

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING
CHEG 2333- Material and Energy Balance
SPRING 2022**

- I. COURSE DESCRIPTION IN ABET FORMAT**
- II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS**
Program Outcomes Assessed in Course
Assessment Summary of Class Semester Averages for Outcomes
End of Semester Course Outcomes Assessment Reports
- II. TESTS**
Summary of Topics covered by Test
Original Test Questions & Master Solution/grading scheme used
(Summary of topics can be a separate page or include on the assignment itself)
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- III. HOMEWORK ASSIGNMENTS**
Summary of Topics covered by Homework
Original Homework Questions & Master Solution/grading scheme used
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- IV. MIDTERM EXAM**
Summary of Topics covered by Midterm Exam
Laboratory Handout/Instructions and Grading Scheme
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- V. FINAL EXAM**
Summary of Topics Covered by Final Exam
Project Problem Statement and Grading Scheme
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)

[Include any other evaluation used and omit any method above method (Test, Quizzes, Homework, Laboratory and Project reports) that was not used]

CHEG 2333: MATERIAL AND ENERGY BALANCES

- | | |
|---|---|
| 1. Course number and name: | CHEG 2333 Material And Energy Balances |
| 2. Credits, contact hours, categorization: | 3 credit hours; 3 contact hours; engineering |
| 3. Instructor's or course coordinator's name: | Dr. Michael Gyamerah |
| 4. Text book: Title: | ELEMENTARY PRINCIPLES OF CHEMICAL PROCESSES |
| Author: | Richard M. Felder, Ronald W. Rousseau, and Lisa G. Bullard |
| Publisher, Year & Edition: | John Wiley and Sons Inc, New Jersey, 2016, 4 th Edition |
| a. Other Supplemental material | 1. "Basic Principles and Calculations in Chemical Engineering" By Himmelblau, D. M. and Riggs, J. B., International Engineering 2003. Pearson Education, ISBN 0-13-123368 |
| 5. Specific course information | |
| a. Brief description of the content of the course (catalog description) | CHEG 2333. (3-1) Credit 3 semester hours. Application of the laws of conservation of mass and energy to reacting and nonreacting, simple and complex chemical systems. Application of both element and species balances to multiple reaction systems. Application of the degrees-of-freedom analysis to single process units and multi- unit process flow-sheets. Numerical solution techniques for the solution of balance equations |
| b. Prerequisites | CHEG 1202; CHEM 1304 or CHEM 1403 and PHYS 2325 |
| c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program | Required |
| 6. a. Specific goals for the course This course prepares engineering students with the following outcomes. | |
| | b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course. |

Students will be able to:

1. Apply knowledge of mathematics, science, and engineering. Perform mass or mole balances on single or multiple units. Perform balances on batch or continuous systems. Determine balances for systems

The specific goals for the course specific outcomes listed on the left column will address the following student learning outcomes:

Outcome D1**

An ability to identify, formulates, and solves fundamental

at steady state. Present and report basic engineering information.

2. Identify systems of units and perform unit conversions. Calculate mole and mass fractions. Determine the total volume, average molar weight, total mass and total number of moles of a mixture

3. Identify, formulate, and solve engineering problems. Solve mass balances with chemical reactions. Solve mass balances without chemical reactions. Determine the extent of reaction. Draw and completely label a flow chart with or without a reactor. Determine the limiting and excess reactants. Determine theoretical air, excess air, and relative humidity. Calculate stream compositions

4. Analyze, formulate, and solve energy balances. Calculate heat, enthalpy, work, and internal, kinetic, and potential energies. Calculate heat and enthalpy entering and leaving a unit.

engineering problems by applying principles of engineering, science, and mathematics.

7 Brief list of topics to be covered

What Some Chemical Engineers Do for a Living	(1 hour)
Introduction to Engineering Calculations	(3 hours)
Processes and Process Variables	(9 hours)
Fundamentals of Material Balances	(20 hours)
Energy and Energy Balances	(1 hours)

II ASSESSMENT RESULTS FOR CURRENT AND PAST TWO PERIODS

Program Outcomes Assessed in this course

Outcome D1:

An ability to identify, formulate, and solve fundamental engineering problems (FEP) by applying principles of engineering, science, and mathematics.

Assessment Summary of Class Semester Averages for Outcomes Spring 2020-Spring 2022

Outcome	Chemical Engineering Department student outcome D1
Semester	Semester Class Average (%)
Spring 2022	70
Spring 2021	82
Spring 2020	83
Comments on Trend of Data (Improving or deteriorating)	The class average for the spring 2022 semester showed a significant drop of 12 and 13 percentage points below those of spring 2021 and 2020 respectively.

*Expected Semester Class Average = 70% (or as defined by the program)

Ideal Semester Class Average =75% (or as defined by the program)

End of Semester Course Assessment Reports Spring 2022 and Last Two Assessment Periods.

Each summary contains the following Information

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department.
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

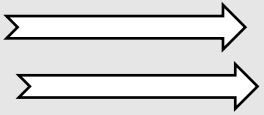
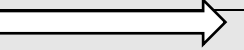
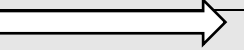
5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer **NO**.

Table 2.1 END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
CHEG 2333-P01: MATERIALS AND ENERGY BALANCES
SPRING 2022 SEMESTER

Report Prepared by: Dr. Michael Gyamerah

Report Date: May 25, 2022

Semester	Analysis Type	Number of Students	Outcome D1 An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.”			
			Expected Class Average	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Spring 2022	Direct	11	75	70	70	45.5
Spring 2021	Direct	7	75	70	82	71.4
Spring 2020	Direct	24	75	70	83	91.7
Implementation Summary		The importance of the pre-requisite courses, Chemistry for Engineers (CHEM 1403), University Physics I (PHYS 2325) and Intro to Computations in CHEG (CHEG 1202) were stressed at the start of the course. The introduction of a student centered active learning and instruction strategy was presented to the students. The students were informed about being assigned a pre-class reading assignment and quiz to be completed prior to class to assist students to be actively engaged and ask questions during class. Using their cell phones, students would respond to formative questions to assess their understanding and help resolve any misconceptions they may have about the course material..				
Perceived Problems		Although the students did well on the pre-class reading assignments quizzes, they could not correctly respond to the same questions when slightly modified to test their understanding of the concepts. The students were inconsistent in following step-by-step approach to solving problems presented several times in class .				
Plans for Addressing Problems		The following is recommended for implementation: Students should be required to upload “bullet point notes” of the pre-class reading assignment in addition to taking the quiz. Students be asked to work in groups on the whiteboard during the newly created recitation section of the course that starts in the next fall 2022 semester				
Overall Trend over Periods		The performance of the students was below the expected class average. In addition, there was 12-13 percentage points drop in the class average compared to the previous two semesters.				
Were Expectations Met?	Class Average $\geq 75\%$ and $\geq 70\%$ of Students Performed at or Above Expected Average.		NO			

MATERIAL AND ENERGY BALANCE SPRING 2022

Title of Assignment: TEST 2

TOPICS COVERED IN TEST 2

Test 2 covered the following topics:

1. Degree of freedom analysis
2. Mass balances on multiple-unit processes
3. Bypass stream
4. Fractional conversion
5. Percent yield
6. Extent of reaction

MATERIAL AND ENERGY BALANCE SPRING 2022

SAMPLE TEST 1 QUESTIONS, SOLUTION, AND GRADING SCHEME FOR TEST 1

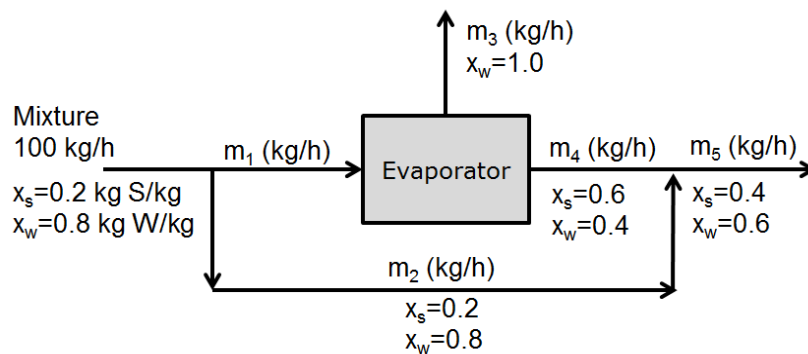
Material and Energy Balances (Spring 2022): Exam 2

May 2, 2022

Answer all questions. You will be graded based on (1) your ability to apply knowledge of chemical reaction stoichiometry involving (i) processes with recycle and bypass, (ii) degrees of freedom analysis, (iii) and determine fractional conversion, percentage yield, selectivity and extents of reactions.

Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

1. The process below is an evaporator for concentrating a salt solution prior to crystallization



- Provide a sketch of the overall and subunits required for a degree of freedom (DOF) analysis
- Determine the degree of freedom (DOF) of the overall and each of the subunits
- Calculate m_1 , m_2 , m_3 , m_4 and m_5

2. The two reactions:



take place in a continuous reactor at steady state. The feed is 85 mol/min of C_2H_6 . The product leaving the reactor contains 42.4 mol of C_2H_6 , 40 mol of C_2H_4 , and 5.2 mol of CH_4 .

If the fractional conversion is given by $\frac{\text{moles reacted}}{\text{moles fed}}$,

the percentage yield =

$$\frac{\text{moles of desired product formed}}{\text{moles that would be formed if there were no side reactions and the limiting reactant were consumed completely}}$$

the selectivity $\frac{\text{moles of desired product formed}}{\text{moles of undesired product formed}}$,

extent of reaction $\xi = \frac{\text{moles of species } i \text{ in the product} - \text{moles of species } i \text{ in the feed}}{\text{Stoichiometric coefficient of species } i}$

and for a set of reactions taking place in a batch or continuous steady-state reactor, the number of moles of species i at any time t is given by

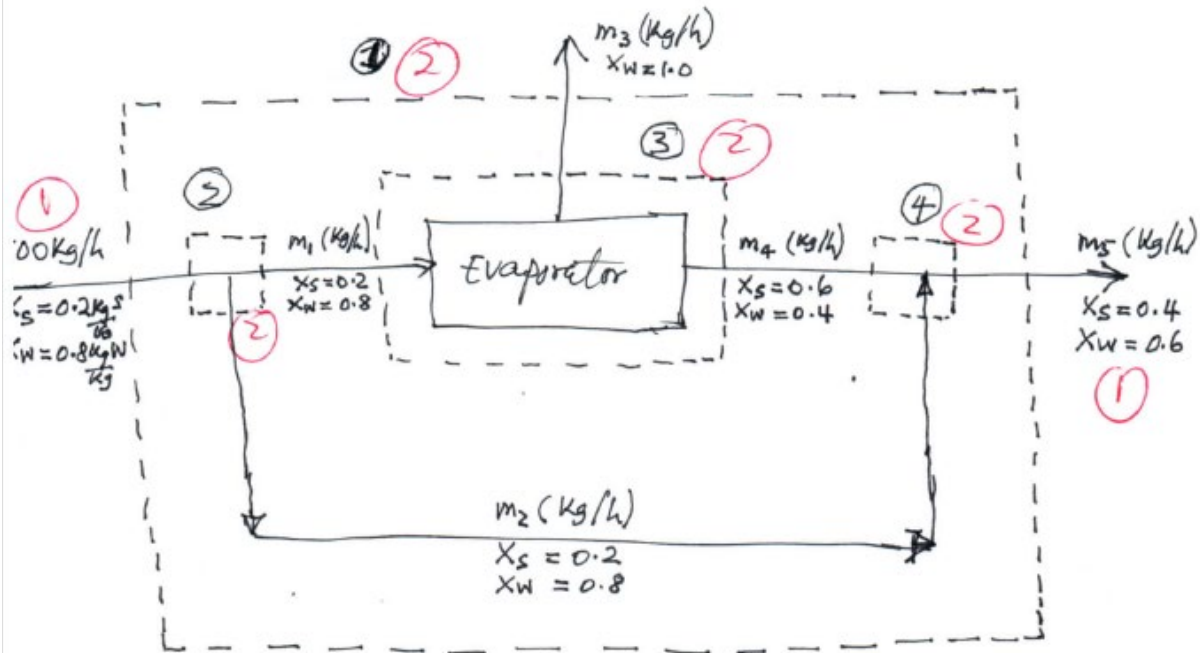
$n_i = n_{i0} + \nu_{i1} \xi_1 + \nu_{i2} \xi_2 + \text{etc}$, where n_{i0} = moles of i when time $t = 0$ and ξ_1 and ξ_2 etc are the extent of reactions 1, 2 etc and ν_{i1} and ν_{i2} are their stoichiometric coefficients respectively,

Calculate:

- The fractional conversion of C_2H_6
- The percentage yield of C_2H_4
- The selectivity of C_2H_4 relative to CH_4
- The extents of the first and second reactions

CHEG 2333 Material & Energy Balances EXAM 2

1 (i)



Basis: 100 kg/h. Mixture (2)

(ii) (a) overall mass balance (mass balance boundary 1)

Unknowns: m_3 and $m_5 = 2$ (1)

(3) Species: S and W = 2, hence 2 mass equations either 1 species balance (1) and one overall balance equation or 2 species balance equations

Degrees-of-freedom: $2 - 2 = \# \text{ of unknowns} - \# \text{ of species}$

$\therefore 2 - 2 = 0$ (1) and Degrees-of-freedom (DOF) = 0

(b) Split point (mass balance boundary 2)

Unknowns: m_1 and $m_2 = 2$ (1)

(3) Species: 1 (Since compositions at the split point are the same and the components or species together may be considered as the same) (1)
S and W may be considered as one species in the 3 streams

Degree-of-freedom = $2 - 1 = 1$ (1)

CHEG-2333 Material & Energy Balances
EXAM 2

1. (ii) Balance over Evaporator (box 3)

Unknowns: $m_1, m_3, m_4 = 3$ (1)

(3) Species: S and W = 2 (1)

Degrees of freedom = $3 - 2 = 1$ (1)

(d) Balance over Unit (Box) 4

Unknown: $m_2, m_4, m_5 = 3$ (1)

(3) Species: S and W = 2 (1)

Degrees of freedom = $3 - 2 = 1$ (1)

(iii) Overall mass balance

$$100 = m_3 + m_5 \quad \text{--- (1) (Box 1)}$$

S-balance over Box 1

$$100(0.2) = (0.4) \times m_5 \quad \text{--- (2)}$$

$$m_5 = \frac{100(0.2)}{0.4} = \frac{100 \times 2}{4} = 50 \text{ kg/h} \quad (5)$$

$$100 = m_3 + m_5$$

$$\therefore 100 = m_3 + 50$$

$$\text{Hence } m_3 = 100 - 50 = 50 \text{ kg/h} \quad (5)$$

(b) Balance over Box 4 (Mixing point)

$$m_2 + m_4 = m_5 = 50$$

$$\therefore m_2 + m_4 = 50$$

S-balance

$$0.2m_2 + 0.6m_4 = 0.4 + 50 = 0.4 \times m_5$$

CHEG 2333 Material & Energy Balances
EXAM

1 (iii) b) $m_2 + m_4 = 50$ — (1)

$$0.2m_2 + 0.6m_4 = 0.4 \times 50 = 20$$

$$m_4 = 50 - m_2$$

$$\therefore 0.2m_2 + 0.6(50 - m_2) = 20$$

$$0.2m_2 + 30 - 0.6m_2 = 20$$

$$0.6m_2 - 0.2m_2 = 30 - 20 = 10$$

$$0.4m_2 = 10$$

$$m_2 = \frac{10}{0.4} = \frac{100}{4} = 25 \text{ kg/h} \quad (5)$$

$$m_2 + m_4 = 50$$

$$\therefore 25 + m_4 = 50$$

$$m_4 = 25 \text{ kg/h} \quad (5)$$

(c) Balance over the Evaporator (Box 3)
overall balance over Box 3

$$m_1 = m_3 + m_4$$

S-balance over Box 3

$$0.2m_1 = 0.0(m_3) + 0.6m_4, \text{ where } m_4 = 25 \text{ kg/h}$$

$$0.2m_1 = 0.6m_4 = 0.6 \times 25$$

$$0.2m_1 = 15$$

$$m_1 = 75 \text{ kg/h} \quad (5)$$

$$m_1 = 75 \text{ kg/h}; m_2 = 25 \text{ kg/h}; m_3 = 50 \text{ kg/h}$$

$$m_4 = 25 \text{ kg/h and } m_5 = 50 \text{ kg/h}$$

CHGG 2333 Material & Energy Balances
EXAM 2



At $t=0$ hr, $C_2H_6 = 85$ mol (1)

At $t=t$ hr, $C_2H_6 = 42.4$ mol (1)

$C_2H_4 = 40$ mol (1)

$CH_4 = 5.2$ mol (1)

(i) Fractional conversion = $\frac{\text{moles reacted}}{\text{moles fed}} = \frac{n_{i0} - n_i}{n_{i0}}$ (2)

where n_{i0} = moles fed

n_i = moles remaining at end of reaction

$\therefore$ fractional conversion = $\frac{n_{i0} - n_i}{n_{i0}} = \frac{85 - 42.4}{85} = \frac{42.6}{85}$
= 0.501 (4)

(ii) % yield of C_2H_4 = $\frac{\text{moles of } C_2H_4 \text{ produced}}{\text{moles of } C_2H_4 \text{ if no side reactions were formed}} \times 100$ (3)
= $\frac{40}{85} \times 100 = 47.1\%$ (4)

(iii) Selectivity = $\frac{\text{moles of desired product formed}}{\text{moles of undesired product formed}} = \frac{40}{5.2}$ (3)
= 7.69 (4)

CH2333 Material & Energy Balances
EXAM 2

(iv) $(n_i)_{C_2H_6} = (n_{i0})_{C_2H_6} - \xi_1 - \xi_2$ (1) where $(n_i)_{C_2H_6}$ = mol of C_2H_6 leaving reactor
 $(n_{i0})_{C_2H_6}$ = mol of C_2H_6 in feed
 ξ_1 = extent of reaction (1)
 ξ_2 = extent of reaction (2)

(b) $(n_i)_{C_2H_4} = (n_{i0})_{C_2H_4} + \xi_1$ (1)

(c) $(n_i)_{H_2} = (n_{i0})_{H_2} + \xi_1 - \xi_2$ (1) as defined in (a) with subscripts representing species not added here.

(d) $(n_i)_{CH_4} = (n_{i0})_{CH_4} + 2\xi_2$ (1)

$(n_{i0})_{C_2H_6} = 85 \text{ mol}$ (1) and $(n_i)_{C_2H_6} = (n_{i0})_{C_2H_6} - \xi_1 - \xi_2$ reduces to:
 $(n_i)_{C_2H_6} = 42.4 \text{ mol}$ (1) $42.4 = 85 - \xi_1 - \xi_2$ (1)

$(n_{i0})_{C_2H_4} = 0$ (1); $(n_i)_{C_2H_4} = 0 + \xi_1 = 40$ where $(n_i)_{C_2H_4} = 40 \text{ mol}$ (1)

$(n_{i0})_{H_2} = 0$ (1); $(n_i)_{H_2} = \xi_1 - \xi_2$ (1)

$(n_{i0})_{CH_4} = 0$ (1); $(n_i)_{CH_4} = 0 + 2\xi_2 = 5.2$ where $(n_i)_{CH_4} = 5.2$ (1)

Hence $\xi_1 = 40$ (1)

(1) $5.2 = 2\xi_2$, and

$42.4 = 85 - \xi_1 - \xi_2 \Rightarrow \xi_1 + \xi_2 = 85 - 42.4$ (1)

(1) $\xi_1 + \xi_2 = 42.6$

$\xi_1 = 40 \Rightarrow 40 + \xi_2 = 42.6$

(1) $\xi_2 = 42.6 - 40 = 2.6$ and $2\xi_2 = 5.2 \Rightarrow \xi_2 = 2.6$

The extent of reaction 1 = $40 = \xi_1$ (1)

The extent of reaction 2 = $2.6 = \xi_2$ (1)

ABOVE AVERAGE

Above Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of chemical reaction stoichiometry and (1) determine degrees of freedom involving processes with recycle and bypass, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

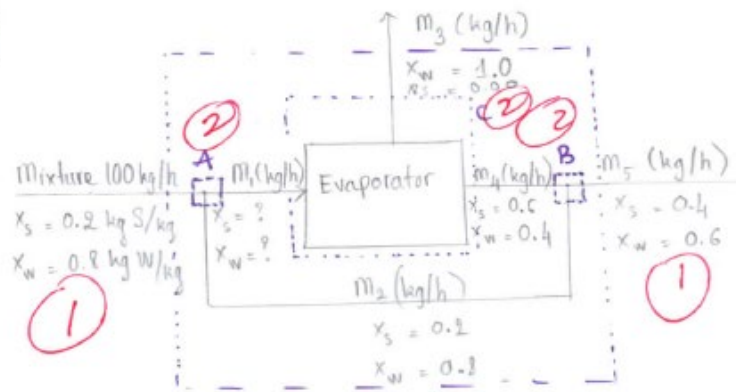
Name: Chau Truong

Title of Assignment: Exam 2 Due Date: 05-02-2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply knowledge of chemical reaction stoichiometry involving (i) processes with recycle and bypass, (ii) degrees of freedom analysis, (iii) and determine fractional conversion, percentage yield, selectivity and extents of reactions. <i>This assignment tests students' knowledge to apply knowledge of chemical reaction stoichiometry and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	96
TOTAL	100	96

Chau, Truong

①



$$\begin{array}{r} 1-44 \\ 2-40 \\ \hline 84 \end{array}$$

(i) 1 overall > 3 subunit are required for DOF analysis

(ii) * DOF of the overall:
- we have 2 unknown: m_3 (kg/h) and m_5 (kg/h)
- 2 species components: x_s and x_w
so, $DOF = 2 - 2 = 0$ (we know we can solve it first)

* DOF of the subunit A:
- 4 unknown: m_1 , m_2 , x_s , x_w
- 2 species components: x_s and x_w
 $DOF = 4 - 2 = 2$

* DOF of the subunit B:
- 3 unknown: m_4 , m_5 , m_2
- 2 species components: x_s , x_w
 $DOF = 3 - 2 = 1$

* DOF of subunit C (evaporator):
- 3 unknown: m_2 , m_4 , m_3
- 2 species component: x_s , x_w
 $DOF = 3 - 2 = 1$

(iii) Basic: 100 kg/h is the mixture input

- For overall system:

① Overall Balance: $100 \text{ (kg/h)} = m_3 + m_5 \quad (1)$

② Components Balance: $0.2 \times 100 = 0.4 m_5 \quad (2)$
$$\frac{0.2 \times 100}{0.4} = m_5 = 50 \text{ (kg/h)}$$

From equation (1) we can solve $m_3 = 100 \text{ (kg/h)} - m_5 \text{ (kg/h)}$

$$m_3 = 100 - 50 = 50 \text{ (kg/h)}$$

Chau. Truong

For subunit B: * overall balance : $m_5 = 50 \text{ (kg/h)} = m_4 \text{ (kg/h)} + m_2 \text{ (kg/h)}$ $m_4 = 50 - m_2 \text{ (kg/h)}$ (3)

* components balance X_5 : $50 \times 0.4 = m_4 \times 0.6 + m_2 \times 0.2$ (4)
 $20 \text{ (kg/h)} = 0.6 m_4 + m_2 \times 0.2$

Put (3) equation into (4) : $20 = 0.6(50 - m_2) + m_2 \times 0.2$

$m_2 = 25 \text{ (kg/h)}$

From (3) we can solve $m_4 = 50 - 25 = 25 \text{ (kg/h)}$

- For sub unit A

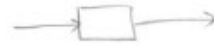
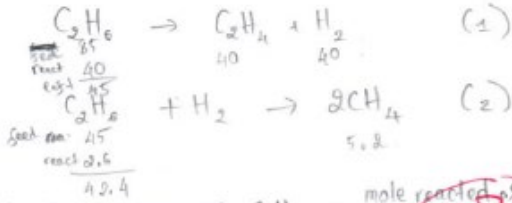
* overall balance : $100 \text{ (kg/h)} = m_1 + m_2 = m_1 + 25 \text{ (kg/h)}$

$m_1 = 100 - 25 = 75 \text{ (kg/h)}$

Chan, Truong

(2)

(40)



a) - The fractional conversion of C_2H_6 in (2) = $\frac{\text{mole reacted of } \text{C}_2\text{H}_6 (1)}{\text{mole fed of } \text{C}_2\text{H}_6 (2)} = \frac{\text{mole product } \text{C}_2\text{H}_4}{\text{mole fed of } \text{C}_2\text{H}_6} = \frac{40 \text{ mol}}{85 \text{ mol}} = 0.47 \text{ or } 47\%$

because coefficients of C_2H_6 and C_2H_4 is 1:1

?? % fractional conversion of C_2H_6 in (2) = $\frac{\text{mole reacted of } \text{C}_2\text{H}_6 (2)}{\text{mole fed of } \text{C}_2\text{H}_6 (2)}$

% yield = ?

* in 1 mol of C_2H_6 created 2 mol CH_4 .

so 5.2 mol CH_4 created we need $\frac{5.2}{2} = 2.6 \text{ mol } \text{C}_2\text{H}_6 (2)$

the mole fed of C_2H_6 in equation 2 was the mole excess of C_2H_6 after reacted in reaction (1). Hence, mole fed of $\text{C}_2\text{H}_6 (2) = \text{Mole excess } \text{C}_2\text{H}_6 (2)$

$= 85 - 40 = 45 \text{ mole}$

- The fractional conversion of C_2H_6 in second reaction = $\frac{2.6}{45} = 0.057 \text{ or } 5.7\%$

c) Selectivity of C_2H_4 relative to CH_4 = $\frac{\text{Mole of } \text{C}_2\text{H}_4}{\text{Mole of } \text{CH}_4} = \frac{40}{5.2} = 7.7$

(4)

2) b) % Yield of C_2H_4 = $\frac{\text{Mole of } C_2H_4 \text{ product formed} \cdot 3}{\text{Mole of } C_2H_4 \text{ would be formed if no side of reaction}}$

but Mole of C_2H_4 would formed if no side of reaction = Mole of C_2H_6 feed in to the system = $\frac{85 \text{ mol}}{\text{min}}$

because $\frac{C_2H_4}{C_2H_6} = 1:1$

% Yield of = $\frac{40 \text{ mol of } C_2H_4 \cdot 2}{85 \text{ mol of } C_2H_6} \times 100 = 47.05\% \cdot 4$

d) $C_2H_6 = 85 \xrightarrow{\text{reac}}$ $\rightarrow n_1 = n_{C_2H_4} = 40 \cdot 1$
 $n_2 = n_{H_2} = ?$
 $n_3 = n_{CH_4} = 5.2 \cdot 1$
 $n_4 = C_2H_6 \text{ left} = 42.4 \cdot 1$

$\xi_1 = \frac{n_{C_2H_4} - n_{C_2H_4}^0}{1} \Rightarrow n_{C_2H_4} = \xi_1 = 40 \cdot 8$

at time $t=0$ $n_{C_2H_4} = 0$ mole

at time $t=0$ $n_{CH_4} = 0$ mole

$\xi_2 = \frac{n_{CH_4} - n_{CH_4}^0}{2} \Rightarrow 2\xi_2 = n_{CH_4} - 0 = 5.2$
 $\xi_2 = \frac{5.2}{2} = 2.6 \cdot 8$

AVERAGE

Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER**

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Name: Juan Pedro Bubang Ngurnu Ayari

Title of Assignment: EXAM 2 Due Date: May 2, 2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply knowledge of chemical reaction stoichiometry involving (i) processes with recycle and bypass, (ii) degrees of freedom analysis, (iii) and determine fractional conversion, percentage yield, selectivity and extents of reactions. <i>This assignment tests students' knowledge to apply knowledge of chemical reaction stoichiometry and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	96
TOTAL	100	96

Juan Pedro Bibang Nguema Ayara

May 2, 2022

Evaporator: overall balance: $m_1 = m_3 + m_4 \Rightarrow m_1 = 50 + m_4$
components balance: $0.5(m_1) = 10(50) + 0.4(m_4)$
based on water

$$0.5 m_1 = 50 + 0.4 m_4 \Rightarrow$$

$$0.5(50 + m_4) = 50 + 0.4 m_4 \Rightarrow$$

$$40 + 0.5 m_4 = 50 + 0.4 m_4 \Rightarrow$$

$$0.4 m_4 = 10 \Rightarrow m_4 = \frac{10}{0.4} = 25$$

$$m_4 = 25 \text{ kg/h}$$

$$m_1 = 50 + m_4 \Rightarrow m_1 = 50 + 25 = 75$$

$$m_1 = 75 \text{ kg/h}$$

Sub unit Y: overall balance:

$$m_2 + m_4 = m_5 \Rightarrow$$

$$m_2 = m_5 - m_4 \Rightarrow$$

$$m_2 = 50 - 25 = 25$$

$$m_2 = 25 \text{ kg/h}$$

$$m_1 = 75 \text{ kg/h}$$

$$m_2 = 25 \text{ kg/h}$$

$$m_3 = 50 \text{ kg/h}$$

$$m_4 = 25 \text{ kg/h}$$

$$m_5 = 50 \text{ kg/h}$$

$$\begin{array}{r} 1-25 \\ 2-21 \\ \hline 46 \end{array}$$

Question 2

a) fractional conversion (C_2H_6) in equation 1 = $\frac{\text{mole reacted } C_2H_6(1)}{\text{mole fed } C_2H_6(1)} = \frac{\text{mole product } C_2H_6}{\text{mole fed } C_2H_6}$ (1)

~~$= \frac{40 \text{ mole}}{85 \text{ mole}} = 0.47 \%$~~ or 47%

fractional conversion = $\frac{\text{moles reacted}}{\text{moles fed}}$

fractional conversion of C_2H_6 in equation 2 = $\frac{\text{mole reacted } C_2H_6(2)}{\text{mole fed } C_2H_6(2)} = \frac{85 - 42.4}{85}$

in 1 mol of C_2H_6 created 2 mol of CH_4

so 5.2 mol CH_4 created we need $\frac{5.2}{2} = 2.6$ mol $C_2H_6(2)$

mole fed of C_2H_6 in (2) = mole excess C_2H_6 in (1) = $85 - 40 = 45$ mole

Then, fractional conversion of C_2H_6 in second reaction = $\frac{2.6}{45} = 0.057$ or 5.7%

c) Selectivity of C_2H_4 relative to CH_4 = $\frac{\text{mole of } C_2H_4}{\text{mole of } CH_4} = \frac{40}{5.2} = 7.7$ (4)

d) $n_3 = n_{CH_4} = 5.2$

$n_4 = C_2H_6 \text{ left} = 42.4$

$\xi_1 = \frac{n_{C_2H_4} - n_{C_2H_4}^0}{1} \Rightarrow n_{C_2H_4} = \xi_1 - 40$ (4)

$\xi_2 = \frac{n_{CH_4} - n_{CH_4}^0}{2} \Rightarrow 2\xi_2 = n_{CH_4} - 0 = 5.2$ (8)

$\xi = \frac{5.2}{2} = 2.6$

(21)

BELOW AVERAGE

Below Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER**

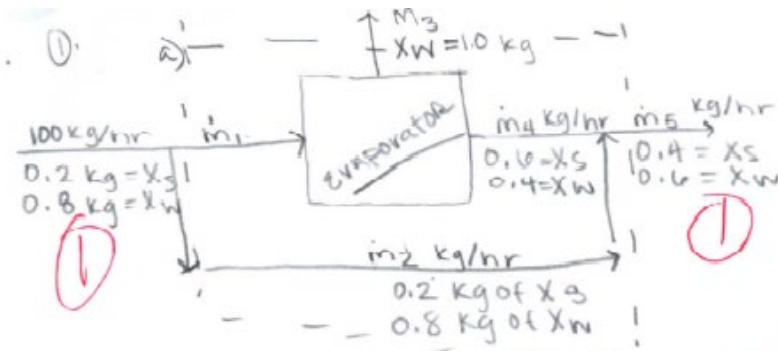
CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of chemical reaction stoichiometry and (1) determine degrees of freedom involving processes with recycle and bypass, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: Maddison Williams

Title of Assignment: Test 2 Due Date: 05-02-2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply knowledge of chemical reaction stoichiometry involving (i) processes with recycle and bypass, (ii) degrees of freedom analysis, (iii) and determine fractional conversion, percentage yield, selectivity and extents of reactions. <i>This assignment tests students' knowledge to apply knowledge of chemical reaction stoichiometry and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	76
TOTAL	100	76



← sketch

1-10
2-16
26

b) D.O.F. overall

Unknowns: 3 (m_1, m_2, m_5)

Knowns: $S, W, 100$ kg/hr being fed to m_1/m_2 flowrate

$3 - 3 = 0$

where are the subunits?

③

Subunits D.O.F.

m_1 : unknown: m_1, m_3, m_5
Known: 100 kg/hr, S, W

$3 - 3 = 0$

m_2 : unknown: m_1, m_2, m_4
Known: S, W

$3 - 2 = 1$

m_3 : unknown: m_1, m_2, m_3
Known: S, W

$3 - 2 = 1$

m_4 : unknown: m_4, m_5, m_1
Known: S, W

$3 - 2 = 1$

m_5 : known: m_1, m_3, m_5
Unknown: S, W

$3 - 2 = 1$

c) Overall BAL:

$100 = m_3 + m_5$ — ①

$100 = m_3 + m_5$

S-BALANCE:

② $0.2(100 \text{ kg/hr}) + 0.2(m_2) + 0.4(m_4) + 0.4(m_5)$

W-BALANCE:

③ $0.8(100 \text{ kg/hr}) + 0.8(m_2) + 0.4(m_4) = 1.0(m_3) + 0.6(m_5)$

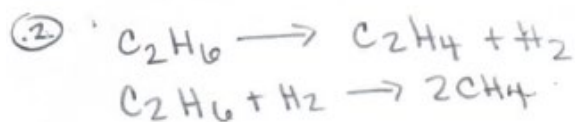
for solving m_2

$100 = m_1 + m_2$

$100(0.2) = m_1 X_S + 0.2 m_2$

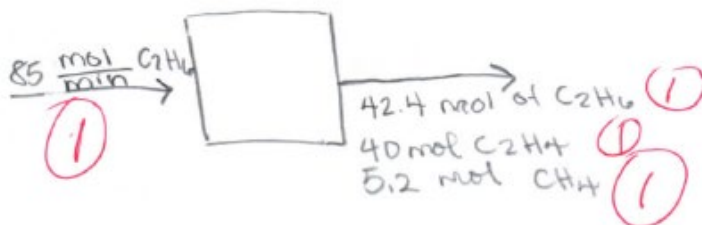
$20 \times 0.2 = 20 + 100 X_S$

①



maddison
williams

Sketch:



i) Fraction conversion: C_2H_6

$$\frac{\text{\# of moles reacted}}{\text{\# of moles fed}} = \frac{42.6 \text{ moles of } C_2H_6}{85 \text{ moles of } C_2H_6} = 0.5012$$

ii) Percentage yield of C_2H_4 :

$$\frac{\text{\# moles formed}}{\text{\# of formed if limiting was used compl.}} = \frac{40}{85} \times 100 = 47.06\%$$

for every C_2H_6 produced a C_2H_4 is formed w/ H_2 . So, since 42.6 C_2H_6 was reacted we can assume 42.6 C_2H_4 were formed!

iii) selectivity of C_2H_4 relative to CH_4 :

$$\frac{\text{\# of product formed}}{\text{moles of not wanted formed}} = \frac{40}{5.2} = 7.69$$

iiii) first reaction:

second reaction:

16

MATERIAL AND ENERGY BALANCE SPRING 2022

Title of Assignment: Homework 1

TOPICS COVERED IN HOMEWORK 1

1. Conversion of Units
2. Dimensional Homogeneity and Dimensionless
3. Process Data Presentation
4. Basis of calculation and process calculations

MATERIAL AND ENERGY BALANCES

SPRING 2022

SAMPLE HOMEWORK 1 QUESTIONS, SOLUTION, AND GRADING SCHEME FOR HOMEWORK 1

Material and Energy Balances (Spring 2022): Home Work 1

February 21, 2022

Due: February 28, 2022

Answer all questions. You will be graded based on (1) your ability to apply knowledge of basic and intermediate mathematics involving algebra, differential and integral calculus, and (2) your ability to apply your knowledge of physics and chemistry. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

1. The velocity v of a particle can be calculated from the following equation:

$$v = A - \frac{\exp(B(\sqrt{\alpha_1\alpha_2}))}{C}$$

where v = velocity in m/s

α_1 is in meters (m)

α_2 is in meters (m)

If the equation is dimensionally consistent, what are the appropriate units for:

- i. A
 - ii. B, and
 - iii. C
2. Two sulfuric acid solutions in water containing 20 wt % H_2SO_4 and 80 wt % are mixed. The mixed solution is 5.313 molar solution (5.313 mol $\text{H}_2\text{SO}_4/\text{L}$). The S.G. of the 20 wt % H_2SO_4 solution is 1.1398 and that of the 80 wt % H_2SO_4 solution is 1.7272. The S.G. of the mixed solution is 5.313 molar solution is 1.3028.
- (i) Calculate the mass fraction of the H_2SO_4 in the mixed solution (product) formed
 - (ii) Calculate the ratio (liters of 20 wt % H_2SO_4 solution)/(liters of 80 wt % H_2SO_4 solution)
 - (iii) How many liters of 80 wt % H_2SO_4 solution will be required to produce 1450 kg of 5.313 molar H_2SO_4 solution.

Material & Energy Balances

Homework 1

1 of 4

30 Velocity $V = A - \frac{\exp(B(\alpha_1 \alpha_2))}{C}$

Units of $V = m/s$

Units of $\alpha_1 = m$

Units of $\alpha_2 = m$

For dimensional homogeneity, all additive terms in a valid equation should have the same dimensions on both sides of the equation

∴ (i) Since V has units m/s , the units of $A = m/s$ (5)

(ii) For $\exp(B(\alpha_1 \alpha_2))$ to be valid,

$B(\alpha_1 \alpha_2)$ should be a number with no units

(5) But $(\alpha_1 \alpha_2)$ has units $(m \cdot m) = m^2$ (5)

(5) ∴ The units of $B = \frac{1}{m}$ or $B(\alpha_1 \alpha_2) = \frac{1}{m} \cdot m^2 = \frac{m}{m} = 1$

(5) Units of $B = m^{-1}$

(iii) $\frac{\exp(B(\alpha_1 \alpha_2))}{C}$ must have the same units as

(5) V and A , that is m/s , for dimensional homogeneity.

But $\exp(B(\alpha_1 \alpha_2))$ is dimensionless

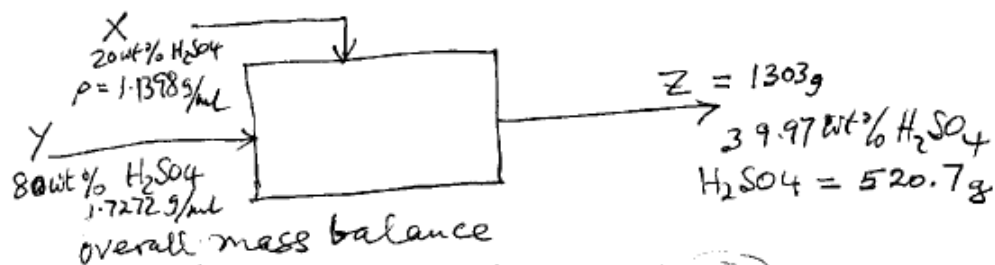
(5) ∴ C has units $= \frac{S}{m} = m^{-1}S$ since $\frac{1}{m^{-1}S} = \frac{m}{S}$

C has units $m^{-1}S$.

Material & Energy Balances Homework 1

3 of 4

2(11)



$$X + Y = Z = 1303 \text{ g} \quad \text{--- (1) } \textcircled{2}$$

H_2SO_4 balance

$$0.2X + 0.8Y = 520.7 \text{ g} \quad \text{--- (2) } \textcircled{2}$$

$X = 1303 - Y$ from (1) and (2)

$$\therefore 0.2(1303 - Y) + 0.8Y = 520.7$$

$$260.6 - 0.2Y + 0.8Y = 520.7$$

$$0.6Y = 260.1$$

$$Y = 433.5 \text{ g} \quad \textcircled{3}$$

$$X + Y = Z \Rightarrow X + 433.5 = 1303$$

$$\therefore X = 869.5 \text{ g} \quad \textcircled{2}$$

$$\text{Volume of } Y = \frac{\text{Mass of } Y}{\rho_{\text{of } Y}} = \frac{433.5 \text{ g}}{1.7272 \text{ g/mL}} = 250.98 \text{ mL} = 0.251 \text{ L} \quad \textcircled{2}$$

$$\text{Volume of } X = \frac{\text{Mass of } X}{\rho_{\text{of } X}} = \frac{869.5 \text{ g}}{1.1398 \text{ g/mL}} = 762.85 \text{ mL} = 0.763 \text{ L} \quad \textcircled{2}$$

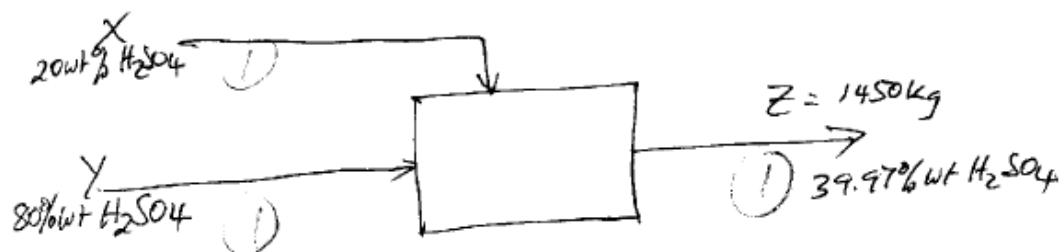
Material & Energy Balances Homework 1

4 of 4

2(ii) Ratio (liters of 20wt% H_2SO_4 soln / liters of 80wt% H_2SO_4 soln)

$$= \frac{\text{Volume of X}}{\text{Volume of Y}} = \frac{0.763 \text{ L}}{0.251 \text{ L}} = 3.04 \quad (4)$$

(iii) Basis: 1450 kg of 5.313 mol H_2SO_4 /L solution



Overall mass balance

$$X + Y = 1450 \text{ kg} \quad (1) \quad (2)$$

$$\text{H}_2\text{SO}_4 \text{ balance}$$

$$0.2X + 0.8Y = 0.3997 \times 1450 \text{ kg}$$

$$0.2X + 0.8Y = 579.6 \quad (2) \quad (2)$$

$$\therefore 0.2(1450 - Y) + 0.8Y = 579.6$$

$$290 - 0.2Y + 0.8Y = 579.6$$

$$0.6Y = 289.6$$

$$Y = 482.6 \text{ kg} \quad (4)$$

$$X = 1450 - Y = 1450 - 482.6 = 967.4 \text{ kg} \quad (2)$$

$$\text{Volume of Y} = \frac{482.6 \text{ kg}}{\text{Density of Y}} = \frac{482.6 \text{ kg}}{1.722 \text{ kg/L}} = 279.4 \text{ L} \quad (2)$$

$$\text{Volume 80wt% H}_2\text{SO}_4 = 279.4 \text{ L} \quad (4)$$

ABOVE AVERAGE

MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of and (1) solve algebraic, integral and differential equations analytically or numerically, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: Chau Tuong

Title of Assignment: Homework 1 Due Date: 02/28/2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply (1) knowledge of basic and intermediate mathematics involving algebra, differential and integral calculus, and (2) knowledge of physics and chemistry. <i>This assignment tests students' knowledge to apply knowledge of algebraic, integral and differential calculus and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	87
TOTAL	100	87

Name : Chau Truong

75

(1) $v = A - \frac{\exp(B\sqrt{x_1 x_2})}{C}$

$$\left(\frac{m}{s}\right) = \frac{m}{s} - \frac{m}{s}$$

$$\Rightarrow A = \frac{\left(\frac{m}{s}\right)}{e^{B\sqrt{x_1 x_2}}} = \frac{m}{s}$$

$$\Rightarrow C = \left(\frac{s}{m}\right)$$

$$B\sqrt{x_1 x_2} = \frac{m \cdot m}{m \cdot m} = B\sqrt{m^2} = B \cdot m = \text{none}$$

$$\Rightarrow B = \left(\frac{1}{m}\right)$$

(2) $SG = \frac{P}{P_{ref}} \Rightarrow P_{output} = SG \cdot P_{ref}$ Basis:

$$P_{H_2SO_4 \text{ solution output}} = 1.3028 \cdot \frac{1g}{cm^3} = 1.3028 \frac{g}{cm^3}$$

- Volume of H_2SO_4 solution output = $V_{sol \text{ output}}$
- Mass of H_2SO_4 solution output = $M_{sol \text{ output}}$
- Mass of H_2SO_4 output = $M_{H_2SO_4 \text{ output}}$

$$\Rightarrow V_{sol} = \frac{M_{sol}}{P_{H_2SO_4 \text{ solution output}}} = \frac{M_{sol}}{1.3028 \frac{g}{cm^3}}$$

$$M_{H_2SO_4} = \frac{M_{H_2SO_4 \text{ output}}}{\text{Molar Mass } H_2SO_4} = \frac{M_{H_2SO_4 \text{ output}}}{98 \frac{g}{mol}}$$

$$\text{Molarity} = \frac{M_{H_2SO_4}}{V_{sol}} = \frac{M_{H_2SO_4 \text{ output}}}{98 \frac{g}{mol}} \cdot \frac{1.3028 \frac{g}{cm^3}}{M_{sol \text{ output}}} = 5.313 \frac{mol}{L}$$

$$\Rightarrow \frac{M_{H_2SO_4 \text{ output}}}{M_{sol \text{ output}}} = \frac{5.313 \frac{mol}{L} \cdot 98 \frac{g}{mol}}{1.3028 \frac{g}{cm^3} \times \frac{1000 cm^3}{1 L}} = 0.4$$

⇒ Mass Fraction of H_2SO_4 in the mixture product

$$= \frac{M_{H_2SO_4 \text{ output}}}{M_{\text{sol output}}} \cdot 100 = 0.4 \cdot 100 = 40\%$$

- ii)
- m_1 = Mass of solution contain 20% wt H_2SO_4 input
 - m_2 = Mass of solution contain 80% wt H_2SO_4 input
 - V_1 = Volume of solution contain 20% wt H_2SO_4 input
 - V_2 = Volume of solution contain 80% wt H_2SO_4 input
 - M = Mass of solution H_2SO_4 and H_2O output

• Total Mass balance : $m_{\text{in}} = m_{\text{out}}$, $m_{\text{in}} = m_1 + m_2 = m_{\text{out}}$

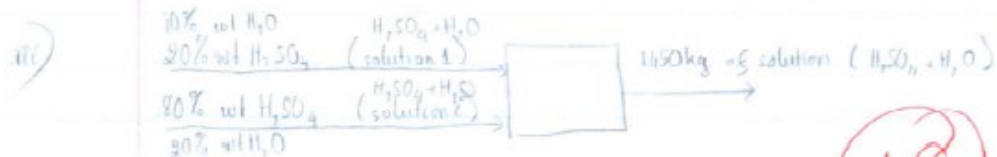
$$M_{H_2SO_4 \text{ in}} = M_{H_2SO_4 \text{ out}} ; 0.2 m_1 + 0.8 m_2 = 0.4 (m_1 + m_2) = 0.4 m_1 + 0.4 m_2$$

$$\Leftrightarrow 0.8 m_2 - 0.4 m_2 = 0.4 m_1 - 0.2 m_1$$

$$\Leftrightarrow 0.4 m_2 = 0.2 m_1$$

$$\Rightarrow \frac{m_1}{m_2} = \frac{0.4}{0.2} = 2$$

$$\Leftrightarrow \frac{1.1592 V_1}{1.7272 V_2} = 2 \rightarrow \boxed{\frac{V_1}{V_2} = 3.03}$$



$$\begin{cases} \frac{m_1}{m_2} = 2 \\ m_1 + m_2 = 1450 \text{ kg} \end{cases} \Rightarrow \begin{cases} m_1 = 367 \text{ kg} \\ m_2 = 483 \text{ kg} \end{cases}$$

• $X_2 = \frac{F}{F_{H_2O}}$ ⇒ Solution 2 (80% wt H_2SO_4 , 20% wt H_2O) = $1.7272 \cdot 1000 \frac{\text{kg}}{\text{m}^3} = 1727.2 \frac{\text{kg}}{\text{m}^3}$

⇒ $V_{\text{solution 2 of 80\% wt } H_2SO_4 \text{ is required}} = \frac{m_2}{\rho_{\text{sol 2 of 80\% wt } H_2SO_4}} = \frac{483 \text{ kg}}{1727.2 \frac{\text{kg}}{\text{m}^3}} = \boxed{279.6 \text{ L}}$

AVERAGE

Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER**

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of and (1) solve algebraic, integral and differential equations analytically or numerically, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: Juan Pedro Bibary Ngueria Oyana

Title of Assignment: ME 3. HOMEWORK 1 Due Date: 2/28/2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply (1) knowledge of basic and intermediate mathematics involving algebra, differential and integral calculus, and (2) knowledge of physics and chemistry. <i>This assignment tests students' knowledge to apply knowledge of algebraic, integral and differential calculus and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	70
TOTAL	100	70

Juan Pedro Bibang Nguema Oyana.

2/28/2022

MEG. HOMEWORK 1

1)
$$V = \frac{A}{C} \exp\left(\frac{B}{m} \left(\sqrt{\frac{a_1}{m} \frac{a_2}{m}}\right)\right)$$

$\frac{m/s}{m/s} = \frac{m/s}{s/m}$

Since the main goal in this case is to have the right units that will give us the velocity in m/s, knowing that:

$V = m/s$

$a_1 = m$

$a_2 = m$

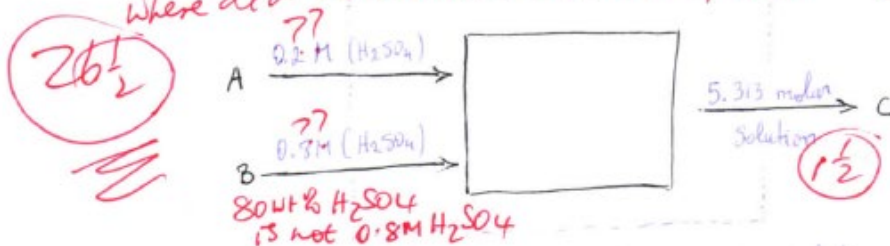
i) $A = m/s$

ii) $B = 1/m$

iii) $C = s/m$

1-20
2-26½
46½

2) Where did the 0.2M and 0.8M come from? Basis:



input + generation - output - consumption = Accumulation $\Rightarrow$ input = output

Molecular mass

of $H_2SO_4 = 2 + 32 + 4(16) = 98g/mol$

i) Let's call the product formed Stream C:

S.G. mixed solution = 1.3028

Mass of H_2SO_4 in solution
 $5.313 \text{ moles} \times 98g/mol = 520.674g$
 $= 0.521 \text{ kg}$

$\rho = S.G. \times \rho_{reference} = 1.3028 \times \frac{1kg \text{ solution}}{1L \text{ solution}} = 1.3028 \frac{kg \text{ solution}}{1L \text{ solution}}$

1

knowing that $5.313 \text{ moles} = \frac{5.313 \text{ mol H}_2\text{SO}_4}{1 \text{ L solution H}_2\text{SO}_4}$

$$\frac{5.313 \text{ mol H}_2\text{SO}_4 / 1 \text{ L solution}}{1.3028 \text{ kg / L}} = \frac{5.313 \text{ mol H}_2\text{SO}_4}{1.3028 \text{ kg of solution}}$$

Dividing the mass of the H_2SO_4 in solution with the density of the solution we get:

$$\text{mass fraction} = \frac{0.522 \text{ kg}}{1.3028 \text{ kg}} \approx 0.40$$

(ii) Assuming that Burns 100 kg 20% wt H_2SO_4

SC = 1.1318

A $\xrightarrow{100 \text{ kg}}$
 $80 \text{ kg H}_2\text{SO}_4/\text{kg}$
 $20 \text{ kg H}_2\text{O}/\text{kg}$

SC = 1.7272

B $\xrightarrow{m_B}$
 $0.8 \text{ kg H}_2\text{SO}_4/\text{kg}$
 $0.2 \text{ kg H}_2\text{O}/\text{kg}$

MC

~~$0.5 \text{ kg H}_2\text{SO}_4/\text{kg}$~~
 ~~$0.5 \text{ kg H}_2\text{O}/\text{kg}$~~

$0.40 \text{ kg H}_2\text{SO}_4/\text{kg}$
 $0.60 \text{ kg H}_2\text{O}/\text{kg}$

The overall mass balance = $100 + m_B = m_C$ (2)

Water balance = $100(0.2) + m_B(0.2) = m_C(0.6)$

$m_C = \frac{100(0.2) + m_B(0.2)}{0.6}$ Substitute this into the overall mass balance equation:

$100 + m_B = \frac{100(0.2) + m_B(0.2)}{0.6} \Rightarrow (100 + m_B)0.6 = 20 + 0.2m_B \Rightarrow 40 + 0.6m_B = 20 + 0.2m_B$

$0.4m_B = 20 \Rightarrow m_B = \frac{20}{0.4} = 50 \text{ kg}$

Therefore $100 + 50 \text{ kg} = 150 \text{ kg} = m_C$

$V_1 = 100 \text{ kg} \times \frac{1 \text{ L}}{1.1318} = 87.73 \text{ L } 20\% \text{ solution}$

$V_2 = 50 \text{ kg} \times \frac{1 \text{ L}}{1.7272} = 28.95 \text{ L } 80\% \text{ solution}$

$\frac{100 \text{ kg}}{1.1318 \text{ kg/L}} = 87.80 \text{ L}$
 $\frac{50 \text{ kg}}{1.7272 \text{ kg/L}} = 28.95 \text{ L}$

$m_C = 100 + 50 = 150 \text{ kg}$

$m_C = \frac{100(0.2) + 0.2m_B}{0.6}$
 $m_C = \frac{800}{6} + \frac{2m_B}{6}$

$100 + m_B = \frac{800}{6} + \frac{2m_B}{6}$

$600 + 6m_B = 800 + 2m_B$

$4m_B = 200 \text{ kg}$
 $m_B = 50 \text{ kg}$

2

Juan Pedro B. M. Oyama.

Problem 2 part(ii) continuation:

Ratio $\frac{V_1}{V_2} = \frac{87.73 \text{ L}}{66.167 \text{ L}} = 1.325 \text{ L}$ $\frac{20\% \text{ solution}}{80\% \text{ solution}}$

(2)

$\frac{V_1}{V_2} = \frac{87.73 \text{ L}}{28.95 \text{ L}} = 3.03$

(iii)

1450 kg	114.285 kg 80%	1 L	= 593.59 L/h
h	214.285 kg kg	1.3028 kg solution	

BELOW AVERAGE

Below Average Student Original Graded Assignment

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Name: Nakaela Malone

Title of Assignment: Homework 1 Due Date: February 28th 2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply (1) knowledge of basic and intermediate mathematics involving algebra, differential and integral calculus, and (2) knowledge of physics and chemistry. <i>This assignment tests students' knowledge to apply knowledge of algebraic, integral and differential calculus and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	58
TOTAL	100	

Homework 1

- i) 1. A - m/s (5) why is it m/s?
- ii. B and -1/m (5) why is it 1/m?
- iii C - s/m (5) why are the units s/m?

2) 2 Sulfuric acid solutions in water

Contains 20wt% H_2SO_4 & 80wt% are mixed

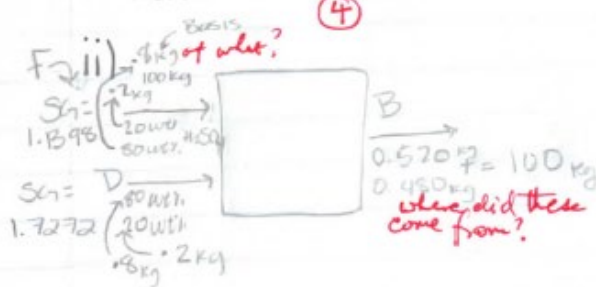
5.313 molar solution.

Scr of 20% wt H_2SO_4 solution = 1.1398 (3)

80% wt H_2SO_4 solution = 1.7272 (3)

Scr of mixed solution is 5.313 molar sol: 1.3028 (3)

- i) 5.313 mol of H_2SO_4 → mass of = 5.313 * 98 = 520.7 kg (1/2)
1.3028 kg of sol ⇒ How did you get 1.3028 kg solution?
= 520.7 / 1.3028 = 0.399 kg mass fraction (2)



$$100 \text{ kg} \times \frac{16}{1.1398} = 47.732 \text{ 20% Sol}$$

$$72.72 \times \frac{16}{1.7272} = 42.101 \text{ 80% Sol}$$

$$\frac{47.73}{42.101} = 2.08$$

Basis = 100 kg of what?

Overall mass Bal.
 $F = D + B$??

$$100(0.4) + 0(0.2) = B(0.4)$$

$$100 + B(0.4) - 100(0.4)$$

$$0.2 = B$$

$$20 + 2.4B - 400 = 0.2B$$

$$2.2B = 380$$

$$B = 172.72 \text{ kg}$$

$$D = 72.72 \text{ kg}$$

From your flowchart or Block flow diagram

$$\underbrace{F + D}_{\text{in}} = \underbrace{B}_{\text{out}} \quad \text{NOT } F = D + B$$

iii) Soluty H_2SO_4 required to Produce:

1450 kg of 5.315 molar H_2SO_4 Solution

$$\begin{array}{r|l} 1450 \text{ kg} & 72.72 \text{ kg sol} \\ h & 172.72 \text{ kg} \end{array} \quad \begin{array}{l} 4.1 \\ 1.3028 \text{ kg sol} \end{array}$$

= 468.5944/h

**MATERIAL AND ENERGY BALANCES
SPRING 2022**

MIDTERM EXAM

TOPICS COVERED IN MIDTERM EXAM

1. Units and Dimensions
2. Conversion of Units
3. Process Calculations

MATERIAL AND ENERGY BALANCE SPRING 2022

SAMPLE MIDTERM EXAM QUESTIONS, SOLUTION, AND GRADING SCHEME FOR MIDTERM EXAM

Material and Energy Balances (Spring 2022): Midterm Exam

March 9, 2022

Answer all questions. You will be graded based on (1) your ability to apply knowledge of basic and intermediate mathematics involving algebra, differential and integral calculus, and (2) your ability to apply your knowledge of physics and chemistry. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

1. The fuel consumption of automobile A is 5.97 L of gasoline per 100 km. An automobile B averages 27.5 miles per gallon gasoline. You may take 1 mile = 1.6093×10^3 meters (m), and 1 gallon = 3.7854 L.
 - (a) Calculate and determine the car with the better fuel efficiency
 - (b) If each automobile is driven for 500 miles, what is the difference in the gallons of gasoline consumed?
2. The production process for sodium hydroxide (NaOH) yields a 28 % by mass solution of sodium hydroxide in water. The 28 wt % NaOH solution is to process that produces 100 lb_m per hour of 10 wt % NaOH solution.
Calculate the quantities of the 28 wt % NaOH solution and the water needed to produce the product.

Material and Energy Balances

Midterm Exam

1. Given:

(i) Fuel consumption of automobile A = $5.97 \text{ L}/100 \text{ km} = \frac{5.97 \text{ L gasoline}}{100 \text{ km}}$

(ii) Fuel consumption of automobile B = $27.5 \text{ miles/gallon} = \frac{27.5 \text{ miles}}{\text{gallon gasoline}}$

(iii) $1 \text{ mile} = 1.6093 \times 10^3 \text{ m}$ and $1 \text{ gallon} = 3.7854 \text{ L}$

(a) The fuel consumption of automobile A, $5.97 \text{ L}/100 \text{ km}$, may be written as $100 \text{ km}/5.97 \text{ L gasoline} = \frac{100 \text{ km}}{5.97 \text{ L}}$ and may

be converted to miles/gallon as follows:

$$\frac{100 \text{ km}}{5.97 \text{ L}} \times \frac{10^3 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ mile}}{1.6093 \times 10^3 \text{ m}} \times \frac{3.7854 \text{ L}}{1 \text{ gallon}}$$

$$\frac{100 \text{ km}}{5.97 \text{ L}} \times \frac{10^3 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ mile}}{1.6093 \times 10^3 \text{ m}} \times \frac{3.7854 \text{ L}}{1 \text{ gallon}}$$

$$= \frac{100}{5.97} \times \frac{3.7854}{1.6093} \frac{\text{miles}}{\text{gallon}} = 16.75 \times 2.352 \text{ miles/gallon}$$

$$= 39.4 \text{ miles/gallon}$$

Since the fuel consumption of automobile B = $27.5 \text{ miles/gallon}$, automobile A with $39.4 \text{ miles/gallon}$ has a better fuel efficiency.

(b) (i) Driving automobile A for 500 miles will require:

$$500 \text{ miles} \times \frac{1 \text{ gallon}}{39.4 \text{ miles}} = 12.69 \text{ gallons}$$

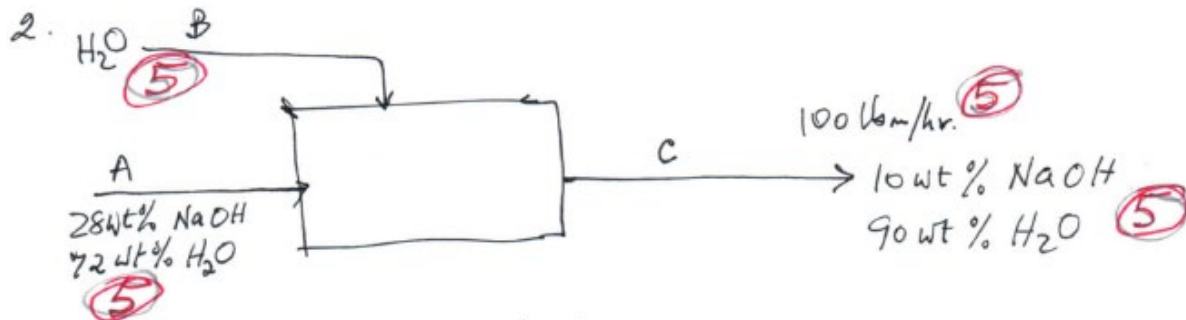
(ii) Driving automobile B for 500 miles will require:

$$500 \text{ miles} \times \frac{1 \text{ gallon}}{27.5 \text{ miles}} = 18.18 \text{ gallons}$$

The difference in gallons of gasoline consumed

$$= (18.18 - 12.69) = 5.5 \text{ gallons}$$

Material and Energy Balances Midterm Exam



overall mass balance

$$A + B = C \quad \text{--- (1) where } C = 100 \text{ lb/h}$$

$$\therefore A + B = 100 \quad \text{--- (2)}$$

NaOH balance

$$A(0.28) + B(0) = C(0.10) \quad \text{--- (3)}$$

$$\therefore 0.28A = 0.1C \quad \text{--- (4)}$$

But $C = 100 \text{ lb/h}$

Hence $0.28A = 0.1(100) = 10$

$$A = \frac{10}{0.28} = 35.7143 \text{ lb/h}$$

But $A + B = 100$

$$\therefore B = (100 - 35.7143) \text{ lb/h} \\ = 64.2857 \text{ lb/h}$$

$\therefore 35.7 \text{ lb/h}$ of 28 wt% NaOH and 64.3 lb/h H₂O will be needed.

ABOVE AVERAGE

Above Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER**

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of and (1) solve algebraic, integral and differential equations analytically or numerically, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: FANAR LOUIS

Title of Assignment: MIDTERM Due Date: 3/9/2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply (1) knowledge of basic and intermediate mathematics involving algebra, differential and integral calculus, and (2) knowledge of physics and chemistry. <i>This assignment tests students' knowledge to apply knowledge of algebraic, integral and differential calculus and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	100
TOTAL	100	100

1. Given

Automobile A

5.97 L gasoline per 100 km

Automobile B

27.5 miles/gallon

Formulate

1 mile = 1.6093×10^3 m, 1 gallon = 3.7854 L

Basis: 1 gallon of gasoline

Solve

$$\frac{5.97 \text{ L}}{3.7854 \text{ L}} = 1.58 \text{ gallons} / 100 \text{ km in automobile A}$$

$$\frac{100 \text{ km}}{1 \text{ km}} \times \frac{1 \text{ mile}}{1.6093 \times 10^3 \text{ m}} = 62.14 \text{ miles}$$

$$\frac{1.58 \text{ gal}}{62.14 \text{ miles}} = \frac{1 \text{ gal}}{x \text{ miles}}$$

$$1.58(x) = 62.14 \rightarrow x = 39.33 \text{ miles}$$

Automobile A = 39.33 miles/gallon

Automobile B = 27.5 miles/gallon

(a) Automobile A has better fuel efficiency

(b)

Automobile A

$$\frac{39.33 \text{ miles}}{1 \text{ gallon}} = \frac{500 \text{ miles}}{x \text{ gallons}}$$

$$39.33(x) = 500 \text{ miles} \rightarrow x = 12.71 \text{ gallons}$$

Automobile A consumes 12.71 gallons in 500 miles

Automobile B

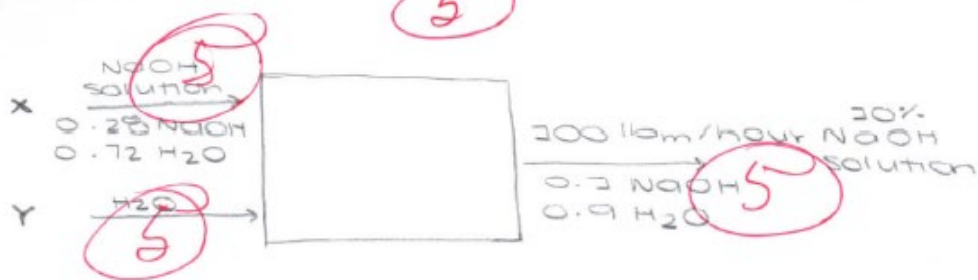
$$\frac{27.5 \text{ miles}}{1 \text{ gallon}} = \frac{500 \text{ miles}}{y \text{ gallons}}$$

$$27.5(y) = 500 \text{ miles} \rightarrow y = 18.18 \text{ gallons}$$

Automobile B consumes 18.18 gallons in 500 miles

$18.18 - 12.71 = 5.47$ consumed gallon difference.

2. Given Basis: 200 lbm of 20% NaOH solution



Formulate

Input - Output + Generation - Consumption = Accumulation

Input = Output

overall balance

$$X + Y = Z = 200 \text{ lbm}$$

H₂O balance

$$0.72(X) + Y = 0.9(Z)$$

$$0.72X + Y = 0.9(200) = 180$$

NaOH balance NaOH in = NaOH out

$$0.28(X) = 0.2(Z)$$

$$0.28X = 0.2(200) = 40$$

Solve

NaOH balance

$$\frac{0.28X}{0.28} = \frac{40}{0.28} \quad X = 35.71 \text{ lbm 28 wt\% NaOH solution}$$

overall balance

$$X + Y = 200$$

$$35.71 + Y = 200$$

$$Y = 164.29 \text{ lbm H}_2\text{O}$$

35.71 lbm 28 wt% NaOH solution

164.29 lbm H₂O

AVERAGE

Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER**

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of and (1) solve algebraic, integral and differential equations analytically or numerically, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: Julian Lamedy

Title of Assignment: Midterm Due Date: 09/03/22

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply (1) knowledge of basic and intermediate mathematics involving algebra, differential and integral calculus, and (2) knowledge of physics and chemistry. <i>This assignment tests students' knowledge to apply knowledge of algebraic, integral and differential calculus and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	82
TOTAL	100	82

Automobile A = 5.97 L gas / 100 km (1/2)

Automobile B = 27.5 miles / gallon gas (for every gallon of gas the car travels 27.5 miles)

$$\frac{27.5 \text{ miles}}{1 \text{ gal}} \times \frac{1.6093 \times 10^3 \text{ m}}{1 \text{ mile}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{1 \text{ gal}}{3.7854 \text{ L}} = \frac{11.65 \text{ km}}{1 \text{ L of gas}} \times \frac{8.5\%}{8.5\%} = \frac{100 \text{ km}}{8.58 \text{ L}} \quad \text{10}$$

$$\frac{11.65 \text{ km}}{1 \text{ L}} \times \frac{5.97}{5.97} = \frac{69.8 \text{ km}}{5.97 \text{ L}}$$

100 / 45.64 = 2.19

a) Automobile A would be considered more fuel efficient than Automobile B due to Automobile A, travelling 100 km with 5.97 L of gasoline, compared to Automobile B, requiring 8.58 L of gasoline to travel 100 km (3)

b) $\frac{5.97 \text{ L}}{100 \text{ km}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{1.6093 \times 10^3 \text{ m}}{1 \text{ mile}} \times \frac{500 \text{ miles}}{3.7854 \text{ L}} = 13.33 \text{ gallons of gasoline consumed in Automobile A at 500 miles}$ (4)

$\frac{27.5 \text{ miles}}{1 \text{ gallon}} \times 18.18 = \frac{500 \text{ miles}}{18.18 \text{ gal}} = 18.18 \text{ gallons of gasoline consumed in Automobile B at 500 miles}$ (5)

$\frac{500}{27.5} = 18.18$

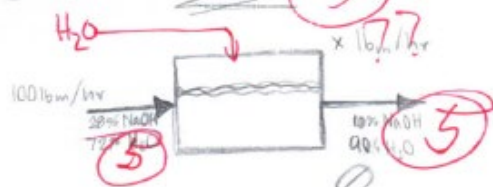
$18.18 - 13.33 = 4.85 \text{ gallon difference between the two automobiles at 500 miles}$ (9)

5.5 gallons

46

2. Basis: 100 lbm/hr - Mixture of NaOH and Water

quantity? How much? in lbm? ; mol?



45400 g/hr

Input - Output + generation - consumption = Accumulation

Input - Output = Accumulation ~~NO accumulation.~~

NaOH Balance

$100 \text{ lbm} \cdot .28 = 28 \text{ lbm of NaOH}$

$100 \text{ lbm} \cdot .72 = 72 \text{ lbm of H}_2\text{O}$

*100 lbm/h is the 10%wt NaOH leaving
I think 28%wt NaOH is the unknown.
You have to do one balance at a time.*

$100 \text{ lbm/hr NaOH} - .72x = 0$

$100 \text{ lb/hr} / .72 = x$

$x = 138.89 \text{ lbm/hr}$

$100 \text{ lbm/hr} - 138.89 = -38.9$ (depleting)

$138.89 \times .1 = x = 13.89 \text{ NaOH}$

13.89 lbm NaOH

$138.89 - 13.89 = 125 \text{ lbm of H}_2\text{O} \Rightarrow 124.91 \text{ lbm of H}_2\text{O}$

$.28 \times 100 \text{ lb/hr NaOH} = 28 \text{ lbm of NaOH} \Rightarrow 49.61 \text{ lbm of NaOH}$

$.72y = 124.91 \text{ lbm/hr H}_2\text{O} \Rightarrow 173 \text{ lbm of H}_2\text{O}$

49.61 lbm NaOH & 173 lbm H₂O are the quantities needed to produce 10% wt of NaOH & 90% wt of H₂O

BELOW AVERAGE

Below Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER**

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of and (1) solve algebraic, integral and differential equations analytically or numerically, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: Alexander Ortiz

Title of Assignment: Mid term 2nd test Due Date: 3/6/22

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply (1) knowledge of basic and intermediate mathematics involving algebra, differential and integral calculus, and (2) knowledge of physics and chemistry. <i>This assignment tests students' knowledge to apply knowledge of algebraic, integral and differential calculus and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	70
TOTAL	100	70

①

B car
27.5 miles per 1 gallon

$1\frac{1}{2}$

$48\frac{1}{2}$

A car

$$5.976 \times \frac{1 \text{ gallon}}{3.78546} = 1.577 \text{ gallons per } \left[\frac{100 \text{ km}}{1 \text{ km}} \times \frac{1000 \text{ m}}{1 \text{ km}} \right] = 100,000 \text{ m}$$

$$100,000 \text{ m} \times \frac{1 \text{ mile}}{1.60934 \times 10^3 \text{ m}} = 62.1388 \text{ miles}$$

$$\begin{array}{r} 1 - 43\frac{1}{2} \\ 2 - 5 \\ \hline 48\frac{1}{2} \end{array}$$

①A for car B, we get 27.5 miles per gallon,
while car A, we get 62.1388 miles per 1.577 gallons,
 $\frac{62.1388 \text{ miles}}{1.577} = 39.4 \text{ miles per 1 gallon}$
if car B were to drive for another 0.5 gallons it
would have traveled 41.25 miles,
Therefore car A has better fuel efficiency

$43\frac{1}{2}$

②

500 miles for car B

$$\frac{27.5 \text{ miles}}{1 \text{ gallon}} \rightarrow \frac{500 \text{ miles}}{x \text{ gallons}} = x \text{ gallons} = \frac{500 \text{ miles} \cdot 1 \text{ gallon}}{27.5 \text{ miles}} = 18.18 \text{ gallons}$$

500 miles for car A

$$\frac{62.13 \text{ miles}}{1.577 \text{ gallons}} \rightarrow \frac{500 \text{ miles}}{x \text{ gallons}} = x \text{ gallons} = \frac{500 \text{ miles} \cdot 1.577 \text{ gallons}}{62.13 \text{ miles}} = 12.68 \text{ gallons}$$

$\Delta \text{gallons} = 5.49$ gallons difference in which car
A spends less gasoline than car B

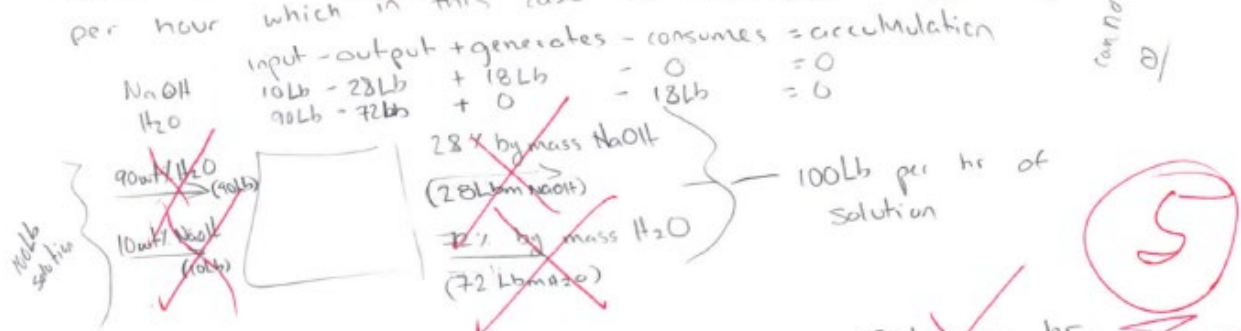
- calculate the quantities of the 28wt% NaOH solution
- water needed to produce the product

28% mass NaOH $\rightarrow$ For every 100lbm per hour of 10wt% NaOH

Basis: 100lbm/h 10wt% NaOH solution

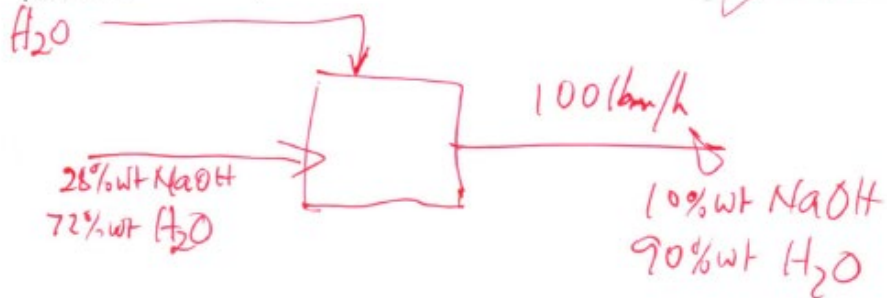
input 100lbm

10wt% of NaOH = $\textcircled{5}$ 20lb_{NaOH} per hour; therefore we pump 90wt% of H₂O per hour which in this case is 90lbm_{H₂O}



Calculate the quantities of the 28wt% NaOH solution = $\frac{28\text{lb}_{\text{NaOH}}}{\text{per hr.}}$

- water needed to produce the product = $\frac{90\text{lb}_{\text{H}_2\text{O}}}{\text{per hr}}$



MATERIAL AND ENERGY BALANCE SPRING 2022

FINAL EXAM

TOPICS COVERED IN FINAL EXAM

1. Molar compositions on wet and dry basis
2. Degree of freedom analysis
3. Balances on Multiple-Unit Processes
4. Chemical Reaction Stoichiometry
5. Balances on Reactive Processes
6. Fractional conversion
7. Percent yield
8. Extent of reaction

MATERIAL AND ENERGY BALANCE SPRING 2022

SAMPLE FINAL EXAM QUESTIONS, SOLUTION, AND GRADING SCHEME FOR FINAL EXAM

Material and Energy Balances (Spring 2022): Final Exam

May 6, 2022

Answer all questions. You will be graded based on (1) your ability to apply knowledge of mass balances and chemical reaction stoichiometry involving (i) processes with and without recycle and bypass, (ii) degrees of freedom analysis, (iii) and determine fractional conversion, percentage yield, selectivity and extents of reactions.

Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

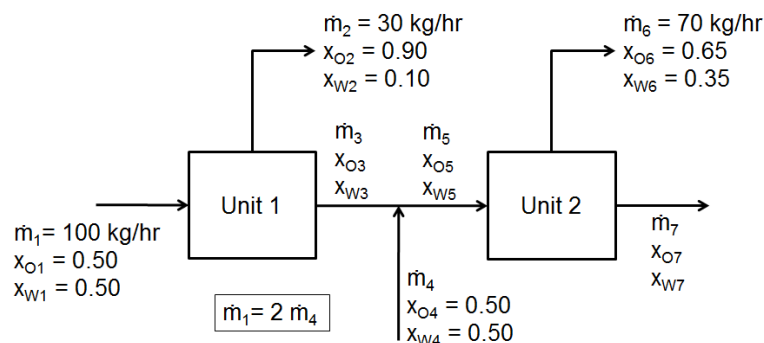
1. Dow Chemical Company produces NaOH (caustic soda) by electrolysis of salt (NaCl) solution in what is known as a membrane cell. The overall reaction for the electrolysis process can be represented as:



If the electrolysis yields 30 % by mass NaOH solution,
Calculate:

- (i) The quantity of water (H₂O) that must be evaporated per ton (2000 lb_m) of the product sold as 50 % by mass NaOH solution
- (ii) The quantity of 30 % by mass of the NaOH solution that needs to be processed
- (iii) The quantities of chlorine (Cl₂) and hydrogen (H₂) produced per ton (2000 lb_m) of 50 % by mass NaOH solution

2.



- (i) Provide a sketch of the overall and subunits required for a degree of freedom (DOF) analysis

- (ii) Determine the degree of freedom (DOF) of the overall and each of the subunits
 (iii) Calculate m_3 , m_4 , m_5 and m_7

3. (a) A gas contains 2 mol H_2 , 4 mol O_2 , and 4 mol H_2O .

- Calculate the molar composition of hydrogen and oxygen on a dry basis?
- Calculate the molar composition of hydrogen and oxygen on a wet basis?

(b) The gas-phase reaction $A + B \rightarrow C$ occurs in a closed, constant temperature vessel (batch process). The partial pressures of A and B at the start of the process are 1 bar and 2 bar, respectively.

Calculate the total pressure in bar after 50% of the A is consumed?

You may assume that $PV = nRT$

4. The two reactions:



took place in a batch reactor fed with 100 mol of N_2O_4 . The final product contains 10 mol of N_2O_4 , 160 mol of NO_2 , and 10 mol of $[NO^+][NO_3^-]$. If the fractional conversion is given by

$\frac{\text{moles reacted}}{\text{moles fed}}$, the percentage yield =

$\frac{\text{moles of desired product formed}}{\text{moles that would be formed if there were no side reactions and the limiting reactant were consumed completely}}$

the selectivity $\frac{\text{moles of desired product formed}}{\text{moles of undesired product formed}}$, and

extent of reaction $\xi = \frac{\text{moles of species } i \text{ at anytime} - \text{moles of species } i \text{ at time } t=0}{\text{Stoichiometric coefficient of species } i}$

and for a set of reactions taking place in a batch or continuous steady-state reactor, the number of moles of species i at any time t is given by

$n_i = n_{i0} + \vartheta_{i1}\xi_1 + \vartheta_{i2}\xi_2 + \text{etc}$, where n_{i0} = moles of i when time $t = 0$ and ξ_1 and ξ_2 etc are the extent of reactions 1, 2 etc and ϑ_{i1} and ϑ_{i2} are their stoichiometric coefficients respectively,

Calculate:

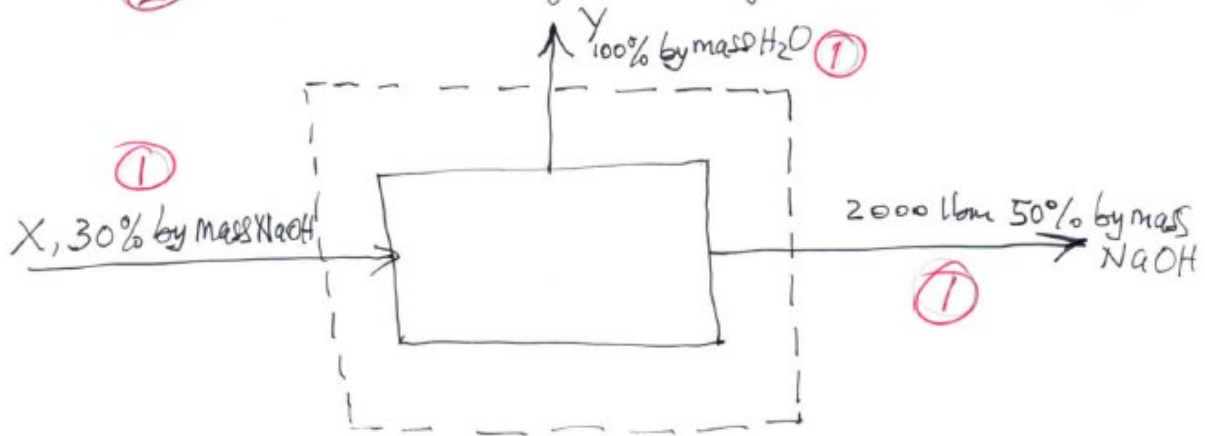
- The fractional conversion of N_2O_4
- The percentage yield of NO_2
- The selectivity of NO_2 relative to $[NO^+][NO_3^-]$
- The extents of the first and second reactions

Material & Energy Balances

FINAL EXAM

1 of 10

1(i) Basis: 2000 lbm of 50% by mass NaOH solution



overall mass balance

$$X = Y + 2000 \text{ lbm} \quad (2)$$

where X = lbm of 30% by mass NaOH solution, and
 Y = lbm of water evaporated

water balance

$$0.7X = Y + 0.5 \times (2000 \text{ lbm})$$

$$(2) \quad 0.7X = Y + 1000 \text{ lbm}$$

$$\text{But } X + Y = 2000 \text{ lbm or } X = 2000 + Y$$

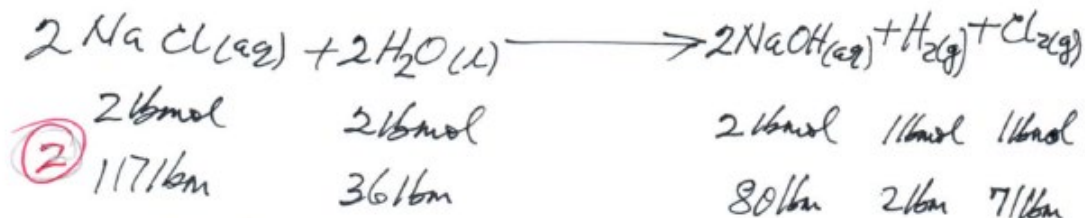
$\therefore 0.7X = Y + 1000 \text{ lbm}$ reduces to

$$(1) \quad 0.7(2000 + Y) = Y + 1000$$

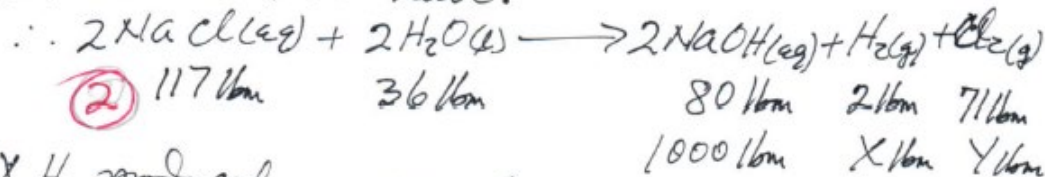
Material & Energy Balances

FINAL EXAM

- 1(iii) The stoichiometric equation for the electrolysis of NaCl(aq) is:



From the stoichiometry, 80 km NaOH are produced with 2 km H_2 and 71 km Cl_2 . For 1000 km NaOH, we have:



$$\frac{X \text{ H}_2 \text{ produced}}{2 \text{ km H}_2} = \frac{1000 \text{ km NaOH}}{80 \text{ km NaOH}}$$

$$\begin{aligned}
 \text{H}_2 \text{ produced, } X &= \frac{1000 \times 2 \text{ km}}{80} \\
 &= 25 \text{ km} \quad \textcircled{2}
 \end{aligned}$$

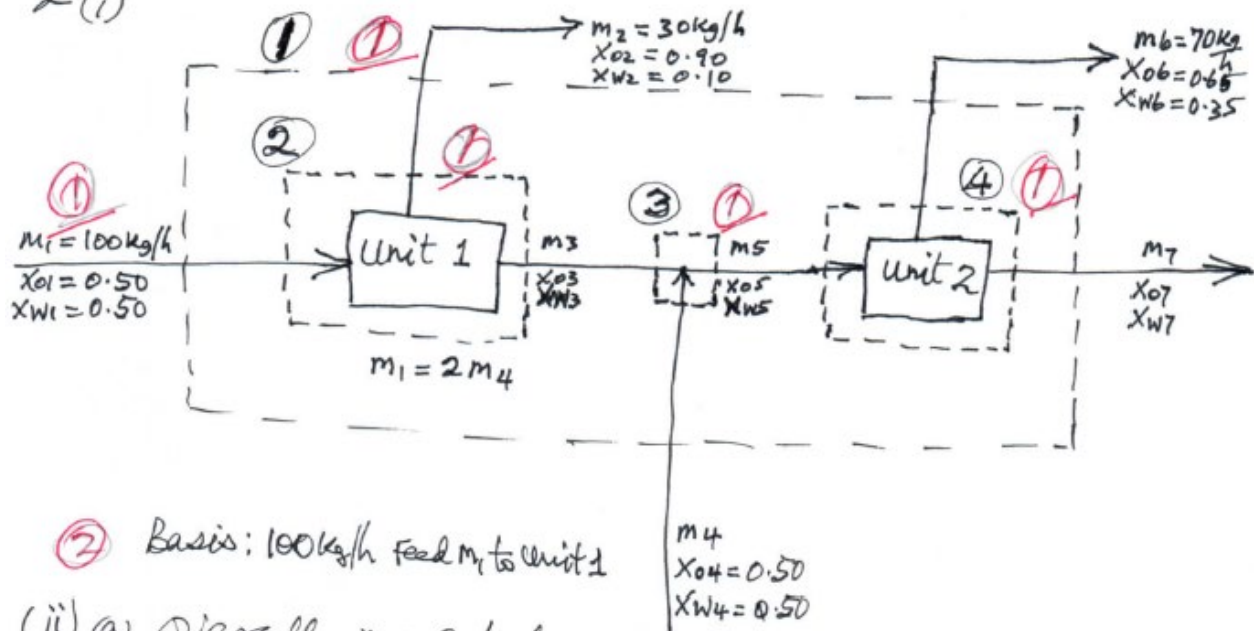
$$\frac{Y \text{ Cl}_2 \text{ produced}}{71 \text{ km Cl}_2} = \frac{1000 \text{ km NaOH}}{80 \text{ km NaOH}}$$

$$\begin{aligned}
 Y \text{ Cl}_2 \text{ produced} &= \frac{1000 \times 71 \text{ km Cl}_2}{80} \\
 &= 887.5 \text{ km} \quad \textcircled{2}
 \end{aligned}$$

Material & Energy Balances

FINAL EXAM

2(i)



② Basis: 100 kg/h feed m_1 to Unit 1

(ii) a) Overall mass balance (mass balance over boundary 1)

Unknowns: m_4, m_7, x_{O7} and $x_{W7} = 4$ ①

Species: O and W = 2 ①

Composition relationship ($x_{O7} + x_{W7} = 1$) = 1 ①

Feed relationship between m_1 and $m_4 = 1$ ①

Degrees-of-freedom = $4 - 2 - 1 - 1 = 4 - 4 = 0$ ①

(b) Balance around Unit 1 (boundary 2)

Unknowns: m_3, x_{O3} and $x_{W3} = 3$ ①

Species: O and W = 2 ①

Composition relationship ($x_{O3} + x_{W3} = 1$) = 1 ①

Degrees-of-freedom = $3 - 2 - 1 = 3 - 3 = 0$ ①

Material & Energy Balances ^{6 of 10}

FINAL EXAM

2(iii) (c) mass balance around Unit 1 (boundary 2)

$$m_1 = m_2 + m_3 \quad \text{where } m_1 = 100 \text{ kg/h and } m_2 = 30 \text{ kg/h}$$

$$\therefore 100 = 30 + m_3$$

$$m_3 = 100 - 30 = 70 \text{ kg/h} \quad (2)$$

(d) mass balance around mixing point (boundary 3)

$$m_3 + m_4 = m_5 \quad \text{where } m_3 = 70 \text{ kg/h and } m_5 = 120 \text{ kg/h}$$

$$70 + m_4 = 120$$

$$(1) \quad m_4 = 50 \text{ kg/h}$$

$$m_1 = 2m_4 \quad \text{or } m_4 = \frac{m_1}{2} = \frac{100}{2} = 50 \text{ kg/h}$$

Material & Energy Balances 7 of 10

FINAL EXAM

3. (a) Gas composition

$$H_2 = 2 \text{ mol}$$

$$O_2 = 4 \text{ mol}$$

$$H_2O = 4 \text{ mol}$$

(i) Molar composition on a dry basis:

$$\text{mol } H_2 = 2 \text{ mol}$$

$$\text{mol } O_2 = 4 \text{ mol}$$

$$\text{Total mol without } H_2O = (2+4) \text{ mol} = 6 \text{ mol} \quad (1)$$

$$\% \text{ mol } H_2 = \frac{2 \text{ mol } H_2 \times 100}{6 \text{ mol}} = \frac{2}{6} \times 100 = 33.3\% \quad (1)$$

$$\% \text{ mol } O_2 = \frac{4 \text{ mol } O_2 \times 100}{6 \text{ mol}} = \frac{4}{6} \times 100 = 66.7\% \quad (1)$$

(ii) molar composition on a wet basis

$$\text{mol } H_2 = 2 \text{ mol}$$

$$\text{mol } O_2 = 4 \text{ mol}$$

$$\text{mol } H_2O = 4 \text{ mol}$$

$$\text{Total mol including } H_2O = (2+4+4) \text{ mol} = 10 \text{ mol} \quad (1)$$

$$\% \text{ mol } H_2 = \frac{2 \text{ mol } H_2}{10 \text{ mol}} \times 100 = 20\% \quad (1)$$

$$\% \text{ mol } O_2 = \frac{4 \text{ mol } O_2}{10 \text{ mol}} \times 100 = 40\% \quad (1)$$

$$\% \text{ mol } H_2O = \frac{4 \text{ mol } H_2O}{10 \text{ mol}} \times 100 = 40\% \quad (1)$$

Material & Energy Balances

8 of 10

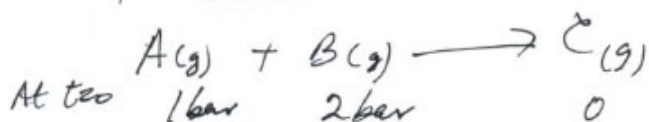
FINAL EXAM

3(b)

Gas phase reaction $A(g) + B(g) \rightarrow C(g)$

$V = \text{constant}$ (closed vessel)

$T = \text{constant}$



Assuming ideal behavior, $PV = nRT$
for constant V and T

$P = k n$ where $n = \text{number of mol of gas}$ and
 $k = \text{constant}$.

At any time $t(h)$, $P_A \propto n_A$ (2) and $P_B \propto n_B$
Where P_A and P_B are the partial pressures of A and B
respectively in bar and n_A and n_B are their
corresponding number of moles.

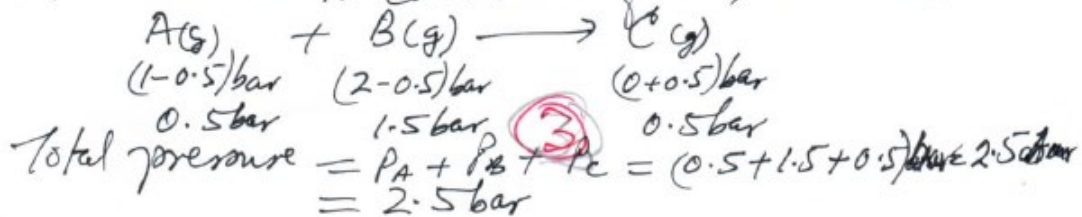
Since at $t=0$, $P_A = 1\text{ bar}$, after 50% of A is consumed
 $P_A = 0.5\text{ bar}$ (2) since $P_A \propto n_A$

But 1 mol A reacts with 1 mol B to give 1 mol of C

$\therefore P_B$ decreases by 0.5 bar since P_A decreases by 0.5 bar

P_C of C increases by 0.5 bar (1)

$\therefore$ At 50% conversion of A, we have



Material & Energy Balances

FINAL EXAM

10/10

4(iv) (a) $(n_i)_{N_2O_4} = (n_{io})_{N_2O_4} - \xi_1 - \xi_2$ where $(n_i)_{N_2O_4}$ = mol of N_2O_4 at the end of reaction
 $(n_{io})_{N_2O_4}$ is mol of N_2O_4 in the feed
 ξ_1 is the extent of reaction $N_2O_4 \rightarrow 2NO_2$, and
 ξ_2 is the extent of reaction $N_2O_4 \rightarrow [NO^+][NO_3^-]$

(b) $(n_i)_{NO_2} = (n_{io})_{NO_2} + 2\xi_1$ where $(n_i)_{NO_2}$ = mol of NO_2 at the end of reaction
 $(n_{io})_{NO_2}$ = mol of NO_2 in the feed

(c) $(n_i)_{[NO^+][NO_3^-]} = (n_{io})_{[NO^+][NO_3^-]} + \xi_2$ where $(n_i)_{[NO^+][NO_3^-]}$ = mol of $[NO^+][NO_3^-]$ at end of reaction
 $(n_{io})_{[NO^+][NO_3^-]}$ = mol of $[NO^+][NO_3^-]$ fed to reactor

(a) $(n_i)_{N_2O_4} = 10 \text{ mol}$
 $(n_{io})_{N_2O_4} = 100 \text{ mol}$

$\therefore (n_i)_{N_2O_4} = (n_{io})_{N_2O_4} - \xi_1 - \xi_2$ reduces to:

$10 = 100 - \xi_1 - \xi_2$ or $\xi_1 + \xi_2 = 90$ (2)

(b) $(n_i)_{NO_2} = 160$

$(n_{io})_{NO_2} = 0$

$\therefore (n_i)_{NO_2} = (n_{io})_{NO_2} + 2\xi_1$ reduces to:

$160 = 0 + 2\xi_1$ or $2\xi_1 = 160$

and $\xi_1 = 80$ (2)

$\xi_1 + \xi_2 = 90$

$\xi_1 = 80$

$\therefore \xi_2 + 80 = 90$

$\therefore \xi_2 = 90 - 80 = 10$ (2)

(c) $(n_i)_{[NO^+][NO_3^-]} = 10 \text{ mol}$

$(n_{io})_{[NO^+][NO_3^-]} = 0$

$\therefore$ From (c)

$10 = 0 + \xi_2$

$\therefore \xi_2 = 10$

ABOVE AVERAGE

Above Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

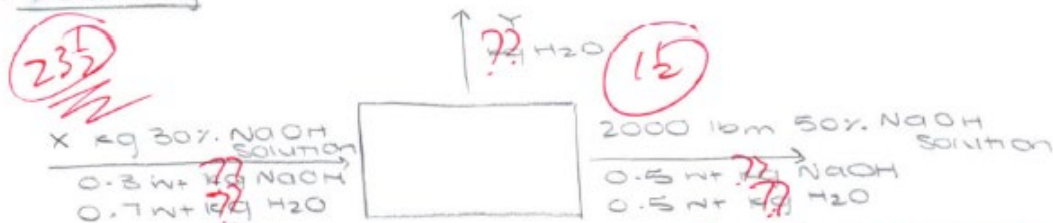
Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of chemical reaction stoichiometry and (1) determine degrees of freedom involving processes with recycle and bypass, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: FAVOR LOUIS

Title of Assignment: Final Exam Due Date: 5/6/2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply knowledge of chemical reaction stoichiometry involving (i) processes with recycle and bypass, (ii) degrees of freedom analysis, (iii) and determine fractional conversion, percentage yield, selectivity and extents of reactions. <i>This assignment tests students' knowledge to apply knowledge of chemical reaction stoichiometry and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	96
TOTAL	100	96

1. Identify



$$DOF = \# \text{ unknown} - \# \text{ equation} \\ = 2 - 2 = 0$$

Why do you mix SI and English Engineering units?

$$0.454 \text{ kg} = 1 \text{ lbm}$$

$$454 \text{ g} = 1 \text{ lbm}$$

Formulate

Basis: 2000 lbm 50% NaOH solution

Overall mass balance

$$X = Y + 2000$$

NaOH mass balance

$$0.3(X) = 0(Y) + 0.5(2000)$$

$$2 \text{ mol NaOH} : 1 \text{ mol H}_2$$

$$2 \text{ mol NaOH} : 1 \text{ mol Cl}_2$$

$$\text{mol} = \frac{\text{mass}}{\text{molar mass}}$$

take mol and $\div$ by 2

$$\text{NaOH} = 23 + 16 + 1 = 40 \text{ g/mol}$$

then $\times$ mol by Av to get mass of Cl_2 and H_2

$$1 - 23\frac{1}{2}$$

$$2 - 22$$

$$3 - 13\frac{1}{2}$$

$$4 - 25$$

$$\hline 84$$

Solve

$$1. \quad 0.3X = 1000$$

$$X = \frac{1000}{0.3} = 3333.33 \text{ lbm 30\% NaOH solution to be processed}$$

2.

$$X = Y + 2000$$

$$Y = X - 2000$$

$$= 3333.33 - 2000$$

$$Y = 1333.33 \text{ lbm H}_2\text{O needs to be evaporated}$$

$$1.1. \quad 1 \text{ lbm NaOH} = 2000 \left(\frac{50}{100} \right) = 1000 \text{ lbm NaOH}$$

$$\frac{1000 \text{ lbm}}{1 \text{ lbm}} \times \frac{454 \text{ g}}{1 \text{ lbm}} = 454000 \text{ g NaOH}$$

$$\text{mol NaOH} = \frac{454000 \text{ g NaOH}}{40 \text{ g/mol NaOH}} = 11350 \text{ mol NaOH}$$

$$2 \text{ mol NaOH} : 1 \text{ mol H}_2 : 1 \text{ mol Cl}_2$$

$$11350 \text{ mol NaOH} : 5675 \text{ mol H}_2 : 5675 \text{ mol Cl}_2$$

$$\text{mass} = \text{mol} \times \text{molar mass}$$

$$\text{mass H}_2 = 5675 \text{ mol H}_2 (2 \text{ g/mol H}_2)$$

$$\text{mass H}_2 = 11350 \text{ g H}_2$$

$$\frac{11350 \text{ g H}_2}{454 \text{ g H}_2} \times \frac{2 \text{ lbm H}_2}{1 \text{ lbm H}_2} = 25 \text{ lbm H}_2 \quad \textcircled{3}$$

$$\text{mass Cl}_2 = 5675 \text{ mol Cl}_2 (70 \text{ g/mol Cl}_2)$$

$$= 397250 \text{ g Cl}_2$$

$$\frac{397250 \text{ g Cl}_2}{454 \text{ g Cl}_2} \times \frac{2 \text{ lbm Cl}_2}{1 \text{ lbm Cl}_2} = 875 \text{ lbm Cl}_2 \quad \textcircled{2} \quad \checkmark -$$

2. Identify

i.



Formulate Basis: 100 kg/h m₁

i. DOF = # unknown - # equation

overall

unknown: m₄, m₇, x_{O7} ①

equations: 3 ② what are the equations?

DOF = 3 - 3 = 0 ①

unit 1

unknown: (m₂), x_{O3}

equations: 2 ② what are the equations?

DOF = 2 - 2 = 0 ①

mixing point

unknown: m₃, x_{O3}, m₅, x_{O5}, (m₄)

equations: 3 ② what are the equations?

DOF = 5 - 3 = 2 ①

unit 2

unknown: m₅, x_{O5}, m₇, x_{O7} ①

equations: 2 ② what are the equations?

DOF = 4 - 2 = 2 ①

overall mass balance

$$\dot{m}_1 + \dot{m}_4 = \dot{m}_2 + \dot{m}_4 + \dot{m}_7$$

overall O balance

$$0.5(\dot{m}_1) + 0.5(\dot{m}_4) = 0.9(\dot{m}_2) + 0.65(\dot{m}_6) + x_{O7}(\dot{m}_7)$$

$$\dot{m}_1 = 2 \cdot \dot{m}_4$$

Solve i.i.i.

$$\dot{m}_1 = 2 \cdot \dot{m}_4$$

$$100 = 2 \cdot \dot{m}_4$$

$$\dot{m}_4 = \frac{100}{2} = 50 \text{ kg/h}$$

unit 1 overall

$$\dot{m}_1 = \dot{m}_2 + \dot{m}_3$$

$$\dot{m}_3 = \dot{m}_1 - \dot{m}_2$$

$$\dot{m}_3 = 100 - 30 \rightarrow \dot{m}_3 = 70 \text{ kg/h}$$

mixing point overall

$$\dot{m}_3 + \dot{m}_4 = \dot{m}_5$$

$$\dot{m}_5 = 70 + 50$$

$$\dot{m}_5 = 120 \text{ kg/h}$$

unit 2 overall

$$\dot{m}_5 = \dot{m}_6 + \dot{m}_7$$

$$\dot{m}_7 = \dot{m}_5 - \dot{m}_6$$

$$\dot{m}_7 = 120 - 70$$

$$\dot{m}_7 = 50 \text{ kg/h}$$

3. (a)

Given

2 mol H_2

4 mol O_2

4 mol H_2O

Formulate

$$\text{mol total} = n_{\text{H}_2} + n_{\text{O}_2} + n_{\text{H}_2\text{O (wet)}}$$

$$\text{molar comp} = \frac{\text{mol A}}{\text{total mol}} \times 100$$

Solve

$$1. \text{ mol total} = 2 + 4 = 6 \text{ mol}$$

$$\text{molar comp. H}_2 = \frac{2}{6} = 0.333, 0.333 \times 100\% = 33.3\% \text{ H}_2$$

$$\text{molar comp. O}_2 = \frac{4}{6} = 0.667, 0.667 \times 100\% = 66.7\% \text{ O}_2$$

$$2. \text{ mol total} = 2 + 4 + 4 = 10 \text{ mol}$$

$$\text{molar comp. H}_2 = \frac{2}{10} = 0.2, 0.2 \times 100 = 20\% \text{ H}_2$$

$$\text{molar comp. O}_2 = \frac{4}{10} = 0.4, 0.4 \times 100 = 40\% \text{ O}_2$$

$$n_{N_2O_4} = n_{N_2O_4,0} - \xi_1 - \xi_2$$

$$n_{NO_2} = n_{NO_2,0} + 2\xi_1 = 2\xi_1$$

$$[NO^+][NO_3^-] = [NO^+][NO_3^-]_0 + \xi_2 = \xi_2$$

Solve

$$a) f_{N_2O_4} = \frac{\text{moles } N_2O_4 \text{ reacted}}{\text{moles } N_2O_4 \text{ fed}} = \frac{200 - 20}{200} = \frac{90}{200}$$

$$f_{N_2O_4} = 0.9 \quad (4)$$

$$b) \begin{array}{l} 1 \text{ mol } N_2O_4 : 2 \text{ mol } NO_2 \\ 200 \text{ mol } N_2O_4 : 200 \text{ mol } NO_2 \end{array}$$

$$\begin{array}{c|c} 200 \text{ mol } N_2O_4 & 2 \text{ mol } NO_2 \\ \hline & 1 \text{ mol } N_2O_4 \\ & = 200 \text{ mol } NO_2 \end{array}$$

$$\text{percentage yield } NO_2 = \frac{160 \text{ mol } NO_2}{200 \text{ mol } NO_2} = 0.8 \text{ } NO_2$$

$$= 0.8 \times 100\% = 80\% \text{ yield } NO_2 \quad (4)$$

$$c) \text{selectivity } \frac{NO_2 \text{ relative}}{+0[NO^+][NO_3^-]} = \frac{160 \text{ mol } NO_2}{10 \text{ mol } [NO^+][NO_3^-]} = 16 \quad (4)$$

d)

$$n_{NO_2} = 2\xi_1$$

$$\xi_1 = \frac{n_{NO_2}}{2} = \frac{160 \text{ mol } NO_2}{2} = 80 = \xi_1 \quad (3)$$

$$[NO^+][NO_3^-] = \xi_2 \quad (3)$$

$$20 = \xi_2$$

AVERAGE

Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of chemical reaction stoichiometry and (1) determine degrees of freedom involving processes with recycle and bypass, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: Chau Truong

Title of Assignment: Final Exam Due Date: 05/06/2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply knowledge of chemical reaction stoichiometry involving (i) processes with recycle and bypass, (ii) degrees of freedom analysis, (iii) and determine fractional conversion, percentage yield, selectivity and extents of reactions. <i>This assignment tests students' knowledge to apply knowledge of chemical reaction stoichiometry and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	80
TOTAL	100	80

(1)



$$\% \text{ Yield} = \frac{\text{Mass NaOH}}{\text{Mass NaCl}} \cdot 100 = 30\% \Rightarrow \text{Mass NaOH} = 0.3 \text{ Mass NaCl}$$

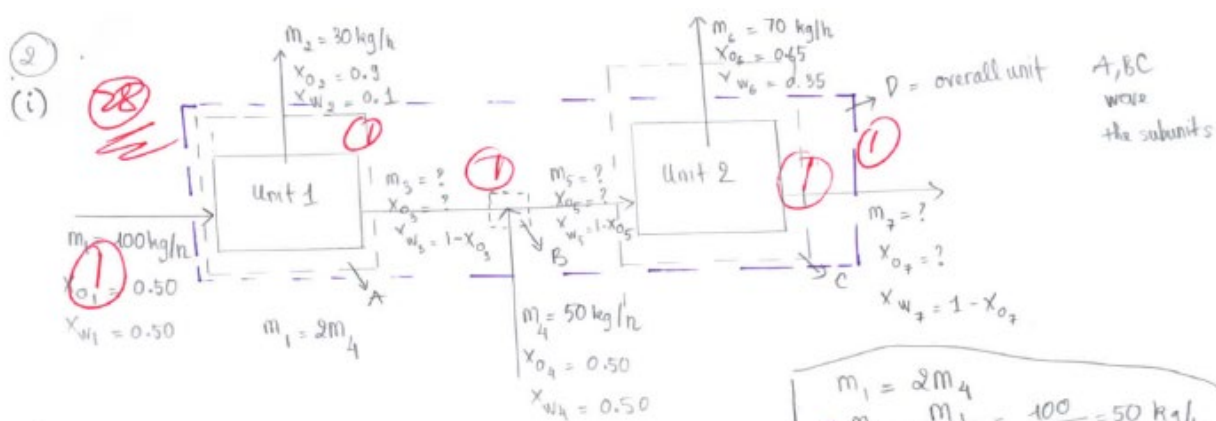
(ii)

⊗ Basic 2000 lbm of product as 50%wt NaOH solution

$$M_{\text{NaOH}} = \frac{50 \times 2000}{100} = 1000 \text{ lbm}$$

$$\text{Mole NaOH} = \frac{\text{Mass NaOH}}{\text{Molar Mass NaOH}} = \frac{1000 \text{ lbm}}{40 \text{ g/mol}} \times \frac{454 \text{ g}}{1 \text{ lbm}} = 11350 \text{ mo}$$

$$\text{Mole H}_2\text{O} = \frac{\text{Mole NaOH}}{2} = \boxed{5675 \text{ mole}}$$



(ii) DOF of overall D

- * 2 unknowns = m_7, x_{O7} ~~unknown~~ ^{My is}
 - * 2 species components = x_O and x_W
- DOF = 2 - 2 = 0

DOF of subunit A

- * 2 unknowns = m_3, x_{O3}
 - * 2 species components = x_O and x_W
- DOF = 2 - 2 = 0

DOF of subunit B

- * 4 unknowns = m_3, m_5, x_{O5}, x_{W5} ~~My is not known~~
 - * 2 species components = x_O, x_W
- Relationship between m_1, m_2 and m_3
- DOF = 4 - 2 = 2
- so we need to find m_3 before solve m_5

DOF of subunit C

- * 4 unknowns = m_5, m_7, x_{O5}, x_{W5}
 - * 2 components = x_O, x_W
- DOF = 4 - 2 = 2

(iii) Basic: 100 kg/hour of m_1 mixture

* Overall D = overall balance:

$$m_1 + m_4 = m_2 + m_6 + m_7$$

$$100 + 50 = 30 + 70 + m_7$$

$$*m_7 = (100 + 50) - (30 + 70) = 50 \text{ kg/h}$$

* subunit A or unit 1: overall balance of A:

$$m_1 = m_2 + m_3$$

$$100 = 30 + m_3$$

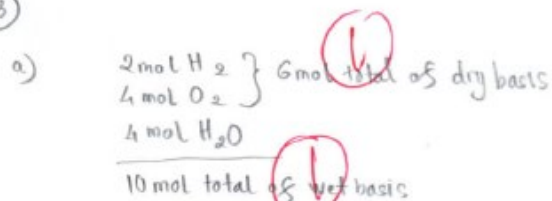
$$*m_3 = 100 - 30 = 70 \text{ kg/h}$$

* subunit B: overall balance of B:

$$m_3 + m_4 = m_5$$

$$70 + 50 = *m_5 = 120 \text{ kg/h}$$

3



(i) the molar composition of H_2 on dry basis = $\frac{2 \text{ mol}}{6 \text{ mol}} = \frac{1}{3} = 0.333$ or 33.3 %

the molar composition of O_2 on dry basis = $\frac{4 \text{ mol}}{6 \text{ mol}} = 0.667$ or 66.6 %

(ii) the molar composition of H_2 on wet basis = $\frac{\text{mole of } H_2}{\text{mol of total wet basis}} = \frac{2 \text{ mol}}{10 \text{ mol}} = 0.2$ or 20 %

the molar composition of O_2 on dry basis = $\frac{\text{mole of } O_2}{\text{mol of total wet basis}} = \frac{4 \text{ mol}}{10 \text{ mol}} = 0.4$ or 40 %



1 bar 2 bar

The partial pressure of A and B at start of the process are 1 bar and 2 bar.
molar ratio of A:B is 1:2, so $B = 2A$

When 50% A is consumed, B need double. Then, $\frac{1}{2}n_A$ and $n_B = n_A \times 2 = 1n_A$

Total pressure $P_{\text{total}} = P_A + P_B$

$\times P_{\text{total}} = \frac{n_{\text{total}} RT}{V}$ $\Rightarrow \frac{n_{\text{total}} RT}{V} = \frac{n_A RT}{V} + \frac{n_B RT}{V} = \frac{(n_A + n_B) RT}{V}$

$\times P_A = \frac{n_A RT}{V}$ $\Rightarrow n_{\text{total}} = n_A + n_B = \frac{1}{2}n_A + n_A = \frac{3}{2}n_A$

$\times P_B = \frac{n_B RT}{V}$ $\Rightarrow$ Therefore after 50% of A is consumed, the total pressure is

$\times V, RT$ are constant because they are in same condition

$\frac{P_A}{P_{\text{total}}} = \frac{n_A}{n_{\text{total}}} = \frac{n_A}{\frac{3}{2}n_A}$

$P_{\text{total}} = \frac{3}{2}P_A = \frac{3}{2} \times 1$

$P_{\text{total}} = \frac{3}{2}$

c) Selectivity of NO_2 relative to $[\text{NO}^+][\text{NO}_3^-] = \frac{\text{mol of desire product formed}}{\text{mol of undesire product formed}}$

* mole of desire product formed is mol of NO_2 160 mol

* mole of undesire product formed is mole of $[\text{NO}^+][\text{NO}_3^-] = 10 \text{ mol}$

$$\text{Selectivity of } \text{NO}_2 \text{ relative to } [\text{NO}^+][\text{NO}_3^-] = \frac{160}{10} = 16$$

d) $\xi_1 = \text{exten of the first reaction} = \frac{n_{\text{NO}_2} - n_{\text{NO}_2,0}}{2}$ $\textcircled{\times} n_{\text{NO}_2} \text{ at beginning } t=0 = 0$

$$= \frac{160 - 0}{2} = 80$$

$\xi_2 = \text{exten of the second reaction} = \frac{n_{[\text{NO}^+][\text{NO}_3^-]} - n_{[\text{NO}^+][\text{NO}_3^-]_0}}{1}$ $\textcircled{\times} n_{[\text{NO}^+][\text{NO}_3^-]} \text{ at } t=0 = 1$

1 < product so it's positive >

$$= \frac{10 \text{ mol} - 0}{1} = 10$$

Hence $\xi_1 = 80$

$\xi_2 = 10$

BELOW AVERAGE

Below Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
MATERIAL AND ENERGY BALANCES CHEG 2333
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR SPRING 2022 SEMESTER**

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of chemical reaction stoichiometry and (1) determine degrees of freedom involving processes with recycle and bypass, and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems.

Name: Alexander Ortiz

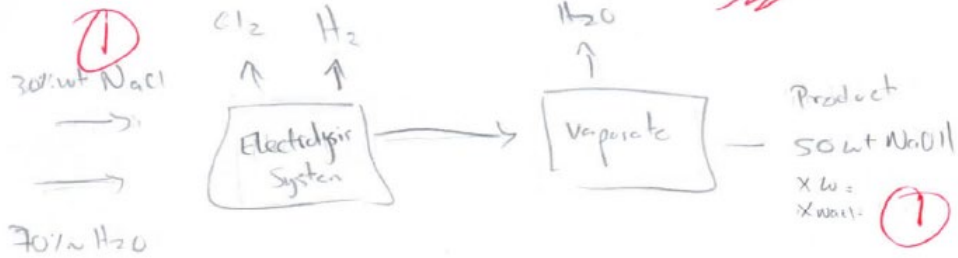
Title of Assignment: Final test Due Date: 5/6/2022

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply knowledge of chemical reaction stoichiometry involving (i) processes with recycle and bypass, (ii) degrees of freedom analysis, (iii) and determine fractional conversion, percentage yield, selectivity and extents of reactions. <i>This assignment tests students' knowledge to apply knowledge of chemical reaction stoichiometry and (2) apply appropriate conservation laws, chemical and physical principles to solve process engineering problems</i>	100	70
TOTAL	100	70

Question #1

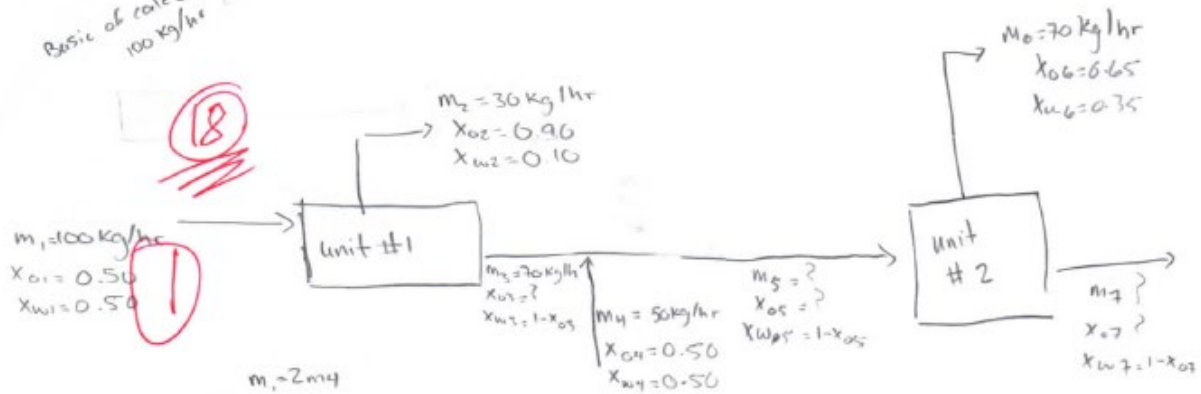


(2)



Question # 2

Basic of calculation
100 kg/hr



Where are Subunits A, B and C?

They are not shown in the flow chart.

- Subunit A where is A?
2 unknowns = m_3 & x_{O3}
2 species component x_O & x_W

Thus $DOF = 2 - 2 = 0$

- Subunit C where is C?

4 unknowns = m_3 , m_2 , x_{O5} , x_{O7}
2 components = x_O , x_W
 $DOF = 4 - 2 = 2$

- Subunit B

4 unknowns = m_3 , m_5 , x_{O5} , x_{O7}
2 species component
1 relationship between m_1 , m_2 and m_3
 $DOF = 4 - 2 = 2$

Overall Balance

$m_1 + m_4 = m_2 + m_5 + m_7$
 $100 + 50 = 30 + 70 + m_7$
 $150 - 100 = m_7$
 $m_7 = 50 \text{ kg/hr}$

Overall Subunit A

$m_1 = m_2 + m_3$

$100 = 30 + m_3$

$m_3 = 70 \text{ kg/hr}$

Overall Subunit B

$m_3 = m_5 + m_7$

$70 + 50 = m_5$

$m_5 = 120 \text{ kg/hr}$

Prises of calculation

$m_1 = 100 \text{ kg/hr}$

Question #3

*1 Gas Mixture is on Wet Bases

$$H_2 = 2 \text{ mol} \quad \text{mole 1.}$$

$$O_2 = 4 \text{ mol} \quad H_2 = \frac{2}{10} \times 100\% = 20\% \quad \left(\frac{1}{2}\right)$$

$$H_2O = 4 \text{ mol} \quad O_2 = \frac{4}{10} \times 100\% = 40\% \quad \left(\frac{1}{2}\right)$$

$$\text{total } 10 \text{ mol} \quad \left(\frac{1}{2}\right)$$



*2 Gas mixture on Dry gas Bases

$$H_2 = 2 \text{ mol} \quad H_2 = \frac{2}{6} \times 100\% = 33.33\% \quad (1)$$

$$O_2 = 4 \text{ mol} \quad O_2 = \frac{4}{6} \times 100\% = 66.66\% \quad (1)$$

$$\text{total} = 6 \text{ mol} \quad \left(\frac{1}{2}\right)$$

b) Gas-phase reaction $PV = nRT$

$$P_{A0} = 1 \text{ bar} \quad \text{consumption 50\%} \quad \text{Ratio A:B 1:2}$$

$$P_{B0} = 2 \text{ bar}$$

$$\text{thus } B = 2A \quad \text{Therefore } \frac{1}{2} n_A \quad \text{and } n_B = A/2 \quad \text{which } n_A = \frac{1}{2} n_B = 1 n_A$$

$$P_A = \frac{n_A R T}{V}$$

$$P_A' = \frac{n_A' R T}{V}$$

$$P_T = \frac{n_T R T}{V}$$

since T constant
 V constant
 R constant

(1)

We can say that
 $A + B = C$

where

$$A = P_A$$

$$B = P_B$$

$$C = P_C$$

$$\frac{n_A R T}{V} + \frac{n_B R T}{V} = \frac{n_T R T}{V} \rightarrow (n_A + n_B) \left(\frac{R T}{V} \right) = n_T \left(\frac{R T}{V} \right)$$

$$n_A + n_B = n_T \rightarrow \frac{1}{2} n_A + 1 n_A = n_T \quad ; \quad n_T = \frac{3}{2} n_A$$

Common ratio

$$\frac{P_A}{P_T} = \frac{n_A}{n_T} = \frac{P_T}{P_A} = \frac{n_T}{n_A} \rightarrow P_T = \frac{2 n_A}{1 n_A} P_A \rightarrow P_T = 2 P_A$$

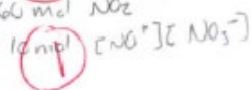
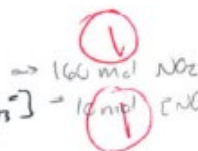
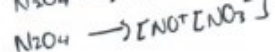
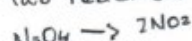
$$P_T = \frac{3}{2} P_A$$

$$P_T = \frac{3}{2} (1)$$

$$P_T = \frac{3}{2}$$

Question #4

Two reactions



21

Feed 100 mol N₂O₄

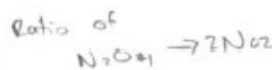
need 2nd equation
1st reaction
2nd reaction

a) fractional conversion of N₂O₄

$$\frac{\text{moles reacted}}{\text{moles feed}} = \frac{90 \text{ mol N}_2\text{O}_4}{100 \text{ mol N}_2\text{O}_4} = 0.9 \text{ Fractional conversion of N}_2\text{O}_4$$

b) Percentage yield of NO₂

$$\frac{160 \text{ mol NO}_2}{200 \text{ mol}}$$



1:2
thus if given 100 mol N₂O₄
we would get 200 mol 2NO₂

$$0.8 \times 100\% = 80\% \text{ yield}$$

c) The selectivity of NO₂ relative to NO⁺NO₃⁻

$$\frac{160 \text{ mol NO}_2}{10 \text{ mol } [\text{NO}^+][\text{NO}_3^-]} = 16 \text{ mol selectivity}$$

d) Extents of the first and second reaction

$$\xi = \frac{\text{moles of species } i \text{ at any time} - \text{moles of species } i \text{ at time } = 0}{\text{Stoichiometric coefficient of species } i}$$

$$\xi_1 = \frac{n_{\text{NO}_2} - n_{\text{NO}_2,0}}{2} = \frac{160 - 0}{2} = 80$$

remember n_{NO₂} at t=0 we get 0

$$\xi_1 = 80$$