National Exams May 2018

16-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. Exam is OPEN BOOK and any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.

4. Each question is of equal value.

5. Questions 1-3 require answers in essay format. Clarity and organization of the answer are important.

Question Number I *(10 Marks)*

a) Define briefly and concisely the following terms that are commonly used in petroleum refining:
   i. Watson characterization factor
   ii. Cut
   iii. Pour point
   iv. Flash point
   v. RON
   vi. Naphtha
   vii. API gravity
   viii. Total Acid Number

b) Gasoline is an important refinery product, name three possible sources of the raw gasoline in a refinery?

c) With the aid of a flow diagram and brief description, explain the delayed coking process and show what it is used for and why?

Question Number II *(10 Marks)*

a) The following processes are widely used in petroleum refining:
   i. Catalytic reforming
   ii. Catalytic cracking
   iii. Hydrocracking
   iv. Fluid coking

Explain briefly and concisely: (a) the main purposes of these processes, (b) their feedstocks, and (c) the possible desirable and undesirable chemical reactions that take place during these processes and their possible chemical reactions?

b) A crude oil having an API equals to 28 and contains 1750 kg/hr sulphur is fed to an atmospheric still. The following products are obtained:

Items	Wt% of Sulphur
Crude oil	1.0
Products: 93-193 °C	 0.17
193-282 °C	0.80
282-349 °C	0.50
349-427 °C	0.90
427^{+} °C	-

Provide a complete material balance table for this process?

Question Number III *(10 Marks)*
The following sketch shows the "black box" of the alkylation unit in a typical refinery.

Answer the followings:

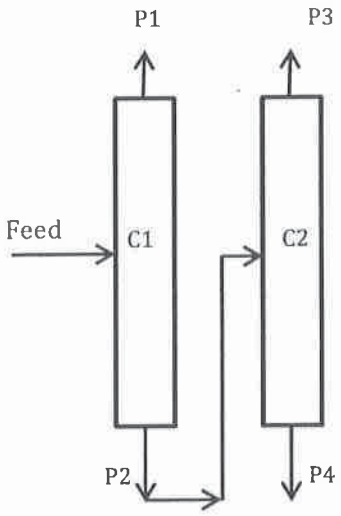
a) What is the main functional role of this unit?
b) What is the typical operating temperature and pressure in this unit?
c) What is the type of catalyst that is typically used in this process?
d) What is the impact of contact time, reactor temperature and catalyst activity on the alkylation reaction?
e) Name the feed (streams 25 and 44) and the generated products (streams 45, 46 and 47)?
f) What is the destination for streams 45 and 47, and what are their functional roles?

Question Number IV *(10 Marks)*

100 mol/s of liquid hydrocarbon mixture containing, by moles, 20% propane, 40% n-butane, and the balance is equimolar of n-pentane and n-hexane, is to be separated in two distillation columns, as per the diagram below. The product P1 contains 95% pure propane and n-butane and n-pentane at a molar ratio of 50/1. The split ratio of n-pentane in C2 equals 0.65.

a. Calculate the flow rates of streams P1 through P4 (please tabulate your results)?
b. What is the recovery for n-butane (based on the process feed)?

Component	Feed	P1	P2	P3	P4
Propane					
n-butane					
n-pentane					
n-hexane					



Question Number V *(10 Marks)*
You are given the following two problems to solve using either Raoult's law or Henry's law. For each problem, before you provide your answers, explain briefly why you want to apply Raoult's law or Henry's law?

a) A liquid mixture contains, by mole, 50% toluene (T) and 50% benzene (B) is in equilibrium with its vapor at 30 °C. Estimate the system pressure and the composition of the vapor phase?

b) A gas containing 1.0 mole% of ethane is in contact with water at 20 °C and 20 atm. Estimate the mole fraction of dissolved ethane in water?

Note:
Antoine's equation $\boldsymbol{log_{10}(P^{sat}) = A - \frac{B}{(T+C)}}$ may be used to estimate P^{sat} using the data in the table below. Unit for P^{sat} is mm Hg and T in °C.

Component	*A*	*B*	*C*
Benzene	*6.906*	*1211*	*220.8*
Toluene	*6.953*	*1343.9*	*219.4*
Water	*8.108*	*1750.27*	*235.0*

Henry's law constant for ethane in water at 20 °C is 2.63×10^4 atm/mole fraction.
Henry's law constant for Benzene is 5.6 atm/mole fraction.
Henry's law constant for Toluene is 6.7 atm/mole fraction.