## II. SPECIFIC GRAVITY OR RELATIVE DENSITY

**295. Definition of Specific Gravity.** — The specific gravity of a mineral is the ratio of its density * to that of water at 4° C. (39·2° F.). This relative density may be learned in any case by comparing the ratio of the weight of a certain volume of the given substance to that of an equal volume of water; hence the specific gravity is often defined as: *the weight of the body divided by the weight of an equal volume of water*.

The statement that the specific gravity of graphite is 2, of corundum 4, of galena 7·5, etc., means that the densities of the minerals named are 2, 4, and 7·5, etc., times that of water; in other words, as familiarly expressed, any volume of them, a cubic inch for example, weighs 2 times, 4 times, 7·5 times, etc., as much as a like volume, a cubic inch, of water.

Strictly speaking, since the density of water varies with its expansion or contraction under change of temperature, the comparison should be made with water at a fixed temperature, namely 4° C. (39·2° F.), at which it has its maximum density. If made at a higher temperature, a suitable correction should be introduced by calculation. Practically, however, since a high degree of accuracy is not often called for, and, indeed, in many cases is impracticable to attain in consequence of the nature of the material at hand, in the ordinary work of obtaining the specific gravity of minerals the temperature at which the observation is made can safely be neglected. Common variations of temperature would seldom affect the value of the specific gravity to the extent of one unit in the third decimal place.

---

* The *density* of a body is strictly *the mass of the unit volume*. Thus if a cubic centimeter of water (at its maximum density, 4° C. or 39·2° F.) is taken as the unit of mass, the density of any body — as gold — is given by the number of grams of mass (about 19) in a cubic centimeter; in this case the same number, 19, gives the relative density or specific gravity. If, however, a pound is taken as the unit of mass, and the cubic foot as the unit of volume, the mass of a cubic foot of water is 62·5 lbs., that of gold about 1188 lbs., and the specific gravity is the ratio of the second to the first, or, again, 19.

For the same reason, it is not necessary to take into consideration the fact that the observed weight of a fragment of a mineral is less than its true weight by the weight of air displaced.

Where the nature of the investigation calls for an *accurate* determination of the specific gravity (*e.g.*, to four decimal places), no one of the precautions in regard to the purity of material, exactness of weight-measurement, temperature, etc., can be neglected.* The accurate values spoken of are needed in the consideration of such problems as the specific volume, the relation of molecular volume to specific gravity, and many others.

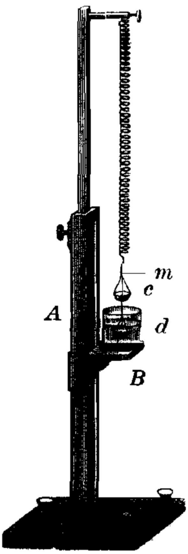
**296. Determination of the Specific Gravity by the Balance.** — The direct comparison by weight of a certain volume of the given mineral with an equal volume of water is not often practicable. By making use, however, of a familiar principle in hydrostatics, viz., that a solid immersed in water, in consequence of the buoyancy of the latter, loses in weight an amount which is equal to the weight of an equal volume of the water (that is, the volume it displaces) — the determination of the specific gravity becomes a very simple process.

The weight of the solid in the air ($w$) is first determined in the usual manner; then the weight in water is found ($w'$); the difference between these weights — that is, the loss by immersion ($w - w'$) — is the weight of a volume of water equal to that of the solid; finally, the quotient of the first weight ($w$) by that of the equal volume of water as determined ($w - w'$) is the specific gravity ($G$).

Hence,

$$G = \frac{w}{w - w'}.$$

505




**Spring or** Jolly Balance for Specific Gravity

A common method of obtaining the specific gravity of a firm fragment of a mineral is as follows: First weigh the specimen accurately on a good chemical balance. Then suspend it from one pan of the balance by a horsehair, silk thread, or, better still, by a fine platinum wire, in a glass of water conveniently placed beneath, and take the weight again with the same care; then use the results as above directed. The platinum wire may be wound around the specimen, or where the latter is small it may be made at one end into a little spiral support.

**297. The Jolly Balance.** — Instead of using an ordinary balance and determining the actual weight, the spiral balance of Jolly, shown in Fig. 505, may be conveniently employed; this is also suitable when the mineral is in the form of small grains. The instrument consists of a spiral spring at the lower end of which are suspended two pans or wire baskets, *c* and *d*, Fig. 505. Upon the movable stand B rests a beaker filled with water. When in adjustment for reading this stand has such a position that the pan *d* is immersed in the water while *c* hangs above it. Upon the upright A there is a mirror upon which is marked a scale. The position of the balance at any time is obtained by so placing the eye that the bead, *m*, and its reflection in the mirror coincide

* Cf. Earl of Berkeley in Min. Mag., **11**, 64, 1895.

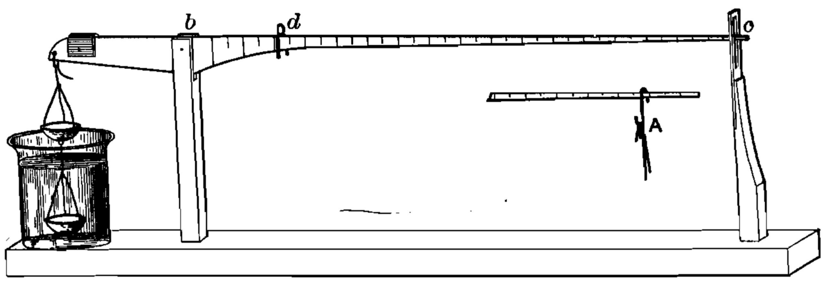
and then reading the position of the top of the bead upon the scale. The first step in the operation consists in getting the position of the spring alone, having the pan $d$ immersed in the water in the beaker. Let this reading be represented by $n$. The mineral whose specific gravity is to be determined is then placed on the pan or basket, $c$, and the platform B raised until $d$ is properly immersed in the water. The position of the bead $m$ is again read. Let this value be represented by $N_1$. If from $N_1$ be subtracted the number $n$, expressing the amount to which the scale is stretched by the weight of spring and pans alone, the difference will be proportional to the weight of the mineral. Next, the mineral is placed in the lower pan, $d$, immersed in the water, and again the corresponding scale number, $N_2$, read. The difference between these readings $(N_1 - N_2)$ is a number proportional to the loss of weight in water. The specific gravity is then

$$G = \frac{N_1 - n}{N_1 - N_2}.$$

It is obviously necessary to have the wires supporting the lower pan immersed to the same depth in the case of each of the three determinations. If care is taken the specific gravity can be obtained accurately to two decimal places.

**298. The Beam Balance.** — A beam balance described by Penfield is another very simple and quite accurate device for measuring the specific gravity. It is illustrated in Fig. 506, which will make clear its essential parts. The beam is so balanced by a weight on its shorter end that it is very nearly in equilibrium when the lower pan is immersed in water. An exact balance is then obtained by the small rider $d$. When the beam is once balanced this rider is kept stationary and its position disregarded in the subsequent readings. The mineral is first placed in the upper pan and the beam balanced by another rider of such a weight that its position will be near the outer end of the beam.

506




Beam Balance for Specific Gravity, $\frac{1}{6}$th Natural Size (after Penfield)

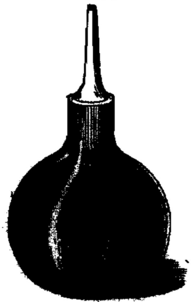
The position of this rider is then read from the scale engraved upon the beam. Let this value be equal to $N_1$. The mineral is next transferred to the lower pan and the beam again brought into balance by moving this same rider back. The second reading may be represented by $N_2$. The formula for obtaining the specific gravity is now:

$$G = \frac{N_1}{N_\cdot - N_2}.$$

**299. Pycnometer.** — If the mineral is in the form of grains or small fragments, the specific gravity may be obtained by use of the *pycnometer.*

This is a small bottle (Fig. 507) having a stopper which fits tightly and ends in a tube with a very fine opening. The bottle is filled with distilled water, the stopper inserted, and the overflowing water carefully removed with a soft cloth and then weighed. The weight of the water is obviously the difference between this last weight and that of the bottle and mineral together, as first determined. The mineral whose density is to be determined is also weighed. Lastly the bottle is weighed with the mineral in it and filled with water as described above.* The weight of the water displaced by the mineral is obviously the difference between this last weight and that of the bottle filled with water plus the weight of the mineral. The specific gravity of the mineral is equal to its weight alone divided by the weight of the equal volume of water thus determined. Where this method is followed with sufficient care, especially avoiding any change of temperature in the water, the results may be highly accurate.

507



Pycnometer

If the mineral forms a porous mass, it may be first reduced to powder, but it is to be noted that it has been shown by Rose that chemical precipitates have uniformly a higher density than belongs to the same substance in a less finely divided state. This increase of density also characterizes, though to a less extent, a mineral in a fine state of mechanical subdivision. It is explained by the condensation of the water on the surface of the powder.

**300. Use of Liquids of High Density.** — It is often found convenient both in the determination of the specific gravity and in the mechanical separation of fragments of different specific gravities (*e.g.*, to obtain pure material for analysis, or again in the study of rocks) to use a liquid of high density — that is, a so-called *heavy solution.* One of these is the solution of mercuric iodide in potassium iodide, called the Sonstadt or Thoulet solution. When made with care it has a maximum density of nearly 3·2, which by dilution may be lowered at will.

A second solution, often employed, is the *Klein solution,* the borotungstate of cadmium, having a maximum density of 3·6. This again may be lowered at will by dilution, observing certain necessary precautions. Still a third solution of much practical value is that proposed by Brauns, methylene iodide, which has a specific gravity of 3·324. A number of other solutions, more or less practical, have also been suggested.† When one of these liquids is to be used for the determination of the specific gravity of fragments of a certain mineral it must be diluted until the fragments just float and the specific gravity then obtained, most conveniently by the Westphal balance (Art. **301**).

When, on the other hand, the liquid is to be used for the separation of the fragments of two or more minerals mixed together, the material is first reduced to the proper degree of fineness, the dust and smallest fragments being sifted out, then it is introduced into the solution and this diluted until one constituent after another sinks and is removed. For the convenient application

* Care should be taken to prevent air-bubbles being included among the mineral particles. This may be accomplished by placing the bottle under an air-pump and exhausting the air or by suspending the bottle for a short time in a beaker filled with boiling water and then allowing it to cool again before weighing.

† Johannsen, Manual of Petrographic Methods, p. 519 *et seq.*, gives in detail an account of the various solutions, the methods of their preparation, etc.

of this method a suitable tube is called for and certain precautions must be observed; compare the papers noted in the literature (p. 200), especially one by Penfield.

**301. Westphal's Balance.** — The Westphal balance is conveniently used to determine the specific gravity of a liquid, and hence of a mineral when a heavy solution is employed (Art. **300**). It consists essentially of a graduated steelyard arm, upon which the weights, in the form of riders, are placed. These must be so adjusted that the sinker is freely suspended in the given liquid while the index at the end points to the zero of the scale and shows that the arm is horizontal (cf. Johannsen, p. 533). The graduation usually allows of the specific gravity being read off directly without calculation.

**302. Relation of Density to Hardness, Chemical Composition, etc.**— The density, or specific gravity, of a solid depends, first, upon the nature of the chemical substances which it contains, and, second, upon the state of molecular aggregation.

Thus, as an illustration of the first point, all lead compounds have a high density (G. = about 6), since lead is a heavy metal, or, chemically expressed, has a high atomic weight (206·4). Similarly, barium sulphate, barite, has a specific gravity of 4·5, while for calcium sulphate or anhydrite the value is only 2·95 (atomic weight for barium 137, for calcium about 40).

On the other hand, while aluminium is a metal of low density (G. = 2·5 and atomic weight = 27), its oxide, corundum, has a remarkably *high* density (G. = 4) and is also very hard (H. = 9). Again, carbon (atomic weight = 12) has a high density in the diamond (G. = 3·5) and low in graphite (G. = 2); also, the first is hard (H. = 10), the second soft (H. = 1·5). In these and similar cases the high density signifies great molecular aggregation, and hence it is natural that it should be accompanied by great hardness and resistance to the attack of acids.

As bearing upon this point, it is to be noted that the density of many substances is altered by fusion. Again, the same mineral in different states of molecular aggregation may differ (but only slightly) in density. Furthermore, minerals having the same chemical composition have sometimes different densities, corresponding to the different crystalline forms in which they appear. Thus in the case of calcium carbonate ($CaCO_3$), calcite has G. = 2·7, aragonite has G. = 2·9.

**303. Average Specific Gravities.** — It is to be noted that among minerals of NON-METALLIC LUSTER the *average* specific gravity ranges from 2·6 to 3. Here belong quartz (2·66), calcite (2·7), the feldspars (2·6–2·75), muscovite (2·8). A specific gravity of 2·5 or less is *low*, and is characteristic of soft minerals, and often those which are hydrous (*e.g.*, gypsum, G. = 2·3). The common species fluorite, tourmaline, apatite, vesuvianite, amphibole, pyroxene, and epidote lie just above the limit given, namely, 3·0 to 3·5. A specific gravity of 3·5 or above is relatively *high*, and belongs to hard minerals (as corundum, see Art. **302**), or to those containing a heavy metal, as compounds of strontium, barium, also iron, tungsten, copper, silver, lead, mercury, etc.

With minerals of METALLIC LUSTER, the average is about 5 (here belong pyrite, hematite, etc.), while if below 4 it is relatively low (graphite 2, stibnite 4·5); if 7 or above, relatively high (as galena, 7·5).

Tables of minerals arranged according to their specific gravity are given in Appendix B.

**304. Constancy of Specific Gravity.** — The specific gravity of a mineral species is a character of fundamental importance, and is highly constant for different specimens of the same species, if pure, free from cavities, solid inclusions, etc., and if essentially constant in composition. In the case of many species, however, a greater or less variation exists in the chemical composition, and this at once causes a variation in specific gravity. The different kinds of garnet illustrate this point; also the various minerals intermediate between the tantalate of iron (and manganese) and the niobate, varying from G. = 7·3 to G. = 5·3.

**305. Practical Suggestions.** — It should be noted that the determination of the specific gravity has little value unless the fragment taken is pure and is free from impurities, internal and external, and not porous. Care must be taken to exclude air-bubbles, and it will often be found well to moisten the surface of the specimen before inserting it in the water, and sometimes boiling (or the use of the air-pump) is necessary to free it from air. If it absorbs water this latter process must be allowed to go on till the substance is fully saturated. No *accurate* determinations can be made unless the changes of temperature are rigorously excluded and the actual temperature noted.

In a mechanical mixture of two constituents in known proportions, when the specific gravity of the whole and of one are known, that of the other can be readily obtained. This method is often important in the study of rocks.

It is to be noted that the hand may be soon trained to detect a difference of specific gravity, if like volumes are taken, even in a small fragment — thus the difference between calcite or albite and barite, even the difference between a small diamond and a quartz crystal, can be detected.

LITERATURE. — *Specific Gravity*

*General:*

**Beudant.** Pogg. Ann., **14,** 474, 1828.
**Jenzsch.** Pogg. Ann., **99,** 151, 1856.
**Jolly.** Ber. Ak. München, 1864, 162.
**Gadolin.** Pogg., **106,** 213, 1859.
**G. Rose.** Pogg. Ann., **73,** 1; **75,** 403, 1848.
**Scheerer.** Pogg. Ann., **67,** 120, 1846.
**Schröder.** Pogg. Ann., **106,** 226, 1859. Jb. Min., 561, 932, 1873; 399, 1874, etc.
**Tschermak.** Ber. Ak. Wien, **47** (1), 292, 1863.
**Websky.** Die Mineralien nach den für das specifische Gewicht derselben angenommenen und gefundenen Werthen. 170 pp. Breslau, 1868.

*Use of Heavy Solutions, etc.:*

**Sonstadt.** Chem. News, **29,** 127, 1874.
**Thoulet.** Bull. Soc. Min., **2,** 17, 189, 1879.
**Bréon.** Bull. Soc. Min., **3,** 46, 1880.
**Goldschmidt.** Jb. Min., Beil.-Bd., **1,** 179, 1881.
**D. Klein.** Bull. Soc. Min., **4,** 149, 1881.
**Rohrbach.** Jb. Min., **2,** 186, 1883.
**Gisevius.** Inaug. Diss., Bonn., 1883.
**Brauns.** Jb. Min., **2,** 72, 1886; **1,** 213, 1888.
**Retgers.** Jb. Min., **2,** 185, 1889.
**Salomon.** Jb. Min., **2,** 214, 1891.
**Penfield.** Am. J. Sc., **50,** 446, 1895.
**Merwin.** Am. J. Sc., **32,** 425, 1911.