LABORATORY ASSESSMENT IN THE CHEMISTRY CLASSROOM

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ABSTRACT

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The objective of this thesis is to propose a comprehensive strategy for Laboratory Assessment in the Chemistry Classroom that effectively evaluates and validates the learning that occurs during laboratory activities. This thesis provides the rationale and methods to implement a cohesive evaluation procedure incorporating ten different forms of laboratory assessment. This Laboratory Assessment procedure was tested on 92 chemistry students of differing abilities. The students and teacher found this comprehensive approach to laboratory assessment highly effective and enjoyable.

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Introduction

Statement of problem and rationale for study

There is an emphasis placed on book oriented learning in today's high school chemistry courses. Due to demands on teaching time made by curriculum, mandated testing, and administration, chemistry programs spend less time in the laboratory and more time on "chalk and talk". Teachers downplay the importance of labs because of textbook constraints, safety concerns, and indefinite assessment results. This is disturbing.

There is a strong intrinsic value in the laboratory experience. Real learning, the true understanding, of scientific concepts comes through everyday world experience. Labs offer students those connections that can transform theory into practice, and ideas into practical applications.

A belief in the importance of laboratory work is not enough. Teachers and students lack the luxury of time to engage in "feel good" activities. To justify the time and expense of labs, the learning that goes on in the laboratory must be assessed and validated. The objective of this thesis is to propose and analyze a series of strategies for laboratory assessment in the chemistry classroom.

Comparison of old with new approach

Many chemistry teachers use lab manuals to manage the paperwork associated with lab activities, since they provide tested procedures and data sheets for each exercise. The regular use of these lab manuals is assumed to provide the students with a quality lab experience that is easy to assess by the teacher. The attraction these manuals have is quite significant for both the student and the teacher – perhaps because they do not require higher level thinking of either. The student only needs to fill in the blanks, and the teacher can quickly grade them by simply surveying the data sheet for completeness.

The skills acquired and emphasized in lab activities must be more substantive than the ability to follow directions and fill in the blanks. The learning that occurs in the lab must be assessed and documented more accurately. Many current lab manuals do not emphasize problem solving and critical thinking skills. However, with modification, common lab activities can be redesigned to encourage higher level thinking and provide richer assessment opportunities. By reconsidering the purpose of laboratory activities in the chemistry classroom and how they are assessed, teachers can better measure and reward the learning that goes on in the laboratory. Through the systematic use of a formalized lab based assessment process, students and teachers can gain a greater insight into the value of laboratory exercises.

The lab based assessment process considered here differs from the traditional approach to chemistry labs and their assessments in that it:

- Encourages the use of open ended laboratory exercises, requiring higher level thinking skills, in place of the more common fill-in-the-blank "cookbook" lab exercises.
- Proposes that every test should contain some manner of hand's-on performance assessment designed to evaluate and reinforce laboratory investigations.
- Proposes a process designed to make the chemistry class and its labs a more cohesive undertaking rather than a collection of disjointed activities that have no connection with what is covered in lectures or on tests.

Where Laboratory Assessment fits into the curriculum

The laboratory based assessment program described in this thesis is designed to be integrated throughout an entire chemistry course. During the ordinary operation of a class, information about students' understanding of science is needed almost continuously. Assessment tasks are not afterthoughts to instructional planning but are built into the design of the teaching. Through a systemic implementation of a variety of assessment activities teachers can gain a greater awareness of the students' understanding of chemistry concepts and their ability to actually perform scientific investigations.

Only by continuously evaluating students can a teacher gain a true impression of the strengths of their students and the effectiveness of their program. If assessment is relegated to a few disconnected "test days" then it becomes an arbitrary intrusion into the flow of the class that is designed to do little more than put scores in the teachers grade book. These scores are false indicators of the students' learning since they may not truly measure what the students understand. Erratic and inconsistent assessment destroys the cohesiveness of the course and conveys a negative impression of the teacher's plan.

This thesis strongly advocates the use of laboratory exercises and legitimate assessment of the learning that occurs during these exercises. This paper will analyze many different forms of laboratory assessment in terms of their efficacy and ease of implementation for both students and the teacher. Legitimate laboratory based assessment is most effective when it is used consistently and constantly throughout an entire chemistry course. It enforces an air of relevance and accountability for the students' learning as it ties the disconnected parts of a chemistry class into an integrated whole. Effective laboratory assessment should be a constant, fixed part of a successful course since it promotes the reality of chemistry as an underlying fabric of our lives rather than as a subject composed of isolated facts.

Literature Review

Rationale for lab experiences in High School Chemistry courses

Chemistry is an experimental science and without labs it's not chemistry at all. (Beach and Stone, 1988) It is clear than an understanding of the principles and *practice* of science is an essential goal for all students. (Michigan State Board of Education, 1991) Since science itself is an active investigation of the world, students must physically explore the concepts and ideas presented in a science course. Through lab work, students can appreciate the connectivity and the complexity of science in the everyday world in a way that goes far beyond book or rote knowledge.

"Laboratory experiments are the most effective method for learning chemistry." (Beach and Stone, 1988) Laboratory investigations can provide practical examples of scientific ideas. These activities can provide the "indisputable evidence and ample personal experience" needed for students to reconstruct correct understandings of their world. (Miller, et. al., 1997) Labs allow students to prove to themselves the truth of science and present students with tasks that are interesting, worthwhile, and relevant to their lives. They can validate the concepts covered in non-lab activities thereby making the entire course more cohesive.

Lab activities deepen students understanding of subject matter through multi-sensory experiences. During a lab activity, a student's hands, mind, eyes and other senses are focused on the task at hand, thus enhancing opportunities for cognitive and personal growth. (Institute for Chemical Education, p.1, 1990)

Many sources agree that "hands-on/minds-on" science education is of a much greater value to students than learning from a book or lecture format. The National Standards support this view of science as an "active process" with its implied physical and mental activity. They state that "Learning science is something students do, not something that is done to them." (National Science Education Standards, 1996)

The wide range of possible student learning associated with well-designed lab activities can be mapped in terms of Bloom's categories. (Institute for Chemical Education, p.2, 1990; Bloom, 1971) Psychomotor outcomes favorably impacted by labs include manipulative, "hands-on/minds-on" skills such as reading a meniscus, and adjusting a burner; as well as less obvious psychomotor skills such as maintaining a readable lab notebook and taking effective action when common lab hazards are encountered. Affective outcomes include the development of positive attitudes towards lab-based instruction and the cultivation of scientific attitudes. Cognitive outcomes such as knowledge, comprehension, application, analysis, synthesis, and evaluation of chemical concepts are all enhanced by lab activities.

Laboratory experiences teach safety applicable to the home and workplace. They see proactive safety procedures that maintain a level of safety in excess of the requirements found in most places outside of schools.

Labs can contribute to a student's self-confidence, decision-making capabilities, and the ability to work as a team. Labs encourage students to become users and controllers of information as they explore their world.

Exploring the need for assessment during labs

If the expense and logistics of labs are to be justified, the benefits must be more substantive than simple enjoyment, teachers must verify what the students are learning in the lab. We must develop ways to document the learning in a realistic, authentic manner that actually evaluates the learning that we expect. It's a common-sense case that says if we value it, we should assess it...If we don't assess it, we won't get it. (Wiggins, May, 1989)

An acronym coined to emphasize this point is called the *WYTIWYG Principle*. It means *What You Test Is What You Get*. In other words, students will strive to master concepts and skills that they believe you will assess. Many teachers commonly believe that "If it's worth learning, it's worth assessing". Students can reverse this logic to produce the observation that "If the teacher doesn't think it's worth assessing than it certainly isn't worth learning"!

"The WYTIWYG principle (What You Test Is What You Get) is as trustworthy as Newton's 3rd law of motion. The implications are obvious: We must make our tests authentic embodiments of our goals; they must represent the kinds of student work we value." (Carlson, 1991) If tests determine what teachers actually teach and what students will study for – and they do – then the road to reform is a straight but steep one: test those capacities and habits we think are essential, and test them in context. (Wiggins, April 1989)

A portion of each student's grade should be influenced by reliable lab based performance scores. Since we need to measure and reward the learning that occurs in the laboratory in an authentic manner we must do more than simply require a completed data sheet at the end of the lab. The students must be inherently aware that what they learn in the lab is going to be on the chapter test and is designed to make a bridge to the lecture learning as well! We must hold the students accountable for the learning incorporated in the lab and require that they demonstrate their understanding in multiple contexts.

We must design and implement multiple assessment strategies that measure the learning that occurs during the lab in both written and performance formats. To those educators who worry that this sounds like teaching to the test – it should! Teachers *should* "teach to the test" – a test that serves our educational goals. At the heart of the science education improvement effort is the promotion of instruction and assessment as an indistinguishable entity. (Lang, 1995) Lab assessments should reflect everyday-life, interdisciplinary challenges in a manner that is worth practicing and repeating. "Assessing science through multiple-choice testing is like assessing Larry Bird's basketball skills by asking him to respond to a set of multiple-choice questions." (Hein, 1991)

We, the educators, must provide opportunities for our students to demonstrate their mastery of chemistry in a laboratory format. We are obligated to give the students authentic tasks that rely on their knowledge of chemistry <u>and</u> their laboratory skills. By implementing a process of laboratory assessment, the students' content knowledge becomes a means to an end, not the end itself. In this manner we can connect chemical concepts to our students' lives and reinforce in them the reality of chemistry as a ubiquitous experimental science rather than just a confusing collection of isolated facts.

Laboratory assessment strategies

There is no question that we should develop rich assessment activities that accurately evaluate our students in the lab. Textbooks almost universally supply lab books that suggest lab activities, complete with worksheets designed to guide and evaluate students. In their attempt to provide a very marketable lab book that will be successful for students and easy to use by teachers, they often produce lab guides that are little more than "cookbooks". These lab guides give too much direction and too little room for exploration and higher level thinking. They fool the teacher into believing that they offer strong lab experiences that allow the teacher to evaluate their students' understanding of important chemical concepts. Instead, they may merely result in students who are very good at following step-by-step directions and filling in blanks. These students are deprived of the opportunity to design their own procedures in open assessment activities and the teacher is left to evaluate the students based on only very minimal data about low level thinking skills.

Designing alternate assessment strategies is the challenge. Good assessment tasks should be natural parts of the curriculum that are feasible, inviting, and capable of meeting the scoring and reporting needs of everyone involved. Successful assessment strategies must be both effective and efficient in their use of time and materials. They must stimulate all levels of thinking and multiple cognitive domains.

Fortunately, the learning environment is replete with opportunities to evaluate our students, particularly during laboratory exercises. We can assess students in a variety of ways: we can observe what they do, listen to what they say, read what they write, and analyze what they produce. Any behavior that can be observed can be adapted for assessment. (Hein, 1991)

The following is a description of alternative assessment strategies that can be used during the lab to give teachers a better understanding of what the students really know:

- Laboratory Notebooks – Instead of using pages from the typical fill-in-the-blank lab books provided by textbook manufacturers, a teacher may require their students to maintain a laboratory notebook, where the student is required to keep a neat and organized log of all the lab activities. The students are responsible for recording all the different steps of the investigations including, for example, Purpose, Procedures, Data & Observations, Calculations, Results, Conclusions and Reflections. In this way the students can learn through example how to begin thinking about how to create a carefully designed experiment while learning the intricacies and advantages of efficiently designed lab notebooks. Only by actual practice can students learn to write the "clear, step-by-step instructions for conducting investigations" advocated by the Benchmarks for Scientific Literacy: Project 2061. (1993) By requiring the use of lab notebooks the teacher encourages individual thinking and higher level learning. The teacher also acquires a yearlong assessment tool that can record growth over time – something that can not be easily evaluated by standard rip-out and hand-in data sheets from a lab book.

- Performance Checklists – These are lists of traits or learning behaviors that the teacher wishes to focus on and record when evidenced by the student. They encourage specific, systematic evaluation in an easy-to-use format. They can provide a clear picture of student progress over time if used regularly throughout the school year. The teacher creates a performance checklist by identifying and listing important target behaviors that they wish to observe and evaluate. The teacher's behavior is a visual cue that the lab activities the students are involved in are important and the students will be held accountable for their actions during the lab. Frequent, obvious use will reduce the students' concern about the evaluation.

  If the teacher wishes to have reliable data, periodic use of performance checklists is necessary, since a single instance does not a pattern make. Students who have truly internalized appropriate lab procedures will demonstrate them consistently – not sporadically.

- Interview Sheets – These are lists of questions used by the teacher to record and evaluate student impressions and insights. They are traditionally used in a conference format either before or after a unit. Interview sheets are equally proficient at ascertaining a student's prior knowledge or exit knowledge. They have the added benefit of encouraging direct communication between the student and teacher about their feelings concerning the student's progress, the lesson, and the teaching associated with a unit. The teacher uses an interview sheet to focus their questioning and to simplify the recording as they discuss with the student their understanding of the lab. A carefully designed interview sheet can target important behaviors and keep the documentation manageable. Effective interview sheets should encourage thorough and efficient assessment.

- Peer Assessments – Informal peer assessment is a constant part of every classroom. A teacher can formalize this process by following up a lab activity with a written evaluation assignment that encourages the students to reflect on their partner's and their own performance in the lab. Students present a work-in-progress while others critique and offer feedback on their impressions of the student's work. Peer assessment can also be used to evaluate teamwork skills and individual contributions. It is a useful technique for fostering cooperation and mature work habits; and encouraging all students to be individually accountable for their work during a lab. Students can acquire the ability to self-evaluate as they evaluate others and are judged by their peers in return. I believe that this process identifies student strengths and weaknesses as a team member and teaches the students tolerance of the different roles students play in group dynamics.
- Performance Tasks – These performance assessments require the student to actually prove that they understand the material as they demonstrate to the teacher specific scientific procedures. Unlike traditional tests that focus on facts and discrete skills, performance assessments are

designed to test what we care about most – the ability of students to use their knowledge and skills in a variety of realistic situations and contexts. An example would be to require the students to experimentally determine the percent of water in a hydrate rather than just do a percent composition math problem on a test. Performance assessments are motivating since the students get to *do* "real" chemistry rather than just talk about it. Performance assessments can connect the classroom and the everyday world by having students demonstrate the chemistry of common products.

Demonstration books offer a large amount of readily available background material for activities that can be modified into performance tasks. Because of the abundant amount of background, explanations, and descriptions provided to teachers, it is very easy to determine the appropriateness of a demonstration for a performance task. These same materials give extensive information on the materials and solutions required for the demonstrations as well as important safety guidelines.

- Open-Ended Laboratory Exercises – This is a form of embedded assessment designed to encourage higher level thinking. These activities provide a minimum of directions from the teacher and an opportunity for the students to design their own approach to the required task. They offer a rich assessment opportunity for the teacher to evaluate the content knowledge, performance abilities, laboratory skills, and conceptual understandings of the student.

Most chemistry teachers have a large collection of laboratory books. Though they are overly structured and inflexible, they do provide exercises with the rigid framework and support some students need when they encounter new material. As written, they offer excellent initial learning opportunities, but they do not truly assess the learning that occurs. By pairing up a set of similar labs we can eliminate this shortcoming. A second, similar lab is modified to be more open-ended and investigative in nature, making it a superior assessment activity that more accurately evaluates the learning the occurred during the first lab. In this way we can assess and confirm the learning that occurred in the first lab and reinforce its value as we hold the students accountable for the learning in the second lab.

The first step in creating this type of assessment exercise is to identify the specific learning objectives to evaluate. The teacher must carefully review the previous practical experiences the students have had related to the objectives. The task must be stimulating, but not overwhelming, and allows the students to successfully apply previously learned skills and knowledge.

Open-ended labs are actually quite easy to devise once the teacher learns to "let go" a little bit. In open-ended labs the teacher takes on the role of facilitator and relinquishes the role of teacher to the students. This is not an easy paradigm shift and it is easy to get baited out of it by students who emotionally plead for specific procedures when all they really need is a hint to nudge them back on to the right track. Teachers who start with a clear view of their intended outcomes in open-ended labs find the process easier for their students to perform and easier for themselves to assess.

- Teacher Demonstrations – The students are required to analyze and explain a chemical reaction performed by the teacher. This form of laboratory assessment is quick to perform, easy to modify, and informative in its evaluation of the students' abilities. It allows the teacher to use highly-motivating "exocharmic demonstrations" that convey the unspoken message that science is exciting. (Shakhashiri, 1983) Teacher demonstrations can maintain the authenticity of a testing assignment while at the same time allowing for multiple modalities of learning. The students actually "see" the reaction they are being asked about rather than having to just picture it in their mind in response to a written question. Teacher demonstrations can be easily modified into Lab Based Assessments suitable for inclusion in unit tests. Since chemical demonstrations are used as a teaching strategy it is natural and even advantageous to also use them to assess the student's comprehension of the material. This approach validates the purpose for doing the demonstrations and holds the students accountable for the ideas presented by demonstrations. In this manner we can engage the students brains as we entertain them with the "magic" of science. Demonstrations should do much more than impress the students – they should actually teach and assess as well.

Teacher demonstrations are modified into Laboratory Based Assessments (LBAs) based on the ideas and skills the teacher wishes to assess. Some skills or ideas that a teacher desires to assess may have only a limited number of activities that can be used to assess them. Often some of those activities that could be particularly effective are not suitable for the students to work with directly. This may be due to the expense of materials such as in activities that use a significant amount of silver nitrate. Another reason for not having the students perform the activities directly might be because of serious safety hazards inherent to the activity – such as in an activity that would require the students to handle concentrated sulfuric acid.

Another advantage to using teacher demonstrations to assess the learning that occurs during lab activities is the efficiency with which a large number of students can be evaluated. Teacher demonstrations are very economical in terms of class time and materials. They also guarantee that everyone gets the same initial information. This helps verify that we are truly assessing the students' ability to interpret the data – not collect it. This can remove the procedural stumbling blocks sometimes present in labs that might mask a student's ability to perform some calculation, interpret data, or analyze results. Since students complete their part of a teacher demonstration independently, it also promotes individual accountability since students can not rely on others to "carry them".

- Lab Oriented Written Tests – These are specifically designed to evaluate the learning that occurs in the lab, and to encourage higher level thinking, through the use of a variety of higher-level questioning techniques including enhanced multiple-choice questions. Enhanced multiple-choice questions are designed to be more challenging in terms of the thinking required to determine the correct response. They are designed to be reflective of experimental data and situations that require the student to identify relevant information and manage the appropriate variables accurately. They can also be made more open-ended by requiring students to defend the choice they make. The appropriate use of scaffolding (information provided in the task itself to help students frame their responses) can improve the quality of responses as it fosters students' best thinking and writing.

  Written assessments are quick, effective ways to check for understanding. They require no additional materials and pose no safety concerns. They force every single student to be individually accountable for the learning and can be very specific in the information they test.

- Conceptualization Activities – These are used to evaluate student's understanding of the theories and concepts required to explain the observations encountered during a lab or demonstration. The main difference between these activities and other forms of assessments is the type and depth of the questions posed by the teacher. In these activities the students' ability to collect and manipulate data is less important than their ability to rationalize how the data supports overriding theories and principles. Whereas most LBAs often test for important basic information and terminology, conceptualization assessments are generally looking for more theoretical explanations such as why certain reactions occur. Unlike other assessment tools in which the student's ability to carefully observe the demonstration is critical, conceptualization activities often use a demonstration only as a prompt to aid student thinking. The physical demonstration offers a bridge from the concrete laboratory activity to more theoretical or abstract concepts.

- Laboratory Practicals – These require the students to demonstrate their knowledge and skill by performing a series of performance tasks in the laboratory. This form of assessment allows the teacher to evaluate numerous student attributes including the ability to follow directions, manipulate equipment, perform labs, analyze data, and perform open-ended investigations.

All of these tools are excellent alternatives to the "cookbook" evaluations offered in traditional lab books. When all, or many, of these assessments are used regularly, they can transform the evaluation process into a richer, livelier process that is rewarding for teachers and learners. "I used to teach children and evaluate their progress. But now I kid watch, facilitate the learning of children and try to discover why learners do what they do." (Mitchell, 1992)

The use of lab based assessments to augment traditional tests

Traditional tests, in spite of their efficiency and economy, often fail to tell us what we want to know the most. (Hart, 1994) Traditional multiple-choice tests hinder teaching and learning by

- Putting too much value on recall and rote learning at the expense of understanding and reflection.
- Promoting the misleading impression that there is a single right answer for most every problem.
- Turning students into passive learners who need only to recognize, not to construct, answers and solutions.
- Forcing teachers to focus more on what can be tested easily than on what is important for students to learn.
- Trivializing content and skill development by reducing whatever is taught to a fill-in-the-bubble format.

Traditional testing has created a lingering false assumption about the purpose of assessment, implying that assessment should bring closure to learning. (Michigan Assessment Team Assessment Guidebook, 1995) This is in direct contrast to the goals of embedded assessment that suggest that assessment should be integrated so that it is an ongoing process rather than a culminating activity. The best time for assessing what children know and can do is *during* instruction while the students are actively involved in the learning process, constructing their own knowledge and finding their own solutions, and not *after* instruction, when students passively fill in bubbles showing that they understand the test designer's solutions. (Annenberg, 1998)

Traditional tests have been used to evaluate students because of their efficiency for a long time, and will continue to be a primary form of assessment in spite of their limitations. Students need to be able to successfully demonstrate their understanding of chemistry on important standardized tests such as the High School Proficiency Test and Advanced Placement Chemistry Exam. They need to acquire both the knowledge of chemistry and the test-taking skills necessary to pass these tests. A teacher must remain aware of the reality of this situation and prepare their students for it. It is in the best interest of the students to teach them in a manner that encourages successful learning and assessment both in the present course and on these external measures of success.

Consequently, teachers must not abandon traditional testing formats altogether. The problem is the overuse of traditional testing to assess our students. This approach turns students into passive learners. It forces teachers to focus only on what can be easily tested and fragments the course into a disjointed collection of lectures, labs, and tests.

Our students will reap the greatest benefit if we assess them regularly using a combination of both formats during each unit of instruction. Combining written tests with laboratory based performance assessments allows the teacher to maximize the learning and assessment opportunities available in both formats while preparing them for the SAT, future courses, and the world at large.

Demographics of classroom

Jackson High School is a large Class A high school with 1648 students enrolled in the ninth through twelfth grades. The school district is the largest in Jackson County with a total enrollment of 7,456 students. It is an urban school district with a diverse student population including a large number of families from the economically depressed "inner-city" areas within Jackson. 32% of our students are minorities and 45% of our student body is financially disadvantaged and qualify for free or reduced lunch programs.

With the advent of today's schools-of-choice we are seeing our student population change since parents have increased freedom to choose whether their children attend our school. This is contributing to our student population becoming more polarized. One group is very school- and career-oriented with strong parental support, and the other group is academically challenged and unmotivated with poor family backgrounds.

The schools-of-choice option has allowed us to successfully recruit over one hundred new students into our high school, since we are generally perceived as having the strongest academic curriculum in the county. For example, the size of our program allows us to offer fourteen different science courses as compared to the average of six science courses offered by other local school districts. The quality of the high school's science, music, and foreign language departments is specifically cited as the main reason many of our new students have transferred to Jackson High School. The typical students attracted to our school by our curriculum are highly motivated and academically successful.

On the other hand, we are also losing students to surrounding school districts at an alarming rate due to perceptions of racial tension and a lack of discipline at our school. These reasons have been specifically cited by the families of some of the more than three hundred students that have left our school district at the elementary and middle school levels. As affluent families continue to move out of Jackson Public School District to the large number of wealthy housing developments in neighboring school districts, we see well-to-do but not particularly academically-oriented students leaving our school. These factors result in a polarization into groups composed of either the high-powered, university-bound students or the economically deprived, at-risk students.

We offer three levels of chemistry at Jackson High School. Our Practical Chemistry course is a "math-less" Chemcom course designed to provide very basic chemical literacy and help meet the needs of student science credits necessary for graduation. The students in our other two levels of chemistry (General and Advanced Placement) have chosen to take these elective courses even though they have already completed the number of science credits needed for graduation. The General Chemistry class, on which this thesis is based, is a math based college-bound chemistry course for both science and non-science majors. Our Advanced Placement Chemistry course is offered only to seniors and is a highly successful college-level chemistry course designed for students wishing to pursue a career in the sciences.

In this study of Laboratory Assessment in the Chemistry Classroom, 92 students (36 male and 56 female) from three General Chemistry classes were involved: 75 sophomores, 15 juniors, and 2 seniors. The average grade point of the students included in these classes was a 2.98 and their average expectation was to spend 1-2 hours a night on homework. The study group included 67 who indicated an intent to take the Advanced Placement Chemistry as seniors and 69 indicating they plan to study science in college. Eighty four percent indicated that they were part of a two-parent family. 15% were identified as being economically disadvantaged and 22% identified themselves as belonging to a minority.

Laboratory Assessment Implementation

The systematic implementation of effective laboratory assessment caused me to thoroughly reevaluate my entire approach to teaching chemistry. I found very few areas that did not require significant revision as I attempted to develop a more cohesive assessment procedure that would be more informative. The following is an outline of the steps I used in developing laboratory assessment in the chemistry classroom:

1. Administration of pretest, survey, and student interviews
2. Implementation of lab notebook procedure
3. Implementation of other assessment options during labs
4. Revision of tests to incorporate lab based assessments, performance tasks, and authentic assessments
5. Development of lab practicals
6. Posttests, surveys and student interviews

Administration of pretest, survey, and student interviews

All of the students involved in this study were given a pretest and survey designed to identify student perceptions about the role of labs in science courses. The pretest was a series of statements to which the students were to indicate their degree of agreement using a numerical scale. The scale ranged from a one (indicating strong disagreement) to a ten (indicating strong agreement). The complete pretest can be found in Appendix A, part 1, and the survey can be found in Appendix A, part 2.

Based on the answers students provided on these pretests a cross-section of students was selected for in-depth interview about these ideas. Students with high, average, and low performances in past science courses were selected. The students were encouraged to discuss their impressions of the purpose and the validity of labs and their assessment in science courses.

Implementation of assessment tools during lab activities

The use of a laboratory notebook was instituted to provide a more authentic assessment of laboratory activities. Each student was required to keep a complete account of all lab activities for the entire chemistry course.

For the sake of uniformity, the students were provided with a blank, spiral-bound, college-ruled notebook. The color-coded name labels identified the class the student was in and simplified the handling of the large number of notebooks. To minimize the wear-and-tear and the number of lost notebooks, the students were encouraged to keep their notebooks in the classroom when they weren't using them.

The students were told at the very beginning of the course that they would be using lab notebooks throughout the entire year to raise their level of laboratory reporting to what would be expected of them in college labs and in a professional, working laboratory. The students were informed of my intent to have them produce a lab write-up for every lab performed in this class. They were given specific instructions on how to use and maintain their notebooks.

I explained to the students that they would usually be given a "pre-lab" paper the day before the lab that would have all the information they would need to begin writing their lab reports into their notebooks. I wanted to ensure that they had read and understood the procedures and safety precautions before they began the lab the next day. These "pre-labs" varied from being very specific in their procedures to being very open-ended, depending on the goals of the lab and the students' gradually improving record keeping abilities.

The students were encouraged to use the lab report format shown in Appendix B, part 1 for all labs in this course. It is an adaptation of the one suggested by the Michigan Department of Education in its Model Instructional Unit. (Michigan Department of Education) The students were given these instructions regarding the appropriate protocols for laboratory notebooks. Appendix B, part 3 lists some advantages gained by the use of these notebooks.

To help the students learn the process and purpose for using this lab report form the class examined a selection of "pre-labs" and acceptable lab reports. Appendix B, part 4 contains one of these sample lab reports. We discussed how "pre-labs", with their background explanations, safety precautions, and lab procedures, should be modified to conform to our standard report format. The students were instructed on how to create their own data tables to record their observations, data, and calculations. After examining the sample, the students were assigned their first lab report to record in their notebooks using this laboratory report format. Before beginning the lab the next day, the lab and the notebooks were discussed in detail.

Students require time to acquire the ability to write accurate, organized lab reports. The students need to clearly understand the teacher's expectations as to what, when and where they should record pertinent information from the lab. Early lab activities must allow for this learning period and frequent feedback from the teacher prior, during, and after the lab will dramatically cut down on the time necessary for the students to create professional reports. I required that the students must have completed the Purpose and Procedure sections of the lab report the night before the lab. For the first few labs of the year, I also required that they show me the data table they planned to use *BEFORE* they began the lab. Many students initially required assistance in developing suitable data tables. I chose to include a suggested data table in some of the early pre-labs. I gradually phased these teacher-created tables out of the pre-labs as the students' abilities improved. The students were expected to record data and observations as the lab progressed and to complete the entire lab report before the next day.

For maximum benefits, the laboratory activities must be rewritten to be "minds-on" as well as "hands-on" so that the major cognitive skill being cultivated is something more than the ability to accurately follow written directions. The decision to use lab notebooks is a major commitment for a teacher. This decision will significantly change the way in which a teacher prepares and evaluates a lab experience. Lab reports encourage deeper learning for the students and give the teacher a much richer assessment of their understanding and abilities.

For an example of this transformation I modified a lab found in Prentice Hall's Laboratory Manual. (Wagner, 1989) The lab is shown as it might be found before (Appendix C, part 1) and after being transformed (Appendix C, part 2).

The major deficiency of the "typical" lab procedure is the general format of the laboratory manual itself. The tendency of my past students was to skim quickly through the procedure and rip out the data sheet so they could hand it in as quickly as possible. The students rarely read the background material since it was just "filler" in between what really counted – the data sheets. They felt that they had completed the lab once they had filled in all the blanks on the data sheet. Their goal was to fill in the blanks, not learn the material.

The data sheets rarely contained graphs or tables to help organize or interpret the students' information. The students developed very little appreciation for how to manipulate and present the data collected during a lab. They were unaware of the amount of interpretation and analysis that occurs in the lab following data collection. Consequently, the students performed very poorly on later assessments that asked them to analyze the processes, data, or reasons for performing these labs.

Some lab manual procedures have deficient or missing sections on safety and equipment. They sometimes make reference to equipment that is not available. They often use materials that are no longer considered safe to use in high school labs. These labs often fail to give sufficient background for the lab. When such information is given, it is often unsuitable and confusing to the students.

Appendix C, parts 1 and 2 show that rewriting a traditional lab into a format suitable for use with the lab report outline can be a lengthy process. I found that the students needed very specific directions about what to include in which portion of the report. This required very careful rewriting of the directions for each lab I planned to use. Coincidentally, it also made it very convenient to modify the lab to my purposes since the students weren't going to use the original lab instructions anyway. I always gave some background about the lab and why we were doing it.

The logistics of using laboratory notebooks requires some additional planning for the teacher. Students must be given the appropriate pre-labs the day before the intended lab day so that they will have sufficient time to record the procedures and create data tables prior to the lab. Sufficient time must be allotted for the students to complete and hand in their notebooks following lab exercises.

Reading and grading the lab notebooks is a time-consuming process. It was easiest to grade every student's report for a specific lab activity all at one sitting. This gave me a better impression of how the students compared to each other and encouraged uniformity in grading. To prevent specific labs from having an undue impact on the grading system, all labs were graded on a basis of ten points. A perfect score of ten was recorded for lab reports that were complete and accurate. Incomplete reports (those missing sections specifically required by the standard laboratory report format) could only earn a maximum of five points. Reports that were complete but inaccurate would earn a score usually between five and ten points. I enjoyed writing comments on their labs that were intended to improve their reporting skills and their understanding. I also used this feedback to show them that I cared about what they wrote. I received many positive reactions from students because of these responses.

Grouping students for lab activities is an important consideration. If we want to hold students truly accountable for their learning we must remove the temptation and possibility of relying on their lab partner to carry them through the lab. Lab notebooks can help fight this temptation – it's difficult to copy an entire lab report! Rotating lab partners will also reduce the tendency for one student to always be the leader and another to always be a follower. If students can not rely on having a "smart" lab partner they are forced to become more self-reliant. The validity of lab based assessments is increased if students are required to perform an assessment activity with a different partner than the one they had during the lab in which they were to learn the skill being evaluated. I developed a workable strategy for the frequent rotation of lab partners that was viewed as being fair by the students. First, I posted all the names of the students for my class in two columns on the bulletin board. The students could see who their partner was for that day's lab by looking to see whose name was next to theirs' on the board. After each lab activity, one column was moved so that the students never had the same lab partner twice in a marking period. In this way the students were held accountable for their own ability to learn and function in the lab.

To maintain the continuity of the course and improve the validity and depth of the evaluation it is beneficial to vary the format of assessment items. Multiple assessment activities will teach students more about the subject as they reveal more about the students to the teacher. In addition to the lab notebooks, I also used performance checklists, interviews, and peer assessments to assess the students in the lab. Each of these assessment tools has its advantages and disadvantages. The assessment strategy being used should be tailored to the learning being evaluated.

An assessment task without a previous learning activity is a test of prior knowledge – not of learning. Consequently, although most of these assessment strategies could be modified to be initial learning activities with built-in embedded assessment, I usually used them as a secondary activity designed to evaluate the students' understandings of learning objectives I had targeted in earlier lab experiences. It was important to match the assessment to the desired lab outcomes. These lab assessments were not, and should not, be limited to lower level knowledge skills. However, assessment of higher order skills is not feasible if the original lab activities were not designed to develop these skills. You can't test what the students haven't practiced!

I varied the assessment strategies I used based on the skills and additional learnings I wished to evaluate. For the sake of this study, I used *all* of these assessment options to evaluate a single lab – one in which I hoped my students had learned to experimentally determine the empirical formula of a compound. This lab was the Copper Formula Lab. The following paragraphs will show how I used the four different forms of laboratory assessment that can be used *during* a lab with this one lab experience.

The students were given a highly structured pre-lab, which they wrote up as a lab report and then performed in lab. This pre-lab as shown in Appendix D, part 1, is one form of lab assessment that could be used during this lab.

As the students performed the Copper Formula Lab, (the I used a performance checklist (Appendix D, part 2) to evaluate their performance. When using performance checklists, I found it helpful to circulate among the students during the lab activity and recorded as many observations as possible. I also used performance checklists to provide important checkpoints during a lab to help manage the flow of the lab. These checkpoints required the students to report their data to me and receive approval before proceeding. These required data checks insured that the class was working at the same pace and reduced the safety concerns inherent to some labs. These checkpoints were also used to collect student data that was then reported to the entire class by displaying various lab groups' data on the board. This technique produced a large amount of data in a timely manner that was useful for graphing or other statistical manipulations.

Another form of assessment that was used during the Copper Formula was the interview sheet. With this tool, I asked the students about their perceptions of the lab by asking questions such as "Why did this lab require two days?" The complete interview sheet can be found in Appendix D, part 3.

Since it is logistically difficult to conduct an interview with every student during a lab, I prefer to use a rotation to assess only a small number of students using interview sheets during any particular lab. I select a small number of students beforehand that represent a cross section of my class. I prefer to use two academically successful students, two medium ability students, and two students who are having academic difficulties in my class. The responses the students offer can give a quick insight to what the labs look like through a student's eyes. By using a heterogeneous sample, I feel that I get a representative indication of the clarity and success of the lesson. Student responses highlight weaknesses in the lesson's design, allowing me to make corrections immediately to improve the lab's effectiveness for the rest of the class. For example, if I find that a large number of students are having the same difficulty or are failing to understand why a particular step in the procedure is necessary, I can correct this problem immediately.

The fourth form of evaluation that I used during the Copper Formula lab was peer assessment. I used peer assessment sporadically, throughout the course – usually in conjunction with some form of teacher moderated assessment. The peer assessment form I used for the Copper Formula lab can be found in Appendix D, part 4.

I felt that to have successful peer assessment I would need to first provide the students a chance to practice this strategy in a non-threatening manner. I used the Clapping Hands performance assessment activity (Busik, 1995) to give the student's the opportunity to rehearse giving each other feedback. Through the discussions generated by this activity I attempted to teach the students how to assess others and what constitutes useful feedback. I felt that the students were much less apprehensive about peer evaluations following this exercise.

Implementation of post lab assessments into unit tests

I wanted to continue to use traditional unit tests because of their inherent advantages and the need to prepare students for standardized testing; yet, I wanted to avoid being over reliant on this strategy. I wanted my students to be constantly responsible for all of the material presented throughout my course and be able to use the lab to physically demonstrate or explain what they have learned in both labs and other non-lab activities. Therefore, I attempted to incorporate a hand's-on, authentic, Lab Based Assessment (LBA) of each student's understanding into *every* test or quiz in my class. LBAs were designed to be physical demonstrations (authentic assessments) of what the students actually know.

The most common form of LBA I used were performance tasks that required the students to carry out certain chemical procedures. These performance tasks were quick and direct evaluations of particular abilities of the students. They tended to be simple in design and minimal in terms of required resources. These tasks were very concrete and specific in the knowledge they assess, such as the ability to determine the density of an irregular solid. They were presented as self-directed labs that ask students to design their own experiments while at the same time reinforcing important laboratory skills such as the ability to write formal laboratory reports.

The Density of Sand Assessment in Appendix E, part 1 is an example of how assessment and reinforcement of skills can occur at the same time. I used the exercise to assess the students' ability to create an experimental design that would solve a realistic density problem. I reinforced their reporting skills by designing the task so that the students would create a suitable lab report as the written product.

The Density of Sand performance task quickly identifies students that are having difficulties with density. Its design encourages higher level thinking as the students create their own experimental procedure. The formatted report requirement provides enough structure to keep the students on the right track and reinforces how lab reports should be written.

Performance tasks can also be designed to be very conceptual or theoretical in nature. An interesting way to present this form of LBA is to design it as a logic problem that the student can solve using recently learned material. Appendix E, part 2 shows an example of how a logic problem can be used as a performance task at the end of a unit, in this case, one on acids, bases, and indicators. To successfully complete this LBA the students need the appropriate chemical knowledge and sufficient prior experience with solving lab-oriented logic problems before beginning this unguided task.

I also used open-ended labs as LBAs. These tend to be longer and more encompassing in nature than performance tasks. Whereas a performance task might assess only one or two ideas, open-ended labs would require and therefore evaluate the student's ability to compile a whole host of ideas and competencies.

At the end of the percent composition unit that included the Copper Formula Lab, the students were given a traditional test to be completed individually. They were then asked to determine the percent iron in an iron chloride compound by using two strips of aluminum and an iron chloride salt. This Lab Based Assessment was an open-ended lab intended to evaluate their understanding of the appropriate chemical process and their ability to physically design and demonstrate a correct laboratory procedure that would accomplish it.

To successfully complete this exercise each student pair was given the same materials used in the Copper Formula lab. The lab activity required me to substitute iron (III) chloride for the copper (II) chloride used in the Copper Formula lab. The procedure and safety items are the same. Since the iron (III) chloride is a hexahydrate, the anticipated student result for the percentage of iron is 55.8 / 270.3 x 100% = 20.6%

This type of performance task is an effective assessment of what was learned in the first experiment. It can be easily modified to elicit specific target behaviors. If the teacher's goal is to evaluate the students' abilities to perform the mechanical aspects of the lab and the associated computations, then the students would be required to produce an experimentally derived value. However, if the teacher wishes to assess the students' abilities to produce a step-by-step written procedure then the students could be required to submit a formal lab report for the process they used during the exercise.

When safety or expense constraints warranted, the LBAs were designed as teacher demonstrations during traditional tests, which the students would be required to explain. These demonstrations can be very simple and direct in what information they require the students to have mastered. They can also be very sophisticated requiring the students to coordinate many previously studied concepts into a single suitable explanation of the demonstration.

The Lab Based Assessment in Appendix E, part 3 was a teacher demonstration designed to evaluate the students' ability to interpret and balance chemical formulas and equations. Important safety and background information as well as teacher instructions for this demonstration can also be found in Appendix E, part 3. I performed this LBA as a series of reactions that converted sand into magnesium silicide, then into silane, and finally back into sand again. The students answered questions and balanced equations for each reaction in the demonstration. This demonstration is based on a silane demonstration presented by Paul Hunter and Sheldon Knoespel (1994) at a Michigan Science Teachers Association convention. This particular demonstration was chosen to be modified into a teacher demonstration assessment because of its multiple, straightforward chemical reactions, its eloquent cyclic nature, and general class appeal. Since this LBA was used early in the course when the idea of balancing was fairly new to the students, it is highly structured and offers hints for those who need a slight nudge in the right direction.

A second form of teacher demonstration is shown in Appendix E, part 4. This LBA was used to assess the learning that occurred in the Copper Formula Lab. It used an experiment very similar in design to the Copper Formula Lab. I arranged several lab setups on the demonstration table depicting important steps in the determination of the percent iron in an iron chloride compound using two strips of aluminum and iron (III) chloride. Student volunteers determined the relevant data and then posted this information for the class.

Occasionally the Laboratory Based Assessments were conducted as written assessments or conceptualization activities. These approaches are particularly suitable for highly conceptual ideas that would be difficult or impossible to actually perform in a high school chemistry laboratory. They also reinforce strong scientific reading and writing abilities that can help students on future standardized tests and eventually in the workplace. I usually included these assessments on the next unit test. There are several advantages to doing this. First – it makes the test more authentic and less intrusive. Second – it sends a clear message that the labs and the learning that occurs in them is important and will be evaluated. Third – it encourages the students to internalize and apply the new learning. The written assessment in Appendix E, part 5 was used following the Copper Formula lab.

Item number one from this assessment was designed to recreate the lab on paper. It determines whether the student could perform the calculations required by the lab and understood all the necessary steps.

Item number two assesses important basic concepts and terminology. Items like this are a means of quickly checking for a basic understanding of scientific terms, formulas, etc.

Item number three is an enhanced multiple-choice question that encourages and assesses higher level thinking skills. Enhanced multiple-choice questions are more authentic than traditional test items in terms of the problems they present and more challenging in terms of the thinking required to determine the correct response. (Hart, 1994)

Items four, five, and six are examples of error analysis tasks. Error analysis is an excellent example of how written assessment items can be used to encourage higher-level thinking. Error analysis is an important part of true scientific inquiry and written post-assessments of labs are probably the most effective, feasible means of doing this. Review of these error analysis items can lead to some excellent post-lab discussions.

Item number seven shows how questions on a written assessment measure the student's ability to apply what they have learned in the lab to an everyday world application. A question like this helps make the subject *"real"* for the students and encourages thinking about the practical implications of theoretical concepts. These questions are a favorite among some of my students who are always asking, "Why are we studying this?"

Item number eight is an example of a question designed to evaluate multiple skills such as the ability to interpret and organize data and the capability to determine percent error. It evaluates higher level thinking skills such as those involved with error analysis. It is also structured enough to be easily graded and yet intricate enough that a student can not simply guess at the best answer.

The conceptualization activities that I used to check for higher level understanding in my students took two different forms. In one form I had the students answer theoretical questions related to a sample reaction.

Appendix E, part 6 is an example of this type of activity that I used following the unit in which the class had discussed the activity series of metals, different types of reactions.

This form of conceptualization activity is very simple to design and present. It is simply a teacher demonstration modified to investigate deeper understandings as a result of the style of questioning. This example illustrates how conceptualization activities can be used to assess whether the students are applying the higher level abstract concepts covered in lectures and textbooks to practical demonstrations performed in the lab.

The second form of conceptualization activity I used involved demonstrations that the students were required to perform and then explain. This type of conceptualization activity is reminiscent of a performance task except that the students' ability to explain *why* the demonstration works or *how* it supports a scientific theory is being assessed rather than the student's ability to simply perform the activity. Appendix E, part 7 contains an example of this type of activity that was used to evaluate the students' understanding of the atomic theory of matter.

This form of conceptualization activity provides a rich experience – one that is written, visual, and hands-on all at the same time. Its constructivist design facilitates learning even as the students are being evaluated making this a more natural, embedded assessment. I believe this approach is more likely to trigger deeper responses and provide a richer assessment of what the student truly knows.

Development of lab practicals

Our school requires semester exams designed to hold the student accountable for the semester's content and encourage long-term retention of the material. When suitably constructed, they can also be used to prepare the students for standardized testing. In designing my semester exam I was strongly influenced by the following three concerns:

1. The need to prepare the students for standardized testing.
2. The desire to provide an authentic assessment of what the students have learned in the laboratory
3. The need to balance my high hopes for my students with realistic expectations of their abilities.

In response to these concerns, I have divided my semester exams into three parts. The students take one part of the exam every six weeks. Since the last part of the exam relies on information from the beginning of the semester the exam is still a cumulative test of what the student knows. This format seems to greatly reduce the student stress. It also allows me to use a much larger, more in-depth assessment than I would be able to if I used a traditional exam format.

The first two parts of the exam, taken during normal class time in the 6^{th} and 12^{th} week of the semester, are traditional paper-oriented tests similar to standardized tests. These tests have a few basic questions, but most of the items on these two tests are open-ended questions or enhanced multiple choice questions. They provide a quick evaluation of the students' content knowledge and provide an opportunity for them to perform some additional writing in science. For illustration, a portion of the written part of the second semester exam has been included in Appendix F, part 1.

The third part of the exam is taken during the regularly scheduled two-hour final exam period assigned by the school's administration. This part of the exam is a laboratory practical based on the ideas of Robert Becker, (1995). It is an open-book, lab-oriented series of activities designed to have the students apply what they have learned in a meaningful way.

The practical evaluates the students' ability to perform various scientific activities in the lab. Appendix F, part 2 is a copy of the first semester practical exam and Appendix F, part 3 is a copy of the second semester practical exam. The students are given a set of approximately ten lab activities that they must accomplish within the two-hour block while working in small groups. These activities cover a wide variety of topics and have a large range of difficulties. It is deliberately too long for any individual student to complete so that the students must work together as they divide their labors according to each student's expertise.

The students are assigned to homogeneous groups of four students based on their semester's academic performance in chemistry. Homogenous grouping eases the expectations for the low achieving students who have already found chemistry to be overwhelming. The strong science students who could benefit from being pushed to a higher level of competition find this type of grouping raises the expectations since they can no longer count on easy opposition. This method of grouping is highly motivational since it makes it possible for every student to earn a satisfying grade by providing realistic expectations based on demonstrated student abilities. Homogeneous grouping encourages every student to be accountable for the material since they are grouped with others with no better command of the subject then themselves and it reduces the stress within the group since the students end up grouped with others having a similar work ethic.

This grouping results in the highest achieving students in each class being grouped together. It also means that the lowest performing students are assigned together in a single group. Students are very concerned about this method of assigning groups until they are assured that groups with widely differing scores will not compete with each other. Instead the groups compete only with other groups that are on their same level or tier. These tiers are composed of lab groups with similar academic performances from all my chemistry classes.

The various lab groups and tiers are posted a week before the practical so that students have time to organize themselves and their studies. Practice worksheets, tasks, and labs are performed by each group the week before the exam to review the necessary information and procedures. Students often use this time to divide up work assignments and solidify individual responsibilities.

On the day of the test, each group of four students is given five copies of the test – one white official copy and four colored work copies. All five copies must be returned at the end of the practical, but only the single white official copy will be graded. All work to be graded must be recorded on the official copy only.

The exams are then graded and the scores for each level are plotted on a graph. This graph allows me to apply a best-fit line to the data from all groups. The intersection of this line with each tier is used as the denominator when dividing the raw scores for each group in that tier. This determines the perfect score for that level. This process results in an appropriate goal for each level with higher expectations for the advanced groups. It makes a perfect 100% possible for any group regardless of past academic performance. It also eliminates the possibility of an unusually high score in a lower group artificially inflating the goal for an entire tier.

Upon completion of the practical, the students are asked to evaluate their lab partners and their contributions. Forewarning of this peer assessment (especially following previous experiences with peer assessment) is a great individual motivator for those students who might be inclined to do less than their share of the work. This has the additional advantage of facilitating more discussion and communication within the group.

Administration of posttests, surveys, and student interviews.

At the conclusion of this study all of the students were given a posttest very similar to the pretest, as shown in Appendix G, part 1. They were also encouraged to recall and rank the various lab assessment strategies using the form in Appendix G, part 2. Each student was given a survey (Appendix G, part 3), composed of twenty two open ended questions.

A series of interviews was also conducted with the students who participated in the original interviews at the beginning of the study. The information from all three of these instruments was used to evaluate the attitudes of the students and the effectiveness of laboratory assessments.

Evaluation

This study was evaluated through the use of pretests, posttests, surveys, interviews of students, and student assessments. These were used to evaluate the effectiveness of the lab assessment strategies and the students' attitudes about them. This information allowed me to refine and modify the activities to more closely meet my objectives for doing them.

Pretests, Surveys, and Student Interviews

After the students had completed the pretests, their responses were carefully examined for trends. Their responses were averaged to determine a numerical value for the mean response to each statement. These values indicated the students' agreement with the statements on a scale of one to ten. It is important to note that higher values connote a stronger agreement with the statements. The results of this pretest are shown in Table 1.

Table 1 – Pretest Results

Item #	Statements	Mean Response
1.	Science courses should offer students lab activities.	9.6
2.	I believe that lectures and discussions teach chemistry more effectively than lab activities.	4.5
3.	I think science courses should offer more lab activities than they do.	7.6
4.	I think that labs are more work than they are worth.	3.5
5.	Lectures and labs in science courses are clearly connected.	7.0
6.	Science course laboratory work has increased my understanding of how scientists actually work.	8.2
7.	Labs make science more relevant to my life.	7.4
8.	Lab work increased my interest in science.	8.1
9.	Lab activities taught me more about science than the book or lectures did.	7.3
10.	I prefer open-ended investigative labs of my own design.	4.5
11.	Lab work improves my understanding of the material covered in lectures.	8.1
12.	Information from lab work should be a part of tests.	6.3
13.	I prefer traditional written tests to nontraditional tests that require me to do something.	4.3
14.	I concentrate more closely on lab work if I know I am going to be tested over the lab.	7.0
15.	I have used laboratory notebooks to record labs in science courses before.	4.9

The first fourteen items on this posttest were designed to evaluate the students' impressions of the relevance and impact of lab activities in previous science courses. The mean scores for these items show that there is a favorable understanding of the role that lab activities can and should play in science courses. Items one and three indicate that the students are strongly convinced that science courses should offer lab activities, and in fact, the study group's mean response indicates that teachers should *increase* the number of labs over the amount already currently employed. The responses to items two and nine show that the students initially felt that labs are moderately more effective than lectures or discussions and significantly more effective than bookwork at teaching chemistry. The students' general disagreement with item four shows that the students consider lab activities well worth the efforts required by them.

The complimentary nature of the lab versus lecture approach to teaching chemistry is reflected in the students' response to number eleven, where the students indicated their belief that lab work improves their understanding of the material covered in lectures. Item five indicates that the students see a cohesiveness between lab activities and lectures. In items six, seven, and eight, the students' mean responses indicate a favorable impression of the impact of laboratory activities in connecting chemistry courses to the real world.

Item ten addresses the question of structured labs versus open-ended labs. It is interesting to note that although the students are strongly in favor of labs they are mildly disinclined towards open-ended labs. This initial impression may be due to a lack of previous experiences with open-ended labs or perhaps due to unfavorable past activities for some students.

The next few items were intended to gauge the students' beliefs about how the students would or should be assessed. Item thirteen shows a mild disinterest in traditional testing whereas item twelve shows that the students believe that information culled from lab activities is appropriate to evaluate during tests. I believe that their mean response to this item is congruent with the students' belief expressed in item five that labs and lectures should be clearly connected. Item fourteen alludes to a secondary reason for including laboratory information on tests. Since the students indicated that they tend to concentrate on the labs if they know they are going to be tested over the information, it makes sense that we better include questions about the lab on future assessments.

Item fifteen was designed to survey the students about their past experience with that very common form of laboratory assessment – the laboratory notebook. A mean response of 4.9 indicates that slightly less than half the students participating in this study have had a past experience with laboratory notebooks.

Surveys

All of the students participating in this study were asked to answer a series of open-ended questions designed to provide them with an opportunity to respond in greater detail than was available on the pretest. I used the students' responses to fifteen questions (Appendix A, part 2) to help interpret the numerical data collected on the pretest.

The students' responses to these questions were then carefully examined. Based on these responses and academic performance, a smaller group of students was selected for further interviews. These twelve students were broken up into three groups:

Group 1: Successful students with grade point averages of 3.00 – 4.00

Group 2: Traditional students with grade point averages of 2.00 – 3.00

Group 3: Challenged students with grade point averages of 0.00 – 2.00.

Each of these students was asked in a face-to-face interview to explain in detail their answers to the open-ended survey questions. I used this information to further evaluate the students' initial impressions of science and the role of laboratory activities in science courses.

The first three questions in the pretest were intended to determine the general attitude of the students regarding science courses in general. The responses indicated that the entire study group of 92 students had a fairly positive impression of science, which is not surprising since this course is an elective and is not required for graduation. Further interviews with the smaller groups did reveal some differences pertaining to the most and least favorable aspects of science. The Group 1 students indicated that their favorite part of science was the *learning* about new things and the relationships to other events and how they impact us. The Group 2 and Group 3 responses typically indicated that their favorite aspect was the hands–on approach of science and seeing something exciting happen. There was also a difference among typical responses in regards to the least favorable parts of science. The Group 1 students commonly mentioned the monotony of some tasks while the Group 2 and Group 3 students almost universally indicated the amount of memorization required in science courses as being their least favorite part. A telling response scattered across the entire study group regarding the least favorite aspect of science was summed up by the student who replied: "Learning about things that probably won't pertain to my future".

Survey questions four through eight explored the perceived role of labs in science courses. The students were overwhelmingly in favor of doing laboratory activities in science courses. The Group 1 and Group 2 students explained that the best part of doing labs was the way they (the labs) help us understand what scientists do and how the labs pull the pieces together – relating science to real-life situations. Group 1 students complained about the time-consuming nature of labs as opposed to the rest of the students who did not have any clear common negative response other than the obligation of cleaning up after a lab.

Question nine about laboratory notebooks had two very different responses. I had anticipated on the pretest that the students would almost universally indicate no prior experience with laboratory notebooks. However, the results of the pretest, (4.9) was a very middle range response belying the polar nature of the question. The students explained this unanticipated response by indicating that one of the science teachers, who worked with almost half of my students last year, had begun using laboratory notebooks in their biology course.

The question about student preferences regarding structured versus open-ended labs drew a variety of responses. Many students answered that they preferred structured labs for reasons including that structured labs "removed the guesswork", "leave less room for mistakes", "are more structured", and "they reduce the chances that I will screw up". Those students in favor of open-ended labs rationalized their preference because "I can find out what *I* want to know", "I can see if I really understand the material", and "open-ended labs are more similar to what real scientists do".

Questions eleven through fourteen asked for the students' opinions about the frequency of labs and how they should be evaluated. While all of the students wished to do lab activities often (usually more than two or three per week) there was a difference in the strategies by which the students wished to be evaluated. Group 1 students suggested more stringent evaluation strategies including comprehension tests, percent error determinations, and the ability of the students to apply what they had learned in the lab to other situations. Group 2 students suggested a number of strategies including being evaluated on whether they "knew what they were supposed to be doing". Group 3 students wished to be graded on participation and the amount of "thought" they put into the lab rather than on whether they were close to the correct answer. Group 3 students also did not believe it would be appropriate to include lab-related information on tests.

In question fifteen the students offered suggestions similar to many beliefs reflected in the National Science Education Standards. The students wanted to spend more time on fewer things so that they could learn more about them. The students in all three groups wanted more labs and hands-on demonstrations to help solidify their understanding of scientific concepts. Almost universally, my students requested that I improve the connection between labs and lectures by using numerous practical examples and daily demonstrations. Some suggested that I reverse traditional teaching by using laboratory activities to teach the course and lectures only when necessary to help tie together the main ideas behind the labs.

This information from the pretest and survey suggests to me that the students have a positive impression of science but are interested in changing the way it is presented in the classroom. They want more relevant, hands-on investigations and are willing to work for it.

Posttests, Surveys, and Student Interviews

The seventeen items of this posttest were designed to re-evaluate the students' impressions of lab activities following the implementation of this intensive laboratory assessment study.

The student responses to the posttest were collected and carefully analyzed. Their responses were then averaged to determine a numerical value for the mean response to each statement as was done in evaluating the pretest. These values indicated the students' agreement with the statements on a scale of one (strongly disagree) to ten (strongly agree). The mean results of this posttest are shown in Table 2.

Table 2 – Posttest Results

Item #	Statements	Mean Response
1.	Science courses should offer students lab activities.	9.5
2.	I believe that lectures and discussions teach chemistry more effectively than lab activities.	5.0
3.	I think science courses should offer more lab activities than they do.	7.3
4.	I think that labs are more work than they are worth.	3.7
5.	Lectures and labs in science courses are clearly connected.	9.0
6.	Science course laboratory work has increased my understanding of how scientists actually work.	8.4
7.	Labs make science more relevant to my life.	7.6
8.	Lab work increased my interest in science.	7.9
9.	Lab activities taught me more about science than the book or lectures did.	7.0
10.	I prefer open-ended investigative labs of my own design.	5.7
11.	Lab work improves my understanding of the material covered in lectures.	8.0
12.	Information from lab work should be a part of tests.	6.3
13.	I prefer traditional written tests to nontraditional tests that require me to do something.	4.0
14.	I concentrate more closely on lab work if I know I am going to be tested over the lab.	7.9
15.	Laboratory notebooks helped me to understand the labs better.	6.7
16.	This science course offered more lab activities than most science courses.	9.3
17.	Lab assessments are harder than traditional tests.	5.1

Since the fourteen items are identical to those found in the pretest, different mean scores should indicate changes in the student's impressions as a result of the strategies and procedures used in this intensive laboratory assessment study. Figure 1 is a comparison of the results of the pre- and posttests.

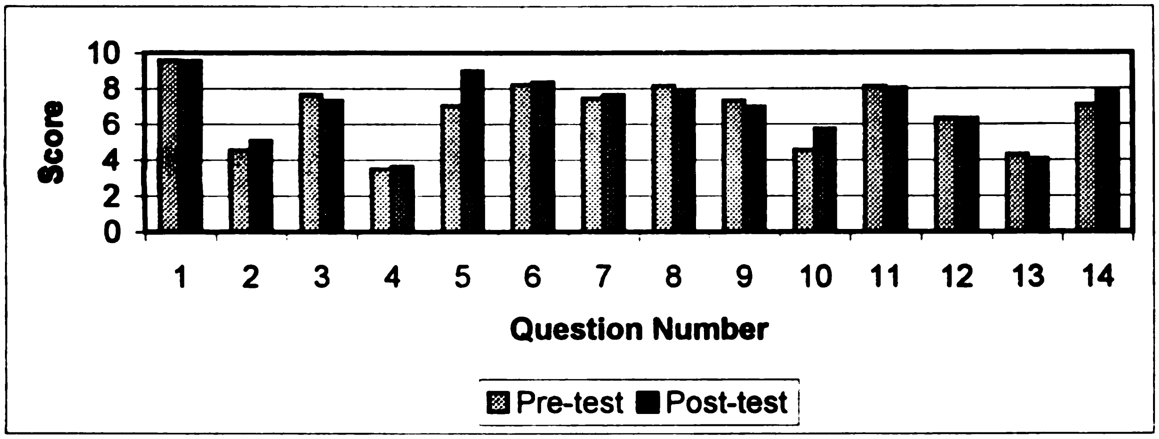

Figure 1 – Average Pre & Posttest Responses

The responses to the statements showed little change between the pretests and posttests for most items. This would imply that the use of multiple laboratory assessment procedures did not incline the students to dramatically change their attitudes about these ideas. This may reflect the well-developed and strongly held opinions about education found in students of this age group.

I did not find the use of pretests and posttests very informative. They only offered information about the students at the very beginning or end of the year. This information was not very useful in developing day-to-day lesson plans.

Between these two tests, item five showed the greatest difference (7.0 - 9.0) in mean scores of all the statements on the pre- and posttests. This item asks the students to indicate their agreement with a statement about whether lectures and labs are clearly connected. The responses indicated that the students increased their impressions that there was a greater connectivity between the different parts of the course. I believe that this very important change was a direct result of using a systematic, comprehensive approach to laboratory assessment.

The lack of a connection between labs and lectures has been a major criticism of the hand's-on approach to teaching. Because of this, it is imperative that a stronger connection be forged to legitimize the use of lab activities in science courses. This data suggests that a more careful, concerted approach to lab activities and their assessments can create the connections we need to tie the different parts of our science courses together into meaningful, cohesive subjects.

Item ten's small shift in preference (4.5 to 5.7) for open-ended labs was meaningful to me. The shift from mild distrust to moderate acceptance of open-ended labs suggests that further positive experiences would create a greater willingness in the students to engage in laboratory activities of their own design. Though Group 1 students were the most successful in open-ended labs, they were also more likely to voice a concern about the lack of guidance provided by open-ended labs.

During the course, the general attitude of the classes towards open-ended labs changed, as the students became more accustomed to them. At first, the students started open-ended labs quietly, waiting for the class leaders to provide some sort of initial direction. By the end of the study, open-ended labs would start almost explosively as students excitedly started the lab according to their designs. Whereas traditional labs seem imbued with a sense of purposefulness, open-ended labs are more often characterized by "Wonderment". Open-ended labs are exciting to watch and produce a large number of new learning experiences for everyone.

Posttest items fifteen, sixteen, and seventeen provide some important information to be considered for evaluating the effectiveness of laboratory assessment. In item fifteen, the students indicated a connection between the use of laboratory notebooks and their understanding lab activities. The mean response to this statement (6.7) indicated that there was a strong belief that the use of laboratory notebooks furthered understanding of the labs. Students do complain a little about the amount of writing and preparation they must perform prior to the lab – something that I didn't hear when I used data sheets and cookbook labs. However, I have far fewer students who do not know what they are supposed to be doing during labs. This results in a greater number of students on task for a larger amount of time, and a safer laboratory environment. It became clear during the interviews that there was a strong correlation between student preference for laboratory notebooks and student achievement. Successful students valued and relied on their lab notebooks while academically challenged students tended to disregard their notebooks. Successful students had better notes from previous labs to refer to when questions arose during a given lab activity. Students who tended to underrate the value of their lab notebooks had poorer write-ups resulting in lower grades on current assignments and poorer examples when working on future lab assignments.

Item sixteen's mean score of 9.3 was predictable in view of my predilection for laboratory activities. The students were involved in either major or minor lab-related activities almost daily. This has helped to make the course very popular with the students. I believe that this also helps to explain the very low absence rate for students in this course. The combination of high success (over 93% of the students successfully pass the course), popularity among the students (creating a waiting list to get into the course), and unusually low absenteeism helps the administration to justify the expense involved in this laboratory oriented course.

The students indicated in item seventeen with a mean score of 5.0 that there is no significant change in the difficulty associated with laboratory assessments. They indicated a very balanced reaction to a statement attempting to determine whether they felt laboratory assessments were harder than traditional tests.

I found the interviews were more valuable than the pretests and posttests because they supplied greater insight into the students' perceptions of the lab activities and provided timely feedback with which to adapt my teaching methods.

Their observations were useful in determining the specific effectiveness of each lab activity and the general attitudes of the students to the entire course.

In the interviews, the students strongly supported the idea that labs are a very important part of a science course. The students suggested that some form of chemical demonstration or practical application should be incorporated into every lesson. They also continued to support the idea that lab work improves the students' understanding of the material covered in lectures.

Assessment Strategy Evaluation

The students were asked to evaluate the various assessment strategies used during this course for their effectiveness and enjoyment. This evaluation can be found in Appendix G, part 2. The responses to this evaluation were compiled and averaged (Table 3). The students in the three in-depth study groups were also interviewed and asked to explain their responses in more detail.

Table 3 – Laboratory Assessment Strategy Evaluation

Laboratory Assessment Strategy	Evaluation Effectiveness	Teaching Effectiveness	Personal Enjoyment
Laboratory Notebooks	7	8	7
Performance Checklists	10	4	7
Student Interviews	9	5	6
Peer Assessments	8	6	6
Performance Tasks	8	9	9
Open-Ended Labs	9	9	8
Teacher Demonstrations	8	9	9
Written Assessments	8	7	5
Conceptualization Activities	7	8	7
Lab Practicals	9	8	7

The data in Table 3 suggests that the students felt that laboratory notebooks effectively evaluate what the students have learned. Interviews substantiated this conclusion, but students in Group 2 and Group 3 also suggested that these notebooks should be graded leniently. They felt that the final grade should be based on the students' abilities to do the lab and understand its message rather than on their ability to get the "right answer".

The students indicated that laboratory notebooks were a more effective tool for teaching than they are for evaluation. By requiring the students to write out the procedures and construct their data tables ahead of time the students developed a better understanding of what they were doing in the lab and why they were doing it. The high personal enjoyment score given to the laboratory notebooks reflects the natural appeal that lab activities have for many students.

Performance checklists were recognized by the students for their obvious evaluation merits. These were given the highest ranking for evaluation effectiveness of all the different laboratory assessment strategies. They were also given the lowest ranking for teaching effectiveness due to their inability to teach new information. Students indicated that they appreciated performance checklists on both the written evaluation and in their interviews. The students commented that checklists seemed like a very clear and straightforward form of assessment.

The next form of assessment was the student interview or interview sheet. The students indicated that they believed these interviews were very effective for evaluating what the students have already learned. I would concur that this form of assessment is very informative and provides an extremely rich form of assessment. This tool provided detailed feedback that strongly influenced my teaching strategy as I planned future lessons. The drawbacks to this form of assessment lie in its limited potential to teach new material and its time-consuming nature. While the written student interviews met with only moderate appreciation, the face-to-face verbal interviews were very pleasant for both the students and the teacher.

The data from Table 3 shows that peer assessments earned high marks for their ability to effectively evaluate the students. It increases student accountability while providing a richer, more authentic assessment of what is actually occurring in the lab. Peer assessments are not well suited for providing content learning opportunities. They can give the students experience at assessing coworkers and help teach students about responsibility and teamwork.

The students varied widely in how much they enjoyed using peer assessment. Individual scores for the enjoyment factor associated with peer assessment ranged from very low (ones) to very high (tens). In the interviews some students stated that they did not feel qualified to judge their lab partners, nor did they feel that they were evaluated justly by others. Other students derived real pleasure from evaluating their peers since they felt they could hold their partners truly accountable for their share of the workload. Peer assessments were considered to be the most fair when homogeneous lab groups were created by the teacher before the lab started.

Performance tasks received strong endorsements from the students in all three categories. The students felt that they were highly effective at both measuring what they had learned as well as teaching them new material. The personal enjoyment was audibly evident as the volume and excitement increased when the students engaged in a performance task as part of a test. Students spoke of looking forward to the tests because of their curiosity about what the performance task would be for that particular unit.

Open-ended labs also received high marks for all three areas. They were considered to be equally strong at measuring what the students knew and at providing new learning opportunities. All three of the in-depth study groups included strong advocates for the continued use of these types of labs. Many suggested that they enjoyed devising their own procedures and learning about what they wanted to know. A few students did indicate, to the contrary, that they did not enjoy the lack of structure inherent to open-ended labs and found them to be stressful situations.

Demonstrations are a very successful teaching strategy. They can also be modified into an effective form of assessment by having the students explain the demonstration instead of the teacher. This technique gives us an effective, new form of assessment without diminishing an already-existing, successful teaching strategy. Teacher demonstrations were considered to be quite effective at assessing students' knowledge. It is interesting to note that the students felt that teacher demonstration *assessments* were also effective at *teaching* new material.

Students stated that the demonstrations provided strong clues and backgrounds for the questions they were asked to answer on tests. In interviews, the students remarked about how exciting teacher demonstrations were. This was due to the fact that the simpler and safer demonstrations were typically transformed into student performance tasks.

When given a written assessment, the classroom typically became very serious and studious. The students applied themselves more thoughtfully and with greater commitment than they usually did when taking traditional tests. Students also indicated that they were not especially fond of written assessments because they were similar to conventional tests and because they "forced the students to think too hard".

Conceptualization activities were considered effective and enjoyable. The academically successful students of Group 1 were the most favorably inclined towards these activities since these activities often asked the students to step back and explain something in terms of the bigger picture. The Group 3 students found conceptualization activities to be enjoyable but somewhat disconcerting since the questions were sometimes "a little too abstract".

Laboratory practicals were also very effective assessment strategies. They posed numerous opportunities for students to demonstrate their knowledge on a variety of levels. They could incorporate almost all of the other forms of laboratory assessment and do so in a situation ripe with new learning opportunities. Students indicated that they enjoyed these practicals much more than traditional tests.

Discussion and Conclusions

As a result of this study, I am convinced of the validity and the effectiveness of laboratory assessment in the chemistry classroom. A comprehensive approach to the systematic evaluation of the learning that occurs in the lab holds significant benefits for both the students and the teacher. Embedded laboratory assessment offers engaging learning opportunities for the students at the same time it appraises their knowledge of both material and processes. The authentic nature of laboratory assessment helps prove to the students the relevance of chemistry concepts in the real world. Thorough use of laboratory assessment validates the use of lab activities by the students as it simultaneously provides a deeper, richer assessment of the students' abilities.

It is important to note that no single part of the laboratory assessment model offered in this study is the best for all situations. I feel that a thoroughly planned, carefully implemented combination of most or all of these strategies will have a positive effect on the learning, assessment, and atmosphere of most chemistry classrooms. Since there are many different aspects of laboratory assessment, teachers wishing to incorporate aspects of this strategy will have to carefully analyze their specific objectives for each lab activity. In the following sections, I will attempt to summarize my findings individually for each of the major components of laboratory assessment.

Laboratory Assessment Strategies Used *During* Laboratory Activities

Laboratory Notebooks

The initial response to lab notebooks was one of dread. Initial student interviews suggested that the students were concerned about my expectations when grading these notebooks. They were also worried about the time and labor required to produce presentable lab notebooks since they require much more time to complete than lab worksheets, which require essentially no time at all to complete.

As the students become more proficient at writing lab reports they require less and less guidance. The need for the teacher to spend time rewriting lab procedures will gradually diminish until it reaches the point where the students can be handed a standard "cookbook" lab from almost any lab book and they will still be able to convert it into the desired lab report format.

Lab notebooks are also more cumbersome to use than the traditional data sheets that can be copied or torn out of publisher's lab books. My standard 100-plus stack of lab notebooks is approximately two feet tall and not very transportable. I established a specific location for students to periodically turn in their notebooks when either they or myself felt the need to evaluate their performance.

Lab notebooks were occasionally more confusing than data sheets, until the students learned the need to adhere to a standard format. With abundant feedback on early lab reports and clearly stated expectations, most students developed very acceptable lab notebooks. I found it helpful to require an up-to-date table of contents page in the front of the notebook. The use of lab notebooks was also made easier by developing a regular routine of when lab reports were to be submitted for evaluation.

I believe the use of laboratory notebooks provided a more authentic laboratory experience bearing greater similarity to the labs my students will experience in college and in the workplace. In their interviews, a number of students indicated that this greatly enhanced the value and relevance of the labs.

I believe the students came into the lab better prepared to safely get to work and had a more meaningful experience as a result of writing their lab reports. The students often surprised me with their reflections and gave me clear indications of what they knew and still needed to learn. In their reflections the students often included important secondary benefits to performing a lab. Examples of some of these reflections taken from lab notebooks are:

"Hot glass looks like cold glass."

"Acid burns don't cool down like heat burns – at least not until you wash off the acid."

"I didn't know that so many things are acids."

Laboratory notebooks gave me an assessment tool that provided a long-term record of the students' performance throughout the course. As a result of using laboratory notebooks, I was able to ask more of my students and receive more in return. This was a great improvement over what I was able to do when I used publisher's lab sheets or data sheets. Consequently, I strongly recommend the use of laboratory notebooks. I would encourage the teachers who use them to consistently drill and reinforce in their students the need for neatness and correct format.

Performance Checklists

To create a performance checklist, a teacher must identify the important behaviors or steps during a lab that they wish to observe their students performing. It is important not to attempt to evaluate too many steps during the lab since it will be difficult to observe all of the students as they proceed through the lab at different speeds.

The obvious use of performance checklists sent a subtle but clear message to my students about what I considered important. It was interesting to note the difference in their behavior when they felt that I was closely watching them. The use of performance checklists targeted behaviors I wished to evaluate and simultaneously identified for the students those behaviors that they needed to change if they were substandard.

Students that typically do well on written tests also performed very well in the lab. I expected to see evidence that some students that did not test well would perform, as well, or better than their peers in the lab. I did not see any evidence of this. Those students that tended to be confused or disengaged during lectures were similarly at a loss during lab activities. Students that tended to be sloppy or haphazard in their paperwork had a similar sloppy, haphazard approach to labs. In view of the current publications on multiple learning styles, I feel that this is surprising and worth further study.

Interview Sheets

Interview sheets provide feedback to the teacher about student perceptions regarding classroom activities. They can be time consuming and therefore work best with small representative samples of students that the teacher has already identified as being indicative of larger groups.

My experience indicates that interview sheets are more successful when the students are asked to respond in writing and then asked to verbally explain what they meant. The students are sometimes surprising in the clarity or depth with which they express themselves orally. Interview sheets can also be used as an opportunity for the students to practice writing in science classes. The process of writing responses to higher-level questions posed by interview sheets can also help the students transfer information learned in the lab to everyday world applications.

I found that by identifying students that are inclined to give clear, detailed feedback, (either positive or negative) the teacher gains an important tool for evaluating the learning in the lab. Their perceptions can also be used to judge the validity of performing a specific activity again in the future.

Peer Assessment

When using peer assessment, I always gave both members of a lab group the opportunity to evaluate both themselves and their lab partner. I found it beneficial to include a comment section in which the students were asked to explain their evaluations. These comments often led to some interesting and frank discussions about the different roles students performed or were expected to fulfill during a lab activity. It was interesting to note the honesty and similarity of the peer assessments within each lab group.

I would encourage the regular use of peer assessments in any laboratory course. It allows the teacher to see and evaluate the students from another point of view. It also offers the students valuable opportunities to practice evaluating their peers and learn in a more authentic manner the appropriateness of their contributions and work ethic.

Laboratory Assessment Strategies Used *After* Laboratory Activities

I used the following laboratory assessment strategies in conjunction with traditional tests to evaluate what the students have learned at the end of a unit. These forms of laboratory assessment indicate the students' exit knowledge and what they have learned and retained as a result of the lab activities.

Performance Tasks

The students were particularly fond of teacher demonstrations as performance tasks. They enjoy the exciting nature of these demonstrations. As the students perform and explain these demonstrations they also provide some important feedback to the teacher on whether the students are "really getting it" when we talk discuss chemical demonstrations.

Open-ended Labs

While most lab exercises provide the students with carefully detailed instructions for every step, open-ended labs require the students to design their own procedures. As the students became adjusted to open-ended labs, the number of students who strongly preferred detailed, traditional labs slowly decreased. Frank discussions about my expectations and the grading eased some of the students' fears. By creating challenging and exciting open-ended labs, I attempted to increase the students' preferences for open-ended labs. I did this because I believe that open-ended labs encourage higher level thinking skills.

I highly recommend the use of rubrics to facilitate the assessment of open-ended labs. The process of developing a rubric for the lab will help crystallize the teacher's objectives for doing the lab. It will also help to identify potential trouble spots that may require guidelines for the students. These guidelines should be used sparingly to maintain the integrity of the open-ended assessment. However, they may be necessary to help communicate the teacher's intentions or to avoid potential health hazards. It is advisable to share the rubric with the students before they start the activity to help provide some framework.

Students will need some introduction to the open-ended lab. This introduction typically provides some background, a timeline, the appropriate rubric, some equipment or materials boundaries, and some safety guidelines. These introductions can become less detailed as the students become more familiar with the process. Appendix H, part 1 is an open-ended lab assessment and rubric designed to evaluate a student's ability to write and perform a chemical bonding investigation. This particular open-ended investigation is unusual since it does not require the students to perform the investigation. Close inspection of the rubric shows that this activity is evaluated only in terms of the student's report. However, all of my students did chose to perform the lab even though it was not absolutely required. Appendix H, Part 2 contains the directions and rubric for the very popular Eggsplosions Open Ended Lab Activity. This activity is very exciting, but it requires very close supervision on the teacher's part.

Teacher Demonstrations

My students indicated a strong preference for this form of laboratory assessment. They said that teacher demonstrations made the tests more exciting. In interviews and informal discussions they spoke of how these demonstrations provided the real-world connections that made the scientific concepts seem important and relevant. By carefully designing the questions to build on what they saw in the demonstration, I was able to encourage the students to look beyond the book for everyday implications.

Many chemistry teachers have large collections of educationally valuable demonstrations that they would like to share with their students but are not able to because of time constraints. Some of these time restrictions are subconsciously self-imposed by the teacher who has failed to see that these demonstrations can be used to both teach and evaluate the students. A strategy that I found to be very successful was to use one demonstration to present a scientific concept and, later in the unit, another related demonstration to see if the student actually internalized the information from the first demonstration.

Written Assessments

Proper written assessments are challenging to write but very easy to grade. The difficulty in writing them stemmed from my need to make sure that I wasn't writing another "standard" test. I had to write every item from scratch. The process was time-consuming because I had to present the students with real data, and in some cases, realistic looking miscalculations, for them to analyze.

Written assessments worked best when they included a variety of questions that evaluated the students on a number of levels. The students who took their labs seriously tended to do very well on the data analysis and error analysis sections of the written assessments. The questions that related the lab to everyday applications often prompted classroom discussions.

Initially I had intended the students to complete written assessments individually. However, I eventually found that they were also conducive to small group activities as well. The discussions that occurred within these small groups were very rewarding for the students and informative to me as their teacher.

Conceptualization Activities

I believe most teachers would find this form of assessment very valuable since it is designed to evaluate a student's deeper understandings. I found that conceptualization activities could easily detect and identify major underlying misconceptions. These mistaken beliefs were then corrected through the use of other activities and the students' understanding of the world fundamentally changed.

It is entertaining and illuminating to watch students attempt to explain the discrepant events commonly found in conceptualization activities. For example, it is surprisingly educational to have students:

- watch boiling water and ask them to explain in detail what is in the bubbles.

- discuss how atoms are mostly empty space and then ask them to explain why they can stand on the floor without simply having their atoms fall through the atoms of the floor.
- watch and explain why a beaker of water in a partial vacuum boils and eventually begins to freeze simultaneously.

Lab Practicals

The use of laboratory practicals as part of my final exam has dramatically changed and improved my course. These practicals were an incredibly powerful form of assessment that was very popular with my students. Many students commented that their chemistry final, including the lab practical, was their favorite exam. They said that the lab practical format reduced their stress levels and made the exam more cooperative than competitive. This was confirmed by the exceptional teamwork and cooperation demonstrated by students of all ability levels during these practicals. I really enjoyed using this format with its homogenous grouping of students for my final exam. It lowered the students' stress, improved their assessment, and streamlined the paperwork.

The students need a lot of time to prepare for practical exams. They need the time for reviewing and practicing important laboratory procedures. They also need time to coordinate their responsibilities within the groups. This is not "down time", time that is "wasted" on review instead of learning new ideas. My experiences during this study indicated that some of the best learning in the classroom occurred during this review section as the students reacted to the pressure of the impending exam and taught each other important lab procedures and scientific concepts.

I found that it was helpful to present a series of labs, tasks, and worksheets to the students the week before the exam. These activities were similar in design to the tasks the students would be required to perform during the exam. This series of activities encouraged the students to engage in the learning/review session. The students found that this review session also identified my expectations and indicated the level of expertise I expected of my students.

Summary

During this study, I discovered and documented the effectiveness of using lab related activities to evaluate almost all aspects of a chemistry course. I believe that these assessments give me more detailed information about my students and what they have learned, than any other evaluation strategy I have ever encountered.

As a result of switching to this lab based assessment process I have seen an improvement in my students' abilities to use and understand chemistry. At the end of the year I find fewer students that are easily stumped by simple demonstrations of chemistry in the everyday world.

The use of systematic laboratory assessment requires a lot of time, work, and preparation – but it is well worth the effort. In the long run, this process of using lab based assessment does not dramatically increase the amount of time a teacher spends on grading. Rather it shifts the time and focus of current assessment activities away from an over reliance on pen and paper tests towards a more hands-on approach to evaluation. I would strongly recommend a similar comprehensive laboratory assessment process for other chemistry teachers who wish to either replace or augment their current assessment procedures.

In Appendix I, parts 1 - 17 I have included a variety of other laboratory assessment activities that I used during this study. These assessments were not directly referenced in this thesis because most of them represent a blending of several evaluation strategies. I thought it would be helpful to include these sample assessment activities to demonstrate more of the many forms of laboratory assessment.

Appendices

Appendix A

Pretest and Survey

Part 1 - Pretest

Please indicate how much you agree with the following statements. Base your answers on this science course only. Record your answers by circling a number from one to ten. Circling a one means that you strongly disagree and circling a ten means you strongly agree.

1. Science courses should offer students lab activities.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

2. I believe that lectures and discussions teach chemistry more effectively than lab activities.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

3. I think science courses should offer more lab activities than they do.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

4. I think that labs are more work than they are worth.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

5. Lectures and labs in science courses are clearly connected.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

6. Science course laboratory work has increased my understanding of how scientists actually work.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

7. Labs make science more relevant to my life.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

8. Lab work increased my interest in science.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

9. Lab activities taught me more about science than the book or lectures did.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

10. I prefer open-ended investigative labs of my own design.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

11. Lab work improves my understanding of the material covered in lectures.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

12. I prefer traditional written tests to nontraditional tests that require me to do something.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

13. Information from lab work should be a part of tests.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

14. I concentrate more closely on lab work if I know I am going to be tested over the lab.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

15. I have used laboratory notebooks to record labs in science courses before.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

Appendix A

Pretest and Survey

Part 2 - Survey

1. Do you enjoy science?
2. What do you enjoy the most about science?
3. What do you enjoy the least about science?
4. Do you enjoy labs?
5. What is the best part about labs?
6. What is the worst part of labs?
7. Why do we perform labs in science courses?
8. Are labs necessary?
9. Have you ever used a lab notebook before?
10. Do you prefer very structured labs or open ended ones? Why?
11. How often should students perform lab activities during a science course?
12. How should teachers evaluate the learning that occurs during lab activities?
13. Should questions about recent labs being included on tests?
14. Should tests include lab activities?
15. How should teachers improve the connection between labs and lectures?

Appendix B

Laboratory Reports

Part 1 – Report Format

Title of Laboratory Activity

Purpose of the Investigation:
This statement summarizes the reason for doing the lab.
Procedure:
This is a sequence of the important activities in the investigation.
Observations and Data:
These are descriptions of what has occurred in the course of the investigation.

Observations are qualitative statements that describe things such as odors, colors, gas or precipitate formation.

Data are quantitative observations collected during the experiment. The number of significant digits used in data collections needs to match the tolerance of the instrument used. Data should be legible, recorded i appropriate table form, and properly labeled. Erasures are not allowed. If an entry needs to be corrected, draw a line through it, then enter the correct data.

Calculations, Results, and Questions:
These processes occur after the data is collected.

Calculations are any mathematical manipulation of data that help answer the central question or clarify the purpose of the investigation.

Results are summary statements of the data. Results could be statements that show patterns, statements that reflect relationships between variables, or graphs that show the relationships between variables.

Questions are often assigned to help you connect the lab with important concepts and to help you apply what you have learned to the real world.

Conclusion:
This statement ties the purpose to the results of the investigation.
Reflection:
Students should assess their own thinking strategies.

Complete one of the following stems:

One thing I learned that I did not know before is ...
One thing that really surprised me is ...
One thing that I will remember five years from now is ...

Figure 2 – Laboratory Report Format

Appendix B

Laboratory Reports

Part 2 – Notebook Instructions

- Students should maintain a table of contents in the front of the notebook that lists where all labs can be found.
- Your Chemistry Notebook will become a written record of the many experiments, demonstrations, and investigations that you will be completing in this class. The most frequent entries in this notebook will be Laboratory Reports. Laboratory Reports are formal written recordings of the procedures and outcomes of lab investigations. They MUST be written out according to the established laboratory report format.
- Write all information from labs directly into the laboratory notebook, not on a scrap of paper to be entered later.
- Lab notebooks require the use a ballpoint pen.
- With the exception of the data table – complete sentences, proper spelling and correct grammar should be used at all times.
- Rather than assign a poor grade to a report, I may ask you to rewrite it. No grade will be recorded until the rewritten report is returned.

Appendix B

Laboratory Reports

Part 3 – Rationale for using Laboratory Notebooks

- Formal laboratory reports are similar to the records kept by professional scientists and are a very real part of "doing" science.
- Laboratory reports act as a chronological record of successful procedures that can be reviewed when later, open-ended experiments are being designed by the student.
- The data and observations from earlier experiments may prove to be a valuable source of "proven" data that later labs or lab assessments will build upon.
- Formalized lab reports encourage awareness of appropriate procedures and safety precautions.
- Lab reports encourage the development of good writing and reporting skills.
- Rewriting the procedures helps develop the students' abilities as critical readers.
- The process of writing and then using procedures written by the student demonstrates the subtle intricacies and advantages of efficiently designed lab notebooks.
- Lab reports avoid the "cookbook" feel of the fill-in-the-blank lab sheets found in textbooks.

- Lab reports should make students fundamentally aware of "why we are doing this" and how the lab is not an intrusion in the unit but actually the "proof" of what we are studying.
- By designing their own procedures and data tables, students practice higher level thinking skills as they interpret, analyze and deduce their own conclusions.

Appendix B

Laboratory Reports

Part 4 – Sample Lab Report

Chemical Analysis of Bug Juice

Purpose: To determine the squish value of bug juice

Procedure:
1. Collect and sort ants according to species.
2. Determine the mass of the ants.
3. Squish the ants using a mortar and pestle.
4. Test the squish with pH paper to determine the acidity of the bug juice.
5. Calculate the squish value using the appropriate data.

Table 4: Bug Juice Data Table

Mass (kg)	Acidity (pH)	Observations
.0015	4.7	Ants were squished when ground with mortar

Calculations and Questions:

pH $= m^2/\text{squish} = (.0015\text{ kg})^2/4.7$ Squish $= m^2/\text{pH} = 4.8 \times 10^{-7}\text{ kg}^2$

Question 1. Which ants appear to have the highest squish coefficient?

Red ants have a higher squish coefficient than do black ants.

Conclusion: The squish value of the bug juice appears to be related to mass and inversely proportional to pH. There also seems to be a variation in the squish value among different ant species.

Reflection: One thing that I learned that I did not know before is that since the ants wiggled and squirmed and in general tried to escape, I concluded that ants do not like to be squished.

Appendix C

Alkaline Earth Metal Lab

Part 1 – Unmodified Lab as Found in "Typical" Lab Manual

Investigate some reactions of some Group 2 elements and gain some insights into the properties of these alkaline earth elements.

Materials

calcium turnings (Ca)

magnesium ribbon (Mg)

magnesium sulfate ($MgSO_4$)

calcium sulfate ($CaSO_4$)

barium sulfate ($BaSO_4$)

distilled water

phenolphthalein solution

Saturated solutions of:

- calcium hydroxide ($Ca(OH)_2$)
- magnesium hydroxide ($Mg(OH)_2$)
- barium hydroxide ($Ba(OH)_2$)

1 Molar solutions of:

- sodium carbonate (Na_2CO_3)
- magnesium chloride ($MgCl_2$)
- calcium chloride ($CaCl_2$)
- barium chloride ($BaCl_2$)

Procedure

PART A

1. Pour about 5 ml of distilled water into a clean, dry test tube and place the test tube in the test tube rack. Add a calcium turning to the water in the tube. To collect the gas being released, invert a clean, dry tube over the reactant tube, holding the inverted tube with a test tube holder.

2. Test for hydrogen by inserting a burning wood splint into the upper end of the inverted tube.
3. Add one drop of phenolphthalein to the solution in the reactant tube. After making your observations, discard the contents in the tube and then clean and dry the tube.
4. Repeat step 1, using a 10-cm piece of magnesium ribbon in place of calcium. If no visible reaction occurs, heat the water to boiling, using a test tube holder to hold the tube over the burner flame. **CAUTION:** Point the tube away from yourself and others while heating.
5. Once the water is boiling, stand the tube in a test tube rack and, using a test tube holder, invert a collecting tube over the reactant tube. Record your observations. Discard the contents of the tube, and clean and dry the tube.
6. Turn off the burner and add a few drops of phenolphthalein to the reactant tube. Record your observations. Discard the contents of the tube, and clean and dry the tube.

PART B

7. Obtain 5-ml samples of saturated solutions of calcium hydroxide, magnesium and barium hydroxide. Test each solution with pH paper. Record the pH of each solution.

PART C

8. Using the laboratory balance, measure out a 1-g sample of magnesium sulfate. Place it in a clean, dry test tube.
9. Repeat step 8 for calcium sulfate and barium sulfate.

10. Add 5-ml of distilled water to each tube. Using a glass stirring rod, stir each mixture thoroughly, getting as much of each solid to dissolve as possible. Record your observations of the relative solubilities of each of these compounds.

11. Conduct a flame test for calcium ions (Ca^{2+}) and for barium ions (Ba^{2+}). Dip the wire loop of the tester into the solution of calcium sulfate. Place the loop in the burner flame. Observe and the color of the flame. Clean the loop and repeat using the barium sulfate solution.

PART D

12. Stand 3 clean, dry test tubes in the test tube rack. Using the 0.1 M solutions, add about 5 ml of the $MgCl_2$ solution to one tube, 5 ml of the $CaCl_2$ solution to a second tube, and 5 ml of $BaCl_2$ to the third tube.

13. To each of the solutions in the test tubes, add about 1 ml of the Na_2CO_3 solution. Record your observations.

Data PART A

Ca + HOH:

Result of test for H_2 gas: ____________________

Result of adding phenolphthalein ____________________

Mg + HOH:

Result of test for H_2 gas (before heating) ____________________

Result of test for H_2 gas (after heating) ____________________

Result of adding phenolphthalein ____________________

PART B

pH readings:

$Mg(OH)_2$ ______ Ca(OH) ______ $Ba(OH)_2$ ______

PART C

Apparent solubility:

$MgSO_4$ ______

$CaSO_4$ ______

$BaSO_4$ ______

Flame test results:

Ca^{2+} ________________

Ba^{2+} ________________

PART D

Observations: ____________________________________

Conclusions and Questions

1. Write balanced equations for each change that occurred as part of this experiment in steps 1, 4, 10, and 13.
2. Describe the reactivity of the Group 2A metals due to their location in the group.
3. How does the reactivity of an alkaline earth metal compare with that of an alkali metal (Group 1) in the same period?
4. What oxidation states can the alkaline earth metals exhibit?
5. Why does the metallic character of the alkaline earth metals increase as you go down the group?

Appendix C

Alkaline Earth Metal Lab

Part 2 – Lab after being Rewritten into Pre-Lab Format

Pre-lab Discussion:

In this lab you will be studying the chemical reactivities of the 2nd Family of elements on the Periodic Table. You should notice both a general similarity in properties and a trend of increasing reactivity as we move down this family. Group 1A -the Alkali Metals would show similar but more dramatic reactivities, however, they are actually so reactive as to make them unsafe to use in the lab.

The elements in Group 2A of the Periodic Table are called the Alkaline Earth Elements. The elements in Group 2A are chemically active and are never found in nature in the elemental state. Like all members of a group, or family, the elements in Group 2A share certain common characteristics.

The metallic character - the tendency to donate electrons during chemical reactions - of the Group 2A elements increases as you go down the group. The more metallic of these elements typically react with water to form hydroxides and hydrogen gas. An example of such a reaction would be:

$$Ca_{(s)} + 2HOH \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$$

As metallic character increases (as you go down the group), the tendency for these elements to form ions increases. Also as you go down the group, the solubilities of the hydroxides formed by the elements of this group increase. The more active the metal, the more basic its saturated hydroxide solution.

The solubilities of Alkaline Earth compounds also show some interesting and useful tendencies. For example, the sulfate compounds of Alkaline Earth Metals show decreasing solubilities as you go down the group. This characteristic is used as a means of separating and identifying metallic ions of this group. Carbonates of all Alkaline Earth Metals are quite insoluble.

Purpose of the Investigation:

To investigate some reactions of some Group 2A elements and gain some insights into the properties of these Alkaline Earth elements and the trends we see in these properties as we move down a family on the periodic table.

Equipment

balance	test tube rack	flame tester
burner	wood splints	filter paper
test tubes,(3)	pH paper	safety goggles
test tube holder	stirrer	lab coat or apron

Materials

calcium turnings (Ca)

magnesium ribbon (Mg)

magnesium sulfate ($MgSO_4$)

calcium sulfate ($CaSO_4$)

barium sulfate ($BaSO_4$)

distilled water

phenolphthalein solution

Saturated solutions of:

- calcium hydroxide ($Ca(OH)_2$)
- magnesium hydroxide ($Mg(OH)_2$)
- barium hydroxide ($Ba(OH)_2$)

1 M sodium carbonate (Na_2CO_3)

1 M magnesium chloride ($MgCl_2$)

1 M calcium chloride ($CaCl_2$)

1 M barium chloride ($BaCl_2$)

Safety

Handle all chemicals with care; avoid spills and contact with your skin. Heat chemicals exactly as instructed. When heating a substance in a test tube, point the tube away from yourself and others. Tie back long hair and secure loose clothing when working with an open flame. Always wear safety goggles when working in the lab.

Procedure:

Part I

1. Pour about 5 ml of distilled water into a test tube and stand the tube in a test tube rack. Add a calcium turning to the water in the tube. To collect the gas being released, invert a test tube over the reactant tube, holding the inverted tube with a test tube holder.
2. Test for hydrogen gas by inserting a burning wood splint into the inverted tube.
3. Add a single drop of phenolphthalein to the reactant tube and record your observations. (Phenolphthalein is a base indicator and will turn bright pink if it detects the presence of the hydroxides which are found in a base. As you can see by the equation in the pre-lab discussion this reaction should produce $Ca(OH)_2$ - calcium hydroxide.)
4. Repeat step 1, using a small strip of magnesium ribbon in place of the calcium. If no visible reaction occurs, heat the water to boiling, using a test tube holder to hold the tube over the burner flame.

5. Once the water is boiling, stand the tube in the rack, and collect the gas in an inverted test tube and test for hydrogen gas as in steps 1 & 2.

6. Test using phenolphthalein.

Part II

8. Obtain small (1-2 ml) samples of calcium hydroxide, magnesium hydroxide, and barium hydroxide. Using forceps, dip a small piece of pH Hydrion paper into a sample and notice its color change. By comparing the color of the paper to the chart on the side of the vial you can get a rough idea of the pH of the solution. Record the pH of each solution.

Part III

9. Obtain 1-gram samples of magnesium sulfate, calcium sulfate, and barium sulfate. Put each sample into its own clean, dry test tube.

10. Add 5 mls of water to each and using your stirring rod attempt to dissolve the solid. In the data table classify these compounds as being soluble, slightly soluble, or insoluble.

Part IV

11. Obtain 5 ml samples of magnesium chloride, calcium chloride, and barium chloride. Be sure to put each in its own dean, dry test tube.

12. Add about 1 ml of sodium carbonate solution to each solution and in your data table indicate whether precipitates form or not.

Observations and Data: Please use a table similar to Table 5.

Table 5 – Data Table for the Alkaline Earth Metal Lab

Part I		
Calcium + HOH	Hydrogen Produced? Yes No	Hydroxide Produced? Yes No
Magnesium + HOH	Hydrogen Produced? Yes No	Hydroxide Produced? Yes No
Part II		
magnesium Hydroxide	pH =	
calcium Hydroxide	pH =	
barium Hydroxide	pH =	
Part III		
magnesium Sulfate	Soluble Slightly Soluble	Insoluble
calcium Sulfate	Soluble Slightly Soluble	Insoluble
barium Sulfate	Soluble Slightly Soluble	Insoluble
Part IV		
$MgCl_2 + Na_2CO_3$	Precipitate	No Precipitate
$CaCl_2 + Na_2CO_3$	Precipitate	No Precipitate
$BaCl_2 + Na_2CO_3$	Precipitate	No Precipitate

Calculations, Results, & Questions

1. The gas tests and pH tests you performed in this lab indicate that when you add an Alkaline metal to water you usually produce what two products?
2. How does the reactivity of Group 2A elements vary as you go down the group?
3. How does the reactivity of an Alkaline Earth Metal compare with that of an Alkali Metal in the same period?
4. Why does the metallic character of the Alkaline Earth Metals increase as you go down the group?

Conclusion:

Write a statement that reflects what you have learned about the Alkaline Earth Metals and general trends in reactivity that occur as you go down a metal family of the periodic table.

Reflection:

Write a sentence about what you learned or will remember from this experiment.

Appendix D

Lab Assessment Strategies Used During Labs

Part 1 – PreLab for the Copper Formula Lab

Pre-lab Discussion:

All compounds have a definite composition in terms of the relative masses of the elements and the number of atoms. However, the same elements may unite in different ratios. Compounds often can be identified by the relative amount of a particular element they contain. For example, by knowing the amount of copper that can be removed from a copper compound, the formula of the compound can be selected from a number of possible choices.

Purpose of the Investigation:

To experimentally determine the percent copper in a compound and to select the formula of that copper-containing compound from a list of possible formulas.

Procedure: *Day One* Record all measurements in the data table.

1. Determine the mass of a 250 ml beaker.
2. (Caution: The copper-containing compound that you will use is toxic. If any gets on your skin, wash the area with water.) Use a small plastic spoon to add approximately two grams of the copper-containing compound to the beaker. Determine the mass of the beaker and contents.
3. Add 75 ml of distilled water to the beaker. Stir with a glass stirring rod to dissolve the salt. Note the results.
4. Determine the combined mass of a piece of filter paper and a watch glass.
5. Gently heat the solution to 40°C or 50°C with either a burner or a hot plate.

6. Remove the beaker from the heat source.
7. (Caution: The following reaction is highly exothermic and a gas is evolved.) Place the ends of two 2 cm x 7 cm strips of aluminum into the solution. Stir with one of the strips.
8. Periodically scrape the copper off the strips of aluminum with a rubber policeman.
9. When the solution's blue color disappears, and the reaction stops (in about 10 min.), rinse any adhering solid off the metal strips and the rubber policeman into the beaker with a few milliliters of distilled water. Remove the aluminum strips.
10. Using the filter paper from Step 4, filter the solution. Use the rubber policeman to transfer the entire solid from the beaker to the filter paper. Use the filtrate to rinse the beaker.
11. Dispose of the filtrate as instructed by your teacher.
12. Rinse the residue on the filter paper with several 15-ml portions of WARM (about 50°C) distilled water. Place the filter paper with collected residue on the pre-weighed watch glass. Open the filter paper to facilitate drying. Place it in the area designated by your teacher until the next day.
13. Wash the aluminum strips and return them as instructed by your teacher.

Day Two

14. After the filter paper and contents have dried, determine the combined mass of the filter paper, watch glass, and contents (copper). Dispose of the filter paper as directed by your teacher.

Observations and Data:

Table 6 – Data Table for the Copper Formula Lab

Data	Mass
1. Empty beaker	
2. Beaker + copper containing salt	
3. Filter paper + watch glass	
4. Filter paper + watch glass + dry copper	

Calculations, Results, & Questions

Table 7 – Calculations Table for the Copper Formula Lab

Calculations	
1. Mass of original copper containing salt	
2. Mass of dry copper produced	
3. Percent by mass of Copper in the salt	
4. Determine the percent by mass in $CuCl_2 \cdot 2H_2O$	
5. Determine the percent by mass in $CuCl \cdot 2H_2O$	
6. Determine the percent by mass in $CuCl_2 \cdot H_2O$	
7. Which of these compounds did you have?	
9. What is your percent error?	

1. Explain whether your calculated percent copper would have been higher or lower if the filter paper had not completely dried.
2. If a blue color appears on the filter paper with the recovered copper, what would this imply?
3. Create a chart that lists other possible sources of error and whether each error would cause a higher or lower result.
4. Why would it be considered a poor laboratory technique for a student to use an aluminum scoop to measure out 5.00 g of $CuCl_2 \bullet 2H_2O$?
5. Why is it doubtful that the reddish-brown product could be rust?

Conclusion:

What did you learn about determining the percent composition of a compound?

Reflection:

Complete one of the following stems:

One thing I learned that I did not know before is . . .

One thing that really surprised me is . . .

One thing that I will remember five years from now is . . .

Appendix D

Lab Assessment Strategies Used During Labs

Part 2 – Copper Formula Lab Performance Checklist

Table 8 – Performance Checklist for the Copper Formula Lab

Item	Students					
	1	2	3	4	5	6
Correct use Of balance						
Filter Technique						
Cleanup Day 1						
Correct storage Of filtrate for day 2						
Correct disposal Of copper day 2						
Completed Calculation						
Student determination of Percent copper by mass						

Appendix D

Lab Assessment Strategies Used During Labs

Part 3 – Copper Formula Interview Sheet

1. When would a scientist need to determine the percent composition of a substance?

2. What do you like best about lab activities?

3. What is the hardest part of this lab?

4. What would you do differently if you were to do a similar lab in the future?

5. How do you think you could improve your results in this lab?

6. Why did this lab require two days?

7. What did you learn from this lab?

Appendix D

Lab Assessment Strategies Used During Labs

Part 4 – Copper Formula Lab Peer Assessment Sheet

Table 9 – Peer Assessment Sheet for the Copper Formula Lab

Peer Assessment Sheet For the Copper Formula Lab (scores recorded as percentages)	Student:	Student:
Collecting / Returning Materials		
Data Collection		
Calculations and Analysis		
Cleanup		
Total Percent Contribution		
Comments:		

Appendix E

Lab Assessment Strategies Used After Labs

Part 1 – The Density of Sand Performance Task

Assignment: Design and perform an experiment that will determine the density of sand. Write a formal laboratory report detailing your procedure, data, and conclusions.

Background: The density of an object is equal to the object's mass divided by its volume. Density is expressed in units such as grams per cubic centimeter. In the laboratory, mass is generally measured on a balance. Volume, however, can be measured in several different ways. The nature of the objects and ways in which their volumes are defined may call for different methods of making the measurement. The volumes of objects having regular geometric shapes, such as spheres, cylinders, and cubes, can be found by first measuring the required dimensions and then using these numbers in the formulas for their volumes. If a sample has an irregular shape, then other, less direct methods must be used to determine the object's volume.

If a sample is composed of particles, as in the case of a pile of sand, one must first consider that the sand particles do not pack perfectly tightly, and that the air between the particles is taking up space. If a scientist wishes to determine the density of a sample made up of small particles, he or she is generally interested in the volume of the particles themselves, and not the volume of the particles plus the air between the particles. An experimental method must then be devised to permit this determination to be made.

Purpose of the Investigation: To determine the density of a sample of sand with air around the sand granules and then the density of the sand alone.

Procedure: Devise and write up an experimental procedure that will accomplish the purpose of this investigation. Get your teacher's approval of your plan before you begin any lab work.

Data: Any data you collect during this lab should be recorded in an appropriate table format.

Calculations & Results: Show your density calculations with and without air.

Conclusion: Write a summary statement of what you determined in this lab.

Reflection: Complete one of the following stems:

- One thing I learned that I did not know before is . . .
- One thing that really surprised me is . . .
- One thing that I will remember five years from now is . . .

Appendix E

Lab Assessment Strategies Used After Labs

Part 2 – Acid / Base Performance Task

Acid / Base Performance Task

You will be given four unlabeled solutions. Your task is to identify the four solutions.

The acids could be: 1 M HCl or 0.5 M HCl or 0.1 M HCl

(phenolphthalein has been added to the acids)

The bases could be: 1 M NaOH or 0.1 M NaOH

You should devise and implement a procedure that will allow you to experimentally determine which solution is in each container. Report your results in the following table:

Solution Set ____________	Acid or Base	Molarity
Solution A		
Solution B		
Solution C		
Solution D		

Figure 3 – Acid / Base Performance Task

Appendix E

Lab Assessment Strategies Used After Labs

Part 3 – Silane Teacher Demonstration Lab Assessment

Watch the demonstrations and answer the associated questions. The following list of chemicals and compounds are involved in the reactions that you will see.

Mg - magnesium

SiO_2 - silicon dioxide (sand)

Mg_2Si - magnesium silicide

MgO - magnesium oxide

HCl - hydrochloric acid

$MgCl_2$ - magnesium chloride

SiH_4 - silane

O_2 - oxygen

H_2O - water

Chemical Equations Lab Assessment Questions

In the first reaction Magnesium and sand are reacted to form Magnesium silicide and Magnesium oxide. What are the chemical formulas for the two reactants in this reaction?

1. ______________ 2. ______________

What are the chemical formulas for the two products in this reaction?

3. ______________ 4. ______________

5. What Law must be obeyed when balancing equations? ______________

6. Balance the following equation by putting the right coefficients on the blanks provided. NOTE - you may leave the blanks empty to indicate a coefficient of one.

______ Mg + _____ SiO_2 → _____Mg_2Si + _____MgO

7. This reaction releases a lot of energy and would therefore be classified as what kind of reaction? _______________

8. If you include the symbol E↗ to represent the energy given off in this equation, on which side of the equation should you put this symbol?

____

9. We had to add energy to start this reaction. This minimum necessary energy needed to start a reaction is called what? _______________

10. The next reaction occurred when we dumped the Magnesium silicide into Hydrochloric acid. Balance the following equation by putting the right coefficients on the blanks provided. NOTE - you may leave the blanks empty to indicate a coefficient of one.

_____ Mg_2Si +_____ HCl → _____$MgCl_2$ +_____SiH_4

11. What type of reaction is this? _______________

12. The last reaction immediately followed the previous one spontaneously. Balance the following equation by putting the right coefficients on the blanks provided. NOTE - you may leave the blanks empty to indicate a coefficient of one.

_____SiH_4 + _____O_2 → _____SiO_2 + _____H_2O

What do the following symbols mean when they are listed in a chemical equation?

13. (g) _____________ 14. (s) _____________ 15. (aq) _____________

Important Safety Guidelines for the Silane Teacher Demonstration

This information should be carefully read and adhered to by teachers intending to perform the Silane Teacher Demonstration. Appropriate safety equipment and procedures must be used at all times.

Silanes are very reactive gases, unstable in air. A mixture of silanes is made by reacting magnesium silicide with dilute hydrochloric acid. Making magnesium silicide is, itself, somewhat counterintuitive, because not often do we consider silica (i.e. sand) as very reactive. However a reaction does occur when it is heated with magnesium, a very strong reducing agent.

$$4Mg(s) + SiO_2(s) \dashrightarrow Mg_2Si(s) + 2MgO(s)$$

Mix together approximately 3.5 grams of magnesium (40 mesh - do not use powder!) and 3 grams of clean sand. This mixture should then be put into an 8-inch test tube and clamped on a ring stand. The mixture should be spread out along the tube. Use a safety shield between the audience and the test tube. Carefully heat the mixture strongly until it begins to glow, and continues to glow by itself. Allow the test tube to cool slightly and then cork the contents. CAUTION - on several occasions I have had the test tube crack as it cools because the reaction weakens the glass tube.

MAKE CERTAIN EVERYTHING YOU USE IS VERY DRY - THE PRESENCE OF WATER INCREASES THE RISK OF AN EXPLOSION!!!

Use a previously prepared and cooled test tube for the next portion of the demonstration. Break loose the cooled contents of the test tube into an evaporating dish and grind up slightly with a pestle. Then sprinkle this ground up mixture into a wide glass dish of 1 M HCl.

$$Mg_2Si + 4\ HCl \dashrightarrow 2MgCl_2(aq) + SiH_4(g)$$

$$SiH_4(g) + 2O_2(g) \dashrightarrow SiO_2(s) + 2H_2O$$

This last step is best observed in a darkened room. Silanes react spontaneously with air and so as soon as they bubble to the surface they ignite. Silanes are silicon-hydrogen analogs of hydrocarbons. While the hydrocarbons are good fuels, silanes are very unstable under similar conditions.

Appendix E

Lab Assessment Strategies Used After Labs

Part 4 – Copper Formula Teacher Demonstration

Table 10 – Data Table for the Copper Formula Teacher Demonstration

Calculations	
1. Mass of original iron containing salt	
2. Mass of dry iron produced	
3. Percent by mass of iron in the salt	
Accepted percent by mass of iron in the salt	20.6%
4. What is your percent error?	

Appendix E

Lab Assessment Strategies Used After Labs

Part 5 – Written Assessment Sample

1. An investigation was completed to determine the percent of oxygen in a lead oxide compound. The mass of the test tube was 18.68 g; the mass of the test tube plus compound was 21.54 g. After the test tube was heated and the oxygen gas driven off, lead remained in the test tube. The mass of the test tube and the lead was 21.03 g.
    A. Prepare a data table that summarizes this experimental data.
    B. Determine the percent of lead in this compound.
    C. Determine the percent error if the accepted value of lead in this compound is 86.6%.
2. Identify by names and formulas the reactants and products in question 1.

3. What part of the lab is most prone to student errors and defend your choice.
    A. Inaccurate use of the laboratory balance.
    B. Improper heating and cooling of the reactants.
    C. Incorrect filtering technique.
    D. Leaving the aluminum strips in the solution too long.
4. In a laboratory investigation to determine the percent zinc in a salt, students calculated these values: Student A, 37.5%; Student B, 41.3%; Student C, 30.9%. The accepted value was 37.6%. Describe the kind of errors that might explain each student's results.

5. A reagent bottle of copper (II) chloride dihydrate was found to have reddish-brown particles in it. Describe a student error that might have caused this.

6. If all the aluminum chloride were not removed during the washing, would this increase or decrease the experimentally determined percent copper value?

7. Explain why copper (II) chloride is not transported in metal containers.

8. The values in the right column were obtained from six different attempts to determine the percent of copper in a copper compound using a laboratory procedure identical to the one used in the Copper Formula lab. The accepted value is 35.0%. Match the sample letter(s) to the statements in the left column keeping in mind that each statement may describe more than one result.

1. There is a percent error of 14.3%.	33.5%
2. This could be a value if the copper had not completely dried.	A. 40.0%
	B. 35.0%
3. This could be a value if all the aluminum chloride had not been removed.	C. 30.0%
	D. 35.3%
4. If some of the copper remained in the beaker, this could have been a value.	E. 38.3%

Appendix E

Lab Assessment Strategies Used After Labs

Part 6 – Conceptualization Activity Example 1

I asked the students to watch as I took a beaker of 0.1M silver nitrate and immersed a bent cone of copper wire into the solution. The students were encouraged to notice the silver crystals that started to grow on the copper wire. They were then asked to answer the following questions:

1. What is happening around the wire?
2. Why is the solution turning blue?
3. What is happening to the silver in the solution?
4. Why does this reaction occur?
5. What role do electrons have in this reaction?

Appendix E

Lab Assessment Strategies Used After Labs

Part 7 – Conceptualization Activity Example #2

Part A

Use an appropriately connected Crooke's Cathode Ray Tube and a magnet to alter the course of a beam of light within the tube. Then answer the following questions:

1. How is the beam of light within the tube created?
2. What does the magnet's ability to deflect the beam of light suggest about this light?
3. What does this deflecting beam of light tell us about the atom?

Part B

Use a straighten paperclip to probe the inside of a ball of clay. Attempt to determine the shape of the object embedded within the clay without opening it up. Then answer the following questions:

4. How is this similar to Rutherford's Gold Foil Experiment?
5. What conclusions about the atom did Rutherford draw from his Gold Foil Experiment?

Part C

Use a spectroscope, the emission tubes, and a power supply to observe the different colors of light given off by different gases when they are electrically stimulated. Then answer the following questions:

6. Explain how these gases emit light:

7. Why do the gases emit unique bright-line spectrums rather than continuous spectrums?
8. What do these bright-line spectrums suggest about the structure of atoms?

Appendix F

Written Exams and Lab Practicals

Part 1 – Semester Exam – Written Section

Short Answer:

1. What is the octet rule?
2. Contrast ionic and covalent bonding:
3. List two effects of Hydrogen bonding:
4. Explain why metals have their characteristic properties of conductivity, malleability, and hardness.
5. Draw the electron dot diagrams for the following molecules:

   HCN $\quad\quad$ OF_2

6. What factors affect solubility of a solute in a solvent?
7. Name two effects that the presence of a solute has on the physical properties of the solvent:
8. What factors affect the reaction rate?
9. What is enthalpy? What usually happens to enthalpy in spontaneous reactions?
10. What is entropy? What usually happens to the entropy in spontaneous reactions?

Multiple Guess Questions:

11. Carefully examine a solubility table and then choose which of the following descriptions applies to a solution that has 55 g of solute dissolved in 100 g of water at 40°C.

    A) a supersaturated solution of KNO_3.

    B) an unsaturated solution of $KClO_3$.

    C) a saturated solution of NH_3.

    D) a supersaturated solution of NH_4Cl.

    E) a supersaturated solution of $NaNO_3$.

    Explain why you chose the answer you did:

12 If 100 g of a solution of KNO_3 contains 55 g of solute at 40°C, which of the following will cause it to become a saturated solution?

    A) adding 5 g of KNO_3.

    B) adding a single crystal of KNO_3.

    C) raising the temperature to 65°C.

    D) lowering the temperature to 34°C.

    E) adding 100 g of solvent.

    How can you determine the answer by looking at a solubility table?

13. The average increase, per degree Celsius, of solubility of $NaNO_3$ between 30°C and 80°C is

A) 96 g/°C.	D) 50 g/°C.
B) 10 g/°C.	E) 146 g/°C.
C) 1 g/°C.	F) 176 g/°C

14. How many grams of NH_3 can be dissolved in 1 kg of water at 70^0C?

A) 710 g
D) 10 g
B) 180 g
E) 7.1 g
C) 18 g
F) 1.7 g

15. A solution contains 80 g of KNO_3 dissolved in 100 g of water at 70^0C. Which of the following will cause the solution to become saturated?

A) heating the solution to 137^0C
C) adding 23 g of solvent
B) adding 55 g of KNO3
D) stirring the solution
C) cooling the solution to 420C

Explain why you chose the answer you did:

Relational-Analysis Questions:

For each of these questions there is an *assertion* (a statement) followed by the word BECAUSE, then a *reason*. Following the question are five letters that represent the following conclusions.

A. both the assertion and the reason are true, and the reason explains the assertion.
B. both the assertion and the reason are true, but the reason doesn't explain this assertion.
C. the assertion is true, but the reason is false.
D. the assertion is false, but the reason is true.
E. both the assertion and the reason are false.

You should circle the letter corresponding to the conclusion you deem most appropriate for each assertion-reason pair.

	Assertion		Reason	
	Neon and Argon do not react chemically.	BECAUSE	their atoms each have an octet of electrons.	
16. (A)	(B)	(C)	(D)	(E)
	Energy is released during endothermic reactions.	BECAUSE	in such reactions the products contain more chemical energy than do the reactants.	
17. (A)	(B)	(C)	(D)	(E)
	A blue Copper Nitrate solution can be heterogeneous	BECAUSE	Copper is a transition element.	
18. (A)	(B)	(C)	(D)	(E)
	A solution that contains 1 mole of solute in 500 cm^3 of solution is 0.5 molar.	BECAUSE	molarity is a measure of moles of solute per dm^3 of solution.	
19. (A)	(B)	(C)	(D)	(E)

Classification Questions:

Each of these questions are followed by three short statements. Following the statements are five letters that represent the following conclusions.

A. All three statements are correct.

B. Only statements I and II are correct.

C. Only statements II and III are correct.

D. Only statement I is correct.

E. Only statement III is correct.

You should circle the letter corresponding to the conclusion you deem most appropriate for each question and statement set.

20. Which of the following contain 10 electrons in their kernels?

I. F II. Na^+ III. Al

(A) (B) (C) (D) (E)

21. Metals

I. tend to gain electrons in reactions.

II. are always magnetic.

III. are malleable.

(A) (B) (C) (D) (E)

22. In order to make a 1.5 molar solution more concentrated, one can

I. raise the temperature.

II. evaporate some solvent.

III. add additional solute.

22. (A) (B) (C) (D) (E)

Appendix F

Written Exams and Lab Practicals

Part 2 – 1st Semester Exam – Lab Practical

Teacher Notes:

The students will have the entire exam period to complete eleven tasks that review information, calculations, and procedures from the 1st semester of this course. These tasks are not about memorization but about actually doing the procedures and chemistry that have been studied. Consequently, the students are encouraged to use notes, books, and other resources found in the classroom.

The time requirements of the different tasks and the desire to more accurately reflect the workplace require that the students work in groups to produce a single test-document that determines their grade. Effective time-management and cooperation among the group-members can significantly increase the amount of work that they can successfully accomplish.

The students are grouped homogeneously, with usually three other members of the class that have demonstrated similar academic performance for the semester. They do not necessarily compete with all the other members of their class, but rather are graded amongst their peers as determined by semester academic performance. The exams are graded and the scores for each level are plotted on a graph. This graph allows me to apply a best fit line to the data from all groups. The intersection of this line with each tier is used as the denominator when dividing the raw scores for each group in that tier. This determines the perfect score for that level. This process results in an appropriate goal for each level with higher expectations for the advanced groups. It makes a perfect 100% possible for any group regardless of past academic performance. It also eliminates the possibility of an unusually high score in a lower group artificially inflating the goal for an entire tier.

Materials needed for each lab station during the 1st semester lab practical

4-beam balance	1 small metal cube
1 meter stick	sodium bicarbonate
1 stop watch	copper oxide
1 piece of paper	zinc
1 thermometer	.3 M HCl
cotton swabs	3 M HCl
1 empty baggie	marble pieces
wooden splints	1 baggie of silicon dioxide
4 sealed Erlenmeyer flasks	Flask with grams of HCl marked
4 labeled flame test solutions	4 sealed graduated cylinders with liquids of varying density
1 unknown flame test solution	

1st Semester Laboratory Practical

Lab Table ____________ ← (This will be assigned by your teacher.)

Tier # ____________ ← (This will be assigned by your teacher.)

All of the substances and equipment used to complete the following tasks can be found at your lab station. As a group you should complete the following eleven chemistry tasks. Remember to record all of your group's answers on ONE MASTER TEST - this will be the only exam paper that will be graded when determining your entire group's grade. Due to time and equipment restraints it is in your own best interests to divide yourselves up so that you are completing several tasks at the same time. A little planning, and effectively using both the time you are given and all the members of your group, will go a long way towards improving your score on this exam.

Task 1 Metrics & Scientific Notation

Determine the area of one of the side laboratory tables in square kilometers being sure to use scientific notation and the correct number of significant figures.

Area of desktop in square kilometers: ____________________

Task 2 Dimensional Analysis

For this task, you will need a stop-watch, meter stick, and a piece of paper. Make a paper airplane and when you are ready, throw it being careful to measure both the distance in centimeters and the time in hundredths of a second that the airplane flies. Compute its speed in meters per second. Convert this speed to miles per hour.

Distance in centimeters: ____________________

Time in hundredths: ____________________

Speed in meters per second: ____________________

Speed in miles per hour: ____________________

Task 3 - Density

Examine the four sealed graduated cylinders at your table. These four liquids are in sealed graduated cylinders (please assume the cylinders have the exact same mass) that should not be opened or tipped. These liquids should be assumed to be insoluble in each other. You should determine the density of these liquids through careful observation and measurement. Predict what color sequence (from top to bottom) the liquids would display if they were all poured into the same tube.

(Top) Layer #1 _______________

Layer #2 _______________

Layer #3 _______________

(Bottom) Layer #4 _______________

Task 4 Substances

Take a look at the substances in the four, labeled Erlenmeyer flasks and classify them as homogeneous mixtures, heterogeneous mixtures, compounds, or elements.

Flask A: ______________________________

Flask B: ______________________________

Flask C: ______________________________

Flask D: ______________________________

Task 5 Physical & Chemical Changes

Complete the following directions and describe the change that occurs in each step as being an example of a physical or chemical change.

Step 1 - Place a medium scoop of sodium bicarbonate ($NaHCO_3$) in 30 mls of water.

____________________ Change

Step 2 - Use a stirring rod to agitate the contents of the beaker and dissolve as much sodium bicarbonate ($NaHCO_3$) as possible.

____________________ Change

Step 3 - Place 30 mls of .3 M hydrochloric acid (HCl) in another beaker. When you are ready, add the contents of the acid beaker to the other beaker and observe.

____________________ Change

Task 6 Flame Tests

Use the 5 solutions found at your lab station for this task. Use the four, labeled test solutions and the cotton swabs to gather some preliminary data on flame tests. When you are ready, test the unknown solution and compare it to your data to determine the ion present in the unknown.

Test Solution	Color of flame	Ion Present
A	________________	________________
B	________________	________________
C	________________	________________
D	________________	________________
Unknown ____	________________	________________

Task 7 Moles

Use the baggie of silicon dioxide for this task. An extra empty baggie is provided so that you can tare the baggie's mass. Assume all baggies have an identical mass. Please determine the following using the appropriate units:

Percent composition of silicon dioxide: ________________

The number of molecules of silicon dioxide in your baggie:

____

The number of atoms of each element in your baggie:

____

Task 8 Specific Heat Capacity

Use the metal cube for this task. After determining its mass, place it in boiling water for ten minutes. Move the piece of metal to beaker of cold water and let it sit for ten minutes. Use your data to determine the specific heat capacity of the metal.

Type of metal: ____________________

Mass of metal: ____________________

Volume of cold water: ____________________

Initial temperature of cold water: ____________________

Final temperature of water: ____________________

Temperature change of water: ____________________

Heat gained by the water: ____________________

Temperature change of metal: ____________________

Heat lost by the metal: ____________________

Specific Heat Capacity of the metal sample: ____________________

Task 9 Stoichiometry

Complete the following laboratory procedure and record the required information below.

1. Take two pieces of $CaCO_3$ and determine their combined masses exactly.
2. Place 20 mls of 3M HCl in a small beaker.
3. Put the marble chips in the acid and observe the reaction.
4. Determine what gas is produced by performing a flame test.
5. Write a balanced equation for this reaction keeping in mind that there are three products: a gas, $CaCl_2$ and water.
6. Determine how many dm^3s of the gas is produced.
7. Identify the limiting agent.
8. Categorize this reaction.

Mass of $CaCO_3$:____________________

What gas is produced: ____________________

Balanced equation for the reaction: ________________________________

dm^3 of the gas produced: ____________________

Limiting agent in the reaction: ____________________

Type of reaction (synthesis, analysis, etc.): ____________________

Task 10 Experimental Stoichiometry

The teacher will give you an empty flask that indicates how many grams of Hydrochloric Acid he will give you when you are ready. You should calculate the exact number of grams of zinc that you will need to completely react with this amount of HCl. Write the balanced equation for this reaction including phases and energy terms. Predict the amounts of each product formed (in grams or volume if a product is a gas). When you are ready, add the zinc to the flask and have your teacher perform the reaction in the fume hood. Give your teacher the flask when the reaction is completed. Your teacher will test to see if all the reactants have been completely consumed.

Balanced equation: ______________________________

Grams of HCl: ____________________

Grams of zinc: ____________________

Grams of zinc chloride: ____________________

dm^3 of gas: ____________________

Task #11 Experimental Empirical Formula & Percent Composition determination

Follow the procedures as outlined on the Copper Oxide Procedures Sheet to perform this mini-lab. Record all of your data and results below:

(A) Mass of empty test tube: ____________________

(B) Mass of test tube and copper oxide: ____________________

(C) Mass of test tube and metallic copper: ____________________

Mass of copper oxide: ____________________

Mass of metallic copper: ____________________

Mass of oxygen: ____________________

Moles of metallic copper: ____________________

Moles of oxygen: ____________________

Empirical Formula of copper oxide: ____________________

Percent Composition of copper oxide: ____________________

Copper Oxide Procedures Sheet

Determine an Empirical Formula through the Reduction of Copper Oxide

(Instructions for Task 11 of the 1st Semester Practical Exam)

Copper oxide can be reduced to yield metallic copper with the use of ordinary methane gas from the classroom outlet. To do this, the copper oxide is strongly heated in an atmosphere of methane gas in a manner which permits all end products except copper to escape the system as gases. It is a dangerous procedure in any laboratory to allow any gas to be freely emitted into the classroom atmosphere. In this activity, you will use an apparatus designed to use the gas produced during the reaction process to fuel the burner flame, thus disposing of the harmful gases. The reaction can be considered as:

copper oxide (s) + methane (g) ---- > copper (s) + carbon dioxide (g) + water (g)

<u>Procedure</u>

1. Determine the mass of the clean, dry, empty, large test tube.
2. Place about 1.50 grams of copper oxide wire in the test tube. Determine the mass of the copper oxide and test tube.
3. Assemble the apparatus so that the natural gas first flows into the test tube that contains the copper oxide and then back out of the test tube and down to the bunsen burner beneath the tube. The teacher has an apparatus correctly assembled on the demonstration desk for you to refer to if you have any questions. Check your apparatus to see that the gas flow and flame height is adequate.

4. Using the assembled apparatus, heat the copper oxide until it is reduced to metallic copper. Watch carefully for gas leaks. This will take approximately 15 to 30 minutes.
5. Heat the walls of the test tube to drive out any condensed water.
6. Remove the burner from underneath the test tube, but allow the flame to burn for an additional 5 minutes or until the copper is cool. This step removes harmful gases and helps cool the copper.
7. Mass the test tube and metallic copper.

Appendix F

Written Exams and Lab Practicals

Part 3 – 2nd Semester Exam – Lab Practical

Teacher Notes:

This is a lab practical. The students have already demonstrated their individual book-knowledge on the separate parts of the final exam given at the end of each marking period. In this lab practical the students will have the entire exam period to complete approximately 12 tasks that review information, calculations, and procedures from the 2nd semester of this course. These tasks are not about memorization but about actually doing the procedures and chemistry that we have studied. Consequently, the students are encouraged to use their notes, books, and other resources found in the classroom.

The time requirements of the different tasks and the desire to more accurately reflect the workplace require that the students work in groups to produce a single test-document that determines their grade. Effective time-management and cooperation among the group-members can significantly increase the amount of work that they can successfully accomplish.

The students are grouped homogeneously, with usually three other members of the class that have demonstrated similar academic performance for the semester. They do not necessarily compete with all the other members of their class, but rather are graded amongst their peers as determined by semester academic performance. The exams are then graded and the scores for each level are plotted on a graph. This graph allows me to apply a best fit line to the data from all groups. The intersection of this line with each tier is used as the denominator when dividing the raw scores for each group in that tier. This determines the perfect score for that level. This process results in an appropriate goal for each level with higher expectations for the advanced groups. It makes a perfect 100% possible for any group regardless of past academic performance. It also eliminates the possibility of an unusually high score in a lower group artificially inflating the goal for an entire tier.

List of Materials to be placed at each lab station

4 heat sensitive periodic tables	paperclips
4 sheets of isomer drawing paper	string
Spot test solutions	index cards
Spot Test grids	label tape
Organic model kits	marker
Blank Paper	food coloring
1 Florence flask	hot glove
1 thermometer	soap
1-hole & solid stoppers for flasks	Alka-Seltzer
1 Erlenmeyer flask	Buret with sulfuric acid solution
balloons to fit Erlenmeyer flask	100 ml 6M HCl
3 ft of glass tubing	6 g Zn

2nd Semester Lab Practical

Lab Table ____________ ← (This will be assigned by your teacher.)

Tier # ____________ ← (This will be assigned by your teacher.)

All of the substances and equipment used to complete the following tasks can be found at your lab station.

Task 1: Phases of Matter

Make a working thermometer complete with an accurate temperature scale indicating a temperature range of at least 50 degrees. Attach some tape with your names on the thermometer and hand it in to the teacher. In the space below, give a concise but very accurate explanation of how a thermometer works.

Task 2: Phases of Matter

Perform the following "Double Boiler" demonstration.

1. Bring a half-filled Florence flask of water to a boil.
2. Carefully remove the flask from the heat source.
3. Using a solid stopper – seal the flask.
4. Carefully invert the sealed flask and run cool water over the outside of the flask until the water inside the flask begins to boil again.

In the space below, give a concise but very accurate explanation of how this demonstration works.

Task 3: Electron Configurations

What is the electron configuration for the Iodine ion (I^{-1})?

Task 4: The Periodic Table

The Periodic Tables found at your lab station change color with the heat from your hand. As the paper cools, it changes back to its original color. Is the change from the second color back to the first color endothermic or exothermic? Explain why in detail:

_____ Endothermic   _____ Exothermic

Why:

Task 5: The Periodic Table

Using the clues given on the next two pages, fill in the following diagram with the appropriate letters of the alphabet. These letters represent the S and P block elements of the top four rows of the periodic table.

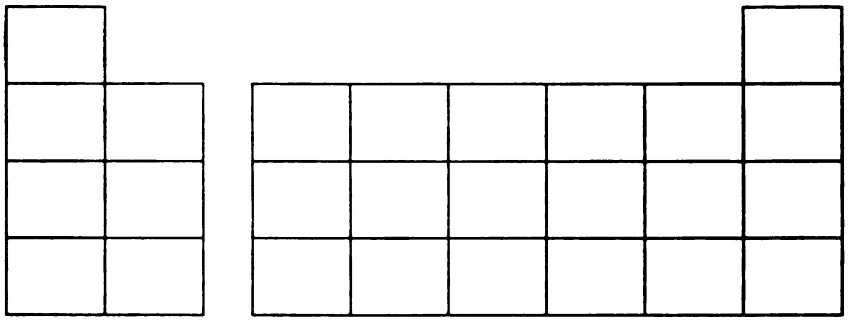

Figure 4 – Practical Exam Periodic Table Grid

Periodic Table – Task 5 continued.

The code letters A to Z have been assigned to the first 26 elements in the short form periodic table. (This table omits the transition elements in period 4.) These code letters do not represent the chemical symbols nor have the letters been assigned in alphabetical order. Study the given clues based on experimental data. Then place the code letters in their correct positions in Figure 4.

Clues

1. The following elements belong together in families: BJW, CFLS, DHR, EGOX, AMU, QVY, NPZ, IKT
2. If this atom formed ions, the ions for H would be +4 or -4.
3. RT_2 is the formula of an oxide.
4. F is a noble gas.
5. G is an alkali metal.
6. Y has 5 electrons in its outermost energy level.
7. B has 2 valence shell electrons.
8. M has an outer electronic configuration of $4s^2\ 4p^1$.
9. N is a halogen.
10. A has the smallest atomic mass in its family.
11. P is a green gas at STP.
12. R has the lowest first ionization energy in its family.
13. S is more metallic than L.
14. The nucleus of C could be called an alpha particle.

Periodic Table – Task 5 continued

15. X is found in table salt.

16. Z is a liquid but N is a gas at room temperature and pressure.

17. F contains ten protons.

18. The electrons of atom V are distributed over four energy levels.

19. O is the least metallic in its group.

20. K is more metallic than either I or T.

21. The atomic mass of B is less than that of J but more than that of W.

22. The atomic number of I is one greater than that of Y.

23. Atoms of G are smaller than those of E.

24. The last term in H's electronic configuration is $3p^4$.

Task 6:Chemical Bonding

Create and show the teacher a demonstration of Hydrogen Bonding.

Task 7: Chemical Kinetics

Experiment with different factors that affect the rate at which Alka-Seltzer dissolves. Describe at least two different strategies of speeding up the reaction between water and Alka-Seltzer. Describe how chemical kinetics, the kinetic theory of matter, and potential energy diagrams explain why these strategies speed up this reaction.

Stategy 1:

Explanation:

Strategy 2:

Explanation:

Task 8: Gas Laws

Using 100.0 ml of 6.00M HCl and 3.00 grams of Zinc in a Erlenmeyer flask, produce and capture in a balloon some Hydrogen gas. Calculate what volume of Hydrogen gas has been captured. Prove that you have produced Hydrogen gas by detonating the balloon at the teacher's desk.

Volume of Hydrogen gas: ___________________

Task 9: Organic Chemistry

Name and draw the structural formulas for all the isomers of DiChloro Pentadiene on the back of this paper.

Task 10:Solutions

Produce a 200.0 ml sample of 2.00M NaOH Solution. You may obtain the necessary mass of NaOH by submitting to your teacher an index card from your lab station showing all the calculations and the actual amount of NaOH you need. When completed with this task you must show your solution to the teacher before attempting task 11. The teacher will check your solution's concentration before you begin task 11.

Task 11: Acid Base Reactions

Use your 2.00M NaOH solution produced in task 10 to determine the molarity of the standard solution of the sulfuric acid solution in the buret at your lab station.

Calculations:

Molarity of Sulfuric acid: ____________

Task 12: Spot Test

Use the solutions listed below and the procedure from the next page to perform the spot test. You should perform the Spot Test on the piece of plastic found at your stations. A blank piece of paper underneath the plastic makes it easier to observe the colors. Please be careful not to contaminate your solutions. Identify your six solutions and record your results here:

Reagents	Reagents
Solution #1: ________________	Solution # 4: ________________
Solution # 2: ________________	Solution # 5: ________________
Solution # 3: ________________	Solution # 6: ________________

Spot Test Directions

Solutions:

1M acetic acid

1M hydrochloric acid

0.2M lead acetate

0.04M mercuric chloride

0.2M potassium iodide

0.04M silver nitrate

Procedure:

Identify the specific ion (and hence the solution) that is in each reagent bottle by the pair-wise mixing of a drop from one bottle with one drop from another bottle. By carefully mixing the solutions drop by drop and comparing the colors of the precipitates that form with the following information you should be able to correctly identify the solutions in each bottle.

Precipitates:

lead iodide (PbI_2) is a deep yellow precipitate.

mercuric iodide (HgI_2) is an orange-red precipitate.

lead chloride ($PbCl_2$) is a white precipitate.

silver iodide (AgI) is a light yellow precipitate.

silver chloride ($AgCl$) forms a white precipitate that gradually turns violet.

acetic acid will not form a precipitate in these reactions.

Appendix G

Posttest, Strategy Evaluation, and Survey

Part 1 – Posttest

Please indicate how much you agree with the following statements. Base your answers on this science course only. Record your answers by circling a number from one to ten. Circling a one means that you strongly disagree and circling a ten means you strongly agree.

1. Science courses should offer students lab activities.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

2. I believe that lectures and discussions teach chemistry more effectively than lab activities.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

3. I think science courses should offer more lab activities than they do.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

4. I think that labs are more work than they are worth.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

5. Lectures and labs in science courses are clearly connected.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

6. Science course laboratory work has increased my understanding of how scientists actually work.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

7. Labs make science more relevant to my life.

   (Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

8. Lab work increased my interest in science.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

9. Lab activities taught me more about science than the book or lectures did.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

10. I prefer open-ended investigative labs of my own design.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

11. Lab work improves my understanding of the material covered in lectures.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

12. I prefer traditional written tests to nontraditional tests that require me to do something.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

13. Information from lab work should be a part of tests.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

14. I concentrate more closely on lab work if I know I am going to be tested over the lab.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

15. Laboratory notebooks helped me to understand the labs better.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

16. This science course offered more lab activities than most science courses.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

17. Lab assessments are harder than traditional tests.

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

Appendix G

Posttest, Strategy Evaluation, and Survey

Part 2 – Laboratory Assessment Strategy Evaluation

Please evaluate the laboratory assessment strategies that were used in this course. There are three areas that I would like you to evaluate about each strategy. First, I would like to know how effective you thought each strategy was in terms of its ability to measure what students have learned. (This is the purpose of laboratory assessment.) Second, I would like you to evaluate how effective you thought each strategy was in terms of its ability to teach new material. (This is an important side benefit of laboratory assessment.) Thirdly, I would also like you to indicate how much you enjoyed the various strategies.

Lab notebooks:

Evaluation effectiveness: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Teaching effectiveness: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Personal enjoyment: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Performance Checklists:

Evaluation effectiveness: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Teaching effectiveness: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Personal enjoyment: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Student Interviews:

Evaluation effectiveness: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Teaching effectiveness: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Personal enjoyment: (Low) 1 2 3 4 5 6 7 8 9 10 (High)

Peer Assessments:

Evaluation effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Teaching effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Personal enjoyment:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)

Performance Tasks:

Evaluation effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Teaching effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Personal enjoyment:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)

Open-ended Labs:

Evaluation effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Teaching effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Personal enjoyment:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)

Teacher Demonstrations:

Evaluation effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Teaching effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Personal enjoyment:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)

Written Assessments:

Evaluation effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Teaching effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Personal enjoyment:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)

Conceptualization Activities:

Evaluation effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Teaching effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Personal enjoyment:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)

Lab Practicals:

Evaluation effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Teaching effectiveness:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)
Personal enjoyment:	(Low)	1	2	3	4	5	6	7	8	9	10	(High)

Appendix G

Posttest, Strategy Evaluation, and Survey

Part 3 – Posttest Survey Questions

1. Did you enjoy this science course?
2. Do you enjoy labs?
3. What is the best part about labs?
4. What is the worst part of labs?
5. Why did we perform labs in this science course?
6. Were the labs necessary?
7. What was the best part about using a lab notebook?
8. Why do you think the teacher required you to use a lab notebook?
9. Would you recommend the use of lab notebooks for future chemistry students? Why?
10. Did you prefer the more structured labs or the open ended ones? Why?
11. How often should students perform lab activities during a science course?
12. How should teachers evaluate the learning that occurs during lab activities?
13. Should questions about recent labs being included on tests?
14. Should tests include lab activities?
15. How should teachers improve the connection between labs and lectures?

16. How did lab activities improve your understanding of chemistry?
17. What teaching strategy (lectures, demos, labs, etc.) taught you the most about chemistry? Why?
18. What type of information or material is most effectively evaluated using laboratory assessment?
19. What was your favorite assessment strategy? Why?
20. Should the teacher continue to use formalized lab assessment in the future? Why?
21. What did you like the most about the lab assessment procedure used in this course?
22. What did you like the least about the lab assessment procedure used in this course?

Appendix H

Open Ended Labs with Rubrics

Part 1 – Chemical Bonding Investigation

Objective:

Your task is to write a procedure one could follow to identify two unknown compounds as having either ionic or covalent bonds.

Scenario:

You are given two unidentified, white, crystalline compounds. You must devise a procedure to be used in the laboratory to classify these compounds as having either Ionic or Covalent bonds.

Instructions:

Your procedure must be clear and detailed enough that any first year chemistry student would be able to follow it. You must include step-by-step instructions. You must specify amounts, proper glassware, lab techniques, safety precautions, disposal procedures, order, observations that should be noted, important qualities for which to watch, etc. You must also include at least two "tests" that will be used to identify the compounds.

Example:

I was asked to devise a system to identify two white materials as either plastic or paper. Each was thin like a sheet of paper, each had similar coloring, and the two could easily be mistaken for one another.

Procedure: (from the example)

1. SAFETY GLASSES SHOULD BE WORN AT ALL TIMES DURING THIS LAB! Obtain the two samples to be tested. Assign each a code letter.
2. Visually inspect the two samples carefully noting any differences.
3. Record 3 observations about each in the data table: (Note: a "slippery" surface might denote plastic and easily ripped samples could identify paper)
4. Next, cut each sample into fourths, keeping the two samples separate.
5. Take one fourth of each sample and place it on the lab table in front of you.
6. With a dropper pipet, drop distilled water (10 drops) onto each of the samples. Record observations in the data table. (Note: paper will traditionally absorb the water droplets but plastic will repel the water leaving the drops intact resting on the surface of the sample)
7. The wet samples may be disposed of in the trashcan.
8. Repeat steps 5, 6, and 7 with a different section of each sample.
9. Take a different fourth of each sample and perform the following test.

10. With tongs hold one of the samples about 15 cm over the top of a Bunsen burner. CAUTION: USE CARE WHEN USING BUNSEN BURNERS. KEEP HAIR AND LOOSE CLOTHING TIED BACK, AWAY FROM FLAMES.

11. Record observations in the data table.

12. With tongs hold the other sample about 15 cm over the top of a Bunsen burner.

13. Record observations in the data table. (Note: The paper sample should burn with a bright orange flame leaving behind a black residue. The plastic sample should not burn, but will melt when held over the flame. The plastic sample may be discolored slightly by the gentle heating, leaving a brown color on the white plastic.)

14. Repeat steps 9 through 13 with two fresh samples.

15. The burned/melted samples should be cooled to room temperature and disposed of in the trash container.

16. Tally data in the data table. The data should show consistent trends for either plastic or paper properties. Determine which substance is paper and which is plastic.

The data table I used for this sample investigation is included on the next page. These instructions and the data table are provided as samples only. Your procedure and data table should be very different from these samples.

Table 11 – Chemical Bonding Investigation Sample Data Table

	Sample Code Letter A	Sample Code Letter B
Visual Inspection	White, slightly shiny, not slippery	White, not shiny, Not slippery
Water Test #1	Water droplets stand up in little round bubbles	Water droplets stand up in little flatten bubbles
Water Test #2	Same as before, water drops leave no wet marks	Same as before, slight wet marks left by drops
Burner Test #1	Melts quickly	Chars and then burns
Burner Test #2	Sample melted then caught on fire	Sample burns completely to a black residue

Conclusion:

Since sample A demonstrated properties during these tests consistent with those of plastic, based on this experiment, I would conclude that Sample A is a type of plastic. Sample B's properties would cause this experimenter to conclude that it is a form of paper.

Chemical Bonding Lab Assessment Rubric

Detail of Instructions (How well can this procedure be followed?)

Easily	– no questions at all	3 pts
Somewhat	– 1 to 3 questions	2 pts
Barely	– 4 to 5 questions	1 pt

Data Table

Complete, useable data table given	2 pts
Incomplete data table	1 pt
Missing data table	0 pts

Thoroughness of Tests

Two tests given to identify compounds	2 pts
Less than two tests given	0 pts

Quality of Tests	**#1**	**and**	**#2**
Test will determine bond character	2 pts		2 pts
Test will not determine bond	0 pts		0 pts
Expected outcome given for both	2 pts		2pts
Expected outcome given for one	1 pt		1pt
No expected outcome given	0 pts		0pts

Safety Precautions

Given for all necessary items	2 pts

Disposal

Given for all disposable materials	1 pt

Appendix H

Open Ended Labs with Rubrics

Part 2 – Eggsplosions Lab Activity

The following pages were given to the students at the beginning of the activity.

Eggsplosions

This is your opportunity to PROVE what you know about chemical reactions, the gas laws, chemical kinetics and thermodynamics.

Your mission is to produce the most spectacular Eggsplosion in class.You will be using hydrogen gas to make a small explosion (under your teacher's supervision) to blow up an empty eggshell on the center table. You should first examine the materials on the side shelf provided by your teacher to decide how you are going to generate the necessary reactants for your eggsplosion. You will be graded on both your eggsplosion and your explanation of it.

You must write out a plan for creating any and all reactants that you will be using. You must show your teacher a specific step-by-step procedure that includes all the applicable safety guidelines and the appropriate chemical reactions. Only after obtaining your teacher's written permission are you to proceed with your experiment!

When you have obtained permission to proceed you may collect your materials. Before you actually start generating your reactants, you should carefully plan how you are going to manage the mechanics of filling your egg. On the same paper as your teacher approved plan you should answer the following procedural questions:

1. How are you going to fill the egg?
2. What amount of which reactants are you going to fill the egg with?
3. How are you going to prevent the premature loss of reactants from the egg?

After answering these questions you should be able to fill your egg. Please mark the outside of your egg, fill it according to your plan, seal it using tape and place it in the place indicated by your teacher. When everyone is ready we will initiate and evaluate your eggsplosions. To earn a passing grade you must also answer the following analysis questions:

1. Why do some eggs explode immediately and others do so only after burning a short while?

2. How does the concentration of the reactants affect this reaction?

3. Why does the egg actually explode instead of just burn?

4. What should today's activity suggest to you about the safety and appropriate use of natural gas to heat our homes?

Suggested Format and Grading Rubric for the Eggsplosions Lab Activity

1) Procedure

This section contains the complete step-by-step directions that you plan to follow in this experiment. You must submit this proposed procedure for approval to your teacher BEFORE continuing to the rest of the experiment. This section is worth up to 3 points.

2) Safety Guidelines

This section should contain a complete set of safety guidelines suitable for this experiment. This section is worth up to 3 points.

3) Chemical Reactions

Please list the complete chemical equations for the reaction used to generate the hydrogen gas and the reaction used to detonate the egg. This section is worth up to 2 points.

4) Procedural Questions

Answer the three procedural questions from the introduction. This section is worth up to 3 points.

5) Analysis Questions

The four analysis questions listed on the introduction should be answered here. This section is worth up to 4 points.

Total Points possible = 15 points.

Appendix I

Various Lab Assessment Activities

Part 1 – Marble Challenge Graphing Assessment

Teacher notes:

This open-ended laboratory is designed for students who have just concluded a unit on scientific measurement including the effective use of graphing. It is designed to challenge the students to design their own logical process for determining the average mass of some marbles sealed in a jar. Each lab group has a different set of jars with different numbers of marbles in them. A preliminary discussion should be held pointing out why taking the difference in mass between two jars and dividing it by the jars' difference in mass would not produce precise or accurate values. The students may also need a review of some basic math associated with graphs such as how to solve for values, slope, etc.

Student Information:

At your lab stations you have been given several sealed jars of marbles, balls, etc. Each jar contains a number of these marbles. You should mass these jars and by extrapolation determine the mass of a single marble. Decide what procedure you will use before you begin experimenting. Record all pertinent data and make a graph of your results. Be sure to answer the questions about this activity.

Procedure: (Use this space to list a step-by-step procedure that you will use.)

1.

2.

3.

4.

5

Data: (Use this space to record your observations and measurements in a neat data table.)

Calculations, Results, & Questions:

Graph: Please attach your graph paper to this sheet. Be sure to title the graph, name and label the axis's, and record your data appropriately.

Slope: Determine the slope of your curve. The equation is y=mx+b, where m is the slope and b is where your curve intercepts the y axis.

Questions:

1. What is the mass of a single one of your marbles? (Use your graph and it's slope!)
2. What would the total mass be for a jar containing (assume it is possible) twentyfive of your marbles?
3. What does (or should) the Y intercept on your graph tell you?

Appendix I

Various Lab Assessment Activities

Part 2 - Observing a Chemical Reaction Performance Task

Teacher notes:

This simple performance task is designed for beginning chemistry students finishing a unit on the scientific method and introductory laboratory skills. A preliminary discussion contrasting observations and interpretations should be conducted before beginning this activity. Students will also need to be aware of the difference between qualitative and quantitative observations. Safety and the need for careful observations should be emphasized

Student Information:

Warning – The copper compound you will be using is quite toxic! Please handle it with care. Wear safety goggles at all times.

1. Place 3 grams of copper (II) chloride dihydrate $CuCl_2{\cdot}2H_2O$ crystals in a medium sized beaker. Describe the crystals in the data table.
2. Add 20 ml of water to another medium sized beaker and without stirring add the crystals from the first beaker to the beaker with the water. Record your observations in the data table.
3. Use a stirring rod to stir the mixture until the crystals are completely dissolved. Record the temperature of the solution along with any other observations you can make.

4. Make a loosely crumpled ball of aluminum foil about the size of a Ping-Pong ball and place it into the solution. Record as many observations as possible.

Table 12 – Data Table for the Observing a Chemical Reaction Task

	Observations
Copper(II) chloride crystals	
Copper(II) chloride in H_2O	
Dissolved copper(II) chloride	
Copper(II) chloride + al foil	

Analysis

1. Examine your observations. Cross out any that are interpretations instead of observations. Circle any observations that are quantitative.
2. What advantages do observations have over interpretations?
3. Why do scientists prefer quantitative observations when possible?
4. When are interpretations useful and appropriate for scientists?
5. Why is it important for scientists to accurately indicate which of their findings are observations and which are interpretations?

Appendix I

Various Lab Assessment Activities

Part 3 – Ziploc Changes Laboratory Assessment

Teacher notes:

In this laboratory assessment, the students demonstrate their abilities to carefully observe an experiment and differentiate between physical and chemical changes. The amounts of the reactants are not critical and therefore this tends to be a very quick and easy to perform activity.

Student Information:

Wear safety goggles at all times. Report any spills to your teacher immediately.

In this activity you will be demonstrating your ability to carefully observe a reaction and document the physical and chemical changes that you detect.

Procedure:

1 Prepare a chart on the back of this paper with a column for physical and a column for chemical changes.

2 To a Ziploc baggie add one small scoop of calcium chloride.

3 Now add one small scoop of sodium bicarbonate to the same baggie.

4 Carefully observe the characteristics of the mixture in your baggie so that you will be able to notice any changes that occur.

5 Using a pipette, obtain a small amount (less than 2 mls) of phenol red (an indicator that turns red in a base and yellow in an acid). When you are ready to carefully observe all the changes that occur in the baggie, squirt the phenol red into the baggie and seal it.

6 Using your senses of sight and touch, look for as many signs of physical and chemical changes as you can observe inside the baggie and record these on the bottom of this paper.

Appendix I

Various Lab Assessment Activities

Part 4 – Unclogging Your Pipes Laboratory Assessment

Teacher notes:

This investigation should be used very early in a chemistry course perhaps in conjunction with a unit test over chemical and physical properties and changes. Students should have a beginning understanding of correct laboratory procedures and laboratory safety. Laboratory activities such as this that investigate the chemical properties of common household products can greatly increase the connections students see between chemistry and the "real" world.

Student Information:

Solid drain cleaners like Drano contain sodium hydroxide pellets, aluminum shavings, coloring material and scent. It is important to remember that the producers of this product are obviously profit motivated. This means that they are interested in producing a cleaner that:

1. Works.
2. Will be popular with the consumer.
3. Sells with an acceptable profit margin.

You should keep in mind that the manufacturers would probably arrange these criteria in the reverse order. By careful analysis we can discover the purpose for each of the ingredients in the drain cleaner.

Warning – The drain-cleaning compound you will be using is quite toxic and caustic! Please handle it with care. Wear safety goggles at all times. Do not let the compound or any liquid containing the compound to come in contact with your skin. Report any spills to your teacher immediately.

Equipment:

1 - 50 ml beaker   1 - 150 ml beaker   1 thermometer   Safety glasses

Procedure:

1. Place a small sample (approx. 1 teaspoon) of Solid Drain Cleaner in your 50 ml beaker. Examine it closely but DO NOT TOUCH it.
2. Place 50 mls of water in your 150 ml beaker. Determine its temperature.
3. Carefully pour the Drain Cleaner into the beaker of water and watch closely what happens. Record the temperature of the reaction.
4. Answer the questions on the back of this paper.
5. Rinse everything carefully with water when finished.

Analysis:

1. Sodium hydroxide (the little pellets) immediately began to dissolve in the water in your beaker. This dissolution of sodium hydroxide is what type of change? (physical or chemical)
2. Was this dissolution of sodium hydroxide an endothermic or exothermic reaction?

3. The dissolved sodium hydroxide is a caustic base. How does this help clean your drain?
4. Why did the producer include small shavings of aluminum?
5. The energy released by this dissolution of sodium hydroxide was sufficient to cause the aluminum shavings to begin to react. What name could be applied to this energy?
6. Did the aluminum undergo a physical or chemical change?
7. Was the change that the aluminum underwent endothermic or exothermic?
8. Where was the hottest part of the reaction in your beaker and how hot was it?
9. How could this temperature increase help break up a clog in a pipe?
10. How could the bubbling help break up the clog?
11. The gas released was the result of the breaking apart of the water molecule. It is explosive! What gas is it?
12. Why is it important to run a lot of water down your pipes after the clog has been broken up?
13. Why did the producer include a scent and coloring agent?
14. Why should a person with aluminum plumbing NEVER use Drano?
15. What should you do if you ever get drain cleaner splashed on you?

Appendix I

Various Lab Assessment Activities

Part 5 – Liquid Nitrogen Conceptualization Activity

Teacher notes:

Before beginning this activity the teacher should share and demonstrate the following information: Rubber balls bounce because they store their kinetic energy by deforming on a hard surface. Steel balls also bounce (but not as well) because they deform the surface they bounce on.

This variation of the standard liquid nitrogen demonstrations can be used to assess the students' understanding of temperature and the Kinetic Theory of Matter. This activity is designed to be demonstrated by the teacher using students to help collect and interpret the data. The graph will show that the frozen ball bounces very well in a manner similar to a steel ball. As the ball warms up, it will lose its bounciness. Then, as the ball returns to room temperature, it will regain its bounce as it becomes sufficiently softer than the surface and begins to demonstrate its typical elasticity. Safety around liquid nitrogen and the need for careful observations should be emphasized.

Student Information:

The teacher will cool a bouncy ball (superball) in liquid nitrogen as the demonstration begins. Once the ball has cooled for ten minutes, two students will be used to collect information on how the temperature of the ball affects its ability to bounce. The students will drop the ball once every five seconds from a height of one meter on to a hard surface and measure how high it bounces on its first bounce. All other students should record this data by plotting the information on a graph. This graph should have the height in centimeters on the vertical axis and the number of the drop on the horizontal axis. The ball will be dropped sixty times in five minutes.

Answer the following questions before the demonstration begins:

1. What is liquid nitrogen?

2. When we throw a "Super Ball" into the liquid nitrogen - it bubbles. What are the bubbles?

3. What is happening to the molecules of the liquid nitrogen as it bubbles?

4. Why does the bubbling eventually stop?

5. What is happening to the molecules in the ball as it sits in the liquid?

6. What conservation law is being obeyed here?

7. How do you think this will affect the ball's ability to bounce?

8. As the ball warms up, will the bounce improve back to its original height?

The demonstration should be performed at this point. The students should then answer the following questions:

9. What is similar about how rubber balls and steel balls bounce?

10. How can this explain what happened to the "Super Ball" after it was immersed in liquid nitrogen?

11. What is the energy being used for during that stage when the "Super Ball" doesn't act like either a rubber ball or a steel ball?

12. What did you learn from this experiment?

Appendix I

Various Lab Assessment Activities

Part 6 – Elements, Mixtures, and Compounds Separation Activity

Teacher notes:

This activity is designed to evaluate the student's understanding of basic laboratory procedures and how matter is organized. It requires the student to design their own laboratory process for separating the materials in a flask prepared for them by the teacher. Typical flasks might contain room air, Italian salad dressing, sand and salt, or alcohol and water. I would suggest having the students outline a process for at least three different flasks.

Student Information:

The flask on your desk contains a mixture of materials. You are to design a laboratory process that will separate the mixture into its basic components.

1. Please describe the contents of your flask:

2. Classify the contents of the flask as one of the following: solid, liquid, or gas.

3. Classify the contents of the flask as an element, compound, or mixture (be sure to specify heterogeneous or homogenous mixture).

4. You should now propose a scheme or process that could be used to separate the contents of the flask. On the bottom of this sheet, please describe this process as if it were to be followed by someone other than a member of your group. You should use pictures or diagrams to help others visualize this process. Remember to use complete sentences, detailed drawings, and don't skip any steps.

Appendix I

Various Lab Assessment Activities

Part 7 – How Big is a Mole Laboratory Assessment Activity

Teacher notes:

This activity can be used to determine how well a student understands the mole concept and associated calculations.

Student Information:

You are to determine the number of molecules in a mouthful of water. Fill a cup with water and determine the mass to the thousandth of a gram. Drink one mouthful of water. Reweigh the cup and remaining water. Calculate the number of molecules that you drank.

Observations:

A. Mass of cup and water initially = ____________________g

B. Mass of cup and water after drinking = ____________________g

C. Mass of water swallowed (A-B) = ____________________g

D. Molar mass of water = ____________________g/mol

(How much does a mole of water weigh?)

E. Moles of water swallowed (C/D) = ____________________mol

F. Number of molecules per mole = _______________molecules/mol

(Avogadro would know this one!)

G. Number of molecules swallowed = ____________________molecules

(E x F please answer in Scientific.Notation)

H. Number of molecules swallowed NOT in scientific notation

= ____ molecules

Analysis

1. Were you surprised at how many molecules of water you drink in every mouthful?

2. How many molecules of water are in an entire bottle (540 g) of bottled water?

Appendix I

Various Lab Assessment Activities

Part 8 – Corrosion of Iron Laboratory Assessment

Teacher notes:

Students enjoy this activity and learn an important rule of fire safety during this mini-lab. To prevent accidental fires, do not let the students pick up batteries and steel wool at the same time. Do not dispense the batteries and steel wool from the same desk.

Student Information:

Be careful to keep the batteries and the steel wool away from each other until you are ready to begin.

Materials

evaporating dish   balance   steel wool   9-volt battery

Procedure:

1. Mass your empty evaporating dish.
2. Obtain a small piece of steel wool and spread it apart.
3. Re-mass the evaporating dish after you have placed the steel wool in it.
4. Touch the 9-volt battery terminals to the steel wool. Observe what happens. Repeat this step until no further reaction takes place.
5. Re-mass the evaporating dish with the burned steel wool.
6. Record your observations and calculations on the back of this paper.

Data

A. Mass of empty evaporating dish __________ g

B. Mass of dish + unburned steel wool __________ g

C. Mass of unburned steel wool __________ g

D. Mass of dish + burned steel wool __________ g

E. Mass of burned steel wool __________ g

F. Change in mass of steel wool __________ g

Analysis

1. Why shouldn't you keep steel wool and batteries together?

2. How did the mass of the steel wool change as a result of burning?

3. What is the formula for the iron oxide made in this experiment if the iron is Fe^{+3} and the oxygen is O^{-2}?

4. Why did the steel wool gain mass?

5. Was this a physical or chemical change?

6. This is the same reaction that occurs when iron rusts. The only difference is the speed of the reaction. How can the rusting (corrosion) of iron be prevented?

Appendix I

Various Lab Assessment Activities

Part 9 – Hydrogen Bonding Laboratory Assessment

Teacher notes:

This activity is a set of three mini-demonstrations performed by the teacher and students and a series of questions that are all designed to evaluate a student's understanding of hydrogen bonding.

Student Information:

Watch the three demonstrations and using your knowledge of hydrogen bonding, answer the questions on this sheet.

The Alcohol Race

Your teacher will drop one drop of each of the following liquids on a piece of slate. You should record the time it takes for the drop of each compound to evaporate.

Compound	Molecular Mass	Time to Evaporate
butanol	74.10 g/mol	__________ seconds
propanol	60.08 g/mol	__________ seconds
ethanol	46.06 g/mol	__________ seconds
methanol	32.04 g/mol	__________ seconds

Predict the time it will take for water to evaporate.

Compound	Molecular Mass	Predicted Time to Evaporate
water	18.02 g/mol	__________ seconds

Now record the actual time it takes for water to evaporate:

Actual __________ seconds

1. Account for differences in your predicted time and the actual time it took for water to evaporate.

Floating Metal

Fill a small beaker almost completely with water. Obtain a sample of straight pins from the front table. Drop the pins (horizontally) onto the surface of the water. Record the number of pins you are able to float on the surface.

Number of pins floated on water: ______________

Watch as a student tries to float pins in a beaker filled with alcohol. Record the number of pins floated on the surface.

Number of pins floated on alcohol: _____________

2. Did more pins float on top of the alcohol or water? Why?:

Pouring Water into a Bucket

Most people have observed the phenomenon of water being poured into a bucket directly below the source from which the water flows. Watch the demonstration of the students pouring water from a beaker into a bucket located a few feet to the side of the source.

3. Explain why the water does not run all over the floor.
4. What enables the water to ignore gravity and travel horizontally along the string?

Testing Your Understanding:

5. Why does it hurt so much when you perform a perfect belly smacker into a pool of water?

6. Name a liquid into which you could fall that would cause less pain to your belly.

7. Why does ice float in liquid water?

8. Why are rain drops actually almost perfectly round until they hit something?

9. Which substance would have a higher boiling point, H_2O or H_2S?. Why?

10. Name at least one substance that would have stronger Hydrogen Bonds than H_2O.

Appendix I

Various Lab Assessment Activities

Part 10 – Solutions and Solubility Assessment

Teacher notes:

This series of demonstrations and mini-labs requires significant preparation but is very popular with the students.

Student information:

Please follow the directions given for each of the following sections of this lab assessment. The Ice Cream demonstration will be performed for you by the teacher, but you will have to perform the rest of the activities yourself. Be sure to follow the directions carefully and answer the associated questions.

ICE CREAM

Because of the time required, your teacher will make the ice cream for you. You should listen to his explanation of how the ingredients are combined, periodically observe the ice cream, and answer the following questions

1. When making ice cream we add salt to crushed ice. Why does the salt melt the ice?

2. A saltwater solution is called brine. Identify the solute and solvent in brine:

3. What state or phase of matter does the salt in brine demonstrate?

4. Salt is not normally found in this phase at standard conditions. How would we normally produce this phase of salt? (*without dissolving it*)

5. Is dissolution an endothermic or exothermic process?

6. How does the use of salt allow us to produce temperatures below the normal freezing point of water that are necessary to make ice cream?

SODIUM ACETATE

A. Obtain a test tube of liquid sodium acetate ($NaC_2H_3O_2$).

B. Carefully add a single crystal of solid sodium acetate to the solution.

C. Watch and feel the bottom of the test tube and observe the changes that occur.

7. What evidence did you observe that the sodium acetate ($NaC_2H_3O_2$) must have been a supersaturated solution?

8. What evidence did you observe of a crystal lattice during this demonstration?

9. Is precipitation an endothermic or exothermic change?

10. How is a supersaturated solution prepared?

WAVE BOTTLES:

A. **Carefully** pour lamp oil or lighter fluid into a clean plastic pop bottle until it is 1/3 full.

B. Carefully add water to the bottle until it is completely full. If you used colorless lamp oil or lighter fluid then you can add a few drops of food coloring at this time to make your wave bottle more attractive.

C. Screw the cap tightly onto the bottle and seal the cap using electrical tape.

D. Wash the outside of the bottle and check to make sure that it doesn't leak.

E. Please answer these questions.

11. Why doesn't the oil and water in the wave bottle mix? (Please use your chemistry to explain this – don't tell me *"because they're insoluble"*.)

12. What is the technical term for liquids that are insoluble in each other?

13. Explain why the food coloring will dissolve in the water but not the oil:

14. Identify the solute and solvent in a water/food coloring solution:

ACETONE & FOAM CUPS

A. Place a foam cup in a glass dish. (Foam cups are made by bubbling nitrogen or some other relatively inert gas through liquid plastic as it cools.)

B. Pour 20mls of acetone (nail polish remover) into the cup and observe what happens.

15. What happened to the cup?

16. What does a chemist mean when they say that *"Like dissolves like"*?

17. Since acetone is a non-polar organic substance, what assumptions can you make about plastic foam cups?

18. What do these same assumptions tell you about water?

19. What are some of the advantages and disadvantages of using the method you explored in this activity to recycle foam cups?

Popcorn rocks and crystals

A. Obtain a small sample of Argonite (a.k.a. Popcorn Rock) from the teacher.

B. Place the sample in a small beaker and cover it just enough vinegar (4% acetic acid) to submerge the sample.

C. Observe what happens to the sample as it sits in the vinegar.

D. The teacher has prepared other samples for you over the last few days so that you can see what will eventually happen to your sample.

20. What happens to the Argonite when it is submerged in the vinegar?

21. Is this an example of a physical or chemical change?

22. At what point does this change stop? Why?

23. What will happen to the vinegar in this setup over the next few days?

24. What happens to the solute in this setup over the next few days?

25. The final product of this investigation is a clump of Argonite crystals that resemble popcorn. Why are these crystals so different in appearance than the original Argonite rock?

(Hint - Why are diamonds and coal different if they are both made of carbon?)

Appendix I

Various Lab Assessment Activities

Part 11 – Supersaturation Mini-Lab

Teacher notes:

The students really enjoy this hands-on example of supersaturation.

Student Information:

Wear safety goggles at all times. Do not touch the sodium acetate solution.

Procedure:

1. Obtain a supersaturated solution of sodium acetate $Na_2C_2H_3O_2$. This was prepared by dissolving 4.5 grams of sodium acetate in 2 mls of water, heating the solution until it dissolved, and then letting it cool. Your solution will probably be a little warm when you get it (it is more stable and easily moved this way), so you will have to let it sit quietly while it cools.
2. When your solution has cooled to room temperature add one small crystal of sodium acetate to the test tube and record all of your observations (including how warm the bottom of the test tube feels) in the data table and answer the analysis questions.

Table 13 – Supersaturation Data Table

	Observations
Test tube before adding crystal of sodium acetate	
Test tube after adding crystal of sodium acetate	

Analysis:

1. What is a supersaturated solution?

2. Why does the test tube change temperature after the crystal is added?

3. Points A, B, and C on the solubility chart on the next page indicate three different concentrations of sodium acetate in water. Using this chart, describe the solutions using the terms unsaturated, saturated, and supersaturated. In the second column please describe how these solutions could be produced, and in the third column indicate what would happen to the solution if a crystal of sodium acetate were added to the solution.

Table 14 – Supersaturation Description Table

	Solution Description	How was the solution produced?	What happens to the solution if a crystal of the solid is added?
A.			
B.			
C.			

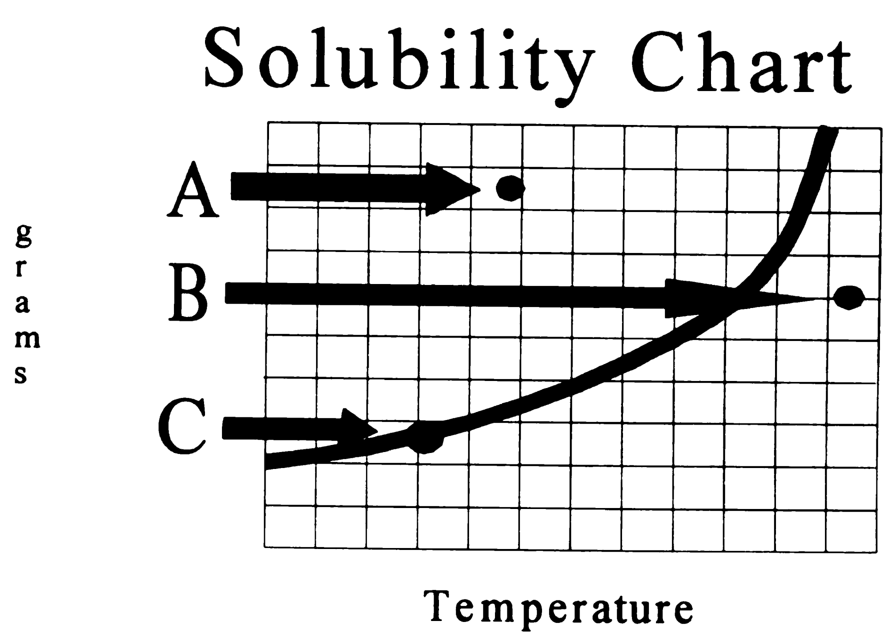

Figure 5 – Supersaturation Solubility Chart

Appendix I

Various Lab Assessment Activities

Part 12 – Open-Ended Hydrates Lab

Teacher notes:

This open-ended lab is intended to evaluate the learning that occurred during a previous lab in which the student experimentally determined the water of hydration in a compound. Students should be capable of writing and performing an acceptable procedure. The teacher should decide if the students will be allowed to refer to their lab notebooks.

Student information:

Part A

Demonstrate your understanding of hydrates by experimentally determining which of the following are hydrates. (The water of hydration normally indicated in the chemical formulas of the hydrates has been omitted for obvious reasons.)

$CuSO_4$ **$MgSO_4$** **NaCl** **Na_2CO_3**

Outline the steps you will use to accomplish this in the space provided. You may use whatever number of steps you wish - but please be complete and remember that part of your grade will be determined by your procedure write-up.

Experimental Procedure: (add steps as necessary)

1.

2.

3.

4.

5.

After receiving your teacher's permission, use the data table to record your observations and results as you follow your procedure.

Table 15 – Hydrates Lab Data Table

Substance	**Observations**	**Is this compound a Hydrate? (Yes/No)**
$CuSO_4$		
$MgSO_4$		
NaCl		
Na_2CO_3		

Part B

Experimentally determine the empirical formula of a compound assigned to you by the teacher. Outline the steps you will use to accomplish this in the space provided below. You may use whatever number of steps you wish - but please be complete and remember that part of your grade will be determined by your procedure write-up. Be sure to design your own data table and include all your data and show your calculations. Clearly label all data. (Neatness counts!)

Experimental Procedure: (add steps as necessary)

1.

2.

3.

4.

5.

Appendix I

Various Lab Assessment Activities

Part 13 – Water Rockets Investigation

Teacher notes:

This activity is suitable for evaluating the student's understanding of chemical reactions and thermodynamics. It can also be adapted for use in a Physics class as a demonstration of impulses and the Law of Conservation of Momentum. The pipet rockets sometimes fly thirty feet!

A launching device will have to be constructed by the teacher prior to this activity. I have made these launching devices three ways:

1. Modifying a piezo-electric cigarette lighter – this requires you to solder some extended leads to the end of the lighter. This type of launcher is prone to mechanical failure.
2. Using a Tesla Coil to provide the spark – the pipets are erected on nails mounted in a wooden launcher and a spark is allowed to jump from the tesla coil to the electrically grounded nails. This type of launcher fails if the spark doesn't jump through the mixture of gases. When the launcher is suitably engineered it will allow for mass launches of twenty rockets or more at once!
3. Using a piezo-electric igniter from a gas grill – this is the easiest, most sure-fire method of launching the rockets. It requires no pre-assembly, is easy to manipulate by the students, and isn't prone to the electrical shorting common in the other launchers.

Student information:

Hydrogen is a clear, colorless gas that is said to be "combustible" - meaning simply that it can burn quite readily. Oxygen is also a clear, colorless gas that is said to "support combustion" meaning that it must be present for combustible materials to burn. In this lab, you will be generating, collecting, and reacting hydrogen and oxygen gas. Hydrochloric acid will be reacted with zinc to generate the hydrogen. Hydrogen peroxide will be added to manganese metal to generate the oxygen. (Hydrogen peroxide decomposes by itself to produce water and oxygen, at a slow, imperceptible rate; the manganese oxide "rust" which is coating the manganese metal acts as a catalyst to speed-up this reaction.) You should ignite different hydrogen/oxygen mixtures to attempt to determine the most reactive mixture. Both gases are needed for combustion to occur. The trick is to get the right proportions! In a counter-intuitive manner, water rockets that contain a small amount of water often fly further! This is an interesting example of the Law of Conservation of Momentum.

Procedure:

1. Put on your goggles.
2. Cut off a plastic pipet so that it has a neck less than 1 cm long.
3. Fill the pipet with water.
4. Invert the water-filled pipet over the **oxygen-generating test tube** your teacher has set up. Let the oxygen displace some of the water from the pipet.

5. Place your pipet (that is now partially filled with oxygen) over your teacher's **hydrogen-generating test tube** so that hydrogen displaces some of the water in the pipet.
6. When you are ready, place your pipet on the firing device at the teacher's desk. This device will produce a spark. If you have an explosive mixture in the pipet – this will launch your pipet towards the target.
7. Answer the following questions.

Please answer the following questions about the Water Rockets Investigation:

1. What is the balanced chemical equation for the reaction that occurs in the hydrogen generator?

2. What is the balanced chemical equation for the reaction that occurs in the oxygen generator? (Keep in mind that the manganese is only a catalyst.)

3. Which will have to be replaced first: the zinc in the hydrogen generator or the manganese in the oxygen generator?

4. What is combustion (burning)?

5. What proportion of hydrogen and oxygen produced the most explosive mixture?

6. Why was this mixture the most explosive?

7. Write the balanced chemical equation for the reaction of hydrogen with oxygen:

8. Why doesn't the hydrogen and oxygen in the pipet react as soon as they mix?

9. If a small spark is needed for a small pipet of hydrogen and oxygen, why don't you need a proportionally larger spark to ignite an entire room full of hydrogen and oxygen?

10. Use the gas laws to explain why the pipets go flying when the mixture within them is ignited:

Appendix I

Various Lab Assessment Activities

Part 14 – Logic Problem

Teacher notes:

This demonstration encourages the students to use careful observations and logic to identify the solutions in four containers. A guided discussion about the sample logic problem may help many students with this deductive process. Prior to the demonstration the teacher should arrange the following materials on the lab table:

- A flask with 150 mls of 1M ammonium hydroxide.
- Beaker number one with 25 mls of water and a few drops of phenolphthalein.
- Beaker number two with 25 mls of dilute magnesium chloride.
- Beaker number three with 25 mls of dilute copper (II) sulfate.

To perform the demonstration the teacher simply pours a small amount of ammonium hydroxide from the flask into each of the three beakers. This will cause these three relatively colorless solutions to change to red, white, and blue.

Student information:

Using careful observations, some logic and a few clues, you are to determine the identity of four solutions based on what colors the solutions displayed as the teacher performed the demonstration. The solutions used are copper (II) sulfate, phenolphthalein, ammonium hydroxide, and magnesium chloride.

Procedure:

1. Study the sample logic problem to re-familiarize yourself with deductive logic.
2. Carefully observe the demonstration.
3. Indicate what final colors you observed in the different pieces of glassware.
4. Use the chart to determine what solutions were in each piece of glassware.

Please record the color of the solution that you observed at the end of the demonstration.

Flask	1st Beaker	2nd Beaker	3rd Beaker
Color: ________	Color: _________	Color: _________	Color: _________

Clues:

1. Ammonium hydroxide is a base.
2. When phenolphthalein and a base are mixed they turn a bright red color.
3. Magnesium chloride will form a white suspension when reacted with ammonium hydroxide.
4. Phenolphthalein was not mixed with copper (II) sulfate

Table 16 – Logic Problem Data

	Phenolphthalein	copper sulfate	Ammonium hydroxide	magnesium chloride
Flask				
Beaker #1				
Beaker #2				
Beaker #3				

Your solution:

Identity of the solution in the flask: ____________________

Identity of the solution in beaker 1: ____________________

Identity of the solution in beaker 2: ____________________

Identity of the solution in beaker 3: ____________________

Logic Sample Problem

This sample problem is designed to familiarize you with the strategy used to solve logic problems like the one you will be solving in this exercise. These problems typically ask you to match certain materials with their characteristics by using clues and a little deductive logic. A simple device used to solve these problems is a chart that allows you to visualize the comparisons and eliminate the choices that are inconsistent with the clues.

Sample Problem:

Your teacher has asked you to set up a chemistry lab that used the following four materials: copper nitrate, calcium carbide, bromine, chlorine

The teacher has decided to test your chemistry skills and logical abilities by asking you to set up the lab correctly after they leave the room. The teacher said that even though they had forgotten to label the containers they were sure that you could figure out which material was in each container if you just thought it out carefully. When you went to the lab you found the following:

1. A sealed glass tube of green gas.
2. An open flask with a blue liquid.
3. An open beaker with a granular gray solid.
4. A sealed flask with a red liquid.
5. A note with the following clues:

The Clues

1. You must keep the green gas sealed because of its poisonous fumes.
2. Chlorine is not a red liquid.
3. Neither copper nitrate nor calcium carbide must be kept in sealed containers.
4. The red liquid is not a compound.
5. Chlorine and calcium carbide are safe handle only when perfectly dry.
6. The blue liquid is an aqueous solution.

Table 17 – Sample Logic Problem Data

	Green gas	Blue liquid	Gray solid	Red Liquid
copper nitrate				
calcium carbide				
bromine				
chlorine				

The Process:

A. The first step is to carefully read over the clues and place marks in the chart that represent what you know. X's are used to indicate impossibilities and O's are used to indicate things that can be proven by using the clues.

B. Clue #1 does not help us at first – it may be useful later on.

C. Clue #2 eliminates the possibility of chlorine being the red liquid so place an X in the square that is the intersection of chlorine and Red liquid.

D. Clue #3 in conjunction with clue #1 proves that neither copper nitrate or calcium carbide can be the green gas so place X's in the first square of the copper nitrate and the calcium carbide rows.

E. Clue #4 proves that the red liquid can not be either copper nitrate or calcium carbide so place X's in those squares.

F. Looking at your chart you should now see that there is only one possibility left for the red liquid. It must be bromine! Place an O in that square.

G. If bromine is a red liquid than it can not be a green gas, a blue liquid, or a gray solid. Place X's in those squares.

H. You should now see that there is now only one possibility for the green gas. It must be chlorine! Place an O in that square.

I. Since chlorine is a green gas it can not be the blue liquid or the gray solid, so place X's in those squares.

J. This still leaves a few blanks on your chart so you will have to keep reading the clues to determine which material is copper nitrate and which is calcium carbide.

K. Clue #5 does not help much by itself, but in conjunctions with clue #6, you should be able to see that calcium carbide can not be the blue liquid. Therefore, calcium carbide must be the gray solid!

L. The process of elimination shows that copper nitrate must then be the blue liquid.

If you have followed the logic carefully, you should now be able to indicate your solution to the sample problem:

The sealed glass tube of green gas is ______________________________.

The open flask with a blue liquid is ________________________________.

The open beaker of gray solid is ________________________________.

The sealed flask with a red liquid is ______________________________.

Appendix I

Various Lab Assessment Activities

Part 5 – Exploring pH with Indicators Performance Task

Teacher notes:

Before beginning this activity the students should have a beginning knowledge of how to use indicators.

Student information:

You will use a variety of indicators to determine the pH of three solutions. The fist solution is 0.1 M ammonium hydroxide. The second solution is 0.1 M acetic acid. The third solution will be an unknown.

Procedure:

1. Place 5 drops of the solution to be tested into a single well in your microplate.
2. Add 1 drop of an indicator to the well and observe what, if any, color change occurs. Compare this to the table entitled pH Ranges of Common Indicators.
3. Repeat steps 1 & 2 as needed until you have determined the pH of the solution.
4. Follow these same instructions for all three solutions.

Results:

pH of 0.1 M ammonium hydroxide: ___________

pH of 0.1 M acetic acid: ___________

pH of an unknown solution ___________

Table 18 – pH Ranges of Common Indicators

Indicator	Color Below Lower pH	Indicator Range	Color Above Higher pH
Methyl violet	Yellow	0.0 – 1.6	Blue
Thymol blue	Red	1.2 – 2.8	Yellow
Methyl yellow	Red	2.9 – 4.0	Yellow
Bromophenol blue	Yellow	3.0 – 4.6	Blue
Congo red	Blue	3.0 – 5.0	Red
Methyl orange	Red	3.2 – 4.4	Yellow
Methyl red	Red	4.8 – 6.0	Yellow
Litmus	Red	5.5 – 8.0	Blue
Bromothymol blue	Yellow	6.0 – 7.6	Blue
Phenol red	Yellow	6.6 – 8.0	Red
Phenolpthalein	Colorless	8.2 – 10.6	Red
Thymolphthalein	Colorless	9.4 – 10.6	Blue
Alizarin yellow	Yellow	10.0 – 12.0	Red
Indigo carmine	Blue	11.4 – 13.0	Yellow

Appendix I

Various Lab Assessment Activities

Part 16 – Neutralization Performance Task

Teacher notes:

In this activity the students will be required to demonstrate their understanding of acid/base neutralization. They will also be required to analyze their experimental results against the theoretical yield.

Student Information:

As you perform this experiment, record your observations and calculations. Be sure to answer the analysis questions when you are finished.

Procedure:

1. Determine the combined mass of your evaporating dish and watch glass. These must both be clean and dry.
2. Add 1 drop of phenolpthalein and 5 mls of 1 M NaOH to the evaporating dish. Record your observations on the data sheet.
3. Stoichiometrically determine how many mls of 0.5 M HCl will be needed to neutralize the NaOH being sure to show all your calculations on the data sheet.
4. Calculate the theoretical amount of salt that will be produced by this reaction – be sure to show all your calculations on the data sheet.
5. Neutralize your NaOH with the amount of HCl that you calculated in step 3. Record your observations on the data sheet.

6. Cover the evaporating dish with the watch glass and heat it according to the teacher's instructions. Evaporate the solution to dryness. Record your observations on the data sheet.
7. Determine the actual mass of salt produced.
8. Compare your actual yield with your theoretical yield and determine your percent error. Show all your calculations. Then dispose of your materials as instructed.

Observations:

Step 2:

Step 5:

Step 6:

Calculations: (Please clearly label all data.)

Step 3. How many mls of 0.5 M HCL will be needed to neutralize the NaOH?

Step 4. What is your theoretical yield of salt?

Step 8. What is your percent error?

Analysis:

1. How does the product that was prepared in this experiment compare with the same product as it is produced commercially?

2. Why should you NOT taste the residue from this reaction?

3. How could you determine whether phenolphthalein remains in the residue of this reaction?

Appendix I

Various Lab Assessment Activities

Part 17 – Polymer Tape Lab Assessment

Teacher notes:

The students will be investigating the nature of a common polymer – plumber's tape (polytetrafluoroethylene). This activity will examine the student's ability to apply their understanding of polymers and organic nomenclature to a real-world application.

Student Information:

Today you will be looking at the physical properties of plumber's tape. This tape is wrapped around the ends of threaded pipes. The slippery tape allows the pipes to slide together tightly and form a water-tight seal without welding. This tape is not sticky and feels like silk. It must be handled carefully or it will roll up into a knot!

Directions:

1. Cut a four-inch piece of plumber's tape using scissors.
2. Carefully lay out the tape on a desk and write a word or two in the center two inches of the tape. (I find the tape is difficult to write on if I drag the pen; it seems to work better if I just dot the pen across the tape.)

Analysis:

1 This tape will only stretch in one direction. Try not to stretch the ends, which will act as handles later on. Which direction does the tape stretch (sideways or lengthwise)?

2 This tape is a polymer. How does this explain the incredible stretching ability of this tape?

3 What happens to the stretched tape when you pull on the two ends?

4 Can you pull the tape back into its original shape so that your message is again legible?

5 What must be happening to the molecular chains when the tape is being stretched?

6 What happens to these chains when the tape shears widthwise?

7 What is the organic name of the following compound?

```
F     F
 \   /
  C=C
 /   \
F     F
```

8 This compound's common name is a 6-letter acronym made from the organic name. What is it?

9 Since this tape is made by polymerizing the compound you named in question number 7, the correct name for the tape simply has the prefix poly added to the front of the organic name. What is the correct name for this tape?

10 Now that you know a little more about this tape's molecular structure and physical properties, please suggest some reasons why this tape is so useful in connecting threaded pipes:

Bibliography

Bibliography

Annenberg/CPB Assessment Workshop. *What's the Point? Assessment in Math and Science.* Providence, RI. Annenberg Institute for School Reform. 1998

Beach, D.H. and H.M. Stone. Provocative Opinion: "Survival of the High School Chemistry Lab". *Journal of Chemical Education.* 65, 619 (1988).

Beach, D.H. and H.M. Stone. Provocative Opinion: "Survival of the High School Chemistry Lab". *Journal of Chemical Education.* 65, 620 (1988).

Becker, Robert. "Final Analysis – Rethinking an Age-Old Practice". *Journal of Chemical Education.* 72, 816 (1995)

Benchmarks for Science Literacy: Project 2061. New York: Oxford University Press. 1993. p. 297

Bloom, Benjamin S, Thomas Hastings, and George F. Madaus. *Handbook on Formative and Summative Evaluation of Student Learning.* 1971

Busik, Kathy. *Clapping Hands.* Michigan Assessment Team Assessment Guidebook, Lansing, MI. Michigan Department of Education. 1995

Carlson, Dale. "Changing the Face of Testing in California". *California Curriculum News Report.* Jan-Feb. 1991. p. 1.

Hart, Diane. *Authentic Assessment: A Handbook for Educators.* Menlo Park, CA: Addison-Wesley Publishing Company Inc. 1994, p. vi

Hart, Diane. *Authentic Assessment: A Handbook for Educators.* Menlo Park, CA: Addison-Wesley Publishing Company Inc. Menlo Park, CA. 1994, p. 46

Hein, George. *Expanding Student Assessment.* ed. Vito Perrone. Alexandria, VA: Association for Supervision and Curriculum Development. 1991. p. 106.

Hein, George. *Expanding Student Assessment.* ed. Vito Perrone. Alexandria, VA: Association for Supervision and Curriculum Development. 1991. p. 116.

Hunter, Paul and Sheldon Knoespel. *Fire and Ice Demonstrations.* Lansing, MI: Michigan Science Teachers Association Conference. 1994

Institute for Chemical Education. *Laboratory Assessment Builds Success.* Berkeley, CA. University of California Press. 1990.

Lang, Mozell. "Ways of Getting at Understanding". *Michigan Assessment Team Assessment Guidebook.* Lansing, MI: Michigan Department of Education. 1995

Michigan Assessment Team Assessment Guidebook. Lansing, MI. Michigan Department of Education. 1995

Michigan Department of Education. *Model Instructional Unit.* ed. Marty Couretas. Detroit, MI: Michigan Science Teachers Association Conference. 1996.

Michigan State Board of Education. *Michigan Essential Goals and Objectives for Science Education.* Lansing, MI. 1991 p. 1.

Miller, J.R., M. K. Heidemann, and J.M. Parker. New Challenges for Educators in Science and Mathematics. [Online] Available ww.dsme.msu.edu. April 28, 1998.

Mitchell, Ruth. *Testing for Learning: How New Approaches to Evaluation Can Improve American Schools.* New York: The Free Press. 1992 p. 16.

National Science Education Standards. Washington, D.C. National Academy Press. 1996. p. 20.

Shakhashiri, Bassam Z.. *Chemical Demonstrations: A Handbook for Teachers of Chemistry.* Madison, WI: University of Wisconsin Press. 1983. p. xiii.

Wagner, Maxine. *Chemistry The Study of Matter Laboratory Manual.* Needham, MA: Prentice Hall. 1989

Wiggins, Grant. "A True Test: Toward More Authentic and Equitable Assessment". *Phi Delta Kappan.* May 1989. pp. 703-4.

Wiggins, Grant. "Teaching to the (Authentic) Test". *Educational Leadership*, Vol. 46. (April 1989). p. 41.