Background information

- Clearly defined and focused research question
- Background information that is relevant to your research question – scientific context
    - Should be at appropriate depth (beyond the scope of the class)
    - Should all be relevant to the research question, methodology
- Background information that is basis for predicted results or expectations
- Statement of independent and dependent variables
- Discussion of methodology
    - Presentation of how methodology was developed
    - Discussion of control variables – what should have been controlled, if it was actively controlled or monitored or neither
    - Discussion of how their methodology is appropriate to address the research question
    - Discussion of what data points were collected and how that was determined (how many replications and which specific values were tested)
        - Chemistry IAs typically require 5 distinct data points with three trials per data point
    - Discussion of trials should be included in this section – what you did, what you learned, and how you modified your methodology based on the trials

Methodology

- Presentation and discussion of materials used
- Procedure
- Should be at sufficient depth for a trained chemist to reproduce
- Does not need to include specifics on standard glassware (i.e. if any graduated cylinder can be used, you don't need to call out 3 10 mL graduated cylinders), does not need to include cleaning the equipment
- Does need to include solution preparation if performed
- Can be paragraph or bullet point or a combination
- MUST include relevant safety, ethical, storage, disposal, environmental considerations relevant to the methodology and chemicals used.

Data

- Raw data should be clearly presented
- Sig figs of raw data should be consistent and based on precision of equipment
- Data figures of raw data should be presented if relevant (should include appropriate axis labels (with units) and a descriptive title
- Any calculations need to include: the formula and a sample calculation with units
- Uncertainties should be presented
- Uncertainties should be propagated for any calculations performed – also presented with a formula and an example calculation and have appropriate sig figs

- Processed data should be presented and sig figs should be consistent with the calculated uncertainties
- Data figures of processed data should be presented if relevant (should include appropriate axis labels (with units) and a descriptive title
- Units, sig figs, uncertainties, labels, titles, etc… should all be well thought out and correct

Analysis

- This section should include a discussion of the data – what does it say and how does it relate to the research question
- A discussion of the calculated uncertainties and the impact those uncertainties would have on the results presented (magnitude, etc…)
- A discussion of any methodological uncertainties that are not already included in the calculated uncertainties
    - May include controls that were not adequately controlled
    - May include discussion of data points that did not match expectations (if so – can you explain why)?
    - What is the magnitude and impact of these uncertainties
    - Important to include major issues that impact the results
    - If certain issues are not significant, they can still be presented and an explanation of why they are not significant should be presented and discussed
    - Should be detailed, in depth, and show critical thinking about the data collected, the methodology, and the results that can realistically be determined from the data
- Discuss the range of data of your replications (i.e. if you had three trials, what was the variability between the trials)
    - How does this relate to your calculated uncertainties? If they are different, why may this be the case?
    - How may this impact the usability of your data

Conclusion

- Present a conclusion that directly addresses your research question
- Discuss the conclusion
    - Does this match your expectations – why or why not
    - If it does not match your expectations, is there a scientific basis for this? Can you explain your conclusion
    - How does your conclusion relate to the scientific context – this should be in-depth and requires citations and discussion of what the scientific context should be
- What is the impact of the uncertainties on your conclusion
- Is your conclusion fully consistent with the data presented (if your errors are too high or the data are not expected, it's better to state that than to try to force a conclusion)
- Present and discuss weaknesses and limitations of your experiment
    - What methodological limitations exist that have a meaningful impact of your ability to draw a valid conclusion from your data

    - Were you unable to sufficiently control certain variables? Did you realize you should have controlled something, but didn't?
    - Were you limited by instrument precision?
    - Did the range of data limit your ability to answer the research question (i.e. did you collect the correct values to test and have enough spacing of your data – like if you collected data at a temperature of 0, 20, 40, 60 and 80 should you have extended it to higher temperatures or had more data in between the selected values?
    - Were there sufficient trials for each data point selected – what was the variability of the data between trials and was three trials enough?
- What are realistic and relevant improvements that could be done to better address your research question
    - This include changes in procedure, methodology, or approach to addressing the research question
    - Need to be well thought out and discussed in depth
    - Need to be relevant to research question and the specific issues you saw when performing the experiment or analyzing your data
    - Need to be realistic and possible to perform in a chemistry lab, but could require more time or better equipment than we have in our specific chemistry lab
- This section should be detailed, precise, and use critical thinking about the data, the conclusions you are able to reach, and your methodology
- Can also include strengths of your methodology, things that were performed well or done well and why that is the case.