BMED 2210 – Conservation Principles in Biomedical Engineering

Exam #3, April 17, 2008

Exam instructions

Show all of your work, box your FINAL answer, and use significant figures and proper units in the final solution. Use diagrams with appropriate labels to depict the described systems, state a basis and provide REASONABLE assumptions necessary to solve the problems. Write out balance equations in terms of variables before

Time permitting, try to attempt each of the problems. It is recommended to read all of the problems before choosing which one to begin first.

Write your name on the top of each page. Problems without a name at the top will not be graded.

Once time is called, pens or pencils must be put down immediately, otherwise you risk not having your exam graded and you will receive a "0" for the entire exam.

Honor Code Statement

Sign the honor code statement below otherwise you will receive a "0" for the entire exam.

By my signature below, I denote that I am fully aware of Georgia Tech's honor code policy and agree to abide by it during the completion of this exam.

Solutions

(Signature)

(Printed name)

Name: ____________________________

Constants & reference information

$\Delta H°_f$ = -393.51 kJ/g mol = CO_2
$\Delta H°_f$ = -285.849 kJ/g mol = H_2O

$\Delta H°_f$ = -1250 kJ/g mol = Glucose ($C_6H_{12}O_6$)

1 atm = 760 mm Hg   1 L•atm = 101.3 J   1 J = 1 $(kg \cdot m^2)/s^2$

$g = 9.81\ m/s^2$

Element atomic masses:

H = 1.0   C = 12.0   N = 14.0   O = 16.0   Na = 23.0   Cl = 35.5

C_v (H_2O) = 4.18 J/(g·K)

STP (for 1 kg mol gas):   T = 273 K   P = 101.3 kPa   V = 22.415 m^3

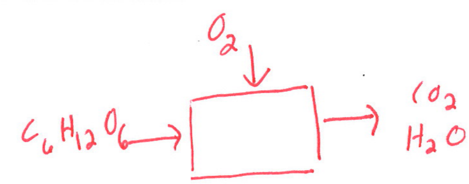
Name: Solution.

Problem #1 **(25 points)**

1) The oxidation of glucose is an exothermic reaction that provides the body with needed energy for carrying out metabolic functions. If the body is only 85% efficient in its conversion of glucose to its metabolic products, what is the heat of reaction when 150 g mol of glucose is consumed?

Assume a stoichiometric amount of oxygen is available for the reaction.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$



Assumptions: Sensible Heats are Negligeable

Input	ΔH_f° (kJ/g·mol)	g mol	ΔH (kJ)
$C_6H_{12}O_6$	-1250	150	-187 500
O_2	$\emptyset$	900 (= 150 × 6)	$\emptyset$
Output			
CO_2	-393.51	900	-354 159
H_2O	-285.85	900	-257 265

$$\Delta H_{RXN}(@\,100\%) = \Delta H_{outputs} - \Delta H_{inputs}$$
$$= (-257265 - 354159) - (-187500)\ kJ$$
$$= -423924\ kJ$$

$$\Delta H_{RXN}(@\,85\%) = (.85)(\Delta H_{RXN} @\ 100\%)$$

$$\boxed{\Delta H_{RXN} = -360,335\ kJ}$$

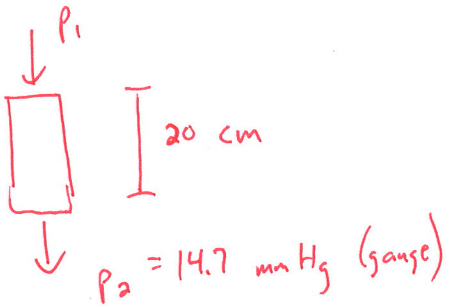
Name: Solution

Problem #2 **(25 points)**

2) The esophagus transports food and liquids from the mouth to the stomach. If a manometer reading at the lower esophageal sphincter (bottom of the esophagus) is 14.7 mmHg (psig) and the length of the average human esophagus is 20.0 cm, how much work is required to ingest a single swallow of water?

14.7 mmHg = 0.0193 atm

Hint: You will need to make assumption(s) to solve this problem.



Assumptions

- No velocity change ($\hat{KE} = \emptyset$)
- No energy dissipation loss ($E_v = \emptyset$)
- Can make assumption about atmospheric pressure (P_1), but unnecessary ($\Delta p = 14.7$ mmHg)
- $\rho_{H_2O} = 1$ g/mL $= 1$ kg/L

Basis: same volume of water (1 swallow ~ 20-50 mL)

$$\hat{W} = \cancel{\hat{KE}}^{\,\emptyset} + \hat{PE} + \frac{\int_{P_1}^{P_2} V\,dp}{m} + \cancel{E_v}^{\,\emptyset} \quad (\text{or } h_f)$$

$$\hat{W} = gh + \frac{\Delta p}{\rho} = (9.81\ m/s^2)(-0.20\ m) + \frac{0.0193\ L\cdot atm}{1.0\ kg}$$

$\Rightarrow$ use unit conversions $\Rightarrow$ $\approx$ $\boxed{\emptyset\ J = W}$

Name: Solution

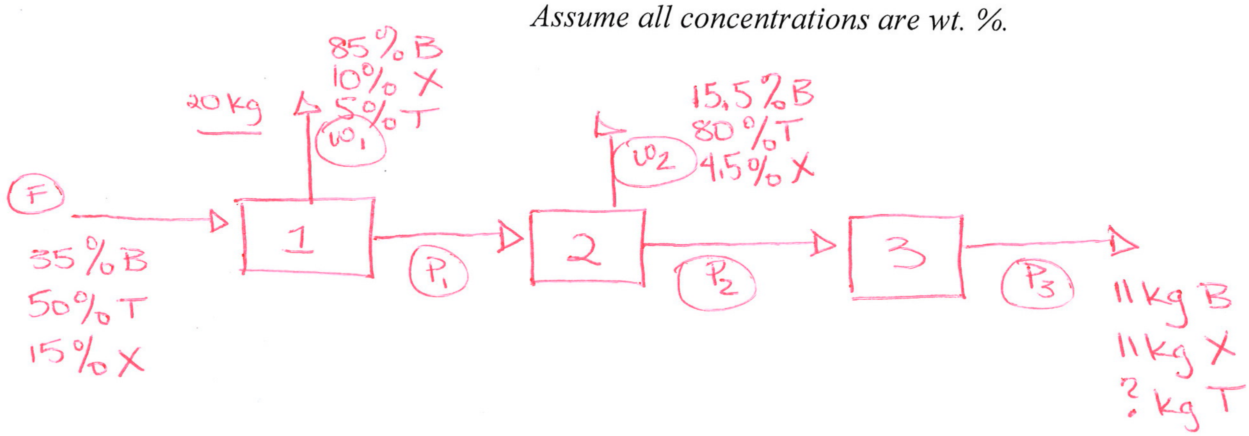
Problem #3 **(25 points)**

3) Benzene (B), toluene (T), and xylene (X) are separated via a multi-unit process. The feed stream that enters the overall process is made up of 35% B, 50% T and 15% X (wt %) and 20 kg of waste, comprised of 85% B and 10% X, exits from the first stage. The resulting product stream from the first stage is further separated into 15.5% B, 80% T and 4.5% X (that exits as waste), while the remainder is fed directly into a cooling tank. The product stream from the cooling tank contains 11 kg of B and 11 kg of X.

a) If all streams contain all three components, what is the amount (kg) of T in the stream that exits the cooling tank?

b) What is the composition and amount of the product stream that leaves the first process?

Assume all concentrations are wt. %.



1. B-Balance ⇒ $(.35)(F) = (.85)(20\text{ kg}) + (.155)(W_2) + 11\text{ kg}$

X-Balance ⇒ $(.15)(F) = (.10)(20\text{ kg}) + (.045)(W_2) + 11\text{ kg}$

Solve 2 Equations w/ 2 unknowns ...

$W_2 \cong 45.8\text{ kg}$

$F \cong 100\text{ kg}$

2. T-Balance ⇒ $(.50)(100\text{ kg}) = (.05)(20\text{ kg}) + (.8)(45.8\text{ kg}) + ?\text{ kg}$

$? \cong 12.4\text{ kg}$

(a) $\boxed{T \text{ in } P_3 = 12.4\text{ kg}}$

Name: Solution

Problem #3 (cont'd)

3. P_1 Balance:

$$F = W_1 + P_1$$

$$100\ kg = 20\ kg + P_1$$

$$\boxed{P_1 = 80\ kg}$$

B - Balance:

$$(.35)(100\ kg) = (.85)(20\ kg) + (x^B_{P_1})(80\ kg)$$

$$\boxed{x^B_{P_1} = 22.5\%}$$

T - Balance:

$$(.50)(100\ kg) = (.05)(20\ kg) + (x^T_{P_1})(80\ kg)$$

$$\boxed{x^T_{P_1} = 61.2\%}$$

X - Balance:

$$(.15)(100\ kg) = (.10)(20\ kg) + (x^X_{P_1})(80\ kg)$$

$$\boxed{x^X_{P_1} = 16.3\%}$$

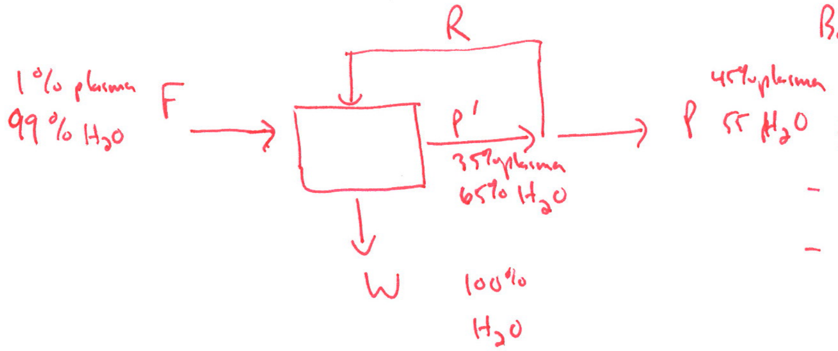
Name: Solution

Problem #4 (25 points)

4) A 1.0% (wt %) plasma solution is concentrated to 35% by a centrifugal filtration device and a portion of the gross product is recycled back into the device to increase the final concentration of the plasma to 45%. The input feed rate to the process is 10 ml / minute.

a) How efficiently is liquid removed from the original plasma solution?

b) What portion of the gross product is recycled?



Basis: 1 minute (10 mL)

Assumptions:

- No plasma lost in waste (W)
- ~~A~~ Non-plasma liquid is H_2O (ρ = 1 g/mL)

a.) Overall balance: $F \rightarrow \boxed{} \rightarrow P$, $\downarrow W$ $\qquad F = P + W$

Species:

Plasma: $0.01\,F = 0.45\,P$

$\Rightarrow P = 0.222$ g

H_2O: $0.99\,F = 0.55\,P + W$

$\Rightarrow W = 9.78$ g

Efficiency:

$\frac{\text{in} - \text{out}}{\text{in}} = \frac{9.9 - 0.122}{9.9} = \boxed{98.8\%}$

b.) Analyze @ splitter,

$P' \rightarrow \boxed{} \rightarrow P$, $\uparrow R$

Overall: $P' = P + R$

Species:

plasma $\quad 0.35\,P' = 0.45\,P + w_p^R R$

H_2O $\quad 0.65\,P' = 0.55\,P + w_w^R R$

4 unknowns $\rightarrow$ underspecified, make add'l assumptions or unsolvable