

The Marble Tray: Shake In Energy, Watch the State Change

Investigation question: When a tray of marbles is shaken harder or more gently, how do the marbles' motion and arrangement change, and what happens to the number of hits on a wall when the same marbles are given less room or more energy?

Physical model

Groups of 4

1 session

Setup 5 · Activity 40 · Cleanup 5 min

MS-PS1-4 · assesses

Name _____

Group _____

Date _____

Your role today

- ☐ **Shaker:** Moves the tray side to side, across its width, in time with the metronome, keeping each stroke between the tape marks for the level being tested.
- ☐ **Timekeeper and metronome operator:** Sets the tempo, times each 10-second trial, and calls 'look' at 8 seconds and 'stop' at 10.
- ☐ **Photographer and counter:** Takes a photo from directly above at the 8-second call (or, without a camera, counts the marbles in Zones 2 and 3 at that moment), then counts the marbles in each zone.
- ☐ **Recorder and hit counter:** Fills the tables and, in Part B, watches only the pressure wall and makes a tally mark for every marble that hits it.

Safety

- Marbles on the floor are a serious slip hazard. Keep the tray over the table, count the marbles out and back in, and pick up any dropped marble at once.
- Shake the tray, not the table, and keep the strokes within the tape marks. If marbles jump the rim, slow down; keep faces above and back from the tray.
- Marbles are a choking hazard for young children. Never put them in your mouth, and store them out of reach of younger visitors.
- Arms tire at level 3; switch shakers between levels rather than pushing on.

Procedure

1. Part A. Count 36 marbles into the tray, rest the high end of the tray on the book so the marbles roll to the low end, and place the tray between the tape marks.
2. Before shaking, write your prediction in q1: at each level, which zones will the marbles reach, and how will they move?
3. Level 1 (cold): set the metronome to 60 beats per minute. On each beat the shaker moves the tray 1 cm side to side, across its width, keeping the low end low. Shake for 10 seconds. At the 8-second 'look' call the photographer takes a photo from directly above, or counts the marbles in Zones 2 and 3 by eye. Watch how the marbles move.

4. Count the marbles in each zone from the photo, record the counts, and write a few words about the motion (for example: jiggling in place, sliding past one another, flying and bouncing). Run a second trial.
5. Level 2 (warm): 120 beats per minute, 3 cm strokes. Run two trials with the same measurements.
6. Level 3 (hot): 180 beats per minute, 5 cm strokes. Run two trials, switching shakers if arms are tired.
7. Cooling: shake at level 3 for 5 seconds, then switch straight to level 1 for 5 seconds without stopping. Watch what the marbles do as the energy drops and answer q2.
8. Make the three-panel drawing of levels 1, 2 and 3, with every marble the same size and arrows showing how the marbles move.
9. Part B. Remove the book so the tray lies flat, and take out all but 10 marbles. These 10 are a gas. Choose one short end wall as the 'pressure wall'.
10. Full tray, level 2: shake for 10 seconds while the hit counter watches only the pressure wall and makes one tally mark for every marble that hits it. Run two trials, then repeat at level 3.
11. Half tray: tape the divider upright across the halfway line so the 10 marbles have only the half that includes the pressure wall. Run two trials at level 3, then average every pair of trials and answer q3.
12. Count the 36 marbles back into their container, then answer the analysis questions individually.

Record your observations

Lab 2 recording sheet: The marble tray

In this model each marble stands for one particle of a pure substance, **shaking the tray adds energy**, and **the tilt plays the part of the attraction** that pulls real particles together. Level 1 = cold (60 beats per minute, 1 cm strokes). Level 2 = warm (120, 3 cm). Level 3 = hot (180, 5 cm).

1. Prediction: at levels 1, 2 and 3, which zones will the marbles reach, and how will they move?

Part A: where the 36 marbles are at the 8-second look

Shake level	Trial	Zone 1 (bottom)	Zone 2 (middle)	Zone 3 (top)	How the marbles moved	Which state does this look like?
1 (cold)	1					
1 (cold)	2					
2 (warm)	1					
2 (warm)	2					
3 (hot)	1					
3 (hot)	2					

2. Cooling: what did the marbles do when the shaking switched from level 3 straight to level 1? Which real change or changes of state does this model?

 Draw the tray at level 1, level 2 and level 3 in three side-by-side boxes. Make every marble the same size, show which end is low, and add arrows for how the marbles move. Label each box with a state.

Part B: hits on the pressure wall in 10 seconds (10 marbles, flat tray)

Condition	Trial 1	Trial 2	Average
Full tray, level 2			
Full tray, level 3			
Half tray, level 3			

3. Which condition gave the most hits on the pressure wall? What does that tell you about pressure?

Analysis questions

4. Use your zone counts to describe how the marbles' arrangement and motion changed from level 1 to level 3. Match each level to solid, liquid or gas, and give the evidence for each match.

5. In this model, what does shaking harder stand for? Use your answer to explain why heating a real solid can turn it into a liquid and then a gas.

6. Did any marble change size, shape or mass between level 1 and level 3? What does that tell you about real particles when a substance melts or boils?

7. The tilt pulled the slowed marbles back together. Predict what would happen in the cooling step if the tray were flat, and explain what this shows about why real gases condense and real liquids freeze when energy is removed.

- 8.** Use Part B to explain gas pressure in particle terms. Why did the half tray give more hits than the full tray at the same level, and why did level 3 give more hits than level 2?

- 9.** A sealed, empty plastic bottle crumples as a car drives down from a mountain to the coast. Use your Part B results to explain why.

- 10.** Name two ways the marble model is not like real particles. For each, say whether it makes the model's predictions wrong or only less detailed.
