|  |
| --- |
| **Task-level phenomenon:**Vehicles and industrial processes are contributing to global climate change by emitting carbon into the atmosphere as a result of using gasoline as a fuel source. Local solutions may be available to address this problem. **Synopsis of high-quality task:**In this task, students use an introductory lab exploration as a model to quantify the release of carbon dioxide from a basic chemical reaction. By extending this model, students quantify CO2 emissions from a given volume of gasoline. In a format of their choice, students rely on these calculations to develop and communicate recommendations to local officials for reducing CO2 emissions within their community.**Anticipated student time spent on task:** 5 sessions, 45-50 minutes each (plus additional time to complete final project) **Type of Task (check one):** \_\_\_\_ 1. Investigation/experimentation/design challenge\_\_X\_ 2. **Data representation, analysis, and interpretation**\_\_\_\_ 3. Explanation **Student task structure(s):** * Group work/class work (part 1 and 2)
* Individual work (part 3 and 4)
 |
| **STE Standards and Science and Engineering Practices:****HS-PS1-7.** Use mathematical representations and provide experimental evidence to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Use the mole concept and proportional relationships to evaluate the quantities (masses or moles) of specific reactants needed in order to obtain a specific amount of product.Clarification Statements:* Mathematical representations include balanced chemical equations that represent the laws of conservation of mass and constant composition (definite proportions), mass-to-mass stoichiometry, and calculations of percent yield.
* Evaluations may involve mass-to-mass stoichiometry and atom economy comparisons, but only for single-step reactions that do not involve complexes.

**Science and Engineering Practices*** Using mathematics and computational thinking
* Engaging in argument from evidence
 |
| **Prior Knowledge:** Previous Standards from [Strand Map](http://www.doe.mass.edu/stem/standards/StrandMaps.html):**8.MS-PS1-5.** Use a model to explain that atoms are rearranged during a chemical reaction to form new substances with new properties. Explain that the atoms present in the reactants are all present in the products and thus the total number of atoms is conserved. Clarification Statement:* Examples of models can include physical models or drawings, including digital forms, that represent atoms.

State Assessment Boundary:* Use of atomic masses, molecular weights, balancing symbolic equations, or intermolecular forces is not expected in state assessment.

Topics previously covered in this course include:* Chemical reactions (products, reactants, balancing)
* Law of conservation of mass
* Stoichiometry and dimensional analysis
 |
| **Connections to the real-world:**The addition of carbon to the atmosphere as a result of the burning of fossil fuels is a significant contributor to global climate change. While students may be aware of this phenomenon, they may not understand in detail its scope. Through this task, students will more deeply understand the impact that they and their community have on climate change by burning a single tank of gasoline. As a result of their calculations, students will understand how much their driving habits contribute to global carbon emissions and be equipped to make changes at the local level.  |
| **Mastery Goals:**Learning Objective:* Students will be able to apply concepts of stoichiometry and the law of conservation of mass to real world problems, specifically through quantifying the production of carbon emissions from the burning of gasoline.

Performance Objective:* Students will be able to construct an ar~~g~~ument using evidence from multiple sources, including evidence from their own calculations, about the impact of CO2 emissions in Massachusetts.

Language Objective:* Students will use academic vocabulary through oral discussion with classmates in small groups as hands-on experimentation and calculations are performed.
* Students will communicate through writing their findings and advocate for local policy changes.
 |
| **Teacher instructions**Part 1: Overview – Analysis of law of conservation of mass* Students observe a demonstration to model CO2 emissions of industry through a reaction of baking soda and vinegar
* Students measure and record the mass of the reactants before and mass of the products after and recognize that the law of conservation of mass is not violated, but CO2 was emitted into the air (therefore cannot be measured).
* Students design and test a procedure to capture the CO2 from the reaction and use data to see if mass is conserved. This procedure serves as a model for students and prepare for more complex calculations to come.

Part 1: Teacher notes & resourcesDuration, 45-50 minutes* Teacher demo: Weigh mass of flask, baking soda, and vinegar separately. Model recording data. Pour the baking soda and vinegar together in a flask and watch the reaction happen. Take the mass of the products in the flask after reaction takes place and engage in class discussion about why mass of reactants does not equal mass of products.
* Instruct students to design their own procedure to capture the CO2 and measure it (see handout). This step includes basic materials (balloons, plastic baggies, rubber bands, tape, etc.) The teacher should encourage students to develop simple yet effective designs. Students should submit a clear, well-reasoned design before being allowed to proceed. *WARNING: Follow all lab safety procedures in Appendix XI of the* [*STE Framework*](http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf) *(e.g., safety goggles are essential), and watch for students using volumes of baking soda and vinegar that are too large that will result in an overabundance of gas that might cause too much pressure within their gas capture design.*
* Some things to consider:
	+ - Students may want to put the baking soda and vinegar in the flask first, and then seal it with a balloon or other material. This would cause some gas to escape. Encourage them to troubleshoot by asking “How can you make sure you’re collecting the gas as soon as the reaction starts?” (One possible solution is to put the baking soda in the balloon and dump it in the flask after balloon is secure on the flask)
		- In their procedure, be sure they plan to take the correct measurements of mass before and after so they can accurately find the mass of the products and compare them to the mass of the reactants.
		- Students may need help understanding that they need to subtract the mass of the flask and other materials used in their design to get the mass of the products alone. This should be modeling during the demo.

Part 2: Overview – Analysis of climate change, CO2 emissions, and use of law of conservation of mass to quantitatively represent CO2 emissions from cars.* Students read an article about how CO2 emissions are related to climate change
	+ http://www.environment.gov.au/climate-change/climate-science-data/climate-science/greenhouse-effect
* Show graphs of CO2 emissions in MA
	+ https://www.mass.gov/service-details/ma-ghg-emission-trends
	+ Students discuss and figure out that petroleum is the biggest contributor to CO2 emissions in MA, so we should focus research around that.
* Students can use stoichiometry and the law of conservation of mass to calculate the amount of CO2 emitted by cars in various scenarios
	+ - Using dimensional analysis: 12 gal tank of gas → liters → grams → moles → moles of CO2
		- Example: Combustion of gasoline in a car.
		- 2 C8H18 (gas) + 25 O2 = 16 CO2 + 18H2O
		- The volume of CO2 emissions can be calculated on either of two scales:
			* Number of registered passenger cars in Massachusetts. https://www.fhwa.dot.gov/policyinformation/statistics/2015/mv1.cfm (2015 data) - OR -
			* The number of vehicles registered in your community. This information can be provided by a City or Town Assessor’s Office through its review of excise tax data. Students can use this number to calculate vehicle CO2 emissions from their residents and businesses.

Part 2: Teacher notes & resourcesDuration, ~90-100 minutes* Go through the article on climate change and engage students in a discussion on climate change and how fossil fuels affect climate.
* Show graphs of CO2 emissions in MA
	+ https://www.mass.gov/service-details/ma-ghg-emission-trends
	+ Students discuss and figure out that petroleum is the biggest contributor to CO2 emissions in MA, so we should focus research around that.
* Allow students to work through dimensional analysis problems related to this material (see handout).
* REMINDER: The number of vehicles (2,305,471 cars) used in the calculations included in the example of student work below were from a source for which permission for use could not be retrieved. This has been replaced by a source that is in the public domain and is available for use. It includes the value 2,349,569 cars in Massachusetts in 2015. https://www.fhwa.dot.gov/policyinformation/statistics/2015/mv1.cfm

*NOTE TO TEACHER: Question 4 involving the article* Which Emits More Carbon Dioxide: Volcanoes or Human Activities? *was added AFTER pilot testing and is not reflected in the example of student work. This question was added in order to help students make meaning of their calculations through a connection to a natural phenomenon to which they can relate. Other natural phenomena that students can compare to may include forest fires. Numerous articles are available online for forest fires. Through calculation, students should reason that the passenger cars in Massachusetts (a very small state) produces approximately 13 million metric tons of CO2 annually (assuming each car burns 12 gallons of gasoline per week). This equals approximately 2% of world-wide annual volcanic CO2 emissions. In the section titled, “Explaining the Situation in Massachusetts” the student calculated the amount of weekly, not annual, CO2 emissions in Massachusetts. It will be important to advise students to calculate annual totals for better comparison.* https://www.climate.gov/news-features/climate-qa/which-emits-more-carbon-dioxide-volcanoes-or-human-activitiesPart 3: Overview – Negative emissions technologies and mitigating climate change* Students use the internet to investigate real world examples of ways to capture CO2 (some possible examples include negative emissions technologies, such as biotic or mechanical carbon sequestration) and analyze pros and cons of each (amount of CO2 absorbed, cost of absorption, etc.).
	+ Reference article: https://n.pr/2P6Hh5d
* Students will use their research to choose one technology that is the most effective.

Part 3: Teacher notes & resourcesDuration, ~45-50 minutes* Have students search “negative emissions technologies” and summarize their research on note sheet (see handout). There are many suitable websites that students can base their research on.

Part 4: Overview – Summative task* Students write an evidence-based letter or create some other evidence-based work product to send to an elected official pitching an idea to reduce CO2 emissions

Part 4: Teacher notes & resourcesDuration will vary – See description of final task in student handouts below.* Students may need help quantifying their idea as well as connecting it to their intended audience. Students will be eager to offer ideas, so it may be helpful to engage in a class discussion and help focus some of the ideas they have and give them guidance on how to quantify their idea and apply evidence.
* For example, students may have the idea to plant more trees. If they are sending this to an elected official, what specifically are they asking them to do? They will then need to quantify how much CO2 a tree would be able to consume and how that would counteract the CO2 released from cause. The quantification step will take some creativity and rely on a lot of assumptions, which should be as realistic as possible. This is where they may need the most support.
 |
| **Instructional Materials/Resources/Tools:** Include:* Student directions for completing the task (See below)
	+ Students may work in predetermined lab groups (e.g., 3-4 students per group)
* A materials list and/or materials management
	+ Safety goggles
	+ 250ml Erlenmeyer Flasks
	+ 250ml beakers
	+ Electronic balance
	+ 5.0g Baking soda
	+ 10 ml Vinegar
	+ A variety of gas capturing materials for students to choose from (e.g., plastic baggies, plastic wrap, non-latex balloons, parafilm, aluminum foil, tape, etc.)
	+ calculators
* Safety information as applicable
* Any handouts, links, books, videos, materials, etc. that is needed for the student to complete the task
	+ Handouts
		- Start with a Model: Baking Soda + Vinegar
		- CO2 Emissions: The Chemistry Behind it and Why We Should Care
* Scoring rubric – Focus on including the standards-content and practices for performance criteria. Less focus should be on presentation style, design, etc., unless it is tied directly to an ELA standard.
 |
| **Accessibility and Supports:** Scaffolds for struggling learners:Template for calculations:* Step one: Convert 12 gallons to liters (1 gallon = 3.785 L)
* Step two: Convert Liters from step 1 to grams, and then to kilograms
* Step three: Convert grams from step 2 to moles using molar mass
* Step four: Use the mole ratio from the balanced equation to convert from moles of gasoline (step 3) to moles of carbon dioxide
* Step five: Convert moles of carbon dioxide from step 4 to grams using molar mass

Strategies to increase rigor for advanced students:Remove useful conversion factors from day 2 worksheet, students must figure out what conversion factors are needed and look them up on their own.  |
| **Task Sources:** * The Ambassador would like to recognize Emily Slyva of Haverhill High School for her contributions to the development of this task.
* Article sources:
	+ Australian Government Department of the Environment and Energy. *Greenhouse Effect* Retrieved 2019, May 23 from http://www.environment.gov.au/climate-change/climate-science-data/climate-science/greenhouse-effect
		- CC BY 3.0 AU
		- Changes were not made to the content on this site.
	+ Massachusetts Executive Office of Energy and Environmental Affairs. *Massachusetts Greenhouse Gas Emissions Trends.* Retrieved 2019, May 23 from https://www.mass.gov/service-details/ma-ghg-emission-trends
		- Public domain website.
		- CC BY 4.0
	+ U.S. Department of Transportation Federal Highway Administration. Office of Policy Information. *State Motor-Vehicle Registrations 2015.* Retrieved 2019, May 23 from <https://www.fhwa.dot.gov/policyinformation/statistics/2015/mv1.cfm>
		- Public domain website.
		- CC BY 4.0
		- NOTE TO TEACHERS: The number of vehicles (2,305,471 cars) used in the calculations included in the example of student work below were from a source for which permission for use could not be retrieved. This source is in the public domain and is available for use and includes the value 2,349,569 cars in Massachusetts in 2015.
	+ National Oceanic and Atmospheric Administration. *Which Emits More Carbon Dioxide: Volcanoes or Human Activities?* Retrieved 2019, May 23 from https://www.climate.gov/news-features/climate-qa/which-emits-more-carbon-dioxide-volcanoes-or-human-activities
		- Public Domain website.
		- CC BY 4.0
 |
| **Sample Student Work:**A Student work sample is included below. |

**Start with a Model: Baking Soda + Vinegar**

**Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_ Per \_\_\_\_**

**Partner(s) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Write the full balanced chemical equation for the reaction of baking soda and vinegar, labeling the products and reactants.**

**Baking soda + Vinegar → carbon dioxide (gas) + water + sodium acetate**

 **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Problem/Purpose:**

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**Part 1: Demo**

**Observe the reaction of baking soda and vinegar. Is the mass of the reactants equal to the mass of the products? If not, does this violate the law of conservation of mass?**

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**Part 2:**

**Your task is to design a procedure to capture the CO2 released by this reaction and measure the mass of the products to prove the law of conservation of mass. Brainstorm with your group ideas. Below is a list of possible materials to use. You MUST have a way to measure the mass of the products at the end, and you must include the mass of baking soda and vinegar initially in your data table.**

**- Plastic Ziploc bags**

**- Metal wire**

**- Beakers/Flasks/Glassware**

**- Balloons**

**- Rubber bands**

**Procedure:**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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**Materials:**

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***Create a data table including all of the measurements you will need to take during your procedure. Check in with your teacher for approval. Once your procedure is approved, you may carry it out.***

**Data (organized, neat table labeled with units):**

**Conclusion questions:**

**1. Summarize the law of conservation of mass. Explain how the law of conservation of mass applies to this experiment.**

**2. Using the mass of baking soda that you started with and the balanced equation, calculate the mass of carbon dioxide produced by the reaction (use your map).**

**3. We can quantify how “close” you were to the correct answer in a lab using Percent Yield.**

 ****

**The number you were supposed to get is known as your “theoretical yield”. The number you actually collected in the lab is your “actual yield”. If those two numbers are the same (which is the goal), you would have a 100% yield. Figure out with your group what values you would use for actual and theoretical yield, and calculate the percent yield from your experiment.**

**4. If your percent yield was not 100%, list possible sources of error/room for improvement in the lab.**

**CO2 Emissions: The Chemistry Behind it and Why We Should Care**

Yesterday we observed a simple model of carbon dioxide being emitted into the air. CO2 is emitted in the air through a variety of processes we rely on every day. This is a serious problem that needs to be addressed.

As a class, we will:

- Investigate climate change and fossil fuels

o http://www.environment.gov.au/climate-change/climate-science-data/climate-science/greenhouse-effect

- Look at data of CO2 emission in MA

What is the main source of CO2 emissions in Massachusetts? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Below is the chemical equation for the combustion of gasoline in a car. Balance the equation and indicate what type of reaction this is.

\_\_\_\_ C8H18 (gas) + \_\_\_\_ O2 → \_\_\_\_ CO2 + \_\_\_\_ H2O Type of reaction \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. A typical car holds 12 gallons of gas. Use dimensional analysis and unit conversions to calculate how much CO2 is released into the atmosphere when a full tank of gas is used up. Show all work.

Some useful conversion factors:

1 gallon = 3.785 L

Density of gasoline = 0.77 kg/L

2. There are 2,305,471 cars registered in Massachusetts. If each car burns one tank of gas per week, how much CO2 is released per week in Massachusetts? Use your answer from question 1 to create a unit conversion.

 3. There are 48,786 cars and light trucks registered in the City of Haverhill. If each vehicle burns one tank of gas per week, how much CO2 is released per week by City of Haverhill residents and businesses? Use your answer from the above questions to create a unit conversion.

4. Deepen Your Understanding: Read the article *Which Emits More Carbon Dioxide: Volcanoes or Human Activities?* via the linbk below. How does the volume of carbon emissions in your calculations compare to those in these natural phenomena? Conduct a broader websearch of natural carbon emissions if you need more information. https://www.climate.gov/news-features/climate-qa/which-emits-more-carbon-dioxide-volcanoes-or-human-activities

 There are a variety of technologies that have been designed to counteract the emission of CO2 called **negative emissions technologies**. Investigate using the internet these technologies and analyze the pros and cons of each (amount of CO2 absorbed, cost of absorption, etc.). Summarize your findings using these three column notes.

|  |  |  |
| --- | --- | --- |
| Technology name:Summary | Pros | Cons |
|          |   |   |
| Technology name:Summary | Pros | Cons |
|          |   |   |
| Technology name:Summary | Pros | Cons |
|           |   |   |
| Technology name:Summary | Pros | Cons |
|           |   |   |

Analyze your research of negative emissions technologies and weigh the pros and cons of each. Decide which technology you think is most effective in reducing the amount of CO2 emissions.

**Your final task is to communicate effectively to an elected official (think of who you could reach out to and how effective their influence could be).**

 **Some options include:**

* **Writing a letter**
* **Creating a Google Slides presentation**
* **Filming a video PSA style**
* **Any other idea that is approved by the teacher**

Your final assessment should include the following, but there is also a lot of room for choice:

* **Summarize** your research on CO2 emissions in Massachusetts.
	+ What are the ways we emit CO2? What is the main source in MA? Be sure to source the data you are referencing.
* **Explain** using your numerical analysis how much CO2 is emitted by the cars in MA each week. Remember, you are explaining this to someone who might not understand chemistry that well, so you need to simplify it.
* **Address the issue**: How does CO2 emissions affect the atmosphere, and why should we care?
* Explain what **negative emissions technologies** are the different types. Then, explain the one you chose was most effective and why.
* **Include one recommendation** to the elected official on how we can combat this issue. This is where you have a lot of choice. You have lots of research to work from. We worked through some scenarios using math, but some other things to consider:
	+ Does speed affect CO2 emissions?
	+ Does type of car affect CO2 emissions?
* Attach ALL calculations as a reference (not necessarily as part of the letter).

\*\*Whatever choice you make, you must come up with a recommendation on how to combat the issue AND **quantify** the issue. For example, if your choice was to focus on decreasing the amount of cars in MA, you can include your numbers on how much CO2 is emitted by all the cars in MA in your argument, as well as a realistic idea to decrease or disincentivize the use of cars. Another example that has already been done is getting rid of all the toll booths in MA. This reduced idle CO2 emissions by cars going through toll booths.

Student work sample:

A student report that was submitted to the Mayor of our community.











