Density Worksheet

Matter is anything that has a mass associated with it, as well as encompassing a particular volume. The more matter there is in a certain volume (i.e.: the more mass within that volume), the more dense that matter is. So the density of matter, D, is the mass of that matter, M, divided by its volume, V.

\[ D = \frac{M}{V} \]  

or rearranged: \[ M = D \times V \]  

or \[ V = \frac{M}{D} \]

Solids normally have densities recorded in units of g/cm\(^3\) whereas liquids are g/mL. Gases are much less dense than liquids or solids and so typically have densities given in units of g/L.

Density is constant for a particular species, unless the temperature changes. Under thermal expansion, the volume of a species increases when it is heated or contracts when cooled. If the mass remains constant while the volume changes upon heating, then the density changes based on the equation above.

Density and Miscibility:

When mixing different liquids together, the properties of the liquids determine the extent in which one dissolves in the other. For solids in liquids, the terms soluble and insoluble apply, whereas for liquids dissolving in liquids, the terms miscible and immiscible are used. When two immiscible liquids are mixed, they separate into layers with the least dense liquid forming the upper layer.

The Density of a Liquid:

In determining the density of any liquid, the volume is easily measured directly from a graduated cylinder or buret. The mass, though, must be measured indirectly through a method called “measuring by difference”. Using this method, the mass of a dry graduated cylinder is subtracted from the mass of that cylinder filled with a measured volume of liquid. This gives the liquid mass, and when divided by its volume, its density.

The Density of a Regularly Shaped Solid:

If a solid is square or rectangular, the volume can be directly measured using a ruler or other similar measuring device. Knowing that the volume of a square or rectangle is length (l) x width (w) x height (h), and with the mass being directly measured on a balance, then the density is easily obtained.

Other solid volumes can be determined if their equation for volume is known (i.e.: Cones, cylinders, spheres).

The Density of an Irregularly Shaped Solid:

It can be very difficult or impossible to directly measure the volume of an irregularly shaped object (like an egg or tooth). A common method used is to measure the volume by water displacement. In this method, the solid object of known mass is placed in a graduated cylinder or other volume measuring device with a pre-recorded volume of water in it. The increase in volume due to addition of the solid is the volume of the solid.

Questions:

1) If a brick has a length of 13.77 cm, a width of 8.50 cm, and a height of 5.12 cm:

a) What is the volume of the brick?  
b) If the brick has a mass of 895.3 g, what is its density?

2) If 8.15 mL of water is placed in a graduated cylinder (dry mass = 56.98 g), and the combined mass of both the cylinder + water is 65.11 g:

a) What is the mass of the water:  
b) What is the density of the water:
3) If an organic liquid, immiscible with water, with a density of 0.88 g/mL were mixed with the water from question #2, would the water or the organic liquid float on top?

4) An oddly shaped mineral ore chunk has a mass of 43.88 g.
   a) If the ore is placed in a graduated cylinder filled initially to 20.1 mL with water, and then rises to a volume of 45.2 mL, what is the volume of the ore chunk:
   b) What is the density:

5) If the density of ethanol (i.e.: booze!) is 0.789 g/cm$^3$, then what mass (in grams) of alcohol was imbibed if you drank a fifth (a fifth is equal to a 1/5 of a gallon, exact). You’d probably be dead by the way……

6) What takes up more volume: 0.425 kg of copper (d = 8.96 g/cm$^3$) or 3.411 pounds of iron (d = 7.87 g/cm$^3$).

7) (a) A lead brick has a mass of 2.556 kg and a volume of 225.4 mL. What is its density in g/cm$^3$?
   (b) A 225 gal vat of mercury has a mass of 12.77 tons. What is its density in g/cm$^3$?
   (c) Would the lead brick float or sink in the vat of mercury?

8) (a) What would the mass (in grams) be of a roomful of oxygen gas. The density of O$_2$ gas at 20 °C is 1.33 g/L and the dimensions of the room are 11.5 ft long, 15.0 ft wide and 7.40 ft high.
   (b) If the air near the floor of the room was heated to 40 °C, would the density of air increase, decrease, or remain the same? What would happen to the air nearest the floor as far as movement?