

8E – PROJECT: DESIGN AN AIRBAG

OVERVIEW

Students will design an airbag system that inflates in 2 seconds or less.

TIME REQUIRED

3 – 5 60-minute class periods.

MATERIALS

- Device with SPARKvue software
- Temperature sensor
- Pressure sensor with tubing and connectors
- Digital balance (readability: 0.01 g)
- Graduated cylinder, 25-mL
- Tape
- Film canister or souffle cup with lid
- Plastic zip bag, quart size
- Plastic bags, sandwich size (2)
- Baking soda or sodium bicarbonate, NaHCO_3
- Vinegar or 5% solution of acetic acid, CH_3COOH

BACKGROUND

Airbags were invented in the early 1950s. Today, all cars are required to have airbags to protect drivers and their passengers from moderate-to-severe front impact collisions. The proper use of airbags and seat belts have reduced the number of deaths by over 20% and reduced severe head injuries by over 60%.

Airbags deploy when sensors detect a significant reduction in vehicle speed. In 1/20th of a second, a driver airbag fills to its capacity of 50-60 L and a passenger airbag fills to 120 L. The airbag must fill quickly with an inert gas such as nitrogen, N_2 , because the function of an airbag is to inflate quickly and reduce the impact of a person's body onto a hard surface such as a steering wheel or dashboard. After all, there's no need to replace one potential hazard (head-on collision) with another (chemical burn). The perfect airbag inflates and deflates very quickly. A deflated air bag will not prevent injury upon impact, but one that stays inflated too long causes injuries. In this project, you will focus only on inflation.

Early designs required a series of reactions to produce enough nitrogen gas to fill the bag in a very short period. The main ingredient in this series of reactions included sodium azide (NaN_3):



As can be seen above the use of sodium azide and sodium metal in two separate and simultaneous reactions produced the nitrogen gas to fill the airbag. To keep toxic chemicals from escaping during airbag deployment, metal oxide products react with silicon dioxide to make silicate glass.



SAFETY

Follow these important safety precautions in addition to your regular classroom procedures.

- Wear safety goggles at all times.
- Do not let the pressure sensor get wet.

PERFORMANCE CRITERIA

Airbags are designed for older children and adults. Your team must design an airbag for young children using common household substances that will form a harmless gas upon reaction. In this case, you will use baking soda (sodium bicarbonate, NaHCO_3) and vinegar (5% acetic acid, CH_3COOH). When baking soda and vinegar react, sodium acetate, water and carbon dioxide are produced.

CONSTRAINTS

The airbag must fill to capacity in less than 2 seconds without exploding.

RESEARCH

Research the design and function of airbags. Watch videos of airbags as they are deployed to better understand how they work. Investigate why current airbag designs are considered dangerous for children. Keep a record of your research results in the space provided on your answer sheet. Attach a separate paper if necessary.

PROCEDURE

1. Open SPARKvue.
2. Open the 08E Design an Airbag lab file in SPARKvue under Experiments > Essential Chemistry.
3. Use the Bluetooth icon to connect the Temperature sensor and the Pressure sensor.
4. On your answer sheet, write a balanced equation representing the reaction of sodium bicarbonate with acetic acid. Review the Performance Criteria section for information about the reaction.
5. Use the balanced equation to determine the mass of NaHCO_3 needed to react with 5.00 mL of vinegar. Assume the density of vinegar is 1.00 g/mL. Show your answer sheet with calculations to your teacher for approval.
6. Upon approval, get the required amount of NaHCO_3 , place it inside the canister and close the lid.
7. Set the temperature sensor inside a sandwich bag so the stainless steel probe sticks out. Tape the bag snugly above the sensor box as shown. Make sure the bag does not touch the end of the probe. Your goal is to measure air temperature while protecting the sensor box from liquids.
8. Use the clear connector to attach about 2.5 inches of tubing to the pressure sensor. Tape the other sandwich bag snugly above the top of the sensor box like the temperature sensor. Make sure the bag does not cover the opening at the top of the tube.
9. Measure 5.00 mL vinegar and pour it into the quart-size plastic bag.
10. Place the closed canister or cup containing NaHCO_3 inside the quart-sized bag.
11. Place the protected temperature and pressure sensors inside the quart bag. Keep the stainless steel tip and tubing pointed towards the bag zipper. Avoid getting the tubing and stainless steel probe wet.



PROCEDURE

12. Push all air out of the quart-size bag and seal it tightly.
13. Start collecting data.
14. With the bag closed, open the film canister and mix the sodium bicarbonate with the vinegar.
15. Observe the time it takes to inflate the bag, the volume of space filled by the gas, and the pressure and temperature of the reaction. Record observations on your answer sheet.
16. When it appears temperature and pressure changes have leveled off, stop collecting data. Fill out the table on your answer sheet.
17. Dispose of the bag contents according to your teacher's directions. Rinse and dry the canister or cup and quart-size bag. Keep the pressure and temperature sensors in their protective bags and dry them.

ANALYSIS

Complete the analysis on your answer sheet.

INITIAL DESIGN

Answer the Initial Design questions on your answer sheet.

RE-DESIGN

Continue exploring different amounts of reactants to experimentally determine the maximum pressure of the bag before it pops/bursts. Also determine the minimum pressure of the bag for proper inflation. Decide as a group how to best organize data and observations for this phase of the design challenge. Attach your results to your answer sheet.

SUMMARY

Present your findings to your class in an objective and scientific tone. You may use a traditional presentation board, PowerPoint presentation and/or another multimedia presentation device such as Animoto, PowToons and/or iMovie. Each member of the lab team must contribute an equal amount of effort and speaking time to the creation and delivery of the presentation.

The presentation must include the data you collected which will justify the amounts of reactants used for the most ideal airbag. How do the temperature and pressure data support your calculations and suggested amounts of reactants? All calculations must be included as well as reasons for failed designs. Include a discussion of things to consider when the design is taken from the small-scale test you attempted to the large-scale design process car manufacturers use when they develop airbags for implementation in cars.

The presentation should also include justifications for either the use of or banning of child-sized airbags. Would they be helpful or harmful in a collision? Should they be required or optional? Give specific reasons for your response and cite at least 2 reliable sources. Your presentation must be less than 3 minutes long.

Review the criteria in the grading rubric on the next page for details on how you will be graded on the presentation.



EXTENSION



For an additional challenge, you may be asked to explore the following options:

1. Test very cold water to determine the rate of temperature change using the beaker. The designed insulator should be able to reduce the overall temperature change for both the hot and cold water.
2. Test the hot water over a 10-15 minute time frame in order to minimize the heat lost in the design relative to the amount of heat lost in the glass beaker.
3. Limit the design to no more than 100 g above the mass of the glass beaker used. You will need to mass the beaker alone and again with the insulated material used.
4. Limit the design to an overall materials cost of no more than \$2.
5. Use recyclable, green material proposing an eco-friendly design that can be recycled upon disposal.


GRADING RUBRIC


Criterion	Criterion Not Met (0 pts.)	Needs Improvement (1 pt.)	Satisfactory (2 pts.)	Excellent (3 pts.)
Time to inflate	Inflation time was not included	Inflation time exceeds 2 seconds.	Inflation time is equal to 2 seconds.	Inflation time is less than 2 seconds.
Data Collection & Analysis	Data from the design and re-designed experiments are not included.	<p>Insufficient data collected to prove the effectiveness of the design.</p> <p>Data may be incomplete or erroneous.</p> <p>Data may be disorganized and difficult to interpret.</p>	<p>Data includes appropriate mass of baking soda and volume of vinegar justified via calculations.</p> <p>Evidence of inflation of “airbag” is included to capacity without deflation.</p> <p>Inflation may be slightly less than capacity but does provide some protection upon impact.</p>	<p>Data includes appropriate mass of baking soda and volume of vinegar justified via calculations.</p> <p>Evidence of proper inflation of “airbag” is included to capacity without deflation.</p> <p>Inflation is to capacity and provides protection upon impact.</p> <p>Students have included a graph comparing multiple data runs.</p>
Visual Presentation	The visual presentation was not included.	The visual presentation is missing key information required.	The visual presentation addresses all required components and is simple.	The visual presentation summarizes all required components and is interesting.
Oral Presentation	The oral presentation was not completed.	The student was unable to explain the design, data and/or airbag performance.	The student could address the design, data and/or airbag performance but did not add in any additional, possibly pertinent information for consideration.	The student could address the design, data and/or airbag performance adding information that was pertinent to the presentation.