

Chapter 1

1.1

- A balloon is being filled with air at a steady rate of 2 g/min. (Answer: Semibatch).
- A bottle of soft drink is taken from the refrigerator and left on the kitchen table. (Answer: transient in heat).

1.2

Mass of water in the tank = $2.0 \text{ m}^3 (1000 \text{ kg/m}^3) = 2000 \text{ kg}$

The tank is half full $2000 \text{ kg}/2 = 1000 \text{ kg}$

The time necessary to fill the tank = $1000 \text{ kg} / (3 \text{ kg/s}) = 333.3 \text{ sec}$

1.3

$$\frac{24 \text{ h}}{\text{day}} \left| \frac{60 \text{ min}}{\text{h}} \right| \left| \frac{60 \text{ s}}{\text{min}} \right| = 86,400 \frac{\text{s}}{\text{day}}$$

1.4

Flow rate in $\text{m}^3 = (50.0 \text{ ft}^3/\text{s})(1 \text{ m}^3/35.3145 \text{ ft}^3) = 1.42 \text{ m}^3/\text{s}$

Flow rate in gal/hr = $(50 \text{ ft}^3/\text{s})(264.17 \text{ gal}/35.3145 \text{ ft}^3)(3600 \text{ s/h}) = 1.35 \times 10^6 \text{ gal/h}$

1.5

Using ideal gas law $P\dot{V} = \dot{n}RT$

$$\dot{n} = \frac{P\dot{V}}{RT}$$

$$P_{\text{abs}} = P_{\text{gage}} + P_{\text{atm}}$$

$$P_{\text{abs}} = 150 \text{ kPa} + 101.32 \text{ kPa}$$

$$P_{\text{abs}} = 251.32 \text{ kPa}$$

Substituting known quantities

$$\dot{n} = \frac{P\dot{V}}{RT} = \frac{(251.32 \text{ kPa}) \left(\frac{1000 \text{ Pa}}{\text{kPa}} \right) \left(\frac{1450 \text{ m}^3}{\text{h}} \right) \left(\frac{\text{h}}{3600 \text{ s}} \right)}{8.314 \frac{\text{m}^3 \cdot \text{Pa}}{\text{mol} \cdot \text{K}} (15+273 \text{ K})} = 42.28 \text{ mol/s}$$

1.6

The units of A is (mol/cm³s) and the units of R is (cal/mol.K).

1.7

Mass = density * volume

$$\text{Mass} = (0.7 * 1 \text{ kg/L}) * 10 \text{ L} = 7 \text{ kg}$$

1.8

$$\left(\frac{1^\circ \text{C}}{1.8^\circ \text{F}}, \frac{1 \text{ K}}{1.8^\circ \text{R}}, \frac{1^\circ \text{C}}{1 \text{ K}} \right)$$

$$C_p = 2.5 \frac{\text{J}}{\text{g} \cdot ^\circ \text{C}} \left| \frac{453.593 \text{ g}}{1 \text{ lbm}} \right| \left| \frac{9.486 \times 10^{-4} \text{ Btu/s}}{1 \text{ J/s}} \right| \left| \frac{1^\circ \text{C}}{1.8^\circ \text{F}} \right|$$

$$C_p = 0.597609 \frac{\text{Btu}}{\text{lbm} \cdot ^\circ \text{F}}$$

1.9

The mass percent and mole percent of polystyrene in the mixture is calculated as:

$$\text{Polystyrene mass percent} = \frac{502 \text{ lb}}{(502 \text{ lb} + 4060 \text{ lb})} \times 100\% = 11 \text{ wt } \%$$

$$\text{There are: } \frac{502 \text{ lb}}{30200 \text{ lb} / \text{lb-mol}} = 0.0166 \text{ lbmol polystyrene}$$

$$\frac{4060 \text{ lb}}{104 \text{ lb} / \text{lb-mol}} = 39.04 \text{ lbmol styrene.}$$

$$\text{Polystyrene mole percent} = \frac{0.0166 \text{ lb-mol}}{0.0166 \text{ lb-mol} + 39.04 \text{ lb-mol}} \times 100\% = 0.0425 \text{ lb-mol}\%$$

The molar mass of glucose and of water is calculated as:

$$180 \text{ g solution} \times \frac{0.12 \text{ g glucose}}{\text{g solution}} \times \frac{1 \text{ mol glucose}}{180 \text{ g}} = 0.12 \text{ mol glucose}$$

$$180 \text{ g solution} \times \frac{0.88 \text{ g water}}{\text{g solution}} \times 1 \text{ mol water} / 18 \text{ g water} = 8.8 \text{ mol water}$$

The volume (cm³) of the vessel using the ideal gas law is calculated as

$$n = 2.7 \text{ lb CO}_2 \cdot \frac{453.59 \text{ g}}{\text{lb}} \cdot \frac{1 \text{ molar mass}}{44 \text{ g}} = 27.8 \text{ molar mass CO}_2$$

$$T = (67^\circ\text{F} - 32) \cdot (5/9) = 19.4^\circ\text{C} + 273.15 = 292.6\text{ K}$$

$$P = 1080\text{ mmHg} \cdot \frac{1\text{ atm}}{760\text{ mmHg}} = 1.42\text{ atm}$$

$$V = \frac{nRT}{P} = \frac{27.8\text{ mol} \cdot 82.057\text{ atm cm}^3/\text{mol K} \cdot 292.6\text{ K}}{1.42\text{ atm}} = 4.7 \cdot 10^5\text{ cm}^3$$

1.10

$$\text{a) } n_1 = \frac{P_1V_1}{RT_1}, n_2 = \frac{P_2V_2}{RT_2}$$

$$\frac{m_1}{m_1 + m_2} = \frac{n_1 \cdot MW_1}{n_1 MW_1 + n_2 MW_2} = \frac{0.15\text{ mol CO}_2 \cdot 44\text{ g/mol}}{1 \cdot 29\text{ g} + 0.15\text{ mol CO}_2 \cdot 44\text{ g/mol}} \cdot 100\% = 18.6$$

$$\text{b) } \frac{n_1}{V} = \frac{Mw \cdot P_1V_1 / RT_1}{V_f} = \frac{44\text{ g/mol} \cdot 0.10\text{ m}^3 \cdot 1.5\text{ atm}}{82.057 \cdot 10^{-6} (\text{atm m}^3 / \text{mol K}) 298\text{ K}} = 270 \frac{\text{g}}{\text{m}^3}$$

$$\text{In kg/m}^3 \rightarrow 270 \frac{\text{g}}{\text{m}^3} \cdot \frac{1\text{ kg}}{1000\text{ g}} \cdot 100\% = 27\%$$

$$\text{c) } \frac{n_1}{n_1 + n_2} = \frac{P_1V_1 / RT_1}{P_2V_2 / RT_2} = \frac{0.15\text{ mol CO}_2}{1 + 0.15\text{ mol CO}_2} = 0.13$$

1.11

$$\text{a) Weight of sucrose/weight of solution} = \frac{5\text{ kg}}{20\text{ kg} + 5\text{ kg}} \cdot 100\% = 20\%$$

$$\text{b) Weight of sucrose per volume} = \frac{5\text{ kg}}{25\text{ kg}} \cdot \frac{\text{m}^3}{1070\text{ kg}} \cdot 100\% = 21.4\%$$

$$\text{c) Mole fraction sucrose} = \frac{5\text{ kg} / 342}{20\text{ kg} / 18 + 5\text{ kg} / 342} = 0.013$$

$$\text{d) Molar concentration} = \frac{5\text{ kg} / 342\text{ kg/kmol}}{25\text{ kg} / 1070\text{ kg/m}^3} = 0.63\text{ kmol/m}^3$$

1.12

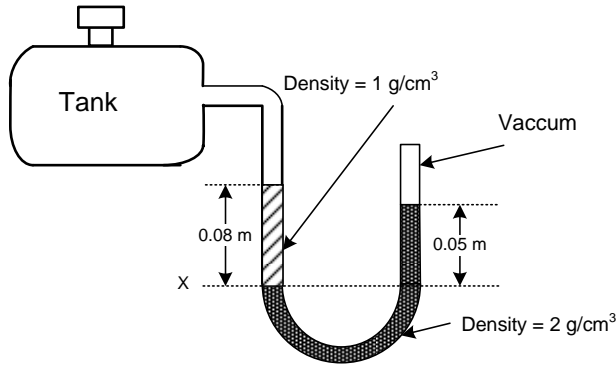


Figure P1.12

At the level marked with the letter “x” the pressure in the more dense fluid (S.G. = 2.00) must be the same since the fluid is not moving. On the right hand side of the manometer, the pressure is equal to the pressure exerted on its free surface plus the pressure from the 5.00 cm segment of this fluid. Since there is a vacuum above the fluid, $P = 0$. Thus the pressure at level x in the more dense fluid is:

$$P_x = \rho gh = 2000 \frac{\text{kg}}{\text{m}^3} (9.81 \frac{\text{m}}{\text{s}^2}) 0.0500 \text{m} = 981 \text{ Pa}$$

At level “x” on the left hand leg of the manometer the pressure must be the same (0.981 Pa). On the left hand leg this pressure is the result of the depth of the less dense fluid plus the pressure from the tank. Thus,

$$P_x = P_{\text{tank}} + \rho gh$$

$$981 \text{ Pa} = P_{\text{tank}} + 1000 \frac{\text{kg}}{\text{m}^3} (9.81 \frac{\text{m}}{\text{s}^2}) 0.0800 \text{m} = P_{\text{tank}} + 785 \text{ Pa}$$

$$P_{\text{tank}} = 981 - 785 = 196 \text{ Pa}$$

The manometer reading is an absolute pressure, because the pressure exerted on the fluid surface in the right hand leg of the manometer is zero (vacuum). Thus, the manometer reading is the absolute pressure.

1.13

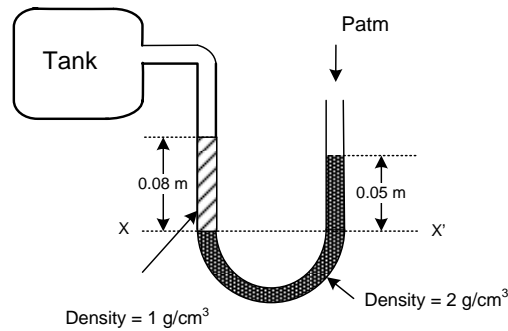


Figure P1.13

At the level marked with the letter “x” the pressure in the more dense fluid (S.G. = 2.00) must be the same since the fluid is not moving. On the right hand side of the manometer this pressure is equal to the pressure exerted on its free surface plus the pressure from the 5.00 cm segment of this fluid. Since there is atmospheric pressure above the fluid (1 atm). Thus the pressure at level x in the more dense fluid is:

$$P_x = \rho gh + P_{atm} = 2000 \frac{kg}{m^3} (9.81 \frac{m}{s^2}) 0.05 m + P_{atm} = 981 Pa + P_{atm}$$

At level “x” in the left hand leg of the manometer the pressure must be the same (0.981 Pa). In the left hand leg this pressure must be the result of the depth of the less dense fluid plus the pressure from the tank. Thus,

$$P_x = P_{tank} + \rho gh = P_{tank} + 1000 \frac{kg}{m^3} (9.81 \frac{m}{s^2}) 0.08 m = P_{tank} + 785 Pa$$

$$P_x = P_{tank} + 785 Pa$$

$$P_x = 981 Pa + P_{atm}$$

$$P_x = P_x = P_{tank} + 785 Pa = 981 Pa + P_{atm}$$

$$P_{tank} = 981 Pa + P_{atm} - 785 Pa$$

Rearranging

$$P_{tank} = 981 Pa + P_{atm} - 785 Pa = 101.521 kPa$$

1.14

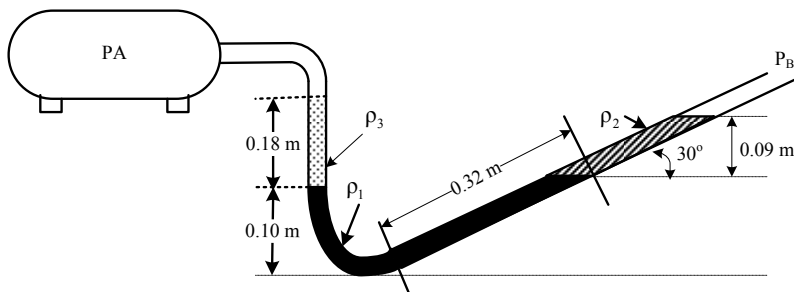


Figure P1.14

$$P_A + \rho_3 g (0.18 m) + \rho_1 g (0.10 m) = P_B + \rho_2 g (0.09 m) + \rho_1 g (h)$$

$$\text{Where } h = 0.32 \sin(30) = 0.16 m$$

Substitute known quantities:

$$\begin{aligned} P_A + \left(1600 \frac{kg}{m^3}\right) \left(9.81 \frac{m}{s^2}\right) (0.18 m) + \left(2000 \frac{kg}{m^3}\right) \left(9.81 \frac{m}{s^2}\right) (0.10 m) \\ = P_B + \left(1000 \frac{kg}{m^3}\right) \left(9.81 \frac{m}{s^2}\right) (0.09 m) + \left(2000 \frac{kg}{m^3}\right) \left(9.81 \frac{m}{s^2}\right) (0.16 m) \end{aligned}$$

Note that:

$$N = \frac{\text{kg} \cdot \text{m}}{\text{s}^2}, \text{ Pa} = \frac{\text{N}}{\text{m}^2}$$

Using this to conversion units gives

$$\begin{aligned} P_A + 2825 \frac{N}{\text{m}^2} \left(\frac{\text{kPa}}{1000 \text{ N/m}^2} \right) + 1962 \frac{N}{\text{m}^2} \left(\frac{\text{kPa}}{1000 \text{ N/m}^2} \right) \\ = 100 \text{ kPa} + 883 \frac{N}{\text{m}^2} \left(\frac{\text{kPa}}{1000 \text{ N/m}^2} \right) + 3139 \frac{N}{\text{m}^2} \left(\frac{\text{kPa}}{1000 \text{ N/m}^2} \right) \end{aligned}$$

Simplifying:

$$P_A + 2.825 \text{ kPa} + 1.962 \text{ kPa} = 100 \text{ kPa} + 0.882 \text{ kPa} + 3.139 \text{ kPa}$$

The pressure in the tank, $P_A = 99 \text{ kPa}$

1.15

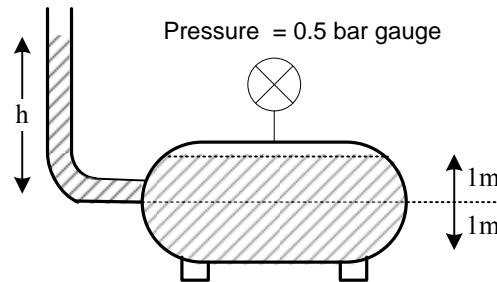


Figure P1.15

$$1000 \frac{\text{kg}}{\text{m}^3} \times 9.81 \frac{\text{m}}{\text{s}^2} \times h + P_{atm} = 1000 \frac{\text{kg}}{\text{m}^3} \times 1.0 \text{m} \times 9.81 \frac{\text{m}}{\text{s}^2} + 0.5 \text{ bar} + P_{atm}$$

$$1000 \frac{\text{kg}}{\text{m}^3} \times 9.81 \frac{\text{m}}{\text{s}^2} \times h = 1000 \frac{\text{kg}}{\text{m}^3} \times 1.0 \text{m} \times 9.81 \frac{\text{m}}{\text{s}^2} + 0.5 \text{ bar} \frac{100000 \text{ Pa}}{\text{bar}} \frac{\text{kg m} / \text{m}^2 \text{ s}^2}{\text{Pa}}$$

$$h = 6.1 \text{ m}$$