Seat No. 

King Mongkut' University of Technology Thonburi
Midterm Examination—1/2008
ChE 103 Material and Energy Balances (Bilingual program)

Date: Monday 21 July 2008, 9:00-12:00

Notes:

1. This exam paper includes 5 problems (100 points) in a total of 11 pages.
2. It is an open-book/notes examination.
3. A calculator and a ditionary are allowed.
4. Students are not allowed to take any exam materials/papers out of the exam room.

Student Name_____ Student ID_____

Written by

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This exam paper has been evaluated and approved by the Department of Chemical Engineering's Committee.

(Assoc. Prof. Dr. Anawat Sangpet)
Departmental Chair

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1. Flue gas composes of 0.6 % CH_4, 2.4% O_2, 85.0% N_2 and 12.0% CO_2 by mole on a dry basis. The humidity of this flue gas is 16.7 % by mole, and the molar flow rate of the gas is 20 kmol/hr at 1 atm gauge and 200°C. Determine

a. The mole fraction of each component on a wet basis. (4 points)

b. The mass fraction of each component on a wet basis. (4 points)

c. The molar flowrate of CH_4. (2 points)

d. The average molecular weight of the flue gas. (4 points)

e. Assuming that this flue gas is an ideal gas, determine the flue gas density at 1 atm gauge and 200°C. (6 points)

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2. Concentrated juice is produced by heat vaporization from fresh juice in an evaporator. In this process, a volatile flavor component (F) and water are evaporated during heating, resulting in the loss of flavor and taste of the juice. To overcome this problem, a fraction of the fresh juice will be by-passed the evaporator and combined with the concentrated juice output stream from the evaporator. Given information:

   - The fresh juice contains 10%wt total solid (S) and 500 ppm (by weight) of the flavor (F).
   - At the evaporator, the flavor component (F) is completely evaporated while none of the total solid (S) is evaporated.
   - The concentrated juice obtained from the process contains 40%wt of total solid (S) and 200 ppm (by weight) of flavor (F).
   - Use 100 kg/hr of fresh juice as the basis of calculation
   - The operation is at steady state.

a. Draw the process flowchart and label known information and unknown variables for each process stream. (10 points)

b. Perform degree of freedom analysis. (5 points)

c. Calculate the rate of water evaporated from the evaporator unit. (5 points)

d. Calculate the concentration of the total solid (%wt) of the concentrated juice in the evaporator outlet stream. (5 points)

e. Calculate the ratio of the by-pass stream to the fresh juice feed stream. (5 points)

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3. (10 points) Ammonia is burned to form nitric oxide in the following reaction:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

If equal mass flow rate of NH_3 and O_2 are fed to a continuous reactor at 100 kilograms per hour:

(a) What is the limiting reactant?

(b) What is the excess reactant?

(c) Calculate the fractional excess of the excess reactant.

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4. (20 points) A dehydrogenation of ethane in a reactor:

$$C_2H_6 \rightarrow C_2H_4 + H_2$$

Ethane is fed to a reactor and the reaction products are separated into two streams. The first stream contains only ethylene and hydrogen gas. The second stream that contains unreacted ethane and 10% of the ethylene in the first stream is recycled to the reactor. Calculate the molar compositions of the products in the first stream.

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5. (20 points) Methane is burned with air. No carbon monoxide is present in the combustion products. Calculate the molar composition of the stack gas on a wet basis if the feed contains 20% excess air and 90% conversion of methane is achieved.