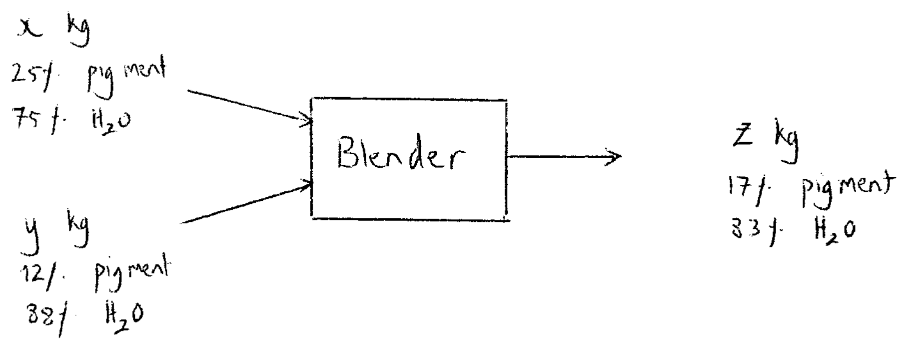
Problem Set A

Problem 1

a)



Choose $z = 1$ kg as a basis for the calculation

Balance on pigment $\quad 0.25x + 0.12y = 0.17 \quad (1)$

Balance on H_2O $\quad 0.75x + 0.88y = 0.83 \quad (2)$

Solve (1) and (2) simultaneously

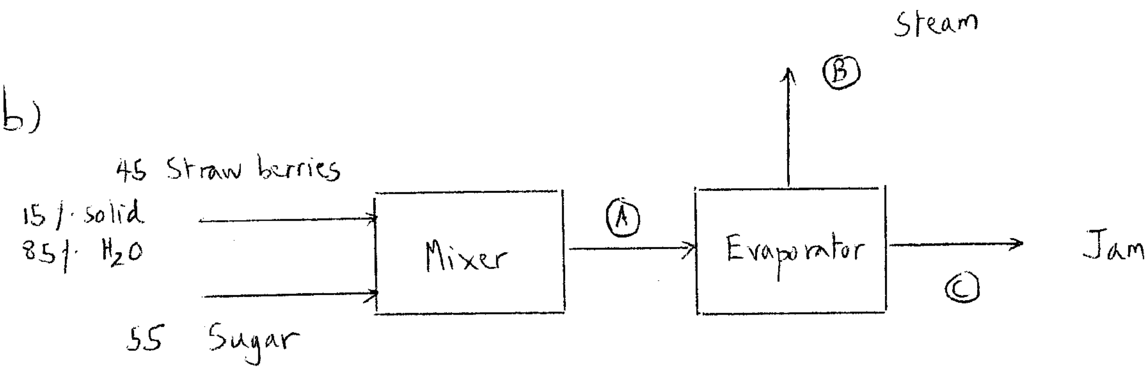
$\implies x = 0.385$

$y = 0.615$

$\therefore$ Cost per kg of retail paint is $(0.385 \times 18) + (0.615 \times 10)$

$= 13.08$

$\therefore$ it should be sold at **\$ 14.39 / kg** b)



Basis : 45 pounds of strawberries
55 pounds of sugar

Assume no reaction and accumulation in the mixer, In = Out

(A) Total mass balance $45 + 55 = 100$ pounds

Solid balance $0.15 \times 45 = 6.75$ pounds of solid

Water balance $0.85 \times 45 = 38.25$ pounds of H_2O

Sugar balance 55 pounds of sugar

In the evaporator water is removed until the residue (jam) contains one-third water by mass

∴ water balance around the evaporator, In = Out

$$38.25 = B + \frac{1}{3}C$$

From total mass balance we know that $100 = B + C$

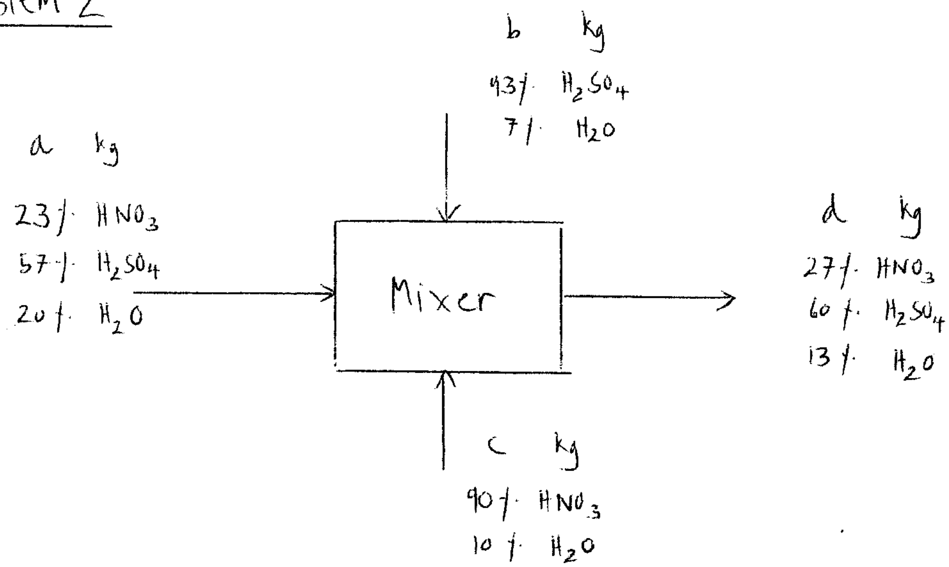
∴ $C = 92.625$ pounds

$B = 7.375$ pounds

To make 1 pound of Jam we need

0.486 pounds of strawberries
0.594 pounds of sugar

Problem 2



Basis $d = 100$ kg

Total mass balance : In = Out

$$a + b + c = 100 \qquad (1)$$

HNO_3 balance : $0.23a + 0.90c = 27$ (2)

H_2SO_4 balance : $0.57a + 0.93b = 60$ (3)

H_2O balance : $0.20a + 0.07b + 0.10c = 13$ (4)

Rearrange (2) ⟹ $c = \dfrac{27 - 0.23}{0.90}$

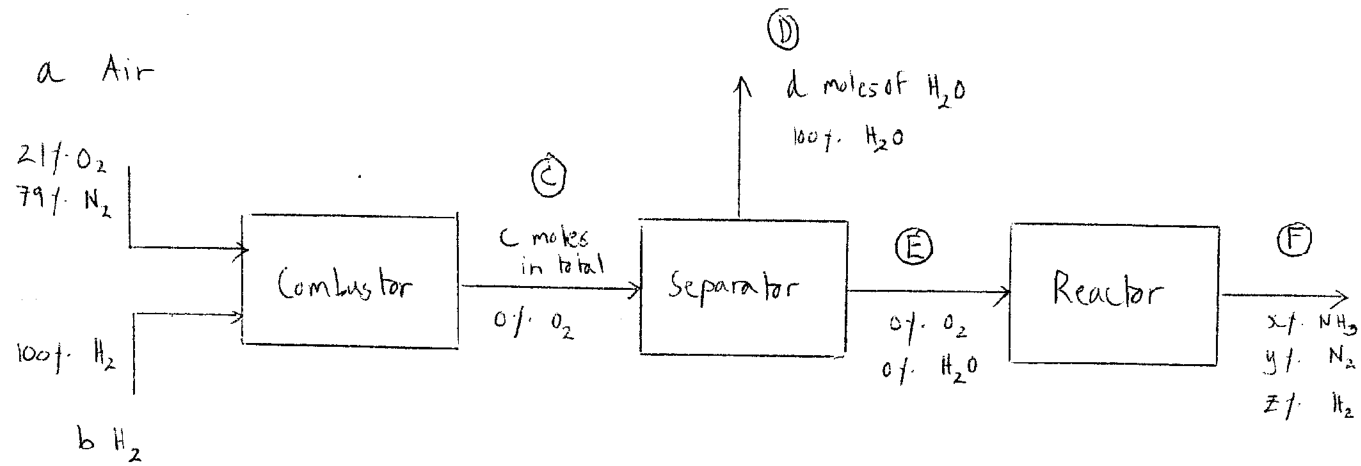
Rearrange (3) ⟹ $b = \dfrac{60 - 0.57a}{0.93}$

substitute into (1) ⟹ $a + \dfrac{60 - 0.57a}{0.93} + \dfrac{27 - 0.23a}{0.90} = 100$

∴ $a = 41.7$ kg $b = 39.0$ kg $c = 19.3$ kg

* Note : eqn (4) can be used to check the answer

Problem 3



Basis : Assume 100 moles of air ie. a = 100 moles

and we have 21 moles O_2 , 79 moles N_2

To deoxygenate air , stream Ⓒ must contain no O_2

this is achieved by the reaction $H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$

Balance on O_2 around the combustor : In + Gen = Out + Acc

$$(0.21 \times 100) + R_{O_2} = 0$$

$$R_{O_2} = -21 \text{ moles}$$

From chemistry $-R_{H_2} = -2R_{O_2} = R_{H_2O}$

$\therefore$ $R_{H_2} = -42$ moles

this reaction produces $R_{H_2O} = 42$ moles

$\therefore$ Stream (C) consists of 79 moles N_2 (from air)

0 moles O_2

$b - 42$ moles H_2

42 moles H_2O

As all 42 moles of H_2O is separated in the separator

$\therefore$ Stream (D) consists of 42 moles H_2O

Stream (E) consists of 79 moles N_2

$b - 42$ moles H_2

In the reactor $N_2 + 3H_2 \longrightarrow 2NH_3$

* assumes 100% conversion

N_2 balance around the reactor : In + Gen = Out + Acc

$$79 + R_{N_2} = 0$$

↑ 100% conversion

$$\therefore R_{N_2}^{reactor} = -79 \text{ moles}$$

From chemistry $$-R_{N_2}^{reactor} = -\frac{1}{3} R_{H_2}^{reactor} = \frac{1}{2} R_{NH_3}^{reactor}$$

$$\therefore R_{H_2}^{reactor} = -237 \text{ moles}$$

$$R_{NH_3}^{reactor} = 158 \text{ moles}$$

H_2 balance around reactor : In + Gen = Out + Acc

$$b - 42 - 237 = 0 \leftarrow \text{100\% conversion}$$

$$b = 279 \text{ moles}$$

NH_3 balance : In + Gen = Out + Acc

$0 + 158 = \text{Out} + 0$

$\therefore$ Out = 158 moles NH_3

$\therefore$ 100 moles air, 279 moles H_2 } ⟶ 158 moles NH_3

Per mole of NH_3 we need

0.633 moles air
1.766 moles H_2

and that $\frac{237}{279} \times 100 = 85\%$ of H_2 is incorporated into NH_3

* It is also possible (and easier) to look at the entire process as a unit and realize that to make 1 mole of NH_3, you need 0.5 moles of N_2 from atomistic balance on N atom

As air is 79% N_2 21% O_2, we need

$\frac{100}{79} \times 0.5 = 0.633$ moles of air

Similarly for H balance, we have 2 reactions

$N_2 + 3H_2 \longrightarrow 2NH_3$

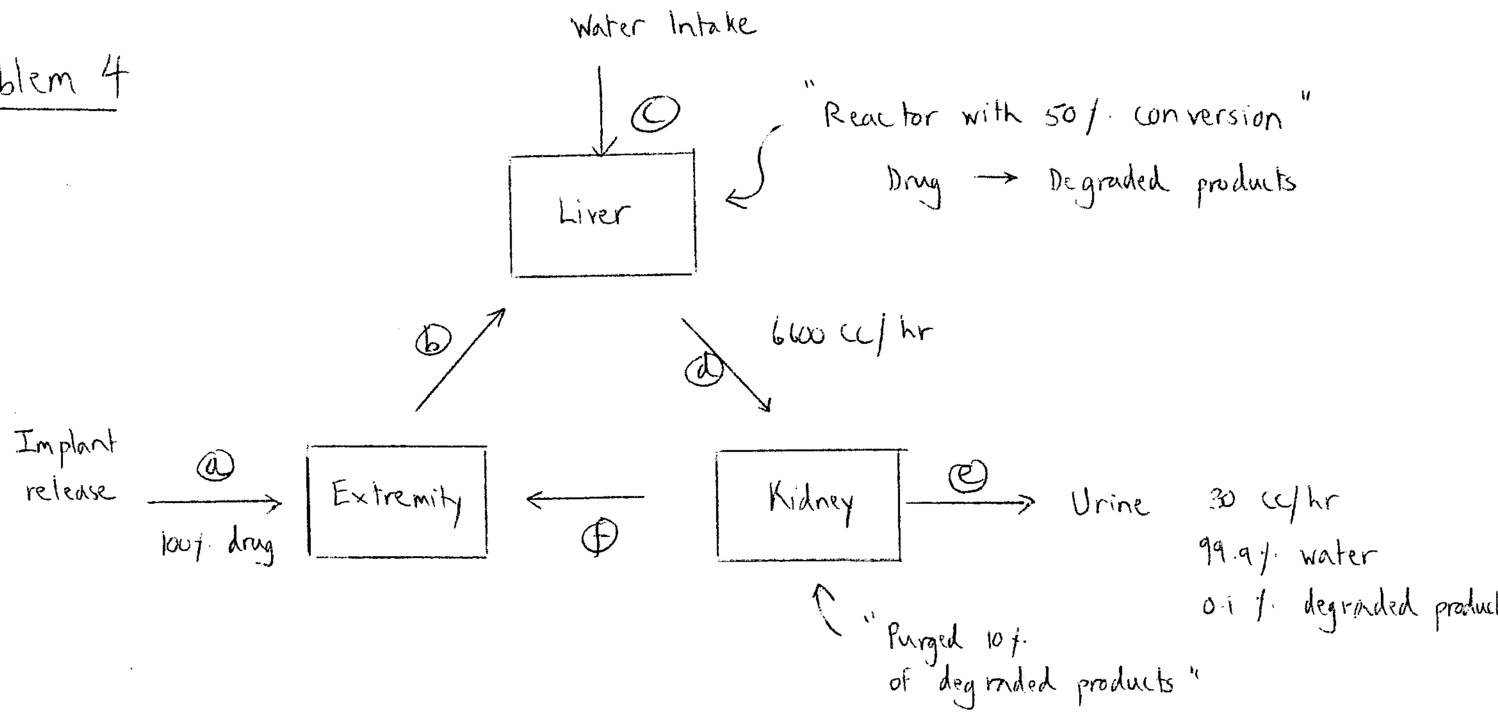
$2H_2 + O_2 \longrightarrow 2H_2O$

1 mole of NH_3 requires $3/2$ moles of H_2

$0.21 \times 0.633 = 0.133$ moles of O_2 need 0.266 moles of H_2

$\therefore$ total H_2 consumption is 1.766 moles

Problem 4

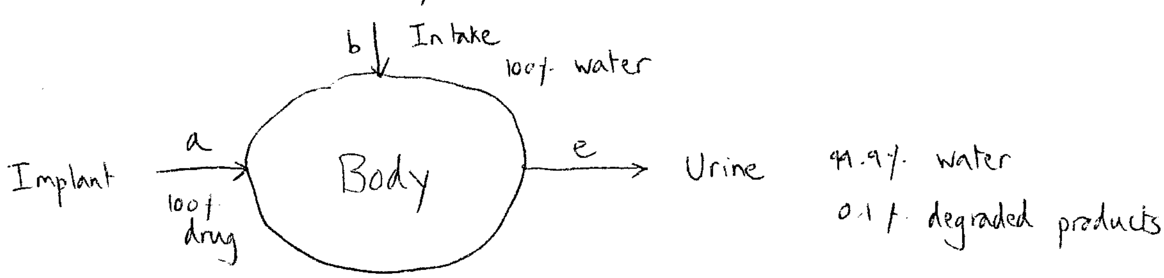


a) For practical purposes of solving this problem, there are only 3 components of body fluid

- Water
- Drug
- Degraded product

Assume 1 vol of drug degrade to 1 vol of degraded product

Drug balance over the entire body In + Gen = Out + Acc



$$a + R_{drug}^{body} = 0$$

$$\therefore \; a = -R_{drug}^{body}$$

ie. the purpose of the implant is to replace drugs degraded in the body

From degraded product balance over the entire body

$$In + \quad = Out + Acc$$

$$0 + R^{body}_{deg\ prod} = \left(\frac{0.1}{100} \times 30\right) + 0$$

$$R^{body}_{deg\ prod} = 0.03 \ cc/hr$$

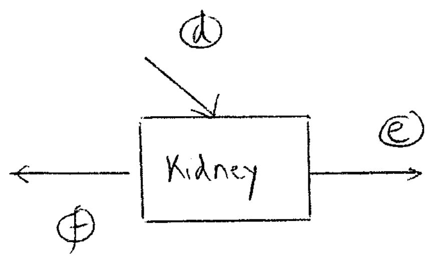
From assume chemistry Drug $\rightarrow$ Degraded Product

$$R^{body}_{deg\ prod} = - R^{body}_{drug}$$

$$\therefore \ d = 0.03 \ cc/hr$$

Implant release 0.03 cc/hr of pure drug

b)

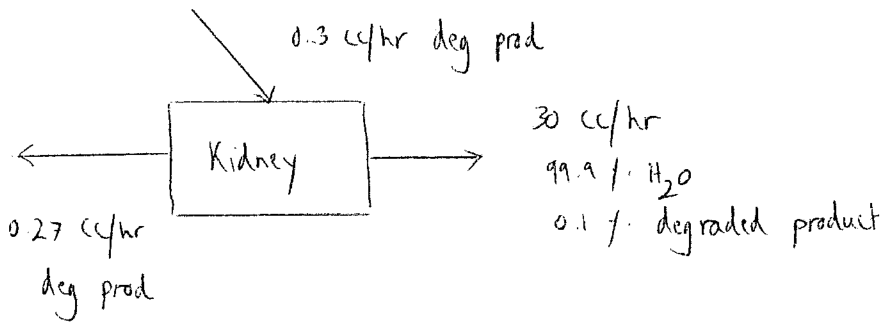


Urine
30 cc/hr
99.9 % H_2O
0.1 % degraded product

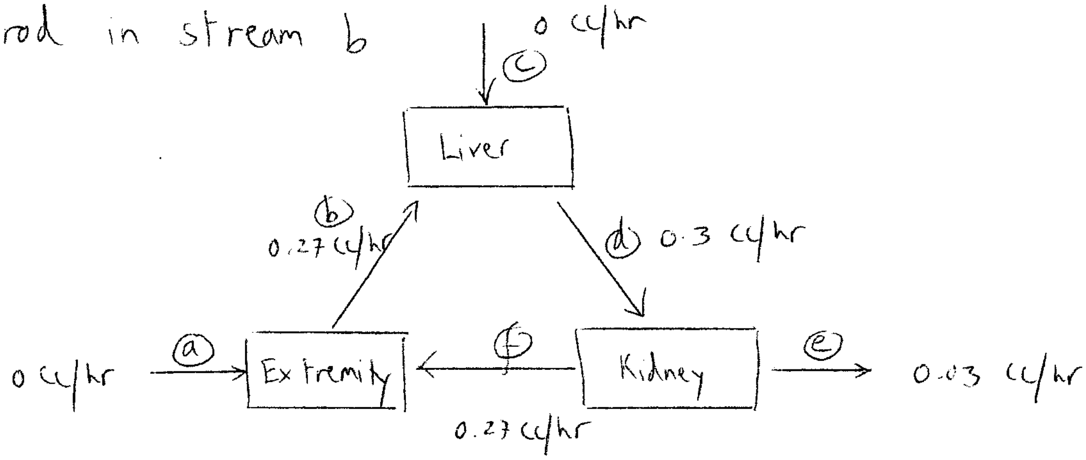
we know that 10 % of the degraded products entering the kidney via stream d is excrete, and therefore 90 % of it is recycle back via stream f

$\therefore$ we have $\left(\frac{0.1}{100} \times 30\right) \times \frac{90}{10} = 0.27$ cc/hr of degraded product in stream f

and hence, we have 0.30 cc/hr of degraded product in d



As the extremity generate no degradation product, we have 0.27 cc/hr of deg prod in stream b



Balance of degraded product around the liver : In + Gen = Out + Ac

$$0.27 + R^{liver}_{deg\ prod} = 0.3 + 0$$

$$R^{liver}_{deg\ prod} = 0.03 \text{ cc/hr}$$

From chemistry $$R^{liver}_{deg\ prod} = -R^{liver}_{drug}$$

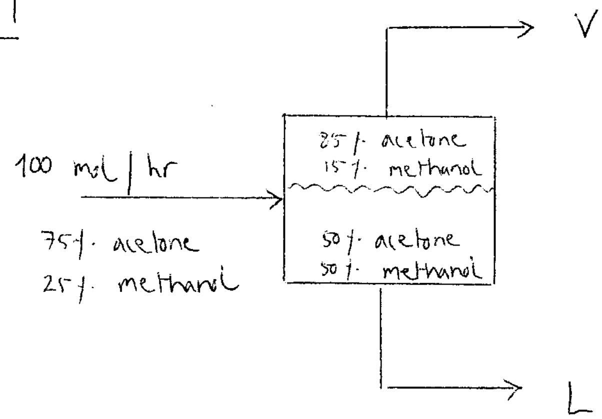
$$\therefore R^{liver}_{drug} = -0.03 \text{ cc/hr}$$

* We know that liver degrade 50% of the drug entering it

$\therefore$ we have 0.06 cc/hr of drug in b
and 0.03 cc/hr of drug in d

$\therefore$ **0.03 cc/hr of drugs flow between kidney and extremities**

Practice P1



Overall balance on total molar Flowrate   In + Gen = Out + Acc

$$100 + 0 = V + L + 0 \qquad (1)$$

Balance on acetone

$$(0.75 \times 100) = (0.85 \cdot V) + (0.50 \cdot L) \qquad (2)$$

$$75 = 0.85V + 0.5L$$

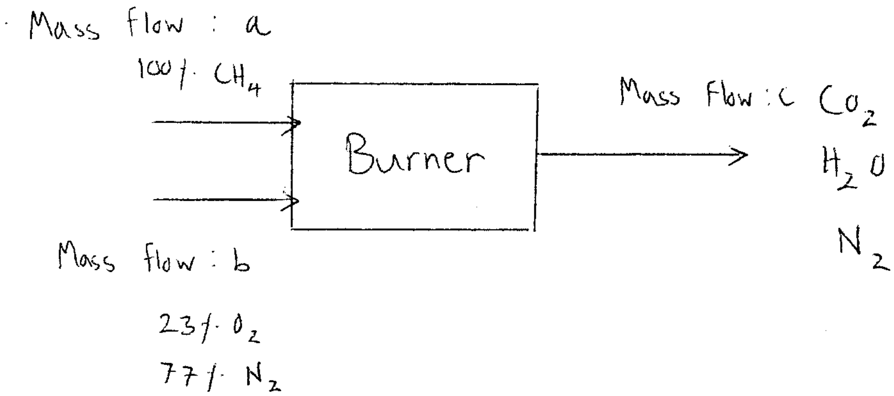
From (1) $V = 100 - L$

$$\therefore \quad 75 = 85 - 0.85L + 0.5L$$

$$\boxed{L = 28.6 \text{ mol/hr}}$$

$$\therefore \quad \boxed{V = 71.4 \text{ mol/hr}}$$

Practice P2



Assume a basis of 100 g / hr of air ie. b = 100 g / hr

∴ we have 23 g / hr of O_2
77 g / hr of N_2

to provide an inert atmosphere, we need to burn away all of the incoming O_2 (notice that exit stream has no O_2)

Using reaction $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

⟹ 1 mole of CH_4 is needed to react with 2 moles O_2.

We have 23 g / hr of O_2 and since O_2 has a molecular weight of 32 g / mol

we have $\frac{23}{32} = 0.719$ mol / hr of O_2

∴ need $\frac{0.719}{2} = 0.359$ mol / hr CH_4

CH_4 has molecular weight of 16 g / mol

∴ need $0.359 \times 16 = 5.75$ g / hr of CH_4 Flow

| Mass ratio of air to CH_4 is $\frac{100}{5.76} = 17.4$ |