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## Preface

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Writing clearly, correctly, and concisely is essential to success in chemistry, and in this electronic age chemists are writing more than ever before. Recently, after surveying many companies, including major employers of trained chemists, the National Commission on Writing suggested that employers perceive college graduates as ill-prepared to do the kind of writing necessary in the modern workplace, where writing clearly and cogently is not only a threshold skill but also vital to career advancement. The simple truth that writing well matters is hard to sell to students inclined to believe that experience with chemical instrumentation and techniques or the possession of excellent laboratory skills will compensate for an inability to communicate well. We know that addressing student writing while covering the essential chemistry content in the course of a semester challenges even the most gifted and energetic instructor; nevertheless, our students really must learn to communicate well. Our goal in creating this book is to provide a resource to help students learn how to communicate effectively in writing, as well as in other forms of communication that are extremely important in chemistry, such as oral and poster presentations.

The material in this book comes primarily from two sources: the highly successful *Short Guide to Writing about Biology*, now in its seventh edition, a vital component of the Pearson Short Guide Series, written by Jan, and the material that Holly and Julian developed over the course of many years for the junior-year "Writing in Chemistry" course at the University of Massachusetts Amherst. We have also drawn from *The ACS Style Guide: Effective Communication of Scientific Information* 3rd Edition edited by Anne Coghill and Lorrin Garson (Oxford University Press, New York, 2006).

Certain fundamental convictions about writing and the teaching of writing inform all aspects of this book. For one thing, we believe that revision is essential to writing well, for novices and experts alike. Writing is both a process and a product, and writing well is a skill acquired and honed through practice; the more constructive and timely the feedback the students get, the more rapidly their skills will improve. We regard writing as a tool for learning: students benefit from being required to write about chemistry not only because it improves their skills as communicators, but

also because it enhances their understanding of content. Writing is a means of discovering what one actually knows and, at times, what one does not know. Clear writing and clear thinking are inseparable, and bad writing often reveals fuzzy thinking. Students who embrace writing about chemistry with seriousness and purpose benefit immeasurably, and instructors who incorporate writing into their teaching of chemistry perform an invaluable service to their students.

Just as Jan's book is grounded in the premise that "Biology is a way of thinking about the world," this book is informed by the belief that chemistry represents a distinct way of understanding the world. Being a chemist is not just about memorizing facts and terminology or about learning to use laboratory apparatus, instruments, and computer software. It is about understanding how the world works by making careful observations, asking specific questions, designing ways to address those questions, manipulating data thoughtfully and thoroughly, and interpreting those data and related observations in terms of the behavior of matter at the atomic and molecular levels. In common with all professionals in academic communities, chemists reevaluate past work, ask new questions, and redefine older questions. Of course, chemistry also requires writing. The hard work of thinking and writing about chemistry is at least as important as the work of doing it. Writing provides a way to examine, to evaluate, and to refine the ideas and insights that come from thinking about chemistry and, ultimately, to share them.

Aware that "we only get one chance to make a first impression" and that often this impression is made through our writing, we remind readers that making a good first impression means paying attention to detail. For chemists, many, many details of style and format are important. We have tried not to swamp readers with the minutiae of chemistry conventions, but rather to deal with only the more commonly encountered situations. We strongly recommend that readers who are on track to be professional chemists obtain a copy of *The ACS Style Guide*.

## ORGANIZATION

In addition to convincing our readers that writing plays an extremely important role in doing chemistry, we expect that students will find this textbook worth consulting repeatedly for reference and guidance throughout their academic careers. To meet the needs of chemistry students when they are initially introduced to the discipline, we provide guidance on lab notebooks, lab reports, and disciplinary conventions

about format and citations. We also anticipate the needs of student writers as they advance in their study by providing material on specific tasks such as writing summaries, critiques, and research proposals, as well as communicating through oral and poster presentations. Finally we provide advice about writing applications and personal statements most likely to be useful to students as they transition from undergraduate life to the workplace or graduate study.

The book is divided into two parts. Part I covers general issues that apply to all types of writing (and reading) in chemistry; Part II provides guidelines for specific tasks. In Chapter 1, we emphasize the benefits of learning to write well in chemistry, describe the sorts of writing that professional chemists do, and review some key principles that characterize all sound scientific writing. Chapter 2 emphasizes the struggle for understanding that must precede any concern with how something is articulated. In it, we discuss how to read the formal scientific literature, how to take useful notes, and how to take them in ways that prevent unintentional plagiarism. Chapter 3 explains how to cite references and prepare a References section. Chapter 4 focuses on the process of revision—for content, clarity, and completeness. Chapter 5 focuses on editing for concision and issues of correctness, including observing the conventions of American Chemical Society (ACS) style. Chapters 4 and 5 also address certain usage issues that loom large when writing about chemistry such as passive and active voice, modifier placement, and concision. We have also included a brief tutorial on using punctuation in Appendix A, which we think will aid anyone unable to use punctuation with confidence.

The rest of the book covers most of the specific writing tasks encountered in chemistry coursework and in professional life: keeping laboratory notebooks (Chapter 6), writing laboratory and other research reports (Chapter 7), writing summaries and critiques (Chapter 8), writing essays and review papers (Chapter 9), writing research reports (Chapter 10), writing research proposals (Chapter 11), answering timed essay questions (Chapter 12), preparing oral and poster presentations (Chapter 13), and writing letters of application for jobs and graduate school (Chapter 14). We recognize that there are significant differences between the conventions of the different branches of chemistry and that, for example, advice about writing a lab report for an organic chemistry class may not be completely applicable to a report for a physical chemistry lab. However, we have tried to keep the material at a more generic level, with the suggestion (made many times) that students should, when there are likely to be such differences, consult their instructors for further details.

Checklists at the ends of the chapters allow students to evaluate their own work and that of their peers. Some of these checklists include page numbers to help students locate the text on which each item is based. Instructors can easily turn these checklists into grading rubrics, which should be shared with students well before the assignments are due. In addition, we have provided a more general "Rubric for Science Writing" in Appendix B, which lays out in descriptive terms the attributes of science writing along a continuum from excellence to serious deficiency, and we encourage instructors to modify it to suit particular assignments. We find that students benefit immensely from knowing what exemplary completion of an assignment looks like, and we recommend sharing positive examples as well.

We recognize that there are ethical issues related to scientific writing. Plagiarism and other acts of academic dishonesty related to the production of written material need to be addressed and have been at the appropriate places. Readers are invited to take the two quizzes on the more common aspects of academic dishonesty at the end of Chapter 9, for which we provide answers and commentary at the end of the book.

We do not anticipate that students will read the chapters in the sequence in which we have presented them or that all readers will find all chapters equally compelling and useful. Thus, we repeat certain key ideas as they become relevant to various aspects of writing about chemistry to make individual chapters capable of standing alone and being useful even if a student has not read or recently reread the other chapters. We sincerely hope that not only will students find the text useful as they progress through their undergraduate careers, but instructors will also regard it as a valuable resource on which to rely as they educate the next generation of chemists to be not only conscientious, disciplined, and innovative scientists, but excellent communicators as well.

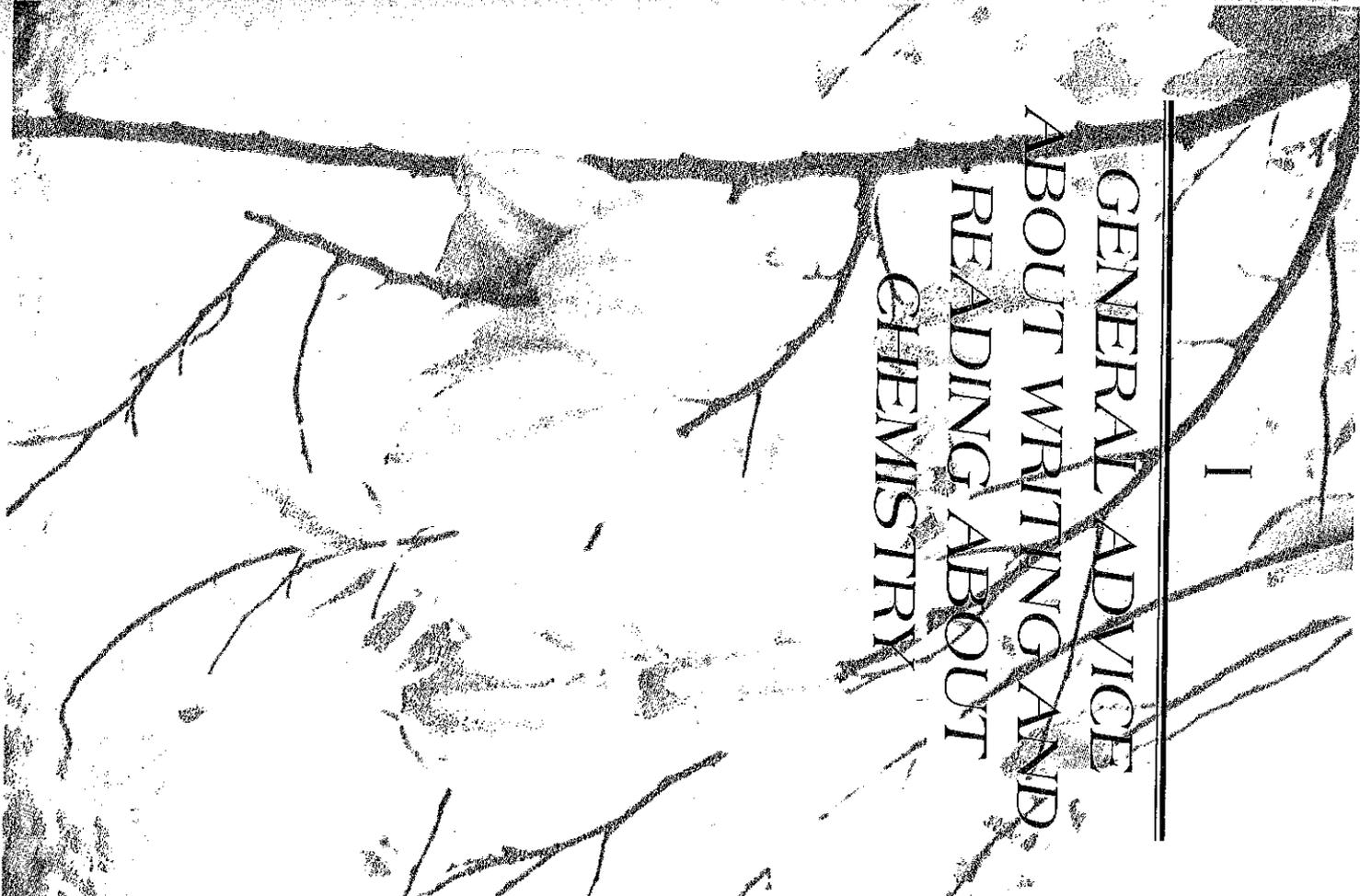
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HOLLY DAVIS  
JULIAN TYSON  
JAN PECHENIK



I

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GENERAL ADVICE  
ABOUT WRITING AND  
READING ABOUT  
CHEMISTRY

# 1

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## WRITING: A THRESHOLD SKILL

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*In science credit goes to the [scientist] who convinces the world, not to the [scientist] to whom the idea first occurs.*

SIR WILLIAM OSLER

### WHAT DO CHEMISTS WRITE ABOUT AND WHY?

An ability to write well is one of the most valuable but difficult skills that can be mastered in college, and the chemistry classroom is an excellent place to practice this skill. Writing is not an elusive, magical skill granted only to some. Ample evidence shows that everyone has the capacity to write and that people learn to write by writing, that is, writing is a skill best acquired through practice.

The ability to write clearly, correctly, and concisely is essential to success in virtually every professional field, including chemistry. In this electronic age, more employees—including chemists—have to write more than ever before. Neither experience with chemical instrumentation and techniques nor the possession of excellent laboratory skills will compensate for an inability to communicate well. In fact, a recent report from the National Commission on Writing, based on a survey of companies that included major employers of trained chemists, such as DuPont, Procter and Gamble, Bristol-Meyers Squibb, Eli-Lilly, Dow, and Pfizer, suggests that employers are unhappy with the preparation of college graduates to do the kind of writing necessary in the modern workplace. Such companies view an ability to write clearly and cogently as a “threshold skill”—that is, one that is necessary even to enter into the workplace.

The sort of writing that professional chemists do (grant proposals, research reports, literature reviews, oral and poster presentations for meetings, letters of recommendation for hiring and promotion) is similar in many respects to the sort of writing you are asked to do in typical college chemistry courses (essays, literature reviews, term papers, and laboratory and research reports). Just like your writing in college, every piece of professional writing must be written clearly, developed logically, and proofread carefully. All statements of opinion must be supported with facts or examples, and all uses of other people's work must be appropriately referenced.

Basically, most of what chemists write is an argument: an attempt to persuade or convince an audience of something. The success of a research proposal, for example, depends on your ability to convince a panel of other chemists that what you want to do is worth doing, that you are capable of doing it, that you are capable of interpreting the results, that the work cannot be done without the funds requested, and that the amount of funding requested is appropriate for the research planned. Research money is not plentiful. Even well-written proposals have a difficult time; poorly written proposals don't stand a chance.

Chemists also spend time preparing the results of their research for publication or for presentation at meetings in order to communicate with other chemists who are doing similar or related research. Academic journals and professional conferences are the means by which scholars in all fields communicate with one another to share their ideas and, in the case of chemistry, their most recent findings, and to consider the implications. Research articles are really just laboratory reports based on data collected over a period much longer than the typical laboratory session; the goals of a research article, as for a laboratory report, are to present data clearly and to interpret the results thoroughly in the context of previous work and basic chemical principles—to convince your audience, in other words, through the clarity of your writing that your results are new, true, and important.

While in all these cases—lab reports, grant proposals, journal articles, literature reviews—chemists are writing for an audience of other chemists, scientists are also frequently called upon to write for readers who are not part of their own professional community, to explain technical information to the general public, and to address scientific issues for broad audiences. Writing such explanations is a much more difficult task than it may at first seem. The additional challenge is to explain what is often highly complex or technical information in such a way that a reader who does not have your scientific expertise can grasp the seriousness of a situation or problem and its broader implications well enough to form a thoughtful opinion about it.

Clearly, being able to write effectively will help advance your career, yet when students in a chemistry course get critical feedback on their writing, they sometimes complain that “this is not an English course.” However, clear, concise, logical writing is an important tool of the chemist’s trade, and learning how to write well is at least as important as learning how to use a spectrophotometer or a pH meter. And unlike the specialized laboratory techniques that you might learn as a student, mastering the art of effective writing will reward you regardless of the field in which you eventually find yourself. If your chemistry instructor is willing to help you by providing feedback on your writing and allowing you to revise it before the grade is assigned, take full advantage of this wonderful opportunity to develop your writing skills.

## THE KEYS TO SUCCESS

**All good writing involves two struggles: the struggle to gain understanding and the struggle to communicate that understanding to readers.** Anyone who has done much writing is acutely aware that it is difficult and that there is no easy way to learn to write well in chemistry or in any other field. Reading a lot of good writing (see Chapter 2), and not just in chemistry, will help, as will keeping in mind that someone is going to be reading what you write. Whether your audience is your college instructor, your classmates, fellow professional chemists, or your supervisor at work, you need to create a document that your readers will understand and accept.

When you write, there is an implied contract between you and your reader. Your reader’s obligation is to be alert and make a good-faith effort to pay attention to the argument you are making. Your obligation as a writer is to create a clear, concise, forward-moving, and accurate text. **Unless you make your readers work, the more they will appreciate your writing.** If your reader has to stop, back up, or reread to make sense of what you’re saying, you are in danger of losing that reader. Vague phrasing, inaccurate word choice, poor organization, even a lack of attention to the conventions of Standard Written English, such as punctuation and spelling, may all breach the contract between you and your reader.

There are no shortcuts to good writing, but there are some basic strategies that will help considerably. We offer here a list of practices that will help you write clearly and effectively about chemistry. Each is discussed more fully in later chapters (note the relevant page numbers). This list is worth reviewing at the start of each semester or whenever you begin a new assignment.

A useful general principle to keep in mind whenever you write is that **good writing is writing that achieves its own particular objectives.**

## TEN STRATEGIES FOR PREPARING YOUR FIRST DRAFT

**Strategy 1. Work to understand your sources (pp. 18–32).** Before you begin to write—or even plan what you will write—you need to understand the data you are writing about. Examine laboratory data until you are confident that you see its significance; read books or research articles carefully; reread sentences you don’t understand, and look up unfamiliar words. Confirm your understanding by making notes in your own words, rather than cutting and pasting or copying from sources; if you can’t put what you have read into your own words, you probably don’t completely understand it. All good scientific writing begins here: with understanding your sources.

**Strategy 2. Think about why you are writing before you begin and as you write (pp. 144–156).** As we said above and will remind you frequently in this book, **good writing is writing that achieves a particular objective.** For example, the words, the voice, and the tone you would choose were you setting out to write a really passionate love letter are not the same words, voice, and tone that you would choose in writing the experimental section of a chemistry lab report because, as we hope you recognize, the two have very different goals. Having a clear sense of your objectives when you write allows you to make better choices about *what* to include (opinions or facts? how much detail?) and *how* to say it (use I and active voice or impersonal passive voice?) The *why* is key to *what* and *how* you write; therefore, it is important to have a clear sense of what your objectives are when you set out to write, even if you do not yet have a clear sense of how you will achieve them.

**Strategy 3. Write in anticipation of discovery (pp. 143–144).** Your ideas about what you want to say and how best to say it may well change as you write and revise, since the act of writing invariably clarifies your thinking and often brings entirely new ideas into focus. Instructors know that asking students to respond in writing to a well-constructed assignment is a very effective way of developing students’ awareness of what they know and don’t know and of developing critical thinking skills,

as well as developing their writing skills. This is called “writing to learn,” and it is intimately linked with “learning to write.”

**Strategy 4. Write to illuminate, not to impress (pp. 58, 127, 146).** Once you do begin to write, use the simplest words and the clearest phrasing available. Make sure your writing is consistent with the needs of your readership. Even if your intended reader is your instructor, try keeping your classmates in mind as you write: what words and concepts will they understand? What needs to be explained? Avoid overusing acronyms and abbreviations, and remember to define specialized terminology. Your goal is to communicate: focus on making your argument or getting your point across, not on trying to impress your readers with big words or highly technical vocabulary or jargon.

**Strategy 5. Use sources responsibly (pp. 156–158).** Passing off someone else’s ideas as your own, or presenting someone else’s words as though they were your original creation, is plagiarism. **Plagiarism is an academic crime.** The result will almost always be a failing grade on your paper and perhaps a failing grade in the course. Plagiarism can get you expelled from college and may cost you a career later. Whenever you restate another writer’s ideas or concepts, you must do so in your own words, and you must credit your source explicitly. Simply changing a few words here and there or changing the order of words in a sentence or paragraph without acknowledging your source is still plagiarism. Incorporating source material into your own writing is always acceptable, but such material must always be incorporated appropriately and acknowledged specifically.

**Strategy 6. Use your own words; do not quote from sources (pp. 27–32).** Direct quotations rarely appear in the formal chemical literature. This practice distinguishes writing in the sciences from writing in disciplines like English or history, where invoking the actual words of an original text serves a useful purpose. In writing about chemistry, your goal is to describe what others have done and the ideas they have presented, but in your own words.

**Strategy 7. Show rather than tell. Support all statements of fact or opinion with evidence (pp. 54, 234, 154).** In any argument, a statement of fact or opinion becomes convincing to the critical reader only when that statement is supported by evidence, research, or explanation; provide it. Cite relevant authoritative sources according to the conventions of chemistry.

**Strategy 8. Always distinguish fact from possibility (pp. 55–56).** In the course of examining your data or reading your notes, you may form an opinion. This is splendid, and it represents the way science advances: by offering opinions based on data, to which other scientists may respond by adding supporting—or contradictory—evidence. But you must be careful not to state your opinion as though it were fact, based on your data alone. For example, “The concentration of trinehy/selenium ion was always less than those of the selenosugars” is a statement of fact and must be supported with references. “Our data suggest that when selenized yeast supplements have been taken, the species of greatest concentration in the urine are selenosugars” expresses your opinion and should be supported by drawing the reader’s attention to relevant results.

**Strategy 9. Write to show that you can “think like a chemist” (pp. 196–197).** Much of the writing you are called on to produce for your instructors in college is a request to show that you can interpret the properties of materials, and their behavior under certain circumstances, in terms of the behavior of the atoms and molecules of the materials and of the nature of the electronic structure of atoms and molecules. Be sure that you take full advantage of the opportunity to do so, especially in “high-stakes” writing, such as answers to exam questions or reports of laboratory work, whether it is a short-term activity (an instructional lab class) or long-term project (a senior thesis).

**Strategy 10. Allow time for revision (pp. 51–69).** Once your first draft is done, you are only partway to the finish line. Accurate, concise, persuasive communication is not easily achieved. Although the act of writing can itself help clarify your thinking, you need to allow time to step away from the first draft and reread it with fresh eyes before making revisions. A “revision” is, after all, a re-vision: another look at what you have written. This second (or third or fourth) look allows you to see whether you have really said what you intended to say and whether you have guided the reader from point to point as masterfully as you had hoped. Remember you are constructing an argument: making an argument fully convincing requires thoughtful revision. Start a writing assignment as soon as possible after receiving it, and always allow a few days between the penultimate and final drafts. If you follow this advice, the quality of what you submit will improve dramatically. You will also, almost certainly, learn more from the assignment.

## TEN STRATEGIES FOR REVISING AND EDITING: GETTING TO YOUR FINAL DRAFT

**Strategy 1. Make sure you say what you mean to say (pp. 60–63).** Words are tricky. If they end up in the wrong place—especially as misplaced modifiers—they can add considerable ambiguity to your sentences. Consider the following sentence.



The bubble was clearly seen using a magnifying glass

In this case, the dangling modifier probably leads only to laughter, not to real misunderstanding; clearly a gas bubble is not capable of using a magnifying glass. The writer meant the bubble was clearly seen when a magnifying glass was used. Sometimes, however, this kind of sloppy language introduces significant misunderstandings. Good science writing is precise. Be sure you say what you mean. It sometimes helps to read aloud what you have written and to listen carefully to what you say as you read.

**Strategy 2. Use transitional words and phrases to keep the reader moving forward (p. 58).** Part of your obligation as a writer is to offer your reader the simplest possible path forward through what you have written. You should try to take the reader by the nose in your first paragraph and lead him or her through to the end, line by line, paragraph by paragraph. Link your sentences carefully, using such transitional words as “therefore” or “in contrast,” or by repeating key words so that a clear argument is developed logically. Link your paragraphs using transitions to continue the thought and to remind readers periodically of what they have already read.

**Strategy 3. Avoid using pronouns like it, this, and they without clear antecedents, that is, without clarifying what such pronouns refer to (pp. 63–65).** Here is an example to show what we mean:

 Our results were based upon observations of short-term changes in temperature. They showed that reaction rates did not depend on the amount of formaldehyde.

The pronoun *they* could refer to *results*, *observations*, or *changes in temperature*. Granted, the reader can back up and figure out what *they*

are, but this ambiguity can be clarified by changing *they* to *these results*. Don't be afraid to repeat a word or phrase from the preceding sentence. If it is the right word and avoids ambiguity, use it. Repetition can at times be an effective way to keep readers moving forward.

**Strategy 4. Don't make readers work harder than they have to; do the work for the readers (pp. 66–68).** If there is interpreting to be done, you, the writer, should be the one to do it. For example, never direct your readers to a table of data without setting them up to see what you consider significant.



The difference in reaction rates is clearly shown in Table 1.

Such a statement puts the burden of effort on the readers and leaves them wondering, “So what?” Instead, provide the readers with guidance that facilitates their ability to grasp more quickly what is being presented.

 As can be seen from the results in Table 1, peptides were more rapidly hydrolyzed in the presence of the protease enzyme than in acid solution, even when the temperature was raised.

Readers now know clearly what you have in mind and can examine Table 1 to see whether they agree with your interpretation.

**Be concise.** Give all the information necessary, but avoid using more words than you need. The next three rules are particular strategies we recommend for achieving concision in your writing when you revise.

**Strategy 5. Eliminate throat clearing (pp. 73–76).** When we write, we often employ mindless little phrases to buy ourselves a little time to think of what to say next. We call this **written throat clearing** as it is the written equivalent of the “ahem, ahem” sound that serves the same purpose in speech. Written throat clearing is a natural part of the process of thinking and writing; of how people wrestle meaning into words, but when you revise, it pays to be alert for instances of unnecessary words, modifiers, or phrases that can be eliminated. Here are two sentences that provide ample illustration of what we mean by written throat clearing.

 There is a considerable body of evidence in the literature to show that the quality of instrumental measurements of trace metallic elements in the environment has improved significantly over the most recent two decades. In view of the fact that the concentrations of trace elements in open and coastal ocean water have been

decreasing, according to the results presented in published papers, it may be deduced that some of the earlier measurements were made under circumstances in which the many and varied interference effects that can be encountered with this type of sample material were not accounted for fully. (99 words)

Here is the same passage edited for throat clearing.

 The reported concentrations of metals in seawater have decreased over the past 20 years because improvements in instrument quality mean that measurements no longer suffer from the interferences that produced the earlier inaccurate high results. (35 words)

By revising for throat clearing, we achieve a reduction of 64%.

**Strategy 6. Avoid a too heavy reliance on weak verbs, such as *to be* and *to use* (pp. 77–78).** The verb *to be* often serves a useful purpose early in the writing process helping the writer make connections or articulate relationships; consequently, it often gets overused at the draft stage. Utilitarian and serviceable, the verb *to be* is also colorless and bland. By working while you edit to avoid a too heavy reliance on it, you can pare down and breathe some life into the flat, unnecessarily wordy prose it produces.

The verb *to use* is a similar sort of work-horse verb that produces lifeless and flat prose when repeatedly employed in place of more specific verbs, as often occurs in the experimental section of research reports. For example:

 A model ZX-100 chronospectrometer was used for all endochronic measurements. For the time dilation experiments a modified 3-electrode cell was used. To remove dissolved gases from the solutions, high purity helium was used, and an infrared radiation lamp was used to heat the solutions. A saturated calomel reference electrode with a triple junction was used as this prevented contamination of the solutions with mercury ions. To record the data, a home-built analog-to-digital converter was used to connect the spectrometer to a personal computer. (83 words)

We replace all of the *was used* constructions with more specific action verbs, and get this revision.

 Endochronicity was measured with a model ZX-100 chronospectrometer, equipped with a modified 3-electrode cell for the time dilation experiments. Solutions were degassed with high

purity helium and heated with an infrared lamp. Mercury contamination from the saturated calomel reference electrode was avoided with a triple junction. Data were recorded by a personal computer interfaced via an analog-to-digital converter built in-house. (80 words)

The revision contains 27% fewer words and much less monotony than the original.

**Strategy 7. Excise unnecessary prepositions (pp. 76–77).** These little connecting words (*of, in, to*) tend to proliferate when we are still thinking our way through a sentence, making connections, and piecing together bits of information. Much like throat clearing and using forms of *to be* to link together concepts, prepositions may serve a useful purpose when we are struggling to understand, but they, too, can contribute to unnecessary wordiness. When you are editing your final draft, you should be vigilant to remove as many unnecessary prepositions as possible. Consider, for example, the following passage in which we have highlighted the prepositions.

 The immobilization of biomolecules is a key feature of the development of biosensing devices. In order to understand the nature of the processes responsible for the change in oscillation frequency of a piezoelectric quartz crystal when subjected to the increased mass load of an adsorbed protein, many different forms of the spectroscopy of surfaces have been used. Several researchers in this area have found that useful information may be obtained from examination with ellipsometry, a form of spectroscopy that depends on the changes in polarization of light reflected off of a surface. (95 words)

Removing the unnecessary prepositions and some instances of throat clearing produces the following considerably shorter, less plodding passage.

 Biomolecule immobilization is a key feature of biosensing device development. Processes responsible for the changes in a piezoelectric quartz crystal oscillation frequency due to protein adsorption have been studied by surface spectroscopy. Ellipsometry, in which the polarization changes on reflection are measured, is particularly useful. (45 words)

**Strategy 8. Use passive and active voice effectively (pp. 80–83).** In English it is possible to describe the same action using two different voices: the active voice or the passive voice. The active voice is preferable

in most situations for a number of reasons. Passive voice obscures who or what is responsible for the central action in a sentence.

Passive: Errors were made in the lab, and as a result the findings were deemed invalid.

Active voice makes it very clear who or what is the agent of the central action, who is doing what, and is usually more direct, concise, and economical than passive voice.

Active: He made errors in the lab that invalidated the findings.

Passive voice does have its uses, especially in scientific writing, but it is often a great enemy of concise writing, which is also highly valued in scientific writing. So which should you use when writing about chemistry? **Use the voice that best suits your purpose in a particular situation.** We discuss passive and active voice in greater detail in Chapter 5.

### Strategy 9. Ensure that your writing is gender neutral (pp. 70–73).

Work to eliminate sexist language habits from your writing by avoiding using masculine nouns such as *man* to refer to both males and females or modifiers derived from masculine nouns such as *manmade*. Instead, substitute neutral alternatives such as nouns like *people* or *chemists* or modifiers like *synthetic* or *artificial*. Also avoid using the masculine pronouns (*he*, *his*, and *him*) to refer to both males and females. This can be accomplished by eliminating pronouns, occasionally using masculine and feminine pronouns in tandem (*he* or *she*), or recasting the sentence in the plural. We do not recommend the use of singular *they*, that is, the substitution of the plural pronoun *they* for the singular pronouns *he* and *she* as a means of achieving gender-neutral prose. Although this usage is a common feature of informal English and may eventually become accepted as Standard Written English, we recommend—that when writing formal prose, you adopt other strategies to avoid sexism in your writing.

### Strategy 10. Handle electronic files carefully and responsibly (p. 151).

Back up your file in a safe location, and leave yourself enough time for printing out a hard copy to account for such possible accidents as printer malfunctions or running out of ink. Never miss a deadline because of a computer-related problem. Instructors do not believe that printer cartridges run out at deadlines any more than they believe that dogs eat homework or flash drives.

## RULES AND CONVENTIONS: THE EASY STUFF

Like all academic disciplines, the field of chemistry has developed its own set of conventions for communicating information among its members. These conventions constitute a kind of shorthand or code that allows chemists to communicate more effectively and efficiently with one another. In order to write successfully about chemistry, you must understand and be able to employ these various conventions correctly.

**1. Follow rules from the American Chemical Society about abbreviation (pp. 84–86).** Abbreviate units of measurement that are preceded by numbers, and always use the same symbol for all values regardless of quantity: 1 mm (millimeter), 50 mm; 1 h (hour), 2 h; 1 g (gram), 454 g (pp. 89–90). Many commonly used instrumental techniques can be referred to by an abbreviation. For example, high-performance liquid chromatography can be abbreviated to HPLC. Such abbreviations are in capital letters, and there are no periods. You should define an abbreviation when the term is first encountered in the text, and then just use the abbreviation.

Be careful not to use an abbreviation inappropriately. You can determine the number of compounds in the reaction mixture by HPLC, but you cannot run the sample on the HPLC. In other words, do not use the abbreviation for the technique to stand for the instrument, even though, in informal conversation, we often do just that.

The following abbreviations are well-known and do not need to be defined: DNA (deoxyribonucleic acid), GC (gas chromatography), IR (infrared), M (molar), NMR (nuclear magnetic resonance), RNA (ribonucleic acid), and UV (ultraviolet) (pp. 84–86).

**2. Observe the conventions of the American Chemical Society about capitalization (pp. 86–87).** Do not capitalize the names of chemical elements, the names of chemical compounds, the periodic table, surnames used as units of measure. Be careful with capitalization in chemical formulae: CO is carbon monoxide; Co is cobalt (p. 92). Capitalize adjectives formed from proper names (such as Boolean), genus names used as formal names (*Bacillus subtilis*), trade names (Teflon), and names when used as modifiers (Erlenmeyer flask). Capitalize the words *figure*, *table*, *chart*, and *scheme* only when they refer to specified numbered items (p. 87).

**3. Pay attention to the discipline-specific conventions of chemistry regarding hyphens and suffixes (pp. 87–89).** Most prefixes are not hyphenated. Use a hyphen to join two or three words that together function as a single modifier (ion-exchange resin), a modifier that contains *well*, *still*, *ever*, *ill*, or *little* (well-deserved award), spelled out fractions (one-tenth), spelled out numbers from 21 to 99 (forty-three), a word that is formed from a word and an initial capital letter (H-bomb), and double surnames (Elizabeth Davis-Calhoun). Use a hyphen to attach prefixes such as *anti*, *non*, and *pre* only under these special circumstances: when the second word in the combination begins with a capital letter (anti-Markovnikov) or a number (pre-2000), when the second word in the combination begins with the same letter that occurs at the end of the prefix (pre-equilibrium), or when the second word in the combination is a chemical term (non-phenyl).

Do not use a hyphen in modifiers that are chemical names (amino acid concentration), to attach multiplying prefixes (triatomic), to join an *ly* adverb and an adjective (accurately measured), or to attach prefixes such as *anti*, *non*, and *pre* to common adjectives (nonspecific).

**4. Pay attention to form and format (pp. 16, 120).** Everything you write should demonstrate that you took the time to read any style and formatting guidelines given to you by your instructor, supervisor, or potential publisher; that you took the assignment seriously and are proud of the result; and that you welcome constructive criticism of your work. Carefully follow guidelines about margins, spacing, length, and typeface, where to put your name and a date, and other formatting issues. Number pages so that a reader can tell immediately if a page is missing or out of order and so that readers can easily reference a particular part of the text (“In the middle of page 7, you imply...”).

### THE ESSENTIAL LAST PASS: PROOFREADING

After you have read your final draft carefully and revised it for clarity, concision, and appropriate use of transitional word and phrases as well as capitals, abbreviations, and formatting, you still have one important task left. Although it is a crucial part of the writing process, few of us like to proofread. By the time we have arrived at this point in the project, we have put in a considerable amount of work and are certain we have done the job correctly. Who wants to read the paper yet another time? Moreover, finding an error means having to make a correction. But put

yourself in the position of your reader. Your reader typically starts off on your side, wanting to give you a good grade or find your paper suitable for publication. A sloppy paper—for example, one with too many typing errors—can lose you a considerable amount of good will as a student and, later, as a practicing scientist. Sloppy writing may suggest to the reader that you are equally sloppy in your work and in your thinking, or that you take little pride in your own efforts. Furthermore, failure to proofread your paper and to make the required corrections implies that you don't value the reader's time, which is neither a flattering nor particularly wise message to send. Never forget that you get only one chance to make a first impression. Shoddily prepared material can easily lower a grade, damage a writer's credibility, reduce the likelihood that a manuscript will be accepted for publication or that a grant proposal will be funded, or cost an applicant a job or admission to professional or graduate school. Why put yourself in such jeopardy for a mere half-hour saved? **Turn in a piece of work that you are proud to have produced.**

### DO NOT DEPEND ON YOUR COMPUTER TO DO YOUR WORK FOR YOU

Although a computer makes revision and editing much easier than if a draft is handwritten, a computer can do little to help you in that all-important first struggle—the struggle for understanding. Nor can it read and synthesize the material from your sources or organize your paper conceptually; it cannot, in short, think. And keep in mind that it cannot even proofread for you—at least not very effectively.

Computerized spell and grammar checkers can catch some typographical and spelling and syntax errors, but chemistry is a field with considerable specialized terminology, much of which is of no use to non-chemists. Many chemical terms are not included in the dictionaries that accompany computerized spelling programs. If you are fortunate enough to be working on your own personal computer, you can easily add words to the computer's dictionary, but the terminology in your papers will be changing with every new assignment. Many of the words you add for today's assignment will probably not be used in next week's assignment. Moreover, spell-check programs cannot distinguish between homophones like *to* and *too*, *there* and *their*, or *it's* and *its*, and the program will miss typographical errors that are real words. Your computer will not know that you have typed *an* when you meant to type *and*. A grammar checker might spot this error—but it might not. By all means use spell-

and grammar-check programs if they are readily available, but don't depend on them as infallible. Use your own sharp eyes and keen intellect—moving word by word and sentence by sentence—to complete the necessary process of proofreading your work.

**Pay attention to formatting issues.** Check, for example, that sections are numbered correctly and that Greek letters or other signs or symbols you may have included have not been transformed by changes you may have made to font or style. Be especially careful with the global “find and replace” feature in the edit toolbox. If you are not absolutely sure how your proposed edit will work, try it on the first few examples you encounter before letting it loose on the entire document. Some changes cannot be reversed easily.

Chemistry writing can contain many superscripts and subscripts: check that these are correctly formatted. Sometimes material that has been created by another program does not print as you expect it to, even though it looks fine on the screen. Pay close attention to any pictures or diagrams that you have inserted from elsewhere, since these may not “translate” well into another software program. Look especially for tables or charts that break inconveniently between pages or for headings that sit by themselves at the bottom of pages. Insert additional page breaks or move elements around to avoid this kind of problem.

Finally, use one part of your word-processing program that really is efficient: the word count feature. Make sure that your paper is within the targeted length of your assignment or publication guidelines.

### CHECKLIST FOR WRITING ABOUT CHEMISTRY

- Work to understand your sources (p. 5).
- Think about why you are writing before you begin to write and as you write (pp. 5–6).
- Write in anticipation of discovery (p. 5).
- Write to illuminate, not to impress (p. 5).
- Use sources responsibly (p. 6).
- Use your own words; do not quote from sources (p. 6).
- Show rather than tell. Support all statements of fact or opinion with evidence (p. 6).
- Always distinguish fact from possibility (p. 7).

- Write to show that you can “think like a chemist” (p. 7).
- Allow time for revision (p. 7).
- Make sure you say what you mean to say (p. 8).
- Use transitional words and phrases to keep the reader moving forward (p. 8).
- Avoid using pronouns like *it*, *they*, *this*, and *their* without clear antecedents, that is, without clarifying what such pronouns refer to (pp. 8–9).
- Do not make readers work harder than they have to; do the work for the reader (p. 9).
- Be concise: Eliminate throat clearing (pp. 9–10).
- Avoid a too heavy reliance on weak verbs (pp. 10–11).
- Excise unnecessary prepositions (p. 11).
- Use passive and active voice effectively (pp. 11–12).
- Ensure that your writing is gender neutral (p. 12).
- Handle electronic files carefully and responsibly (p. 12).
- Follow rules from the American Chemical Society about abbreviation (p. 13).
- Observe the conventions of the American Chemical Society about capitalization (p. 13).
- Pay attention to the discipline-specific conventions of chemistry regarding hyphens and suffixes (p. 14).
- Pay attention to form and format (p. 14).
- Proofread, proofread, proofread (pp. 14–15).
- Do not rely too heavily on your spelling- and grammar-checking software (pp. 15–16).
- Pay attention to formatting issues (p. 16).
- Use the word count tool. (p. 16).

## GENERAL ADVICE ON READING AND TAKING NOTES

*That is one of the worst feelings I can think of, to have had a wonderful moment or insight or vision or phrase, to know you had it, and then lose it. So now I use note cards.*

ANNE LAMOTT

### WHY READ AND WHAT TO READ

By now you will have realized that a college education consists mostly of guided self-teaching, a pedagogy in which reading features prominently. That is, much of what you learn in college, particularly with regard to the content of your various courses, you learn by interacting with "written" material whether it be on the screen of your computer, in the pages of a book, or in an original research article in a scientific journal. Chemists refer to articles in scientific journals as the **primary literature**.

The **primary literature** is based on original observations and experiments; it includes information about how those observations or experiments were made or conducted. Review articles, which summarize the primary literature, that appear in scientific journals are known as the **secondary literature**. Chemists call textbooks and encyclopedia entries the **tertiary literature**.

Reading secondary and tertiary sources is an excellent way to get up to speed in a new area, but you will generally be learning more about what is known than about how we have come to know it or what remains to be found. For many assignments in upper-level undergraduate chemistry

courses, and certainly in a graduate program, you will be asked to go beyond the factual foundation of the field to interpret, evaluate, synthesize, ask new questions, and maybe even design experiments to address those questions.

To see the basis for—and often the limits of—our current knowledge, you will need to explore the primary literature. Reading that literature is very different from reading the secondary or tertiary literature. It is a skill that requires some practice and guidance.

### EFFECTIVE READING

Too many students think of reading as the mechanical act of moving the eyes left to right, line by line, to the end of the page, and repeating the process page after page to the end of the chapter or assignment. We call this "brain-off" reading. When the last page has been "read," the task is over and it's on to something else. In the same way, some students typically "listen" to a lecture by furiously copying whatever the instructor writes or says, without really thinking about the information while it is being presented.

Whether you are reading a textbook, a review article, or a paper from the primary research literature, you must interact intellectually with the material if you hope to understand it in a useful way and to have something worthwhile to write about later. As you read, you must become a "brain-on" reader, wrestling thoughtfully with every sentence, every graph, every figure, and every table. If you do not fully understand any part of what you are reading, you must work through the problem until it is resolved rather than skipping over the difficult material and moving along to something more accessible. This is especially true when reading the primary research literature; it must be read slowly, thoughtfully, and patiently, and a single paper must usually be reread several times before it can be thoroughly understood. Don't become discouraged after only one or two readings. As with playing tennis or sight reading music, reading the primary literature gets easier with practice.

This kind of reading is inevitably a time-consuming process, but you can do a number of things to smooth the way. Always begin by carefully reading the appropriate sections of your textbook and any relevant class notes to get a solid overview of your general subject. You should also look for review articles or other books on the subject, and at this point, you might find it helpful to talk to a reference librarian about finding such

suitable secondary and tertiary sources. In addition to books specifically written for students, there are books specifically written for professional chemists. These books fall into two categories: **monographs**, which are in-depth treatments of one particular topic, and **handbooks**, which are in-depth treatments of a particular field. Your library will probably have a number of these books available.

Almost all articles published in chemistry journals appear in a standard format containing the following sections: Title, Abstract, Introduction, Experimental, Results, Discussion, Acknowledgments, and References. Often, the Results and Discussion are combined into one section, and some journal articles also have a Conclusion section. A more recent trend is to decrease the number of experimental results that appear in the print version of the article and make these available as supplemental material that can be downloaded from a Web site. First, read the Title and Abstract to get an overview of the paper. Next, read the last paragraph of the Introduction. If the paper is written well, this is where the researchers will describe what is new about the material in the article and will state the specific issues or questions that were addressed. Then read the titles of the tables and the captions for the figures, so that you can see exactly what sorts of data are being presented. At this point you may find that the article is not really relevant to your topic after all or that it is of little help in developing your theme. If so, this preliminary reading will have saved you from wasted note taking. On the other hand, if the paper is of interest, you can now start at the beginning and read the material in the sequence that the researchers present it.

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?
- Are numerical results accompanied by appropriate statistical evaluations of errors?
- Are any results presented that are not discussed?
- What questions remain unanswered?

If you are planning to write a research proposal, you should ask one additional question:

- What are the next steps to be taken?

## EFFECTIVE NOTE-TAKING AND NOTE-ORGANIZING

We all know that if you want to learn something from an oral presentation or seminar, taking notes is a good idea. Taking notes keeps you active: you have to engage with the material to decide whether to write or not. Note-taking is a basic skill that college instructors assume you have mastered and one you will need in many professional settings. The purpose of taking notes is to create a fuller written document containing all of the important material at a later time. The sooner you revisit those notes, the more you will be able to recall. Too many students do not revisit their notes until it is (almost) too late—often just before a test or exam. One of your goals in attending college is to acquire skills that will transfer over into life after college, when you are responsible for your own learning. It is a good idea to get into the habit of rewriting your lecture notes within 24 hours rather than 24 days.

Taking notes about what you are reading is much like taking notes during a lecture: you are keeping active, you are identifying the material that is unfamiliar, you are collecting material that is potentially useful, and you are creating a record of your thoughts and activity. If you are in the early stages of gathering material from multiple sources to create an essay or term paper, you will want to record accurately the details of what information came from what source. You will probably need to provide citations to your sources (for more details see Chapter 3), and since you may well want to find a particular source again, keep careful records of what you read.

It is worth giving a little thought to how you are going to organize your notes. Almost certainly you will not want to record material in a bound notebook because it can be difficult to rearrange the order of the material or to insert new material other than at the end. You may want to use a loose-leaf, three-ring binder, or perhaps you should invest in some file index cards, and a suitable box with dividers. It is, of course, perfectly possible to create notes as electronic text on your computer, although there are certain logistical issues to be considered such as portability, battery life, and, if your reading is to be done in the library, work-surface availability. Viewing and organizing notes about even modest numbers of topics can be difficult on the virtual desktop.

If you are reading the original literature in the form of text you have printed for your own use from a pdf version of the article, then do not hesitate to write all over it. In this way, you can readily identify those parts of the article you do not understand or find convincing, and you can write

appropriate comments and questions in the margins. You should still make separate notes about each article that you read and add those to your collection for the project.

### READING DATA: PLUMBING THE DEPTHS OF FIGURES AND TABLES

In addition to text, most research articles will contain tables and figures in which the researchers present the results of experiments. The claims the authors make will be based on the data or information presented in the tables and figures, and so you should pay particular attention to those results. If the tables and figures were carefully executed, there will be enough information in the figure caption and in the axis labels for you to understand the essential details of the experiment. As you scrutinize the figures and tables, ask yourself *what* experiment was done, *why* it was done, *how* it was done, and *what* the key results seem to be. Try to form your own opinions about what the data mean before you read the text of the Results section.

An example of a table from a journal article is shown in Figure 1. The title of the article is "Arsenic Speciation in Rice and Soil Containing Related Compounds of Chemical Warfare Agents"; the authors are Koji Baba, Tomohito Arao, Yuji Maejima, Eiki Watanabe, Heesoo Eun, and Masumi Ishizaka; and the journal, year, volume, and page numbers are *Anal. Chem.* **2008**, *80*, 5768–5775. We see that the title of the table does not tell us what the numbers are, and we have to read the heading above the numbers to find that these are concentrations expressed in  $\text{mg kg}^{-1}$  (or ppm) of arsenic. We also note that there are three materials (grain, straw, and soil) even though there are only two "straddle" headings (as the horizontal lines with text above are called). Each number is accompanied by a  $\pm$  term, but this is not defined (we would look to see if there was a footnote to explain this) and so we make a mental note that maybe this information is in the text. We note that each number is based on the results for three samples (this is how we interpret " $n = 3$ "). We see that for each extraction solvent the concentration of each species is given, and that several of the arsenic-containing compounds are referred to by 3-, 4-, and 5-letter abbreviations, as is one of the solvents. We will have to look in the text to find the identity of these. We note that the solvents used for extracting arsenic compounds from soil are not the same as those for extracting arsenic compounds from the rice, grain, and straw.

Table 1. Extraction of Arsenic Species with Various Media ( $n = 3$ )

	extraction media ( $\text{mg of As kg}^{-1}$ )				digest ( $\text{mg of As kg}^{-1}$ )
	H <sub>2</sub> O	50% CH <sub>3</sub> OH	TFA	HNO <sub>3</sub>	
grain					
inorganic As	0.167 ± 0.005	0.164 ± 0.019	0.226 ± 0.034	0.255 ± 0.039	
DPAA	0.048 ± 0.006	0.072 ± 0.005	0.076 ± 0.007	0.071 ± 0.005	
MPAA	0.262 ± 0.013	0.323 ± 0.008	0.426 ± 0.024	0.408 ± 0.010	
total	0.475 ± 0.011	0.555 ± 0.021	0.732 ± 0.009	0.729 ± 0.027	0.752 ± 0.032
overall recovery (%) <sup>a</sup>	63.2 ± 1.5	73.8 ± 2.8	97.3 ± 1.2	96.9 ± 3.6	
straw					
inorganic As	1.094 ± 0.100	1.068 ± 0.012	1.062 ± 0.105	1.661 ± 0.038	
MAA+DMAA	0.064 ± 0.004	0.067 ± 0.004	0.091 ± 0.003	0.272 ± 0.028	
MPAA	0.107 ± 0.007	0.125 ± 0.007	0.209 ± 0.003	0.216 ± 0.010	
DMPAO	0.834 ± 0.064	1.162 ± 0.069	1.112 ± 0.022	1.742 ± 0.032	
MDPAO	0.072 ± 0.005	0.115 ± 0.011	0.125 ± 0.005	0.124 ± 0.004	
total	2.189 ± 0.138	2.537 ± 0.100	2.599 ± 0.094	4.020 ± 0.096	5.018 ± 0.134
overall recovery (%) <sup>a</sup>	43.6 ± 2.8	50.6 ± 2.0	51.8 ± 1.9	80.1 ± 1.9	
	extraction media ( $\text{mg of As kg}^{-1}$ )				digest ( $\text{mg of As kg}^{-1}$ )
	H <sub>2</sub> O	H <sub>2</sub> PO <sub>4</sub>	NaOH	HNO <sub>3</sub>	
soil					
inorganic As	nd <sup>b</sup>	3.363 ± 0.069	1.041 ± 0.048	5.856 ± 0.191	
MAA+DMAA	nd <sup>b</sup>	0.173 ± 0.018	0.208 ± 0.012	0.524 ± 0.015	
PAA	0.051 ± 0.005	1.130 ± 0.027	1.247 ± 0.066	1.355 ± 0.070	
DPAA	0.107 ± 0.007	0.217 ± 0.008	0.267 ± 0.025	0.338 ± 0.022	
MPAA	0.152 ± 0.007	0.626 ± 0.032	0.750 ± 0.031	0.762 ± 0.058	
DMPAO	0.071 ± 0.002	0.142 ± 0.014	0.188 ± 0.007	0.347 ± 0.019	
MDPAO	0.117 ± 0.007	0.232 ± 0.003	0.373 ± 0.027	0.449 ± 0.025	
total	0.498 ± 0.004	3.383 ± 0.137	4.074 ± 0.193	9.632 ± 0.364	9.803 ± 0.396
overall recovery (%) <sup>a</sup>	5.1 ± 0.0	34.5 ± 1.4	41.6 ± 2.0	98.3 ± 3.7	

<sup>a</sup>  $100 \times [\text{chromatographic total As}] / [\text{digested total As}]$ . <sup>b</sup> Below instrumental detection limit.

Figure 1. Table 1 from the article "Arsenic Speciation in Rice and Soil Containing Related Compounds of Chemical Warfare Agents."

We note that the concentrations of the phosphoric acid, sodium hydroxide, and nitric acid are not given, and therefore we will have to find this information in the text. We also see that the researchers have analyzed the materials for total arsenic, and the values are given in the column headed "digest." We see that the units are the same (and note that there is a word-processing error in one of these where a "+" and "-1" appear in the wrong order).

The way the overall original figure has been calculated is explained in the footnote for which we have to interpret the use of "[ ]" to mean concentrations. There is enough information to check the researchers' calculations. So for the extraction of arsenic compounds from rice grain by water, we can add  $0.167 + 0.048 + 0.262$  to get  $0.477$ , which is close to the value of  $0.475$  given in the table. We note that there are similar issues with the other columns of numbers, but as  $475$  divided by  $752$  is  $0.632$ , the  $63.2\%$  given as the overall recovery is correct. We note that not all compounds are listed for each of the three materials, and so we assume that compounds not listed were not detected in any of the extracts. We see that in terms of accounting for all the arsenic, nitric acid is the best solvent, though TFA took out nearly all of the arsenic from the rice grains. We can see that compared with the relative proportions of inorganic arsenic and organic arsenic compounds in the soil, the rice grain and straw contain higher amounts of organic arsenic. We probably think it would be easier to express some of these numbers in a bar chart format, and so we are gratified to find on the next page of the article some figures that do just that. One of these figures is shown in Figure 2.

Because the caption of the figure does not explain how these numbers were obtained, we speculate that this was based on the analysis of a nitric acid extract, as we already know that for grain and soil, this solvent can extract about  $97\%$  of the arsenic present. We can look to see whether the numbers in the figure agree with the numbers in the table. Now we encounter a problem, as we see, for example, that the total arsenic in the straw was about  $13 \text{ mg kg}^{-1}$  according to the figure but only  $5 \text{ mg kg}^{-1}$  according to the table. We can, however, clearly see that there is not much arsenic in the rice grain, but there is much more in the straw. We can also see that the compound DMPAO is taken up by the straw to a much greater extent than any other compound, even though the concentration in soil was one of the lowest.

An important part of the way in which science advances is that other scientists scrutinize the results presented and ask whether the data really support the conclusions drawn. It is unlikely that your instructor will assign you an article to read that contains seriously flawed interpretations

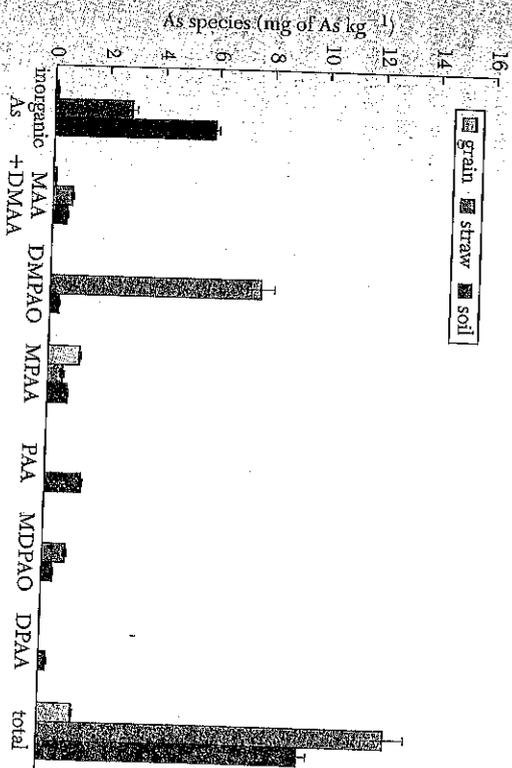


Figure 9. Uptake of arsenicals by rice cultivated with a contaminated soil. Arsenic concentrations in rice grain, straw, and soil were expressed by the white, gray, and black bars, respectively ( $n = 3$ ).

Figure 2. Figure from the article "Arsenic Speciation in Rice and Soil Containing Related Compounds of Chemical Warfare Agents."

of the data, but if you have selected the article yourself, then you should be aware that publication in a primary journal is no guarantee that the science is flawless, and no guarantee that the presentation is error free (as we saw above from examining the figures and tables in a published article). The scientists who reviewed the material before publication may have had some questions that were not fully answered in the resubmission, but in the judgment of the journal's editor, the positive features of the work outweighed the negative features, and the article was accepted for publication. Always reading with a skeptical eye can give you interesting things to write about, and sometimes it even leads to interesting new research questions. We discuss the process by which chemists publish their research results to the rest of the community in Chapter 10.

### READING TEXT: SUMMARIZE AS YOU GO

Resist the temptation to copy your source's words verbatim. Instead, try to summarize sections of the material as you read. In this way, you will

be processing information as you read it, and you will be one major step closer to having something interesting to write about later. To summarize effectively, you must first determine what is important. Consider the following paragraph from a 2004 review article, published in the journal *Clinical Chemistry*, by Kevin Francesconi and Florence Pannier.

In addition to the scientific interest in selenium, there is also considerable public awareness because of its purported efficacy as a treatment against certain types of cancer. Encouraging results, reported in 1996 from a study carried out in the United States [5]\*, provided the impetus for an ongoing 12-year study involving 32,000 individuals to test the efficacy of selenium intake against prostate cancer [6]. 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. These supplements are thought to be more effective when the selenium is ingested in an "organic" form, and many suppliers provide the selenium as selenized yeast, which contains largely selenomethionine bound in proteins in addition to many other unknown selenium species [7]. Consumers of such products intent on improved health should be aware, however, of the toxicity of selenium and the possible toxic consequences of overindulgence.

What are the key points in this paragraph? What information would the authors be unhappy to see left out?

- Selenium compounds may prevent some cancers.
- People should be aware that selenium compounds are toxic, so overdosing with supplements may be dangerous.

Here is a possible one-sentence summary that incorporates both points:

People who take selenium supplements should be aware that, although there is evidence that selenium prevents some types of cancer, overdosing is dangerous because selenium compounds are toxic.

\*A number that appears in the text like this (sometimes as a superscript) refers to the source from which the writers are taking their information. This is known as "citing" a source. At the end of the article, there will be a collection of sources cited under the heading "References." In Chapter 3, we discuss references and how to cite them.

The original paragraph illustrates one or two conventions of chemistry writing, which have been incorporated into the summary sentence. The first is that **writers use the name of the element as shorthand for "a variety of compounds of the element."** When we are told that selenium may prevent prostate cancer, the writers do not mean that participants in the trial will be eating ground-up elemental selenium. They mean that participants will be given a compound of selenium, an example of which—selenomethionine—is given later in the original paragraph. The other convention is that **it is understood that all chemicals are toxic, but that not all chemicals are equally toxic, and that in addition to dose and the time over which the interaction occurs, toxicity depends on how the chemical and organism interact.** It is not necessary to write that selenium compounds are toxic at high doses because, by definition, anything is toxic at a "high" dose. What we are really being told is that compared with the amounts of chemicals commonly eaten such as various compounds of, for example, calcium, carbon, hydrogen, nitrogen, oxygen, sodium, sulfur, and phosphorus, the amount of a selenium compound that it is safe to eat is much lower.

The important features of the summary sentence are that it is (1) accurate, (2) complete, (3) self-sufficient (it makes sense even if the reader has never read the original text), and (4) in your own words. Although taking these kinds of notes may be a real challenge at first, if you get into the habit of writing such summaries as you read, you will find that the eventual payoff is tremendous. Moreover, summarizing in your own words is an excellent way to avoid plagiarism, an act of academic dishonesty that is not tolerated in academic and professional communities. Submitting anyone else's work under your own name is plagiarism, even if you alter some words or reorder some sentences. Presenting someone else's ideas as your own is also plagiarism. We discuss plagiarism in more detail in Chapter 7, which deals with writing essays and reviews.

### Take Notes in Your Own Words

Photocopying an article or book chapter does not constitute note taking; neither does highlighting or even copying a passage by hand, occasionally substituting a synonym for a word in the original text. Take notes using your own words. Do not be awed and overwhelmed by other people's words; rather, build confidence in your own thoughts and phrasings.

Taking notes involves critical evaluation; as you read you must decide either that particular facts or ideas are relevant to your topic or that they are not. **If an idea is relevant, you should jot down a summary in your own words**, as discussed earlier. Try not to write complete sentences as you take notes as this will help you avoid unintentional plagiarism later and will encourage you to see through to the essence of a statement. For the same reasons, do not write while looking at the source.

Sometimes the author's words seem so perfect that you cannot see how they might be revised to best advantage for your paper. In this case, you may wish to copy a phrase or sentence or two verbatim in your notes, but be sure to enclose the material in quotation marks as you write, and clearly indicate the source from which the quotation derives. If you modify the original wording slightly as you take notes, you should indicate this as well, perhaps by using modified quotation marks: % . . . %. If you feel that there is any danger that you will not be able to distinguish between your words and those of the original text, we suggest preceding your notes with the word *Me* and a colon. If you take notes this way, you will avoid the unintentional plagiarism that might occur if you later forget who is responsible for the wording of your notes or for the origin of an idea.

If you find yourself copying verbatim or paraphrasing your source, be sure it is not simply because you do not understand what you are reading. Be honest with yourself. **It is always best to summarize in your own words as you read**; at the very least, you should think your way to some good questions about what you are reading and write those questions down. Sooner or later serious intellectual engagement is required; there are no shortcuts available here.

Here is an example of some notes taken using the suggested system of notation based on the introduction to a review paper by Dan Melamed (*Anal. Chim. Acta*, 532, 2005, 1–13). The notes were being taken for the introduction to a research proposal concerning the determination of arsenic in drinking water. Note that **the student has avoided using complete sentences**, focusing instead on the basic points and pinning down a few words and phrases that might be useful later. Notice also that **the student has taken notes selectively and has clearly distinguished his or her own thoughts from those of Melamed** by preceding such thoughts with *Me* and a colon. The original text is shown in Figure 3, and the student's notes are shown in Figure 4.

Having been selective and taken care to label his or her own thoughts while recording these notes, this student will not have to worry

Arsenic is a relatively common, toxic element that is also a known carcinogen [1]. Arsenic is found in a wide variety of chemical forms throughout the environment and can be readily transformed by microbes; changes in geochemical conditions, and other environmental processes [2]. While arsenic occurs naturally, it also may be found as a result of a variety of industrial applications [3], including leather and wood treatments [4], and pesticides [5]. Anthropogenic arsenic contamination results from a variety of activities: manufacturing metals and alloys, refining petroleum, and burning fossil fuels and wastes. These activities have created a strong legacy of arsenic pollution throughout the world. The combination of high toxicity and widespread occurrence has created a pressing need for effective monitoring and measurement of arsenic in soils and groundwater. Toxic concentrations of arsenic have been detected in water supply wells in the United States [6] and abroad [7], creating a health risk for a large fraction of the world's population [8]. Arsenic is second only to lead as the main inorganic contaminant in the original National Priority List (NPL) of Superfund sites [9]. It also is one of the toxic materials regulated under the Resource Conservation and Recovery Act (RCRA). Therefore, the need exists for arsenic monitoring at Superfund sites, RCRA landfills, facilities handling arsenic-containing wastes, and sites where arsenic is found at toxic concentrations in groundwater. The current maximum contaminant level (MCL) for all forms of arsenic in groundwater is 50  $\mu\text{g/l}$  (50 ppb), set by EPA in 1975 based on a Public Health Service standard originally established in 1942. On 22 January 2001, EPA adopted a new standard for arsenic in drinking water at 10 ppb, to be enforced by January 2006 [10]. Arsenic-contaminated waste is restricted under RCRA as a hazardous waste and must be treated to meet limits determined by a prescribed aqueous extraction protocol, the toxicity characteristic leaching procedure (TCLP), usually performed in a laboratory. However, recent studies have shown that the TCLP may not accurately measure the ability for arsenic to migrate from a landfill [11]. Arsenic-contaminated soil is often treated as a hazardous waste with the same limitations on treatment or disposal, and often, additional regulations [12,13]. Specific limits requirements vary but soil arsenic requires measurements down to mg/kg (ppm) concentrations. The new groundwater limits may affect disposal procedures for waste-containing arsenic, increasing the pressure to directly monitor RCRA waste sites, as well as arsenic containing soils for their potential to leach arsenic into groundwater. Unlike organic pollutants, arsenic cannot be transformed into a non-toxic material; it can only be transformed into a form that is less toxic to organisms in the environment. Because arsenic is a permanent part of the environment, there is a long-term need for regular monitoring at sites where arsenic-containing waste is collected and at sites where it occurs naturally at elevated concentrations. A range of analytical field assays for pollutants such as arsenic provide valuable tools to support improved site characterization [14].

Figure 3. Taken from Melamed, D. *Anal. Chim. Acta*, 2005, 532, 1–13. The numbers and arrows indicate the text that informs the notes shown in Figure 4.

Arsenic widely distributed in environment especially soils and waters, of concentrations likely to be harmful.

1. Sources of arsenic both natural and human, including some deliberate applications in the environment such as pesticides and wood preservation. Inadvertent release from metal prodn, leather treat, fossil fuel burn, petrol refine and wastes. **Me:** does this mean landfills? Possible quote: "strong legacy of arsenic pollution throughout the world." What about chicken manure? known to contain residues of arsenic-containing feed additives, but maybe not a major source of contamination?
2. Cones in some drinking waters too high in both US and rest of world. **Me:** where has arsenic come from and what chemical forms?
3. US has regulations about pollutants: National Priority list (Pb first then As), Superfund sites, Resource Conservation and Recovery Act. **Me:** Superfund? better check ref 9.
4. USEPA limit for drinking water now (Jan 2006) 10 ppb.
5. Waste treatment not relevant except that if As leaches from waste sites it may contaminate ground water. **Me:** surely landfills are made so that they don't leak? Could be important topic, but off-task.
6. Arsenic compounds cannot be made non-toxic. **Me:** what about arsenobetaine and arsenocholine? Need to check if these turn up in environment. So need to measure at As-containing waste sites and places where background cones are high. Check ref 14 for more info about on-site measurements.

Figure 4. Handwritten notes based on the passage shown in Figure 3. Numbers in the margin correspond to the indicated portions of Figure 3.

about accidental plagiarism when writing a proposal based on these notes. Moreover, all of the active thinking the student has done while reading has generated the foundation for a good introduction to a research proposal.

### Split-Page Note-Taking: A Can't-Fail System

*Perfectly organized notes that cover everything are beautiful, but they live on paper, not in your mind.*

PETER ELBOW

If you have trouble taking notes in your own words and thinking while you read, try the split-page note-taking system. With this system,

you divide a page into left and right halves. On the left side, you write factual information as you read—preferably in your own words, but it is also okay to quote directly. On the right side, write your response to the entry you just made on the left side. Try to respond to everything that you write on the left as you read. Your response could be a simple question ("Is arsenic common?"), a more thoughtful question ("What other environmental processes could be involved?"), a reminiscence ("That reminds me of what Professor Shea said in last week's seminar about..."), or a comparison ("Interesting: the issue of chicken manure contaminated with residues of arsenic-containing drugs is not mentioned and so may not be as important as these other sources"). Write whatever you happen to think of when you look at what you wrote on the left side. Figure 5 is an example based on the material from the Melamed article.

### Final Thoughts on Note-Taking: Document Your Sources

As you take notes, be sure to make a complete record of each source used: author(s), title of article, title of journal, year of publication, volume number, and page numbers. It is not always easy to relocate a source once it has been returned to the library stacks; in fact, the source you forgot to record completely is always the one that vanishes as soon as you realize that you need it again. Furthermore, before you finish with a source, it is good practice to read the material one last time to be sure that your notes accurately reflect the content.

**CHECKLIST FOR READING AND TAKING NOTES**

- Become a brain-on reader: work to understand your sources fully; sentence by sentence, figure by figure, table by table.
- Take notes thoughtfully. In particular, practice summarizing information as you go along. Your summary must be accurate, complete, self-sufficient, and written in your own words.
- When taking notes, be careful to distinguish your words and thoughts from those of the author(s) to avoid unintentional plagiarism.
- Be sure to record the complete citation information for every-thing on which you take notes.

Facts	Responses
<p>Arsenic is a relatively common, toxic, carcinogen, occurs in a wide variety of chemical forms throughout the environment. Can be readily transformed by microbes, changes in geochemical conditions, and other environmental processes.</p>	<p>"Arsenic" means arsenic compounds. Example of biogeochemistry in action.</p>
<p>Occurs naturally, but also from industrial applications: leather and wood treatment and pesticides, manufacturing metals and alloys, refining petroleum, and burning fossil fuels and wastes.</p>	<p>Some contamination from As into environment deliberately; some contamination is accidental. What about residues from chicken drugs?</p>
<p>These activities have created a strong legacy of arsenic pollution throughout the world.</p>	<p>Good quote to use.</p>
<p>The combination of high toxicity and widespread occurrence has created a pressing need for effective monitoring and measurement of arsenic in soils and groundwater.</p>	<p>Could be another useful quote or maybe just paraphrase?</p>
<p>Toxic concentrations of arsenic found in wells in the United States and elsewhere. Large fraction of the world's population at risk.</p>	<p>Hmm—just how large a fraction?</p>
<p>As second only to Pb as inorganic contaminant on the original National Priority List (NPL) of Superfund sites [9]. Also regulated under the Resource Conservation and Recovery Act (RCRA).</p>	<p>What are Superfund sites? How do inorganic contaminants compare with organics on the list? Do Gov't regulations just address total elemental As, or is speciation involved? Prob. not. Approach would be to measure total arsenic and then assume all present as most toxic compound. But this ignores bioavailability. Not a problem for drinking water (assume all bioavailable) but what about soil?</p>

Figure 5. An example of split-page note taking based on part of the material shown in Figure 3.

## 3

## CITING SOURCES AND LISTING REFERENCES

### CITING SOURCES

As described briefly in Chapter 1, **all statements of fact and opinion require support in order to be convincing to the thoughtful, critical reader.** The firmer the statement, the more important it is to your argument, the greater the need for support. As the writer, you should expect your readers to ask, "How do you know?" or "Who says?" In research reports (including lab reports), review papers ("term papers"), theses, and dissertations, factual statements are usually supported by reference to the source (or sources) of the facts presented. In a separate section at the end of your manuscript, you must list all the books, research articles, Web sites, and any other sources referred to so that they can be located by interested (or skeptical) readers.

While you should try to cite only sources that are reliable (i.e., have been subject to the peer review process) and verifiable (i.e., can be independently consulted by your readers), you may sometimes need to cite sources that are more difficult to check in order to avoid being dishonest (see page 40). There are also instances when, as a student, you may need to cite the manual for your laboratory class or even something that was said by an instructor in a lecture. We will explain how to deal with such sources of information later.

When backing up assertions, some judgment is called for, because there are many facts that the chemistry community will accept without question. The challenge is to determine which facts are considered "common knowledge." As a general rule, when making statements that need to be supported by reference to authoritative sources, consider that you are

writing for an audience of your peers—other students at the same stage of their careers as you are—even though what you are writing will be read (and graded) by one of your professors. For example, you would not need to cite any sources to support the statement that elemental mercury is a liquid at room temperature and atmospheric pressure, nor to support the statement that the vapor pressure of the monatomic vapor is such that mercury can be detected by atomic absorption spectroscopy at room temperature. These are phenomena that are so reproducible that they are considered to be facts. However, if you were to state that mercury may be determined in fish tissue at concentrations below  $1 \text{ ng kg}^{-1}$  using cold vapor-atomic absorption spectrometry (AAS), you would need to support that statement, even if you were writing for an audience that is knowledgeable about the capabilities of AAS. Why? Because the capabilities of AAS are such that the detection claimed seems beyond the scope of current measurement technology.

Clearly, for the student writer, there are issues here. Until you become very familiar with the topic about which you are writing, you will have some difficulty judging what needs to be supported and what does not. In general, if you think that you might need the support of some well-known authority of the scholarly chemistry community to convince your classmates that your statements are valid, provide references to appropriate sources.

What does the chemistry community regard as an authoritative source? As we explain in Chapter 10, research findings are disseminated to other members of the relevant community by a process of peer review, through this process, other knowledgeable scientists scrutinize the quality of the material before it is added to the record in the form of a journal article. Peer review is not a foolproof procedure. There are plenty of examples of pathological science (the researchers were deluding themselves), of inaccurate science (the measurement tools were not up to the job), and, unfortunately, of deliberate fraud that have fooled the reviewers and appeared in print. On the other hand, there are also examples of major breakthroughs that have been rejected by the review process when first presented for consideration. So, although the system is slightly flawed, it is what the community works with, and articles in peer-reviewed journals are considered to be accurate accounts of extensive experiments by reputable researchers. If the material has not been subjected to the peer-review process, it must be regarded as suspect.

Although it is quite acceptable to use Internet sources, such as Wikipedia, as a first stage in finding information, you cannot use such sources to substantiate your claims, because such material has not been subjected to peer review. Here is a quotation from the Wikipedia "About" page:

Because Wikipedia is an on-going work to which in principle anybody can contribute, it differs from a paper-based reference source in some very important ways. In particular, older articles tend to be more comprehensive and balanced, while newer articles may still contain significant misinformation, unencyclopedic content, or vandalism. Users need to be aware of this in order to obtain valid information and avoid misinformation that has been recently added and not yet removed.

Just to clarify what we said earlier about writing for an audience of your peers: you must cite a source if you think that your classmates might not accept your statement, but the source that you cite must be acceptable to your instructor. Most chemistry professors will not accept Wikipedia as an authoritative source. On the other hand, most will accept the *Encyclopædia Britannica* (On-line). Ask your instructor for guidance.

## SOME GUIDELINES FOR CITING SOURCES IN CHEMISTRY

Here are a few general rules to follow when citing sources to back up your statements or to acknowledge prior experimental work or the origin of an idea. These rules apply to review papers, essays, and research reports (theses, dissertations, manuscripts submitted for publication, and perhaps reports of laboratory exercises, depending on the format that is required by your instructor). We will deal first with how to cite a source in your text and then explain how to assemble the sources (chemists refer to them as "references") at the end of your piece. At first you may think that all this attention to "superscripts after the punctuation" and how to refer to more than one author and other rules is just so much busywork; however, all these details are really important. Chemists, like other scientists, are fanatical about paying attention to detail, and if you show in your writing that you are not paying attention, you may give the impression that you don't pay attention to other

things, such as your experimental design or the care with which you analyze and present your data.

1. **Cite by inserting a number in the text.** In most published chemistry research papers, references are cited by inserting a superscript number at the most appropriate place, as in the following example:

Arsenobetaine, which occurs in seafood, is not toxic.<sup>1</sup>

Note that the number comes after the punctuation. This rule also applies when the number is more appropriately inserted before the end of the sentence:

As a result of the widespread application of lead-containing pesticides to fruit trees,<sup>2</sup> the soils of old orchards may be severely contaminated.

2. **Cite references in numerical order, starting with number one.** The sequence is disrupted only if you need to cite a source again, when you will use the same number again. Multiple references are indicated by the appropriate numbers separated by commas with no spaces. If you revise your text and change the order of the citations, you will need to renumber. This can be taken care of automatically with suitable software, such as EndNote. The superscript number convention is not the only one in current use: some journals use a parenthetical style such as (1) or (1) or [1]. In this case, the convention is that the number comes before the punctuation. Note that chemistry publications rarely use the "author-date" convention often found in biology publications. In this convention, the citation is given in the form of the surname of the first-named author together with the year of publication, e.g., (Bunsen, 1855). None of the 35 journals published by the American Chemical Society use this convention. You can, however, create more interesting text if you incorporate the names of the researchers into your writing. For example,

The copper concentration in the sediment was determined by Jones using atomic absorption spectrometry.<sup>3</sup>

The sentence can be considerably improved by adopting the active voice (see Chapter 5), thereby replacing the feeble word *using* with some real action (the determination of copper):

Jones determined the copper concentration in the sediment by atomic absorption spectrometry.<sup>3</sup>

### 3. Observe the established practices in chemistry when referring to authors.

- The usual convention is to give **only the surname and not the researcher's first name, initials, or title.**
- When **two researchers' names** appear on a publication, the standard practice is to give both names separated by *and*. For example,

Agrawal and Wood devised a cost-effective procedure for decreasing NO<sub>x</sub> emissions.<sup>4</sup>

- When **more than two names are associated with the publication**, the convention is that the first-named author is given together with the abbreviation *et al.*, which is short for *et alii* meaning, in Latin, *and the others*.

Driscoll et al. have examined many aspects of acid rain in the Northeastern United States.<sup>5</sup>

As *al.* is an abbreviation created by removing some letters from the end of the word, the convention is that it terminates in a period.

- When you want to cite multiple sources that have the same principal author but a variety of coauthors (probably transient members of the research group, such as students, academic visitors, and postdoctoral researchers), the convention is to **identify the principal researcher by name and add *and coworkers***. For example,

 Steehler and coworkers have characterized the surfaces of acrylate polymers by X-ray photoelectron spectroscopy.<sup>1-4,5,8</sup>

The person directing the research enterprise usually can be identified by a footnote showing which of the researchers is the “corresponding author”—meaning the person to whom comments and questions (correspondence) about the article's contents should be addressed. Note the hyphen-like character between the 1 and the 4. This is the convention for dealing with three or more consecutive reference numbers. Also there should be no spaces after the commas.

We think it is a good idea to use the researchers' names in your writing even though you will see many pages in published chemistry journals and books in which the writing is in the disembodied passive voice. Rather than identifying the researcher by name and using the active voice as above,

“Steehler and coworkers devised . . .” sometimes you will see sentences or even entire articles written in the passive voice in which the human beings actually doing the original creative work are never identified, as in this rewrite of the previous example:

 A number of strategies for characterizing the surfaces of acrylate polymers have been devised.<sup>1-4,5,8</sup>

You should bear in mind that much of what is published in the original chemical literature is not necessarily written very well, and one of the goals of this book is to improve the quality of what is written by the next generation of chemists. Real people do research, and if you have ambitions to be a researcher yourself, you need to know who the key players are. Also, if you use the names of the researchers, it is much less likely that you will overlook mistakes in your references. If your text indicates that the number refers to an article by Driscoll et al., you are unlikely to mistakenly assign a paper written by Agrawal and Wood to this number in your reference list.

**4 Make the relevance of the cited reference clear to the reader.** It is quite permissible to put the reference number at a location other than the end of the sentence. Indeed, this is desirable if you are going to mention more than one set of researchers in the same sentence. For example, if you were to write,

 D'Ulivo and coworkers investigated the mechanism by which arsine is formed from the reaction between arsenite and tetrahydroborate in acid solution by adopting the deuterated reagent approach of Pergantis et al.<sup>12,15,16</sup>

your readers must turn to your list of references to be reassured that you are not citing three papers by Pergantis et al. and have neglected to cite the D'Ulivo work. If you place the numbers as in the following sentence, then you do not interrupt the flow of communication:

 D'Ulivo and coworkers<sup>12,15</sup> investigated the mechanism by which arsine is formed from the reaction between arsenite and tetrahydroborate in acid solution by adopting the deuterated reagent approach of Pergantis et al.<sup>16</sup>

**Notice the different tenses in the sentence:** D'Ulivo's group *investigated*, but arsine *is* formed. The convention is that any chemical phenomenon that can be considered reproducible (i.e., there is no argument that the phenomenon is a fact) is referred to in the present tense.

What the researchers did in the behavioral sense is referred to in the past tense, since the work was completed in the past. This whole business of what tense to adopt when writing about published work can be a bit tricky. (See also pp. 63, 115, 127, 136, 139, and 187).

**5. Is it necessary to have read everything that I am citing?** For most students the answer is "yes." In most cases, you are citing sources to support statements in your own writing and you need to be confident that you are in fact getting the support you require from your source. You may also be citing the source to demonstrate that you are knowledgeable about relevant work that has already been done, and you may be called upon to demonstrate such knowledge in a high-stakes situation, such as answering questions after an oral presentation on your lab report, senior thesis, original research proposal, or even doctoral dissertation defense.

You may, however, occasionally have to cite a source that you have not actually read. For example, significant chemistry research has been—and, to a lesser extent, still is—published in foreign-language journals, and you may not be able to read the original paper even if you could obtain a copy. In this case, you would have to rely on your reading of the English-language abstract.

**6. When citing a review of a paper, also cite the original article.** When citing a review of a paper that does not include the original data supporting a particular statement that you wish to make, **reference both the original article and the review article and indicate in your text that you are relying on the reviewer's interpretation.** For example,

Evans et al. reviewed sample introduction for atomic spectrometry<sup>9</sup> and concluded that the only significant advance in hydride generation procedures was the procedure for the determination of lead devised by Chuachnad and Tyson.<sup>10</sup>

As a general strategy in your writing, taking someone else's word for the content of a paper is to be discouraged, although it is probably acceptable when you are writing about your first research activities (junior-year independent study report, for example). The purpose of a review article, after all, is to draw the reader's attention to the worthwhile information, and if you are interested you should read the original article. As you will discover as you advance in your scientific career, the literature contains some errors; you should not propagate them. It is possible, for example, that in the process of sifting through the 2000-odd publications that Evans et al. considered before writing their review, they made a mistake in describing

the work of Chuachnad and Tyson in such glowing terms, or maybe the Chuachnad and Tyson paper was about the determination of cadmium and not lead.

**7. Avoid citation overkill.** How many references should you cite? This is another good question; the answer depends on the purpose of the piece of writing and the audience. Most undergraduate writing assignments will come with some guidelines from the instructor; if not, ask your instructor. In writing an introduction to a research report, you need to exercise some judgment about the number of references you cite. Many such reports are going to be evaluated on the basis of your ability to "read and make critical use of the literature" (to quote from the UMass Graduate School bulletin's instructions for the preparation of master's theses and doctoral dissertations). This criterion also applies to undergraduate-project reports, independent-study reports (maybe even lab reports), introductions to manuscripts being submitted for publication, and proposals submitted to external-funding agencies, such as the National Science Foundation. At one end of the spectrum, citing every paper on a topic does not demonstrate a critical evaluation of the material; continuing advances in research eventually make it unnecessary to cite much of the early literature. We will offer a word of warning about that later. On the other hand, if you cite only one or two papers (assuming that there are, in fact, many on the topic), your readers will think that you have been lazy about your literature search and that your writing is not very authoritative because you do not know what has been done previously.

Deciding how many references to cite is tricky. Context is everything. For students writing about the literature as an exercise assigned by an instructor, or creating a "full" laboratory report, or writing a report on a semester-long independent study, our advice is ask for guidance. If the guidance is vague or if you think your readers may not be knowledgeable about the extent of activity in the field, then it can be helpful to survey the field. It is very easy, with the aid of databases such as the Web of Science and SciFinder Scholar, to analyze any subset of articles you have identified according to the year of publication or the identity of the principal author or the country where the work was done. For example, you might start your term paper on the cancer chemoprevention properties of selenium as follows:

Over the past 25 years there has been a steady increase in the number of journal articles dealing with the impact of selenium compounds on cancer, such that the current rate is 35–40

publications per year. Nearly 60% of the total literature of about 500 publications describes work conducted in the U.S. with significant contributions from as many as 20 research groups. The single largest contribution is from The Roswell Park Cancer Institute. The cancer chemoprevention literature contains the results of 8 trials with humans and 100 trials with small animals.

Now you could make a good case for concentrating on a small subset of the publications, say those that dealt with the eight human trials.

Deciding how many references to cite can also be a matter of experience. The more you read the professional literature, the more familiar you will become with the normal practice.

Now for that caveat about citing the early work: chemists, like other scientists, can be touchy about the issue of getting credit for something new; consequently, if there is any possibility that your piece will be read by one of the senior figures in the relevant field, it is a good idea to acknowledge his or her early work.

## PREPARING THE REFERENCES SECTION

### Listing the References—General Rules

**Include only those references that you specifically mention in your report or paper, and include all of the references that you cite.** As discussed earlier (p. 40), do not cite references that you have not read. Unless you are told otherwise by your instructor, list references in the numerical order in which they appear in your text.

Many possible sources exist, including journal articles, books, electronic media (including Web sites), magazines, patents, conference proceedings, theses, dissertations, technical reports, material safety data sheets, and personal communications. We will show you how to deal with journal articles, books, and Web sites, as well as instructions in laboratory handouts, manuals, and the information that instructors give you in the lab. Guidelines on how to deal with other sources can be found in *The ACS Style Guide*.

The number one rule is to be consistent—use the same format for all references. The number two rule is to adopt the format of a major publisher (such as the American Chemical Society or the Royal Society of Chemistry). Note that the formats of these two publishers are very different. Note also that some agencies are very strict about the format for references. For example, the National Science Foundation (NSF)

will not review proposals unless the references are in the NSF's particular format. All journals and granting agencies provide very specific guidelines on citation formatting, so read them carefully. You can also look at copies of journals, but beware: journals change the format every now and then, so look at only very recent issues. Also, some journals have a different format for references at the end of review articles than at the end of regular research articles. A uniform model for formatting acceptable to all publishers would be in the best interest of scholarship and science, but no such consensus exists at present.

### Format for Journal Articles

**When citing journal articles, the minimum information you must include is as follows: the initials and surnames of all the authors (in the order they appear on the first page of the article), the name of the journal suitably abbreviated (more about this later), the year of publication, the volume number of the journal, and the first page number of the article.** In some cases, you will also need to provide the title of the article and the last page number of the article. This latter requirement is called "inclusive pagination." You may also need to give the issue of the journal, which often corresponds to the month in which the issue was published. Here is an example of a reference to a journal article in the ACS format.

O'Levy, S. G.; Tyson, J. F.; Seare, N. J.; Kibbie, H. A. B. *J. Anal. At. Spectrom.* 1991, 6, 133–138.

Notice the order of surname and initials and the convoluted punctuation with semicolons, commas, and periods. Notice that the year of publication is in bold type and the volume is in italics. Notice that the journal title (*The Journal of Analytical Atomic Spectrometry*) has been abbreviated according to the *Chemical Abstracts Service Source Index* (CASSI) abbreviations and is in italics. *The ACS Style Guide* includes a list of more than 1,000 commonly cited journals.

Just a word or two about the convention for numbers: the basic goal is to avoid confusion between year, volume, and page number. In the previous example, there is no ambiguity (inclusive pagination means the page numbers are obvious), but consider for a moment a style that does not rely on inclusive pagination. Many journals publish several thousand pages each year, so if the numbers "1991, 6, 1996"

appeared after the journal title, you would not be able to distinguish between the year of publication and the page number. The volume number, if it can be identified (possible confusion with page number), may not help because many journals publish more than one volume each year, in which case there may not be a simple relationship between these two numbers.

Here is the same reference in the Royal Society of Chemistry (RSC) format.

S. G. Offley, N. J. Seare, J. F. Tyson and H. A. B. Kibble, *J. Anal. At. Spectrom.*, 1991, 6, 133–138.

Notice the order of surname and initials, and the slightly less convoluted punctuation with commas and periods. Notice that there is no comma before *and*, but there are commas after the last-named author and after the journal title. Notice that the year of publication and page numbers are in regular type and the volume is in bold type.

### Format for Books

By now, you should have gotten the general idea: **provide sufficient information to describe the source completely and unambiguously in a consistent format.** Basically there are two types of scientific books: either the book was written by one or more authors, or each chapter was written by a different author (or authors) and one person collected the material and turned it into a coherent account. The following are examples, using the ACS conventions, of references to these two types of books.

#### A book written by one author (or several authors)

Marcus, R. K.; Broekaert, J. A. C. *Glow Discharge Plasmas in Analytical Spectroscopy*; John Wiley and Sons Ltd: Chichester, 2003; pp 125–130.

Note the punctuation and that the information given is as follows: authors (and here there are two), title (in italics), publisher, place of publication (may be difficult to discern, pick a major city listed in the publisher's address), year of publication, and page numbers (pp is an abbreviation for pages). It is a good idea to try to give relevant page numbers, since citing a whole book may not be all that helpful to a reader who wants to check out one of your sources.

**A book in which one author has collected the materials of many different authors**

Montaser, A.; Minnich, M. G.; McLean, J. A.; Liu, H.; Caruso, J. A.; McLeod, C. W. Sample Introduction in ICP-MS. In *Inductively Coupled Plasma Mass Spectrometry*; Montaser, A., Ed.; Wiley-VCH: New York, 1998; pp 87–102.

### Format for Internet Sources

The same rules apply. Identify the author (indicate if this is a home page) or the organization responsible and give the title of the article and the uniform resource locator (URL), together with the month, day, and year accessed. For example, once again according to the ACS convention:

Julian Tyson's Arsenic Project at UMass. <http://courses.umass.edu/chemh01/> (accessed Aug 30, 2006).

Because Internet sources can be ephemeral, here today and gone tomorrow, it is important that you tell your readers the date on which you obtained the information. Just to keep you on your toes, the ACS format does not put a period at the end of the abbreviation for the month of the year, though as you will have noticed, a period does appear at the end of the abbreviations for journal titles.

Despite the temptation to do so, since the relevant material can be easily copied and pasted, do not give references to journal articles by simply pasting in the URL that corresponds to the final stages of your Internet search, as in the following example:

 Katz, S. A.; Salem, H. Chemistry and toxicology of building timbers pressure-treated with chromated copper arsenate: a review. [http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list\\_uids=16689035&query\\_h=1&tool=pubmed\\_docsum](http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=16689035&query_h=1&tool=pubmed_docsum) (accessed Aug 30, 2006).

Or

 Katz, S. A.; Salem, H. Chemistry and toxicology of building timbers pressure-treated with chromated copper arsenate: a review. <http://www3.interscience.wiley.com/cgi-bin/abstract/109875414/ABSTRACT> (accessed Aug 30, 2006).

These formats ask your reader (needlessly) to retrace your search steps and do not disclose the nature of the source (such as the title of the

journal, for example). The format that is acceptable is the one that allows the reader to find the article by knowing the details of the journal in which the article was published.



Katz, S. A.; Salem, H. Chemistry and toxicology of building timbers pressure-treated with chromated copper arsenate: a review. *J. Appl. Toxicol.* 2005, 25, 1-7.

Notice that giving the journal title conveys much more information than does the format without the journal title (e.g., Katz, S. A.; Salem, H. *J. Appl. Toxicol.* 2005, 25, 1-7). Unfortunately, many journals do not adopt the "with title" format.

As noted above (see page 35) information posted on Web sites is ephemeral and has usually not been peer reviewed. Avoid using Web pages as sources of information unless you are fully confident of the accuracy of the material presented. In general, this means relying only on peer-reviewed electronic journals or Web sites maintained by recognized scientific authorities, such as those associated with major museums, research institutions, or government organizations, such as the National Academies of Science or National Institutes of Standards and Technology. Some reputable journals are only published electronically and therefore only accessible via the Web. Many other journals have both a print version and an electronic version that, again, is accessible via the Web. In addition, many journals publish material electronically on the Web before the print version is available. These "prepublication" articles are legitimate sources and will be identified by a unique digital object identifier (DOI) code that should be cited together with the indication that the material is "on-line early access." An example of this is given in the sample reference list on page 48.

### Format for a Laboratory Manual or Handout

Refer to the laboratory manual or handout as though it were a book if the instructor's name appears on the document, then start with this. For example,

Sommerfeld, D., Determination of Calcium in Orange Juice; *Chem 312 Laboratory Manual*, UMass, Amherst, 2006; pp 25-28.

If the instructor is not identified, start with the "chapter" title.

Determination of Roxarsone in Chicken Manure; *Chem 312 Laboratory Manual*, UMass, Amherst, 2006; pp 48-50.

If your source is just a handout for one particular experiment, the page numbers are not informative.

Determination of Gold Nanoparticles in Rat Brain Tissue; *Chem 513 Laboratory Instructions*, UMass, Amherst, 2006.

### Format for Information Received from Your Instructor

This material comes under the general classification of a "personal communication," a category which includes electronic communication such as e-mail or "instant messenger," or material created by an instructor that might be posted on the course Web site (such as lecture notes transcripts). Unlike the lab manual situation described above, **this is a serious professional category of citation**. If someone comes by your poster presentation at an ACS national or regional conference and makes a substantive suggestion that you subsequently try out back at the lab and the work is published, you need to acknowledge the input of the person you met at the conference as a personal communication. You need to get the full names of people you talk to at professional meetings (ask for their business cards).

This is how you cite such a source:

Mendeleev, D. University of St. Petersburg, Russia, Personal communication, 2006.

### A SAMPLE REFERENCES SECTION

The examples above should help you prepare your own reference sections, but since citation formats differ so much among journals, check to see if your instructor wants you to follow a particular format or the format used by a particular journal.

The most important rule in preparing the references section is to **provide all the information required and to be consistent in the manner in which you present it**. If you are using bibliographic management software, this can be specified with a few clicks of the mouse. When preparing a paper for publication, follow the format used by the specific journal to which you are submitting the paper, and follow it to the last detail. The same advice applies to grant applications, theses, and dissertations: locate and download the guidelines, read them, and follow them. Remember, you only get one chance to make a first impression. Don't blow it by not paying attention to the formatting of your references.

The following list contains examples of the format for a multiauthor journal article (1), a journal that is only published electronically (2), an article that has been published on the Web in advance of the print publication (3), a textbook without an editor or editors (4), a textbook with an editor (5), a chapter in a textbook with an editor (6), and, finally, a Web site (7). All of the references appear in the American Chemical Society (ACS) format.

## References

1. Block, E.; Glass, R. S.; Jacobsen, N. E.; Johnson, S.; Kakachi, C.; Kaminski, R.; Skowronska, A.; Boakye, H. T.; Tyson, J. F.; Uden, P. C. Identification and Synthesis of a Novel Selenium-Sulfur Amino Acid Found in Selenized Yeast: Rapid Indirect Detection NMR Methods for Characterizing Low-Level Organoselenium Compounds in Complex Matrices. *J. Agric. Food Chem.* **2004**, *52*, 3761–3771.
2. Fahey, A. M.; Tyson, J. F. Education and Training of BS Analytical Chemists for Entry-Level Positions in Industry: A Survey. *Chem. Educator* [Online], **2006**, *11*, 445–450. <http://chemeducator.org/index.htm> (accessed Dec 13, 2006).
3. Hernandez, P. C.; Tyson, J. F.; Uden, P. C.; Yates, D. Determination of Selenium by Flow Injection Hydride Generation Inductively Coupled Plasma Optical Emission Spectrometry. *J. Anal. At. Spectrom.* [Online 2006]. DOI: 10.1039/b6126558h. Published Online: Dec 12, 2006. <http://www.rsc.org/Publishing/Journals/JA/Article.asp?Typos=AdvArticle> (accessed Dec 13, 2006).
4. Skoog, D. A.; West, D. M.; Holler, F. J.; Crouch, S. R. *Analytical Chemistry An Introduction*, 7th ed.; Thompson Learning: USA, 2000.
5. *Trace Elements in Clinical Medicine*; Tomita, H., Ed.; Springer-Verlag: Tokyo, 1990.
6. Tyson, J. F.; Yourd, E. Flame Atomic Absorption Spectroscopy, Including Hydride Generation and Cold Vapor Techniques. In *Atomic Spectroscopy in Elemental Analysis*. Cullen, M., Ed., Blackwell Publishing: Oxford, 2004; pp. 239–281.
7. The Graining Challenge, National Academy of Engineering of the National Academies. <http://www.nae.edu/graining.nsf> (accessed Dec 16 2006).

## A Word or Two about Italics and Bold Type

It is common practice in scholarly writing to italicize foreign words, especially Latin words. However, in the particular cases of *et al.* and one or two other abbreviations of Latin words (see page 85 in Chapter 5) that

are in common use in the U.S. chemistry community, the practice is generally not to italicize, though it is still done in the U.K. chemistry community. Note that in almost all reference formats, however, the journal title is given in italics, as are the titles of books. In the chemical literature, underlining is almost never used, and certainly never in the reference section, but bold-faced type may be used for headings and one or two items in the reference section, such as the year of publication or volume number (depending on which journal format is adopted).

## Reference-Management Software

Bibliographic-management or citation-management software typically consists of a database in which details of the article or book can be stored together with a way of creating selective lists of subsets of your stored material. Depending on the services offered by your library, it may be possible to populate your personal database directly from a larger database to which your institution has access (such as the Web of Science). Bibliographic software can interact with your word-processing software to create reference lists in any one of several predefined formats while you are creating your text. Using such software means that you will avoid inserting a reference that is not cited in the text and that it is unlikely that you will cite the same reference twice with different numbers. Of greater importance, it ensures that all of your references are in the same format, assuming that all of the fields in the database have been populated correctly. Some institutions may offer access to bibliographic-management software as part of the library services. Ask your reference librarian for information and a training session.

## CHECKLIST FOR CITING SOURCES

- Cite references by inserting numbers in the text, in numerical order, starting with number one.
- Observe the established practices in chemistry when referring to authors.

Use only the surnames of researchers.

When there are two researchers, use both surnames separated by *and*.

When there are more than two researchers, use the first-named author followed by *et al.*

- Try to make the relevance of the cited reference clear to the reader.
- Cite only sources you have actually read.
- When citing a review of a paper, cite the original article as well.
- Exercise good judgment regarding how many sources you cite; when in doubt, seek guidance from your instructor.

### CHECKLIST FOR PREPARING THE REFERENCES SECTION

- Include only those references specifically mentioned in your report or paper.
- Include a reference for every source cited in your paper.
- Adopt the format of a major publisher, such as the American Chemical Society.
- Use the same format consistently for every reference.
- Provide all the information required for each type of entry.

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## 4

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# REVISING

*The biggest problem with communication is the illusion that it has been accomplished.*

GEORGE BERNARD SHAW

### WHY REVISE?

Much of this book concerns the reading, note-taking, thinking, synthesizing, and organizing that permit you to capture your thoughts in a first draft. This chapter concerns the revising that must follow. As do most experienced writers, we, the authors of this book, revise our own writing four or five times before letting anyone else see it, and several more times after others have reviewed it. Only those who have had little experience actually writing harbor delusions that it is possible to do a really excellent job with a writing task without spending time revising. Don't feel inadequate for not producing flawless prose on your first or second draft: **the key to good writing is revision—a lot of it.**

Writing a first draft gives you the opportunity to get facts, ideas, and phrases on paper, where they won't escape. Writing involves a process of discovery. Sometimes you discover that you need to do more research or more reading or more in-depth thinking in order to write something that makes sense. If you wait until the night before the paper is due to begin to write and make this discovery (shocking thought, but some students do procrastinate), you won't have time to do a thorough job.

Once you have a working draft and have captured your thoughts, you can concentrate on reorganizing, expanding, and rephrasing them in the clearest, most logical way. **All writing benefits from revision.** Writing and then rereading what you have written typically clarify your thinking. Then, even when you know precisely what it is you want to say, there is

the universal difficulty of getting any point across intact to a reader. Revising your work improves communication and often leads you to a finer understanding of your subject.

It is difficult to revise your own work effectively unless you can examine it with fresh eyes. You know what you wanted to say, but without some distance from the work, you can't really tell whether you have actually said it. For this reason, **plan to complete your first draft at least three days before (and even more when possible) the final product is due, to allow time for careful revision.** Reading your paper aloud—and listening to yourself as you read—often reveals weaknesses that you would otherwise miss. It also helps to have one or more fellow students read and comment on your draft; it is always easier to identify writing problems—wordiness, ambiguity, faulty logic, factual errors, faulty organization, spelling and grammatical errors—in the work of others. Most colleges and universities have writing centers staffed by tutors trained to help you recognize patterns in your own writing, such as problems with clarity or wordiness or a too heavy reliance on passive voice. Choose whatever system works best for you, but **always revise your papers before submitting them.**

No matter how sound, or even brilliant, your thoughts and arguments are, how you express them will determine whether they are understood and appreciated. With pencil or pen at the ready, the time has come to revise your first draft: for content, for clarity, for completeness, for conciseness, and for correctness. If you are writing with a computer, make at least your first set of revisions on printed copy rather than on the screen. To edit effectively you must see more than one screen of text at a time. Continue editing and revising—printout by printout—until your work is ready for the eyes of the instructor, admission committee, journal editor, or potential employer. This chapter, as well as Chapter 5, should help you recognize when you have arrived at that point.

## REVISING FOR CONTENT

### Make Sure Every Sentence Says Something Worth Saying

Consider the following sentence for a paper on the dangers posed worldwide by arsenic contamination of groundwater.

Arsenic is a naturally occurring and potentially harmful element.

What does this sentence say? Does the writer really think the readers need to be told that arsenic occurs naturally in the environment or that it can harm humans? Even though it is true that not all elements occur naturally,

this is one of those sentences that provokes the reader to ask, "So what?" It amounts to little more than what we call written throat clearing: a bid for time while the writer thinks of something more substantive and specific to say. (For a more detailed discussion of throat clearing, see Chapter 5, pp. 73–76.) A careful editor will delete the sentence and begin anew with a sentence that says something worth reading. For example,

 Arsenic compounds are widespread in nature and are drawing increasing attention due to the contamination of ground water used for drinking and irrigation in several parts of the world.

Similarly, a sentence like

 Arsenic can be harmful to humans if ingested, could profitably be revised to read,

 Chronic arsenic exposure may increase the risk of skin, lung, and bladder cancer or damage the immune and cardio vascular systems.

The authors of the revised opening sentences know where their essays are headed, and so does the reader. The original versions got the writers started; the revision process focused the writers' attention on a destination.

Take a careful look at the first sentence of each paragraph that you write for a first draft. You will often find instances of throat clearing: with the substance of the paragraph delayed until the second or even third sentence. Consider the following example from a student's paper on the biological role of selenium in which the opening sentence suggests that the topic here is the chemical form and concentration of selenium:

 The multiple roles of selenium depend on the chemical form and concentration. The active site of the enzyme glutathione peroxidase contains selenium in the form of the amino acid selenocysteine. This enzyme catalyses the reduction of reactive oxygen species, such as hydrogen peroxide and lipid hydroperoxides. It also has cancer prevention properties. Selenium deficiency has been linked to some diseases in China. DNA damage by reactive oxygen species could arise from antioxidant deficiency. Much research suggests that selenium plays an important role in human health.

The first sentence is a classic example of throat clearing; but it provides an excellent illustration of why even effective writers resort to throat clearing when they are still thinking on paper or, in the case of most

writers these days, thinking at the keyboard as the words appear on the screen. The first sentence serves a useful purpose in writing the early draft: it buys the writer a few seconds to come up with the next, more substantive observation and then the next. Then, like a horse out of the gate, the writer is off and moving, accumulating a series of considerably more specific observations that, when it comes time to revise, make the first sentence seem inane because it is so general and, in this case, misleading. *That* is the beauty of revision. From the vantage point of increased insight, you can go back, eliminate the throat clearing and the rat-a-tat-tat cadence that thinking on screen often produces, and you can rethink the sequence in which you offer the observations to the reader, as illustrated by the following revision:



Selenium plays an important role in human health.<sup>1-5</sup> For example, selenium, in the form of the amino acid selenocysteine, is found in the active site of the enzyme glutathione peroxidase that catalyzes the reduction of reactive oxygen species, such as hydrogen peroxide and lipid hydroperoxides. Some diseases arising from DNA damage by reactive oxygen species have been associated with selenium deficiency, particularly in parts of China. Selenium also has cancer prevention properties that are related to the chemical form and concentration.

In the original draft, it is not until the end of the paragraph that the writer finally articulates the central point of the paragraph: that selenium plays an important role in human health. Now able to *re-vision* his paragraph, the writer crafts a much more effective topic sentence, dispenses with unnecessary verbiage (“Much research suggests”), and directs the reader’s attention to the relevant research that supports his assertion by referencing articles in superscript. As soon as the writer has figured out where the paragraph is going, reorganizing the rest of the sentences is relatively easy, and the result is a paragraph that does the work for the reader, instead of requiring the reader to make sense of a jumble of seemingly random observations.

### Show Rather Than Tell

A very useful principle to bear in mind when writing, not only about chemistry but writing in general, is to show rather than simply tell. As readers, we prefer to draw conclusions for ourselves as opposed to being told what to think. Writing that provides sufficient evidence to allow readers to draw their own evaluative conclusions is more effective than writing that offers glib opinions or unsupported conclusions.

**For example, never tell a reader that something is interesting.** Provide sufficient information to allow the reader to be the judge. Consider this rather uninformative sentence:



Surfactants are a particularly interesting class of molecules.

Are surfactants interesting? If so, don’t waste time simply telling the reader. Ask yourself why you find them interesting, and then share that information with your readers; *show* how this is true, so that they are right there with you, nodding, concluding as you have that there is indeed something interesting about surfactants. This example could, for instance, be rewritten as follows:



As the concentration of a surfactant in aqueous solution increases, the molecules spontaneously assemble into clusters in which the less polar parts of the molecule form the interior and the more polar parts are on the outside.

Given this information, readers can conclude for themselves that surfactants deserve their attention.

As a second example, consider the use of the word *relatively* in the following sentence in which the writer **tells** rather than shows:



Dendrimer molecules are relatively large.

The thoughtful reader wonders, “Relative to what?” because the writer has some evidence in mind that has led her to this conclusion but has not shared it with the reader. Consider the different effect when the writer shows what she means by “relatively large” by including the detail that informs her conclusion that will lead the reader to the very same conclusion:



Dendrimer molecules can contain many hundreds of atoms.



Dendrimers are made up of several smaller molecules connected in successive layers of branches.

Each of these sentences provides sufficient information to allow the readers to conclude for themselves that, on the scale of molecular sizes, dendrimers are toward the large end.

### Be Cautious in Drawing Conclusions but Not Overly So

When interpreting chemical data, it is always wise to be careful, particularly with access to only a few experiments or small data sets. For instance,

write, "These data suggest" rather than "These data demonstrate," or "prove that." Do not get carried away, as in the following example:



The data suggest the possibility that copper (II) ions may catalyze the formation of the fibrils.

Here the author hedges three times in one sentence, using the words *suggests*, *possibility*, and *may*. Limit yourself to one hedge per sentence, as in the following rewrite:



The data suggest that copper (II) ions catalyze the formation of the fibrils.

If you are too unsure of your opinion to write such a sentence, re-examine your opinion.

### Ensure That Your Writing Is Self-Sufficient

Good writing is always self-sufficient: the reader should not have to leave the text itself to consult textbooks or other sources in order to understand what you are saying. To make your writing self-sufficient, you must **anticipate the needs of your audience**. In particular, be sure to define all scientific terms and abbreviations; it is not enough simply to use them properly. Brief definitions will help keep the attention of readers who may not know or may not remember the meaning of some terms. It will also demonstrate to your instructor that you know the meaning of the specialized terminology you are using.

For example, the author of this sentence assumes the reader's familiarity with laser ablation sample introduction in a way that may confuse some readers:



Laser ablation sample introduction overcomes the problems associated with the dissolution of samples to form aqueous solutions.

The addition of a simple definition of what is involved in laser ablation makes the sentence much more reader friendly and effective.



The problems associated with the dissolution of samples to form aqueous solutions can be overcome by laser ablation, in which an aerosol of the solids generated by the interaction of a pulse of laser light with the sample surface.

By incorporating a brief explanation, the writer ensures that the reader moves steadily forward, head nodding, able to follow what was written.

## REVISING FOR CLARITY

When revising for clarity, it is essential to keep in mind the writer's obligation to do the work for the reader. Your goal is a reader whose head is nodding in a way that signals comprehension and engagement.

### Tip #1 Anticipate the Needs of Your Reader

To do the work for your readers, you need to anticipate their needs, but to do so, you need to know *who* your readers are. When you write papers or lab reports in chemistry classes, for whom are you writing? Writing with your professor in mind as your audience can create problems. Your professor, of course, knows much more than you do about the subject you are studying, and you may be tempted to think that he or she knows what you mean and not explain everything as clearly as you might otherwise. Or you may be so concerned with impressing the professor that you inadvertently sacrifice being clear and concise. We advise that you think of your reader as being someone who is at the same level in his or her academic career as you. Anticipating the needs of your reader can help you with many of the judgment calls you make such as *what* you write (what to include and how much detail) as well as *how* you write (what words to use and how formal to be).

For example, if you were writing the experimental section of a lab report for organic chemistry on synthesizing bromobutane, and part of the procedure is to add two boiling stones, if you think of your reader as someone less knowledgeable, you might feel a need to explain why this step was necessary.



Two boiling stones were added to the mixture in order to prevent bumping, namely the slight super heating followed by a large release of vapor, which produces smooth boiling on the edge of the stones where gas bubbles are nucleated. The mixture was boiled for 30 min.

If you envision your reader as a peer, you will probably conclude that your fellow student already knows why the boiling stones are added, so this is unnecessary wordiness. So, you can write a much more clear, more concise sentence:



Two boiling stones were added and the mixture was boiled for 30 min.

Anticipating and meeting the needs of your reader are key to writing effectively.

### Tip #2 Avoid Overusing Acronyms and Abbreviations

Overuse of acronyms and abbreviations can drive away potentially interested readers. Keep in mind though that *acronym* and *abbreviation* are not synonyms. DNA and IR are examples of abbreviations; FAOSS, which stands for the Federation of Analytical Chemistry and Spectroscopy Societies, is an example of an acronym because the initial letters form a pronounceable word. Some abbreviations, like DNA, are so widely known they never need to be defined. (See pp. 84–86 for more on abbreviations and acronyms.) When you are in doubt, err on the side of caution. You may be steeped in reading and thinking about a particular research topic, but you risk confusing your reader if you do not clarify the meaning of acronyms and abbreviations that are not widely used.

**Write to inform and enlighten, not to impress.** Often the names of techniques and chemicals are very long and are repeated frequently throughout a paper; in which case, it makes sense to use acronyms and abbreviations. What is a thoughtful writer to do? The American Chemical Society (ACS) advises that the first time you use a term, spell it out in full and place the abbreviation or acronym immediately after in parentheses. Once you have defined it, you can use the abbreviation or acronym throughout the rest of the paper.

First use:



The yield was significantly increased when the surfactant cetyltrimethylammonium bromide (CTAB) was added.

Thereafter:



All subsequent reactions were carried out in 0.1 M CTAB solutions.

### Tip #3 Keep the Reader Moving Forward

When you write a sentence that the reader finds confusing, you force the reader to back up and reread that sentence and puzzle out the intended meaning. As the author of the sentence, you, of course, know the intended meaning. It therefore requires some additional effort on your part to anticipate any source of potential confusion lurking in your sentence that might elicit head scratching on the part of the reader. For example, writers often find it difficult to write clearly about comparisons:

Consider the following sentence, in which the reader's progress is impeded because of ambiguity about what is being compared.



The column packed with silica particles accumulated 67% more phosphomolybdate than Teflon beads.

The initial assumption is that the ability of silica to accumulate two different materials is being compared, but when the reader encounters the words *Teflon beads*, it becomes clear that the writer is comparing two different packing materials and that silica accumulated more of the target compound than did Teflon. The alert reader can back up and figure out what the writer means, but if you are doing your job as a writer, you will avoid writing sentences that make it necessary for the reader to work so hard to grasp your meaning. The following revision makes clear in one straight-forward sentence exactly what is being compared to what:



The columns packed with silica particles accumulated 67% more phosphomolybdate than did the columns containing Teflon beads.

Here is another example, in which the points of comparison are not quite clear and the reader is forced to pause and ask, "In good agreement with what?"



When compared with the reference materials, the mercury concentrations were in good agreement

Backing up a couple sentences and rereading and giving it a moment's thought will lead the astute reader to conclude that the writer means "in good agreement with the mercury concentrations in the reference materials." The reader, however, should not need to puzzle over the intended meaning and should not have to backup and reread. With the simple goal of **keeping the reader moving forward in mind**, we would write a much better sentence:



The mercury concentrations measured were in good agreement with those of the reference materials.

Readers should never have to guess what the proper comparisons are; the less your readers have to work, the more they will appreciate your writing. In your efforts to keep the reader moving forward, you should make effective use of punctuation whenever possible. Punctuation marks such as commas, semicolons, and dashes are, after all, simply graphic symbols used by writers to assist their readers in grasping the intended meaning of the words in a sentence on a first reading. For example, read the

following sentences silently to yourself and notice what happens while you read:

1. For pharmaceuticals development and approval can take over seven years.
2. For some time after these results were regarded as definitive.
3. Finally the two liquid phases turned blue and green crystals formed.
4. While the crystals were forming a white solid appeared at the surface.
5. When a wet gas cools a mist may form.

More than likely you began reading the sentence with one expectation of the direction in which the sentence was headed, and then in each instance reached a point where you realized you had been misled by the absence of punctuation and were forced to go back and reread. When a writer anticipates the needs of the reader and uses punctuation effectively, rereading is not necessary. A comma signals the reader to pause ever so slightly in order to grasp the intended meaning in each of the sentences above. When in doubt, read your sentence aloud. If you find yourself pausing in order to convey the meaning you intend, a comma will assist the reader in reading it that way as well. Placing a comma to denote a pause is not a failsafe rule for comma use, but it can help in many situations. For a more thorough discussion of comma rules as well as other forms of punctuation that you will find helpful in making your writing more clear and correct, see Appendix A.

#### Tip #4 Beware of Modifiers and Their Perils

**Misplaced Modifiers.** In English, word order matters; that is, where words are placed relative to other words in a sentence affects meaning, especially words or phrases that modify other words in a sentence. Writing a sentence with either a misplaced modifier (one placed in such a way that it modifies the wrong word) or a dangling modifier (one that is left dangling because no word appears in the sentence that it can sensibly modify) can lead to ambiguity. Modifiers can take the form of a single word, a phrase, or even a clause, and in terms of meaning, they attach to the nearest noun or verb possible. Consider, for example, the following sentence from a campus newspaper describing a potentially disastrous incident in the chemistry building (we have bolded the errant modifier).

 The fire in the lab was put out before any damage was done by the local fire department.

In all likelihood, the student reporting on this incident did not intend to malign the local fire department whose prompt arrival and efficient handling of the fire were essential in averting what could have been a much more serious event. Written in this way, however, the modifying phrase *by the local fire department* attaches to the closest verb *done* so that the meaning of this sentence is that the fire was extinguished before the local fire department was able to do any damage. The author of this report probably meant to say,

 The fire in the lab was put out by the local fire department before any damage was done.

Repositioning the modifier here makes it clear that the worthy, dependable local firefighters arrived in time to put out the fire before the blaze did any damage.

Clearly, placement of modifiers matters because it affects meaning and clarity. Writing in chemistry often calls for the passive voice, and whenever a writer abandons the active voice, the perils of modifiers loom larger and additional vigilance is required to avoid mistaking them. For example, consider the following sentence written in the passive voice:

 Much research has been published in recent years on single-walled carbon nanotubes.

Single-walled carbon nanotubes seem an odd medium for publishing groundbreaking research. The modifying phrase *on single-walled carbon nanotubes* is misplaced and attaches to the verb *published*. Revision that places the modifying phrase so as to modify the noun *research* conveys a more sensible meaning:

 Much research on single-walled carbon nanotubes has been published in recent years.

**Dangling Modifiers.** While the revisions above required merely moving the misplaced modifiers to a different position, modifiers are sometimes left “dangling” because the word they should modify does not appear in the sentence. Dangling modifiers require more active intervention. Writing the experimental section of lab reports is a veritable minefield when it comes to dangling modifiers

because of the need to use passive voice and avoid the personal pronouns *I* or *we*. For example, consider the following sentence written in the passive voice:

 Before running the reaction, the apparatus was flame dried from bottom to top.

The phrase *before running the reaction* should attach to and modify human being, presumably the author of the sentence who did the experimental procedure, but disciplinary convention prohibits mention of the author. Thus the modifying phrase dangles and instead attaches to the word *apparatus* creating the ridiculous meaning that the apparatus ran the reaction. If active voice were an option, we could insert a human agent into the sentence and remedy the problem this way:

 Before I ran the reaction, I flame dried the apparatus from bottom to top.

However, if required to use the passive voice, we need to bring the modifying phrase in line with the rest of the sentence:

 Before the reaction was run, the apparatus was flame dried from top to bottom.

Problems with modifiers also frequently occur when students write about what appears in the published literature, especially when they introduce the research findings reported in a scientific paper with prepositional phrases such as *in this article* or *in this paper*. Even when using the active voice, as in the sentence below, it is easy to slip and place the phrase so that it attaches to the wrong verb and inadvertently misrepresents what occurs in the article. For example,

 In this article, Kemery, Steelner, and Bohn studied electric field mediated transport in nanometer diameter channels.

 In this paper, Caruso et al. interface chromatography with element-specific detection.

Each of these sentences makes it sound as if the studying and interfacing actually occurred *in* the article, which is of course impossible. The modifying phrases *In this article* and *In this paper* are left dangling because a more suitable verb, such as *report* or *discuss*, simply does not appear in the sentence. Remember to make clear that the work was not done *in the article*, but rather that the article *reports* on the work

that was done prior to the writing of the paper, most likely in a laboratory setting.

 In this article, Kemery, Steelner, and Bohn discuss . . .

 In this paper, Caruso et al. report the results obtained by . . .

**Note: Observe the convention of the eternal present** When you write, the convention with regard to verb tense, in chemistry and all academic writing, is to refer to what appears in print, electronically or in hard copy, whether it is a textbook, a scholarly article, or a magazine article in the present tense. For example, it may have taken Joe Caruso and his grad students a year to complete the research, but in the article they publish, they “describe” in the present tense what they “found when they interfaced” in the past tense. When you, in turn, write about their research, you should refer to what they claim or report in their paper in the present tense and what they did in the past tense.

### Tip #5 Avoid Ambiguity: The Dangers of *It*, *This*, and Other Pronouns

Frequent use of the pronouns *it*, *they*, *this*, *them*, *these*, *those*, and *that* in your writing should sound an alarm: probable ambiguity ahead. It is the writer’s job to make sure that the antecedent (the word the pronoun refers back to) is absolutely clear to the reader.

The following example demonstrates the ambiguity that can be caused by the pronoun *it*:

 As long as the number of protons in the nucleus of an atom does not change, it preserves its chemical individuality.

To what does *it* refer? What preserves its chemical individuality, the nucleus or the atom?

Similarly, the pronoun *it* makes the second part of the following sentence equally ambiguous.

 The chemical signal compound must then be transported to the specific target tissue, but it is effective only if it possesses appropriate receptors.

Are these receptors needed by the chemical signal compound or the target tissue? It is not clear.

In the next example, *these* causes similar problems for the reader.

 Broadening processes occur in the injection valve, column, and connecting tubings. These combine to give the overall chromatographic peak shape.

Presumably the “Broadening processes,” not the “connecting tubings,” are combining, although the author has certainly not made this clear.

The ambiguity created by the use of *these* in this sentence could be eliminated in several ways. We could begin the second sentence with *The broadening processes* . . . , but this results in a somewhat irritating singsong repetition. Another possibility is to use the relative pronoun *that*, as follows:

 Broadening processes that occur in the injection valve, column, and connecting tubings combine to give the overall chromatographic peak shape.

In the following sentence, the ambiguity about what the pronoun *them* refers to creates two distinct solutions to the problem of safe handling of volatile chemicals in the laboratory setting.

 To ensure that students do not have access to volatile chemicals, lock them in a storage facility.

Does *them* refer to the students or the volatile chemicals? While locking students in the closet would prevent them from having access to dangerous chemical substances, this hardly seems the most practical solution and incarcerating students is not likely to be popular with students, parents, or the administration. Placing the chemicals under lock and key seems a much more sensible solution, so we suggest a revision that makes clear that intended meaning:

 Volatile chemicals should be locked in a storage facility to ensure that students do not have access to them.

A patient reader will puzzle out the more sensible meaning, but its author has certainly violated one of our key principles: **never make the reader back up.**

In short, when revising your work, read it carefully and with skepticism, checking that you have said exactly what you mean. Never make the reader guess what you have in mind. Everything you write must make sense—to you and to your reader. As you read each sentence you have written ask yourself: what does this sentence really say? What did I mean

to say? Make each sentence work on your behalf, leading the reader easily from fact to fact, from thought to thought.

You need not be a grammarian to write clearly and correctly. With a little practice, especially if you read your work aloud, you can quickly learn to recognize a sentence in difficulty and sense how to fix it without even knowing the name of the grammatical rule that was violated.

### Tip #6 Revise for Parallelism

Parallelism—the use of similar grammatical structures to express similar elements of meaning—is a time-honored principle of style. Parallel structures not only create an ear-pleasing cadence, rhythm, and balance, but also allow a writer to create emphasis to help the reader grasp the intended meaning. When you are listing or pairing ideas or joining them together, use similar or parallel grammatical forms whenever possible to clarify and support content.

For example, consider this informative, but plodding, statement about the characteristics of aluminum.

 Aluminum is more abundant than any other metal in the earth's crust, is easy to reshape, silvery white in color, and after refinement from bauxite it costs less than fifteen cents per pound.

The sentence is not only leaden, but wordy and cumbersome. By listing each of the characteristics ascribed to aluminum in a parallel way, we get much more clear, more concise sentence.

 Aluminum is abundant, malleable, silvery white, and inexpensive.

If concision is not the main goal, and we really want to retain some of the detail of the original sentence because it suits our purposes, revising for parallelism makes it possible to work in a lot of information, but still write balanced, more ear-pleasing sentence.

 Aluminum, the most abundant metal in the earth's crust, is malleable, silvery white, and inexpensive, at fifteen cents per pound when refined from bauxite.

Let's consider some special attributes of another element and revise for parallelism.

 Calcium does play a role that is very significant in the biological functioning of the body because for one thing blood clotting is helped by it, and it plays a role in heartbeat regulation and also in enabling muscle contractions.



Calcium, which plays a vital role in biological functions, serves to facilitate blood clotting, to regulate heartbeat, and to enable muscle contractions.

At the thinking and drafting stage, ideas don't necessarily pour forth in perfect parallel structure, but once you have a draft, parallelism is a very useful tool to provide clarity to help your reader grasp your intended meaning, and to streamline and balance your sentence.

## REVISING FOR COMPLETENESS

### Do Not Assume the Reader Knows What You Mean

Revising for completeness brings us back once again to anticipating the needs of the reader. Sometimes writing is unclear because we are still mired in the struggle to understand what we are writing about. Even when we do understand, writing clearly is difficult because, in deciding how best to communicate what we know, it requires us to anticipate the needs of the reader who does not necessarily share our own knowledge or point of view. When we write, we must always think about how much information the reader needs in order to grasp what we are trying to say. Because it seems clear to us, we sometimes stop short of providing enough information for the reader to grasp our meaning, thereby invoking the “you-know-what-I-mean” defense.

When writing, you may know what you mean, but that does not guarantee that your reader will know what you mean. Remember that it is the writer's job to do the work for the reader, and part of that is to make sure that each thought is complete. Be specific in making assertions. For example, the following statement is much too vague because the writer has not provided sufficient context for the reader to grasp the meaning of *many*.



Many selenium compounds have been detected in urine.

How many is *many*? You may have a clear sense of what this means in the context that you are referring to, but will your reader? After editing the sentence might read,



About a dozen selenium compounds have been detected in urine.

Similarly, the following sentence gives us only a general sense of what the rate of arsine formation was when borohydride was the generating

reagent; contrast to when powdered zinc and acid were the generating reagents.



The rate of arsine formation was higher when the generating reagent was borohydride compared with the rate for the reaction with powdered zinc and acid.

Why stop with the vague *higher*, if you know it was 10 times higher?



The rate of arsine formation was 10 times higher when the generating reagent was borohydride compared with the rate for the reaction with powdered zinc and acid.

### Do the Work for the Reader: Avoid Using Etc.

Be especially careful to revise for completeness whenever you find that you have written *etc.*, an abbreviation for the Latin term *et cetera*, meaning *and other things* or *and the rest*. While you might use *etc.* at the draft stage when you would rather not interrupt the flow of your thoughts by thinking about exactly what *other things* you have in mind, when revising replace *etc.* with words of substance. In scientific writing, *etc.* makes the reader suspect fuzzy thinking. Ask yourself, “What exactly do I have in mind here?” If you come up with additional items for your list, add them. If you find that you have nothing to add, simply replace the *etc.* with a period and you will have produced a shorter, clearer sentence.

Consider the following sentence and its revision:



The amount of product formed in a given time depends on a number of factors, such as concentration of reactants, etc.



The amount of product formed in a given time depends on a number of factors, such as concentration of reactants, temperature, and pressure.

In the original version, the author dodged the responsibility of clear writing and doing the work for the reader by forcing the reader to determine what is meant by *etc.* The sentence, although grammatically correct, is incomplete, waiting for the reader to fill in the missing information. The reader may justifiably wonder if the writer knows what other factors influence the extent of a chemical reaction. The revised sentence clearly indicates what the writer had in mind. Revising for completeness often requires you to return to your notes or the sources upon which your notes are based in order to fulfill your obligation to your reader.