Density Is a Periodic Property — Experiment 5

Objectives:

- To measure mass and volume data for silicon, tin, and lead
- To calculate their densities
- Use results to predict the density of geranium, Mendeleev's "undiscovered" element in the Group IV family of elements
- To measure the volume of the elements using water displacement

Background:

Dmitri Mendeleev proposed the periodic law for the classification of elements in 1869-1871. After observing trends in the properties of elements when they were arranged in order of increasing atomic mass, Mendeleev made a startling prediction. He predicted the existence and properties of at least three undiscovered elements.

At the time Mendeleev proposed the periodic law, the foundation of the modern periodic table for the classification of elements, 63 elements were known. Their physical and chemical properties had been studied and their atomic masses measured. Mendeleev arranged the known elements in a calendar-like table of rows and columns in order of increasing atomic masses and repeating chemical properties. It is at this point, however, that Mendeleev made a giant leap of discovery – he suggested that there were some gaps or missing elements in the list of known elements.

Among the Group IV elements in Mendeleev's classification scheme, carbon appeared in the second row, followed by silicon in the third row. Both tin and lead shared similar chemical properties with carbon and silicon and were also known at this time. Because of their high atomic masses, however, these metals were placed in later rows of Mendeleev's Group IV column of elements. In 1871, Mendeleev proposed that there existed an as-yet-unknown element beneath silicon in the Group IV elements. He named the missing element *eka*-silicon and predicted its physical properties (atomic mass, melting point, density, and specific heat). In 1886 the element germanium was discovered by the German chemist Clemens Winkler. In his report of the discovery, Winkler stated: "*... There can be no longer any doubt that the new element is no other than the eka-silicon prognosticated fifteen years ago by Mendeleev.*"

Within 15 years of Mendeleev's prediction of the existence of missing elements, three of the elements had been discovered, their properties in excellent agreement with those predicted by Mendeleev. Is it possible to recreate some of the experiments that followed the prediction and discovery of Mendeleev's missing elements?

Safety:

Lead powder is extremely toxic by inhalation and ingestion; lead fumes or dust are possible carcinogens. Using lead shot does not present a powder or dust hazard. Silicon is flammable in powder form and is slightly toxic. Do not breathe or handle any fine silicon powder remaining on the bottom of the reagent bottle. Wear chemical splash goggles, and wash your hands with soap and water before leaving the laboratory.

State a hypothesis:

Materials:

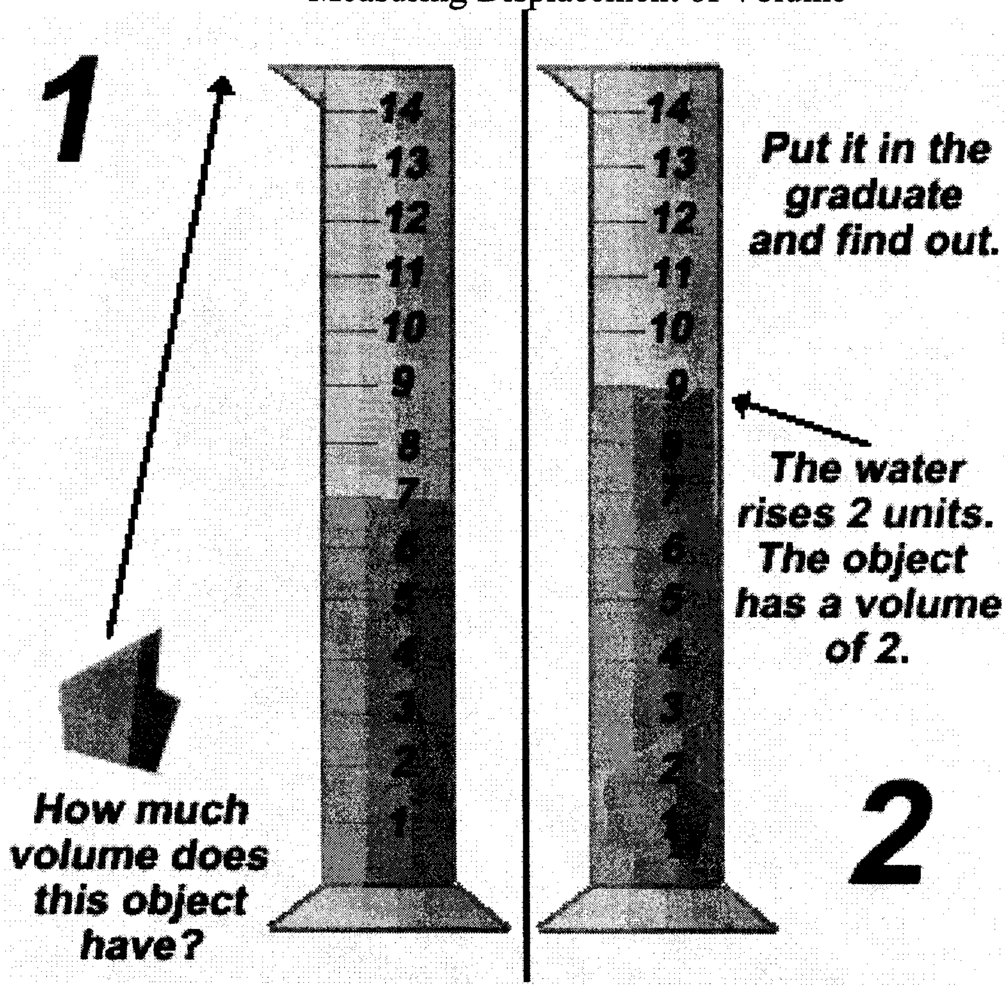
Lead shot, Pb, 35 g	Balance, centigram (0.01 g precision)
Silicon lumps, Si, 8 g	Beakers, 50-mL, or small cups, 3
Tin shot, Sn, 25 g	Forceps or tongs
Water	Graduated cylinder, 25-mL
Paper towels	Marking pencil or pen

Procedure:

1. Label three 50-mL beakers or small containers Si (silicon), Sn (tin) and Pb (lead).
2. Obtain approx. 8 g of silicon chunks in the appropriately labeled beaker. Measure the combined mass of the beaker plus the solid to the nearest 0.01-g and record the value in the Data Table. (Initial mass for sample 1)
3. Fill a 25-mL graduated cylinder approx. half-full with water. Measure the initial volume of water and record the value to the nearest 0.1 mL in the Data Table.

4. Using forceps or tongs, *carefully* add about one-third of the silicon chunks to the graduated cylinder (enough to raise the water level in the cylinder by at least 1.0 mL). Add the solid slowly, so as to avoid splashing or breaking the glass cylinder.
5. Measure and record the new (final) volume of water plus solid in the graduated cylinder.
6. Measure and record the combined mass of the labeled beaker and remaining solid in the Data Table. (This value is the final mass for sample 1)
7. Repeat steps 4-6 *twice* with some of the remaining amount of solid in the beaker. Do NOT empty the graduated cylinder between samples. The final volume of the previous sample becomes the initial volume for the next sample.
8. Record all initial and final mass and volume in the Data Table. There should be a total of three sets of mass and volume data (samples 1-3).
9. After all three trials have been completed, empty the water from the graduated cylinder. Carefully pour all the silicon chunks onto a paper towel and allow them to dry. Do not allow any of the solid to go down the drain.
10. Rinse the graduated cylinder with water.
11. Obtain approx. 25 g of tin shot in the appropriately labeled beaker. Measure the initial mass of the beaker plus solid to the nearest 0.01 g and record the value in the Data Table.
12. Repeat steps 3-10 using tin. Record all initial and final mass and volume data in the Data Table.
13. Obtain approx. 35 g of lead shot in the appropriately labeled beaker. Measure the initial mass of the beaker plus solid to the nearest 0.01 g and record the value in the Data Table.
14. Repeat steps 3-10 using lead. Record all initial and final mass and volume data in the Data Table.
15. Return the correctly labeled solids to your instructor for reuse.

Measuring Displacement of Volume



Hint: Volume = Final volume – Initial Volume

Data Table:

Element	Sample	Initial Mass (g)	Final Mass (g)	Mass of Solid (g)	Initial Volume (mL)	Final Volume (mL)	Volume of Solid (mL)	Density (g/mL)	Average Density (g/mL)
Silicon	1								
	2								
	3								
Tin	1								
	2								
	3								
Lead	1								
	2								
	3								

Calculations and Analysis:

1. Complete the Data Table: Calculate both the mass (initial mass – final mass) and volume (final volume – initial volume) of each sample 1-3 for all three elements, silicon, tin, and lead. Record these results in the Data Table.
2. Using the mass and volume data, calculate the density of each sample 1-3 for all three elements. Record results in the Data Table.
3. Calculate the average density for all three elements: silicon, tin, and lead. Record results in the Data Table.
4. On a graph, plot the period number of Si, Sn, and Pb on the x-axis versus the average density of each element on the y-axis. Using a ruler or straightedge, draw a "best-fit" straight line through the data points. Use the "best-fit" straight line to predict the density of germanium.
5. Look up the actual density of germanium in a reference source and calculate the percent error between the predicted and actual values.

$$\% \text{ error} = \frac{|\text{actual} - \text{predicted}|}{\text{actual}} \times 100$$

Conclusion:

1. Accept or reject your hypothesis.
2. Summarize what you did in the lab.
3. Include your percent error.