Format for Experiment Preparation and Write-Up

Scientists try to answer questions by applying consistent, logical reasoning to describe, explain, and predict observations; and by performing experiments to test these predictions.

Laboratory reports are a useful way to communicate effectively any scientific investigation. In the same way, a permanent record of your lab observations will help you to answer many scientific questions.

Your lab report will often concern topics you have not yet discussed in class. The reason for this is that we are trying to wean you away from the activity involving mere regurgitation of observations or statements. Instead you will have the opportunity to draw your own conclusions from the facts that you yourself have observed.

The lab report should be a clear concise statement of what you did in the laboratory, observed upon performing the experiment; and what conclusions you were able to make from your observations.
The ability to organize data and information and the proficiency in being able to create generalizations and make conclusions from raw data and communicate your ideas is a skill that will help you in any walk of life.

The following guidelines will help you in the writing of a lab report.

COVER PAGE

Experiment:#?
Date: [this is the date of the experiment, not write-up]
Unit:

Student Name [Underlined]
Lab Partner's Name (s)
Duration of Experiment

Pre–lab

- The purpose of the prelab questions is to provide the background information, to demonstrate the relationship to the theory, to explain a new lab technique; and to prepare you for the work to be performed in the lab.
- The prelab questions will acquaint you with the problem being investigated, and to clarify the pertinent reasons for performing the experiment.

Raw Data

- Always record your name, the title of the experiment, the date when the observations were made.
- Enter all raw data and observations neatly. Use tabular form – preparing data tables before coming to the lab.
- Raw data must include qualitative as well as quantitative data.
- State all observations before, during, and after the procedure in a separate qualitative table. For example, in a titration: record the colour of the solutions, indicator, and the colour change at the end point stating if the colour observed was too dark, or if the end point was overshot.
- State units and uncertainties when recording quantitative data, making sure that the data is recorded to the correct number of decimal places. (E.g., buret readings should be to 2 decimal places and the uncertainty listed: 18.80 ± 0.02 cm^3 , and not 18.8)
- Record all data at the time you make the observation in ink.

- Data are never made on scrap paper.
- An error in data is corrected by putting a single line through it, and re-writing the corrected number near–by. The original wrong number must be legible. White–out must never be used on data.
- Raw data must be clearly presented, allowing for easy interpretation.
- Raw data should not be recopied !!!

Research Question

- This should be expressed as a question and you must be able to define the aim of the experiment or to identify a focused research question.
- This is one or more statements describing the investigation. Stated in a list if more than one objective exists:
  1.
  2.
  3.
- Although the purpose of the experiment is usually provided, however you will be expected to identify the purpose of the experiment before, during and after the lab work has been performed.

Hypothesis

- The hypothesis is your prediction and should be formulated to be an answer to the research question and should explain the rational used to state the prediction, i.e. using theory for your hypothesis.
- The hypothesis should relate directly to the research question.
- It should be specific and quantitative.
- This should express a possible relationship between two or more variables, e.g. "If ..... (manipulated variable)..... is done, then ..... (responding variable) ..... will occur ..... because ..... (reasoning) .....".
- The hypothesis to the research question may also be explained in terms of a scientific concept (for example, a theory, law, or generalization), or another authority (for example, a reference source, or a label on a bottle).
- Qualitative and quantitative reasoning should be included in the hypothesis.
- Note that your hypothesis does not need to be correct, i.e. your investigation might prove it incorrect.

Variables

- State the main variables explicitly and explain why each is relevant to this investigation.
- State which variables are independent and which are dependent (manipulated and responding).
- Indicate which variables need to be controlled
- Manipulated variable: is the factor that you, the experimenter, investigate or change in a systematic manner during the experiment.
- Responding variable: is the result or change that occurs because of the manipulated variable.
- Controlled variable: those other factors which must be held constant so that they do not affect the responding variables.

Apparatus and Materials

- These are reported as separate vertical columns.
- State a complete list of all equipment and chemicals including sizes and quantities.
- List all major pieces of apparatus in detail (i.e. specific: 100 cm^3 beaker instead of simply stating "beaker", e.g. thermometer, –10 ^{O}C to 110 ^{O}C range, 0.2 ^{O}C graduations).
- When more complex equipment configurations are required, a diagram of the apparatus set up is included at this point.

Method /Procedure

- Usually this reads as "refer to resource lab sheet please".
- If the students design their own labs (as is the case several times in the year) the procedures are then stated by the student here.
- Design a method which collects sufficient and relevant data for the variables under investigation and controls the other variables.
- The procedure is detailed set of numbered, in vertical columns, with one set of instruction per step in the correct sequence (i.e. in the order you would do them in the investigation).
- Provide sufficient details so that another person could repeat your work.
- Your procedure should allow collection of sufficient relevant data.
- The final step may include a statement of any safety precautions and waste disposals specific to the procedure.
- The design of the experiment may be concept maps or flow charts of simple apparatus diagrams which are numbered to indicate order or sequence. Creativity is encouraged, without loss of clarity to convey information to the reader for purposes of "lab reproducibility".
- If a diagram is used to show the arrangement of the apparatus, then it should be a large clearly labelled diagram.
- State any assumptions that are valid in the method chosen for the experiment.
- Note that lab design is different from a Lab Report where you would describe the method in paragraph form and in past tense.

Data Collection / Observations

- The observations include all qualitative and quantitative observations relevant to answering the research question.
- Organize your observations in tables, (number tables in Roman numerals).
- Use of tables makes observations well-organized and thus easier to interpret.
- Give an identifying title to each table.
- The contents of the column should include: quantity, unit, and uncertainty. (This means that the units do not have to be included in the individual cells.)
- Arrange entries so that they follow logically. This may be different from the order in which the data are observed, ('mass of beaker + mass of water', followed by 'mass of beaker').
- Raw data: See above

Data Processing / Data Analysis and Presentation

- Data analysis includes calculations and interpretations based on the observations.
- Calculation of results, do one sample calculation, identical calculations do not need to be repeated.
- Show all steps clearly, using significant figures appropriately.
- Keep one extra significant figure throughout a calculation to reduce rounding errors, the final result should be consistent with the number of significant figures in the experimental measurements.
- For repeated trials, calculate a final result for each trial; do not use an average of raw data.
- Calculate an average result, based on final results of repeated trials.
- Any assumptions made in the experiment should be stated.
- Do not forget to include balanced chemical equations.
- Once the data analysis has been completed, the results should be presented so that they are easy to follow and understand.
- The results may be presented in a summary table.
- Graphs may be useful, especially for several values of continuous variables: show title and axes, using standard notation, using an appropriate size (larger, rather than smaller), using an appropriate scale (the origin may not need to be included, indicating points clearly, and showing relationship by fitting points to line(s) or a smooth curve. [Label the manipulated variable on the x-axis, and the responding variable on the y-axis.]
- Conclude the analysis with a statement of your experimental answer to the research question, including a phrase such as, "according to the observations obtained in this experiment, ...(answer).....").

Conclusion and Evaluation

- This section should answer the question in the problem by summarizing the observations and / or inferences and indicating whether or not the original prediction was correct.
- In addition the conclusion should state whether the results of the experiment support or refute the reasoning in the hypothesis.
- Compare with literature or accepted value or reasonable value where possible.
- Calculate percent error where possible.
- Limitations to conclusions should be clearly stated, i.e. are tests conclusive, are interpretations possible?

Experimental Errors:

Discuss the sources of errors in the observations made arising from limitations of the measuring instruments, limitations of the experimental procedure and skill of the experimenter.

The evaluation includes your judgement of the procedure, i.e. the limitations of the procedures.

For identified weaknesses, suggest improvements: suggestions should be realistic, not involving unavailable equipment or materials, suggestions should be specific, not vague (e.g. "More careful work"). Purposed changes should try to eliminate or reduce errors, improve control of variables, provide other procedures for better measurements.

Write your evaluation in paragraph form, using the topic sentences suggested below, or similar to them. Show as much independent, critical, and creative thought as possible in support of your judgement.

1. "The experimental design [name it] is judged to be adequate / in adequate because ...."
   Were you able to answer the problem/the research question using the chosen experimental design?
   Are there any obvious flaws in the design?
   what alternative designs [better or worse] are available?

2. "The procedure is judged to be adequate / inadequate because...."
   Were the steps you used in the laboratory correctly sequenced, and adequate to gather sufficient evidence?
   What improvements could be made to the procedure?
   What, steps, if not done correctly, would have significantly affected the results?

3. "The technological skills are judged to be adequate/inadequate because...."
   Which skills could you could you improve on that would have the greatest effect on the experimental results.
   Was the evidence from repeated trials similar?

4. "The percent difference between the experimental result and the predicted value is ...."
   How does this difference compare with your estimated total uncertainty?

5. "The prediction is judged to be verified/inconclusive because ..."
   How confident do you feel about your conclusion?

These helpful hints will help you to successfully write a formal lab report.