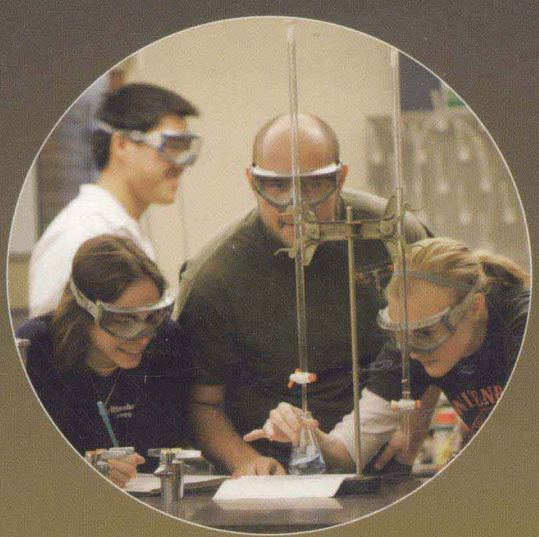
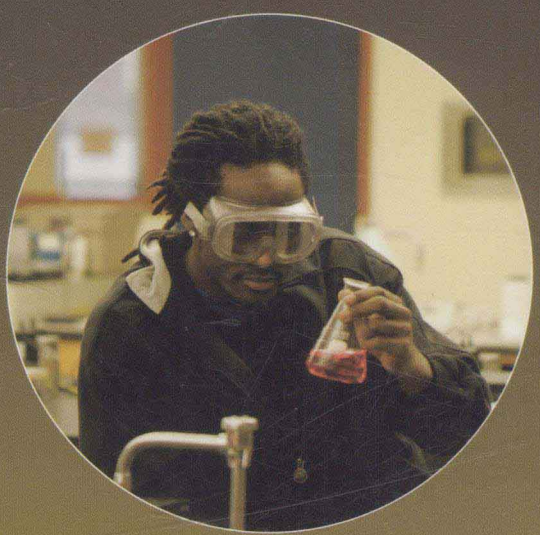
LABORATORY SAFETY FOR CHEMISTRY STUDENTS





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WILEY

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LABORATORY SAFETY FOR CHEMISTRY STUDENTS

To those who have suffered personal loss, injuries, and even death in laboratory incidents that were preventable. May we use the knowledge from these incidents to teach the next generation of scientists about laboratory and chemical safety.

PREFACE: TO THE STUDENTS

THERE IS probably no single course in "laboratory safety or chemical safety" at your college or university. Why not? Chemistry curricula have developed over many decades with a focus on the main topics of chemistry: organic, inorganic, physical chemistry, analytical chemistry, and (more recently) biochemistry. For decades, the topic of chemical safety was included at the margins of lab courses, mostly taught in a small way as a footnote to various lab experiments and procedures. Some chemists and chemistry teachers were aware of the importance of safety, while many were not. In the late twentieth century, and now even more in the twenty-first century, for a variety of legal, ethical, and educational reasons, the topic of chemical safety has been taught much more, but it is still not considered by most as "mainstream content area" of chemistry. The absence of good resources (a void we hope this book fills) contributed to this stature. In summary, many chemistry faculty simply don't consider instruction in laboratory and chemical safety to be very important—or at least important enough to devote a whole course to the topic.

While this textbook could easily be used as a primary textbook for a course in chemical safety, the authors actually strongly prefer that it be used instead throughout the curriculum. We believe that safety instruction is so important that it should be included in *all chemistry laboratory courses*. Additionally, the small "bites" of lab safety included among the 70 sections used separately over an extended four-year period provide constant reinforcement of the importance of safety that nurtures a strong safety ethic. This book has been written with that use in mind.

How so? As you will see, the eight chapters in the book are "layered" in three tiers, with a variety to topics suited to introductory, intermediate, and advanced courses. Each section presents information on a "need to know" basis. For example, there's actually a lot to know about wearing gloves in labs, but you don't need to know everything right away. The first section about gloves is written for introductory courses; a later section is written for organic and advanced students. The same is true for eye protection and for chemical hoods. In this regard, the book is structured unlike any other college textbook you've ever seen. It really is a book that will last for four years (and beyond).

We expect that most of the sections in this book will be tied to various experiments that you are conducting in labs. Again, let's learn what we need to learn on a "need to know" basis. Working with flammable chemicals? Read about solvents and fires. Working with a strong acid or oxidizing agent? Read about corrosives. Worried about lab emergencies or lab incidents? Read about emergency response. This may be the most practical textbook you use in college!

Why should you learn about safety? Well, to stay safe, of course, in the laboratory. This reason alone is enough, but there are additional advantages to knowing about safety. First, it's cheap. Accidents always cost more money than whatever is spent on safety equipment and materials that help prevent these incidents. Second, being safe prevents injuries, damage to health, perhaps even death, and these outcomes have costs that obviously go beyond money. Third, it's environmentally responsible. Knowing how to use chemicals and dispose of wastes legally and appropriately is being environmentally conscious (in a way, frankly, that the chemical industry was not for many decades in the twentieth century). Fourth, you develop habits that will make you a valuable employee someday. Chemical companies now understand, better than many colleges and universities, that being safe is the soundest financial practice a company can adopt. And as more laws and regulations have been developed over the past several

decades, employers and employees really have no choice about many aspects of laboratory safety. Your understanding of this situation, upon graduation, will make you an attractive candidate for a job.

While much of this book is very practical and "informational" in nature, some early sections discuss the issue of one's mental attitude about safety, which may seem more philosophical in nature at first. But, in reality, adopting a positive attitude about safety is *the* most important, practical step you can take to be safe. With this mindset, all other actions in a laboratory are performed only after stopping to think about hazards and risks and the means by which you can stay safe in the lab.

We hope you find this book valuable as part of your chemical education. As chemists, the authors have the same passion for chemistry as do your teachers. Understanding nature through the "filter of chemistry" provides great insight and intrinsic joy to most chemists, in addition to the tremendous power of chemistry to improve the quality of the human condition. We are passionate about safety, too, and hope that your time in the lab is both intellectually rewarding and safe! There is much to learn, as the size of this book indicates, and the book offers not much more than an introduction to most topics. We hope that you continue your "safety education" long after you graduate from college.

Finally, you will notice that each section begins with an "Incident". Stories are powerful, and often memorable, ways to learn a principle or to reveal a danger. We hope you find these incidents useful and we encourage you to share your story about safety with us! Hopefully, the story is a happy one about what "almost happened" (although you will see that most of our incidents are not "near misses"). If you have a story that will help some future student learn from your experience, please contact us at dfinster@wittenberg.edu or roberth_hill@mindspring.com. Maybe your story will be in the next edition of the book! We'd also like to hear how you like the book or have suggestions for improvement. Stay safe!

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Springfield, Ohio
March 2010

TO THE INSTRUCTOR

Purpose

THE PRINCIPAL purpose of this textbook is to provide a resource that can be used to help teach undergraduate chemistry students the basics of laboratory and chemical safety. This textbook is not designed for a single course but rather its concept is to use short sections in laboratory sessions (or perhaps some lecture sessions) over the four years of undergraduate study. It can be used as a companion text for each laboratory chemistry course throughout the curriculum, including research, using specific sections that fit the topics and hazards of the laboratory experiments.

It is the vision and hope of the authors that if the chemistry academic community has a textbook about laboratory and chemical safety that they will use parts or all of it in the laboratory or classroom curriculum. This book was written from the heart as a result of a passion for laboratory and chemical safety. The authors recognize, as do many others, that there is a need to improve the level of knowledge and education about laboratory and chemical safety among new and upcoming chemists and other laboratory scientists who work in laboratories and handle chemicals and other hazardous materials in their operations.

We believe that laboratory and chemical safety should be integral parts of the entire chemistry educational process, touching virtually all fields of chemistry, since we see laboratory and chemical safety as subdisciplines of the field of chemistry that cross-cuts virtually all areas of chemistry. Thus, teaching safety is a long-term effort that requires attention as each area of chemistry is introduced and advances so that a strong knowledge and positive attitude toward laboratory and chemical safety can be developed. Our approach is to teach laboratory and chemical safety in small sections throughout the chemical education process. This iterative process is practical from a learning point of view and sends the message to students: safety is always important.

Audience

This textbook is written primarily for undergraduate chemistry students, but we believe other laboratory science students, scientists, technicians, and investigators will also find it useful. Many graduate and working chemists will find this book useful since it is likely that they are unfamiliar with the level of laboratory and chemical safety education found in this book. Those working in industrial, government, and other independent laboratory situations will also find this book useful. Although designed as a teaching tool and not a resource text, it can serve in the latter capacity and contains many references to other resources.

Scope

This book is broad in scope since it introduces most areas of laboratory and chemical safety. This book is not a comprehensive treatise on laboratory and chemical safety and it does not go into great detail with specific procedures or methods. It presents various topics on a "need to know" basis, targeting

different levels of instruction throughout a chemistry curriculum. This book will help chemists and other scientists use four simple principles of laboratory and chemical safety to:

1. **R**ecognize hazards;
2. **A**ssess the risks of those hazards;
3. **M**inimize, manage, or control those hazards; and
4. **P**repare to respond to emergencies.

We use the acronym RAMP to remind the student of these principles—RAMP up for safety.

Unique Approach and Organization

This is a unique textbook designed to be used throughout the four years of undergraduate study. Topics are targeted toward each level (year) of study by the students over their undergraduate experience. Topically, it is divided into eight chapters, and further into 70 sections for introductory (year 1) intermediate (year 2) and advanced topics (years 3 and 4).

- Chapter 1 Principles, Ethics, and Practices
- Chapter 2 Emergency Response
- Chapter 3 Understanding and Communicating About Laboratory Hazards
- Chapter 4 Recognizing Laboratory Hazards: Toxic Substances and Biological Agents
- Chapter 5 Recognizing Laboratory Hazards: Physical Hazards
- Chapter 6 Risk Assessment
- Chapter 7 Minimizing, Controlling, and Managing Hazards
- Chapter 8 Chemical Management: Inspections, Storage, Wastes, and Security

Each section begins with a preview, a quote, and a laboratory incident that asks "What lessons can be learned from this incident?" This is followed by the text that is relevant to the topic and incident with references that often contain links to the Internet. Dispersed through out the book are *Chemical Connections* that seek to demonstrate how safety uses chemical principles and *Special Topics* that seek to explain relevant topics of interest to a particular section. Each section also concludes with a series of multiple choice questions about the topic.

Safety, like other disciplines, is principle driven. The student must be encouraged to use critical thinking in applying safety principles and practices to conduct chemical work safely and to identify the need for additional information about the safety in operations handling chemicals or other hazardous agents.

How This Book Can Be Used

We anticipate several ways in which the book may be used. It may be used directly by the student and taught by an instructor. However, the authors are well aware of the difficulty of adding more to the curriculum and believe that each section can be used as a prelaboratory assignment session. The student can be directed to go to a web site to take an electronic quiz for each section with results going to the laboratory instructor to ensure that each student has been successful in understanding the basic topics presented in a section before the laboratory session.

More specifically, we anticipate two models for using the sections as prelab assignments:

1. An instructor can assign a reading and electronic quiz, and do little more. This practice alone may represent an improvement in safety instruction, requires virtually no additional work on the part of the instructor and no allocation of class/lab time, and provides some form of assessment of student learning.
2. An instructor can assign a reading and the electronic quiz, and follow this up in a prelab session with discussion of the topic, probably making specific reference to the experiment of the day,

which is likely to be related to the safety topic. The degree to which the instructor elaborates on the topic can be considerable. Discussion questions and "what if" scenarios are easy to develop. The value of the book is that precious lab time is not spent on "covering the basics" and "information transfer." Students will come to the lab with some background knowledge, which allows for a more productive, and likely more sophisticated, discussion of a particular safety topic.

Ultimately, our goal in providing this resource is to minimize, if not eliminate, the activation energy barrier that prevents many faculty from discussing safety more in their classes and labs. The excuse that "there's not enough time" is eliminated when no class or lab time, in the first model above, is used. The excuse that "I'm not trained in safety" is eliminated since the book provides the expertise and thoughtful presentation of the safety topics. The American Chemical Society Committee on Professional Training requires (as stated in the Guidelines and Evaluation Procedures for Bachelor's Degree Programs) the "approved programs should promote a safety-conscious culture in which students understand the concepts of safe laboratory practices and how to apply them." Use of this book meets that learning goal.

Ideally, this book would be purchased in the first year for chemistry majors and used as a supplementary text throughout the entire undergraduate chemistry curriculum. However, the authors recognize that many students in introductory courses are not chemistry majors and will not continue in the chemistry curriculum. Using the Wiley Custom Select option, there is also the opportunity to make single sections of the book available for clustering in faculty—designed packets that are individually suited to particular teachers, courses, and/or campuses. This will be at an attractive price that makes use of the packets reasonably as a supplementary purchase for students. The strategy can be pursued throughout the curriculum, although at some point the purchase of the entire book, particularly for chemistry majors, would seem prudent.

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R. H. H., Jr.
D. C. F.

ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienist
ACS	American Chemical Society
AIDS	Acquired immunodeficiency syndrome
ALARA	As low as reasonable achievable
APHIS	Animal and Plant Health Inspection Service
ANSI	American National Standards Institute
ASSE	American Society of Safety Engineers
BBP	Blood-borne pathogens
BEI	Biological exposure index
BLEVE	Boiling liquid expanding vapor explosion
BMBL	Biosafety in Microbiological and Biomedical Laboratories
BSL	Biosafety Levels
CAS	Chemical Abstracts Service
CCW	Counterclockwise
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CHO	Chemical Hygiene Officer
CHP	Chemical Hygiene Plan
CLIPS	Chemical Laboratory Information Profiles
CNS	Central nervous system
CPR	Cardiopulmonary resuscitation
CSB	U.S. Chemical Safety and Hazard Investigation Board
CW	Clockwise
DOL	Department of Labor
DHS	Department of Homeland Security
DOT	Department of Transportation
ELF	Extremely low frequency
EMF	Electromagnetic frequency
EMT	Emergency medical technician
EPCRA	Emergency Planning and Community Right-to-Know Act
EPA	U.S. Environmental Protection Agency
FAS	Fetal alcohol syndrome
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GFCI	Ground fault circuit interrupters
GHS	Globally Harmonized System of Classification and Labeling of Chemicals
HAZWOPER	Hazardous Waste Operations and Emergency Response
HBV	Hepatitis B virus
HEPA	High efficiency particulate air
HHS	Department of Health and Human Services
HVAC	Heating, vacuum, and air conditioning
IARC	International Agency for Research on Cancer
IDLH	Immediately dangerous to life and health
IEC	International Electrotechnical Commission
IR	Infrared
LCSSs	Laboratory Chemical Safety Summaries
MRI	Magnetic resonance imaging
MSDS	Material Safety Data Sheet
NFPA	National Fire Protection Association
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NMR	Nuclear magnetic resonance
NRC	Nuclear Regulatory Commission
NSF	National Sanitation Foundation (can also be National Science Foundation)
NTP	National Toxicology Program
OEL	Occupational exposure limit
OJT	On the job training

OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PHA	Process hazard analysis
PSM	Process Safety Management of Highly Hazardous Materials
RCA	Root Cause Analysis
RCRA	Resource Conservation and Recovery Act
RAMP	Recognize, Assess, Minimize, Prepare
REL	Recommended exposure limit
RF	Radio frequency
SDS	Safety Data Sheet
SI	Système International
STEL	Short-term exposure limit
SWDA	Safe Water Drinking Act
TLV	Threshold Limit Value
TSCA	Toxic Substances Control Act
TWA	Time-weighted average
UL	Underwriter's Laboratory
USDA	U.S. Department of Agriculture
UV	Ultraviolet
VLF	Very low frequency
WHO	World Health Organization
RSO	Radiation Safety Officer
RSP	Radiation Safety Program
RSC	Radiation Safety Committee
SCBA	Self-contained breathing apparatus

CONTENTS