Chemistry 230
Problem Set # 4 — 9/15/99

Recommended Problems: 2.29, 2.41, 2.43, 2.45-48, 2.50.

1. (a) What is the average power production in watts of a 75-kg man who burns 2500 kcal of food in a day? (b) Estimate the additional power production if the man is climbing a mountain at the rate of 20 m (vertical) per minute. (c) Return to the first case (a) and assume the man is a complete couch potato and that all of his metabolic activity shows up ultimately as heat production. Treat the man as a closed system with the heat capacity of water. Assuming no heat loss, estimate his temperature rise in a day. (d) The main mechanism of heat loss is water evaporation. How much water must be evaporated in a day to maintain his temperature at 37˚C? (ΔH_{vap} for water at 37˚C is 2405 J/g.)

2. Calculate the work done on the surroundings when 1.00 mole of water at 1.00 atm (a) freezes at 0˚C; (b) is heated from 0˚C to 100˚C; (c) boils at 100˚C. Compare these figures with the latent heats of fusion and vaporization, 79.7 and 539.4 cal/g, respectively. [ρ = 0.99987 g/cm^3 for H_2O (l,0˚C); 0.95838 g/cm^3 (l,100˚C); 0.9168 g/cm^3 (s,0˚C)]

3. 1.00 kg of ethylene is compressed from 0.100 m^3 to 0.0100 m^3 at a constant temperature of 27˚C. Assume the compression is done reversibly and calculate the work done on the gas (in J), treating it as (a) ideal, and (b) as a real gas obeying the van der Waals equation ($a = 4.47 \times 10^6$ cm^6 atm mol^{-2} and b = 57.1 cm^3 mol^{-1}).

4. A gas follows the equation of state, $PV = nRT$, and has heat capacity, $C_{P,m}$ (J K^{-1} mol^{-1}) = $29.4 + 8.40 \times 10^{-3}\ T$. [**Hint:** See notes at the beginning of Section 2.8.]

   (a) Obtain an expression for $C_{V,m}$ as a function of T.

   (b) Design an adiabatic process for taking 1.00 mol of this gas from the conditions (P, V) = (20.00 atm, 2.00 L) to the final conditions (5.00 atm, 8.00 L).

   (c) Calculate ΔU and ΔH for the process in (b).

5. It is not easy to measure heat capacities accurately for gases, because both C_P and C_V are small per unit volume. However, accurate values of the heat capacity <u>ratio</u> γ are easy to obtain (for example, from measurements of the speed of sound). For gaseous CCl_4 at 0.10 bar and 20˚C, experiment gives γ = 1.13. Obtain $C_{P,m}$ and $C_{V,m}$ for $CCl_4(g)$ at 20˚C and 1.0 bar.

6. For each of the following gaseous species, give (a) the number of translational degrees of freedom, (b) the number of rotational degrees of freedom, and (c) the number of vibrational degrees of freedom:

   Ar, CO, CO_2, H_2O, CCl_4

   Use this information to estimate: (a) the contributions to $C_{V,m}$ and U_m due to translation and rotation, and (b) the minimum and maximum possible contributions to $C_{V,m}$ and U_m from vibration.