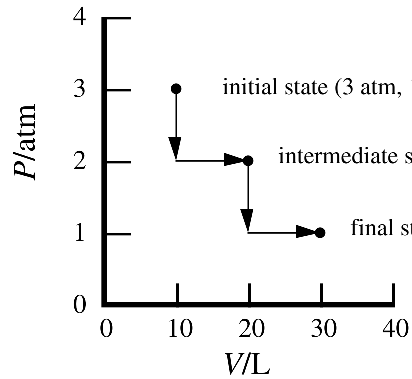
Problem Set 6 (For February 17)

Recommended Text Problems: 9.29, 9.32, 9.37, 9.47, 9.51, 9.63

1 . (From an old exam...) An ideal gas at T = 200 K, P = 3.00 atm, V = 10 L is first subjected to the two-stage, irreversible, expansion graphed below. The final state of the gas is T = 200 K, P = 1.00 atm, V = 30 L.



(a) Calculate w, q, ΔE, and ΔH for this first process.
(b) Next, the gas container is sealed (making its volume constant), and energy is transferred as heat until the pressure rises to 3.00 atm. Calculate w, q, ΔE, and ΔH for this second process.

2 . *Here's a problem that is more important for the physical concepts behind it than for the details of its solution: a gas is subjected to an energy input as work, and, being thermally insulated, the increase in energy due to the work has no place to go. It stays in the gas, raising its temperature.* A certain number of moles of a monatomic ideal gas is confined in a thermally insulated container at the initial state T_i = 300 K, P_i = 2.00 atm, and V_i = 50.0 L. It is compressed by a piston that exerts a constant pressure of 5.00 atm until equilibrium is attained. Follow these steps to find the final state of the gas and its energy change, ΔE. First, note that the system is insulated, so there is no heat: $q = 0$. But there is non-zero work. Write an expression for the work symbolically first, in terms of the final pressure P_f and the initial and final volumes, V_i and V_f. Next, note that $\Delta E = w$ and is not zero, so the temperature of the gas changes. Write an expression for ΔE in terms of the number of moles of gas, n, the molar heat capacity of the gas, C_V (see Table 9.2 and the expressions on page 357), and the final and initial temperatures, T_f and T_i. Your expression, when expanded, should contain factors of nRT, one for T_f and one for T_i. Use the equalities $P_iV_i = nRT_i$ and $P_fV_f = nRT_f$ to write this ΔE expression in terms of pressures and volumes only. You should now have an expression for w in which V_f is the only unknown and one for ΔE in which V_f is also the only unknown. Because $q = 0$, these are equal. Write this equality, and solve for the final volume, V_f. You should find V_f = 32.0 L. You can now find the final temperature, T_f. It should be 480 K. What is ΔE?

3 . In the course of your work for NASA, you hit upon the invention shown at the top of the next page. It is a thermos bottle (an *adiabatic container*) with three compartments: one which holds about 1 cup (~0.25 L or 14 mol) of water (or broth, soup, etc.), one which holds Na(s), and one which holds $Cl_2(g)$. The partition between the latter two is removed to initiate the reaction $Na(s) + (1/2)Cl_2(g) \rightarrow NaCl(s)$, which, being exothermic, heats the water and provides salt for seasoning at the same time! If the water starts at around 70 °F (21 °C) and should be heated to 200 °F (93 °C), how many moles of Na(s) and $Cl_2(g)$ should be used? For NaCl(s), $\Delta H_f^o = -411.15$ kJ mol^{-1}, and the molar heat capacity of liquid water is $C_P = 75.3$ J K^{-1} mol^{-1}.

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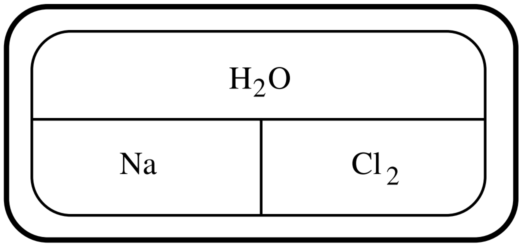

4 . Shown below are several reactions involving various nitrogen oxide compounds. The standard molar enthalpy of reaction for each is also shown. Use these data to calculate the standard molar enthalpy of formation, ΔH_f^o, for dinitrogen pentoxide, $N_2O_5(g)$.

$$N_2(g) + O_2(g) \rightleftarrows 2\ NO(g) \qquad \Delta H^o = 180.6 \text{ kJ mol}^{-1}$$

$$2\ NO_2(g) \rightleftarrows 2\ NO(g) + O_2(g) \qquad \Delta H^o = 114.4 \text{ kJ mol}^{-1}$$

$$2\ N_2O_5(g) \rightleftarrows 4\ NO_2(g) + O_2(g) \qquad \Delta H^o = 113.4 \text{ kJ mol}^{-1}$$

5 . In celebration of St. Valentine's day, imagine burning diamond, a form of pure carbon, in oxygen:

$$C(\text{diamond}) + O_2(g) \rightleftarrows CO_2(g) \qquad \Delta H^o = -395.4 \text{ kJ mol}^{-1}$$

This is an exothermic reaction, as the negative sign of ΔH^o shows. A more common form of carbon, of course, is graphite, which also burns exothermically:

$$C(\text{graphite}) + O_2(g) \rightleftarrows CO_2(g) \qquad \Delta H^o = -393.5 \text{ kJ mol}^{-1}$$

Is the conversion of graphite to diamond endothermic or exothermic? What is the standard molar enthalpy of formation of diamond and of graphite? (Read page 373 in the text for a major clue, but don't peek at Appendix 4! See also Problem 9.26 in the text for a similar system.)