

# Chemistry

These subject guidelines should be read in conjunction with the “Introduction”, “Outline” and “Details—all essays” sections of this guide.

## Overview

An extended essay in chemistry provides students with an opportunity to investigate a particular aspect of the materials of our environment. Such extended essays must be characterized by a particular chemical emphasis within a more general set of research criteria.

The outcome of the research should be a coherent and structured piece of writing that effectively addresses a particular issue or research question and arrives at a particular, and preferably personal, conclusion.

## Choice of topic

It is important that the extended essay has a clear chemical emphasis and is not more closely related to another subject. Chemistry is the science that deals with the composition, characterization and transformation of substances. A chemistry extended essay should, therefore, incorporate chemical principles and theory, and emphasize the essential nature of chemistry, relating to the study of matter and of the changes it undergoes.

Although the same assessment criteria apply to all extended essays, for an extended essay submitted in chemistry the topic chosen must allow an approach that distinctly involves chemistry. Where a topic might be approached from different viewpoints, the treatment of the material must be approached from a chemistry perspective. For example, an extended essay in an interdisciplinary area such as biochemistry will, if registered as a chemistry extended essay, be judged on its chemical content, not its biological content.

The scope of the topic and the research associated with it should enable all the criteria to be addressed. A good topic is one where the 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 given to the topic by the student. Broad or complex survey topics (for example, investigations into health problems caused by water pollution, chemotherapy for cancer treatment or the use of spectroscopy in chemical analysis) will not permit the student to discuss conflicting ideas and theories, nor to produce an in-depth personal analysis within the word limit.

Some topics may be unsuitable for investigation because of 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 are available.

Other topics may be unsuitable because the outcome is already well known and documented in standard textbooks, **and** the student may not be able to show any personal input. An example might be a study of the reactions of the alkali metals with water as this is already covered by the syllabus. However, some care does need to be exercised in deciding whether a topic is suitable or not; for example, previously, the study of the allotropes of carbon might have been thought to be trivial but this would not be the case today.

The following examples of titles for chemistry extended essays are intended as guidance only. The pairings illustrate that focused topics (indicated by the first title) should be encouraged rather than broad topics (indicated by the second title).

- "The ratio of the gases evolved at the positive electrode during the electrolysis of common salt solution" **is better than** "Electrolysis of solutions".
- "Spectrophotometric determination of trace amounts of lead in drinking water" **is better than** "Water analysis".
- "The effects of sugar-free chewing gum on the pH of saliva in the mouth after a meal" **is better than** "Acid–base chemistry".
- "How can the natural oxidant rutin be extracted and purified from the seed of the Chinese Scholartree?" **is better than** "Extraction of natural products from plants".

Moreover, it may help if the student further defines and refines the topic chosen for study in the form of a research question or statement.

<b>Title</b>	<b>The ratio of the gases evolved at the positive electrode during the electrolysis of common salt solution</b>
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?
<b>Title</b>	<b>The caffeine content of a cup of tea</b>
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?
<b>Title</b>	<b>Analysis of strawberry jellies by paper chromatography</b>
Research question	The use of paper chromatography to determine whether strawberry jellies obtained from 24 different countries in 5 different continents all contain the same red dyes.

## Treatment of the topic

An extended essay in chemistry may be based on literature, theoretical models or experimental data. Whichever category or combination of categories is chosen, the student should ensure that sufficient data is available for evaluation and that the topic can be researched accurately using locally available resources.

Students who choose to write an extended essay based on literature and/or surveys should ensure that their extended essay clearly shows its chemical basis. Essays written at the level of a newspaper or news magazine article are unlikely to achieve a high mark.

Since chemistry is an experimental science, students are strongly encouraged to undertake experimental work as part of their research, although this is not compulsory. In order to place their research into the appropriate context, students should research the area of the investigation before commencing any experimental work. Where possible, they should consult original research using scientific journals, personal communications and the Internet. Textbooks should never be the only source of information.

All essays involving experimental work undertaken by the student should include a clear and concise description of the experimental work. Students should indicate clearly whether they have personally designed the experiment, or give the source of an existing experiment method that they have used and state how they have adapted and improved upon it. All essays must be supervised by a school supervisor. Many of the best essays are written by students investigating relatively simple phenomena using apparatus and materials that can be found in most school laboratories, and this approach is to be encouraged. If the practical work is carried out in an industrial or university laboratory, the essay should be accompanied by a letter from the external supervisor outlining the nature of the supervision and the level of guidance provided. The school supervisor must be satisfied that the work described in the essay is genuine and essentially that of the student.

Data collected from an experiment designed by the student is of little value unless it is analysed using appropriate scientific techniques, evaluated and perhaps compared with appropriate models.

It is possible to produce an extended essay in chemistry in which the student has used data collected elsewhere as the primary source. In such cases, the element of personal analysis and evaluation is extremely important.

In any chemistry extended essay, students should be able to demonstrate that they understand the theory underlying any experimental work and state any assumptions made. They should show an understanding of 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 and any systematic errors. Students should be encouraged to consider unresolved questions in their research, and to suggest new questions and areas for further investigation in their conclusion. Throughout the whole of the essay, students should emphasize clearly their own personal contribution.

## Interpreting the assessment criteria

### **Criterion A: research question**

Many research questions can be formulated as an actual question or questions. A typical example is: "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 an actual question. "An analysis of the amount of aluminium in three different brands of underarm deodorant by visible spectroscopy" and "The kinetics of oxidation of iodide ions with hydrogen peroxide in acidic solutions" 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.

**Criterion B: introduction**

The purpose of the introduction is to set the research question into context, that is, to relate the research question to existing knowledge in chemistry. It is usually appropriate to include also the underlying chemical theory required to understand how the research question has arisen. Some research questions require some 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 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.

**Criterion C: investigation**

The way in which the investigation is undertaken will depend very much on whether or not the essay contains experimental work performed by the student. For non-experimental essays, students should endeavour to show clearly how the data has been selected. They should distinguish between primary sources (original scientific publications, personal communications, interviews) and secondary sources (textbooks, newspaper articles, reviews), and show awareness of how reliable these sources are. For experimental work, sufficient information should be provided so that the work could be repeated if necessary by an independent worker. Students should make it clear which experiments they have designed themselves and which they have altered, adapted or improved from existing methods.

**Criterion D: knowledge and understanding of the topic studied**

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

**Criterion E: reasoned argument**

Students should be aware of the need to give their essays the backbone of a developing argument. A good argument in chemistry will almost certainly include consideration and comparison of different approaches and methods directly relevant to the research question. Straightforward descriptive or narrative accounts that lack analysis do not usually advance an argument and should be avoided.

**Criterion 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.

**Criterion G: use of language appropriate to the subject**

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

### **Criterion H: conclusion**

The conclusion must be consistent with the argument presented and should not merely repeat material in the introduction or introduce new or extraneous points to the argument. In chemistry, it is almost always pertinent to consider unresolved questions and to suggest areas for further investigation.

### **Criterion I: 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. The presentation of essays that omit a bibliography or that do not give references is deemed unacceptable (level 0). Essays that omit one of the required elements—title page, table of contents, page numbers—are deemed no better than satisfactory (maximum level 2), while essays that omit two of them are deemed poor at best (maximum level 1).

The essay must not exceed 4,000 words of narrative. Graphs, figures, calculations, diagrams, formulas and equations 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.

### **Criterion J: abstract**

The abstract is judged on the clarity with which it presents an overview of the research and the essay, not on the quality of the research question itself, nor on the quality of the argument or the conclusions.

### **Criterion K: holistic judgment**

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.
- Insight and depth of understanding: These are most likely to be demonstrated as a consequence of detailed research and thorough reflection, and by a 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.