

National Exams May 2015

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), 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.
- (b) Explain the impact of pressure and temperature on this reaction?
2
- 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 15% of detergent. After a single pass of evaporation a concentrate containing 65% of detergent would be obtained.



- 5 i. If the desired concentration of detergent needed at the exit of the evaporator is 50%; Show graphically and explain concisely what you would do, to obtain this level of (50%) detergent concentration after only one pass.
- 5 ii. Calculate what would then be the production rate of 50% concentrated detergent solution, assuming a dilute feed rate of 5000 lbmol/hr?

Problem 2 (20 marks)

- 4 (a) Use a flow sheet to provide a brief description of an alkylation unit.
- (b) What are the standard catalyst types and typical feedstock used for alkylation?
2
- (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 petroleum coke that contains 75% carbon, 2% hydrogen and 23% ash by weight. It operates with 40% excess air and the ash formed contains 5% unburned carbon. 80% of the carbon burned in the furnace forms carbon dioxide and the balance carbon monoxide.
- 3 (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
- 2 (iii) Calculate the weight of ash produced per 100kg of petroleum coke burned.
- 2 (iv) Calculate the weight of carbon lost per 100 kg of petroleum coke burned.

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.

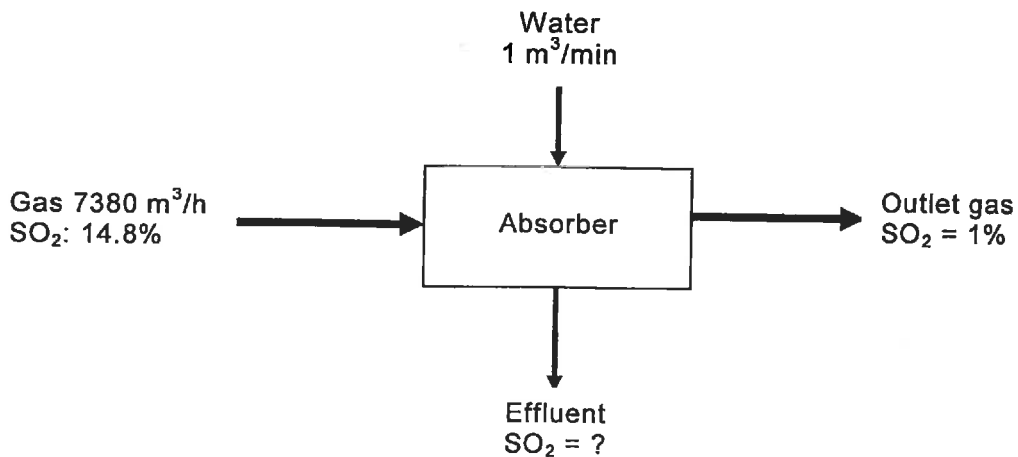
Problem 3 (20 marks)

- 4 (a) Explain briefly why crude oil needs to be refined and how this is done.
- 1 (b) What are the most common leading features used for the specification of the following petroleum products:
i. Gasoline

- 1 ii. Naphtha and kerosene
- 1 iii. Gas oils
- 1 iv. Fuel oils
- 1 v. Lubricating oils
- 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.

- 5 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.



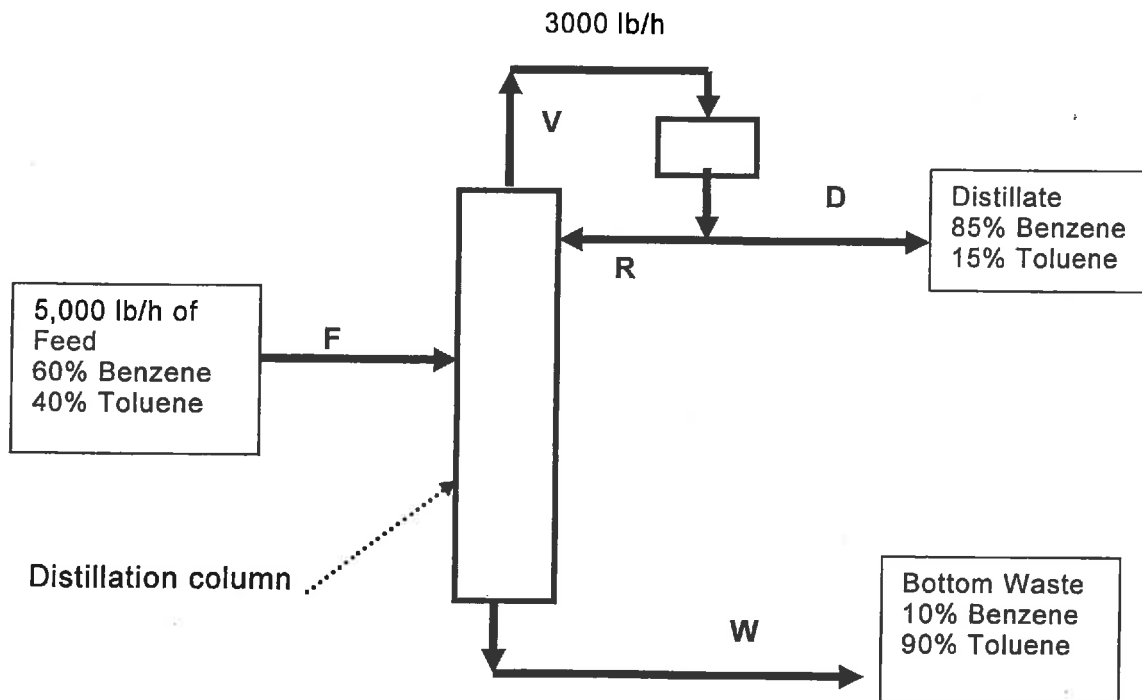
Problem 4 (20 marks)

- 2 (a) Explain briefly what is the cloud point of a petroleum product

- 4 (b) Several processes are used in modern refineries to produce hydrogen. Describe in a clear and concise manner two of the processes used in modern refineries to produce hydrogen?
- 4 (c) Provide a concise definition of API gravity and show how it relates to specific gravity.
- 5 (d) 10,000 barrels of 22° API gas oil are blended with 20,000 barrels of 11° API fuel oil. What is the density of the mixture in the following units:
- Lb per US Gallon
 - Lb per ft³.
- Note: Assume that the volumes are additive.
1 barrel = 42 US gallons
The density of water at 60 °F is 0.999 g/cm³.
- 5

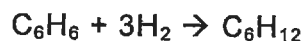
Problem 5 (20 marks)

- 3 (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:
- 3 (i) What is the meaning of each of these properties?
 - 3 (ii) Why are these properties important?
- 4 (d) Explain briefly what is solvent dewaxing and which product it is used for?
- 10 (e) A distillation column separates 5,000 lb/hr of a mixture containing 60% benzene and 40% toluene. The product recovered from the condenser at the top of the column contains 85% benzene, and the bottom waste from the column contains 90% toluene. The stream entering the condenser from the top of the column is 3000 lbs/h. A portion of the product is returned to the column as reflux, and the rest is withdrawn for downstream application. Assume the compositions of the streams at the top of the column (V), the product withdrawn (D), and the reflux (R) are identical. Determine the ratio of the amount refluxed to the product withdrawn.



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 85%, and its single – pass conversion is 35%. Assume that 25% excess hydrogen is used in

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the fresh feed, and that the composition of the recycle stream is 30 mol % of benzene and 70 mol % of hydrogen.

