What does a pycnometer do?

Science, Physics

Density determination by pycnometer is a very precise method. It uses a working liquid with well-known density, such as water. For the purpose of this experiment, distilled water was used. The pycnometer is a glass flask with a close-fitting ground glass stopper with a capillary hole through it. This fine hole releases a spare liquid after closing a top-filled pycnometer and allows for obtaining a given volume of measured and/or working liquid with a high accuracy.

The mass density or density of a material is defined as its mass per unit volume. The symbol most often used for density is ρ (the lower case Greek letter rho). In some cases (for instance, in the United States oil and gas industry), density is also defined as its weight per unit volume;[1] although, this quantity is more properly called specific weight. Different materials usually have different densities, so density is an important concept regarding buoyancy, purity and packaging. Osmium and iridium are the densest known metal elements at standard conditions for temperature and pressure but not the densest materials.

Less dense fluids float on more dense fluids if they do not mix. This concept can be extended, with some care, to less dense solids floating on more dense fluids. If the average density (including any air below the waterline) of an object is less than water (1000 kg/m3) it will float in water and if it is more than water's it will sink in water.

In some cases density is expressed as the dimensionless quantities specific gravity (SG) or relative density (RD), in which case it is expressed in multiples of the density of some other standard material, usually water or air/gas. (For example, a specific gravity less than one means that the substance floats in water.)

The mass density of a material varies with temperature and pressure. (The variance is typically small for solids and liquids and much greater for gasses.) Increasing the pressure on an object decreases the volume of the object and therefore increase its density. Increasing the temperature of a substance (with some exceptions) decreases its density by increasing the volume of that substance. In most materials, heating the bottom of a fluid results in convection of the heat from bottom to top of the fluid due to the decrease of the density of the heated fluid. This causes it to rise relative to more dense unheated material.

The reciprocal of the density of a substance is called its specific volume, a representation commonly used in thermodynamics. Density is an intensive property in that increasing the amount of a substance does not increase its density; rather it increases its mass.

Changes of density

In general, density can be changed by changing either the pressure or the temperature. Increasing the pressure always increases the density of a material. Increasing the temperature generally decreases the density, but there are notable exceptions to this generalization. For example, the density of water increases between its melting point at 0 °C and 4 °C; similar behavior is observed in silicon at low temperatures.

The effect of pressure and temperature on the densities of liquids and solids is small. The compressibility for a typical liquid or solid is 10^{-6} bar^{-1} (1 bar= 0. 1 MPa) and a typical thermal expansivity is 10^{-5} K^{-1}. This roughly translates into needing around ten thousand times atmospheric pressure to reduce the volume of a substance by one percent. (Although the pressures needed may be around a thousand times smaller for sandy soil and some clays.) A one percent expansion of volume typically requires a temperature increase on the order of thousands of degrees Celsius.

CHAPTER TWO

Theory:

Archimedes' Principle states that any object completely or partially submerged in a fluid is

buoyed up by a force with magnitude equal to the weight of the weight of the fluid displaced by the

object:

$B = \rho_{fluid} V_{fluid} g$,

where ρ_{fluid} is the density of the fluid and V_{fluid} is the volume of the displaced fluid. In this lab, all the forces and weights are measured in the unit of grams using the triple beam balance, then the above equation becomes:

$B = \rho_{fluid} V_{fluid}$.

When measuring the weight of an object completely submerged in a fluid, the volume of the displaced fluid is equal to the volume of the object, and the reading on the balance ($W_{in\text{-}fluid}$), the buoyant force, and its weight in air ($W_{in\text{-}air}$) should satisfy the following equation:

$B = W_{in\text{-}air} - W_{in\text{-}fluid} = \rho_{fluid} V_{object}$.

Thus, the volume of the object can be determined as:

$V_{object} = (W_{in\text{-}air} - W_{in\text{-}fluid})/ \rho_{fluid}$,

and the density and the specific gravity of the object are, respectively:

$\rho_{object} = W_{in\text{-}air} / V_{object} = \rho_{fluid} W_{in\text{-}air} / (W_{in\text{-}air} - W_{in\text{-}fluid})$,

$s.\ g. = \rho_{object} / \rho_{water}$.

Mathematically, density is defined as mass divided by volume:

where ρ is the density, m is the mass, and V is the volume. From this equation, mass density must have units of a unit of mass per unit of volume. As there are many units of mass and volume covering many different magnitudes there are a large number of units for mass density in use.

The SI unit of kilogram per cubic metre (kg/m^3) and the cgs unit of gram per cubic centimetre (g/cm^3) are probably the most common used units for density. (The cubic centimeter can be alternately called a millilitre or a cc.) 1000kg/m^3 equals one g/cm^3. In industry, other larger or smaller units of mass and or volume are often more practical and US customary units may be used. See below for a list of some of the most common units of density.

Further, density may be expressed in terms of weight density (the weight of the material per unit volume) or as a ratio of the density with the density of a common material such as air or water.

Measurement of density

The density at any point of a homogeneous object equals its total mass divided by its total volume. The mass is normally measured with an appropriate scale or balance; the volume may be measured directly (from the geometry of the object) or by the displacement of a fluid. For determining the density of a liquid or a gas, a hydrometer or dasymeter may be used, respectively. Similarly, hydrostatic weighing uses the displacement of water due to a submerged object to determine the density of the object.

If the body is not homogeneous, then the density is a function of the position. In that case the density around any given location is determined by calculating the density of a small volume around that location. In the limit of an infinitesimal volume the density of an inhomogeneous object at a point becomes: $\rho(r) = dm/dV$, where dV is an elementary volume at position r. The mass of the body then can be expressed as

Density of solutions

The density of a solution is the sum of mass (massic) concentrations of the components of that solution.

Mass (massic) concentration of a given component ρ_i in a solution can be called partial density of that component.

Expressed as a function of the densities of pure components of the mixture and their volume participation, it reads:

Density of composite material

In the United States, ASTM specification D792-00[11] describes the steps to calculate the density of a composite material.

where:

ρ is the density of the composite material, in g/cm3

and

Wa is the weight of the specimen when hung in the air

Ww is the weight of the partly immersed wire holding the specimen

Wbρ is the weight of the specimen when immersed fully in distilled water, along with the partly immersed wire holding the specimen

is the density in g/cm3 of the distilled water at testing temperature (for example 0. 9975 g/cm3 at 23 °C)

common units

The SI unit for density is:

kilograms per cubic metre (kg/m^3)

Litres and metric tons are not part of the SI, but are acceptable for use with it, leading to the following units:

kilograms per litre (kg/L)

grams per millilitre (g/mL)

metric tons per cubic metre (t/m^3)

Densities using the following metric units all have exactly the same numerical value, one thousandth of the value in (kg/m^3). Liquid water has a density of about 1 kg/dm^3, making any of these SI units numerically convenient to use as most solids and liquids have densities between 0. 1 and 20 kg/dm^3.

kilograms per cubic decimetre (kg/dm^3)

grams per cubic centimetre (g/cc, gm/cc or g/cm^3)

megagrams per cubic metre (Mg/m^3)

Specific gravity is the ratio of the density (mass of a unit volume) of a substance to the density (mass of the same unit volume) of a reference substance. Apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance. The reference substance is nearly always water for liquids or air for gases. Temperature and pressure must be specified for both the sample and the reference. Pressure is nearly always 1 atm equal to 101. 325 kPa. Temperatures for both sample and reference vary from industry to industry. In British brewing practice the specific gravity as specified above is multiplied by 1000.[1] Specific gravity is commonly used in industry as a simple means of obtaining information about the concentration of solutions of various materials such as brines, hydrocarbons, sugar solutions (syrups, juices, honeys, brewers wort, must etc.) and acids.

Specific gravity, as it is the ratio of densities, is a dimensionless quantity. Specific gravity varies with temperature; reference and sample must be compared at the same temperature, or corrected to a standard reference temperature. Substances with a specific gravity of 1 are neutrally buoyant in water, those with SG greater than one are denser than water, and so (ignoring surface tension effects) will sink in it, and those with an SG of less than one are less dense than water, and so will float. In scientific work the relationship of mass to volume is usually expressed directly in terms of the density (mass per unit volume) of the substance under study. It is in industry where specific gravity finds wide application, often for historical reasons.

True specific gravity, can be expressed mathematically as:

where is the density of the sample and is the density of water.

The apparent specific gravity is simply the ratio of the weights of equal volumes of sample and water in air:

where represents the weight of sample and the weight of water, both measured in air.

It can be shown that true specific gravity can be computed from different properties:

where is the local acceleration due to gravity, is the volume of the sample and of water (the same for both), is the density of the sample, is the density of water and represents a weight obtained in vacuum.

API Gravity

1. API gravity represents a dimensionless property similar to specific gravity. The measure itself derives from specific gravity (see Reference 3): API = (141. 5 / SG) - 131. 5. Note that because specific gravity appears in the denominator of the equation, API gravity and specific gravity exhibit an inverse relationship: A liquid with high specific gravity will exhibit low API gravity and vice-versa

CHAPTER THREE

EXPERIMENTATION

The experiment carried under room temperature at 34oC, was aimed at determining the density/specific gravity of five varying samples (PMS, DPK, Crude Oil, PKO, and Soap Solution) using two different measuring apparatus; a weighing balance and a measuring cylinder applying the Archimedes principle of floatation to obtain values in ml and then subsequently in grams.

PROCEDURE

1. The weights (sliders) on the beam of the weighing balance apparatus was set to zero before measurements. A dry empty pycometer was then placed on the scale pan to obtain its weight for which results were recorded after careful observations of the beam’s calibrations in grams.

2. The weight was determined by locking three different sets of weights (sliders) on their respective number-calibrations (in grams), for which the beam was balanced. The values which these weights rested on at beam-balance were then added up to give the mass of the empty pycometer.

3. The weights on the beam were set back to zero and the pycometer lifted off the pan to restart the process but this time to measure the mass of the pycometer filled with a sample; DPK in this case.

4. 50 milliliters of DPK was measured with a cylinder and poured into the pycometer, then corked with a small glass-like capillary tube. A small volume of the liquid sample (DPK), which was spilled as a result of the pressure from corking the pycometer, was noted as negligible. The DPK-filled pycometer; a combined weight of both the pycometer and the DPK fluid, was then placed on the pan scale for the second time to acquire readings in grams.

5. The same method for measurement, as explained in the earlier paragraphs, was used to accurately determine the mass of the DPK-filled pycometer and then subsequently recorded.

The above elaborated procedures for the determination of were further carried out for three more samples; PMS, Crude Oil, and PKO to determine their masses. First, the masses of the empty pycometers were measured, followed by the combined masses of the pycometers and samples and then subsequently, the individual masses of the fluid samples were calculated.

In the supplementary method involving the application of the Archimedes principle of floatation –

1. The measuring cylinder was filled with water and the initial volume was observed and recorded. A piece of string was then tied around a dry empty pycometer and attached to the retort stand so that it dropped directly into the measuring cylinder enough to submerge itself in the containing water so that the volume increased. The new volume of water was then noted and recorded in milliliters. The difference between the initial volumes of the water before the introduction of the empty pycometer and after the submergence of the pycometer was also calculated and recorded in grams as the mass of the empty pycometer.