

# Chemistry: Subject-specific guidance

See also: EE generic guide and EE Teacher support material

## Overview

An extended essay (EE) in chemistry provides students with an opportunity to investigate a specific aspect of a material of our environment. The essay must be characterized by a particular chemical emphasis within a more general set of research criteria.

Chemistry is the science that deals with the composition, characterization and transformation of substances. A chemistry EE should incorporate chemical principles and theory, and emphasize the study of matter and of the changes it undergoes.

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

## Choice of topic

The topic must allow an approach that specifically involves chemistry. Where a topic might be approached from different viewpoints, the treatment of the material must be from a chemistry perspective. For example, an EE in an option area of the IB syllabus such as biochemistry will, if registered as a chemistry EE, be judged on its content within the scope of the biochemistry option of the syllabus.

The scope of the topic and the research associated with it should enable all the criteria to be addressed. The research question must be sharply focused and able to be treated effectively within the word limit.

## Suitability of topics

Broad or complex literature-based topics do not allow the student to discuss conflicting ideas and theories, nor to produce an in-depth personal analysis within the word limit. Students should therefore avoid these topics (eg investigations into health problems caused by water pollution, chemotherapy for cancer treatment or the use of spectroscopy in chemical analysis).



Some topics may be unsuitable for investigation because of safety issues. These are clearly stated in the chemistry guide and all students must be aware of them before embarking on their EE. Experiments involving toxic or dangerous chemicals, carcinogenic substances or radioactive materials are strictly prohibited.

Other topics may be unsuitable because the outcome is already well known and documented in standard textbooks.

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.

## Examples of topics

These examples are just for guidance. Students must ensure their choice of topic is focused (left-hand column) rather than broad (right-hand column).

Focused topics 	Broad topics 
Determination of chloride, nitrate and calcium ion concentration in sea water	Study of sea water
Spectrophotometric determination of vitamin B2 content in cow's milk	Study of milk
Investigating the possibility of substituting hydrazine for kerosene as a rocket fuel	Theoretical investigation of hydrazine
Extracting DNA from peas using two different primary alcohols	DNA in plants

Once they have chosen their topic, students must then further define and refine it for study by expressing it in the form of a research question.

## Treatment of the topic

An EE in chemistry may be based on:

- literature
- theoretical models
- experimental data.

Whichever approach is chosen, the student must ensure that they have access to sufficient data to research the topic effectively.

Students who choose to write a literature- or survey-based essay should ensure that it 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
- online sources
- textbooks.

The internet should never be the sole 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 used an existing method. If they use an existing method, they must give its source and state how they have adapted and improved upon it.

## Supervision

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.

The supervisor has the responsibility to ensure that students understand that the EE must not duplicate the research topic, data or the results of the internal assessment. A statement to that effect should be included in the supervisor's comment on the cover of the EE.

Generating and presenting data should not be an end in itself; students must analyse data using appropriate techniques, evaluate it and where appropriate compare it with appropriate models or literature values.

## Use of secondary data

Students can also use data collected elsewhere. For example, for a research question that requires calculation of enthalpy changes in reactions, students can obtain average bond enthalpies from databases and manipulate these in order to answer the question.

However, to achieve high marks, students must devise their own method to analyse the secondary data in a way that leads to a specific answer to their research question.

In any chemistry EE, students must 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. Throughout the essay, students should emphasize clearly their own personal contribution.

## Examples of topics, research questions and suggested approaches

Once students have identified their topic and written their research question, they can decide how to research their answer. They may find it helpful to write a statement outlining their broad approach. These examples are for guidance only.

Topic	<b>The effect of storage temperature on alkaline battery discharge time</b>
Research question	What is the effect of storage temperature on the operational lifespan of an alkaline battery?
Approach	Experimental: set of 3 batteries is subjected to 5°C, 20°C, 30°C, 40°C, 50°C for a specific period of time, after which the batteries are discharged. Voltage is measured before and after storage period.

Topic	<b>Investigation of changing reflux time on the yield of aspirin</b>
Research question	Does increasing reflux time increase the percent yield of aspirin for the reaction between acetic anhydride and salicylic acid?
Approach	Experimental: aspirin is produced from acetic anhydride and salicylic acid at varying reflux time intervals.

Topic	<b>Replacement of coal with natural gas for electric power generation</b>
Research question	What would be the reduction in CO <sub>2</sub> emission (measured as % change by mass) in Germany of replacing all coal-fired power plants with modern CH <sub>4</sub> power stations?
Approach	Data based: calculate the CO <sub>2</sub> emission per kWh using public domain data for the heat of combustion, composition and efficiency of coal and natural gas power plants.

Topic	<b>Periodic properties of super-heavy elements 113–118</b>
Research question	Can the physical and chemical properties of the undiscovered elements be predicted using the law of periodicity?
Approach	Literature based: examine the ionization potential, electron affinity and other periodic trends, predict if the super-heavy elements obey the periodic law.

### An important note on “double-dipping”

Students must ensure that their EE does not duplicate other work they are submitting for the Diploma Programme.

### The chemistry EE and internal assessment

An EE in chemistry is not an extension of the internal assessment (IA) task. Students must ensure that they understand the differences between the two.

- The IA is more likely to focus on the syllabus content, whereas the EE could explore aspects of chemistry not covered in the syllabus.

- The IA must include data collection and analysis (from hands-on experiments, databases, simulations or modelling) and cannot purely be a literature review.
- The EE must construct a theoretical framework for the underlying chemistry of the chosen topic, whereas the IA focuses on the application of the scientific method to a problem of interest and will only include some background information.
- The EE explicitly assesses the students' ability to analyse and evaluate scientific arguments.

**Supervisors play an important role in guiding students on these distinctions. Students risk their diploma if academic misconduct is detected.**

## Interpreting the EE assessment criteria

### Criterion A: Focus and method

(Strands: Topic, Research question, Methodology)

The EE in chemistry must have a clear chemical emphasis and should focus on the chemistry aspect of the investigation.

It should incorporate chemical principles and relate to the study of matter and its chemical changes.

The topic can come from:

- the core
- the AHL topics or
- one of the IB Chemistry options of the syllabus.

However, the emphasis should be on chemistry.

The research question must be formulated as an actual question, such as "Can the spectator ions influence the rate of oxidation-reduction reaction?"

To address the research question the student must research the existing literature on the topic and choose an appropriate methodology to pursue the investigation by:

- undertaking work in the laboratory or
- basing their research on existing data.

If practical work is undertaken, the rationale for choosing the procedure should be clearly explained.

If the investigation is undertaken in an external laboratory, students have to show clearly their understanding of the methods and materials, and their role in collecting the data.

### Criterion B: Knowledge and understanding

(Strands: Context, Subject-specific terminology and concepts)

Students are expected to show understanding of the relevant chemical principles and ideas and to apply them correctly.

Students must demonstrate clearly the underlying chemistry behind the research question and the techniques and apparatus chosen.

The source materials accessed should be:

- clearly relevant and appropriate to the research question
- effectively referenced and incorporated into the main body of the essay in a way that demonstrates the students' understanding.

Literature cited should predominantly come from acknowledged scientific sources.

The student must try to maintain a consistent linguistic style throughout the essay.

Chemical nomenclature and terminology should be used consistently and effectively throughout the essay. Students should also use appropriately and consistently:

- relevant chemical and structural formulas
- balanced equations with state symbols
- mechanisms of reactions
- significant digits
- SI units.

## Criterion C: Critical thinking

(Strands: Research, Analysis and Discussion and evaluation)

In a chemistry EE, the "research" refers to both literature sources and data collected by the students themselves. This research must be consistently relevant to the research question.

Students must demonstrate the ability to apply their selected sources and methods effectively in support of their argument.

The student is expected to appropriately present and analyse the data. This analysis will often include:

- mathematical transformations
- statistical analysis
- tables of processed data and graphs.

If the data are analysed statistically, the student must clearly show understanding of why that particular test was chosen and what the results mean.

If graphs are used, they must be correctly selected and drawn to illustrate key elements of the analysis. They should only be included if they improve communication.

Students must analyse and present their data in such a way that they support and clarify the argument leading to the conclusion.

Students must make a particular effort to maintain a reasoned, logical argument that focuses on the research question. Essays that attempt to deal with a large number of variables are unlikely to be focused and coherent. A clear and logical argument can be achieved by making repeated reference to the research question.

An assessment of the extent to which the question is answered, either by the data or by information accessed, should form part of the argument.

The stated conclusion(s) must be based on and be consistent with the research presented in the essay.

The original research question need 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.

Inadequate experimental design or any systematic errors should be exposed. The uncertainties of the measurements should be evaluated and discussed.

The student must comment on the quality, balance and quantity of their sources. Students are expected to show an awareness of any limitations or uncertainties inherent in their approach. In particular, they should critically comment on the validity and reliability of their data relative to their management of variables within the investigation.

## Criterion D: Presentation

(Strands: Structure, Layout)

This criterion relates to the extent to which the essay conforms to accepted academic standards in relation to how research papers should be presented. It also relates to how well these elements support the reading, understanding and evaluation of the essay.

Students may use numbered and headed paragraphs to impose a clear structure. Subheadings should not distract from the overall structure of the essay or argument presented.

### Use of charts, images and tables

Any charts, images or tables from literature sources included in the essay must be carefully selected and labelled. They should only be used if they are directly relevant to the research question, contribute towards the understanding of the argument and are of a good graphic quality.

Large tables of raw data collected by the student are best included in an appendix, where they should be carefully labelled. Tables of processed data should be designed to clearly display the information in the most appropriate form. Graphs or charts drawn from the analysed data should be selected to highlight only the most pertinent aspects related to the argument. Too many graphs, charts and tables will distract from the overall quality of the communication.

Only processed data that is central to the argument of the essay should be included in the body of the essay, as close as possible to its first reference. Tables should enhance a written explanation but not themselves include significant bodies of text. If they do, then these words must be included in the word count.

If an experimental method is long and complex, students may place the raw data in an appendix and include a summary of the methods in the body of the essay. Students who choose this option must be careful to ensure that the summary contains all elements that contribute to the quality of the investigation, since appendices are not an essential section of the EE and examiners are not required to read them.

In other words, any important information that contributes to the evaluation of the method must be in the body of the essay and not the appendix. 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 in the main body of the essay. The remainder can be displayed in tabular or graphical form.

Any material that is not original must be carefully acknowledged, with specific attention paid to the acknowledgment and referencing of quotes and ideas. This acknowledgment and referencing is applicable to audiovisual material, text, graphs and data published in print and electronic sources. If the referencing does not meet the minimum standard as indicated in the guide (name of author, date of publication, title of source and page numbers as applicable), and is not consistently applied, work will be considered as a case of possible academic misconduct.

A bibliography is essential and has to be presented in a standard format. Title page, table of contents, page numbers, etc must contribute to the quality of presentation.

The essay must not exceed 4,000 words of narrative. Students should be aware that examiners will not read beyond the 4,000-word limit, nor assess any material presented thereafter. Graphs, figures, calculations, diagrams, formulas and equations are not included in the word count.

## Criterion E: Engagement

(Strands: Reflections on planning and progress)

This criterion assesses the student's engagement with their research focus and the research process. It will be applied by the examiner at the end of the assessment of the essay, and is based solely on the candidate's reflections as detailed on the [RPPF](#), with the supervisory comments and extended essay itself as context.

Students are expected to provide reflections on the decision-making and planning process undertaken in completing the essay. Students must demonstrate how they arrived at a topic as well as the methods and approach used. This criterion assesses the extent to which a student has evidenced the rationale for decisions made throughout the planning process and the skills and understandings developed.

For example, students may reflect on:



- the approach and strategies they chose, and their relative success
- the *Approaches to learning* skills they have developed and their effect on the student as a learner
- how their conceptual understandings have developed or changed as a result of their research
- challenges they faced in their research and how they overcame these
- questions that emerged as a result of their research
- what they would do differently if they were to undertake the research again.

Effective reflection highlights the journey the student has engaged in through the EE process. Students must show evidence of critical and reflective thinking that goes beyond simply describing the procedures that have been followed.

The reflections must provide the examiner with an insight into **student** thinking, creativity and originality within the research process. The **student** voice must be clearly present and demonstrate the learning that has taken place.