Name: Solution

Problem #1 **(30 points)**

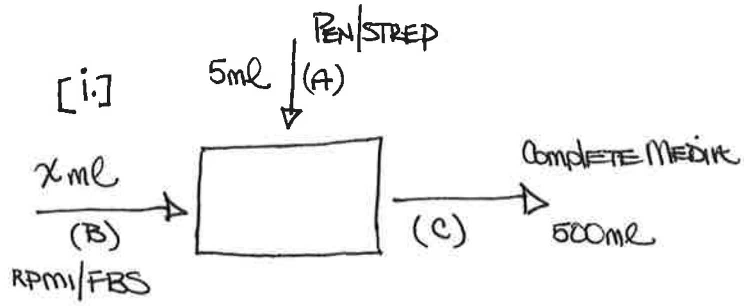
1. RPMI media is supplemented with 5.0% fetal bovine serum (FBS) and 5.0 ml of an antibiotic solution of Penicillin/Streptomycin (Pen/Strep) to yield a half liter of cell culture media. The density of the Pen/Strep solution (equal-parts-by-mass) is 3.0 g/L prior to addition.

a) What is the final mass ratio of RPMI media to Penicillin in the resulting solution?

b) If a different cell type requires 15% FBS and the RPMI:Penicillin mass ratio is to remain the same as in (a), what is the percent reduction of Pen/Strep added to the media?

(a)

[i.]



A: 50% Pen, 50% Strep } by mass

B: 5% FBS, 95% RPMI } by volume

C: $?_1$ Pen, $?_2$ Strep, $?_3$ FBS, $?_4$ RPMI } by mass

[ii.]

Assumptions:

ρ RPMI/FBS = 1 g/mL

FBS = 5% by Volume

[iii.]

Total $\Rightarrow$ A + B = C (Volume)

B = 495 ml

PEN $\Rightarrow$ $A_{pen} + B_{pen} = C_{pen}$ (mass)

$(5\,ml)(3\,g/L)\left(\frac{1\,L}{1000\,mL}\right)(0.50) = .0075\,g$ Pen $= A_{pen}$

$(495\,ml)(1\,g/mL)(0) = 0\,g$ Pen $= B_{pen}$

$\therefore C_{pen} = .0075\,g$

RPMI $\Rightarrow$ $A_{RPMI} + B_{RPMI} = C_{RPMI}$ (mass)

$(5\,ml)(3\,g/L)\left(\frac{1\,L}{1000\,mL}\right)(0) = 0\,g$ RPMI $= A_{RPMI}$

$(495\,ml)(.95)(1\,g/mL) = 470.25\,g$ RPMI $= B_{RPMI}$

$\therefore C_{RPMI} = 470.25\,g$

[iv.] $y = \frac{\text{mass RPMI}}{\text{mass Pen}}$

$= \frac{470.25\,g\ \text{RPMI}}{.0075\,g\ \text{Pen}}$

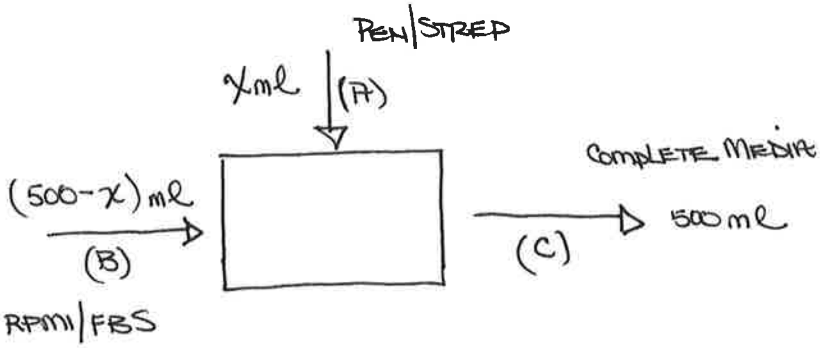
$\cong 6.30 \times 10^4$

[v.] $\boxed{y \cong 6.30 \times 10^4}$

Name: Solution

Problem #1 (cont'd)

(b) [i]



A: 50% Pen, 50% Strep } by Mass

B: 15% FBS, 85% RPMI } by Volume

C: ?$_1$ Pen, ?$_2$ STREP, ?$_3$ FBS, ?$_4$ RPMI } by Mass

[ii]

Assumptions:

ρ RPMI = 1g/mL

FBS = 15% by Volume

[iii]

Total ⟹ A + B = C (Volume)

$[x + (500 - x)]$ ml = 500 ml

500 ml = 500 ml

PEN ⟹ $A_{pen} + B_{pen} = C_{pen}$ (mass)

$(x\,\text{mL})(3\,\text{g/L})\left(\frac{1\,\text{L}}{1000\,\text{mL}}\right)(.50) = .0015x$ g Pen $= A_{pen}$

$(500 - x\,\text{ml})(1\,\text{g/mL})(0) = 0$ g Pen $= B_{pen}$

$\therefore C_{pen} = .0015x$ g

RPMI ⟹ $A_{RPMI} + B_{RPMI} = C_{RPMI}$ (mass)

$(x\,\text{mL})(3\,\text{g/L})\left(\frac{1\,\text{L}}{1000\,\text{mL}}\right)(0) = 0$g RPMI $= A_{RPMI}$

$(500 - x\,\text{mL})(1\,\text{g/mL})(.85) = (.85)(500 - x)$ g RPMI $= B_{RPMI}$

$\therefore C_{RPMI} = (.85)(500 - x)$ g

[iv]

$y = \frac{\text{mass RPMI}}{\text{mass PEN}} = 6.30 \times 10^4$

$6.30 \times 10^4 = \frac{(.85)(500 - x)\text{ g RPMI}}{(.0015x)\text{ g PEN}}$

X = 4.47 ml = PEN|STREP Volume.

[v.] Reduction in Volume = $\frac{4.47\text{ ml}}{5.0\text{ ml}} = 89\%$

$\therefore$ $\boxed{\%\ \text{REDUCTION} \cong 11\%}$

Name: Solution

Problem #2 **(30 points)**

2) The Thingamajig removes water from gaseous mixtures. Saturated air at 98.6 kPa and 95°C (dew point of 60°C) enters the Thingamajig at 50.0 m^3/min.

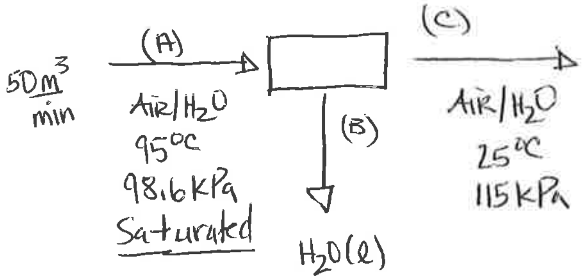
a) What is the volumetric flow rate of the H_2O that is drained from the Thingamajig if the exiting gas is at 25°C and 115 kPa?

b) If the air entering the Thingamajig is only at 60% RH (other conditions the same) and 0.5 kg mol of liquid water/min is drained, what is the % RH of the exiting gas at STP?

(a)

* Modeled in Part After Example 17.4 *

[i]



[ii] Assumptions

Basis = 1 min

Volume Air/H_2O = Constant

Air Exiting = Saturated

η = mole symbol

[iii]

Total $\quad A = B + C$ (By moles)

Air $\quad \eta^A_{air} = \cancel{\eta^{B}_{Air}}^{\,0} + \eta^C_{Air} \Rightarrow \eta^A_{Air} = \eta^C_{Air}$

$H_2O \quad \eta^A_{H_2O} = \eta^B_{H_2O} + \eta^C_{H_2O}$

[iv]a. If you didn't know R...

$$\frac{P_1\cancel{V_1}}{P_2\cancel{V_2}} = \frac{\eta_1 R T_1}{\eta_2 R T_2}$$

$P_2V_2\eta_2T_2$ = @ STP

$P_1V_1\eta_1T_1$ = @ 95°C 98.6 kPa

$V_1 = V_2 = 50.0\ m^3$

η_2 = moles total at STP & 50.0 m^3 volume.

[iv]b $\quad PV = \eta RT \Rightarrow (98.6\ kPa)(50.0\ m^3) = (\eta_{total})(8.314\ \frac{kPa \cdot m^3}{kg\,mol \cdot K})(95 + 273\ K)$

η_{total} = 1.61 kg mol = η_1 Solved for in [iv]a.

$$\frac{P^*_{H_2O}}{P_{Air}} = \frac{\eta_{H_2O}}{\eta_{Air}} \Rightarrow \frac{10.2\ kPa}{(98.6 - 10.2\ kPa)} = \frac{\eta_{H_2O}}{(1.61 - \eta_{H_2O})} \Rightarrow \eta^{(A)}_{H_2O} = .166\ kg\,mol$$

η_{Air} = 1.44 kg mol

$$\frac{P^*_{H_2O}}{P_{Air}} = \frac{\eta_{H_2O}}{\eta_{Air}} \Rightarrow \frac{1.60\ kPa}{(115 - 1.60\ kPa)} = \frac{\eta_{H_2O}}{(1.44\ kg\,mol)} \Rightarrow \eta^{(C)}_{H_2O} = 0.020\ kg\,mol$$

Name: Solution

Problem #2 (cont'd)

[v]

$$B_{H_2O} = A_{H_2O} - C_{H_2O} \Rightarrow \eta^B_{H_2O} = \eta^A_{H_2O} - \eta^C_{H_2O} = (.166 - .020)\ \text{kg mol}$$

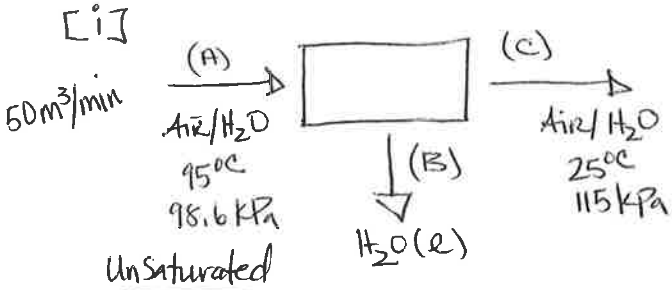
$$\eta^B_{H_2O} = .146\ \text{kg mol}$$

[vi]

$$.146\ \cancel{\text{kg mol } H_2O}\,(l) \times \frac{18\ \cancel{\text{kg } H_2O}}{1\ \cancel{\text{kg mol } H_2O}} \times \frac{1\ \text{mL } H_2O}{1\ \cancel{\text{g } H_2O}} \times \frac{1000\ \cancel{\text{g } H_2O}}{1\ \cancel{\text{kg } H_2O}} = \boxed{2.6\ \text{ml of } H_2O}$$

(b)

[i]



[ii] Total Moles, A, is Same Value from (a).

[iii]

$$\frac{(P^*_{H_2O})(.60)}{P_{AIR}} = \frac{\eta_{H_2O}}{\eta_{AIR}} \Rightarrow \frac{6.12\ \text{kPa}}{(98.6\ \text{kPa} - 6.12\ \text{kPa})} = \frac{\eta_{H_2O}}{(1.4\ \text{kg mol} - \eta_{H_2O})} \Rightarrow \eta_{H_2O} = .099\ \text{kg mol}$$

$$\eta_{H_2O}\ \text{Condensed} = 0.5\ \text{kg mol} \Rightarrow C_{H_2O} = \underbrace{-.401\ \text{kg moles}}$$

B/c Value is (−), the RH of Exiting Gas Stream is Automatically 0%!

No Additional Work Required !!.

Name: Solutions

Problem #3 **(40 points)**

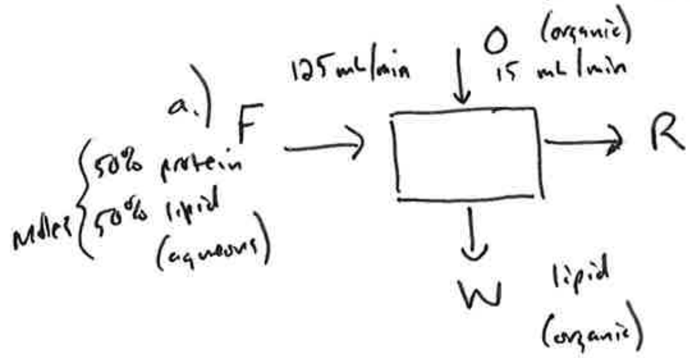
3) In order to extract a contaminating lipid (MW 1.0 kDa) from an aqueous protein (MW 12 kDa) solution, an organic solvent is added at 15 mL/minute to the protein/lipid mixture. The initial equimolar protein/lipid mixture is fed into a filtration device at 125 mL/minute and the resulting concentration of the lipid in the organic waste stream is 1.5 mg/mL and 20.0 mg/ml in the final protein solution.

a) What is the purity of the final purified protein solution? (Hint: initial mixture is 50% pure).

b) In order to further purify the protein from the lipid, the product of (a) is run over an affinity chromatography column capable of specifically adsorbing protein species. How much adsorbent is required to capture 95% of the protein from a 250 mL batch coming from the filtration device in (a) if the isotherm that describes protein adsorption to the adsorbent is:

$$y = 24.56x^{0.46} \quad \text{(mg protein/g adsorbent)}$$

a.)



Assume:

- aqueous & organic don't mix

$\Rightarrow \dot{W} = 15$ mL/min

$\dot{R} = 125$ mL/min

$[\text{lipid}_W] = 1.5$ mg/mL

$[\text{lipid}_R] = 20$ mg/mL

Basis: 1 min

Balances:

$F + O = R + W$

aqueous: $F = R$

organic: $O = W$

lipid: $F \cdot [\text{lipid}_F] = W[\text{lipid}_W] + R[\text{lipid}_R]$

protein: $F \cdot [\text{protein}_F] = R[\text{protein}_R]$

$\Rightarrow \text{protein}_F = \text{protein}_R$

lipid: $125 \text{ mL} [\text{lipid}_F] = 15 (1.5 \text{ mg/mL}) + 125 (20 \text{ mg/mL})$

$\Rightarrow [\text{lipid}_F] = 20.18 \text{ mg/mL} = 0.0202 \text{ M}$

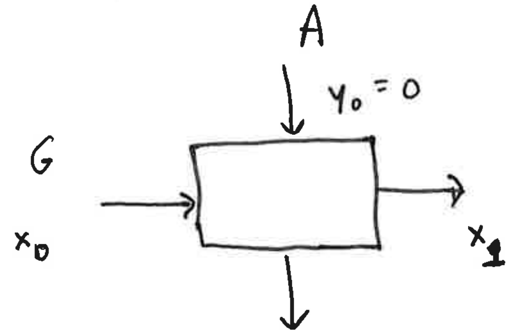
$\therefore n_{\text{protein}} = 2.525 \text{ mmol}$

& Purity $= \dfrac{n_{\text{protein}}}{n_{\text{total}}} = \dfrac{2.525 \text{ mmol}}{2.525 + 2.5 \text{ mmol}} = \boxed{50.2\%}$

Name: Solutions

Problem #3 (cont'd)

b.)



Basis: 250 mL G

$y_1 = 24.56\, x^{0.46}$

* Modeled after Example 20.3

from (a):

$[\text{protein}_G] = 242.16$ mg/mL

$x_0 = 60.54$ g (250 mL)

$x_1 = 3.03$ g (5% of x_0)

$$\frac{A}{G} = \frac{(x_0 - x_1)}{y_1} = \frac{(60.54 - 3.03)\ \text{g}}{24.56\,(3.03 \times 10^3)^{0.46}} = \frac{57.51 \text{ g protein}}{981.05\ \frac{\text{mg protein}}{\text{g adsorbent}}}$$

$$\Rightarrow \boxed{58.6 \text{ g adsorbent}}$$