National Exams December 2014

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) List four key physical properties of petroleum fractions. Explain in a concise manner their meaning and the units in which they are usually reported.

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(b) What is the meaning of the total acid number for a crude oil?

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

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(d) Consider the distillation of a petroleum mixture containing only two compounds (C1) and (C2), with (C1) representing 30% of the mixture by mass. An overhead stream of 80 weight % of compound (C2) is produced and 70% of compound (C1) leaves the distillation column in the bottom stream. For a feed rate of 1000 kg/h of petroleum mixture,

(i) Determine the overhead flow rate and

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(ii) The mass flow rates of compounds (C1) and (C2) in the bottom stream.

5

Problem 2 (20 marks)

(a) Many crude oils contain dissolved hydrogen sulphide (H_2S) and carbon dioxide (CO_2) that are generally referred as acid gases. These acid gases are removed from the fuel gas by a number processes. Describe briefly and concisely three removal processes for each of these two acid gases.

6

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

4

(c) 100 moles per hour of propane and 3000 moles per hour of air are fed into a combustor. Calculate the percent excess air for this combustion process.

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Problem 3 (20 marks)

(a) There are two major coking processes: delayed coking and fluid coking. Explain in a very concise manner:

(i) The main characteristics of these two coking processes;

4

(ii) And how these two processes differ.

4

(b) Explain in a clear and concise manner whether a heavier crude oil has a lower or higher API gravity?

2

(c) An acetylene plant is shown in the schematic below. Pure methane (CH_4), and pure oxygen (O_2) are reacted in a burner to produce acetylene (C_2H_2) according to the following reactions:

$CH_4 + 2\ O_2 \rightarrow 2H_2O + CO_2$ (Equation 1)

$CH_4 + 1.5\ O_2 \rightarrow 2H_2O + CO$ (Equation 2)

$2CH_4 \rightarrow C_2H_2 + 3H_2$ (Equation 3)

(i) Calculate the molar ratio of oxygen (O_2) to methane (CH_4) fed to the burner.

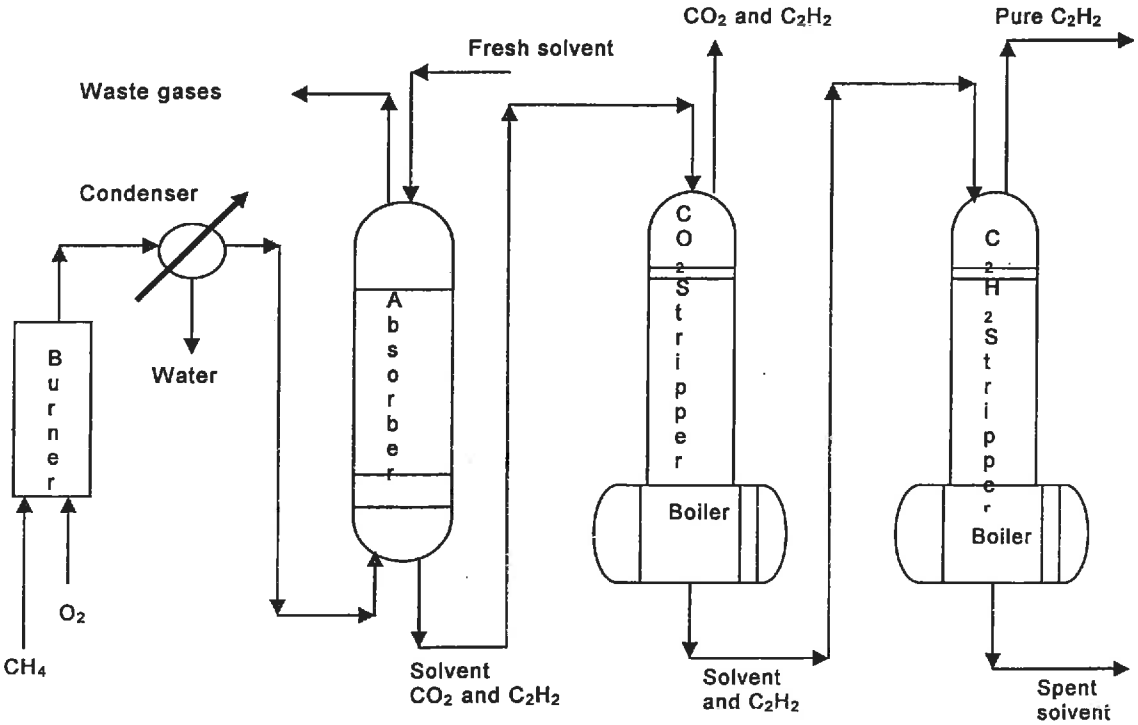
4

(ii) On the basis of 100 lbmol of gas leaving the condenser, calculate how many pounds of water are removed by the condenser.

4

(iii) What is the overall percentage yield of pure C_2H_2 product, based on the carbon in the natural gas entering the burner?

2



Problem 4 (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?

3

(ii) Why are these properties important?

3

b) Provide a concise definition of API gravity and show how it relates to specific gravity.

4

c) 8000 barrels of 26° API gas oil are blended with 20,000 barrels of 16° API fuel oil. What is the density of the mixture in the following units:

i. Lb per US Gallon

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ii. Lb per ft^3.

Note: Assume that the volumes are additive.
1 barrel = 42 US gallons
The density of water at 60 °F is 0.999 g/cm^3.

5

Problem 5 (20 marks)

(a) What are the most important factors that must be considered by a refinery to select a particular alkylation process?

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(b) Explain why the above factors are so important.

3

(c) Explain concisely what are the main safety risks around an alkylation plant?

3

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

2

(e) Describe in a clear and concise manner two of the processes used in modern refineries to produce hydrogen? Write the equations of the main chemical reactions involved as well as the operating conditions.

6

(f) Describe in a concise manner three main types of industrial processes used for the recovery of a concentrated hydrogen stream from a dilute gas mixture containing in addition to the hydrogen, methane and other hydrocarbon vapours.

3

Problem 6 (20 marks)

(a) As a petrochemical engineer, your role is to run your plant as efficiently as possible while complying with several environmental restrictions or guidelines.

i. List a few of the potential environmental risks (to air, land and water) from a petroleum refinery.

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ii. What you would do to prevent these risks from occurring?

3

(b) List four key design parameters for a hydrocracking reactor.

2

(c) Explain why the above reactor design parameters are important.

2

(d) A vapour stream entering a sieve plate (shown below) in a distillation column contains 40 mole percent of benzene and 60 mole percent of toluene. Its flow rate is 550 kg-mole/hr. Liquid flows into the tray at a rate of 700 kg-mole/hr and with a composition of 45 mole percent benzene and 55 mole percent toluene. Under the conditions on the plate, the composition of the vapour leaving the tray (y mole fraction benzene) is related to the composition of the liquid leaving the tray (x mole fraction benzene) by the simple equation:

$$y = 1.3\,x$$

The liquid and vapour streams leaving the plate have the same total molar flow rates as those entering the plate.

Calculate the compositions of the streams leaving the plate.

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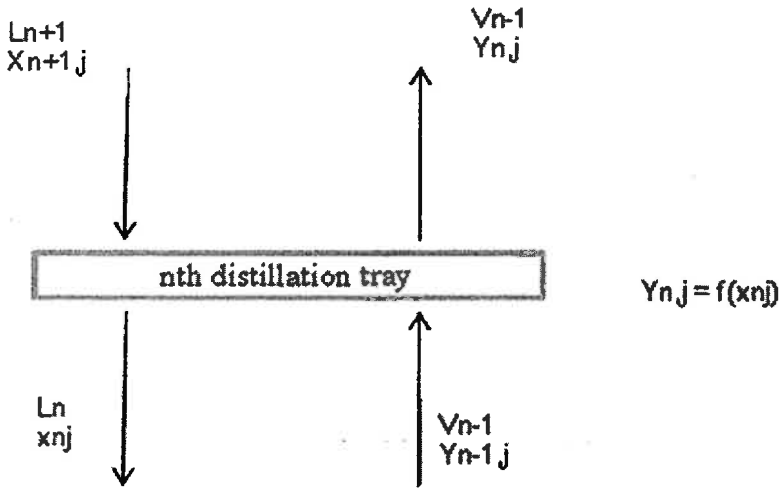
Ln+1
Xn+1 j
Vn-1
Yn j
nth distillation tray
Yn j = f(xnj)
Ln
xnj
Vn-1
Yn-1 j