A Streak of Inspiration

Some of us do our best thinking while in the shower. According to legend, Archimedes recognized the law of buoyancy while taking a bath. King Hiero of Syracuse had asked Archimedes whether it was possible to determine the purity of a gold crown that the king had commissioned. While universally acclaimed as beautiful, the crown had raised suspicions that the goldsmith had mixed the precious metal with baser silver.

Writing a couple of centuries after Archimedes' death, the Roman architect Vitruvius relates how Archimedes, while lowering himself into a public bath, noticed that more and more water spilled over the sides. The bolt of insight struck, and Archimedes reportedly ran home through the streets of Syracuse, naked, shouting "Eureka! Eureka!" ("I have found it! I have found it!")

Now, drop the nugget into a glass of water, which has a density of 1.0 g/cc. The gold displaces its own volume – one cubic centimeter – of water. By Archimedes' Principle, the buoyant force is equal to the weight of this displaced water, i.e. one gram. Therefore, if you could weigh the gold in the water, you would come up with 19.3 – 1.0 = 18.3 grams. This is a reduction in weight of about 5%.

Bronze, another metal known in antiquity, has a density of about 8 grams per cubic centimeter (the exact value depends on the mix of copper, tin, and other metals). A nugget of bronze with the exact same shape and size as the gold would weigh 8 grams in air and 7 grams in water, a reduction of 12.5%. Aluminum has a density of 2.70 g/cc and was emphatically not known to Archimedes (look up the Google reference on page 224 of Volume 1). Dropping an identically shaped nugget of aluminum into water leads to a weight reduction of almost 40%.

How does this mental experiment help? Clearly, denser materials, such as gold, experience a smaller reduction in weight when immersed in water. More importantly, you can do a little mathematics and demonstrate the following relation:

$$\text{density} = \frac{\text{dry weight}}{\text{dry weight} - \text{wet weight}}$$

This will let you convert dry and wet measurements directly to the density of the unknown sample.

20.2.2 The "Suspension Gizmo" – A Simple Density Measuring Device

In this section, you will learn how to build a relatively simple mechanism based on Archimedes' moment of genius. This device, in combination with a good set of scales, will allow you to determine the density of small samples of gem rough with sufficient accuracy to identify the material. For those paying attention since Chapter 12, the suspension gizmo actually makes a measurement relative to water, and hence evaluates the specific gravity, not the density, of the sample.