# IB Chemistry: Guide to a Successful Internal Assessment (IA)

## Be sure to read pages 177-178 in "Baby Blue" for IA hints.

The Internal Assessment write-up should be **<u>between 6 and 12 pages long</u>**. Investigations exceeding this length will be penalized in the communication criterion as lacking in conciseness.

The following outline is suggested for your IA, however, you may adjust in any way you choose.
You do not need a title page.

- **Diploma Candidate Number** – Please put this at the top of each page of your investigation. Do not place your name anywhere on this document.
- **Investigation Title –** Identifies the topic of your investigation
- **Research Question** – Clearly and concisely state your research question.
- **Introduction –** Set the context for your investigation by discussing background information you have found, through your research, regarding what is already known about the topic of your investigation. You may describe alternate methods of gathering data that you discovered during your research and explain why you have chosen the method you will use.
- **Prediction –** Predict what you think the outcome of your investigation will be.
- **Method -** This is your procedure. This must be written with great detail. See below.
- **Analysis –** See below.
- **Evaluation –** See below.
- **Citation –** Bibliography- Use APA Format

The following information provides detailed guidance for your IA. The bold categories represent the criteria that are being evaluated and the rubrics incorporated into this document are the grading rubrics used by IB to evaluate your IA. Before submitting your document, you should read all of the included rubrics and evaluate your IA against the rubric.

**Criterion: Personal Engagement**
This criterion assesses the extent to which the student engages with the exploration and makes it their own. Personal engagement may be recognized in different attributes and skills. These could include addressing personal interests or showing evidence of independent thinking, creativity or initiative in the designing, implementation or presentation of the investigation.

If your exploration involves a method that can easily be found with an internet search, your work is too simplistic. You might start with a method found through a search, but you must change the investigation to study a variable that is unique and your interest in this variable is described with mild enthusiasm.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1 | **The evidence of personal engagement with the exploration is limited with little independent thinking, initiative or creativity**.<br>The justification given for choosing the research question and/or the topic under investigation does not demonstrate **personal significance**, **interest or curiosity**.<br>There is little evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation. |
| 2 | **The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative or creativity.**<br>The justification given for choosing the research question and/or the topic under investigation demonstrates **personal significance**, **interest or curiosity**.<br>There is evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation. |

**Criterion: Exploration**

This criterion assesses the extent to which the student establishes the scientific context for the work, states **a clear and focused research question** and uses concepts and techniques appropriate to the Diploma Program level. Where appropriate, this criterion also assesses awareness of safety, environmental, and ethical considerations.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | The topic of the investigation is identified and a research question of some relevance is **stated but it is not focused**.<br><br>The background information provided for the investigation is **superficial** or of limited relevance and does not aid the understanding of the context of the investigation.<br><br>The methodology of the investigation is only appropriate to address the research question to a very limited extent since it takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br><br>The report shows evidence of limited awareness of the significant safety, ethical or environmental issues that are **relevant to the methodology of the investigation***. |
| 3–4 | The topic of the investigation is identified and a relevant but not fully focused research question is described.<br><br>The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation.<br><br>The methodology of the investigation is mainly appropriate to address the research question but has limitations since it takes into consideration only some of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br><br>The report shows evidence of some awareness of the significant safety**,** ethical or environmental issues that are **relevant to the methodology of the investigation.*** |
| 5–6 | The topic of the investigation is identified and a relevant and fully focused research question is clearly described.<br><br>The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation.<br><br>The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br><br>The report shows evidence of full awareness of the significant safety, ethical or environmental issues that are **relevant to the methodology of the investigation.*** |

**Methodology (Procedure):**

- In great detail, outline the steps of your procedure in chronological order.
- **Your methods of controlling variables should be very apparent in your procedural steps**. If the control of certain variables is not practically possible, some effort should be made to monitor or control the variable(s) in a limited way. It will be important to discuss your inability to control a variable in your evaluation.
- You must have 5 manipulations (variations) of your independent variable and you should run 3 trials for each manipulation.
- If you will be graphing your data, you must have at least 5 data points. If you are determining a specific value such as density you should have an initial trial and then as many repeated trials as necessary until consistent results are obtained (usually 5 or more trials).
- Include safety precautions and clean-up/disposal procedures. Research all chemicals and indicate all safety and disposal precautions. If there is danger of burning skin, indicate how to avoid this such as stating you should use beaker tongs to remove a hot beaker. At a minimum, indicate that goggles and an apron must be worn.

- Be very specific about the equipment used. Always name the piece of equipment to be used and indicate what size should be used as well. For example: use a 100.0mL graduated cylinder to measure 75.0 mL of water.
- Once you're done, read through the lab and make sure you can visualize each step as you read it.
- Do not use the first person "I", "we", etc. when writing the steps of your procedure.

**Criterion: Analysis**

In this section you will record all **qualitative** as well as **quantitative** data you collected during your experiment. Qualitative data could include things such as a description of an odor if present, changes in color or solubility, gas production, heat released or absorbed, and so on. While conducting the lab you should record all of your observations, measurements, or any other data you collect. For any measurements, be sure to include uncertainties and units. Data should be organized in tables whenever possible. The following recommendations should be considered when creating data tables:

**Recording Raw Data**

- Data is collected independently.
- Data is primarily quantitative (numerical)
- Data must include qualitative observations. (This may provide inspiration in the conclusion and especially the evaluation later.)
- Raw data should be recorded in suitable format(s) as described below.

Table organization

- Must have a title
- Column headings should include the name of the variable, its associated metric unit and measurement uncertainty if it is the same for all measures in the column or row. The estimated digit in recorded measurements should match the decimal position of the measuring tool's uncertainty
- Column & row headers identical to graph axes labels (if table is source of graph data)
- Uses specific terms (ie. NaCl instead of *salt*; volume instead of *amount*; length instead of *size*)
- Do not split tables between pages
- Cells contain only one value
- Tables show grid lines

Table numbers

- Uncertainty in column headings after units. Absolute uncertainties expressed to 1 sig fig.
- Align decimals
- All values in a column must end at the same decimal place
- Mean/average contains one more digit than significant figures in values

Table units

- Units in column headings, not in cells
- No parentheses
- Use SI units - according to IB
- Variable that is measured or recorded is clearly stated (e.g. in the column heading in a table).
- Units for every variable.
- Uncertainty of measurements – based on significant digits –in the column headings.
- The same level of precision (number of decimal places) is used for all the items of a variable.

You will also carry out all processing of your data necessary to draw a conclusion to your research question. The **<u>work for calculations must be shown.</u>** Include one example for **ALL** calculations and **ALL** results in a clear and concise manner using headings to describe your calculations. <u>Brief</u> explanations should be used to create a flow in calculations. Be meticulous and label **EVERYTHING!** You must show the propagation of uncertainties here. Be sure to calculate a percent uncertainty and an absolute uncertainty. Also you must calculate a % error if there is an accepted value with which you may compare your results. If it is appropriate, display data in the form of a graph.

A second data table with a title should be created to show ALL calculated results.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | The report includes **insufficient relevant** raw data to support a valid conclusion to the research question.<br>Some **basic** data processing is carried out but is either too **inaccurate or too insufficient to lead to a valid** conclusion.<br>The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis.<br>The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete. |
| 3–4 | The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question.<br>Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing.<br>The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis.<br>The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced. |
| 5–6 | The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question.<br>Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data.<br>The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis.<br>The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced. |

**Criterion: Evaluation**

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context. The evaluation criterion is allocated six marks and focuses on describing and justifying a conclusion, identifying weaknesses in the procedure and suggesting improvements to the investigation.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | A conclusion is **outlined** which is not relevant to the research question or is not supported by the data presented.<br>The conclusion makes superficial comparison to the accepted scientific context.<br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **outlined** but are restricted to an **account** of **the practical** or **procedural issues** faced.<br>The student has **outlined** very few realistic and relevant suggestions for the improvement and extension of the investigation. |
| 3–4 | A conclusion is **described** which is relevant to the research question and supported by the data presented.<br>A conclusion is described which makes some relevant comparison to the accepted scientific context.<br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **described** and provide evidence of some awareness of the **methodological issues*** involved in establishing the conclusion.<br>The student has **described** some realistic and relevant suggestions for the improvement and extension of the investigation. |
| 5–6 | A detailed conclusion is **described and justified** which is entirely relevant to the research question and fully supported by the data presented.<br>A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context.<br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the **methodological issues*** involved in establishing the conclusion.<br>The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation. |

**Describing and Justifying Your Conclusion**

*A common error is for students to want to get their investigation 'over and done with' at this point and not spend enough time and effort on this section. Although you are nearly at the finishing line, it is important to keep up with your hard work in order to archive the best possible grade for your investigation.*

- To be awarded a high mark in this section, you should aim to write a conclusion that is fully justified (explains how the data in the analysis section supports your conclusion). Trends in the data that you identified in the analysis section should now be explained using your scientific knowledge. This should involve referring back to your research question and background research in the exploration section of the investigation. Does your data answer the research question? You must draw a conclusion that clearly relates to your research question. Indicate if your conclusion supports your original thinking on the topic. If it does not, a consideration of why it does not will lead into an evaluation of the limitations of the method and suggestions as to how the method and approach could be adjusted to generate data that could help draw a firmer conclusion. For example, data collected might have such great variability that no reasonable conclusion can be drawn.

- You must justify your conclusion by comparing your result to an accepted scientific context or value. If a percentage error was calculated, you should comment on that percentage error. Discuss the precision and accuracy of your measurements in terms of their limitations on your data and the role they played as a source of error. Commenting on your percent error and **comparing your percent error to your percent uncertainty** is required and will help support your discussion of precision and accuracy. Compare your percent error to your percent uncertainty (random error). Percent uncertainty indicates how far your experimental values are allowed to be from the accepted value due to the limitations of your measuring tools. If your percent error is greater than your percent uncertainty, this indicates that there are flaws in your methods (systematic error) that are causing your experimental density to be further away from the accepted value.

- Further justification of your conclusion is required through the discussion of whether systematic errors or random errors were encountered. The direction of systematic errors and their impact on your conclusion must be discussed. For example, let's say you are finding a density. If you have a graduated cylinder with a glass bubble occupying a portion of the measured volume, this would cause the measure of volume to always be greater than it should be. You would need to also discuss the impact this systematically higher volume has on density. Since the volume measure is higher than it should be, when mass is divided by volume to find density, this would result in a density that is lower than it actually is.

  Systematic errors arise from a problem in the experimental set-up that results in the measured values always deviating from the accepted value in the same direction-that is, always higher or always lower. An example would be a miscalibrated thermometer that always measures temperature as 0.30 degrees higher that the true temperature. Another example would be a poorly insulated device that allows heat that should be absorbed by water in a container to escape to the surroundings. The temperature of the water would always be measured as lower than it should be due to the loss of that heat.

  Random errors arise from the imprecision of measurements due to the limitations of measuring tools. These errors can lead to readings being above or below the accepted value. Random errors can be reduced with the use of more precise measuring equipment or their effect can be minimized through repeating measurements so that the random errors cancel out.

**Identifying Weaknesses and Suggesting Improvements**

- In this section, strengths and weaknesses or limitations in the procedure should be identified and explained. In addition, improvements to your investigation should be suggested. If you wish to score highly in this section, a simple list of possible procedural improvements will not suffice. Reflect upon how you could adapt the method to deal with significant factors such as range, sample size, or alternative reaction system so that your conclusion is more valid. This should include a discussion of the uncertainties that you calculated in the analysis section and how they might have affected the results of your investigation. In addition, experimental errors should be classified as random or systematic. The direction of error may be determined by comparing the % error with % uncertainty (an example is shown below).
- When suggesting improvements to your procedure, you should refer back to the random or systematic errors identified in the conclusion and explain how they can be minimized or prevented. The precision of the apparatus used in your investigation should also be considered. For example, a volumetric pipette has a higher precision than a graduated cylinder and can help reduce random errors. Make suggestions as to how the effects of random uncertainties may be reduced and systematic errors eliminated. You should be aware that random errors (not systematic errors), are reduced by taking repeated measurements. Suggested improvements to your investigation should be related to the weaknesses or limitations in the procedure and the types of errors identified. You should avoid suggesting improvements that are superficial or unrealistic or non-feasible in the environment of a school context or course. Errors due to careless manipulation of apparatus or events of which there is no evidence should not be included. Don't just say use better measuring tools. If a better tool should be used, suggest a specific tool and give justification. Don't just say find a different method, research and with detail suggest an improvement to the current method. If more trials would improve the lab, indicate how many more and why that would be an improvement.

- Finally, possible extensions to your investigation should be discussed with reference to your research question and methodology. Here, you should discuss realistic extensions to your investigation that would further help answer the research question. For extension, discuss a new variable or factor that could be investigated that is tied to the topic of your current investigation.

***Example Evaluation:***

*Following on from the example in the analysis section where the enthalpy change of neutralization was calculated, we will now calculate the percentage error and classify the types of errors in the investigation.*

*The ΔH for the reaction was calculated as - 44 ± 5 kJ mol$^{-1}$.*

*The literature value for the enthalpy change of neutralization is - 57 kJ mol$^{-1}$. The percentage error can be calculated using the following equation:*

*Percentage error = (experimental value – theoretical value) ÷ theoretical value × 100*

*Percentage error = (-44 - -57) ÷ -57 × 100 = - 23% (the negative sign means that the experimental value was lower than the literature value).*

*Comparing this with the percentage uncertainty, which was 12%, it can be seen that the percentage error is greater, meaning that the major types of error in the investigation were systematic errors. These will be discussed in more detail in the evaluation section.*

*In the conclusion, the main types of errors in the investigation were identified as systematic errors. These are caused by heat being lost to the surroundings as the reaction took place. As soon as the reactants were mixed, the temperature of the mixture started to increase, which was expected as neutralization is an exothermic process. However, some of the heat was lost to the surroundings as the polystyrene cup is not a perfect insulator. This would cause the increase in temperature to be lower, which would result in the calculated ΔH value for the reaction being less than the literature value. An improvement to the investigation would be to use a material for the cup that is a more effective insulator than polystyrene or perhaps using two cups together to reduce heat loss. In addition, a lid could also be added to the cups to reduce the heat loss from the top. There were also assumptions made when calculating the ΔH, mainly that the density and specific heat capacity of the solution were the same as that of water. Looking at the balanced equation for the reaction, the products are salt (NaCl) and water, not pure water. Therefore, the specific heat capacity and density of salt water could be used to get a more accurate result.*

*This investigation could be extended by conducting the experiment at varying ambient temperatures. Does the initial temperature of the surroundings have an impact on the change in enthalpy for the reaction? The reaction could be carried out by heating and cooling the room to different temperatures prior to the start of the reaction.*

**Criterion: Communication**

This criterion assesses whether the investigation is presented and reported in a way that supports effective communication of the focus, process and outcomes.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | **The presentation of the investigation is unclear, making it difficult to understand the focus, process and outcomes.**<br>The report is not well structured and is unclear: the necessary information on focus, process and outcomes is missing or is presented in an incoherent or disorganized way.<br>The understanding of the focus, process and outcomes of the investigation is obscured by the presence of inappropriate or irrelevant information.<br>There are many errors in the use of subject specific terminology and conventions*. |
| 3–4 | **The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes**.<br>The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way.<br>The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation.<br>The use of subject specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding. |

*For example, incorrect/missing labelling of graphs, tables, images; use of units, decimal places. For issues of referencing and citations refer to the "Academic honesty" section.