BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI -PILANI CAMPUS
II Semester 2016-2017
CHE F 419: Chemical Process Technology
Misemester Examination: 11/03/2017: Closed Book: SET B

Total Duration: 1 hour 30 minutes   **MM: 15+50+25= 90**

_____

Name: **ID No.**

_____

  Marks obtained = _____ + _____ =

_____

1. **Paper is completely CLOSED BOOK:BLANKS+ Q/A of TOTAl = 90 marks**
2. **Blanks are to be attempted in the given portion only.**
3. **Q 1-3 is to be attempted in question paper itself.**
4. **Q-4 IS TO BE ATTEMPTED IN SEPARATE ANSWERSHEET.**
5. **Restrict the answers appropriately in space provided.**
6. **Make the suitable assumptions if any.**

1. Most important catalytic processes in the oil refinery, in terms of throughput, are fluid catalytic cracking (FCC), hydrotreating, hydrocracking, _____ and alkylation.
2. Cetane numbers are highest for linear alkanes, while_____, have the lowest cetane numbers.
3. Propane deasphalting is based on the _____ of hydrocarbons in propane, that is, on the type of molecule.
4. The cracker feed is diluted with steam for better _____ and fed to the riser reactor together with regenerated catalyst in FCC.
5. There is an increasing incentive for the production of larger amounts of C3 and C4 alkenes in FCC units, because these are valuable as _____ feedstocks.
6. Alkanes can be converted relatively easily and when decomposed produce high yields of light products such as ethene and propene as a result of their high _____ content.
7. Crude oil often contains water, _____ , _____and water-soluble trace metals.
8. Coke-forming tendencies of heavier distillation products (mainly atmospheric and vacuum residue) can be reduced by removal of "asphaltenic" materials (large aromatic compounds) by means of _____.
9. A good example is the production of coke for _____, which in fact is the largest non-fuel end use for petroleum coke.
10. Gas leaving the heater in Flexicoking process is cooled by steam generation and then passes through a _____ and _____for the removal of coke fines.
11. The Lurgi *moving bed gasifier* (Figure 5.13), is operated countercurrently; the coal enters the gasifier at the top and is slowly heated and dried (partial pyrolysis) on its way down while _____the product gas as it exits the reactor.
12. Updraft gasifiers produce 5 % to 20% _____and so are unsuitable for operation of engines.
13. Winkler *fluidized bed gasifier i*s a _____reactor in which coal particles in the feedare well mixed with coal particles already undergoing gasification.

1. **Answer the following questions**

   a) Why are so many stripper combinations required after main fractionator in modern crude distillation unit?   [3]

   b) Expalin one important difference between updraft and down draft biomass gasification technologies .   [4]

   c) How is the direction of outlet streams explained for the reactor & heater combination in the flexicoing process?   [3]
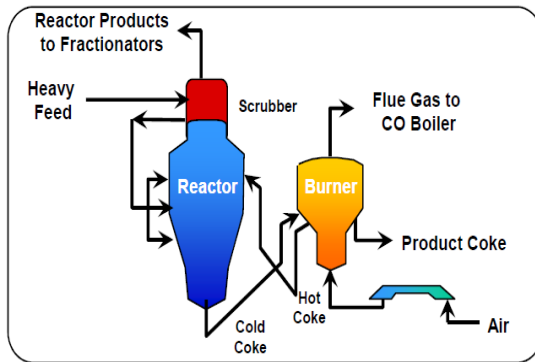
d) Given below is the plot shoing the *effect of temperature and pressure on equilibrium gas composition in autothermal gasification of coal.* How does one explain this obtained trend? [5]
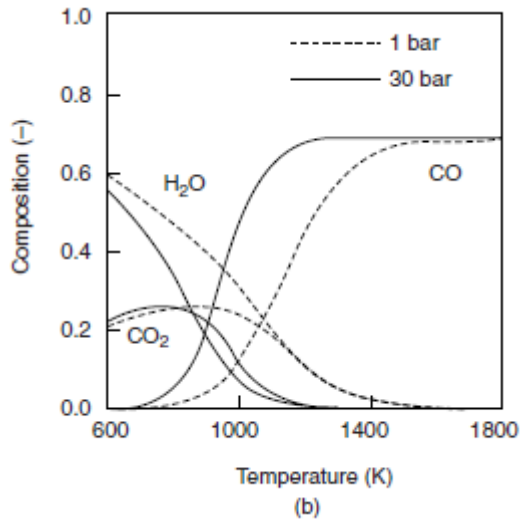
e) How does one explain the data sets given below for the catalytic reforming process (semi, fully & continuous regenerative processes) for naptha? Explain for two parameters only: feed & pressure.
[5]

Table 3.9   Operating conditions in catalytic reforming.

	Semi	Fully	Continuous
Feed H$_2$/HC (mol/mol)	10	4–8	4–8
Pressure (bar)	15–35	7–15	3–4
Temperature (K)	740–780	740–780	770–800
Catalyst life	0.5 – 1.5 y	days – weeks	days – weeks

2. **Alkane dehydrogenation is highly endothermic and high temperatures are required. Furthermore, the thermodynamic equilibrium limits the conversion per pass. Several catalytic dehydrogenation processes are commercially available. These processes differ in the type of catalyst used, the reactor design, the method of heat supply, and the method used for catalyst regeneration. Given the data sheet for all the four techonolgies in this area, how does one explain the conversion and selectivity for dehydrogenation process for propane & isobutane? How is the trade off established in any two chosen process for the production of desired alkenes?** [10+5=15]

Table 4.5 *Performance of propane and isobutane dehydrogenation processes [17, 19, 21, 22].*

Process	Oleflex	Catofin	STAR[a]	FBD
Reactor	adiabatic moving beds	parallel adiabatic fixed beds with swing reactor	isothermal tubular reactors in furnace	fluidized bed
Catalyst	Pt/Al_2O_3	Cr/Al_2O_3	$Pt-Sn/Zn-Al_2O_3$	Cr/Al_2O_3
Catalyst life (y)	1–3	1–2	1–2	not available
Temperature (K)	820–890	860–920	750–890	820–870
Pressure (bar)	1–3	0.1–0.7	3–8	1.1–1.5
Conversion (%)[b]	P: 25	P: 48–65	P: 30–40	P: 40
	IB: 35	IB: 60–65	IB: 40–55	IB: 50
Selectivity (%)[b]	P: 89–91	P: 82–87	P: 80–90	P: 89
	IB: 91–93	IB: 93	IB: 92–98	IB: 91

[a]Without oxydehydrogenation reactor.
[b]P: propane dehydrogenation; IB: isobutane dehydrogenation.

3. **Hydrotreating is essential as a pretreatment step for catalytic reforming of naphtha. The sulfur content of the feed to the reforming unit should not exceed 1 ppm. In simple naphtha hydrotreating, the feed is evaporated and led through a fixed bed reactor. Draw a complete flowsheet of hydrotreatig plant of heavy oil showing all the iputs & output streams, taking care of heat integration and separation system used in such plants developments.** **[15]**

4. THIS IS TO BE ATTEMPTED IN SEPARATE ANSWERSHEET & MAKE A SUITABLE ASSUMPTION IS ANY.

2.7 billion lb/stream day of ethylene is produced using commercial grade ethane as feedstock using steam reformer. Ethane arrives in liquid state at 700 psig and 80° F: Reactants & Product specs.

[25]

a. Show what all steps would be needed to complete the design of steam cracker.
b. Carry out the complete material balance for the given process..
c. Draw the schematic of steam cracker showing all the inputs & outputs from the cracker.

SNO	Component	Mole %
1.	CH_4	3
2.	C_2H_6	94
3.	C_3H_8	3
4.	CO_2	800 ppm
5.	S	Very less in ppm

SNo	Component	Mole %
1.	CH_4	0.6
2.	C_2H_6	0.4
3.	C_2H_4	99
4.	C_2H_2	<10 ppm
5.	H_2S	<5 ppm
6.	CO_2	<100 ppm

The first-order rate constant for ethane is obtained from Table 10.4, p. 446[1].

$$k_c = 4.717 \times 10^{14}\, e^{-72,240/R'T}, \text{ sec}^{-1} \qquad \text{(CS-2.1)}$$

where $T = {}^{\circ}K$ or

$$k_p = \frac{k_c}{RT} = \frac{4.717 \times 10^{14}}{RT}\, e^{-130,032/R'T}, \frac{\text{lb mole}}{(\text{atm})(\text{ft}^3)(\text{sec})} \qquad \text{(CS-2.2)}$$

where $T = {}^{\circ}R$ and $R = 0.73$.

			A	E, kcal/g mole
Initiation	$C_2H_6 \rightarrow 2CH_3\cdot$	(1)	1.0×10^{16}	86
Propagation	$CH_3 + C_2H_6 \rightarrow CH_4 + C_2H_5\cdot$	(2)	3.16×10^8	10.8
	$C_2H_5\cdot \rightarrow C_2H_4 + H$	(3)	3.98×10^{13}	38
	$H\cdot + C_2H_6 \rightarrow H_2 + C_2H_5\cdot$	(4)	1.25×10^{11}	9.7
Termination	$C_2H_5\cdot + C_2H_5\cdot \rightarrow n\text{-}C_4H_{10}$	(5a)	2.511×10^{10}	0
	$C_2H_5\cdot + C_2H_5\cdot \rightarrow C_2H_6 + C_2H_4$	(5b)		
Propylene formation	$C_2H_5\cdot + C_2H_4 \rightarrow C_3H_6 + CH_3\cdot$	(6)	3.16×10^9	19
	$C_2H_5\cdot + C_2H_4 \rightleftarrows 1\text{-}C_4H_9\cdot$			
	$1\text{-}C_4H_9\cdot \rightarrow 2\text{-}C_4H_9\cdot$			
	$2\text{-}C_4H_9\cdot \rightarrow C_3H_6 + CH_3\cdot$			
Inhibition	$H\cdot + C_2H_4 \rightarrow C_2H_5\cdot$	(7)	5.0118×10^{10}	−0.8

Units for $A = \text{sec}^{-1}$ for Reactions 1 and 3, and $1.(\text{g mole})^{-1}\text{sec}^{-1}$ for others.

Fig. CS-2.1 Free-radical mechanism for ethane cracking. [Reaction 5a can be neglected in terms of product produced and a combined rate constant used, $k_5 = 1.15k_{5a}(1)$. Rate equations in terms of partial pressures may be written using $R'T$ corrections.]