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King Mongkut' University of Technology Thonburi
Midterm Examination—1/2009
ChE 103 Material and Energy Balances (Bilingual program)

Date: Tuesday 28 July 2009, 13:00-16:00

Notes:

1. This exam paper includes 7 problems (100 points) in a total of 12 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.

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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. Given the gas constant (R) equals 8.3143 kPa·m^3 kmole^{-1} K^{-1}, show that it is equivalent to R = 0.7302 atm·ft^3 lb-mol^{-1} °R^{-1} by using the table of conversion factors. (4 points)

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2. A cubic tank that is 1 ft wide, 2 ft long, and 10 ft deep is full with water (the level of water is 10 ft in height). What is the pressure at the base of the tank in atm if the tank is an open end, and the atmospheric pressure is 1 atm? (4 points)

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3. A stripper of CO_2 from ethylene oxide (EO, C_2H_4O)

A feed containing EO, CO_2 and H_2O is fed to a stripper to separate CO_2 from EO as shown in Figure 1. To perform material balances on this process, some data on flow rates and stream compositions are collected and shown in Table 1.

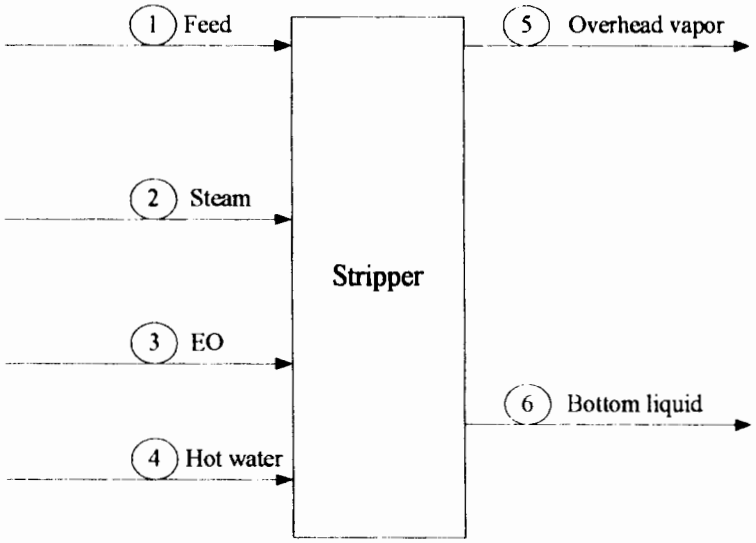

Figure 1. A flowchart

Table 1. Information for the stripping process of CO_2 from ethylene oxide

Stream	ข้อมูล
1. Feed	Total mass flow rate = 44000 kg/h Mass composition: EO 8.5%, CO_2 0.2% and H_2O 91.3 % by mass
2. Steam (H_2O)	Mass composition: EO 0.2%, and steam (H_2O) 99.8 % by mass
3. EO	Mass flow rate of pure EO = 800 kgEO/h
4. Hot water	Mass flow rate of water = 2500 kgH_2O/h
5. Overhead vapor	No H_2O in the overhead vapor (H_2O = 0%)
6. Bottom liquid	Total mass flow rate 2500 kmol/h Molar composition: EO 4 % and H_2O 96 % by mole, and no CO_2 is present

3.1 Calculate the total mass flow rate and % mass composition of the bottom liquid (stream6). (4 points)

3.2 Fill in all known variable values, and label unknown stream variables on the Figure 1. (9 points)

3.3 Perform degree of freedom analysis (3 points)

3.4 Calculate the mass flow rate and %mass composition of the overhead vapor (stream 5) (9 points)

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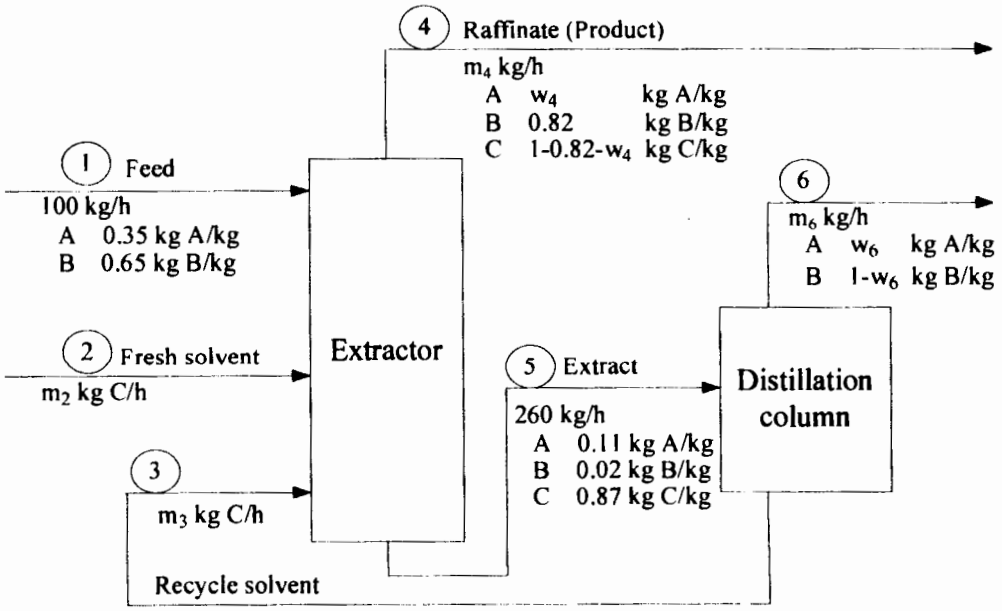
4. An extraction process of a mixture of A and B using C as a solvent is shown in the flow chart below.

A mixture of A and B (stream 1), the fresh solvent C (stream 2) and recycle solvent C (stream3) are fed to an extractor. The raffinate (stream 4) which is a product leaves the extractor at the top. The extract (stream 5) leaving the extraction unit is further sent to a fractionator to recover the solvent that is recycled back to the extractor (stream 3). Note that the stream 3 only contains the solvent C, while the stream 6 has no solvent C. The fresh solvent (stream 2) is a pure solvent.



(a) Perform degree of freedom analysis on the overall process and each subsystem. (5 points)
(b) Determine m_2, m_3, m_4, w_4, m_6 and w_6 (12 points)

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5. Acetylene is hydrogenated to form ethane. The feed to the reactor contains 1.50 mol H_2/mol C_2H_2.
   (a) Calculate the stoichiometric reactant ratio (mol H_2 react/mol C_2H_2 react) and the yield ratio (kmol C_2H_6 formed/kmol H_2 react.) (5 points)
   (b) Determine the limiting reactant and calculate the percentage by which the other reactant is in excess. (5 points)
   (c) Calculate the mass feed rate of hydrogen (kg/s) required to produce $4x10^6$ tons of ethane per year, assuming that the reaction goes to completion and that the process operates for 24 hours a day, 300 days a year. (10 points)

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6. A catalytic reactor is used to produce formaldehyde from methanol in the reaction

$$CH_3OH \rightarrow HCHO + H_2$$

A conversion of 60.0% is achieved in the reactor. The methanol in the reactor product is separated from the formaldehyde and hydrogen in a multiple-unit process. The production rate of formaldehyde is 900.0 kg/h.

(a) Calculate the required feed rate of methanol to the process (kmol/h) if there is no recycle. (10 points)

(b) Suppose the recovered methanol is recycled to the reactor and the single-pass conversion remain 60%. Determine the required fresh feed rate of methanol (kmol/h) and the rates (kmol/h) at which methanol enters and leaves the reactor. (10 points)

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7. Butane (C_4H_{10}) is burned with air. No carbon monoxide (CO) 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 butane is achieved. (10 points)