Front Page

National Exams December 2010

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) Explain concisely, what are the main physical characteristics of fuel that can influence carburetion

2

(b) Methane reacts with oxygen to form carbon dioxide and water. 200 lbmol/hr of a feed consisting of 25% methane, 65% oxygen and 10% carbon dioxide are fed to a reactor that achieves a 90% conversion of the limiting reactant.

i. What is the percent excess of the excess reactant?

3

ii. What is the molar flow rate of CH_4 in the product stream?

3

iii. What is the molar flow rate of the product stream?

3

iv. What is the mole fraction of CO_2 in the product stream?

3

v. If the total pressure is 14.7 psia, what is the partial pressure of oxygen?

3

vi. If the temperature of the product gas is 360 °F, what is the volume flow rate of the product gas?

3

Problem 2 (20 marks)

(a) Explain briefly what is alkylation for the petro-chemical industry?

2

(b) A distillation column is designed to separate 200 lbmol/hr of a mixture of 40% (mol%) n-hexane and 60% n-heptane into a top product containing 95% n-hexane and a bottom product containing 90% n-heptane.

i. What is the mass flow rate of the bottom product?

3

ii. What is the mass flow rate of the top product?

3

iii. If a reflux ratio of 2:1 is used, what is the flow rate of the reflux stream?

3

iv. What is the slope of the operating line for the rectifying section?

3

v. What is the y-intercept of the operating line for the rectifying section?

3

vi. What is the slope of the operating line for the stripping section?

3

Problem 3 (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 one potential environmental risk from a petroleum refinery to each of the following media: air, land and water.

3

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

3

(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) Thermal cracking is one means of producing gasoline from petroleum fractions that boil above the gasoline boiling range. Distillate oil, also called gas oil, which has a boiling range from 450 to about 700°F, may be separated by distillation from the crude petroleum and cracked to its ultimate yields of gas, gasoline, and dark color fuel oil (tar). The thermal cracking operation is usually carried out by pumping the gas oil through a coil of tubes in a furnace.

A distillate oil (or gas oil) is processed by cracking it in one pass (once-through) through a coil at 25% by liquid – volume crack per pass. The recycle gas oil is processed in a separate coil at 12% crack per pass (net) to its ultimate yields. The maximum gasoline yield from this distillate oil (with sharp fractionation) is 68.1% by volume. The recycle gas oil contains 10% by volume of gasoline:

i. What net yield of gasoline is obtained?

5

ii. What is the charge to recycle gas oil coil per 100 volumes of initial distillate oil?

5

Problem 4 (20 marks)

(a) Explain briefly how the following gases can be removed from valuable product streams:

(i) Hydrogen sulphide (H_2S)

2

(ii) Carbon dioxide (CO_2)

2

(iii) Low aliphatic mercaptans

2

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

4

(c) The homogeneous reaction for the dehydrogenation of ethane can be written as follows:

$$C_2H_6 \leftrightarrow C_2H_4 + H_2$$

The reaction-rate constant for the forward reaction at 551 °C is 2.8 $\times 10^{-5}$ sec^{-1}, and the constant for the reverse reaction at that temperature is 7.76 $\times 10^{-2}$ litre / (mole)(sec). What is the equilibrium constant at 551 °C expressed in pressure units?

10

Problem 5 (20 marks)

(a) There are several types of petroleum coke products depending upon the process which is used, the operating conditions and feedstock properties.

(i) Describe in a concise manner three types of petroleum coke.

6

(ii) Cite four different uses for petroleum coke.

4

(b) The chemical reaction to produce ammonia is the following:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

(i) Design using a flow sheet a process or series of processes that would produce pure ammonia (NH_3) if you only have as raw material, the following feedstock: air, methane (CH_4) and water. You can use any process or unit operation you judge suitable.

6

(ii) Describe in a concise manner how the process you have designed above works.

4

Hint:
(1) Air contains two elements that might be of interest.
(2) You may think of processes that can be used to purify your raw materials.
(3) With the feedstock you have access to and with your petrochemical knowledge you should be able to produce on site, all raw materials you would need.

Problem 6 (20 marks)

(a) Explain clearly and concisely the meaning of the following two most widely used correlation factors: UOP or Watson Characterisation factor and the US Bureau of Mines Correlation Index (CI).

4

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

2

(c) Explain in a concise manner, what is used in the petroleum industry to reduce knock.

4

(d) A fuel gas containing 3.1 mol %H_2, 27.2% CO, 5.6% CO_2, 0.5% O_2, and 63.6% N_2 is burned in refinery furnace with 20% excess air (that is the Air over and above what is necessary for complete combustion to CO_2 and H_2O). The combustion of CO is only 98% complete. For 100 kg mol of fuel gas, calculate the moles of each component in the exit flue gas.

10