PUTTING THE THINKING IN STUDENTS' HANDS LEADS TO DEEPER CONCEPTUAL UNDERSTANDING OF CONSERVATION OF MASS

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ABSTRACT: This article first presents a cookbook activity that leads students step-by-step through determining the density of a gas produced in a chemical reaction. This activity is problematic for two reasons. First, students may simply follow the provided directions without really understanding the investigative set-up and procedure. Second, the cookbook activity ignores the difficulties students have accepting that gases have mass and that mass is conserved in chemical reactions. I illustrate how the activity may be modified to address the common misconception that gases have no mass, and develop a deeper understanding of conservation of mass. *This article promotes National Science Education Content Standards A and B and Iowa Teaching Standards 2, 3, 4, and 5.*

Introduction

Density and conservation of mass have been identified as fundamental science concepts by both the Iowa Core Curriculum (http://www.iowamodelcore.org/) and the National Science Education Standards (NRC, 1996). Activities investigating these concepts are germane to most physical science and chemistry curricula. Unfortunately, many times the way in which these activities are structured and delivered places students in a mentally passive role of simply following directions and filling in provided data tables.

Step-by-Step Approach for Determining the Density of a Gas

Figure 1 provides an example of a typical activity aimed at investigating the density of a gas. The step-by-step manner in which this lab is presented enables students to conduct this experiment with very little mental engagement. By implementing effective inquiry strategies and identifying likely student stumbling blocks, this kind of activity may be greatly enriched.

FIGURE 1
Example of a common cookbook activity addressing density of a gas.

Part 1. Procedure:
1. Mass the test tube (25 x 150 mm) filled 1/4 with water, and the sample of Alka-Seltzer.
2. Drop the Alka-Seltzer into the water in the test tube, secure the stopper in the test tube and allow the gas to bubble into the collection bottle.
3. See diagram for lab set up [Diagram shows the test tube with Alka-Seltzer connected with rubber tubing to a flask inverted in a trough of water]. Be sure the collection bottle is completely full, with no air bubbles.
4. When reaction is complete, re-mass the test tube and contents to determine the difference.
5. Determine a method of measuring the gas in the bottle.

Part 2. Data:

Mass of Alka-Seltzer and water before	
- Mass of Alka-Seltzer and water after	
= Mass of Gas*	

*(record mass change to the nearest 0.01g)

Part 3. Calculations:
1. Use the mass and volume of the gas to determine its density (Density = mass/volume).
2. The known value for the density of CO_2 is 2.0×10^{-3} g/mL. How does your answer compare to this value?

At first glance, this cookbook laboratory approach may seem both straightforward and benign. However, a number of embedded concepts that lurk beneath the surface will prove problematic for students. The notion that gases have mass is an abstract concept with which many students struggle. For instance:

- Conceptually understanding this activity demands students to recognize that the mass of gas collected in the inverted container should be equal to the change in Alka-Seltzer mass. Research makes clear that students often think that gases have no mass or less mass than the change in mass of the substance from which the gas was derived (Stavy, 1990).
- Despite having partaken in numerous density activities from perhaps as early on as middle school, many students struggle to conceptually understand this concept.

The activity in Figure 1 is problematic because it permits students to complete the lab whether or not they really understand that gases have mass, that mass is conserved in a chemical reaction, or how to determine density. While that may seem like a virtue, it masks underlying fundamental problems students may have.

Making a few key modifications to this step-by-step laboratory procedure will encourage students to be far more mentally engaged in thinking about what they are doing and linking that to

(1) the idea that gases have mass,
(2) the idea that mass is conserved in a chemical reaction, and
(3) the process of determine the density of a gas.

However, these laboratory modifications may bring to light significant problems students have understanding these concepts. In some sense that is positive and it is evidence that those concepts need to be revisited in more depth.

The Modified Activity

Part 1

Rather than simply assuming that students understand the idea that gases have mass, I provide a concrete example for students. I produce a plastic bottle of soda from a cooler. Be sure the soda bottle is dry and not so cold that water vapor condenses on it. Even non-soda drinkers will be intrigued by the teacher sitting down amongst them with a beverage. Using soda provides a concrete and familiar example for the students. Before beginning, ask the students a series of predictive questions such as:

- What will happen when I open this bottle of soda?
- What is the source of the released pressure?
- Where do the bubbles come from?

Students will have little problem stating that the bubbling is due to carbonation or the carbonated liquid. You may have to ask what carbonation means to draw from them that the gas bubbles consist of CO_2. Continue questioning the students as follows:

- What can you tell me about CO_2, or any gas for that matter, in regards to mass?
- If gases do have mass, what would we expect to happen to the mass of the bottle as the CO_2 leaves the soda?
- How might we illustrate or test this?
- What instrument do we have to measure mass?

Students should suggest that we place the open bottle of soda on a balance or calibrated electronic scale and see what happens to the mass of the bottle as the bubbles continue to rise and leave the surface of the soda in the bottle. Have the students read the mass of the recently opened soda bottle and then throughout the class period return their attention to the scale and note the mass. Students may question whether the decrease in mass is caused by the release of gas or by evaporation of the liquid. If this is the case, ask the students how they might go about testing this question.

Alternatively, one could suggest that this question could be answered by comparing the change in mass of a recently opened bottle of soda, to that of previously opened bottle of soda that has lost its carbonation. By adding this concrete example as a preface to the lab activity the students are in a far better position to determine the mass of gas formed in the reaction of Alka-Seltzer and water without being told how to do so. The significance of this is they have a better understanding of the conservation of mass and that gases do have mass.

Part 2

Fill an empty plastic soda bottle one-quarter to one-half full of water. Place the flask with water in it on the scale, along with the amount of Alka-Seltzer that you have previously tested and deemed safe, and the bottle cap. Alka-Seltzer is an inexpensive and familiar material to use. Using simple materials such as this help students to see the principle at hand without confusing the matter with mysterious chemicals and complicated set-ups. Next, ask the following series of questions:

- What do you think will happen when I drop the Alka-Seltzer in the bottle of water?
- What causes the bubbling?
- If I cap this flask after I drop in the Alka-Seltzer, what will happen to the mass of my system once I have tightly capped it? Why?
- How should we set up this test to determine what does happen to the mass?
- What are some similarities between this system and an unopened bottle of soda?

Next, drop the Alka-Seltzer into the flask and IMMEDIATELY screw the bottle top on, sealing the bottle. Let the tablet(s) completely react. Use the scale to measure the mass of the flask while the lid is still on it. Have the students observe the mass, the tablets, and ask the following questions:

- What is happening to the tablets?
- Why are they getting smaller? Here students may say that they are simply dissolving. Ask further questions to help them understand that a chemical reaction is also occurring which produces gas.
- What will happen to the gas when I un-stopper this flask?
- If the gas leaves, what would you expect to happen to the mass of the flask?

Slowly unscrew the soda bottle cap and continue unscrewing it until gas freely leaves the bottle. Let it sit for a moment. Use the balance to again measure the flask with the liquid and the stopper. Have the students observe the change in mass on the balance.

- How do you account for the change in mass?
- How is this similar to soda that we opened earlier?
- What is the difference in mass between the start of this demo and now?
- If we could collect all the gas that escaped, what would its mass be? Why?

The last several questions above are aimed at getting students to make a prediction based on their understanding of conservation of mass. Students should now have no need for the information and data table that was provided in part two of the step-by-step procedure.

Part 3

At this point the instructor has a decision to make based on how prepared the students are to handle this scenario. Three scenarios are:

1. For advanced classes that have worked extensively with a variety of laboratory equipment and set-ups, have students wrestle with how to collect the gas.

2. For intermediate classes, provide the lab equipment (test tube, stopper with tube, gas collection water bath) set up for the students and have them create a procedure.

3. For students early in a physical science or chemistry course, show them the precise set-up in the cookbook activity, but have them explain the rationale for the set-up.

At the very least the instructor should ask the following questions regarding the original procedure listed at the beginning of this article:

- Why is securing the stopper in the test tube as quickly as possible so important?
- How might the length of the tubing affect the amount of gas collected?
- Why is removing all bubbles from the collection container important?
- Why is this apparatus needed? Or, why can't we just hold another vessel up to the test tube and collect the gas that way?
- How might you set up your representation of data? Students will likely suggest a data table, and follow this with “Why do we commonly use tables to display our data?”

Summary

Clearly the alterations suggested above will substantially increase both the engagement in the process and depth of understanding of the content. By making the above changes, the teacher can affect a shift to a classroom where students must think, speculate, and provide rationales for their ideas. The latter is more conducive to promoting learning, and these simple changes radically change the intellectual climate of the classroom. Students will not only develop a much deeper and robust understanding of gases having mass, the conservation of mass in chemical reactions, and this laboratory set-up, they are also now in a much better position to deeply understand that gases have density and how to determine it. Moreover, they will also develop several other equally important outcomes such as creativity, critical thinking, problem solving, effective communication skills, and applying science concepts to everyday phenomena.

References:

Haber-Schaim, U. (1972). *Introductory Physical Science*. Englewood Cliffs, New Jersey. Prentice Hall.*

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* A useful source of activities for teaching conservation of mass concepts is *Introductory Physical Science* (Haber-Schaim, 1972).

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