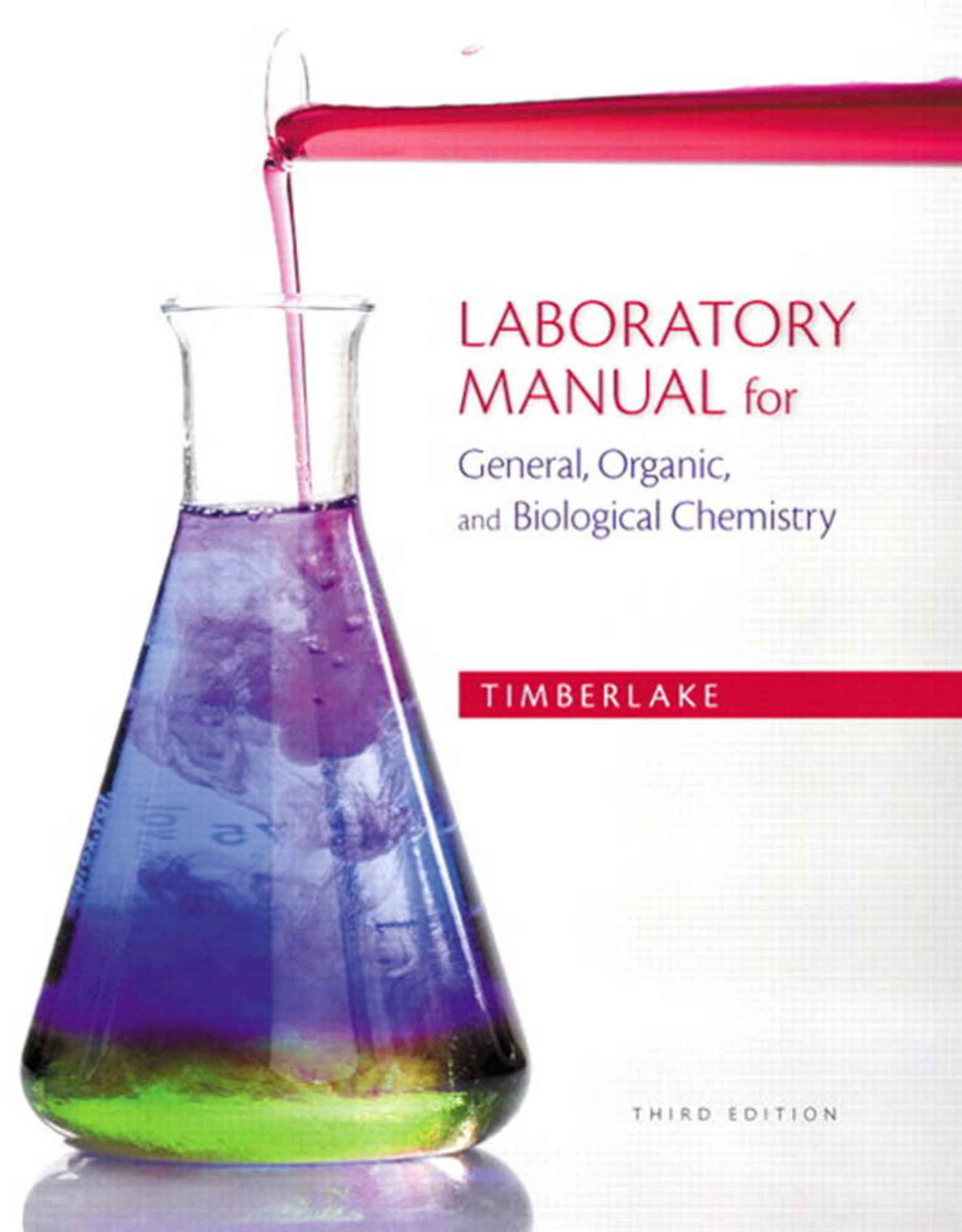
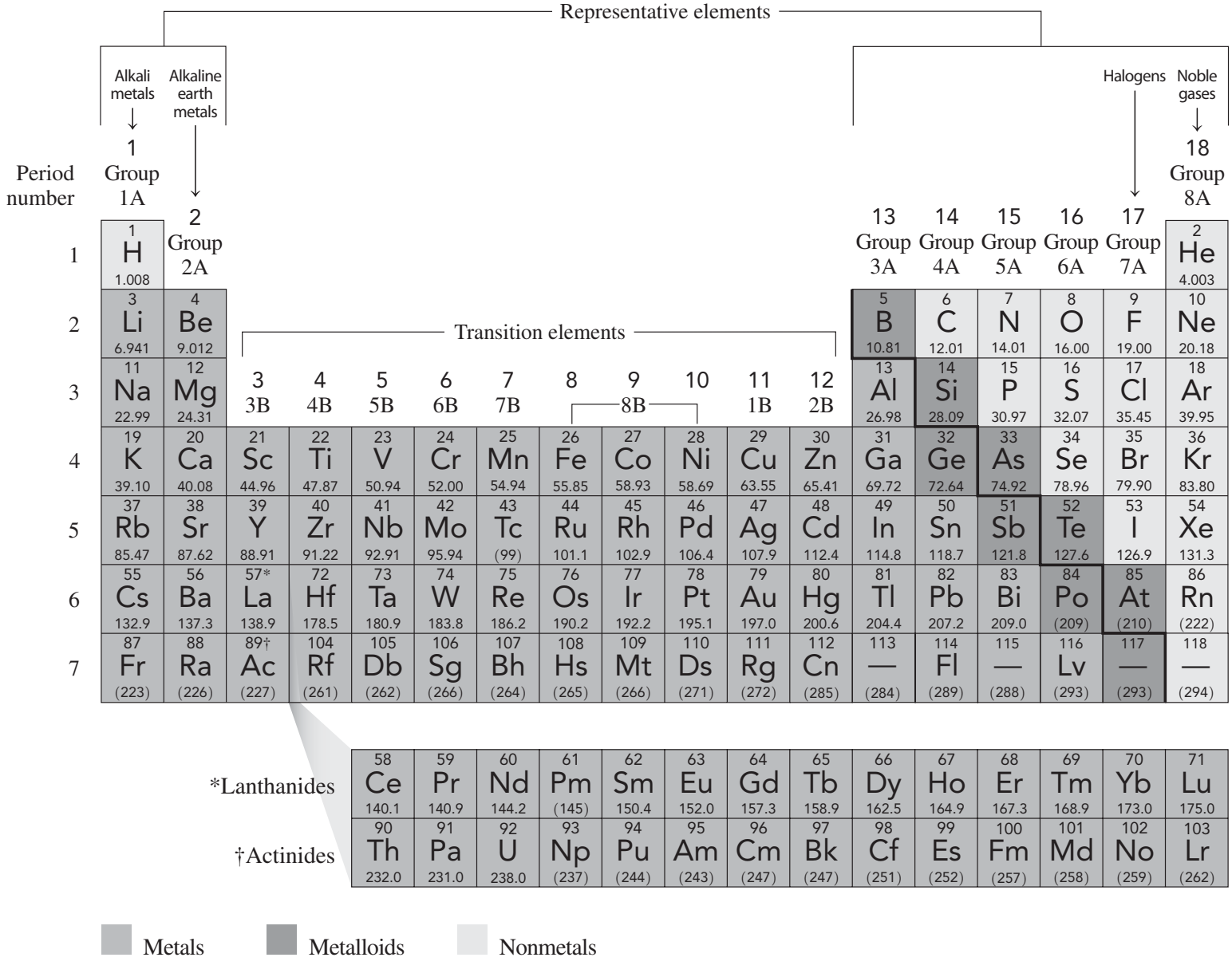


# LABORATORY MANUAL for

## General, Organic, and Biological Chemistry

TIMBERLAKE

THIRD EDITION


Representative elements
Alkali metals
Alkaline earth metals
Halogens
Noble gases
Period number
1 Group 1A
2 Group 2A
13 Group 3A
14 Group 4A
15 Group 5A
16 Group 6A
17 Group 7A
18 Group 8A
Transition elements
3 3B
4 4B
5 5B
6 6B
7 7B
8
9 8B
10
11 1B
12 2B
1 H 1.008
2 He 4.003
3 Li 6.941
4 Be 9.012
5 B 10.81
6 C 12.01
7 N 14.01
8 O 16.00
9 F 19.00
10 Ne 20.18
11 Na 22.99
12 Mg 24.31
13 Al 26.98
14 Si 28.09
15 P 30.97
16 S 32.07
17 Cl 35.45
18 Ar 39.95
19 K 39.10
20 Ca 40.08
21 Sc 44.96
22 Ti 47.87
23 V 50.94
24 Cr 52.00
25 Mn 54.94
26 Fe 55.85
27 Co 58.93
28 Ni 58.69
29 Cu 63.55
30 Zn 65.41
31 Ga 69.72
32 Ge 72.64
33 As 74.92
34 Se 78.96
35 Br 79.90
36 Kr 83.80
37 Rb 85.47
38 Sr 87.62
39 Y 88.91
40 Zr 91.22
41 Nb 92.91
42 Mo 95.94
43 Tc (99)
44 Ru 101.1
45 Rh 102.9
46 Pd 106.4
47 Ag 107.9
48 Cd 112.4
49 In 114.8
50 Sn 118.7
51 Sb 121.8
52 Te 127.6
53 I 126.9
54 Xe 131.3
55 Cs 132.9
56 Ba 137.3
57* La 138.9
72 Hf 178.5
73 Ta 180.9
74 W 183.8
75 Re 186.2
76 Os 190.2
77 Ir 192.2
78 Pt 195.1
79 Au 197.0
80 Hg 200.6
81 Tl 204.4
82 Pb 207.2
83 Bi 209.0
84 Po (209)
85 At (210)
86 Rn (222)
87 Fr (223)
88 Ra (226)
89† Ac (227)
104 Rf (261)
105 Db (262)
106 Sg (266)
107 Bh (264)
108 Hs (265)
109 Mt (266)
110 Ds (271)
111 Rg (272)
112 Cn (285)
113 — (284)
114 Fl (289)
115 — (288)
116 Lv (293)
117 — (293)
118 — (294)
*Lanthanides
58 Ce 140.1
59 Pr 140.9
60 Nd 144.2
61 Pm (145)
62 Sm 150.4
63 Eu 152.0
64 Gd 157.3
65 Tb 158.9
66 Dy 162.5
67 Ho 164.9
68 Er 167.3
69 Tm 168.9
70 Yb 173.0
71 Lu 175.0
†Actinides
90 Th 232.0
91 Pa 231.0
92 U 238.0
93 Np (237)
94 Pu (244)
95 Am (243)
96 Cm (247)
97 Bk (247)
98 Cf (251)
99 Es (252)
100 Fm (257)
101 Md (258)
102 No (259)
103 Lr (262)
Metals
Metalloids
Nonmetals

# LABORATORY MANUAL for

## General, Organic, and Biological Chemistry

THIRD EDITION

TIMBERLAKE

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Editor in Chief: Adam Jaworski
Executive Editor: Jeanne Zalesky
Senior Marketing Manager: Jonathan Cottrell
Project Editor: Jessica Moro
Assistant Editor: Lisa R. Pierce
Editorial Assistant: Lisa Tarabokjia
Marketing Assistant: Nicola Houston
Executive Editorial Media Producer: Deb Perry
Managing Editor, Chemistry and Geosciences: Gina M. Cheselka
Production Project Manager: Wendy Perez
Full Service/Composition: PreMediaGlobal
Project Manager, Full Service: Revathi Viswanathan
Photo Manager: Maya Melenchuck
Photo Permissions Specialist: Eric Schrader
Text Permissions Manager: Alison Bruckner
Text Permissions Specialist: Danielle Simon, Creative Compliance
Operations Specialist: Jeffrey Sargent
Cover Designer: Seventeenth Street Studios
Cover Photograph: *shoot4u/Fotolia*

Credits and acknowledgments borrowed from other sources and reproduced, with permission, in this textbook appear on the appropriate page within the text.



ISBN-10: 0-321-81185-2; ISBN-13: 978-0-321-81185-1

PEARSON **www.pearsonhighered.com** 1 2 3 4 5 6 7 8 9 10—VHO—16 15 14 13 12

# Contents

# Preface

In the process of writing the lab manual for *General, Organic, and Biological Chemistry*, I have developed experiments that illustrate each of the chemical principles we discuss in our chemistry classes. I have also taken care to make each experiment workable as well as provide critical-thinking tools. The main organizational concepts of this laboratory manual are as follows:

- **Experiments relate to basic concepts of chemistry.** Experiments are designed to illustrate the chemical principles we discuss in our classes.
- **Experiments are flexible.** Each experiment includes a flexible group of sections that can be taught in any order, which allows instructors to select sections that fit into their weekly laboratory schedule. Lab times and comments are given for each.
- **Safety.** A detailed safety section in this preface includes a safety quiz. The aim here is to highlight the safety and equipment preparation on the first day of lab. In addition, each lab section contains instructions on safe behavior in the laboratory specific to that section. Students are reminded to wear goggles for every lab session. Some experiments are recommended as instructor demonstrations.
- **Experiment format provides clear instructions and evaluation.** Each lab section begins with a set of laboratory goals, a discussion of the chemical concepts, and examples of calculations. The report sheets begin with pre-lab questions to prepare students for laboratory work. Students obtain data, draw graphs, make calculations, and write conclusions about their results. Each lab contains questions and problems that require the student to discuss the experiment, make additional calculations, and use critical thinking to apply concepts to real life.

I hope that this laboratory manual will help you in your chemistry instruction and that students will find they learn more chemistry by participating in the laboratory experience.

Karen C. Timberlake
Los Angeles Valley College
Valley Glen, CA 91401

# New to This Edition

- Each experiment now begins with the Laboratory Goals and Lab Information.
- The Chemical Concepts (formerly called 'Discussion') now include a complete discussion of the chemistry topics relevant to the experiment.
- Art has been added to the Chemical Concepts, including figures from the text that give visual representations of the concepts.
- The diagrams of Laboratory Equipment in the Preface were updated and new illustrations were added.
- Section titled *Using a Pipet* was added to the Preface.
- Layout of the Experimental Procedures section was revised. Changes include:
  - An overview statement with each procedure to indicate what students will be doing.
  - Procedures rewritten for clarity and consolidated for better flow of laboratory work.
  - Removal of the boxed-type framework and procedures keyed to the Report Sheet.
- All experiments were revised for this edition to create a more efficient lab experience for students.
- A Correlation Guide that matches each experiment lab to the corresponding chapters in all Timberlake texts is placed on the Instructor Resource Center at *www.pearsonhighered.com/chemistry*.
- The Appendices, which include materials needed for each lab for 20 students, have been moved to the Instructor Resource Center at *www.pearsonhighered.com/chemistry.*
- Inclusion of both new and rewritten Pre-lab questions for clarity and stronger assessment of concept comprehension.
- Increased font size for the Pre-lab questions and Report Sheets to improve legibility.

# To the Student

Here you are in a chemistry laboratory with your laboratory book in front of you. Perhaps you have already been assigned a laboratory drawer, full of glassware and equipment you may never have seen before. Looking around the laboratory, you see bottles of chemical compounds, balances, burners, and other equipment that you are going to use. This may very well be your first experience with experimental procedures. At this point you might have some questions about what is expected of you. This laboratory manual is written with those considerations in mind.

The activities in this manual were written specifically to parallel the topics you are learning in your chemistry class. Many of the laboratory activities include materials that will be familiar to you, such as household products, diet drinks, cabbage juice, antacids, and aspirin. In this way, chemical topics are related to the real world and to your own science experience. Some of the labs teach basic skills; others encourage you to extend your scientific curiosity beyond the lab.

It is important to realize that the value of the laboratory experience depends on you investing time and effort in it. Only then will you find that the laboratory can be a valuable learning experience and an integral part of the chemistry class. The laboratory gives you an opportunity to go beyond the lectures and words in your textbook and experience the scientific process from which conclusions and theories concerning chemical behavior are drawn. In some experiments, the concepts are correlated with health and biological concepts. Chemistry is not an inanimate science, but one that helps us to understand the behavior of living systems.

A section on laboratory safety is included in the preface and followed by a detailed Safety Quiz, which highlights safety and equipment. Each lab also includes reminders of safe behavior and the author specifically recommends certain experiments for instructor demonstrations.

# Using This Laboratory Manual

- Each experiment begins with a clear set of laboratory goals to give you an overview of the topics you will be studying in that experiment.
- There are Pre-Lab Study Questions on easy-to-remove pages at the beginning of each laboratory report section. These questions should be completed before you come to lab. Your laboratory instructor may require that you hand in the Pre-Lab Study Questions before you begin your laboratory work.
- Each experiment is correlated to concepts you are currently learning in your chemistry class. Your instructor will indicate which activities you are to do. You will find a list of the materials needed at the beginning of each of the experiments.
- When you are ready to begin a lab, remove the Report Sheets and place them next to the Laboratory Procedures for that experiment.
- The Experimental Procedures give instructions for you to complete each experiment successfully. The steps are numbered to guide you as you proceed to measure carefully, report your data, and complete calculations.
- Questions throughout the report sheet are designed to test your understanding of the chemical concepts from the experiment.

It is my hope that the laboratory experience will help illustrate the concepts you are learning in your chemistry class. The experimental process can help make chemistry a real and exciting part of your life and provide you with skills necessary for your future.

# Working Safely in the Laboratory

The chemistry laboratory with its equipment, glassware, and chemicals is a place where accidents can occur. Precautions must be taken by every student to ensure the safety of everyone working in the laboratory. By following the rules for handling chemicals safely and carrying out only the approved procedures, you will help to create a safe environment in the laboratory. After you have read the following sections, complete the safety quiz and the questions on laboratory equipment. Then sign and submit the lab safety commitment to your instructor.

## A. Preparing for Laboratory Work

**Pre-read** Before you come to the laboratory, read the discussion of and directions for the experiment you will be doing that day. Make sure you know what the experiment is about before you start the actual work. If you have a question, ask your instructor to clarify the procedures.

**Do assigned work only** Do only the experiments that have been assigned by your instructor. No unauthorized experiments are to be carried out in the laboratory. Experiments are done at assigned times, unless you have an open lab situation. Your instructor must approve any change in procedure.

### Do not work alone in a laboratory.

**Safety awareness** Learn the location and use of the emergency eyewash fountains, the emergency shower, fire blanket, fire extinguishers, and exits. Memorize their locations in the laboratory. Be aware of other students in the lab carrying chemicals to their desk or to a balance.

**Safety goggles must be worn all the time when you are in the lab** In the Experimental Procedures for each lab, you will see the following reminder to wear your safety goggles:

**EXPERIMENTAL PROCEDURES**  ***GOGGLES REQUIRED!***

The particular type of goggles you should wear depends on state law, which usually requires industrial-quality eye protection. Contact lenses may be worn in the lab if needed for therapeutic reasons, provided that safety goggles are worn over the contact lenses. Contact lenses without goggles are dangerous because splashed chemicals make them difficult to remove. If chemicals accumulate under a lens, permanent eye damage can result. If a chemical should splash into your eyes, flood the eyes with water at the eyewash fountain. Continue to rinse with water for at least 10 minutes.

**Wear protective clothing** Wear sensible clothing in the laboratory. Loose sleeves, shorts, or open-toed shoes can be dangerous. A lab coat is useful in protecting clothes and covering arms. Wear shoes that cover your feet to prevent glass cuts; wear long pants and long-sleeved shirts to protect skin. Long hair must be tied back so it does not fall into chemicals or a flame from a Bunsen burner.

**No food or drink is allowed at any time in the laboratory** Do not let your friends or children visit while you are working in the lab; have them wait outside.

**Prepare your work area** Before you begin a lab, clear the lab bench or work area of all your personal items, such as backpacks, books, sweaters, and coats. Find a storage place in the lab for them. All you will need is your laboratory manual, a calculator, a pen or pencil, the text, and equipment from your lab drawer.

## B. Handling Chemicals Safely

**Check labels twice** Be sure you take the correct chemical. DOUBLE-CHECK THE LABEL on the bottle before you remove a chemical from its container because some chemical names are similar. For example, sodium sulfate ($Na_2SO_4$) could be mistaken for sodium sulfite ($Na_2SO_3$) if the label is not read carefully.

**Use small amounts of chemicals** Pour or transfer a chemical into a small, clean container (beaker, test tube, flask, etc.) available in your lab drawer. To avoid contamination of the chemical reagents, never insert droppers, pipets, or spatulas into the reagent bottles. Take only the quantity of chemical you need for the experiment. Do not keep a reagent bottle at your desk; return it to its proper location in the laboratory. Immediately label the container that you transfer the chemical to. Many containers have etched sections on which you can write in pencil. If not, use tape or a marking pencil.

**Do not return chemicals to the original containers** To avoid contamination of chemical reagent bottles, dispose of used chemicals according to your instructor's instructions. Never return unused chemicals to reagent bottles. Some liquids and water-soluble compounds may be washed down the sink with plenty of water, but check with your instructor first. Dispose of organic compounds in specially marked containers in the hoods.

**Do not taste chemicals; smell a chemical cautiously** Never use any equipment such as a beaker to drink from. When required to note the odor of a chemical, first take a deep breath of fresh air while you use your hand to fan some vapors toward your nose and note the odor. Do not inhale the fumes directly. If a compound gives off an irritating vapor, use it in the fume hood to avoid exposure to it.

**Do not shake laboratory thermometers** Laboratory thermometers respond quickly to the temperature of their environment. Shaking a thermometer is unnecessary and can cause breakage.

**Liquid spills** Clean up spills of water or liquids at your work area or floor immediately. Small spills of liquid chemicals can be cleaned up with a paper towel. Large chemical spills must be treated with absorbent material such as cat litter. Place the contaminated material in the proper waste container and label it. If a liquid chemical is spilled on the skin, flood immediately with water for at least 10 minutes. Any clothing soaked with a chemical must be removed immediately, because it can continue to damage the skin.

**Mercury spills** The cleanup of mercury requires special attention. Mercury spills may occur from broken thermometers. Notify your instructor immediately of any mercury spills so that special methods can be used to clean up the mercury. Place any free mercury and mercury cleanup material in special containers for mercury only.

**Laboratory accidents** Always notify your instructor of any chemical spill or accident in the laboratory. Broken glass can be swept up with a brush and dust pan and placed in a specially labeled container for broken glass. Cuts are the most common injuries in a lab. If a cut should occur, wash, elevate, and apply pressure if necessary.

**Clean up** Wash glassware as you work. Begin your final cleanup 15 min before the end of the laboratory session. Return any borrowed equipment to the stockroom. Be sure that you always turn off the gas and water at your work area. Make sure you leave a clean desk. Wash your hands before you leave the laboratory.

## C. Heating Chemicals Safely

**Heat only heat-resistant glassware** Only glassware marked Pyrex or Kimax can be heated; other glassware may shatter at high temperatures. To heat a substance in a test tube, use a test tube holder. Holding the test tube at an angle, move it continuously through the flame. Never point the open end of the test tube at anyone or look directly into it. A hot piece of iron or glass looks the same as it does at room temperature. Place a hot object on a tile or a wire screen to cool.

**Flammable liquids** Never heat a flammable liquid over an open flame. If heating is necessary, your instructor will indicate the use of a steam bath or a hot plate.

**Never heat a closed container** When a closed system is heated, it can explode as pressure inside builds.

**Fire** Small fires can be extinguished by covering them with a watch glass. If a larger fire is involved, use a fire extinguisher to douse the flames. *Do not direct a fire extinguisher at other people in the laboratory.* Shut off gas burners in the laboratory. When working in a lab, tie long hair back away from the face. If another student's clothing or hair catches on fire, get the student to the floor and roll him or her into a fire blanket. You can also place the student under a nearby safety shower to extinguish flames. Cold water or ice may be applied to small burns.

## D. Waste Disposal

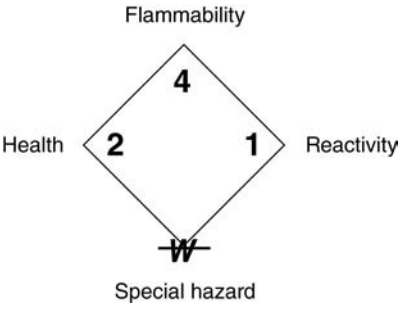
Chemical wastes are produced when you work in the laboratory. Although you will use small quantities of materials, some waste products are unavoidable. To dispose of these waste products safely, you need to know some general rules for chemical waste disposal.

**Metals** Metals should be placed in a designated container to be recycled.

**Nonhazardous chemical waste**s Substances such as sodium chloride (NaCl) that are soluble in water and are not hazardous may be emptied into the sink and rinsed down the drain with running water. If the waste is a solid, dissolve it in water before disposal or simply throw into the regular trash.

**Hazardous chemical wastes** If a substance is hazardous or not soluble in water, it must be placed in a container that is labeled for waste disposal. Your instructor will inform you if chemical wastes are hazardous and identify the proper waste containers. If you are not sure about the proper disposal of a substance, ask your instructor. The labels on a waste container should indicate if the contents are hazardous, the name of the chemical waste, and the date that the container was placed in the lab.

**Hazard rating** The general hazards of a chemical are presented in a spatial arrangement of numbers with the flammability rating at the twelve o'clock position, the reactivity rating at three o'clock, and the health rating at nine o'clock. At the six o'clock position, information may be given on the reactivity of the substance with water. If there is unusual reactivity with water, the symbol W (do not mix with water) is shown. In the laboratory, you may see these ratings in color with blue for health hazard, red for flammability, and yellow for reactivity hazards.




A chemical is assigned a relative hazard rating that ranges from 1 (little hazard) to 4 (extreme hazard). The health hazard indicates the likelihood that a material will cause injury due to exposure by contact, inhalation, or ingestion. The flammability hazard indicates the potential for burning. The reactivity hazard indicates the instability of the material by itself or with water with subsequent release of energy. Special hazards may be included such as W for reactivity with water or OX for oxidizing properties.

## E. Safety Quiz

This quiz will test you on the preceding safety discussion. Circle the correct answer(s) in each of the following questions and check your answers.

1. Approved eye protection is to be worn
   a. for certain experiments
   b. only for hazardous experiments
   c. all the time

2. Eating in the laboratory is
   a. not permitted
   b. allowed at lunch time
   c. all right if you are careful

3. If you need to smell a chemical, you should
   a. inhale deeply over the test tube
   b. take a breath of air and fan the vapors toward you
   c. put some of the chemical in your hand, and smell it

4. When heating liquids in a test tube, you should
   a. move the tube back and forth through the flame
   b. look directly into the open end of the test tube to see what is happening
   c. direct the open end of the tube away from other students

5. Unauthorized experiments are
   a. all right as long as they don't seem hazardous
   b. all right as long as no one finds out
   c. not allowed

6. If a chemical is spilled on your skin, you should
   a. wait to see if it stings
   b. flood the area with water for 10 minutes
   c. add another chemical to absorb it

7. When taking liquids from a reagent bottle,
   a. insert a dropper
   b. pour the reagent into a small container
   c. put back what you don't use

8. In the laboratory, open-toed shoes and shorts are
   a. okay if the weather is hot
   b. all right if you wear a lab apron
   c. dangerous and should not be worn

9. When is it all right to taste a chemical used in the lab?
   a. never
   b. when the chemical is not hazardous
   c. when you use a clean beaker

10. After you use a reagent bottle,
    a. keep it at your desk in case you need more
    b. return it to its proper location
    c. play a joke on your friends and hide it

11. Before starting an experiment,
    a. read the entire procedure
    b. ask your lab partner how to do the experiment
    c. skip to the laboratory report and try to figure out what to do

12. Working alone in the laboratory without supervision is
    a. all right if the experiment is not too hazardous
    b. not allowed
    c. allowed if you are sure you can complete the experiment without help

13. You should wash your hands
    a. only if they are dirty
    b. before eating lunch in the lab
    c. before you leave the lab

14. Personal items (books, clothes, etc.) should be
    a. kept on your lab bench
    b. left outside
    c. stored out of the way, not on the lab bench

15. When you have taken too much of a chemical, you should
    a. return the excess to the reagent bottle
    b. store it in your lab locker for future use
    c. discard it using proper disposal procedures

16. In the lab, you should wear
    a. practical, protective clothing
    b. something fashionable
    c. shorts and loose-sleeved shirts

17. If a chemical is spilled on the table,
    a. clean it up right away
    b. let the stockroom help clean it up
    c. use appropriate adsorbent if necessary

18. If mercury is spilled,
    a. pick it up with a dropper
    b. call your instructor
    c. push it under the table where no one can see it

19. If a student's hair or shirt catches on fire,
    a. use the safety shower to extinguish the flames
    b. get the student to the floor and roll
    c. roll the student in a fire blanket

20. Hazardous waste should be
    a. placed in a special waste container
    b. washed down the drain
    c. placed in the wastebasket

## Answer Key to Safety Quiz

| Question | Answer | Question | Answer | Question | Answer |
|---|---|---|---|---|---|
| 1 | C | 8 | C | 15 | C |
| 2 | A | 9 | A | 16 | A |
| 3 | B | 10 | B | 17 | A, C |
| 4 | A, C | 11 | A | 18 | B |
| 5 | C | 12 | B | 19 | A, B, C |
| 6 | B | 13 | C | 20 | A |
| 7 | B | 14 | C | | |

# Commitment to Safety in the Laboratory

I have read the laboratory preparation and safety procedures. I agree to comply with the safety rules by carrying out the following procedures. I will

_____ Read laboratory instructions ahead of lab time.

_____ Know the locations of eyewash fountains, fire extinguishers, safety showers, and exits.

_____ Wear safety goggles or safety glasses in the laboratory at all times.

_____ Use the proper equipment for laboratory procedures.

_____ Never perform any unauthorized experiments or work alone in the laboratory.

_____ Remember what is still hot if I have used the Bunsen burner or hot plate.

_____ Immediately clean up chemical spills and broken glass.

_____ Immediately inform the instructor of a chemical spill or accident in the laboratory.

_____ Never eat or drink in the laboratory.

_____ Wear sensible clothing and closed shoes, and if my hair is long, I will tie it back in the laboratory.

_____ Read the labels on reagent bottles carefully, remove only small amounts of reagent with the proper tools, and never return unused chemical to the bottle or insert droppers or any other equipment into the bottle.

_____ Dispose of broken glass and waste chemicals in the appropriate waste container.

_____ Never leave an experiment when substances are heating or reacting.

_____ Wash my hands and leave a clean work area when I leave the lab.

_____

Signature

_____

Printed name

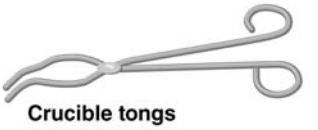
_____ _____

Laboratory class and section Date

# Laboratory Equipment

**Evaporating dish**
Used to evaporate a solution to dryness

**Crucible and cover**
Used to heat small samples to high temperatures



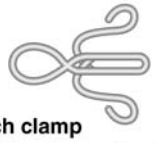
**Crucible tongs**
Used to pick up a crucible

**Watch glass**
Used to cover a beaker or to hold a small amount of a substance



**Stirring rod**
Used to mix or combine two or more substances in a test tube or a beaker

**Forceps**
Used to pick up a small object or one that is hot



**Pinch clamp**
Used to close rubber tubing

**Spatula**
Used to transfer small amounts of a solid

**Buchner funnel**
Used to separate solids from liquids using a vacuum

**Thermometer**
Used to measure the temperature of a substance

**Pipet**
Used to transfer a specific volume of liquid solution to a container

**Buret**
Used to deliver a measured amount of solution with a known concentration

**Medicine dropper**
Used to deliver drops of a solution or liquid