

Three Cups in Numbers: Temperature Clues and the Recovery Test

Learning target: I can graph temperature data, calculate before-and-after differences in solubility, and use those numbers to decide which cup made a new substance and which only looked like it did.

Data and graphing

About 45 min

Individual

MS-PS1-2 · assesses

data analysis

independent practice

Name

Date

Period

Directions

Both tables are teaching datasets: the numbers were invented to be realistic, not copied from a real trial. Part A asks you to graph temperature and calculate how much each cup warmed or cooled. Part B gives the results of a recovery test on the solids. Show every calculation with units. Write a sign (+ or −) on every change. Answer in complete sentences where lines are given.

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

Part A: The temperature story

Mr. Delgado's class repeated the three-bag demonstration in open cups so that a thermometer could stand in each one. Cup A held 2.5 g of baking soda (half as much, so that the vinegar was enough to use all of it up), and 50 mL of white vinegar was poured in. Cup B held 5.0 g of calcium chloride pellets, and 50 mL of water was poured in. Cup C held 5.0 g of Epsom salt, and 50 mL of water was poured in. Every liquid and every cup started at 21.0 °C, and the room stayed at 21 °C the whole time. Cup A fizzed for about two minutes. In Cups B and C the solids disappeared within a minute. The class read each thermometer at the times shown.

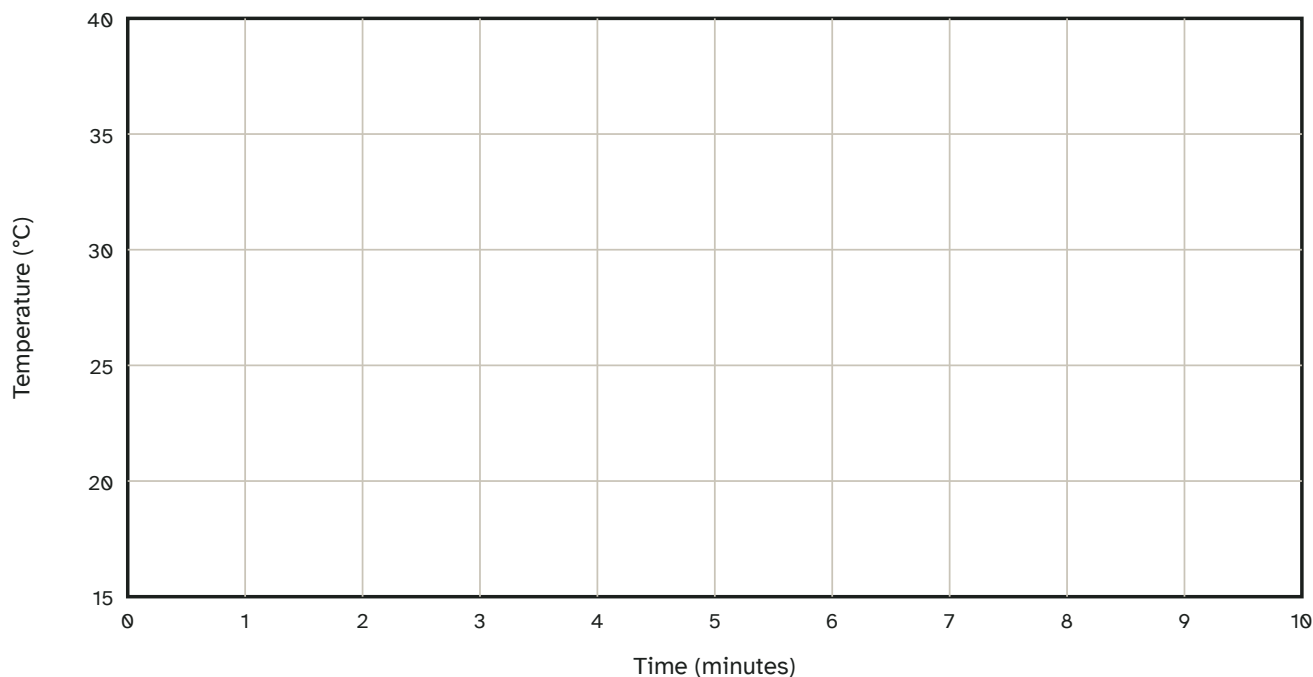
Table 1. Temperature in each cup (teaching dataset)

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

Time (minutes)	Cup A: baking soda + vinegar (°C)	Cup B: calcium chloride + water (°C)	Cup C: Epsom salt + water (°C)
0	21.0	21.0	21.0
1	18.9	31.4	19.9
2	17.8	36.2	19.2
3	17.5	37.0	19.0
5	17.9	35.1	19.3
10	19.4	30.6	20.2

Simulated data for teaching. Realistic for the amounts described, each in 50 mL of liquid at room temperature.

Temperature in each cup over ten minutes



1. For each cup, find the reading farthest from the starting temperature and calculate the change (that reading minus 21.0 °C). Write a + sign for warming and a – sign for cooling, and say at what time it happened.

2. Describe the shape of each line. Then explain why all three lines head back toward 21 °C by 10 minutes, even though nothing new was added to the cups.

3. Cups A and C both cooled. Using **only** Table 1 and your graph, can you tell which cup, if either, made a new substance? Explain what temperature data can and cannot show.

4. Which statement about Cup B is best supported by Part A alone?
- ☐ A. A chemical reaction happened, because the cup got hot.
- ☐ B. The pellets dissolved, which is a physical change.
- ☐ C. Something happened that released energy to the water, but these data do not show whether a new substance formed.
- ☐ D. The thermometer in Cup B must have been faulty, because water cannot warm up on its own.

Part B: The recovery test

The class left each cup uncovered on a warm shelf for three days, until the liquid was gone. They scraped the dry solid out of each cup and tested it beside a fresh sample of the solid that had gone into that cup. Every solubility test was done at 20 °C by stirring the solid into 100 mL of water a little at a time until no more would dissolve. When the class repeated a solubility test on the **same** powder, the two results were always within 2 g per 100 mL of each other.

Table 2. Before-and-after tests on the solids (teaching dataset)

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

Cup	Solid tested	Appearance	Solubility at 20 °C (g per 100 mL)	Fizzes when vinegar is added?	Odor
A	Baking soda (before)	white powder	9.6	yes, strongly	none
A	Solid recovered (after)	white, slightly glassy crust	121	no	none
B	Calcium chloride (before)	white pellets	74	no	none
B	Solid recovered (after)	white crust	75	no	none
C	Epsom salt (before)	clear, colorless crystals	71	no	none
C	Solid recovered (after)	clear, colorless crystals	70	no	none

Simulated data for teaching. 'Before' is the solid that went into the cup; 'after' is the dry solid recovered when the liquid was gone.

5. For each cup, calculate the change in solubility (after minus before) in g per 100 mL. Then calculate how many times larger Cup A's 'after' solubility is than its 'before' solubility (divide). Round to one decimal place.

6. Cups B and C each show a difference of 1 g per 100 mL. Use the sentence about repeated tests in the Part B description to explain why a difference this small is **not** evidence of a new substance.

7. Which cup made a new substance? Give **two independent** pieces of evidence from Table 2, and name the one property in that cup's row that did **not** change.

8. Cup B warmed the most of all three cups, yet Table 2 shows no change. What happened to the calcium chloride in Cup B, what kind of change is it, and which Table 2 result shows it?

9. A student wants to repeat the Cup A solubility tests with only 25 mL of water at 20 °C. Using Table 2, calculate how many grams of baking soda and how many grams of the recovered Cup A solid should dissolve in 25 mL. Show your work.

10. Three kinds of evidence appeared in this investigation: a temperature change (Table 1), fizzing (seen in Cup A), and a difference in solubility measured at the same temperature (Table 2). Rank them from **weakest** to **strongest** as evidence that a new substance formed. Justify each ranking with a specific cup.

Changes have signs

A change is always 'after minus before'. If the answer is negative, the cup cooled or the value dropped; if it is positive, the cup warmed or the value rose. For q1, run your finger down each cup's column, mark the reading farthest from 21.0, and subtract 21.0 from it. For q5, Table 2 comes in pairs: the 'after' row sits right under the 'before' row for the same cup, so subtract the upper number from the lower one.

Design Cup D and spot the temperature trap

Reference values: table salt (sodium chloride) dissolves 36 g per 100 mL of water at 20 °C and 39 g per 100 mL at 100 °C. Imagine a Cup D with 5.0 g of table salt and 50 mL of water. Predict its two rows of Table 2 (before and after) and its temperature change in Table 1, with a reason for each prediction. Then explain the trap: a student measures the 'before' solubility in 20 °C water and the 'after' solubility in freshly boiled water. What numbers would that student get, what would they wrongly conclude, and how does the 2 g per 100 mL repeat-test spread help you decide whether a 3 g difference is real?