Problem 4: Thermal cracking of ethane

The thermal cracking of ethane is carried out in long coils that are horizontally placed inside a gas-fired furnace with the burners are located on both sides of the tubes. Let's consider a case study where two coils are running in parallel through the furnace. The coil length is 100 m and the internal diameter of the tube is 0.108 m. The gas mixture feed per coil is 68.68 kg/(m^2·s). The ethane is 98.2 mol per cent pure, the impurities being C_2H_4 (1 mol per cent) and C_3H_6 (0.8 mol per cent). The inlet pressure is 2.93 bars and the inlet temperature is 680°C. The heat flow supplied to the reactor per unit of area is equal to 80 kJ/(m^2·s).

a) Study the evolution of the temperature and the concentration and yields (expressed by kg of component per 100 kg of ethane) of each component along the reactor.

b) Repeat part a) taking into account the effect of the pressure drop through the reactor. Assume that the viscosity of the gas mixture is equal to a 10^{-5} Pa·s, and that the friction factor can be calculated as: $f = 0.046\,\mathrm{Re}^{-0.2}$ where Re is the Reynolds number.

Data

Reaction	Total reaction order	k_0 (s^{-1} ó m^3/(kmol·s))	E (kJ/kmol)	$\Delta H^{\circ}_{298\,K}$ (kJ/kmol)
1. $C_2H_6 \rightarrow C_2H_4 + H_2$	1	$4.65\cdot10^{13}$	273020	136300
2. $C_2H_4 + H_2 \rightarrow C_2H_6$	2	$8.75\cdot10^{8}$	136870	-136300
3. $2C_2H_6 \rightarrow C_3H_8 + CH_4$	1	$3.85\cdot10^{11}$	273190	-11400
4. $C_3H_6 \rightarrow C_2H_2 + CH_4$	1	$9.81\cdot10^{8}$	154580	133900
5. $C_2H_2 + CH_4 \rightarrow C_3H_6$	2	$5.87\cdot10^{4}$	29480	-133900
6. $C_2H_2 + C_2H_4 \rightarrow C_4H_6$	2	$1.03\cdot10^{12}$	172750	-170800
7. $C_2H_4 + C_2H_6 \rightarrow C_3H_6 + CH_4$	2	$7.08\cdot10^{13}$	253010	-23100

Assume that the heat capacity of each component remains constant in the temperature range used.

	CH_4	C_2H_2	C_2H_4	C_2H_6	C_3H_6	C_3H_8	C_4H_6	H2
Cp (kJ/(kmol·K)	34.3	42.4	40.8	49.4	59.6	68.0	73.5	28.8