THE SHORT GUIDE SERIES
FROM PEARSON LONGMAN

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A Short Guide to Writing about Chemistry

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kinds of learners—figure out what works for you) any unfamiliar terms or the names of unfamiliar techniques so that you can look them up before you reread the paper.

After you have read the entire paper once, write down what you remember about the paper, what you don’t understand about what you read, and any questions that come to mind as you write. This will help you focus your attention on some of the major points for a second reading.

During the second, more careful reading of the paper, pay special attention to the Experimental, Results, and Discussion sections.

As you read, pay special attention to the following:

- What was the goal of the work reported?
- Did the researchers achieve this goal?
- What evidence is presented to convince you that the goal was achieved?
- Do you believe the evidence and the author’s interpretation of that evidence? (Examine the tables and figures carefully.)
- Are numerical results accompanied by appropriate statistical evaluations of errors?
- Are there any results presented that are not discussed?
- What questions remain unanswered?

Try to develop your own interpretations of the data before rereading the researchers’ interpretations. We are readily influenced by the opinions of others, especially when those opinions are well written by “experts.” Keep an open mind when reading the researchers’ words, but try to form your own opinions about the data first: you may see something that the researchers did not. You may also notice features of the results that are NOT discussed by the researchers; this is useful material for the “critique” part of your assignment.

**WRITING THE FIRST DRAFT**

You will know that you are ready to write your first draft of the assignment when you can distill the essence of the paper into a single, intoxicating, summary sentence—or, at most, two summary sentences. These sentences should include all the key points, present an accurate summary of the study, be fully comprehensible to someone who has never read the paper, and be expressed in your own words. As a general rule, do not begin to write a review until you can write such an abbreviated

**summary.** This exercise will help you discriminate between the essential points of the paper and the extra, complementary details. An example of a good summary sentence is given later (see page 137).

If you cannot write a satisfactory one- or two-sentence summary, reread the article; you’ll get it eventually. After your summary sentence has been committed to paper, ask yourself these questions:

1. Why was the study undertaken? To answer this, draw especially from the information given in the Introduction (check that last paragraph) and Discussion sections of the paper.
2. What were the specific goals of the work undertaken? Summarize each goal in a single sentence.
3. What experiments were done? How did they relate to the goals on your list?
4. What assumptions about prior work were made by the researcher(s)? Might any of them be wrong? Are they testable? How might they be tested?
5. What were the major findings?
6. What is particularly interesting about the study? The questions asked? Some aspect of the methodology? Some particular result or set of results?
7. What aspects of the results are not dealt with satisfactorily in the article?
8. What questions remain unanswered? These may be questions addressed by the study but not answered conclusively, or they may be new questions arising from the findings of the study under consideration.

**WRITING THE SUMMARY**

When you can answer these questions without referring to the paper you have read, you are ready to write. Writing without looking at the original paper will help you avoid unintentional plagiarism (see pp. 28, 148, 156) and will test your understanding of the paper. You can (and should) always go back to the original paper later to double-check and fill in specific factual details.

Instructors often specify a maximum number of words or pages, and you should take that directive seriously. Economy of expression is highly valued in scientific writing, and the ability to write to a target length is a useful skill to develop. Chemists frequently encounter rigid word constraints in their writing: an abstract submitted for consideration in a
conference program is commonly limited to 250 words, the summary of a
grant application may be capped at one page, or the contents page entry in
a journal may be limited to one sentence of no more than 30 words. If your
instructor asks for text to be double-spaced, in 12-point font with 1-inch
margins all the way round, you will only be able to get about 300 words on
one page. Even in the absence of such specifications, it is a mistake to
think that creative tinkering with margins or use of alternative fonts will
fool the instructor into thinking that you have achieved the kind of econ-
omy of expression a word limit clearly demands. If you exceed the word
limit, keep revising for concision (see Chapter 5) until you achieve your
target length.

At the top of the page—below your name, the course designation,
and the date—give the complete citation (in ACS format, see Chapter 3)
for the paper being discussed, beginning at the left-hand margin: names
of authors, title of the paper, title of the journal in which the paper was
published, year of publication, and volume and page numbers of the arti-
cle. On a new line, indent five spaces and begin your summary with a few
sentences of background information. Your introductory sentences must
lead up to a statement of the specific goals the researchers set out to
achieve. Next, tell (1) what approaches were used and (2) what major
results were obtained.

Present the researchers’ results using the past tense Be sure to
state, as succinctly as possible, exactly what was learned from the study.
Use the present tense to describe the contents of the article. As you
will also use the present tense to make your own evaluative comments, you
need to make sure that readers know when you are summarizing the con-
tents of the article and when you are making your own comments. To do
this, credit the researchers when they are the source of the idea.

The results show that the electrochemical procedure has a lower
limit of detection than that of the spectrophotometric method used
currently by the brewing industry.

The sentence above creates ambiguity by failing to clarify the source
of this observation: is it your original observation or simply a sum-
mary of what the researchers themselves reported in the article? A few
carefully placed words serve to avoid such ambiguity, as in the follow-
ing example:

The researchers point out that their electrochemical procedure has
a lower limit of detection than that of the spectrophotometric method
used currently by the brewing industry.

To condense the contents of a journal article into one printed page is
no small feat, but it can be done if you fully understand what you have
read. Consider the following example. Before writing the summary, the
student condensed the paper into these two sentences:

By building on previous work showing the benefits of the dual-pulse
pretreatment of the platinum working electrode, Fung and Mo
determined the ethanol content of beer by using an optimized flow
injection voltammetric method that they validated by comparison
with a reference method. They improved the detection limit with a
staircase waveform, so that they only needed to pretreat their
samples by diluting them with sodium hydroxide solution, thereby
avoiding the usual requirement of removing the dissolved oxygen.

Note that the two-sentence distillation contains considerable detail
despite its brevity, implying impressive mastery of the paper’s contents; it
is complete, accurate, and self-sufficient. When you can write such sen-
tences, pat yourself on the back and proceed; the hardest work is over.

A Sample Student Summary

B. John Barleycorn

Chem 391A

October 6th, 2007

Fung, Y; Mo, S. Determination of Ethanol in Beer by Flow Injection Dual-

As the production of alcoholic beverages is subject to taxation,
rapid, automated methods for measuring ethanol content are needed.
Fung and Mo have developed a flow injection (FI) voltammetric method
for determining ethanol content in beer based on measuring the oxida-
tion current at a platinum electrode in a thin-layer flow-through cell. The
goal was to develop an interference-free method, with a large linear
range, for which it was not necessary to remove dissolved oxygen. A
major problem of previous studies, namely the rapid loss of electrode
activity, was overcome by a dual-pulse pretreatment, which LaCourse
and coworkers had shown to allow detection of alcohols and sugars
were overcome. The next paragraph summarizes the experiments conducted to develop the method, including the various parameters that were optimized and how possible interferences were investigated. The paragraph concludes with a sentence that summarizes the sample pretreatment. The final paragraph explains how the procedure was validated, that is, how it was shown to give the right answers when applied to analyses of real samples. The summary contains 360 words.

Note that the writer used the past tense in describing the work done by the researchers in their laboratory, but uses the present tense to describe the big picture: “as the production of alcoholic beverages is subject to taxation, rapid, automated methods for the measurement of the ethanol content are needed.” The writer also uses the present tense to refer to a feature of the paper, namely a conclusion drawn by the researchers (“The researchers conclude, therefore, that the method should be interference free when applied to beer samples”). Note also that there are no evaluative comments. The summary writer’s job is to produce a concise, accurate account of the important features of the research.

**WRITING THE CRITIQUE**

A critique is much like a summary, except that you add your own assessment of the paper you have read. The opportunity to assess does not mean you should tear the paper to shreds. A critical review is a thoughtful summary and analysis, not an exercise in character assassination. Most chemical studies have shortcomings, which often become obvious only in hindsight. Yet every piece of research contributes some information, even when the original goals of the study are not attained. Emphasize the positive: focus on what was learned from the study. Although you should not dwell on the study’s limitations, you should point out those limitations toward the end of your critique.

When the manuscript of a paper is submitted to a journal, the reviewers are often asked to respond to a series of questions that might be summarized as

1. Is it new?
2. Is it true?

Unless you have encyclopedic knowledge of the research already published, it will be hard for you to answer the first question; you would need to search the literature independently. This is more than your
thinking and writing about your topic—following the methods advocated in Chapter 2—we can almost guarantee that it will happen for you. If you wait to begin reading and thinking until a week or so before the report is due, we can almost guarantee that it will not, and you will have missed the opportunity to learn how to do something really useful.

WRITING THE PAPER

Getting Underway: Taking and Organizing Your Notes

Some instructors will help by monitoring your progress, such as asking to see your notes, lists of papers read, summaries of those papers (see Chapter 6), and partial drafts. This is splendid for you because it puts you on a schedule. Otherwise, you must schedule yourself. **Start on the project as soon as possible** and allocate at least a few hours a week to it, every week, until it is done.

As soon as you have at least a draft of a thesis statement, begin the formal process by reading all of your notes. After reading your notes to get an overview of what you have accomplished, sort your ideas into categories. Many of us who did not grow up with personal computers may have made notes on index cards; these are very easy to sort, provided that only one idea is written on each card. If you made your notes on full-sized sheets of paper, you may need to annotate with pens of different colors, with each color representing a particular aspect of a topic. Alternatively, you might snip out sections of the notes with scissors and then group the resulting pieces of paper into piles of related ideas. This is how one of the authors of this book used to work. Another of the authors, who contributes to a major review article every year, organizes the material by printing the titles, authors, and abstracts of the relevant articles onto individual sheets of paper, which he then annotates in handwriting with the help of highlighter pens of two or three different colors. He then organizes the individual sheets into piles that correspond to the major subsections of the article. He says he finds it easier to deal with the several hundred possible articles this way rather than to work entirely electronically. For some jobs, a large table or even the floor are more effective work surfaces than the computer's virtual desktop.

Most of these activities can, of course, be done entirely electronically. If you have made notes directly on your computer, you can highlight and cut, copy, and paste to group together notes on related issues. You should experiment to find a system that works well for you. Be sure to back up electronic material regularly to some storage location that is independent of your personal computer. Most colleges and universities allocate to each student several megabytes of storage space on a server that can be accessed via the Web. Inexpensive and highly portable flash drives are also useful for this purpose. Be sure to use a sensible system for naming files that readily indicates which is the latest version of a document. It can be difficult to retrieve your latest version if you inadvertently overwrite that file with an earlier version. We usually include the revision date in our file names.

At this point, you must eliminate any notes that are irrelevant to your specific topic. No matter how interesting a fact or idea is, it has no place in your paper unless it clearly relates to your thesis statement and therefore helps you develop your argument. Some of the notes you took early on in your exploration of the literature are especially likely to be irrelevant to your essay, because these notes were taken before you had developed a firm focus. Put these irrelevant notes in a safe place for later use; **don't let them sneak into your paper.**

You must next decide how best to arrange your categorized notes so that your essay or term paper progresses toward some conclusion. Again, ask yourself whether a particular section of your notes seems especially interesting to you and, if so, why. Look for connections among the various items as you sort.

The Crucial First Paragraph

The direction your paper will take must be clearly and specifically indicated in the opening paragraph, as in the following examples written by student A:

Many researchers consider that not only has arsenic no biological function in humans, but also that there is no exposure that can be considered safe. 1-3 Our efforts to control our environment and improve the quality of life through the application of appropriate science and technology have resulted in the accumulation, in both rural and urban areas, of considerable amounts of various arsenic compounds that have been widely distributed as pesticides, herbicides, and timber preservatives. 4 However, arsenic, mostly as simple inorganic oxoanions and the various mono through tetra methyl derivatives, is widely distributed in the environment due to natural processes of mineral weathering, water movement, volcanic activity, and microbiological activity. 5 Concentrations of a few mg
kg\(^{-1}\) in soil and a few \(\mu g\) L\(^{-1}\) in waters are common.\(^5\) I will argue that, as we have evolved in an environment that has always been contaminated with arsenic, humans, in common with microorganisms, plants, and other animals, have developed a tolerance to the daily intake of a few \(\mu g\) of various forms of arsenic in our diet. I will examine the human metabolism of arsenic and compare it with the metabolism of that substance by other organisms, especially those that have developed tolerances to very high concentrations in their immediate environment.

The nature of the problem being addressed is clearly indicated in this first paragraph, and student A tells us clearly why the problem is of interest: (1) arsenic is toxic and is widely distributed due to human activity, (2) but arsenic has for a long time also been widely distributed in the environment through natural processes, and (3) many living organisms have a high tolerance toward arsenic, (4) so humans might also tolerate low concentrations of arsenic. Note that the use of the pronoun I is now perfectly acceptable in scientific writing, but be aware that not all instructors will find it acceptable.

In contrast to the previous example, consider the following weaker (although not horrible) first paragraph written by student B on the same subject:

Arsenic, element 33 in group 5A of the periodic table, is poisonous and it is generally accepted that high concentrations of arsenic compounds are toxic to all life forms.\(^1,2\) This is the reason that arsenic compounds are widely used as pesticides, herbicides, timber preservatives, and even embalming fluids.\(^3-6\) However, some species of fern have the ability to tolerate and accumulate high concentrations of arsenic as compounds with sulfur-rich peptides,\(^7\) and some microorganisms can convert arsenic to the volatile trimethylarsine gas.\(^5\) Humans, in common with many other living organisms can methylate arsenic compounds, thereby decreasing their toxicity.\(^9\) The tetramethyl arsonium compounds found in many marine organisms, including several that we eat, are completely harmless.\(^10\) The beneficial effects of the ingestion of small daily doses of arsenic were known to the inhabitants of the Austrian Tyrol\(^11\) well over a hundred years ago, and as arsenic has been in our environment since life first evolved, living organisms are tolerant to low concentrations of this element as they are to many other elements. Examples of such tolerance will be presented.

In this example, the opening sentence contains a certain amount of throat clearing and redundancy and could be edited to the following:

It is generally accepted that high concentrations of arsenic compounds are toxic to all life forms.

Student B weakens the paragraph by prematurely referring to the ferns and microorganisms that can handle high concentrations of arsenic in sentence three. Since student B has not yet articulated a thesis, the reader is likely to be puzzled by the introduction of a situation that seems to contradict the opening two sentences. The reader is further puzzled by the reference to compounds that are, apparently, harmless and present in the seafood we commonly consume, when the paragraph started with an assertion that all arsenic compounds are toxic. While the reader is still trying to absorb the startling news about seafood containing arsenic, which is "toxic" yet "harmless," student B cites the "beneficial effects" of arsenic enjoyed by a community of people living in the Austrian Tyrol a century ago who apparently ingested arsenic intentionally. When the reader arrives at the end of the opening paragraph, where we expect to see the thesis articulated, student B offers a fuzzy observation that falls short of making sense of the preceding string of seemingly contradictory statements. This is not the sort of writing likely to elicit a comprehending nod from the reader; the more likely response is a puzzled grimace.

The first paragraph of a paper must be an introduction, not a summary. It must set the stage for all that follows. Although the last sentence of student B's paragraph does clearly state what is coming, the reader must ask, "To what end?" The writer has set the reader up for a book report, not a critical evaluation or a persuasive argument.

Reread the paragraph written by student A and notice how the same information has been used so much more effectively, introducing a thoughtful essay rather than a tedious recitation of facts. Student A's paragraph was written with a clear sense of purpose, with each sentence carrying the reader forward to the final sentence of intent, the argument on which the rest of the paper will be based. You might guess (correctly as it turns out) from reading student B's first paragraph that the rest of the paper was somewhat unfocused and rambling. In contrast, student A's first paragraph clearly signals that what follows will be well focused and tightly organized. It might take three or four revisions, but get your papers off to an equally strong start.
Another example of a typical, but not especially effective, first paragraph might be helpful:

Proteins are complex organic molecules that have biological function because of their three-dimensional shape as well as their functional group composition. Many enzymes are proteins with shapes that are specific for the substrates in the reactions that they catalyze. The study of protein folding is currently one of the most important areas of research at the chemistry-biology interface, and recent developments will be discussed in this term paper.

What is wrong with this introductory paragraph? The author is certainly off to a strong start with the first sentence. The second sentence, however, begins by repeating information already given in the first sentence and ends by saying nothing of substance (enzymes are proteins that are catalysts). The last sentence sets up a book report even though the author calls it a term paper.

Why will protein folding be discussed? More to the point, why should the reader be interested? The reader will more readily be drawn into your net if you indicate not only where you are heading, but also why you are undertaking the journey.

The first paragraph of your paper must state clearly what you are setting out to accomplish and why. Every paragraph that follows the first paragraph should advance your argument clearly and logically toward the stated goal.

**Supporting Your Argument**

State your case, and build it carefully. Use your information and ideas to build an argument, to develop a point, to synthesize. **Avoid simply summarizing the papers one by one:*** the researchers did this, then they did that, and then they suggested the following explanation. Instead, set out to compare (point out what is similar), to contrast (point out significant differences), to illustrate, and to discuss.

As described more fully in Chapter 3, you must back up all statements of facts or opinion with supporting documentation; this documentation may be an example drawn from the literature you have read or a reference to a paper or group of papers that support your statement, as in the following example:

> According to Harauchi,¹ metalomics is a new scientific area that integrates the various research fields related to metals in biological systems. Several researchers have determined²⁻⁵ that certain metals play key roles in such systems. There are several enzymes whose active sites contain a metal ion; for example urease, which catalyzes the conversion of urea to ammonia, contains nickel.⁶

Similarly the opening sentences in the student examples on pages 151 and 152 are supported by references. In contrast, the statement by student C on page 154 has no such support, weakening considerably the authority of the writer.

In referring to experiments, **don't simply state that a particular experiment supports some particular hypothesis, or that a researcher reached a particular conclusion. Describe the relevant parts of the experiment, and explain how the results relate to the hypothesis in question.** For example, how potent are the following sentences?

> Many researchers¹⁻⁴ appear to have accepted the suggestion by Humphrey and Davey⁵ that, in aqueous acid solutions, the tetrahydroborate anion, BH₄⁻, hydrolyzes to release nascent (or atomic) hydrogen. This highly reactive species then reacts with other solutes, such as selenite, to form volatile hydrides.⁶

There is nothing in these sentences to convince readers of anything, not even that their author has read more than the title and abstract of the papers cited. In contrast, look at how much more convincing the following paragraph is:

> D'Ulivo and coworkers¹⁻³ studied the mechanism of the formation of volatile hydrides, such as those of antimony, arsenic, bismuth, germanium, and selenium, by the reaction of tetrahydroborate with the relevant ion in aqueous acid solution. They determined the identity of the reaction products by gas chromatography with mass spectrometry detection in a systematic study in which water, tetrahydroborate, and the acid were replaced by the deuterated counterpart. They showed that the absence of hydrides containing mixtures of hydrogen and deuterium was consistent with a reaction mechanism in which hydrogen was transferred directly from the borohydride; however, if nascent hydrogen was formed, both hydrogen and deuterium would be incorporated into the final product.

**In all your writing, avoid quotations unless they are absolutely necessary; in writing about chemistry they almost never are appropriate.** Rely on your own words and your own understanding of what you have read.
The Closing Paragraph

At the end of your essay, summarize the problem addressed and the major points you have made, as in the following example:

There seems little doubt that chemical vapor generation, particularly hydride generation, as a means of sample introduction in atomic spectrometry is a successful procedure with several advantages over conventional nebulization, including improved detection limits and elimination of spectral interferences. Recent developments in characterizing the mechanisms of the relevant tetrahydroborate reactions have brought closure to a long-running debate over the role of nascent hydrogen in such reactions. However, it seems likely that hydrogen atoms or radicals are involved in both the electrochemical generation of hydrides and the generation at the surface of the zinc powder used in the well-known Gutzeit reaction that forms the basis of a widely adopted field test kit for the estimation of arsenic in groundwater. In the case of the generation of volatile derivatives by the UV irradiation of solutions containing low-molecular-weight carboxylic acids, further work is needed to resolve the differences between the free-radical mechanisms proposed by Guo et al., and those involving the formation of carbon monoxide or ketene proposed, on the basis of computational modeling, by Takatani et al.

Never introduce any new information in your summary paragraph. Bear in mind that this will probably be the last part of your paper that your instructor will read before assigning a grade, so make your closing statements as strong as possible.

PLAGIARISM

There is zero tolerance in academic communities for academic dishonesty. It is very important, therefore, that in creating an original essay or review that you will present as your own work, you neither present someone else’s ideas as though they were your own, nor fail to acknowledge the sources from which you obtained the information.

As an example, consider this sentence from the review by Francesconi and Pannier mentioned in Chapter 2 (see page 26):

Furthermore, although there are no demonstrated health benefits from having selenium intake above physiologic requirements, there is a general perception that increased selenium ingestion is beneficial, which has led to a flourishing market in selenium supplements.

Now consider this sentence based on the paragraph:

In addition, although health benefits from having selenium intake above physiologic requirements have not been demonstrated, there is a general perception that increased selenium ingestion is beneficial, and this has led to a flourishing market in selenium supplements.

The degree of similarity between this paragraph and the original paragraph renders this a clear example of plagiarism. We have placed in bold the words that are taken verbatim from the original to show that all the writer has done is replace one or two words with synonyms and changed the word order a little, without crediting the source. It is easy to commit this sort of plagiarism accidentally if you copy the exact words from a source into your notes without indicating that these are the author’s exact words, or if you simply copy and paste the original text into your notes electronically without recording the source.

Here is an acceptable way to incorporate this material into your own writing:

Francesconi and Pannier [1] point out that although no one has demonstrated any benefits to taking selenium above the minimum needed to stay healthy, selenium supplements are widely available as people think that taking additional selenium is good for them.

Always present the results of previously published work in a way that makes it clear who is responsible for the ideas.

Consider the following two paragraphs:

Kearns [1] found that in the flow injection determination of arsenate by the molybdenum blue method, phosphate interfered to an extent that depended on the residence time. Ben-DAat [2], however, indicated that the interference was related to the solution pH downstream of the confluence point and that residence time had no effect if the pH was below 2.5.

In the flow injection determination of arsenate by the molybdenum blue method, the phosphate interference might depend on residence time. However, Ben-DAat [1] showed that this was not the case. It is likely that the interference is dependent instead on the pH of the solution after the reagents have merged.

The first example is fine; every idea is clearly associated with a source. In the second example, however, the writer has not taken care to attribute the ideas to their sources and takes credit for the ideas of Kearns (who is not even mentioned) and Ben-DAat. In doing so, the writer has plagiarized.