

SUBJECT AREA: CHEMISTRY

Chemistry is the science that deals with the composition, characterization, and transformation of substances. Therefore, an extended essay in chemistry should focus on chemical principles and theory, and should emphasize the essential nature of chemistry relating to the study of matter and of the changes it undergoes.

The examiner will be looking for you to investigate personally a particular aspect of the materials of our environment. This is why IB strongly recommends the performance of an experiment by any candidate choosing this subject area for his/her extended essay.

You will be graded on your ability to show the following:

- 1. Use of chemistry principles and ideas to describe and explain the properties and behavior of materials:**
- 2. Use of methods and sources appropriate to chemistry:**
- 3. Reasoning surrounding the research and its limitations:**

Choosing your topic:

The IB manual reminds us that whatever the topic you choose, it must allow for an approach that distinctively involves chemistry.

Where a topic may be presented through many different subject area view points (i.e. medical or biological), your treatment of information must be approached from a chemical perspective. For example: an extended essay in an interdisciplinary area, such as biochemistry, will be judged only on its chemical content-- not on its biological content. Consequently, all work on research which is inherently biological will have been done in vain-- yielding no points whatsoever for your score.

The scope of your chosen topic and the research associated with it should enable all criteria to be addressed.

A good topic is one in which a single research question is sharply focused, and can be treated effectively within the word limit. Perhaps the most important factor is the depth of treatment that can be presented by the candidate.

IB warns us to be careful to avoid selecting a topic that might be unsuitable for several reasons:

Some topics may raise safety issues. For example, experiments involving toxic or dangerous chemicals, carcinogenic substances, or radioactive materials should be avoided unless adequate safety apparatus and qualified supervision is available.

Other topics may be unsuitable because the outcome is already well known and documented in standard text books, and the candidate may not be able to show any personal input. An example of this would be the study of reactions of alkali metals with water--as this is already covered by the syllabus.

On the other hand, some care may need to be exercised in deciding whether a topic is suitable or not. The passage of time and the evolution of technology can influence such a decision. For example, a few years ago the study of allotropes of carbon may have been thought to be trivial, but this would not be the case today.

Examples of topics which have been used for previous essays :

- * *Spectrophotometric determination of trace amounts of lead in drinking water*
- * *The kinetics of oxidation of iodine ions with hydrogen peroxide in acidic solutions*
- * *The analysis of the red dyes present in different brands of tomato ketchup by thin layer chromatography*
- * *Is it better to use dried animal manure as a fertilizer, or as a fuel?*
- * *The effects of sugar-free chewing gum on the pH in the mouth after a meal*

Range and variety of Sources:

Use as many different types of sources as possible, so long as they are relevant to your chosen topic in Chemistry. See examples below:

- * Scientific journals which report studies similar to your experiment
- * TV documentaries, and news features reporting on events relating to your chosen issue.
- * Books covering specific issues relative to chemistry
- * Government records and documents
- * Photocopies of product packages and labels

Include both **primary** and **secondary** sources.

Your **primary source** is the raw data from your experiment. Your **secondary source** may be any related study which could back up the findings you glean from your experiment.

Regarding information found online:

IBO warns us to use **online sources** sparingly. Though the Internet may seem more convenient, IBO stresses the importance of being careful about the quality of information found there. Frequently this information lacks accuracy, authenticity and reliability. Also occasional piracy exists in some websites. This could put your diploma at risk for malpractice penalties. Unless you are prepared to question and evaluate ideas found on the web as you present them in your essay, it is wise to stick with printed materials which respect copyrights and which have been examined for accuracy.

Treatment of the topic:

An extended essay in chemistry may be based on literature, theoretical models, or experimental data.

Of the three above mentioned options, the one least likely to produce a successful score is that based on literature. Too many candidates interpret this as a simple “way out”-- one in which writing the essay can be accomplished by reading some material from a book, and submitting a report summarizing the facts. Candidates who choose to write an extended essay based on literature and/or surveys should take special effort to show its chemical basis. Essays written at the level of a “newspaper, or news magazine article” are unlikely to score well.

Additionally, basing your essay on literature makes it extremely difficult for you to demonstrate personal understanding of the data, and obscures any personal role you may have played in putting together your argument and conclusion.

Since chemistry is an experimental science, candidates are strongly encouraged to undertake experimental work as part of their research. In doing this, IB warns us to avoid several possible pitfalls. The IB manual tells us to remember that data collected from an experiment is of little value unless it is analyzed, using appropriate techniques, evaluated and hopefully compared with appropriate models illustrating similar experiments or studies done by professionals. Such information forms the basis of the “argument” section of your essay, and should take up the majority of pages that compose your product.

Any experiment designed by the candidate should be described in sufficient detail to allow the work to be repeated by others. Specifically, listing materials used, explaining step by step procedures, and justifying these by referring to predicted outcomes must be included early on, preferably in your introduction.

Whatever approach is chosen, the candidate should ensure that the essay is primarily based in the field of chemistry, that sufficient data will be available for evaluation, and since personal involvement is so important for success, the topic should be able to be researched accurately using resources that are locally accessible to the candidate.

It is possible to produce an extended essay in Chemistry in which the candidate has used data collected elsewhere from professional studies described in scientific journals as a primary source. In such cases, the element of personal analysis and evaluation is especially important.

For any Chemistry extended essay IB urges candidates to demonstrate that they understand the theory underlying any experimental work, whether it is an experiment of their own design, or a study of the work of others. Candidates should state any assumptions made, analyze the results obtained and be able to interpret them with reference to the research question posed. They should be critical of inadequate experimental design, the limitations of the experimental method used, and any systematic errors encountered. The IB manual encourages you to consider unresolved questions which arise during the research and findings stages, and to suggest new questions and areas for further investigation in your conclusion.

The following are some examples of titles, research questions, and approaches to a topic that have been used in the past:

Title: The ratio of the gases evolved at the positive electrode during the electrolysis of common salt solution

Research question: Is there a relationship between the concentration of aqueous sodium chloride solution and the ratio of the amounts of oxygen and chlorine gas that are evolved at the positive electrode during electrolysis?

Title: The caffeine content of a cup of tea

Research question: Does the time it takes to brew a cup of tea using a specific commercial brand of tea leaves significantly alter the amount of caffeine that is dissolved in the drink?

Title: Analysis of strawberry jellies by paper chromatography

Research question: Using paper chromatography this experiment will determine whether stawberry jellies obtained from 24 different countries in 5 different continents all contain the same red dyes.

FOLLOWING IS A LIST OF ASSESSMENT CRITERIA RELATIVE TO THE CHEMISTRY EXTENDED ESSAY:

CRITERIA A: The research question

The research question can be thought of as an actual question that the research will attempt to answer. For example: "What gas is evolved when zinc is added to copper (II) sulfate solution and what factors affect its formation?" However, in chemistry extended essays it is perfectly reasonable to formulate the research question as a statement or as a hypothesis rather than a question. "Analysis will determine the amount of aluminum in three different brands of underarm deodorant by visible spectroscopy" and "The kinetics of oxidation of iodide ions with hydrogen peroxide in acidic solutions will be explored" are two such examples where a statement rather than a question is appropriate. Whichever way it is formulated, it should be identified clearly as the research question and set out prominently in the introduction.

CRITERIA B: The introduction

The purpose of the introduction is to state the research question and set it into context--that is to relate the research question to existing knowledge in chemistry. It is usually appropriate to include the general underlying chemical theory required to understand the research question. Some research questions require background knowledge that is not related to chemistry--for example, "Do the fossils found in different strata of rocks at a particular location contain different amounts of sulfur?" For the essay to make sense, it would be important to state the ages of the rocks and give some geological background. In such cases, only the essential non-chemistry information should be provided in the introduction, as the essay will be marked primarily on its chemical content. If it is necessary to include more non-chemistry (For example, geological) information, then the appropriate place for it is the appendix.

CRITERIA C: The investigation

The way in which the investigation is written will depend very much on whether or not the essay is based on experimental work performed by the student. For experimental work, sufficient information on the methodology should be provided to allow the work to be repeated by an independent researcher. Students should demonstrate that they understand the theory behind any techniques or apparatus used. They are also expected to show an awareness of any limitations or uncertainties inherent in their techniques or apparatus used. Students should make it clear which experiments they have designed themselves and which they have altered, adapted or improved from existing methods.

For essays that are based on data taken from written sources, the student should explain clearly how the data has been selected and should comment on its reliability. They should distinguish between primary (For example, original scientific publications, personal communications, interviews, etc) and secondary sources (textbooks, newspaper articles, and reviews, etc.) All cited material should be used to support the student's own argument and not to substitute for it. A statement made by an scientific expert should be challenged wherever there is evidence to do so. All material used from sources must be acknowledged

in references. If students make use of internet-based sources, they should do so critically demonstrating a full awareness of the source's potential unreliability.

CRITERIA D: Knowledge and understanding of the topic studied

Students should show that they understand fully the underlying chemistry behind the context of the research question and their subsequent investigation. They are not expected to explain basic chemistry forming part of an IB chemistry course, but they are expected to show that they fully understand the relevant principles and ideas learned in class and can apply them correctly. They should also demonstrate that they understand the theory behind any techniques or apparatus used.

CRITERIA E: The reasoned argument

Students writing a chemistry extended essay must make a special effort to maintain a reasoned, logical argument that focuses on the research question. A clear and logical argument can be achieved by making repeated reference to the research question and to include consideration and comparison of different approaches and methods directly relevant to the research question.

CRITERIA F: Application of analytical and evaluative skills appropriate to the subject

A thorough understanding of the reliability of all data used to support the argument should be shown. Inadequate experimental design or any systematic errors should be exposed. The magnitude of uncertainties in physical data should be evaluated and discussed. Approximations in models should be accounted for and all assumptions examined thoroughly. Where possible, the quality of sources accessed or data generated should be verified by secondary sources or by direct calculations.

CRITERIA G: Use of language appropriate to the subject

Correct chemical terminology and nomenclature should be used consistently and effectively throughout the essay. Relevant chemical formulas, (including structural formulas), balanced equations (including state symbols) and mechanisms should be included. The correct units for physical quantities must be given and the proper use of significant figures is expected.

CRITERIA H: The conclusion

The conclusion should relate directly to the research question and should point out the main findings of the research and reasons the research supports or refutes the original hypothesis. Chemical research often reveals unexpected outcomes and these should be pointed out, even if they were not part of the original plan. The original research question may not be fully answered by the investigation. In these cases, the student should point out unresolved issues and make suggestions as to how these might be further investigated.

CRITERIA I: The formal presentation

This criterion relates to the extent to which the essay conforms to academic standards about the way in which research papers should be presented. Omitting a bibliography or any one of the required elements- title page, table of contents, page numbers- are deemed no better than level 2, while essays that omit two of these will receive no more than a level 1.

The essay must not exceed 4,000 words of narrative. Though chemistry investigations often require the support of referenced material, such as diagrams or drawings, graphs, figures, calculations, diagrams, formulas, these are not included in the word count. For experiments where numerical results are calculated from data obtained by changing one of the variables, it is generally good practice to show one example of the calculation. The remainder can be displayed in tabular or graphical form.

CRITERIA J: The abstract

For a biological investigation, the abstract must include the research question and a conclusion that directly relates to the research question. In addition, the description of how the research was conducted must include a description of the methodology and the scope of the study.

CRITERIA K: Holistic judgement

Qualities that are rewarded under this criterion include the following:

Intellectual initiative: Ways of demonstrating this in Chemistry essays include the choice of topic and research question, and the use of novel or innovative approaches to address the research question.

Incite and depth of understanding: These are most likely to be demonstrated as a consequence of detailed research, reflection that is thorough and well informed, and reasoned argument that consistently and effectively addresses the research question.

Originality and creativity: These will be apparent by clear evidence of a personal approach backed up by solid research and reasoning.

Problems demonstrated by students in past essays:

Following are problems reported by examiners relative to several important areas with respect to the Chemistry extended essay--

Principles and ideas used to describe and explain the properties and behavior of materials:

Expectation : Relevant principles and ideas relating to chemistry are included and there is good evidence that they are fully understood and applied correctly.

Problems in the past: In some essays there was no evidence of any chemistry principles. In other cases ideas relating to chemistry were mentioned, but little use was made of them.

It is important that candidates show a clear comprehension of the underlying chemistry of the essay. Theory which is covered in the regular teaching program need not be repeated in detail. For instance, where a visible spectrometer is used the underlying theory including the Beer-Lambert law should be included to show that the candidate fully understands what he/she is doing. Where multiple similar calculations are involved, at least one example should be worked through fully as a demonstration, although it is then quite acceptable for the rest to be set out in table form. Equations should be given wherever possible and structural formulas whenever appropriate.

Use of methods and sources appropriate to chemistry:

Expectation : The methods or sources used are appropriate to chemistry and relevant to the research question. These are carefully chosen, and used competently, and there is clear evidence of a personal approach to their application.

Problems in the past: In some essays there was a minimal amount of methods discussed, or the sources used were not relevant or were not appropriate to chemistry. In other essays, methods and sources used were essentially appropriate to chemistry, but either they were not carefully chosen or they were not competently used.

To gain full marks on this criterion it is essential that the candidate demonstrates a personal approach. This is generally much easier done in a school laboratory than in a research laboratory where more sophisticated equipment tends to be used. Essays that were carried out in a professional research, or university laboratory did

not score well because it was very hard for the candidate to show how much of the work (s)he had actually undertaken personally. In some cases, there were examples of "mini PhD" essays in which the topic was obviously an extension of a university study and appeared too sophisticated for the candidate to show real mastery of the experiment and to display personal input.

The best essays were those in which the candidate used relatively unsophisticated equipment and was able to demonstrate clearly a high degree of initiative and personal input.

One essay analyzed the aluminum content of underarm deodorants and then went on to try to determine how much aluminum is absorbed through the skin each time they are used.

Reasoning surrounding the research and its limitations:

Expectation : Uncertainties in experimental data are thoroughly analyzed and approximations in models are accounted for. Inadequate experimental design or any systematic error is explained. The quality of sources accessed is verified by secondary sources or by direct calculations. Explanations, confirmations and refutations are supported by this analysis.

Problems in the past: Sometimes there was no awareness of the quality of experimental design, and no quality of sources verified, or such things were only briefly mentioned with limited attempts at analysis-- and little supporting evidence for explanations, confirmations, or refutations.

It is important that candidates fully analyze the quality of their experimental method as well as the assumptions made in arriving at conclusions. Too often candidates were tempted to end their essays by making broad sweeping conclusions which could not be justified by the work done, whereas a more specific conclusion could have been clearly justified. Candidates should also remember to include new questions that have emerged from their research, even if it is not possible to propose a realistic method to solve them.

There is a tendency to assume that "modern" apparatus is more sophisticated error analysis if the initial data itself is suspect. Due to time restrictions it is not always practical or possible to get repeat results, but this limitation should be stated clearly in the analysis.