ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2018 SESSION

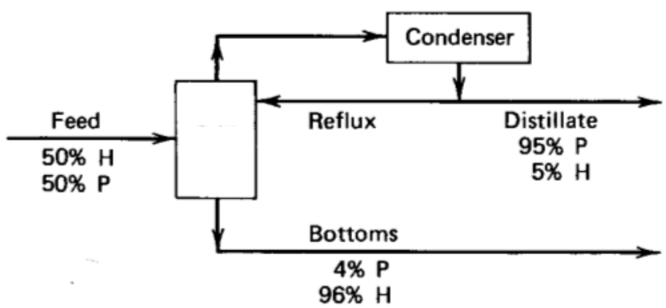
Open-book examination Calculators : only authorized models Duration : 3 hours

Total : 20 pts

16-CH-A1 PROCESS BALANCES AND CHEMICAL THERMODYNAMICS

(4 pts) 1. Distillation columm

A distillation column is to be designed to separate a liquid solution mixture containing 50 wt % pentane, C_5H_{12}, (P) and 50 wt % hexane, C_6H_{14}, (H). The stream at the top of the column contains 95 wt % hexane is condensed and a part is returned to the column at a reflux ratio of 0.6 kg/kg of distillate.



For a feed of 1000 kmol/h:

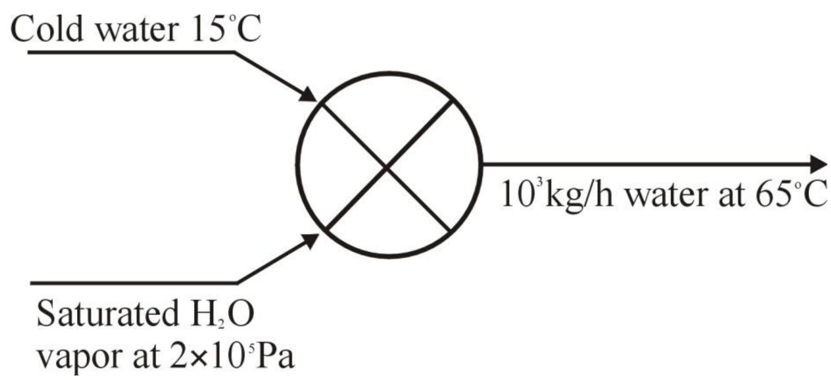
a) What is the flow rate of the feed in kg/h?

b) Calculate the flow rates of the distillate and bottom product (kg/h).

c) Calculate the flow of the distillate returning to the column.

(4pts) 2. Heating of water

1000 kg/h of hot water at 65°C and 10^5 Pa are required in an industrial plant. It is proposed to mix a current of cold water at 15°C and saturated water vapor at 2×10^5 Pa through a valve as illustrated. Heat losses to the surrounding represent 10 % of the latent heat of condensation of the saturated vapor.



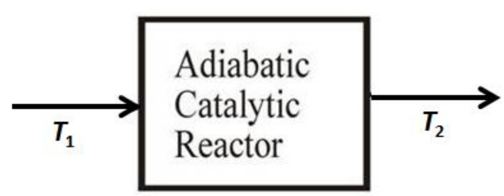
a) Determine the required flow rates (kg/h) for the cold water and the saturated steam.

b) Is this process reversible? Compute the variation of entropy for this process and conclude.

(4pts) 3. <u>Removal of CO</u>

To reduce the emission of CO in the atmosphere of the effluent of a plant, it is proposed to use a catalytic reactor operating under adiabatic conditions to convert the CO.

The plant effluents at 25°C and 1 atm contain 3% (mol) of CO and 97% of air. This stream is heated up to temperature 300 °C (T_1) and then fed to the reactor.



a) Assuming a conversion at equilibrium of 100% at the exit of the adiabatic reactor, determine the temperature (T_2) of the stream leaving the reactor.

b) Check the value for the conversion using the equilibrium constant from the attached figure (in appendix) and obtain the gas composition at the exit of the reactor.

N.B. We assume that the heat capacities are constant and equal to:

$$\overline{C}^{o}_{p_{O_2}} = \overline{C}^{o}_{P_{N_2}} = 29.3 \text{ kJ/kmol.K}$$

$$\overline{C}^{o}_{p_{CO}} = 33.4 \text{ kJ/kmol.K}$$

$$\overline{C}^{o}_{p_{CO_2}} = 56.4 \text{ kJ/kmol.K}$$

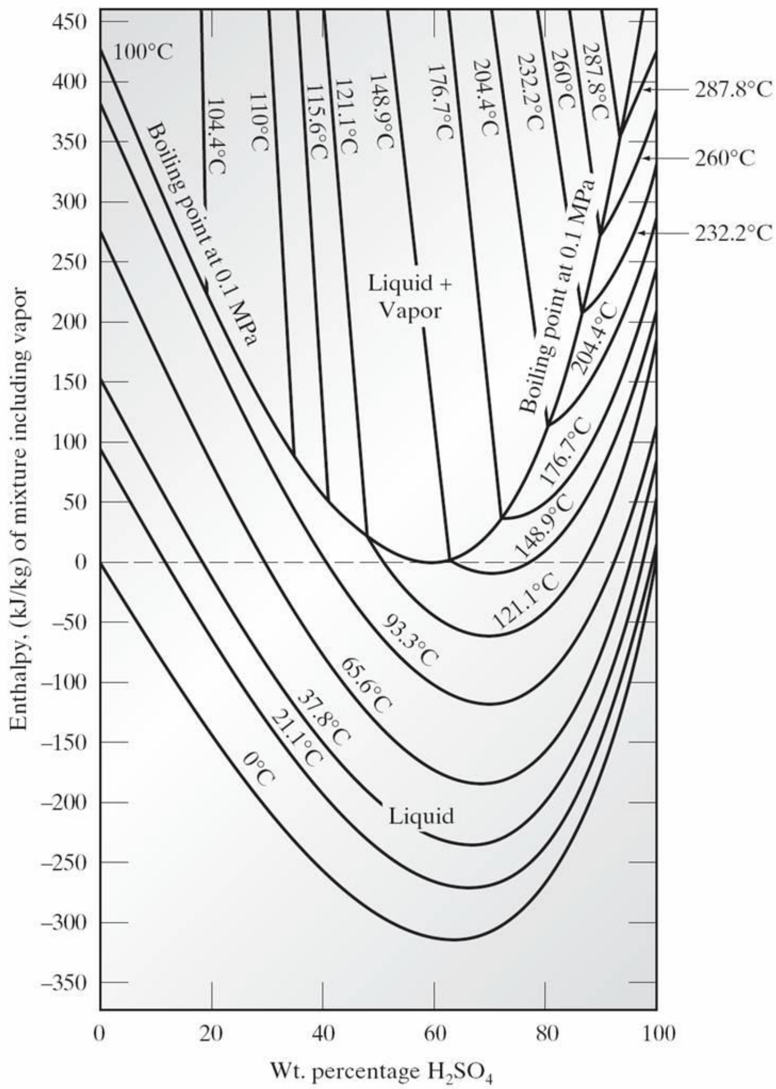
Standard heat of formation at 25 °C:

$$\Delta \bar{h}^{o}_{f_{CO_2}} = -393.5 \text{ kJ/mol}$$

$$\Delta \bar{h}^{o}_{f_{CO}} = -110.5 \text{ kJ/mol}$$

(4pts) 4. <u>Sulfuric acid</u>

The enthalpy concentration diagram for aqueous sulfuric acid is the following:



1000 kg/h of 40 wt % aqueous sulfuric acid (stream P) is to be prepared using 20 wt% sulfuric acid (stream A) and a 98 wt % one (stream B), both streams at 21.1 ^{o}C.

a) Determine the flow rates of streams A and B, kg/h.
b) What will be the temperature of stream P if the process is adiabatic?

c) How much heat must be added or removed if the process is isothermal?

(4pts) 5. Compression of liquid methanol

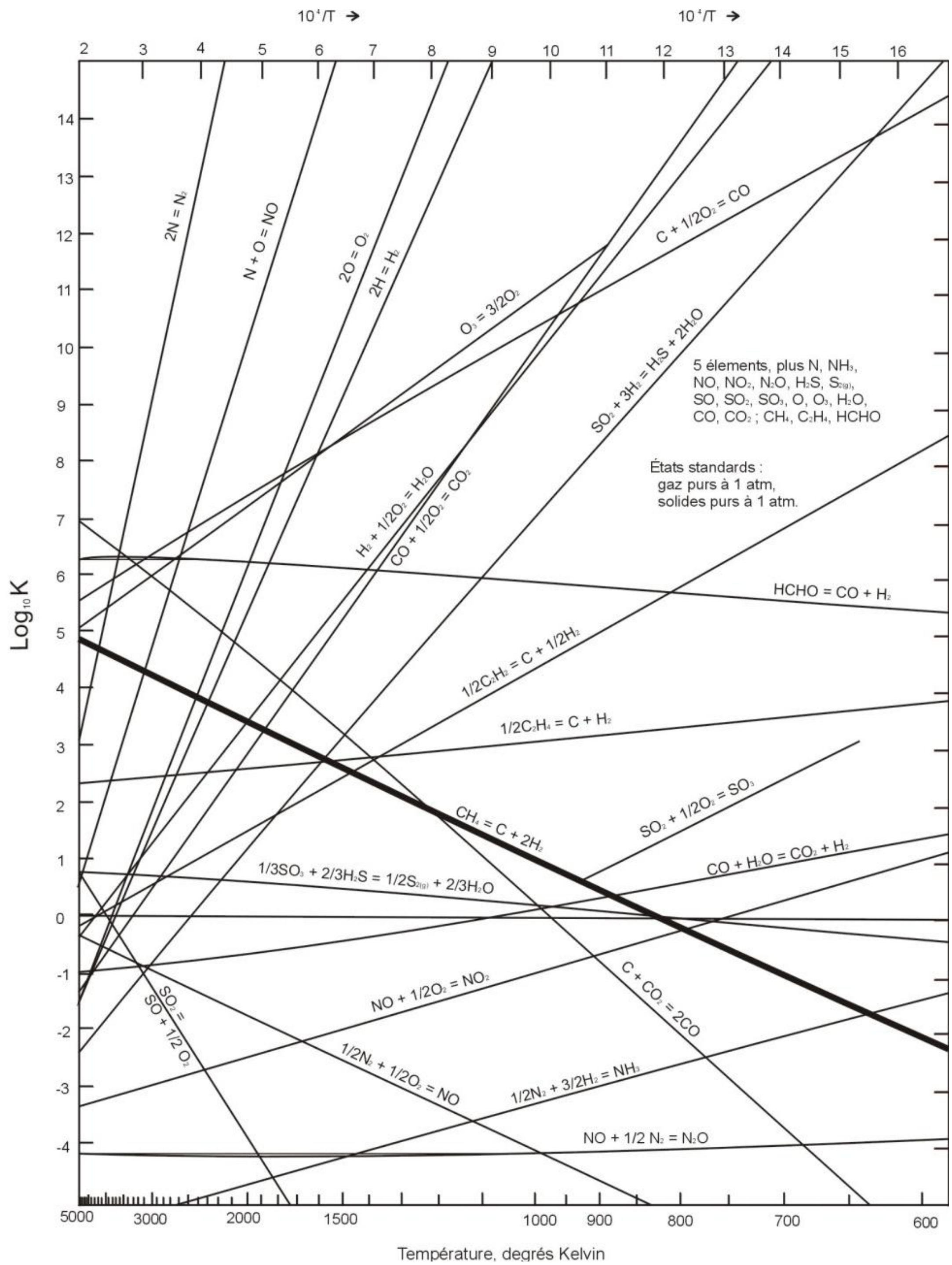
10 L of liquid methanol at 20°C and 100 kPa are compressed in a reversible and isothermal process to the pressure of 20 MPa. The isothermal compression coefficient of methanol is $\beta_T = 1.22\times10^{-9}\ \text{Pa}^{-1}$ and its density is $\rho = 787\ \text{kg/m}^3$.

a) First show that for an isothermal compression the work per kg is given:

$$w = -\left(\int_1^2 v\beta_T P dP\right)_T = -\left(\int_1^2 \frac{1}{\rho}\beta_T P dP\right)_T$$

b) Obtain the required work, J.

c) Does the entropy of the methanol increase or decrease? Briefly discuss.



Equilibrium constants for combustion and reduction reactions