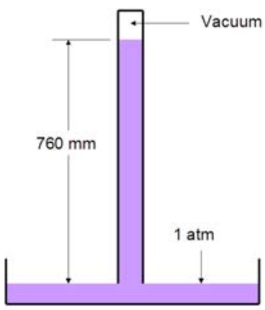
Practice Problems

GASES **#1

1. A mercury barometer is shown in the figure. One atmosphere of pressure corresponds to a supported column of Hg that is 760 mm high.
   A. Calculate the density of mercury. Show your work.
   B. Suppose the barometer is taken to the top of Mt. Mitchell, the highest point in North Carolina. Assume that Mt. Mitchell is 2000 m in elevation at the top. How high will the column of Hg be at that elevation.



2. What is the density of air inside a bicycle tire that has been inflated to 45 $lbs./in.^2$ of pressure?

3. A child releases a He balloon into the air. Assuming that the balloon is inelastic (has a constant shape) determine the elevation to which it will rise.

FIRST LAW **#2

Consider a cylinder in a 4 liter V-8 engine (i.e. 8 cylinders with a total expanded volume of 4 liters). Let's look at the work extracted during expansion in two phases:

I. Isothermal expansion
II. Adiabatic cooling and expansion

1. Calculate the maximum isothermal work of expansion possible when 0.05 moles of n-octane is combusted perfectly in a cylinder at a temperature of 500 K. Assume that H_2O in the combusted products is a gas. Assume that the initial headspace volume during fuel injection is 0.002 L. Assume further that the isothermal expansion is carried out only to 0.142 L.

2. The ambient temperature is 300 K. Assuming that the gas in the cylinder cools adiabatically, how much further would the gas expand. You may assume that the heat capacity for a diatomic gas applies here.

3. Calculate the work done during the adiabatic expansion.

4. Imagine that the design for the engine was very poor and that the isothermal step in question 1. Was a one step expansion against an external pressure of 1 atm. Calculate the work of expansion in this case (again from 0.002 to 0.142 L).

5. Assume that an adiabatic expansion is carried out following the single-step irreversible expansion. Calculate the final volume with the same assumptions as question 2.

6. Calculate the work of adiabatic expansion following the single-step irreversible expansion step of question 4. Use the same assumptions as in question 3.

ENTHALPY AND ENTROPY ***********************************#3

1. A hiker caught in a rainstorm absorbs 1 liter of water in his/her clothing. It is windy so that this volume is quickly evaporated at 20^{o}C (the heat of vaporization of water is 2447 kJ/kg at this temperature).
   a. If the hiker is the "system" calculate q, the heat transferred when 1 L evaporates. (10 points)

b. If all this heat were removed from the hiker what drop in body temperature would the hiker experience (ignore the metabolism of the hiker)? The hiker weighs 60 kg and has a specific heat capacity equal to that of water (4.18 kJ/kg-K). (15 points)

c. How many grams of sucrose would the hiker have to metabolize (quickly) to replace the heat of evaporating one liter of water to maintain his/her original body temperature? You can use the heat of reaction for the combustion of sucrose at 25^{o}C. The heat of formation of sucrose is 2222 kJ/mol. The reaction is (15 points):

$$\text{Sucrose (s) + oxygen (g)} \rightarrow \text{carbon dioxide (g) + water (l)}$$

2. a. An engineer is designing a solar heating unit for a house. A bed of granite rocks with a surface area of 100 m^2 and volume of 10 m^3 will be heated by direct sunlight. The specific heat of the rocks is 4 $Jg^{-1}K^{-1}$ and the average density is 4000 kg/m^3. Assume that the effective radiant flux (power per unit area) of the sun is 1 kW/m^2 and that there are six hours of effective heating per day. Assuming a morning temperature of 298 K, perfect heat transfer, and no losses, what final temperature will be achieved by the rocks at the end of the day? (10 points)

b. Assuming perfect heat exchange between the rocks and pumped air, what volume of air (C_P = 29.0 $Jmol^{-1}K^{-1}$) can be heated by 10 K? (15 points)

3. a. How much solar energy is required to heat 1 mole of circulation water from 300 K to 310 K? (5 points)

b. A flow of air at 275 K enters a heat exchanger at 22.5 L/sec. The hot water (310 K) supplied from a flat plate solar panel enters the inner tubing of the heat exchanger at 0.018 L/sec. Assuming that the heat exchanger has no losses and that the water and air reach equilibrium as they exit calculate the temperature of the heated air (10 points).

c. Treating the heat exchange process as a constant pressure expansion of the atmosphere and compression of liquid water, calculate the volume change of 1 L of air (10 points).

d. Calculate the entropy change in both the water and air separately and the total entropy change for the process. Be sure to include both temperature and volume changes for the air (10 points).

FREE ENERGY **#4

1. Calculate the molar free energy of mixing of a salt solution of 0.1 M sodium carbonate and 0.1 M magnesium carbonate at 300 K.

2. In class we calculated the value of the pressure for which diamond is in equilibrium with graphite. Suppose that you are working for a company that wants to make diamond and they determine that they need a chemical potential of -80 kJ/mol for the reaction. What pressure does this correspond to?

3. Consider the reaction:
   $2\ NO_2\ (g) \rightarrow N_2O_4\ (g)$
   The reaction takes place in a closed container at constant pressure. If the initial presssures are $P_{NO2} = 1$ atm, what is the pressure of N_2O_4 at equilibrium?

a. Construct a table to determine the partial pressure of the gases at equilibrium in terms of the extent of reaction, x.

b. Use free energy values to determine the magnitude of the equilibrium constant.

c. Determine the relationship between the extent of reaction, x and the equilibrium constant.

d. Calculate the extent of reaction, x.