Educational Innovations Inc.®

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Density Cubes

DEN-220

Students identify each metal cube by determining its density. This classic lab includes extra large (easy-to-measure) 2.5 cm cubes of six different metals. Each set includes one cube each: aluminum, brass, copper, iron, lead, and zinc. Students can use the density of the samples to calculate the purity!

NGSS Correlations

Our Density Cubes and these lesson ideas will support your students' understanding of these Next Generation Science Standards (NGSS):

Elementary

2-PS1-1
Students can use the Density Cubes in an investigation to describe and classify different kinds of materials by their observable properties.

2-PS1-2
Students can analyze data obtained from testing the Density Cubes to determine which materials have the properties that are best suited for an intended purpose.

5-PS1-1
Students can use the Density Cubes in an investigation to develop a model to describe that matter is made of particles too small to be seen.

5-PS1-3
Students can make observations and measurements of the Density Cubes to identify materials based on their properties.

Middle School

MS-PS1-1
Students can use the Density Cubes in an investigation to develop models to describe the atomic composition of simple molecules and extended structures.

High School

HS-PS1-1
Students can use the Density Cubes in an investigation to predict properties of elements. Students can use the Periodic Table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

HS-PS2-6
Students can use the Density Cubes in an investigation to communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Suggested Idea(s)

2-PS1-1 • 2-PS1-2 • 5-PS1-1 • 5-PS1-3 • MS-PS1-1 • HS-PS1-1 • HS-PS2-6

Students can use the Density Cubes in a variety of investigations to make sense of the subatomic structure of matter (metals) and how that relates to its properties. Secondary students can do the math (detailed lesson plan on website) to determine the density of each of the six different samples.

What is Density? Some background information.

Density is a fundamental property of matter. Density is defined as mass divided by unit volume, usually expressed in grams per cubic centimeter, or kilograms per cubic meter. The Greek letter rho (ρ) is the symbol for density.

$$\rho = m \div v \qquad\qquad \text{density} = \text{mass} \div \text{volume}$$

Often we define density as weight per unit volume; however, this is actually called specific weight.

It is important to distinguish between mass and weight even though we tend to use them interchangeably. Mass is a measure of the quantity of matter and is constant wherever that matter might be in the universe. Weight is the force exerted on a body by gravity, and is proportional to mass. For example, consider a brick which weighs 12 kg on Earth, but only 2 kg on the moon, which has gravity one sixth that of earth. The mass of the brick hasn't changed, merely the weight.

Although mass is constant, volume is not. More pressure on an object decreases its volume, while increasing the temperature usually increases the volume. Increasing the volume of an object decreases its density; decreasing the volume increases the density. Often it is important to know the temperature and pressure at which the volume was measured. Densities are frequently given at STP, standard temperature and pressure, defined as 0^{o} C (32^{o} F) and 100 kPa (14.504 psi, 0.986 atm, 1 bar).

Specific gravity defines the density of a material as a multiple of the density of another standard material, usually water. Specific gravity is dimensionless. Materials with a specific gravity greater than one sink in water, those less than one float. Geologists use specific gravity to help identify minerals.

The density of a pure metal is determined by a number of factors. The size of the atom, the length of the bond between atoms, and the way atoms are arranged in the crystal lattice all play a role. Metallurgy, a subspecialty of material science, is the study of metals; crystallography is the study of crystals.

Demonstration Materials:

glass marbles of the same color and diameter (available from craft stores)

plastic or wooden beads of the same color and diameter (available from craft stores) ***or*** dried, nearly spherical beans such as garbanzo or soy

glue suitable for non-porous materials ***or*** 4 identical, opaque 8-16 oz dairy product containers with snap on lids and 2 similar, identical containers of a different volume

periodic table

Materials for Activity #1: Practice Determining Density

Density Cubes – Six Metals (#DEN-220); enough sets to provide one cube per team of students

You may want to coat the lead cube with a very thin layer of colorless nail polish
Label blocks with numbers - Copper-1, Lead-2, Iron-3, Aluminum-4, Brass-5, Zinc-6

One ruler marked with centimeters and millimeters per team of students

Balance(s) accurate to the nearest gram or better

Materials for Activity #2: Archimedes' Dilemma

Samples of unknown metals: (assign each item a letter)

Copper: plumbing fixtures (home centers, hardware stores)
Iron: plumbing fixtures, larger nails (home centers, hardware stores)
Aluminum: rods, certain nails and washers (home centers, hardware stores)
Zinc: pennies (pennies since 1982 are 97.5% zinc with a thin plating of copper)
Brass: house or car keys, large screws and cup hooks, hinges, solid brass decorative hardware (home centers, hardware stores)
Lead: fishing sinkers (sporting goods stores, outfitters), drapery weights

Notes: 1.You may want to coat the lead items with a very thin layer of colorless nail polish.
2. Supply more than one of smaller items like coins or nails to allow students the option to select larger total sample sizes, which should produce more accurate results.
3. There are other Educational Innovations products which have metal samples which could be used:

#DEN 210	*Density Identification Set (copper, aluminum, brass)*
#DEN-952	*Classroom Density Assortment (aluminum)*
#DEN-40	*Density & Slope Set (aluminum)*
#MOL-500	*Mole Element Sample Set (aluminum, copper, iron, zinc)*

Tools for determining volume and weight:

Unmarked plastic cups, jars, and bowls of assorted sizes
Graduated cylinders (plastic)
Rulers marked with centimeters and millimeters
String
Outside and inside calipers and/or drafting compasses
Calculators
Water
Balance(s) accurate to the nearest gram or better
"Useful Information" sheets

Demonstration

Consider one of two demonstrations before beginning the experiments with the students. The first is better, but its success depends, in part, on how handy you are with glue!

Demonstration using crystal lattice models:

Prepare four models of cubic crystal lattices. Three should be roughly the same width, length and height:

a. all glass marbles
b. all wooden or plastic beads, or beans, whichever you have on hand
c. half glass and half other bead or bean (think sodium chloride, NaCl)

The fourth model should be all one type of "atom" but significantly larger or smaller than the other three. Suggestions for how to easily assemble these models are included.

Explain that matter is made up of elements, and that the atom is the smallest unit of an element. The Periodic Table shows all of the known chemical elements arranged by atomic number. Point out the portion of the table where the metals are located. Elements which are metals are good conductors of heat and electricity. Most can be hammered or rolled into thin sheets, and reflect light.

Density is a fundamental property of matter; each element has a characteristic density which can used to help identify it. Density is defined as mass divided by unit volume. As long as we stay on Earth we can substitute the weight for mass for most purposes.

Display the two "single-atom" models of the same dimensions. These models represent atoms of metals in the simplest crystal lattice. Table salt, sodium chloride, forms the same type of crystal; if you look closely at salt crystals at home you will see that they are tiny cubes. We can determine the density of these "two-metal" samples by measuring the width, length, and height of the cubes in centimeters, then multiplying those three values to get the volume in cubic centimeters. We divide the weight of the cube in grams by the volume to obtain density in grams per cubic centimeter.

The density of a material is the same regardless of how large the sample of that material is. This concept can be demonstrated by repeating the process using the larger (or smaller) model. Now the class is ready to begin the first activity.

Demonstration using containers of loose "atoms":

Prepare three identical containers. Fill one with the glass marbles, representing the atoms of one elemental metal. Fill another with the wooden or plastic beads, or dried beans, which represent atoms of another elemental metal. Fill the third with a roughly 1:1 by volume mixture of the two "elements" to represent an alloy. Replace the covers on all three containers. Retain an identical, empty container with lid to use to tare the balance.

Explain that matter is made up of elements, and that the atom is the smallest unit of an element. The Periodic Table shows all of the known chemical elements arranged by atomic number. Point out the portion of the table where the metals are located. Elements which are metals are good conductors of heat and electricity. Most can be hammered or rolled into thin sheets, and reflect light.

Density is a fundamental property of matter; each element has a characteristic density which can be used to help identify it. Density is defined as mass divided by unit volume. As long as we stay on Earth we can substitute the weight for mass for most purposes.

Now show the two containers with only one “element”. The marbles and beads (or beans) represent atoms of two different elemental metals. In reality atoms aren’t tumbling around inside a piece of metal but are held together in a rigid framework or lattice. We can calculate the density of these “metals” by dividing the weight by the volume. The volume in milliliters is probably written on the containers already. Since one milliliter equals one cubic centimeter that quantity does not need to be directly measured. Using the empty container to demonstrate how to tare the balance, weigh the two containers of “metal”, and then calculate the densities with the students.

The density of a material is the same regardless of how large the sample of that material is. This concept can be demonstrated by repeating the process using the larger container of “metal”. Now the class is ready to begin the first activity.

Activity #1: Determining the Density of Metal Cubes

This activity gives the students an opportunity to practice determining the density of samples of relatively pure metals: copper, lead, iron, brass, and aluminum, and of an alloy of zinc and aluminum. Their task is to identify the metal in each sample cube by determining the density of each cube, and comparing their results with known values.

Safety Precaution: Before you begin the activity remind the students that they must always wash their hands thoroughly after handling unknown samples.

Each team of 2 or 3 students should have a ruler measured in centimeters and millimeters, one of the metal cubes, a calculator, and the first worksheet. If you desire, team members can choose or be assigned specific roles such as “communicator”, “measurer”, “calculator” etc.

Students measure the width, length, and height of the cube to the nearest tenth of a centimeter using the ruler, and then record the information in the appropriate line of the table. They measure the weight of the cube to the nearest gram, or tenth of a gram depending on the capability of the available balances, and then record this information in the mass column. Students can now calculate and record the density of the cube of metal. The teams of students pass the cubes until each team has determined the density of each of the six cubes.

Once the students have determined the densities of all six samples they can compare those results with the densities of pure elements in the table. They should be able to match sample numbers 1-5 with elements, but number 6, zinc, should have a density value that does not match any value in the table.

You might ask the students if they found a sample has a density that doesn't match any value in the table, and what they think might be the reason. Answers could include errors in measurement or calculation, but some might wonder if the sample was really pure zinc. Most of the metals we use today are alloys of two or more metals. Alloys have properties that differ from the elemental metals they are made from. For example, stainless steel, which is an alloy of iron and chromium, does not rust and is not magnetic. Display the crystal lattice model or container of spheres, the ones which contain a mixture of the two "elements". As before, determine the density of sample. You should obtain a value in between that of the two "metals" containing just one "element". This model or container represents an alloy of two different elemental metals.

Give the students the second worksheet with the chart of aluminum/zinc alloy densities so they can estimate what percentage of the sixth sample is zinc.

Activity #2: Archimedes' Dilemma

In the first experiment, students followed a given procedure to confirm the density values for cubes of known metals. The second experiment allows them to use what they've learned to conduct an investigation based on a historical event.

Introduce the activity by relating the story of King Hiero II of Syracuse, Archimedes, and a crown of suspicious composition.

One of the leading scientists in ancient times was the Greek mathematician, physicist, engineer and inventor Archimedes. He was born about 287 BC, and lived in the city of Syracuse in what is now Italy. The Roman writer Vitruvius recorded a story about Archimedes and Hiero II, king of Syracuse. The king had given gold to a goldsmith to create a votive crown, possibly shaped like a delicate wreath of leaves. The finished crown weighed the same as the original gold, but the king suspected that the goldsmith had kept some of the gold for himself, mixing the remainder with less expensive and less dense silver to make the crown. King Hiero asked Archimedes to find out if the goldsmith had cheated.

Ask the students what problem Archimedes faced in solving this problem. They should recognize the difficulty in determining the volume of the crown without crushing it into a cube, or melting it down into some other easy to measure shape.

Display the various tools available for the students to use that are not unlike those Archimedes might have had available: rulers, calipers, containers which hold water or measure the volume of liquids, and scales or balances to determine weight. Tell the students that they have a similar challenge, to determine the metal content of an irregularly shaped object. Each team of students chooses or is assigned the object(s) to study. Tell them that each object is primarily composed of one of the six metals; copper, aluminum, iron, lead, zinc, and brass.

There are many ways that the students can approach the problem, some more accurate than others. Depending on the shape of the object students might try to calculate the volume mathematically after measuring its dimensions. Some might immerse the item in a graduated cylinder, noting the volume of water displaced. They might also immerse the item in a container already filled to the brim with water, collecting and weighing the water that spills. Students compare the densities measured with the densities of pure metals in the table from the first activity.

After the students determine the metal composing their object(s) allow them to check their answers. Have the teams present their findings to the class, including their approach and the level of their success. Student teams can compare their approaches to the problem, perhaps deciding which method appeared to work best. Did the shape of the sample indicate the approach to use? Did sample size make a difference? This would be important when investigating pennies; would it be better to use one penny, or twenty pennies? You might ask about color. Color can be very deceptive, for example, pennies are copper colored because they have a very thin coating of copper metal on zinc. You might show a piece of gold-colored costume jewelry…which is attracted to a magnet! Can the students suggest ways to improve their approaches to the problem?

To conclude the exercise, finish the story of Archimedes. Vitruvius reported that Archimedes observed water spilling out of a tub when he got in to take a bath. He realized that he could divide the weight of the crown by the volume of water it displaced. The scientist reportedly ran to the palace shouting "Eureka" (Greek for "I have found it!), a term we still use to indicate when we've made an important discovery. Archimedes was able to prove that the goldsmith had indeed cheated the king.

This story does not appear in any of Archimedes' own writings, and some question whether he could have weighed the displaced water accurately enough to reliably detect such as alloy. It is more likely that he relied on what is still called Archimedes' principle, something he described and demonstrated in his own work titled "On Floating Bodies". If you put two items of the same weight onto the sides of a pan balance, then suspend the pans and items completely in water, the pan holding the least dense item will rise relative to the other. You might challenge the students to try this on their own at home.

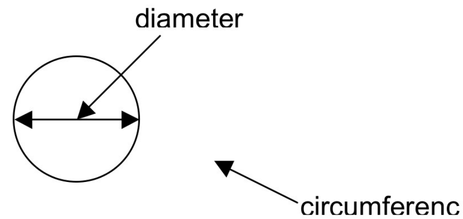
Assembling a Basic Cubic Lattice

For a 3 x 3x 3 cube, obtain 27 identical marbles or spheres. Determine what the length (L) of each side will be. Cut strips of stiff paper about 4.5 times that length. Fold the strips into square frames with each side L in length. Arrange nine spheres inside each square frame. Glue the spheres to each other with a suitable adhesive; do not use “super” glue since you’ll want to be able to adjust the spheres before the glue sets. Make sure that each layer of nine spheres is square before setting them aside to dry.

Once the layers are rigid enough to move, stack and glue the layers one to another. Make sure the assembly is a cube before setting aside to dry.

Remove the paper frame when the glue has set.

Useful Information



r = radius   d = diameter $\pi \sim 3.14$

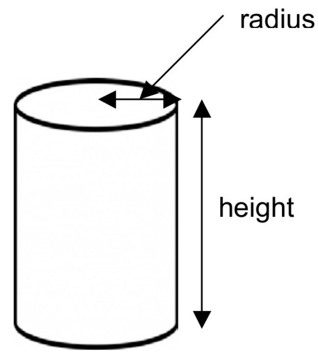
$d = 2 \times r$ diameter = twice the radius

Area of a Circle $= \pi \times r^2 = 3.14 \times$ (radius × radius)

$= \pi \times (d \div 2)^2 =$ 3.14 × (one half of the diameter × one half of the diameter)

Circumference of a Circle $= \pi \times d = 3.14 \times$ diameter

$= \pi \times 2 \times r = 3.14 \times$ (2 × radius)

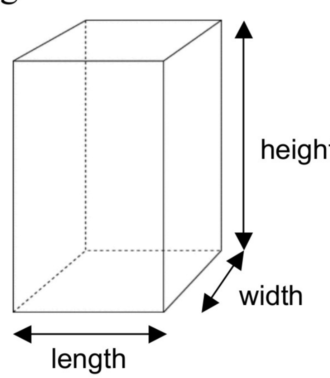


Volume of a Cylinder = cross section area times height

$= \pi \times r^2 \times$ height

$= 3.14 \times (d \div 2)^2 \times$ height

Volume of a Rectangular Prism = width × height × length



One milliliter (ml) is equal to one cubic centimeter (cm^3) in volume.

One milliliter of water weighs one gram.

Practice Measuring Density Worksheet

Sample Number	Mass (m) grams	Width (W) in centimeters	Length (L) in centimeters	Height (H) in centimeters	Volume (V) W x L x H cm^3	Density m ÷ v g/cm^3	Metal
1							
2							
3							
4							
5							
6							

Metal	Density in Purest Form g/cm^3
Lead	11.3
Copper	8.9
Iron	7.9
Brass	8.6
Zinc	7.1
Aluminum	2.7

Compare the density values you measured with the density values for six metals in their purest forms. The metal samples you measured aren't entirely pure, each contains traces of other metals, but five should be close to the values in the table. Did you find one sample that didn't seem to match any of the values in the table?

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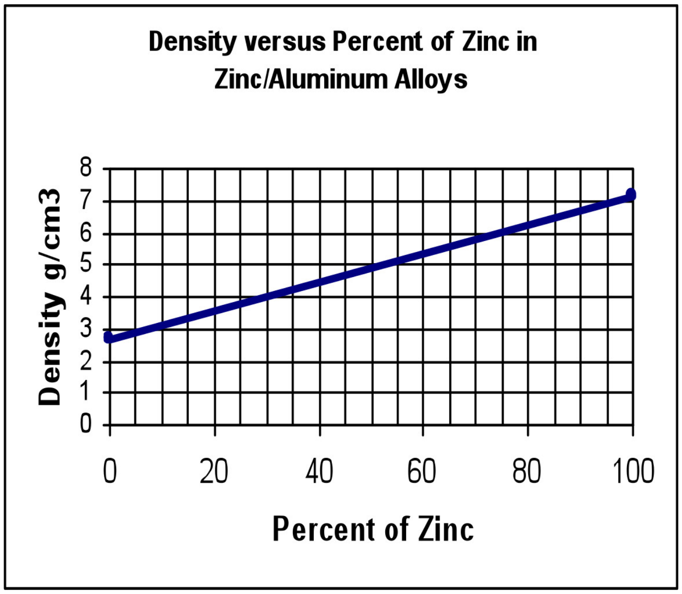
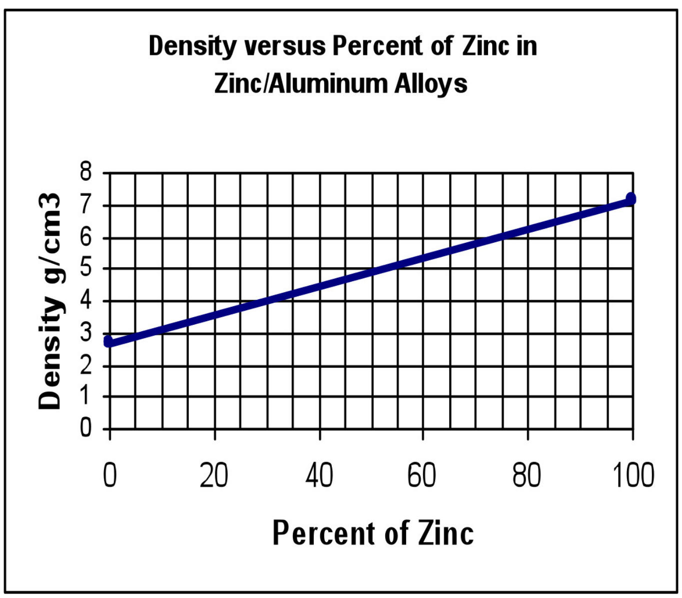
Compare the density values you measured with the density values for six metals in their purest forms. The metal samples you measured aren't entirely pure, each contains traces of other metals, but five should be close to the values in the table. Did you find one sample that didn't seem to match any of the values in the table?



The sample that has a density which doesn't match any of the values in the table is actually an alloy, or mixture, of zinc and aluminum. Alloys have properties that are different from the metals they are made from. The brass sample is an alloy of copper and zinc; it is yellow in color while copper is reddish-orange and zinc is silvery in color. You can estimate the percent of zinc in your sample using the chart. For example, if the density you measured was 5 g/cm^3, the percentage of zinc in your sample is about 55%. If the density you measured was 4 g/cm^3, then the percentage of zinc in your sample is about 30%. What do you think the percentage of zinc is in your sample?



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Take Your Lesson Further

As science teachers ourselves, we know how much effort goes into preparing lessons.
For us, "*Teachers Serving Teachers*" isn't just a slogan—it's our promise to you!

Please visit our website for more lesson ideas:

TeacherSource.com/lessons

Check our blog for classroom-tested teaching plans on dozens of topics:

http://blog.TeacherSource.com

To extend your lesson, consider these Educational Innovations products:

Mole Element Sample Set (MOL-505)
Each sample of aluminum, copper, iron, and zinc contains 6.02 x 10^{23} atoms of the metal. Great for chemistry students learning the mole concept and for determining densities and specific heats!

Density Sphere Experiment Kit (DEN-12)
This awesome kit is designed to permit students to discover and apply concepts of density and buoyancy. In this kit students make a density gradient from sugar or salt in a plastic column. Students then float five small spheres of different densities in the solution. Each sphere floats at a different level! By manipulating the density gradient, students can change the level at which the spheres float. Kit includes full instructions and write-up as well as spheres made of the following materials: polyethylene, polystyrene, nylon, acrylic, and cellulose acetate. Even unknown plastics are included for student density determination. Great for an elementary science table or as a terrific lab for middle school, high school, or college.

Steel Sphere Density Kit (DEN-350)

How are they the same?
How are they different?
One floats and one doesn't! Which is which?
Great for teaching the skills of observation and deduction!
Although these two shiny, metal spheres have about the same mass, one has a diameter significantly smaller than the other, making their densities vastly different. Seeing the large one float in water seems unbelievable! Bowl not included.