The University of Jordan
Faculty of Engineering & Technology
Chemical Engineering Department

(0905211) Chemical Engineering Principles

Instructor : **Prof. Naim M. Faqir**
Date : **De. 14, 2017**
Duration : **60 minutes**

Section: ⑨ أد.نكار.عبير الدبس **First Semester – 2017/2018**

2nd Midterm Exam (Closed Book)

Name: Maram Al-Atalleh **ID #** ____________

Question #	Gained points	Full points
1	15.0	15
2	15.0	15
3	19.0	20
Total		50

49/50 Excellent

Question 1: [15 points]
The synthesis of ammonia proceeds according to the following reaction

$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$

In a given plant, 4202 lb of nitrogen and 1046 lb of hydrogen are fed to the synthesis reactor per hour. Production of pure ammonia from this reactor is 3060 lb per hour.

1. What is the limiting reactant?
2. What is the percent excess reactant?
3. What is the percent conversion obtained (based on the limiting reactant).

$N_2 + 3H_2 \longrightarrow 2NH_3$

① 1 3

3 الخلف ←

~~4202 1046~~

~~$\frac{4202 \text{ lbmol } N_2}{1 \text{ lbmol } N_2}$ $\frac{1046 \text{ lbmol } H_2}{3 \text{ lbmol } H_2}$~~

~~4202 > 348.6 → so the H_2 is limited~~

~~② % excess N_2 = $\frac{n_{fed} - n_{stoich}}{n_{stoich}}$~~

~~n_{N_2}(stoich) = $\frac{1046 \text{ lbmol } H_2}{} \Big| \frac{1 \text{ lbmol } N_2}{3 \text{ lbmol } H_2}$ = $\boxed{\frac{348.67 \text{ lbmol } N_2}{\text{stoich}}}$~~

~~% excess = $\frac{4202 - 348.67}{348.67}$ ×100% =~~

Q1

$Mw\ H_2 = 2$

$Mw\ N_2 = 28$

$Mw\ NH_3 = 17.03$

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

$\dot{m} = 3060$ lbm / h

4202 lb N_2 | 1046 lb H_2

$\dot{n}_{NH_3} = \frac{\dot{m}}{Mw} = \frac{3060 \text{ lbm/h}}{17.03 \text{ lbm/lbmol}}$

$\boxed{\dot{n}_{NH_3} = 179.7 \text{ lbmol}}$

$\dot{n}\ N_2 = \frac{m}{Mw}$

$= 150.1$ lbmol/h

$\dot{n}\ H_2 = 523$ lbmol/h

① stoichemetry ratio

$\frac{150.1 \text{ lbmol } N_2/h}{1} \ ? \ \frac{523 \text{ lbmol } H_2/h}{2}$

$150.1 \text{ lbmol } N_2/h < 261.5 \text{ lbmol } H_2/h$

So N_2 is limited reactant.

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② $\%\text{excess}_{H_2} = \frac{n_{fed} - n_{stoich}}{n_{stoich}}$

$n_{stoich(H_2)} = \frac{150.1 \text{ lbmol } N_2}{h} \Big| \frac{3 \text{ lbmol } H_2}{1 \text{ lbmol } N_2} = \boxed{450.2 \text{ lbmol } H_2/h}$

$\%\text{excess} = \frac{523 \text{ lbmol/h} - 450.2 \text{ lbmol/h}}{450.2 \text{ lbmol/h}} = \boxed{16.17\%}$

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③ present conv. by N_2 $= \frac{n_{reacted}}{n_{fed}} \times 100\% = \frac{n_{input} - n_{output}}{n_{input}}$

$\dot{n}_{reacted\ N_2} = \frac{179.7 \text{ lbmol } NH_3}{h} \Big| \frac{1 \text{ lbmol } N_2}{2 \text{ lbmol } NH_3} = \boxed{89.85 \text{ lbmol } N_2/h}$

present conv by N_2 $= \frac{89.85 \text{ lbmol } N_2/h}{150.1 \text{ lbmol } N_2/h} = \boxed{59.86\%}$ conv N_2

1 atm = 14.696 psi

$P_{absolute} = P_{gage} + P_{atmosphere}$

$= 300 psi + 14.696 = \boxed{314.696 \ psi_a}$ N_2

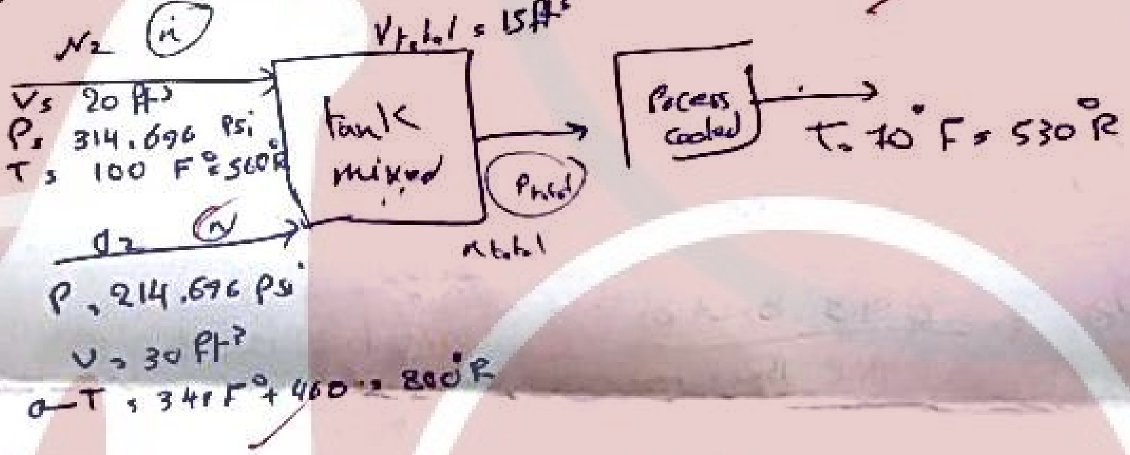
gage

Question 2: [15 points]
20 ft^3 of nitrogen gas at 300 psig and 100°F and 30 ft^3 of oxygen gas at 200 psig and 340°F are mixed in a 15 ft^3 tank. The tank is then cooled to 70°F: Find the pressure, and the mole fraction and partial pressure of each component in the 15 ft^3 tank. Assume that the ideal gas law applies.

$P_{absolute} = 200 + 14.696$

$P = 214.696$ absolute psi

R=10.73 ft^3.psia/lb-mole.°R
T[°R] = T[°F]+460



for N_2

$PV = nRT$

$$n = \frac{PV}{RT} = \frac{314.696 psi (20 ft^3)}{10.73 \left(\frac{ft^3 . psia}{lbmol . °R}\right) (560°R)} = \boxed{1.05 \ lbmol \ N_2}$$

for O_2

$PV = nRT$

$$n = \frac{PV}{RT} = \frac{214.696 psi (30 ft^3)}{10.73 \left(\frac{ft^3 . psia}{lbmol . R}\right) (800°R)} = \boxed{0.75 \ lbmol \ O_2}$$

mol mixture = mol N_2 + mol O_2 = $\boxed{1.8 \ lbmol \ mixture}$

$V_{mix} = 15 ft^3$

$T_{mix} = 530°R$ cooled. → calculated P_{total}

$$PV = nRT \longrightarrow P_T = \frac{n_{mix} R T}{V} = \frac{(530°R) \times 1.8 lbmol (10.73 ft^3 . psia/lbmol)}{15 ft^3}$$

$\boxed{P_{total} = 682.428 \ psi}$

Ⓠ2 mole fraction , partial pressure

~~P total at same condition~~

~~$\frac{P_1 V_1}{P_2 V_2} = \frac{n R T_1}{n R T_2}$~~

~~$PV = nRT$~~

$P =$

$P_A = P (y_a)$

mol fraction

mol total = 1.8 lbmol mix

mol N_2 = 1.05 lbmol N_2

mol O_2 = 0.75 lbmol O_2

$$y_{N_2} = \frac{\text{mol } N_2}{\text{Total mol}}$$

$$= \frac{1.05 \text{ lbmol } N_2}{1.8 \text{ lbmol mix}}$$

$$\boxed{y_{N_2} = 0.583 \text{ lbmol } N_2 / \text{lbmol}}$$

$$\boxed{y_{O_2} = \frac{0.75 \text{ lbmol } O_2}{1.8 \text{ lbmol mix}} = 0.416 \text{ lbmol } O_2/\text{lbmol}}$$

partial pressure

$P_{total} = 682.428$ Psi

$P_A = P_{total}\, y_a$ psi

$$P_{N_2} = (682.428)\left(\frac{0.583 \text{ lbmol } N_2}{\text{lbmol}}\right) = \boxed{397.85 \text{ Psi } N_2}$$

$$P_{O_2} = 682.428 \text{ Psi}\left(\frac{0.416 \text{ lbmol } O_2}{\text{lbmol}}\right) = \boxed{283.89 \text{ Psi } O_2}$$

10

تتابع العملية ① ← ② ← (ع)

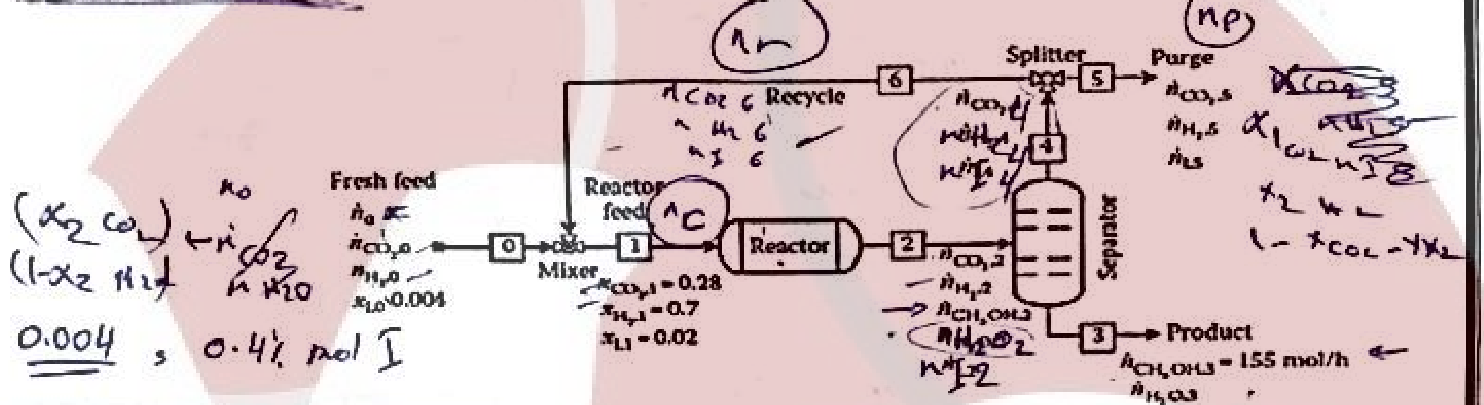
حل السؤال

Question 3: [15 points]

Methanol is produced by the reaction of carbon dioxide and hydrogen:

$$CO_2 + 3H_2 \longrightarrow CH_3OH + H_2O$$

The fresh feed to the process contains hydrogen, carbon dioxide, and **0.40 mol% inert (I)**. The reactor effluent passes to a separator that removes essentially all of the methanol and water formed, but none of the reactants or inert. The methanol produced in the reactor is **155 mol CH₃OH/h**. The latter substances are recycled to the reactor. To avoid buildup of the inert in the system, a purge stream is withdrawn from the recycle as shown in the following figure. The feed to the reactor (not the fresh feed to the process) contains **28.0 mol% CO₂, 70.0 mol% H₂, and 2.00 mol% inert**. The single-pass conversion of hydrogen **is 60.0%.** Calculate the molar flow rates and molar compositions of the fresh feed, the total feed to the reactor, the recycle stream, and the purge stream. Use the extent of reaction method.



0.004 = 0.4% mol I

Dof

unit	unknown	equation	Dof
overall	7 unknown (n_0, $n_{CO_2,0}$ $n_{H_2,0}$, $n_{H_2O(3)}$ $n_{CO_2(5)}$, $n_{H_2(5)}$, $n_{I(5)}$	4 (can represent by ε) 1 (M. B) Inert 1 reaction	~~1~~ 0
mix	7 unknown	~~4 species ε~~ 5 M. B	3
reactor	5 unknown (n_c $n_{CO_2(2)}$, $n_{H_2O(2)}$ n_{H_2}, $(I)_2$	4 sepecies (ε) 1 conv.	0
separator	8 unknown	4 ~~species~~ M.B	4
Purge	9	1 M.B	

<u>reactor</u> :

$\dot{n}_{CO_2(2)} = n_{CO_2,1} - \varepsilon \longrightarrow$ $\quad n_{CO_2,1} = 0.28\,n_c - 155\ \text{Kmol/h}$

$\dot{n}_{H_2(2)} = n_{o(H_2)1} - 3\varepsilon$ $\quad \dot{n}_{H_2(2)} = 0.7\,n_c - 465\ \text{Kmol/h}$

$n_{H_2O(2)} = \varepsilon$ $\quad (\dot{n}_{H_2O(2)} = 155\ \text{Kmol/h})$

$n_{CH_3OH,2} = \boxed{\varepsilon = 155\ \text{Kmol/h}}$

$\varepsilon = 155\ \text{Kmol/h}$

Q3

reactor

by conv H_2 = 60%

$$f_{conv} = \frac{n_{fed} - n_{out}}{n_{fed}} \times 100\% = 60\%$$

$$= \frac{0.7(n_c) - (0.7n_c - 465)}{0.7\,n_c} \times 100\% = 60\%$$

$0.42\,n_c = \cancel{0.7n_c} - \cancel{0.7n_c} + 465$

$0.42\,n_c = 465$

$\boxed{n_c = 1107.14\ mol/h}$ ✓

$n_I = 0.02(1107.14)$

$\boxed{n_{I_2} = 22.14\ mol\ I/h}$

back to eque ξ of Carbon dioxide

$n(CO_2)_2 = 0.28\,n_c - 155$ ✓

$n(CO_2)_2 = 154.9 = \boxed{155\ mol/h\ CO_2}$

$n(H_2)_2 = 0.7\,n_c - 465$

$n(H_2)_2 = 309.9 \approx \boxed{310\ mol/h\ H_2}$ ✓

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over all:

$n(CO_2)_5 = n(CO_2)_0 - \xi$ → $n_{CO_2(5)} = n_{CO_2\,0} - 155$

$n(H_2)_5 = n(H_2)_0 - 3\xi$ — $n_{H_2(5)} = n_{H_2\,0} - 465$

$n_{CH_3OH} = \xi = 155\ mol/h$

$(n_{H_2O})_3 = \xi = 155\ mol/h$ — $0.318\,n_p = x_{CO_2}\,n_0 - 155$

by overall inert.

$0.004\,n_0 = n_5$

90=5 ②

n_{Total} of go of seperator above stream

$n_{Total} = n_{CO_2}{}_4 + n_{H_2}{}_4 + n_{I}{}_4$

$= 155 + 310 + 22.14$

$\boxed{n_{Total} = 487.14}$ ✓

~~Seperator~~

$x_{CO_2} = \frac{n_{CO_2}}{487.14} = \frac{155 \text{ mol/h } CO_2}{487.14}$ ✓

$\boxed{x_{CO_2(1)} = 0.318 \text{ mol } CO_2/\text{mol}}$ ✓

$\boxed{x_{H_2(1)} = \frac{310}{487.14} = 0.636 \text{ mol } H_2/\text{mol}}$

$x_I = \frac{~~22.14~~}{} \quad \frac{22.14}{487.14} = \boxed{0.045 \text{ mol } I/\text{mol}}$

by mixing pocub.

total balance

$n_0 + n_r = n_c \rightarrow \boxed{n_0 + n_r = 1107.14}$

balace CO_2

~~$x_2 n_0 + 0.318 n_r = 0.28 n_c$~~

بدك كل الحصة
على ملف الحصة
مكررة

by inert

$0.004 n_0 + 0.045 n_r = 2$

$\boxed{n_0 = ~~412.5 \text{ mol/h}~~ ~~\text{Total}~~ \; 67508 \text{ mol}}$

~~$n_r = 5.4$ mol/h~~

$\boxed{n_r = 432.05 \text{ mol}}$

$n_{Total \text{ of Seprator}} = n_p + n_r$

~~$487.14 = n_p + 5$~~

$\boxed{n_p = 674.95 \text{ mol}}$

by ~~basis~~ 100

Composition of fresh feed

$n_0 = 675.08$

balance CO2

$(x_{CO_2})_2 n_0 + (x_{CO_2})_5 n_r = 0.28 n_c$

$\boxed{(x_{CO_2})_2 = 0.225}$

$(x_{H_2})_2 = 1 - 0.004 - 0.225$

$= 0.771$