Lecture Three

Density

Density is mass per unit volume of a substance. *(g/cc).*

$\text{Density} = \frac{\text{mass}}{\text{volume}}$ Thus, if 10 mL of olive oil weighs 9.1 g, its density is:

$$Desity = \frac{9.1(g)}{10(mL)} = 0.91 \text{ grams per milliliter}$$

Specific Gravity

Specific gravity (sp gr) is a ratio, expressed decimally, of the weight of a substance to the weight of an equal volume of a substance chosen as a standard (Water for liquids and solids; while hydrogen for gases).

$$\text{Specific gravity} = \frac{\text{Weight of substance}}{\text{Weight of equal volume of water}}$$

Thus, if 10 mL of olive oil weighs 9.1 g, and 10 mL of water, under similar conditions, weighs 10 g, the specific gravity of the oil is:

$$\text{Specific gravity} = \frac{9.1(\text{g})}{10(\text{g})} = 0.91$$

- *Substances that have a specific gravity less than 1 are lighter than water.*
- *Substances that have a specific gravity greater than 1 are heavier than water.*

In the *United States Pharmacopeia,* the standard temperature for specific gravities is 25°C, except for that of alcohol, which is 15.56°C by government regulation.

Density Versus Specific Gravity

The density has various units of measure, while specific gravity has no dimension and is therefore a constant value for each substance (when measured under controlled conditions). Thus, whereas the density of water may be variously expressed as 1 g/mL, *1000 g/L*, or 62.5 lb/cu ft, the specific gravity of water is always 1.

TABLE 5.1 SOME REPRESENTATIVE SPECIFIC GRAVITIES AT 25°C

AGENT	SP GR
Ether (at 20°C)	0.71
Isopropyl alcohol	0.78
Acetone	0.79
Alcohol	0.81
Liquid petrolatum	0.87
Peppermint oil	0.90
Olive oil	0.91
Peanut oil	0.92
Cod liver oil	0.92
Castor oil	0.96
Water	**1.00**
Propylene glycol	1.03
Clove oil	1.04
Liquefied phenol	1.07
Polysorbate 80	1.08
Polyethylene glycol 400	1.13
Glycerin	1.25
Syrup	1.31
Hydrochloric acid	1.37
Nitric acid	1.42
Chloroform	1.47
Nitroglycerin	1.59
Phosphoric acid	1.70
Mercury	13.6

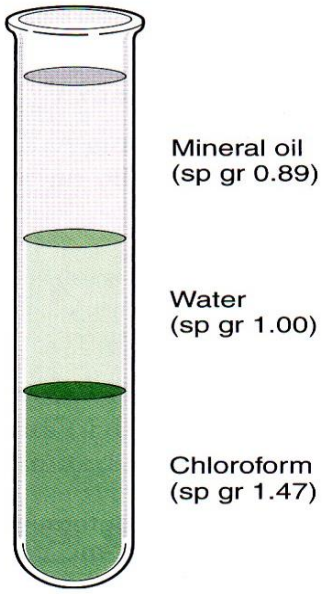

Figure 1

Table 5.1 presents some representative specific gravities. Figure 1 depicts the layering of immiscible liquids due to their relative weights.

Calculating the Specific Gravity of Liquids Known Weight and Volume

Calculating the specific gravity of a liquid when its weight and volume are known involves the use of the equation:

Examples: page 69

If 54.96 mL of an oil weighs 52.78 g, what is the specific gravity of the oil?
54.96 mL of water weighs 54.96 g

$$\text{Specific gravity of oil} = \frac{\text{Weight of substance}}{\text{Weight of equal volum of water}} = \frac{52.78\,(\text{g})}{54.96\,(\text{g})} = 0.9603, \textit{answer}.$$

Pycnometer or Specific Gravity Bottle

A pycnometer is a special glass bottle used to determine specific gravity (Fig. 2). Pycnometers are generally available for laboratory use in volumes ranging from 1 mL to 50 mL. Pycnometers have fitted glass stoppers with a capillary opening to allow trapped air and excess fluid to escape.

In using a pycnometer, it is first weighed empty and then weighed again when filled to capacity with water. The weight of the water is calculated by difference. Since 1 g of water equals 1 mL, the exact volume of the pycnometer becomes known. Then, when any other liquid subsequently is placed in the pycnometer, it is of equal volume to the water, and its specific gravity may be determined.

Fig. 2
Pycnometer

Example:
A 50 mL pycnometer is found to weigh 120 g when empty, 171 g when filled with water, and 160 g when filled with an unknown liquid. Calculate the specific gravity of the unknown liquid.

Weight of water: 171 g - 120 g = 51 g
Weight of unknown liquid: 160 g - 120 g = 40 g

$$\text{Specific gravity of unknown liquid} = \frac{\text{Weight of substance (unknown liquid)}}{\text{Weight of equal volum of water}} = \frac{40\,(\text{g})}{51\,(\text{g})} = 0.78$$

Displacement or Plummet Method

Calculating the specific gravity of a liquid determined by the displacement or plummet method is based on *Archimedes' principle,* which states that a body immersed in a liquid displaces an amount of the liquid equal to its own volume and suffers an apparent loss in weight equal to the weight of the displaced liquid. Thus, we can weigh a plummet when suspended in water and when suspended in a liquid the specific gravity of which we want to determine; and by subtracting these weights from the weight of the plummet in air, we get the *weights of equal volumes of the liquids* needed in our calculation.

Example:

A glass plummet weighs 12.64 g in air, 8.57 g when immersed in water, and 9.12 g when immersed in an oil. Calculate the specific gravity of the oil.

12.64 g — 9.12 g = 3.52 g of displaced oil
12.64 g — 8.57 g = 4.07 g of displaced water

$$\text{Specific gravity of oil} = \frac{3.52\,(\text{g})}{4.07\,(\text{g})} = 0.865$$

Use of Specific Gravity in Calculations of Weight and Volume

The specific gravity is a *factor* that expresses how much heavier or lighter a substance is than water, the standard with a specific gravity of 1.

For example, a liquid with a specific gravity of 1.25 is 1.25 times as heavy as water, and a liquid with a specific gravity of 0.85 is 0.85 times as heavy as water.

Thus, if we had 50 mL of a liquid with a specific gravity of 1.2, it would weigh 1.2 times as much as an equivalent volume of water. An equivalent volume of water, 50 mL, would weigh 50 g, and therefore the liquid would weigh 1.2 times that, or 60 g.

Calculating Weight, Knowing the Volume and Specific Gravity

Based on the explanation in the previous paragraphs, we can derive the following equation:

☒ Grams = Milliliters X Specific gravity

Although it is both obvious and true that one cannot multiply milliliters by specific gravity and have a product *in grams, the equation "works" because the volume of the liquid in question is assumed to be the same volume as water for which milliliters equal grams. So, in essence, the true equation would be:*

Grams (other liquid) = Grams (of equal volume of water) X Specific gravity (other liquid) *Examples:*

What is the weight, in grams, of 3620 mL of alcohol with a specific gravity of 0.820?

3620 mL of water weigh 3620 g

3620 g X 0.820 = 2968 g, *answer.*

What is the weight, in grams, of 2 fl. oz. of a liquid having a specific gravity of 1.118?

In this type of problem, it is best to convert the given volume to its metric equivalent first and then solve the problem in the metric system.

2 X 29.57 mL = 59.14 mL

59.14 mL of water weigh 59.14 g

59.14 g X 1.118 = 66.12 g, *answer.*

Calculating Volume, Knowing the Weight and Specific Gravity

By rearranging the previous equation, we can calculate the volume of a liquid using the equation:

Milliliters = Grams / Specific gravity

Examples: page 72.

Special Considerations of Specific Gravity

Pharmaceutical Applications

Specific gravity is used to

1- Convert the weight of an ingredient or preparation to volume or vice versa.
2- Calculate the equivalent strength of a preparation on the basis of either weight or volume.
3- Preparation of total parenteral nutrition (TPN) admixtures.

Clinical Application

Specific gravity is an important factor in urinalysis. In normal adults, the specific gravity of urine is usually within the range of 1.010 and 1.025 with a normal fluid intake (this range may vary with the reference source).

✓ A higher-than-normal specific gravity indicates that the urine is concentrated. This may be due to:

1- The presence of excess waste products or electrolytes in the urine.
2- The presence of glucose (glucosuria) or protein (proteinuria).
3- Excessive water loss, decreased fluid intake, or other factors.

✓ A low specific gravity indicates that the urine is dilute, which may be a result of

1- Diabetes insipidus.
2- Renal disease (by virtue of the kidney's reduced ability to concentrate urine).
3- Increased fluid intake, intravenous hydration, or other factors.

Calculating Specific Volume

Specific *volume*, in pharmaceutical practice, is a ratio, *expressed decimally*, of the volume of a substance to the volume of an equal weight of another substance taken as a standard, both having the same temperature. Water is the standard. Whereas specific gravity is a comparison of weights of equal volumes, specific volume is a comparison of volumes of equal weights. Because of this relationship, specific gravity and specific volume are *reciprocals;* that is, if they are multiplied together, the product is 1.

Specific volume tells us how much greater (or smaller) in volume a mass is than the same weight of water. It may be calculated by dividing the volume of a given mass by the volume of an equal weight of water.

Thus, if 25 g of glycerin measures 20 mL and 25 g of water measures 25 mL under the same conditions, the specific volume of the glycerin is:

$$\frac{\text{Volume of 25 g of glycerin}}{\text{Volume of 25 g of water}} = \frac{20(mL)}{25(mL)} = 0.8$$

Calculating the specific volume of a liquid, given the volume of a specified weight, involves the following type of calculation.

Example:

Calculate the specific volume of a syrup, 91 mL of which weighs 107.16 g.

107.16 g of water measures 107.16 mL

Specific volume of syrup =91mL / 107.16 mL= 0.849, *answer.*

Because specific gravity and specific volume are reciprocals, a substance that is heavier than water will have a higher specific gravity and a lower specific volume, whereas a substance that is lighter than water will have a lower specific gravity and a higher specific volume. It follows, therefore, that we may determine the specific volume of a substance by dividing 1 by its specific gravity, and we may determine the specific gravity of a substance by dividing 1 by its specific volume.

Examples:

What is the specific volume of phosphoric acid having a specific gravity of 1.71 ?

1/ 1.71 = 0.585, answer

If a liquid has a specific volume of 1.396,what is its specific gravity?
1 / 1.396 = 0.716