degree of uncertainty associated with it.  (not necessary, but useful)  List the relevant variables for your investigation  Independent 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.  Risk assessment and management  Fill in a table like this one for the things in your experiment which may be a source of harm. Check with your teacher for some if you are not sure  You are also supposed to do the same for any ethical or environmental issues… not done here!  **Results**  Present your raw data first.  A table will have a heading such as:  *Table 1: Description of the data in the 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).  Show your trials and averages.  Your table should have at least 5variations of your independent variable and 3 trials of each – this should be “sufficient”. Easy mark  Processing Data (and uncertainty calculations)  This section with provide an example of all the calculations you have done. It will also show all the uncertainty and error (if you have a “known” value to compare to) calculations. Do not confuse uncertainty and error.  Secondary Data  This should be a simple table relating your independent and dependent variables. Use table formatting rules with correct heading and #notes where necessary. Include the amount of error with each value  Note in this experiment there has been no uncertainty calculated for the concentration values.  The independent and dependant variable should be graphed. This is very, very likely to be a scatter plot with a trend line. Rarely is it a bar or column graph, so see your teacher before you use a bar graph.  Analysis of trends and relationships  There is only one trend in the data, but it is a curved trend so is a little complex.  Start with a broad description and support with data  Then explain the complexity and what that means. Describe the trend using a specific mathematical equation. If the trends cannot be described mathematically, try to be as specific as possible This section sets up your conclusions.  Analysis of data validity  This section provides a description of the uncertainty within the data, and the limitations of the data. This can be quite simple, or very complicated.  Firstly – Uncertainty.   * You have a calculated uncert in the rate values. So, discuss the calculated uncert first. Identify if it is high or low… use your judgement. Justify using data. * There is also the uncertainty of your trend line. 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 are to the trend line the more certain you are (= low uncert) that the trend line accurately represents the trend in the data.   Second - limitations  You have to think of these. One may be the number of trials if your uncertainty is high for your data points. Another may be that you need more data points to get an accurate trend. Think!  **Conclusion**  The first sentence should be a broad description of the relationship between your independent variable and your dependent variable. Follow this with a detailed description and math eqn.  A good mark hinges on the word “justified”. Make a broader, more general conclusion which explains the implications of this relationship. Show that you understand what this relationship means in terms of the context you described in the rationale.  **Evaluation of reliability and validity**  Note that this section should address the broader experimental process, not just the data itself. Reliability is easy… look back at the uncertainty you described in the earlier. Discuss the uncertainty of the data and the trend line – they are separate issues.  Validity is about “did the experiment measure what it was supposed to measure?”. This can be hard and you have to make a judgement call.  **Recomendations**  You need both improvements AND extensions. An improvement would be a change which improves the reliability and/or validity of the experiment. Note these must relate to your earlier analysis of the data validity.  An extension would be a suggestion which involves a change in the independent or dependant variable. Or which places the experiment within a different context.  . | **REPORT**  **Acid rain and Calcium carbonate structures**  **How does changing the concentration of acid affect the rate of decomposition of calcium carbonate structures?**  **Rationale**  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. Acid rain can form when pollutants such as sulphur dioxide and nitrogen oxides mix with water vapour in the air, forming aqueous solutions of acids. The acidic vapour can then condense and fall as precipitation(*Manchester Metropolitan University1, 1999)*. Acid rain can therefore be a significant and very widespread problem wherever industrial and car pollution is not controlled.  Diagram 1  *http://archive.thedailystar.net/beta2/news/sustainer-of-life-or-angel-of-death/*  One of the very visible effects of acid rain is the damages it causes to [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.2, 2008).* The damage caused to statues is often the first noticeable sign of the long term caused by Acid rain (see diagram 1).  Marble and Limestone are both affected by acid rain because they are both forms of the mineral CaCO3 - Calcium Carbonate. This mineral is a very hard rock like substance. Calcium Carbonate reacts with the acid in rain as per the equation below. In the equation below, the acid is Sulphuric acid (H2SO4), the most common form of acid found in acid rain.  CaCO3(S) + H2SO4(aq) → CaSO4(s) + H2O(l) + CO2 (g)  Marble Sulphuric Acid Calcium Sulphate Water Carbon Dioxide  The only product of the reaction which is a solid - calcium sulphate - is more like a powder than a rock. Therefore, acid rain causes very hard marble and limestone to gradually crumble and erode away. This reaction is very slow, but the damage accumulates over many years and is irreversible. In a laboratory the rate of the reaction can be determined by measuring the production of Carbon dioxide. As CO2 is produced it leaves the reaction mixture, so there is decrease in mass. By calculating the moles of CO2, the rate reaction can be calculated using.  This investigation will identify the relationship between Sulphuric acid concentration and rate of the reaction. Marble chips will be used as Calcium carbonate, and the loss of mass in the reaction will be measured over the first 30 seconds. Identifying the relationship between the concentration of acid in the rain and the rate of decomposition is important for two reasons. Firstly, a better understanding of this relationship will allow more accurate prediction of the degree of damage caused by acid rain (assuming pollutant concentrations are known). Secondly, understanding of the relationship may provide further insight towards the importance of reducing the emission of pollutants into the air.  **Research Question**  How does changing the concentration of Sulphuric acid (1.0M, 1.2M, 1.4M, 1.6M, 1.8M, 2M) affect the rate of reaction between sulphuric acid and calcium carbonate (marble chips) over 30 seconds?  **Methodology**  A previous experimental procedure published internally within the science department of Maroochydore SHS involved a method for measuring the mass loss of a reaction mixture of Sulphuric acid and marble chips.  Modifications to Methodology  Similar to the original experiment, this experiment will use the loss of mass caused by Carbon dioxide gas to provide a way of measuring the rate of reaction. However the previous experiment did not determine a relationship between concentration of acid and rate, which is the intent of this investigation. Modifications made include   * The marble chips used in this experiment will be much smaller (consistently with a diameter of 0.001 to 0.003 metres) than the original experiment which used larger structures. The reason for this is the electronic balances available for this experiment do not measure mass to four decimal places, but only to two decimal places. This imposes a limitation on the sensitivity of measuring the mass loss, but it is anticipated that using smaller calcium carbonate structures (greater surface area) will increase the rate significantly and allow for mass loss to be measured with accuracy on a two decimal place balance. * The mass loss of the mixture will be determined once, at three minutes, rather than measured every 30 seconds for twelve minutes. This modification saves a considerable amount of time, and is appropriate because significant mass loss was not previously observed much beyond a three minute time period. A shorter time was not chosen as a shorter time may not have allowed a large enough mass loss to register on a two decimal place balance * The concentration of Sulphuric acid was not varied in the original experiment. In this investigation it is the independent variable and will be varied from 0.4, 0.5, 0.6, 0.8, 1.0 M. These concentrations are far higher than those found in acid rain. However, “Real” acid rain decomposition occurs over years, which is not a practicable time period for this investigation. A stock solution of 1.0 M will be used with dilutions made using burettes (± 0.05mL). The volume of acid used for each trial will be 25 ml (± 0.5 mL) * Three trials will be conducted for each concentration variation. This will provide greater reliability as an average result rather than individual values. More trials would create a higher degree of reliability, however the additional time needed for more trials was not available. * The initial mass of Calcium carbonate was reduced to 2.50g (± 0.02g). This was a compromise between having a large enough mass to generate a mass loss which could be determined by a two decimal place electronic balance, and wasting Calcium carbonate, most of which had to be disposed of after the three minute experiment.   Independent Variable = Concentration of Sulphuric Acid  Dependent Variable = Mass loss in three minutes  Controlled Variables = Volume of Sulphuric acid, initial temperature of Sulphuric Acid, mass of Marble Chips, size and shape of the Beaker, time for reaction(3 minutes)    **Risk assessment and Management:**  Table 1 – Risks in experiment   |  |  |  |  | | --- | --- | --- | --- | | Source of risk | What amount of harm could it cause? | Safety precautions taken | If an incident occurred what should I do? | | Sulphuric acid | major | * Safty glasses * Spill kit available * Care taken with carrying and exposure. * Dispose of acid down sick with plenty of rinse water | * Notify teacher immediately. * Use eye wash if necessary. * Wash any skin. * If spill is significant use spill kit available. | | Glassware breaking | Significant | * Do not touch broken glass * Care taken transporting glassware | * Notify teacher immediately and follow instructions. | | Carbon dioxide poisoning | Minor | * Avoid accumulation of Carbon dioxide in immediate environment by using in open lab with air movement | * Inform teacher immediately. * Modify conditions to create draft and air flow through lab area. |   **Results – Raw Data**  The table below records the mass lost from the reaction between Sulphuric acid and Marble chips for three trials after a time period of three minutes.  Table 2: Mass loss after three minutes – Marble chips in Acid   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Concentration of Sulphuric Acid (M)** | **Mass loss after 3 minutes (g)** (± 0.005) | | | | | **Trial 1** | **Trial 2** | **Trial 3** | **Average** | | 1 | 0.56 | 0.53 | 0.58 | 0.557 | | 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 | 0.183 | | 0.4 | 0.17 | 0.23 | 0.17 | 0.19 |   \**this result was identified as an anomaly. The other two trials broadly agree and this trial is greater than 50% variation from the other trials. This value was not used to calculate an average for this concentration*  **Results – Processing Data**  The data from Table 2 above was used to determine the rate of the reaction in moles of calcium Carbonate decomposed per sec. Other values used in this processing was   * Volume of Acid solution 25 mL (±0.1)   Table 3: Processing data and uncertainty calculations   |  |  |  | | --- | --- | --- | | Steps in the processing of Data using **0.8 M** concentration data | Uncertainty calculations | | | Calculating mean **mass loss of carbon dioxide** | | | | = **0.38 ± 0.03 g** | Measurement uncertainty  = 0.005 g | g | | Calculating the **moles of carbon dioxide** from the mass of carbon dioxide | | | | = 0.0086 ± 0.00069 moles  = **8.6 ± 0.69 x 10-3 moles of CO2** |  | | | Calculating **moles of Calcium carbonate** from Carbon Dioxide using reaction ratio (1:1)  **1**CaCO3 + H2SO4 → CaSO4 + H2O + **1**CO2 | | | | = **8.6 ± 0.69 x 10-3 moles CaCO3** | Uncertainty as a percentage is carried (multiplied by 1), absolute uncertainty remains the same (multiplied by 1) | | | Calculating **Rate of reaction** as moles of Calcium Carbonate reacted per second. | | | | **= 2.9 ± 0.3 x 10-4 moles/sec** |  | |   **Results – Secondary Data**  Table 4: mass loss and rate of reaction for the acid decomposition of Calcium Carbonate.   |  |  |  | | --- | --- | --- | | **Concentration of Sulphuric Acid (M)** | **Rate of reaction**  **(moles CaCO3 per second)** | **Rate Uncertainty** | | 1 | 4.2 x 10-4 | 3.0 x 10-5 | | 0.8 | 2.9 x 10-4 | 3.0 x 10-5 | | 0.6 | 1.7 x 10-4 | 2.0 x 10-5 | | 0.5 | 1.4 x 10-4 | 9.0 x 10-6 | | 0.4 | 1.4 x 10-4 | 3.0 x 10-5 |   Graph 1: Concentration of Acid versus rate of decomposition of Calcium carbonate.  **Analysis of trends and relationships**  The concentration of the Sulphuric acid does affect the rate of reaction between the Sulphuric acid and the calcium carbonate. 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. The trend line is curved upwards which suggests that the mathematical relationship between acid concentration and mass loss is exponential and not linear. The trend appears to be best described by a second order polynomial;  Rate = 0.0006 x concentration**2**  - 0.0004 x concentration + 0.0002  This trend suggests that high concentrations of acid would cause a greater than expected mass loss than if the relationship was linear. The trend line shows that at a concentration of 0.5M a rate of reaction of 1.5 x 10-4 moles/sec is predicted. At double this concentration (1.0M), the trend line predicts a rate of reaction of 4.3 x 10-4 moles/sec, considerably more than double the mass loss predicted by a linear relationship.  The polynomial relationship predicts that the point at which concentration has no effect on rate is 0.33M concentration of acid. This relationship also predicts that as concentration falls lower than 0.33M, the rate of the reaction stops decreasing and actually starts to increase again.  **Uncertainty and limitation of the data**  There appears to be significant uncertainty in the data describing the rate of reaction. Th percentage uncertainty in each of the rate values varies from 6% (1.4 ± 0.09 x 10-4) to 21% (1.4 ± 0.3 x 10-4). This large variation in uncertainty suggests the data lacks accuracy, and should have been avoided by doing more trials at each concentration of acid.  However, the relationship described by the second order polynomial appears to accurately describe the trend in the data. The data points closely adhere to the trend line and appear to form a consistent trend. This is supported by an R2 value of 0.99, meaning the variation in rate of reaction can almost completely be explained by the variation in the concentration of acid.  However there does appear significant inconsistency in two of the data points. The average mass loss determined at a concentration of 0.5M was less than the mass loss determined at 0.4M. This is not consistent with the overall trend within the data, and suggests there is a greater uncertainty in the trend than indicated by the very high R2 value. Experimenting with lower concentrations can lead to a greater degree of numerical uncertainty in values such as the one observed in this experiment. Two practices could be introduced to mitigate the effect of random error. Firstly, improving the attention to detail in diluting to low concentration solutions would go some way to reducing error. Secondly increasing the number of trials should also reduce random error within the data.  One clear limitation of the data is the low number of trials. Three trials were conducted at each concentration, and the degree of uncertainty suggests greater number of trials should have been used to reduce random error. Another limitation is the use of only five variations of acid concentration. A greater number of data points on the graph would allow a more accurate determination of the trend. A third limitation was the relative accuracy of the electronic balance. It would be preferable to use a three decimal place balance rather than a two decimal place balance. This would allow a more precise determination of mass loss. A more accurate balance would have enabled the experiment to include less concentrated acid. which would have caused very small mass losses.  **CONCLUSION**  Varying the concentration of sulphuric acid changes the rate of reaction between the acid and the marble. The relationship is best described by second order polynomial relationship  Rate = 0.0006 x concentration**2** - 0.0004 x concentration + 0.0002  A 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 decomposition of calcium carbonate structures. This demonstrates that gradual increases in pollutants which cause acid rain may have greater than expected effects on Calcium carbonate structures such as statues. Conversely however, it also suggests that decreasing the concentration of acid rain (by reducing pollution) may have greater than expected benefits in reducing the decomposition of such structures.  **Evaluation of Reliability and Validity**  The relationship above appears visually to accurately describe the trend in the data, and this is corroborated by a high R2 value. However individual data points indicate a degree of inconsistency with the data itself. This inconsistency was more evident in the measurements taken at lower concentrations of the acid. The average percentage uncertainty associated with the rate calculation was 11%. This degree of uncertainty is significant and suggests that despite the apparent accuracy of the trend line, the data is not reliable. Therefore, despite the apparent reliability of the trendline, the fact that the data points are not significantly reliable suggests that the experimental process used in the experiment should be improved.  The experimental process investigated the effect of acid concentration on marble, at concentrations of acid from 0.4M to 1.0M. these concentrations are not representative of the concentration of acid rain, which are significantly lower, closer to 0.01M. The concentrations used were chosen because it meant results could be collected in the limited amount of time available. However, it does mean that the experimental process does not validly represent the conditions of acid rain exposure. Additionally, acid rain falls intermittently, and in a much lower frequency than fair weather. This means the marble is only occasionally immersed, or in contact with acid, and such conditions may affect the way acid reacts with the marble. This was not done in the experiment and compromises the validity of the conclusions.  **Recomendations**  One improvement would be to increase the number of trials in order to reduce the random uncertainty and increase the reliability of the data. Another improvement would be to include more variations of acid concentration at the lower end of the concentration values. This should also reduce the effect of random error (random uncertainty), and improve the reliability of the trendline and mathematical relationship between concentration and rate of reaction. A more precise (three decimal place) balance would allow the variations of concentration to be lower, and more accurately reflect acid rain concentration, thus improving the validity of the experiment.  An extension to this experiment would investigate the effect of varying the concentration of nitric acid (another component of acid rain) on the rate of decomposition of calcium carbonate. Given that acid rain also has other environmental effects such as soil degradation, and acidification of fresh water bodies, further investigation of the effect of concentration on these areas is also recommended.  **References**   1. Watley, R., Williams, H., Heathcote, J. Temperature variation and acid rain efficacy. Journal of Environmental Issues Today, May, p.31-33. 2. Manchester Metropolitan University. 1999. *Acid Rain*. [ONLINE] Available at: <https://chemlinks.beloit.edu/Rain/copy/mmu/03uk.html>. [Accessed 12 January 2016]. 3. Singh, A., & Agrawal, M. (2008). Acid rain and its ecological consequences. Journal of Environmental Biology, 29(1), p.15-24 | **MARKING**  **What to do:** highlight the description above which best describes the rationale on the left. Underline or highlight parts of the rationale and annotate it in order to justify your decision. In the rubric on the last page, highlight the description you have chosen.  **START OF RESEARCH AND PLANNING CRITERION**  **Rationale**   * a considered rationale for the experiment * a reasonable rationale for the experiment * a vague or irrelevant rationale for the experiment * does not satisfy any of the descriptors above   **Research Question**   * a specific and relevant research question * a relevant research question * an inappropriate research question * does not satisfy any of the descriptors above   **Modification to Methodology**   * justified modifications to the methodology * feasible modifications to the methodology * inappropriate modifications to the methodology * does not satisfy any of the descriptors above   **Methodology allowing for the collection of data**   * a methodology that enables the collection of sufficient, relevant data * a methodology that enables the collection of relevant data * a methodology that causes the collection of insufficient and irrelevant data * does not satisfy any of the descriptors above   **Risk Management**   * considered management of risks and ethical or environmental issues * management of risks and ethical or environmental issues * inadequate management of risks and ethical or environmental issues * does not satisfy any of the descriptors above   **END OF RESEARCH AND PLANNING CRITERION**  **START OF ANALYSIS OF EVIDENCE CRITERION**  **Collection of raw data**   * collection of sufficient and relevant raw data * collection of relevant raw data * collection of insufficient and irrelevant raw data * does not satisfy any of the descriptors above   **Processing Data**   * correct and relevant processing of data * basic processing of data * by incorrect or irrelevant processing of data * does not satisfy any of the descriptors above   **Analysis of trends and relationships**   * thorough identification of relevant trends, patterns or relationships * identification of obvious trends, patterns or relationships * identification of incorrect or irrelevant trends, patterns or relationships * does not satisfy any of the descriptors above   **Data validity**   * thorough and appropriate identification of the uncertainty and limitations of evidence * basic identification of uncertainty and limitations of evidence * incorrect or insufficient identification of uncertainty and limitations of evidence * does not satisfy any of the descriptors above   **END OF ANALYSIS OF EVIDENCE CRITERION**  **START OF INTERPRETATION AND EVALUATION CRITERION**  **Conclusion about research Q**   * justified conclusion/s linked to the research question * reasonable conclusion/s relevant to the research question * inappropriate or irrelevant conclusion * does not satisfy any of the descriptors above   **Evaluation of reliability and validity**   * justified discussion of the reliability and validity of the experimental process * reasonable description of the reliability and validity of the experimental process * cursory or simplistic statements about the reliability and validity of the experimental process * does not satisfy any of the descriptors above   **Recommendations**   * suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence * suggested improvements and extensions to the experiment that are related to the analysis of evidence * ineffective or irrelevant suggestions * does not satisfy any of the descriptors above |

**Criterion: Research and Planning**

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| **The student work has the following characteristics:** | **Marks** | **Definitions** |
| * informed application of understanding of TOPIC dynamics to modify experimental methodologies demonstrated by   + a considered rationale for the experiment   + justified modifications to the methodology * effective and efficient investigation of phenomena associated with TOPIC demonstrated by   + a specific and relevant research question   + a methodology that enables the collection of sufficient, relevant data   + considered management of risks and ethical or environmental issues. | 5–6 | **informed** – knowledgeable; learned; having relevant knowledge; being conversant with the topic; based on an understanding of the facts of the situation (of a decision or judgement)  **modify** – change the form or qualities of; make partial or minor changes to something  **considered** – formed after careful and deliberate thought  **justified** – sound reasons or evidence are provided to support an argument, statement or conclusion  **effective** – successful in producing the intended, desired or expected result; meeting the assigned purpose  **efficient** – working in a well-organised and competent way; maximum productivity with minimal expenditure of effort; acting or producing effectively with a minimum of waste, expense or unnecessary effort  **specific** – clearly defined or identified; precise and clear in making statements or issuing instructions; having a special application or reference; explicit, or definite  **relevant** – bearing upon or connected with the matter in hand; to the purpose; applicable and pertinent; having a direct bearing on  **sufficient** – enough or adequate for the purpose |
| * adequate application of understanding of TOPIC to modify experimental methodologies demonstrated by   + a reasonable rationale for the experiment feasible modifications to the methodology * effective investigation of phenomena associated with TOPIC 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 | **adequate** – satisfactory or acceptable in quality or quantity equal to the requirement or occasion  **reasonable** – endowed with reason; having sound judgment; fair and sensible; based on good sense; average; appropriate, moderate  **feasible** – capable of being achieved, accomplished or put into effect; reasonable enough to be believed or accepted; probable; likely  **effective** – successful in producing the intended, desired or expected result; meeting the assigned purpose  **relevant** – bearing upon or connected with the matter in hand; to the purpose; applicable and pertinent; having a direct bearing on |
| * rudimentary application of understanding of TOPIC to modify experimental methodologies demonstrated by   + a vague or irrelevant rationale for the experiment   + inappropriate modifications to the methodology   + ineffective investigation of phenomena associated with TOPIC 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 | **rudimentary** – relating to rudiments or first principles; elementary; undeveloped: involving or limited to basic principles; relating to an immature, undeveloped or basic form  **vague**   * not definite in statement or meaning; not explicit or precise; not definitely fixed, determined or known; not clear in thought or understanding; * couched in general or indefinite terms; not definitely or precisely expressed; deficient in details or particulars’ * thinking or communication in an unfocused or imprecise way   **inappropriate** – not suitable or proper in the circumstances  **ineffective** – not producing a result, or not producing any significant result; not producing the intended, desired or expected result  **irrelevant** – not relevant; not applicable or pertinent; not connected with or relevant to something  **inadequate** – not satisfactory or acceptable in quality and/or quantity to the requirements of the situation |
| * does not satisfy any of the descriptors above. | 0 |  |

**Instrument-specific marking guide (IA2): Student experiment**

**Criterion: Analysis of evidence**

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| **The student work has the following characteristics:** | **Marks** | **Definitions** |
| * appropriate application of algorithms, visual and graphical representations of data about TOPIC demonstrated by correct and relevant processing of data * systematic and effective analysis of experimental evidence about TOPIC demonstrated by   + thorough identification of relevant trends, patterns or relationships   + thorough and appropriate identification of the uncertainty and limitations of evidence * effective and efficient investigation of phenomena associated with TOPIC demonstrated by the collection of sufficient and relevant raw data. | 5–6 | **appropriate** – acceptable; suitable or fitting for a particular purpose, circumstance, context etc.  **systematic -** done or acting according to a fixed plan or system; methodical; organised and logical; having, showing, or involving a system, method, or plan; characterised by system or method; methodical; arranged in, or comprising an ordered system  **effective** – successful in producing the intended, desired or expected result; meeting the assigned purpose  **thorough** -carried out through, or applied to the whole of something, carried out completely and carefully; including all that is required. Complete with attention to every detail: not superficial or partial; performed or written with care and completeness; taking pains to do something carefully and completely.  **efficient** – working in a well-organised and competent way; maximum productivity with minimal expenditure of effort; acting or producing effectively with a minimum of waste, expense or unnecessary effort |
| * adequate application of algorithms, visual and graphical representations of data about TOPIC demonstrated by basic processing of data * effective analysis of experimental evidence about TOPIC demonstrated by   + identification of obvious trends, patterns or relationships   + basic identification of uncertainty and limitations of evidence * Effective investigation of phenomena associated with TOPIC demonstrated by the collection of relevant raw data. | 3–4 | **adequate** – satisfactory or acceptable in quality or quantity equal to the requirement or occasion  **basic** – fundamental  **effective** – successful in producing the intended, desired or expected result; meeting the assigned purpose  **obvious** – clearly perceptible or evident; easily seen, recognised or understood |
| * rudimentary application of algorithms, visual and graphical representations of data about TOPIC demonstrated by incorrect or irrelevant processing of data * ineffective analysis of experimental evidence about TOPIC demonstrated by   + identification of incorrect or irrelevant trends, patterns or relationships   + incorrect or insufficient identification of uncertainty and limitations of evidence * Ineffective investigation of phenomena associated with TOPIC demonstrated by the collection of insufficient and irrelevant raw data. | 1–2 | **rudimentary** – relating to rudiments or first principles; elementary; undeveloped: involving or limited to basic principles; relating to an immature, undeveloped or basic form  **incorrect** – not conforming to fact or truth  **irrelevant** – not relevant; not applicable or pertinent; not connected with or relevant to something  **ineffective** – not producing a result, or not producing any significant result; not producing the intended, desired or expected result  **insufficient** – not enough; inadequate for the purpose |
| * does not satisfy any of the descriptors above. | 0 |  |

**Criterion: Interpretation and evaluation**

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| **The student work has the following characteristics:** | **Marks** | **Definitions** |
| * insightful interpretation of experimental evidence about TOPIC demonstrated by justified conclusion/s linked to the research question * critical evaluation of experimental processes about TOPIC demonstrated by   + justified discussion of the reliability and validity of the experimental process   + suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence. | 5–6 | **insightful** – showing understanding of a situation or process; understanding relationships in complex situations; informed by observation and deduction  **justified** – sound reasons or evidence are provided to support an argument, statement or conclusion  **link** – anything serving to connect one part or thing with another  **critical** – involving skillful judgment as to trust, merit, etc.; involving the objective analysis and evaluation of an issue in order to form a judgment; expressing or involving an analysis of the merits and faults of a work of literature, music, or art; incorporating a detailed and scholarly analysis and commentary (of a text); rationally appraising for logical consistency and merit  **justified** – sound reasons or evidence are provided to support an argument, statement or conclusion  **logically** – according to the rules of logic or formal argument; in a way that shows clear, sound reasoning; in a way that is expected or sensible |
| * adequate interpretation of experimental evidence about TOPIC demonstrated by reasonable conclusion/s relevant to the research question * basic evaluation of experimental processes about TOPIC demonstrated by   + reasonable description of the reliability and validity of the experimental process   + suggested improvements and extensions to the experiment that are related to the analysis of evidence. | 3–4 | **adequate** – satisfactory or acceptable in quality or quantity equal to the requirement or occasion  **reasonable** – endowed with reason; having sound judgment; fair and sensible; based on good sense; average; appropriate, moderate  **relevant** – bearing upon or connected with the matter in hand; to the purpose; applicable and pertinent; having a direct bearing on  **basic** – fundamental |
| * invalid interpretation of experimental evidence about TOPIC demonstrated by inappropriate or irrelevant conclusion/s * superficial evaluation of experimental processes about TOPIC demonstrated by   + cursory or simplistic statements about the reliability and validity of the experimental process   + ineffective or irrelevant suggestions. | 1–2 | **invalid** – not sound, just or well-founded; not having a sound basis in logic or fact (of an argument or point); not reasonable or cogent; not able to be supported; not legitimate or defensible; not applicable  **inappropriate** – not suitable or proper in the circumstances  **superficial -** concerned with or comprehending only what is on the surface or obvious; shallow; not profound, thorough, deep or complete; existing or occurring at or on the surface; cursory; lacing depth of character or understanding; apparent and sometimes trivial  **cursory** – hasty, and therefore not thorough or detailed; performed with little attention to detail; going rapidly over something, without noticing details; hasty; superficial  **simplistic** – characterised by extreme simplification, especially if misleading; oversimplified  **ineffective** – not producing a result, or not producing any significant result; not producing the intended, desired or expected result |
| * does not satisfy any of the descriptors above. | 0 |  |

**Criterion: Communication**

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| **The student work has the following characteristics:** | **Marks** | **Definitions** |
| * effective communication of understandings and experimental findings, arguments and conclusions about TOPIC demonstrated by   + fluent and concise use of scientific language and representations   + appropriate use of genre conventions   + acknowledgment sources of information through appropriate use of referencing conventions. | 2 | **effective** – successful in producing the intended, desired or expected result; meeting the assigned purpose  **fluent** – spoken or written with ease; able to speak or write smoothly, easily or readily; articulate; eloquent; in artistic performance, characteristic of a highly developed and excellently controlled technique; flowing; polished; flowing smoothly, easily and effortlessly  **appropriate** – acceptable; suitable or fitting for a particular purpose, circumstance, context etc. |
| * adequate communication of understandings and experimental findings, arguments and conclusions about TOPIC demonstrated by   + competent use of scientific language and representations   + use of basic genre conventions   + use of basic referencing conventions. | 1 | **adequate** – satisfactory or acceptable in quality or quantity equal to the requirement or occasion  **competent** – having suitable or sufficient skills, knowledge, experience, etc. for some purpose; adequate but not exceptional; capable; suitable or sufficient for the purpose;having the necessary ability, knowledge or skill to do something successfully; efficient and capable (of a person); acceptable and satisfactory, though not outstanding  **basic** – fundamental |
| * does not satisfy any of the descriptors above. | 0 |  |