Teacher Version: Alchemists Go Fishing With Archimedes (Density of Metals)

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Introduction

Wildlife can be exposed to lead through lead shot and fishing sinkers, and awareness is growing about the toxic effects of lead on wild fowl and the corresponding entry of lead into the food chain. The scope of lead pollution in the environment due to fishing and hunting varies by region, and the popularity and use of non-lead based shot and fishing weights varies. The solubility of lead is greater in acidic solutions, so acid rain, and thus the acidification of bodies of water, has accelerated the release of lead from shot and sinkers.

Pre-Activity Discussion

The pre-activity brainstorming discussion outlined below is designed for instructors to engage students in understanding the goals of the investigation and possible approaches to doing the investigation. In cases where teachers use inquiry and facilitate student proposed and designed investigations, this discussion provides a starting point for that process. In cases where teachers supply students with a procedure for the investigation, this discussion incorporates some elements of student inquiry into the activity.

To begin the activity, you might introduce students to the problem of lead in hunting shot or fishing weights as an environmental pollutant and explain that they will play the role of fishermen who want figure out if some unlabeled fishing sinkers are probably made of lead. Through discussion, help students draw on their previous experiences to pose methods to determine whether the sinkers are lead. An important idea to discuss is what it means for two objects to be the same “substance.” if objects are made of the same substance, the small particles making up the objects have the same identity and arrangement. Somehow, we need to “look inside” the object and get clues about these particles.

Students should recall that in a previous activity, “Metallic Elements and Metal Compounds,” density was presented an example of an *intrinsic property*, a property that does not change with the amount of the substance. This makes density a property that can be used to help decide if two substances have the same type and arrangement of particles. Through discussion, help students think about what density tells us about a substance. Density, the ratio of mass to volume, gives us clues about the identity and arrangement of the particles that make up a substance. Ask students to consider two substances made up of particles that have a similar mass. In one substance, the particles are more closely spaced and in

the other substance more widely spaced. Which substance has the greater density? Have them consider two other substances: One substance has particles with a greater mass than the other, but the particles in both are spaced about the same. Which of these has the greater density?

If two objects have different densities (under the same conditions of temperature and pressure), we can conclude that the particles inside each are probably different, and that the substances are probably not the same. What if the densities of two objects are the same? They could have the same identity and arrangement of particles and therefore be the same substance. But, they might just have the same mass to volume ratio even with particles of different identities and arrangements. So, while density is a clue, it is not a definitive test.

Ask students to suggest ways to measure the mass and volume of the various fishing weights. As part of this discussion, you might tell or remind students about the early alchemists who were usually trying to make a quick buck by turning cheaper (base) metals such as lead into gold. Ask students if they know the story of an ancient scientist determining that an irregular shaped gold object was not be made of pure gold. Students may bring up the story of how Archimedes discovered how the volume of irregular shaped objects could be determined. In the discussion, students will probably mention that a large object will displace a large amount of water and a small object will displace a small amount of water, telling us the volume (size) of the object.

Materials

- Fishing weights and/or hunting shot (BBs), both lead and non-lead varieties, some labeled and others unknowns
  Note: Specialty sports stores are more likely to have non-lead fishing weights. In the sports section of discount and big box stores, lead fishing weights are the most common type. (FYI: Copper colored BBs are not solid copper.)
- Balances (weighing to 0.1 grams at least)
- Graduated cylinders, test tubes, or barrels of plastic pipets that the fishing weight(s) will fit inside.
- Beakers
- Optional: LeadCheck™ Swabs (or other EPA recognized brand)
- Graph paper

Procedure

The procedure outlined below is written to the teacher. In cases where teachers have students propose and design their own investigations, this procedure serves as an example for the teacher of a tested procedure that produces observable outcomes. While finding no observable outcome is a viable result in itself, and certainly may happen in student-directed investigations, having a tested procedure as a reference point can help teachers facilitate discussions with students as they propose their own procedures. In cases where teachers supply students with a procedure for the investigation, the written procedure can be quickly adapted for students to read directly.

CAUTION: Students investigating lead fishing weights should wash their hands after performing this laboratory activity. Students might also wear gloves for this investigation to minimize exposure. Most commercial packages of lead fishing weights identify the weights as containing lead. If the use of the lead fishing weights is not feasible, different metal objects, such as different types of construction nails could be substituted for the lead fishing sinkers in this activity.

The following procedure is suggested to guide students in developing their own procedure.

Note: *Small sized samples should be weighed and their volume measured as a group of individual samples such as 10 small weights, 20 very small weights. Have students enter data into a table similar to the one provided.*

1. Carefully label each known and unknown sample.
2. Weigh the samples.
3. Measure the volume of water displaced when each sample is added to a known volume of water.
   Note: Students can completely fill a test tube with water, place the test tube in a dry beaker, put the sample in the test tube, and collect and measure the displaced water. Or, students can put a specific amount of water into a small graduated cylinder, place a sample in the water, measure the new volume, and subtract the original volume of water.
4. Determine the density of each sample by dividing the mass by the volume.
5. Identify unknown fishing weights by comparing the density of unknowns to the density of known fishing weights.
   Note: Students will need to know the density of possible fishing weights from library or internet research. In addition to the cheap fishing weight material lead (11.34 g/cm^3), fishing weights might be made of stainless steel (7.9-8.03 g/cm^3), bismuth (9.75 g/cm^3), copper (8.94 g/cm^3), brass (8.4-8.7 g/cm^3) or tungsten (19.25 g /cm^3).

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Data Table

Sample	Mass	Volume	Mass/Volume = Density

1. What claims can you make about the composition of fishing weights?
2. What is the evidence to support your claims?

3. Explain in writing why your evidence and its interpretation fit your claims and explain how your claims fit what is known about density.

Data Graph

One way to help students build more understanding of the relationship of mass and volume to density is to have them graph their data with mass on the Y-axis versus volume on the x-axis. (See sample graph.) Points that fall near a best-fit line represent materials with the same density. The slope of the best-fit line is equal to the density of the material. Points that fall outside the best-fit line may represent experimental error or materials that actually have a different density. This creates a perfect opportunity to discuss the definitions of accuracy and precision in scientific work. In everyday speech, accuracy and precision might be used interchangeably, but in the context of science they have specific meanings. Accuracy is the degree of closeness of a measurement to the actual value. So, if a sample has a mass of 13.5 g, the measurement is accurate if it equals or comes very close to 13.5. Precision is the degree to which a measurement can be reproduced under the same conditions. So, if a 13.5g item is weighed five times, the resulting measurements are precise if the value of each measurement is very close. You might want to have students test the precision of their technique in this experiment by having different groups take turns finding the mass and volume of one sample and comparing results.

By using a best-fit line, small errors in precision are not as important, because even though individual data points might fall slightly off the line, the slope gives the density. Creating a graph like this would work particularly well if each group of students has a set of the same materials but with samples that vary in mass from group to group. Each group could then add their data to a class graph, and the best-fit lines could be found for the class results.

Post-Activity Discussion

The post-activity discussion is designed to help the teacher facilitate student learning as students summarize their observations and make claims about the outcome of the investigation using their data as evidence. Whether students use a provided procedure or have designed one of their own, this discussion incorporates key components of inquiry-based learning into the lesson.

Observations/Data

- How accurate were your measurements of mass and volume? How precise?
- How do your measurements determine the accuracy of the measured density?
- How many significant figures belong in your density determination?
- What additional information might be needed to identify the composition of fishing weights?

Claims/Evidence

- What fishing weight material is closest to the density of gold (19.30 g/cm^3)?

Reflection

- Fishing weights might also be made of composites, or more than one material, such as plastic and a metal or plastic and ceramic. Describe what the density of a composite fishing weight might be.
- Lead is a relatively cheap metal. To reduce lead in the environment and prevent wild fowl exposure to toxic lead, some states have banned the use of lead shot or fishing weights. Should sportsman be required to pay more for these items made of alternate more expensive materials? Would you pay more for nonlead shot or fishing weights voluntarily? How should sportsman be informed on which type of shot or fishing weights to buy?