Front Page

National Exams December 2015

04-Chem-B6 - Petroleum Refining and Petrochemicals

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. This is a CLOSED BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) problems constitute a complete exam paper.
   The first five problems as they appear in the answer book will be marked.

4. Each problem is of equal value.

5. Note that the questions (a), (b), (c), (d), (e), (f) or (g) of each problem can be treated independently.

6. Most questions require an answer in essay format. Clarity and organization of the answer are important. Some of the questions require calculations please show all your steps.

Problem 1 (20 marks)

(a) What is polymerization in the petroleum industry?

2

(b) Explain briefly the main characteristics of thermal polymerization, sulphuric acid polymerization and phosphoric acid polymerization.

4

(c) To separate crude oil into its different fractions, distillation may be used. Explain how and why this separation method works for crude oils.

4

(d) A gas containing 75% propane (C_3H_8) and 25% O_2 is burned with 150% excess air in one of the dedicated boilers of a modern refinery. 80% of the propane goes to CO_2, 15% goes to CO, and 5% remains unburned. Calculate the composition of the flue gases at the stack.

10

Problem 2 (20 marks)

(a) Octane numbers for gasoline engines are determined as MON and RON.

(i) Explain briefly the difference, if any, between these two methods.

4

(ii) Describe concisely what these two octane numbers represent.

4

(b) Provide a concise definition of the flash point for a fuel.

2

(c) A catalytic dehydrogenation process is shown in the diagram below. It produces 1, 3 butadiene (C_4H_6) from pure normal butane (C_4H_{10}). The product stream contains 65 mole/hr of H_2; 15 mole/hr of C_4H_{10} and n mole/hr of C_4H_6. The recycle stream is composed of 20% (mole) C_4H_{10} and 80% (mole) C_4H_6 and its flow rate is 20 mole/hr.

The equation of the chemical reaction is:

$$C_4H_4 \rightarrow C_4H_6 + 2H_2$$

(i) What is the feed rate in mole/hr of pure C_4H_{10}?

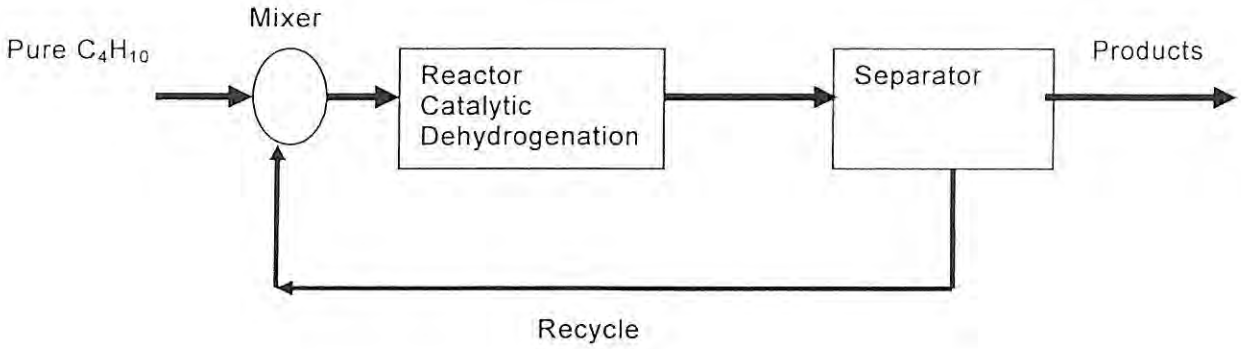
4

(ii) What is the product flow rate of C_4H_6 leaving the process?

4

(iii) What is the single pass conversion of butane in the process?

2



Problem 3 (20 marks)

(a) Explain clearly and concisely the meaning of the following two most widely used correlation factors: UOP or Watson Characterization factor and the US Bureau of Mines Correlation Index (CI).

4

(b) Explain briefly and concisely:

(i) What is visbreaking?

3

(ii) What are the typical operating conditions used to conduct visbreaking?

3

(iii) What are the principal reactions that occur during a visbreaking operation?

2

(c) If you have a 30 lb of sulphur dioxide in a 40 ft^3 tank at 18 ◦C. What will the pressure gauge on the tank read?
Hint: Assume sulphur dioxide to be an ideal gas.

8

Problem 4 (20 marks)

(a) Alkylation reaction is an important process for the petrochemical industry.

(i) Explain in a concise manner what are the main safety risks around an alkylation plant?

4

(ii) What would be the precautions that need to be taken to prevent these safety risks to occur?

4

(b) What is the meaning of the "pour point" for a crude oil?

2

(c) In the distillation column of petrochemical plant, 100 mol/h of a feed containing 60% of A and 40% of B is fractionated. The overhead product contains 90% of component A and the bottom product contains 85% of component B. Calculate the quantities of distillate and bottom products that are produced from this distillation process.

10

Problem 5 (20 marks)

(a) The Reid vapour pressure, boiling range, and antiknock characteristics are three of the most important properties of gasoline. Could you explain in a brief and concise manner:

i. What is the meaning of each of these properties

4

ii. Why are these properties important?

4

(b) 1000 lbmole/h of a dilute solution of soap contains 12% detergent. This solution is being concentrated to 50% using a single pass evaporation process. Since the only evaporator available at this plant, can achieve in one single pass 60% detergent concentration, to get the desired product concentration of 50%, a portion of the dilute feed was made to by-pass the evaporator.

(i) Draw a schematic diagram of this process

3

(ii) Calculate the production rate of the concentrated detergent solution

3

(iii) What is the rate of evaporation of the water?

3

(iv) What is the fraction of the feed that by-passes the evaporator?

3

Problem 6 (20 marks)

(a) Explain briefly why crude oil needs to be refined and how this is done.

4

(b) What are the most common leading features used for the specification of the following petroleum products:

i. Gasoline

1

ii. Naphtha and kerosene

1

iii. Gas oils

1

iv. Fuel oils

1

v. Lubricating oils

1

vi. Asphalts

1

(c) An equimolar liquid mixture of benzene (B) and Toluene (T) is in equilibrium with its vapour at 40 °C.

i. Determine the system pressure.

5

ii. What is the composition of the vapour?

5

Hint: See note on Raoult's and Henry's Laws at the back of this examination paper.

Notes for Problem 6

Antoine equation

$Log_{10}\ p^* = A - B/\ (T+C)$

Where P* is the vapour pressure of a pure substance in mm of mercury and T is the temperature in degree Celsius. The values of A, B and C, for water, benzene and toluene are provided as follows:

Substance	Formula	Range, C	A	B	C
Benzene	C_6H_6	-	6.906	1211.033	220.790
Toluene	C_7H_8	-	6.953	1750.286	235.0
Water	H_2O	60-150	7.967	1668.21	228.0

Raoult's Law

$y_A\ P = x_A\ P^*_A(T)$

$P^*_A(T)$ is the vapour pressure of pure liquid A at temperature T
x_A is the mole fraction of substance A in liquid phase
y_A is the mole fraction of substance A in the gas phase.

Henry's Law

$y_A\ P = x_A\ H_A(T)$

$H_A(T)$ is the Henry's law constant for substance A in a specific solvent.