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National Exams May 2014

04-Chem-B6 - Petroleum Refining and Petrochemicals

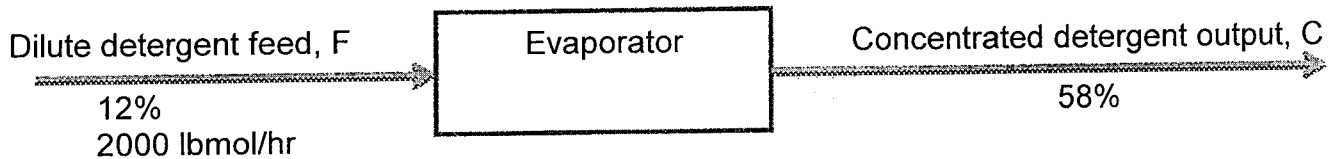
3 hours duration

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)

- 4 (a) Write the reforming reactions using the methane steam reaction.
- 2 (b) Explain the impact of pressure and temperature on this reaction?
- 4 (c) Explain concisely, what are the main physical characteristics of fuel that can influence carburetion
- (d) Carburetors and fuel injector components of certain types of engines benefit from detergents additives in the fuel to prevent fouling. An evaporator shown below is used to get the desired concentration of detergent from a dilute solution containing 12% of detergent. After a single pass of evaporation a concentrate containing 58% of detergent would be obtained.



- 5 i. If the desired concentration of detergent needed at the exit of the evaporator is 45%; Show graphically and explain concisely what you would do, to obtain this level of (45%) detergent concentration after only one pass.
- 5 ii. Calculate what would then be the production rate of 45% concentrated detergent solution, assuming a dilute feed rate of 2000 lbmol/hr?

Problem 2 (20 marks)

- 4 (a) Use a flow sheet to provide a brief description of an alkylation unit.
- 2 (b) What are the standard catalyst types and typical feedstock used for alkylation?
- (c) The naphtha cracking process is frequently used to produce light olefins.

- 2
- (i) Explain briefly and concisely how you would increase the yield of light olefins in a naphtha cracker?
- 2
- (ii) Explain clearly and concisely why steam is introduced in the tubes of the naphtha cracker?
- (d) A furnace in a petroleum refinery uses coke that contains 80% carbon, 0.5% hydrogen and 19.5% ash by weight. It operates with 50% excess air and the ash formed contains 2% unburned carbon. 95% of the carbon burned in the furnace forms carbon dioxide and the balance carbon monoxide.
- (i) Write the equations of the main chemical reactions that would occur
- 3
- (ii) Calculate the composition of the flue gas at the furnace exit
- 3
- (iii) Calculate the weight of ash produced per 100kg of coke burned.
- 2
- (iv) Calculate the weight of carbon lost per 100 kg of coke burned.
- 2

Note: Specific information about air

- Average molecular weight of air is 29;
- Volume or mole per cent of oxygen in air is 21 vol % or 21 mol %.
- Weight percent of oxygen in air = 23%
- 1 kmol of air at normal temperature and pressure occupies 22.4 m³.
- In air, 1 mol of oxygen is accompanied by 3.76 mol of nitrogen.

Problem 3 (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:
- 1
- i. Gasoline
- 1
- ii. Naphtha and kerosene
- 1
- iii. Gas oils
- 1
- iv. Fuel oils
- 1
- v. Lubricating oils

1
1

vi. Asphalts

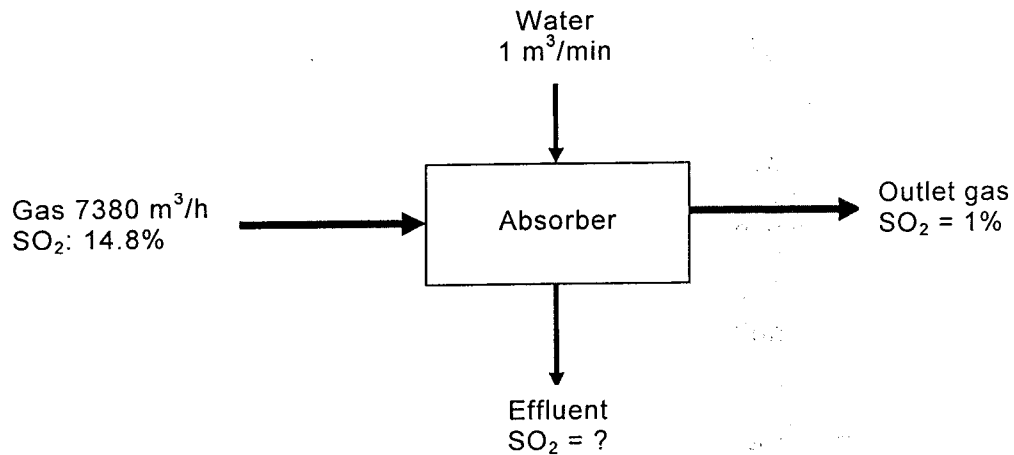
(c) Absorption of sulphur dioxide is carried in a packed tower as shown below. A gas stream containing 14.8% of sulphur dioxide and the rest inert gases enters the tower while the leaving gases contain 1% sulphur dioxide. Water flows at the rate of $1 \text{ m}^3/\text{min}$. The tower handles $7380 \text{ m}^3/\text{h}$ of gas at 303 K and 1 bar.

i. Find the sulphur dioxide concentration of the effluent from the tower.

5

ii. Find the volume of the gases leaving the tower at 0.95 bar and 293 K.

5



Problem 4 (20 marks)

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

4

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

4

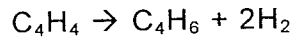
(ii) Describe concisely what these two octane numbers represent.

2

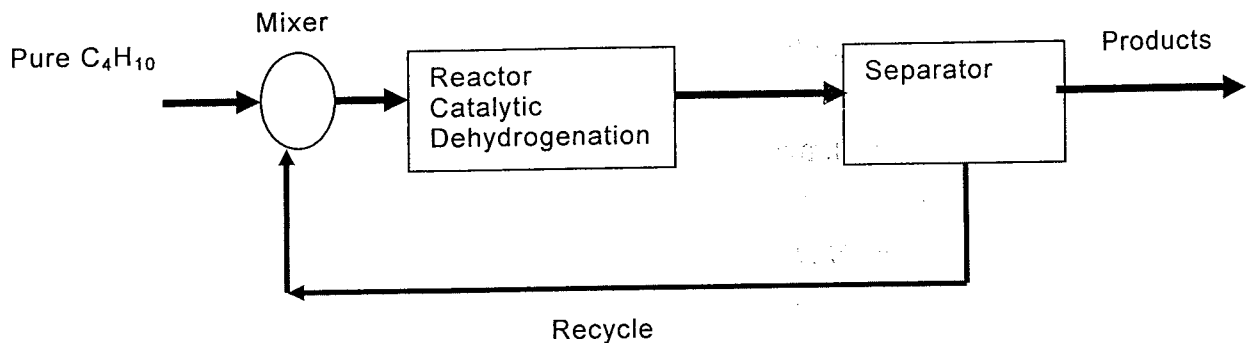
(b) Provide a concise definition of the flash point for a fuel.

(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:



- 4
- (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?
- 2
- (iii) What is the single pass conversion of butane in the process?



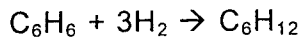
Problem 5 (20 marks)

- 4
- (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).
- 3
- (b) Explain briefly and concisely:
- 3
- (i) What is visbreaking?
- 3
- (ii) What are the typical operating conditions used to conduct visbreaking?
- 2
- (iii) What are the principal reactions that occur during a visbreaking operation?
- (c) If you have a 20 lb of sulphur dioxide in a 40 ft³ tank at 26 °C. What will the pressure gauge on the tank read?
Hint: Assume sulphur dioxide to be an ideal gas.

8

Problem 6 (20 marks)

- (a) What is the meaning of the “pour point” for a crude oil?
3
- (b) Explain in a concise manner, what is used in the petroleum industry to reduce knock.
3
- (c) Describe in a concise manner two 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.
4
- (d) Cyclohexane (C_6H_{12}) can be made by reacting benzene (C_6H_6) with hydrogen according to the following reaction:



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 90%, and its single – pass conversion is 20%. Assume that 20% excess hydrogen is used in the fresh feed, and that the composition of the recycle stream is 40 mol % of benzene and 60 mol % of hydrogen.

10

