[Journal of the Scholarship of Teaching and Learning for Christians in Higher Education](http://digitalshowcase.oru.edu/sotl_ched)

Volume 1 | Issue 1 Article 7

2006

Effectiveness of a Writing Intensive Program to Increase Student Learning in an Introductory Chemistry Laboratory

Kenneth M. Weed
Oral Roberts University

Effectiveness of a Writing Intensive Program to Increase Student Learning in an Introductory Chemistry Laboratory

by Kenneth M. Weed

Abstract

Student writing in the chemistry laboratory has always been an important part of the laboratory experience. Student learning is a complex process including many different factors. Proponents of writing to learn theory suggest that using writing in the laboratory experience should increase the amount of student learning in chemistry. To evaluate the impact of writing on student learning during an introductory chemistry laboratory experience, several lab sections participated in a study to compare student learning in non-writing labs to student learning in writing intensive labs. To compare student learning among the differing lab sections, students in each completed a pre-test at the beginning of the lab course followed by an identical post-test during the final lab period. The responses attempted to evaluate true student learning by focusing on the concepts presented in the lab and avoiding testing on information specific to any one lab. In an attempt to further increase student learning, the writing intensive lab incorporated Calibrated Peer Review™ (2005) as a process for students to evaluate their written work. Analysis of questions dealing with critical thinking indicates a significant difference in student learning. The results indicate writing, in particular the writing-intensive method, may enhance the overall student learning experience.

Introduction

Student writing in the chemistry lab has always been an important part of the laboratory experience (Kovac & Sherwood, 2001). When discussing the importance of student writing in chemistry, researchers often point to the importance of students learning to communicate with each other and the public at large (Whelan & Zare, 2003). It is argued that developing writing skills in all disciplines not only increases communication skills, but also writing can be an important process to increase student learning (Van Ryswyk, 2005; Hedengren, 2004; Kovac & Sherwood, 1999; Bressette & Breton, 2001). This process, termed "writing to learn," allows students to focus on discipline specific material through the process of writing (Emig, 1977). Recently, Ochsner and Fowler (2004) have noted the absence of experimental evidence linking writing with quantifiable student learning.

Proponents of writing to learn theory claim writing to be very effective at increasing student learning and understanding of discipline specific subject material (Maimon & Peritz, 2003). Using writing in the introductory chemistry laboratory can require time and energy from both the student and the instructor, especially when the student is uncomfortable with writing. Most lab experiences already require extensive amounts of time. To include writing in lab just to increase the communication skills of students may not be an effective use of time. However, if writing truly increases student learning about chemistry in the laboratory, it should remain an integral part of the experience.

To simplify the process and minimize the amount of time required for teaching and evaluating writing in the chemistry lab, many universities use online writing to learn technology tools, such as the Calibrated Peer Review™ (CPR, 2005). These tools enable instructors to define specific assignments and to use quantitative evaluation methods that both simplify grading and assist students in evaluating their own work and the work of others. The online environment allows peer-to-peer interactions to happen among students in the lab anonymously. The anonymous nature of the experience tends to allow students to communicate both positive and negative responses to student work in a non-threatening environment. The process of student peer-reviewed writing reflects the anonymous peer-review process used in professional writing and broadens student exposure to different writing styles (Shibley, Milakofsky, & Nicotera, 2001).

This study attempts to evaluate the influence of writing on student learning by considering student performance in eight different lab sections offered during one academic year. Student learning is a complex process including many different factors. Some of the factors the study attempts to control are the influence of differing instructors, differing pre-knowledge and abilities of incoming students, and the timing of lab experience.

Materials and Methodology

Format of Instruction

The laboratory portion of an introductory chemistry course under investigation met once a week for a four-hour, hands-on learning experience. Students chose from three or four sections scheduled at various times. Several lab sections, referred to in this paper as standard labs, used data charts, short answer evaluations, and weekly quizzes to demonstrate learning. These lab sections participated in 11 laboratory experiences but required no formal writing assignments.

To compare the effectiveness of a writing intensive teaching method to the standard lab teaching method, one lab section each semester used a writing intensive (WI) method while the remaining sections continued to use the standard method. The writing intensive lab section consisted of nine laboratory experiences and seven writing assignments. The writing assignments used the content of the laboratory experiences to teach students, in a stepwise format, how to write a lab report. Schedules and computer availability were modified so total student experiential time, including both lab and computer work, were approximately equal in both standard and writing intensive lab sections.

Format of Evaluation

To compare student learning among the differing lab sections, students in each completed a pre-test at the beginning of the lab course followed by an identical post-test during the final lab period. The diagnostic test contained 21 different response items requiring matching, short answer, equation balancing, and reaction prediction. Using split-half reliability, the resulting coefficient was 0.851. This indicates a moderate level of reliability.

The development of the diagnostic test focused on the course outcomes listed in the lab syllabus. The responses attempted to evaluate true student learning by focusing on the concepts presented in the lab and avoiding testing on information specific to any one lab.

Ten of the responses on the diagnostic test evaluated material presented in all of the lab sections and covered by writing assignments in the writing intensive lab. Responses from this portion of the diagnostic test focused on topics requiring some form of critical thinking. The topics included discussion of scientific method, using definitions of terms appropriately, and developing experimental methods to solve problems.

The remaining responses on the diagnostic test evaluated material presented in all of the lab sections but not directly covered by writing assignments in the writing intensive lab. Responses from this portion of the diagnostic test focused on topics requiring some form of analytical reasoning. The responses included the proper use of nomenclature, balancing equations, and predicting reactions.

The responses in the diagnostic test evaluated under the heading of “critical thinking” include numbers 1, 2, 6, 7, 8, 10, and 12. The responses evaluated under the heading of “analytical reasoning” include 3, 4, 5, 9, and 11. Most of these questions required multiple responses.

To evaluate the impact on student learning due to the instructor, the instructor teaching the writing intensive lab also taught one of the standard labs. Two other instructors taught the remaining standard labs. The information content and laboratory procedures used in all lab sections were held as consistent as possible. Instructors repeated the entire process during the following semester. During the second semester, only one instructor taught two of the lab sections using the standard method.

Instructors, both at the beginning and at the end of the course, informed students that while the results of the diagnostic test would not affect their grade, the results of the test would be published. In compliance with the IRB approval, instructors also informed students that while the study would incorporate the results of the tests into conclusions, the study would use no personally identifying information. While the above information, especially the grade impact, may have affected student performance, all students were given the same information.

Format of Writing Intensive Teaching Method

In the writing intensive lab section, the writing assignments introduced the method and then separated the writing of a complete lab report into assignments based on the introduction, the results and conclusion section, and the experimental section. Finally, the lab section required the writing of two complete laboratory reports. Each of the writing assignments derived content from a different laboratory experience. For example, students wrote an introduction section of a lab report after performing an extraction of beta-carotene from spinach, and they wrote a results section after performing an analysis of the hardness of city tap water. Each experience provided information to focus on a single part of an overall lab report. The last two lab experiences, an analysis of fat and protein in meat and the vitamin C content of various juices, included a requirement to write a complete lab report.

In an attempt to further increase student learning, the writing intensive lab incorporated CPR (2005) as a process for students to evaluate their written work. The CPR process attempts to enhance student learning by first requiring students to evaluate instructor-derived examples of the writing assignment. Three instructor-derived responses for each writing assignment demonstrate poor, satisfactory, and excellent writing examples to students to provide a basis for evaluating each specific writing assignment. This provides the student a calibration to use for assessing peer student work. Following the evaluation of instructor-derived work, the students evaluate the work of three anonymous peers. After reviewing the instructor responses and evaluating three peers, the students return to evaluate their own assignment.

The CPR (2005) web-program, developed by UCLA, fully automates and tracks student progress online. Use of the program significantly reduces the amount of time and energy the instructor must apply to evaluation and grading. This time-saving feature enables instructors of multiple lab sections to continue to use writing while evaluating the work of many students in several labs occurring during the same semester. All student information may be accessed and evaluated by the instructor at any time.

Results

Comparison of Lab Sections

Assessment of the lab sections occurred during two consecutive semesters and followed 130 students distributed among eight laboratory sections. The one-semester lecture course with associated lab section experience was the exact same course taught in two consecutive semesters with no students repeating the second semester. All of the students for each semester attended the same lecture course and separated only for the lab experiences. One instructor with the help of a lab assistant taught each lab section. During the first semester, three instructors referred to as Professors A, B, and C taught four lab sections of the course with Professor A teaching two lab sections. Table 1 indicates the breakdown of the lab sections by semester, instructor, teaching method, and number of students in each section.

Table 1
Instructional Format of Lab Sections

	Semester 1		Semester 2	
Lab	Instructor	Method	Instructor	Method
1	A	WI n=13	A	WI n=15
2	A	S n=16	A	S n=21
3	B	S n=21	C	S n=18
4	C	S n=16	C	S n=10

S=Standard; WI=Writing Intensive; n= number of students in the lab

Analysis of Diagnostic Test Results

Results from the diagnostic test (Table 2) demonstrate that statistically significant student learning occurred in all of the lab sections (paired t-test, $p<0.001$ for all labs). The design of the test focused on general student learning outcomes or the “big ideas” of the lab experience. In an attempt to measure student learning more effectively, the design of the test attempted to prevent students from achieving the maximum score.

Table 2
Diagnostic Test Results

		Semester 1		Semester 2	
		Pre	Post	Pre	Post
Prof A	Mean Raw Score	3.4	7.0	3.2	6.0
	Standard Dev.	1.8	2.6	1.9	2.7
	No. Students	n = 16		n = 21	
Prof B-Fall Prof C-Spring	Mean Raw Score	3.7	7.7	3.7	7.7
	Standard Dev.	1.8	3.0	1.4	2.1
	No. Students	n = 16		n = 10	
Prof C	Mean Raw Score	3.4	7.3	3.9	6.9
	Standard Dev.	1.7	3.0	1.7	2.3
	No. Students	n = 21		n = 18	
Writing Intensive	Mean Raw Score	2.9	9.8	2.9	8.1
	Standard Dev.	0.9	3.5	1.9	3.4
	No. Students	n = 13		n = 15	

Evaluation of any increase in student performance from the pre- to post-test allows for a comparison of the effect of the WI teaching method to the standard teaching method. Further analyses focus on the difference between students' individual pre-and post-test results. Analysis (ANOVA, $p<0.001$) of the differences in the test scores among all of the WI labs and all of the standard labs shows a significant difference exists between the two teaching methods with the WI method showing the greatest improvement in test scores (WI mean test score improvement= 6.0, Standard mean test score improvement=3.5).

Analysis of the results from the six standard labs taken together shows no significant difference exists among them (ANOVA, $p=0.457$). When analyzed together, the two WI labs show no significant difference (t-test, $p=0.206$). In a comparison of each standard lab's results to the corresponding semester's WI lab results, a significant difference (t-test, $p\leq0.02$ for each comparison) was detected with the WI labs showing improvement in test scores.

When both semesters' results from the WI labs are evaluated as a group and compared to the grouped results of the standard labs, analysis shows a significant difference (ANOVA, $p<0.001$). While the results clearly indicate a difference in the results between the WI labs and the standard labs, factors in addition to the change in teaching methodology may have affected the outcome. Possible additional factors include variance in instructor influence, variance in student background and ability, and the types of questions used in the diagnostic test.

Comparison of Percent Change in Diagnostic Test Results

Percent change in the diagnostic test results indicates an increase in student learning. Figure 1 displays the percent change of the test results grouped by instructor (teaching method) and semester. Note the difference in the percent change of the WI labs as compared to the standard labs in each semester. Observing the results from two consecutive semesters may indicate reproducibility. Prof A was the instructor of record for two consecutive standard labs as well as two consecutive WI labs.

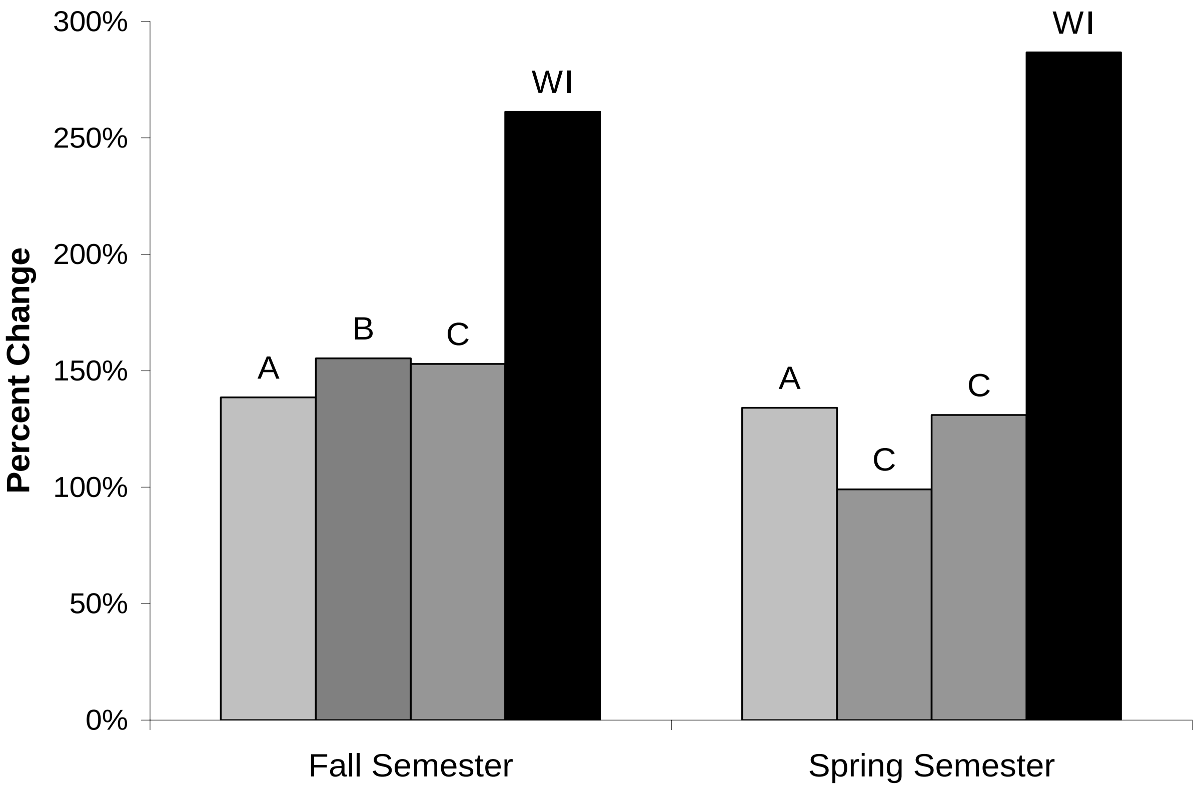


Figure 1. Average percent change in students' diagnostic test results grouped by instructor or teaching method and separated by semester. Percent change calculated by dividing the difference between each student's post-test score and the student's pre-test score by the student's pre-test score.

Comparison of Student Educational Backgrounds

Students enrolled in the introductory chemistry lab course were most often fulfilling a general education requirement and entered with a variety of educational backgrounds. Data collected on student background separated the students into three categories: no previous chemistry experience, 1 year of high school chemistry experience, and 2 years of high school chemistry experience or some college experience. All of the students with previous college chemistry experience referred to previous enrollment in a physical science course.

Comparison of student background exposure in chemistry to percent change on the diagnostic test indicate a general, but not significant (Two way ANOVA, p=0.110), tendency for students with the least amount of background in chemistry to have the most improvement. This tendency could have affected the overall results. However, there was a great diversity of student background found within each lab. A comparison of students' final score in chemistry lecture to percent change on the diagnostic test indicate no significant tendency (Two way ANOVA, p=0.660) for students with high lecture grades to have a greater percent increase on the test.

Grouping individual test questions according to type indicates significant differences. The test consisted of two types of questions, half of the questions dealing with analytical reasoning and half dealing with critical thinking. Figure 2 indicates a role the WI method plays in developing student learning, especially in critical thinking skills. Both the standard and WI teaching methods enabled students to develop analytical reasoning skills as measured by the test. Analysis of questions dealing with critical thinking indicated significant difference in student learning. Students learning using the standard method averaged a 10% increase in score on each of the individual critical thinking questions. Students learning using the WI method averaged a 46% increase in score on each of the individual critical thinking questions.

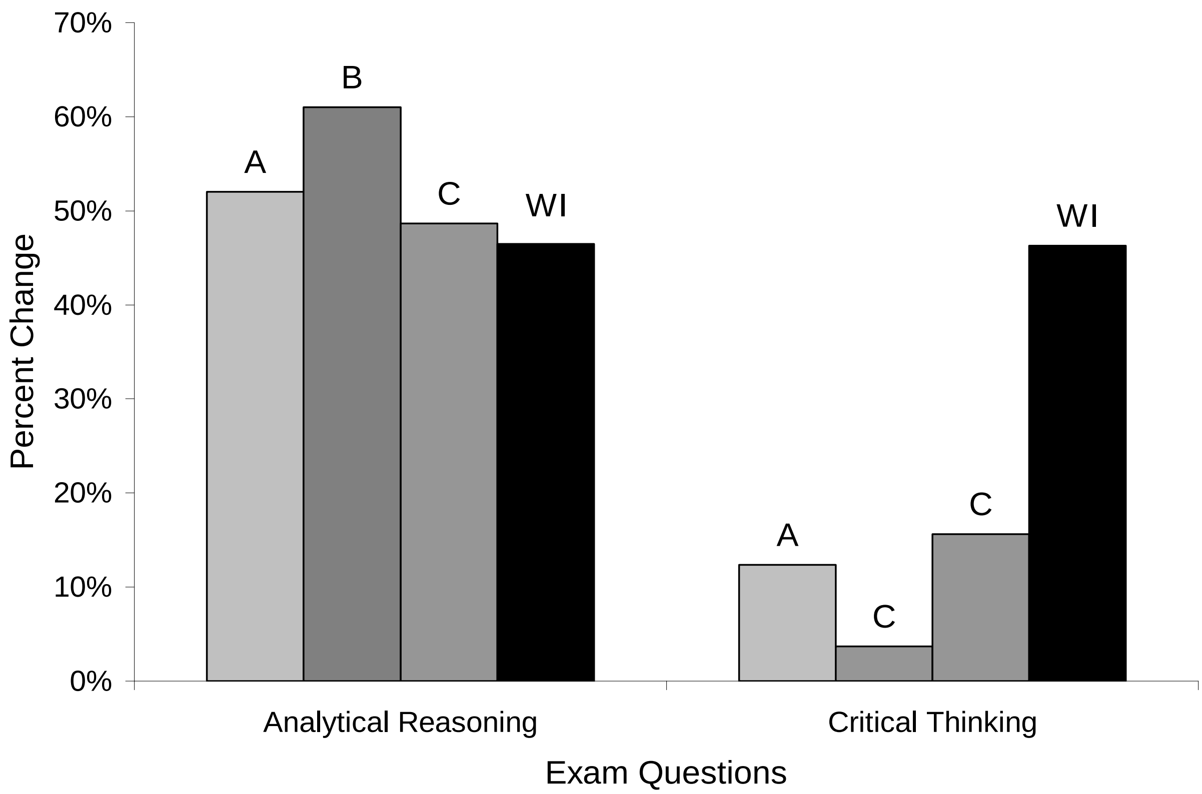


Figure 2. Average percent change on diagnostic test questions grouped by instructor or teaching method and separated by question type. Percent change calculated by dividing the average of the differences between pre- and post-test scores on questions of a similar type for each lab instructor or teaching method by the number of questions of that type.

Discussion and Conclusion

This study compares two differing teaching approaches to the same material. The results suggest that when students reconsider lab material after the lab experience and restate the material in their own words through writing, students more effectively develop the ability to explain and describe the material learned. Students who simply study and recall the studied material without the use of writing are less able to effectively explain and describe the information. Students learn basic facts and information using both of these techniques, but writing provides students an additional opportunity to enhance the learning experience. The reproducibility of learning between semesters clearly indicates the instructor has a vital role in student learning, but the overall effect of the instructor on student learning is muted by the choice of teaching method. This study suggests personal variations among differing lab instructors using the same material and the same method have a similar effect on student learning.

An unexpected result of the study indicates writing may assist students in learning specific skills otherwise missed by students in non-writing laboratory experiences. Student learning as indicated by the results occurs in the absence of writing, which validates that laboratory experiences are truly learning experiences. Students can learn facts and even apply these facts to the solving of problems without the use of academic writing. However, when challenged to think critically about lab results or processes by developing the ability to express the information through writing, students increase their ability to retain, explain, and use descriptive information. This result indicates writing enhances the overall student learning experience beyond the laboratory experience itself.

The results of this study indicate the amount of learning students experience in laboratory settings can be enhanced through the use of writing without increasing the amount of student or faculty time required. Increasing student learning without requiring additional time is a value-added asset for any lab course. As a result, all introductory chemistry laboratory sections of this participating university now use writing to enhance student learning.

Acknowledgements

This work is one result of an extensive effort by Lori Kanitz to form an interdisciplinary writing learning community at Oral Roberts University involving Leighanne Locke, Laurie Dorner, Fleta Buckles, and the author, with administrative support from the Dean of Instruction, Debbie Sowell, and financial support from a generous alumnus. Portions of this work were presented at the seventh Writing across the Curriculum conference in St. Louis, Missouri, 2004.

References

Bressette, A. R., & Breton, G. W. (2001). Using writing to enhance the undergraduate research experience. *Journal of Chemical Education, 78*, 1626.

CPR, Calibrated Peer Review™. (2005, May 5). Retrieved February 28, 2006, from http://cpr.molsci.ucla.edu

Emig, J. (1977). Writing as a mode of learning. *College Composition and Communication, 28*, 122-128.

Hedengren, B. F. (2004). *A TA's guide to teaching writing in all disciplines.* Boston: Bedford/St Martin's.

Kovac, J., & Sherwood, D. W. (1999). Writing in chemistry: An effective learning tool. *Journal of Chemical Education*, *76*, 1399-1403.

Kovac, J., & Sherwood, D. W. (2001). *Writing across the chemistry curriculum: An instructor's handbook.* Upper Saddle River, NJ: Prentice Hall.

Maimon, E. P., & Peritz, J. H. (2003). *A writer's resource: A handbook for writing and research.* New York: McGraw-Hill.

Ochsner, R., & Fowler, J. (2004). Playing devil's advocate: Evaluating the literature of the WAC/WID movement. *Review of Educational Research, 74*(2), 117-140.

Shibley, I. A., Jr., Milakofsky, L. K., & Nicotera, C. L. (2001). Incorporating a substantial writing assignment into Organic Chemistry: Library research, peer review, and assessment. Journal of Chemical Education, 78, 50-53.

Van Ryswyk, H. (2005). Writing-intensive multimedia projects in the instrumental methods course. *Journal of Chemical Education, 82*, 70-72.

Whelan, R. J., & Zare, R. N. (2003). Teaching effective communication in a writing-intensive analytical chemistry course. Journal of Chemical Education, 80, 904-906.

Kenneth M. Weed received a B.S. in BioMedical Chemistry from Oral Roberts University in 1986 and a Ph.D. in Physical/Analytical Chemistry from a joint program between San Diego State University and the University of California-San Diego in 1993. He joined the faculty of Oral Roberts University in 1996, and his primary teaching responsibilities have been in the general education chemistry program and in the upper-division biochemistry and environmental chemistry series. In 2005 he received the Eugene Swearingen Outstanding Faculty Member Award for excellence in teaching at Oral Roberts University. He with his wife and three children enjoy celebrating life in Tulsa, Oklahoma. Dr. Weed can be reached at kweed@oru.edu.

Principles of Chemistry
Laboratory Pre-Test

1. List in order the following 5 steps of the steps of the scientific method:

   Hypothesis, Experiment, Question, Conclusion, Observation

   What is the purpose of the hypothesis?

   What is the purpose of the question?

2. Distillation and chromatography are both techniques to do what?

3. Match the following techniques to the appropriate physical property by drawing a line from one term to another:

Filtration	Polarity
Distillation	Boiling Point
Chromatography	Permeability

4. Name the following compounds:

   $CuCl_2$:

   CS_2:

   KBr:

5. Write the chemical formula for the following:

    calcium iodide

    iron (III) nitride

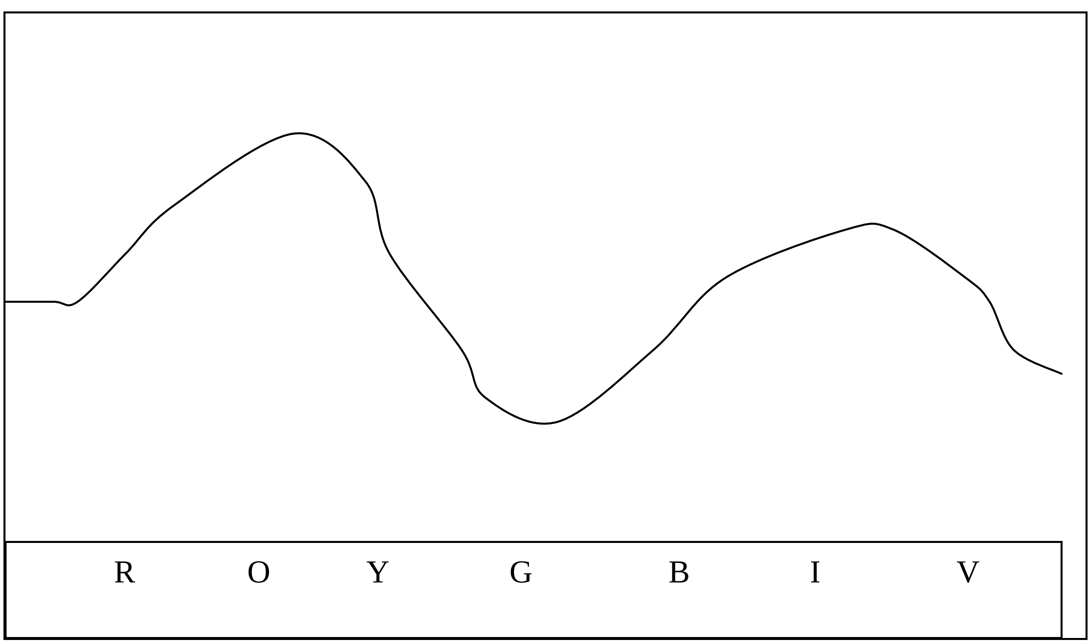
    dibromine heptafluoride

6. Which of the following is the most accurate piece of laboratory glassware to measure exactly 10.0 ml of liquid? (Circle one)

    Buret Pipet Graduated Cylinder

7. When is it preferred to use a buret instead of a pipet?

8. What is the color of the chemical that yields the following Spec 20 data?



Vol. 1 no. 1 ISSN 1559-8624 http://www.sotl_ched.oru.edu
SoTL_CHEd@oru.edu

9. Balance the following equation describing the reaction between Na_2CO_3 and HCl that eventually produces gaseous CO_2.

__Na_2CO_3	+	__HCl	→	__ _____	+	__ _____	→	__ _____	+	__CO_2	+	__ NaCl
#		#		# cmpd		# cmpd		# cmpd		#		#

10. Use the following information to answer the questions below:

	Diphacinone	Benzene	10% HCl
LD_{50}	485	930	2300
Inhalation	No	Yes	No
Ingestion	Yes	Yes	No
Absorption	No	Yes	Yes

Which is the most toxic when swallowed?

Which is the most toxic when poured on your skin?

11. Balance the following equation:

$$\_\_\_ \; C_6H_{12}O_6 + \_\_\_ \; O_2 \rightarrow \_\_\_ \; CO_2 + \_\_\_ \; H_2O$$

12. Given a mixture of salt and pepper in a glass of water, describe a method (without the use of tweezers or a magnifying glass) that could be used to separate the two, resulting in a pile of salt and a pile of pepper.

Vol. 1 no. 1 ISSN 1559-8624 http://www.sotl_ched.oru.edu
SoTL_CHEd@oru.edu