# NYC Companion Lesson

# Identifying Substances

## Overview

This hands-on activity builds on and reinforces students' understanding of properties of substances. Students make careful observations of five cubes, each composed of a different metal. Among other differences, students observe that the cubes seem to weigh different amounts, even though they are the same size. Students are introduced to the terms *mass*, *volume*, and *density*. They examine a table of metals and their properties, including their densities. Students make initial claims about the identity of each metal, based on evidence. The class then measures the mass of each cube and calculates its density. Students use this evidence to revise and further support their claims. Next, students are challenged to calculate the density of an irregularly shaped object and to apply their new understanding to a mystery-substance scenario. The purpose of this lesson is to reinforce students' understanding that different substances have different properties and that density is a property that can be used to identify a sample of matter.

**Recommended Placement:** *Chemical Reactions*, after Lesson 1.3
**Suggested Time Frame:** 60 minutes

## NYS P–12 Science Learning Standards

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| **Performance Expectations** | • **MS-PS1-7:** Use evidence to illustrate that density is a property that can be used to identify samples of matter. |
| **Disciplinary Core Ideas** | • **PS1.A: Structure and Properties of Matter:**<br>° (NYSED) Each substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-7) (Note: This Disciplinary Core Idea is also addressed by MS-PS1-2 and MS-PS1-3.) |

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| **Science and Engineering Practices** | • **Practice 1:** Asking Questions and Defining Problems<br>• **Practice 3:** Planning and Carrying Out Investigations<br>• **Practice 4:** Analyzing and Interpreting Data<br>• **Practice 5:** Using Mathematics and Computational Thinking<br>• **Practice 7:** Engaging in Argument from Evidence |
| **Crosscutting Concepts** | • Scale, Proportion, and Quantity |

## Vocabulary

- density
- mass
- property
- substance
- volume

## Materials & Preparation

### Materials

#### For the Class

- Identifying Substances copymaster
- digital scale
- 2 AAA batteries
- 25 small white stickers
- isopropyl alcohol
- 1 plastic cup, 9 oz.
- marker*
- water*
- 3 large index cards*

#### For Each Group of Eight Students

- 1 set of 5 metal cubes
- optional: 1 digital scale*

#### For Each Group of Four Students

- 1 tray*
- 1 steel bolt
- 1 plastic graduated cylinder, 25 mL
- 1 plastic cup, 9 oz.

#### For Each Student

- Identifying Substances student sheets*

*teacher provided

## Preparation

1. **Print Identifying Substances copymaster.** Locate the Identifying Substances copymaster on the New York City Resources webpage: www.amplify.com/amplify-science-new-york-city-resources. Make one copy of all pages for each student.
2. **Create and post vocabulary cards on the classroom wall.** With a marker, write "density," "volume," and "mass" in large print on three individual index cards. Post these cards on the classroom wall.
3. **Relabel metal cubes.** Place a white sticker on each metal cube so the abbreviated name marked on each cube is covered. If the stickers will not stick, clean the cubes with rubbing alcohol before applying the sticker. Label each cube with a letter as follows:
   - Zinc: A
   - Brass: B
   - Steel: C
   - Copper: D
   - Aluminum: E
4. **Test digital scale(s).** Practice using the digital scale(s) and check their accuracy. The aluminum cube should have a mass of about 2.7 grams. Practice measuring the mass of 10 milliliters (mL) of water, using the TARE button when an empty cup is on the scale to account for the mass of the cup; 10 mL of water should have a mass of 10 grams.
5. **Fill cups of water.** For each group of four students, fill one cup about half full with water.
6. **Prepare trays of materials for each group of four students.** On each tray, place the following materials:
   - 1 steel bolt
   - 1 graduated cylinder
   - 1 cup with water
7. **Locate and review rubrics.** Review the Rubrics for Assessing Students' Use of Mathematics in Identifying Substances in the Assessment section of this lesson. These rubrics can help you plan ways to support students as they compare the mystery samples and draw conclusions during the lesson. After the lesson, use the rubrics to formatively assess students' developing facility with Science and Engineering Practices as well as their understanding of Disciplinary Core Ideas.

8. **Immediately before the lesson, have on hand the following materials:**
   - student sheets
   - sets of labeled metal cubes
   - trays of materials
   - an empty plastic cup
   - digital scale(s)

## Notes

### Support with Reading a Graduated Cylinder

To get a more precise density of the bolt, students will need to be able to read the volume of liquid in the graduated cylinder to a tenth of a milliliter. Consider giving extra instruction on how to identify the meniscus and approximate the volume between two graduations.

### Resetting the Lesson

You will need to make a plan to reset the demonstrations and materials for students between each class period. Students can pour the water back into the cups for the next class, and they can place all materials back on the trays.

## Science Background

Density is the amount of matter in a certain amount of space. The density of a material is its mass per unit volume. Weight is a measure of the force of gravity on an object and is proportional to its mass. As long as all measurements are taken on Earth (as in this lesson), the weight of an object is its mass. Each substance has a particular density, so measuring the density of a sample of a substance can help identify the substance. Unlike weight or mass and volume, which vary depending on the amount of the substance, density is the same for any amount. Density depends on the mass of the molecules (or atoms or ions) of the material, their size, and how spread apart they are. In gases, molecules can move away from one another and so are more spread out than the molecules of a liquid or solid; therefore, gases have much lower densities than liquids or solids. The density of a material varies with temperature and pressure. This variation is typically small for solids and liquids but much greater for gases. The molecules

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of materials that are higher in temperature move faster and take up more space. As temperature increases, density decreases (with a few exceptions). Increasing the pressure on an object causes the molecules to get closer together, which decreases the volume of the object and, thus, increases its density.

On Earth, weight is the force of gravity exerted by Earth on an object. If you were standing on the Moon or another planet, your weight would be the force exerted by whatever object you were standing on, and it would be different from your weight on Earth. Weight is different in different places. Mass, on the other hand, is a property of an object, and it does not change in different places. An object's mass is the same no matter how strong the gravitational pull of Earth or the Moon or another planet. The kilogram is a unit of mass, not weight. Since kilograms are used in everyday life on Earth, it is common to think of a kilogram as a measure of weight. Many scales for weighing, even scientific ones, are marked in kilograms. Scales are, in fact, responding to the weight or force of gravity on an object, but scales that are marked in kilograms are calibrated to the gravity on Earth and provide a readout of the mass of the object.

# Instructional Guide

## Explore and Activate Prior Knowledge

1. **Review concepts about substances and properties.** Invite students to review what they have learned about how you can tell one substance from another. Ask probing questions, if necessary, to ensure that the class reviews the idea that different substances have different properties such as color, texture, odor, melting point, and boiling point.
2. **Give instructions for observing five substances.** Hold up a tray with the five metal cubes. Explain that students will carefully observe the properties of the cubes, looking for any differences in their properties. Once students have a bit more evidence, they will try to use the properties they observed to identify what the cubes are made of. Encourage students to share the materials, making sure everyone gets to handle each cube.
3. **Distribute sets of metal cubes and have students make observations.** Two groups of four students will share one set of metal cubes. If necessary, prompt students to pick up each cube and observe with their sense of touch as well as their sense of sight.
4. **Share observations.** Call on volunteers to share observations.

## Build Foundational Knowledge

5. **Highlight observations about weight.** It is likely that some students will have noticed that some cubes are heavier than others. Highlight this observation and ask all students to feel the weight of the cubes.
6. **Introduce the word *mass*.** Explain that the weight of an object tells us about the mass of the object. When something is heavy, it has more mass. When something is light, it has less mass. Therefore, an object's weight can be used to figure out its mass, and scales that measure in grams or kilograms can measure mass.

   Mass is the amount of matter an object has. It is often measured in grams.

   Point out that the vocabulary word is posted on the classroom wall. Students can also find the definition in the glossary at the back of their Student Editions.
7. **Discuss whether mass is a property that can be used to identify substances.** Have pairs or small groups discuss this question. Call on a few volunteers to share. Then, ask the following questions:

   Would a drop of water have the same mass (or weigh the same) as a bucket of water?
   [No.]

   Are they both the same substance?
   [Yes.]

8. **Introduce the word *volume*.** Hold up a metal cube and explain that each cube takes up the same amount of space. They have the same volume.

   Volume is how much space an object or material takes up. Volume can be measured in cubic centimeters. Each of these cubes is 1 cubic centimeter.

   Point out that the vocabulary word is also posted on the classroom wall and students can find the definition in the glossary at the back of their Student Editions.

9. **Measure the mass of 10 mL (10 cubic centimeters [$cm^3$]) of water.** Explain that the volume of liquids is often measured in milliliters (mL)—1 mL is the same as 1 $cm^3$. Place an empty cup on the digital scale and press TARE. Using the supplies from one of the student trays, measure 10 mL of water in the graduated cylinder. Pour it into the cup and read the mass on the scale (10 grams). On the board, write "water 10 $cm^3$ = 10 grams."

10. **Measure the mass of 20 mL (20 $cm^3$) of water.** Pour the water from the cup back into the graduated cylinder. Add more water so you have 20 mL. Pour this back into the cup and read the mass on the scale (20 grams). On the board, write "water 20 $cm^3$ = 20 grams."

11. **Introduce the word *density*.**

    Mass is not a property of a substance since it changes depending on how much of the substance you have. However, we can use mass and volume together to calculate density.

    Density is the amount of matter in a certain amount of space. To calculate density, divide the weight by the volume.

    Point out that the vocabulary words are also posted on the classroom wall and students can find the definitions in the glossary at the back of their Student Editions.

    Demonstrate on the board for the first measurement. Write "10 grams ÷ 10 $cm^3$ = 1 gram/$cm^3$" and point out that 10 divided by 10 equals 1.

    Demonstrate on the board for the second measurement, write "20 grams ÷ 20 $cm^3$ = 1 gram/$cm^3$" and point out that 20 divided by 20 also equals 1.

    Density does not change, no matter how much of that substance you have. The density of water is 1 gram per cubic centimeter, whether you have one drop or a full bucket.

## Construct New Ideas

12. **Distribute the Identifying Substances student sheets.**

13. **Introduce table of metals and their properties.** Direct students to the Properties of Metals student sheet and refer to the table. Explain that students will use the information in this table, including data about density, to try to identify what each cube is made of. Emphasize that they will record their first ideas, and it is fine if they are not yet sure.

14. **Students make initial claims about the identity of the cubes.** Have groups discuss what they think each cube is made of and why. If necessary, encourage students to refer to the density data; although they have not calculated density for the cubes, they may be able to predict which are more dense and which are less dense based on how heavy they feel. Have students record their initial ideas in Part 1: Initial Claims of Metal Cubes of their student sheets.
15. **Discuss how to gather more evidence.** Invite students to share suggestions for how the class could gather more evidence about the cubes and be more certain about what they are made of. [Find the mass and volume of each cube and calculate density.]
16. **Measure the mass of each cube.** Explain that since each cube is 1 $cm^3$, when you divide the weight by the volume, you will divide by 1, which won't change the number! Have a volunteer measure the mass of each cube. (Alternatively, if you have a scale for each group, have each group measure and record the mass of the cubes. Then, call on each group to share.) Record the densities on the board (your values may differ slightly):

    **Density**

    - Cube A: 7.1 grams/$cm^3$
    - Cube B: 8.4 grams/$cm^3$
    - Cube C: 7.9 grams/$cm^3$
    - Cube D: 9.0 grams/$cm^3$
    - Cube E: 2.7 grams/$cm^3$
17. **Discuss the precision of measurements.** Explain that students may have results that are different from the densities in the table. This is because different measurement equipment can be more or less precise. The measurements used to calculate the densities in the table were taken on very precise equipment, and the measurements were repeated many times. The equipment used in the classroom is not as precise, so student measurements may differ.
18. **Students revise claims and write arguments.** Have students return to the Properties of Metals student sheet. Now that they have density data for each cube, have students discuss what they think each cube is made of. Have students revise their claims as needed and write arguments for their claims in Part 2: Identifying Metal Cubes, using evidence from their observations and data.
19. **Distribute trays of materials and introduce new challenge: metal bolt.** Hold up a metal bolt and explain that the class will try to figure out what metal this is made of. Ask what the class needs to measure in order to find the density of the bolt. [Its mass and volume.] Ask what might make this more challenging than the cubes. [Its volume is not exactly 1 $cm^3$. It is not a cube, so its volume will be more difficult to calculate.]

20. **Measure the mass of the bolt.** Measure the mass of the bolt. Alternatively, if groups have their own scales, have them measure the mass of the bolt. Record the mass on the board.
21. **Discuss how to measure the bolt's volume.** Invite groups to discuss how they could measure the volume of the bolt. Call on volunteers to share their ideas. If no one suggests measuring how much water the bolt displaces, give the class a hint by telling them to think about how they could use water. Remind them that 1 mL of water is equal to 1 $cm^3$. Have groups discuss again and then help the class agree on the method: put a certain number of milliliters of water in a graduated cylinder, drop the bolt into the water, and measure by how many milliliters the water level increases.
22. **Groups of four measure the volume.** If needed, support students with how to read a graduated cylinder to a tenth of a mL.
23. **Students calculate the density.** Have each student use paper and pencil or a calculator to divide the mass of the bolt by its volume and calculate its density.
24. **Discuss the identity of the bolt's metal.** Have students review the Properties of Metals student sheet and discuss what they think the bolt is likely made of. Remind students that they may not get a density that matches anything in the table because their measurements may not be precise enough. After discussing, note that the bolt is made of steel.
25. **Emphasize key idea.** Emphasize that each substance has characteristic physical properties, including density, which can be used to identify it.

## Apply New Ideas

26. **Introduce a new scenario.** Direct students to the Part 3: Mystery Substances Scenario student sheet and review the instructions.
27. **Students write their investigation plans.** Give students about five minutes to record their plans for investigating the mystery substances.

# Rubrics for Assessing Students' Use of Mathematics in Identifying Substances

The rubrics below may be used with students' plans for investigating the mystery samples to formatively assess students' developing facility with science and engineering practices and understanding of disciplinary core ideas.

## Rubric 1: Assessing Students' Performance of the Practice of Using Mathematics and Computational Thinking

Note that this rubric applies to students' investigation plans in the Identifying Substances student sheets, Part 3: Mystery Substances Scenario. Rubric 1 is designed to monitor and support students as they develop dexterity with the science and engineering practice of Using Mathematics and Computational Thinking. For each criterion, levels are described to monitor students' progress by indicating the degree to which students can independently demonstrate fluency with the science practice. This rubric may be used formatively to support students' facility with the practice of Using Mathematics and Computational Thinking. It features targeted questions a teacher may use to assess students' plans for comparing the samples and provides specific feedback for revisions and for future encounters with the practice.

| Rubric 1: Assessing Students' Performance of the Practice of Using Mathematics and Computational Thinking | | |
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| **Criteria** | **Description and possible feedback** | **Level** |
| **Applies mathematical concepts or processes to scientific problems.**<br><br>Are mathematical concepts or processes applied to figure out a scientific problem? | Students don't apply any mathematical concepts or processes to figure out whether or not the samples are the same.<br>Possible feedback: *How might you figure out the density of each sample?* | 0 |
| | Students apply mathematical concepts or processes, but the concepts or processes they apply would not help them figure out whether or not the samples are the same.<br>Example: The scientists should calculate the volume of both samples. Then they can multiply the volume by the mass to calculate density.<br>Possible feedback: *How did you calculate density with the metal cubes you identified?* | 1 |
| | Students apply mathematical concepts or processes, and the concepts or processes they apply would help them figure out whether or not the samples are the same.<br>Example: The scientists should calculate the volume of both samples. Then they can divide the mass by the volume to calculate density. | 2 |

## Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit

Note that this rubric applies to students' investigation plans in the Identifying Substances student sheets. Rubric 2 considers whether students have constructed and applied ideas in a way that is consistent with accepted science ideas. This rubric is designed to be formative, and space is provided to note if students are demonstrating understanding or are struggling with each idea. If students are having difficulty, you might consider returning to students' claims about the cubes and leading a student discussion. Help all students build the idea that density is a property that can be used to identify samples of matter by reviewing the arguments they used to support their claims.

| Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit | | |
|---|---|---|
| **Criteria** | **Description** | **Is there evidence of student understanding?** |
| **Consistent with accepted science ideas.**<br><br>Are students' predictions consistent with accepted science ideas? | Students demonstrate understanding of the idea that density is a property that can be used to identify substances.<br><br>Example: If both samples have the same density, then they might be the same substance. | |
| | Students demonstrate understanding of the idea that both volume and mass are needed in order to find the density of a sample.<br><br>Example: The scientists should cut the same volume piece off each sample. For example, they could cut an equal volume piece of each sample. Then, they can measure the mass of each piece and see if each piece has the same mass. | |

# Identifying Substances

## Properties of Metals

| Metal | Color | Density | Other properties |
|---|---|---|---|
| aluminum | silvery-white | 2.7 grams/cm$^3$ | |
| brass (mixture of copper and zinc) | gold | 8.4 grams/cm$^3$ | |
| copper | reddish-orange | 9.0 grams/cm$^3$ | |
| gold | gold | 19.3 grams/cm$^3$ | |
| iron | silvery-white | 7.9 grams/cm$^3$ | attracted to magnets |
| lead | gray | 11.3 grams/cm$^3$ | |
| magnesium | gray-white | 1.7 grams/cm$^3$ | |
| mercury | silver | 13.4 grams/cm$^3$ | liquid at room temperature |
| silver | silver | 10.5 grams/cm$^3$ | |
| steel (mixture of iron and carbon) | silver | 7.5 grams/cm$^3$ | most types attracted to magnets |
| titanium | silver | 4.5 grams/cm$^3$ | |
| zinc | dark gray | 7.1 grams/cm$^3$ | |

Possible Student Responses

# Identifying Substances (continued)

## Part 1: Initial Claims of Metal Cubes

Record your initial claims for what each cube is made of:

Cube A: Answers will vary.

Cube B: Answers will vary.

Cube C: Answers will vary.

Cube D: Answers will vary.

Cube E: Answers will vary.

# Identifying Substances (continued)

## Part 2: Identifying Metal Cubes

Revise your claim for the identity of each cube below and write an argument to support your claim. In your argument, use evidence from your observations and the data you gathered.

Cube A:

I think Cube A is zinc because it has a density close to 7.1 grams/cm$^3$ and is dark gray. I thought maybe lead, but lead has a much higher density.

Cube B:

I think Cube B is brass because it has a density close to 8.4 grams/cm$^3$ and is gold colored. Gold has a much higher density.

Cube C:

I think Cube C is steel because it has a density close to 7.5 grams/cm$^3$ and is gray. It could also be iron, but it looks more gray than silvery-white.

Cube D:

I think Cube D is copper because it has a density close to 9.0 grams/cm$^3$ and is orange.

Cube E:

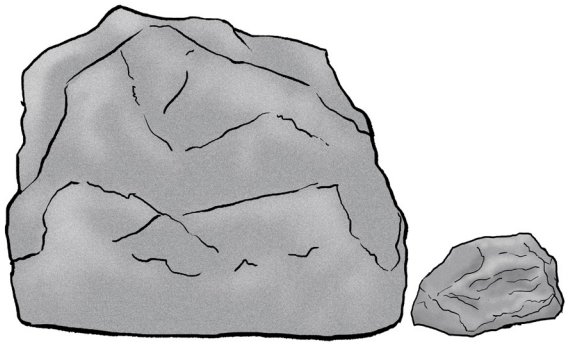
I think Cube E is aluminum because it has a density close to 2.7 grams/cm$^3$. You can tell it is much lighter than the other cubes.

Possible Student Responses

# Identifying Substances (continued)

## Part 3: Mystery Substances Scenario

Spacecraft bring back samples from two asteroids. One brings back a small sample, and the other brings back a large sample. Back on Earth, scientists observe that the samples have similar color and hardness. Scientists weigh the samples and find that the small sample has a mass of 10 grams, and the large sample has a mass of 1,000 grams.



mass: 1,000 g mass: 10 g

Describe an investigation plan that would help the scientists gather more evidence about whether the two samples are likely to be the same substance.

The scientists should cut the same volume piece off each sample. For example, they could cut an equal volume piece of each sample. Then, they can measure the mass of each piece and see if each piece has the same mass.

OR

The scientists should calculate the volume of both samples. Then, they can divide the mass by the volume to calculate density. If both samples have the same density, then they might be the same substance. If they do not have the same density, then they are different substances.