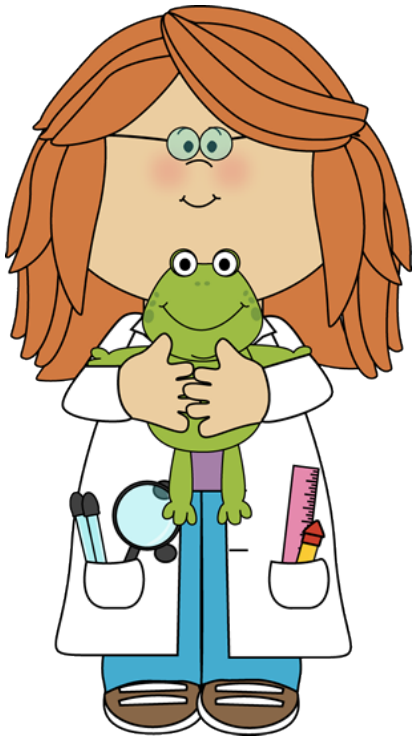
# Group 4 IA Guide



**Name** _____

# Group 4 Internal Assessment

The major piece of assessment in Group 4 subjects, in addition to the exams is the Lab Investigation.

The Lab Investigation is marked using 5 criteria

- Personal Engagement
- Exploration
- Analysis
- Evaluation
- Communication

The final IA task to be completed in Grade 12 will count as 20% of your final IBDP Grade. You will have opportunity to practice using the criteria in school-based assessment.

| Personal engagement | Exploration | Analysis | Evaluation | Communication | Total |
|---|---|---|---|---|---|
| 2 (8%) | 6 (25%) | 6 (25%) | 6 (25%) | 4 (17%) | 24 (100%) |

# Personal engagement

This criterion assesses the extent to which you engage with the exploration and makes it your 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.

| 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. |

**Writing Introductions**

When deciding on a topic of investigation research should first be done to make sure there is enough literature to support your investigation. The topic chosen should be unique and your introduction should show how the topic is relevant to you. Third person is the correct form for a scientific paper but first person can be used in one paragraph to show your connection to the topic.

When writing an introduction ask yourself the following questions?

Is this experiment just replicating another? – if the answer is yes then its not suitable
Is this topic worthy of investigation? - if the answer is no then its not suitable
Is there enough literature to support my investigation? – in text referencing should be used and at least five sources of information.

**Writing Research Questions**

The Research Question should be clearly stated, and the reason for its investigation, as part of the introduction. The research question should be sharply focused and refer to both the independent variable and the dependent variable.

*Good Research Question*
How does the concentration of caffeine affect the rate of decomposition of hydrogen peroxide in liver in the presence of paracetamol?

*Poor Research Question*
Does coffee contain more caffeine that tea?

# Exploration

This criterion assesses the extent to which you establish the scientific context for the work, state a clear and focused research question and use concepts and techniques appropriate to the Diploma Programme 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**.* |

# Designing experiments

## Example format for design

**Title: Example** ' The effect changing x has on y' or 'How x affects y'

**Introduction: -** must explain why the topic is worthy of investigation and give sufficient background information

***Research Question (included in the introduction):*** must refer to both the independent and the dependent variables

**Independent Variable:** What are **you** going to change?

**Dependent Variable:** What will change because the independent variable is changed?

**Controlled Variable:** use the table format below when outlining the controlled variables

| Variable to be controlled | Way the variable is to be controlled. |
|---|---|
| | |

**Materials**: Include the number and type (volume/dimensions) of equipment required. In brackets include the uncertainty (refer to the IA student guidebook if unsure of values)

**Safety instructions**: Refer to the MSDS and make note of any safety equipment required

**Method**: (step by step instructions (numbered), include the concentrations and exact volumes to be used. Make references to the controls if deemed necessary. Ensure sufficient collection of relevant data by replicating at least three times and allowing for more then 6 data points if investigating a trend). Include a diagram/s of your equipment set up.

Diagrams, tables and graphs to be numbered and titled (e.g. Table 1a or Graph 2)

## Investigation Engagement and Exploration Checklist

- ☐ Is the research question carefully worded?
- ☐ Does the research question include the dependent and independent variable?
- ☐ Is the independent variable clearly stated?
- ☐ Does the dependent variable directly stem from the independent variable?
- ☐ Are all controlled variables clearly stated and explained as to how they remain constant?
- ☐ Are the experimental groups and control groups evident? – controls should be in table format.
- ☐ Does the control group differ from the experimental group(s) only by the independent variable?
- ☐ Are the independent and the dependent variables quantitative?
- ☐ Is the independent variable set up so there are 5 intervals?
- ☐ Are there at least 5 trials at each interval of the independent variable?
- ☐ Are regular measurements of controlled variables included?
- ☐ Is there a clear picture or diagram of the experimental apparatus?
- ☐ Are all materials used clearly and precisely listed? (exact sizes of containers and concentrations of solutions must be stated)

# Analysis

This criterion assesses the extent to which you report provides evidence that you have selected, recorded, processed and interpreted the data in ways that are relevant to the research question and can support a conclusion.

| 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><br>Some **basic** data processing is carried out but is either too **inaccurate or too insufficient to lead to a valid** conclusion.<br><br>The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis.<br><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><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><br>The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis.<br><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><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><br>The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis.<br><br>The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced. |

## Recording Raw Data

- Record ALL relevant data and observations using a table
  - Include quantitative data (*e.g,* measurements of temperature, mass, volume, absorbance, pressure – all with the appropriate ***units***)
  - Include qualitative observations before and after the experiment. (*e.g.* "the final color at the endpoint was a faint pink", "during the reaction, the bromine water changed from being a bright yellow to solution of no color").
- Include uncertainty of measurements which can be estimated or is available from the measuring device
- Within tables of quantitative data, write the units and uncertainty in the column heading.
- Significant digits in the data and the uncertainty in the data must be consistent
- Use the same number of decimal places for your raw data
- You are not expected to state the level of precision in the concentration of a solution prepared for you

## Processing Raw Data

- Always process and show your results mathematically in some way (e.g. use averages or calculations with appropriate formula to process your results)
  - Include SI/ metric unit for your calculated quantities
  - Express your calculated quantities with the proper number of significant figures
- Include a paragraph that gives an overview of how and why you decided to process and present the data in the form that you choose
- Transform your data in graphical form
  - Draw the best fit line and determine the gradient (or extrapolate or interpolate your graph)
  - Make sure that the correct scale is chosen to utilize most of the graph space.
- Consider the uncertainties and errors in your processed data
  - You need to propagate the uncertainties in percentage form

## Presenting Processed Data

- Include headings or title for calculations, tables and graphs
- Graphs should have appropriate scales, labeled axes with units, and accurately plotted data points with a suitable best-fit line or curve (not a scatter graph with data-point to data-point connecting lines)
- Include uncertainty bars where significant (*Biology* and *Physics only*)
- Draw lines of minimum and maximum gradients (*Physics only*)
- Determine the uncertainty in the best straight-line gradient (*Physics only*)
- Present all the stages of your data processing so that final result can be followed easily
- Make sure that someone else could understand exactly what your data means.
- Complete a T test if the data set is suitable (*Biology* only)
- Don't use 1.3 E10-3! Use the proper subscript ($_{lower}$) and superscript ($^{upper}$) forms, i.e. $3x10^{-3}$ is good. C4H8 is bad!!!

## Example format for analysis

**Raw data:**

Raw data should be presented in a data table.
Raw data must have uncertainties where possible
Any relevant observations should be included in this section (qualitative data)

**Data Analysis:**

Graphs: Label each axis and include units including uncertainties. Use a line of best fit if a trend is seen. Graphs should have a minimum of 5 data points to identify a trend. Title all graphs and make reference to them in your written analysis.

The independent variable should be on the x axis and the dependent variable on the y axis. Units should have the correct number of significant figures when compared to the uncertainty value.

Anomalous data should be graphed but not included when drawing trend lines. Make reference to anomalous data in the error analysis section and propose reasons for the

If a trend line is identified the gradient equation should be recorded.

Average calculations should be attached as an appendix and averages shown in a table in this section. Any data excluded when calculating the average should be highlighted (identified)

Uncertainty calculations should included using the uncertainty values for the equipment used.

## Dealing with Uncertainties

**Addition and subtraction of values with uncertainties:**
Number of decimals determines the precision of the calculated value.
Uncertainty of the answer is the sum of the absolute uncertainties.

**Multiplication and division of values with uncertainties:**
The total percentage uncertainty is the sum of the individual percentage uncertainties.
Answers must have the correct number of significant figures

## Analysis check list

- ☐ Is the raw data presented in a table with an appropriate title and in the proper format?
- ☐ Are all parts of tables presented clearly labeled?
- ☐ Is the precision of the measuring device(s) used included with each table? (This includes ± the smallest division of the device.)
- ☐ Are all uncertainties presented?
- ☐ Is the raw data properly processed? (This may include statistical tests, percent change, or simple means.)
- ☐ Is the processed data presented properly in a table or in a graphical representation?
- ☐ Is the use of decimals consistent?
- ☐ Do the decimals not exceed the capability of the measuring devices?
- ☐ Are uncertainties included with tables or graphs showing processed data?
- ☐ Has a trend line been identified?
- ☐ For statistical tests, is a clear explanation of the test given with at least one clear example of the test being applied to the raw data?

# Evaluation

This criterion assesses the extent to which your report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

| 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><br>The conclusion makes superficial comparison to the accepted scientific context.<br><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><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><br>A conclusion is described which makes some relevant comparison to the accepted scientific context.<br><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><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><br>A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context.<br><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><br>The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation. |

## Writing conclusions

- Make a valid conclusion and relate it to the aim or the hypothesis
  - Use detailed scientific knowledge to explain a valid conclusion given the evidence available from your results.
  - Try to identify observation, trends or patterns in the results to backup your conclusion.
  - Explain how your results support or don't support your original hypothesis if appropriate.
- You must take into account any systematic or random errors and uncertainties.

  - A percentage error should be compared with the total estimated random error as derived from the propagation of uncertainties.
  - Discuss whether systematic error or further random errors were encountered
  - Include comparisons of different graphs or descriptions of trends shown in graphs.
- When measuring an already known and accepted value of a physical quantity, compare the experimental value with the textbook or literature value. Be sure to reference the literature used
- If applicable, state the theoretical or expected value and compare your result to it using the % difference calculation results

**When writing a conclusion consider the following:**

Considering how large is the errors or uncertainties in your results, how confident are you in the results? Are they fairly conclusive, or are other interpretations/results possible?

**Effect of Error**

- Was your value too low? What errors contributed to making it low?
- Was your value too high? What errors contributed to making it too high?
- Which error, of those listed, was the most significant?
- Are your results reliable, given the errors listed? Justify this.
- Estimate the magnitude of errors if possible

**Limitations of the Experimental Procedure**

- Identify and discuss significant errors and limitations that could have affected the outcome of your experiment. Were there important variables that were not controlled? Were there flaws in the procedure you chose which could affect the results? Are measurements and observations reliable? Were enough trials done to know precision?
- Your emphasis in this section should be on systematic errors, not the random errors that always occur in reading instruments and taking measurements.
- You must identify the source of error and if possible, state how it affected results.
- Acceptable Example: “Because the simple calorimeter we used was made from a tin can, some heat was lost to the surroundings—metals conduct heat well. Therefore, the value obtained for the heat gained by the water in the calorimeter was lower than it should have been.”
- Unacceptable Examples: “The test tubes weren’t clean” “Human Error”
- Are there flaws in the procedures which could affect the results?
- Are important variables not controlled?
- Are measurements and observations reliable?
- Is precision unknown because of lack of replication?
- Analyze possible sources of error and distinguish systematic and random error
- Main emphasis should be on possible systematic errors
- Indicate the direction and magnitude of the effects on the final result

**Limitations of conclusions**

- Are tests conclusive? Are other interpretations possible?
- Take account of magnitudes of errors and uncertainties in considering the reliabilities and limitations of conclusions.

**Suggestions for Improvement**

- Suggest improvements or fixes for the weaknesses you identified in the previous section. These suggestions should be realistic, keeping in mind the type of equipment normally found in high school or college general chemistry labs. Suggestions should focus on specific pieces of equipment or techniques you used.
- Vague comments such as “We should have worked more carefully” or “I should have been given a better calorimeter” won't cut it! For identified weaknesses, suggest improvements
- Suggestions should be realistic, not involving unavailable equipment…
- Suggestions should be specific (not “more careful work” or “more time”)
- Proposed changes may do any or all of the following
- Eliminate or reduce errors
- Improve control of variables
- Reduce approximations
- Provide other procedures for better measurements.
- State if modifications are unnecessary or impossible (standard procedures used…)

## Evaluating investigations

- Evaluate your method.
  - Comment on random and systematic errors.
  - State any assumptions that were made which may affect the result.
- Comment on the limitations of the method chosen.
  - Identify any weaknesses and explain how significant the weaknesses are.
  - Include comments about the precision and accuracy of the measurements
  - You need to specifically look at the processes, use of equipment and management
- Give realistic and clear suggestions for improvement
  - Suggestions should be based on the weaknesses and limitations mentioned in aspect 2.
  - You should suggest how to reduce random error, remove systematic error and/or obtain greater control of variables.
  - Suggestions should deal with issues of precision, accuracy and reproducibility of the results.
- Don't list trivial broad suggestions – i.e. I should have concentrated more, we should have used a more precise instrument, we should have prepared more….

## Evaluation checklist

- ☐ Is there a clear pattern shown by your processed data?
- ☐ Is a clear conclusion, using the processed data, presented?
- ☐ Has the Research Question been appropriately answered?
- ☐ Is the actual processed data used in the conclusion?
- ☐ Is there a correlation between your work and literature values? (if applicable)
- ☐ Has the percentage discrepancy been calculated? (if applicable)
- ☐ Are weaknesses of experimental design stated?
- ☐ Is the quality of the data discussed? – systematic and random errors referred to.
- ☐ Are there references to equipment or processes in the discussion of the design weaknesses?
- ☐ Are suggested modifications to the design presented based on the weaknesses presented?
- ☐ Are the suggested modifications specific and significant?

## Example format for Evaluation (and Conclusions)

**Conclusion**

When the objective of the lab is to obtain a numerical result, you must also compare your experimental result with the literature value and determine the percent error. You then must analyze whether the error is due to random error alone, or whether systematic error in your experiment was also present. This process is called **error analysis**.

Research for literature values or use your data booklet. If found find the % discrepancy and comment on this value. Compare this value to your final uncertainty values.

$$\% \text{ discrepancy} = (\text{experimental} - \text{actual})/\text{actual} \times 100\%$$

Errors can be systematic or random, identify the type and make sure to explain how your results could have been affected (use anomalous data to explain your type of errors)

Identifying systematic error – all data points are close to or on the trend line. All trials produced similar results.

Examples of systematic errors include:

- measuring the volume of water from the top of the meniscus rather than on the bottom which results in volumes being too high
- overshooting the volume of liquid delivered in a titration
- heat losses in an exothermic reaction
- Scales not calibrated correctly (or any electronic equipment)

Identifying random error – trials do not produce similar results. Data does not sit on a trend line. Large percentage of inaccuracy, when compared to published/literature data. Range is large.

Random errors can be caused by readability of the measuring instrument, the effects of the changes in the surroundings such as temperature, insufficient data, an observer misinterpreting the reading

State a conclusion about your lab – at least 4 sentences about any trends identified and future applications of the findings

**Evaluation:**

State the weaknesses of the experiment and ways that the error caused by those weaknesses can be improved

| Weaknesses | Significance | Improvements |
|---|---|---|
| 1. number each weakness<br><br>2. | | 1. relate the improvement to the numbered weakness<br><br>2. |

# 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 labeling of graphs, tables, images; uses of units, decimal places

By using the example format structures given in this guide you will be able to write a well-structured and clear report.