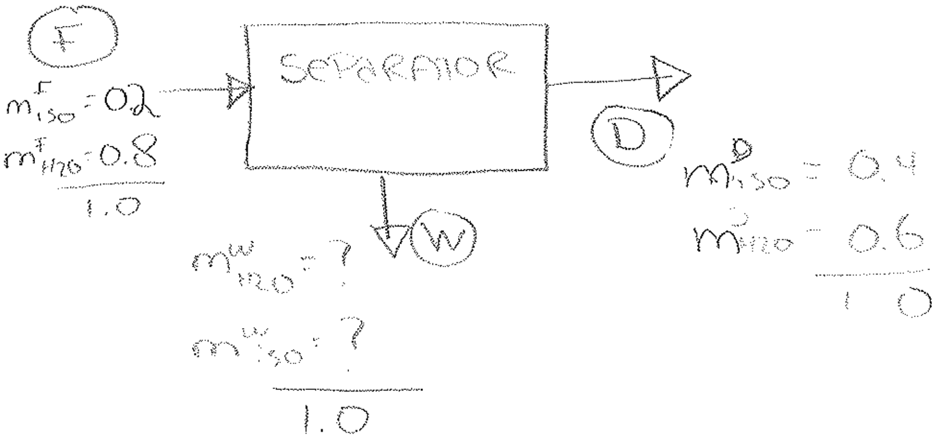
Name: SOLUTIONS

Problem #1 **(25 points)**

A solution containing 20% isopropanol (C_3H_8O) and 80% water (by mass) is run over a distillation column. The distillate collected contains 40% isopropanol and 60% water. If the condensed waste, containing a mixture of water and isopropanol, is equivalent to 80% of the initial solution fed (by mass), what is the molar ratio of isopropanol to water in the waste?



LEGEND

F = mass into separator from feed (g)

D = mass out of separator in distillate (g)

W = mass out of separator in waste (g)

m^i_n = mass fraction in stream i of species n.

MOLECULAR WEIGHTS

H_2O: $1\frac{g}{mol}(2) + 16\frac{g}{mol} = 18\frac{g}{mol}$

C_3H_8O: $12\frac{g}{mol}(3) + 1\frac{g}{mol}(8) + 16\frac{g}{mol} = 60\frac{g}{mol}$

KNOW

$W = 0.8F$

ASSUME

- no RXN

BASIS

1g feed (F = 1g)

BALANCE EQUATIONS

(1) $F = D + W$

$1g = D + 0.8F \rightarrow D = 0.2g$

(2) $Fm^F_{H_2O} = Wm^W_{H_2O} + Dm^D_{H_2O}$

$1g(0.8) = Wm^W_{H_2O} + 0.2g(0.6) \longrightarrow Wm^W_{H_2O} = 0.68g$

(3) $Fm^F_{iso} = Wm^W_{iso} + Dm^D_{iso}$

$1g(0.2) = Wm^W_{iso} + 0.2g(0.4) \longrightarrow Wm^W_{iso} = 0.12g$

FIND MOLAR RATIO OF $C_3H_8O : H_2O$

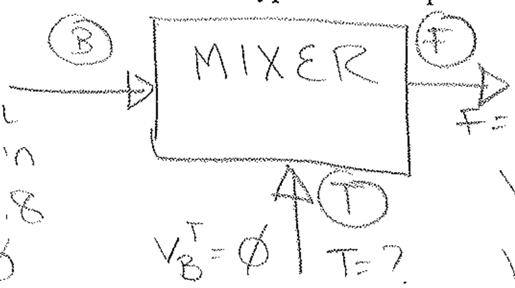
$$\frac{\dfrac{0.12g\text{ iso} \;\big|\; 1\text{mol iso}}{60g} = .002\text{mol iso}}{\dfrac{0.68g\ H_2O \;\big|\; 1\text{mol } H_2O}{18g} = .03778\text{mol } H_2O} = \boxed{.05\ \frac{\text{mol iso}}{\text{mol } H_2O}}$$

Name: SOLUTIONS

Problem #2 (25 points)

B cells and T cells are being combined; the B cell stream is entering at a rate of 2ml/min. The B cell suspension contains 80% cells by volume, whereas the T cell mixture contains only 20% cells by volume. What volumetric flow rate of the input T cell stream is needed to ensure that the final output stream contains a 3:2 mixture of B cells to T cells?

Assume both cell types are of equal size and density.



$B = 2\frac{mL}{min}$

$V_B^B = 0.8$

$V_T^B = \emptyset$

$V_B^T = \emptyset$

$V_T^T = 0.2$

$V_B^F = ?$

$V_T^T = ?$

LEGEND

B = flow in from stream B (mL)

T = flow in from stream T (mL)

F = flow out from mixer; final output (mL)

V_n^i = volumetric fraction of cell type n in stream i

Know

inf, B cells, T cells = 3:2

BASIS: 1 min

Assume: Steady State

cells equal size & density

Balanced Equations

$BV_B^B + \cancel{TV_B^T}^{\emptyset} = FV_B^F \rightarrow FV_B^F = 2(0.8)\,mL$

$\cancel{BV_T^B}^{\emptyset} + TV_T^T = FV_T^T \rightarrow FV_T^T = T(0.2)\,mL$

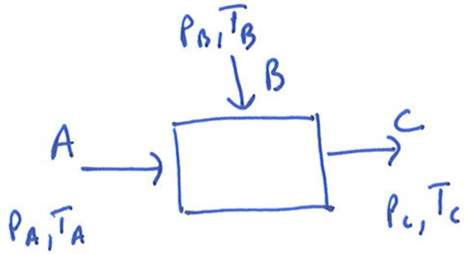
$$\frac{FV_B^F}{FV_T^T} = \frac{3}{2} = \frac{BV_B^B}{TV_T^T} = \frac{2(0.8)\,mL}{T(0.2)\,mL}$$

$$\frac{3}{2} = \frac{1.6}{T(0.2)} \rightarrow \boxed{T = 5\frac{mL}{min}}$$

Name: Solutions

Problem #3 (25 points)

Gases A and B are combined such that the final partial pressure of A is exactly half that of B. If gas A is stored 10°C cooler than gas B, what is the volumetric ratio of gas A:gas B? Solve only in terms of the temperature of gas B and reduce to simplest terms. Show all balance equations in solution.



Basis: Fix n_A, n_B or n_C

$$p_A^C = 0.5\, p_B^C \quad \therefore \quad n_A^C = 0.5\, n_B^C$$

$$T_A = T_B - 10$$

Assume: $P_A = P_B$ (@ inputs)

• ideal gases

Balances:

Total $A + B = C$

(A) $n_A^A = n_A^C$ (or $n_A^{in} = n_A^{out}$)

(B) $n_B^B = n_B^C$ (or $n_B^{in} = n_B^{out}$)

$$\left. \begin{aligned} n_A^A &= \frac{P_A V_A}{R T_A} \\ n_B^B &= \frac{P_B V_B}{R T_B} \end{aligned} \right\} \text{using ideal gas law}$$

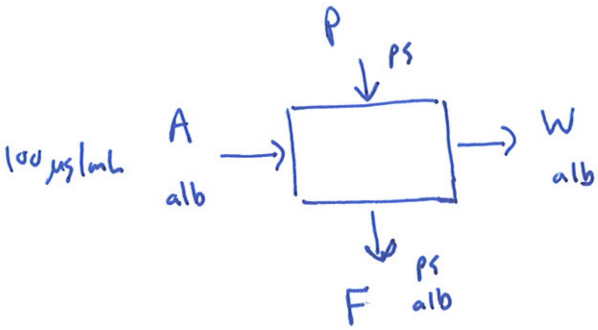
$\Rightarrow n_B = 2 n_A$ (using p.p. info from above)

$$\frac{V_A}{V_B} = \frac{(n_A R T_A / \cancel{P_A})}{(n_B R T_B / \cancel{P_B})} = \frac{\cancel{n_A} \cancel{R} (T_B - 10)}{2 \cancel{n_A} \cancel{R}\, T_B} = \boxed{\frac{T_B - 10}{2 T_B}}$$

Name: Solutions

Problem #4 **(25 points)**

Albumin (70 kDa) adsorbs to polystyrene surfaces at a density of 10 μg/mm^2. If 1 ml of a polystyrene microsphere solution is added per every 10 ml of a 100 μg/ml albumin solution, what is the minimum concentration of 200 μm (diameter) solid polystyrene microspheres needed to deplete at least 90% of albumin from the initial solution?



Basis: 1 mL PS sol'n

OR 10 mL alb sol'n

$S.A._{sphere} = 4\pi r^2$

$F_{alb} = 0.9\,A_{alb}$

Balances:

$A + P = W + F$ (total)

$A_{alb} = F_{alb} + W_{alb}$ (albumin) $\Rightarrow F_{alb} = 900\ \mu g$ & $W_{alb} = 100\ \mu g$

$P_{PS} = F_{PS}$ (polystyrene) $\Rightarrow F_{PS} = \dfrac{F_{alb}}{10\ \mu g/mm^2} = \dfrac{900\ \mu g}{10\ \mu g/mm^2} = 90\ mm^2$

$S.A._{PS\ sphere} = 4\pi(0.1\ mm)^2 = 0.04\pi\ mm^2 = 0.1256\ mm^2/sphere$

$\Rightarrow \dfrac{\text{necessary S.A.}}{\text{S.A./sphere}} = \dfrac{90\ mm^2}{0.1256\ mm^2/sph} = 716.6\ MS(/mL)$

so $\boxed{717,\ 720,\ \text{or}\ 800\ \text{Microspheres/mL}}$

(depending on sig figs)

"700" incorrect because below minimum conc. needed