

Open Cup, Capped Bottle: Tracking Mass Through a Reaction

Learning target: I can graph and calculate from balance readings taken during a reaction to show that mass only leaves or joins a system when matter crosses its boundary, and that a closed system keeps its mass.

Data and graphing

About 40 min

Individual

MS-PS1-5 · practice

data analysis

independent practice

Name _____

Date _____

Period _____

Directions

Both parts use teaching datasets: the numbers were written to be realistic for these amounts, not measured in a real classroom. Part A follows the vinegar and baking soda reaction on a balance, once in an open cup and once in a capped bottle. Part B follows steel wool pads of different sizes as they burn. Graph with a ruler, show every calculation with units, and write answers in complete sentences. When a question asks you to explain, use the words *atoms* and *boundary*.

You will need: This worksheet, Pencil, Ruler, Calculator (optional)

Part A: The same reaction, two containers

A teacher set up two runs of the vinegar and baking soda reaction. **Open cup:** an empty cup (100.00 g) with 60.00 g of vinegar sat on a balance reading to 0.01 g; at time 0 she tipped in a 2.00 g packet of baking soda. **Capped bottle:** a rigid 2-liter plastic bottle held 60.00 g of vinegar and a small open vial with 2.00 g of baking soda standing upright inside; she screwed the cap on tight, put the whole bottle on a second balance, and at time 0 tipped it to mix. Both mixtures fizzed. The bottle stayed capped for 180 seconds; then she unscrewed the cap, squeezed the bottle gently a few times to push out the gas, left the cap off, and read the balance again at 300 seconds: **164.52 g**.

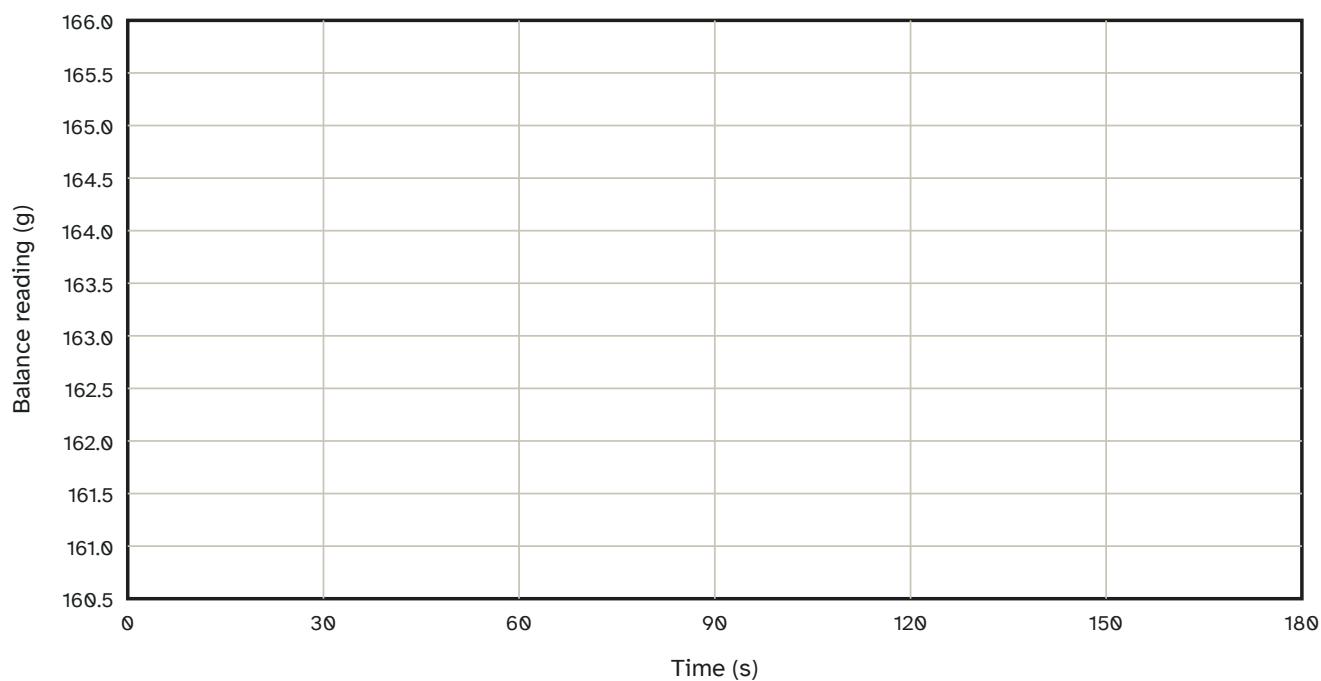
Balance readings during the reaction (teaching dataset)

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

Time (s)	Open cup (g)	Capped bottle (g)
0	162.00	165.50
30	161.42	165.50
60	161.18	165.50
90	161.08	165.50
120	161.03	165.50
150	161.01	165.50
180	161.00	165.50

Simulated data for teaching, realistic for 2.00 g of baking soda in 60 g of vinegar. The bottle was rigid, so its size did not change as gas formed inside.

Mass of each container versus time



1. Calculate the total change in the balance reading from 0 s to 180 s for the open cup and for the capped bottle. Write each change with a sign (+ or –) and units.

2. For the open cup, calculate the mass lost during the first 30 seconds and during the last 30 seconds (150 s to 180 s). Then calculate the average rate of loss during the first minute in grams per second.

3. Describe the shape of each line on your graph. What does the shape of the open-cup line tell you about how fast gas was leaving at the start compared with the end, and why did it change?

4. Calculate how much the bottle's reading dropped after the cap was removed (180 s reading to 300 s reading). Compare this to the open cup's total loss from q1. Give one reason the two numbers are not exactly equal.

5. Explain all three results (the cup's loss, the bottle's steady reading, and the bottle's drop after opening) with one explanation about atoms. Say where the atoms of the 'missing' mass were at 180 s in each container.

6. A classmate says, 'The bottle's reading never changed, so no reaction happened inside it.' Give two observations from the setup or the data that show a reaction did happen in the bottle.

Part B: Steel wool pads that gain mass

In a teacher demonstration (behind a shield; students never handle flame), four pads of fine steel wool of different masses were heated until they glowed, allowed to go dark and cool, and then every crumb was

returned to the balance. In a separate described experiment, a 2.00 g pad was sealed inside a glass flask of air, the whole flask was weighed (250.00 g), the pad was heated through the glass until it darkened, and the sealed flask was weighed again: **250.00 g**. When the stopper was then removed, air hissed in and the flask read **250.14 g**.

Steel wool pads heated in open air (teaching dataset)

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

Pad	Mass before heating (g)	Mass after cooling (g)
A	1.00	1.07
B	2.00	2.15
C	3.00	3.21
D	4.00	4.29

Simulated data for teaching. Only part of the iron in each pad reacts, so the gains are smaller than a complete reaction would give.

7. Complete the table. Mass gained = after – before. Gain per gram = mass gained ÷ mass before. Show one full calculation below the table and give the average to three decimal places.

Mass gained (g)	Gain per gram of pad (g/g)
Pad A	
Pad B	
Pad C	
Pad D	
Average	

8. Use your average gain per gram to predict the mass after heating of a 6.00 g pad treated the same way. Show the calculation.

9. Explain the three flask readings (250.00 g sealed before, 250.00 g sealed after, 250.14 g after opening). Where did the pad's extra mass come from, and why did air hiss in?

10. Part A shows a reaction whose open reading fell; Part B shows one whose open reading rose. Write one rule about atoms and boundaries that explains all four readings: the open cup, the capped bottle, the open pads and the sealed flask. Then say what a balance reading can and cannot tell you about whether matter was created or destroyed.

Reading the table before you graph

Before plotting, run your finger down the open-cup column and write the drop between each pair of readings in the margin: 0.58, 0.24, 0.10, 0.05, 0.02, 0.01. The drops get smaller, so your curve should be steep at first and nearly flat by the end. The bottle column never changes, so its line is flat. For the rate in q2, $\text{rate} = \text{mass lost} \div \text{time}$, and the unit is grams per second. In Part B, 'gain per gram' means divide the gain by the starting mass, so a 2.00 g pad that gains 0.15 g has $0.15 \div 2.00 = 0.075$ g of gain for each gram of pad.

The gas that stayed behind

The bottle lost 0.98 g after opening, but the chemistry predicts that 2.00 g of baking soda in this much vinegar should make about 1.05 g of carbon dioxide. Some gas stays dissolved in the liquid, the way carbon dioxide stays in a soda. Design a fair test to find out how much carbon dioxide stayed dissolved: say what you would do to the opened mixture (for example, warm it gently or stir it), what you would measure, and how you would calculate the dissolved amount. Predict the result and explain why stirring a soda makes it go flat.