

**Subject:** Chemistry  
**Developer Name:** Jody Stone

**Unit Title:** Chemical Reactions: from Atoms to Moles  
**Location:** Price Laboratory School, UNI

**Course Description:**

This is a beginning level, high school chemistry course designed to serve all abilities of students in our school. While some of the activities would be appropriate for a 9<sup>th</sup> grade physical science class in which chemistry is one of the major topics, it is unlikely that the mole concept would be introduced at that level.

**Unit Context:**

This unit is designed to introduce students to chemical change through the basics of balancing chemical equations. The experiences provided in this unit will strengthen student understanding of chemical formulas, conservation of mass and the mole concept. Previous knowledge of the mole concept is required for successful completion and understanding of the experiences presented in this unit. In addition, students will use and strengthen inquiry skills that have been practiced and refined since the beginning of the course. The success of this unit depends to a large extent on the students' abilities and confidence in the laboratory and on their abilities to carry out those skills identified as "inquiry" skills.

**Length of Unit:** 1 – 1 ½ weeks

**Iowa Tests Core Content Standards and Benchmarks**

**Core Content Standards and Benchmarks**

- Students can understand and apply the processes and skills of scientific inquiry.
- Students can draw conclusions, make inferences, and deduce meaning.
- Students can reason quantitatively.
- Students can analyze and interpret scientific information.

**ICC Essential Concepts and Skills**

**Concepts**

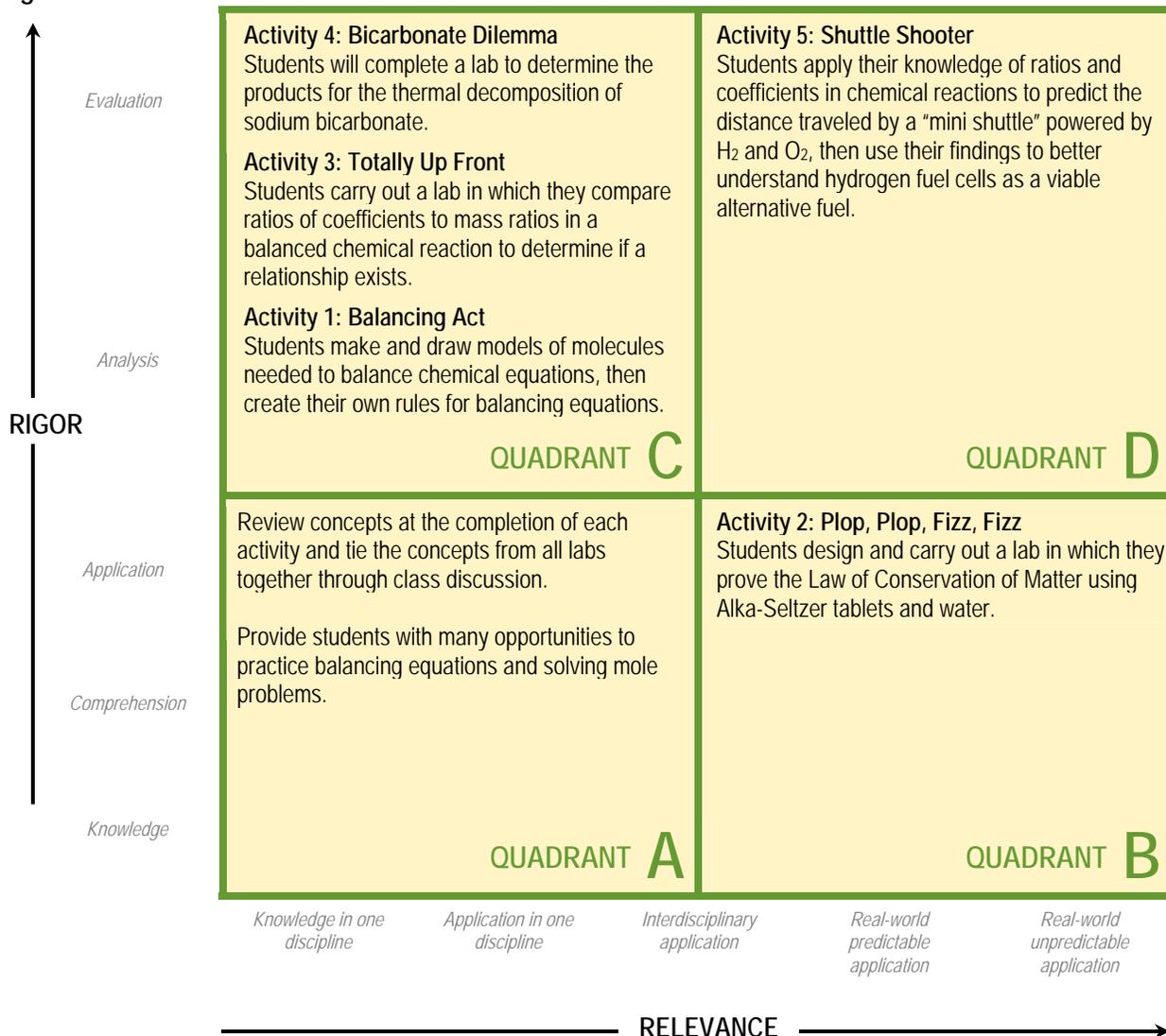
- Understands that atoms may be bonded together into molecules. A compound is formed when two or more kinds of atoms bind together chemically.
- Understands and applies knowledge of chemical reactions.

**Skills**

- Identifies questions and concepts that guide scientific investigations.
- Designs and conducts scientific investigations.
- Uses mathematics to improve investigations and communications.
- Formulates and revises scientific explanations and models using logic and evidence.
- Recognizes and analyzes alternative explanations and models.
- Communicates and defends a scientific argument.

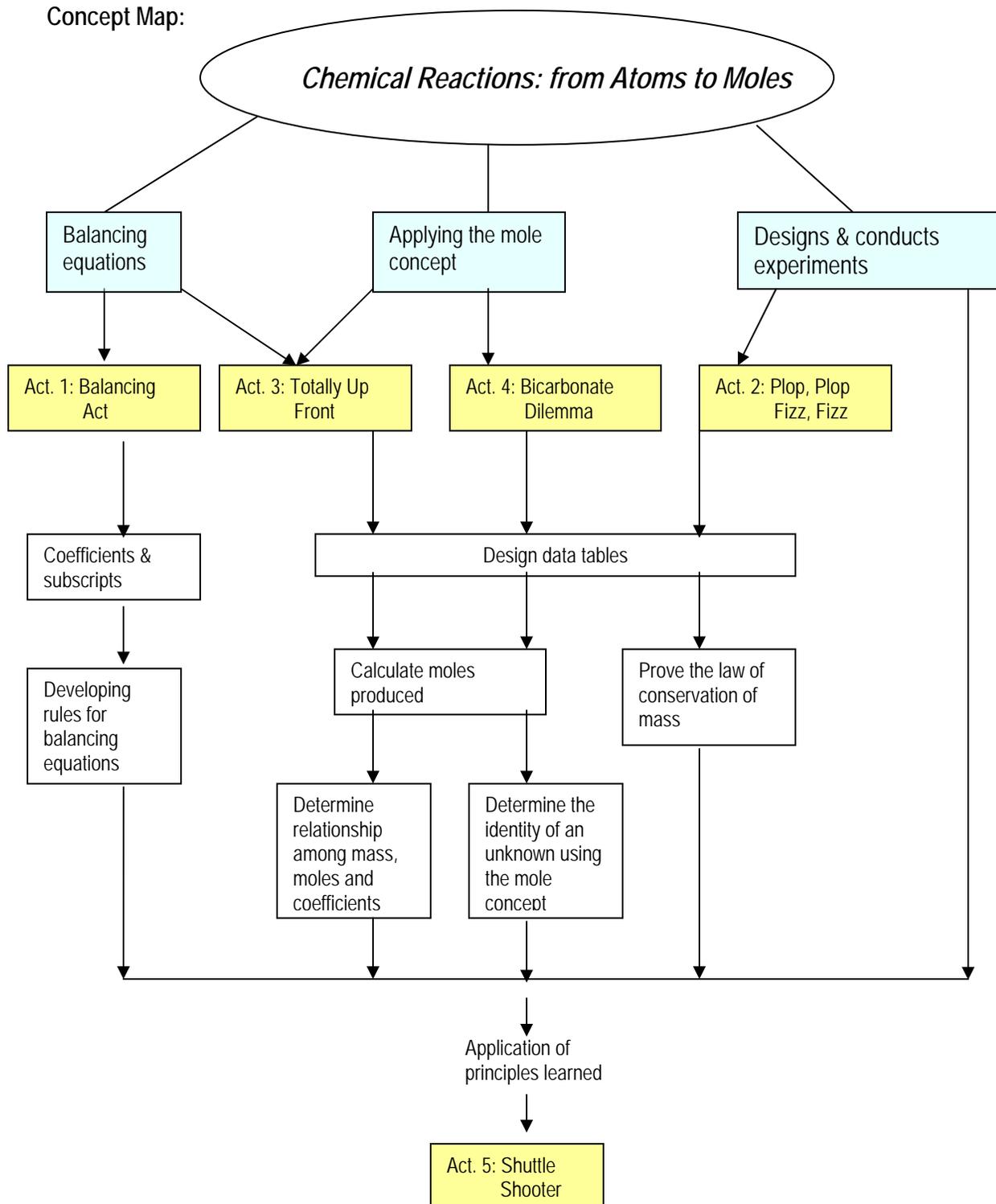
## Big Ideas Addressed in Each Activity

|   |
|---|
| <b>Activity 1: Balancing Act</b>  |
| <ul style="list-style-type: none"><li>◦ In reactions, atoms rearrange to form new molecules. In this process, atoms are not created nor destroyed. The number and kinds of atoms on the product side must be equal to the number and kinds of atoms on the reactant side in a correctly balanced equation.</li><li>◦ There are common approaches to balancing equations which students can develop themselves using skills of analysis and synthesis. Students can develop and apply their own rules for balancing equations.</li></ul> |
| <b>Activity 2: Plop, Plop, Fizz, Fizz</b>   |
| <ul style="list-style-type: none"><li>◦ Mass is always conserved in chemical reactions. By capturing all of the products in a reaction, students can prove the law of conservation of mass.</li></ul>   |
| <b>Activity 3: Totally Up Front</b>   |
| <ul style="list-style-type: none"><li>◦ Ideas from the mole concept can be applied to actual chemical reactions to provide useful information about the reactions. The relationship among mass, moles and the coefficients in a balanced equation can be discovered by knowing the products and reactants in a chemical equation and applying knowledge of the mole concept.</li></ul>  |
| <b>Activity 4: Bicarbonate Dilemma</b>  |
| <ul style="list-style-type: none"><li>◦ Understanding the mole concept and applying that concept to actual chemical reactions makes it possible to select which of a number of possible reactions is actually occurring based on product mass.</li></ul>  |
| <b>Activity 5: Shuttle Shooter</b>  |
| <ul style="list-style-type: none"><li>◦ Designing a well controlled experiment is the key to the development of good problem solving skills and can help students answer real questions.</li><li>◦ Understanding of the mole concept can be applied to situations in order to not only predict the outcome, but to determine the most effective means of producing the “best” products.</li><li>◦ Hydrogen gas is a potential fuel of the future, but has pros and cons that must be understood by the average citizen.</li></ul>       |

**Rigor & Relevance Plot: Chemical Reactions: from Atoms to Moles**


Reference: The activities *Balancing Act*, *Totally Up Front*, *Bicarbonate Dilemma*, *Plop, Plop, Fizz, Fizz*, and *Shuttle Shooter* are from the program entitled **CRISTAL**, edited by Stone at Price Laboratory School, UNI.

Concept Map:



**ACTIVITY 1**


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**Activity 1 Overview: Balancing Act**

|  |   |   |                                     |   |  |                                 |
|--|---|---|-------------------------------------|---|--|---------------------------------|
| <b>Iowa Core Curriculum Essential Skills/Concepts:</b> | <ul style="list-style-type: none"> <li>○ Understands and applies knowledge of chemical reactions.</li> <li>○ Formulates and revises scientific explanations and models using logic and evidence.</li> <li>○ Recognizes and analyzes alternative explanations and models.</li> <li>○ Communicates and defends a scientific argument.</li> </ul>  |   |                                     |   |  |                                 |
| <b>Big Ideas</b>                                       | <ul style="list-style-type: none"> <li>○ Recognizes and analyzes alternative explanations and models.</li> <li>○ In reactions, atoms rearrange to form new molecules. In this process, atoms are not created or destroyed. The number and kinds of atoms on the product side must be equal to the number and kinds of atoms on the reactant side in a correctly balanced equation.</li> <li>○ There are common approaches to balancing equations which students can develop themselves using skills of analysis and synthesis. Students can develop and apply their own rules for balancing equations.</li> </ul> |   |                                     |   |  |                                 |
| <b>Characteristics of Instructional Core</b>           | <input checked="" type="checkbox"/>   | Encourages collaboration in learning      | <input checked="" type="checkbox"/> | Teaches for understanding                       | <input type="checkbox"/>                               | Develops global perspectives    |
|  | <input checked="" type="checkbox"/>   | Student centered                          | <input checked="" type="checkbox"/> | Develops conceptual and/or procedural knowledge | <input type="checkbox"/>                               | Provides authentic learning     |
|  | <input checked="" type="checkbox"/>   | Teaches through problem solving & inquiry | <input checked="" type="checkbox"/> | Assesses for learning                           | <input type="checkbox"/>                               | Incorporates current technology |
| <b>Cognitive Domain</b>                                | <input type="checkbox"/>  | Remembering                               | <input type="checkbox"/>            | Applying  | <input type="checkbox"/>                               | Evaluating                      |
|  | <input checked="" type="checkbox"/>   | Understanding                             | <input checked="" type="checkbox"/> | Analyzing                                       | <input type="checkbox"/>                               | Creating                        |
| <b>Connections to Students' Lives</b>                  | <input checked="" type="checkbox"/>   | Isolated within discipline                | <input type="checkbox"/>            | Connected to other disciplines                  | <input type="checkbox"/>                               | Connected to student lives      |
|  | <input type="checkbox"/>  | Connected within discipline               | <input checked="" type="checkbox"/> | Has value beyond school purposes                | <input type="checkbox"/>                               |                                 |
| <b>Support for Literacy</b>                            | <input type="checkbox"/>  | Using the literacy process for inquiry    |                                     | <input type="checkbox"/>                        | Increasing reading volume                              |                                 |
|  | <input type="checkbox"/>  | Increasing access to print                |                                     | <input type="checkbox"/>                        | Engaging students with texts                           |                                 |
|  | <input checked="" type="checkbox"/>   | Involving students in discussion          |                                     | <input type="checkbox"/>                        | Reading aloud in content areas                         |                                 |
|  | <input type="checkbox"/>  | Increasing reading fluency                |                                     | <input type="checkbox"/>                        | Explicitly instructing in vocabulary and comprehension |                                 |
|  | <input checked="" type="checkbox"/>   | Writing to learn across content areas     |                                     | <input type="checkbox"/>                        |  |                                 |
| <b>Class Time</b>                                      | 1 class period(s)   |   | 45 total minutes                    |   |  |                                 |

**Materials & Set-up:**

ball & stick molecular models, Styrofoam balls & toothpicks, or gum drops & toothpicks  
 colored pencils  
 zip lock baggies

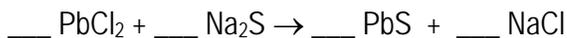
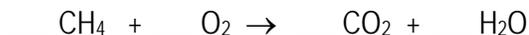
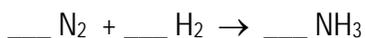
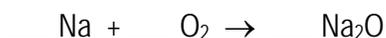
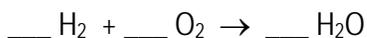
Before class, prepare several copies of each of the six equations that need to be balanced. Do so by writing the unbalanced equation on the front of the baggie and placing the correct number of balls and connectors in each baggie to allow students to prepare a balanced equation without any left over parts.

**Teaching Tips:**

The main idea of this activity is to have the students "physically" balance equations using models and the law of conservation of atoms. This will allow the students to see and manipulate a three dimensional physical model rather than beginning with a sheet of paper containing a list of equations. This activity will address a number of misconceptions students may have regarding balancing equations. To give students a starting point, pose these statements and ask students to indicate which are true and which are false. Once the activity has been completed, ask students to revisit these statements and to use their balanced equations to prove whether each of the statements is true or false:

- \_\_\_ A balanced equation is one with the same number of molecules on the reactants and products side.
- \_\_\_ A balanced equation is one with the same number of atoms on the reactants and products side.
- \_\_\_ In order to balance equations, subscripts in molecules can be changed.
- \_\_\_ In order to balance equations, coefficients in equations can be changed.

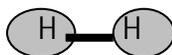
Here is a list of some simple equations for which you might consider constructing models. You may or may not wish to place blanks in front of each symbol to aid students in placing the numbers in the correct spot when balancing.



In this activity, students may struggle with the difference between coefficients and subscripts, for example 2 H as opposed to H<sub>2</sub>. This will become apparent in their drawings of the different chemical reactions. It is important to circulate around the class while students are completing their drawings in order to catch these misconceptions early. Look for student examples in which H<sub>2</sub> is drawn as two separate atoms:



Incorrect representation.  
 This is 2 H, not H<sub>2</sub>



Correct representation  
 This is H<sub>2</sub>

In order to test student generated “rules” for balancing equations, it would be helpful to actually have the students use their rules to teach middle school students to balance equations.

For students who need more practice or a different type of experience, do a web search for “interactive balancing equations.” Many potential sites will emerge. The site entitled “Fun Based Learning” uses a teeter totter design that many students will find helpful.

| Teacher Tasks   | Student Tasks   |
|---|---|
| <ul style="list-style-type: none"> <li>• Pose the 4 statements listed in the teacher tips and ask students to write whether they believe each statement is true or false.</li> </ul>                      | <ul style="list-style-type: none"> <li>• Students write whether each of the four statements supplied by the teacher are true or false and keep their responses for later.</li> </ul>                |
| <ul style="list-style-type: none"> <li>• Provide an example of the procedure to follow in balancing equations.</li> </ul>   | <ul style="list-style-type: none"> <li>• Students work through the example along with the teachers.</li> </ul>  |
| <ul style="list-style-type: none"> <li>• Provide an example of how to draw the equation.</li> </ul>   | <ul style="list-style-type: none"> <li>• Students draw the example problem.</li> </ul>  |
| <ul style="list-style-type: none"> <li>• Provide students with materials to complete 3-6 equations with partners.</li> </ul>  | <ul style="list-style-type: none"> <li>• Students manipulate the materials, building the models needed to correctly balance the equations. Sketches are made of each completed equation.</li> </ul> |
| <ul style="list-style-type: none"> <li>• Circulate around to each group checking on progress and asking probing questions. Makes sure both the balancing and the drawings are being completed.</li> </ul> |   |
| <ul style="list-style-type: none"> <li>• Direct students to complete the <i>Summing Up</i> questions.</li> </ul>  | <ul style="list-style-type: none"> <li>• Complete the <i>Summing Up</i> questions.</li> </ul>   |
| <ul style="list-style-type: none"> <li>• Locate areas of confusion for individual students by reading their responses.</li> </ul>   | <ul style="list-style-type: none"> <li>• Make corrections to <i>Summing Up</i> questions based on teacher feedback.</li> </ul>  |

### Differentiation Tasks

#### Less-Than-Proficient

**Prioritized vocabulary, skills, concepts:** atoms, molecules, coefficient, balanced, distributive property, reactants, products, multiplying/adding up atoms on each side of a reaction equation.

#### **Suggestions for supplemental instruction**

- It is a good idea to provide students with manipulatives such as colored pencils (that match the model colors) as this will help them keep the atoms straight.
- Prepare a number of more simplistic sets of materials for students having difficulty.
- For students who need more practice or a different type of experience, do a web search for “interactive balancing equations.” Many potential sites will emerge. The site entitled “Fun Based Learning” uses a teeter totter design that many students will find helpful.
- Use strategic partnerships by placing students who are at similar levels of understanding together. When one student easily understands while the other does not, both students tend to proceed even though understanding has not been achieved.

- Some students may need calculators to double check their mental math.

### Highly Proficient

#### Suggestions for supplemental instruction

- Prepare a number of more challenging sets of equations for students who complete their models early.
- Pretest to identify students who do not need the concrete manipulative models to understand this big idea.
- Challenge students to prove that mass is conserved in these balanced equations, but not in the unbalanced ones. (Weighing the models will reinforce conservation of mass.)

### Assessment:

#### *Formative Assessments:*

- Monitoring student engagement throughout the activity makes active involvement an explicit part of the assessment.
- In addition, provide ongoing guidance and feedback to individual students as points of confusion are observed. Asking probing questions, even to those students who appear to have a strong understanding of the concepts being taught, will help strengthen understanding. For example, check student sketches as they progress through the different equations. Some students may be connecting all atoms together, even if they represent different molecules. It helps to build a model of exactly what students have sketched. This will clearly illustrate the difference between having two separate molecules and one big one.

#### *Summative Assessments*

- Student responses to the *Summing Up* questions serve as the assessment for this activity. It is best to allow students the opportunity to make corrections to any incorrect or weakly formulated *Summing Up* answers where necessary. They will receive teacher guidance on this, but may also prefer to work with a partner in trying to make their corrections.
- Sample Answers to Summing Up:
  1. Student answers will vary depending on the number and kind of reactions given. Make certain that student sketches are accurate in terms of numbers of atoms/molecules and that they distinguish, via their drawings, between atoms and molecules.
  2. Sample Answers:
 

|   |  |
|---|--|
| $\underline{2} \text{H}_2 + \text{O}_2 \rightarrow \underline{2} \text{H}_2\text{O}$          | $\text{PbCl}_2 + \text{Na}_2\text{S} \rightarrow \underline{1} \text{PbS} + \underline{2} \text{NaCl}$ |
| $\text{N}_2 + \underline{3} \text{H}_2 \rightarrow \underline{2} \text{NH}_3$                 | $\underline{4} \text{Na} + \text{O}_2 \rightarrow \underline{2} \text{Na}_2\text{O}$                   |
| $\underline{2} \text{KClO}_3 \rightarrow \underline{2} \text{KCl} + \underline{3} \text{O}_2$ | $\text{CH}_4 + \underline{2} \text{O}_2 \rightarrow \text{CO}_2 + \underline{2} \text{H}_2\text{O}$    |
  3. The number of atoms is conserved in a balanced chemical equation. For example, there are four atoms of sodium and two atoms of oxygen in the equation shown above. However, while there are two molecules of products, there are not two molecules on the reactants side.

4. Student guidelines will vary, but should include all of the terms listed in the question. They should also include ideas such as the number of atoms on the reactants side of the equation must be equal to the number of atoms on the products side of the equation. Atoms rearrange to form new molecules, but do so without creating or destroying any atoms. The number of atoms on the products and reactants side of the equation can be equalized by adding whole numbers in front of each molecule or atom, but formulas may not be changed. This means that no subscripts may be altered, but coefficients may be added in front of the atoms and molecules.
- o Give students the 4 statements to which they responded earlier and once again ask them to indicate whether each statement is true or false. This time ask students to back up their responses with data from the equations they balanced. This data should either prove each statement true or false.

**Reflect:**

This activity seemed somewhat chaotic in its first few minutes as students were floundering with how to start. In my next section, I presented one example, that was different from the equations students would be solving, demonstrating how to approach the problem and how a sketch of the reaction would look. This helped clear up this initial confusion without giving students too much information. It is important that the teacher be constantly on the move from one group to another, as the best time to address points of confusion is while students are working with the models, not after they have completed the assignment.

The addition of the 4 true or false statements which students respond to both before and after this activity elevate the activity to a new level by forcing students to confront common misconceptions with the actual data from their experiments.

**Attachments: (Student Handout)**

Problem: What does it mean to say that an equation is "balanced"?

Materials: Baggies containing molecular models  
Colored pencils

Procedure:

A chemical equation is a statement representing microscale events which are not directly observable due to the extremely small size of atoms and molecules. Chemical equations use symbols to represent the atoms and/or molecules that react and the atoms and/or molecules that are formed in a chemical change.

Two major components within an equation are the reactants and the products. The reactants are those chemicals that react and the products are those chemicals that are produced. Symbolically, the reactants and products are separated by an arrow. The arrow is used to mean "produced" or "yields" and points in the direction of the change that occurs (from reactants to products).

### Reactants → Products

When writing symbols representing reactants and products, the equation for the reaction must be balanced to show that mass is conserved. There are six baggies containing balls representing the atoms in the chemical reaction written on the front of the baggie. Your job is to "balance" these written equations by using the models provided. Your models must match the equation written on each baggie. When the equation is balanced, there should be no leftovers. Keep accurate notes as you go from one station to the next. You should read through the "Summing Up" questions before beginning so you know what information you need to keep track of.

Summing Up:

1. For each of the balanced equations constructed, sketch all of the molecules and/or atoms used.
2. From the sketches made, write balanced equations with symbols. Indicate the numbers of molecules and atoms needed by placing whole numbers in front of the symbols.
3. Study your balanced equation. Are both the number of atoms and the number of molecules conserved in each of the equations? Explain your answer.
4. Write a list of guidelines you can use to balance equations. Use each of these terms in a meaningful way in your guidelines: equation, molecule, atom, subscript, coefficient, products, reactants, and balanced.

## ACTIVITY 2

### Activity 2 Overview: Plop, Plop, Fizz, Fizz

|  |   |   |                                     |   |  |                                 |
|--|---|---|-------------------------------------|---|--|---------------------------------|
| <b>Iowa Core Curriculum Essential Skills/Concepts:</b> | <ul style="list-style-type: none"> <li>○ Understands and applies knowledge of chemical reactions</li> <li>○ Designs and conducts scientific investigations</li> <li>○ Formulates and revises scientific explanations and models using logic and evidence</li> </ul> |   |                                     |   |  |                                 |
| <b>Big Ideas</b>                                       | <ul style="list-style-type: none"> <li>○ Designs and conducts scientific investigations. Mass is always conserved in chemical reactions. By capturing all of the products in a reaction, students can prove the law of conservation of mass.</li> </ul>             |   |                                     |   |  |                                 |
| <b>Characteristics of Instructional Core</b>           | <input checked="" type="checkbox"/>   | Encourages collaboration in learning      | <input checked="" type="checkbox"/> | Teaches for understanding                       | <input type="checkbox"/>                               | Develops global perspectives    |
|  | <input checked="" type="checkbox"/>   | Student centered                          | <input checked="" type="checkbox"/> | Develops conceptual and/or procedural knowledge | <input checked="" type="checkbox"/>                    | Provides authentic learning     |
|  | <input checked="" type="checkbox"/>   | Teaches through problem solving & inquiry | <input checked="" type="checkbox"/> | Assesses for learning                           | <input type="checkbox"/>                               | Incorporates current technology |
| <b>Cognitive Domain</b>                                | <input type="checkbox"/>  | Remembering                               | <input checked="" type="checkbox"/> | Applying  | <input type="checkbox"/>                               | Evaluating                      |
|  | <input checked="" type="checkbox"/>   | Understanding                             | <input checked="" type="checkbox"/> | Analyzing                                       | <input type="checkbox"/>                               | Creating                        |
| <b>Connections to Students' Lives</b>                  | <input type="checkbox"/>  | Isolated within discipline                | <input type="checkbox"/>            | Connected to other disciplines                  | <input type="checkbox"/>                               | Connected to student lives      |
|  | <input checked="" type="checkbox"/>   | Connected within discipline               | <input checked="" type="checkbox"/> | Has value beyond school purposes                | <input type="checkbox"/>                               |                                 |
| <b>Support for Literacy</b>                            | <input checked="" type="checkbox"/>   | Using the literacy process for inquiry    |                                     | <input type="checkbox"/>                        | Increasing reading volume                              |                                 |
|  | <input type="checkbox"/>  | Increasing access to print                |                                     | <input type="checkbox"/>                        | Engaging students with texts                           |                                 |
|  | <input checked="" type="checkbox"/>   | Involving students in discussion          |                                     | <input type="checkbox"/>                        | Reading aloud in content areas                         |                                 |
|  | <input type="checkbox"/>  | Increasing reading fluency                |                                     | <input type="checkbox"/>                        | Explicitly instructing in vocabulary and comprehension |                                 |
|  | <input type="checkbox"/>  | Writing to learn across content areas     |                                     | <input type="checkbox"/>                        |  |                                 |
| <b>Class Time</b>                                      | 1 class period  |   | 45 total minutes                    |   |  |                                 |

#### Materials & Set-up:

effervescent medication (Alka-Seltzer tablets)  
 common lab equipment and metric scales  
 rubber tubing

Ziploc baggies  
 balloons

#### Teaching Tips:

Successfully completing this lab requires a combination of good data collection skills and problem-solving skills. By working in pairs, students can collaborate in brainstorming ideas for how to capture all of the gas produced as the Alka-Seltzer tablet dissolves. Resist the urge to give students hints on how to proceed. This is a lab that can be easily redone by students in order to improve their results and more effectively learn proper lab techniques.

| Teacher Tasks  | Student Tasks   |
|--|---|
| <ul style="list-style-type: none"> <li>Set up the scenario by asking for ideas on the Law of Conservation of Matter &amp; gauging student knowledge about Alka-Seltzer.</li> </ul>   | <ul style="list-style-type: none"> <li>Working in pairs, students brainstorm the problem, thinking about data they will need to collect and how they might effectively contain all of the gas produced in this reaction.</li> </ul> |
| <ul style="list-style-type: none"> <li>Provide students materials they request for their individual designs.</li> </ul>  | <ul style="list-style-type: none"> <li>Prepare a data table and list of final procedures.</li> </ul>  |
| <ul style="list-style-type: none"> <li>Circulate around to each group checking on progress and asking probing questions.</li> </ul>  | <ul style="list-style-type: none"> <li>Collect materials and begin collecting data. Evaluate the effectiveness of their design, make modifications and redo if necessary.</li> </ul>  |
| <ul style="list-style-type: none"> <li>Direct students to complete the <i>Summing Up</i> questions.</li> </ul>   | <ul style="list-style-type: none"> <li>Answer the <i>Summing Up</i> questions.</li> </ul>   |
| <ul style="list-style-type: none"> <li>Locate areas of confusion for individual students by reading their responses.</li> </ul>  | <ul style="list-style-type: none"> <li>Make corrections to <i>Summing Up</i> questions based on teacher feedback.</li> </ul>  |
| Differentiation Tasks  |   |
| <p><b><u>Less-Than-Proficient</u></b><br/> <b>Prioritized vocabulary, skills, concepts:</b> reactants, products, concept of controlling variables.<br/> <b>Suggestions for supplemental instruction</b></p> <ul style="list-style-type: none"> <li>Some students may need assistance in deciding how to design their experiment. This can be addressed by helping them focus in on what data they will need to collect. Ask probing questions such as: "What do you need to get the Alka-Seltzer to react?" "How can you tell a chemical reaction is occurring?" "Are the bubbles part of the reaction?" "Do you think you will need to weigh the bubbles?" How might you weigh bubbles?" Or, such questions may be captured in a scaffold or graphic organizer.</li> <li>Some students may need more explicit scaffolding than verbal questioning: their experimental design can be scaffolded to some extent with guiding questions and cloze procedures.</li> <li>If co-teaching, have both teachers circulating and monitoring student progress.</li> </ul> <p><b><u>Highly Proficient</u></b><br/> <b>Suggestions for supplemental instruction</b></p> <ul style="list-style-type: none"> <li>Challenge students to devise procedures that will result in this reaction occurring in a totally enclosed reaction chamber.</li> <li>Challenge students to devise and carry out an experiment that will allow them to determine the mass and volume of gas produced by a single tablet.</li> <li>Challenge students to devise and carry out an experiment that will quantitatively determine the relationship between the rate of the Alka-Seltzer/water reaction and the temperature of the water.</li> <li>Challenge students to prove mass is conserved in a more complicated reaction such as the reaction between citric acid (<math>\text{H}_3\text{C}_6\text{H}_5\text{O}_7</math>) and baking soda (<math>\text{NaHCO}_3</math>). The reaction can only occur in the presence of water. The reaction produces a gas (<math>\text{CO}_2</math>) and the compound sodium citrate (<math>\text{Na}_3\text{C}_6\text{H}_5\text{O}_7</math>).</li> </ul> |   |

### Assessment:

#### *Formative Assessments:*

- Once again, monitor student engagement throughout the activity to make active involvement an explicit part of the assessment.
- Provide ongoing guidance and feedback to individual students as points of confusion are observed. Asking probing questions, even to those students who appear to have a strong understanding of the concepts being taught, will help strengthen understanding. Addressing points of confusion related to performing mole calculations early in this activity will help to ensure that students don't get overwhelmed by this difficult concept.

#### *Summative Assessments*

- Student responses to the Summing Up questions serve as the assessment for this activity. It is best to allow students the opportunity to make corrections to any incorrect or weakly formulated Summing Up answers where necessary. They will receive teacher guidance on this, but may also prefer to work with a partner in trying to make their corrections. In addition, students will be using ideas from this activity as they complete the final lesson for this unit and should be assessed on their grasp of the ideas of conservation of mass at that time as well.

#### Sample Answers to Summing Up Questions:

- Procedures should include how to capture the gas and find the mass before and after the reaction.
- Problems probably involved capturing the gas.
- The gas produced can be tested using a lighted splint. If the gas is hydrogen, it will pop. If it is oxygen, it will flame up and if it is carbon Dioxide, the flame will flare up.
- Gas was likely to have escaped at the beginning of the lab when the tablet was first added, but before the "container" was sealed.
- Students are likely to focus their responses on finding a better way to prevent any gas from escaping once the reactants are mixed. One suggestion they may make is to place the tablet into some type of container that can be added to the vinegar once the bag is sealed.
- From "Balancing Act" and "Plop, Plop, Fizz, Fizz", students' results will show the Law of Conservation of Matter is upheld and from there they should conclude all reactions will follow the same pattern.

### Reflect:

As students were working in groups to design their experiments, they were initially focused on "capturing the bubbles" and did not consider basic items such as weighing the starting materials. When starting materials were weighed, in several instances, students did not bother to mass the water. Their focus was on the disappearing tablet, so they ignored the tablet. Rather than pointing out these errors to students, it was better to have additional tablets available to allow students to redo the experiment. The learning was greatly increased in those students who redesigned their first attempts and carried out the lab a second time.

### Attachments:

**Student Handout**


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**Plop, Plop, Fizz, Fizz**


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**Problem:**

How do chemical reactions support the Law of Conservation of Matter?

**Materials:**

effervescent tablets

common lab equipment

**Procedure:**

Devise a method to determine if the reaction between an effervescent tablet and water supports the Law of Conservation of Matter. Decide what data you will need to collect and construct a data table in which to record this information. Also, find a way to prove the identity of the gas produced. Carry out your experiment.

**Summing Up:**

1. Explain the procedure you used to complete the task.
2. Describe any problems you encountered in carrying out your experiment.
3. How did you prove what type of gas was produced? What was the identity of the gas?
4. Do you believe that any gas was able to escape during this experiment? If so, at what point?
5. How do you think this experiment can be improved? Be specific.
6. From your experiences with this lab, is the Law of Conservation of Matter upheld by all reactions? Provide numerical evidence.

**ACTIVITY 3**


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**Activity 3 Overview: Totally Up Front**

|  |  |                                      |                                     |   |                                     |                                 |
|--|--|--------------------------------------|-------------------------------------|---|-------------------------------------|---------------------------------|
| <b>Iowa Core Curriculum Essential Skills/Concepts:</b> | <ul style="list-style-type: none"> <li>○ Understands and applies knowledge of chemical reactions</li> <li>○ Uses technology and mathematics to improve investigations and communications</li> <li>○ Communicates and defends a scientific argument</li> </ul>  |                                      |                                     |   |                                     |                                 |
| <b>Big Ideas</b>                                       | <ul style="list-style-type: none"> <li>○ Ideas from the mole concept can be applied to actual chemical reactions to provide useful information about the reactions. The relationship among mass, moles and the coefficients in a balanced equation can be discovered by knowing the products and reactants in a chemical equation and applying knowledge of the mole concept.</li> </ul> |                                      |                                     |   |                                     |                                 |
| <b>Characteristics of Instructional Core</b>           | <input checked="" type="checkbox"/>  | Encourages collaboration in learning | <input checked="" type="checkbox"/> | Teaches for understanding                       | <input type="checkbox"/>            | Develops global perspectives    |
|  | <input checked="" type="checkbox"/>  | Student centered                     | <input checked="" type="checkbox"/> | Develops conceptual and/or procedural knowledge | <input checked="" type="checkbox"/> | Provides authentic learning     |
|  | <input checked="" type="checkbox"/>  | Teaches through problem solving &    | <input checked="" type="checkbox"/> | Assesses for learning                           | <input type="checkbox"/>            | Incorporates current technology |

|                                       |                                       |  |   |                                  |  |
|---------------------------------------|---------------------------------------|--|---|----------------------------------|--|
|                                       |                                       | inquiry                                |   |                                  |  |
| <b>Cognitive Domain</b>               |                                       | Remembering                            | X | Applying                         | X  |
|                                       | X                                     | Understanding                          | X | Analyzing                        |  |
| <b>Connections to Students' Lives</b> | X                                     | Isolated within discipline             |   | Connected to other disciplines   |  |
|                                       |                                       | Connected within discipline            |   | Has value beyond school purposes |  |
| <b>Support for Literacy</b>           | X                                     | Using the literacy process for inquiry |   |                                  | Increasing reading volume                              |
|                                       |                                       | Increasing access to print             |   |                                  | Engaging students with texts                           |
|                                       | X                                     | Involving students in discussion       |   |                                  | Reading aloud in content areas                         |
|                                       |                                       | Increasing reading fluency             |   |                                  | Explicitly instructing in vocabulary and comprehension |
| X                                     | Writing to learn across content areas |  |   |                                  |  |
| <b>Class Time</b>                     |                                       | 1 class period                         |   | 45 total minutes                 |  |

**Materials & Set-up:**

|  |               |
|--|---------------|
| metric balance                             | Bunsen burner |
| watch glass                                | tongs         |
| magnesium strips (about 20 cm per student) | sand paper    |

**Hazard Warning:**

Have students wear safety goggles during the burning process. Caution students not to look directly at the burning magnesium, as the bright light can damage the retina. Also caution students to not touch the magnesium ash, as it will be extremely hot.

**Teaching Tips:**

This laboratory requires that students have prior knowledge of the mole and abilities to complete mole calculations. Make certain that this activity is placed at a developmentally appropriate place in the year. Students should be required to make a data table and record their measurements as they are taken.

It is important that any oxidized MgO be removed from the starting strip of Mg before burning. This can be accomplished using sand paper on the surface of the Mg until it is shiny. Students need to hold the burning Mg several cm above the empty watch glass in case some of the ash falls while the Mg is still burning. All burned ash should be placed directly on the watch glass for massing. Remind students to check for unreacted Mg on the tongs. This can either be repositioned and burned, or weighed and subtracted from the starting mass of Mg. The results of the lab should be the starting point for a discussion of mass-mass stoichiometry. You may want to have students use the blackboard to share their data with the entire class.

**Sample Data**

Mass of watch glass = 43.184 g  
 Mass of Mg = 0.347 g  
 Mass of watch glass and MgO = 43.407 g  
 Mass of MgO = 0.256 g

For students in need of a greater challenge, a similar experiment may be carried out using anhydrous sodium carbonate. Challenge students to consult references to determine the chemical formula of the products formed when the sodium carbonate decomposes upon heating.

| Teacher Tasks   | Student Tasks  |
|---|--|
| <ul style="list-style-type: none"> <li>Set the stage by posing some general questions: "Do you think there is a relationship between the mass of the reactants and products in a balanced equation and the coefficients in the balanced equation?" "What might that relationship be?"</li> </ul>  | <ul style="list-style-type: none"> <li>Working in pairs, students prepare an appropriate data table.</li> </ul>              |
| <ul style="list-style-type: none"> <li>Review safety.</li> </ul>  |  |
| <ul style="list-style-type: none"> <li>Circulate around to each group checking on progress and asking probing questions.</li> </ul>   | <ul style="list-style-type: none"> <li>Students carry out the lab.</li> </ul>  |
| <ul style="list-style-type: none"> <li>Direct students to complete the <i>Summing Up</i> questions.</li> </ul>  | <ul style="list-style-type: none"> <li>Answer the <i>Summing Up</i> questions.</li> </ul>                                    |
| <ul style="list-style-type: none"> <li>Locate areas of confusion for individual students by reading their responses.</li> </ul>   | <ul style="list-style-type: none"> <li>Make corrections to <i>Summing Up</i> questions based on teacher feedback.</li> </ul> |
| Differentiation Tasks   |  |
| <p><b><u>Prioritized vocabulary, skills, concepts:</u></b> atoms, molecules, moles, mass, products, reactants</p> <p><b><u>Suggestions for supplemental instruction</u></b></p> <ul style="list-style-type: none"> <li>Some students will have undue difficulty deciding what data to record and will need assistance preparing a data table. Prepare a data table template to give to some students to ease this process.</li> <li>Some students may have difficulty with the calculations. Providing the units in equation format, then having students insert their data will help ease this process. Only supply this additional support when necessary.</li> </ul> <p><b><u>Highly Proficient</u></b></p> <p><b><u>Suggestions for supplemental instruction</u></b></p> <ul style="list-style-type: none"> <li>For students in need of a greater challenge, a similar experiment may be carried out using anhydrous sodium carbonate.</li> </ul> |  |

### Assessment:

#### *Formative Assessments:*

- Provide ongoing guidance and feedback to individual students as points of confusion are observed throughout the activity. Asking probing questions, even to those students who appear to have a strong understanding of the concepts being taught to stretch student understanding.
- In addition, monitoring student engagement throughout the activity to ensure that active student involvement is an explicit part of the assessment.

#### *Summative Assessments*

- Student responses to the *Summing Up* questions serve as the assessment for this activity. It is best to allow students the opportunity to make corrections to any incorrect or weakly formulated *Summing Up* answers where necessary.
- The ideas from the mole concept should also be assessed through some sort of final exam, in addition to the final activity, as students need practice with traditional assessments which they will likely to be given in college science courses.
- Sample Answers to Summing Up Questions:
  1. The balanced equation for the reaction is:  

$$\text{Mg (s)} + \text{O}_2 \text{ (g)} \rightarrow \text{MgO (s)}$$
  2. Moles of Mg used =  $\frac{0.347 \text{ g Mg}}{24.3 \text{ g/mole}} = 0.0143 \text{ moles Mg}$   
 Moles of MgO produced =  $\frac{0.550 \text{ g MgO}}{40.3 \text{ g/mole}} = 0.0136 \text{ moles MgO}$
  3. The ratio of the coefficients of Mg:MgO is 1:1 in the balanced equation, while the ratio of the masses is 0.347:0.550 or about 1:2. These ratios are different.
  4. The ratio of the coefficients of Mg:MgO is 1:1 in the balanced equation, while the ratio of their moles is 0.0143 to 0.0136 or about 1:1. These ratios are the same.
  5. In a balanced chemical equation, the coefficients signify the number of moles in the reaction. There is no relationship between the coefficients in a balanced equation and the masses of the reactants and products.

**Reflect:**

This is an important lab in this sequence because it directly addresses a common misconception that students have: that the masses of the reactants are somehow equivalent to the coefficients in a balanced equation. However, it is also possible for students to complete the lab and not really make this connection. This is why teacher questioning is vital throughout this lab. Give students a chance to make corrections on their *Summing Up* questions or a thorough understanding will not be achieved.

**Attachments:**

*Student Page/Handout***Totally Up Front**Problem:

How does the ratio of masses of substances in a chemical reaction compare with the ratio of their coefficients in a balanced equation?

Materials:

|                |                  |
|----------------|------------------|
| metric balance | Bunsen burner    |
| watch glass    | magnesium ribbon |
| sand paper     | tongs            |

Hazard Warning:

Wear safety goggles while burning the Mg and do not look directly at the bright flame as it can damage your retina. Do not touch the ash produced from burning the Mg, as it may be extremely hot.

Procedure:

Before beginning, read through the entire procedure. You will be completely burning a piece of magnesium ribbon to collect data that will allow you to explore the relationship between the masses of reactants and products, the moles of reactants and products, and the coefficients used in balancing equations. By burning a shiny piece of Mg ribbon catching the ashes on a watch glass you can gather data about the mass of one of the reactants and of the products. To burn the Mg, you will need a strip of Mg that has all oxides removed from the outside. To do this, sand a piece of Mg that is about 20 cm in length. Coil the Mg ribbon before burning it, but keep all surfaces exposed to air. Light the Mg using a Bunsen burner, then hold the burning strip a few cm above a watch glass. Collect the ash on the watch glass. Do not touch any of the ash or place your hand near the burning Mg, as it will cause a severe burn. Decide what data you will need to collect and make your data table.

Summing Up:

1. Write a balanced equation for the burning of magnesium.
2. From their masses, determine the number of moles of Mg and MgO. Hint: use your periodic table. Show your calculations.
3. How does the ratio of the coefficients of Mg to MgO in the balanced equation compare with the ratio of their masses?
4. How does the ratio of the coefficients of Mg to MgO compare with the ratio of their moles?
5. How do you explain the differences in the ratio in #3 above compared to the ratio in #4?

**GOGGLES**

**ACTIVITY 4**
**Activity 4 Overview: Bicarbonate Dilemma**

|  |   |   |                  |  |   |                                 |
|--|---|---|------------------|--|---|---------------------------------|
| <b>Iowa Core Curriculum Essential Skills/Concepts:</b> | <ul style="list-style-type: none"> <li>○ Understands and applies knowledge of chemical reactions</li> <li>○ Uses technology and mathematics to improve investigations and communications</li> <li>○ Formulates and revises scientific explanations and models using logic and evidence</li> <li>○ Communicates and defends a scientific argument</li> </ul> |   |                  |  |   |                                 |
| <b>Big Ideas</b>                                       | <ul style="list-style-type: none"> <li>○ Understanding the mole concept and applying that concept to actual chemical reactions makes it possible to select which of a number of possible reactions is actually occurring based on product mass.</li> </ul>  |   |                  |  |   |                                 |
| <b>Characteristics of Instructional Core</b>           | X   | Encourages collaboration in learning      | X                | Teaches for understanding                              | □ | Develops global perspectives    |
|  | X   | Student centered                          | X                | Develops conceptual and/or procedural knowledge        | X | Provides authentic learning     |
|  | X   | Teaches through problem solving & inquiry | X                | Assesses for learning                                  | □ | Incorporates current technology |
| <b>Cognitive Domain</b>                                | □   | Remembering                               | X                | Applying   | □ | Evaluating                      |
|  | X   | Understanding                             | X                | Analyzing  | □ | Creating                        |
| <b>Connections to Students' Lives</b>                  | X   | Isolated within discipline                | □                | Connected to other disciplines                         | □ | Connected to student lives      |
|  | □   | Connected within discipline               | X                | Has value beyond school purposes                       | □ |                                 |
| <b>Support for Literacy</b>                            | X   | Using the literacy process for inquiry    | □                | Increasing reading volume                              |   |                                 |
|  | □   | Increasing access to print                | □                | Engaging students with texts                           |   |                                 |
|  | X   | Involving students in discussion          | □                | Reading aloud in content areas                         |   |                                 |
|  | □   | Increasing reading fluency                | □                | Explicitly instructing in vocabulary and comprehension |   |                                 |
| <b>Class Time</b>                                      | 1 class period  |   | 45 total minutes |  |   |                                 |

**Materials & Set-up:**

crucibles

Bunsen burner

metric balance

ring and stand

sodium bicarbonate (solid)

**Teaching Tips:**

Require students to construct a data table prior to beginning the actual experimenting. It would be quite appropriate to assist students with the laboratory apparatus, but please keep in mind that the purpose of the experiment is to place students in a situation where the use of stoichiometry is required to solve the problem. Don't give them too many hints on the mathematics involved. During the experiment you might

want to ask students the questions: "How do you know when the reaction is done?" "Can this be done by observation or by measurement?" "How can you tell a reaction is occurring?" This would be an excellent time to remind students about heating to a constant mass and about the fact that not all chemical reactions undergo a visible change. It is important that you stress the importance of measuring accuracy in this lab. The best results can be obtained using electronic balances that mass to the 0.001 place.

**Sample Data:**

|   |                        |
|---|------------------------|
| Mass of crucible:                               | 17.553 grams           |
| Initial mass of crucible & NaHCO <sub>3</sub> : | 20.946 grams           |
| Mass of NaHCO <sub>3</sub> :                    | 3.393 grams            |
| Final mass of crucible & product:               | 19.669 g (1st massing) |
| Final mass of crucible & product:               | 19.669 g (2nd massing) |
| Mass of product:                                | 2.116 grams            |

| Teacher Tasks  | Student Tasks  |
|--|--|
| <ul style="list-style-type: none"> <li>Set the stage by talking about the smell of baking cookies and asking which chemical is responsible for cakes &amp; cookies rising. Present the possible products for this decomposition reaction.</li> </ul> | <ul style="list-style-type: none"> <li>Students take part in the initial discussion to see what knowledge they have about this topic.</li> </ul> |
| <ul style="list-style-type: none"> <li>Review safety.</li> </ul>   | <ul style="list-style-type: none"> <li>Students wear safety goggles while Bunsen burners are lit.</li> </ul>                                     |
| <ul style="list-style-type: none"> <li>Remind students to construct their data table prior to collecting data.</li> </ul>  |  |
| <ul style="list-style-type: none"> <li>Circulate around to each group checking on progress and asking probing questions.</li> </ul>  | <ul style="list-style-type: none"> <li>Students carry out the lab by getting out their own materials and setting them up properly.</li> </ul>    |
| <ul style="list-style-type: none"> <li>Direct students to complete the <i>Summing Up</i> questions.</li> </ul>   | <ul style="list-style-type: none"> <li>Answer the <i>Summing Up</i> questions.</li> </ul>  |
| <ul style="list-style-type: none"> <li>Locate areas of confusion for individual students by reading their responses.</li> </ul>  | <ul style="list-style-type: none"> <li>Make corrections to <i>Summing Up</i> questions based on teacher feedback.</li> </ul>                     |

**Differentiation Tasks**

**Prioritized vocabulary, skills, concepts:** atoms, molecules, moles, mass, products, reactants.

**Suggestions for supplemental instruction**

- Some students will have difficulty deciding what data to record and will need assistance preparing a data table. Prepare a data table template to give students to ease this process.
- Some students may have difficulty with the calculations. Providing the units in equation format, then having students insert their data will help ease this process. Only supply this additional support when necessary.
- Have calculators available for all students.

**Highly Proficient**
**Suggestions for supplemental instruction**

- Challenge students to determine how many moles are in a number of common substances such as a

sugar cube or a piece of chalk. They could even determine the number of moles of  $\text{CaCO}_3$  in their name by writing it with chalk of a chalkboard.

### Assessment:

#### *Formative Assessments:*

- Provide ongoing guidance and feedback to individual students as points of confusion are observed throughout the activity. This is especially true while students are working on the calculations for this lab. Asking probing questions, even to those students who appear to have a strong understanding of the concepts being taught will stretch student understanding.

#### *Summative Assessments*

- Student responses to the *Summing Up* questions serve as the assessment for this activity. It is best to allow students the opportunity to make corrections to any incorrect or weakly formulated Summing Up answers where necessary. Students' abilities in performing mole calculation should also be assessed through some sort of final exam, in addition to the final activity, as students need practice with traditional assessments which they are likely to be given in college science courses.

- Sample Answers to Summing Up:

1. You could tell that a chemical reaction was occurring because the mass of the substance was decreasing.
2. The reaction was completed when the mass remained constant after repeated massings.
3. Balanced equations:
  - a.  $\text{NaHCO}_3(\text{s}) \rightarrow \text{NaOH}(\text{s}) + \text{CO}_2(\text{g})$
  - b.  $\underline{2} \text{NaHCO}_3(\text{s}) \rightarrow \underline{2} \text{Na}(\text{s}) + \text{H}_2(\text{g}) + \underline{2} \text{C}(\text{s}) + \underline{3} \text{O}_2(\text{g})$
  - c.  $\underline{2} \text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
  - d.  $\underline{2} \text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{O}(\text{s}) + \underline{2} \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
4. Some students may eliminate equation b since  $\text{CO}_2$  is not one of the products formed and  $\text{CO}_2$  is needed to cause dough to rise. If students do not notice this, they may calculate the grams of product, as shown in b below.

$$\text{a. } 3.393\text{g NaHCO}_3 \times \frac{1 \text{ mole NaHCO}_3}{84 \text{ g NaHCO}_3} \times \frac{1 \text{ mole NaOH}}{1 \text{ mole NaHCO}_3} \times \frac{40 \text{ g NaOH}}{1 \text{ mole NaOH}} = 1.616 \text{ grams NaOH}$$

$$\text{b. } 3.393\text{g NaHCO}_3 \times \frac{1 \text{ mole NaHCO}_3}{84 \text{ g NaHCO}_3} \times \frac{2 \text{ mole Na}}{2 \text{ mole NaHCO}_3} \times \frac{23 \text{ g Na}}{1 \text{ mole Na}} = 0.929 \text{ grams Na}$$

$$3.393\text{g NaHCO}_3 \times \frac{1 \text{ mole NaHCO}_3}{84 \text{ g NaHCO}_3} \times \frac{2 \text{ mole C}}{2 \text{ mole NaHCO}_3} \times \frac{12 \text{ g C}}{1 \text{ mole C}} = 0.485 \text{ grams C}$$

Total mass of solid produced = 1.414 grams C & Na

$$\text{c. } 3.393\text{g NaHCO}_3 \times \frac{1 \text{ mole NaHCO}_3}{84 \text{ g NaHCO}_3} \times \frac{1 \text{ mole Na}_2\text{CO}_3}{2 \text{ mole NaHCO}_3} \times \frac{106 \text{ g Na}_2\text{CO}_3}{1 \text{ mole Na}_2\text{CO}_3} = 2.141 \text{ grams Na}_2\text{CO}_3$$

d.  $3.393 \text{ g NaHCO}_3 \times \frac{1 \text{ mole NaHCO}_3}{84 \text{ g NaHCO}_3} \times \frac{1 \text{ mole Na}_2\text{O}}{2 \text{ mole NaHCO}_3} \times \frac{62 \text{ g Na}_2\text{O}}{1 \text{ mole Na}_2\text{O}} = 1.252 \text{ grams Na}_2\text{O}$

5. The correct equation is equation 3 since the number of grams of solid product produced is close to the number of grams of solid produced in the experiment.

**Reflect:**

While this lab fits well in the sequence of activities comprising this unit, the collection of data itself is rather uneventful, as no visible reaction occurs. Students simply heat the baking soda and it decomposes without any noticeable differences. It helps to prepare students for these “non-eventful” results by discussing observable vs. unobservable changes. It is also extremely important that accurate measurements be taken, as the mass change is rather small. Weighing to constant mass is an important concept to share with students and helps to impress upon them how big changes can sometimes come in small mass increments.

**Attachments:**

Student Page/Handout


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**The Bicarbonate Dilemma**


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Problem:

How can you determine the products of a chemical reaction?

Materials:

|                            |                |
|----------------------------|----------------|
| sodium bicarbonate (solid) | metric balance |
| Bunsen burner              | ring and stand |
| crucible                   |                |

Hazard Warning:

Wear your safety goggles for this entire laboratory.

Procedure:

One of the most appetizing smells in the world might be that of freshly baked cakes and muffins. In order to make such tasty morsels light and fluffy, the substance known as sodium bicarbonate ( $\text{NaHCO}_3$ ) must be included in the recipe. Sodium bicarbonate, alias baking soda, is the substance that causes many baked goods to rise. One of the reasons this rising action occurs is because when strongly heated in the oven, baking soda decomposes producing carbon dioxide ( $\text{CO}_2$ ) gas. The carbon dioxide becomes trapped within the mixture to form the "air pockets" which provide the fluffy texture.

A problem many beginning chemistry students face is the ability to predict the products for a particular reaction. The decomposition of sodium bicarbonate presents an interesting dilemma because it seems to have four plausible but different products as shown below.

- $\text{NaHCO}_3(\text{s}) \rightarrow \text{NaOH}(\text{s}) + \text{CO}_2(\text{g})$
- $\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}(\text{s}) + \text{H}_2(\text{g}) + \text{C}(\text{s}) + \text{O}_2(\text{g})$
- $\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
- $\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{O}(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$

Using a known amount of  $\text{NaHCO}_3$  and the laboratory equipment provided, your task is to determine which of the above equations predicts the correct products. Before beginning the heating process, decide what data you will need to collect to determine the number of grams of solid product produced in the reaction. Prepare a table in which to record your data. Ask your teacher to look over your data table before beginning.

Summing Up:

- How did you know that a reaction was occurring?
- How did you know when this reaction was done?
- Write a balanced equation for each of the equations listed above.
- Using the information from your balanced equations and the mass of the solid you started with, determine the number of grams of solid product which should have been produced in each of the equations above. Show all of your calculations, including units.
- Based on the results from your experiment and calculations, which of the reactions listed above seems to be the most probable? Why?

**GOGGLES**

**ACTIVITY 5**
**Activity 5 Overview: Shuttle Shooter**

|  |   |   |                                     |  |                                     |                                 |
|--|---|---|-------------------------------------|--|-------------------------------------|---------------------------------|
| <b>Iowa Core Curriculum Essential Skills/Concepts:</b> | <ul style="list-style-type: none"> <li>○ Understands and applies knowledge of chemical reactions</li> <li>○ Designs and conducts scientific investigations</li> <li>○ Uses technology and mathematics to improve investigations and communications</li> <li>○ Formulates and revises scientific explanations and models using logic and evidence</li> <li>○ Recognizes and analyzes alternative explanations and models</li> <li>○ Communicates and defends a scientific argument</li> </ul>  |   |                                     |  |                                     |                                 |
| <b>Big Ideas</b>                                       | <ul style="list-style-type: none"> <li>○ Designing a well controlled experiment is the key to the development of good problem solving skills and can help students answer real questions.</li> <li>○ Understanding of the mole concept can be applied to situations in order to not only predict the outcome, but to determine the most effective means of producing the “best” products.</li> <li>○ Hydrogen gas is a potential fuel of the future, but has pros and cons that must be understood by the average citizen.</li> </ul> |   |                                     |  |                                     |                                 |
| <b>Characteristics of Instructional Core</b>           | <input checked="" type="checkbox"/>   | Encourages collaboration in learning      | <input checked="" type="checkbox"/> | Teaches for understanding                              | <input checked="" type="checkbox"/> | Develops global perspectives    |
|  | <input checked="" type="checkbox"/>   | Student centered                          | <input checked="" type="checkbox"/> | Develops conceptual and/or procedural knowledge        | <input checked="" type="checkbox"/> | Provides authentic learning     |
|  | <input checked="" type="checkbox"/>   | Teaches through problem solving & inquiry | <input checked="" type="checkbox"/> | Assesses for learning                                  | <input type="checkbox"/>            | Incorporates current technology |
| <b>Cognitive Domain</b>                                | <input type="checkbox"/>  | Remembering                               | <input checked="" type="checkbox"/> | Applying   | <input type="checkbox"/>            | Evaluating                      |
|  | <input checked="" type="checkbox"/>   | Understanding                             | <input checked="" type="checkbox"/> | Analyzing  | <input checked="" type="checkbox"/> | Creating                        |
| <b>Connections to Students’ Lives</b>                  | <input type="checkbox"/>  | Isolated within discipline                | <input checked="" type="checkbox"/> | Connected to other disciplines                         | <input checked="" type="checkbox"/> | Connected to student lives      |
|  | <input type="checkbox"/>  | Connected within discipline               | <input checked="" type="checkbox"/> | Has value beyond school purposes                       | <input type="checkbox"/>            |                                 |
| <b>Support for Literacy</b>                            | <input checked="" type="checkbox"/>   | Using the literacy process for inquiry    | <input type="checkbox"/>            | Increasing reading volume                              | <input type="checkbox"/>            |                                 |
|  | <input type="checkbox"/>  | Increasing access to print                | <input checked="" type="checkbox"/> | Engaging students with texts                           | <input type="checkbox"/>            |                                 |
|  | <input checked="" type="checkbox"/>   | Involving students in discussion          | <input type="checkbox"/>            | Reading aloud in content areas                         | <input type="checkbox"/>            |                                 |
|  | <input type="checkbox"/>  | Increasing reading fluency                | <input type="checkbox"/>            | Explicitly instructing in vocabulary and comprehension | <input type="checkbox"/>            |                                 |
| <input checked="" type="checkbox"/>                    | Writing to learn across content areas   | <input type="checkbox"/>                  |                                     |  |                                     |                                 |
| <b>Class Time</b>                                      | 2-3 class periods   |   | 100-150 total minutes               |  |                                     |                                 |

**Materials & Set-up:**

hydrogen generator: film canister containing a few pieces of mossy zinc. Use a small nail to punch a hole in the center of the lid and place a 2-3 cm length of the stem end of a Beral pipette through the hole. Add 1 M HCl to begin production of H<sub>2</sub> gas.

oxygen generator: make a second film canister set-up. Use a small amount of manganese dioxide and add hydrogen peroxide to begin O<sub>2</sub> production. As an alternative, yeast and hydrogen peroxide can be used.

collection bulbs: bulb of a Beral pipette cut off to leave 3 mm of stem to slide over the generator nozzle

1.0 M hydrochloric acid: 51.3 mL concentrated HCl diluted to 1 L

hydrogen peroxide: 3% commercial antiseptic

launch pad: small board containing nail set at a 45 degree angle

Tesla coil: for igniting rocket on launch pad

Ground wire: 30 cm length of insulated wire

**Hazard Warning:**

Wear safety goggles and apron throughout this experiment, including when the “rockets” are ignited. Using small gas generators and small collection bulbs helps to keep the lab safe. Explain to students the importance of keeping all active hydrogen and oxygen generators well away from flames and from the Tesla coil.

**Teaching Tips:**

This lab is self-motivating and fun. Begin by demonstrating how to produce and collect hydrogen and oxygen gas, but do not tell students how to measure the amounts of each gas collected. This is one of their challenges and will require creativity and some trial and error on their part. Students may struggle with devising their method of measuring amounts. A good way would be to prepare a collection bulb with the help of a graduated cylinder and pen. Increment an inverted pipette bulb to show 0.5 mL increments. This way, students can see how much gas they are adding to the bulb.

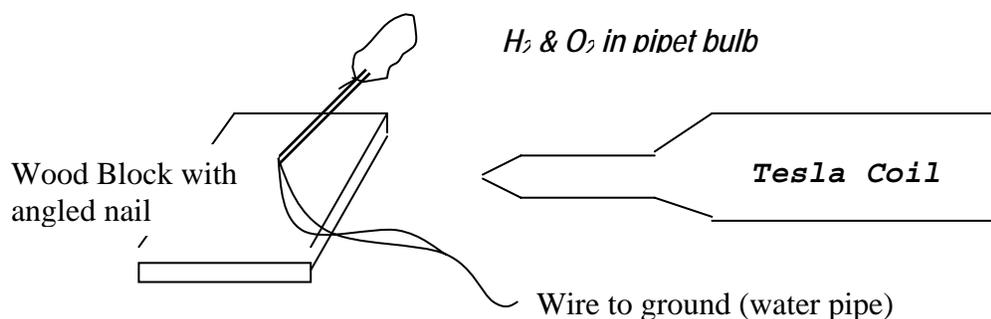
Without mentioning the incrementing method, demonstrate how to fill the bulb with gas. Do this by first filling the bulb with water. Demonstrate how to prepare both gases. Prepare a hydrogen generator by placing several pieces of zinc metal into the bottom of a film canister. Prepare lids by punching a hole in the center of each lid with a small nail then inserting a 2-3 cm piece of the stem of a Beral pipette through the hole. You might want to prepare several of these before class to save time. To prepare hydrogen gas add enough HCl to fill the film canister about half full. CAUTION: Remember to wear your safety goggles. Replace the lid and begin filling the water filled bulb. As the bulb fills it will force the water out. Leave a small amount of water in the bulb to prevent the gas from escaping. Allow the generator to run for about 10 seconds to force out the air. Fill the collection bulb completely with hydrogen gas by attaching the nozzle from the hydrogen generator to the end of the collection bulb.

CAUTION students to set the hydrogen generator well back from any flames. To test the gas, hold the collection bulb containing the hydrogen gas such that it is horizontal with a lighted wood splint. Gently squeeze a very small portion of the contents into the flame. Observe. Squeeze again. Observe and record your observations. Students will be using the hydrogen generator again. Just set it aside for now.

Prepare an oxygen generator by placing manganese dioxide powder in the bottom of a second film canister. Place a small amount of manganese dioxide powder in the canister then add enough hydrogen peroxide to fill the canister about half way. Replace the lid and fill a bulb with the gas for testing. Remember to let the generator run for 10 seconds before collecting gas for testing. It should be enough to demonstrate the gas collection method once for students, then allow them to make and test their own gas.

Make sure students are recording their observations. Not all students will agree that the same mixture makes the loudest pop. Once students start launching rockets, the agreement will be much better.

The combined volume of the hydrogen and oxygen mixture in each collection bulb should be constant. This will assure that the volume of water remaining in the stem of the collection bulb is the same for all tests. Construct a launch pad like the one shown below. You will need to use a Tesla coil to ignite the gases.



| Teacher Tasks  | Student Tasks   |
|--|---|
| <ul style="list-style-type: none"> <li>Set the stage by talking about potential alternative fuels. Ask students to tell what they know about them and what is driving the need for alternative fuels.</li> </ul> | <ul style="list-style-type: none"> <li>Participate in this teacher led discussion</li> </ul>  |
| <ul style="list-style-type: none"> <li>Demonstrate how both H<sub>2</sub> and O<sub>2</sub> can be generated and captured in a pipette bulb and safely ignited.</li> </ul>                                       |   |
| <ul style="list-style-type: none"> <li>Present the challenge of using problem solving skills to develop an accurate method for measuring specific amounts of each gas into the bulbs.</li> </ul>                 | <ul style="list-style-type: none"> <li>Working in pairs, students experiment with and devise a method that will work for calibrating their pipettes.</li> </ul> |
| <ul style="list-style-type: none"> <li>Review and stress safety.</li> </ul>  |   |
| <ul style="list-style-type: none"> <li>Remind students to construct their data table prior to collecting data.</li> </ul>  | <ul style="list-style-type: none"> <li>Prepare a data table</li> </ul>  |
| <ul style="list-style-type: none"> <li>Circulate around to each group checking on progress and asking probing questions.</li> </ul>  | <ul style="list-style-type: none"> <li>Students carry out the lab.</li> </ul>   |
| <ul style="list-style-type: none"> <li>Direct students to complete the <i>Summing Up</i> questions. Share with students the rubric for the</li> </ul>  | <ul style="list-style-type: none"> <li>Answer the <i>Summing Up</i> questions, including researching hydrogen as a viable alternative</li> </ul>                |

|  |  |
|--|--|
| question on hydrogen as an alternative fuel.   | fuel and preparing their Futurecast.   |
| <ul style="list-style-type: none"> <li>Have students present their futurecasts about hydrogen as an alternative fuel to the class and direct a class discussion.</li> </ul>  | <ul style="list-style-type: none"> <li>Present findings to the class. Be prepared to provide a fact-based rationale and to ask questions of other students.</li> </ul> |
| <b>Differentiation Tasks</b>   |  |
| <p><b>Prioritized vocabulary, skills, concepts:</b> designing experiments, analyzing data</p> <p><b>Suggestions for supplemental instruction</b></p> <ul style="list-style-type: none"> <li>Some students will have difficulty devising a method of calibrating their bulbs. Providing a small graduated cylinder is sometimes all the hint that is needed to get kids on the right track.</li> <li>Prepare a data table template or scaffold to give students may be necessary.</li> </ul> <p><b>Highly Proficient</b></p> <p><b>Suggestions for supplemental instruction</b></p> <p>If students finish early, challenge them to make a slightly larger “rocket”. Using a small, plastic drinking water bottle, students can devise the best combination of H<sub>2</sub> and O<sub>2</sub> to produce the best rocket. These should be tested outdoors by placing the filled “rockets” on a ring stand and touching the Tesla coil to the bottom of the stand. Goggles must be worn and the person igniting the rocket should be lying on the ground. This must be closely supervised by the teacher, as the rocket is quite powerful.</p> |  |

### Assessment:

#### *Formative Assessments:*

- Provide specific suggestions for evaluating students as they progress through the activity. In addition, provide ongoing guidance and feedback to individual students as points of confusion are observed throughout the activity, but resist the urge to tell students what to do. This is especially true while students are working on designing their own experiment. Asking probing questions, even to those students who appear to have a strong understanding of the concepts being taught, to stretch student understanding.
- In addition, monitoring student engagement throughout the activity to ensure that active student involvement is an explicit part of the assessment.

#### *Summative Assessments*

- Student responses to the *Summing Up* questions serve as the assessment for this activity. It is best to allow students the opportunity to make corrections to any incorrect or weakly formulated *Summing Up* answers where necessary.
- Students’ abilities to design and control experiments are assessed through this activity and will be evident through their experimental design and their representation of data. A separate rubric is attached for assessing the Futurecast portion of this activity.
- Sample Answers to Summing Up:
  1. The method students develop to measure exact amounts of both of the gases into the pipette bulbs will vary with student groups. Many students are likely to use a graduated cylinder, then pour 0.5 mL increments into the bulb and mark each amount with a pen. This will result in the bulb itself being like a mini-graduated cylinder.
  2. The balanced equation is:  $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

The combining ratio of 3 hydrogen to 2 oxygen is the closest to the ratio of the coefficients in the balanced equation. Since the bulbs only hold about 5 mL, the perfect ratio is not likely to be tested by students.

3. The limiting reactant in each pop test is listed in the data table.

| Amount of H <sub>2</sub> | Amount of O <sub>2</sub> | Limiting Reactant | Relative Sound |
|--------------------------|--------------------------|-------------------|----------------|
| 5                        | 0                        | oxygen            | 3              |
| 4                        | 1                        | oxygen            | 2              |
| 3                        | 2                        | oxygen            | 1 (loudest)    |
| 2                        | 3                        | hydrogen          | 2              |
| 1                        | 4                        | hydrogen          | 3              |
| 0                        | 5                        | hydrogen          | 4 (softest)    |

4. To be loud requires a combination of both hydrogen and oxygen, with twice as much hydrogen as oxygen, which occurs in the 3:2 trial.
5. Student research into the use of hydrogen as a potential fuel for alternative fuel vehicles will vary. It is important to take the time to share and discuss the pros and cons of using hydrogen as a fuel and to provide students the opportunity to share their opinions. Make sure that each student provides a rationale for their opinion that is based on facts. Do your homework by making sure you are familiar with the current thoughts on hydrogen as a viable alternative fuel. Display student handouts around the classroom and the school to better inform others.

**Reflect:**

The fact that this lab allows students to apply their knowledge of balancing equations to observable phenomenon in the lab makes this an excellent culminating experience for this unit. Tying this lab to alternative fuels is very important. By first completing the lab, students gain first-hand knowledge of the explosive power generated by igniting hydrogen. This highlights some potential problems of using hydrogen as a fuel that are not immediately obvious to the average adult reading about the potential of hydrogen as a viable alternative fuel.

**Attachments:**

Student handout

## Student Page/Handout

## Shuttle Shooter

Problem:

What hydrogen:oxygen ratio makes the best rocket fuel?

Materials:

film canister hydrogen generator, 1 M HCl and pieces of mossy zinc  
film canister oxygen generator, hydrogen peroxide and manganese dioxide  
collection bulbs

Hazard Warning:

Wear safety goggles throughout this experiment. Be sure to keep your gas generator well away from any flames and from the Tesla coil!

Procedure:

Hydrogen is a clear, colorless gas which is said to be combustible, meaning simply that it can burn quite readily. Oxygen is also a clear, colorless gas that is said to support combustion, meaning it must be present for combustible materials to burn. In this lab you will be generating, collecting and testing hydrogen and oxygen. By collecting and pop-testing different hydrogen:oxygen mixtures, you will audibly determine the most reactive mixture. You will then launch a rocket containing that mixture.

Record all observations as you go. Read through the entire procedure before beginning the gas generation process. Make sure that you have all the materials ready before actually beginning to generate the gases.

1. With both gases being generated side by side, devise a way to collect and test all possible whole number increment ratios of hydrogen and oxygen.
2. Prepare a data table in which to record the amounts of  $H_2$  and  $O_2$  gas, as well as the relative loudness of each test. (If either generator slows, pour off the old liquid and add fresh.)
3. Using the procedure demonstrated by your teacher, fill bulbs with the desired amounts of  $H_2$  and  $O_2$ . Remember to keep your gas generators well away from any flames.
4. Fill your collection bulb with the loudest mixture. Take it to the launch pad and see how it blasts off.

Summing Up:

1. Describe the method you developed to measure exact amounts of both of the gases into the pipette bulbs.
2. Write the balanced equation for the combination of hydrogen and oxygen. How does the combining ratio of the loudest mixture compare with the mole ratio in the balanced equation?
3. Identify the limiting reactant in each pop test.
4. Explain why the test with pure hydrogen was not the loudest.
5. Do some research into the use of hydrogen as a potential fuel for alternative fuel vehicles. Find the pros and cons of using hydrogen as a fuel. After studying these pros and cons, formulate a personal opinion on what you believe the future is for hydrogen as a viable alternative fuel for alternative fuel

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vehicles. Include a rationale for your opinion. Present your pros and cons, along with your "Futurecast" and rationale in a colorful, one page handout.

## Grading Rubric for Futurecast on Hydrogen Fuel

|                                     | 7  | 4  | 1   |
|-------------------------------------|--|--|---|
| <b>Pros &amp; Cons</b>              | <ul style="list-style-type: none"> <li>Pros &amp; cons are accurate and complete in that they match those points most commonly included in the literature</li> </ul>               | <ul style="list-style-type: none"> <li>Pros and cons are fairly complete, but 2-4 key issues, as cited in the literature, are not included.</li> </ul>   | <ul style="list-style-type: none"> <li>Pros and cons are sketchy and exclude more than 5 key points cited in the literature.</li> </ul>                           |
| <b>Personal Opinion</b>             | <ul style="list-style-type: none"> <li>Student's opinion is clearly stated.</li> <li>Rationale is supported with facts.</li> </ul>   | <ul style="list-style-type: none"> <li>Student's opinion does not take a clear stance.</li> <li>Rationale does not fit the opinion stated.</li> </ul>  | <ul style="list-style-type: none"> <li>Student's opinion is not included.</li> </ul>  |
| <b>Writing, Visual Presentation</b> | <ul style="list-style-type: none"> <li>Correct spelling, punctuation &amp; grammar.</li> <li>Visually interesting, making effective use of color, spacing, and visuals.</li> </ul> | <ul style="list-style-type: none"> <li>2-3 errors in spelling, grammar or punctuation.</li> <li>Somewhat visually interesting, making some use of color, spacing and visuals.</li> </ul>   | <ul style="list-style-type: none"> <li>5 or more errors in spelling, grammar or punctuation.</li> <li>Visually uninteresting, poor to no use of color,</li> </ul> |
| <b>Oral Quality</b>                 | <ul style="list-style-type: none"> <li>Student is able to articulately present his/her position.</li> <li>Student position is backed up with appropriate facts.</li> </ul>         | <ul style="list-style-type: none"> <li>A somewhat articulate presentation of the students' position is provided.</li> <li>A minimal number of facts are used to support the students' position or those facts do not all support the selected position.</li> </ul> | <ul style="list-style-type: none"> <li>Student is not able to give or explain his/her position.</li> <li>No facts are used in support.</li> </ul>                 |