Name_____

BMED 2210
February 17, 2016

Exam 1
This exam has two parts. Part 1 is closed book, closed notes. As soon as you finish Part 1 and turn it over, you can start part 2, which is the open-book part of the exam. Do NOT go back to Part 1 once you have opened your book. To do so would be an honors violation.

Write on only one side of each page. Show all your work, pay attention to significant figures, and box your final answers. You MUST include a well-labeled diagram of the process to receive full credit on mass balance problems. Please put your full name on the first page of each question of this exam. If you separate the pages, please write your initials on each page.

Exam 1, PART 1 (Closed book, closed notes)

Question 1 (20 points)
Carry out the conversions below. Show all your work and estimate your answer to one significant figure. CALCULATORS are NOT allowed for this part of the exam.

a. A temperature change of 122K =

$$122\,K \left| \frac{1.8\,^\circ F}{1\,K} \right. = \approx 200\ ^\circ F$$

b. 111 kPa =

$$111\ kPa \left| \frac{34\ ft\ H_2O}{101.3\ kPa} \right. \simeq \frac{3000}{100} \approx 30\ ft\ H_2O$$

(40 is OK too)

c. 72 L of liquid water

$$72\,L\ H_2O \left| \frac{1000\,mL}{L} \right| \frac{1\,g}{mL} \left| \frac{1\,lbm}{454\,g} \right. \simeq \frac{70000}{500} \approx 100\ lbm$$

(200 is OK too)

d. Mass fraction of Nitrogen in dry air =

Basis 100 mols: $\frac{(79)(28)}{(79)(28)+(21)(32)} \simeq \frac{2400}{2400+600} \approx 0.8$

e. What is the molecular weight of Dimethylsulfoniopropionate (DMSP) [$(CH_3)_2S^+CH_2CH_2COO^-$]? (DMSP is an osmolyte, which means it plays a role in maintaining cell volume and fluid balance in plants)

$5(12)+10(1)+32+2(16) = \approx 100$

2

grading

- 2 points for correct conversions
  - ↳ if use any wrong conversions no credit
  - ↳ for minor typo, -1
- 2 point for correct answer reported to 1 sig fig
  - ↳ -1 if write correct answer w/ > 1 sig fig

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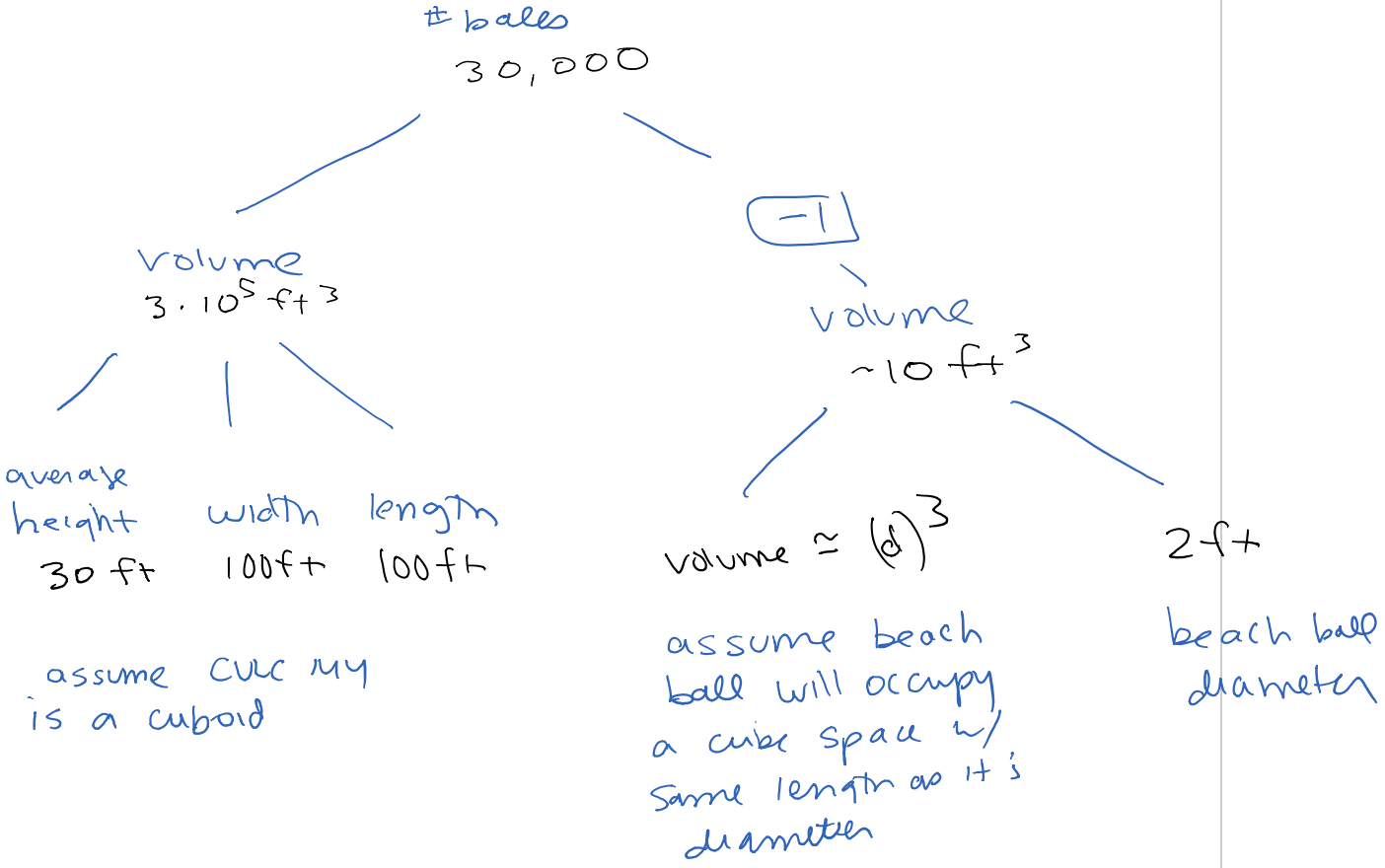
Question 2 (10 points)
How many beach balls could you fit in the room you are currently in?



Grading

6 points for room volume estimate
↳ h, w, l 2 points each

2 points for beach ball volume estimate

3

2 points for
1 sig fig
estimate

↳ 1 pt: consistent w/ their other work

↳ 1 pt for being moderately reasonable
($>10^3$, $<10^6$)

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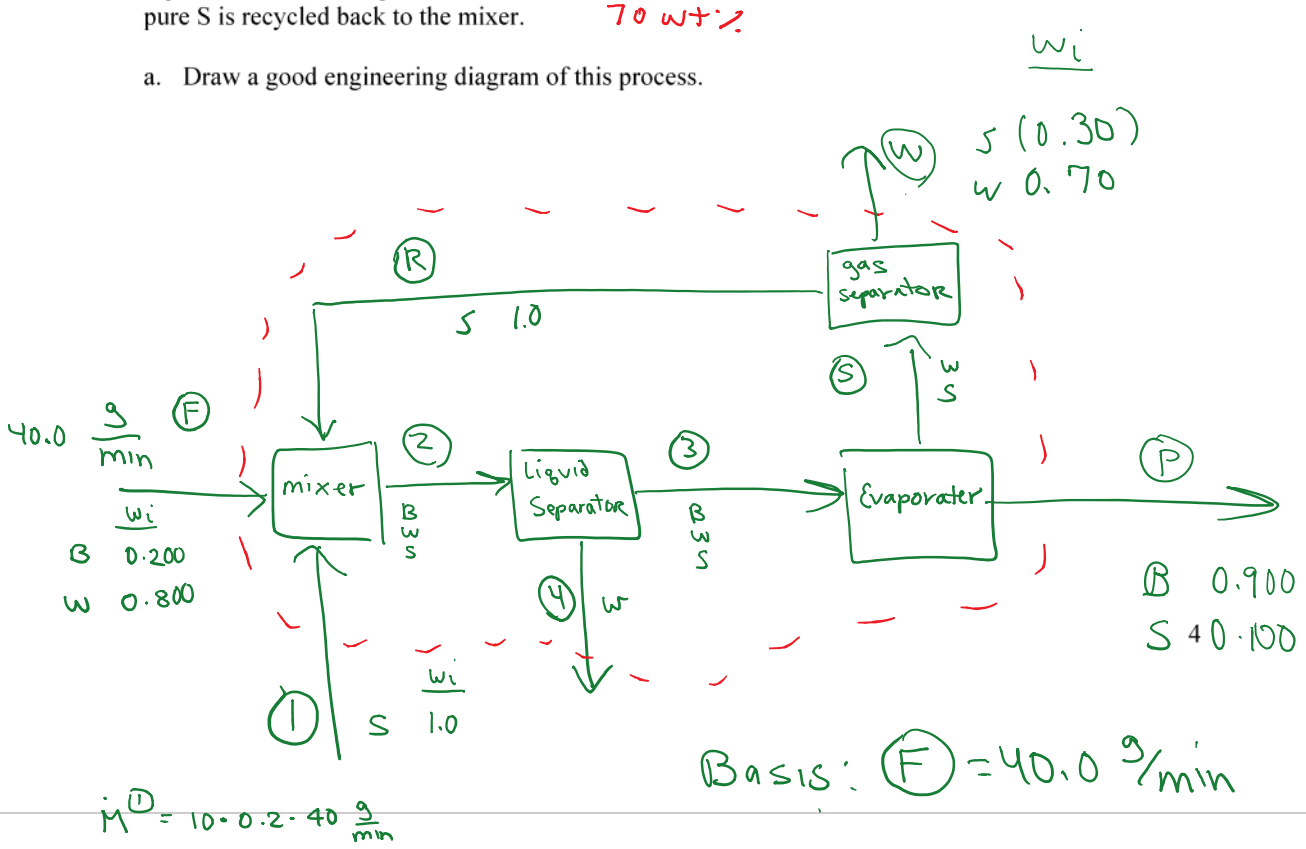
Exam 1, Open Book Part

Question 3 (35 points)
You are working on a process to purify a valuable biologic from an aqueous solution. (NOTE: a biologic is a genetically-engineered protein derived from human genes). The biologic rapidly loses its activity when dissolved in an aqueous solution. To address this problem, a process is designed to transfer the biologic to a polar solvent, after which the solvent is evaporated to leave a stable dry form of the biologic.

Here is a description of this steady-state process:
A solution containing 20.0 wt% biologic and 80.0 wt% water is fed to a mixer at 40.0 g/min. Pure fresh polar solvent (S) enters the mixer via a second stream at a mass flow rate 10.0 times greater than the mass flow rate of biologic into the mixer. S also enters the mixer via a third stream – a recycle stream (described later). The stream exiting the mixer is fed to a liquid separator that removes some of the water. The remaining material is fed to an evaporator. Two streams of material exit the evaporator – a stream that is 90.0 wt% biologic (with the rest being S), and a gas stream composed of water and S. This gas stream enters a gas separator. Two streams exit the gas separator – one that is pure S and one that is ~~5.0~~ 70 wt% water and the remainder S. This stream of pure S is recycled back to the mixer.

a. Draw a good engineering diagram of this process.



$(\dot{m}^{①} = 80 \frac{g}{min})$

Grading rubric

Professional Practices	Points	
Drew correct structure (correct # units & streams	2	a
Wrote which species are in each stream	2	b
Wrote all specifications in appropriate location on diagram	2	c
Explicitly wrote a Basis	2	d

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b. Perform a degree-of-freedom analysis for each subunit in this system, and for the overall subunit.

acc = in - out + ~~gen~~ - ~~cons~~

0

S.S.

0 0

not reacting

	mixer	Liq sep	Evap	gas sep	Overall
unknowns	7	7	7	5	8
MB equations	3	3	3	2	3
mass flow rates/ratio	2	0	0	0	2
mass fractions	1	0	1	1	3
DF	+1	+4	+3	+2	0
after overall	-0 +1	-1 +3	-1 +2	-1 +1	

5

For each

For each subunit	Points	
correct # unknowns	2.5	0.5 pts each e
correct # mass balance equations	2.5	f
correct # of speciations	2.5	g

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c. Based on your degree of freedom analysis to justify your answer, describe how you would approach solving for the unknown mass flow rates in this system.

Answer:

I would begin with the overall subunit balances and solve all of them, since the DF = 0 for that system.

After that, no other subunit has a DF = 0, so I won't be able to solve for ALL the unknowns.

Therefore, what I would do next would depend on the specific question I was asked. To solve for ALL the unknowns, I would need to make one additional estimate or assumption.

Practice	Points	
concluded correct subsystem to start with based on DF	1.5	h
updated DF table correctly	1	i
drew correct conclusion from this	1	j

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d. The problem statement says that *the stream exiting the mixer is fed to a liquid separator that removes some of the water*. How much water does the liquid separator remove? Report your answer in [g/min].

overall balances

(I) B : $0 = 8 - 0.9(P)$

(II) w : $0 = 32 - (4) - 0.70(w)$

(III) s : $0 = 80 - 0.1(P) - 0.30(w)$

(IV) Total : $0 = 40 + 80 - (4) - (P) - (w)$

I : $(P) = 8.\overline{8}\ \frac{g}{min}$

III : $0.1(8.\overline{8}) + 0.30(w) = 80$

$(w) = 263.70\ \frac{g}{min}$

IV : $120 = (4) + 8.\overline{8} + 263.70$

$(4) = -152.59\ \frac{g}{min} \rightarrow -150.\ \frac{g}{min}$

This makes no sense. Something is wrong. Perhaps water is entering the separator or elsewhere. Or one of the measurements is wrong.

(II) : check : $32 \stackrel{?}{=} (4) + 0.70(w)$

$\checkmark\ 32 \stackrel{?}{=} -152.59 + 0.7(263.70)$

Practice | Parts

Practice	Points	
wrote out 4 mass balance (MB) equations for overall subunit	2	(0.5 pt each) K
wrote the MB eqns correctly	8	(2 pts each) I
used them to solve for ① ② ④	1 1 1	M
any kind of reasonable check and realization that the something about the system as described is not possible	2	n
report correct answer with units [g/min]	0.5	o
used 3 sig figs	0.5	p

measurements is wrong.

used 3 sig figs | 0.5 P

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Exam 1, Open Book Part

Question 4 (35 points)

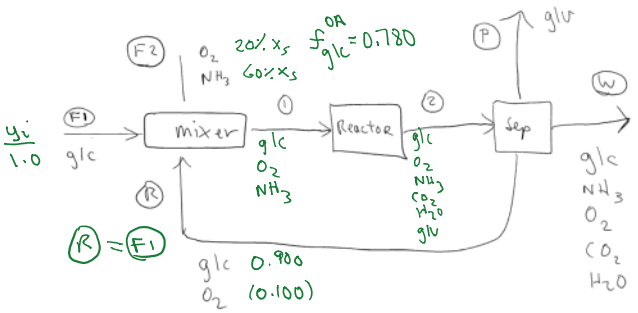
Glutamic acid ($C_5H_9NO_4$) can be produced from glucose ($C_6H_{12}O_6$) via the following reaction:

$$C_6H_{12}O_6 + NH_3 + 1.5\ O_2 \rightarrow C_5H_9NO_4 + CO_2 + 3H_2O$$

Three streams enter a mixer upstream of the reactor: F1, F2, and R. Stream F1 is pure glucose (glc); Stream F2 contains O_2 and NH_3, and R (a recycle stream). The stream that exits the mixer (Stream 1) enters the reactor. Stream 2 exits the reactor and enters a separator from which three streams exit: P, W, and R. Stream P contains only glutamic acid (glu), stream W contains all the products and reactants other than glutamic acid, and stream R contains only glucose and O_2.

The overall system conversion of glucose is 78.0%. The recycle molar flow rate is equal to the fresh inlet molar flow rate of glucose. The flow rates of fresh O_2 and NH_3 are in 20.0% and 60.0% excess respectively, of the glucose in the fresh feed. The recycle stream contains 90.0 mol% glucose and the rest is O_2.

a. Update the diagram as needed to make it a good engineering diagram
b. What is the extent of reaction?
c. What is the single pass fraction conversion of glucose?
d. The overall conversion of glucose is different than the single pass conversion of glucose. Explain why.



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Practice	Points
write species next to each stream	2
write specifications at appropriate location on diagram	2

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b. gcc = in - out + gen - cons

S.S

$0 = IN - OUT + NS$

Basis: (F1) = 100 mols

(R) = 100 mols

glc: $0 = 100 - 0.22(100) - \xi$

$\xi = 78.0$ mols reacting

practice	Points
wrote general mol balance equation	2
Simplified it for S.S. (acc = 0)	2
explicitly established a basis	3
Solved for ξ	3
report ξ with 3 sig figs and correct units	1

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C. use various mol balances to find f_{sp}

Separator balance

glc: $0 = ②_{glc} - 22 - 0.9(100)$

$②_{glc} = 22 + 90 =$ **112 mols = $②_{glc}$**

Mixer balance

glc: $0 = 100 + 90 - ①_{glc}$

$①_{glc}$ = 190 mols

Reactor balance (check)

glc: $0 = 190 - 112 - 78$ ✓ correct

$$f_{sp,\,glucose} = \frac{190-112}{190} = \mathbf{0.411 = f_{sp,glc}}$$

practice	points
use appropriate mol balance equations to find needed mols	8 (4 pts each)
check answer with independent	4

independent balance	4
solve for fsp, glucose	2
report w/ 3 sig figs	2

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d. unreacted reactants are returned to the reactor so they have more opportunity to react.

grading (4 pts)

any reasonable answer along these lines