2009W CHBE 241 MATERIAL and ENERGY BALANCES

Department of Chemical and Biological Engineering, The University of British Columbia

MIDTERM (2) 10. November. 2009 **CHBE 2.04 (3.00 - 4.50) pm**

Problem 1 (15 points)

Hydrogen (H_2) can react with oxygen by *Reaction 1* to produce hydrogen peroxide (H_2O_2) or by *Reaction 2* to produce water (H_2O)

$H_2 + O_2 \rightarrow H_2O_2$ *Reaction 1*

$H_2 + O_2 \rightarrow H_2O$ *Reaction 2*

Reactions 1 and 2 are competitive reactions that occur in parallel when hydrogen reacts with oxygen on a special catalyst. There are no other reactions.

The initial reaction mixture (before reaction) contains: 5 kmol H_2 + 3 kmol O_2

The final reaction mixture (after reactions) contains: 1 kmol H_2O_2 + 2 kmol H_2O + unreacted H_2 and O_2

a) (5 points) Balance the equations
b) (10 points) Calculate the conversion of H_2 and the extents of Reactions 1 and 2.

Problem 2 (15 points)

Write the material balance equations and draw the diagrams for each of the following situations:

a) Water is pumped into a large tank that contains sugar crystals. The sugar dissolves and a sugar solution is pumped out of the reservoir
b) Ethylene and air are pumped into a reactor operating at steady-state where 30% of the ethylene reacts with oxygen to produce ethylene oxide. System: reactor. Component: ethylene oxide.
c) Ethylene and air are pumped into a reactor operating at steady-state where 30% of the ethylene reacts with oxygen to produce ethylene oxide. System: reactor. Component: Nitrogen.

Problem 3 (20 points)

1000 g/h of a 10wt% glucose solution is fed to an isomerization reactor where part of the glucose ($C_6H_{12}O_6$) is converted to fructose. The reactor output steam is 9% wt glucose solution. a) (5 points) What is R_g and ε

b) (5 points) What is the yield of fructose from glucose and what is the fractional conversion

The products stream of the reactor is fed to a separator. Two new product streams are produced.

c) (5 points) One of the streams is 400 g/h of a 10% glucose/1% fructose. What is the fractional recovery of this stream?

d) (5 points) What is the composition and fractional recovery of the second stream?

Problem 4 (20 points)

Water flows into a tank. The water flow rate m_w is a function of time t, where m_w is in kg/h and t is in hours.

a) How much water (kg) is in the tank in 2 h if $m_w = 1+2t$ and the tank is initially empty?
b) How much water (kg) is in the tank in 1 h if $m_w = 3e^{2t}$ and the tank initially contains 10kg of water.

Problem 5 (30 points)

Fresh juice contains 88wt% water and 12 wt% solids. A fruit juice processor buys fresh juice every week and makes concentrated juice by evaporating most of the water off. When the evaporator is clean, it removes water at a rate of 1000 kg/day. Over the course of a week, however, the evaporator worsens because of fouling. At the end of the week the evaporator is shut down and cleaned. The plant engineer estimates the evaporation rate decreases by 10%. The concentrated juice must be 44% solids. Derive an equation that expresses the fresh feed rate as a function of the day. How much fresh juice should the processor buy per week?