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Should I Get My Mole Checked Out?

Using Indirect Measurements to Determine Mole Ratios

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Grade Level	9th – 12th Grade	**Time Frame**	150 minutes
Subject	Science	**Duration**	2-3 class periods
Course	Chemistry, Physical Science		

Essential Question

How can we best measure that which we cannot directly see?

Summary

This lesson validates the concept of mole to mole ratios within a chemical equation. It is a lab that uses an indirect variable (in this case, temperature change) to determine optimal ratios of reactants, thus the ratio of reactants that create the most products (which is the mole to mole ratio). This can be used in the unit of mole ratios or as review later in the year, but the concept of a mole and the relationship between moles and mass should already have been introduced.

Snapshot

Engage

Students try to draw an image of the inside of a box without seeing inside the box.

Explore

Students conduct a lab exploring different volume ratios and measure temperature change.

Explain

Students process the data from the lab and share their findings.

Extend

Students read and construct a metaphor from an article on the history of Avogadro's Hypothesis.

Evaluate

Students display their completed metaphor from Extend.

Standards

ACT College and Career Readiness Standards - Science (6-12)

IOD202: Identify basic features of a table, graph, or diagram (e.g., units of measurement)
IOD304: Determine how the values of variables change as the value of another variable changes in a simple data presentation
IOD403: Translate information into a table, graph, or diagram
IOD404: Perform a simple interpolation or simple extrapolation using data in a table or graph
IOD502: Compare or combine data from a complex data presentation
IOD504: Determine and/or use a simple (e.g., linear) mathematical relationship that exists between data
SIN201: Find basic information in text that describes a simple experiment
SIN301: Understand the methods used in a simple experiment
SIN502: Predict the results of an additional trial or measurement in an experiment
SIN503: Determine the experimental conditions that would produce specified results
SIN702: Predict the effects of modifying the design or methods of an experiment
EMI401: Determine which simple hypothesis, prediction, or conclusion is, or is not, consistent with a data presentation, model, or piece of information in text
EMI502: Determine whether presented information, or new information, supports or contradicts a simple hypothesis or conclusion, and why
EMI505: Determine which experimental results or models support or contradict a hypothesis, prediction, or conclusion

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Oklahoma Academic Standards (Physical Science)

CH.PS1.7 : Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
CH.PS1.7.1: The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Oklahoma Academic Standards (Physical Science)

PS.PS1.7 : Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
PS.PS1.7.1: The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Attachments

- Avogadro's Hypothesis and the Duhemian Pitfall—Should I Get My Mole Checked Out - Spanish.docx
- Avogadro's Hypothesis and the Duhemian Pitfall—Should I Get My Mole Checked Out - Spanish.pdf
- Avogadro's Hypothesis and the Duhemian Pitfall—Should I Get My Mole Checked Out.docx
- Avogadro's Hypothesis and the Duhemian Pitfall—Should I Get My Mole Checked Out.pdf
- Lesson Slides—Should I Get My Mole Checked Out.pptx
- Mole-Mole Ratio Lab (Teacher)—Should I Get My Mole Checked Out.docx
- Mole-Mole Ratio Lab (Teacher)—Should I Get My Mole Checked Out.pdf
- Mole-Mole Ratio Lab—Should I Get My Mole Checked Out - Spanish.docx
- Mole-Mole Ratio Lab—Should I Get My Mole Checked Out - Spanish.pdf
- Mole-Mole Ratio Lab—Should I Get My Mole Checked Out.docx
- Mole-Mole Ratio Lab—Should I Get My Mole Checked Out.pdf
- What Is in the Black Box—Should I Get My Mole Checked Out - Spanish.docx
- What Is in the Black Box—Should I Get My Mole Checked Out - Spanish.pdf
- What Is in the Black Box—Should I Get My Mole Checked Out.docx
- What Is in the Black Box—Should I Get My Mole Checked Out.pdf

Materials

- Lesson Slides (attached)
- Mole-Mole Ratio Lab (attached; one per student)
- Mole-Mole Ratio Lab, Teacher (attached)
- What Is in the Black Box? handout (attached; one per group)
- Avogadro's Hypothesis and the Duhemian Pitfall (article; attached and linked below)
- Black box
- Marble
- Foam
- Tape
- Sodium hydroxide
- Sodium thiosulfate
- Bleach (sodium hypochlorite)
- Temperature probe and collection device
- Styrofoam cups and lids
- Pipettes
- Graduated cylinder
- Ring stand and clamp
- Large strips of paper (for Evaluate)

Engage

Teacher's Note: Making a Black Box

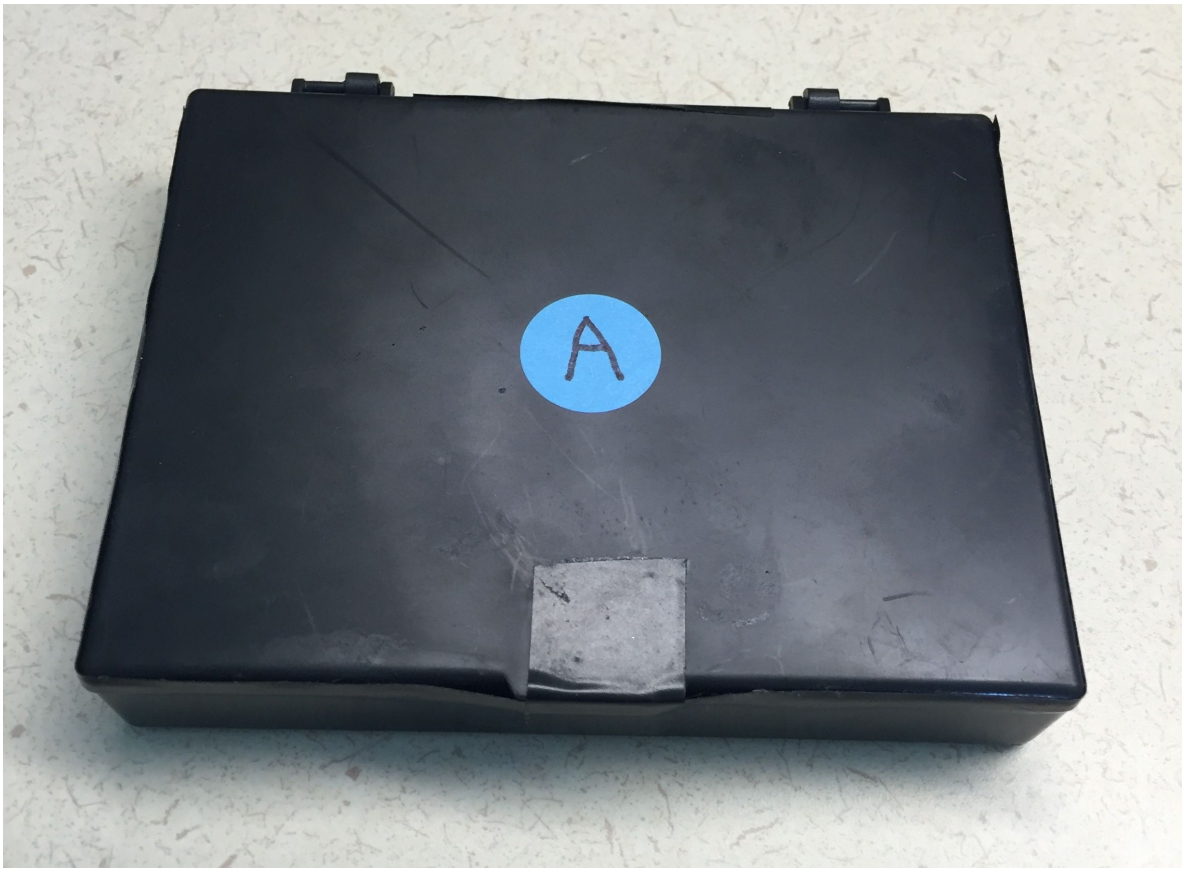
Black boxes come in many shapes and sizes, and different things happen with each. The goal of the black box in this activity is to force students to use other observations to make inferences about what they can't observe. They can't see what's inside, so they have to rely on what they hear and feel outside the box to figure out what is inside. It doesn't even have to be a black box. It just has to be opaque enough not to see inside it.

Preferably, have the open space inside the box only be 1.5 cm tall, so that the marble rolls in only two dimensions, not three. Then, use foam (or anything sturdy enough to withstand marble collisions) to cut either ramps or walls to put into the box. Make sure they are simple shapes; otherwise, they'll be harder to figure out once the box is closed and sealed. Depending on how much you trust the students, seal the edges with glue or tape to ensure no peeking.

A set of black boxes will be out for students when they walk in. Assign each pair a black box. Make sure the objective, "What is the map within the box?" is written on the board. Before students start, ask them to create questions using the Question Generating strategy.

Pass out the attached **What Is in the Black Box?** handout. Have students brainstorm questions about any barriers or challenges that will prevent them from completing the task, which is: *Figure out what is inside the box without opening it*. Draw a diagram on your handout.

Tell them that those questions will be presented to the whole group and possible answers will be discussed. Suggest that students tilt and rotate the box, listening to how the marble inside rolls around and listening for any barriers that stop the marble's progress. Assign them to draw what they think is inside the box on the handout.



Outside of Sample Black Box



Inside of Sample Black Box

Teacher's Note: To Show or Not to Show?

It's an option to share what the inside actually looks like, but it's recommended that the true inside is never revealed, just like it is with real scientific principles. If students struggle emotionally with that, you could have the pairs do the task for each box and from the different drawings from each group decide as a class what the inside looks like for each box. Keep in mind, though, that this extension alone could easily take up a class period or two.

Explore

Pre-lab setup:

For advanced/honors students, consider having them do their own full set-up and clean-up. With this option, little teacher preparation is needed. Just make sure the supplies exist (if possible, don't even get them out of the closet or storage—have the students do that, just like real scientists).

If you're setting the lab up for the students, both solutions and lab stations need to be considered. The solutions aren't time sensitive, so you can do them the day before with no problem.

Prepare the 0.50 M NaClO solution by diluting 745 mL of bleach (if it's labeled as 5.25% NaClO by mass) with distilled water to get a total of 1.0 L (each group will probably use about 200 mL, so adjust the ratios as needed). If using Ultra bleach (6% NaClO by mass), use 653 mL of bleach and add enough distilled water to bring the entire solution to 1.0 L.

Prepare the 0.50 M $Na_2S_2O_3$ in three steps (the sodium thiosulfate produces the best result when created in a basic solution). First, dissolve 124 g of $Na_2S_2O_3 * 5H_2O$ (or 79.1 g of anhydrous $Na_2S_2O_3$) in 500 mL of distilled water. Then, add 8 g of solid NaOH and stir the mixture until all dissolved. Finally, add enough distilled water to bring the total volume to 1.0 L (once again, each group will probably use around 200 mL, so adjust as needed).

Ensure that each station has a temperature probe and collection device (or a thermometer if you don't have LabQuests, EasyLinks, or CBLs), pipettes (two per station, one for each reactant), two styrofoam cups (or a cup and lid), and a graduated cylinder (calibrated at least to 1 mL). If available, provide a ring stand with utility clamp to hold the temperature probe. It is not necessary if not available.

Teacher's Note: Letting Go of Fear

Yes, this set-up can seem intimidating. Yes, the preparation is tedious (the molarities MUST be equal, so your measurements must be as exact as possible), and there's a lot of it. However, this is a lab in which students generally have high success rates at getting good data (that is, the correct ratio), which makes this lab a great one to do. Just remember that every time you make a solution, it'll be easier to make the solution the next time you try.

Day of lab:

Assign students to groups no greater than three, if possible. This is to make sure conversations are happening and each student is still involved and active.

Using the strategy Thinking Notes, have the students read through the procedures and pre-lab questions, putting stars next to steps that directly relate to data collection, an exclamation mark next to details about measurements (for example, the specific volume, or not just initial temperature but temperature readings throughout each trial), and question marks where the procedures are confusing or unclear to them.

Have the lab groups discuss and answer the pre-lab questions, reflecting back to the procedures to add stars or exclamation points and/or to see if the answers clear up confusion.

Teacher's Note: Pre-Lab?

There are pre-lab questions in the lab packet. You may wish to assign them as homework or in-class work before students start the lab. But, yes, have them answer the pre-lab questions before they start executing the procedures.

The questions are intended to prompt thinking about why each step of the procedure is important and not only how the data is collected but what to do with the data once it exists. This is a great time to see what students understand and what they don't, clearing up misconceptions about the lab and allowing them to analyze why they are collecting the data the way the procedure asks them to

Once students have finished their pre-lab questions and found resolutions to the confusing parts of the procedure, direct them to their lab stations and instruct them to get started collecting data.

Walk among the groups to help troubleshoot, but try not to take over if it isn't perfect; students need to learn the subtle art of exactness through their own experiences with only gentle prompts from the teacher.

Possible Student Errors

Mixing the solutions then inserting the temperature probe, or not waiting long enough to stop collecting temperatures, are the two biggest errors. Initial temperature, before the reaction starts, is needed to determine the temperature change. Then, enough temperature measurements need to be made to show the rise, then the fall, since maximum temperature change is what the students need. Once the temperature starts falling, the peak has already been reached—but don't throw the baby out with the bath water. There needs to be a defined, multi-point decline.

Teacher's Note: Safety

The students will be handling bleach. Protective eyewear is a must, and gloves are also recommended. You should warn students the day before and the day of the experiment because bleach will stain clothes permanently.

Explain to students that they will be combining different ratios of reactants, starting with equal volumes of each (thus a 1:1 ratio) and keeping the total volume the same but shifting the amount of each.

If students are stuck with what amounts they should choose, nudge them in the direction that would give them less than 10. Whole number ratios, like 20 mL of NaClO and 30 mL of $Na_2S_2O_3$ is a 2:3 ratio, but 12 mL of one and 38 mL of the other is a 6:19 ratio. If the students want to try the weird ratios, though, let them. They can still get usable data points from them; they just won't be the right answer.

Key

The correct ratio is 4 NaClO to 1 $Na_2S_2O_3$.

Explain

Once students have collected at least seven different trials, have the groups return to their seats to process their data. Have them read the post-lab questions as a guide through the process of determining the optimal mole:mole ratio. Also ask questions relating to auxiliary ideas (like limiting reactant and justifying equal total volumes for each trial).

When students are done, have them do the 4-2-1 strategy. Students, individually, will write down four conclusions that can be drawn from the lab. They will find a partner (who wasn't part of their original lab group), share their four conclusions, and together, they will decide what two are the most important conclusions. Then, make groups of four to decide which one conclusion is the most important (or insightful) of those the group has and have groups share these with the whole class.

Finally, have students do a 3-5 minute Quick Write over what they've learned, explaining the information in enough depth for someone who doesn't know it. Regroup students to share and discuss their quick writes. During this discussion, point out the essential question (written on the board), "How can we best measure what we cannot directly see?"

Have students relate what they've written to their response to the essential question, allowing students to add to their quick write and retain it as part of their notes.

Extend

Pass out a copy of the article Avogadro's Hypothesis and the Duhemian Pitfall (or use the attached **Lesson Slides** summarizing the article) for each student to read.

Teacher's Note: Reach for More

The slides are a summary of the article for students who need the easier option. However, if you want the published article, it's also provided. It's only two and a half pages and is a pretty easy read (in comparison to other science journal articles).

After they have read the story, have students pair up for Metaphorical Thinking. Prompt them connect to the struggles the scientists faced with experiences of their own and discuss this with their partner. Then, have them construct a metaphor or simile and give the rationale for their comparison.

Teacher's Note: Set Them Free and Let Them Fly

To get great comparisons that have meaning to the students, giving them the freedom to explore their own experiences and connect them to the lesson is a must. Relinquishing control is a challenge, but the results will be more varied and insightful if you just let it go. Don't let it get out of hand, but try not to guide students in a particular direction.

After the pairs have discussed the assigned topic, have the students form groups of three or four with students different from their pair partner. Share their responses; then have groups share (with the whole class) those responses they felt were the most compelling or interesting.

Evaluate

Have students write their metaphors on large strips of paper. Hang them around the room and down the hall so students can read work from other classes. You never know, they may use them for inspiration when they're experiencing "the struggle."

Resources

- Causey, R.L. (1971). Avogadro's hypothesis and the Duhemian pitfall. Journal of Chemical Education, 48(6), 365-367. https://doi.org/10.1021/ed048p365
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