Homework #2
Problems (#9-#15)

9. One mole of ideal gas at 298 K is in a piston at a pressure of 100 atm.

    a. What is the work done by the gas if it expands isothermally against a constant pressure of 10 atm?

    b. What is the total work done by the gas if the piston expands against constant pressure in 3 stages, reaching equilibrium between each stage:
    first against 50 atm, then against 20 atm, and finally against 10 atm.

    c. What is the total work done by the gas if it expands reversibly and isothermally from its initial 100 atm to 10 atm?

    d. How does the work done by the gas compare for a vs b vs c ?

    e. Plot, on the same P vs V diagram, the expansion paths in a, b, and c. Do the areas under the curves reflect the conclusions in part d.

10. [from Raff #2.14] One mole of a monatomic ideal gas at a temperature of 500 K and a pressure of 6 atm is subjected to the following changes:

    STEP 1: The gas is expanded isothermally and reversibly to a final pressure of 5atm.

    STEP 2: After completion of STEP 1, the gas is expanded adiabatically and reversibly until the pressure reaches 4 atm.

    STEP 3: After STEP 2 is completed, the gas is compressed isothermally and reversibly to a final pressure of 4.800 atm.

    STEP 4: After STEP 3, the gas is compressed adiabatically and reversibly to a pressure of 6 atm, returning the gas to a temperature of 500 K .

    a. Compute *w, q, and* ΔU for STEP 1.

    b. At the completion of STEP 2, what are the temperature and volume of the gas? Compute the amount of work done in STEP 2.

    c. Compute *w, q, and* ΔU for STEP 3.

    d. Compute the amount of work done in STEP 4.

    e. Compute *w, q, and* ΔU *for* the entire process.

11. E&R #2.11 *[values changed from 2nd ed]*
A cylindrical vessel with rigid adiabatic walls is separated into two parts by a frictionless adiabatic piston. Each part contains 45.0 L of an ideal monatomic gas with $C_{V,m} \equiv \bar{C}_V = \frac{3R}{2}$. Initially, $T_i = 300K$ and $P_i = 1.75 \times 10^5\,\text{Pa}$ in each part. Heat is slowly introduced into the left part using an electrical heater until the piston has moved sufficiently to the right to result in a final pressure in the $P_f = 4.0\ \text{bar}$ right part. Consider the compression of the gas in the right part to be a reversible process.
   a. Calculate the work done on the right part in this process and the final temperature in the right part.
   b. Calculate the final temperature in the left part and the amount of heat that flowed into this part.
   and also
   c. **part c**. Also calculate the total ΔU and ΔH (sum of the two chambers).

ALL ANSWERS SHOULD BE IN UNITS OF kJ (or J) AND degrees K

12. Derive the following for any closed system, with only P-V work:

$$C_V = -\left(\frac{\partial U}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_U$$

13. *****. E&R P3.23 *[same as 2nd ed]*
Note: treat $\left(\frac{\partial U}{\partial \bar{V}}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_{\bar{V}} - P$ as a 'given' equation
(we will prove this relationship very soon)

14. (from *Basic Chemical Thermodynamics*, by J. Waser, published by Benjamin Cummings)
Indicate whether each of the following statements is true of false. If the statement is not true, indicate in what way it is false (or give a counter example) and whether it could be made into a true statement by a slight change in wording. If the statement is true but unnecessarily restricted, indicate what qualifying words or phrases could be omitted [assume that in each example we are referring to a **closed system** (closed with respect to exchange of material or change of phase)]:

   a. The work done by the system on the surroundings is never greater than the decrease in the energy of the system.

   b. The enthalpy of a system cannot change during an adiabatic process.

   c. When a system undergoes a given isothermal change (an isothermal change between specific initial and final states), its enthalpy does not depend on the process involved.

d. For any process, the change in enthalpy of the system must be equal and opposite to that of the surroundings ($\Delta H_{sys} = - \Delta H_{surr}$).

e. A spontaneous change is always accompanied by a decrease in the energy of the system.

f. The equation $\Delta U = q + w$ is applicable to any change in a closed system when no electrical work is done by the system on the surroundings.

g. For any change in an isolated system $\Delta U = 0$ and $\Delta H = 0$.

h. For any constant pressure process, the increase in enthalpy equals the heat absorbed whether electrical work is done during the process or not.

i. When a real gas expands into a vacuum (against $P_{ext}=0$), it does work since the molecules of the gas have to be separated from one another against attractive (van der Waals) forces.

15. In lecture we showed that for an ideal gas undergoing a reversible, adiabatic volume
change (compression/expansion)

$$T_2^{\frac{\overline{C}_V}{R}} V_2 = T_1^{\frac{\overline{C}_V}{R}} V_1 \quad \text{(i.e. } T^{\frac{\overline{C}_V}{R}} V = \text{constant along path)}$$

Show that also:

a. $$\frac{T_2^{\frac{\overline{C}_P}{R}}}{P_2} = \frac{T_1^{\frac{\overline{C}_P}{R}}}{P_1} \quad \text{(i.e.} \frac{T^{\frac{\overline{C}_P}{R}}}{P} = \text{constant along the path)}$$

and

b. $$P_2 V_2^{\gamma} = P_1 V_1^{\gamma} \quad \text{where} \quad \gamma = \frac{\overline{C}_P}{\overline{C}_V} \qquad \text{(i.e. } PV^{\gamma} = \text{constant along the path)}$$