

# Grams per Stroke and the Halfway Rule: Two Datasets

**Learning target:** I can graph and calculate from data to show that invisible air adds mass in a steady pattern, and test how well the halfway rule predicts the middle element of a triad.

Data and graphing   About 40 min   Individual   MS-PS1-1 · supports   data analysis   independent practice

Name

Date

Period

**Directions**

This sheet has two parts. Part A uses a teaching dataset about a basketball on a balance; the numbers were invented to be realistic, not measured in a real lab. Part B uses real rounded atomic masses. Graph carefully with a ruler, show every calculation, and write units on every number.

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

## Part A: How much mass does each pump stroke add?

A student put a rigid basketball on a balance that reads to 0.1 g, pumped it ten strokes at a time, and recorded the mass after each set of strokes. Then she let all the air out and repeated the whole procedure (Trial 2). The ball's size did not change during the test.

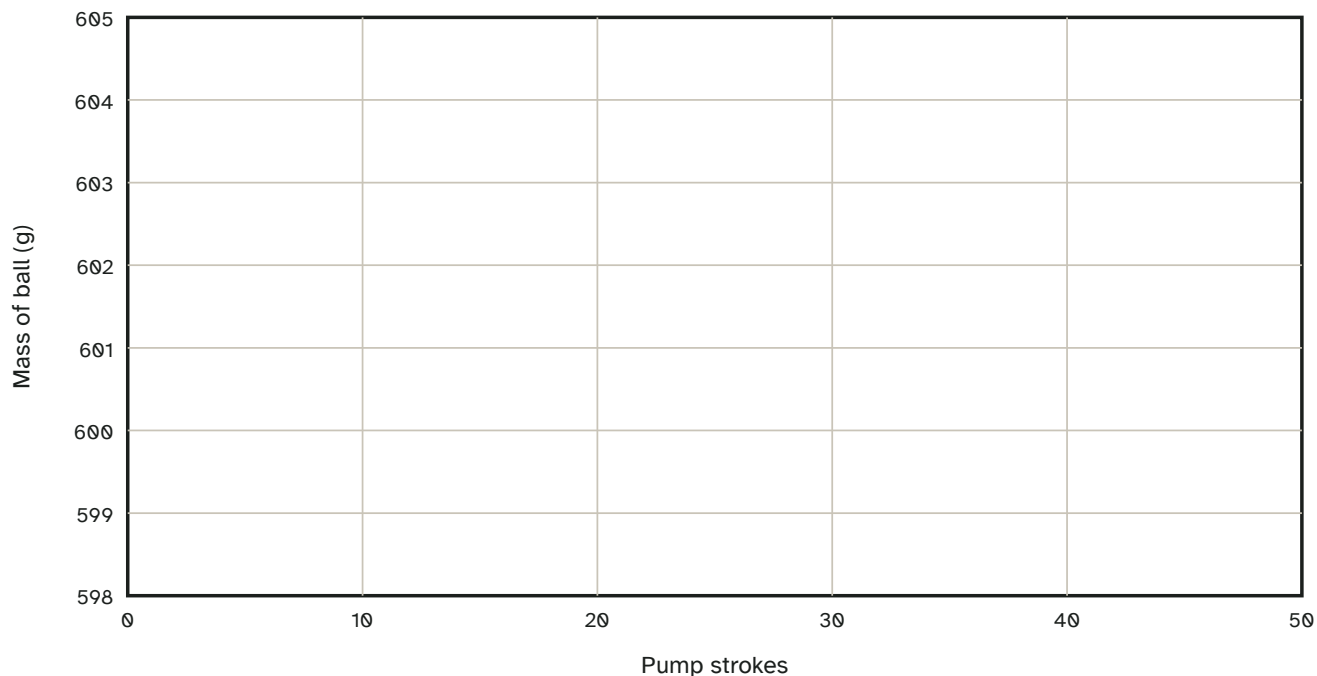
### Mass of a rigid basketball after pumping (teaching dataset)

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

| Pump strokes | Trial 1 mass (g) | Trial 2 mass (g) |
|--------------|------------------|------------------|
| 0            | 598.4            | 598.4            |
| 10           | 599.6            | 599.5            |
| 20           | 600.8            | 600.7            |
| 30           | 601.9            | 602.0            |
| 40           | 603.1            | 603.2            |
| 50           | 604.3            | 604.2            |

Simulated data for teaching. Realistic for a 7.1 liter ball and a small hand pump.

## Mass of the ball versus pump strokes



1. Calculate the total mass gained from 0 to 50 strokes in Trial 1 and in Trial 2. Then find the average of the two gains. Show your work.

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2. Using your average gain from q1, calculate the mass added per pump stroke. Round to the nearest hundredth of a gram.

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3. Describe the shape of your graph. What does the shape tell you about how much air each stroke adds?

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4. Predict the mass of the ball after 100 strokes if the pattern continues. Show the calculation. Then give one reason the real reading might be a little lower than your prediction.

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5. The ball looked exactly the same before and after pumping. Using the numbers, explain what this dataset proves about air, and what it suggests about the particles air is made of.

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## Part B: Testing the halfway rule on four triads

In 1829 Döbereiner noticed that in some sets of three similar elements, the middle element's atomic mass is close to the average of the outer two. The table gives real, rounded atomic masses for four of his triads. Test the rule yourself.

### Four triads (real rounded atomic masses, in daltons)

| Triad                                     | Lightest element | Middle element | Heaviest element |
|-------------------------------------------|------------------|----------------|------------------|
| Metals that react with water              | Lithium 7        | Sodium 23      | Potassium 39     |
| Reactive gases and solids that form salts | Chlorine 35.5    | Bromine 80     | Iodine 127       |
| Metals in chalky minerals                 | Calcium 40       | Strontium 88   | Barium 137       |
| Yellow, red and gray nonmetals            | Sulfur 32        | Selenium 79    | Tellurium 128    |

6. Complete the table. For each triad, average the lightest and heaviest masses, write the real middle mass, and subtract. Show one full calculation below the table.

| Average of outer two (Da) | Actual middle mass (Da) | Difference (average – actual) |
|---------------------------|-------------------------|-------------------------------|
| Li, Na, K                 |                         |                               |
| Cl, Br, I                 |                         |                               |
| Ca, Sr, Ba                |                         |                               |
| S, Se, Te                 |                         |                               |

7. Which triad fits the halfway rule best, and which fits worst? Use the differences from your table as evidence.

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8. Suppose bromine had not been discovered yet. Using the halfway rule, what mass would you predict for the missing element between chlorine and iodine, and how close would the prediction be to bromine's real 80 Da?

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9. Look at both parts of this sheet. Part A shows that mass rises by a steady amount with each stroke. Part B shows that masses rise in a fairly regular way down a column. Explain why finding **regular patterns** in numbers was so important for scientists who could not see atoms.

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### Averaging in two steps

To average two numbers, add them and divide by 2. Write the addition on one line and the division on the next line so that you can check each step. Example with made-up numbers:  $12 + 30 = 42$ ;  $42 \div 2 = 21$ . For the per-stroke calculation in q2, remember that you are dividing a mass (in grams) by a number of strokes, so the unit of your answer is grams per stroke.

### How many atoms is that?

Air is mostly nitrogen particles, each made of two nitrogen atoms (atomic mass 14 Da each), so one nitrogen particle has a mass of about 28 Da. One dalton is about  $1.66 \times 10^{-24}$  g. Estimate how many nitrogen particles are in the 0.12 g that one pump stroke adds, treating the air as if it were all nitrogen. Write your answer in scientific notation and explain in one sentence why this number supports the idea that atoms are on a completely different scale from everyday objects.