Chemical Reactions Unit: Baking Soda Challenge

For the Teacher:

The objective of this challenge is for students to find the optimal combination of vinegar and baking soda that produces the greatest amount of carbon dioxide bubbles which allow the Ping-Pong ball to reach the greatest height. Students can use only a total of 50 grams of combined substances.

Materials:
- Clear plastic tube (1 5/8 inch inner diameter, 1 3/4 inch outer diameter, 1 meter long) with cap at one end – 1 per team **
- Ping-Pong ball – 1 per team
- Meter stick – 1 per team
- Rubber bands – 2 per team
- Stop-watch or timer – 1 per team
- Support stand with clamp – 1 per team
- Data sheet – 1 per team
- Baking soda
- Vinegar
- Liquid dish soap
- Pipettes or eyedroppers – (1 for vinegar, 1 for soap)
- Digital scale (0.01g accuracy)
- Plastic spoon (for spooning out the baking soda)
- Paper cups (for measuring test substances and for cleaning the tube)
- Large pail or a sink (for cleaning the tube)
- Water
- Paper towels (for drying the tube)

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Set-up:
- Place the cap on one end of the plastic tube. Measure 2-1/2 inches (6.5 cm) up from the bottom of the capped end and mark a line at this point. Wrap a piece of masking tape or colored tape around the tube so that the top edge of the tape is at this height. This is the point the height where the ping pong ball starts when the reaction begins immediately upon contact with the vinegar and baking soda.
- Attach the meter stick to the tube using the rubber bands. Make sure that the bottom of the meter stick (the "zero" end) lines up with either the line marked on the plastic tube or the top edge of the tape.
- Attach the tube securely to the support stand using the support stand and clamps.

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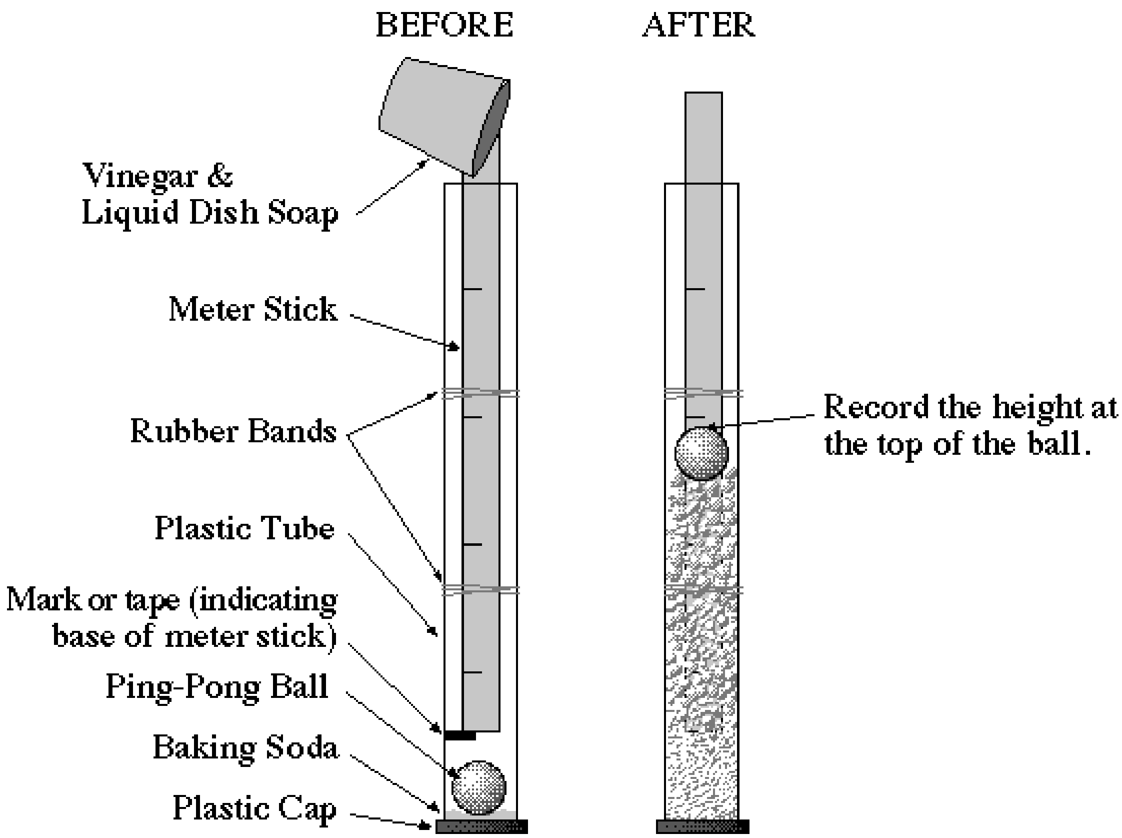
Students should be sure to place the ping pong ball in the tube after adding the baking soda. The reaction is instantaneous and students must be sure to start the stopwatch as soon as the vinegar reaches the bottom of the tube. The soap is added to the vinegar to give the bubbles more strength to support the ping pong ball. Occasionally, bubbles will break in the tube, causing the ping pong ball to fall several centimeters in the tube. Students should note this in their data which may later explain a "dip" in their graph.

Students should record the height of the Ping-Pong ball at 30-second intervals for 6 minutes. The height of the ping pong ball is always measured at the **top** of the ball. It is important that they take measurements for the entire six minutes even though a reaction may have appeared to stop. This maintains consistency in the data.

All students should begin with 25g of vinegar and 25g of baking soda. They may choose any combination to proceed with their testing or the class can brainstorm which amounts to try. The class may also want to assign various combinations to different groups in order to cover a wider range of combinations. One strategy is to put a large graph either on the board or on a posterchart (identical to the graph shown below that they will be filling out). Upon discussion of what results they think will happen, students can then plot two points that they will already know: 0g vinegar/50g baking soda and 50g vinegar/0g baking soda since neither one of these will produce a reaction, thus yielding a ping pong ball height of 0 cm in each case. Students can then continue the discussion of what trend they may expect to see upon successive trials. It is a good idea to have students predict the shape of the graph prior to testing, indicating various groups' predictions in different colors on the graph. From this, the groups may choose what combinations of baking soda and vinegar to test in order to determine the optimal combination to get the highest column of bubbles. Students should be sure to test as many combinations as possible in order to fill in the graph and map the trend completely. (The optimal combination is approximately 47g vinegar and 3g baking soda. However, this information should ***not*** be shared with the students. They are encouraged to use the information form their testing to determine what is the optimal combination.)

As students repeat the step with varying amounts of baking soda and vinegar they should keep in mind that they may only use a total of 50g of baking soda and vinegar combined. Results should all be recorded on a class graph as well in order for the students to compare results and retest specific trials if they have differing data. The tube should be rinsed and cleaned after each test to eliminate any residue from leftover baking soda or vinegar which may affect the next trial, giving inaccurate results for the combination of substances (see below for instructions). Be sure that no residue remains in the tube or its cap after each cleaning.

Students should discuss their results after examining their data and graphs as well as the class graph. Use the questions below to review the challenge with the students.



Procedure for Cleaning the Tube

1. Remove the meter stick from the tube.
2. Take the tube to the cleaning station in your classroom.
3. Pour a cup of water into the tube.
4. Place your hand over the top of the tube, covering it completely, and slosh the water back and forth.
5. Drain the water into the sink or pail.
6. Remove the cap from the bottom of the tube. Be sure to rinse out the residue in the cap.

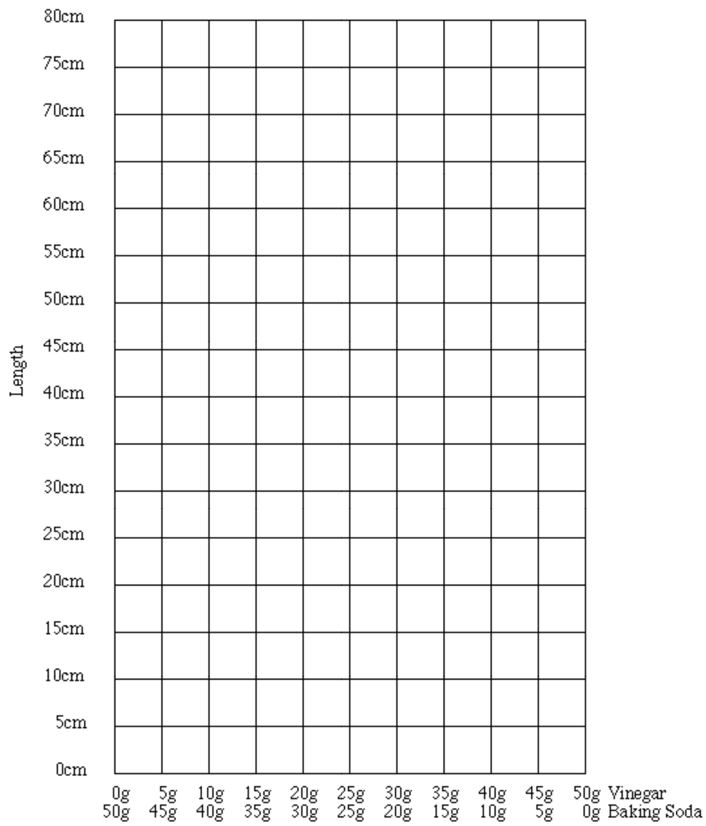
Return to your testing area. Crumple two paper towels and stuff them into one end of the tube. Push them all the way through with the meter stick to dry the tube as much as possible.

Class Discussion:

1. Observe the points plotted on the graph. What is the shape of the graph? What conclusions can you draw from this graph?
2. Is the graph of your team's data different from the graph of the data from the entire class? Can you explain any difference?
3. How does the shape of the graph compare with your predictions?
4. If you double the amount of vinegar, how does the height of the Ping-Pong ball change? What would happen? Can you predict your outcome?
5. Do you think that the liquid changes as the gas escapes? Explain.
6. Were your results similar to your original prediction or different? Explain your results, and give evidence to support your findings.

Baking Soda Model Graph

Your teacher will provide you with a graph that looks like the one below. Plot the <u>length</u> of the line of carbon dioxide pieces from each baking soda model test that you ran on the graph. The vertical axis is the length in centimeters, while the horizontal axis is the amount of vinegar that you measured in grams.



Discuss the following questions in your group. Record your group's answers in your notebook:

1. How do the ratios of vinegar and baking soda affect the amount of carbon dioxide that is produced?
2. Can you use the model to predict the column height without taking the baking soda apart? Explain.
3. Why do you think the vinegar pieces in the model are larger than the carbon dioxide pieces?

Modeling the Reaction

For the Teacher:

Making the Model Pieces:

The baking soda model consists of just three pieces that represent the major parts of the reaction: vinegar, baking soda remnant, and a gas called carbon dioxide. The vinegar and carbon dioxide pieces are cut from plain manila file folders. The vinegar piece is the large rectangle, while the carbon dioxide piece is the small rectangle. The baking soda remnant piece is the plastic paper clip.

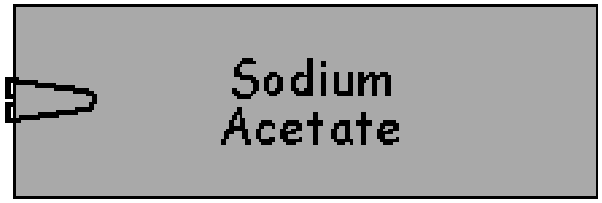
The dimensions of the vinegar piece are 14.8 cm long by 5.0 cm wide. This piece has a mass of 1.60 g. The baking soda remnant – a plastic paper clip, approximately 2 cm long (see equipment purchasing info) has a mass of approximately 0.12g. The carbon dioxide piece is a 2cm by 2cm square piece with a mass of approximately 0.08g. Together, the mass of the carbon dioxide piece with the paperclip attached to it is 0.20g. These masses are important when predicting the reaction using the model. The model pieces are proportional to the molecular dimensions of the chemicals used in the reaction. It is best, therefore to have a digital balance to use for this exercise although a very rough approximation can be seen using a good quality triple beam balance.

To begin with, all of the clips (baking soda remnant) should each be attached to one carbon dioxide piece to form the baking soda model piece.

[***RULE: only ONE baking soda remnant is allowed on ONE end of each vinegar piece.***]

After "zeroing" the scale, students can place vinegar pieces on the scale until it reads approximately 25.0 g. Remove these from the scale. Next, place a small box or container on the scale (to hold all of the baking soda pieces) and then "zero" the scale. Gradually add the baking soda pieces until the scale reads approximately 25.0 g.

At this point, students are ready to "model" the reaction. They may only use the pieces that have been measured out on the scale. Remove enough baking soda remnant pieces (paper clips) from the carbon dioxide pieces (small squares) to place ONE baking soda remnant on only ONE end of each vinegar piece. [***RULE: only ONE baking soda remnant is allowed on ONE end of each vinegar piece.***] This creates a new piece, called sodium acetate, which occurs as a result of the chemical reaction.



Once the students have removed as many of the paper clips from the baking soda pieces, (simulating what happens in a chemical reaction) and attached them to only as many vinegar pieces as can be matched according to the rule above (one clip to one vinegar piece), they have completed the reaction for the amount of material with which they started. There may be leftover baking soda pieces or leftover vinegar pieces in some of their combinations. The leftovers indicate material that was not used in the reaction even though it was present. The idea behind chemical reactions is that only so much of each material involved in the reaction will be used, based on the availability of other materials with which to combine.

Following this step, students will then take each of the lone carbon dioxide pieces (the remaining 2 by 2cm squares with the clip now removed) and line them up end to end. After all of the pieces have been closely and carefully lined up, use a meter stick to measure the total length of the line of carbon dioxide pieces. This corresponds approximately to the height of the carbon dioxide that forms in the tube as a result of the baking soda and vinegar reaction using 25 g of each. (Students may see some variation that may be a result of the exact dimensions of the manila folder pieces or extensive handling of the pieces as they have worn out. This can be something they discuss as reasons for minor discrepancies.) Students should compare their results with this measurement. This length can then be plotted on the graph to compare the length of CO_2 for the baking soda/vinegar combination used.

Repeat the modeling activity, using various baking soda/vinegar combinations and plotting them on the graph. Compare this graph with the actual experimental results. Discuss how they are similar or different.

<u>Baking Soda: Suggestions to the Teacher</u>

(Note: Compiled from DESIGNS summer institute teacher participant comments.)

Ideas for additional activities / homework.

1. Trona
   After first reading of Julia / Marcus story, it's a good idea to let students handle, smell, etc., an actual piece of trona. Maybe have class gather around a table. Students who have an idea can propose it; class briefly discusses what might happen; student who proposed idea—e.g. "Let's try pouring orange juice onto it."—gets to execute it. Class discusses.

2. Uncle Felix's model.
   This could be an activity or a homework assignment.
   Individually or in a group
   Students make their own model to demonstrate or explain the reaction as Uncle Felix did with leaves. Assignment could be: "Can you make what you think is a better or a more modern model?"

3. More on Trona
   Students could research: What do countries with large trona deposits do with it? Come to class prepared to present and discuss (BRIEFLY) what they learned.
   Could be done as homework or even as in-class activity if class is wired with I-Book Carts, etc.

4. Women & Science
   Students might find it incredible that women of Julia's era could have considered a career in science. Students could research other women of note from that era and report back to class on what they found out and discuss.

5. Weird Food Buffet
   Students find recipe that involves vinegar (or other acid) and baking soda; vary the ratios and bring in the results for a weird—but still edible—food buffet.
   Seemed like a nice fun break between "Modeling the Reaction" and "Other Chemical Reactions."

6. Another possibility for between "Modeling the Reaction" and "Other Chemical Reactions": Volcano Competition. Students could employ their new understanding of baking soda & vinegar to build the best "volcano" ever.

7. During "Other Chemical Reactions," try to demonstrate or have an activity involving one of the chemical reactions mentioned in passing in the unit, maybe one from the pre/post-test?

General ideas on classroom / lab strategy

1. Teachers may want to make a large-size version of Uncle Felix's leaf model to have on hand during the reading of the first part of the story.

2. With so many activities and labs teachers should BE SURE to let students know what jobs will be involved in each activity and then give student groups time to discuss and assign those jobs BEFORE any work / activity begins!

3. Observations:
   Early on teachers need to emphasize that the observer in the group should be looking at the TOP of the Ping Pong ball to get the height numbers for the column.

4. Teachers should be prepared for a great hue and cry, "Do we HAVE to wait the whole SIX MINUTES?" (This will sound as though six centuries are at stake.) We think this is a point where the teacher must think like a Marine corps drill instructor. A time to BE TOUGH: "Yes. You have to wait the full six minutes. No exceptions."

5. How to collect the data:
   a) Each group could be responsible for certain ratios and repeats for those ratios.
   b) Students can do whatever ratios they want from the data sheet.
      In this case, a good idea is to have a large data sheet and/or graph at the front of the classroom. Groups must post their data as soon as it is collected so the class can see where the holes are, what still needs to be done.

6. Cleaning the cylinder;
   Teachers should be prepared for cylinder to still look bubbly after one rinse with water. THAT IS OKAY! Those bubbles will not queer the results of the next combination. (Also we are not doing a liver transplant here; we don't need to be THAT clean.) CONTINUE FOLLOWING THE DIRECTIONS. Rinse the cap; wipe out the cylinder and you are good to go.

7. Teachers need to be prepared for student enthusiasm for these activities, including students wanting to try EXTREME combinations of baking soda, vinegar & soap. A good way to handle this is to tell students that after they have conscientiously collected the data they are responsible for, recorded it, etc., the teacher will make sure there is time for them to do their extreme ideas.

   A good way to avoid a total melee is to have each group pick one extreme idea to try, then have class travel table-to-table, group-to-group to make predictions, witness and discuss these extreme combinations.

8. After-activity discussions.
   One member of each lab group should have the job of group spokesperson. After data collection, discussion with partners, answering questions included in unit, the

class should reconvene in a semi-formal forum where each group presents their results, thoughts and answers.

The results should be posted in a large format at the front of the class that can accommodate all the data gathered by all the groups.

9. Materials Security:
   Teachers need to be prepared for how attractive some of these materials will be to students. Each activity / lab. Should include time for the teacher to make sure all materials—especially the Ping Pong balls—are accounted for. Part of the grade for the unit could be based on the condition and timeliness with which each group returned their materials every day.

10. Homework
    Some teachers may feel that assigning written homework does not lead to learning due to a tendency of many students to simply copy (if handwritten) or to e-mail, download and print each other's work. In this case, more learning might occur if the teacher allows time in class for students to work on questions in their groups or individually.

11. The Paper Model
    This seems like the most likely point where teachers are going to be faced with questions about molecules, molecule size, compounds and the realities of the chemical reaction. If these questions don't come up now, inevitably they will at some point.

    Rather than dodging these questions or giving evasive or simplistic answers—which puts the teacher in the position of undermining his or her own credibility—we think the best strategy at this point is for the teacher to be prepared to show the students—either on the board or on a prepared overhead (because it takes so long to write out)—the actual reaction, so the class can see the mind-boggling complexity of it and then agree as a class: "We do NOT want to go there."

12. Conservation of Mass
    Clarify demo directions and illustrations.
    Need at least one large 500—1000 ml. container.
    And—counter-intuitively—it is the baking soda, NOT the vinegar, that should go in this large beaker / container.

13. Younger grade students (i.e., 7th vs. 8th grade) may need to have more supports and check points in place as they conduct the challenge. The older students seem to be able to take a more mature approach to conducting the challenge activities. The results from the older students may be more accurate than those of younger students.

The T Word

Because many teachers are under pressure from their departments, school administrations and districts to test, test, test, we think it would be a good idea to include ideas / concepts that teachers could use to create quizzes and/or tests for the unit. Teachers could use some, all or none at all. Some possibilities include (but are not limited to):

- Vocabulary (could easily draw from the unit's glossary)

- Science skills
  - Observation, using all senses.
  - Reporting observations.
  - Recording observations.
  - Displaying observations / data.
  - Drawing conclusions.
  - New questions.

- Regarding the reaction
  - What physical changes occurred?
  - What chemical changes occurred?
  - How was mass conserved?
  - If mass was "lost" during a reaction, where did it go?

- Scientific thinking
  - Evidence
  - Model
  - Inference
  - More evidence
  - Adjust model
  - New inferences

Visuals

1. Maps, maps, maps. No such thing as too many maps.
   World
   Egypt
   Memphis
   Alexandria, including any depiction of the library
   Trona deposit locations worldwide

2. Would be neat to have story illustrated in a style of that era. For example, the black and orange vases (if illustrations have to be black and white, could just eliminate the orange and do as a line drawing with vase just suggested). Or hieroglyphic style.

3. What to illustrate:
   Julia wearing her toga & carrying the jug.
   Uncle Felix and the library.
   Cracked jug; vinegar spilling; one soil reacting; the other not.
   Family dinner. (This one would be difficult because this type of family did not actually eat together; the women ate separately from the men. This situation is deliberately not described in the text so as not to over-burden the science curriculum with cultural histories.)
   Julia with four bowls doing the experiment.

4. "The Mass of a Gas"
   Maybe include diagram showing how to extend platform of a small scale to accommodate two containers.