Exam 2 MW Closed

Wednesday, March 16, 2016 5:35 PM

Exam 2 Part 1 MW

Name/Initials: Solutions

Circle your section: A B E F

BMED 2210
EXAM 2

March 16, 2016

The first part of Exam 2 is closed book, closed notes. The only things you can use for this part of the exam are your pencil (or pen) and paper. Calculators are not allowed. When you are ready to turn in this part of the exam and receive the 2nd part of the exam, turn your exam over and raise your hand. Once you turn in this part of the exam, you cannot get it back for any revisions. You have up to 30 minutes to complete this part of the exam. After 30 minutes have passed, everyone will be required to turn in part 1. The second part of Exam 2 is open book, closed notes, calculators allowed.

<u>Honor Code Statement</u>
By taking this exam you pledge that this is your work and you have neither given nor received inappropriate help during the taking of this exam, in compliance with the Academic Honor Code of Georgia Tech. Do not sign this exam, or take this exam, if you do not agree to abide by the honor code or the statement below.

Academic misconduct will not be tolerated:

1. Keep your eyes on your own paper.
2. Do your best to prevent anyone else from seeing your work.
3. Do not communicate with anyone (other than a proctor) for any reason, in any language, in any manner.
4. Do not share <u>anything</u> during the exam. This includes pencils, paper, and erasers.
5. Stop all writing immediately when you are told to stop. Your exam grade will be reduced by 20 points if you fail to stop writing IMMEDIATELY after the end of the exam.
6. For PART 1 of this exam you are NOT allowed to use your book.

I commit to uphold the ideals of the honor and integrity by refusing to betray the trust bestowed upon me as a member of the Georgia Tech community.

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Signature:____

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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 (4 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. 1000 J = $\frac{1000\,J \mid 778\,ft\cdot lbf}{\mid 1055\,J} =$ 700 ft-lb_f (800 is ok)

b. 10 hp = $\frac{10\,hp \mid 1\,kW \mid 1000\,W}{\mid 1.34\,hp \mid 1\,kW} =$ 7000 W (8000 is ok)

grading

	Points
for conversion factors	1
for correct value and sig figs	1

} each

Question 2 (8 points)
You have a 5 lb of H_2 in a 10 ft^3 hydrogen tank at 25°C. Estimate to one significant figure what the pressure gauge on the tank will read in psig.

$$\bar{V} = \frac{5\,lb \mid lbmol \mid}{\mid 2\,lb \mid 10\,ft^3} = 0.25\,\frac{lbmol}{ft^3}$$

$$\frac{1\,lbmol \mid \cancel{298K} \mid P}{359\,ft^3 \mid \cancel{298K} \mid 14.7\,psia} = 0.25\,\frac{lbmol}{ft^3}$$

$$P \simeq 1400\,psia \simeq \boxed{1000\,psig}$$

	Points
Calculate $\bar{V} = 0.25\,\frac{lbmol}{ft^3}$	2
Set up equation that relates P to $\bar{V}$	4
solve for P	1
report w/ 1 sig fig and units	1

Exam 2 MW Open

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Exam 2 Part 2 MW

Name/Initials:____________________________

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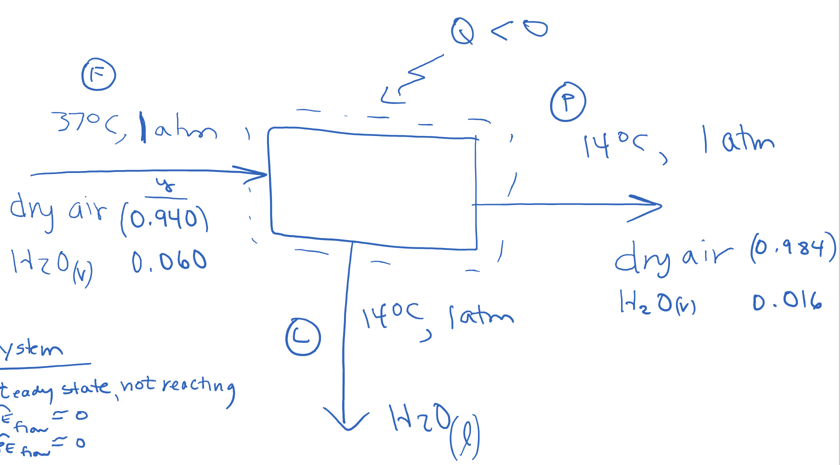
This part of the exam is open book but closed notes. Write on only one side of each page. Show all your work, pay attention to significant figures, and box your final answers. You MUST include a well-labeled diagram of the process to receive full credit on mass balance problems. Please put your full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

Exam 2, Open Book Part

Question 4 (40 points)
An experimental device to condense the water vapor in air exhaled by humans cools the inlet gas to the point that some of the water vapor condenses. The purpose of the device is to analyze biomarkers that are entrained in the condensate.

You are testing the device by operating it continuously. The feed stream is composed of dry air and water vapor (6.0 mol%). It is fed to the device 6.0 L/min at 37°C and 1 atm The device cools the humid air to 14°C. Two streams exit the device: a gas stream that dry air and water vapor (1.6 mol%), and a liquid water stream.

a. Draw a diagram of the system



System

steady state, not reacting

$\Delta \hat{KE}_{flow} \approx 0$

$\Delta \hat{PE}_{flow} \approx 0$

$w = 0$

$\boxed{\Delta H = Q}$, and $\boxed{0 = N_i^{in} - N_i^{out}}$

1

grading

- Correct # streams 1
- species labeled in each stream 1
- All relevant info put at correct location 2
- write simplified MB eqn w/ justifications 2
- write simplified EB eqn w/ justifications 2

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b. Determine the degrees of freedom for this problem, accounting for the use of both mass balances and an energy balance.

mass EB

MB DF

Correct values for

mass

unk	5
MB	2
mfr	2
Basis	1
DF	0

EB

T,P	6
Q,W	2
EB	1
T,P	6
Q,W	1
DF	0

Values for
- unk |
- MB |
- # specifications |

EB DF

correct values
- for knowns (T,P,Q,W) |
- for EB eqn |
- for knowns |

Q5_MW_grading_scheme

Name:

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c. How much heat does the device transfer from the humid air? Report your answer in J/min. Show ALL your work.

	ref state	$\dot{N}^{(F)}$ [mol/min]	$\hat{H}^{(F)}$ [J/mol]	$H^{(F)}$ [J/min]	$\dot{N}^{(P)}$	$\hat{H}^{(P)}$	$H^{(P)}$	$\dot{N}^{(L)}$	$\hat{H}^{(L)}$	$H^{(L)}$
Dry air	Table D.6 (273K, 1 atm air, gas)	0.2254	1075.2	242.4	0.2254	406.8	91.69	0		
H_2O	Steam Tables (0.01°C, H_2O, ℓ, 0.00611 bar)	0.0142	46420	659.2	0.00365	45490	166.0	0.0105	1058.4	11.11
				$\Sigma = 901.6$			$\Sigma = 257.69$			$\Sigma = 11.11$

$$\text{Basis: } \frac{6\,L}{min}\left|\frac{273}{37+273}\right|\frac{mol}{22.4\,L} = 0.2359\ \frac{mol}{min}$$

mol balances

air: $0.94(0.2359) = 0.984(N^{(P)})$

$N^{(P)} = 0.2254\ \frac{mol}{min}$

Total: $0 = 0.2359 - N^{(L)} - 0.2254$

$N^{(L)} = 0.0105\ \frac{mol}{min}$

Check w/ H_2O: $0 \overset{?}{=} 0.06(0.2359) - 0.0105 - 0.016(.2254)$

✓

From SMS pg 520:

$$\hat{H}^{(F)}_{H_2O(v)} = \frac{2570.8 + 2567.2}{2} = 2569\ \frac{J}{g}\left|\frac{18\,g}{mol}\right. = 46420$$

$$\hat{H}^{(P)}_{H_2O(v)} = 2527.2\ \frac{J}{g}\left|\frac{18\,g}{mol}\right. = 45{,}490$$

$$\hat{H}^{(L)}_{H_2O(\ell)} = 58.8\ \frac{J}{g}\left|\frac{18\,g}{mol}\right. = 1058.4$$

From Table D.6

$$\hat{H}^{(F)}_{dry\,air} = (3696 - 784)0.1 + 784 = 1075.2\ \frac{J}{mol}$$

$$\hat{H}^{(P)}_{dry\,air} = \left(\frac{287-273}{291-273}\right)523 = 406.8\ \frac{J}{mol}$$

$$\Delta H = \left[(11.11 + 257.69) - 901.6\right]\frac{J}{min} = Q$$

Basis 4

mol balances

↳ write 2 4

↳ use correctly to solve 2

↳ check w/ 3rd 2

• Establish ref states 2

• Solve for each of 4 $\hat{H}$'s correctly (1.5 points each) 6

• Solve EB eqn for Q 4

$\Delta H = \left[(11.11 + 257.69) - 901.6\right] \frac{J}{min} = Q$

$Q = -632.8 \frac{J}{min}$

$\boxed{\text{2 sig figs: } 630 \frac{J}{min} \text{ must be transferred from the system}}$

eqn for Q 1

- report correct answer w/ 2 sig figs 2

4

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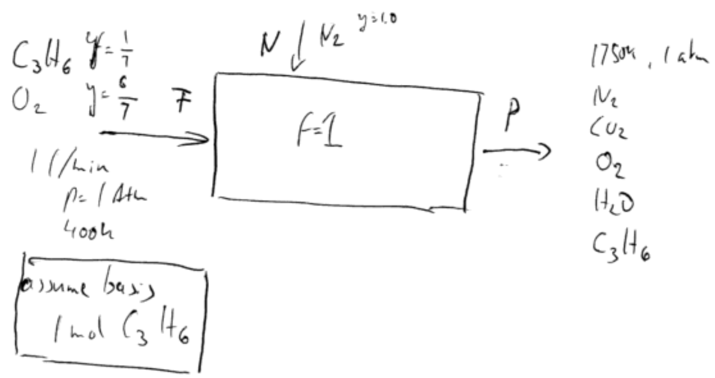
Question 5 (40 points)
Cyclopropane is a simple hydrocarbon molecule with the structure C_3H_6. It is of interest as a high energy-content fuel. Energy is generated by reacting it with oxygen to form CO_2 and H_2O. The standard heat of formation for Cyclopropane is 53.5 kJ/mol and its heat capacity at 400.0K is estimated to be 70 J/(mol*K).

You are working with the following reactor:
A mixture containing cyclopropane and oxygen at a molar ratio of 1:6 is entering the reactor at 1 atm and 400.0K and a flow rate of 1 L/min. An (adjustable) stream of pure nitrogen gas enters the reactor at the same temperature and pressure as the cyclopropane/oxygen mixture. There is a 100% conversion of C_3H_6 to CO_2. Nitrogen leaves the reactor with the product stream, which has a temperature of 1750K and a pressure of 1 atm. The reactor is thermally well insulated.

a. Draw a diagram of the system



MW question 9b, degree of freedom analysis:

MBE

1. N_2 is taken into account

U	8 (in: C3H6, O2, N2 out: C3H6(!), O2,N2, CO2, H2O)
ξ	1
MBE	-5 (equations for all components incl. N2)
molar ratio:	-1
basis:	-1
ξ	-1
DF	1

Alternative solution: N2 is ignored as "solvent" (this must be stated clearly!)

U	6 (in: C3H6, O2 out: C3H6(!), O2, CO2, H2O)
ξ	1
MBE	-4 (equations for all components excluding N2)
molar ratio:	-1
basis:	-1
ξ	-1
DF	0

EBE

p,T	6
W,Q	2 (or 0 if recognized that there is no W,Q acting on the system)
EBE	-1
p,T	-6
W,Q	2 (or 0 if recognized that there is no W,Q acting on the system)
DF	-1

extra credit

p,T	6
W,Q,ΔH	3 (no W,Q in the system, however in d) we solve for ΔH)
EBE	-1
p,T	-6
W,Q, ,ΔH	-2 (W=Q=0.)
DF	0

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c. Provide the reaction equation with correct stochiometric coefficients along with a complete mass balance analysis for the given reactor.

$$C_3H_6 + 4.5\,O_2 \rightarrow 3\,CO_2 + 3\,H_2O$$

M.B.E $0 = in_i - out_i + \nu_i \xi_i$ for each component

C_3H_6: $0 = 1\,mol - 0\,mol - \xi = 0$; $\xi = 1\,mol$

(limiting reactant) $C_3H_6^{out} = 0$

O_2: $0 = 6.0\,mol - n_{out}^{O_2} - 4.5\,\xi$; $n_{out}^{O_2} = 1.5\,mol$

O_2: $0 = 6.0\,mol - n_{out}^{O_2} - 4.5\xi$; $n_{out}^{O_2} = 1.5\,mol$

CO_2: $0 = 0 - n_{out}^{CO_2} + 3\xi$; $n_{out}^{CO_2} = 3\,mol$

H_2O $0 = 0 - n_{out}^{H_2O} + 3\xi$; $n_{out}^{H_2O} = 3\,mol$

N_2 $0 = n_{in}^{N_2} - n_{out}^{N_2} \Rightarrow n_{in}^{N_2} = n_{out}^{N_2}$

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d) Use the energy balance equation to calculate the flow rate of nitrogen required to ensure that the temperature of the outlet stream is at 1750K.

$\Delta(\bar{U}+\bar{E}kin+\bar{E}pot)\,M = \Sigma(\hat{H}+\bar{E}kin+\bar{E}pot)_{in}m_{in} - \Sigma\,(\hat{H}+\bar{E}kin+\bar{E}pot)_{out}m_{out} - dW/dt - dQ/dt$

The system is: steady state, adiabatic, there is no external work, Ekin and Epot is negligible

$0 = \Sigma\hat{H}_{in}m_{in} - \Sigma\hat{H}_{out}\,m_{out}$

substance	state	T=400K			T=1750K		
		Nin	molar H [kJ]	total H [kJ]	Nout	molar H	total H
-	-	-	-	-	-	-	-
C3H6	g	1	53.5+.07*102 ($\Delta H_f^0+C_p\Delta T$)	60.5	0	0	0
O2	g	6	3.75-.73 ($H^{400}-H^{298}$)	18.12	1.5	50.55-.73 $H^{1700}-H^{298}$	74.73
CO2	g	0	0	0	3	-393.5+77.45-0.91 $\Delta H_f^0+H^{1700}-H^{298}$	-950.88
H2O	g	0	0	0	3	-241.8-0.84+60.75 $\Delta H_f^0+H^{1700}-H^{298}$	-545.67
N2	g	N	3.70	3.70*N	N	47.94	47.94*N

Entries in the tables for $\hat{H}$ are calculated as follows:

$$\hat{H} = \Delta H_f^0 \quad \int_{298}^{T(400\text{ or }1750)} C_p\, dT$$

solving this integral by assuming a constant, T-independent value of Cp is "risky due to the large temperature range of the integral. Especially for gases Cp cannot be assumed to be independent of the temperature. Due to the accuracy of the initial question (inlet stream for educts is given with only 1 sig fig.) no substantial mistake is made using this approach.

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JL: you might want to print out the rubric for Each exam and fill it out during grading. This saves a lot of time.

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It is better take the integral values from the table:

$$\hat{H} = \Delta H_f^0 + \int_{298}^{T(400\text{ or }1750)} C_p\, dT \quad = \Delta H_f^0 - \hat{H}^{298} + \hat{H}^{400}$$

Note the common mistake:
ΔH_f^0 needs to be accounted for all components involved in the reaction for products and educts. Especially values for the educts CO_2 and H_2O were often ignored.

Calculation of the molar amount of Nitrogen (basis: 1 mol Cyclopropane)

H_{out}= N(47.94)-545.67-950.88+74.73
H_{in}= N(3.7)+60.5+18.12

H_{out}= H_{in} => N=33.9 mol

We have been working with a basis of 1 mol of cyclopropane. The original problem was using a flow for F of 1l/min. 1/7th of that will be Cyclopropane. Since the streams F and N have the same T and p (and are considered to be ideal gases) the flow for N will be

We have been working with a basis of 1 mol of cyclopropane. The original problem was using a flow for F of 1l/min. 1/7th of that will be Cyclopropane. Since the streams F and N have the same T and p (and are considered to be ideal gases) the flow for N will be

$Flow_N$= (1/7)*33.9 l/min= 5 l/min (1 sig fig)

Note:
The problem can certainly be solved by using a different basis.
Many students solved the problem for a basis of 1l/min and the corresponding molar amounts determined via the ideal gas-equation.
This will directly provide the flow in mol/min for stream N. The flow can then converted back to l/min using the ideal gas equation.

section: A B E F

Q5 Rubric:

(a)
diagram 6 pt

correct structure :	/3 (box, flow streams, system boundaries)
diagram labeled correctly:	/2 (correct labels: all species + conditions)
information in correct place:	/.5
basis is given	/.5

(b)
DOF 9 pt

correct analysis for Mass balances	/4
recognized that MB cannot be solved for N2	/1
correct analysis for EB	/4
(extra credit: recognize that H should be included in EB	/1)

(c)
Mass balances 9 pt

correct reaction equation	/2.5
Write general MBE	/1
list MBE for all reactants	/2.5 (0.5 for each component, incl.N_2)
solve MBE for individual outputs	/2
state + show that it is not possible to solve for N2	/1

(d)
Energy balances to calculate F: 16 pt

List general EB-equation	/1
simplify EB-equation + explain	/2
recognize how the amount of N_2 is calculated	/4
correct entries in table	/5 (1 pt for each correct row)
calculated N correctly	/1
calculated nitrogen flow correctly	/2
result reported with correct sig. fig.	/1

1