

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING
CHEG 2333 – MATERIAL & ENERGY BALANCES
FALL 2021**

- I. COURSE DESCRIPTION IN ABET FORMAT**
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Average (Graded original work)
Below Average (Graded original work)
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Average (Graded original work)
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Average (Graded original work)
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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]

(Note: All Pages shown in Yellow should be printed on YELLOW PAPER)
(Note: All Pages shown in Blue should be printed on BLUE PAPER)

ABET Format Course Syllabus

CHEG 2333 MATERIAL AND ENERGY BALANCES

1. **Course number and name:** CHEG 2333 MATERIAL AND ENERGY BALANCES
2. **Credits and contact hours:** 3 credit hours; 3 contact hours
3. **Instructor's or course coordinator's name:** Dr. Keisha Antoine
4. **Text book:** Title: **Elementary Principles of Chemical Processes**
Author: **Richard M. Felder, Ronald W. Rousseau, Lisa G. Bullard**

Publisher, Year & Edition: Wiley, 2019 4th Edition

a. Other Supplemental material "Basic Principles and Calculations in Chemical Engineering", D. M. Himmelblau and J. B. Riggs, 2003, Pearson Education
5. **Specific course information**
 - a. Brief description of the content of the course (catalog description) ***CHEG 2333 Material and Energy Balances: 3 semester hours.***
Application of laws of conservation of mass and energy to reacting and non-reacting, 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 or Co-requisites CHEM 1403 or CHEM 1034
PHYS 2325 or PHYS 2513
 - 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 specific outcomes of instruction (e.g. The student will be able to explain the significance of current research about a particular topic.) <i>Students will be able to :</i> 1. An ability to apply conservation laws.	b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course. <i>The specific goals for the course specific outcomes listed on the left column will address the following student learning outcomes:</i>
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2. An ability to present and report basic engineering information.

3. An ability to analyze, formulate and solve mass balances with and without chemical reactions.

4. An ability to analyze, formulate and solve energy balances.

Outcome D1

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

7 Brief list of topics to be covered

- 1.Intro to Engineering Calculations (12 hours)
- 2.Processes and Process Variables (8 hours)
- 3.Fundamentals of Material Balances (20 hours)

***Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group

II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS

Program Outcomes Assessed in this course

Outcome D1:

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

Assessment Summary of Class Semester Averages for Outcomes (Should be provided for Fall 2019 through Spring 2022 Assessment Period)

Outcomes	D1
Semester	Semester Class Average (%)
Fall 2021	52.9
Spring 2021	70.5
Spring 2020	71.8
Fall 2019	50
Comments on Trend of Data (Improving or deteriorating)	Significant drop in class average coincides with recent return to in-person classes after virtual learning during COVID-19 restrictions.

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

End of Semester Course Assessment Reports Fall 2021 and Last Three 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

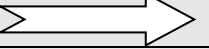
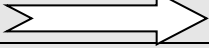
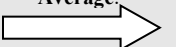
- Instructors summary of overall performance trend for each outcome measured over the last three periods.

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**.

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
CHEG 2333 P01 MATERIAL AND ENERGY BALANCE: FALL 2021 SEMESTER

Report Prepared by: Dr. KEISHA ANTOINE Report Date: December 18, 2021

Semester	Analysis Type	Number of Students	Outcome D1 An ability to identify, formulate, and solve fundamental 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
Fall 2021	Direct	16	75	70	52.9	25
Spring 2021	Direct	11	75	70	70.5	73
Spring 2020	Direct	23	75	70	71.8	66.7
Fall 2019	Direct	20	75	70	54	8
Spring 2019	Direct	11	75	70	83	84
Implementation Summary	Items implemented from previous report or after meeting previous instructor 	First third of the course was spent instructing on basics – mathematical manipulations statistics, linear interpolation, calibration; physics and chemistry: pressure, moles, molecular weight balancing equations and stoichiometry. Emphasized relating the general mass balance equation to its application for non-reactive and reactive systems. Spent a lot of time on sketching to show how a sketch of the flowsheet relates to formulation of the problem.				
Perceived Problems	Perceived problems are directly related to the PC and the sub items under them 	This cohort of students seemed to move at a slower pace and took longer to understand the material when compared to previous cohorts. They struggled with problem identification and formulation, so additional time was allocated to in-class, instructor-led problem-solving on the whiteboard. Perhaps this is due to many of the students experiencing in-person college courses for the first time.				
Plans for Addressing Problems	Plans for address specific measures to address PC and their sub areas 	The instructor continued to provide homework problems to be worked out during the class periods. Adding 2 or 3 more group assignments interspersed with regular homework assignments may help to fix some concepts.				
Overall Trend over Periods	Ascertain if there were improvements over previous semesters 	The percentage of students meeting the average for D1 decreased compared to the previous assessment period.				
Were Expectations Met?	Class Average $\geq 75\%$ and $\geq 70\%$ of Students Performed at or Above Expected Average. 	Class average above 75% → NO % of Students meeting/exceeding average → NO				

MATERIAL & ENERGY BALANCES SPRING 2021

Title of Assignment: TEST 1

TOPICS COVERED IN TEST 1

Test 1 covered the following topics:

1. Unit conversion
2. Dimensional homogeneity
3. Linear interpolation
4. Calculating mass fractions, mole fractions
5. Specific gravity, mass flow rate, molar flow rate, volumetric flow rate

**MATERIAL & ENERGY BALANCES
SPRING 2021**

**SAMPLE TEST QUESTIONS, SOLUTIONS,
AND GRADING SCHEME FOR TEST 1**

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

1. Estimate the gauge pressure (psig) in the Gulf of Mexico at a depth of 5053 ft. Assume that seawater has a specific gravity of 1.03.

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

2. Calculate the densities in lb_m/ft^3 of the following substances:
NOTE: Remember to state your assumptions and show your work.
 - a. A liquid with density of 995 kg/m^3 [10 points]

- b. A solid with a specific gravity of 5.7. [10 points]

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

3. Liquid toluene (C_7H_8) is flowing through a pipe at a rate of $175 \text{ m}^3/\text{h}$.
a. What is the mass flow rate of this stream in kg/min ? (SG of toluene = 0.867) [15 points]

- b. What is the molar flow rate in mol/s ? [10 points]

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

4. The solubilities of L-serine (L-ser) in water have been measured at several temperatures producing the following data:

$T(K)$	283.4	285.9	289.3	299.1	316.0	317.8	322.9	327.1
x (mole fraction L-Ser)	0.0400	0.0426	0.0523	0.0702	0.1091	0.1144	0.1181	0.1248

What is the value of x for $T = 325K$? [25 points]

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

5. A mixture is 12.0 mole% methyl alcohol (CH_3O), 73.0 mole% methyl acetate ($\text{C}_3\text{H}_6\text{O}_2$) and 15 mole% acetic acid ($\text{C}_2\text{H}_4\text{O}_2$). [$M(\text{carbon}) = 12$; $M(\text{hydrogen}) = 1$; $M(\text{oxygen}) = 16$]
- a. Calculate the mass fractions of each compound. [15 points]

- b. What is the average molecular weight of the mixture? [10 points]

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

Student Name: _____

Student Name: _____

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton (tonne) = 2.20462 lb _m = 35.27392 oz 1 lb _m = 16 oz = 5 × 10 ⁻⁴ ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10 ⁶ microns (μm) = 10 ¹⁰ angstroms (Å) = 39.37 in = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m ³ = 1000 L = 10 ⁶ cm ³ = 10 ⁶ mL = 35.3145 ft ³ = 219.97 imperial gallons = 264.17 gal = 1056.68 qt 1 ft ³ = 1728 in ³ = 7.4805 gal = 29.922 qt = 0.028317 m ³ = 28.317 L
Density	1 g/cm ³ = 1000 kg/m ³ = 62.43 lb _m /ft ³ = density of liquid water at 4°C (reference for specific gravities)
Force	1 N = 1 kg·m/s ² = 10 ⁵ dynes = 10 ⁵ g·cm/s ² = 0.22481 lb _f 1 lb _f = 32.174 lb _m ·ft/s ² = 4.4482 N = 4.4482 × 10 ⁵ dynes
Pressure	1 atm = 1.01325 × 10 ⁵ N/m ² (Pa) = 101.325 kPa = 1.01325 bar = 1.01325 × 10 ⁶ dynes/cm ² = 14.696 lb _f /in ² (psi) = 760 mm Hg at 0°C (torr) = 10.333 m H ₂ O(l) at 4°C = 29.921 inches Hg at 0°C = 406.8 inches H ₂ O(l) at 4°C
Energy	1 J = 1 N·m = 10 ⁷ ergs = 10 ⁷ dyne·cm = 1 kg·m ² /s ² = 2.778 × 10 ⁻⁷ kW·h = 0.23901 cal = 0.23901 × 10 ⁻³ kcal (food caloric) = 0.7376 ft·lb _f = 9.486 × 10 ⁻⁴ Btu
Power	1 W = 1 J/s = 1 N·m/s = 0.23901 cal/s = 0.7376 ft·lb _f /s = 9.486 × 10 ⁻⁴ Btu/s = 1.341 × 10 ⁻³ hp

Example: The factor to convert grams to lb_m is $\left(\frac{2.20462 \text{ lb}_m}{1000 \text{ g}}\right)$ or $\left(\frac{1 \text{ lb}_m}{453.593 \text{ g}}\right)$.

$$\bar{M} = y_1 M_1 + y_2 M_2 + \dots = \sum_{\text{all components}} y_i M_i$$

$$\frac{1}{\bar{M}} = \frac{x_1}{M_1} + \frac{x_2}{M_2} + \dots = \sum_{\text{all components}} \frac{x_i}{M_i}$$

ABOVE AVERAGE

Above Average Student Original Graded Assignment

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: Cameron Braun

1. Estimate the gauge pressure (psig) in the Gulf of Mexico at a depth of 5053 ft. Assume that seawater has a specific gravity of 1.03.

$$\text{gauge pressure} = P_{gh}$$

$$SG = \frac{P_{\text{actual}}}{P_{\text{ref (water)}}}$$

$$1.03 = \frac{P}{62.43 \text{ lbm/ft}^3} \rightarrow P = 64.3029$$

$$P = (1.03)(62.43)$$

$$P = 64.3029$$

$$(64.3029)(9.8)(5053)$$
$$3.18 \times 10^6$$

Material & Energy Balances
Test 1

CHEG 2333 P01
10/11/2021

Student Name: _____

2. Calculate the densities in lbm/ft^3 of the following substances:
NOTE: Remember to state your assumptions and show your work.
a. A liquid with density of 995 kg/m^3 [10 points]

$$\frac{995 \text{ kg}}{1 \text{ m}^3} \times \frac{2.20462 \text{ lbm}}{1 \text{ kg}} \times \frac{1 \text{ m}^3}{3.2808 \text{ ft}^3} = 668.62 \text{ lbm/ft}^3$$

- b. A solid with a specific gravity of 5.7. [10 points]

$$SG = \frac{P_{\text{actual}}}{P_{\text{ref (water)}}}$$

$$5.7 = \frac{P}{62.43 \text{ lbm/ft}^3}$$

$$(5.7)(62.43) = P$$

$$355.85 = P$$

$$355.85 \text{ lbm/ft}^3$$

Dr. Antoine

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

3. Liquid toluene (C_7H_8) is flowing through a pipe at a rate of $175 \text{ m}^3/\text{h}$.
a. What is the mass flow rate of this stream in kg/min ? (SG of toluene = 0.867) [15 points]

$$SG = \frac{\rho_{\text{actual}}}{\rho_{\text{ref}}}$$

$$0.867 = \frac{\rho}{1000 \text{ kg}/\text{m}^3}$$

$$(0.867)(1000) = \rho$$

$$867 \text{ kg}/\text{m}^3 = \rho$$

$$\frac{\rho}{\text{SG}} = \frac{\rho_{\text{ref}}}{\text{SG}}$$

$$\frac{175 \text{ m}^3}{1 \text{ h}} \times \frac{1 \text{ h}}{60 \text{ min}} = 2.917 \text{ m}^3/\text{min}$$

$$\dot{m} = (2.917 \text{ m}^3/\text{min})(867 \text{ kg}/\text{m}^3)$$

$$\dot{m} = 2528.75 \text{ kg}/\text{min}$$

- b. What is the molar flow rate in mol/s ? [10 points]

$$\dot{n} = \frac{\text{mol}}{\text{time}}$$

$$\dot{n} = \frac{\dot{m}}{MW}$$

$$MW = (12 \times 7) + (8 \times 1) = 92 \text{ g}/\text{mol}$$

$$\frac{92 \text{ g}}{1 \text{ mol}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.092 \text{ kg}/\text{mol}$$

$$\frac{2528.75 \text{ kg}}{1 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 42.146 \text{ kg}/\text{sec}$$

$$\dot{n} = \frac{42.146 \text{ kg}/\text{sec}}{0.092 \text{ kg}/\text{mol}} = 458.107 \text{ mol}/\text{s}$$

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

4. The solubilities of L-serine (L-ser) in water have been measured at several temperatures producing the following data:

T (K)	283.4	285.9	289.3	299.1	316.0	317.8	322.9	327.1
mole fraction (L-ser)	0.0400	0.0426	0.0523	0.0702	0.1091	0.1144	0.1181	0.1248

What is the value of s for $T = 325 \text{ K}$? [25 points]

$$y = y_1 + \frac{x - x_1}{x_2 - x_1} (y_2 - y_1)$$

in K and K

$$y_1 = 322.9 \quad x_1 = 0.1181$$

$$y_2 = 327.1 \quad x_2 = 0.1248$$

$$y = 325$$

Switch x & y

$$x = x_1 + \frac{y - y_1}{y_2 - y_1} (x_2 - x_1)$$

$$x = 0.1181 + \frac{325 - 322.9}{327.1 - 322.9} (0.1248 - 0.1181)$$

$$\text{mole fraction L-ser} = 0.12145 \text{ at } 325 \text{ K}$$

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

5. A mixture is 12.0 mole% methyl alcohol (CH_4O), 73.0 mole% methyl acetate ($\text{C}_3\text{H}_6\text{O}_2$) and 15 mole% acetic acid ($\text{C}_2\text{H}_4\text{O}_2$). $M(\text{carbon}) = 12$; $M(\text{hydrogen}) = 1$; $M(\text{oxygen}) = 16$
- a. Calculate the mass fractions of each compound. [15 points]

$12 + 73 + 15 = 100$

$n = \frac{\text{mass}}{\text{mw}}$ 0.574

mol frac $\times 100 = \text{mol } \%$

$12\% = \frac{12 \text{ mol}}{100} \times 100 = 12 \text{ mol}$

$73\% = \frac{73 \text{ mol}}{100} \times 100 = 73 \text{ mol}$

$15\% = \frac{15 \text{ mol}}{100} \times 100 = 15 \text{ mol}$

$\text{mass} = n \times \text{mw}$

compound	mol	mw g/mol	mass
CH_4O	12	$(12 \times 1) + (1 \times 4) + (16) = 32$	$12 \times 32 = 384$
$\text{C}_3\text{H}_6\text{O}_2$	73	$(12 \times 3) + (1 \times 6) + (16 \times 2) = 74$	$73 \times 74 = 5402$
$\text{C}_2\text{H}_4\text{O}_2$	15	$(12 \times 2) + (1 \times 4) + (16 \times 2) = 60$	$15 \times 60 = 900$

$\sum = 6686$

$\text{CH}_4\text{O} : \frac{384}{6686}$ $\text{C}_3\text{H}_6\text{O}_2 : \frac{5402}{6686}$ $\text{C}_2\text{H}_4\text{O}_2 : \frac{900}{6686}$

b. What is the average molecular weight of the mixture? [10 points]

$\bar{mw} = (y_1 \text{mw}_1) + (y_2 \text{mw}_2) + (y_3 \text{mw}_3)$

$(0.12 \times 32) + (0.73 \times 74) + (0.15 \times 60)$

$3.84 + 54.02 + 9$

$\bar{mw} = 66.86 \text{ g/mol}$

AVERAGE

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CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: Aicha Linné

1. Estimate the gauge pressure (psig) in the Gulf of Mexico at a depth of 5053 ft. Assume that seawater has a specific gravity of 1.03.

$$P_{\text{gauge}} = \rho h g$$

$$= 64.3079 \times 5053 \times$$

$$9.1 = 45937.3$$

$$S.G. = \frac{\rho}{\rho_{\text{water}}}$$

$$\rho = S.G. \times \rho_{\text{water}}$$

$$= 1.03 \times 62.43 \text{ lbm/ft}^3$$

$$= 64.3029$$

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Student Name: _____

2. Calculate the densities in lbm/ft^3 of the following substances:
NOTE: Remember to state your assumptions and show your work.

a. A liquid with density of 995 kg/m^3 [10 points]

$$\rho_{\text{kg}} = 2.20462 \text{ lbm} \quad \rho_{\text{m}} = 3.2808$$
$$\frac{995 \text{ kg}}{\text{m}^3} \times \frac{2.20462 \text{ lbm}}{1 \text{ kg}} \times \frac{\text{m}^3}{3.2808^3 \text{ ft}^3}$$

- b. A solid with a specific gravity of 5.7. [10 points]

$$S.G. = \frac{\text{density of reference}}{\text{density of water}} \Rightarrow \text{density of}$$

density of

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Dr. Antoine

Student Name: _____

3. Liquid toluene (C_7H_8) is flowing through a pipe at a rate of $175 \text{ m}^3/\text{h}$.
a. What is the mass flow rate of this stream in kg/min ? (SG of toluene = 0.867) [15 points]

Let find the mass of toluene

$$S.G. = \frac{\rho_{\text{toluene}}}{\rho_{\text{water}}} \Rightarrow \rho_{\text{toluene}} = S.G. \times \rho_{\text{water}} \\ = 0.867 \times 1000 \text{ kg/m}^3 = 867 \text{ kg/m}^3$$

$$\dot{m} = \frac{\dot{V} \rho}{V} \Rightarrow$$

- b. What is the molar flow rate in mol/s ? [10 points]

CHEG 2333 P01
10/11/2021

Material & Energy Balances
Test 1

Student Name: _____

4. The solubilities of L-serine (L-ser) in water have been measured at the following data:

T(K)	283.4	285.9	289.3	299.1
x(mole fraction L-Ser)	0.0400	0.0426	0.0523	0.0702

What is the value of x for $T = 325\text{K}$? [25 points]

let use interpolation:

$$y = y_1 + \frac{x - x_1}{x_2 - x_1} (y_2 - y_1)$$

$$y = 0.1181 + \frac{325 - 322.9}{327.1 - 322.9} (0.1343 - 0.1181)$$

$$y = 0.1215 \text{ L-Ser}$$

Student Name: _____

5. A mixture is 12.0 mole% methyl alcohol (CH_4O), 73.0 mole% methyl acetate ($\text{C}_3\text{H}_6\text{O}_2$) and 15 mole% acetic acid ($\text{C}_2\text{H}_4\text{O}_2$). [$M(\text{carbon}) = 12$; $M(\text{hydrogen}) = 1$; $M(\text{oxygen}) = 16$]

a. Calculate the mass fractions of each compound. [15 points]

Let's calculate the molecular weight:

$$\text{CH}_4\text{O} = 12 + (4 \times 1) + 16 = 32 \text{ g/mol}$$

$$\text{C}_3\text{H}_6\text{O}_2 = (3 \times 12) + (6 \times 1) + (2 \times 16) = 74 \text{ g/mol}$$

$$\text{C}_2\text{H}_4\text{O}_2 = (2 \times 12) + (4 \times 1) + (2 \times 16) = 60 \text{ g/mol}$$

Let's calculate the mass = $n \times M$

$$12 \times 32 = 384 \text{ g}$$

$$73 \times 74 = 5402 \text{ g}$$

$$15 \times 60 = 900 \text{ g}$$

The total mass is:

$$384 + 5402 + 900 = 6686 \text{ g}$$

So mass fractions is:

$$\text{CH}_4\text{O} \rightarrow \frac{384}{6686} = 0.057$$

$$\text{C}_3\text{H}_6\text{O}_2 \rightarrow \frac{5402}{6686} = 0.807$$

b. What is the average molecular weight of the mixture? [10 points]

$$12\% \text{ CH}_4\text{O} \rightarrow 12/100 = 0.12$$

$$73\% \text{ C}_3\text{H}_6\text{O}_2 \rightarrow 73/100 = 0.73$$

$$15\% \text{ C}_2\text{H}_4\text{O}_2 \rightarrow 15/100 = 0.15$$

$$\text{CH}_4\text{O} = \frac{0.12}{32}$$

$$\text{C}_3\text{H}_6\text{O}_2 = \frac{0.73}{74}$$

$$\text{C}_2\text{H}_4\text{O}_2 = \frac{0.15}{60}$$

$$\frac{1}{M_w} = \frac{x_1}{M_1} + \frac{x_2}{M_2}$$

$$\frac{1}{M_w} = \frac{0.12}{32} + \frac{0.73}{74} + \frac{0.15}{60} = 0.01612$$

$$\frac{1}{M_w} = 0.01612 \Rightarrow M_w = 62.035 \text{ g/mol}$$

$$12\% \text{ CH}_4\text{O}$$

$$73\% \text{ C}_3\text{H}_6\text{O}_2$$

$$15\% \text{ C}_2\text{H}_4\text{O}_2$$

The number of moles are:

$$12 \text{ moles CH}_4\text{O}$$

$$73 \text{ moles C}_3\text{H}_6\text{O}_2$$

$$15 \text{ moles C}_2\text{H}_4\text{O}_2$$

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BELOW AVERAGE

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Student Name: Maya Culpepper

1. Estimate the gauge pressure (psig) in the Gulf of Mexico at a depth of 5053 ft. Assume that seawater has a specific gravity of 1.03.

Given: Gulf of Mexico @ depth of 5053 ft.

Find: estimate the gauge pressure (psig)

$$SG_{\text{seawater}} = 1.03$$

$$SG = \frac{\rho}{\rho_{\text{ref}}}$$

$$P = SG \cdot \rho_{\text{ref}} \cdot h$$

$$1 \text{ atm} = 14.696 \text{ lbf/in}^2 \text{ (ps)}$$

$$P = \rho \cdot h$$

$$20919 = 200 = \rho \cdot h = 9$$

$$20919 = \rho \cdot 9$$

$$(20919 \text{ lbf/in}^2) / (9 \text{ ft}) = \rho \text{ (lbf/ft}^3) = 9$$

Student Name: _____

2. Calculate the densities in lb_m/ft³ of the following substances:
NOTE: Remember to state your assumptions and show your work.

- a. A liquid with density of 995 kg/m³ [10 points]

Given: 995 kg/m³ = Density

Find: density in lb_m/ft³

$$\rho = m/v = SG = \frac{\rho}{\rho_{\text{ref}}}$$

$$\rho_{\text{water}} = 62.43 \text{ lb}_m/\text{ft}^3 = 1000 \text{ kg/m}^3$$

$$995 \text{ kg/m}^3 = \frac{62.43 \text{ lb}_m/\text{ft}^3}{1000 \text{ kg/m}^3} = \left(\frac{995 \text{ kg/m}^3}{1000 \text{ kg/m}^3} \right) (62.43 \text{ lb}_m/\text{ft}^3)$$

$$= \underline{\hspace{2cm}} \text{ lb}_m/\text{ft}^3$$

$$995 \text{ kg/m}^3 \times \frac{0.0624 \text{ lb}_m/\text{ft}^3}{1 \text{ kg/m}^3}$$

forgot calculator

- b. A solid with a specific gravity of 5.7. [10 points]

Given: SG = 5.7

$$\rho = m/v = SG = \frac{\rho}{\rho_{\text{ref}}}$$

$$5.7 = \frac{\rho}{\rho_{\text{ref}}}$$

$$\rho = (5.7) \rho_{\text{ref}} = (5.7) (62.43 \text{ lb}_m/\text{ft}^3)$$

Student Name: _____

3. Liquid toluene (C_7H_8) is flowing through a pipe at a rate of $175 \text{ m}^3/\text{h}$.
a. What is the mass flow rate of this stream in kg/min ? (SG of toluene = 0.867) [15 points]

Given: Liquid toluene (C_7H_8): rate of $175 \text{ m}^3/\text{h}$

Find: mass flow rate in kg/min

$\dot{m}$ = mass/time

$$C = 7 \times 12 = 84$$

$$H = 8 \times 1 = 8$$

$$92 \text{ g/mol}$$

$$175 \frac{\text{m}^3}{\text{h}} \cdot \frac{1 \text{ hr}}{60 \text{ min}} \cdot \frac{1000 \text{ kg}}{\text{m}^3} = \frac{(175 \cdot 1000)}{60 \text{ min}} = \underline{\underline{2916.67 \text{ kg/min}}}$$

$$\dot{M} = \frac{\text{mass of A}}{\text{total mass}} = \frac{92 \text{ g/mol}}{175 \text{ m}^3/\text{h}}$$

- b. What is the molar flow rate in mol/s ? [10 points]

Given: Liquid toluene (C_7H_8): rate of $175 \text{ m}^3/\text{h}$

Find: molar flow rate in mol/s

$\dot{n}$ = moles/time

$$175 \frac{\text{m}^3}{\text{h}} \cdot \frac{1 \text{ hr}}{60 \text{ min}} \cdot \frac{1 \text{ min}}{60 \text{ sec}} = \underline{\underline{0.486 \text{ m}^3/\text{s}}}$$

Student Name: _____

4. The solubilities of L-serine (L-ser) in water have been measured at several temperatures producing the following data:

T(K)	283.4	285.9	289.3	299.1	316.0	317.8	322.9	327.1
x(mole fraction L-Ser)	0.0400	0.0426	0.0523	0.0702	0.1091	0.1144	0.1181	0.1248

What is the value of x for $T = 325 \text{ K}$? [25 points]

Find: value of x for $T = 325 \text{ K}$

We know it's going to be between $0.1181 + 0.1248$ because
 $T = 325 \text{ K}$ falls between 322.9 and 327.1 .

$$\frac{325 - 322.9}{327.1 - 322.9} = \frac{x - 0.1181}{0.1248 - 0.1181}$$

Student Name: _____

5. A mixture is 12.0 mole% methyl alcohol (CH_4O), 73.0 mole% methyl acetate ($\text{C}_3\text{H}_6\text{O}_2$) and 15 mole% acetic acid ($\text{C}_2\text{H}_4\text{O}_2$). [$M(\text{carbon}) = 12$; $M(\text{hydrogen}) = 1$; $M(\text{oxygen}) = 16$]
a. Calculate the mass fractions of each compound. [15 points]

$$X_A = \frac{\text{mass of A}}{\text{total mass}}$$

$$\text{CH}_4\text{O} = 32 \text{ total g/mol} \rightarrow \frac{12\%}{32 \text{ g/mol}} =$$

$$\text{C}_3\text{H}_6\text{O}_2 = 74 \text{ total g/mol} \rightarrow \frac{73\%}{74 \text{ g/mol}} =$$

$$\text{C}_2\text{H}_4\text{O}_2 = 60 \text{ total g/mol} \rightarrow \frac{15\%}{60 \text{ g/mol}} =$$

$$\begin{array}{r} 0.12 \\ 4 \\ \hline 16 \\ 32 \\ \hline 0.36 \\ 6 \\ \hline 42 \\ + 32 \\ \hline 74 \end{array}$$

$$\begin{array}{r} 21 \\ 0.28 \\ 32 \\ \hline 60 \end{array}$$

- b. What is the average molecular weight of the mixture? [10 points]

~~$$\text{CH}_4\text{O} = 32 \text{ g/mol}$$~~

~~$$\text{C}_3\text{H}_6\text{O}_2 = 74 \text{ g/mol}$$~~

~~$$\text{C}_2\text{H}_4\text{O}_2 = 60 \text{ g/mol}$$~~

~~$$\text{Total} = 166 \text{ g/mol}$$~~

~~$$3160 = 120 \text{ g/mol} = \text{avg. mol. weight}$$~~

$$\begin{array}{r} 32 \text{ g/mol} \\ + 74 \\ \hline 106 \\ + 60 \\ \hline 166 \end{array}$$

$$\begin{array}{r} 55.3 \\ 3 \overline{) 166} \\ \underline{154} \\ 12 \\ \underline{10} \\ 2 \end{array}$$

$$55.3 \text{ avg. mol. weight}$$

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MATERIAL AND ENERGY BALANCES FALL 2021

Title of Assignment: FINAL EXAM

TOPICS COVERED IN FINAL EXAM

Final Exam covered the following topics:

1. Engineering calculations – linear interpolation, density, composition
2. Scaling
3. Identifying systems
4. Sketching flowsheets
5. Material balance of non-reactive systems
6. Stoichiometry

**MATERIAL AND ENERGY BALANCES
FALL 2021**

**SAMPLE TEST QUESTIONS, SOLUTIONS,
AND GRADING SCHEME FOR FINAL EXAM**

Student Name: _____

Dear CHEG 2333 P01 Class,

This is the FINAL EXAM. This is a comprehensive exam. You will be tested on Chapters 1 – 4 of the text, with a focus on Chapter 4 - non-reactive systems and reactive systems. This test is open book and open notes.

Good luck.
Dr. Antoine

Multiple Choice
Questions 1 – 5: 5 points each

Essay
Question 6: 25 points
Question 7: 50 points

Student Name: _____

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton (tonne) = 2.20462 lb _m = 35.27392 oz 1 lb _m = 16 oz = 5 × 10 ⁻⁴ ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10 ⁶ microns (μm) = 10 ¹⁰ angstroms (Å) = 39.37 in = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m ³ = 1000 L = 10 ⁶ cm ³ = 10 ⁶ mL = 35.3145 ft ³ = 219.97 imperial gallons = 264.17 gal = 1056.68 qt 1 ft ³ = 1728 in ³ = 7.4805 gal = 29.922 qt = 0.028317 m ³ = 28.317 L
Density	1 g/cm ³ = 1000 kg/m ³ = 62.43 lb _m /ft ³ = density of liquid water at 4°C (reference for specific gravities)
Force	1 N = 1 kg·m/s ² = 10 ⁵ dynes = 10 ⁵ g·cm/s ² = 0.22481 lb _f 1 lb _f = 32.174 lb _m ·ft/s ² = 4.4482 N = 4.4482 × 10 ⁵ dynes
Pressure	1 atm = 1.01325 × 10 ⁵ N/m ² (Pa) = 101.325 kPa = 1.01325 bar = 1.01325 × 10 ⁶ dynes/cm ² = 14.696 lb _f /in ² (psi) = 760 mm Hg at 0°C (torr) = 10.333 m H ₂ O(l) at 4°C = 29.921 inches Hg at 0°C = 406.8 inches H ₂ O(l) at 4°C
Energy	1 J = 1 N·m = 10 ⁷ ergs = 10 ⁷ dyne·cm = 1 kg·m ² /s ² = 2.778 × 10 ⁻⁷ kW·h = 0.23901 cal = 0.23901 × 10 ⁻³ kcal (food calorie) = 0.7376 ft·lb _f = 9.486 × 10 ⁻⁴ Btu
Power	1 W = 1 J/s = 1 N·m/s = 0.23901 cal/s = 0.7376 ft·lb _f /s = 9.486 × 10 ⁻⁴ Btu/s = 1.341 × 10 ⁻³ hp

Example: The factor to convert grams to lb_m is $\left(\frac{2.20462 \text{ lb}_m}{1000 \text{ g}}\right)$ or $\left(\frac{1 \text{ lb}_m}{453.593 \text{ g}}\right)$.

$$\bar{M} = y_1 M_1 + y_2 M_2 + \dots = \sum_{\text{all components}} y_i M_i$$

$$\frac{1}{\bar{M}} = \frac{x_1}{M_1} + \frac{x_2}{M_2} + \dots = \sum_{\text{components}} \frac{x_i}{M_i}$$

Student Name: _____

1. A mixture of gases has the following composition by mass:

O ₂	16%
CO	4.0%
CO ₂	12%
N ₂	68%

The molar composition in mole fraction is most nearly [5 points]

- O₂ – 0.15, CO – 0.043, CO₂ – 0.081, N₂ – 0.73
- O₂ – 0.13, CO – 0.044, CO₂ – 0.082, N₂ – 0.73
- O₂ – 0.16, CO – 0.044, CO₂ – 0.082, N₂ – 0.70
- O₂ – 0.16, CO – 0.041, CO₂ – 0.082, N₂ – 0.73

2. Gauge pressure is given by [5 points]

- phg
- P₀ + phg
- P₀

3. To effectively scale a process, you should do the following (choose all that apply) [5 points]:

- Balance the process flowsheet
- Choose a basis
- Multiply the scaling factor by the mass fractions and the masses of all streams
- Scale masses to moles by simple multiplication

4. Aqueous solutions of the amino acid L-isoleucine (Ile) are prepared by putting 100.0 grams of pure water into each of six flasks and adding different precisely weighed quantities of Ile to each flask. The densities of the solutions at 50.0 ± 0.05°C are then measured with a precision densitometer, with the following results:

r (g Ile/100 g H ₂ O)	0.0000	0.8821	1.7683	2.6412	3.4093	4.2064
ρ (g solution/cm ³)	0.98803	0.98984	0.99148	0.99297	0.99439	0.99580

What is the density, ρ in g solution/cm³ for an aqueous solution of Ile of 1.6230 g Ile/100 g H₂O? [5 points]

- 0.98972
- 0.99126
- 0.99135
- 0.99410

Student Name: _____

5. Scale the following flowchart as directed. C₂H₆ is mixed with air. Basis of calculation: 2100 mol of exit stream. Scale to an exit stream of 1500 kmol/h.

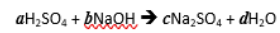


What is the new value for the flow of air in kmol/h? [5 points]

- 1504
- 2323
- 1428.6
- 83.2

Student Name: _____

6. The neutralization of H_2SO_4 with NaOH is given by the equation below.



- a. Balance the equation above, where a , b , c , and d are the coefficients of the species in the reaction [5 points]:
- b. A continuous steady state reaction of the neutralization above is made to occur at room temperature. The H_2SO_4 feed stream has a molar flow rate of 65 kmol/h and the NaOH feed stream as a molar flow rate of 100 kmol/h. What is the molar flow rate of the NaOH required for complete neutralization to occur? Show all your work. [15 points]
- c. Based on your answer in part b) above, identify the limiting reactant. [5 points]

Student Name: _____

7. One thousand, three hundred kilograms per hour of a mixture containing equal parts by mass of methanol and water is distilled. Product streams leave the top and bottom of the distillation column. The flow rate of the bottom stream is measured and found to be 874.9 kg/h, and the overhead stream is analyzed and found to contain 96.0 wt% methanol.
- a. Draw and label a flow chart of the process. [5 points]
- b. Calculate the flow rate of the distillate. [5 points]

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12/3/2021

Material & Energy Balances
FINAL EXAM

Dr. Antoine

Student Name: _____

- c. Calculate the mass fractions and the mass flow rates of methanol and water in the bottom stream.
[40 points]

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FINAL EXAM

Dr. Antoine

Student Name: _____

ABOVE AVERAGE

Above Average Student Original Graded Assignment

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12/3/2021

Material & Energy Balances
FINAL EXAM

Dr. Antoine

Student Name: Janine Ramtahal

95
100 !!!

Dear CHEG 2333 P01 Class,

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Good luck.
Dr. Antoine

Multiple Choice
Questions 1 – 5: 5 points each

Essay
Question 6: 25 points
Question 7: 50 points

CHEG 2333 P01
12/3/2021

Material & Energy Balances
FINAL EXAM

Dr. Antoine

Student Name: Janine Ramtahal

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Energy	1 J = 1 N·m = 10 ⁷ ergs = 10 ⁷ dyne·cm = 1 kg·m ² /s ² = 2.778 × 10 ⁻⁷ kWh = 0.23901 cal = 0.23901 × 10 ⁻³ kcal (food calorie) = 0.7376 ft·lb _f = 9.486 × 10 ⁻⁴ Btu
Power	1 W = 1 J/s = 1 N·m/s = 0.23901 cal/s = 0.7376 ft·lb _f /s = 9.486 × 10 ⁻⁴ Btu/s = 1.341 × 10 ⁻³ hp

Example: The factor to convert grams to lb_m is $\left\{ \frac{2.20462 \text{ lb}_m}{1000 \text{ g}} \right\}$ or $\left\{ \frac{1 \text{ lb}_m}{453.593 \text{ g}} \right\}$.

$$\bar{M} = y_1 M_1 + y_2 M_2 + \dots = \sum_{\text{components}} y_i M_i$$

$$\frac{1}{\bar{M}} = \frac{x_1}{M_1} + \frac{x_2}{M_2} + \dots = \sum_{\text{components}} \frac{x_i}{M_i}$$

Student Name: Janine Ramtahal

1. A mixture of gases has the following composition by mass:

O ₂	16%	$16/32 = 0.5$	$0.5/3.34 = 0.149$	O ₂
CO	4.0%	$4/28 = 0.142$	$0.142/3.34 = 0.043$	CO
CO ₂	12%	$12/44 = 0.2727$	$0.273/3.34 = 0.082$	CO ₂
N ₂	68%	$68/28 = 2.429$	$2.429/3.34 = 0.727$	N ₂

The molar composition in mole fraction is most nearly [5 points]

- 5 a. O₂ - 0.15, CO - 0.043, CO₂ - 0.081, N₂ - 0.73
 b. O₂ - 0.13, CO - 0.044, CO₂ - 0.082, N₂ - 0.73
 c. O₂ - 0.16, CO - 0.044, CO₂ - 0.082, N₂ - 0.70
 d. O₂ - 0.16, CO - 0.041, CO₂ - 0.082, N₂ - 0.73

2. Gauge pressure is given by [5 points]

- 5 a. p_{hg}
 b. $P_0 + p_{hg}$
 c. P_0

3. To effectively scale a process, you should do the following (choose all that apply) [5 points]:

- 0x a. Balance the process flowsheet
 b. Choose a basis
 c. Multiply the scaling factor by the mass fractions and the masses of all streams
 d. Scale masses to moles by simple multiplication

4. Aqueous solutions of the amino acid L-isoleucine (Ile) are prepared by putting 100.0 grams of pure water into each of six flasks and adding different precisely weighed quantities of Ile to each flask. The densities of the solutions at
- $50.0 \pm 0.05^\circ\text{C}$
- are then measured with a precision densitometer, with the following results:

x	r (g Ile/100 g H ₂ O)	0.0000	0.8821	1.7683	2.6412	3.4093	4.2064
y	ρ (g solution/cm ³)	0.98803	0.98984	0.99148	0.99297	0.99439	0.99580

What is the density, ρ in g solution/cm³ for an aqueous solution of Ile of 1.6230 g Ile/100 g H₂O? [5 points]

$$y = y_1 + \frac{x - x_1}{x_2 - x_1} (y_2 - y_1)$$

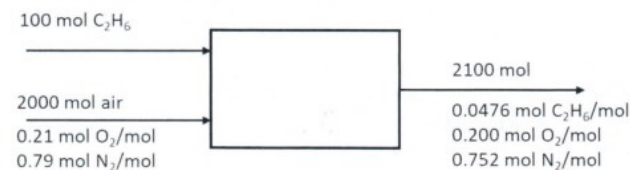
$$0.98984 + \frac{1.6230 - 0.8821}{1.7683 - 0.8821} * (0.99148 - 0.98984)$$

$$= 0.98984 + 0.836 * 0.00164$$

$$= 0.9912 \text{ (g solution/cm}^3\text{)}$$

Student Name: Janine Ramtahal

5. Scale the following flowchart as directed. C
- ₂
- H
- ₆
- is mixed with air. Basis of calculation: 2100 mol of exit stream. Scale to an exit stream of 1500 kmol/h.



What is the new value for the flow of air in kmol/h? [5 points]

- a. 1504
 b. 2323
 5 c. 1428.6
 d. 83.2

$$\left(\frac{1500 \text{ kmol/h mixture}}{2100 \text{ mol mixture}} \right) (2100 \text{ mol mixture}) = 1500 \text{ kmol/h of mixture}$$

$$\left(\frac{1500 \text{ kmol/h mixture}}{2100 \text{ mol mixture}} \right) (2000 \text{ mol air}) = 1428.57 \text{ kmol/h of air}$$

$$\left(\frac{1500 \text{ kmol/h mixture}}{2100 \text{ mol mixture}} \right) (100 \text{ mol C}_2\text{H}_6) = 71.43 \text{ kmol/h C}_2\text{H}_6$$

Student Name: Janine Ramtahal

6. The neutralization of H_2SO_4 with NaOH is given by the equation below.



- a. Balance the equation above, where a , b , c and d are the coefficients of the species in the reaction [5 points]:

$$\begin{aligned} a &= 1 & d &= 2 \\ b &= 2 & c &= 1 \end{aligned}$$



- b. A continuous steady state reaction of the neutralization above is made to occur at room temperature. The H_2SO_4 feed stream has a molar flow rate of 65 kmol/h and the NaOH feed stream as a molar flow rate of 100 kmol/h. What is the molar flow rate of the NaOH required for complete neutralization to occur? Show all your work. [15 points]

$$\frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol NaOH}} \quad \frac{2 \text{ mol NaOH}}{1 \text{ mol H}_2\text{SO}_4} \quad 1 \text{ mol of H}_2\text{SO}_4 \text{ requires } 2 \text{ mol of NaOH for neutralization}$$

$$\left(\frac{2 \text{ mol NaOH}}{1 \text{ mol H}_2\text{SO}_4} \right) (65 \text{ kmol/h H}_2\text{SO}_4) = \boxed{130 \text{ kmol/h NaOH}}$$

required for complete neutralization to occur

15/15

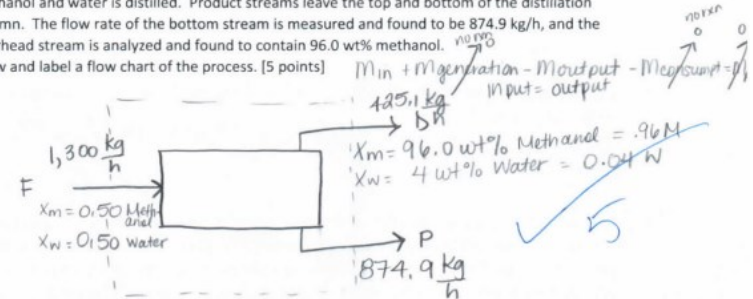
- c. Based on your answer in part b) above, identify the limiting reactant. [5 points]

NaOH is the limiting reactant because it requires 130 kmol/h NaOH and it has a molar flow rate of 100 kmol/h.

5/5

Student Name: Janine Ramtahal

7. One thousand, three hundred kilograms per hour of a mixture containing equal parts by mass of methanol and water is distilled. Product streams leave the top and bottom of the distillation column. The flow rate of the bottom stream is measured and found to be 874.9 kg/h, and the overhead stream is analyzed and found to contain 96.0 wt% methanol. ^{no rxn}
a. Draw and label a flow chart of the process. [5 points]



- b. Calculate the flow rate of the distillate. [5 points]

$$\begin{aligned} \text{Flow rate of Feed} &= 1,300 \frac{\text{kg}}{\text{h}} \\ \text{Flow rate of } P &= 874.9 \frac{\text{kg}}{\text{h}} \end{aligned}$$

$$F = D + P$$

$$F - P = D$$

$$\text{Flow rate of } D = 1,300 \frac{\text{kg}}{\text{h}} - 874.9 \frac{\text{kg}}{\text{h}}$$

$$D = \boxed{425.1 \frac{\text{kg}}{\text{h}}}$$

5/5

Student Name: _____

- c. Calculate the mass fractions and the mass flow rates of methanol and water in the bottom stream.
[40 points]

$$\text{methanol balance: } (1,300)(0.50) = \dot{m} (0.96) + (874.9)(x_{mp})$$

40
40

$$650 = (425.1)(0.96) + (874.9)(x_{mp})$$

$$650 = 408.096 + 874.9 x_{mp}$$

$$-408.096 \quad -408.096$$

$$\text{Mass Flow rate for methanol in bottom stream} \rightarrow \frac{241.904}{874.9} = \frac{874.9 x_{m,p}}{874.9}$$

241.904 Kg/h
mass flow rate for
methanol in bottom stream

$$x_{m,p} = 0.2765 \text{ methanol}$$

$$\text{water balance: } (1300)(0.50) = (425.1)(.04) + (874.9)(x_{wp})$$

$$650 = 17.004 + 874.9 x_{wp}$$

$$-17.004 \quad -17.004$$

$$\text{mass flow rate for } x_{wp} \rightarrow \frac{632.996}{874.9} = \frac{874.9 x_{wp}}{874.9}$$

$$x_{wp} = 0.7235 \text{ H}_2\text{O}$$

632.996 Kg/h is the mass flow rate for
H₂O in bottom stream

Student Name: Jamini Ramtahal

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Student Name: _____

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Power	1 W = 1 J/s = 1 N·m/s = 0.23901 cal/s = 0.7376 ft·lb _f /s = 9.486 × 10 ⁻⁴ Btu/s = 1.341 × 10 ⁻³ hp

Example: The factor to convert grams to lb_m is $\left(\frac{2.20462 \text{ lb}_m}{1000 \text{ g}}\right)$ or $\left(\frac{1 \text{ lb}_m}{453.593 \text{ g}}\right)$.

$$\bar{M} = y_1 M_1 + y_2 M_2 + \dots = \sum_{\text{components}} y_i M_i$$

$$\frac{1}{\bar{M}} = \frac{x_1}{M_1} + \frac{x_2}{M_2} + \dots = \sum_{\text{components}} \frac{x_i}{M_i}$$

Student Name: _____

Dear CHEG 2333 P01 Class,

This is the FINAL EXAM. This is a comprehensive exam. You will be tested on Chapters 1 – 4 of the text, with a focus on Chapter 4 - non-reactive systems and reactive systems. This test is open book and open notes.

Good luck.
Dr. Antoine

Multiple Choice
Questions 1 – 5: 5 points each

Essay
Question 6: 25 points
Question 7: 50 points

72/100

Student Name: _____

5. Scale the following flowchart as directed. C_2H_6 is mixed with air. Basis of calculation: 2100 mol of exit stream. Scale to an exit stream of 1500 kmol/h.



What is the new value for the flow of air in kmol/h? [5 points]

- a. 1504
b. 2323
c. 1428.6
d. 83.2

$100 \text{ mol } C_2H_6 \rightarrow 1 \text{ kmol} \Rightarrow 100 \text{ mol } C_2H_6 \times \frac{1 \text{ kmol}}{100 \text{ mol}} = 0.1 \text{ kmol}$
 $2100 \text{ mol} \rightarrow 1 \text{ kmol} \Rightarrow 2100 \times \frac{1 \text{ kmol}}{1000 \text{ mol}} = 2.1 \text{ kmol}$
 $2000 \text{ mol} \rightarrow 1 \text{ kmol} \Rightarrow 2000 \text{ mol} \times \frac{1 \text{ kmol}}{1000 \text{ mol}} = 2 \text{ kmol}$
 let's calculate the total amount of C_2H_6 coming out with 1500 kmol/h
 $0.1 \text{ kmol } C_2H_6 \rightarrow 2.1 \text{ kmol}$
 $1500 \text{ kmol/h} \times 0.1 \text{ kmol } C_2H_6 = 150 \text{ kmol/h}$
 $2.1 \text{ kmol} = 150 \text{ kmol/h}$

The new value for the flow of air:

$2 \text{ kmol air} \rightarrow 2.1 \text{ kmol}$
 $\leftarrow 1500 \text{ kmol/h}$

$\frac{1500 \text{ kmol}}{h} \times 2 \text{ kmol}$
 $2.1 \text{ kmol} = 1428.57 \text{ kmol/h}$

Student Name: _____

1. A mixture of gases has the following composition by mass:

O_2	16%
CO	4.0%
CO_2	12%
N_2	68%

basis of 100 g
 $n = \frac{m}{M}$
 $n_{O_2} = \frac{16}{32} = 0.5$
 $n_{CO} = \frac{4}{28} = 0.14$
 $n_{CO_2} = \frac{12}{44} = 0.27$
 $n_{N_2} = \frac{68}{28} = 2.43$
 $n_T = 3.34$

The molar composition in mole fraction is most nearly [5 points]

- a. $O_2 - 0.15$, CO - 0.043, $CO_2 - 0.081$, $N_2 - 0.73$
 b. $O_2 - 0.13$, CO - 0.044, $CO_2 - 0.082$, $N_2 - 0.73$
 c. $O_2 - 0.16$, CO - 0.044, $CO_2 - 0.082$, $N_2 - 0.70$
 d. $O_2 - 0.16$, CO - 0.041, $CO_2 - 0.082$, $N_2 - 0.73$

2. Gauge pressure is given by [5 points]

- a. phg
 b. $P_0 + \text{phg}$
 c. P_0

3. To effectively scale a process, you should do the following (choose all that apply) [5 points]:

- a. Balance the process flowsheet
 b. Choose a basis
 c. Multiply the scaling factor by the mass fractions and the masses of all streams
 d. Scale masses to moles by simple multiplication

4. Aqueous solutions of the amino acid L-isoleucine (Ile) are prepared by putting 100.0 grams of pure water into each of six flasks and adding different precisely weighed quantities of Ile to each flask. The densities of the solutions at $50.0 \pm 0.05^\circ\text{C}$ are then measured with a precision densitometer, with the following results:

r (g Ile/100 g H_2O)	0.0000	0.8821	1.7683	2.6412	3.4093	4.2064
ρ (g solution/ cm^3)	0.98803	0.98984	0.99148	0.99297	0.99439	0.99580

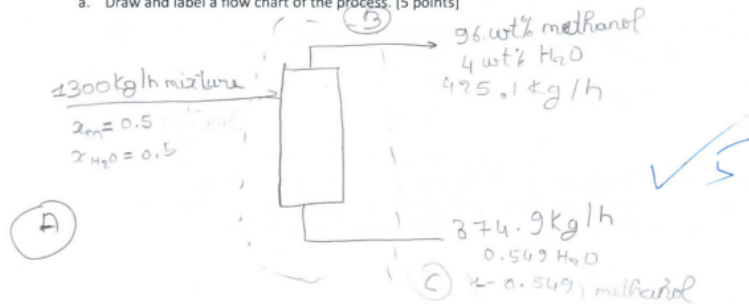
What is the density, ρ in g solution/ cm^3 for an aqueous solution of Ile of 1.6230 g Ile/100 g H_2O ? [5 points]

- a. 0.98972
 b. 0.99126
 c. 0.99135
 d. 0.99410

$\rho = \frac{m}{V}$
 $y = y_1 + \frac{x - x_1}{x_2 - x_1} (y_2 - y_1)$
 $y = 0.98984 + \frac{1.6230 - 0.8821}{1.7683 - 0.8821} (0.99148 - 0.98984)$
 $= 0.98984 + 0.83604153 = 0.99818$

Student Name: _____

7. One thousand, three hundred kilograms per hour of a mixture containing equal parts by mass of methanol and water is distilled. Product streams leave the top and bottom of the distillation column. The flow rate of the bottom stream is measured and found to be 874.9 kg/h, and the overhead stream is analyzed and found to contain 96.0 wt% methanol.
- a. Draw and label a flow chart of the process. [5 points]



- b. Calculate the flow rate of the distillate. [5 points]

let's write the general mass balance equation:
input - output - consumption + generation = accumulation
no reaction no reaction because there is a flow rate

$$A = B + C \quad m_{in} = m_{out}$$

$$1300 \text{ kg/h} = B + 874.9 \text{ kg/h}$$

$$B = 1300 \text{ kg/h} - 874.9 \text{ kg/h}$$

$$B = 425.1 \text{ kg/h}$$

let's now let's calculate the flow rate of the distillate
we know $m_{in} = m_{out}$

$$(x_{H_2O})(m_{H_2O})A = (x_{H_2O})(m_{H_2O})B + (x_{H_2O})(m_{H_2O})C$$

$$(0.5)(1300) = (0.4)(425.1) + x(874.9)$$

$$650 = 170.04 + x(874.9)$$

$$874.9x = 479.69$$

$$x = 0.549$$

So the flow rate of water is

$$0.549 \times 874.9$$

$$= 479.96 \text{ kg/h}$$

Student Name: _____

6. The neutralization of H_2SO_4 with $NaOH$ is given by the equation below.



- a. Balance the equation above, where a , b , c and d are the coefficients of the species in the reaction [5 points]:



- b. A continuous steady state reaction of the neutralization above is made to occur at room temperature. The H_2SO_4 feed stream has a molar flow rate of 65 kmol/h and the $NaOH$ feed stream as a molar flow rate of 100 kmol/h. What is the molar flow rate of the $NaOH$ required for complete neutralization to occur? Show all your work. [15 points]



According to the general mass balance equation:
input + cost + generation - consumption = accumulation
use on the stoichiometric equations, for complete neutralization:

$$\frac{65}{15}$$

- c. Based on your answer in part b) above, identify the limiting reactant. [5 points]

Based on the b) the limiting reactant will be $NaOH$, because it will be less.

Student Name: Pichu Gauri

Student Name: _____

- c. Calculate the mass fractions and the mass flow rates of methanol and water in the bottom stream.
[40 points]

let's write the general mass balance equation? Steady State because of the flow rates

$$\dot{m}_{in} - \text{output} - \text{consumption} + \text{generation} = \text{accumulation}$$

no reaction no reaction no reaction

$\dot{m}_{in} = \dot{m}_{out}$

The mass flow rate of water in the bottom:

$$\dot{m}_{H_2O}(\dot{m}) = \dot{m}_{H_2O}(\dot{m}) + \dot{m}_{H_2O}(\dot{m})$$

$$650 = (0.41)(475.1) + 874.9x$$

↑ missing decimal place

$$874.9x = 479.65$$

+ $x = 0.549$

so the molar flow rate of water at the bottom is $0.549 \times 874.9 = 479.96 \text{ kg/h}$

32
40
propagation error
 ± 4

The mass fraction of methanol at the bottom is: $x_{methanol}$

$$1 - x_{H_2O} \Rightarrow x_{methanol} = 1 - 0.549 = 0.451$$

The mass flow rate of methanol at the bottom is

$$\dot{m}_{methanol} = (x)(\text{flow rates}) \Rightarrow \dot{m}_{methanol} = (0.451)(874.9)$$

$$\dot{m}_{methanol} = 394.58 \text{ kg/h}$$

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CHEG 2333 P01
12/3/2021

Material & Energy Balances
FINAL EXAM

Dr. Antoine

Student Name: _____

Dear CHEG 2333 P01 Class,

This is the FINAL EXAM. This is a comprehensive exam. You will be tested on Chapters 1 – 4 of the text, with a focus on Chapter 4 - non-reactive systems and reactive systems. This test is open book and open notes.

Good luck.
Dr. Antoine

Multiple Choice
Questions 1 – 5: 5 points each

Essay
Question 6: 25 points
Question 7: 50 points

CHEG 2333 P01
12/3/2021

Material & Energy Balances
FINAL EXAM

Dr. Antoine

Student Name: _____

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton (tonnes) = 2.20462 lb _m = 35.27392 oz 1 lb _m = 16 oz = 5 × 10 ⁻⁴ ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10 ³ microns (μm) = 10 ⁹ angstroms (Å) = 39.37 in = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in = 1.3 yd = 0.3048 m = 30.48 cm
Volume	1 m ³ = 1000 L = 10 ³ cm ³ = 10 ³ mL = 35.3145 ft ³ = 219.97 imperial gallons = 264.17 gal = 1056.68 qt 1 ft ³ = 1.728 m ³ = 7.4805 gal = 29.922 qt = 0.028317 m ³ = 28.317 L
Density	1 g/cm ³ = 1000 kg/m ³ = 62.43 lb _m /ft ³ = density of liquid water at 4°C (reference for specific gravities)
Force	1 N = 1 kg·m/s ² = 10 ⁵ dynes = 10 ⁵ g·cm/s ² = 0.22481 lb 1 lb = 32.174 lb _m ·ft/s ² = 4.4482 N = 4.4482 × 10 ⁵ dynes
Pressure	1 atm = 1.01325 × 10 ⁵ N/m ² (Pa) = 101.325 kPa = 1.01325 bar = 1.01325 × 10 ⁵ dynes/cm ² = 14.696 lb _f /in ² (psia) = 760 mm Hg at 0°C (torr) = 10.333 m H ₂ O at 4°C = 29.921 inches Hg at 0°C = 406.8 inches H ₂ O at 4°C
Energy	1 J = 1 N·m = 10 ⁷ ergs = 10 ⁷ dyne·cm = 1 kg·m ² /s ² = 2.778 × 10 ⁻⁷ kW·h = 0.23901 cal = 0.23901 × 10 ⁻³ kcal (food calories) = 0.7376 ft·lb _f = 9.486 × 10 ⁻⁴ Btu
Power	1 W = 1 J/s = 1 N·m/s = 0.23901 cal/s = 0.7376 ft·lb _f /s = 9.486 × 10 ⁻⁴ Btu/s = 1.341 × 10 ⁻³ hp

Example: The factor to convert grams to lb_m is $\left\{ \frac{2.20462 \text{ lb}_m}{1000 \text{ g}} \right\}$ or $\left\{ \frac{1 \text{ lb}_m}{453.593 \text{ g}} \right\}$.

$$\bar{M} = y_1 M_1 + y_2 M_2 + \dots = \sum_{\text{all components}} y_i M_i$$

$$\frac{1}{\bar{M}} = \frac{x_1}{M_1} + \frac{x_2}{M_2} + \dots = \sum_{\text{all components}} \frac{x_i}{M_i}$$

Student Name: _____

1. A mixture of gases has the following composition by mass:

O ₂	32	16%
CO	28	4.0%
CO ₂	44	12%
N ₂	8	68%

$O = 16 \times$

The molar composition in mole fraction is most nearly [5 points]

- a. O₂ – 0.15, CO – 0.043, CO₂ – 0.081, N₂ – 0.73
 b. O₂ – 0.13, CO – 0.044, CO₂ – 0.082, N₂ – 0.73
 c. O₂ – 0.16, CO – 0.044, CO₂ – 0.082, N₂ – 0.70
 d. O₂ – 0.16, CO – 0.041, CO₂ – 0.082, N₂ – 0.73

2. Gauge pressure is given by [5 points]

- a. p_{hg}
 b. $P_0 + p_{hg}$
 c. P_0

$P_{abs} = P_0 + P_{hg}$

3. To effectively scale a process, you should do the following (choose all that apply) [5 points]:

- a. Balance the process flowsheet
 b. Choose a basis
 c. Multiply the scaling factor by the mass fractions and the masses of all streams
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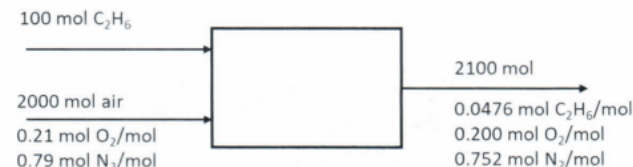
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What is the density, ρ in g solution/cm³ for an aqueous solution of Ile of 1.6230 g Ile/100 g H₂O? [5 points]

- a. 0.98972
 b. 0.99126
 c. 0.99135
 d. 0.99410

Student Name: _____

5. Scale the following flowchart as directed. C₂H₆ is mixed with air. Basis of calculation: 2100 mol of exit stream. Scale to an exit stream of 1500 kmol/h.



What is the new value for the flow of air in kmol/h? [5 points]

- a. 1504
 b. 2323
 c. 1428.6
 d. 83.2

$$\left(\frac{1500 \text{ kmol/h}}{2100 \text{ mol}} \right) 100 \text{ mol} \rightarrow$$

$$\left(\frac{1500 \text{ kmol/h}}{2100 \text{ mol}} \right) 2000 \text{ mol air} \rightarrow$$

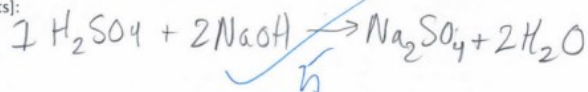
$$= 1428.6$$

Student Name: _____

6. The neutralization of
- H_2SO_4
- with
- NaOH
- is given by the equation below.



- a. Balance the equation above, where
- a
- ,
- b
- ,
- c
- and
- d
- are the coefficients of the species in the reaction [5 points]:



- b. A continuous steady state reaction of the neutralization above is made to occur at room temperature. The
- H_2SO_4
- feed stream has a molar flow rate of 65 kmol/h and the
- NaOH
- feed stream as a molar flow rate of 100 kmol/h. What is the molar flow rate of the
- NaOH
- required for complete neutralization to occur? Show all your work. [15 points]

$\frac{0}{15}$

$$\frac{(65 \text{ kmol/h})(1)}{(100 \text{ kmol/h})(2)} = 0.325 \text{ m}^3/\text{min}$$

- c. Based on your answer in part b) above, identify the limiting reactant. [5 points]

$\frac{0}{5}$

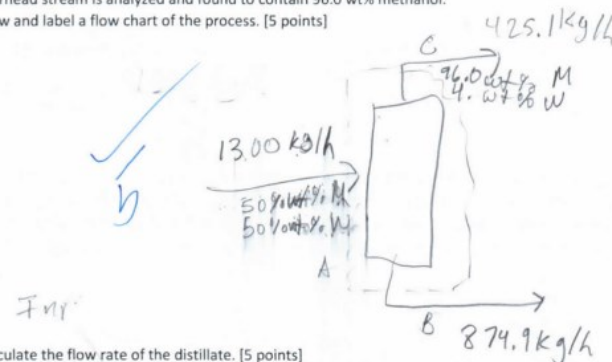
0.325 is limiting reactant

$1 - 0.325 =$

Student Name: _____

7. One thousand, three hundred kilograms per hour of a mixture containing equal parts by mass of methanol and water is distilled. Product streams leave the top and bottom of the distillation column. The flow rate of the bottom stream is measured and found to be 874.9 kg/h, and the overhead stream is analyzed and found to contain 96.0 wt% methanol.

- a. Draw and label a flow chart of the process. [5 points]



- b. Calculate the flow rate of the distillate. [5 points]

$A = C + B$

$1300 \text{ kg/h} = C + 874.9 \text{ kg/h}$

$1300 \text{ kg/h} - 874.9 \text{ kg/h} = 425.1$

$C = 425.1 \text{ kg/h}$

$\frac{0}{5}$

Student Name: _____

- c. Calculate the mass fractions and the mass flow rates of methanol and water in the bottom stream.
[40 points]

$$\dot{m}_{\text{meth},A} = (.50)(1300 \text{ kg/h}) = 650 \text{ kg/h}$$

$$\dot{m}_{\text{water},A} = (.50)(1300 \text{ kg/h}) = 650 \text{ kg/h}$$

$$\dot{m}_{\text{meth},C} = (.96)(425.1 \text{ kg/h}) = 408.1 \text{ kg/h}$$

$$\dot{m}_{\text{water},C} = (.04)(425.1 \text{ kg/h}) = 17 \text{ kg/h}$$

$$\dot{m}_{\text{meth},A} = \dot{m}_{\text{meth},C} + \dot{m}_{\text{meth},B}$$

$$650 \text{ kg/h} = 650 \text{ kg/h} + \dot{m}_{\text{meth},B}$$

$$650 \text{ kg/h} - 650 \text{ kg/h} = \dot{m}_{\text{meth},B}$$

$$\dot{m}_{\text{meth}} = 0 \text{ kg/h}$$

$$\dot{m}_{\text{water},A} = \dot{m}_{\text{water},C} + \dot{m}_{\text{water},B}$$

$$\dot{m}_{\text{water},B} = 650 \text{ kg/h} - 17 \text{ kg/h} = 633 \text{ kg/h}$$

$$\dot{m}_{\text{meth},A} = \dot{m}_{\text{meth},C} + \dot{m}_{\text{meth},B}$$

$$\dot{m}_{\text{meth},B} = 650 \text{ kg/h} - 408.1 \text{ kg/h} = 241.9 \text{ kg/h}$$

Student Name: Chimanya D. D. D.