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DENSITIES OF LIQUIDS AND GASES

OBJECT: To determine the densities of a liquid and a gas by using a balance.

METHOD: Suitable closed vessels of known volume are weighed empty. Each is then filled with either a liquid or a gas and again weighed. By knowing the mass of the liquid or gas, its density is readily calculated.

THEORY: The density of a substance is defined as its mass per unit volume and in the metric system is measured in grams per cubic centimeter. The specific gravity of a substance is defined as the ratio of the mass or weight of a given volume of the substance to the mass or weight of an equal volume of a standard substance. Although water is the standard substance in terms of which specific gravity is expressed for solids and liquids, hydrogen is frequently taken as the base of reference for gases. In any case, specific gravity is a dimensionless quantity; but density must be expressed in terms of suitably chosen units of mass and volume. It is apparent that density and specific gravity become numerically equal when water is taken as the standard of reference for specific gravity and density is expressed in grams per cubic centimeter.

Fig. 1. Specific Gravity Bottle for determining densities of liquids.

Let M be the mass of an empty specific gravity bottle of the type shown in Fig. 1, and let M_1 be the mass of the same bottle filled with pure water at a temperature t˚C. Then if d is the density of water at t˚C, the volume of the vessel at this temperature is

$$V = (M_1 - M)/d \qquad (1)$$

If M_2 is the total mass of the bottle when filled with a liquid of density p at the lame temperature t˚C, then

$$p = \frac{M_2 - M}{M_1 - M} \cdot d \qquad (2)$$

For accurate work the temperature of the bottle and liquid should be the same throughout the experiment, as not only does the density of the liquid change with temperature, but also the volume of the vessel.

The density of a gas is determined by a method similar to that used for a liquid. However, in this case the temperature and pressure of the gas must be known. Suppose M is the mass of a closed vessel when dry and evacuated, while M_l is its mass when filled with dry air at a temperature of t˚C and a pressure of p cm of mercury. If V is the volume of the vessel at t˚C, the density D of the gas at a temperature of t˚C and a pressure p is

Fig. 2. Balance for determining masses of specific gravity bottles.

$$D = (M_1 - M)/V \qquad (3)$$

To determine the density D_o of the air at 0°C and 76cm of mercury (normal temperature and pressure), it is necessary to make use of the perfect gas law which states that pV/T = a constant. From this it follows that

Fig. 3. Box of weights to be used with balance.

$$D_0 = D \times \frac{76}{p} \times \frac{273 + t}{273} \qquad (4)$$

where (273 +) is the absolute temperature corresponding to t°C and 273 the absolute temperature corresponding to 0°C.

APPARATUS: For determining the density of a liquid a specific gravity bottle of the type shown in Fig. 1 is needed, together with a cloth or paper towel to remove any excess liquid which overflows when the stopper is put in place. A good balance such as that shown in Fig. 2, a suitable set of weights (Fig. 3), a thermometer, a barometer; and bottles of distilled water and of other liquids whose densities are to be measured are necessary.

Fig. 4. Flask for determining the densities of gases.

A flask of the type shown in Fig. 4 is used for determining the density of air or of any other gas. To evacuate this flask a vacuum pump such as that shown in Fig. 5 is needed. It is recommended that when weighing the flask with a balance (Fig. 2), a similar closed flask be hung from the other arm to act as a counterpoise. In this way any change in the density of the air in the room and consequent change in the buoyant the flask which may occur during the experiment will be approximately balanced by a similar effect on the flask acting as a counterpoise.

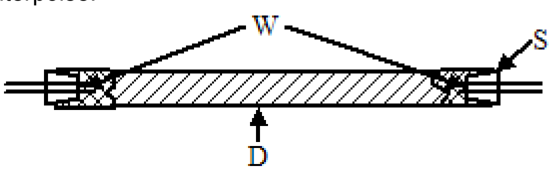

Fig. 6. Tube containing Dessigel S for drying gases.

Acetone of USP grade, or alcohol and ether, and a drying tube (Fig. 6) containing Dessigel S* are needed for drying purposes. The drying tube is made from glass tubing about an inch in diameter and afoot in length and has a stopper S carrying a glass tube inserted in each end. Dessigel S (D) is prepared in small granules. They should be loosely packed in the tube. Glass wool W at each end prevents loose particles from escaping through the glass tubes when air is being drawn through.

*This is one of the more powerful and convenient drying agents.

PROCEDURE:

Experimental: **Part I. Density of a Liquid**: Carefully clean and dry the specific gravity bottle. This may necessitate rinsing with water and then with USP grade acetone or with alcohol and ether. In the latter case, use only a small amount of ether and keep the flask away from any open flame. When the fluids have evaporated, weigh the bottle and stopper. Fill it with distilled water and replace the stopper, removing with a cloth or paper towel any excess water which runs out. Weigh the bottle and water. Empty and dry the bottle, and fill it with the liquid whose density is to be found. Weigh the bottle and liquid.

Part II. Density of Air: The flask should be thoroughly cleaned. Its volume may be given by the instructor; if not, fill the flask with water at a known temperature and determine its weight. This necessitates the use of a special balance capable of weighing a large mass.

After rinsing the flask with drying with drying fluid, shake it to remove as much of the fluid as possible. With rubber hose, connect one stem of the flask to the vacuum pump and the other to the drying tube. In this way dry air is drawn through the flask and vapors are quickly carried away. After a few minutes pumping, close the stopcock to the drying tube and the flask and vapors are quickly carried away. After a few minutes pumping, close the stopcock to the drying tube and evacuate the vessel. Now close the stopcock to the vacuum pump, and open the stopcock to the drying tube. Allow dry air to fill the flask. If the stopcock is not closed too quickly, the temperature and pressure of the air in the flask will be the same as that of the air in the room. Note this temperature and pressure, and weigh the flask containing the dry air. Afterwards, the flask should be again attached to the pump, again evacuated, and the weight of the empty vessel determined.

If the density of another gas is required, proceed in the same manner, but allow dry gas at a known temperature and pressure to enter.

Calculations: From Eq. (1) and the table of density of water, calculate the volume of the specific gravity bottle. Using Eq. (2), calculate the density of the liquid.

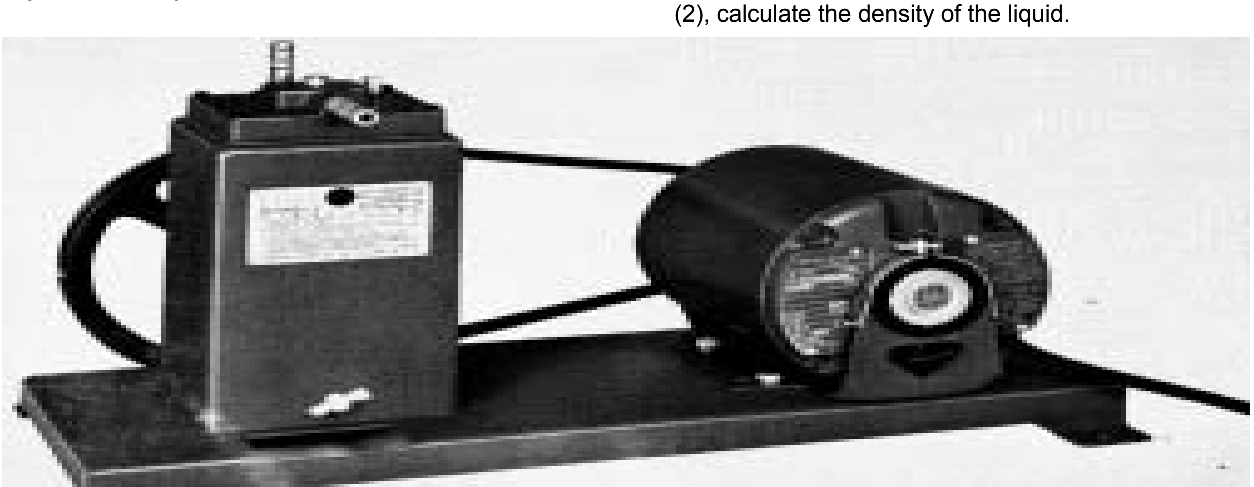

Fig. 5. Pump for evacuating the glass flasks.

Calculate from Eq. (3) the density of air for the temperature and pressure used in the experiment. From Eq. (4) find its density at normal temperature and pressure.

QUESTIONS: 1. If the smallest change in weight which the balance will detect is ten milligrams, what percentage error does this introduce in the determination of (a) the density of the liquid, (b) the density of the air?

2. If, in determining the density of air, the air were not dry, but contained some water vapor, would this make the density of air as determined by this experiment greater or less than the true value?

3. If no vacuum pump were available, state how the density of air might still be obtained with this flask and a tank of compressed air.

4. Using the perfect gas law, pV/T = constant, derive Eq. (4) of the text.

5. Why is it necessary that the flask, used as a counterpoise in the density of air experiment, be closed? Would it affect the results of the experiment if the flask were evacuated?

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