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 m^3 (1000 kg/m^3) = 2000 kg

The tank is half full 2000 kg/2 = 1000 kg

The time necessary to fill the tank = 1000 kg /(3 kg/s) = 333.3 sec

1.3

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

1.4

Flow rate in m^3 = (50.0 ft^3/s)(1 m^3/35.3145 ft^3) = 1.42 m^3/s

Flow rate in gal/hr = (50 ft^3/s)(264.17 gal/35.3145 ft^3)(3600 s/h) = 1.35×10^6 gal/h

1.5

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

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

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

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

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

Substituting known quantities

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

1.6

The units of A is ($\text{mol/cm}^3\text{s}$) and the units of R is (cal/mol.K).

1.7

Mass = density * volume

Mass = (0.7 *1 kg/L)*10 L = 7 kg

1.8

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

$$C_p=2.5\frac{\text{J}}{\text{g.}^\circ\text{C}}\left|\frac{453.593\,\text{g}}{1\,\text{lbm}}\right|\frac{9.486\times10^{-4}\text{Btu/s}}{1\text{J/s}}\left|\frac{1^\circ\text{C}}{1.8\,^\circ\text{F}}\right.$$

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

1.9

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

$$\text{Polystyrene mass percent}=\frac{502\text{ lb}}{(502\text{ lb}+4060\text{ lb})}\times100\%=11\text{ wt }\%$$

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

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

$$\text{Polystyrene mole percent}=\frac{0.0166\text{ lb-mol}}{0.0166\text{ lb-mol}+39.04\text{ lb-mol}}\times100\%=0.0425\text{ lb-mol\%}$$ The molar mass of glucose and of water is calculated as:

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

$$180\text{ g solution}\times\frac{0.88\text{ g water}}{\text{g solution}}\times1\text{ mol water / 18 g water}=8.8\text{ mol water}$$

The volume (cm^3) of the vessel using the ideal gas law is calculated as

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

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

$$P = 1080\ \text{mmHg} \times \left(\frac{1\ \text{atm}}{760\ \text{mmHg}}\right) = 1.42\ \text{atm}$$

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

1.10

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

$$\frac{m_1}{m_1 + m_2} = \frac{n_1 * MW_1}{n_1MW_1 + n_2MW_2} = \frac{0.15\,mol\,CO_2 \times 44g/mol}{1 \times 29g + 0.15\,mol\,CO_2 \times 44g/mol} \times 100\% = 18.6$$

b) $$\frac{n_1}{V} = \frac{Mw \times P_1V_1/RT_1}{V_f} = \frac{\dfrac{44g/mol \times 0.10\,m^3 \times 1.5\,atm}{82.057 \times 10^{-6}\left(atm\,m^3/mol\,K\right)298K}}{1.0\,m^3} = 270\frac{g}{m^3}$$

In kg/m^3 → $270\dfrac{g}{m^3} \times \dfrac{1kg}{1000\,g} \times 100\% = 27\%$

c) $$\frac{n_1}{n_1 + n_2} = \frac{P_1V_1/RT_1}{P_2V_2/RT_2} = \frac{0.15\,mol\,CO_2}{1 + 0.15\,mol\,CO_2} = 0.13$$

1.11

a) Weight of sucrose/weight of solution $= \dfrac{5\ kg}{20\,kg + 5kg} \times 100\% = 20\%$

b) Weight of sucrose per volume= $\dfrac{5\ kg}{25\,kg\,\dfrac{m^3}{1070kg}}\dfrac{m^3}{1000\,liter} \times 100\% = 21.4\%$

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

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

1.12

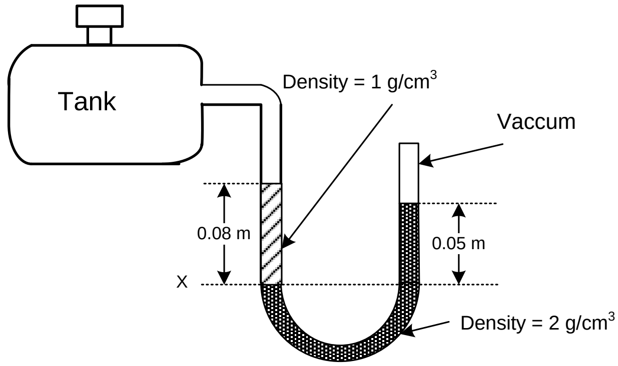

Figure P1.12

At the level marked with the letter "x" the pressure ~~in~~ of 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:

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

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,

$$P_x = P_{\text{tank}} + \rho g h$$

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

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

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

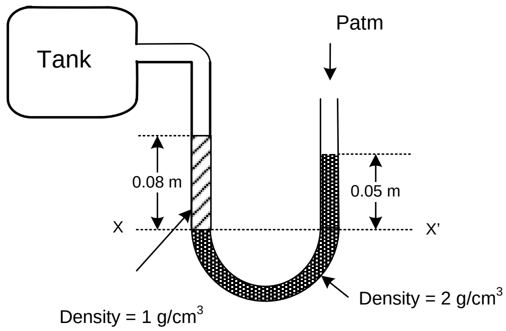

Figure P1.13

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:

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

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 the result of the depth of the less dense fluid plus the pressure from the tank. Thus,

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

$$P_x = P_{\text{tank}} + 785\,Pa$$

$$P_{x'} = 981\,Pa + Patm$$

$$P_x = P_{x'} = P_{\text{tank}} + 785\,Pa = 981\,Pa + Patm$$

$$P_{\text{tank}} = 981\,Pa + Patm - 785\,Pa$$

Rearranging

$$P_{\text{tank}} = 981\,Pa + Patm - 785\,Pa = 101.521\,kPa$$

1.14

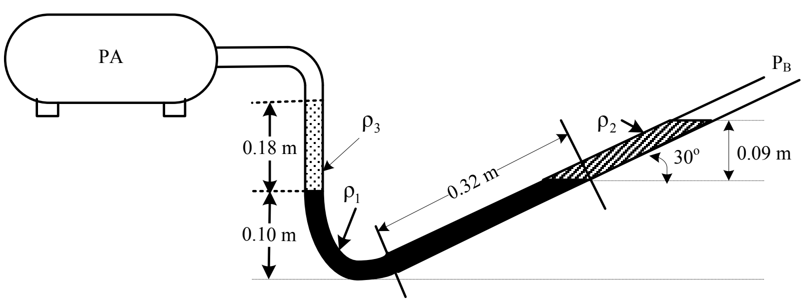

Figure P1.14

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

Where $h = 0.32\sin(30) = 0.16\,m$

Substitute known quantities:

$$P_A + \left(1600\frac{kg}{m^3}\right)\left(9.81\frac{m}{s^2}\right)(0.18\,m) + \left(2000\frac{kg}{m^3}\right)\left(9.81\frac{m}{s^2}\right)(0.10\,m)$$

$$= P_B + \left(1000\frac{kg}{m^3}\right)\left(9.81\frac{m}{s^2}\right)(0.09\,m) + \left(2000\frac{kg}{m^3}\right)\left(9.81\frac{m}{s^2}\right)(0.16\,m)$$

Note that:

$$\mathrm{N}=\frac{\mathrm{kg.m}}{\mathrm{s}^2},\ \mathrm{Pa}=\frac{\mathrm{N}}{\mathrm{m}^2}$$

Using this to conversion units gives

$$P_A+2825\frac{N}{m^2}\left(\frac{\mathrm{kPa}}{1000\,\mathrm{N/m^2}}\right)+1962\frac{N}{m^2}\left(\frac{\mathrm{kPa}}{1000\,\mathrm{N/m^2}}\right)$$

$$=100\,kPa+883\frac{N}{m^2}\left(\frac{\mathrm{kPa}}{1000\,\mathrm{N/m^2}}\right)+3139\frac{N}{m^2}\left(\frac{\mathrm{kPa}}{1000\,\mathrm{N/m^2}}\right)$$

Simplifying:

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

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

1.15

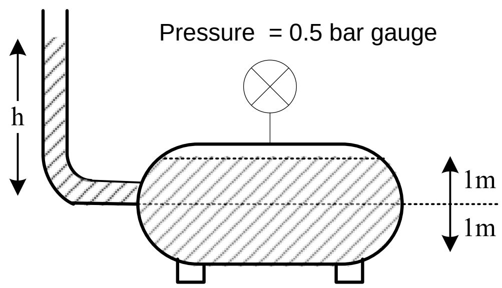

Figure P1.15

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

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

$$h=6.1m$$