Gemology for Faceters #5

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In the last newsletter issue we looked at magnification, thus rounding out the triad upon which most gemological determinations are based - the refractometer, the spectroscope and the microscope. In this issue we'll discuss a property of gemstones that is also helpful in establishing their identity, specific gravity.

Density

First we shall address the issue of density which can be defined as "mass per unit volume." By convention, density is, according to the International System of Units, described as kilograms per cubic meter (kg/m^3). In the U.S. an equivalent might be pounds per cubic yard, or more usefully, pounds per cubic foot or ounces per cubic inch. In gemology, the measurement is typically grams per cubic centimeter (g/cm^3). To determine density you simply weigh a substance and divide the mass by the substance's volume.

Specific Gravity

Specific Gravity is dimensionless and is referred to as "relative density." It is the ratio of the weight of a substance in air and the weight of an equal volume of water at 4° C. Since virtually no gem materials float, we know that any S.G. we record will be >1. The S.G. of corundum (e.g. sapphire or ruby), is 4.00 and so corundum weighs four times what an equivalent volume of water weighs.

By rule of thumb, typically, a well proportioned round brilliant cut diamond of 6.5 mm in diameter will weigh approximately one carat. If you cut a CZ of the same proportions that is 6.5 mm in diameter it will resemble a one carat diamond but it will actually weigh more than one carat because CZ has a higher specific gravity, usually about 5.6 as opposed to 3.52 for diamond. You can calculate the weight of a 6.5 mm CZ round brilliant by dividing 5.60 by 3.52, the result being 1.59. So, the CZ would weigh roughly, 1.59 carats.

Individual specimens of a gem species typically typically fall into a narrow range of S.G. because of their unique crystal chemistry (e.g. chemical composition and atomic structure). So, S.G. is a useful property to determine when you need additional information to identify a gem species, or in some cases to separate a natural gem from its man-made synthetic counterpart.

Measuring Specific Gravity

There are a number of ways to measure S.G., but for us the most useful method is to use a hydrostatic balance. This is simply a balance, usually a top loading balance like those so often used in the gem trade, with some added components that allow you to get the weight of the gem while it is immersed in water. The calculation for determining S.G. is simply the weight of the substance in air divided by its weight loss in water:

$$\frac{\text{weight in air}}{\text{weight in air - weight in water}}$$

So, the first step is to weigh the stone in air and it is useful to use the most sensitive and accurate balance that you have to improve your results. Ideally, you should use a balance/scale that is

Step 1: Weight of the gem in air.

accurate to 0.01 carats if possible. As you can see in Step 1, we are weighing a blue piece of irregular rough and the weight is 34.20 carats.

Next, we'll set up our specific gravity kit with the scale. The one I use is sold by Mineralab and costs $79. It consists of a base and stand to hold the included beaker, filled with water, over the scale. There is also a wire cage that connects to the weighing area of your balance and suspends a thin wire holder for the stone

Step 2: Set up the S.G. kit on the scale and tare the scale so it reads zero.

which is immersed in the water.

After you've set up the components then tare the scale so that it reads zero.

Step 3 is to very carefully, with a pair of tweezers, place the stone on the wire platform and record the weight. In this case the weight in water is 21.64 carats.

The final step is to calculate the S.G. using our formula which results in:

$$\frac{34.20 \text{ cts}}{34.20 \text{ cts} - 21.64 \text{ cts}}$$

Step 3: Carefully place the stone on the wire holder in the water

A quick few buttons on the calculator gives us the result of 2.72.

Suppose for the sake of argument we are not certain of the identification of the piece of rough for which we've just determined the specific gravity. We might expect that based on its color it is either aquamarine, blue topaz or blue zircon. We can go to any number of gemological texts or the Gemology Tools software and look up 2.72. It does not take long to find this is the S.G. for aquamarine with a range of approximately +.18 and -.05, meaning the maximum S.G. for aqua is 2.90 and the minimum is 2.67. Now lets look up the S.G. for zircon and blue topaz. Well, zircon is 4.70 and topaz is 3.53, both very far removed from our 2.72.

Precautions

There are a few things to consider when using a hydrostatic balance. First, the accuracy of the resulting S.G. numbers, assuming your technique is appropriate, is related to the precision and accuracy of your scale. As a rule of thumb, with a scale that weighs to 0.01 cts you can accurately measure the S.G. of a stone

that weighs as little as 0.40 carats. If you have a top loading analytical balance or a scale accurate to .001 carats then you can expect to get accurate S.G.s down to a size of about 0.04 carats.

You must also be careful about setting up the scale. Make sure the cage that suspends the weighing basket does not contact any portion of the stand holding the beaker of water, and be certain the weighing basket does not contact the sides of the beaker. Also make sure that there are no entrained air bubbles underwater on either the weighing basket or the stone itself. Either case can create significant errors.

If you are doing one S.G. measurement, with a little practice you'll be able to do it in about three minutes. If you have several stones to test, it goes even faster.

There are two more practical ways for the gemologist to measure S.G., with heavy liquids, or with a direct reading balance.

Heavy Liquids

Heavy liquids are those that are more dense than water. Gems will either float or sink in them when immersed and this can be a good technique for a quick check of S.G. The method is particularly attractive when you have a small stone as an unknown - too small to expect accurate results from the hydrostatic method.

There are a number of heavy liquids available and these can be mixed to produce a liquid of the specific required density. Among the most useful are methylene iodide (diiodomethane) with an S.G. of 3.32 at room temperature, bromoform, at approximately 2.85 and benzyl benzoate at 1.17. There are, of course, many others, including Clerici

solution, a highly toxic and poisonous mixture of thallium formate and mallonate with a S.G. of up to 4.20. It is often mixed with water to reach 4.00, useful for determining corundum.

As an aside, bromoform and metheylene iodide are also commonly used as immersion fluids for optical inspection of gems. Bromoform has an R.I. of 1.598 and methylene iodide, 1.745. Methylene iodide is the main ingredient in R.I. fluid used in a refractometer.

For years GIA's gem instruments made an S.G. gravity set that was comprised of five wide mouth bottles at five separate S.G.s. These were:

2.57: feldspar vs chalcedony

2.62: chalcedony vs. quartz

2.67: flux syn. emerald vs. emerald

3.05: tourmaline vs. topaz & spodumene

3.32: nephrite vs. jadeite

Each bottle has two indicator minerals inside, one slightly less dense than the liquid so that it floats, and one slightly more dense so that it sinks.

Technique

The technique for using heavy liquids is quite simple. First, clean the stone then using tweezers immerse it in the S.G. liquid. Tapping the stone and tweezers against the sides of the bottle will make certain any air bubbles are dislodged. Release the stone and note whether it rises, sinks or remains suspended in the column of liquid. Obviously if it sinks, it is heavier than the liquid, if it floats it is lighter and if it is suspended it is equivalent to the S.G. of the liquid. The rate at which the stone floats or sinks is also useful in estimating S.G.

If necessary, you can test the stone in a series of liquids just remembering to clean the stone in between immersions so there is no contamination.

Be sure to take appropriate safety precautions, including using the liquids in a well ventilated area and wearing gloves and eye protection. Store the liquids in a cool, dark place.

You can buy liquids of pre-determined densities from Cargille labs and they have a gemology heavy liquid kit with five liquids for $277. Most liquids can be adjusted by adding either methylene iodide to increase density or a very small amount of benzyl benzoate to decrease density. The density of a liquid can be measured by using a pycnometer or specific gravity bottle. The device and a scale are all that is required.

Direct Reading S.G. Balance

Dr. Bill Hanneman has championed yet another method of S.G. determination, the direct reading S.G. balance. This is a modified beam balance that allows you to weigh the stone in air and in water and to slide a weight down the beam and read the specific gravity directly. No calculations are necessary. For those of you who attended my USFG talk in Tucson, Dr. Hanneman spoke briefly about the concept. You can buy an S.G. balance kit directly from him (E-mail: hanneman@netzero.net) or Mineralab sells a version for $129.