

16-CHEM-A5, CHEMICAL PLANT DESIGN and ECONOMICS

MAY 2017

3 hours duration

NOTES

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. The examination is a **CLOSED BOOK EXAM**. One aid sheet allowed written on both sides.
3. Candidates may use approved **Sharp/Casio** calculator.
4. **Five (5) questions** constitute a complete exam paper.
5. The questions are of equal value (**20 points each**).
6. Only the **first five questions** as they appear in the answer book(s) will be marked.
7. Clarity and organization of the answer are important. For questions that require calculations, please show all your steps.
8. State all assumptions clearly.

Q1. A gas mixture has the following composition by volume:

Component	N ₂	CH ₄	C ₂ H ₆	C ₃ H ₈
Mole Fraction	0.05	0.65	0.20	0.10

It is fed to an absorber where 75% of the propane (C₃H₈) is recovered. The total amount absorbed is 50 mol/hr. The absorber has four theoretical plates and operates at 135 psig and 100°F. All of the absorbed material is recovered in a steam stripper that has a large number of plates and operates at 25 psig and 230°F.

Water is condensed out of the stripped gas at 100°F. After compression to 50 psig, that gas is combined with a recycle stream. The mixture is diluted with an equal volume of steam and charged to a reactor where pyrolysis of the propane occurs at a temperature of 1300°F. The reaction may be assumed to be simply C₃H₈ → C₂H₄ + CH₄ with a specific reaction rate constant (k) of 0.28 sec⁻¹. Conversion of propane is 60% and pressure drop in the reactor is 20 psi.

Reaction effluent is cooled to remove the steam, compressed to 285 psig, passed through an activated alumina drying stream to remove further amounts of water, and then fed to the first fractionator. In that vessel, 95% of the unconverted propane is recovered as a bottoms product. This stream also contains 3% ethane (C₂H₆) as an impurity. It is throttled to 50 psig and recycled to the reactor. In two subsequent towers, ethylene is separated from light and heavy impurities. These separations may be taken as complete.

Construct a process flow diagram of this plant including auxiliary equipment such as drums, heat exchangers, pumps, and compressors. Show operating conditions and flow quantities where calculable with the given data.

- Q2.** A company has the alternative of investing in one of two projects, A or B. The capital cost of both projects is \$10 million. The predicted annual cash flows for both projects are shown in the table below.

Year	Cash flows (\$10 ⁶)	
	Project A	Project B
0	-10	-10
1	1.6	6.5
2	2.8	5.2
3	4.0	4.0
4	5.2	2.8
5	6.4	1.6

Capital is restricted, and a choice is to be made between the two projects on the basis of discounted cash flow rate of return on a five-year lifetime. Which project should be chosen? Please show your calculations.

- Q3.** Before a chemical process design can be properly started, all participants in the proposed plant design must agree upon a certain body of information. Participants include engineering, research, plant supervision, safety and health personnel, environmental personnel, and plant management. The required data may be classified into basic design and specific design data. These data form the basis for the project scope that is essential for any design. List at least 20 items that must be included in the scope of a typical chemical process design.
- Q4.** Pumps are used in chemical plants for a great number of purposes in transferring liquids, colloidal solutions, or solids suspended in gases or liquids from one point to another.
- [8 points]** List and briefly describe four important types of pumps.
 - [4 points]** Briefly describe different materials used for construction of pumps.
 - [8 points]** List 10 important information required for selecting pumps.

Q5. Recognition of safety and fire hazards of the processes they are operating is very important to Chemical Engineers. From every standpoint, these hazards are liabilities, and their actual and potential costs must be emphasized in the process design and plans. List the important safety considerations for the following in chemical industries:

- a) [4 points] Building and Process Equipment.
- b) [4 points] Fire Prevention and Control.
- c) [4 points] Mechanical Hazards.
- d) [4 points] Electrical Hazards.
- e) [4 points] Chemical Hazards.

Q6. One of the stages in the chemical plant design after the management has surveyed the process development economics is the approval to proceed with the final plans for constructing and operating the plant. The final plans require detailed specification work and cost estimations on equipment and auxiliaries, building design, and site development. Factors that generally apply to the economic and operability aspects of the plant site location are classified into two major groups: primary factors and specific factors. The primary factors apply to choice of a region, whereas the specific factors are looked at in choosing an exact location site within the region. List and briefly describe the following:

- a) [7 points] 5 primary factors to consider when locating a chemical plant.
- b) [13 points] 10 specific factors to consider when locating a chemical plant.

