# BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
## Second SEMESTER 2007-2008

## CHE C332: Process Design Decisions
## Comprehensive Examination

**DATE: 02-06-2008**

**TOTAL DURATION: 3 hours** **MAXIMUM MARKS: 120**

Duration for PART A: 1 hour

I.D. No. Student's Signature

Invigilator's Signature (with date)

**Note: Attempt ALL questions. Part A is to be attempted in this paper itself, and has to be submitted within ONE HOUR. Part B is to be attempted in separate answer-sheet.**

## PART – A [30 Marks]

**Each of the following questions carries ONE MARK each.**
***Tick ( ✔ ) the correct option:***

1. For vapor-liquid processes, if the reactor effluent is all vapor, we cool stream to
a) 35 $^{o}$F b) 35 $^{o}$C c) 100 K d) 100 $^{o}$C

2. In the design of a process at the screening stage, it is desirable to recover more than ……….. % of valuable components:
a) 75 b) 95 c) 80 d) 99

3. Liquid recovery system comes under which hierarchy of decisions in conceptual design:
a) input-output structure, b) recycle structure,
c) Batch vs. continuous, d) general structure

4 For a project to be feasible, the capital charge factor (CCF) should be ……… per year:
a) 0.999, b) 0.555, c) 0.333, d) 0.111

5. In process design, the heuristic to choose the solvent flow rate for an isothermal, dilute gas absorber is
a) L = 1.4, b) L = 1.4 G, c) L = mG, d) G = 1.4 L

6. The input information that we need to undertake a design problem includes
I. The reaction and reaction conditions
II. The desired production rate
III. The availability of skilled manpower
a) I, II, III, b) I and II, c) I and III, d) II and III

7. A batch reactor is
a) Suitable for gas-phase reactions on commercial scale
b) Suitable for liquid-phase reactions involving small production rate
c) Least expensive to operate for a given rate
d) Most suitable for very large production rate

8. To determine the general structure of the separation system, we first determine the phase of the
a) reactor feed streams, b) reactor exit streams,
c) The recycle stream d) the purge stream

9. We normally do not use distillation to split adjacent components when
a) $\alpha > 1.1$, b) $\alpha < 1.1$, c) $\alpha = 1.1$, d) $\alpha = 1.4$

10. Vapor recovery system comes under which hierarchy of decisions?
a) level-1, b) level-2, c) level-3, d) level-4

11 The most widely used method for estimating depreciation is
a) Straight-line method, b) declining balance method,
c) sum-of-the-years-digits method, d) MACRS

12. If an impurity in a liquid feed stream is a product or by-product
a) As a first guess process the impurity
b) Feed the process through the separation system
c) Remove it after reaction
d) None of the above

13. For vapor-liquid processes if a phase split is not obtained then we check
a) If we can pressurize the reactor system
b) We can send the reactor effluent directly to a vapor recovery
c) Possibility of using refrigerated partial condenser
d) All of the above.

14. The gas recycle and purge stream is used in a process, if the light reactant is boiled at boiling point lower than the boiling point of:
a) ethylene, b) propylene, c) propane, d) ethane.

15. Which of the following is the measure of profitability?
a) Sum-of-the-years-digits method, b) Present Worth Method,
c) Payout Time, d) Sinking Fund Method.

16. Normally the cost of a distillation column is specified in terms of the
a) column diameter, b) number of plates in the column,
c) length of the column, d) both a and b, e) both a and c.

17. In DCFROR, the present value of investment is equated to ..... .... at the zeroth year.

18 In Level-2 decisions, with reference to feed condition, if the feed impurity is present as an azeotrope with reactant than the better option is ...................... the impurity.

**Each of the following questions carries TWO MARKS each:**

19. The operating conditions (temperature and pressure) of a set of reactions taking place in a chemical process plant are given below:

| | |
|---|---|
| $A + B \rightarrow C$ | (700 $^oC$ and 1 atm) |
| $B + C \rightarrow D + E$ | (400 $^oC$ and 1 atm) |
| $D + A \rightarrow F + D$ | (400 $^oC$ and 1 atm) |
| $C + D \rightarrow F + G$ | (400 $^oC$ and 2 atm) |
| $C + D \rightarrow H + I$ | (400 $^oC$ and 2 atm) |

How many reactor systems are required at Level – 3 of conceptual design?

20. If there are five components with their boiling points and destination codes as listed below, how many product streams will be there?

| Component | Boiling Point $^oC$ | Destination Code |
|---|---|---|
| Benzene | 80 | Primary Product |
| Methane | -161 | Recycle and Purge |
| Diphenyl | 253 | Fuel |
| Hydrogen | -253 | Recycle and Purge |
| Toluene | 111 | Recycle |

21. Based on the heuristic; arrange the following components on the basis of their separation order:

| | |
|---|---|
| **A** | Corrosive component |
| **B** | Distillate product |
| **C** | Reactive component |

If an amount is doubled in 8 years, what is the annual rate of return?

23. Write any two decisions to be made in Level – 3 of decision making of conceptual design?

24. Between the Liquid Separation System and the Vapor Recovery System, which should be designed first and why?

*** End of Part A

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## PART – B [90 Marks]

**Note: Part B is to be attempted in separate answer-sheet. Detach this part from the Part A and keep with yourself.**

1. A chemical process has two hot streams to be cooled and three cold streams to be heated. Assuming HRAT = 20 °C for the stream data given below, carry out the energy integration analysis using Pinch Technology by determining the following:
   (a) Minimum hot and cold utility requirements based on second law, [12]
   (b) Hot and cold pinch temperatures, [4]
   (c) Minimum number of exchangers based on first law, [2]
   (d) Minimum number of exchangers based on second law. [2]

| Stream No. | Source Temperature (°C) | Target Temperature (°C) | Heat Capacity Flow rate (kW/°C) |
|---|---|---|---|
| 1 | 400 | 60 | 300 |
| 2 | 210 | 40 | 500 |
| 3 | 20 | 160 | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] |

2. For the heat exchanger network synthesis problem given below, hot and cold utility requirements for HRAT = 10 °C are 360 MW and 60 MW, respectively. The pinch temperature is 165 °C. [15]

| Stream No. | Source Temperature (°C) | Target Temperature (°C) | Heat Capacity Flow rate (MW/°C) |
|---|---|---|---|
| 1 | 190 | 40 | 3.0 |
| 2 | 170 | 50 | 4.0 |
| 3 | 20 | 230 | 6.0 |

   (a) Synthesize an MER network featuring minimum number of units, and draw it on the grid diagram; clearly indicating heat exchanger loads and intermediate stream temperatures.

(b) Show the results in the form of following table (do not show utility exchangers).

| Exchanger No. | Hot Stream | | Cold Stream | |
|---|---|---|---|---|
| | Inlet Temperature (°C) | Outlet Temperature (°C) | Inlet Temperature (°C) | Outlet Temperature (°C) |
| 1 | | | | |
| 2 | | | | |
| ... | | | | |

3 In the final design stage of a project, the question has arisen as to whether to use a water-cooled exchanger or an air-cooled exchanger in the overhead condenser loop of a distillation tower. The information available on the two pieces of equipment is provided below:

| | **Initial Investment** | **Yearly Operating Cost** |
|---|---|---|
| Air-cooled | \$23, 000 | \$1, 200 |
| Water-cooled | \$12, 000 | \$3, 300 |

Both pieces of equipment have service lives of 12 years. For an internal rate of return of 8% p.a., which piece of equipment represents the better choice? At what internal rate of return, both equipments will be equally attractive? [6 + 9]

4. Consider a very oversimplified design problem where the process consists only of a reactor, where two reactions $A_1 \rightarrow B_1$ and $A_2 \rightarrow B_2$ take place; the costs of the raw materials are $C_{f1}$ and $C_{f2}$; the desired production rates of $B_1$ and $B_2$ are $P_1$ and $P_2$ moles/hr, respectively; both reactions are first-order, isothermal, and irreversible with reaction rate constants $k_1$ and $k_2$; the densities are $\rho_1$ and $\rho_2$; the reactor downtimes are $t_{d1}$ and $t_{d2}$; the number of batches per year are $n_1$ and $n_2$; and only one reactor is used to make both products.
Write the cost model with raw material and reactor costs for Total Annual Cost (TAC). How do the results for using two separate reactors compare to the results for using a single reactor for a case where the reactor cost is given by the following expression: Reactor cost = $C_v V^b$ $b < 1$. [15]

5 The reactions of interest for a simplified version of a process to produce ethylene via ethane cracking are:

$C_2H_6 \rightarrow C_2H_4 + H_2$
$2\ C_2H_6 \rightarrow C_2H_4 + 2\ CH_4$
Some of the results for the product distribution are

| **Component** | **Yield pattern, wt %** | | | | | |
|---|---|---|---|---|---|---|
| $H_2$ | 2.00 | 2.47 | 2.98 | 3.51 | 4.07 | 4.64 |
| $CH_4$ | 1.28 | 1.68 | 2.13 | 2.66 | 3.26 | 3.93 |
| $C_2H_4$ | 28.90 | 35.80 | 43.20 | 51.10 | 59.40 | 67.80 |
| $C_2H_6$ | 67.80 | 60.10 | 51.70 | 42.70 | 33.30 | 23.60 |

Convert the data from weight percent to mole percent, and then develop a correlation for the selectivity (moles of $C_2H_4$ at the reactor exit per mole of $C_2H_6$ converted). [20]

6. The relative volatilities of four components (A, B, C, and D) of a mixture are given below:

| Component | Relative Volatilities |
|---|---|
| A | 3.7 |
| D | 1.59 |
| B | 2.7 |
| C | 1.6 |

Draw the distillation train for the separation of above mixture. [5]