Guidelines for Design Lab Reports

The formats for the 2 types of report differ in the Introduction and Methods sections. In the introduction, you need to make a hypothesis and identify your variables and in the methods section, you need to write detailed procedures in which you explain your procedural choices.

I. Introduction

1. Title and Formatting
   a. Make the title meaningful, describing the nature of your work.
      i. eg: "Lab experiment" is not an acceptable title but "Observations on Melting Ice" is.
      ii. If testing a cause and effect relationship use: The Effect of (independent variable) on (dependent variable).
   b. All sections should be clearly headed and distinguished from the other sections.
   c. The parts of lab reports which can be easily typed should be. It is usually easier however to hand write the calculations that you do. The handwritten data should be attached to the end of the lab report.
   d. Include a title page—Title, Student's name, candidate number, class, date, & teacher's name

2. Background Information (may be combined with the Problem/Question section)
   a. Provide justification for choosing the research question and/or the topic under investigation which demonstrates personal significance, interest or curiosity. There needs to be evidence of personal input and initiative in the designing, implementation or presentation of the investigation.
   b. Background information should include the context of the experiment. Why is this experiment important? What larger idea(s) is this related to? Discuss all the variables that could affect the dependent variable (very important in design labs and may not be needed in most labs). What do we already know about the investigation as outlined in the curriculum or research?
      i. E.g. When investigating the size of a drop your background information might include that disposable pipets are often used in microscale experiments and it is often assumed that one drop is the same as the next drop, when, in fact, several variables are changing that could affect the size of the drop. Since some experiments rely on an accurate volume, it's important to know what variables affect the size of a drop. You could then go on to explain all the variables that could affect the size of the drop.

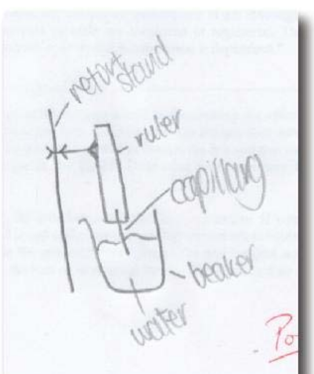
3. Problem/Question (may be combined with Background Information)
   a. What are you trying to figure out by doing this lab?
   b. At the IB level you should not repeat the question/statement given to you. It should be more focused.
   c. The question is very specific and written so that the answer may be found through a controlled experiment.
      i. *E.g. What is the effect of a changing glucose concentration on cell respiration in yeast? Five different concentrations of glucose (0.0 M, 0.25 M, 0.50M, 0.75M and 1M) will be used to see how the growth of yeast changes. The growth of yeast will be measured by the amount of CO_2 produced which is an indication of the amount of cell respiration taking place. It is expected that increasing the glucose concentration will increase the amount of $C0_2$ produced which will suggest that the rate of cell respiration has increased.*

4. Hypothesis
   a. Relates the hypothesis or prediction directly to the research question.
   b. Needs to make a prediction: If you include a hypothesis to help focus your research question then it needs to be an "if….then…" statement that includes the independent and dependent variables. Your hypothesis should be supported with an explanation.
      i. Eg. ***If*** *the glucose concentration is increased,* **then** *the amount of $C0_2$ produced will also increase. This is because glucose is used by yeast to make ATP through cellular respiration. The more glucose that is available, the faster the rate of cell respiration, and the more $C0_2$ that will be produced. $C0_2$ is a product of cell respiration in yeast, so the more $C0_2$ the faster the rate of cell respiration.*
   c. Explains hypothesis, at the molecular/electron level and quantitatively where appropriate

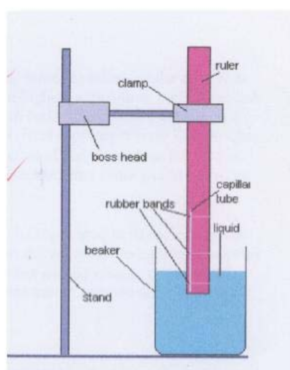
5. Variables
   a. Identify manipulated variable (independent). This is the one YOU change.
   b. Identify measured variable (dependent) and how it will be measured. This is the variable that should change in response to changes in the independent variable.
      i. Can include both quantitative and qualitative variables
   c. Identify variables that will be held constant. These are your **controlled** variables. An explanation of how these will be held constant is important. There should be several of these for any controlled experiment. If you can't actively control a specific variable, then your method should include a means of monitoring it.
   d. Example:
      i. Independent: amount of calcium chloride measured in grams
      ii. Dependent: temperature of water measured in °C
      iii. Constants: Amount of water, calorimeter used for mixing, thoroughness of mixing, thermometer used, starting temperature of water

II. Materials & Methods

6. Materials and apparatus
   a. Includes all reagents with concentration when applicable
      i. 0.5 M $CuSO_4$
      ii. 20 g $CuSO_4$-$5H_2O$
   b. Describes details of apparatus
      i. Glassware (ex: 4 200-mL beakers)
      ii. Thermometers (ex: -10°C to 110°C range 0.2°C gradations)
      iii. Power supplies (ex: D.C. voltmeter, 0 to 10 V)
   c. Includes a picture of apparatus where an unconventional set-up was used. (sketch or photo)



Poorly Done



Well Done

   d. Includes brand names for commercial products.

7. Procedure
   a. Methods
      i. Start with an overall method that explains the basic procedures and how you plan to collect data and how it will be analyzed.
      ii. This should be writing in paragraph format, not a bulleted list. Use "impersonal language"; which means no words such as "I", "we", "they", "you" etc.
         1. Eg: "I weighed out 0.50 g of magnesium and then I added 2.0 cm^3 of 2M hydrochloric acid" *should be rewritten as* "Add 0.5 g magnesium to 200 cm^3 of 2M hydrochloric acid"
      iii. The methods section describes what measurements will be taken so that when data is processed there is sufficient data.
         1. List the equations you will be using and state how each variable will be measured.

Eg. *Say a student is calculating the heat of solution using Q=mcT. They should list that equation and state that Q will be calculated, m will be measured by taking the mass of the solution after the final temperature has been recorded, the ΔT will be measured by taking the temperature before and after the solute is added*

2. Ensure that you change the independent variable enough times to collect enough points for a reasonable line of best fit. A minimum of **five data points** is required for any graph and more should be collected if time and materials allow.
3. Consider whether or not the graph needs many data points or whether more repeating would be more worthwhile. If the graph has a complex shape e.g. a titration or cooling curve, then the more points the better. If the graph is linear then repeating the experiment for each point would be a better way to improve the correlation coefficient than simply collecting more points (assuming you already have 8 – 10 points).
4. The method should include sufficient repeats of trials to ensure that random errors are at least minimized. Don't leave this for your evaluation as repeating the experiment is a pretty lame suggestion – doubly so if you should have had it in your method in the first place.
5. Make sure you record the amounts of materials to a sufficient precision in your method. *Eg: If you weighed 20 g of magnesium using a volumetric pipette this should be recorded as 20.00 g and not just 20 g. Why? Because the scale has a precision of two decimal points.*
6. Don't include "obvious" steps in your methods. Steps such as: "collect and put on safety equipment" "clean up bench and return apparatus to the storage room" These steps would be relevant to pretty much any experiment and so don't need to be included.
7. Include what qualitative data will be taken.
   Eg. colors of solutions and indicators and color changes if appropriate
8. Example of insufficient data collected:
   a. In order to calculate the heat given off in a reaction, the student needs to know the mass of the solution but they didn't measure the mass, they only measured the volume.
   b. Student made a graph but the graph only has 2 or 3 points over a small range.

b. Procedures with explanation of controls (this should be a numbered list of steps but…)
   i. Procedures should not just be a list of steps. You should also include an explanation of how you control the variables.
      1. One way to explain controls is to explain the reasoning behind each step as a bullet under each step.
      2. Another way is to include a paragraph where you explicitly describe your assumptions and how you are controlling each variable you listed in the introduction. This may seem redundant if you've listed variables in the variables section but you need to explain your choices and how you will control the control variables here.
         a. List a bunch of errors that could occur and then explain how you will address them.
         b. What errors could occur in measuring the variables?
         c. How do you keep control variables controlled? (How do you keep temperature, pressure, etc. constant?)
         d. Write down any assumptions that you are making.
            i. For example, if you are measuring the heat of fusion of ice you are might be assuming the starting temperature of the ice is 0°C.
            ii. Procedures should be clear and organized

8. Safety
   a. Start with the basic attire and procedures which keeps you and everyone else in the room safe during the lab.
   b. Explain the safety precautions for each of your materials

IV. Data- Collecting and processing

1. Collecting raw data
   a. There are several aspects to data collection. Don't overlook any of the following:
      i. Quantitative data (i.e. numerical values)
      ii. Qualitative data (i.e. observations)
      iii. Uncertainties in apparatus
2. When preparing your tables you must address the following:
   a. The units must be included. They should be cited ONCE in brackets in each column heading. Don't put the units after each piece of data.
   b. The uncertainty of the quantitative data and the units of the uncertainty need to be recorded once in the column heading (see Table 1 below).
   c. All data in a column must be given to the same number of decimal places.
   d. Tables and columns need border. The data in a column needs to be centered in the column.
   e. The table needs a suitable and descriptive heading ("Table 1", "Data Collection" or "Results" are not suitable headings).
   f. Do not split tables over two pages if your table is not more than one page long.

Table 1: Gas evolved from magnesium on addition of hydrochloric acid.

Temperature (°C ± 0.05°C)	**Amount of H_2 evolved in 10 minutes ($cm^3 \pm 0.5\ cm^3$)**
10.20	12.2
22.33	24.0
30.45	38.4
40.10	41.0 [a]

a. Time taken in this instance was only 5 minutes

3. Calculations and graphs are correct
   a. Error propagation performed where relevant
4. Results Presentation
   a. Results are clearly presented in tables and graphs with units and uncertainties
   b. Is there a more effective way to represent your data? Such as a graph, hierarchy, flow chart, etc.
      i. calculate averages
      ii. calculate lines of best fit (trendline)—include the equation and correlation coefficient when necessary
      iii. look for other ways to graph the data to get more information
   c. Calculations clearly laid out
      i. Shows equation used and unit analysis.
      ii. Footnote calculated data shown in data table with the sample calculations. You should probably do them on scratch paper first and then copy them neatly into your final report.
      iii. Briefly head each calculation with what is being solved for.
      iv. Error propagation shown.

V. Conclusion and Evaluation

1. Analysis and Conclusion
   a. Summarize what was done - restate purpose of experiment.
   b. Remember a hypothesis can only be supported or refuted. **It cannot be "proven"!**.
   c. Look for any patterns you can find: look for upward trends/downward trends etc.
      i. Eg. *The data from table 5 is graphed in Graph 1 which clearly shows a positive and linear relationship between the amount of salt added to water and the maximum temperature achieved. However, once the amount of salt reaches a certain point, the maximum temperature reached flattens out, indicating that there*

is a limitation. Since it was observed that not all the salt dissolved in the last few trials, it may be that there is a limit to the amount of salt water can dissolve and that is what is causing the limitation.

2. Interpret your results and draw a conclusion
   a. Describes and explain theory behind calculations that were performed on the data
      i. *Eg. The amount of energy given off as heat can be calculated by taken into consideration the mass of the object, the magnitude of the change in temperature and how readily the object gains or loses heat. In this experiment I measured the heat given off when a salt dissolves. My results showed that as the amount of salt increases, the heat given off increases. The heat evolves from the difference in potential energy of the ionic bond and the energy of the "hydration" bond (ion-water molecule bond). Each salt molecule contributes to the total amount of heat given off. Therefore, when there are more ions present in solution, more heat is given off and the difference in temperature increases.*
3. Give reasonable alternative explanations for results
   a. Compares to literature values and provides % yield, % error where appropriate (if there is no literature value than be sure to discuss the applicable concept/theory)
   b. Use actual data (e.g. chemical formula, name of unknown, etc.) from your experiment to defend you conclusion.
   c. Leave detailed analysis of error out of this paragraph and focus more on what your results DO tell you rather than on why they might not be valid.

4. Error Analysis
   a. Identification of Errors
      i. Leave out: human error, miscalculations, time allotted, not enough materials, etc. Focus on the errors in the lab procedure, equipment, and management of time.
      ii. Differentiate between random and systematic errors
      iii. What are the limitations, weaknesses or errors in your procedures?
      iv. Were there important variables not controlled?
      v. Are there things that came up that you didn't account for?
      vi. Did you forget to calibrate the equipment?
      vii. Is your technique poor, causing large random errors?
   b. Effect of Errors
      i. Was your value too low? What errors contributed to making it low?
      ii. Was your value too high? What errors contributed to making it too high?
      iii. Which error, of those listed, was the most significant?
      iv. Are your results reliable, given the errors listed? Justify this.
      v. Estimate the magnitude of errors if possible
         1. *Eg testing the heat gained by water in an aluminum can. Some heat is gained by the aluminum can. Estimate how much using the specific heat capacity of the aluminum. If this is a small amount than you can discount this source of error. If this is large than you can use this to explain why your results don't match literature values.*

5. Improvements
   a. State realistic ideas to improve the investigation, specifically the procedure.
   b. For each of the sources of error listed in the evaluation section, suggest an improvement and explain how this will lead to a reduction in systematic or random errors.

6. References
   a. List references using standard documentation guidelines (MLA, APA, Chicago, etc.)
   b. Include references for:
      i. Background information used in forming a hypothesis
      ii. Procedures
      iii. Literature values