

PART II - ENGINEERING AND SCIENCE FUNDAMENTALS

Chapter 5 Units and Definitions

Problems and Solutions

PROBLEM 5.1. If a 250 cm³ volume of liquid weighs 550 g, determine what volume of liquid will weigh 3.2 g.

SOLUTION: The information given provides a ratio of mass to volume for this liquid, which can be used in a dimensional calculation as follows:

$$(250 \text{ cm}^3/550 \text{ g}) (3.2 \text{ g}) = 1.45 \text{ cm}^3$$

Therefore, 1.45 cm³ sample of the liquid will weigh 3.2 g.

PROBLEM 5.2. If a manufacturing process yields 54 g of solid pollutant each day, determine the amount of pollutant in kg produced in 1 year considering the process is performed continuously 5 days per week.

SOLUTION: The information given can be converted to weight per unit time as follows:

$$(54 \text{ g/d}) (5 \text{ d/wk}) (52 \text{ wk/yr}) (1 \text{ kg}/1,000 \text{ g}) = 14.04 \text{ kg/yr}$$

PROBLEM 5.3. If the density of carbon tetrachloride (CCl₄) is 99.2 lb/ft³ at 68°F and atmospheric pressure, determine the density in g/cm³ at the same conditions.

SOLUTION: The density of carbon tetrachloride can be converted from lb/ft³ to g/cm³ as follows:

$$(99.2 \text{ lb/ft}^3) (453.6 \text{ g/lb}) (1 \text{ ft}^3/0.02832 \text{ m}^3) (1 \text{ m}^3/10^6 \text{ cm}^3) = 1.59 \text{ g/cm}^3$$

PROBLEM 5.4. Thermal conductivity provides a measure of how fast (or how easily) heat flows through a substance and is defined as the amount of heat that flows per unit time through a unit area of unit thickness as a result of a unit difference in temperature. If the thermal conductivity of methanol is 0.0512 cal/m-s-°C at 60°F, convert this value to English engineering units (i.e., Btu, ft, hr, and °F).

SOLUTION: The thermal conductivity of methanol can be converted from cal/m-s-°C to Btu/ft-h-°F as follows:

$$(0.512 \text{ cal/m-s-}^{\circ}\text{C}) (1 \text{ Btu}/252 \text{ cal}) (0.3048 \text{ m}/1 \text{ ft}) (3600 \text{ s}/1 \text{ hr}) (1 \text{ }^{\circ}\text{C}/1.8^{\circ}\text{F}) = \\ 0.124 \text{ Btu/ft-h-}^{\circ}\text{F}$$

NOTE: the usual engineering notation for thermal conductivity is k. To convert from cal/m-s-°C to Btu/ft-h-°F, a direct conversion factor of 2.419 can be used.

PROBLEM 5.5. The viscosity of a fluid provides a measure of the fluid's resistance to flow. If the viscosity of methanol is 0.64 cP at 60°F, convert this value to English engineering units (i.e., lb, ft and s).

SOLUTION: The viscosity of methanol can be converted from centipoise (cP) to lb/ft-s as follows:

$$(0.64 \text{ cP}) (6.72 \times 10^{-4} \text{ lb/ft-s-cP}) = 4.3 \times 10^{-4} \text{ lb/ft-s}$$

NOTE: The notation for viscosity is μ . The kinematic viscosity (γ) is defined as the ratio of the viscosity to density ($\gamma = \mu/\rho$) with units of length²/time. Interestingly, the viscosity of gases increases, while the viscosity of liquids decreases with increasing temperature.

PROBLEM 5.6. Express the concentration 72 g of HCl in 128 cm³ of water in terms of fraction and percentage by weight, ppm and molarity.

SOLUTION: The fraction by weight can be calculated as follows, by first determining the weight of water making up the solution.

$$(128 \text{ cm}^3 \text{ of water}) (1 \text{ g/cm}^3 \text{ of water}) = 128 \text{ g water}$$

The weight fraction of this HCl solution is then:

$$(72 \text{ g}/128 \text{ g}) = 0.5625$$

The percentage by weight can be calculated from the fraction by weight as follows:

$$(0.5625) (100) = 56.25\%$$

Then the ppm (parts per million) on a weight basis can be calculated as follows:

$$(72 \text{ g}/128 \text{ g}) (10^6) = 562,500 \text{ ppm}$$

The Molarity (M) is moles of solute/volume of solution (L), and can be calculated as follows by first determining the number of moles of HCl in solution as:

$$\text{MW of HCl} = 1.0079 + 35.453 = 36.4609$$

$$M = [(72 \text{ g HCl})/(36.4609 \text{ g/gmol HCl})] / [(128 \text{ cm}^3)/(1000 \text{ cm}^3/\text{L})]$$

$$M = (1.97 \text{ gmol HCL})/(0.128 \text{ L}) = 15.43 \text{ mol/L}$$