PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Midterm Examination: Semester II

Date: 26 December 2008

Subject: 230 - 432 Chemical Engineering Plant

Design

Academic Year: 2008

Time: 13.30 - 16.30

Room: A401

Student Name: .... Code: ....

Number of questions : 4

Time : 3 hours

Total marks : 100

Books and notes are not allowed

Calculators and writing in pencil are allowed.

Question	Full Marks	Marks Received
1	35	
2	25	
3	15	
4	25	
Total	100	

ทุจริตในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

1. a) Give the names of two international licensors and two international contractors in chemical process industries. (3 marks)

    b) Give sources of information for process survey in designing a chemical process plant. (3 marks)

    c) What are the job responsibilities of a process engineer in a chemical company? (3 marks)

    d) List all steps in estimating the fixed-capital cost for a new chemical plant investment. (3 marks)

    e) From the "heuristics" for process design, what is the criterion used when there is a valuable or toxic reactant in the process? (3 marks)

    f) Consider the process shown below. The process requires a reactor to change the feed into product and byproduct. A separation system consisting of two distillation columns is needed to separate the product at the required purity. The unreacted feed is recycled, and the product and byproduct are removed from the process. The flowsheet shows heating and cooling by external steam and cooling water.

    Redraw the flowsheet in order to further improve heat recovery by exchange of heat between those streams which need to be cooled and those which need to be heated. (Note that stream1, 8 and 9 are feed, product and byproduct, respectively.) (5 marks)
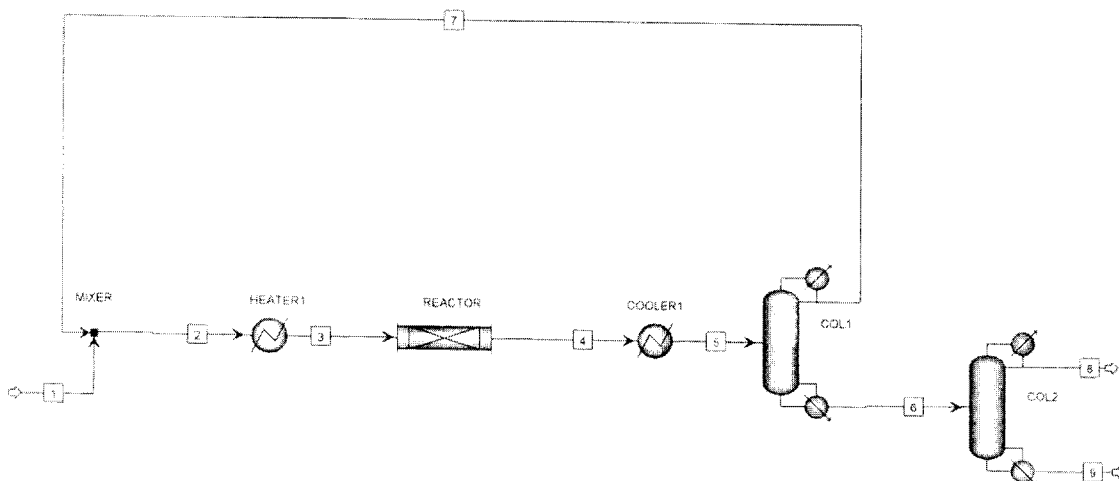
g) Acetone is produced by catalytic dehydrogenation of isopropyl alcohol. The reaction is as follow:

$$(CH_3)_2CHOH \longrightarrow (CH_3)_2CO + H_2$$

isopropyl alcohol   acetone
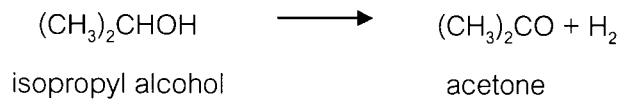
Chemicals	Boiling Point (^{o}C) @ 1 bar	Mol Wt
Isopropyl alcohol	82.5	60.09
Acetone	56.5	58.08
Water	100	18.01

Zinc oxide is used as the catalyst in the reactor. The reaction conditions are 40 psig pressure and 400°C. The reactor conversion is 85 per cent per pass through the reactor. The reactor products and the remaining reactants are cooled before separations. Water is used to scrub acetone vapor in the gas product from the reactor into liquid phase. High purity of 95% is required for acetone product. Draw a process flow diagram for this process. Give reasons for sequence or order of position of equipment. Show equipment types and chemical components on each process stream.

(15 marks)

2. In nitric acid process, the hot gas mixture from the oxidizer is cooled down and the removed heat is used to produce steam for plant uses in a waste-heat boiler. There is no reaction and composition change in the gas. The information for component flows and conditions at the waste-heat boiler are given below.

Steam 11 Bar, 184°C   Water 25°C

Hot gas 900°C   Cooled gas 234°C
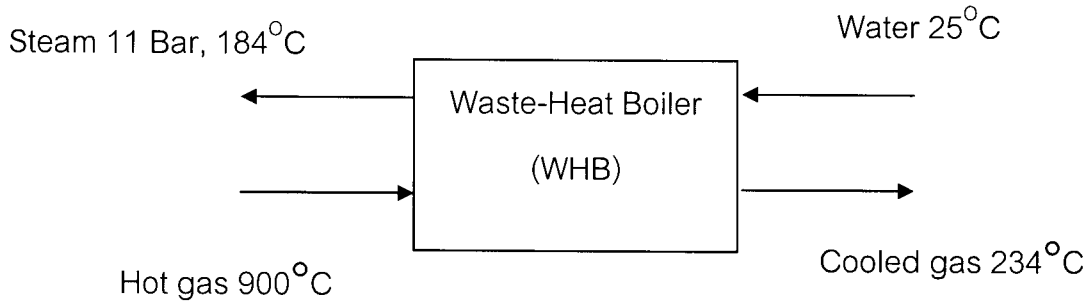
Hot gas component flow rates and temperature constant values for C_p are:

Component	Flow rates, kg mol/h	Constant values for C_p			
		a	b	c	d
NO	41.3	a_1	b_1	c_1	d_1
H_2O	64.5	a_2	b_2	c_2	d_2
O_2	29.2	a_3	b_3	c_3	d_3
N_2	309.6	a_4	b_4	c_4	d_4

The C_p values for all components change with temperature according to equation

$C_p = a + bT + cT^2 + dT^3$ kJ/kgmol K where T is temperature, K.

a) Write a spreadsheet for Excel program on the provided sheet for calculation of heat transferred to steam. Show the cell formula for the heat content of NO component in the hot gas inlet stream in kJ/kg mol.

(15 marks)

b) If heat transferred to steam is 10.0 GJ/h, calculate the amount of steam produced in kg/h. The enthalpy of saturated steam at 11 bar is 2781 kJ/kg and enthalpy of water at $25^{\circ}C$ is 86 kJ/kg.

(5 marks)

c) In a process where there is purge and recycle of reactants from a separator to the reactor, explain how you would solve mass balance by hand calculation and excel spreadsheet calculation.

(5 marks)

Answer to Q2a.

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Answer to Q2a (continued)

	A	B	C	D	E	F	G	H	I
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3. The chemical product D is produced in two separated reaction steps in two reactors by reaction (3.1) and (3.2). At reactor R-1, the reactant A enters as a gas at $25^{\circ}C$ and reactant B enters as a liquid at $25^{\circ}C$. The intermediate product C leaves as a vapor at $183^{\circ}C$ and is fed to reactor R-2 where it is heated and decomposed to product D and byproduct E.

$$A + B \longrightarrow C \qquad \text{reaction (3.1)}$$
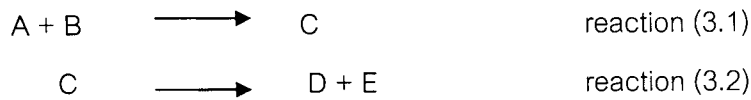
$$C \longrightarrow D + E \qquad \text{reaction (3.2)}$$

The reaction conversions are not complete. For each kg mol of D produced in the process, 0.54 kg mol of C is produced in reactor R-1.

Standard enthalpy of reaction at $25\,^{\circ}C$ for reaction (3.1) is – 180 MJ/kg mol of C

Standard enthalpy of reaction at $25\,^{\circ}C$ for reaction (3.2) is 120 MJ/kg mol of D

Chemicals	C_p MJ/kg mol K	Heat of vaporization MJ/kg mol
A	0.049	14
B	0.036	20
C	0.125	32
D	0.182	18
E	0.058	16

At datum temperature $25\,^{\circ}C$, calculate Q_{R-1}, the heat that must be added or removed at reactor R-1 in MJ per Kg mol of product D.

(15 marks)

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4.a) In designing a gas absorber for production of nitric acid, suggest factors that should be considered in details.

(5 marks)

b) Suggest the factors that should be considered in the layout of the above gas absorber in question 4a in the plant.

(3 marks)

c) In selecting the plant site or location for a new process plant, a number of factors must be considered. Write short comments on

1) Transportation facilities

2) Waste disposals

(5 marks)

d) Explain the meanings of LD_{50}, TLV-TWA, and OSHA

(6 marks)

e) Explain the meaning of Tray Rating.

(3 marks)

f) For Preflash column in Aspen Plus petroleum processing plant, compare flow rates of C1 (hydrocarbon with one carbon atom) component in LIGHTS and NAPHTHA top products.

(3 marks)