Chemistry 230
Problem Set 4 -- 1999

1. (a) 121 W (b) 245 W (c) ΔT = 33.3 K (d) 4.35 kg
   [1.2×10^2 2×10^2 33 4.4]

2. (a) 0.165 J (0.17) (b) 0.079 J (0.08) (c) 3.10 kJ

   All of these work values are MUCH less than the corresponding heats associated with the given processes. Only for (c), where a mole of gas is created, is the work term at all significant.

3. (a) 205 kJ (b) 171 kJ

4. (a) $C_{V,\mathrm{m}} = 21.1\ \mathrm{J\ mol^{-1}\ K^{-1}} + 0.00840\ T\ \mathrm{J\ mol^{-1}\ K^{-2}}$.

   (b) $P_1V_1 = P_2V_2$, so T is constant. Use a Joule expansion.

   (c) $\Delta U = \Delta H = 0$.

5. $C_{V,\mathrm{m}} = 64\ \mathrm{J\ mol^{-1}\ K^{-1}}$; $C_{P,\mathrm{m}} = 72\ \mathrm{J\ mol^{-1}\ K^{-1}}$. (64.0 and 72.3 O.K.)

6. Ar: 3 transl. only $\rightarrow U_\mathrm{m} = {}^3/_2RT$, $C_{V,\mathrm{m}} = {}^3/_2R$.

   CO: (See Prob. 2.45 in Levine) 3 transl., 2 rot., 1 vib. Since CO is a "light" molecule, its vibrational frequency is >> kT at room T, meaning $U_\mathrm{m} = {}^5/_2RT$, $C_{V,\mathrm{m}} = {}^5/_2R$ at room T. At high T (~3000 K), the vibrational contribution becomes significant, increasing U_m by RT and $C_{V,\mathrm{m}}$ by R.

   CO_2: (linear) 3 transl., 2 rot., 4 vib. Again, CO_2 is "light," so the contributions from vibration are not significant at room T. The contributions from translation and rotation are the same as for CO. The vibrational contributions to U_m and $C_{V,\mathrm{m}}$ range from $0 \rightarrow 4RT$ and $0 \rightarrow 4R$, respectively.

   H_2O: (nonlinear) 3 transl., 3 rot., 3 vib. Here again, H_2O is "light," so vibration is inactive at room T. The contributions from translation and rotation yield $U_\mathrm{m} = 3RT$, $C_{V,\mathrm{m}} = 3R$. The vibrational contributions to U_m and $C_{V,\mathrm{m}}$ range from $0 \rightarrow 3RT$ and $0 \rightarrow 3R$, respectively.

   CCl_4: (nonlinear) 3 transl., 3 rot., 9 vib. The contributions from translation and rotation are the same as for H_2O. The contributions from vibration to U_m and $C_{V,\mathrm{m}}$ range from $0 \rightarrow 9RT$ and $0 \rightarrow 9R$, respectively. In this case there will be some significant contribution from vibration already at room T, but this cannot be easily estimated.