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National Exams December 2013

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 four 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), 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) Several processes are used in modern refineries to produce hydrogen.

(i) Describe in a clear and concise manner two of these processes used in modern refineries to produce hydrogen?

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(ii) Write the equations of the main chemical reactions involved

3

(iii) Indicate also the operating conditions

3

(b) Cyclohexane (C_6H_{12}) can be made by reacting benzene (C_6H_6) with hydrogen according to the following reaction:

$C_6H_6 + 3H_2 \rightarrow C_6H_{12}$

This hydrogenation reaction is shown schematically by the process shown below.

Determine the ratio of the recycle stream to the fresh feed stream if the overall conversion of benzene is 95%, and its single – pass conversion is 25%. Assume that 20% excess hydrogen is used in the fresh feed, and that the composition of the recycle stream is 30 mol % of benzene and 70 mol % of hydrogen.

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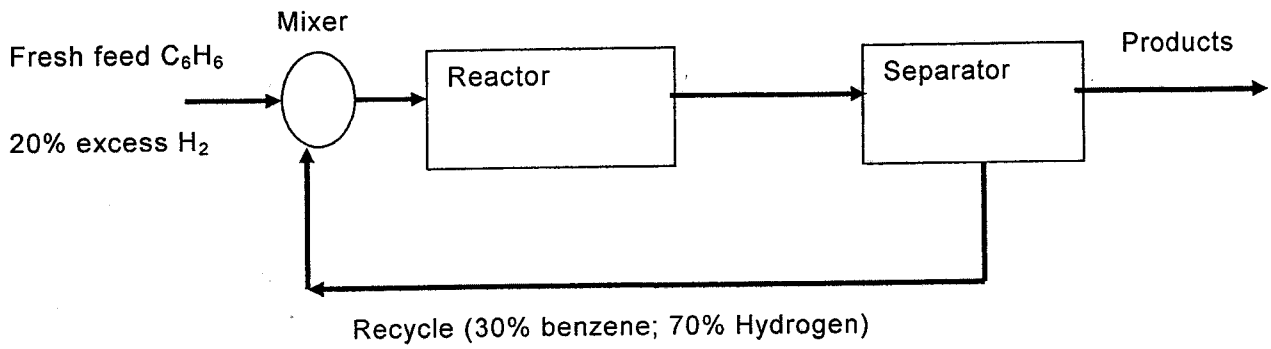

Problem 2 (20 marks)

(a) Explain briefly and concisely:

(i) The meaning of visbreaking for the petrochemical industry

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

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

3

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

3

(c) Flue gas from a refinery boiler has the following composition in mole percent:

- CO_2: 14.6 mole percent
- H_2O: 9.2 mole percent
- N_2: 73.4 mole percent
- O_2: 2.8 mole percent

Convert these concentrations into weight percent.

8

Problem 3 (20 marks)

(a) Explain in concise manner:

(i) What are the main modes of characterisation of petroleum fractions?

3

(ii) What would be their advantages and limitations?

4

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

3

(c) Consider a cylindrical gas storage tank in a refinery that contains air (molecular mass = 29). If the storage tank has an inner diameter of 3m and a length of 7m, calculate the mass of air in the full tank at 80°C and 2500 kPa absolute pressure.

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Problem 4 (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 of processes. Describe briefly and concisely three removal processes for each of these two acid gases.

6

(b) Explain very concisely the importance of isomerisation in the petroleum refining operation.

4

(c) A gas containing 80% ethane and 20% oxygen is burned with 200% excess air in one of the dedicated boilers of a modern refinery. 80% of the ethane goes to carbon dioxide, 10% goes to carbon monoxide, and 10% remains unburned. Calculate the composition of flue gases at the stack.

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Problem 5 (20 marks)

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

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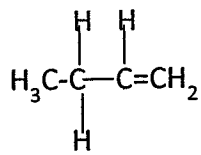
(b) What are the important reactions that occur during thermal cracking? Use the case of  to illustrate these reactions.

4

(c) What are the typical temperature and pressure ranges used during hydrocarbon thermal cracking?

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(d) A distillation column in a petroleum refinery is shown in the diagram below with all known information on the feed and distillate. Calculate the amount of alcohol lost in the bottom.

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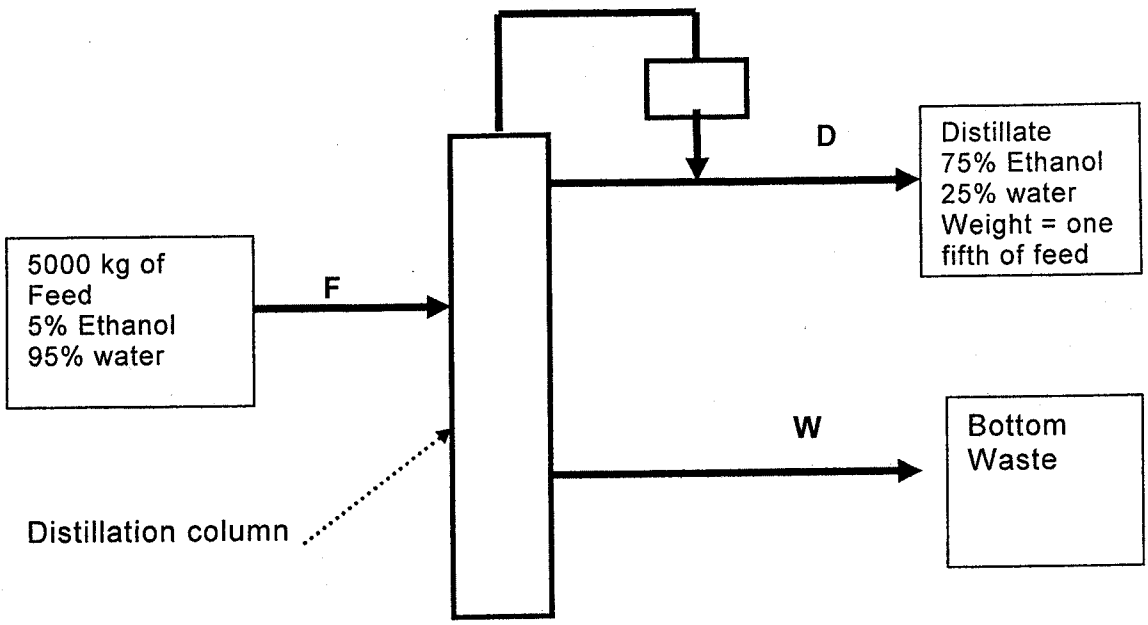

D
Distillate
75% Ethanol
25% water
Weight = one
fifth of feed
5000 kg of
Feed
5% Ethanol
95% water
F
W
Bottom
Waste
Distillation column

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

3

(ii) Why are these properties important?

3

(b) Most catalysts used during catalytic reforming processes lose gradually their activity. Explain what causes this deactivation process and why it occurs?

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.

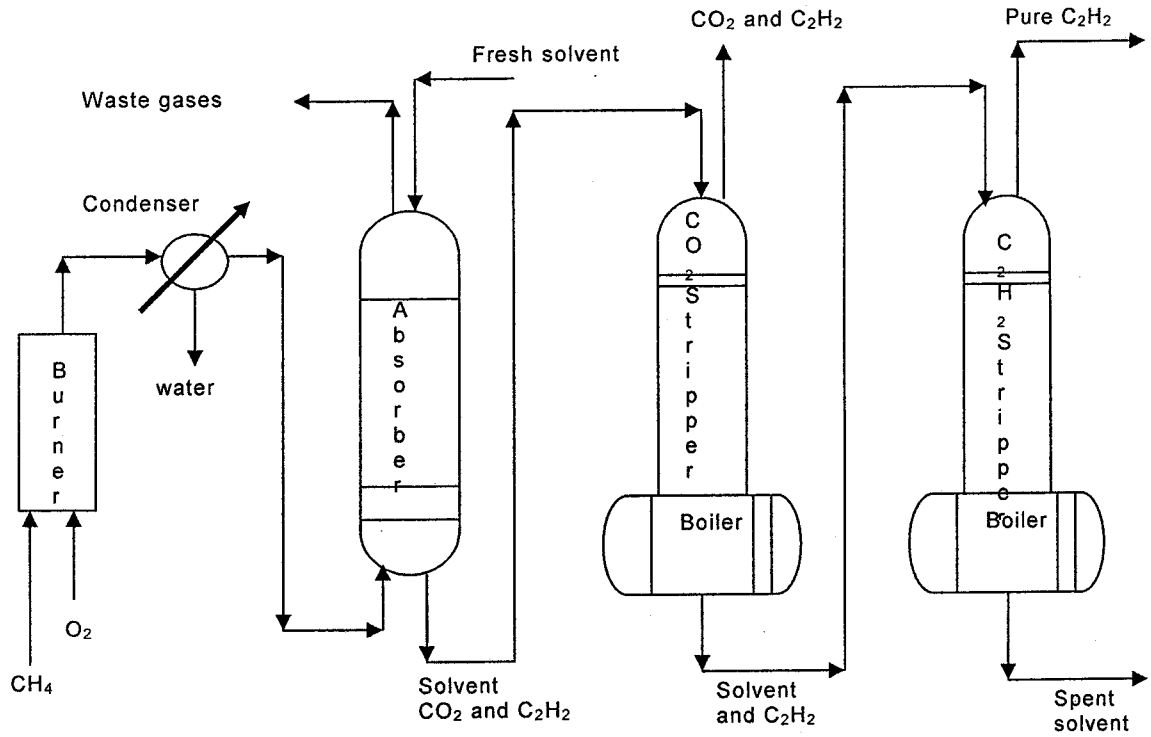
4

(ii) On the basis of 100 Lb mole 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?

4


CO_2 and C_2H_2
Pure C_2H_2
Fresh solvent
Waste gases
Condenser
water
Burner
Absorber
CO_2 Stripper
C_2H_2 Stripper
Boiler
Boiler
O_2
CH_4
Solvent
CO_2 and C_2H_2
Solvent
and C_2H_2
Spent
solvent