Mechanical Engineering 804: Physical Gas Dynamics

Homework assignment #2 (due Wednesday, January 27)

1. In a mixture of CO_2, CO, and C at P=1 atm, the partial pressure of CO in equilibrium with CO_2 and C varies with temperature as follows:

T (^{0}C)	810	900	980
P_{CO} (atm)	0.931	0.978	0.991

Calculate the standard heat of reaction $CO_2 + C \rightarrow 2CO$, $\Delta H^{(0)}$

2. Using thermochemical data for O_2 and O (in a file thermo.dat, attached), calculate and plot the following parameters as functions of temperature at P=1 atm:

(a) equilibrium constant of the dissociation reaction, $O_2 = O + O$

(b) degree of dissociation (α) and mole fraction of O atoms, x_O

(c) enthalpy of the mixture, $H = \sum H_i x_i$

(d) "frozen" specific heat of the mixture, $C_{p,\ frozen} = \frac{d}{dT}\left[\sum H_i x_i\right]_{x_i = const} = \sum C_{pi} x_i$

(e) "equilibrium" specific heat of the mixture, $C_{p,\ eq} = \frac{d}{dT}\left[\sum H_i x_i\right] = \sum C_{pi} x_i + \sum H_i \frac{dx_i}{dT}$

(f) Qualitatively explain why the behavior of the two specific heats is so different.

The frozen specific heat assumes that, as the mixture temperature varies, chemical reactions do not occur at all (which could be realized in the experiment if heating or cooling occurs very rapidly, such as in a supersonic nozzle expansion or behind a shock wave). On the contrary, the equilibrium specific heat assumes that chemical reactions occur much faster than the temperature varies (infinitely fast).

3. Using Saha equilibrium equation, calculate and plot degree of ionization (φ) and mole fraction of electrons, x_e, in cesium vapor at P=0.01 atm as functions of temperature. Ionization energy of cesium is I=3.89 eV. What are the temperatures at which ionization fraction reaches 1% and 10%?