LECTURE 6:
Density, Specific Gravity, and Specific Volume

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Objectives

- Define density, specific gravity, and specific volume
- Determine each through appropriate calculations
- Calculate specific gravity from data derived from the use of a pycnometer.
- Apply specific gravity correctly in converting weight to volume and volume to weight

Density (d)

- Density (d): is weight (mass) per unit volume of a substance (W/V).
- Unite: it has units of grams per cubic centimeter (g/cc) or g/ml.
- Density = $\frac{\text{mass}}{\text{volume}}$
  - Example: Calculate the density of sulfuric acid if 10 mL of sulfuric acid weighs 18 g.
    - Density = $\frac{\text{mass}}{\text{volume}} = \frac{18\ \text{g}}{10\ \text{ml}} = 1.8\ \text{g/ml}$
- Because the gram is defined as the mass of 1 cc of water at 4 °C, → the density of water is 1 g/cc. therefore it is expressed as 1 g/ml

Specific Gravity (sp. gr)

- Specific Gravity: is a ratio expressed decimally نسبة معبر عنها بشكل عشري, of the weight of a substance to the weight of an equal volume of a substance chosen as a standard.

→ both substances at the same T or the T of each being definitely known

- Water is the standard for the sp. gr of liquids and solids
- Hydrogen is the standard for gases.
- Specific gravity $= \frac{\text{weight of substance}}{\text{weight of equal volume of water}}$

– Example: What is the specific gravity of sulfuric acid if 10 mL of sulfuric acid weighs 18 g and 10 mL of water under similar conditions weighs 10 g?

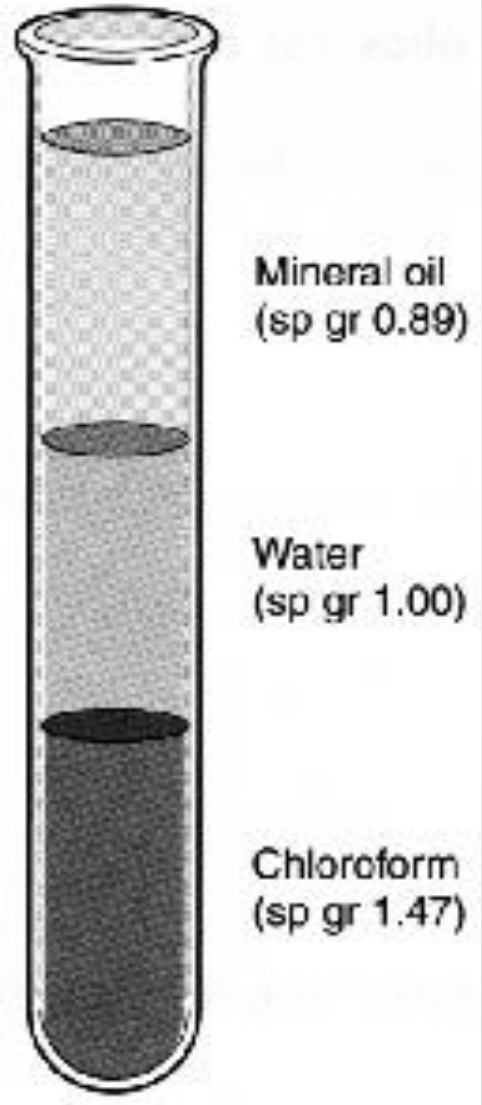
$$\text{Specific gravity} = \frac{18\ (g)}{10\ (g)} = 1.8$$

❑ Why is specific gravity important?

- Substances that have sp. gr <1 are lighter than water.
- Substances with sp. gr >1 are heavier than water.

Specific Gravity (sp. gr)

- This is a figure depicting the layering of immiscible liquids in a test tube, with mineral oil being lighter than water and chloroform being heavier.
- When temperatures change, substances expand or contract at various rates, therefore accurate work must account for differences in specific gravity.
- The standard temperature for specific gravities in the US Pharmacopeia is 25°C, except for alcohol, which is 15.56°C under government regulation.



Density Versus Specific Gravity

- Density
  - The density of a substance is a concrete محدد number (e.g. 1.8 g/mL)
  - varies with the units of measure used
  - e.g.: The density of water may be variously expressed as 1 g/mL, 1000 g/L, or 62½ lb/cu ft,
- Specific gravity a ratio between like quantities,
  - is an abstract number (1.8).
  - Sp.gr has no units (or dimension) and is therefore a constant value for each substance (when measured under controlled conditions).
  - the specific gravity of water is always 1.

Specific Gravity (sp. gr)

Calculating the Specific Gravity of Liquids

Known Weight and Volume.

- The specific gravity of a liquid can be calculated when its weight and volume are known using the following equation:

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

- if a pint نصف لتر of a certain liquid weighs 601 g, what is the specific gravity of the liquid?
  - 1 pint = 16 fl. oz.
  - 16 fl. oz. of water weigh 473 g
  - Specific gravity of liquid = $\frac{601}{473}$ =1.27

Pycnometer or Specific Gravity Bottle

- ***Pycnometers***

- are a special glass bottle used to determine specific gravity
- are generally available for laboratory use in volumes ranging from 1 mL to 50 mL.
- It have fitted glass stoppers with a capillary opening to allow trapped air and excess fluid to escape.
- Some pycnometers have thermometers affixed, because temperature is a factor in specific gravity determinations.

Pycnometer or Specific Gravity Bottle

- ***Pycnometers***

- Determine weight of pycnometer→ A
- Determine weight of pycnometer + water. → B
- Weight of water = (weight of pycnometer + water) – weight of pycnometer. (B-A)
- Determine weight of pycnometer + liquid → C
- Weight of liquid = (weight of pycnometer + liquid) – weight of pycnometer. (C-A)
- Liquid has equal volume with water!!!

Pycnometer or Specific Gravity Bottle

- 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 sp. gr of the unknown liquid.

Answer

- Weight of water = 171g – 120 g = 51 g
- Weight of liquid = 160 g – 120 g = 40 g
- Sp gr = $\frac{\text{weight of L}\textit{iquid 40}\,(\text{g})}{\text{weight of equal volume of water 51 (g)}}$ = (g)= 0.78

- Example: A specific gravity bottle weighs 23.66 g. When filled with water, it weighs 72.95 g; when filled with another liquid, it weighs 73.56 g. What is the specific gravity of the liquid?

answer

- 73.56 g - 23.66 g = 49.90 g of liquid
- 72.95 g - 23.66 g = 49.29 g of water
- Specific gravity of liquid = $\frac{49.\ 90\ (\text{g})}{49.29\ (\text{g})}$ = 1.012.

Displacement or Plummet Method.

Displacement or Plummet Method.

- This 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.
- We can weigh a plummet when suspended in water and when suspended in a liquid the specific gravity of which is to be determined,
  - weight of displaced water = Weight of plummet (in air – in water).
  - weight of displaced liquid = Weight of plummet (in air - in liquid).
- sp. gr. of oil = $\frac{\text{wt of displaced oil}}{\text{wt of displaced water}}$

Displacement or Plummet Method.

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.***

answer

- Weight of plummet (in air – in oil) = l12.64 g - 9.12 g = 3.52 g → of displaced oil
- Weight of plummet (in air - in water) = l12.64 g - 8.57 g = 4.07 g → of displaced water
- Specific gravity of oil = $\frac{3.52\ \text{g}}{4.07\ \text{g}} = 0.865,.$

Calculating the Specific Gravity of Solids

Solids Heavier Than and Insoluble in Water.

- simply divide the weight of the solid in air by the weight of water that it displaces when immersed in it.
- The weight of water displaced (apparent loss of weight in water) is equal to the weight of an equal volume of water.

❑ Example: A piece of glass weighs 38.525 g in air and 23.525 g when immersed in water. What is its specific gravity?

answer

- 38.525 g - 23.525 g = 15.000 g of displaced water (weight of an equal volume of water)

– Specific gravity of glass = 38.525 g/15.000 = 2.568.

Calculating the Specific Gravity of Solids

Solids Heavier Than and Soluble in Water.

- The weights of equal volumes of any two substances are proportional to their specific gravities. → Therefore, given a solid heavier than and soluble in water,
- we may use the method just discussed, but substituting some liquid of known specific gravity in which the solid is insoluble.

❑ Example: ***A crystal of a chemical salt weighs 6.423 g in air and 2.873 g when immersed in an oil having a specific gravity of 0.858. What is the specific gravity of the salt?***

Answer

- 6.423 g - 2.873 g = 3.550 g of displaced oil

$$\frac{3.55\ (g\ of\ oil)}{6.423\ (g\ of\ salt)} = \frac{0.858\ (sp.gr.of\ oil)}{x\ (sp.gr.of\ salt)} = \quad \text{so x = 1.55}$$

Use of Specific Gravity in Calculations of Weight and Volume

- It is important to remember that specific gravity is a factor that expresses how much heavier or lighter a substance is than water, (the standard with a specific gravity of 1.0).
  - For example, a liquid with a specific gravity of 1.25 is 1.25 times as heavy as water,
  - 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 sp. Gr (g =ml X sp. gr)

From: Specific gravity = $\frac{\text{weight of substance}}{\text{weight of equal volume of water}}$

- Weight of subs.(g) = Sp gr × weight of equal vol. of water
- weight of equal volume of water = volume of water = volume of substance
- Thus, Weight of subst. = volume of substance × sp. gr or
  g = mL × Sp. Gr

❑ What is the weight, in grams, of 3620 mL of alcohol with a specific gravity of0.820 ?

answer

- Equal volume of water (3620 mL) weighs = 3620 g
- W.t of alcohol = Sp. gr × weight of eq. vol. of water = 3620 g × 0.820 = 2968 g

Calculating weight, knowing the volume and sp. Gr (g =ml X sp. gr)

- What is the weight, in grams, of 2 fluidounces of a liquid having a specific gravity of 1.118?

Answer

$2 \times 30\ mL = 60\ mL$

- Equal volume of water (60 mL) weighs = 60 g
- W.t of liquid = Sp. gr × weight of eq. vol. of water = 60 g × 1.118 = 67.08 g

Calculating volume, knowing the weight and sp. Gr (g =ml X sp. gr)

- By rearranging the previous equation, we can calculate the volume of a liquid using the equation: **Milliliters** = $\frac{\textbf{Grams}}{\textbf{Specific gravity}}$

Examples

- What is the volume, in milliliters, of 492 g of nitric acid with a specific gravity of 1.40?

Answer

- 492 g of water measure 492 mL
- weight of equal volume of water = $\frac{\text{weight of substance}}{\text{Specific gravity}}$
- $\frac{492\ \text{ml}}{1.4}$ =351 mL

Calculating volume, knowing the weight and sp. Gr (g =ml X sp. gr)

$$\text{Milliliters} = \frac{\text{Grams}}{\text{Specific gravity}}$$

Examples

- *What is the volume, in milliliters, of 1 lb of methyl salicylate with a specific gravity of1.185?*

answer

- 1 lb = 454 g
- 454 g of water measure 454 mL
- ML = $\frac{454\ ml}{1.185}$ =383.1 mL.
- *What is the volume, in pints, of 50 lb of glycerin having a specific gravity of 1.25?*

answer

- 50 lb = 454 X 50 = 22700 g
- 22700 g of water measure 22700 mL and 1 pint =
- 473 mL
- ML = 22.700/1.25= 18,160 mL ÷ 473 mL = 38.4 pints,

Cost of Given Volume of Liquid by Weight

- *Examples: What is the cost of 1000 mL of glycerin, specific gravity 1.25, bought at $54.25 per pound?*

Answer

- 1000 mL of water weigh 1000 g
- Weight of 1000 mL of glycerin =1000g × 1.25 = 1250 g
- 1 lb = 454 g.

$$\frac{454\ (g)}{1250\ (g)} = \frac{54.25\ (\$)}{x\ (\$)} = 149.37\ \$$$

- *What is the cost of 1 pint of chloroform, specific gravity 1.475, bought at $25.25 per pound?*

- 1 pint =473 mL
- 473 mL of water weigh 473 g
- Weight of 473 mL of chloroform = 473 g × 1.475 = 697.7 g
- 1 lb = 454 g

$$\frac{454\ (g)}{697.7\ (g)} = \frac{25.25\ (\$)}{x\ (\$)} = 38.80\ \$$$

Special Considerations of Specific Gravity

Pharmaceutical Applications

- Specific gravity is employed when a pharmacist wishes to convert the weight of an ingredient or preparation to volume or vice versa.
  - liquid materials are usually the objects of the conversions.
- Specific gravity is also used to calculate the equivalent strength of a preparation on the basis of either weight or volume.
- Specific gravity is in automated pharmaceutical equipment used by pharmacists to prepare total parenteral nutrition (TPN) admixtures.
  - The purpose of the specific gravity of the large-volume liquids being mixed is to determine the **weights of components** (e.g., dextrose, amino acids, and water).
  - Based on the admixture's solutions' specific gravity, volume, and percentage concentration (e.g., 70% dextrose injection), component weights are automatically determined.
  - The automatic compounder then mixes the solution by weight rather than volume.

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).
  - The specific gravity of urine generally decreases with age.
  - In newborns, it is generally within the range of 1.001 to 1.020.
  - Specific gravity is an indicator of both the concentration of particles in the urine and a patient's degree of hydration.
- A higher-than-normal sp. gr indicates that the urine is concentrated

  This may be due to
  - the presence of excess waste products or electrolytes in the urine,

  → the presence of glucose (glucosuria) or protein (proteinuria)

  → excessive water loss, decreased fluid intake, ect.

Clinical Application

- A low specific gravity indicates that the urine is dilute, which may be a result of
  - diabetes insipidus, renal disease (by virtue of the kidney's reduced ability to concentrate urine),
  - increased fluid intake, intravenous hydration, or other factors.

Note:

- In the modern clinical laboratory, the specific gravity of urine is determined (using the refractive index method) as a component of a comprehensive urinalysis performed by sophisticated, fully automated equipment that determines, in seconds, urine chemistry, specific gravity, pH, color, and clarity.

https://www.youtube.com/watch?v=l8yysa48nkQ

CASE IN POINT

R_x/ Lactic Acid
Salicylic Acid aa. 1.5 g
Flexible Collodion qs ad 15 mL
Sig: Apply one drop to wart twice a day.
Label: Wart remover. For external use only.

Lactic acid is available as a liquid containing 85 g of the acid in 100 g of solution (sp.gr. 1.21). Calculate the quantity of this solution, in milliliters, needed to fill the prescription.

Answer

- Quantity of lactic acid needed to fill Rx: 1.5 g
- Source of lactic acid: liquid containing 85 g/100 g; or, by using
- specific gravity: 100 g ÷ 1.21 = 82.64 mL
- Thus, 85 g of lactic acid are in 82.64 mL of the source liquid.
- By proportion:

$$\frac{85\ g}{82.64\ ml} = \frac{1.5\ g}{x\ ml}$$

so x = 1.64 ml

Specific Volume

- Specific Volume: is defined as an abstract number which is the ratio of the volume of a substance to the volume of an equal weight of another substance taken as a standard.
- Water is the standard for liquids and solids.
- Specific volume shows how much greater or smaller in volume a weight is compared to the same weight of water.
- Specific gravity is a comparison of weights of equal volumes and specific volume is a comparison of volumes of equal weights
- Specific gravity and specific volume are reciprocals.

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

Specific Volume

Note:

- 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.

❑ Calculate the specific volume of a syrup, 91.0 mL of which weighs 107.16 g.

- 107.16 g of water measures 107.16 mL
- Specific volume of syrup = $(91\ ml)/(107.16\ ml) = 0.849$

❑ What is the specific volume of phosphoric acid having a specific gravity of 1.71? (answer = 0.585) .

❑ If 2 fl. Oz. of glycerol weighs 74.1 g, what is its specific gravity? Hint: 1 fl. Oz. = 30 mL (Answer: 1.235).

Specific Volume

- 870 grams of sucrose are dissolved in 470 mL of water, and the resulting volume is 1010 mL. Calculate the specific gravity of the solution. (Answer: 1.326)

- In making a certain syrup, 6800 g of sucrose were dissolved in enough water to make 8 liters. Assuming the specific gravity of the syrup to be 1.313, how many milliliters of water were used? (Answer: 3704 mL)