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Heavy Metal

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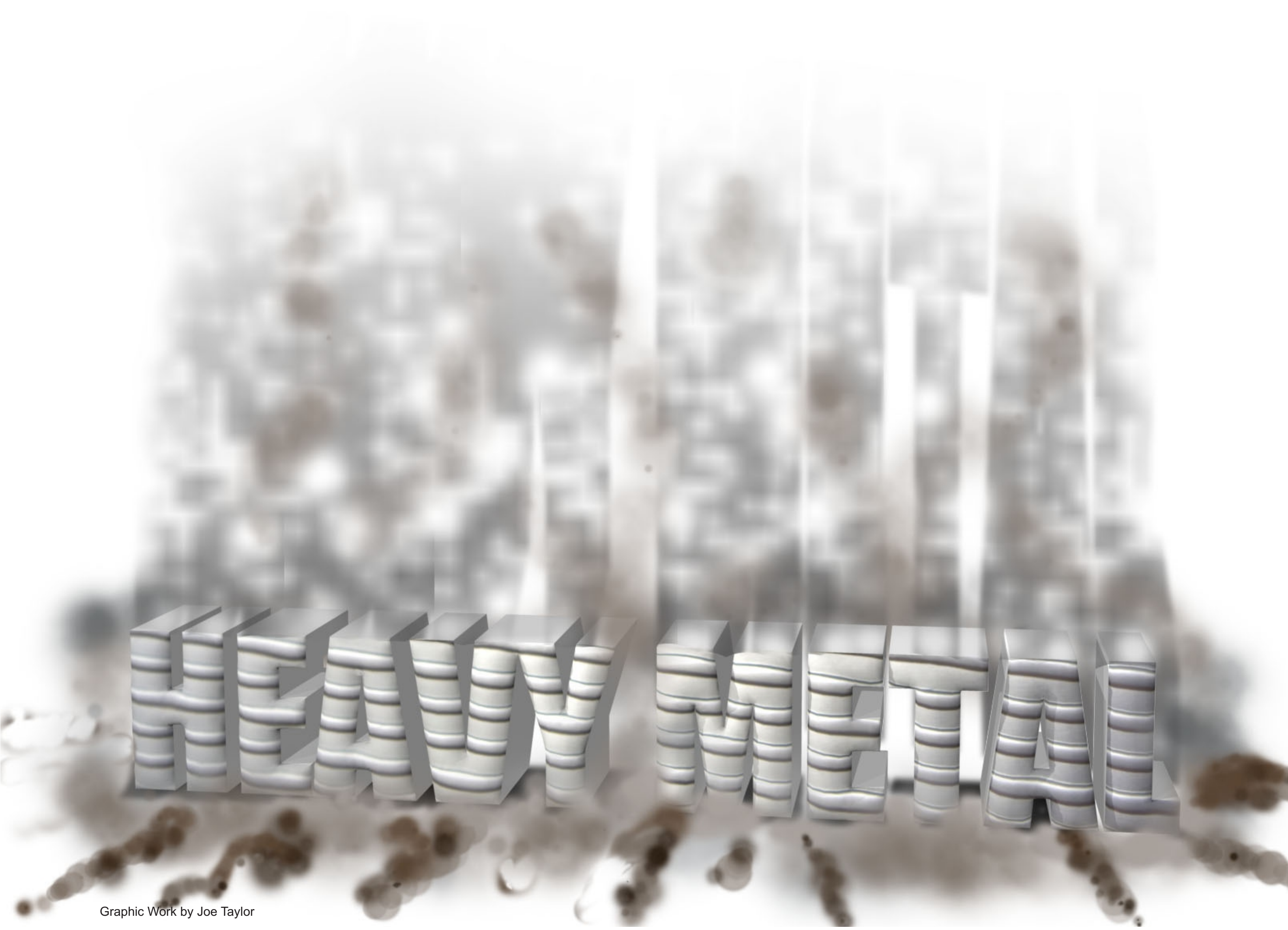

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USING COMBUSTION TO TARGET COMMON MISCONCEPTIONS ABOUT MASS

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ABSTRACT: We use this metal oxidation inquiry activity to encourage students to investigate the law of conservation of matter by performing combustion reactions on readily available metals such as aluminum, copper, iron, tin, and zinc. After observing mass changes, we challenge students to consider from where additional mass of products comes. *This activity promotes National Science Education Content Standards A, B, and G and Iowa Teaching Standards 1, 2, and 3.*

The law of the conservation of matter is fundamental to a deep understanding of many chemistry concepts. Properties of matter underlie the physical science standards for grades 9-12 (National Research Council, 1996), including the application of knowledge of chemical reactions as highlighted in the Iowa Core Curriculum.

Traditionally, students are taught the law of the conservation of mass by memorizing a definition such as “the total mass remains constant during a chemical change during a chemical reaction” (Ebbing, 1996), but little explicit connection is made to actual phenomena. Through the activities described below, modified from a Countertop Chemistry lab (Science House, 2006), we challenge students' understanding of matter and encourage them to mentally wrestle with ways in which the law of conservation of matter applies in various situations.

Previous Content Covered

This activity fits within our unit on combustion. We use this activity to specifically confront two common misconceptions students have about mass:

- mass changes in a chemical reaction (i.e., that combustion causes 'stuff' to disappear)
- gases do not have mass

Before combusting metals in this activity, students already investigated how hydrocarbons such as paper, wood splints, or wax react with oxygen to form carbon dioxide and water vapor, and that the resulting solid's mass is reduced. In this activity students observe a combusted solid gaining mass – which conflicts with their expectation that a burning object must lose some of its mass. The quest to explain the increased mass provides an opportunity to confront the misconception that gases do not have mass.

Teacher Demonstration

We start this investigation through a demonstration rather than having students in the lab so that we might draw students' attention to proper technique and safety. We also can more easily draw out student predictions and reasoning during whole class discussion using this demonstration. While asking students to make predictions during group lab settings is nice, we know that students will often jump ahead to the "doing" and skip the "thinking." Students tend to focus on the "wow" factor of demonstrations, so encouraging them to slow down and explain their thinking is important for helping them make meaningful connections between what they see and the targeted chemical concepts.

We begin with a Bunsen burner, steel wool, tongs, and a scale. Students put on safety goggles and gather around. We ask

- "What will happen when I hold this steel wool in the flame of the Bunsen burner?"

Typical student responses include:

"Nothing – metal doesn't burn."
"It will melt."
"It will burn."

To push student thinking toward our goals we ask

- "What do you think will happen to the mass of the steel wool?"

We wait after each question for a minimum of 3-4 seconds to give students enough time to process the questions and respond. We also wait for a few seconds after each student response to encourage more student responses and comments on each other's ideas. If students say the mass will go down, we ask them to explain where the mass went. We ask this question to reinforce that mass does not "disappear." Some students predict the mass will not change, and we ask them to explain their reasoning. In our experience, very few students have predicted the mass to increase.

After exhausting student predictions and reasoning, we ask

- "What could we do to investigate the effect of burning on the mass?"

Students are quick to suggest measuring the mass before and after heating the steel wool. We then mass the steel wool, ensuring that all students see the value of the mass – an electronic scale should be fine as long as students understand how it is calibrated to read mass – and proceed with heating the steel wool. The wool may turn the color of rust, but will probably appear bluish-black, and the mass will increase.

After observing the mass increase, we ask students to explain what happened. At this point we are not concerned with accuracy, but that students discuss possibilities. We give recognition to all student ideas, and rather than reject inaccurate ideas, we ask students to elaborate or ask the class to compare divergent ideas. Throughout this discussion we are guiding student thinking by asking for elaboration or building upon student ideas. A questioning sequence to lead students to understand that a chemical change occurred and that the additional mass came from the air might go as follows

- "What evidence is there of chemical change?" (mass change, color change, glowing)
- "What do you know about mass changes in a chemical change?" (mass is conserved)
- "Where did the mass go when we burned the paper?" (became a gas and went into the air)
- "Where, then, did the additional mass come from when burning the metal?" (students may say "from the air" providing an opportunity to discuss the chemical reaction taking place or the questioning could continue)
- "What role does oxygen play in combustion?"
- "What can you tell me about the mass of oxygen?"
- "How could the mass of oxygen help explain our observations when heating the metal?"

To assess student understanding we sometimes ask students to discuss the following question with their partners, or answer it in their notebooks.

- "If we burned 2 grams of steel wool in a closed container for an extended period of time with only 0.5 grams of oxygen, what would the new mass of the steel wool be? Explain."

While the question does not hold up to close scrutiny (the problem does not take into account the oxygen needed for the Bunsen burner), student responses give us a clear indication to what extent the students understand the fundamental concept.

Student Data Collection

Once students begin to grasp what is happening in the reaction, we ask them to collect additional data. We ask the students for some possible metals they might expose to heat to collect additional data. Some suggestions may be logical, but impractical or unsafe in school lab settings. If a student suggests beryllium, for instance, we ask students to suggest common metals. Good elements to have on hand are aluminum, copper, tin, zinc, and nickel.

We spread out the work and create data repetition by assigning pairs to test a few of the common metals using Bunsen burners at their lab stations. Before sending the students off to collect data we ask how we will keep track of the data. Students typically suggest a table that includes four columns: Metal, initial mass, final mass, & mass difference. As students work, we walk around the room to monitor student work and encourage them to connect their data to the demonstration and the law of conservation of mass.

Sample questions the teacher may ask groups while they work include

- “What problems are you having?”
- “How will you know how mass changes?”
- “How do you know if you have burned your sample long enough?”
- “What would be the benefits of having a common procedure for testing different metals?”
- “Why will having multiple tests, by multiple groups, give us more confidence in our results?”
- “What would be the problem if you lost some of your sample?”
- “How can you be sure not to lose any sample” (aluminum pie pans, for instance, to catch bits of oxide that fall off)
- “How did your group perform a test differently after seeing how another group did theirs?”
- “How are the things you are doing like what scientists do?”
- “How are they different?”

After data collection

Now that students have collected various data, we ask them to list some commonalities among their trials. We then ask students to try and explain their data and encourage them to make connections to the first demonstration. If students struggle, we take a more explicit approach in our questioning

- “What role does oxygen play in burning?"
- "How might this reaction be similar?”

Then we ask

- “How could the role of oxygen help us explain that the metals gained mass?”
- “How could we represent the reaction in an equation?”

From these guiding questions and encouraging students to balance their equations, the students are often able to write the equation:

$2Fe_{(s)} + O_{2(g)} \rightarrow 2FeO_{(s)}$

From their work with burning hydrocarbons, our students know that oxygen combines with other reactants in a combustion reaction. However, some students may not be able to derive the equation. If not, you might tell them what the product is and revisit it later after students learn about oxidation states.

From these experiences and discussions students start to notice that metals react with oxygen to form metal oxides. We then revisit the combustion of hydrocarbons and help students compare those reactions to the heating of metals through questions such as:

- “How do the products of the two reactions compare?”
- “How does the mass of the solid change in the reaction of metal compared to wood/paper?"
- "How can we explain the increase of mass in one reaction and decrease in the other?”
- “What reaction equations can we write?”
- “What do you notice between the location of the combusted elements on the periodic table and their products when reacted with oxygen?”

At this point, students begin to realize that a similar reaction is occurring, but the products differ and hence the observed mass differences of remaining solids. We go on to further confront the notion that mass is not conserved by having students either discuss or reflectively write on questions such as:

- “Imagine we did these experiments inside a large sealed container so that no gas can get in or out. How would the mass of the whole system change as we burned each substance? Explain your reasoning.”

Continually reinforcing the concept that mass is conserved in a reaction is essential so students will not cling to the common misconception that mass changes in a chemical reaction.

Conclusion

If this activity is explicitly connected to previous content it can be effective in creating cognitive conflict about two common conceptual difficulties – mass is conserved and gases have mass. Through engaging students' thinking via probing questions, students gain a deeper, more robust understanding of combustion. This deeper understanding of combustion prepares students for deeper understanding of oxidation when this concept is introduced later in the school year.

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