

DENSITY and SPECIFIC GRAVITY

Most students have felt how heavy “normal” rocks and minerals are. But many have never handled especially light minerals such as borax, or very heavy ones, such as a nugget of pure gold. This gives you an opportunity to surprise them, for some of the lightest and heaviest (more correctly, least and most dense) solids known are to be found among our naturally occurring minerals. Many ore minerals can be used to teach about these properties.

Density and Specific Gravity defined

Density is expressed in terms of mass per unit volume. The density of water, often used for comparisons, can be expressed as 1.0 g/cm^3 or $1,000 \text{ kg/m}^3$. Mineralogists often use the unit-less measurements of *specific gravity*, which is the density of a mineral *relative to that of an equivalent volume of water*. A mineral that weighs four times as much as water has a specific gravity (abbreviated SG) of 4.0.

Here is one example. Galena (chemically, lead sulfide) has long been mined for the lead, which was widely used in Roman times to make water pipes. (The Latin name, *plumbum*, is the origin of the English word *plumbing*, although modern pipes are not made with lead.) Galena often occurs with perfect cubic cleavage. If you were to make a cube of pure galena measuring exactly 1.0 cm on a side and place that cube on a laboratory balance, you would find that its mass is 7.58 g—its density is 7.58 g/cm^3 , and its specific gravity is: $7.58 \text{ g/cm}^3 \div 1.0 \text{ g/cm}^3 = 7.58$

Densities of minerals

Most common minerals in Earth’s crust have specific gravities ranging from 2.6 to 2.8. Quartz, for example, has a specific gravity of 2.65, calcite 2.72, and the common feldspars from 2.60 to 2.75.

Among all minerals, densities range widely, from about 1.5 to almost 23. Here’s a short list, in three categories:

Low specific gravity (2.5 or less)		Medium specific gravity (2.5 – 7.0)		High specific gravity (more than 7.0)	
Natron	1.5	Dolomite	2.8	Galena	7.6
Borax	1.7	Azurite	3.8	Copper	8.9
Sulfur	2.0	Chalcopyrite	4.2	Silver	10.5
Halite	2.2	Magnetite	5.2	Lead	11.4
				Mercury	13.6
				Gold	19.3

If you were to compare the densities of most minerals with their chemical formulas, several patterns would emerge. First, minerals of low specific gravity tend to be made of elements from the upper rows of the Periodic Table. For example, minerals in the left column of this list contain only lightweight metals. Natron is $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, borax is $\text{Na}_2\text{B}_4\text{O}_7$, and halite is NaCl . All these elements have atomic masses of 40 or less. Minerals with specific gravities in the range 4 – 8 commonly contain a heavy metal such as copper, lead, or tin, in combination with a much lighter nonmetal. Azurite is a copper carbonate ore, chalcopyrite has copper, iron, and sulfur, and magnetite is iron oxide. Minerals with high specific gravities contain metals that may be combined with non-metals, such as galena, or occur as “native metals”—uncombined with other elements. The main elements in the right column have atomic masses ranging from 108 (silver) to 207 (lead).

How well you will be able to demonstrate density differences in your classroom depends on what is available from the school mineral collection, or what you are willing to purchase to supplement it. Fortunately, even a modest school collection is apt to contain some common minerals useful for illustrating density differences, and deficiencies are easily overcome.

Discussion

Many minerals with a metallic luster are either oxides of metals (such as magnetite) or sulfides such as (pyrite, galena, marcasite, and sphalerite). In all of these, 70% or more of the mineral's weight is due to its metal content, so these minerals are heavy.

Most minerals with nonmetallic luster are either silicates or carbonates, in which a metal is bonded to a polyatomic anion containing elements of low atomic mass (silicon, carbon, oxygen). So silicate and carbonate minerals tend to be much lower in density. Of course, there are exceptions to these general rules. Barite (BaSO_4) contains barium, with atomic mass 137. Its name comes from the Greek word *baros*, meaning heavy, and refers to its unexpected property.

Exactly how the atoms of a mineral are arranged—the atomic structure of the mineral—has great influence on its density. Diamond, with a specific gravity of 3.4, is a moderately heavy mineral even though it consists only of carbon, an element of low atomic mass. The atoms in diamond are arranged in an exceptionally tight-knit structure. The carbon atoms in graphite occur in a structure that is more open, so graphite has a specific gravity of only 2.3. Structure and chemical composition both determine the densities of minerals.

Mineral prospectors even from ancient times were aware of mineral densities. With little more than a hammer and a dream, they explored locations seeking ores and used their experience to develop a feel for density and sense even slight departures from the norm simply by hefting rocks or minerals. They knew that the denser the rock, the more likely it is to contain ore of commercial value. During the American "Gold Rush," miners dumped sediments from streams into sieves (pans with screens on the bottom) to wash away lighter minerals and collect the denser gold.

Calculations by astronomers of the angular momentum of the Earth have found that our planet has an average density of 5.5 g/cm^3 . Most of the rocks in the crust of the Earth have an average density of only 2.7 g/cm^3 . That means that minerals and other matter in Earth's mantle and core must be of considerably higher density. It is generally accepted that much of earth's inner core may be an iron-nickel alloy with a density in excess of 13 g/cm^3 .

Activity

You can use mineral density to help students develop laboratory skills and learn about sources of error in measurements. This activity uses the “water displacement method” to find the volume of an irregularly-shape object. It goes back to the famous story of the Greek scientist, Archimedes, who may or may not have discovered this when asked by his king to determine whether a crown was pure gold.

1. Using a set of minerals with different densities, find their masses and record the values.
2. Place enough water in a graduated cylinder to cover the sample completely. Record the starting level.
3. Carefully drop a mineral sample in the cylinder and record the new level of the water and mineral. Then remove the mineral sample.
4. Calculate the difference between the level of the water alone and the level of the water and mineral: this is the volume of the mineral.
5. Repeat steps 2 – 4 for all the minerals.
6. Divide the mass by the volume to calculate the density of the samples, and record these.
7. To find how accurate your measurements are, look up the “accepted density” for that mineral. Calculate the “percent error” using this formula:

$$[(\text{measured density value}) - (\text{accepted density value})] / (\text{accepted density value}) \times 100\%$$

Example: Students measure the density of a sample of magnetite to be 5.4 g/cm^3 , and the accepted value is 5.2 g/cm^3 . The percent error is:

$$[(5.4 \text{ g/cm}^3) - (5.2 \text{ g/cm}^3)] / (5.2 \text{ g/cm}^3) \times 100\% = [0.2 \text{ g/cm}^3] / 5.2 \text{ g/cm}^3 \times 100\% = 0.039 \times 100\% = 3.9\%$$

In this example, the measurement was about 4% too high. This can be used to teach how much error is allowable in conducting investigations.

8. Explain what might be the source of any errors.

Adapted from: “Density and Specific Gravity” by Earl R. Verbeek, Sterling Hill Mining Museum, Ogdensburg, NJ, USA