

Forces You Cannot See

Plan a fair test, collect measurements, and evaluate evidence about surface attractions.

HS-PS1-3 "Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles..."

NAME _____

DATE _____

1 READ AND MARK _____ Read it twice

YOUR JOB Underline the quantity measured in mL. Box the term 'surface tension' to mark the property that measurement helps investigate. Circle any three controllable variables. Complete the plan, live test and analysis in order. The table is for your measurements.

Compare two liquid surfaces

- ① Particle model: water molecules have an uneven distribution of charge, so opposite-charge regions of neighboring molecules attract. Detergent adds molecules with water-attracting heads and water-avoiding tails. At the surface, heads interact with water while tails point away; this changes the arrangement and net cohesive interactions at the surface. Surface tension describes resistance to stretching the surface. Compare water alone with detergent solution using the maximum volume held on a coin, in mL. This bulk measurement is an indirect proxy for surface behavior, not a measurement of individual particle forces. Use the model and your measurements together to explain the liquids' different behavior.
- ② Work in pairs with teacher approval. Supplies: clean coin, level tray, water, teacher-prepared dilute dish-detergent solution, two labeled cups, one needle-free 1 mL syringe marked in 0.01 mL divisions, ruler, paper towels, goggles, and rinse water. Wear goggles; do not taste the liquids. Clean spills and wash hands. Use the same coin face and syringe for both liquids; rinse them thoroughly with clean water and dry the coin between trials to prevent detergent carryover.

- ③ Plan before testing. Add each liquid to the coin in 0.05 mL increments, using the syringe to control volume rather than counting unequal drops. Choose and keep the tip height, addition pace and room temperature consistent. Record the last total volume held before spilling, and note the dome shape. Complete three trials per liquid. This classroom proxy is affected by wetting and cleanliness as well as surface tension; interpret it cautiously. Record all results, even unexpected ones.

YOUR MEASUREMENTS: MAXIMUM VOLUME HELD (mL)

Trial	Water (mL)	Detergent solution (mL)	Dome/spill notes
1			
2			
3			
Mean			
Range (min-max)			

2 ANSWER WITH EVIDENCE _____ Use the passage

- ① Plan before collecting data: state the test question and predict which liquid will hold more volume. Choose tip height and addition pace, name two other controls, and explain why repeated trials are needed.

- ② Conduct the approved test and fill every measurement row above. Compute each liquid's mean and min-max range. Record an equipment limitation or irregular trial here; keep the original data.

- 3** Compare your two means and ranges. Use numbers from your table to say whether the difference is convincing relative to trial-to-trial variation. If evidence overlaps or is inconsistent, say so.

- 4** What tentative comparison of surface cohesion does your evidence support? Explain one competing explanation and why this test cannot measure an individual molecular force.

3 YOUR TURN _____ Your own words

Improve the investigation using what happened in your first three trials. Run a new trial of each liquid with your improved control, then report whether it strengthens or changes your explanation.

Refine and retest

Choose one source of uncertainty to reduce while keeping the same 0.05 mL increments. Explain the change and get teacher approval. Run one new trial per liquid. Record both maximum volumes and observations; keep these separate from the original means.

Final evidence-based explanation

Use the particle model in paragraph 1 to compare the composition and surface arrangement of water alone and detergent solution. Explain how this can change net electrical attractions and bulk surface behavior. Cite your original and retest measurements, explain whether the retest supports your inference, and state a limit or further measurement needed. Write five or six sentences; do not claim to measure individual forces or weaken every particle interaction.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

PART 1 • READ AND MARK

Underline the quantity measured in mL. Box the term 'surface tension' to mark the property that measurement helps investigate. Circle any three controllable variables. Complete the plan, live test and analysis in order. The table is for your measurements. Accept any marking that follows this job and points at the right text.

PART 2 • ANSWERS

#	QUESTION	ANSWER
1	Plan before collecting data: state the test question and predict which liquid will hold more volume. Choose tip height and addition pace, name two other controls, and explain why repeated trials are needed.	Plans compare water and detergent solution with controlled increment volume, coin face, cleanliness, temperature, height and pace. Prediction may vary. Repeats reveal variation; students must not change their results to match predictions.
2	Conduct the approved test and fill every measurement row above. Compute each liquid's mean and min-max range. Record an equipment limitation or irregular trial here; keep the original data.	Check actual recorded trials, means and ranges. Do not substitute model numbers for observations. The 0.05 mL steps locate the spill threshold only within an interval, and handling/reading differences add uncertainty.
3	Compare your two means and ranges. Use numbers from your table to say whether the difference is convincing relative to trial-to-trial variation. If evidence overlaps or is inconsistent, say so.	Accept either a supported difference or an inconclusive result. The interpretation must use the student's values and variability, not assume a predetermined outcome.
4	What tentative comparison of surface cohesion does your evidence support? Explain one competing explanation and why this test cannot measure an individual molecular force.	If water consistently holds more volume, this is consistent with greater surface cohesion than the detergent solution. Overlap can make the result inconclusive. Wetting, residue and technique also affect volume, so the evidence cannot alone quantify pairwise particle forces.

PART 3 · YOUR TURN (SAMPLE ANSWER)

Retest record: example criteria. Students might standardize the syringe height with a ruler after noticing that it varied. Require one new measured volume for each liquid and a description of the improvement. No invented results should replace student observations.

Illustrative explanation using hypothetical data, not expected results. My first water trials held 0.45, 0.50 and 0.45 mL, compared with 0.20, 0.25 and 0.20 mL for detergent solution. Their means were about 0.47 and 0.22 mL, with nonoverlapping ranges of 0.45-0.50 and 0.20-0.25 mL. After controlling tip height more carefully, retests held 0.45 and 0.20 mL, which supported the original pattern. The greater water capacity is consistent with stronger surface cohesion. Unlike water alone, the solution contains detergent molecules whose heads interact with water while tails point away at the surface; the changed arrangement changes net cohesive electrical interactions, consistent with its lower capacity. Coin wetting and residue also influence capacity, so a direct surface-tension measurement would strengthen the inference; these volumes do not measure individual molecular forces.

TEACHER ASSESSMENT NOTES

Prepare one consistent dilute dish-detergent solution (for example, 1 mL plain dish detergent in 100 mL water) and supply all equipment. Approve plans before work; require complete original and retest records, not just a proposed experiment. Keep syringe tip from touching the coin; thoroughly rinse between liquids. Alternate liquid order across pairs to reveal carryover effects. Assess controls, uncertainty, numerical reasoning and cautious inference, not agreement with the hypothetical key. This compares water with a mixture, not a ranking of pure substances. Background experiment reference: American Chemical Society, Middle School Chemistry, Lesson 5.2 Surface Tension (acs.org/middleschoolchemistry/lessonplans/chapter5/lesson2.html); this locally authored high-school task adds volumetric control, repeated measurements and retesting.