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Activity

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Laboratory Activity on Sample Handling and Maintaining a Laboratory Notebook through Simple pH Measurements

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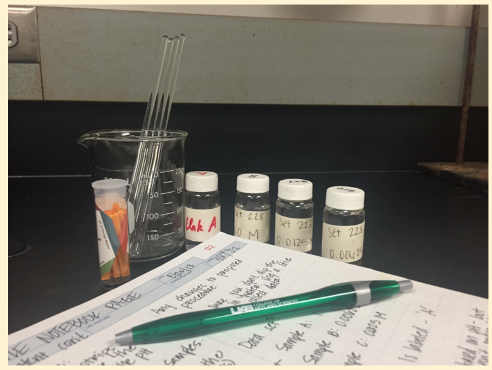
Supporting Information

ABSTRACT: Sample handling and laboratory notebook maintenance are necessary skills but can seem abstract if not presented to students in context. An introductory exercise focusing on proper sample handling, data collection and laboratory notebook keeping for the general chemistry laboratory was developed to emphasize the importance of keeping an accurate notebook. The exercise requires minimal technique or prior knowledge, and as such provides students a comfortable introduction to the college laboratory setting. Details of the activity, including preparation, background, procedure, and postactivity instruction, are provided. Alternative uses and application of the activity are also proposed.



KEYWORDS: *First-Year Undergraduate/General, Laboratory Instruction, Inquiry-Based/Discovery Learning*

■ INTRODUCTION

Laboratory instruction has long been considered a crucial part of general chemistry education.[1−6] Documentation supporting the importance of a well-kept laboratory notebook first appeared in The Journal as a five-part symposium in 1933.[7−11] Many published manuals discuss the importance of the laboratory notebook but provide fill-in-the-blank data sheets. These data sheets imply that a laboratory notebook is not expected or used in conjunction with the manual. Discovery or guided-inquiry-based manuals sometimes provide an introduction to the scientific notebook but do not present activities specifically designed to experience the value of a well-documented experiment.[12,13] This void in instruction can leave students unsure of themselves in the laboratory setting and may open the door for ethical issues associated with misinterpreted or incomplete data.

Prior authors have theorized that if emphasis is placed on the laboratory notebook, students may see it as a valuable part of the learning process,[14] but that merely giving students guidelines and expecting them to excel is rarely sufficient.[15] The activity described here seeks to narrow this gap in instruction and place an emphasis on proper record keeping. The laboratory exercise provides students an opportunity to learn to keep a notebook during a low-stakes data collection assignment. The activity also provides laboratory instructors the opportunity to introduce students to the ethical dilemmas of poorly collected or missing data through actual data collected by the entire laboratory section.

The importance of introducing students to scientific ethics is well represented in the literature. Case studies are commonly used as a framework for delivery of ethics related content.[16−18] Gillette described a writing assignment designed to introduce freshman chemistry majors to scientific ethics[19] and Kandel used a similar approach.[20] Kovac argues that students will best learn scientific ethics when they are introduced to ethical questions through realistic situations.[21] The described activity is a simple approach to utilizing data points that students collect, and provides discussion topics that frequently arise in the laboratory.

The data mentioned above takes the guise of determining the pH of a set of dilute ammonia samples. Ammonia samples were chosen as the introductory topic because ammonia is a chemical that is available to the public in most stores and students will see it often throughout the semester. We chose to measure pH because it can easily be tested with inexpensive pH strips that were already on hand. This simple determination allows students to collect real data on the first day of lab regardless of their prior exposure to proper laboratory techniques. Students are introduced to the concept of pH and the relationship between ammonia concentration and pH is generally described (as ammonia concentration increases, a solution will become more basic and thus will have a higher pH).

This paper describes a first day exercise for the introductory chemistry laboratory. This activity serves as an ice-breaker for students to meet their new laboratory partners, and has two main instructional purposes:

(1) Provide students a foundation for proper notebook keeping.
(2) Introduce students to some of the essential skills of data collection and handling.

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The activity is designed to introduce students to their laboratory environment and, as such, is brief and requires minimal skill in the laboratory or a priori knowledge. This activity was developed and initially performed in a college-based introductory chemistry setting but is easily adaptable for use with secondary school students.

■ ABOUT THE ACTIVITY

Laboratory Manual Write-Up

Background material relating the goal of the experiment and general scientific terms are presented in the student laboratory manual.[13] This material introduces students to a number of general scientific terms (quantitative vs qualitative, etc.) and contains a narrative explaining how the current activity relates to those that will be performed later in the term. Students are given a list of materials available to them and asked to predict the steps they would need to take in order to determine the pH of the samples. However, in the spirit of a guided inquiry activity, minimal instructions are included regarding the specific data to collect or how to organize the information.

Materials

Prior to beginning the activity, students obtain a sample set of solutions, pH strips, a wash bottle, a waste beaker, and glass stir rods. As performed at the authors' institution, the sample set was comprised of three dilute ammonia solutions that gave distinctly different colors on the pH strips. These solutions had concentrations of 0.00625 M (~pH of 8), 0.0125 M (~pH of 9) and 1.0 M (~pH of 10) ammonia. The solutions were kept in storage vials that had been labeled with both an identification number and a concentration. Thirteen solution sets were prepared for each section of 39 students; eight sets were labeled with the correct concentration, and five sets had the concentrations purposely mislabeled (a detailed labeling scheme is presented in the Supporting Information). Unknown samples are prepared from the same three stock solutions by labeling the containers A, B, or C. Additional sample preparation notes can be found in the Supporting Information.

Pre-Activity Instruction

Pre-activity instruction given by the teaching assistant includes a review of the background information presented in the lab manual, how to properly use the pH strips, and the relevance of properly recording measurements in a laboratory notebook. Students are instructed to consider how pH may be affected by ammonia concentration and given the concentrations of the three solutions they will test. They are then asked to predict which order the concentration of the solutions should be placed to demonstrate an increase in pH. The pre-activity lecture details the general laboratory ideas presented in the laboratory manual and describes the value of recording data and observations in the notebook. The idea that the pH values to be recorded are subjective due to the observation of color is described, and the potential that not all vials were properly labeled is introduced. The combination of the lack of accuracy of the pH strips and the mislabeling of samples is intended to emphasize both the importance of recording any and all observations and working to ensure that the correct samples and observations are paired. The postactivity discussion builds on these ideas and can move toward the ethics involved with changing recorded data or putting pressure on classmates to alter their results.

The pre-activity lecture introduces students to proper record keeping in a scientific notebook, including such items as recording sample labels and taking measurements in triplicate.

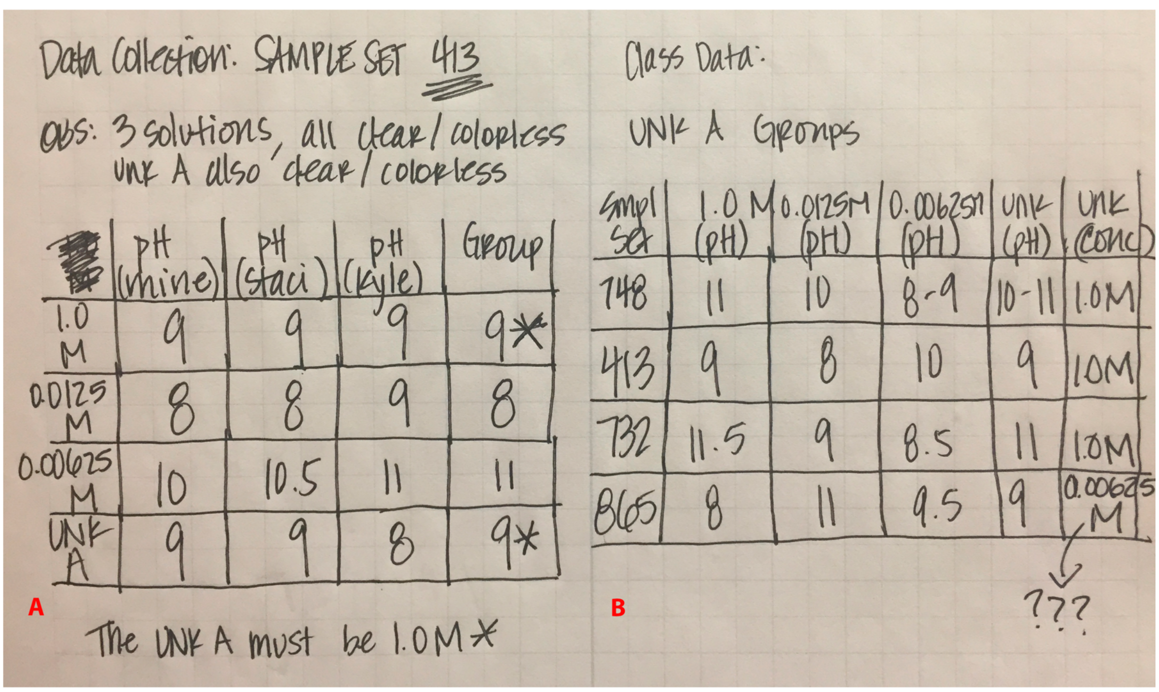

Figure 1. (a) Example student notebook showing group data. The notebook includes collected data for the pH of the three labeled samples and the unknown "A". When there was disagreement among the group, a consensus value was agreed upon. (b) Example student notebook showing compiled class data. The table shows the data for lab groups that tested unknown "A". The inconsistency between the trends in concentration and pH enable students to determine which sample sets were mislabeled. The particular set of solutions chosen for this data table show this inconsistency in both the group and class data.

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Laboratory instructors demonstrate how to properly test the pH of a solution using a glass stir rod and pH strips (i.e., the pH strip should not be dipped directly into the solution but instead the rod wetted with solution should be placed on the strip). The safe handling of dilute ammonia solutions is also emphasized. Since some solutions are mislabeled, students are told at the beginning of the exercise to treat all solutions as if they were 1.0 M ammonia solution; avoiding contact with the skin and working in a well-ventilated area.

Student Workflow

Each student group (3−4 students per group) collects a sample set of solutions from the laboratory instructor. Each member of the group is required to determine the approximate pH of each of the three samples using the pH indicator strips. See Figure 1 for sample student data. The accuracy of pH values taken from pH test strips is expected to be poor, so there is often wide variation regarding assigned pH even within each group. Each group is required to reach a consensus pH value for each solution to be reported to the entire class.

Once pH values are reported to the class (typically on the whiteboard), the laboratory instructor reviews the reported values with each group and assigns the group one of three unknown samples to test. Students follow the same pH test procedure with their unknown, assigning the unknown one of the concentrations on the labeled samples. The unknowns are assigned such that there are enough groups testing the same unknown and at least one group will incorrectly report the concentration due to observing mislabeled knowns. Once each group reaches a consensus on the concentration of their unknown, they record their concentration on the whiteboard and the post-activity discussion begins.

Post-Activity Discussion

When all laboratory groups have collected their data, all students in the laboratory assemble and participate in a postactivity discussion. The postactivity discussion is instructor-led and is guided by the class data. Teaching assistants are instructed to have intergroup discussion about what information was used to identify the mislabeled sample sets, which serves as an engaging way for students to introduce themselves to a different group of students in the laboratory. In general, students quickly recognize which sample sets are mislabeled on the basis of comparison of the pH and concentration of sets that follow the predicted trends and those that are anomalous. The results facilitate conversation regarding data collection and reporting.

The activity was introduced to our curriculum in the Fall of 2011 and has been run multiple times a year since then. Similar discussion topics have arisen with each group that has undergone the exercise. Examples of the typical topics that arise after review of compiled data are presented in Box 1. This list is provided to instructors prior to the activity so they can prepare for the discussion accordingly.

The activity was included as part of our curriculum to provide our students with a basic understanding proper notebook keeping and to briefly introduce them to the ethics associated with data recording and reporting. The ethics conversation begins during the postactivity discussion and generally includes items such as proper sample labeling, what to do if pressured to alter one's recorded results, and the importance of reporting reproducible values.

Rigorous assessment of the impact on student learning has not been undertaken, but a review of in-class assignments completed by students following the postactivity discussion indicate that the activity emphasizes the importance of careful note taking in the laboratory. As detailed in the next section, when asked what the "take-home message" of the activity was, typical student responses indicate that their teaching assistant had emphasized the importance of sample handling, data collection and reporting and that there are negative implications if record keeping procedures are not adequately followed. Teaching assistants have provided informal feedback that the activity has led to greater interaction among student laboratory groups and the class as a whole early in the semester. Teaching assistants have also indicated that they enjoy teaching this activity as it benefits from assertive instruction and provides the students an excellent introduction to the teaching style of their teaching assistant on the first day of the course.

Box 1. Representative Post-Activity Discussion topics

Sample labeling and data handling. A number of student groups will not have written down the three digit code on the labeled sample vial or the identity of the unknown (A, B, or C). Instructors should mention that without properly identifying the samples used during an experiment, it is not possible to repeat the experiment with any success.

Error among class data. Students should be polled whether they feel it is reasonable to use data collected from many different people or if it is better to average results from the same experimenter. Instructors should take the opportunity to discuss the error among the class data in terms of variation in technical ability among the members of the laboratory and tie this into the poll results.

Pressure to conform to reported results. Many students who feel they are unprepared for techniques required of them in the laboratory may feel the need to change their results to conform to the rest of their group. The instructor should point out that although it may be necessary to retest a result, it is unethical of your group to force you to change your results.

Ethics of reporting data you know to be incorrect. Students should be polled to determine their comfort level with reporting data they know to be incorrect. In the class discussion, instructors should identify the social implications of reporting incorrect data.

Recognizing patterns in data. Compiled student group data can be used to point out where a pattern in the general data fails. This can help students in future situations when they are attempting to determine the appropriateness of a data point.

Proper use of significant digits. An excellent opportunity to tie the pre- and postactivity lectures together is in the reporting of significant figures. Many students are unaware of how to properly report qualitative data. If students report pH values to the tenths place, these values can be used to discuss the importance of significant figures.

Sample Student Responses from In-Class Assignment

Students complete an in-class assignment in groups prior to leaving the laboratory. This assignment includes a few items concerning the data collection, but the primary focus is on reiterating the themes that emerged from the postactivity discussion. In-class assignments are administered and graded by the teaching assistant for the section. A detailed grading rubric is given to teaching assistants prior to the activity. Both the In-class assignment and the grading rubric can be found in the Supporting Information.

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A small sample of responses submitted by student groups ($N = 21$ groups, 61 students) were reviewed to ascertain whether the activity was successful in reinforcing the importance of recording keeping and data reporting. When asked what the take-home message of the assignment is, 13 student groups (62%) earned full credit by reporting answers such as being careful to record data, ensuring that contamination is avoided, and insisting that trials be performed in triplicate. Only 2 student groups (10%) of students reported a response that completely missed the message of the class discussion. The last question on the in-class worksheet requires students to provide three unique concrete reasons why it is important to collect and record laboratory data carefully. Only 1 student group (5%) was unable to provide more than one reason why laboratory data was important. Of the remaining 20 groups, 13 (62%) were able to provide three unique themes that arose during the postactivity discussion. These positive results are an indication that the activity successfully introduces students to typical data collection and the type of observations that should be included in a laboratory manual. The last item on the in-class assignment requires those students who have come to the first class period with a laboratory notebook to submit the carbon-copy form of their notes. This student population traditionally is not very large, but this practice provides a basis for the routine of submitting notebook pages each subsequent laboratory meeting. All student data was collected under the guidance of the university's Institutional Review Board for Human Use, protocol number E160328006.

■ HAZARDS

It is important that all students follow standard laboratory safety protocol when completing this activity. Ammonia may be fatal if ingested, inhaled, or absorbed through the skin at high concentration. Solutions of ammonia may also cause irritation to the eyes and respiratory system and may cause burns if contact is made with the skin. Ammonia is considered dangerous for aquatic wildlife and the environment in even low concentrations and should be disposed of carefully. Care must be taken when handling ammonia solutions of any concentration. Though safety glasses should be worn throughout the experiment, additional PPE should not be necessary with such dilute solutions.

■ SUMMARY

This paper discusses an introductory chemistry laboratory activity that details proper sample handling, data collection and notebook keeping. The activity engages students and requires them to work in groups to collect data with little stress, as the technical demands and prior knowledge required to complete the assignment are minimal. Discussion of sample labeling and the ethical issues involved in poor data collection offer students an opportunity to start the semester on good footing. Both graduate and undergraduate TAs have successfully led this activity for eight semesters with minimal training. Though formal assessment of impact on student learning has not been conducted, the activity has been well received by students as gauged through personal interactions, and participation in the postactivity discussion among students enrolled in all laboratory sections that the author has taught have been high. Assessment plans include collecting pre-/post-test data to determine if students knowledge of and comfort level with notebook-keeping and data-handling practices has increased as a result of completing the activity. Teaching assistants have reported that students appear to have a more sound understanding of proper notebook keeping after completing the activity. The authors feel that this activity offers instructors in a wide variety of educational situations an easy and effective way to introduce data collection ethics into their courses.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00623.

Detailed instructor notes on preparing for and carrying out this activity, the experimental outline provided to students in the laboratory manual, the pre-activity quiz, and the postactivity assignment. (PDF)

Detailed instructor notes on preparing for and carrying out this activity, the experimental outline provided to students in the laboratory manual, the pre-activity quiz, and the postactivity assignment. (DOCX)

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Notes

The authors declare no competing financial interest.

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