

**Density Is a Periodic Property Discovering an Element**

**Introduction**

*"With the periodic and atomic relations now shown to exist between all atoms and the properties of their elements, we see the possibility not only of noting the absence of some of them but even of determining…* *properties of these as yet unknown elements."*

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. Mendeleev saw what other scientists before him had missed-he saw what wasn't there!

**Concepts** • Periodic law • Density  • Group IV elements • Period number

**Background**

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 mass 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 excitement that followed the prediction and discovery of Mendeleev's missing elements?

***Experiment Overview***

The purpose of this experiment is to measure mass and volume data for silicon, tin, and lead, calculate their densities, and use these results to predict the density of germanium, Mendeleev's "undiscovered" element in the Group IV family of elements. The volume of the elements will be measured by water displacement.

**Pre-Lab Questions**

1. One of the elements Mendeleev predicted was eka-aluminum. The density of aluminum (period 3) is 2.70, that of indium (period 5) 7.31, and that of thallium (period 6) 11.85 g/cm3. Make a graph of period number on the x-axis versus density on the y-axis for each of these elements.



1. Use your graph to predict the density of eka-aluminum which is in period 4. What known element in the modern Periodic Table corresponds to eka-aluminum? Look up the density of the modern element in a reference source and record its actual and predicted density values.

***Safety Precautions***

*Lead powder is extremely toxic by inhalation and ingestion; lead fume or dust is a possible carcinogen. Using lead shot should not present a powder or dust hazard. Do not work with lead powder. 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 chemical-resistant gloves and apron. Wash your hands with soap and water before leaving the laboratory.*

**Procedure**

1. Label three containers of Si (silicon), Sn (tin) and Pb (lead).
2. Obtain of silicon chunks. Measure the combined mass of the container plus solid to the nearest 0.01-g and record the value in the Data Table. *(Note:* This value is the initial mass for sample 1.)
3. Fill a 25-mL graduated cylinder to the 12mL mark 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 silicon chunks to the graduated cylinder until the water level in the cylinder rises by 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 (with the solid in it) in the graduated cylinder.
6. Measure and record the final, combined mass of the remaining solid (in the container) in the Data Table. *(Note:* This value is the final mass for sample 1.)
7. Complete two more trials of adding samples of the solid, each time adding solid until the water goes up by 1mL. Record all initial and final mass and volume data in the Data Table. There should be a total of three sets of mass and volume data (samples 1-3).
8. Empty the water from the graduated cylinder and carefully pour the silicon chunks onto a paper towel and allow them to dry. Do not allow any of the solid to go down the drain.
9. Rinse the graduated cylinder with water to make sure that the entire solid has been removed.
10. Obtain the tin shots. Measure the initial mass of the container plus solid to the nearest 0.01 g and record the value in the Data Table.
11. Repeat steps 3-9 using tin. Record all initial and final mass and volume data in the Data Table.
12. Obtain the lead shots. Measure the initial mass of the container plus solid to the nearest 0.01 g and record the value in the Data Table.
13. Repeat steps 3-9 using lead. Record all initial and final mass and volume data in the Data Table. Return the correctly labeled solids to your instructor for reuse.

**Data Table**

**Density Is a Periodic Property**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Element** | **Sample** | **Initial Mass****(g)** | **Final Mass (g)** | **Mass of Solid****(g)** | **Initial Volume (mL)** | **Final Volume (mL)** | **Volume of Solid****(mL)** | **Density** |
| **Silicon** | **1** |  |  |  |  |  |  |  |
| **2** |  |  |  |  |  |  |  |
| **3** |  |  |  |  |  |  |  |
| **Tin** | **1** |  |  |  |  |  |  |  |
| **2** |  |  |  |  |  |  |  |
| **3** |  |  |  |  |  |  |  |
| **Lead** | **1** |  |  |  |  |  |  |  |
| **2** |  |  |  |  |  |  |  |
| **3** |  |  |  |  |  |  |  |

**Post-Lab Calculations and Analysis**

1. *Complete the Data Table:* Calculate the Mass of Solid (initial mass- final mass) and Volume of Solid (final volume -initial volume) of each sample 1-3 for all three elements, silicon, tin, and lead. Record these results in the Data Table. (NGSS-4)
2. Using the mass and volume data, calculate the density of each sample 1-3 for all three elements. Show work for one here:
3. Calculate the average value (mean) of the density calculations 1-3 for each element, silicon, tin, and lead.

Average Density for silicon \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Average Density for lead\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Average Density tin \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. 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 this "best-fit" straight line to predict the density of germanium. (NGSS-6)



1. Look up the actual density of germanium in a reference source. How does your value compare to the actual reference value?