MT 202 Metallurgical Thermodynamics

Fall 2006

Home Assignment 1

1. (Lupis, 1.5, p.44)
   (a) Calculate the heat of reaction (combustion) of methane (CH_4) with air at 298 K, assuming that the products of the reaction are CO_2 and H_2O (gas). Give your answer in Joules per mole of methane.
   (b) Determine the heat of combustion of ethane (C_2H_6).
   (c) Determine the heat of combustion of natural gas (per cubic meter of it at 298 K and 1 atm) with 83 % CH_4, 16 % C_2H_6 and 1 % nitrogen (N_2).

2. (Lupis, 1.6, p.44)
   The natural gas described in the above problem is mixed with air, also at 298 K, and in 10 % excess of the amount theoretically needed for complete combustion. The composition of air may be approximated as 21 % O_2 and 79 % N_2.

   Calculate the composition of the flue gases and their heat content on the basis of one mole of natural gas; assume that all of the fuel's carbon is converted into CO_2, and hydrogen to H_2O (gas).

   Describe how you would estimate the temperature of the flue gases.

3. (Laidler and Meiser, 2.12, p.84)
   A sample of liquid benzene weighing 0.633 g is burned in a bomb calorimeter at 298 K and 26.54 kJ of heat is evolved.
   (a) Calculate ΔU per mole of benzene.
   (b) Calculate ΔH per mole of benzene.

4. (Laidler and Meiser, 2.19, p.84)
   The bacterium *Acetobacter suboxydans* obtains energy for growth by oxidizing ethanol in two stages, as follows:

   C_2H_5OH (l) + $\frac{1}{2}O_2$ (g) $\rightarrow$ CH_3CHO (l) + H_2O (l)

   CH_3CHO (l) + $\frac{1}{2}O_2$ (g) $\rightarrow$ CH_3COOH (l)

   The enthalpy increases in the complete combustion (to gaseous CO_2 and liquid H_2O) of the three compounds ethanol (l), acetaldehyde (l) and acetic acid (l) (per mole of the compound) are, respectively, -1370.7, -1167.3 and -876.1 kJ mol^{-1}. Calculate the ΔH^o value for each of the above two reactions.

5. (Laidler and Meiser, 2.25, p.84)
   An ice cube at 273 K weighing 100 g is dropped into 1 kg of water at 293 K. Does all the ice melt? If not, how much of it remains? What is the final temperature? The latent heat of fusion of ice at 273 K 6.025 kJ mol^{-1}, the molar heat capacity of water C_p is 75.3 J K^{-1} mol^{-1}, and that of ice is 36.8 J K^{-1} mol^{-1}.

   What is the change in entropy of the system?

   Perform the same calculations with 10 ice cubes, each weighing 100 g dropped into 1 kg of water.

6. Calculate the entropy change during the (irreversible) freezing of one mole of water to ice at 263 K.

7. Consider an isolated system that contains two pieces of copper separated by an (internal) insulating wall. Initially, the first piece is at 400 K and the second is at 300 K. Calculate the entropy change in the system when the insulating wall is removed; assume that each piece has half a mole of copper in it.

8. Consider an adiabatically sealed box with a partition that separates it into two halves; one half of the box contains one mole of a gas, while the other is evacuated. Calculate the entropy change in the gas during the process of its (free) expansion on removing the partition.

9. Consider a box with a partition that divides it into two halves. If the two halves initially contain one mole each of two different gases, calculate the entropy change in the system during the process of mixing of the two gases on removing the partition.

10. Draw a schematic of molar enthalpy and molar entropy of zinc as its temperature is raised from 298 K (at which it is solid) to 2000 K (at which it is a gas) at a pressure of 1 atm.