PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Midterm Examination : Semester II — Academic Year : 2006

Date : 19 December 2006 — Time : 13.30 - 16.30

Subject : 230 - 432 Chemical Engineering Plant Design — Room : A401

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

Number of questions : 4

Time : 3 hours

Total marks : 110

Books and notes are not allowed

Calculators and writing in pencil are allowed.

Question	Full Marks	Marks Received
1	30	
2	25	
3	30	
4	25	
Total	110	

ทุจริตในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

1. a) Describe the three business sectors in chemical process industries.

   b) What factor or figure would you use to determine the business size of a chemical company?

   c) What factor or figure would you use to determine how active a chemical company is in research and development of its product and technology?

   d) Give a list of three names of contractors with operating business in chemical process industries in Thailand.

   e) From the "heuristics" for equipment design, what parameters are used to determine the operating pressure in a distillation column?

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

f) Explain the heuristic for heat removal in process design which says that "To remove a highly exothermic heat of reaction, consider the use of excess reactant or an inert diluent. These affect the distribution of chemicals and should be inserted early in process synthesis".

(30 marks)

Answer to Q1.

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

Answer to Q1.(continued)

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

2. a) The lower flammability limits, LFL values for n-octane and n-nonane are 0.1 and 0.8 percent by volume in air, respectively. If the working environment in your company contains the mixture of 50 mole percent n-octane and 50 mole percent n-nonane excluding air, determine if it is safe when the concentration of this mixture is 0.9 percent by volume in air.

Note that:

$$LFL_{mix} = \frac{1}{\sum_{i=1}^{C} (y_i/LFL_i)}$$

where LFL_i is the lower flammability limits of species i, and y_i is the mole fraction of species i in the vapor, and C is the number of chemical species in the mixture, excluding air.

b) If you are in a project team which is choosing a new plant site, what would you consider or look for on the following two factors?

b.1) Water supply.

b.2) Taxation and legal restrictions.

c) What is the minimum distance a chemical company must be located away from a school?

d) What is the maximum allowable vertical height of stairs on/at a unit operation in a chemical company?

e) An excel spreadsheet on next page shows estimation for exit temperature from the reactor. Stream 3 and 4 are feed and product streams, respectively. T_3 is inlet temperature and T_4 is the outlet temperature at the reactor for nitric acid process. Try to understand the cell layout. Write the formula for cell H4.

(25 marks)

Answer to Q2.

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

Answer to Q2. (continued)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Energy balance at the Oxidizer						File:ENERBAL1.XLS					
2	Tref(K) =	298	T3 (K) =	477	T4 (K) =	1151.7						
3	COMP	FEED 3 (Kmol/h)	PROD 4 (Kmol/h)	a	b	c	d	H at T3 (KJ/Kmol)	H at T4 (KJ/Kmol)	H at T3 (KJ/h)	H at T4 (KJ/h)	
4	NH3	43	0	27.32	2.383E-02	1.707E-05	-1.186E-08	6880.15	41422.05	295846.43	0.00	
5	O2	82.1	29.2	28.11	-3.680E-06	1.746E-05	-1.065E-08	5392.23	28068.69	442702.06	819605.69	
6	N2	308.7	309.6	31.15	-1.360E-02	2.680E-05	-1.168E-08	5237.52	26473.10	1616822.20	8196070.46	
7	NO	0	41.3	29.35	-9.400E-04	9.750E-06	-4.190E-09	5409.20	27518.53	0.00	1136515.22	
8	H2O	0	64.5	32.24	1.924E-03	1.050E-05	-3.600E-09	6152.16	32391.61	0.00	2089259.02	
9										2355370.69	12241450.38	
10	Exothermic Reactions				Kmol/h	KJ/Kmol	KJ/h					
11				rxn1 exoht	41.30	-226334.00	-9347594.2					
12				rxn2 exoht	1.70	-316776.00	-538519.2					
13				total exo ht			-9886113.4					
14												
15	ENERGYBALANCE :		H3 = exo ht + H4									
16			H3 - exo ht	12,241,484.09	KJ/h							
17			H4	12,241,450.38	KJ/h							
18				BALANCED !								

Answer:

Formular for cell H4 is ....

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

3. Styrene is produced from toluene and methanol using a catalyst. Liquid toluene and methanol in storage tanks (at 30°C, 101 kPa) are fed to respective vaporizers. The saturated vapor feed streams of toluene and methanol are mixed in the stoichiometric ratio, superheated in an interchanger and a fired heater, and then fed to a catalytic reactor where the following reactions take place:

$$\underset{\text{toluene}}{C_6H_5CH_3} + \underset{\text{methanol}}{CH_3OH} \rightarrow \underset{\text{styrene}}{C_6H_5C_2H_3} + H_2O + H_2$$

$$C_6H_5CH_3 + CH_3OH \rightarrow \underset{\text{ethylbenzene}}{C_6H_5C_2H_5} + H_2O$$

The byproduct ethylbenzene by the second reaction is also sold as a commercial product. Reaction data are shown below.

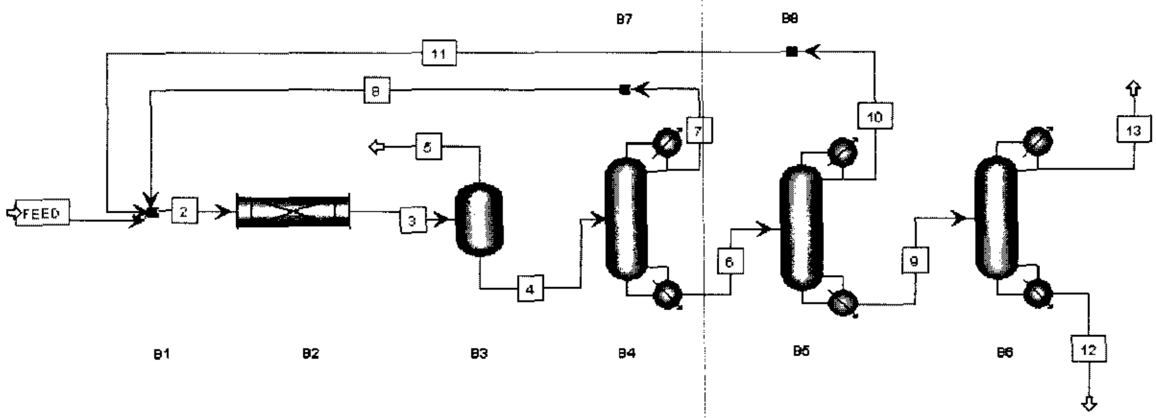
Inlet Temperature, °C	525
Inlet pressure, kPa	400
Conversion	0.82
Yield	0.72
Reaction rate	190
Conversion = moles toluene reacted/mole toluene fed	
Yield = moles styrene formed/moles toluene reacted	
Reaction rate = moles toluene reacted/m^3 reactor volume/min	

A process flow diagram is shown on next page.

Net production rate of styrene product is 346.6 kmol/hr.

Styrene is produced according to the stoichiometry of the reactions.

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



B2 = reactor B3= separator B4, B5, B6 = distillation column

Stream	Components
Feed	methanol, toluene
5	hydrogen
8	methanol, recycle
11	toluene, recycle
12	styrene
13	ethylbenzene, water

Estimate the followings by filling in the table provided.

(30 marks)

Answer to Q3.

Required Answers	Value
Feed rate of toluene in stream 2, kmol/hr	
Recycle toluene in stream 11, kmol/hr	
Fresh feed of toluene in FEED stream, kmol/hr	
Ethylbenzene in stream 13, kmol/hr	
Hydrogen in stream 5, kmol/hr	
Water in stream 13, kmol/hr	
Reactor volume, m^3	

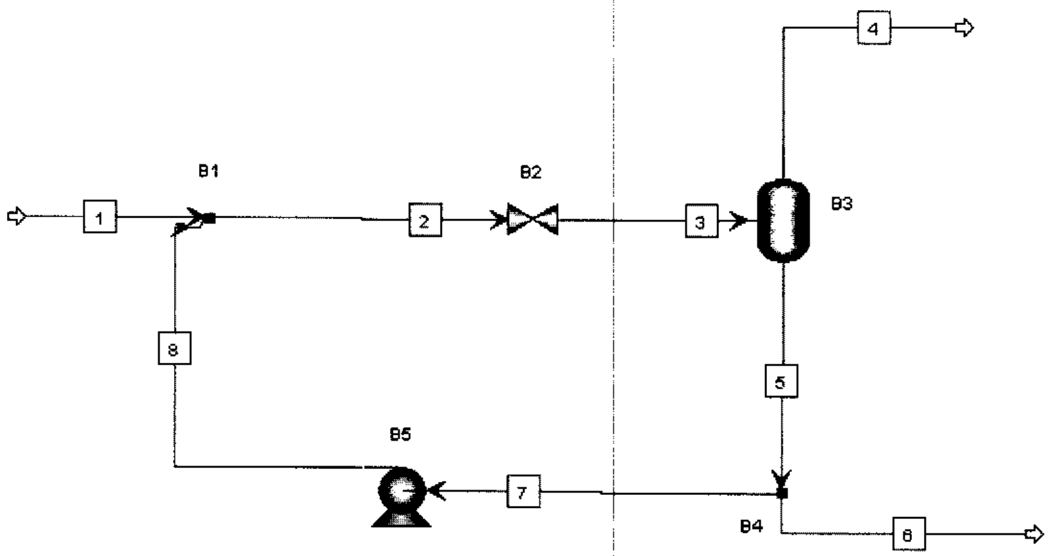
Student Name: .... Code : ....

4. Aspen Plus simulation program has been used to simulate a flash process with recycle. PFD and result summary of streams are shown below and on the following page.

a) Describe in details the steps for drawing and specifying all of information for this process flow diagram before running the simulation.

b) If there is heat removal at the separator, describe how you would redraw and simulate the program.

(25 marks)



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

Result Summary Streams Material

2		Streams							
3		1	2	3	4	5	6	7	8
4	Temperature C	85	65.48087	65.484911	5	5	5	5	5.1059215
5	Pressure bar	6.8947573	6.8947573	6.8947573	1.7236893	1.7236893	1.7236893	1.7236893	6.8947573
6	Vapor Frac	0.5918542	0.3605944	0.3606379	1	0	0	0	0
7	Mole Flow kmol/hr	35.013144	49.701154	49.701154	12.981387	36.719767	22.03186	14.687907	14.687907
8	Mass Flow kg/hr	3640.5323	5671.2678	5671.2678	594.44437	5076.8242	3046.0945	2030.7297	2030.7297
9	Volume Flow cum/hr	84.547596	70.774155	70.782814	168.21636	4.4170815	2.6502489	1.7668326	1.7670248
10	Enthalpy MMkcal/hr	-0.867415	-1.292107	-1.292107	-0.34973	-1.062333	-0.6374	-0.424933	-0.424691
11	Mole Flow kmol/hr								
12	METHA-01	1.413698	1.4302966	1.4302966	1.3888015	0.0414943	0.0248966	0.0165977	0.0165977
13	ETHAN-01	1.5084729	1.6268198	1.6268198	1.3309635	0.2958565	0.1775133	0.1183422	0.1183422
14	PROPA-01	7.200447	8.9314235	8.9314235	4.6040731	4.3273485	2.5964091	1.7309394	1.7309394
15	N-BUT-01	6.7894404	9.9516384	9.9516384	2.0461938	7.905445	4.743267	3.162178	3.162178
16	ISOBU-01	9.1774504	12.889175	12.889175	3.6099584	9.2792168	5.5675301	3.7116867	3.7116867
17	HEXAC-01	8.9236349	14.8718	14.8718	0.0013966	14.870407	8.922244	5.9481627	5.9481627

2		Streams							
3		1	2	3	4	5	6	7	8
4	Mole Frac								
5	METHA-01	0.0403762	0.0287779	0.0287779	0.1069841	0.00113	0.00113	0.00113	0.00113
6	ETHAN-01	0.043083	0.032732	0.032732	0.1025286	0.0080571	0.0080571	0.0080571	0.0080571
7	PROPA-01	0.2056498	0.1797025	0.1797025	0.3546673	0.1178479	0.1178479	0.1178479	0.1178479
8	N-BUT-01	0.1939112	0.2002295	0.2002295	0.1576252	0.2152913	0.2152913	0.2152913	0.2152913
9	ISOBU-01	0.2621144	0.2593335	0.2593335	0.2780873	0.2527036	0.2527036	0.2527036	0.2527036
10	HEXAC-01	0.2548653	0.2992244	0.2992244	0.0001076	0.4049701	0.4049701	0.4049701	0.4049701
11	*** VAPOR PHASE **								
12	Density kg/cum	12.562713	13.122873	13.122925	3.5338082				
13	Viscosity cP	0.0098356	0.0094098	0.0094099	0.0078169				
14	*** LIQUID PHASE **								
15	Density kg/cum	1265.9995	1141.8625	1141.89		1149.3617	1149.3617	1149.3617	1149.2367
16	Viscosity cP	0.4214099	0.3610969	0.3611102		0.697724	0.697724	0.697724	0.6965733
17	Surface Ten dyne/cm	47.628807	40.986679	40.988224		45.708531	45.708531	45.708531	45.692342