

National Exams May 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.
A Casio or Sharp approved 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 physico-chemical properties of lubricating oils and explain why you think these properties are important.
4
- (b) What is the meaning of the total acid number for a crude oil?
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- (c) What are the main characteristics of a gasoline fuel that are important in ensuring the correct performance of an engine?
4
- (d) Use Raoult's Law or Henry's Law to estimate the mole fraction of dissolved ethane in water at 20 °C and 20 atm, knowing that this water has been in contact with a gas containing two mole percent of ethane. *Please see note on Raoult's and Henry's Laws at the back of this examination paper.*
10

Problem 2 (20 marks)

- (a) What is polymerization in the petroleum industry?
2
- (b) Explain briefly the main characteristics of thermal polymerization, sulphuric acid polymerization and phosphoric acid polymerization.
4
- (c) To separate crude oil into its different fractions, distillation may be used. Explain how and why this separation method works for crude oils.
4
- (d) A gas containing 80% ethane (C₂H₆) and 20% O₂ is burned with 200% excess air in one of the dedicated boilers of a modern refinery. 75% of the ethane goes to CO₂, 15% goes to CO, and 10% remains unburned. Calculate the composition of the flue gases at the stack.
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Problem 3 (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) An equimolar liquid mixture of benzene (B) and Toluene (T) is in equilibrium with its vapour at 40 °C.
- 5 i. Determine the system pressure.
- 5 ii. What is the composition of the vapour?

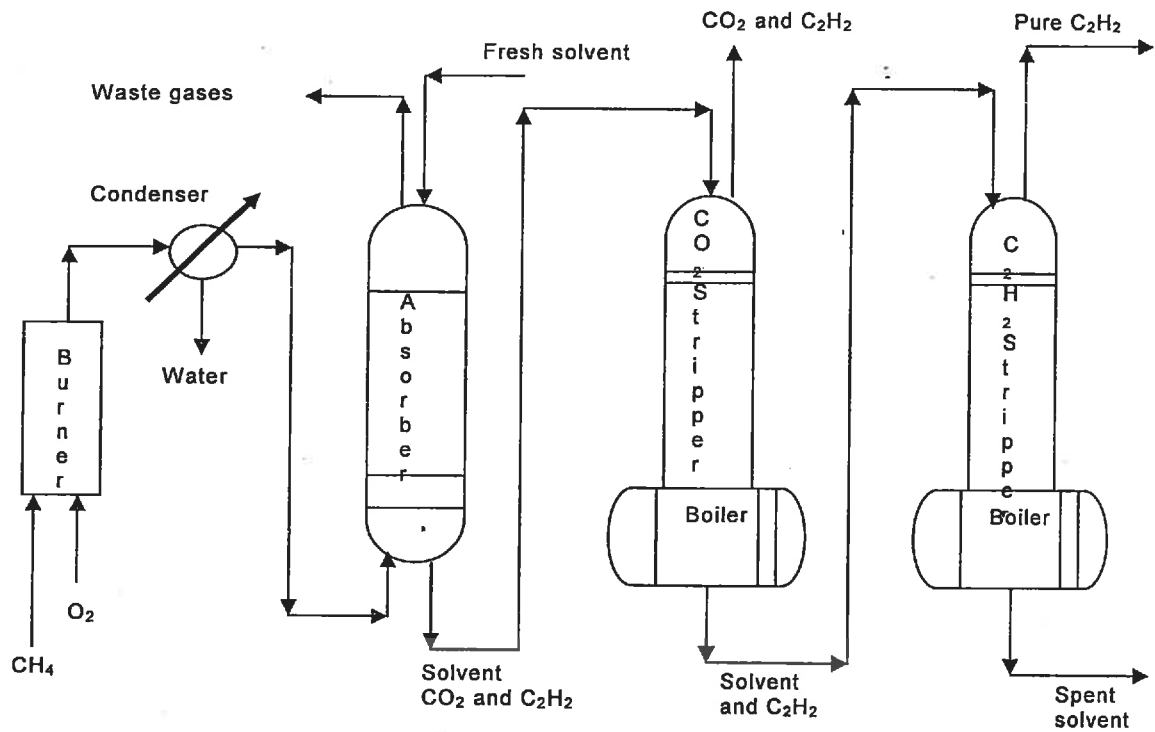
Hint: See note on Raoult's and Henry's Laws at the back of this examination paper.

Problem 4 (20 marks)

- (a) There are two major coking processes: delayed coking and fluid coking. Explain in a very concise manner:
- 4 (i) The main characteristics of these two coking processes;
- 4 (ii) And how these two processes differ.
- (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 (CH₄), and pure oxygen (O₂) are reacted in a burner to produce acetylene (C₂H₂) according to the following reactions:
- $$\text{CH}_4 + 2 \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{CO}_2 \quad \text{(Equation 1)}$$
- $$\text{CH}_4 + 1.5 \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{CO} \quad \text{(Equation 2)}$$
- $$2\text{CH}_4 \rightarrow \text{C}_2\text{H}_2 + 3\text{H}_2 \quad \text{(Equation 3)}$$
- (i) Calculate the molar ratio of oxygen (O₂) to methane (CH₄) 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 5 (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) 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:



(i) What is the feed rate in mole/hr of pure C_4H_{10} ?

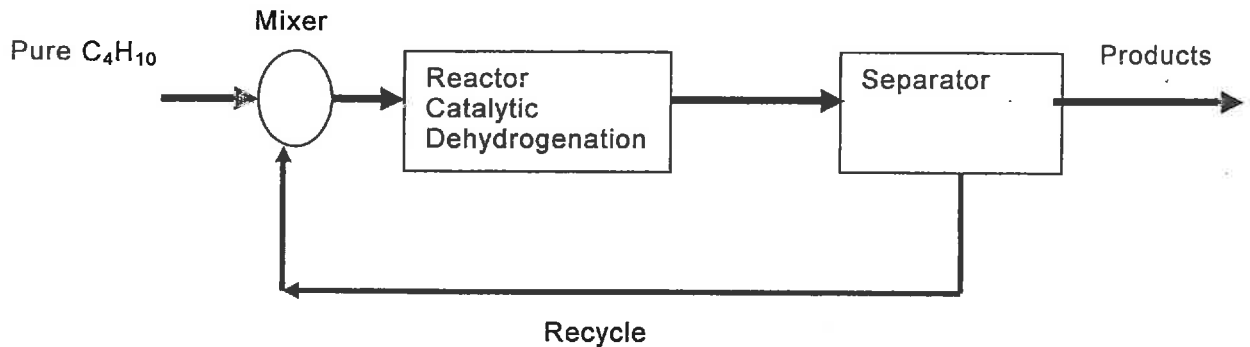
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4

(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 6 (20 marks)

(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).

4

(b) Explain briefly and concisely:

(i) What is visbreaking?

3

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

3

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

2

(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

Notes for Problems 1 and 3

Antoine equation

$$\text{Log}_{10} p^* = A - B / (T+C)$$

Where P^* is the vapour pressure of a pure substance in mm of mercury and T is the temperature in degree Celsius. The values of A , B and C , for water, benzene and toluene are provided as follows:

Substance	Formula	Range, C	A	B	C
Benzene	C_6H_6	-	6.906	1211.033	220.790
Toluene	C_7H_8	-	6.953	1750.286	235.0
Water	H_2O	60-150	7.967	1668.21	228.0

Raoult's Law

$$y_A P = x_A P_A^*(T)$$

$P_A^*(T)$ is the vapour pressure of pure liquid A at temperature T

x_A is the mole fraction of substance A in liquid phase

y_A is the mole fraction of substance A in the gas phase.

Henry's Law

$$y_A P = x_A H_A(T)$$

$H_A(T)$ is the Henry's law constant for substance A in a specific solvent.