Problem Set #9  Due: 11/23/05

This problem set is designed to give you practice using thermodynamic relations, and help you understand the thermodynamics of chemical reactions.

1. 13.29
2. 14.37
3. On May 11, 1996, a ValuJet DC-9 jetliner with 109 people aboard crashed in the Florida Everglades shortly after takeoff from Miami International Airport. The plane was carrying in the cargo compartment 50 to 60 oxygen generators and three aircraft tires. The oxygen generators produce oxygen by the following reaction:

   Fe + NaClO₃ = NaCl + FeO + O₂.

   Not only does this reaction produce oxygen but it is also highly exothermic. It is believed that the heat and oxygen released from the uncontrolled reaction of these reactants in the cargo bay ignited the tires and caused the crash.

   The way the oxygen generators, which are about 8" long and 4" in diameter, are supposed to work is as follows. When an airplane cabin depressurizes and the first of the oxygen masks supplied by the generator is pulled, iron powder is sprinkled into solid sodium chlorate, releasing controlled amounts of oxygen. However, if the entire contents of a generator are mixed together suddenly, the reaction will be violent. Normally, these oxygen generators are treated as hazardous cargo, but in the ValuJet case they were not recognized as such.

   (a) Assuming the oxygen generator holds Fe and NaClO₃ powder in the ideal proportions; half the volume of an oxygen generator is filled with these two solid powders; the packed powder is 75% dense (i.e. 25% air fills the gaps), how many kilojoules is released by the complete reaction of the contents of one oxygen generator?

   (b) If the reaction proceeds so rapidly as to be adiabatic, what is the final temperature of the reaction product?

State all assumptions explicitly.

Use the following data, obtained (mostly) from the CRC Handbook of Chemistry & Physics:

- $M_{\text{Fe}} = 55.8$ g/mol
- $M_{\text{NaClO₃}} = 106.4$ g/mol
- $\rho_{\text{Fe}} = 7.87$ g/cm³
- $\rho_{\text{NaClO₃}} = 2.49$ g/cm³
- $C_p^{\text{NaCl}} = 53.73$ J/(mol K)
- $C_p^{\text{FeO}} = 45.25$ J/(mol K)
- $C_p^{\text{O₂}} = 30$ J/(mol K)
- $\overline{h}_f^{\circ, \text{NaCl}} = -98.23$ kcal/mol
- $\overline{h}_f^{\circ, \text{FeO}} = -63.7$ kcal/mol
- $\overline{h}_f^{\circ, \text{Fe}} = 0$
- $\overline{h}_f^{\circ, \text{O₂}} = 0$
- $\overline{h}_f^{\circ, \text{NaClO₃}} = -85.73$ kcal/mol

4. 14.96