To the Teacher

Many factors discourage teachers from doing as much laboratory work as students need:

1. Considerable preparation time is needed.
2. Laboratory work is slow, and fewer topics are covered in the course when extensive laboratory work is done.
3. The time needed to evaluate laboratory reports is extensive.

In spite of these difficulties, many teachers spend as much as half of their class time in laboratory activities. How do they manage?

Most teachers who spend extensive time in laboratory work view chemistry as an experimental science and treat laboratory work as the central part of the course. Rather than using laboratory work to supplement study in the text, the text is used as an important source of information to supplement the scientific investigation that centres around the laboratory. The course is organized around questions, and the purpose of the course is to answer those questions using one's own resources. The text provides background information needed to suggest investigation and to interpret observations.

The success of the laboratory program will depend to a great extent on your willingness and ability to have the students become participants in the learning of chemistry. By using the suggestions presented in this manual, you can organize a laboratory program through which your students will develop many of the characteristics and attitudes typical of research chemists. During the year, they should acquire a realistic concept of the relationship between theoretical and experimental chemistry.

The philosophy of *Heath Chemistry Laboratory Experiments* grows out of research conducted during the 1960s as part of the Chemical Bond Approach Project. Although the CBA program did not acquire a strong foothold in high schools, the laboratory program developed as part of that project is probably the best researched and most carefully developed high school laboratory program available today.

We are indebted to Tony Neidig at Lebanon Valley College and the many teachers who worked with him during that development for their excellent ideas. The following suggestions for conducting the laboratory program are adapted from the Teacher's Guide to *Investigating Chemical Systems: Chemical Bond Approach Project*, Earlham College Press, 1964.

Planning an Experiment

Each experiment should be carried out in three phases:

1. prelab session
2. laboratory work
3. post lab session

PRELAB SESSIONS

The Prelab Discussion should take place after students have answered the Prelab Questions. Completing the Prelab Questions will require students to give some thought to the experiment and to do some planning prior to beginning laboratory work.

Objectives of prelab sessions. The purpose of a prelab session is to prepare students for the work to be done in the laboratory. The Prelab Discussion should acquaint students with the problem being investigated, point out the reasons for doing the experiment, and make clear what is expected in the laboratory. The items that are usually considered during Prelab Discussion include:

1. background information relative to the problem being investigated
2. relationship of the problem to text material and previous experiments
3. scope of the problem to be studied, type of data to be collected, and experimental procedure to be followed
4. explanation of new laboratory techniques
5. safety precautions to be observed

For each experiment, specific suggestions are given in *Heath Chemistry Laboratory Experiments* about the major points to be included in the Prelab Discussion.

Background information. Any background information not appearing in the text but pertinent to the experiment should be included in this discussion.

Relationship to text and previous experiments. The relationship should be established between the experiment and the text material currently being discussed, or previously discussed. Previous experiments that are members of a group of experiments associated with the vertical development of an idea or concept should be reviewed.

Laboratory techniques. If the laboratory procedure to be used involves techniques that are new to the students, the important features of the manipulations should be demonstrated and discussed.

Safety precautions. Direct the students' attention to the safety precautions that must be observed during the laboratory work. If any hazardous materials are to be used, the dangers, as well as suggestions for handling these substances, should be discussed. Important information on this subject can be found in the Safety Guidelines section of *Heath Chemistry Laboratory Experiments.*

LABORATORY WORK

The nature of the experiments selected for *Heath Chemistry Laboratory Experiments* provides you with considerable flexibility in making specific assignments to students. Students should work in pairs for many of the experiments. Suggestions are given in the manual about the student assignments.

Procedural hints and suggestions are provided for you when necessary. Use these hints to help you save time while providing students with a safe, successful learning experience.

POST LAB SESSIONS

Prior to the post lab session, students should read the Post Lab Discussion section that appears at the end of each experiment. The student should then complete the Questions and Calculations, Follow-up Questions, and Conclusion sections. Answers to all of the questions appear in the Teacher's Edition of *Heath Chemistry Laboratory Experiments.* You may notice that some of the Follow-up Questions are similar to questions raised in the text. This is because these questions focus on the relationship between the lab work and the text material—a relationship that students too often miss.

Objectives of post lab sessions. The purpose of the post lab session is to have the class correlate, interpret, and evaluate the data they have obtained. The experimental results should be related to questions raised in the text and to overall problems that are being considered in the course.

Students should be encouraged to draw their own conclusions based on the experimental evidence. They should also be encouraged to recognize the limitations of the data and the difficulties that can occur when one tries to correlate laboratory data with theory. Finally, students should be able to formulate new questions based on their results and suggest further experiments that might attempt to answer these questions.

Conducting post lab sessions. As in the prelab session, the Post Lab Discussion requires guidance. Care should be taken to organize the reporting procedure used by students in order to utilize the available time as efficiently as possible.

Students should be given the responsibility for suggesting appropriate conclusions or solutions to the problem being investigated. It is important that you resist the temptation to force students to a "correct" answer rather than allow them to present conclusions based on their experimental results.

It may happen that the experimental results appear to conflict with expectations based on theory. When this is the case, use part of the post lab session to discuss additional experiments that could be done to resolve the conflict. If possible, have some or all of the students devote time to carrying out these investigations.

Laboratory Reports

Traditionally, students are expected to prepare a written report of laboratory work. This procedure reflects the idea that communication skills are important, as is the ability to organize data and information. One of the problems with laboratory reports, however, is that they are time consuming and difficult to evaluate conscientiously. If there is at least one laboratory experiment each week, the time required for evaluating this work may be prohibitive. Teachers are encouraged, therefore, to consider some alternatives to the written laboratory report. You may not want to use an alternative method with every experiment, but by providing some variation in the lab report format you will probably find that you not only save time, but stimulate student interest as well.

ORAL PRESENTATIONS

If you follow our recommendations for the laboratory program, each experiment will culminate in a post lab session during which data will be presented, discussed, and analyzed. These sessions can provide ample opportunity to assess each student's understanding of the laboratory work. If a grade for the laboratory work is desired, it can be given on the basis of the students' oral presentations at this time.

For many investigations, individuals or small groups of students will conduct separate experiments and report their results to the class. The results obtained by each individual or group must be communicated clearly to the rest of the class. It is appropriate to use this opportunity to help students improve their communication skills. If a student or group has organized their information in a particularly useful way, this can be pointed out as an example of effective communication. If another presentation was difficult to follow or understand, suggestions can be made for improving organization and delivery for the next occasion.

USE OF TRANSPARENCIES

Class reports can be time consuming if students must write masses of data on the chalkboard for others to view. Time can be saved if students are issued acetate sheets and marking pens to prepare tables of data prior to class. Tables can then be shown on the overhead projector during the presentation.

ONE WRITES: ANOTHER PRESENTS

Oral reports are valuable, but they do not strengthen writing skills. How can you provide useful feedback concerning writing skills in the context of a post lab session?

You might have one individual or group prepare a written report for another student to present to the class. Such a task is realistic in that we are often required to interpret reports of others. In addition, a real challenge is provided for the writer. If a student must prepare a report for someone else to give, the report must be clearly written or the presenter will be unable to explain the ideas. Furthermore, the presenter will usually be direct about what may be ambiguous in the report.

A similar activity can be used after a prelab session when additional experiments are to be carried out. Instead of having students prepare descriptions of their own experimental procedures, have them write the procedure for another student to carry out. If the procedure is not clear, the experiment either cannot be done, or it will be done incorrectly. The experimenter will inform the writer that the writing is deficient. Thus, the importance of clear communication will be brought home in a natural way.

PARTIAL REPORTS

The format of the experiments in *Heath Chemistry Laboratory Experiments* can effectively reduce your time in evaluating lab reports. After establishing the content for laboratory reports, grading time can be reduced by evaluating only one specified part at a time. The part to be evaluated can be varied from one experiment to another so that you can provide feedback for various parts of a laboratory report over the course of the year.

Similarly, students may be asked to write their own conclusions concerning an experiment after a Post Lab Discussion. This technique would be particularly effective when the data were ambiguous, and clear-cut conclusions were not possible. Students can be told that their work will be evaluated on the basis of how well they support their conclusions with the data presented, how they deal with ambiguities in the data, and how they allow for alternative interpretations.

In some experiments you will want to know that students can perform necessary calculations on the laboratory data. For example, experiments that use titration or experiments that apply gas laws involve important calculations. For these activities, students may be asked to show only their raw data and their calculations in the written report. These can be graded and returned to the students before the Post Lab Session, if desired.

GROUP REPORTS

Consider the possibility of having students work in small groups to prepare a report. In work settings, group reports are the rule. A research team or a committee is charged with preparing a report for general dissemination. Members of the group assume responsibility for preparing rough drafts of various sections of the report. The rough drafts are reviewed by each member of the group, and suggestions are made for revision. When the final draft is prepared and submitted, the group is commended or criticized for their effort. In the process, they learn from each other.

By following a similar process in preparing laboratory reports, your grading time can be substantially reduced. If this process is to be successful, students, like members of any group, must work together. You will have to provide some direction to ensure that all students gain experience in each phase of report writing.

If you choose this option, you may want to raise standards for the reports. One reason for group preparation is that we assume that a better product results from a group working together than from any one individual.

FULL REPORTS, PARTIAL GRADING

If you feel that individual students should prepare full reports for each experiment, you may want to check that reports have been completed but *carefully* grade only a portion of the work, such as the Data section or the Conclusion section. The section chosen for grading can vary from experiment to experiment. When this is done, students should be informed that the evaluation was done on only that section, so they will not incorrectly assume that unmarked sections of the report are without fault.

Laboratory Management

Preparing materials and equipment for laboratory work can be time consuming. The following ideas can help streamline these jobs.

PARAPROFESSIONAL HELP

Some schools employ paraprofessionals to assist science teachers with laboratory maintenance. If your school follows this practice, there are several things that you can do to utilize the paraprofessional effectively as a lab assistant.

1. Plan ahead. Try to anticipate your needs well in advance so that the lab assistant can plan. Usually the assistant will be working for several teachers. By knowing the needs well in advance, all needs can be met.

COMMON LABORATORY EQUIPMENT