MASSACHESUTS ISNTITUTE OF TECHNOLOGY
FUNDAMNETALS OF ADVANCED ENEFRGY CONVERSION
SPRING 04
HOMEWORK III
DUE DATE, March 1, 2004

Most fuel cells run on pure hydrogen, or a mixture of inert gases and hydrogen, as a fuel; and pure oxygen, or air as an oxidizer. Storing hydrogen requires either a high-pressure tank, if kept in the gaseous phase, or a cryogenic tank, if maintained in the liquid phase. Instead. One can start with another, easier to store fuel, e.g., methane CH4, reform that fuel to H2 and CO, and use this mixture in the cell. High temperature solid oxide fuel cells are particularly suitable for processing such mixture. In the homework, you will use a thermochemical properties code, EQUIL to estimate the reforming requirements, and the cell efficiency.

The reforming process proposed here is a combined steam reforming and gas shift in one step, that is:

$$CH4 + 2H2O \Rightarrow CO2 + 4H2\,.$$
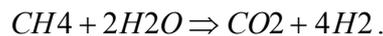
However, as we saw in class, this is a reversible reaction and at any state, the mixture, in general, is composed on CH4, H2O, CO, CO2, H2. The mixture composition depends strongly on the temperature.

- (1)   Use EQUIL to determine the composition of the gas mixture as it exits a reformer at T = 1100 K. Gaseous methane and liquid water enter the reformer at 300 K. The reformer operates at atmospheric pressure.

- (2)   Calculate the heat transfer to the reformer per unit mass of the mixture.

- (3)   Since the reformed gas contains, besides H2, CO, we will use it in a Solid Oxide fuel cell, which itself is maintained at 1100 K, and is supplied, besides the reformed gases, with air at 1100 K. Calculate the maximum electrical work transfer from the fuel cell, per unit mass of the reformer mixture, and the heat transfer to the cell from an environment maintained at 1100 K.

- (4)   Calculate the maximum EMF for this cell (open circuit voltage), knowing that for each molecule of H2 or CO consumed, the anode produces two electrons.

The curve in the next page shows the impact of the temperature at the reformer exit on the composition of the reformed gases. It was obtained using EQUIL, starting with one mole of CH4 and two moles of water in the liquid form.