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Preface

Introduction

Some instructors of an introductory chemistry course may consider their students to be "difficult to teach." Commonly these students have poor math and/or weak science backgrounds from high school. As a result, the students are often convinced that science is too complicated and difficult for them to learn successfully. Teaching such a class requires patience and understanding, but can ultimately be very rewarding. The *laboratory* is an excellent place for an instructor to gain the confidence of his or her students, largely because the interaction between teacher and students is more intimate and friendly in the laboratory than in the lecture hall. The laboratory is also an excellent place for students to gain confidence in themselves: as they see their experiments "coming out right," they begin to feel that maybe they can master the material after all!

The laboratory is also the place for students to be introduced to *safe and efficient working habits*. The ability to work effectively—but still *safely*—is a skill that will serve students well in whatever careers they may choose. The instructor is reminded that he or she has a strong moral (as well as legal!) obligation to provide students with a safe work environment and with knowledge about reagents and procedures in order to enable students to minimize the risk to themselves.

New In This Edition

In the interest of saving time, reagent expense, and class time, this *Instructor's Resource Guide* contains small-scale ("microscale") version of four of the experiments. One of us (jl) has long been involved with designing small-scale experiments for the core high school class and for the AP Chemistry program, and has found in the past several years of teaching at a community college, that all the benefits of small scale that are enjoyed in the high school program (reduced cost, reduced waste, shorter time for completion of labs) extend to the next level. The authors are aware that many who use this manual teach at community college/junior college institutions, so have started to add some small-scale. We also know that some high schools use the *Introductory Chemistry* text itself for their honors/Pre-AP programs, so inclusion of small-scale experiments is also an effort to meet the needs of those teachers. Based on how they're received, we hope to add more in the future. These experiments are found at the end of this *Guide*, and each has a brief set of Teacher Notes.

In addition, while the ideal situation is for all students work as individuals, space and budget restrictions don't always make that a real possibility, especially in the crowded classes found in community colleges, so starting with this edition, equipment quantities are based on the assumption that students are working in 2-student teams, and reflect the amount needed per team unless "per section" is specified. Allowance is made for excess in all cases.

Finally, in previous editions, for experiments that call for students to prepare graphs of their data, they were told that the graph paper was located at the end of the manual. Such was not always the case, unfortunately. In the present edition of the student manual, those experiments have graph paper included immediately following the Report Sheet, and several additional sheets have been included following the appendices.

About This Manual

This *Instructor's Resource Guide* is intended to make the preparation for, and administration of the introductory chemistry laboratory as painless and rewarding as possible, for students and instructor alike. The notes for each experiment are divided into four lettered sections for easy reference.

Part A, *General Notes*, provides an introduction to the experiment from the instructor's point of view, indicating what students are expected to learn from the experiment and often pointing out possible pitfalls. Specific suggestions for specialized equipment, or possible modifications for the experiment, are given in many instances. Where appropriate, suggestions for alternate reagents or variation of the procedure have been made in the interest of safety.

Part B lists the *Materials Required* for each experiment. Instructions are given for the preparation of the solutions required, and are generally given in terms of preparing *one liter* of solution, even though the experiment as performed may call for more or less than this amount. One liter was chosen as a standard amount, since it should allow the instructor or assistant to calculate relatively easily the actual amounts of solute/solvent needed for the number of students in the laboratory. For some special reagents, requiring more complicated preparation, instructions are given for the specific amount required for the experiment as performed. For acids and bases, directions are given for starting with concentrated acid and solid base (e.g., NaOH pellets). If other concentrations of stock solutions are available, they can, of course, be used instead. Solutions of acids and bases in many different concentrations are available from suppliers, too.
If the instructor assigns the preparation of solutions to a student assistant, *the instructor should adequately supervise the student assistant during the handling of all chemical substances*, and should ensure that the assistant works in a *safe and responsible manner.*

Part C contains the answers to the *Pre-Laboratory Questions* given with each experiment, and Part D provides answers to questions given as part of the laboratory report (*Post-Laboratory Questions).* Questions requiring students to look up a definition or explanation are keyed as far as possible to the *Zumdahl/DeCoste* text. Questions involving the looking up of physical data are generally keyed to the *CRC Handbook of Chemistry and Physics*, but use of internet sources is also encouraged.

In all but two cases (Experiments 7 and 30), the four sections of notes for each experiment fit on two pages. As a convenience to the instructor (or laboratory assistant), we have set it up so that the two pages face each other. That means you can lay this guide open on the desk top and view the entire guide without turning page. An option that some instructors prefer is to transfer the pages for only those labs they intend to use to a three-ring binder, which is more prone to lying flat.

As always, the authors welcome input from users of the laboratory manual and *This Guide*. Good luck, to you and to your students, in all your endeavors.

John G. Little
James F. Hall

1. The Laboratory Balance: Mass Determinations

A. General Notes

The correct measurement of mass is essential to students' future performance in the general chemistry laboratory, and this experiment will give the instructor a chance to identify those students who may have difficulties in the future. In particular, students will need great help in learning to read and record masses correctly, to the appropriate precision permitted by the balances you have available. Altogether too many scientific instruments (including balances) have digital displays: students may have learned to trust such devices absolutely, and may not be able easily to read an analog scale correctly. It is especially difficult for students to appreciate the concept of estimating between the smallest scale divisions of a device to obtain the last significant figure of the measurement. An experiment using an analog scale such as on a triple-beam balance allows students to see for themselves why the last digit in the measurement is "uncertain."

As this experiment progresses, it is wise for the instructor to examine student data as it is being recorded by circulating regularly in the lab. In this manner, if it is discovered that a student is reading or recording data incorrectly, the student can be corrected before he or she mentally reinforces the incorrect technique. For example, if the instructor discovers that a student is not estimating between the smallest scale divisions of the triple beam balance to obtain the final significant figure, it is more helpful to the student if he or she can be corrected while the balance is available for examination (rather than later on a lab report grade).

This experiment is written without specific reference to a particular type of balance, since so many types of balances are available. The instructor therefore should present a short discussion of the particular type of balance present in the laboratory, and should demonstrate the use of the balance to small groups of students. If more than one type of balance is available for student use, discuss the rationale for which balance is to be used in which circumstances (e.g., why an analytical balance capable of measuring mass to 0.1 mg would not likely be used when an experiment only calls for an approximate amount).

Estimated time to complete: 90 min.

B. Materials Required

2 unknown objects per group for mass determination. These may be such things as different sized rubber or glass stoppers, or items sold commercially for such purposes.

The items should be coded or marked somehow with an identification number (very small items may be dispensed in coded vials).

The correct masses of the items should be measured by the instructor or stockroom staff before the laboratory period, so that students may check their results during the lab. Students must be strongly encouraged to turn in these mass unknowns at the end of the lab period for use by later sections.

C. Answers to Pre-Laboratory Questions

1. Mass is a measure of the amount of matter in a sample, whereas weight is a measure of the force of gravity acting on the sample. In the laboratory, we determine the mass of a sample by comparison (on a balance) to standard reference masses.

2. This statement means that the overall mass of the sample should be in the neighborhood of 5 grams, but that the precise mass of the sample must be known to the third decimal place.

3. Many balances, particularly the traditional beam balances, are difficult to "zero" manually (requiring the adjustment of a counter-weight screw, or the addition/subtraction of ballast mass from the pan support). The balance point of a beam balance may vary with the humidity, for example. If the mass of an item is determined by first balancing an empty container, and then the same container with the object present, the difference in readings will be the correct mass of the object, even though the individual readings may be incorrect.

4. If an object is warm, it heats the air around it. Since warm air rises, an upward flowing air current is created around the balance pan, which results in an apparent mass which is less than the true mass.

5. Most balances contain metal parts. If the metal parts of a balance were to become wet, they would tend to corrode more quickly.

6. Any tare errors (see Question 3) will cancel out if the same balance is used.

D. Answers to Post-Laboratory Questions

1. The mass determinations of the unknown sample, using Beaker A and Beaker B, were done by a "difference" method. The empty mass of a given beaker was determined, followed by the mass of the beaker containing the object of interest. The difference between these two masses was the mass of the object of interest.

2. Balances contain carefully machined moving parts. If the balance becomes dirty because of spilled chemical residues or excessive dirt or dust, the moving parts of the balances may be obstructed in their motion.

3. A primary reason why this manual calls for all items to be weighed in a beaker or other container, rather than directly on the pan of the balance, is to overcome any "zeroing" error in the balance. Although most electronic balances can be set to read zero when the pan is empty, beam balances are still in wide usage. Beam balances may not balance to zero when empty because of humidity and temperature variations. Beam balances typically can only be re-zeroed by opening up the balance and either adding or removing lead shot from the balance – a job that takes a lot of time and effort if there are many balances in use. By balancing an empty vessel, and then the same vessel containing the object of interest, any error in the zero of the balance will cancel out. However, if a different balance is used, the zero error of the second balance is unlikely to be the same as the zero error of the first balance.

2. The Use of Volumetric Glassware

A. General Notes

This experiment introduces students to volumetric measuring glassware. In particular, students become familiar with the manipulations involved in the use of volumetric transfer pipets and burets in such a manner that the instructor can easily determine if students are using these devices correctly. Later experiments in the manual require these devices to be used efficiently and precisely, and it is very worthwhile to nip in the bud any improper techniques at this point.

Since several types of pipet safety bulbs may be available, the instructor should demonstrate the type of bulb that students will actually be using. Students should be warned explicitly about the dangers of mouth-pipetting. Other disciplines may still be allowing mouth-pipetting as “easier,” despite the obvious hazards involved, so it’s important for students to be made aware of those hazards.

Since students may not have yet covered the concept of density in their lecture course, it is suggested that the calculations of how to convert between a particular *volume* of water and its *mass* be covered in the lab at the chalkboard.

Estimated time to complete: 150–180 minutes

B. Materials Required

Set-up of several different-sized graduated cylinders (e.g., 10-, 25-, 50-, and 100-mL) containing different amounts of colored water. The cylinders should be marked with a code letter for students to distinguish them. The cylinders should either be sealed with a rubber stopper to prevent evaporation, or the instructor should read and record the volume of liquid in the cylinders at the start of the lab period.

Volumetric (or Mohr) pipets, 25-mL, 1/group

Pipet safety bulbs, 1/group

50-mL burets and buret stands/clamps, 1/group

Buret brushes, 5-6/section

Beakers, assorted