CENCO Physics

Selective Experiments In Physics

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DENSITY OF LIQUIDS AND SOLIDS – PYCNOMETER METHOD

OBJECT: To determine the density of a liquid and of a solid, using the pycnometer method.

METHOD: The mass of an irregular solid is determined by weighing. When the solid is placed in a pycnometer (Fig. 1) filled with a liquid of known density, the volume of the liquid which will overflow is equal to the volume of the solid. The mass of the liquid which will overflow is determined as the difference between the sum of the mass of the pycnometer filled with liquid plus the mass of the solid and the mass of the pycnometer filled with liquid after the solid has been placed inside. The volume occupied by this mass is determined from the known density of the liquid. It is necessary that the solid be insoluble in the liquid used. The density of the solid is determined from these measurements of mass and volume.

THEORY: Density is defined as the ratio of the mass of a body to its volume. Its experimental determination requires the measurement of these two quantities for the selected piece of material. Let *M* represent the mass of the pycnometer empty, and *Mw* be the mass of the pycnometer filled with water at t˚C. Then *Mw - M* is the mass of water contained in the pycnometer at this temperature. Thus if *d* is the density of water at t˚C, the volume *V* of the pycnometer at this temperature is

$$V = (Mw - M)/d \qquad (1)$$

Let M_L be the mass of the pycnometer when filled with the liquid whose density is to be determined. The mass of this liquid is $M_L - M$. If this mass is determined at the temperature t˚C, the density d_L of the liquid is the ratio of this mass to its volume as given by Eq. (1). That is,

$$d_L = (M_L - M)/V = d(M_L - M)/(Mw - M) \qquad (2)$$

When the problem is the determination of the density of a granular solid or a solid in small particles, the volume of this material is determined from the mass of the liquid which it displaces when put in the pycnometer. Let M_L' equal the mass of the pycnometer filled with a liquid in which the solid is insoluble. Also, let Ms be the mass of the solid, and $M_{L's}$ be the mass of the pycnometer containing the granular solid and filled with the liquid. In this case, the mass of the liquid displaced is

$$M_{L'} + M_s - M_{L's} \qquad (3)$$

Since the volume of the solid is equal to the ratio of the mass of the liquid displaced to *d'*, the density of this liquid at t˚C, it is possible to express the volume of the solid at this temperature as

$$(M_{L'} + M_s - M_{L's})/d' \qquad (4)$$

Since both the mass of the solid and its volume are now known, it is possible to form the ratio for d_s, its density at t˚C. It is

$$d_s = M_s d'/(M_{L'} + M_s - M_{L's}) \qquad (5)$$

APPARATUS: The apparatus consists of a pycnometer, a triple beam centigram balance, a thermometer, and the liquid and solid objects of measurement. A filter pump, or compressed air, should be available for drying the pycnometer.

A pycnometer such as shown in Fig. 1 is a small flask with a glass stopper. A capillary opening which runs along the length of the stopper makes it possible to fill the pycnometer completely- that is, without leaving a bubble of air in the flask.

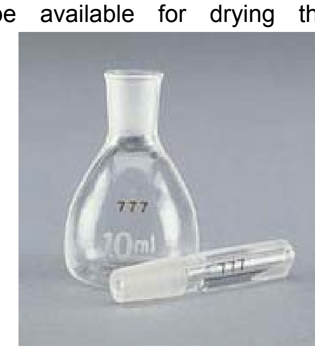

Fig. 1. The Pycnometer

The *triple beam centigram balance* is illustrated in Fig; 2. The front beam A is divided into one hundred divisions, each indicating one centigram. Readings, taken on this scale from the position of the rider H, range from zero to one hundred centigrams. The middle beam B is divided into ten divisions having a value of ten grams each. The rider on the scale B is designated by I; its position indicates mass values from zero to one hundred grams. The back beam C is also divided into ten divisions, each indicating one gram. Readings, taken from the position of rider J, range from zero to ten grams. The knurled head screw K operates an eccentric which lifts the knife edge from its agate bearing. This protects the knife edge and the bearing from damage while the balance is being moved about. After the balance has been placed on the table in the position where it is to be used, the riders should all be moved to their respective zero positions on the scale and the balance adjusted by means of the counterpoise M so that the indicator B is in the zero position of the scale.

PROCEDURE: Weigh the pycnometer when dry and empty. Fill it with distilled water and allow air bubbles to rise to the top before inserting the stopper. To avoid expansion of the

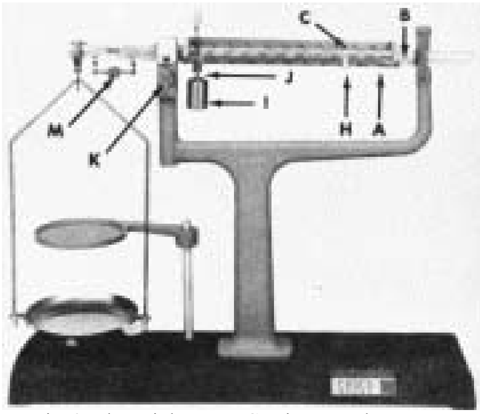

Fig. 2. The Triple Beam Centigram Balance

pycnometer due to the heat of the hand, pick it up by the neck with one or two layers of paper between the fingers and the bottle. Weigh it again when filled with water. Since this weighing is made for the purpose of determining the volume of the pycnometer at t˚C, the temperature of the distilled water should be carefully noted. The results of the experiment will have high precision only if the pycnometer is used at this temperature throughout the experiment. The proper value of the density of water to be used in determining the volume at this temperature may be found in Table I. pycnometers are sometimes adjusted by the manufacturer to contain a given volume within a small tolerance at a specified temperature. If the pycnometer used in performing the experiment has been adjusted in this way, its specification may be checked by this procedure.

Carefully weigh a portion of the granular solid. Pour about half of the water out of the pycnometer and carefully put in it the granular solid. Then fill it up with water and weigh it again.

Next empty the bottle of both solid and liquid, and dry it with the aid of the filter pump. Fill carefully with the liquid furnished and again determine its weight.

In case the solid is a fine powder, like chalk dust, it will be difficult to expel the air completely or to remove the fine bubbles which cling to the particles of the material. This can be done most conveniently by placing the pycnometer under a bell jar on the plate of an air pump and exhausting the air. Two stages in the removal of the air will be noted. First, the air dissolved in the water will come out and then at a lower pressure the air in the powder will be released.

Calculate the density of the liquid and that of the granular solid from the observations made.


Fig. 3. Filter Pump

QUESTIONS: 1. If, in the experiment, twice the mass of the granular solid employed had been used, how much would this have increased the precision of the density determination, assuming that all weighings were made with an accuracy of 0.01gm?

2. A piece of copper whose density is 8.93gm/cm^3 weighs 180gm in air and 162gm when submerged in a certain liquid. What is the density of the liquid?

3. A piece of glass of unknown density loses 43.71gm when weighed in water and 80.36gm when weighed in concentrated sulfuric acid. What is the specific gravity of the acid?

4. If in the determination of the density of a granular solid, half a cubic centimeter of air is left in the pycnometer when weighed with the solid, will the resulting value of the density be too large or too small? Explain.

5. When placed in a pycnometer, 20gm of salt displaces 7.6gm of coal oil. If density of coal oil is 0.83gm/cm^3, find the volume and density of the salt.

TABLE I

Density of pure water

10ºC	0.99973 gm per cm^3	18ºC	0.99862 gm per cm^3
12ºC	0.99953	20ºC	0.99823
14ºC	0.99927	22ºC	0.99780
16ºC	0.99897	24ºC	0.99732