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National Exams December 2012

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.
One of two calculators is permitted any Casio or Sharp approved models.
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)

- 4
- (a) List four key physical properties of petroleum fractions. Explain in a concise manner their meaning and the units in which they are usually reported.
- 3
- (b) What is the meaning of the total acid number for a crude oil?
- 3
- (c) Provide a concise definition of the flash point for a fuel.
- (d) Consider the distillation of a petroleum mixture containing only two compounds (C1) and (C2), with (C1) representing 45% of the mixture by mass. An overhead stream of 90 weight % of compound (C2) is produced and 10% of compound (C1) leaves the distillation column in the bottom stream. For a feed rate of 2000 kg/h of petroleum mixture,
- 5
- (i) Determine the overhead flow rate and
- (ii) The mass flow rates of compounds (C1) and (C2) in the bottom stream.
- 5

Problem 2 (20 marks)

- (a) The naphtha cracking process is frequently used to produce light olefins.
- 4
- (i) Explain briefly and concisely how you would increase the yield of light olefins in a naphtha cracker?
- 4
- (ii) Explain clearly and concisely why steam is introduced in the tubes of the naphtha cracker?
- (b) Acrylonitrile is produced by the reaction of propylene, ammonia, and oxygen as shown in the following chemical equation:
- $$\text{C}_3\text{H}_6 + \text{NH}_3 + 1.5 \text{O}_2 \rightarrow \text{C}_3\text{H}_3\text{N} + 3\text{H}_2\text{O}$$
- If 200 kg-moles of a feed mixture containing 10 mole % propylene, 12 mole % ammonia and 78 mole % air is fed to a chemical reactor for the production of acrylonitrile,

- 4
- (i) Which one of the reactant will be the limiting one?
- 4
- (ii) What is the percentage by which each of the other reactants is in excess?
- 4
- (iii) Calculate the amount of acrylonitrile produced for 30% conversion of the limiting reactant.

Problem 3 (20 marks)

- (a) Hydrogen is an essential ingredient for the petrochemical industry.
- (i) Explain briefly and concisely the principal methods used to produce hydrogen from hydrocarbons
- 4
- (ii) List a few impurities formed during the hydrogen production
- 2
- (iii) Explain briefly what processes you would use to remove these impurities in order to obtain purified hydrogen.
- 4
- (b) 100 moles per hour of butane and 5000 moles per hour of air are fed into a combustor. Calculate the percent excess air for this combustion process.
- 10

Problem 4 (20 marks)

- (a) There are several types of petroleum coke products depending upon the process which is used, the operating conditions and feedstock properties.
- (i) Describe in a concise manner three types of petroleum coke.
- 3
- (ii) Cite four different uses of petroleum coke.
- 4
- (b) Explain in a clear and concise manner whether a heavier crude oil has a lower or higher API gravity?
- 3

- (c) Ethane C_2H_6 is burned with 50% excess air. The percentage conversion of the ethane is 90%. Of the ethane burned, 25% reacts to form CO and the balance to form CO_2 . Calculate the composition of the flue gas and the ratio of water to dry flue gas.

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Problem 5 (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?

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(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?

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- (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.

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Problem 6 (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

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(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 42% using a single pass evaporation process. Since the only evaporator available at this plant, can achieve in one single pass 58% detergent concentration, to get the desired product concentration of 42%, a portion of the dilute feed was made to by-pass the evaporator.

- 3 (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?