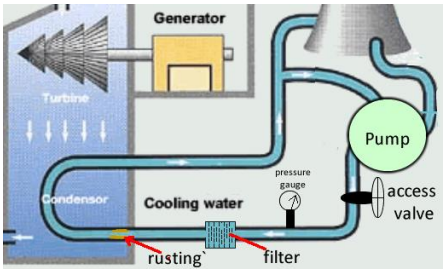
Chemical and engineering challenge

At a remote Arctic station a large electrical generator is used to produce power needed to sustain the heating unit of the station, as well as lighting. Water flows through the cooling pipes of the generator at a steady speed of 2 m/s at 110 ^{o}C . A crucial section of pipe is starting to become heavily corroded, as shown in the diagram on the right.
Chemists prepare a quick and cheap solution to the problem and with the help of engineers devise a way to deliver this chemical to the site of rusting in order to prevent further damage.



An anti-rust chemical is prepared that will reverse the rusting process that has already occurred. It is decided that the chemical will be delivered through an access valve, located near the water pump. A major problem, however, has been identified by the engineers and chemists. “The anti-rust chemical will start to dissolve the rubber seals in the pressure gauge if it comes into contact with the rubber for any length of time”

The chemists decide to solve this problem by preparing the anti-rust chemical in tablet form that dissolves slowly in water.

The tablet must not be fully dissolved when it passes the pressure gauge, but must be fully dissolved when it gets to the water filter.

It is crucial for the engineers to know how long it will take the tablet to dissolve at 110^{o}C, in the swirling water, so they can adjust the speed of the pump to make sure the flow rate of the water is such that the tablet arrives at the gauge partially undissolved but gets to the filter fully dissolved.

It is impossible, however, to heat water beyond 100 ^{o}C in the laboratory so the scientists can conduct trials to see how quickly the tablet will dissolve at 110 ^{o}C.

An investigation must be conducted to measure the time taken to dissolve a tablet of the chemical at different temperatures of swirling water. As the tablet dissolves it releases gas which is obvious from the bubbles that form and rise in the water.

Task 1 - Design a method for the scientific investigation that will lead to enough valid results that will enable the construction of a graph of temperature against time taken to dissolve the tablet of anti-rust chemical.

Things to keep in mind when writing the method. These are briefly stated below but can be found in greater detail in Appendix 3

1) Outline the problem that is being tested

2) Outline the variables and how to manipulate or measure them.

3) Outline a testable hypothesis using scientific reasoning

4) Design a complete, logical and safe sequence of steps that can be followed as in order to complete the collection of data.

5) Detailed set of equipment and chemicals that will be needed on the day of the investigation. A photograph may be included.

Task 2 – Collect and organise enough data and display it in appropriate form so that trends can easily be seen. Use the graph and table below in appendix 1 if wish.

Things to keep in mind when discussing the results. These are briefly stated below but can be found in greater detail in Appendix 4

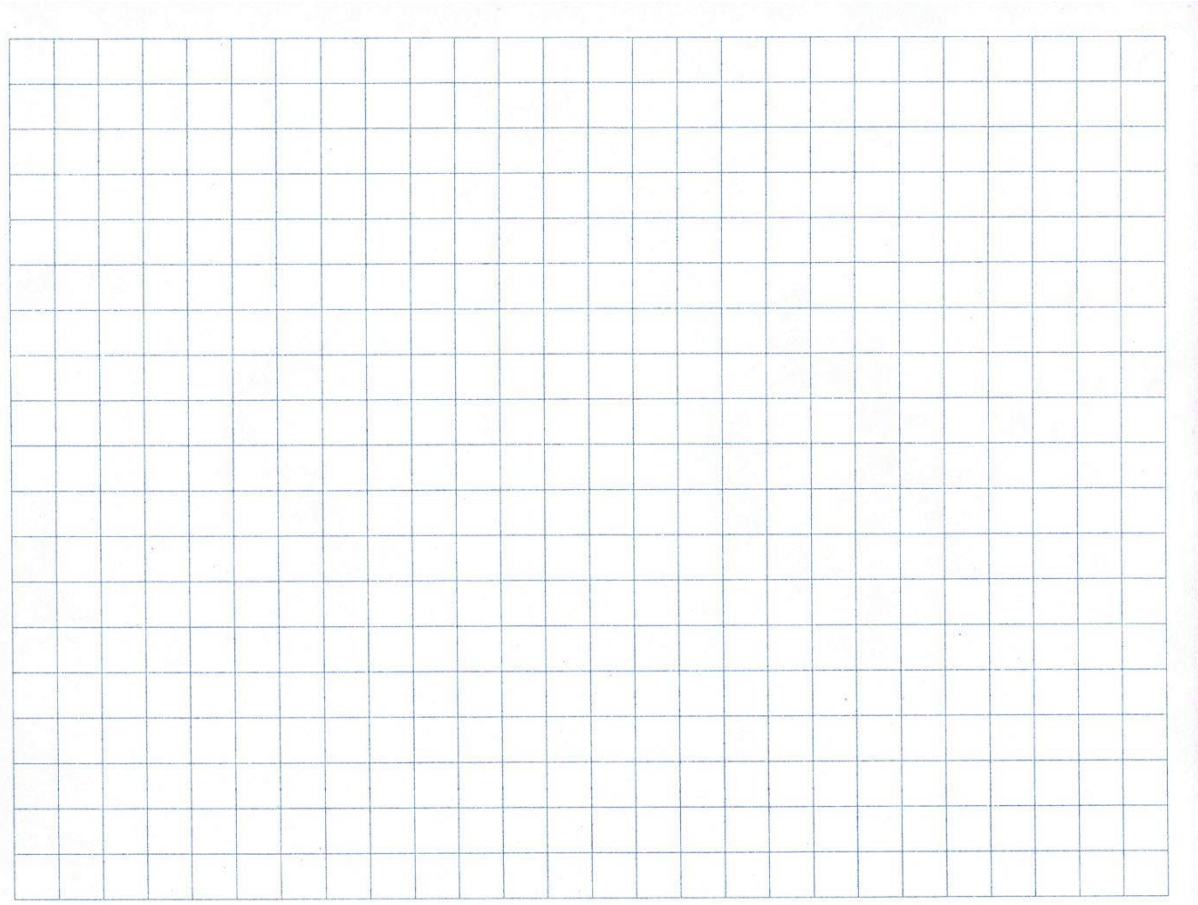
1) Collect , organise and present the data .

2) Discuss whether the data supports the hypothesis.

3) Discuss if the method designed above was adequate in collecting accurate data from which you could answer the question stated in task 1 above.

4) Discuss improvements or extensions that could be made to this investigation that may be of benefit to answering the problem or question stated in task 1 above.

Appendix 1



Temperature	Time

Appendix 2

Criterion B: *Inquiring and Designing*

IB Level	Task specific descriptors
8 7	I have: **i.** given brief details of the question to be answered by a scientific investigation and described how it relates to the problem to be solved in this activity. **ii.** **outlined and explained** a testable hypothesis **using correct scientific reasoning (**Particle theory of matter and Collision theory) **iii.** **described** how to manipulate the variables, and **describe** how **sufficient, relevant** data will be collected - I have identified all the variables and described how the independent variable will change and by how many increments at any one time and how the dependent variable will be measured and how many times it will be repeated for greater accuracy. - I have identified all the controlled variables and outlined how these variables will be manipulated and **explained** the reasons why each controlled variable must be kept constant. **iv.** designed a **logical, complete and safe method** in which I have **selected appropriate materials and equipment**. - I have identified all the risks involved with conducting this investigation and described what steps will be taken to eliminated each risk . - I have included a complete and detailed list of equipment and materials that will be used for this investigation. - I have also included a detailed and logical sequence of steps so that anyone else undertaking this investigation will repeat the investigation exactly as was conducted originally. - Where possible, I may include a photo or diagram to clarify the set-up used.
6 5	I have: i. given brief details of the question to be answered by a scientific investigation and described how it relates to the problem to be solved in this activity. ii. **outlined and explained** a testable hypothesis **using correct scientific reasoning (**Particle theory of matter and Collision theory) iii. **outlined** how to manipulate the variables, as well as how **sufficient, relevant** data will be collected - I have identified some of the variables and described how the independent variable will change and by how many increments at any one time and how the dependent variable will be measured and how many times it will be repeated for greater accuracy. - I have identified some of the controlled variables and outlined how these variables will be manipulated and gave reasons why these controlled variables must be kept constant. iv. designed a **logical, complete and safe method** in which I have **selected appropriate materials and equipment**. - I have identified most of the risks involved with conducting this investigation and outlined steps that will be taken to eliminated each risk . - I have included a detailed list of equipment and materials that will be used for this investigation. - I have also included a detailed and logical sequence of steps so that anyone else undertaking this investigation will repeat the investigation exactly as was conducted originally. - Where possible, I may include a photo or diagram to clarify the set-up used.

4 3	I have: i. **stated** the question to be tested by a scientific investigation and outlined how the question is relevant to the problem that is presented in this activity. ii. **outlined** a testable hypothesis **using scientific reasoning** with limited success iii. **outlined** how to manipulate the variables, and **state** how **relevant data** will be collected - I have identified the dependent and independent variables and described how the independent variable will change and how the dependent variable will be measured. - I have identified one or two of the controlled variables and outlined how these variables will be manipulated and stated the impact on the results if these variables are not kept constant iv. designed a **safe method** where I have **selected materials and equipment.** - I have identified one or two risks involved with conducting this investigation and outlined the steps that will be taken to eliminated each risk . - I have included a list of equipment and materials that will be used for this investigation. - I have also included a logical sequence of steps for anyone else to follow when repeating this investigation..
2 1	I have: **i.** **stated** a problem or question to be tested by a scientific investigation, with **limited success** and did not discuss the relevance to the problem presented in the activity. **ii.** **stated** a testable hypothesis and made no mention of the scientific reasoning (Particle theory of matter or Collision theory) **iii.** **stated** the variables - I have identified some of the variables and briefly mentioned how they will manipulated or measured. - I have made little reference to controlled variables and their impact on the investigation **iv.** designed **a method, with limited success**. - I have provided an incomplete list of equipment and materials to be used - I - I have made little reference to safety issues and how minimize the risks.
0	• The student has not reached a standard described by any of the descriptors given above.

Appendix 3 Collecting and evaluating data

Criterion C: *Processing and Evaluating* (Rate of reaction at different temperatures)

IB Level	Task specific descriptors *(from subject guide)*
8 7	i. I have **correctly collected, organized, transformed and presented** data in a table and graph. I have correctly organized the data I collected in my solubility investigation using a properly formatted **table** that included units in the proper place. I **processed** my **data** by averaging the results of several measurements at a given temperature and showed examples of my calculations. My graph of temperature vs time is correct, including titles, correctly labelled axis with proper spacing of units, and I have used a line of best fit. I considered the dot points below. As well as table and graph I have also included observations I made while carrying out my investigation. ii. I have correctly used knowledge and understanding of science to recognize **patterns** and draw conclusions from the data. I have correctly given an account of how and why the variables are related using my knowledge of "Collision Theory" and was able to use the trend provided by my line of best fit to accurately predict the rate (time) of the reaction at 110^{o}C. iii. I have used the data to clearly **discuss** if my hypothesis has been supported or not. I used my understanding of the Particle theory of matter and the Collision theory and other sources to help explain my reasons. - I stated my original hypothesis. - I discussed why my data supported / did not support /partially support my hypothesis. - I discussed reasons based on scientific reasoning iv. I have **evaluated my method** by considering the strengths and limitations of my method and laboratory work. I have **discussed** the validity and reliability of my method considering the following dot points. - I gave reasons as to why the method I followed did allow / did not allow/ partially allowed me to answer the research question. - I identified and discussed some *strengths and weaknesses* in the method - I also identified some tasks that were *difficult* in carrying out or measure and explained how these may influence the final result - I also gave more than one reason as to why, if I was to repeat this investigation, I would / would not use the same method. v. I have **described** in detail how I can improve the limitations in my method. These suggestions are realistic and based on my experience it conducting this investigation and scientific knowledge. I considered the points below. - What improvements I could make to the method and the reasons why. - What new question this investigation has made me think of that would be beneficial to know the answer to and I have described how this question could be tested. I have also described why this question is important to know the answer to. -

6 5	i. I have **correctly collected, organized and presented** data in a table and graph . I have correctly organized the data I collected in my solubility investigation using a correctly formatted **table** that included units in the proper place. My graph of temperature vs time is correct, including titles, correctly labelled axis with proper spacing of units, and I have tried to use a line of best fit. ii. I have correctly used knowledge and understanding of science to recognize **patterns** and draw conclusions from the data. I have correctly given an account of how and why the variables are related using my knowledge of "Collison Theory" and was able to use the trend provided by my line of best fit to accurately predict the rate (time) of the reaction at $110^{o}C$. iii. I have used the data to **outline** if my hypothesis has been supported or not. I used my understanding of the Particle theory of matter and the Collision theory and other sources to help explain my reasons. I followed the dot points below. - I stated my original hypothesis. - Outlined why my data supported / did not support /partially support my hypothesis. - I outlined a reason based on scientific reasoning. iv. I have **evaluated my method** by considering the strengths and limitations of my method and laboratory work. I have **outlined** the validity and reliability of my method considering the following dot points. - I **outlined** some reasons as to why the method I followed did allow / did not allow/ partially allowed me to answer the research question. - I identified and discussed a *strength and weakness* in the method - I also identified a task that was *difficult* in carrying out or measure and **outlined** how this may influence the final result - I also gave a reason as to why, if I was to repeat this investigation, I would / would not use the same method. v. I have **outlined** how I can improve the limitations in my method. These suggestions are realistic and based on my experience it conducting this investigation and scientific knowledge. I considered the points below. - What improvements I could make to the method and the reasons why. - What new question this investigation has made me think of that would be beneficial to know the answer to and I have described how this question could be tested.

4	i.	I have **correctly collected and presented** data in a table and graph . My graph of temperature vs time is correct, including titles, correctly labelled axis with proper spacing of units, and I have attempted to use a line of best fit.
3	ii.	I have correctly used knowledge and understanding of science to recognize **patterns** and draw conclusions from the data. I have correctly given an account of how the variables are related using little or no scientific reasoning.
	iii.	I have used the data to **state** if my hypothesis has been supported or not. I stated my hypothesis and stated whether the data support / do not support /partially support my hypothesis.
	iv.	I have **evaluated my method** by considering a strength and limitation of my method and laboratory work. I have **stated** the validity and reliability of my method considering the following dot points. - I **stated** a reason as to why the method I followed did allow / did not allow/ partially allowed me to answer the research question. - I identified and discussed a *strength and weakness* in the method - I also identified a task that was *difficult* in carrying out or measure and **stated** how this may influence the final result
	v.	I have **stated** how I can improve my method with limited success. These suggestions are limited and may not be accurate, however, are realistic and based on my experience in conducting this investigation and scientific knowledge. I considered the points below. - What improvements I could make to the method. - **Stated** a new question this investigation has made me think of that is somehow linked to this investigation.

2 1	i. I have **collected and presented** data in a visual form. My graph of temperature vs time has some errors and I have not attempted to use a line of best fit. ii. I have correctly used knowledge and understanding of science to recognize **patterns** and draw conclusions from the data. I have correctly given an account of how the variables are related. iii. I have used the data to **state** if my hypothesis has been supported or not. I stated my hypothesis and stated whether the data support / do not support /partially support my hypothesis. iv. I have **evaluated my method** and attempted to identify a strength and limitation of my method and laboratory work. I have **stated** the validity and reliability of my method considering the following dot points. - I **stated** a reason, with limited success, as to why the method I followed did allow / did not allow/ partially allowed me to answer the research question. - I identified and stated a *strength and weakness* in the method with limited success - I also identified a task that was *difficult* in carrying out or measure and **stated** how this may influence the final result v. I have **stated** limited improvement to my method. These suggestions may not be accurate, however, are realistic and based on my experience it conducting this investigation and scientific knowledge. I considered the points below. - What improvements I could make to the method. - **Stated** a new question, with limited success, that this investigation has made me think of that would add value to the topic I am investigating.
0	• The student has not reached a standard described by any of the descriptors given above.

Command terms

State - Give a specific name, value or other brief answer without explanation or calculation.

Discuss - Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.

Describe - Give a detailed account or picture of a situation, event, pattern or process. ***State*** - Give a specific name, value or other brief answer without explanation or calculation.

Outline – Give a brief account

Appendix 4
ATL skills and Science skills covered

ATL Skills covered	Science skills covered
Collect and analyse data to identify solutions and make informed decisions	Organise and present data in tables and graphs
Process data and report results	Draw a line of best fit through a scatter plot
	Reading results accurately off the line of best fit
	Taking measurements using a thermometer
	Design a method and select appropriate materials and equipment.
	Identifying risks

Appendix 5 Writing a laboratory report

Sourced from(25/08/2018 1.22pm) http://ismackinsey.weebly.com/uploads/1/3/7/2/13724948/writing_a_myp_laboratory_report.pdf

Writing a Laboratory Report for Science.

Title - The title should be general, explaining what the experiment is about.

Aim - The aim should be a question stating what you are trying to find out.

Hypothesis - State what you expect to find out in your experiment and why using scientific reasoning. That is, what you expect the answer to the question of the aim to be and why.

Variables and Fair Testing - The variables are the things you measure in the investigation. List them under the following headings:

- Control Variables: These are the ones that must be the same in each experiment.
- Independent Variable: This is the one variable that you deliberately change in the experiment. There should only be one!
- Dependent Variable: This is the one variable you measure to find your results.

Materials/Apparatus - List all the apparatus and materials used. Include a relevant diagram at this point.

Method - Write instructions explaining how to do the experiment. They must be detailed enough for somebody else to follow so they can do the experiment. Point form is suitable. Explain how to control the variables.

Results - Using tables, record what happened, including measurements and observations (also anything you heard, saw, smelled if applicable). Tables must be clearly presented and easy to read with titles and units. The data from the tables should be analysed and presented as a suitable graph(s) if possible. Graphs should include a title, labelled axes and units. The independent variable should be on the horizontal axis. Include any calculations. The graph(s) should be analyzed and explained using scientific reasoning. Examples of analysis include: finding and interpreting the meaning of the gradient (slope) and/or intercepts, interpreting the shape of the graph(s), finding the equation(s) of the line of best fit (trendline), comparing graphs to one another or to the control, etc.

Conclusion - This section explains what you found out from your investigation. You should: Read the question of the aim again and try answering it by looking at the results. Write down why you know your hypothesis was correct/incorrect. Explain any unexpected results. Comment on the reliability/validity of the data given the strength of correlation supported by your data, and sources of error. Write down some ways you could improve your experiment. This should be changes to the method, not comments like “I should have done my calculations more neatly.” Think of any further things you would like to investigate.