The heat capacities of the components are given by the equation

$$\frac{C_P}{R} = A + BT + CT^2 + \frac{D}{T^2},$$

with T in kelvin and with parameters given below:

	A	$10^3 \times B$	$10^6 \times C$	$10^{-5} \times D$
SO_2	5.699	0.801	–	−1.1015
O_2	3.639	0.506	–	−0.227
N_2	3.280	0.593	–	0.040
SO_3	8.060	1.056	–	−2.028

Problem 14.18: Consider the esterification reaction

$$CH_3COOH(l) + CH_3CH_2OH(l) = CH_3COOCH_2CH_3(l) + H_2O(l).$$

a) Calculate the equilibrium constant at 25 °C.
b) A reactor is loaded with a solution of acetic acid in ethanol containing 80% acetic acid by mole. The reaction is allowed to proceed to equilibrium at constant temperature of 25 °C. Assuming the components to form an ideal solution, calculate the composition of the equilibrium mixture.
c) Repeat the calculation using activity coefficients calculated from UNIFAC.

Problem 14.19: ~~(40%)~~ The water gas shift reaction

$$CO(g) + H_2O(g) = CO_2(g) + H_2(g),$$

is used to produce high-purity hydrogen. The reaction is carried out in a 10 m^3 reactor that contains a copper catalyst and is operated at 1000 K and 1.5 bar. The equilibrium constant is given by

$$K(T) = e^{-5.057+4951.4/T},$$

where T is in K.
a) Is the reaction exothermic or endothermic?
b) Calculate the value of K_P at 1000 K, with P in bar. What are the units of K_P?
c) The composition of the reactor feed is 1 mole of CO and 5 moles of steam. Assuming the reaction to reach equilibrium, what is the composition (in terms of mole fraction) of the stream exiting the reactor?
d) After reading your report, your boss points out that for fuel cell applications, the mol fraction of CO must not exceed 5×10^{-3} in order to avoid poisoning of