

Trap Every Gram: Design a Gas Catcher for a Fair Mass Test

Investigation question: Which features of three cheap gas-trap designs should be combined so that a fizzing reaction keeps every gram on the balance, seals fast, and costs the least?

Engineering design challenge

Groups of 4

2 sessions

Setup 10 · Activity 90 · Cleanup 10 min

MS-ETS1-3 · assesses

MS-ETS1-1 · practice

MS-PS1-5 · assesses

Name _____

Group _____

Date _____

Your role today

- ☐ **Builder:** Assembles each trap exactly as described, loads the baking soda packet, and runs the mixing step on the balance.
- ☐ **Timer and balance reader:** Zeroes the balance, reads 'before' and 'after' aloud twice, and runs the stopwatch from the moment the reactants touch until the seal is complete.
- ☐ **Recorder:** Writes the criteria, constraints, every reading, the cost from the price list, and the group's results on the class board.
- ☐ **Safety and boundary checker:** Confirms goggles are on, that no trap is a capped bottle or lidded jar, says what the system is and what could cross its boundary before each run, and keeps faces back during mixing.

Safety

- Goggles on for the whole lab. Vinegar stings eyes; rinse with water for several minutes if it gets in. Domes and balloons can spray droplets when they let go.
- Never seal this reaction inside a rigid container with a cap or lid (a bottle, a jar, a food container). The balloon, the bag and the wrap are allowed because they stretch or let go long before dangerous pressure builds. The Safety checker refuses any design that caps a bottle. The optional rigid-bottle demonstration in the debrief is for the teacher only.
- Use one pre-measured half-teaspoon packet per run and 30 mL of vinegar, never more; a bigger charge makes more gas than a balloon or bag should hold.
- Balloons: use non-latex balloons if anyone has a latex allergy; never put a balloon near the mouth or inhale from it; a balloon that slips off releases a puff of gas and droplets, so point the bottle away from faces; pick up any burst-balloon pieces at once, as they are a choking hazard.
- Keep faces back and hands clear while a trap inflates. If a bag or balloon is tight and still growing, open it away from faces.
- Wipe spills immediately (vinegar on the floor is a slip hazard), keep liquids off the balance, and wash hands at the end of each session. Nothing is tasted.

Procedure

1. Session 1, criteria first. Read the challenge and the price list. As a group, fill in the criteria and constraints table: how you will measure 'traps all the gas', 'seals fast' and 'costs little', one criterion of your own (for example, stays steady on the balance pan), the constraints you must obey, and a target for each. No building until the table is done.
2. Design A, balloon trap. Pour 30 mL of vinegar into the bottle. Make a paper cone and pour one baking soda packet into a balloon. Stretch the balloon's neck over the bottle mouth without letting any soda fall in, and let the balloon hang down beside the bottle. Put the whole assembly on the balance (nothing else), let the Safety checker name the system and its boundary, and record 'before'.
3. Lift the balloon upright so the soda falls into the vinegar. Sealing time is 0 s because the trap was sealed before mixing; record that. Point the bottle away from faces. When the fizzing stops and the reading has been steady for 30 seconds, record 'after', compute the change, note anything that went wrong (balloon slipped, soda stuck in the balloon), and compute the cost per run from the price list.
4. Design B, bag race. Put one soda packet (unfolded, soda loose) into a gallon zip bag and set the bag on the balance with a cup holding 30 mL of vinegar beside it; record 'before'. Timer ready. Pour the vinegar into the bag, set the empty cup back on the balance, and zip the bag closed; the timer runs from the moment vinegar touches soda until the zip is fully shut. Record the sealing time, wait for a steady reading, record 'after', the change and the cost.
5. Design C, cup dome. Put 30 mL of vinegar in a cup. Wrap one soda packet's worth in a tissue square and twist it closed. Put the cup, the tissue packet, a wrap square and a rubber band on the balance; record 'before'. Drop the packet in and start the timer, cover the cup with the wrap and band it tight; stop the timer when the band is on. Record the sealing time, wait, record 'after', the change and the cost. Expect the dome to lift or hiss at the rim.
6. Pool the data. The Recorder writes the group's three changes, times and costs in the class table on the board. Copy the class averages and the best single result for each design into the pooled table on your sheet. Note for the whole class: every trap puffs up, and a puffed-up trap is lifted by the air around it (roughly 1.2 g for every liter of puff), so even a perfect trap reads about 0.6 to 0.7 g low with this charge, which makes about 0.6 L of gas. Compare designs with each other, with that perfect-trap mark (about -0.7 g) and with the open-cup loss from Lab 1 (about -1.1 g), not with zero.
7. Session 2, analysis. For each criterion, decide from the pooled data which design won and name the feature that made it win (for example: sealed before mixing; wide opening and easy pour; cheapest parts; delay packet). Fill in the 'strongest feature' column. Then name the weakest point of each design.
8. Redesign. Sketch a combined trap that uses at least one feature from each of two different starters. Label every borrowed feature with the letter of the design it came from. Check it against every constraint (no cap, same amounts, fits on the pan, under the budget). Predict its mass change, sealing time and cost and write the predictions before building.
9. Build and test the redesign with the same amounts and the same reading rules as session 1. Record 'before', sealing time, 'after', change and cost. If it fails a constraint during the run (for example a seal pops), record what happened and the reading anyway.
10. Compare the redesign with all three starters on every criterion, add the class's best redesign to your table, and answer the analysis questions on your own before discussing them in your group.

Record your observations

Lab 3 recording sheet: Trap every gram

The hard rule — Sealed means a balloon, a bag or a plastic-wrap cover. A capped bottle or a lidded jar is never allowed, because the gas this reaction makes would build pressure inside it. Every design, including your redesign, must pass the Safety checker before it goes on the balance.

Criteria and constraints

Criterion or constraint	How we will measure or check it	Target or limit
Criterion 1: traps all the gas		
Criterion 2: seals fast		
Criterion 3: costs little		
Criterion 4 (your own)		
Constraint: materials and amounts		
Constraint: safety (no rigid sealed container)		
Constraint: fits on the balance pan, built in 10 minutes		

Price list for the challenge (play-money prices, invented for this lab)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Part	Price per run (play dollars)
Bottle (reused, charged per run)	0.10
Balloon (single use)	0.15
Gallon zip bag	0.20
Cup	0.05
Plastic-wrap square	0.03
Rubber band	0.02
Tissue square	0.01
Paper cone	0.01
Vinegar and baking soda (every design)	0.10

These prices are made up so that cost can be compared fairly. Add the price of every part your design uses.

Starter design tests (our group)

Design	Mass before (g)	Mass after (g)	Change (after minus before, g)	Sealing time (s)	Cost per run	What leaked or went wrong
A: balloon on bottle						
B: bag race						
C: cup dome						

Pooled class data and the strongest feature of each design

Design	Class average change (g)	Best single change (g)	Average sealing time (s)	Cost per run	Strongest feature, and the criterion it wins	Weakest point
A: balloon on bottle						
B: bag race						
C: cup dome						

-  Sketch your combined trap. Label every part, and next to each borrowed feature write the letter of the starter design it came from (A, B or C). Under the sketch write your three predictions: mass change, sealing time and cost per run.

Redesign test

Run	Mass before (g)	Mass after (g)	Change (g)	Sealing time (s)	Cost per run	Predicted change (g)	Did it pass every constraint?
Our redesign							
Class best redesign							

1. Name one starter design that won one criterion but lost another. Give the numbers for both criteria.

2. Which feature did you borrow from each starter for your redesign, and which number in the pooled table told you to borrow it?

Analysis questions

3. A perfect trap keeps the same mass before and after. Explain why using atoms: where are the carbon and oxygen atoms of the carbon dioxide before the reaction, where are they after, and what has to be true of the boundary for the mass to stay the same?

4. Design C's change was usually the largest. Did that reaction destroy more matter than the others? Where did the missing grams go?

5. Even a trap that never leaked reads about 0.6 to 0.7 g low. Explain the lift of a puffed-up bag or balloon and why it is not lost matter. What kind of container would not puff up, and why are students not allowed to use one here?

6. The open cup in Lab 1 lost about 1.1 g, and a perfect trap reads about 0.7 g low from lift alone. Suppose your Design C read 0.9 g low (use your own number if you have it). Estimate the fraction of the gas that escaped as $(C's\ drop - 0.7\ g) \div (1.1\ g - 0.7\ g)$, then the fraction the dome kept. Show the subtraction and the division.

7. The standard this lab is built on says pieces of several designs can be combined into one that beats each of them. Did your redesign beat all three starters on every criterion? Use numbers. If it lost on one criterion, which one, and would you accept that trade-off? Why?

8. Which criterion did the price list pull against? Describe one feature that improved the mass result but raised the cost, and explain how your group decided whether it was worth it.

9. Name one thing that would make you distrust a design's mass data (for example, vinegar spilled on the balance pan during the pour). How would you catch it, and what would you do with that run's numbers?
