LABORATORY MANUAL FOR PRINCIPLES OF GENERAL CHEMISTRY

TENTH EDITION

J.A.Beran

WILEY

Name of Chemist ______________________ Tel. No. (optional) ______________________

Local Address (optional) ______________________

Local Laboratory Information

	First Term	Second Term	Third Term
1. Laboratory Instructor's Name			
2. Laboratory Section Number			
3. Laboratory Room Number			
4. Desk Number			
5. Month / Day / Year			

Location of Safety Equipment Nearest to Your Laboratory Bench

1. Safety Shower			
2. Eye Wash Fountain			
3. Fire Extinguisher			
4. Fume Hood			

QUICK REFERENCE FOR ICONS USED IN THIS TEXT

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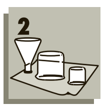

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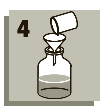

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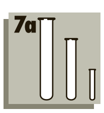

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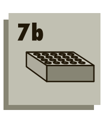

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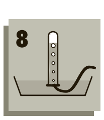

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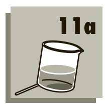

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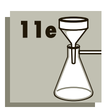

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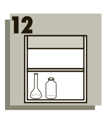

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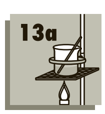

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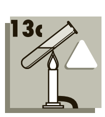

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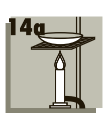

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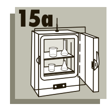

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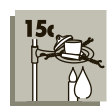

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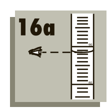

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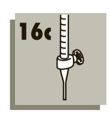

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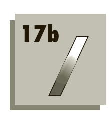

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Laboratory Manual for Principles of General Chemistry

10th Edition

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WILEY

The author of this manual has outlined extensive safety precautions in each experiment. Ultimately, it is your responsibility to practice safe laboratory guidelines. The author and publisher disclaim any liability for any loss or damage claimed to have resulted from, or been related to, the experiments.

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Preface

Chemistry laboratories have changed with advances in technology and safety issues.

Which came first in chemistry? Was it the experiments that led to well-documented principles or was it the principles that led to developing experiments? The answer is obvious … historically, observations of chemical phenomena were made from which explanations were developed. Experiments were undertaken from which explanations were made and written in textbooks. Serendipity in chemistry has played a major role in break through discoveries; an unexpected observation was made, analyzed, and interpreted and new science was born. Good scientists believe in their data. Therefore, the sequence for science development is that

experiments write textbooks, textbooks don't write experiments.

The **Laboratory Manual for Principles of General Chemistry** has focused on the laboratory experience through each of its nine previous editions. Realizing that all experimental conclusions are not the same, each conclusion is dependent upon identifying an appropriate experimental procedure, selecting the proper apparatus, employing the proper techniques while systematically analyzing and interpreting the data, and minimizing the inherent variables associated with the student scientist. As a result of "good" data, a scientific and analytical conclusion is made which may or may not "be right," but consistent with the data. This approach has been prevalent throughout the previous nine editions of this manual.

The Front Cover. The front cover of the 10^{th} edition was selected to illustrate how a student's scientific knowledge steadily grows and matures when various experiences and observations associated with the scientific experience are encountered.

Growing a plant in a flower bed or glazed pottery requires time, patience, practice and experience. The weather, the soil, the moisture, the fertilizer all factor into the growth of a plant. Nutrients and environmental factors affect the development and the maturation process of the young, vulnerable test tube plant. Experimentation provides the avenue by which the plant matures with desirable characteristic and properties.

Students of general chemistry and the general chemistry laboratory in particular, grow through this same process. Chemicals are mixed in test tubes under varying conditions of temperature, pressure, and concentrations resulting in observations from which interpretations and hypotheses result. Further experimentation provides additional "cause & affect" observations leading to an even better understanding and appreciation of the experiment. The process continues. Consequently, the scientific maturation process of the student continues much like the challenges of the "plant."

The general chemistry laboratory is a beginning for observing chemical phenomena from which chemical principles develop for a better understanding, not only for chemistry majors but also for all students who desire to have a career in a science-based discipline.

With this focus, reviewers have supported the challenges and format offered in previous editions—the experiments are interesting, informative, challenging, and have good pedagogy regarding laboratory techniques, safety, and experimental procedures. The reporting and analyzing of the data and the questions (pre- and post-lab) seek to focus on the intuitiveness of the experiment. In the 10^{th} edition, an emphasis for handling data has been moved to the front of the manual and entitled **Data Analysis**; points of analysis are placed as margin notes as appropriate in the experiments.

While all comments of users and reviewers from the previous editions have been heavily weighed, the task of presenting the "perfect" manual, like chemistry and science in general, is impossible. The manual, in itself, is an ongoing experiment and will continue to be.

Breadth (and Level) of the 10th Edition

This manual covers two semesters (or three quarters) of a general chemistry laboratory program. A student may expect to spend three hours per experiment in the laboratory; limited, advanced preparation and/or extensive analysis of the data may lengthen this time. The experiments were chosen and written so that they may accompany any general chemistry text.

Features of the 10th Edition

Safety and Disposal. "Safety first" is again emphasized throughout the manual, with recent advisories and guidelines being added. **Laboratory Safety and Guidelines** outlines personal and laboratory safety rules and issues. Icons in the Experimental Procedures cite **Cautions** for handling various chemicals, the proper **Disposal** of chemicals, and the proper **Cleanup** of laboratory equipment. ***Prelaboratory Assignment*** questions often ask students to review the safety issues for the experiment.

Laboratory Techniques. Numbered icons cited at the beginning of each experiment and within the Experimental Procedure are referenced to basic laboratory techniques that enable the student to complete the experiment more safely and efficiently. The **Laboratory Techniques** section provides a full explanation of 17 basic general chemistry laboratory techniques (along with the corresponding icons) that are used throughout the manual.

Handling small test tubes are encountered throughout the manual – those techniques have been moved from Dry Lab 4, to the **Laboratory Techniques** section. The technique for mixing solutions in a test tube has been added to Laboratory Technique 7, Handling Small Volumes; the technique for heating solutions in test tubes, flasks, or beakers has been added to Laboratory Technique 13, Heating Liquids and Solutions.

Data Analysis. A new section toward the front of the manual incorporates a greater emphasis on presenting and analyzing experimental data. The seven parts (A–G) of the **Data Analysis** section includes emphasis on the use and significance of significant figures and of data averages, standard deviations, and relative standard deviations. Additionally, graphing guidelines are included for the construction of graphical data and the interpretations that can be gathered from graphs. These analytical techniques are emphasized throughout the manual as margin notes where appropriate.

Organization. The experiments are categorized according to subject matter. This format was widely accepted by users and reviewers and retained in the 10th edition. For example, all redox experiments are grouped in Part J such that the sequential numbering of the experiments within Part J indicates a greater degree of complexity. *Experiment 27*, Oxidation–Reduction Reactions, is the simplest of the experiments involving oxidation–reduction reactions, and *Experiment 33*, Electrolytic Cells: Avogadro's Number, is perhaps the most difficult of the oxidation–reduction experiemnts.

Report Sheets. Report Sheets are more user-friendly! Data entries on the Report Sheet are distinguished from calculated entries—the calculated entries are shaded on the Report Sheet. Students also are encouraged to engage appropriate software for analyzing and plotting data.

Additionally, at the discretion of the instructor, the web site www.wiley.com/college/chem/brean provides downloadable Excel Report Sheet templates for each experiment where a numerical analysis is required.

New to the 10th Edition

Prelaboratory Assignment and Laboratory Questions. New to the Prelaboratory Assignment is a problem that analyzes representative experimental data solved in a format paralleling that of the Report Sheet for analyzing data from the Experimental Procedure. Only the experiments that require an analytical analysis have this type of question in the Prelaboratory Assignments. The design of the question is to better prepare the handling and the reporting of experimental data.

Additionally, many of the questions are new or revised in the ***Prelaboratory Assignment*** and ***Laboratory Questions*** in the 10th edition and all of the questions have been reviewed for clarity.

Revised Experiments. All of experiments from the ninth edition have been retained but have been addressed for clarity in the Experimental Procedures for obtaining good data while using proper chemical techniques and on the Report Sheet for recording and analyzing data. These refinements have become increasingly important for today's students who continue to develop, in general, a multitude of state-of-the-art electronic skills.

The Next Step. The Next Step is a feature added to the eighth edition and has been met with anticipated inclusion into open-ended laboratory programs. Based on the tools and techniques gained with completion of the experiment, The Next Step takes students from its completion to ideas for an independent, self-designed experience or experiment.

Laboratory Equipment. Simple laboratory glassware and equipment, shown in the early sections of the manual, are necessary for completing most experiments. Where appropriate, the apparatus or technique is shown in the experiment with a line drawing or photograph. Analytical balances, spectrophotometers (*Experiments 34* and *35*), pH meters (*Experiment 18*), and multimeters (*Experiments 32* and *33*) are suggested; however, if this instrumentation is unavailable, these experiments can be modified without penalizing students.

Contents of the Tenth Edition

The manual has five major sections:

- **Laboratory Safety and Guidelines.** Information on self-protection, what to do in case of an accident, general laboratory rules, and work ethics in the laboratory are presented.
- **Laboratory Documentation.** Guidelines for recording and reporting data are described. Suggestions for setting up a laboratory notebook are presented.
- **Data Analysis.** Seven topics focus on presenting reliable and interpretive data that are collected and analyzed.
- **Laboratory Techniques.** Seventeen basic laboratory techniques present the proper procedures for handling chemicals and apparatus. Techniques unique to qualitative analysis (*Experiments 37–39*) are presented in *Dry Lab 4*.
- **Experiments and Dry Labs.** Thirty-nine experiments and four "dry labs" are subdivided into 12 basic chemical principles.
- **Appendices.** Five appendices include conversion factors, names of common chemicals, vapor pressure of water, concentrations of acids and bases, and water solubility of inorganic salts.

Contents of Each Experiment

Each experiment has six sections:

- *Objectives.* One or more statements establish the purposes and goals of the experiment. The "flavor" of the experiment is introduced with an opening photograph.
- *Techniques.* Icons identify various laboratory techniques that are used in the Experimental Procedure. The icons refer students to the **Laboratory Techniques** section where the techniques are described and illustrated.
- *Introduction.* The chemical principles, including appropriate equations and calculations that are applicable to the experiment, and general interest information are presented in the opening paragraphs. New and revised illustrations have been added to this section to further enhance the understanding of the chemical principles that are used in the experiment.
- *Experimental Procedure*. The Procedure Overview, a short introductory paragraph, provides a perspective of the Experimental Procedure. Detailed, stepwise directions are presented in the Experimental Procedure. Occasionally, calculations for amounts of chemicals to be used in the experiment must precede any experimentation.
- *Prelaboratory Assignment*. Questions and problems about the experiment prepare students for the laboratory experience. The questions and problems can be answered easily after studying the Introduction and Experimental Procedure. The new Prelaboratory Assignment question, formatted to that of the Report Sheet, is designed to subsequently facilitate the analysis of data in the experiment. This question-type appears in those experiments requiring quantitative results.
- *Report Sheet*. The Report Sheet organizes the observations and the collection and analysis of data. Data entries on the Report Sheet are distinguished from calculated (shaded) entries. *Laboratory Questions*, for which students must have a thorough understanding of the experiment, appears at the end of the Report Sheet.

Instructor's Resource Manual

The *Instructor's Resource Manual* (available to instructors from Wiley) continues to be most explicit in presenting the details of each experiment. Sections for each experiment include:

- Overview of the experiment
- Instructor's Lecture Outline
- Teaching Hints
- Representative or expected data and results
- Chemicals Required
- Special Equipment
- Suggested Unknowns
- Answers to the Prelaboratory Assignment and Laboratory Questions
- Laboratory Quiz

Offered as a supplement to the *Instructor's Resource Manual* is a Report Sheet template for those experiments requiring the numerical analysis of data. The format of the templates is based on Microsoft Excel software and is available from Wiley on adoption.

The Appendices of the *Instructor's Resource Manual* detail the preparation of all of the solutions, including indicators, a list of the pure substances, and a list of the special equipment used in the manual *and* the corresponding experiment number for each listing. Users of the laboratory manual have made mention of the value of the *Instructor's Resource Manual* to the laboratory package.

Reviewers

The valuable suggestions provided by the following reviewers for this ninth edition are greatly appreciated:

Sylvia Diaz
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Adelphi University

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What a staff at Wiley! Thanks to Jennifer Yee, Senior Project Editor, for her keen insight, helpful suggestions, and unending commitment to see the manual through its birth; Joyce Poh, Associate Production Manager, for coordinating the production of the manual; Lisa Gee, Senior Photo Editor, for assistance in obtaining the photographs for this edition; Kenji Ngieng, Designer; Kristine Ruff, Senior Marketing Manager; and Ashley Gayle, former Editorial Assistant for Chemistry at Wiley.

A special note of appreciation is for Judi, who has unselfishly permitted me to follow my professional dreams and ambitions since long before the first edition of this manual in 1978. She has been the "rock" in my life. And also to Kyle and Greg, who by now have each launched their own families and careers—a Dad could not be more proud of them and their personal and professional accomplishments. My father and mother gave their children the drive, initiative, work ethic, and their blessings to challenge the world beyond that of our small Kansas farm. I shall be forever grateful to them for giving us those tools for success.

James E. Brady, St. Johns University, Jamaica, NY, who was a coauthor of the manual in the early editions, remains the motivator to review and update the manual and to stay at the forefront of general chemistry education. Gary Carlson, my *first* chemistry editor at Wiley, gave me the opportunity to kick off my career in a way I never thought possible or even anticipated. Thanks Jim and Gary.

The author invites corrections and suggestions from colleagues and students.

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Contents

Appendixes

Courtesy of Thermo Fisher Scientific

Wearing proper laboratory attire protects against chemical burns and irritations.

Laboratory Safety and Guidelines

The chemistry laboratory is one of the safest environments in an academic or industrial facility. Every chemist, trained to be aware of the potential dangers of chemicals, is additionally careful in handling, storing, and disposing of chemicals. Laboratory safety should be a constant concern and practice for everyone in the laboratory.

Be sure that you and your partners practice laboratory safety and follow basic laboratory rules. It is your responsibility, *not* the instructor's, to *play it safe*. A little extra effort on your part will assure others that the chemistry laboratory continues to be safe. Accidents do and will occur, but most often they are caused by carelessness, thoughtlessness, or neglect.

The inside front cover of this manual has space to list the location of important safety equipment and other valuable reference information that are useful in the laboratory. You will be asked to complete this at your earliest laboratory meeting.

This section of the manual has guidelines for making laboratory work a safe and meaningful venture. Depending on the specific laboratory setting or experiment, other guidelines for a safe laboratory may be enforced. Study the following guidelines carefully before answering the questions on the ***Report Sheet*** of *Dry Lab 1*.

Courtesy of Thermo Fisher Scientific

Goggles for eye protection.

A. Self-Protection

1. Approved safety goggles or eye shields *must be worn* at all times to guard against the laboratory accidents of others as well as your own. Contact lenses should be replaced with prescription glasses. Where contact lenses must be worn, eye protection (safety goggles) is *absolutely necessary*. A person wearing prescription glasses must also wear safety goggles or an eye shield. Discuss any interpretations of this with your laboratory instructor.
2. Shoes *must* be worn. Wear only shoes that shed liquids. High-heeled shoes; open-toed shoes; sandals; shoe tops of canvas, leather, or fabric straps or other woven material are *not* permitted.
3. Clothing should be only nonsynthetic (cotton). Shirts and blouses should not be torn, frilled, frayed, or flared. Sleeves should be close-fit. Clothing should cover the skin from "neck to below the knee (preferable to the ankle) and *at least* to the wrist." Long pants that cover the tops of the shoes are preferred.

   Discuss any interpretations of this with your laboratory instructor.
4. Laboratory aprons or coats (nonflammable, nonporous, and with snap fasteners) are highly recommended to protect outer clothing.
5. Gloves are to be worn to protect the hand when transferring corrosive liquids. If you are known to be allergic to latex gloves, consult with your instructor.
6. Jewelry should be removed. Chemicals can cause a severe irritation if concentrated, under a ring, wristwatch, or bracelet; chemicals on

Adam Gault/Getty Images

Laboratory gloves protect the skin from chemicals.

fingers or gloves can cause irritation around earrings, necklaces, and so on. It is just a good practice of laboratory safety to remove jewelry.

7. Secure long hair and remove (or secure) neckties and scarves.

8. Cosmetics, antibiotics, or moisturizers are *not* to be applied in the laboratory.

9. *Never* taste, smell, or touch a chemical or solution (see B.4 below). Individual allergic or sensitivity responses to chemicals cannot be anticipated. Poisonous substances are not always labeled.

10. *Technique 3*, page 20, provides an extensive overview of the proper handling of chemicals, from the dispensing of chemicals to the safety advisories for chemicals (NFPA standards). Additionally, online access to the MSDS collection of chemicals[1] provides further specifics for all chemicals that are used in this manual.

All other techniques in the **Laboratory Techniques** section describe procedures for safely conducting an experiment. Be sure to read each technique carefully before the laboratory session for completing a safe and successful experiment.

11. Wash your hands often during the laboratory, but *always* wash your hands with soap and water before leaving the laboratory! Thereafter, wash your hands and face in the washroom. Toxic or otherwise dangerous chemicals may be inadvertently transferred to the skin and from the skin to the mouth.

B. Laboratory Accidents

Doug Martin/Science Source

An eye wash can quickly remove chemicals from the eyes; a safety shower can quickly remove chemicals from the body.

1. Locate the laboratory safety equipment such as eyewash fountains, safety showers, fire extinguishers, and fume hoods. Identify their locations on the inside front cover of this manual.

2. **Report all accidents** or injuries, even if considered minor, *immediately* to your instructor. A written report of any and all accidents that occur in the laboratory may be required. Consult with your laboratory instructor.

3. If an **accident occurs,** *do not panic*! The most important first action after an accident is the care of the individual. ***Alert your laboratory instructor immediately!*** If a person is injured, provide or seek aid *immediately*. Clothing and books can be replaced and experiments can be performed again later. Second, take the appropriate action regarding the accident: clean up the chemical (see B.8, page 3), use the fire extinguisher (see B.6 below), and so on.

4. Whenever your skin (hands, arms, face, etc.) comes into contact with chemicals, quickly flush the affected area for several minutes with tap water followed by thorough washing with soap and water. Use the eyewash fountain to flush chemicals from the eyes and face. *Get help immediately.* Do *not* rub the affected area, especially the face or eyes, with your hands before washing (see A.11 above).

5. Chemical spills over a large part of the body require immediate action. Using the safety shower, flood the affected area for at least 5 minutes. Remove all contaminated clothing if necessary. Use a mild detergent and water only (no salves, creams, lotions, etc.). Get medical attention as directed by your instructor.

6. In case of fire, discharge a fire extinguisher at the base of the flames and move it from one side to the other. Small flames can be smothered with a watchglass (do *not* use a towel because it may catch on fire). Do *not* discharge a fire extinguisher when a person's clothing is on fire—use the safety shower. Once the fire appears to be out of control, *immediately* evacuate the laboratory.

7. For abrasions or cuts, flush the affected area with water. Any further treatment should be given only after consulting with the laboratory instructor.

[1]See http://ilpi.com/msds

For burns, the affected area should be rubbed with ice, submerged in an ice-water bath, or placed under running water for several minutes to withdraw heat from the burned area. More serious burns require immediate medical attention. Consult with your laboratory instructor.

8. Treat chemical spills in the laboratory as follows:
   - Alert your neighbors and the laboratory instructor
   - Clean up the spill as directed by the laboratory instructor
   - If the substance is volatile, flammable, or toxic, warn everyone of the accident
9. *Technique 4*, page 21, provides information for the proper disposal of chemicals after being used in the experiment. Improper disposal can result in serious laboratory accidents. Read that section carefully—it may prevent an "undesirable" laboratory accident. If you are uncertain of the proper procedure for the disposing of a chemical, ***ask!***

C. Laboratory Rules

In addition to the guidelines for self-protection (Part A), the following rules must be followed.

1. *Smoking, drinking, eating, and chewing* (including gum and tobacco) are not permitted at any time because chemicals may inadvertently enter the mouth or lungs. Your hands may be contaminated with an "unsafe" chemical. Do not place any objects, including pens or pencils, in your mouth during or after the laboratory period. These objects may have picked up a contaminant from the laboratory bench.
2. Do *not* work in the laboratory alone. The laboratory instructor must be present.
3. Assemble your laboratory apparatus away from the edge of the lab bench ($\geq$ 8 inches or $\geq$ 20 cm) to avoid accidents.
4. Do *not* leave your experiment unattended during the laboratory period: This is often a time when accidents occur.
5. Inquisitiveness and creativeness in the laboratory are encouraged. However, variations or alterations of the Experimental Procedure are forbidden without prior approval of the laboratory instructor. If your chemical intuition suggests further experimentation, first consult with your laboratory instructor.
6. Maintain an orderly, clean laboratory desk and drawer. Immediately clean up all chemical spills, paper scraps, and glassware. Discard wastes as directed by your laboratory instructor.
7. Keep drawers or cabinets closed and the aisles free of any obstructions. Do *not* place book bags, athletic equipment, or other items on the floor near any lab bench.

Jack Hollingsworth/Photodisc/Getty Images

Laboratory facilities must be designed for safety.

8. At the end of the laboratory period, completely clear the lab bench of equipment, clean it with a damp sponge or paper towel (and properly discard), and clean the sinks of all debris. Also clean all glassware used in the experiment (see *Technique 2*, page 19).
9. Be aware of your neighbors' activities: You may be a victim of their mistakes. Advise them of improper techniques or unsafe practices. If necessary, tell the instructor.
10. For all other rules, **listen to your instructor!** Additional laboratory rules and guidelines can be added to this list at the bottom of this page.

D. Working in the Laboratory

1. Maintain a wholesome, professional attitude. Horseplay and other careless acts are prohibited.
2. The operation of cell phones and other electronic "entertainment" equipment is strictly forbidden.
3. Do *not* entertain guests in the laboratory. Your total concentration on the experiment is required for a safe, meaningful laboratory experience. You may socialize with others in the lab, but do not have a party! You are expected to maintain a learning, scientific environment.
4. Scientists learn much by discussion with one another. Likewise, you may profit by discussion with your laboratory instructor or classmates—but *not* by copying from them.
5. *Prepare for each experiment.* Review the Objectives and Introduction to determine the "chemistry" of the experiment, the chemical system, the stoichiometry of the reactions, the color changes to anticipate, and the calculations that will be required. A thorough knowledge of the experiment will make the laboratory experience more time efficient and scientifically more meaningful (and result in a better grade!). Complete the ***Prelaboratory Assignment*.**
6. Review the Experimental Procedure.
   - Try to understand the purpose of each step.
   - Determine if any extra equipment is needed and be ready to obtain it all at once from the stockroom.
   - Determine what data are to be collected and how they are to be analyzed (calculations, graphs, etc.). Review the **Data Analysis** section.
   - Review the **Laboratory Techniques** and the **Cautions,** because they are important for conducting a safe and rewarding experiment.
7. Review the ***Report Sheet*.** Complete any calculations required before data collection can begin during the laboratory period. Determine the data to be collected, the number of suggested trials, and the data analysis required (e.g., calculations, graphs).
8. Review the Laboratory Questions at the conclusion of the ***Report Sheet*** before *and* as you perform the experiment. These questions are intended to enhance your understanding of the chemical principles on which the experiment is based.
9. Above all, *enjoy* the laboratory experience. Be prepared, observe, think, and anticipate during the course of the experiment. Ultimately, you will be rewarded.

Notes on Laboratory Safety and Guidelines

Masterfile

Laboratory data should be carefully recorded.

Data Documentation

The lifeblood of a good scientist depends on the collection of reliable and reproducible data from experimental observations and on the analysis of that data. The data must be presented in a logical and credible format; that is, the data must appear such that other scientists will believe in and rely on the data that you have collected.

Believe in your data, and others will have confidence in it also. A scientist's most priceless possession is integrity. Be a scientist. Scientists are conscientious in their efforts to observe, collect, record, and interpret the experimental data as best possible. Only honest scientific work is acceptable.

You may be asked to present your data on the ***Report Sheet*** that appears at the end of each experiment, or you may be asked to keep a laboratory notebook (see Part C for guidelines). For either method, a customary procedure for collecting, recording, and presenting data is to be followed. A thorough preview of the experiment will assist in your collection and presentation of data.

A. Recording Data

1. Record all data entries *as they are being collected* on the ***Report Sheet*** or in your laboratory notebook. Be sure to include appropriate units after numerical entries. Data on scraps of paper (such as mass measurements in the balance room) may be confiscated.
2. Record the data *in permanent ink* as you perform the experiment.
3. If a mistake is made in recording data, cross out the incorrect data entry with a *single* line (do *not* erase, white out, overwrite, or obliterate) and clearly enter the corrected data nearby (see Figure A.1). If a large section of data is deemed incorrect, then write a short notation as to why the data are in error, place a single diagonal line across the data, and note where the correct data are recorded.
4. For clarity, record data entries of values <1 with a zero in the "one" position of the number; for example, record a mass measurement as 0.218 g rather than .218 g (see Figure A.1).
5. Data collected from an instrument or computer printout should be securely attached to the ***Report Sheet***.

	Trial 1
Mass of $CaCO_3$ sample, initial	0.218 g
Mass of $CaCO_3$, after heating	~~0.184~~ 0.164 g
Mass of CO_2 in sample	0.054 g

Figure A.1 Procedures for recording and correcting data.

B. Accessing Supplementary Data

You may profit by frequent references to your textbook or, for tabular data on the properties of chemicals, the *CRC Handbook of Chemistry and Physics,* published by the Chemical Rubber Publishing Company of Cleveland, Ohio, or the *Merck Index,* published by Merck & Co., Inc., of Rahway, New Jersey. Books are generally more reliable and more complete sources of technical information than are classmates.

The Internet has a wealth of information available at your fingertips. Search the Web for additional insights into each experiment. In your search, keep in mind that many Web sites are not peer-reviewed and therefore must be judged for accuracy and truth before being used.

There are several search engines that can lead you to most any information regarding your experiment; equipment, safety of chemicals, procedures, representative data, etc.

Masterfile

Scientific data can be obtained from the Internet or analyzed with appropriate software.

C. Laboratory Notebook

The laboratory notebook is a personal, permanent record—that is, a journal, of the activities associated with the experiment or laboratory activity. The first 3–4 pages of the notebook should be reserved for a table of contents. The laboratory notebook should have a sewn binding, and the pages must be numbered in sequence.

Each new experiment in the laboratory notebook should begin on the right-hand side of a new page in the laboratory notebook, and it should include the following sections with clear, distinct headings:

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Laboratory notebook

- The title of the experiment
- Beginning date of the experiment
- Bibliographic source of the experiment
- Coworkers for the experiment
- The purpose and/or objective(s) of the experiment
- A brief, but clearly written Experimental Procedure that includes the appropriate balanced equations for the chemical reactions and/or any modifications of the procedure
- A list of cautions and safety concerns
- A brief description or sketch of the apparatus
- A section for the data that is recorded (see **Data Documentation**, Part A and **Data Analysis**, Part A) as the experiment is in progress, (i.e., the ***Report Sheet***). This data section must be planned and organized carefully. The quantitative data is to be organized, neat, and recorded with the appropriate significant figures and units: Any observed, qualitative data must be written legibly, briefly, and with proper grammar. All data must be recorded in *permanent ink*. Allow plenty of room to record observations, comments, notes, and so on.

Data Analysis

- A section for data analysis that includes representative calculations, an error analysis, instrument and computer printouts, graphical analyses (see **Data Analysis** in the next section), and organized tables. Where calculations using data are involved, be orderly with the first set of data. Do *not* clutter the data analysis section with arithmetic details. All computer printouts must be securely attached.
- A section for results and discussion

At the completion of each day's laboratory activities, the laboratory activity should be dated and signed by the chemist, any coworker, *and* the laboratory instructor at the bottom of of each page.

The laboratory instructor will outline any specific instructions that are unique to your laboratory program.

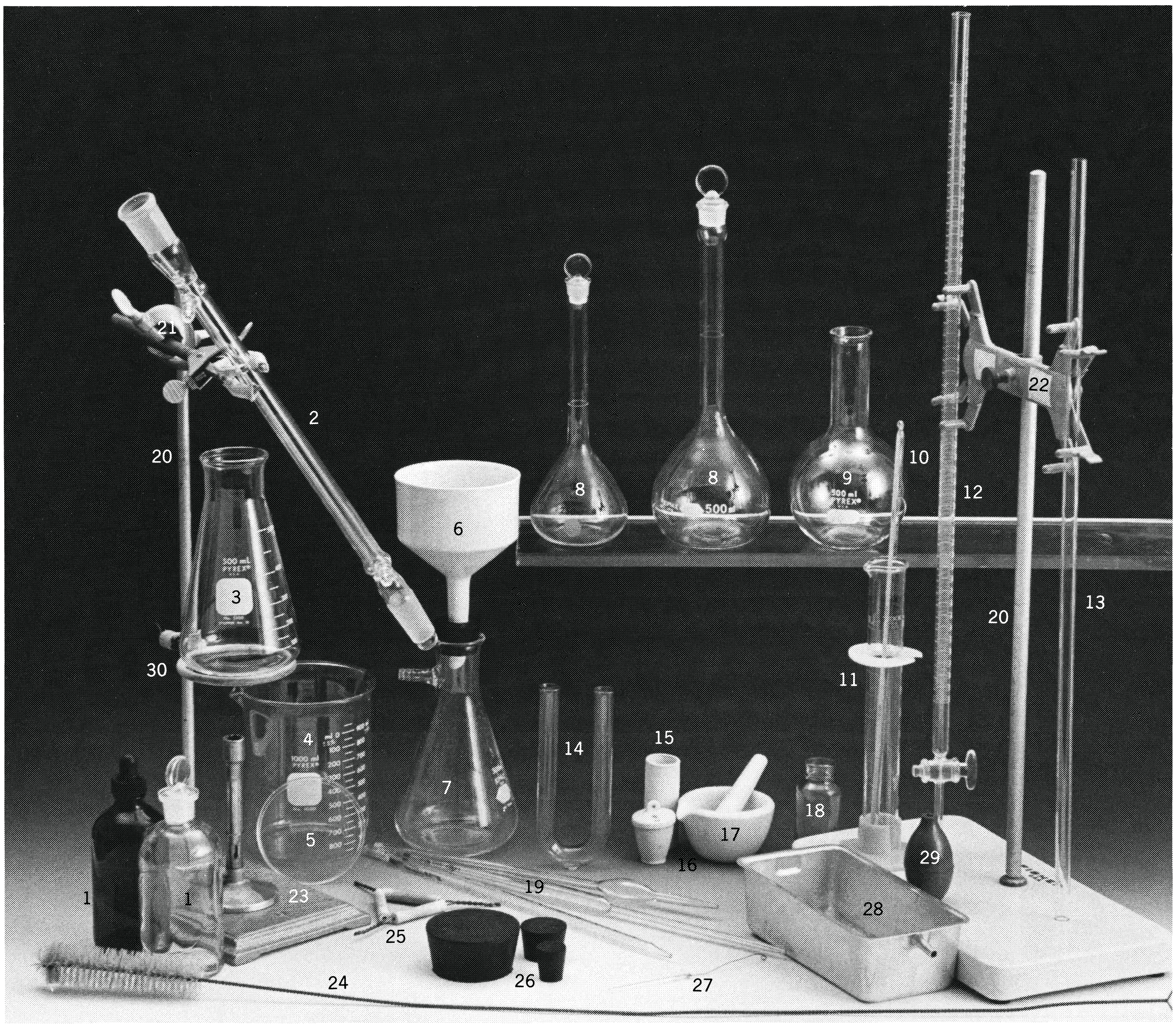
Common Laboratory Desk Equipment Checklist

No.	Quantity	Size	Item	First Term In	First Term Out	Second Term In	Second Term Out	Third Term In	Third Term Out
1	1	10-mL	graduated cylinder						
2	1	50-mL	graduated cylinder						
3	5	—	beakers						
4	2	—	stirring rods						
5	1	500-mL	wash bottle						
6	1	75-mm, 60°	funnel						
7	1	125-mL	Erlenmeyer flask						
8	1	250-mL	Erlenmeyer flask						
9	2	25 × 200-mm	test tubes						
10	6	18 × 150-mm	test tubes						
11	8	10 × 75-mm	test tubes						
12	1	large	test tube rack						
13	1	small	test tube rack						
14	1	—	glass plate						
15	1	—	wire gauze						
16	1	—	crucible tongs						
17	1	—	spatula						
18	2	—	litmus, red and blue						
19	2	90-mm	watch glasses						
20	1	75-mm	evaporating dish						
21	4	—	dropping pipets						
22	1	—	test tube holder						
23	1	large	test tube brush						
24	1	small	test tube brush						
	1	—	marking pen						

Yoav Levy/Phototake

Special Laboratory Equipment

Number	Item	Number	Item
1	reagent bottles	16	porcelain crucible and cover
2	condenser	17	mortar and pestle
3	500-mL Erlenmeyer flask	18	glass bottle
4	1000-mL beaker	19	pipets
5	Petri dish	20	ring and buret stands
6	Büchner funnel	21	clamp
7	Büchner (filter) flask	22	double buret clamp
8	volumetric flasks	23	Bunsen burner
9	500-mL Florence flask	24	buret brush
10	–10°C–110°C thermometer	25	clay pipe-stem triangle
11	100-mL graduated cylinder	26	rubber stoppers
12	50-mL buret	27	wire loop for flame test
13	glass tubing	28	pneumatic trough
14	U-tube	29	rubber pipet bulb
15	porous ceramic cup	30	iron support ring



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Data Analysis

Calculators with graphing capabilities are an asset for analyzing scientific data

Confidence in a scientific theory depends on the reliability of the experimental data on which the theory is based. For this reason, a scientist must be concerned about the quality of the data he or she collects. Of prime importance are the **accuracy** of the data—how closely the measured values lie to the true values and the **precision**—how reproducible are the collected data.

To obtain accurate data, we must use instruments that are carefully calibrated for a properly designed experimental procedure. Miscalibrated equipment, such as a balance or buret, may result in reproducible but erred data. Flawed instruments or experimental procedures result in **systematic errors**—errors that can be detected and corrected. As a result of systematic errors, the data may have good **precision** but not necessarily have good **accuracy**. To have good accuracy of data, the systematic errors must be minimized.

Systematic errors: Determinate errors that arise from flawed equipment or experimental design

Precision: Data with small deviations from an average value have high precision

Accuracy: Data with small deviations from an accepted or accurate value have good accuracy

Random errors: Indeterminate errors that arise from the bias of a chemist in observing and recording measurements

Because scientists collect data, **random errors** may also occur in measurements. Random errors are a result of reading or interpreting the value from the measuring instrument. For example, reading the volume of a liquid in a graduated cylinder to the nearest milliliter depends on the best view of the bottom of the meniscus, the judgment of the bottom of the meniscus relative to the volume scale, and even the temperature of the liquid. A volume reading of 10.2 mL may be read as 10.1 or 10.3, depending on the chemist and the laboratory conditions. When the random errors are small, all measurements are close to one another, and we say the data are of *high precision*. When the random errors are large, the values cover a much broader range and the data are of *low precision*. Generally, data of high precision are also of high accuracy, especially if the measuring device is properly calibrated.

A. Significant Figures

Quantitative data, both collected and calculated, must reflect the reliability and precision of the measurements obtained from laboratory instruments and equipment. The significance of significant figures lies in an indication of the precision of those measurements and the calculated results. Keep in mind that recording and calculating data with the correct number of significant figures does not improve the accuracy of the final result, only the precision.

Thus, significant figures indicate clearly the precision of the instrument for each measurement.