DENSITY & ISOSTASY revisited

Part I: What does DENSITY mean?

We all know that lead and gold have high density, while Styrofoam is low in density. Another way to say this is that if we have exactly the same volume of lead, gold and Styrofoam, the lead and gold would have a higher mass than the foam. So what makes some things, such as lead and gold have high density? The modern explanation of their density really came after the discovery of X-rays which was at the turn of the twentieth century. X-rays are similar to visible light, but much shorter in wavelength and more able to penetrate solid materials. Using X-rays that are slightly more energetic than medical X-rays, we can examine the internal structure of solid materials.

The patterns created by the bending of these X-rays as they pass through a crystal tell us the internal structure of the crystal. In some materials it is clear that the space between atoms is less than the space between atoms in other materials. If the same atoms are closer together, the material will have more mass per unit volume and be a denser mineral.

Remember the Mystery Boxes module? That is where we indicated that we create models to help us understand our complex world. One such model is how we represent atoms and the bonds that hold them together.

Go the web site below to view some of the models of the internal structure of some minerals:

http://www.soils.wisc.edu/virtual_museum/displays.html

Click on the “Element Gallery” and go to graphite. If you depress the mouse button while the cursor is inside the display window you can move the model to different orientations. If you click on the “spacefill” button at the bottom of the page, the display will change to a different way to represent the graphite molecule.

Next do this same procedure for diamond. Diamond is composed of the same element (carbon) as graphite, but the bonding in the diamond is totally different. Graphite is used as the “lead” in pencils and is very soft and slippery, while diamond is the hardest mineral known. Since graphite and carbon are made of the same element, would you expect graphite and diamond to have the same density? Explain.
By the way—the density of graphite is 2.3 gm/cc while diamond is 3.5 gm/cc

Go back to the main menu of the web site and find the mineral galena (under the sulfides gallery) and open the image. The image that appears is a model of the structure of galena. The grayish balls are the lead atoms, the yellow are the sulfur atoms and the lines between the balls represent the bonds that hold galena together. Move the image around so that you can see its structure. Return the main menu and do the same for halite (look under the halides gallery). Move this model around to examine the structure of halite. What is similar about the atomic structure of these two minerals? What is different about the atomic structure of these two minerals?

Ask your instructor for a piece of galena and a piece of halite. Approximate the density of each mineral (your volume calculation may be slightly off, but do the best you can and we will compare answers with other groups. As we observed on the mineral web site we visited above, the internal arrangement of the atoms in both the galena and the halite are the same. However, the galena contains lead and sulfur, while the halite is sodium and chlorine (this mineral is mined for table salt!). Why are things composed of lead so dense?

A periodic table of the elements is posted in the classroom. Lead is shown on the periodic table by the symbol Pb. Notice that Pb has two numbers connected to that spot on the periodic table, the atomic number and the atomic mass. As you already know, atoms are made of electrons, protons, and neutrons. In stable elements, the number of electrons (negative charges) is equal to the number of protons (positive charges). Sometimes atoms will gain or lose an electron (or electrons) producing a charged particle called an ion. We will not be studying ions in this part of the course, so all of the elements we consider will have an equal number of protons and electrons. The number of protons is called the atomic number. How many protons does lead have?

Although all of these sub-atomic particles are very, very small, the electrons are much “lighter” than the protons and the neutrons. If we add the mass of all of the subatomic particles, the electrons are essentially zero, so the atomic mass is the number of the protons plus the number of neutrons. If you look at the periodic table, you will notice that the atomic mass is not a whole number—how could there be fractional protons or neutrons? Actually, as far as we know there are no fractions of a proton or neutron. The reason that the atomic mass appears as a decimal number is that this is the weighted average of the various isotopes of lead. This weighted average is determined by the relative abundances of the different isotopes. An isotope is an element that has the same number of protons, but a different number of neutrons. Lead for example has isotopes from mass 181 to mass 215 with 206, 207, and 208 as the stable isotopes that are common in nature. The remaining lead isotopes are unstable and change over time to other elements through radioactive decay. If we average the masses of all isotopes together according to their abundance in nature, we get the atomic mass given on the periodic table.
Now, let’s look at sodium which is found in the halite; its symbol is Na. How many protons does Na have? How many electrons does Na have? How about the number of neutrons? (The neutrons are a little more difficult to determine, but take a guess).

If we compare a mineral that contains lead and another mineral that contains sodium, it makes sense that the mineral with lead in it will be denser due to a greater number of protons and neutrons (assuming the atoms are about the same distance apart).

Part II: Floating and Sinking – a review!!

- Remember this situation? You were asked to imagine that we had three blocks of wood that varied in size and shape, but were made from the same piece of wood (same composition) that has a density about 0.5 grams per cubic cm. You ten drew how the blocks would appear is placed in the tub of regular tap water. Do that again below:

![Diagram of blocks A, B, and C floating in water]

Last quarter we came up with some relationships that could help you figure out how much of a floating object would be below the water line, and how much would be above the water line. In the space below, write down those relationships (HINT: ONE HAD TO DO WITH THE VOLUME OF THE OBJECT, THE OTHER HAD TO DO WITH THE MASS OF THE OBJECT). We will discuss these as a class before you proceed with the rest of this module.

Pumice is a naturally occurring volcanic rock that has many gas bubble holes that make pumice very light in weight. Can a rock float? This one can, most of the time, if there are enough holes. If we put pumice in water, eventually most pumice will sink as the holes fill with water.
Let’s determine the density of the pumice, given that the density of water is 1 g/cc. Discuss a method with your group and write your method in the space below:

Get a piece of pumice from the front desk or cart and conduct an experiment to determine the density of the pumice.

What is the approximate density of the pumice, based upon your experiment?
Part III: Applications of sinking and floating to understanding the Earth:

Imagine the circle below is the perimeter of the Earth. How deep do you think we have drilled into the Earth?
If we say that some oil and exploratory wells have gone thousands of feet beneath the Earth’s surface, it sounds very deep. However, we could not even see the deepest well drilled into the Earth on the diagram on the previous page!! So how do we know what is inside the Earth? (This should sound familiar from the Mystery Boxes module you completed last quarter.) Earthquake waves (seismic waves) are transmitted through most of the Earth and we can use the velocity of those waves to determine the structure of the inside of the Earth in a manner not unlike having an X-ray done of your hand.

Go to the web site below and read the short description of the Earth’s Interior provided by the U.S. Geological Survey (USGS):

http://pubs.usgs.gov/gip/interior/

You found that the various zones inside the Earth vary in density. The density of the materials and the thickness of the crust determine the level of the land. This helps us explain why there are mountains!

One of the zones that is not illustrated well in the USGS publication on the Earth’s interior is the upper part of the mantle, known as the Asthenosphere. This zone in the solid, rocky mantle is soft and behaves like a very slow moving fluid, although it is actually a solid (it appears that it deforms easily under stress – think warm Silly Putty©).

The Lithosphere (composed of the crust and the very topmost part of the mantle) behaves as rigid rock. The lithosphere seems to “float” on the Asthenosphere, so many of the principles we apply to wooden blocks in water can be applied to understand the vertical positions of various parts of the lithosphere. The application of these buoyancy principles to the Earth is called isostasy.

Go to the web site noted below and answer the questions below:

http://www.globalchange.umich.edu/globalchange1/current/lectures/topography/topography.html

(When you get to the site, scroll down to the topic of Isostasy. There you can play around with the floating block).

In this simulation, you can change the density of the block, the density of the liquid, and the height of the block.

- What happens if you increase the density of the block to 3.0 g/cm³ but leave the thickness constant?

What percentage of the block is above the level of the fluid?
• Leave the density of the block at 3.0 g/cm$^3$ and decrease the height of the block to 12 km.

How much of the block is above the fluid?

Is this the same percentage as before? Explain your answer.

• Although there are many different types of rocks on the Earth's surface, as a start let's assume that there are only two rock types, basalt (density about 3.0 g/cm$^3$) and granite (density about 2.6-2.7 g/cm$^3$). Further, let's assume that at any place we find the basalt, we find that the crust of the Earth is relatively thin (6-10 km), while areas of granite range in thickness from 30-70 km. Use the isostasy website to predict which of these rocks would form ocean basins and which would form continents.

Explain your logic using the concept of isostasy.

In summary, ocean basins are formed of ______________ and are low in elevation due to:

While continents consists of rocks similar in composition to ______________ and rise higher in elevation due to: