TEACHING CHEMISTRY CONCEPTS USING DIFFERENTIATED INSTRUCTION VIA TIERED LABS AND ACTIVITY MENUS

By

Betsy C. Collins

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Physical Science - Interdepartmental - Master of Science

2013

ABSTRACT

TEACHING CHEMISTRY CONCEPTS USING DIFFERENTIATED INSTRUCTION VIA TIERED LABS AND ACTIVITY MENUS

By

Betsy C. Collins

Today's high school classrooms are composed of students with different levels of knowing and ways of understanding. Differentiating the type of work that they are asked to do to achieve the same objective is one way to meet each student's special circumstances on a somewhat equal playing field. By doing so, students are being challenged at their level rather than just blindly going through the same motions that they see others around them doing. Offering students choices to better understand a concept places the student in the driver seat of their educational journey. The purpose of this research project was to design and implement choice activities within the chemistry classroom to more appropriately teach and assess chemistry concepts and assess understanding of those concepts. These choice activities included tiered-laboratory investigations and activity menus.

This project was implemented over the course of two trimesters in a high school chemistry classroom. Topics covered included calculating and interpreting density and applying significant figures, calculating and interpreting percent composition with the mole concept, and stoichiometry. The effectiveness of the tiered-labs and activity menus were evaluated using pre and post test comparisons, student surveys, and general in-class observations. Gains in conceptual understanding and student motivation were documented. These findings indicated that allowing choice and leveling of skills to achieve the same conceptual understanding promoted student learning and the overall enjoyment and motivation for learning.

ACKNOWLEDGEMENTS

Many people played pivotal roles in helping me to complete this project and I would like to take this opportunity to express my deepest gratitude. I am completely in debt to my advisor Merle Heidemann. She has been and continues to be a mentor and support system for me in the educational arena. I am so thankful for her knowledge, wonderful advice, and assistance throughout the past few years. I was also blessed to have a number of amazing colleagues that guided and stood by me for the past 4 summers. From them I have gained friendship, laughter, and insight. I appreciate each and every one of you.

Most of all I must thank the patience, love, and support of my wonderful husband Mike and my amazing boys Max and Evan. They willingly sacrificed that I could achieve this goal.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Today's classroom teacher is challenged to create an environment for learning that is rigorous, yet where each student has the capacity to achieve academically. Teachers are faced with the immense responsibility to not only meet the needs of so many different learning styles (visual, auditory, and tactile) but to push students beyond their comfort zones to become active, successful learners. Classrooms today are anything but homogeneous; rather they are mixtures of students on caseload, advanced students, second-language learners, and individuals with highly diverse cultural and economic backgrounds (Tomlinson, et al., 2003). In addition to these challenges, requirements for graduation are increasing. The national science and math high school course requirement average has increased from 2.0 credits to 2.7 credits (Cavanagh, 2008). Faced with such a daunting task, instruction based on the idea of one-size-fits-all is not appropriate (VanSciver, 2005). In an attempt to reach all learners, differentiated instruction looks to be a viable and optimistic option for educators at all levels. The basic idea behind differentiation is to create lesson plans, projects, laboratory activities, assessments, and learning environments to accommodate the individual readiness, interests, and learning profile of each student (George, 2005). In doing so, educators need to take caution to not lower the learning objectives, but rather find alternative ways for presenting and teaching the content (DiMartino & Miles, 2005). Differentiated instruction is a way of teaching that provides students with a variety of entry points to access learning that is compatible with their way of understanding (Hall, Strangman, & Meyer, 2003). It is a method that offers options and is a teaching technique that changes to meet the needs of all while still ensuring that everyone is achieving the same learning objective. According to Preszler 2006, "[A] fundamental premise of differentiating instruction is that certain steps must be taken to guarantee students will learn what they need to learn in order to meet curriculum guidelines and state standards." Differentiated instruction takes the stance that not all students are the same and as a result teaching and assessment methods must change to avoid "teaching to the middle" (Willis and Mann, 2000).

A traditional science classroom where the teacher presents information in a lecture style and then provides each student with the same laboratory investigation is designed for only those that have good attention spans and are left-brained learners. Unfortunately, only about one-quarter of the population of students fits this basic description (Willis and Mann, 2000). When the content doesn't stir interest or the material is too difficult to understand, students tend to check out (Anderson, 2007). Failure to recognize and rectify this situation leads to classrooms filled with wasted potential. Most educators would agree that altering the instruction and modifying the tasks would help improve student success but the challenge is how to translate the ideas and beliefs of differentiated instruction into action (Wehrmann, 2000). This task becomes increasingly demanding when today's educators are already overwhelmed by reduced funding, pressures of achieving high standardized test scores, and diverse student backgrounds (Ashman & Kraayenoord, 1998). These ever present restraints provide teachers with little time and money for flexibility and creativity. The tendency is to then conform by developing lessons and activities directed to the average learner (Tomlinson, 2001). One intent of this study is to demonstrate the ease of utilizing differentiated instruction by implementing tiered-laboratory investigations and activity menus without exhausting the pocketbook or extending the time needed to complete the tasks.

Another obstacle in the way of implementing differentiated instruction is the belief that it is a form of tracking. Tracking is a teaching system that views equal level learners to be more successful when kept together. Unfortunately, educators are quick to assume that they can easily recognize and identify low from high level learners. Low level learners are viewed as those that need very basic information presented to them slowly with lots of repetition. It is also assumed that high level learners want information fast and lots of independence. This way of thinking keeps low students low and prevents high level learners from reaching their full capabilities (Tomlinson, 2006). Based on the group in which they are placed , students determine quickly if they are low, medium , or high. This realization tends to establish how they perceive their educational abilities (Ashman & Kraayenoord, 1998). Differentiated instruction is the complete opposite of grouping or tracking. It is intended to be a way to allow access to understanding the content to all levels of learners. The beauty of adapting differentiated instruction is that there is no one way to implement differentiated instruction. It is a content, process, and assessment method that is done in response to student readiness, interest level, and learning style (Tomlinson, 1999). Differentiated instruction is a way of teaching that allows an educator to challenge the bright students, guide the struggling student, and raise the middle student up to the top. Differentiated instruction is a proactive approach to guide all learners to have the opportunity to be successful in education. Providing choices and giving students a variety of ways to understand creates an environment where each learner is at the center. It is not just a strategy but rather a way of life (The Connecting Link, 2003). The most important thing to remember when implementing differentiated instruction techniques is to make all learning meaningful.

The tiered labs and activity menus were designed for a chemistry classroom as chemistry is a difficult content area for students to grasp and it is now a graduation requirement for all students at Mason High School. The concepts taught in any chemistry class are abstract and difficult to relate to real-world experiences (Yaron et al 2003). The more activities and choices students are provided with in the classroom setting the greater the chance for success. In the absence of practical activities "the traditional educational approach strips out the very essence of science and leaves behind a confusing bag of tricks" (Yaron et al 2003). Thus, the alternative goal of the tiered labs and activities menus was to provide students with tangible ways to better understand and apply some of the basic ideas of chemistry.

The goal of this study was to implement and assess the effectiveness of tiered laboratory investigations and activity menus. The hypothesis was that by incorporating tiered labs and activity menus into a high school chemistry course, students would show a statistically significant gain in their understanding of chemistry content measured by pre and post test assessments and to improve motivation in the classroom setting.

This study was conducted during the 2011-2012 school year at Mason High School in Mason, Michigan, a rural area just south of Lansing, Michigan. Mason has a historic, small town feel with a communal square in the center of town. This small community has a lot of pride, love, and concern for its members. The socio-economic status of the students varies widely due to the large number of farms and close proximity to Lansing. The school district is predominantly Caucasian with only 12% of the population non-Caucasian.

This study was conducted in three chemistry A sections taught during the first trimester, September 2011-November 2011 and three chemistry B sections taught during second trimester, December 2011- March 2012. The content in chemistry A included scientific methods, laboratory equipment and safety, measurements and significant figures, classification of matter and the mole concept, atomic structure and electron configurations, periodicity, and bonding. The content in chemistry B included chemical reactions and balancing, stoichiometry, solutions, acids and bases, and gases. All chemistry sections were taught by the author. All sections of chemistry had an even distribution of juniors and sophomores with only a handful of seniors. All students had previously taken a minimum of two trimesters of biology. In addition to biology, the juniors and seniors had taken two trimesters of either physical science or honors physical science. The physical science course was phased out of the Mason High School system as of the fall of 2010. Out of the 79 students enrolled in chemistry A, 46 gave consent (Appendix U) to participate in the study. In chemistry B, 53 of the 70 students enrolled provided consent to participate.

IMPLEMENTATION

The differentiated instruction methods utilized in this study were tiered-laboratory investigations and activity menus. A tiered-laboratory investigation is a way to guide student to the same outcome utilizing different laboratory skills and techniques. The goal of a tiered task is to challenge each student to work and think beyond their comfort zone to promote learning for each student (Sylwester, 2003). By providing students with choices, students are in charge of their learning process and tend to take on a higher level of responsibility in the task at hand (Betts, 2004; George, 2005). The laboratory investigations in this study were leveled, meaning each activity was designed with specific learning level in mind. The levels are; I - traditional lab, student must follow basic instructions, make some predictions, II - minimal instructions, the tasks are left to the student to determine, III - all problem solving is left to the student to determine. When utilizing tiered labs, an educator may allow students to choose which option best suits their interest or the labs may be assigned based on readiness. In this study the tiered labs were assigned based on student readiness. Students were given a pre-test to determine their level of understand and ask to self evaluate where they felt they were in terms of the concepts being studied.

An activity menu on the other hand, provides students with a variety of tasks that they may choose from to achieve the same learning goal. A set amount of time is given and the students must complete a minimum number of activities to demonstrate full understanding. A dinner menu was designed to make the selection more interesting. Students are all required to complete a basic level task and then are given options of other activities that address different learning styles and have different levels of challenge.

The tiered labs and activity menus were designed during the summer months of 2011 at Michigan State University. Much time was spent evaluating the effectiveness of the labs, utilizing input and evaluation from colleagues and advisors. Approval was obtained from both the high school principal at Mason High School and the Institutional Review Board at Michigan State University as this project involves of human subjects in an educational study.

The tiered labs and/or activity menus were implemented in three different units of the chemistry curriculum near the completion of each of the units as a way to summarize and piece together each students' understanding of the concepts studied. The units included laboratory techniques and measurement, matter and the mole concept, and stoichiometry. Unit 1, laboratory techniques and measurement, and Unit 2, matter and the mole concept are both a part of the chemistry A curriculum. Unit 7, stoichiometry, is a part of the chemistry B curriculum. These units were selected due to the ease of developing varied activities that incorporated all learning styles and abilities. All of the units began with a typical lecture and class discussion of the basic concepts. The students were then given pretest to assess their understanding of the concepts. The pretest was then followed by the implementation of the activity menu or the tiered laboratory investigations. The time frame in which the activities or tiered labs were implemented is shown in Tables 1, 2, and 3.

Table 1: Laboratory Techniques and Measurement Daily Agenda and Activities

Activity	Description
Introduction	Introduction to chemistry class, basic lab safety demonstrations
Laboratory equipment	Basic laboratory equipment was discussed as a whole group (teacher-lead), students were then given an opportunity to match the equipment in their lab draws with the functions provided.

Table 1 (cont'd)

Significant figures and measurements	Basic lecture on significant figures and their use, applied the idea of significant figures to various types of measurements in a typical chemistry lab. Students conducted stations where they made measurements and practiced applying significant figures
Significant figures lab	Student worked on a traditional lab measuring various objects and applying significant figures to measurements and calculations
Density	Basic lecture on the idea of density and how to measure and calculate density. Students took **Pre Test**
Density Activity Menu **(Differentiated Instruction Technique)**	Students were given the activity menu designed to help them better understand measurements and significant figures in a typical chemistry laboratory setting. They were given 2 full class days to select and complete these activities.
Assessment	Students were given the **Post Test** and **Survey**

*bold denotes activities related to this study

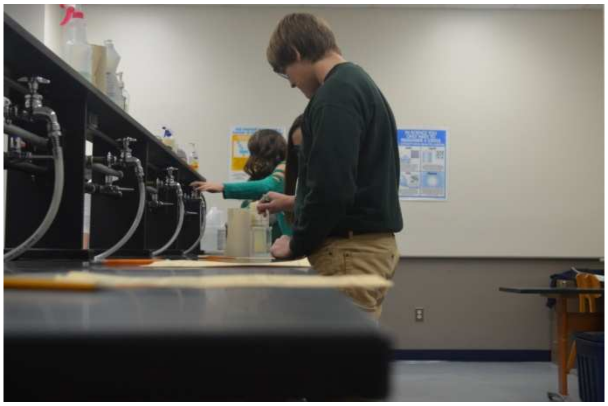
Density is a property that is invaluable in chemistry as it allows for the identification of an unknown substance and can predict physical and chemical properties of that substance. Students have a tendency to struggle making and applying the measurements necessary to better understand this property as it combines laboratory skills, significant figures, and mathematical skills. The activity menu (Appendix A) required that all students practice the skill of determining the density of both an irregularly-shaped solid, utilizing the technique of volume displacement and determining the density of an unknown liquid, incorporating the proper use of an electronic scale (Appendix B). The remainder of the activities (Appendices C, D, and E) ranged from basic problem solving to an open-ended labs to determine the thickness of aluminum foil or the density of an egg.

After completing the required appetizer activity, each student had to select one entree activity to complete. The entree activities included determining the linear density of a wire or determining the density of an egg. If a student selected the linear density of a wire activity, they had to measure the length and mass of several different pieces of wire. The measurements were used to plot a graph. The graph was then used to determine the linear density. On the other hand, a student could have selected to use an indirect technique to determine the density of an egg. No instructions were provided, rather the student had to utilize their understanding of the property of density and basic laboratory technique to mathematically determine the density of an egg.

Each student had to complete a minimum of two side dish activities or they could by-pass the side dishes and complete the more advanced dessert activity. The first side dish entitled "Does Size Matter?"required that a student measured the mass of six different volumes of a liquid. The volumes and masses were graphed and the student had to interpret the relationship between mass and volume. The second side dish activity entitled "Neutral Buoyancy" required a student to create an object that has neutral buoyancy but the student was limited to using the materials provided. The third side dish activity, "Density Problem Set", was a collection of seven density-related mathematical problems. The fourth side dish activity, "What is the Liquid?", required a student to use their understanding of the property of density to determine the identity of an unknown liquid. The final side dish activity, "Test Tube Challenge" demanded that a student make a test tube with four different layers of liquids, each with a different density. The liquids had to be made using sugar, water, and food coloring so that the layers could be distinguished from one another. The optional dessert activity required a high level of understanding. If a student selected this activity they had to figure out how to make measurements and use the known density of aluminum to determine the thickness of the aluminum foil.

All of the activities involved calculations, measurements, and critical thinking. Students could select the activities that fit their interest level. They were permitted to work either independently or with a partner, as seen in Figure 1. The teacher was available to provide direction, instruction, and recommendations throughout the three-day period.

Figure 1: Students working to determine the density of an egg



For interpretation of the references to color in this and all other figures the reader is referred to the electronic version of this thesis.

Table 2: Matter and the Mole Concept Daily Agenda and Activities

Activity	Description
Introduction	Introduction to phases of matter and energy changes. Students worked at various stations to apply the kinetic molecular theory
More with Matter	More lecture/discussion about phases of matter and energy changes. Students worked on calculations involving q
Types of Matter	Students worked in groups to develop a matter concept map
The mole concept	Teacher led discussion about the mole concept and it's relationship to matter. Students worked on practice problems involving the mole
Mole Lab	Students worked on a traditional lab measuring quantities and doing basic mole conversions
Percent composition	Teacher led discussion on percent composition and its relationship to the mole. Students took a **pre test**
Percent composition activity menu **(Differentiated Instruction Technique)**	Students were given the activity menu designed to help them better understand how to measure and apply percent composition in a typical chemistry laboratory setting. They were given 2 full class days to select and complete these activities.
Assessment	Students were given the **Post Test** and **Survey**

*bold denotes activities related to this study

Percent by mass is a concept that students better conceptualize when able to do activities that make the concept more real. This concept is taught when discussing types of matter such as elements, compounds, and mixtures. Percent by mass calculations tends to be more challenging as the calculations incorporate the mole concept. A lecture and discussion on percent by mass was conducted prior to handing out the activity menu (Appendix I). As with the density activity menu, all the students were required to complete the same basic lab activity. This was the "appetizer" for the percent by mass menu and involved writing and explaining the formula for determining percent by mass. The remainder of the activities were based on student choice, interest, and understanding. Each student had to complete one entree activity; drawing a picture to explain percent composition, providing examples of percent composition from the real world, or creating a concept map to explain how percent composition fits into the matter unit. In addition to completing the appetizer and one entree, students had the option to complete two side dish activities or completing one dessert activity that required a higher level of understanding (Appendix K). One side dish activity was an open-lab (no instructions provided) to determine the percent by mass of water in a popcorn kernel. Determining the percent by mass of sugar in bubble gum was another side dish activity that was also an open-lab (no instructions provided). A third side dish activity involved calculating the percent by mass of calcium in a piece of chalk and in a sample of $Ca_3(PO_4)_2$. The last side dish option required a student to build a model to explain percent composition. The optional dessert activity was an advanced, open-lab that asked the student to determine the percent by mass of sugar in soda. The students had the option to complete these activities on their own or with a partner (Figure 2).

Table 3: Stoichiometry Daily Agenda and Activities

Activity	Description
Introduction	Revisiting the idea of the mole concept, students worked on activities to reinforce basic mole conversions previously learned
Stoichiometry	Introductory lecture/discussion about stoichiometry. Students took a **pre test**
Stoichiometry activities	Students worked in groups to develop a better understanding of stoichiometry using s'mores and BLT sandwiches
Stoichiometry Tiered Lab	Based on pre test scores and student self evaluations, students were assigned a lab to complete involving stoichiometry. This required TWO days.
Limiting and Excess Reagents	Teacher led discussion about limiting and excess reagents, demonstrations were conducted. Students worked on practice problems.
Limiting and Excess Reagents Tiered Labs	Based on pre test scores and student self evaluations, students were assigned a lab to complete involving limiting and excess reagents. This required TWO days.
Assessment	Students were given the **Post Test** and **Survey**

*bold denotes activities related to this study

Stoichiometry, which is the application of quantities of reactants and products in a chemical reaction, is a keystone concept in chemistry. The labs that were developed for this unit of study focused on meeting each student at their level of understanding and then demanding that they take raise that level of understanding. One of three labs were assigned to each of the students based on the students' evaluation of their current understanding of stoichiometry as well the author's evaluation of the student's understanding. The level I/II lab was a traditional lab that had in previous years been conducted by all students (Appendix O). This lab had clear, step by step instructions with the intent to have the student better understand how two different substances in a balanced chemical reaction relate. The level II/III lab lacked clear step by step instructions (Appendix P). This lab involved the same reaction as the level I/II lab but required the student to advance their understanding of stoichiometry to fill a baggie (each student was given a different size bag to avoid copying) to adequate "plumpness", (Figure 3).

Figure 2: Students work to determine the amount of sodium bicarbonate needed to completely fill the baggie provided.

The level III lab (Appendix Q) took the same ideas and concepts further by requiring the student to use two different reactions to fill two different baggies to the same "plumpness". All of the labs involved the reaction between 1.0M hydrochloric acid and solid sodium bicarbonate to produce carbon dioxide gas, water, and sodium chloride. Students were given the freedom to collaborate with each other. After these labs were completed, time was spent discussing the concept of limiting and excess reagents. A demonstration was performed to allow students to see what happens when there is more than enough or not enough reactant. Students were assigned a problem set and a hands on activity involving cut outs to better grasp the concept of limiting and excess reagents. Students were asked to rate their comfort level with this concept. This evaluation, combined with the author's assessment of the student's abilities, was the basis for assigning an appropriate level lab. The level I/II limiting lab involved measuring different amount of solid aluminum and copper(II) chloride (formed into a solution), setting up the reactions, and allowing them to sit over night. The next day, the students were able to observe whether the copper chloride or the aluminum had been completely converted utilizing both qualitative and quantitative observations (Figure 4).

Figure 3: Image of several reactions involving copper (II) chloride and aluminum to better understand limiting and excess reagents

The level III lab required that the students perform a single replacement reaction involving aluminum and copper (II) sulfate to collect a minimum of 1.00g of solid copper. Assigning students a lab based on readiness was utilized to determine if the success rate varied depending on teacher assigned versus student selected activities.

RESULTS AND DATA

A pretest and posttest were given for each of the major areas explored in this study; density, percent by mass, and stoichiometry (Appendices F, H, and T). Each consisted of a variety of short answer and problem solving questions. All of the pretests were given to the students at the beginning of the topic area explored; the posttest was administered after completion of the activity menus or tiered labs. The students were assessed using a standards based grading scale as shown in table 4 and 5. Student understanding of each content standard was evaluated according to this scale for all assessments.

Table 4: Grading scale description of scoring for the content standards for density, percent by mass, and stoichiometry.

Scale	**Description**
4.0	Student can demonstrate a complete understanding of simple and complex topics introduced in class. **Student can also apply knowledge to situations not explicitly mentioned in class**
3.0	Student can demonstrate a complete understanding of simple and complex topics introduced in class.
2.0	Student can demonstrate a complete understanding of simple topics, but is prone to conceptual errors or omissions on more complex topics.
1.0	Student can only demonstrate understanding of simple topics with assistance.
0.0	No attempt is made to demonstrate understanding.

Table 5: Translation of score to traditional percentage score.

Standard Score	Percentage	Letter Grade
4.0	100	A
3.75	97	A
3.50	95	A
3.25	93	A
3.0	90	A-
2.75	88	B+
2.50	84	B
2.25	80	B-
2.00	76	C
1.75	70	C-
1.50	67	D+
1.25	64	D
1.00	60	D-
0	50	E

Table 6: Unit Content Standards

UNIT	CONTENT STANDARD
Density	Student can determine, compare, and understand the chemical importance of densities of various substances.
Percent by Mass	Student can use the mole concept to determine the percent by mass of each element in a compound.
Stoichiometry	1. Student can explain of how the mole concept relates to a balanced chemical reaction. 2. Student can to convert from the quantity of one substance to a quantity of another substance using information provided in a balanced chemical reaction. 3. Student can determine the amount of product that can be formed given two different starting amounts (limiting vs. excess reagents). 4. Student can use a balanced chemical reaction to determine percent yield and interpret what the percent means.

Means were determined for each pre and posttest. A paired t-test was completed for each set of data (pre vs. posttest) and a p-value was determined (Table 7 and 8). All posttest scores when compared to pretest scores were considered statistically significant utilizing a $p<0.0001$ criterion. The results for the density and percent composition tests are shown in Table 7.

Table 7: Average pretest and posttest scores for Density and Percent by Mass Units, n=46

	Density Pretest	Density Posttest	Percent Composition Pretest	Percent Composition Posttest
Average score	1.853	3.256	1.967	3.375
P-Value	<0.0001		<0.0001	

The stoichiometry test was assessed based on four different standards (Table 6). The average scores for the following standards on both pre and posttests are presented (Table 8).

Table 8: Average pretest and posttest scores for Stoichiometry Unit, n=53

	Standard 1 Pretest	Standard 1 Posttest	Standard 2 Pretest	Standard 2 Posttest	Standard 3 Pretest	Standard 3 Posttest	Standard 4 Pretest	Standard 4 Posttest
Average Score	2.230	2.991	1.450	2.764	0.884	2.967	0.502	2.486
P-Value	0.001		<0.0001		<0.0001		<0.0001	

Students completed surveys (Appendices H, N, and V) at the termination of each unit to gain feedback about the activities. Results are shown in Table 9,10 and 11. In all of the areas students found the activities to be physically engaging, mentally engaging, interesting, and at a relatively high level of learning. The lowest scores for all the activities were recorded for the required appetizer activities for both the density and percent by mass. The highest scores were recorded in the optional areas for density and percent by mass and also in the level III tiered labs for stoichiometry.

Table 9: Results of Student Survey on the Density Activities, n=46

Activity	Percent Participation	Physically Engaging (5 high, 1 low)	Mentally Engaging (5 high, 1 low)	Interesting (5 high, 1 low)	Learning (5 high, 1 low)
Appetizer Activity (Required by all)	100%	3.78	3.44	2.78	3.44
Entree Activity Wired OR Eggsperiment	Wired - 33.3% Egg - 67.7%	4.22	4.22	3.89	3.78

Table 9 (cont'd)

Side Dish Activities (everyone selected 2)	Neutral buoyancy - 33.3% Density problems - 77.8% Unknown liquid- 55.6% 4Layers - 44.4%	3.67	4.22	3.17	3.72
Dessert Activity Optional	66.7%	3.83	4.33	3.5	3.67

Table 10: Results of Student Survey on Percent by Mass Activities, n=46

Activity (only some participated)	Percent Participation	Physically Engaging (5 high, 1 low)	Mentally Engaging (5 high, 1 low)	Interesting (5 high, 1 low)	Learning (5 high, 1 low)
Appetizer Activity (Required by all)	100%	3.78	4.11	2.89	4.33
Entree Activity (Everyone selected ONE)	Drawing a picture - 55.6% Real world examples - 33.3% Concept map - 11.1%	3.78	4.56	3.11	4.11
Side Dish Activity (Everyone selected TWO)	Water in Popcorn - 55.6% Sugar in gum - 88.9% Determining mass of Ca - 33.3% Creating a model - 0%	4.56	4.56	4.33	4.22
Dessert Activity (Optional)	Percent mass Sugar in Soda- 11.1%	4.77	5.00	4.11	5.00

Table 11: Results of Student Survey on Stoichiometry Tiered Lab Activities, n=53

Activity	Percent Participation	Physically Engaging (5 high, 1 low)	Mentally Engaging (5 high, 1 low)	Interesting (5 high, 1 low)	Learning (5 high, 1 low)
Basic Stoichiometry Tiered Lab	What's the ratio? (Level I/II) - 13.1% Fill it up! (Level II/III) - 70.2% Make it Equal (Level III) - 16.7%	4.11	4.67	4.56	4.11
Limiting/Excess Reactant Tiered Lab	Collecting a Known Mass of Copper (Level III) - 17.4% What is Limiting this Reaction? (Level I/II)- 82.6%	4.11	4.22	3.89	4.11

DISCUSSION

This project was conducted to improve student comprehension and motivation for various chemistry concepts by utilizing differentiated instruction methods including tiered labs and activity menus. By allowing variation, student choice, combined with improved student and teacher assessment of readiness, it can be concluded from the data presented in Table 7 and Table 8 that the hypothesis that student motivation and understanding will improve with the use of tiered labs and activity menus can be supported. There was a huge increase when comparing pretest to posttest scores in each of the three topic areas explored. In the *Density* unit, the average initial score was a 1.853 (equivalent to a 72.4% on a traditional 100 point scale) to a posttest score of 3.266 (equivalent to a 93.5% on a traditional 100 point scale). This is a dramatic 21.1% increase. Looking at the *Percent by Mass* unit data, there was a increase from 1.967 to 3.375. On a traditional scale this is an improvement from 74.8% to 93.7%. This is an 18.9% increase in the score from pretest to posttest. Both the *Density* and *Percent by Mass* units involved the completion of activities that were selected by the student without teacher involvement. Similar improvement was recorded in the *Stoichiometry* unit. Students had an average score of 1.267 (64.3% on a traditional scale) on the pretest compared to an average score of 2.802 (88.5% on a traditional scale). This is a 24.2% gain from pre to posttest assessment. The *Stoichiometry* unit involved teacher-assigned labs that were designed for various levels of student readiness. It can be concluded that both activity menus and tiered laboratory activities are effective classroom tools for improving student comprehension.

Determining whether it is better to have student's select the activities based on interest or to have the teacher assign the activity based on readiness was another intent of this study. Upon initial observation of the data it can be concluded that there was a greater increase in improvement in the unit that had students working on laboratory investigations that were assigned by the author based solely on student readiness. This type of assigning was done in the *Stoichiometry* unit where there was an average 24.2% gain from pretest to posttest. Both the *Density* and *Percent by Mass* unit involved only student selection without teacher involvement. The *Density* and *Percent by Mass* unit has increases of 21.1% and 18.9% respectively. These value are only slightly lower than the *Stoichiometry* data but overall the *Density* and *Percent by Mass* units had higher overall average scores of 93.5% and 93.7% respectively compared to the *Stoichiometry* unit which had an average high score of 88.5%.

There are several factors that could have contributed to the slight variation in improvement in the three different units. First, the *Density* unit is taught at the very beginning of the school year. Students tend to have a higher level of engagement as most are determined to stay on task and do better than the year prior. In addition, density is not a foreign topic to the students. They are familiar with mass and volume. The topics that are unfamiliar to the students tend to be significant figures, basic laboratory skills and equipment, and working through an open-ended laboratory investigation. These areas of uncertainty seemed to be alleviated by allowing each student to select the activity that met their interest. It has been shown that test scores and student understanding greatly increase through intrinsic motivation (Patrick 2007). They were also allowed to work with another person and change their mind and pursue another activity if they were really struggling. This also holds true for the *Percent by Mass* unit. Students have good background knowledge of how to determine a percentage from their math classes. Their areas of weakness on this topic include associating percents with chemistry concepts and implementation of laboratory techniques and equipment necessary to complete the tasks. Once again, in this unit, any deficiencies that the student may have had they were able to select activities that worked for them. Also, students enjoy any activity that involves consumption of food. In the percent by mass activity menu they were able to chew gum and make popcorn. These types of activities tend to pique interest.

Due to solid background knowledge the pretest scores were higher in the *Density* and *Percent by Mass* unit, 72.4% and 74.8% respectively. Whereas in the *Stoichiometry* unit, the average pretest score was a 64.3%. Stoichiometry is a concept that is relatively new to most students in an introductory high school chemistry class. The students have already had an introduction to the mole concept and balancing chemical reactions but have yet to understand how to piece these two ideas together. With a lower pretest score, students had a greater chance for improvement. Thus, it cannot be determined if the greater percent of improvement from pre to posttest in the stoichiometry unit compared to the *Density* and *Percent by Mass* unit can actually be contributed to the teacher-assigned activities or if it is due to lower prior knowledge about the topic.

It can be concluded that differentiating the activities that students are asked to complete in a chemistry classroom drastically increased student motivation and performance level as indicated by feedback from the students.   Feedback obtained from student surveys (Tables 9. 10, 11) indicated that the enjoyment level was higher when there were a variety of activities going on in the room. Comments included but were not limited to:

"I liked it because we had options to choose our own activities "

"It was great because if there was something I absolutely did not want to do, I didn't choose it."

"It gave me a better understanding and it was great practice for the test."

"I liked being able to do something that interested me."

"These activities allowed me to focus on areas that I struggled with."

The student surveys clearly indicated that variation within the classroom has a positive effect on both learning and motivation. When learning is connected to interests, there will be an increase in productivity, achievement, and understanding (Tomlinson et al., 2003) . This kind of environment helps improve teaching. When every student is engaged in a different activity or type of learning it encourages the teacher to be more involved and aware of what students are actually doing. It reduces the need to watch for copying and idleness. Students have to become involved because they are being held responsible for not only completing activities but choosing the activity.

During the activities, it was observed that students were taking more ownership in their learning process. They were more collaborative discussions than normal. Typically in a laboratory environment, there are students that take the lead and others that passively follow. In this situation, no one could be a passive follower. By allowing students the opportunity to choose or by assigning a task based on readiness, students were more willing to be active participants. Students also enjoyed the fact that they didn't have to do everything. Students were engaged in more meaningful conversations as they had to do more than just ask their neighbor for the answer. They had to have discussions about what they were attempting to solve and how to initiate, develop, or complete the process. Their final laboratory write-ups indicated a higher level of understanding then if they had completed the same investigation as everyone else. Student motivation is directly correlated with retention and success (Vacca, 2006).

There were a few issues that did develop throughout the study. The time period within a unit to incorporate these activities is always in question. Activities tend to take up more time than lecturing on a topic. Even though everyone was working on different things at different times, because they were either working on an interest area or something that was at their learning level, time to complete the tasks seemed to be appropriate. There were fewer than normal students that had to complete the tasks before or after school compared to when everyone is asked to complete the same task. Progress has been made on developing and implementing more activity menus and tiered labs in every unit of study but it is difficult to insert them into an already exhausted time line.

Another issue, although minor, involved set-up. When the entire class is asked to complete the same laboratory activity it is easier to prepare for the lab. In this situation, the amount of materials was not a known. There were situations where materials ran out due to high demand and other materials were in excess. In the future this problem could be alleviated by having the student indicate which activities they plan to participate in rather than going into the activities blind.

In the end, incorporation of tiered labs and activity menus into a high school chemistry curriculum has been greatly supported by this study. There are immense gains in allowing variation and student choice within the classroom. Copying is reduced, learning is enhanced, motivation is increased, and student creativity is inspired. From the teacher perspective, it can be concluded that the learning environment is much more interesting. It is enjoyable to see everyone actively involved. It requires that every member of the classroom maintains a high level of engagement. Activity menus and tiered laboratory investigations will continue to be teaching and learning tools within the author's classroom.

Teachers need to be willing to adapt their classrooms to meet the needs of each and every one of the learners. Opportunities need to be made that permit students to move at a pace that is suitable for them in attempt to reduce either boredom or overload . Each type of learner needs to be given the opportunity to quality levels of work so that they can be challenged (Morelock & Morrison, 1999). Tiered laboratory investigations and activity menus are two types of differentiated instruction that can provide different learners with the opportunities that they need to be successful. These are proactive approaches because they account for varied abilities rather than just teaching to the middle group (Tomlinson, 2001). By implementing techniques such as tiered laboratory investigations and activities menus, classroom predictability is reduced and student engagement is enhanced (Crump, 1995).

Differentiated instruction is a way of teaching the embraces and celebrates all learning styles and learning levels (Tomlinson, 2006). Students are encouraged to learn at their own pace and select activities that are appropriate for them based on readiness and interest. Each student has a Zone of Proximal Development (ZPD), this is considered to be the comfort zone for each student in terms of learning (Morelock & Morrison, 1999). The intent of differentiated instruction is to provide content, learning activities, and assessments that work within this comfort zone. If activities are created with only one learning style in mind then the vast majority of students are asked to work outside of their ZPD, and true success is not achieved. By implementing activity menus and tiered laboratory investigations students are given choices and opportunities to work within their ZPD. Choices encourage all students to become engaged and take responsibility in the classroom (Baglieri & Knopf, 2004).

Student motivation is also enhanced when students are given choices. Learners have a tendency, which was evident in this study, to invest more into a learning activity if there is interest. Increased motivation tends to lead to higher levels of success. Providing students with the opportunity to choose an activity develops an improved level of student learning and allows students the opportunity to work on skills where and when needed (Hughes, 1999). Tiered activities allow students the opportunity to meet the same learning objective but with choices (Mawhinney, 2000). Evidence of understanding is then evaluated by giving each student the same final assessment. The emphasis is still placed on the same learning goal but differentiated instruction provides each student with the opportunity to select the path that they want to take to get to the learning objective.

Differentiated instruction, when implemented correctly, is a viable option for meeting the needs of some many different learning styles and learning abilities in today's classrooms. Differentiated instruction is a lot of work, but, the successes out-weigh the negatives. Educators need to embrace differences within the classroom and be willing to allow for variation in hopes that it will lead to a higher level of student motivation and success.

APPENDICES

Appendix A: Density Activity Menu

COLLINS' CHEMISTRY CUISINE — Today's Specialty: DENSITY

Appetizer (Everyone)

- Perform the lab to determine the density of two irregular shaped objects and two liquids.

Entrée (Select One)

- Determine the linear density of a wire by measuring the length and mass of three different size wires and then plotting the data on a graph.
- Determine the density of an egg using various salt solutions.

Side Dishes (Select Two or Skip and have Dessert)

- Create an apparatus that has neutral buoyancy in water. You must use quantitative data to solve this problem.
- Density Problem Set.
- Given a list of known densities, collect data and determine the identity of the unknown liquid on the front counter.
- Prepare a test tube with three distinct layers of liquid using any equipment from your lab drawer, tap water, sugar, and salt (food coloring may be used to identify the different layers). One written paragraph is required explaining how you completed the challenge and why it worked. The finished test tube must be displayed.

Dessert (Optional)

- Use density to determine the thickness of aluminum foil.

Appendix B: Density Appetizer Activity

Chemistry A Name___________________________

Appetizer Density Lab

Background:

Different materials pack together differently. This leads to differences in densities. We can use the known densities of materials to determine the identity of an unknown object. For now, however, we'll settle for just determining the densities of solids and liquids experimentally.

Materials

Balance	Graduated cylinder	Assorted liquids (at least 2)
2 solid objects	Weigh boat	Beaker

Objective

Determine the density of two liquids and two solid objects.

Procedure I: Determining the density of an irregular shaped object

1. Determine the solid's mass using a weigh boat and electronic balance. Record the mass in the data table.
2. Partially fill a graduated cylinder with water, record the volume of water.
3. Gently place the object into the water in the graduated cylinder, if any water splashes out you must start over. The object must be completely submerged. Record the new volume of the water.
4. Determine the volume of the object be subtracting the two volumes.
5. Gently pour out the water, dry off the object.
6. Repeat steps 1-5 for each object and then get an average mass and average volume.
7. Repeat steps 1-5 with one other solid object.

Data

	Mass (g)	Average mass (g)	Initial Volume (mL)	Final Volume (mL)	Volume of object (mL)	Average Volume	Density
Object _ Trial 1							
Object _ Trial 2							
Object _ Trial 1							
Object _ Trial 2							

Show your work below for determining density:

Procedure II: Determining the Density of 2 Liquids

1. Place an empty, dry graduated cylinder on the electronic balance and record the mass.
2. Mass the cylinder with the liquid and record the mass.
3. Record the volume of the liquid
4. Pour out the liquid and repeat steps 1-3.
5. Obtain a new liquid and repeat.

Data

	Mass of graduated cylinder (g)	Mass of graduated cylinder and liquid (g)	Mass of liquid (g)	Average mass of liquid (g)	Volume (mL)	Average volume (mL)	Density
Liquid __ Trial 1							
Liquid __ Trial 2							
Liquid __ Trial 1							
Liquid __ Trial 2							

Show your work below for determining density:

Questions:

1. Does the size of a sample have any affect on density? Explain your reasoning by incorporating evidence from the lab.

2. Briefly explain how density can used.

3. Use the information at the right to answer the following questions:

	Color	Density
Ethanol	Clear	0.789 g/mL
Kerosene	Clear	0.81 g/mL
Corn Oil	Yellow	0.923 g/mL
Water	Clear	0.998 g/mL
Sulfur Dichloride	Red	1.261 g/mL

a. a liquid has a volume of 15.75 mL. Its mass if found to be 12.758 g. What is the identify of the liquid?

b. A red liquid has a volume of 0.923 mL. What is its mass?

Appendix C: Density Side Dish Activity Options

Chemistry A Name_______________________________

DENSITY – Does Size Matter?

A Side Dish Activity

Liquid samples: Using an appropriate graduated cylinder, measure the masses of 6 different volumes of liquid.

VOLUME (mL)	MASS (g)

Solid samples: Use water displacement to determine the volume and respective masses for different size samples of the same substance.

VOLUME (mL)	MASS (g)

From your data tables, graph and analyze the relationship between mass and volume for the liquid and solids below.

LIQUID SAMPLES

SOLID SAMPLES

Determine the slope of each line and discuss what this slope means.

Given accepted values for the density of various liquids and solids, identify each and calculate percent error.

Chemistry A Name________________________________

NEUTRAL BUOYANCY
A Density Side Dish Activity

Objective: To create an object that will be neutrally buoyant in water.
Introduction: An object is considered to be neutrally buoyant when its density is equal to the density of the surrounding fluid. You will be provided with a couple of plastic cups and a water tank. Your task is to use materials to make the density of the plastic cups equal to the density of water. You may NOT fill the cups with water. You must fill with any of the materials available in the box labeled “neutral buoyancy activity materials”.

Materials:

Plastic cups	Paper clips	Miscellaneous Items
Water tank (2-Liter bottle with the top cut off)		Water

You must complete the following:

- Brief description of how you were able to make your cups neutrally buoyant (include quantitative data)
- Drawing of your apparatus
- Verification that your apparatus is neutrally buoyant

Chemistry A Name______________________________

Density Problem Set
A Density Side Dish Activity

1. Determine the mass of a 2.5 L sample of air. Air has a density of $1.3x10^{-3}$ g/cm^3.

2. Find the volume occupied by 1600 g of iron (density of Fe = 7.87 g/mL).

3. A brick used in the construction of pottery kilns is 11.0 cm wide, 6.0cm tall, and 22.7 cm long. The brick has a mass of 2.95 kg. What is the density of the brick in g/cm^3?

4. Mercury is a liquid at room temperature, and it has a density of 13.6 g/cm^3. Would a bar of aluminum sink or float in mercury? What about iron? What about gold? Explain your answer.

5. The density of chlorine gas is 3.16 g/L. What is the volume of a 16 g sample of chlorine?

6. Object A has a mass of 500g and a density of 5.0g/cm^3. Object B has a mass of 650g and a density of 6.5 g/cm^3.
   a. Which object would displace the most liquid? Explain.

   b. Could the two objects be made of the same substance? EXPLAIN.

7. Iron is sold in sheets that are 2.0 cm thick and 120.0 cm wide. You want to buy a sheet of iron with a mass of 50,000.0 g. What must be the length of the sheet of iron?

Chemistry A Name______________________________

What is that Liquid?
A Density Side Dish Activity

Objective: To use density to determine the identity of a clear, colorless liquid.

Below is a list of possible liquids the unknown could be. Your task is to use this information and your knowledge of how to determine density to reveal the identity of the unknown assigned to you.

Water	1.000g/mL
Isopropyl Alcohol	0.786g/mL
Hydrogen Peroxide	1.015g/mL
Salt Water	1.100g/mL
Baby Oil	0.840g/mL

Describe the steps you took to solve this problem:

Data:

Conclusion (Identify the liquid and provide support):

Chemistry A Name________________________________

TEST TUBE CHALLENGE

A Density Side Dish Activity

Your challenge is to prepare a test tube with three distinct layers of liquid. You may use any equipment in your lab basket, tap water, sugar, salt, and food coloring. (A complete layer of food coloring is not permitted use just a drop or two to color the layers).

Brief description of how you completed this challenge.

Show your test tube to Mrs. Collins for verification.

Appendix D: Density Entree Activity Options

Chemistry A Name______________________________

WIRED on DENSITY

A Density Entrée Activity

Objective: To determine the linear density of wire.

Procedure:

1. Measure the length of a piece of wire in meters
2. Measure the mass of a piece of wire in grams
3. Repeat with 2 other pieces of wire.
4. Calculate the ratio of mass to length of each wire (linear density)
5. Graph mass vs. length

Data

	MASS (g)	LENGTH (m)	LINEAR DENSITY (g/m)
WIRE 1			
WIRE 2			
WIRE 3			

Look at the densities of each piece of wire. Is there a relationship between the densities?

Find the slope of your graph. What does this number respresent?

If another lab group had the same gauge wire made of the same metal, would your graph work for them? Why or why not?

Mass the spools of wire available at the front table. Based on the mass, determine the length of wire left on the spool.

	SPOOL A	SPOOL B	SPOOL C
Mass			
Predicted Length of wire			

Briefly describe how you made your predictions.

Chemistry A Name______________________________

DENSITY EGGSPERIMENT

An Entree Activity

Objective: Indirectly determine the density of an egg by using salt solutions.
An egg will sink when placed in water due to its density. Your task is to create different salt solutions in an attempt to make an egg float. If an egg becomes neutrally buoyant (floats in the middle) then its density will be equivalent to the density of the solution.

Materials:

Beaker	Tap water	Table Salt	Spoon or scoopula
Electronic balance	graduated cylinder	Raw egg	

Data/Calculations:
(record data and calculations to determine the density of an egg in the space below)

Conclusions:
Briefly describe the steps you took to solve the density of the egg. Explain your reasoning.

Appendix E: Density Dessert Activity

Chemistry A Name________________________________

DON'T GET FOILED!
A Density Dessert Activity

Objective: To use the density of aluminum to determine the thickness of the aluminum foil.

Materials:

Piece of Al foil metric ruler Electronic balance

Known density of Al = 2.699 g/cm^3

Data:

Conclusions: Briefly describe how you determined the thickness of the foil.

Appendix F: Density Pre/Post Test

Chemistry A Name________________________________
Measurement and Density Pre/Post Test

1. What is density?

2. Density is dependent on the amount of matter present. True or False

   Provide an example to support your answer.

3. Everyday experiences can often be explained using scientific ideas about the way particles are arranged in solids, liquids and gases. In the boxes below, show how the particles are arranged in a typical solid, liquid and gas (in each case, use the symbol X to represent each particle).

solid		liquid		gas

4. Based on the arrangement of particles, which phase of matter would have the following characteristics:

   a. The highest density ________________________________

   b. the lowest density ________________________________

5. Gases, unlike solids, may be easily compressed because
   A. gas molecules are softer than those in solids
   B. gas molecules are smaller than those in solids
   C. gas molecules can move but those in solids cannot
   D. gas molecules are far apart but those in solids are touching

6. The density of ethanol (ethyl alcohol) is 0.789 g/mL. Calculate the mass of 10.0 mL

7. What is the mass of 2.0 mL of air, d = 1.2 g/L?

8. The density of paper is 1.20 g/cm^3. What is the mass of the paper in a notebook that is 76 mm thick, 215.9 mm wide, and 279.4mm long?

9. The density of an unknown substance in the liquid state at 0^{o}C is 0.9999 g/mL, and the density of the unknown substance at the solid state at 0^{o}C is 0.9168 g/mL.
    A. based on the data above, does this substance expand or contract when it goes from a liquid to a solid state?

    B. Suppose you have a 250 mL container filled with this substance in the solid state, what volume would be present if it went from a solid to liquid state?

    C. Based on your answer in b, would liquid spill out? If so how much? If not, how much more liquid could be added to the container?

10. Below shows the densities of some metals.

Lithium	0.53 g/mL
Sodium	0.97g/mL
Potassium	0.86 g/mL
Rubidium	1.53 g/mL

a. Which metal sinks in benzene (density of liquid = 0.88 g/cm^3) but floats in nitrobenzene (density of liquid = 1.2 g/cm^3)?

b. Which metal(s) would float in water (density of water 1.00 g/cm^3)?

11. You are given a sample of the one of the metals listed in the chart below but you do not know which metal it is. Briefly describe how you would determine the identity of the metal given the following materials: the metal, a graduated cylinder, an electronic scale, and water.

Magneiusm	1.738 g/mL
Aluminum	2.698 g/mL
Silicon	2.329g/mL
Titanium	4.540 g/mL

Appendix G: Density Pre/Post Test Answer Key

Chemistry A Name_______________________________

Measurement and Density Pre/Post Test Answer Key

1. What is density? **Answers will vary**

   Mass per unit volume, a measurement that is independent amount

2. Density is dependent on the amount of matter present. True or **False**

   Provide an example to support your answer. **Answers will vary**

   Ex. Density of water is 1.00g/mL no matter the amount of water present

3. Everyday experiences can often be explained using scientific ideas about the way particles are arranged in solids, liquids and gases. In the boxes below, show how the particles are arranged in a typical solid, liquid and gas (in each case, use the symbol X to represent each particle).

XXXXXXXXX solid		X X X X X X X liquid		X X gas

4. Based on the arrangement of particles, which phase of matter would have the following characteristics:

   a. The highest density _______**SOLID**________________

   b. the lowest density _______**GAS**__________________

5. Gases, unlike solids, may be easily compressed because

   A. gas molecules are softer than those in solids
   B. gas molecules are smaller than those in solids
   C. gas molecules can move but those in solids cannot
   D. gas molecules are far apart but those in solids are touching

6. The density of ethanol (ethyl alcohol) is 0.789 g/mL. Calculate the mass of 10.0 mL

(0.789g/mL)(10.0mL) = 7.89g

7. What is the mass of 2.0 mL of air, d = 1.2 g/L?

2.0mL = .0020L **(.0020L)(1.2g/L) = .0024g air**

8. The density of paper is 1.20 g/cm^3. What is the mass of the paper in a notebook that is 76 mm thick, 215.9 mm wide, and 279.4mm long?

(7.6cm)(21.59cm)(27.94cm) = 4584.5cm^3= 4600cm^3

(1.20g/cm^3)(4600cm^3) = 5520g = 5500g ***apply significant figures**

9. The density of an unknown substance in the liquid state at 0^{O}C is 0.9999 g/mL, and the density of the unknown substance at the solid state at 0^{O}C is 0.9168 g/mL.

A. based on the data above, does this substance expand or contract when it goes from a liquid to a solid state?

It expands when it goes from a liquid to a solid. This can be concluded because the density of the substance decreases from liquid to solid.

B. Suppose you have a 250.0 mL container filled with this substance in the solid state, what volume would be present if it went from a solid to liquid state?

(250.0mL)(0.9168 g/mL) = 229.2g

(229.2g)/0.9999g/mL = 229.2 mL

C. Based on your answer in b, would liquid spill out? If so how much? If not, how much more liquid could be added to the container?

No, the liquid would not spill out. 20.8mL of liquid could be added.

250mL - 229.2 mL = 20.8mL

10. The list below shows the densities of some metals.

A. Lithium	0.53 g/mL
B. Sodium	0.97g/mL
C. Potassium	0.86 g/mL
D. Rubidium	1.53 g/mL

a. Which metal sinks in benzene (density of liquid = 0.88 g/cm^3) but floats in nitrobenzene (density of liquid = 1.2 g/cm^3)?

B. sodium It has a density greater than 0.88 but less than 1.2g/mL.

b. Which metal(s) would float in water (density of water 1.00 g/cm^3)?

A. lithium, B. sodium, and C. potassium
They all have densities less than 1.00g/mL

11. You are given a sample of the one of the metals listed in the chart below but you do not know which metal it is. Briefly describe how you would determine the identity of the metal given the following materials: the metal, a graduated cylinder, an electronic scale, and water.

Magneiusm	1.738 g/mL
Aluminum	2.698 g/mL
Silicon	2.329g/mL
Titanium	4.540 g/mL

The density of the metal must be measured. First the mass of the metal could be recorded by using an electronic scale. Then the volume of the metal should be measured using the volume displacement technique. This technique involves the use of a graduated cylinder, some water, and the piece of metal. A small amount of water is put in the cylinder. The volume of the water must be recorded. The metal is then carefully placed in the graduated cylinder (be careful not to spill any water). The volume of the water and metal are recorded. The two volumes are subtracted to determine the volume of the metal. The mass of the metal is divided by the volume of the metal. This is the density. The density is compared to the list of known densities. The closest density would be the identity of the metal.

Appendix H: Density Student Survey

Chemistry A   Name____________________________________Period _______________

Collins' Chemistry Cuisine Density Dinner Menu Student Survey

Directions: This survey will be kept completely anonymous. Names will be cut off once study participants have been identified. Please answer the following questions as honestly as possible. The more truthful and complete you are in your responses, the more helpful it will be.

Part 1: General Feedback. Answer the following questions, including specific examples or details.

1. Did you find the Collins' Chemistry Cuisine Activity Menu on Density helpful? If so, what was helpful? If not, what could be done to improve it?

____

____

____

____

2. Do you feel you have a better understanding of density as a result of doing the activities in the menu? Why or why not?

____

____

____

3. Was it a benefit to have choices of activities to do? Why or why not?

____

____

____

4. Is there anything that you still feel uncertain about in terms of density? If yes, please explain.

____

Part 2: Activity Rating: In the spaces below, rate each of the activities in this unit on a scale of 1-5 (1= low, 5=high) according to the following criteria.

Column 1 – Physically Engaging. How physically engaging was this activity? Were you actively participating throughout this activity?
Column 2 - Mentally Engaging. How mentally engaging was this activity? Did you find yourself really thinking through the process as you performed the activity?
Column 3 - Interesting. How interesting did you find this activity? Did you enjoy the activity?
Column 4 - Learning. How much did you learn from this activity? Did you feel that it helped model the topic for you in a way that helped you learn?

Table 12: Student rating of density menu activities

Activity	Physically Engaging	Mentally Engaging	Interesting	Learning
Determining the density of two irregular shaped objects and two liquids				
Circle the one you selected: Wired on Density OR Density Eggsperiment				
Circle the one of the two you selected: • Neutral buoyancy apparatus • Density problem • Unknown liquid • Test tube with 4 layers				
Circle the one of the two you selected: • Neutral buoyancy apparatus • Density problem • Unknown liquid • Test tube with 4 layers				
Determining the thickness of aluminum foil (optional)				

Part 3: Additional Comments. Feel free to make any additional comments about the Collins' Chemistry Cuisine Activity Menu for Density below.

Appendix I: Percent by Mass Activity Menu

COLLINS' CHEMISTRY CUISINE— Today's Special: Percent by Mass

Appetizer (Everyone)

- Write and explain the general formula for determining the percent by mass of an element in a compound

Entrée (Select One)

- Draw a picture to represent the concept of percent composition
- Select and explain a few examples of how percent composition is used in the real world.
- Create a concept map to demonstrate how percent composition fits into the matter unit

Side Dishes (Select Two OR Skip and Select Dessert)

- Conduct a lab to determine the percent composition of water in one popcorn kernel.
- Perform an investigation to determine the percent composition of sugar in gum.
- Solve the following problem: Determine which has a greater mass of calcium

  a. 25g of chalk, $CaCO_3$ b. 18g of $Ca(OH)_2$ c. 26g of $Ca_3(PO_4)_2$
- Create a model to represent percent composition.

Dessert

- Perform an open-ended lab to determine the percent by mass of sugar in soda by comparing to known sugar solutions.

Appendix J: Percent by Mass Activities Answer Sheet

Chemistry A Name____________________

PERCENT BY MASS

Appetizer

Entrée

Side Dishes OR Dessert

Appendix K: Percent by Mass Activity Sheets

Chemistry A Name____________________________

WHAT A SWEETIE!
Percent by Mass Laboratory Investigation

Objective: To determine the percent by mass of sugar in soda.

Introduction: Non-diet soft drinks are primarily sugar, water, and carbon dioxide. Your task is to figure out a way to determine the percent by mass of sugar in a sample of 7-UP. The soda has been sitting out and has been warmed to remove all the carbon dioxide bubbles. You will be making the assumption that the remaining ingredients are table sugar, sucrose ($C_{12}H_{22}O_{11}$) and water. In order to determine the percent by mass of the sugar in the 7-UP sample you will be provided with some sucrose and distilled water. You will need to make up various sugar-water solutions, measure the % mass sugar of the solutions, determine the density, and then make a graph to plot % mass vs. density of these known samples. You can then use to the graph and then use the density of the 7-UP sample to determine the mass of the sugar in the sample.

Materials:

7-up	Table sugar	Distilled water	Graduated cylinders	
Syringes	Beakers	Stirring rod	Ruler	Electronic Balance

You will be responsible for turning in the following:

- A brief description of the process you used
- Data table
- Calculations
- Graph of mass vs. density

Chemistry A Name______________________________

Determining Percent Water in Popcorn

Objective: To determine the percent by mass of water in one popcorn kernel.

Introduction: Popcorn pops because of the natural moisture inside each kernel. When the internal water is heated above 100°C, the liquid water boils and changes to a gas, this takes up much more space than the liquid, so the kernel expands rapidly and eventually pops. Your task is to devise a method to determine the percent by mass of water in one popcorn kernel.

Materials:
Small aluminum container
Popcorn kernels
Oil
Hot plate
Tongs
Electronic Balance

You are responsible for the following:

- Brief description of your method
- Data and calculations to determine the percent by mass of water in one popcorn kernel
- Summary of any problems or errors

*You may eat your popcorn after you have completed your data collection and calculations. More than one trial may be necessary.

Chemistry A Name______________________________

Determining the Percent by Mass Sugar in Bubble Gum

Objective: To determine the percent by mass of sugar in one piece of bubble gum.

Introduction: All commercial food producers must list all ingredients found in their food products on the retail packaging for the foods. These ingredients must be listed in order of decreasing concentration by mass but they do not have to list the actual quantities.

Bubble gum is composed of mostly sugar. The most convenient way to remove sugar from gum is to chew it. During chewing the sugar is dissolved by saliva and is swallowed, leaving an insoluble rubber in the mouth. This laboratory exercise will establish the percent by mass sugar in bubble gum.

Materials:
1 piece of bubble gum
Electronic balance
Weighing boats

You are responsible for turning in the following:
- Basic procedure
- Data and calculations to determine the percent by mass of sugar in bubble gum
- Summary of any problems or errors

*Make sure that you chew the gum for a reasonable amount of time, allow the gum adequate time to dry (you do not want to mass your saliva), and remember to not let your gum come into contact with any surfaces that may have chemicals on them. Happy chewing!!!!

Appendix L: Percent by Mass Pre/Post Test

Chemistry A Name__________________________

Percent Composition Pre/Post Test

1. Briefly describe how to determine the percent of something.

2. Determine the molar mass of each of the following

   A. $CaCO_3$ B. KCl

3. Using the molar mass of $CaCO_3$ from question number 2, determine the percent by mass of each element in the compound

   % Ca

   %C

   %O

4. Determine the percent composition of oxygen in potassium chlorate, $KClO_3$.

5. Determine the actual mass of oxygen in a 50.0g sample of glass, SiO_2.

6. Nicotine, the additive drug in cigarettes, contains 74.0% carbon, 8.6% hydrogen, and 17.3% nitrogen. What mass of each element can be recovered from a 55.0 g sample of nicotine?

7. The percent of oxygen in a colorless liquid is determined to be 94.1%. Is this liquid water or hydrogen peroxide (H_2O_2)?

8. Which of the following would have a greater mass of Ca? (Show your work to receive full credit)

   A. 45.00g $Ca_3(PO_4)_2$ B. 8.25g Ca

Appendix M: Percent by Mass Pre/Post Test Answer Key

Chemistry A Name__________________________

Percent Composition Pre/Post Test Answer Key

1. Briefly describe how to determine the percent of something.
<u>Answers will vary</u>
    -Part of a whole
    -Determine the part, divide by the total amount and then multiply by 100

2. Determine the molar mass of each of the following

A. $CaCO_3$

Ca = 40.08g
C = 12.01g
O = (16.00g)3 = 48.00g
Total = <u>100.09g</u>

B. KCl

K = 39.10g
Cl = 35.45g
Total = <u>74.46g</u>

3. Using the molar mass of $CaCO_3$ from question number 2, determine the percent by mass of each element in the compound

% Ca (**40.08g/100.09g)x100 = <u>40.04%</u>**

%C **(12.01g/100.09g)x100 = <u>12.00%</u>**

%O **(16.00g/100.09g)x100 = <u>15.99%</u>**

4. Determine the percent composition of oxygen in potassium chlorate, $KClO_3$.

K=39.10g
Cl = 35.45g
O = (16.00g)3 = 48.00g
Total = 122.55g

O = (48.00g/122.55g)x100 = <u>39.17%</u>

5. Determine the actual mass of oxygen in a 50.0g sample of glass, SiO_2.
Si = 28.09g
O = (16.00g)2 = 32.00g
Total = 60.09g

% O = 32.00g/60.09g = .5325
Mass O = (50.0g)(.5325) = <u>26.63g O</u>

6. Nicotine, the additive drug in cigarettes, contains 74.0% carbon, 8.6% hydrogen, and 17.3% nitrogen. What mass of each element can be recovered from a 55.0 g sample of nicotine?
   C = (55.0g)(.740) = <u>40.7g C</u>
   H = (55.0g)(.086) = <u>4.7g H</u>
   N = (55.0g)(.173) = <u>9.52g N</u>

7. The percent of oxygen in a colorless liquid is determined to be 94.1%. Is this liquid water or hydrogen peroxide (H_2O_2)?

Water	**Hydrogen Peroxide**
H = (1.01g) 2 = 2.02g	**H = (1.01g)2 = 2.02g**
O = (16.00g)1 = 16.00g	**O = (16.00g)2 = 32.00g**
Total = 18.02g	**Total = 34.02g**
% O = (16.00g/18.02g) x100 = 88.79%	**%O = (32.00g/34.02g)x100 = 94.06%**

   <u>ANSWER: Hydrogen peroxide</u>

8. Which of the following would have a greater mass of Ca? (Show your work to receive full credit)

   A. 45.00g $Ca_3(PO_4)_2$ B. 8.25g Ca

   Ca = (40.08g)3 = 120.24g
   P = (30.97g)2 = 61.94g
   O = (16.00g)8 = 128.00g
   Total = 310.18g

   %Ca = (120.24g/310.18g) = .3876
   Mass of Ca = (.3876)(45.00g) = 17.44g Ca

   <u>ANSWER: 45.00g $Ca_3(PO_4)_2$</u>

Appendix N: Percent by Mass Student Survey

Chemistry A Name_______________________________________Period _______________

Collins' Chemistry Cuisine Percent by Mass Dinner Menu Student Survey

Directions: This survey will be kept completely anonymous. Names will be cut off once study participants have been identified. Please answer the following questions as honestly as possible. The more truthful and complete you are in your responses, the more helpful it will be.

Part 1: General Feedback. Answer the following questions, including specific examples or details.

5. Did you find the Collins' Chemistry Cuisine Activity Menu on Percent by Mass helpful? If so, what was helpful? If not, what could be done to improve it?

____

____

____

____

6. Do you feel you have a better understanding of percent by mass as a result of doing the activities in the menu? Why or why not?

____

____

____

7. Was it a benefit to have choices of activities to do? Why or why not?

____

____

____

8. Is there anything that you still feel uncertain about in terms of percent by mass? If yes, please explain.

____

____

Part 2: Activity Rating: In the spaces below, rate each of the activities in this unit on a scale of 1-5 (1= low, 5=high) according to the following criteria.

Column 1 – Physically Engaging. How physically engaging was this activity? Were you actively participating throughout this activity?

Column 2 - Mentally Engaging. How mentally engaging was this activity? Did you find yourself really thinking through the process as you performed the activity?

Column 3 - Interesting. How interesting did you find this activity? Did you enjoy the activity?

Column 4 - Learning. How much did you learn from this activity? Did you feel that it helped model the topic for you in a way that helped you learn?

Table 13: Student rating of percent by mass menu activities

Activity	Physically Engaging	Mentally Engaging	Interesting	Learning
Writing and explaining the general formula for percent by mass				
Circle the one you selected: • Drawing a picture to represent percent by mass • Explaining a few real world examples of percent by mass • Percent by mass concept map				
Circle the one of the two you selected: • Determining the percent water in a popcorn kernel • Determining the percent sugar in bubble gum • Determining the greatest mass of calcium • Creating a model to represent percent composition • Determining the percent by mass sugar in soda pop				
Circle the one of the two you selected: • Determining the percent water in a popcorn kernel • Determining the percent sugar in bubble gum • Determining the greatest mass of calcium • Creating a model to represent percent composition • Determining the percent by mass sugar in soda pop				

Part 3: Additional Comments. Feel free to make any additional comments about the Collins' Chemistry Cuisine Activity Menu for Percent by Mass below.

Appendix O: Stoichiometry Level I/II Tiered Lab

Chemistry B
Level I-II

Name__________________________

WHAT'S THE RATIO?
Introduction to Stoichiometry Lab

Objective: To react solid sodium carbonate with a solution of hydrochloric acid, HCl, to determine the mole to mole relationship using both lab data and stoichiometry. In other words, you are going to verify the coefficients in the balanced chemical reaction using lab data.

WRITE THE BALANCED CHEMICAL EQUATION (including state symbols):

Solid sodium carbonate reacts with a solution of hydrochloric acid, HCl, to produce water, carbon dioxide gas, and sodium chloride.

Materials:

50 mL beaker	sodium carbonate	1.0 M HCl	Graduated cylinder
Electronic Scale	Scoopula	Hot plate	

Procedure:

1. Put on lab safety goggles
2. Mass a clean, dry 50mL beaker. Mass of beaker = ____________________.
3. Carefully place a small sample of sodium carbonate into the beaker using a scoopula
4. Mass the beaker and sodium carbonate. Mass of beaker and sodium carbonate=____________________.
5. Determine the mass of sodium carbonate= ______________________________________.
6. Use stoichiometry to convert the mass of sodium carbonate into the mass of sodium chloride that should be produced (show your work below):
7. Obtain 2-5 mL of 1.0 M HCl solution using a clean graduated cylinder.
8. Add the HCl to the sodium carbonate. Gently swirl the beaker to allow the reaction to proceed. It should bubble as carbon dioxide gas is one of the products.
9. When the reaction is completed, place the beaker on a hotplate and gently heat the beaker to evaporate the water.

10. Once all the water is evaporated, the only product that should remain is sodium chloride. Mass the beaker and with the sodium chloride= ______________________________
11. Determine the mass of just the sodium chloride:

    Mass of sodium chloride collected in the lab = _________________________________

12. Clean the beaker, return all supplies, and make sure the hot plate is unplugged.

Conclusions:

1. Look at the overall balanced chemical equation. What is the mole to mole relationship between sodium carbonate and sodium chloride? (Look at the coefficients to determine this)

2. Convert the mass of sodium carbonate you used into moles of sodium carbonate.

3. Convert the mass of sodium chloride you produced into moles of sodium chloride.

4. Do the number of moles you calculated in problems #2 and #3 above match the balanced chemical equation? If the moles do not, provide some reasons for your error.

5. How much sodium chloride should you have produced? (look at your calculation from #6 in the procedure section).

6. How much sodium chloride did you produce? (look at your data in #11 of the procedure section).

7. How do the masses in #5 and #6 compare? Provide an explanation.

Appendix P: Stoichiometry Level II/III tiered lab

Chemistry B
Level II/III

Name___________________

FILL IT UP!
Introductory Stoichiometry Lab

Objective: Solid sodium bicarbonate reacts with a solution of hydrochloric acid (HCl) to produce water, carbon dioxide gas, and a solution of sodium chloride. Your task is to use this reaction to generate enough carbon dioxide gas to fill a plastic storage baggie. The ideal result will be to fill the bag to the appropriate plumpness, not to overinflate or under-inflate the baggie. This will be checked with a poke test. The bag may also contain unreacted chemicals and/or other products of the reaction. You will be responsible for writing down the procedure you usee to fill the baggie.

Materials Available: (These are available to you but you do NOT need to use each one)

- Baggie (put your name on your baggie)
  Snack Sandwich Quart
- Graduated cylinder
- Sodium bicarbonate
- 1.0 M HCl (1 mole per liter)
- Weigh boat
- Scoopula
- Electronic Balance
- Beakers

Amounts of Hydrochloric acid that you should use based on baggie size!

Snack size baggie = 28.0 mL
Sandwich baggie = 65.0 mL
Quart size baggie = 115.0 mL

You must come up with a way to determine the following:

1. volume of the baggie (this will be equivalent to the amount of carbon dioxide you need to produce)
2. figure out a way to have both the acid and the sodium carbonate in the baggie at the same time without making contact until you want the reaction to proceed.

DATA/PROCEDURES:

Volume of baggie = ________________ (this is the amount of carbon dioxide gas you need to produce)

Briefly explain how you determined the volume of the baggie.

Balanced chemical reaction (with state symbols)

Solid sodium bicarbonate reacts with a solution of hydrochloric acid (HCl) to produce water, carbon dioxide gas, and a solution of sodium chloride.

Calculations for determining the mass of sodium bicarbonate needed:

Briefly explain how you were able to place both the sodium bicarbonate and the hydrochloric acid into the baggie and seal it without the substances reacting.

Plumpness rating (performed by Mrs. Collins - you must have calculations performed above before plumpness will be checked) **VALUE = 25% of lab grade**

0 1 2 3 4

Appendix Q: Stoichiometry Level III tiered lab

Chemistry B
Level III

Name________________________

MAKE IT EQUAL
Introduction to Stoichiometry Lab

Objective: To determine the amount of SODIUM BICARBONATE and the amount of SODIUM CARBONATE needed to react with 1.0 M HCl to fill 2 plastic baggies to the same size. When either solid is placed in a solution of hydrochloric acid, HCl, the products are water, carbon dioxide gas, and a solution of sodium chloride.

You will need to calculate the correct mass of each needed to fill plastic baggies to completion when reacting with HCl.

Materials Available (you do not need to use all the materials listed)

- Sodium bicarbonate
- Sodium carbonate
- 1.0M HCl
- Weighing boats
- Electronic Scale
- Assigned Baggies (write your name on the baggies)
  Snack Sandwich Quart
- Graduated cylinder
- Beakers
- Scoopula

You will be responsible for turning in the following

Written procedure used to solve the problem
Balanced chemical reactions with state symbols included.
Calculations
Sealed baggies (identify which is which and the degree of plumpness will be part of your score)

Appendix R: Stoichiometry Limiting/Excess Reactant Level I/II Tiered Lab

WHAT IS LIMITING THIS REACTION?

Chemistry B- Stoichiometry Lab

OBJECTIVES

1. To identify the limiting and excess reagents from the reaction between aluminum metal and $CuCl_2$ solution.
2. To demonstrate and apply stoichiometric calculations.

PROBLEM / TASK

How is the amount of product formed determined by the amount of reactant that is used?

You will conducting the same reaction 4 different times, each time using a different amount of reactants. Your job will be to determine the reactant that is limiting (runs out first) and the reactant that is in excess (extra or left over). This will be done qualitatively (what you see) and quantitatively (mathematically). The reaction will be a single replacement between Al metal and $CuCl_2$ solution.

PRIOR KNOWLEDGE

Review this list to help refresh your memory on past chemistry concepts that might help you in this endeavor.

1. Identifying types of reactions
2. Writing and balancing chemical reactions with phases of matter identified
3. Predicting possible products of a reaction
4. Stoichiometry
5. Lab safety
6. Basic lab procedures

SAFETY

Copper (II) chloride ($CuCl_2$) solution is slightly toxic by ingestion and has no odor. Contact the teacher immediately if skin contact occurs.

MATERIALS

$CuCl_2$ powder, water, 4 cups, stirring rod, aluminum foil, and 100 ml graduated cylinder

Mass of Aluminum	Mass of $CuCl_2$	Volume of Water
1.00g	4.00g	100 mL
0.50g	3.00g	100 mL
0.25g	2.25g	100 mL
2.00g	5.00g	100 mL

- **Use each cup at a weigh boat to mass the $CuCl_2$, then add 100mL of water to make a solution of $CuCl_2$**

DATA & OBSERVATIONS

Fill in the necessary information on the data table for initial and final observations, actual masses, and volumes.

RESULTS / ANALYSIS / CONCLUSIONS

This is where your calculations to determine limiting and excess reactant will be located. You will discuss the rationale behind your observations.

CHECKPOINTS

1. Write the balanced chemical equation for your reaction including phases of matter.

2. Identification of what will be observed if aluminum is in excess or limiting AND if Cu^{2+} is in excess or limiting.

4. Calculate how much Cu metal each reactant can produce. Be sure to show ALL labeled math work.

Chemistry B

Name_______________________________

Lab Partner_________________________

Purpose of the Lab Activity:

Overall Balanced Equation with State Symbols:

Data & Observations:

Reaction Trials: (record below the ACTUAL amounts that you measure and use)

Trial	Mass of Al (g)	Mass of $CuCl_2$ (g)	Volume of Water (mL)
1			
2			
3			
4			

Observe the reactants on day 1 and record below what they look like. Observe products for each reaction on day 2. Record qualitative observations for each of the 4 reactions

Reactants (day 1)	Products (day 2)
	Trial 1:
	Trial 2:
	Trial 3:
	Trial 4:

What should the products look like aluminum is the limiting reactant?

What should the products look like if copper (II) chloride is the limiting reactant?

Results/Analysis/Conclusions:

CALCULATIONS:

Trial	Mathematically determine the amount of Cu(s) that should be produced. Based on your calculations CIRCLE the reactant that is limiting and BOX in the reactant that is in excess.
1	
2	
3	
4	

CONCLUSIONS: (briefly explain using complete sentences in paragraph form how you were able to determine the limiting and excess reagents using both **qualitative and quantitative** data - in other words do your qualitative observations match your quantitative observations. For example if you calculated that aluminum is limiting, did you observe that all the aluminum was used up and that the solution was still blue???? If not, provide some reasons for your error!)

Appendix S: Stoichiometry Limiting/Excess Reactant Level III Tiered Lab

COLLECTING a KNOWN MASS of SOLID COPPER

OBJECTIVES

1. To identify the correct type of reaction in order to isolate copper metal from $CuSO_4$ solution.
2. To write a procedure in order to extract 1.00 g of copper metal
3. To demonstrate and apply stoichiometric calculations.

PROBLEM / TASK

How do chemists perform reactions to make a set amount of product?

You will be starting with a solution that is 200.0 mL of 0.100 M $CuSO_4$ (aq). You job will be to react the $CuSO_4$ solution with a substance to produce and collect 1.00g of pure copper metal.

You will need to determine what you will need to react the copper sulfate solution with, write up a procedure that will produce only1.00 g of pure copper metal, collect the metal and analyze your results. You will have graded check points along the way to insure safety and progress. After the procedure is accepted you will carry out your experiment and calculate the percent yield to the nearest 0.01%. The higher the percent yield the better.

PRIOR KNOWLEDGE

Review this list to help refresh your memory on past chemistry concepts that might help you in this endeavor.

1. Identifying types of reactions (what could you react $CuSO_4$ solution with to isolate out the Cu)
2. Writing and balancing chemical reactions with phases of matter identified
3. Predicting possible products of a reaction
4. Stoichiometry
5. Lab safety
7. Basic lab procedures
8. Percent yield calculations

SAFETY

Copper (II) sulfate ($CuSO_4$) solution is slightly toxic by ingestion and has no odor. Contact the teacher immediately if skin contact occurs.

MATERIALS

Develop a detailed materials list to submit to your teacher.

DATA & OBSERVATIONS

Be sure to create a quality data table for everything you measure. Include your detailed observations in a separate table or section.

RESULTS / ANALYSIS

This is where your calculations for the percent yield will be located. Include reasoning to justify if and why your procedures were (or were not) successful.

A grading rubric will be applied to the checkpoints.

CHECKPOINTS

After each checkpoint has been discussed with your lab partner and agreed upon, have the teacher sign off.

1. What type of reaction is needed?

Consider these questions to help you address this: What are the types of reactions have we learned? Is there one in which a metal was produced through electron transfer?

2. Explain your reasoning for question #1. What is your evidence that this is correct?

3. Write the balanced chemical equation for your reaction including phases of matter.

4. Calculate how much of each reactant you want to use. Be sure to show ALL labeled math work. You do not want to just add unknown amounts of reactants together to see what happens. Be sure to consider the concept of a limiting reactant.

5. Write up a step by step procedure for this experiment. You'll need to be thorough and detailed enough so that someone else could follow your steps and get the same outcome. Include any safety concerns. Note that possible materials are available at the back table. If you think you need different equipment, ask the teacher for assistance.

6. Perform the experiment. Record data, observations, and calculations to be turned in to the teacher. Be sure to clean up your lab area before leaving.

Appendix T: Stoichiometry Pre/Post Test

Chemistry B Name___________________________

Stoichiometry Pre/Post Test

1. Perform the following mole conversions:

   a. Determine the number of moles in 18.5g $Pb(NO_3)_2$

   b. Determine the mass of 3.25 L N_2 gas.

   c. Determine the number of particles in 100.50g FeS

2. Which of the following is a correct interpretation of this balanced equation?

   $2Al(s) + 3Pb(NO_3)_2(aq) \rightarrow 2Al(NO_3)_3(aq) + 3Pb(s)$

   a. 2 grams Al + 3 grams $Pb(NO_3)_2 \rightarrow$ 2 grams $Al(NO_3)_3$ + 3 grams Pb
   b. 2 atoms Al + 3 units $Pb(NO_3)_2 \rightarrow$ 2 units $Al(NO_3)_3$ + 3 atoms Pb
   c. 2 moles Al + 3 moles $Pb(NO_3)_2 \rightarrow$ 2 moles $Al(NO_3)_3$ + 3 moles Pb
   d. both b and c

3. Use the following balanced reaction to answer the questions below:

   $6HCl + Fe_2O_3 \rightarrow 2FeCl_3 + 3 H_2O$

   A. If 3 moles of HCl are used, how many moles of $FeCl_3$ are produced?

   B. If 6 moles of $FeCl_3$ must be produced then how many moles of Fe_2O_3 must be reacted?

   C. What mass of H_2O can be produced from 2 moles of HCl and excess Fe_2O_3?

   D. What mass of Fe_2O_3 is needed to produce 2.35×10^{24} molecules of H_2O?

4. True or False. All reactants are used up in a chemical reaction to form the product.

   Provide support for your selection:

5. True or False. Adding more reactant will always result in more product being formed in a chemical reaction.

   Provide support for your selection:

6. Given the following reaction:

$$\_\_\ \mathbf{PH_3} + \_\_\ \mathbf{O_2} \rightarrow \_\_\ \mathbf{P_4O_{10}} + \_\_\ \mathbf{H_2O}$$

   A. Balance the reaction.

   B. Determine the mass of P_4O_{10} that can be formed if 68.00g of O_2 react with 68.00g PH_3.

   C. Identify the limiting reactant: ____________________

   D. Identify the excess reactant: _____________________

7. Read the following laboratory scenario:

   A student is asked to react copper metal, Cu, with 20 mL of a 1.5M solution of AgCl in an attempt to collect 0.75g of solid Ag. The student determined the volume of silver chloride solution contains 4.30g of AgCl. The student then determined the mass of solid copper needed to produce the amount of solid silver desired. The product was dried and massed. The student collected 0.66g of solid silver.

   A. Write the balanced chemical reaction including states of matter symbols.

   B. Briefly discuss how the student was able to determine the mass of copper metal needed to produce 0.75g of solid silver.

   C. Determine the percent yield.

Appendix U: Stoichiometry Pre/Post Test Answer Key

Chemistry B Name_________________________

Stoichiometry Pre/Post Test

8. Perform the following mole conversions:

   a. Determine the number of moles in 18.5g $Pb(NO_3)_2$

   $$\mathbf{18.5g\ Pb(NO_3)_2\ \frac{(1\ mole\ Pb(NO_3)_2)}{331.22g\ Pb(NO_3)_2} = \underline{0.0559\ moles\ Pb(NO_3)_2}}$$

   b. Determine the mass of 3.25 L N_2 gas.

   $$\mathbf{3.25\ L\ N_2\ \frac{(1\ mol\ N_2)}{(22.4L)}\ \frac{(28.02g\ N_2)}{(1mol\ N_2)} = \underline{4.07g\ N_2}}$$

   c. Determine the number of particles in 100.50g FeS

   $$\mathbf{100.5gFeS\ \frac{(1mol\ FeS)}{(87.92gFeS)}\ \frac{(6.02x10^{23}\ particles\ FeS)}{(1\ mol\ FeS)} = \underline{6.8813x10^{23}\ particles\ FeS}}$$

9. Which of the following is a correct interpretation of this balanced equation?

   $2Al(s) + 3Pb(NO_3)_2(aq) \rightarrow 2Al(NO_3)_3(aq) + 3Pb(s)$

   a. 2 grams Al + 3 grams $Pb(NO_3)_2 \rightarrow$ 2 grams $Al(NO_3)_3$ + 3 grams Pb
   b. 2 atoms Al + 3 units $Pb(NO_3)_2 \rightarrow$ 2 units $Al(NO_3)_3$ + 3 atoms Pb
   c. 2 moles Al + 3 moles $Pb(NO_3)_2 \rightarrow$ 2 moles $Al(NO_3)_3$ + 3 moles Pb
   d. both b and c

   ANSWER: letter d

10. Use the following balanced reaction to answer the questions below:

    $6HCl + Fe_2O_3 \rightarrow 2FeCl_3 + 3\ H_2O$

    A. If 3 moles of HCl are used, how many moles of $FeCl_3$ are produced?

    1 mole $FeCl_s$

    B. If 6 moles of $FeCl_3$ must be produced then how many moles of Fe_2O_3 must be reacted?

    3 moles Fe_2O_3

    C. What mass of H_2O can be produced from 2 moles of HCl and excess Fe_2O_3?

    $$\mathbf{2\ moles\ HCl\ \frac{(3\ moles\ H_2O)}{(6\ moles\ HCl)}\ \frac{(18.02g\ H_2O)}{(1\ mole\ H_2O)} = \underline{18.02g\ H_2O}}$$

D. What mass of Fe_2O_3 is needed to produce 2.35×10^{24} molecules of H_2O?

$$\mathbf{2.35 \times 10^{24}\ molecules\ H_2O\ \frac{(1\ mol\ H_2O)}{(6.02 \times 10^{23})}\ \frac{(1\ mol\ Fe_2O_3)}{(3\ mole\ H_2O)}\ \frac{(159.7g\ Fe_2O_3)}{(1\ mol\ Fe_2O_3)} = \underline{208g\ Fe_2O_3}}$$

11. True or **False**. All reactants are used up in a chemical reaction to form the product.

    Provide support for your selection: **Answers will vary!**

12. True or **False.** Adding more reactant will always result in more product being formed in a chemical reaction.

    Provide support for your selection: **Answers will vary! (need to add the reactant that is needed)**

13. Given the following reaction:

$$\mathbf{\_4\_\ PH_3 + \_8\_\ O_2 \rightarrow \_1\_\ P_4O_{10} + \_6\_\ H_2O}$$

D. Balance the reaction.

E. Determine the mass of P_4O_{10} that can be formed if 68.00g of O_2 react with 68.00g PH_3.

$$\mathbf{68.00g\ O_2 \frac{(1\ mol\ O_2)}{(32.00g\ O_2)}\ \frac{(1\ mol\ P_4O_{10})}{(8mol\ O_2)}\ \frac{(283.88gP_4O_{10})}{(1\ mol\ P_4O_{10})} = \underline{67.03g\ P_4O_{10}}}$$

$$\mathbf{68.00gPH_3 \frac{(1\ mol\ PH_3)}{(34.00g\ PH_3)}\ \frac{(1mol\ P_4O_{10})}{(4\ mol\ PH_3)}\ \frac{(283.88g\ P_4O_{10})}{(1mol\ P_4O_{10})} == 141.9g}$$

F. Identify the limiting reactant: ________**O_2**____________

D. Identify the excess reactant: ________**PH_3**____________

14. Read the following laboratory scenario:
    A student is asked to react copper metal, Cu, with 20 mL of a 1.5M solution of AgCl in an attempt to collect 0.75g of solid Ag. The student determined the volume of silver chloride solution contains 4.30g of AgCl. The student then determined the mass of solid copper needed to produce the amount of solid silver desired. The product was dried and massed. The student collected 0.66g of solid silver.

    Write the balanced chemical reaction including states of matter symbols.

    $\mathbf{Cu_{(s)} + 2AgCl_{(aq)} \text{-->} 2Ag_{(s)} + CuCl_{2(aq)}}$

    Briefly discuss how the student was able to determine the mass of copper metal needed to produce 0.75g of solid silver.

    Answers will vary

    Determine the percent yield.

    (0.66g Ag/ 0.75g Ag) x100 = 88%

Appendix V: Stoichiometry Student Survey

Chemistry B Name___________________________________Period ______________

Stoichiometry Post Unit Student Survey

Directions: This survey will be kept completely anonymous. Names will be cut off once study participants have been identified. Please answer the following questions as honestly as possible. The more truthful and complete you are in your responses, the more helpful it will be.

Part 1: General Feedback. Answer the following questions, including specific examples or details.

1. Did you find the lab activities for stoichiometry helpful? If so, what was helpful? If not, what could be done to improve them?

____

____

____

____

2. Do you feel you have a better understanding of stoichiometry a result of doing the lab activities? Why or why not?

____

____

____

3. Was it a benefit to be assigned a different lab rather than doing the same lab as everyone in the class? Why or why not?

____

____

4. Is there anything that you still feel uncertain about in terms of stoichiometry? If yes, please explain.

____

____

Part 2: Activity Rating: In the table below, rate each of the activities in this unit on a scale of 1-5 (1= low, 5=high) according to the following criteria.

Column 1 – Physically Engaging. How physically engaging was this activity? Were you actively participating throughout this activity?

Column 2 - Mentally Engaging. How mentally engaging was this activity? Did you find yourself really thinking through the process as you performed the activity?

Column 3 - Interesting. How interesting did you find this activity? Did you enjoy the activity?

Column 4 - Learning. How much did you learn from this activity? Did you feel that it helped model the topic for you in a way that helped you learn?

Table 14: Student rating of stochiometry tiered activities

Laboratory Activity	Physically Engaging	Mentally Engaging	Interesting	Learning
Circle the one you completed: • What's the ratio? • Fill it up! • Make it Equal				
Circle the one you completed: • Collecting a Known Mass of Copper • What is Limiting this Reaction?				

Part 3: Additional Comments. Feel free to make any additional comments about the Collins' Chemistry Cuisine Activity Menu for Percent by Mass below.

Appendix W: Parent Consent and Student Assent Form

PARENT CONSENT and STUDENT ASSENT FORM

Analysis of the Effectiveness of Tiered Laboratory Investigations and Activities in Improving Student Comprehension in Chemistry

I am currently enrolled as a graduate student at Michigan State University in the Department of Science and Mathematics Education. For my thesis research, I have developed a couple of units that incorporate the use of tiered labs and activities. This means that all students will be asked to learn and meet the same objective but the means by which they meet this objective will vary. Each student is different and brings to a classroom individual ways of learning and knowing about the world. These activities are designed with this in mind in the hopes of making better thinkers and learners by meeting students at their learning level.

Data for this research study will be collected from pre and post tests, lab activities, and student opinion surveys, all of which is normal class work. I am asking for your permission to include your child's data in my thesis. Their identity will be protected to the maximum extend by law. During this study, I will collect and copy student work. I will not know the identity of those participating in the study until after grades have been posted and report cards have been sent. Participating will have absolutely no affect on your student's grade. Names will be removed from materials prior to use in the study and will be stored in a locked cabinet until my thesis is finished, after which all will be shredded at that time. In addition, your child's identity will not be attached to any data in my thesis paper or any images used in the thesis presentation.

Participation in this study is completely voluntary. Students who do not participate will not be penalized in any way. They will still be performing the same work, their scores and opinions will not be used in my thesis project. You may request that your child's information not be included in this study at any time and your request will be honored. Participation in this study may contribute to determining better methods of incorporating inquiry into chemistry laboratory activities for high school students.

If you are willing to allow your child to participate in this study for Chemistry A, please complete and sign the attached form and return it to Mrs. Betsy Collins by September 10, 2011. Please seal it in the provided envelope with your child's name on the outside of the envelope. The envelopes will be stored in a locked cabinet and opened after the trimester is completed and grades have been assigned.

If you have any questions about the study, please contact me by email at bcollins@mason.k12.mi.us or by phone (517)676-9055 ext. 262. Questions about the study may also be directed to Dr. Merle Heidemann at the Department of Geological Science by email at heidema2@msu.edu, by phone at (517)432-2152, or by mail at 118 North Kedzie, East Lansing, Michigan 48824.

Thank you,

Mrs. Betsy Collins
Chemistry Teacher
Mason High School

I voluntarily agree to allow ______________________________ to participate in this study.
(Print Student Name)

Please check all that apply.

________ I give Mrs. Collins permission to use data generated from my child's work in Chemistry A to be used in the thesis project. I understand that all data from my child will remain confidential.

________ I do not wish to have my child' work used in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of participation in the study.

________ I give Mrs. Collins permission to use pictures of my child during work on this thesis project. My child will not be identified in these pictures.

________ I do not wish to have my child's pictures used at any time during this thesis project.

____ ______________________________

(Parent/Guardian Signature) (Date)

REFERENCES

REFERENCES

Anderson, K. (2007). Tips for teaching differentiating instruction to include all students. *Preventing School Failure, 51*(3), 49-53.

Ashman, F., & Kraayenoord, C. (1998). Educational characteristics of students with high or low self-concept. *Psychology in the Schools, 35*(6), 391-398.

Baglieri, S., & Knopf, J. (2004). Normalizing differences in inclusive teaching. *Journal of Learning Disabilities, 37*(6), 525-529.

Betts, G. (2004). Fostering autonomous learners through levels of differentiation. *Roeper Review*, *26*(4), 190-191.

Cavanagh, S. (2008). States Heeding Calls To Strengthen STEM. Education Week, 27(30), 10, 12-16, 22-3.

Crump, C.A. (1995). *Motivating students: A teacher's challenge.* Norman, OK: Paper presented at the Annual Sooner Communication Conference. (ERIC Document)

DiMartino, J., & Miles, S. (2005). *Reaching equity in schools* [Electronic version]. Education Digest, *70*(3), 9-13.

George, P. S. (2005). A rationale for differentiated instruction in the regular classroom. *Theory into practice, 44*(3), 185-193. (ERIC Document)

Hall, T., Strangman, N. & Meyer A. (2003). *Differentiated instruction and implication for udl implementation*. Wakefield, MA: National Center on Accessing the General Curriculum Retrieved April 3, 2013, from http://www.cast.org/publications/ncac_diffinstructudlhtml

Hughes, L. (1999). Action research and practical inquiry: How can I meet the needs of the high-ability student within my regular education classroom? *Journal for the Education of the Gifted, 22*(3), 282-297.

Mawhinney, T. (2000). Finding the answer. *Principal Leadership, 1*(4), 44-48.

Morelock, M., & Morrison, K. (1999). Differentiating "developmentally appropriate": The multidimensional curriculum model for young gifted children. *RoeperReview*, *21*(3), 195-200.

Patrick, A. O., Kpangban, E., & Chibueze, O. (2007). Motivation Effects on Test Scores of Senior Secondary School Science Students. *Student home Commission on Science*, *1*(1), 57- 64.

Preszler, R.W. 2006. Student- and teacher-centered learning in biology workshops. *Bioscene: Journal of College Biology Teaching* 32: 21-25.

The Connecting Link. (2003). *The differentiated classroom.* Ventura, CA: Author.

Sylwester, R. (2003). A Biological brain in a cultural classroom. Thousand Oaks, CA: Corwin Press.

Tomlinson, C. (1999). *The differentiated classroom: Responding to the needs of all learners.* Alexandria, VA: Association for Supervision and Curriculum Development.

Tomlinson, C. (2001). How to differentiate instruction in mixed-ability classrooms (2nd ed.). Virginia: Association for Supervision and Curriculum Development.

Tomlinson, C. A., Brighton, C., Hertberg, H., Callahan, C. M., Moon, T. R., Brimijoin, K., et al. (2003). Differentiating instruction in response to student readiness, interest, and learning profile in academically diverse classrooms: A review of literature. *Journal for the Education of the Gifted, 27*(2/3), 199-145.

Tomlinson, C. (2006, April). An alternative to ability grouping. *Principal Leadership, 6*(8), 31-32.

VanSciver, J. H. (2005) Motherhood, apple pie, and differentiated instruction. *Phi Delta Kappan, 86,* 534-535.

Wehrmann, K. S. (2000, September). Baby steps: A beginner’s guide. *Educational Leadership, 58,* 19-23.

Willis, S., & Mann, L. (2000). Differentiating Instruction: Finding Manageable Ways to Meet Individual Needs.